HYDROLOGIC CALIBRATION OF THE CUB RUN WATERSHED

USING THE PC VERSION OF THE

HYDROLOGICAL SIMULATION PROGRAM - FORTRAN (HSPF)

by

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(ABSTRACT)

The Hydrological Simulation Program - FORTRAN (HSPF) in its personal computer version, release 10.10, was used to perform the hydrological simulation of a sub-watershed of the Occoquan River drainage basin. The sub-watershed selected was the Cub Run Watershed located in the northern area of the Occoquan River catchment. A model in the form of a User Control Input (UCI) file was prepared. The Cub Run Watershed was analyzed considering its geological, edaphic and weather characteristics, and segmented accordingly. The model was calibrated to adjust simulated results to observed data. Several calibration runs were executed and a final run was done considering a further segmented watershed. The simulation results were good even when not all the desired data could be found. The annual percent difference between the best calibration run and the observed results was 21.28%. The ten-month percent difference, excluding June and July, was 5.82%. The first value is a fair result for hydrologic calibration, the second value is an excellent result for the same type of calibration. Additional segmentation did not further improve the results obtained during the best calibration run. Differences in the calibration when considering just a pervious segment or two segments (one pervious and one impervious) could be noted, indicating the importance of considering impervious surfaces for the simulation. HSPF reacted quite logically to variations in the calibration parameters and the results from those variations could be predicted beforehand. In summary, the PC version of HSPF was demonstrated to be a good management tool for the hydrological simulation of this watershed.

To

Adriana and Martín

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I. INTRODUCTION

The Occoquan River is one of the major tributaries of the Potomac River. Located at the southwest of the Washington Metropolitan Area, its watershed (see Figure 1) covers the eastern part of Fauquier County, most of Prince William County[1], the western part of Fairfax County, and a small triangular area at the south of Loudoun County. Included in this area are the towns of Manassas and Manassas Park. In the late 50's, the Occoquan Dam was constructed just downstream of the point at which the Hooes Run pours its waters into the Occoquan River. The direct consequence was the formation of the Occoquan Reservoir. The Reservoir[2] has its tailwaters where Bull Run and Occoquan Creek meet. Actually, the Reservoir extends approximately 2.5 miles up into each of these two major Occoquan River tributaries. This impoundment has a full-pool capacity of 3.71×10^7 cubic meters (m^3) and constitutes one of the main raw water supplies for the area.

Between 55 and 60 percent of the Occoquan Watershed used to be covered by forests, about 35 percent with agricultural lands and between 5 and 10 percent with urban developments (industrial, commercial and residential). However, in the early 70's a strong urban development process began, the pace of which has been accelerating during the 80's and the 90's. As a result, this urbanization caused not only a more intense need for raw water supplies, but also a strong

[1]Except for the small southern sub-basins of the Chopawamsic, Quantico, Powells, and Neabsco creeks, which drain directly to the Potomac River, the Occoquan River Watershed completely covers Prince William County.

[2]When the words reservoir and watershed refer to the Occoquan Reservoir and the Occoquan Watershed respectively, they will be capitalized (e.g. the Reservoir, the Watershed). When they are used in a general context, they will be written in lowercase.

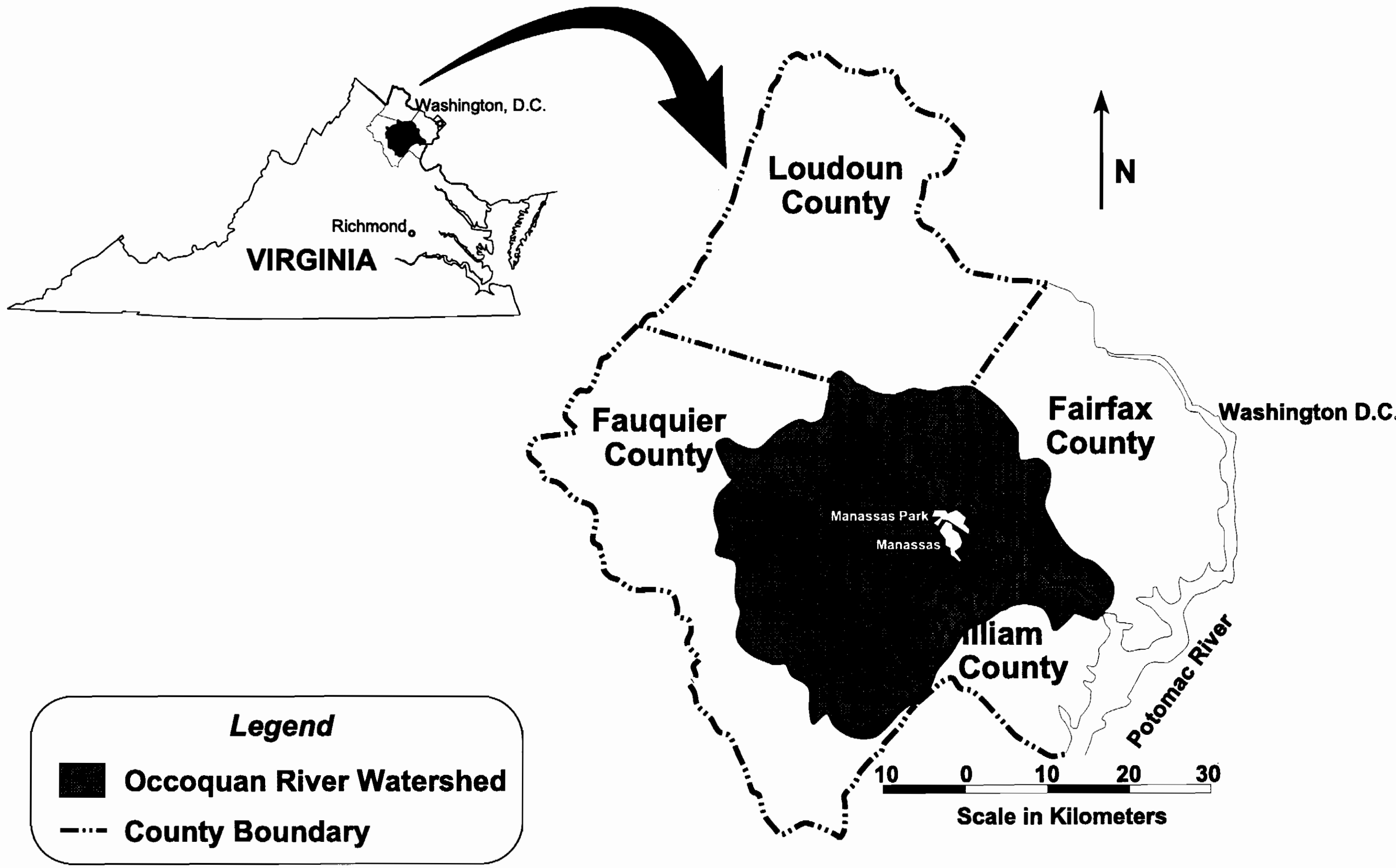

Figure 1: Location of the Occoquan River Watershed

necessity for protection of existent sources. The expansion of impervious surface due to the construction of roads, streets, parking lots, residences, commerce, and industrial parks, caused an increase in the amount of stormwater reaching the streams. Fairfax and Prince William counties have been considered for several decades two of the fastest developing regions in the country. This fact has generated concern for the effects this urbanization could cause in the area and its water bodies.

The administration of natural resources and practices for a drainage basin the size of the Occoquan Watershed (approx. 600 square miles) could be a very complex situation. The use of management tools like mathematical computer models, to simulate the Watershed hydrologic and water quality processes, have been demonstrated to be very useful in helping managers in the decision-making process. One of these computer models, the Hydrologic Simulation Program - FORTRAN (HSPF), was designed for application in watersheds as an effective tool for the characterization and forecast of hydrologic and water quality conditions. Proved in a large number of basins in the United States and around the world and with the support, continuous development and maintenance of the Environmental Research Laboratory of the United States Environmental Protection Agency (EPA), HSPF has been considered for many years as one of the most complete and comprehensive simulation programs of its type.

The arrival of the personal computer (PC) version of this simulation program brought the way in which modeling of complex systems was regarded into a new perspective. Powerful desktop and even portable computers eliminated the need of a mainframe system to run this program, making it a more economical, convenient and, for some situations, faster tool for watershed management.

Although the Northern Virginia Planning District Commission (NVPDC) was, at the time of this research, involved in an effort to translate the mainframe version of their Occoquan Basin Model into an executable version for the PC release of HSPF, an operative PC model for this region could not be found.

The initial objective of this study was to demonstrate an application of the PC version of HSPF for a subwatershed of the Occoquan River drainage basin from the hydrological standpoint. The size of the Occoquan Watershed and the complexity and intensive data requirements of HSPF would not allow for a complete test of the program for the entire watershed in the time frame dedicated to this study. Instead, a representative subwatershed was selected to develop a hydrological model and attempt the calibration of such a model. The selected subwatershed was the Cub Run drainage basin (see Figures 2 and 3) and it was selected because of certain observed characteristics. Its area was representative of the whole watershed, there was a flow gaging station at the very end of the stream (see Figure 4, station ST50), and the subwatershed was independent of the input from other subwatersheds. Besides, this drainage basin was one of the fifteen segments defined by the NVPDC in their mainframe model. More detailed information about the selection process is presented in Appendix A.

When developing a simulation model for a program with the characteristics of HSPF, two processes should be considered with attention: the segmentation of the watershed and the calibration of the model. Segmentation is the process by which the watershed is divided into smaller sections called segments. Each segment should contain lands with similar characteristics and it is suposed to respond similarly to the simulation process. The type and grade of segmentation for the area of study is very important. Calibration is the process used to adjust

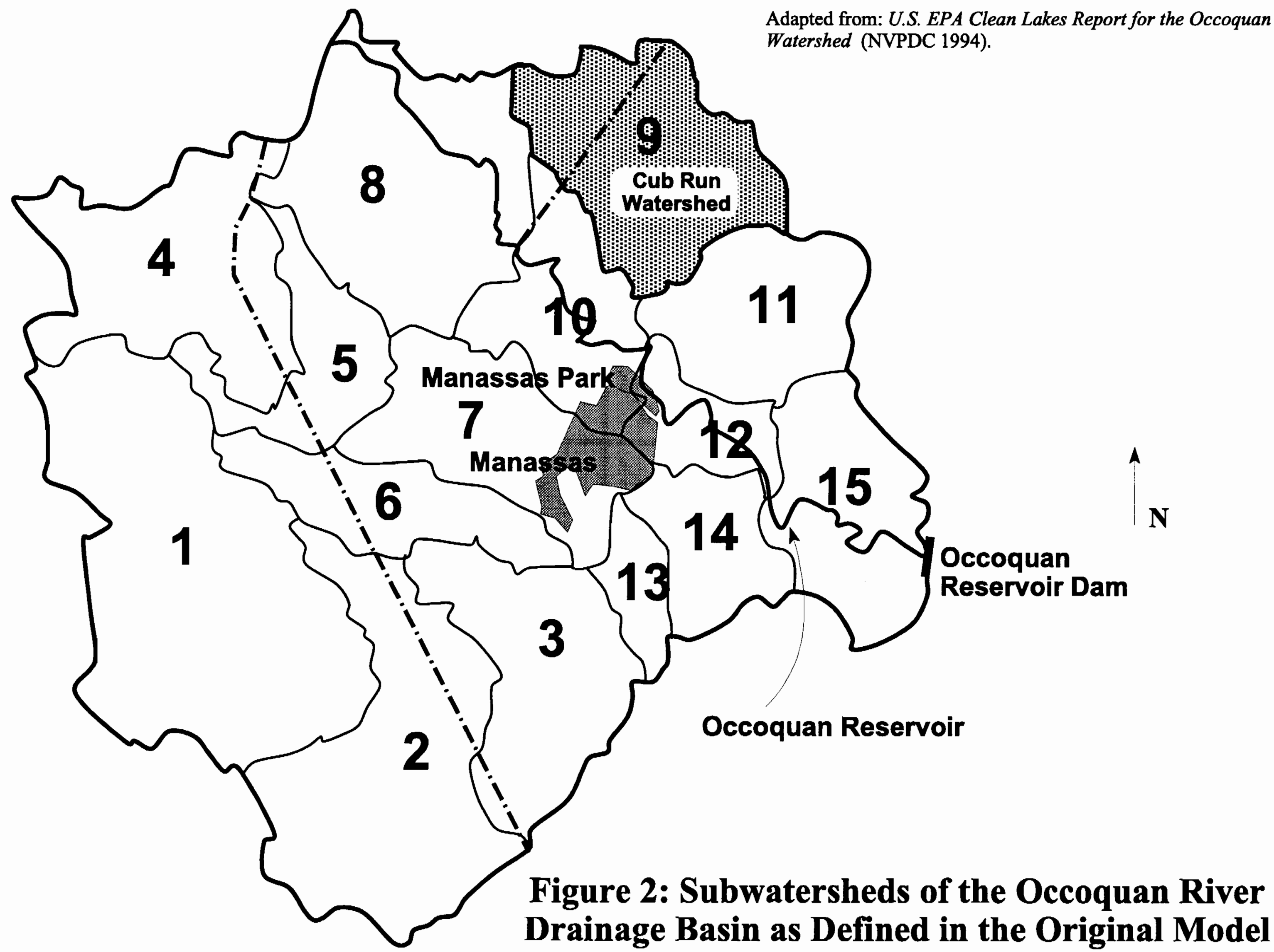

Figure 2: Subwatersheds of the Occoquan River Drainage Basin as Defined in the Original Model

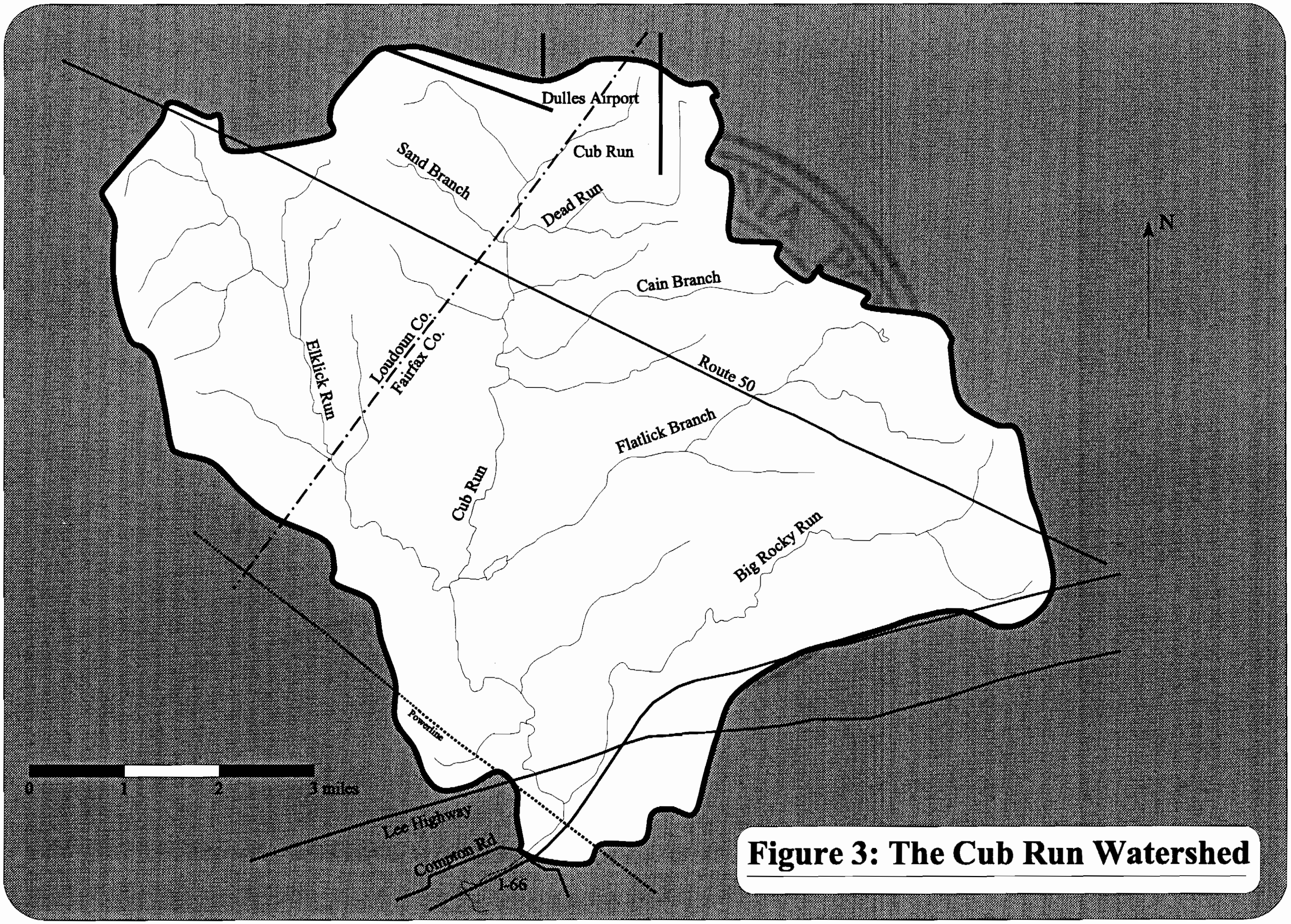

Figure 3: The Cub Run Watershed

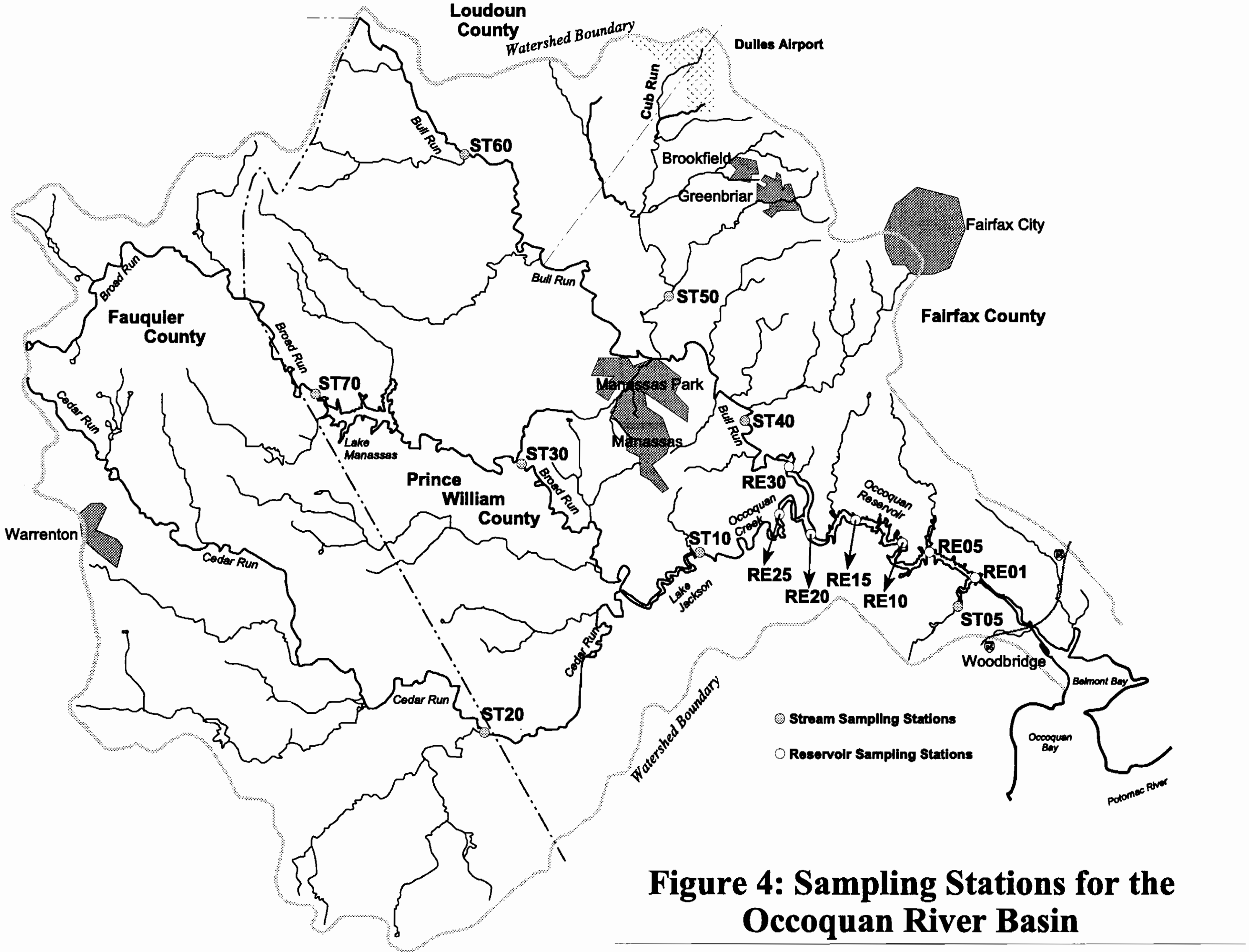

Figure 4: Sampling Stations for the Occoquan River Basin

model parameters[3] so that the differences between model predictions and observed values fall within the criteria for simulation performance.

The specific objectives of this study were:

1. To hydrologically simulate the Cub Run Subwatershed using the PC version of the HSPF model.
2. To perform a more detailed segmentation of the watershed comparing the results of simulation for the modified model with the ones obtained in previous runs.
3. To study the response of the simulated results to the modification of selected parameters in an effort of calibration.

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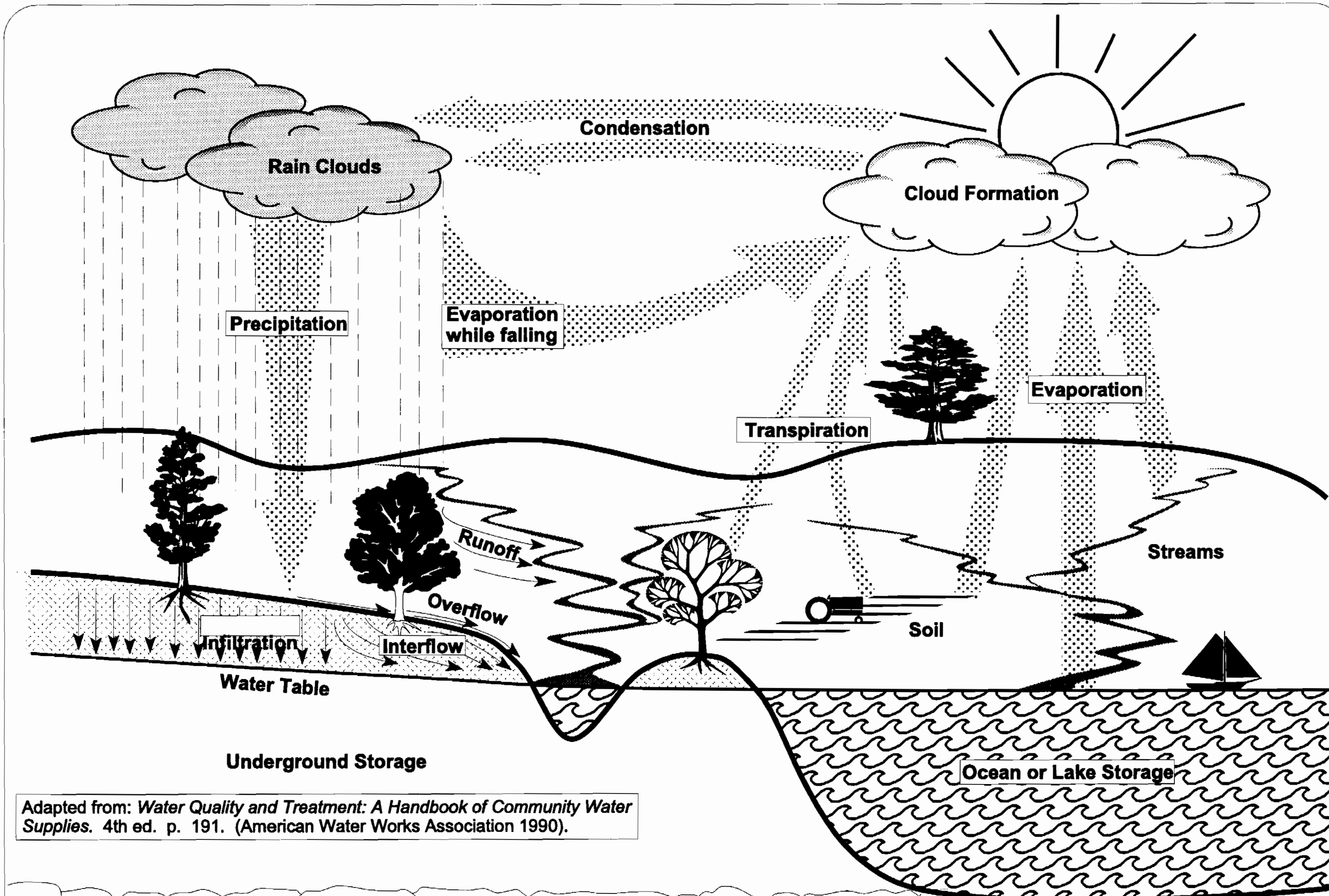
[3]The selection criteria may differ from one study to another. However, there are two situations that define a calibration parameter: the first is when no value is available for a parameter, then this parameter can be calibrated to fit the results of simulation close to the observed values; the second is when a parameter allows the characterization of a watershed. Since HSPF is a general simulation model, meaning applicable to very different watersheds, calibration of certain parameters permit one to individualize the watershed being studied.

II. REVIEW OF THE LITERATURE

1. Watershed Management

a. Introduction

The paths through which water is cycled in the terrestrial biosphere are normally known as the hydrologic cycle (American Water Works Association 1990, pp. 190-91). This continuous exchange of water above, on and below the earth's surface can be described as a succession of processes (see Figure 5). Water from oceans, rivers, lakes, and other impoundments evaporates and forms clouds in the atmosphere. Transpiration from vegetation also contributes to this cloud formation process. Through condensation, these clouds generate precipitation in one or several of its many forms: rain, snow, sleet, hail, mist. This precipitation wets vegetation and other surfaces forming a water storage from which some water will evaporate, re-initializing the cycle again. Eventually, rain will reach the soil and will begin to infiltrate into the ground. First, infiltration replaces soil moisture, then when the soil is saturated with water, infiltration percolates slowly, moving downward and to the sides reaching sometimes the groundwater table or emerging on hillsides, forming springs. Besides, water seeps on the bottoms of streams and lakes or beneath the oceans. If the infiltration rate is exceeded by the rate of precipitation, that excess of water will flow over the land in the direction in which it finds less resistance. This downhill overland flow will eventually find and contribute its waters to a stream. Streams, formed by overland flow and groundwater discharge, will move to discharge into larger containers and eventually into the oceans. Waters reaching the surface and running forming streams, or



Adapted from: *Water Quality and Treatment: A Handbook of Community Water Supplies.* 4th ed. p. 191. (American Water Works Association 1990).

Figure 5: The Hydrologic Cycle

contained in ponds, lakes and oceans, or moistening the soil, or intercepted by vegetation or any impervious surface, evaporate again, restarting the hydrologic cycle.

The hydrologic cycle is very important because it generates and maintains surface water and groundwater. The former may be further classified as running waters, such as rivers, streams, creeks, and brooks; or quiescent waters, such as lakes, reservoirs and ponds. Surface water is fed by runoff of precipitation, overland flow, direct precipitation, and groundwater seepage. Water will follow the path in which it will find less opposition going downhill and forming bigger and bigger streams. The network of streams will slope down toward one primary water course. This drainage area is normally known as a watershed or drainage basin. Its boundaries are defined by the ridges of high grounds that divide the precipitation in one direction or another, dividing thus one watershed from another (see Figure 6).

Another important aspect of the hydrologic cycle is that it defines the different points and locations in the biosphere in which different types of pollution might be introduced. During the cycle, contaminants may be concentrated, diluted, decomposed, transformed, or simply carried out through the pathways the water takes. An appropriate watershed management plan has to look for a decrease of those inputs in the waters of that river basin.

There are basically two types of factors affecting the water condition in a basin: natural factors and human factors. Natural factors may have a truly important impact in the water quality, and generally cannot be controlled immediately. Human factors may be subdivided into point sources and nonpoint sources of contamination. Table 1 shows a classification of natural and human factors (AWWA 1990, pp. 194-206).

Adapted from: *Water Quality and Treatment: A Handbook of Community Water Supplies.* 4th ed. p. 192. (American Water Works Association 1990).

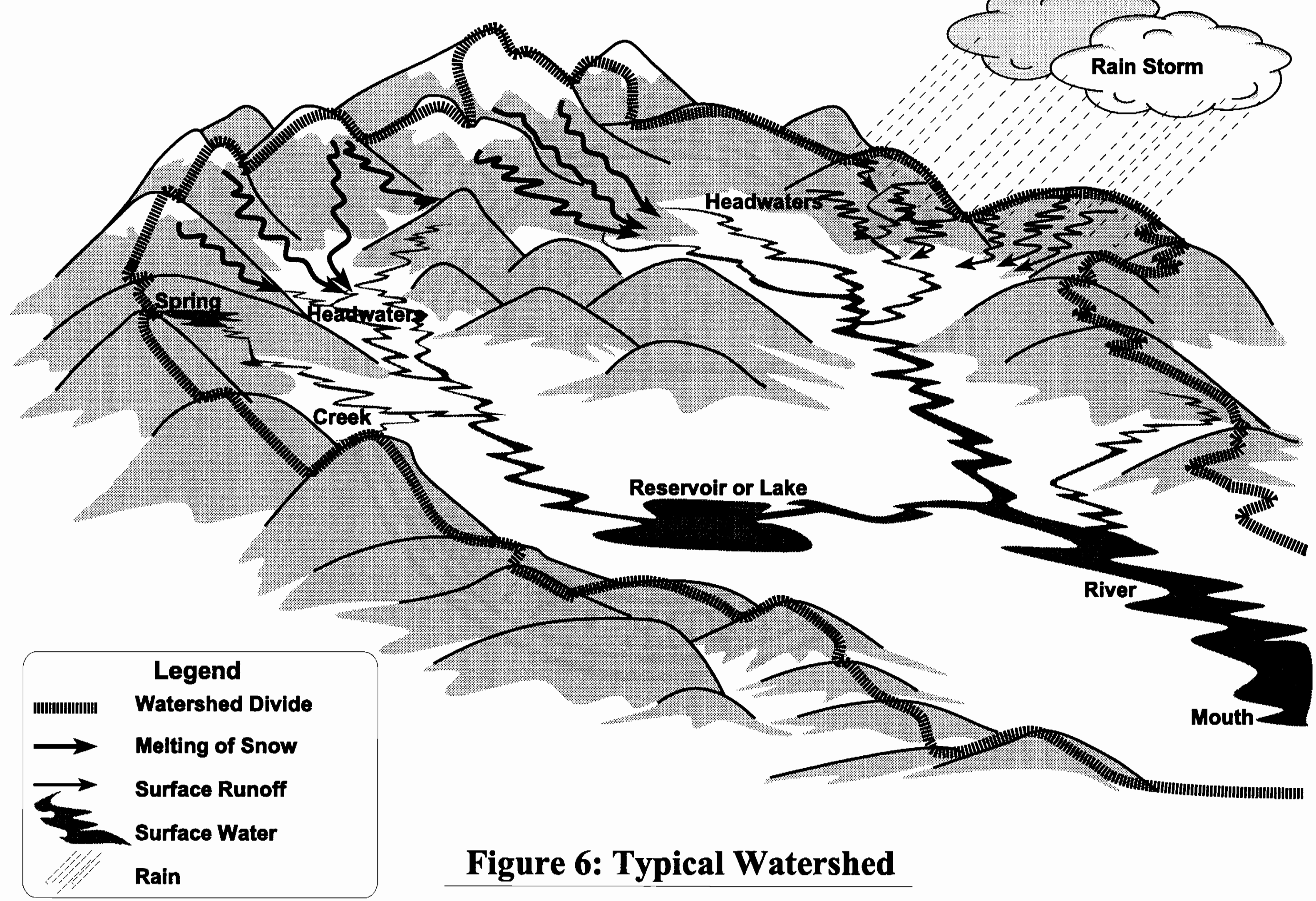


Figure 6: Typical Watershed

Table 1
Factors influencing water quality in a Watershed

Natural Factors	Human Factors	
	Point Source	Nonpoint Source
Climate	Wastewater discharges	Agricultural runoff
Watershed characteristics	Industrial discharges	Livestock
Geology	Hazardous waste facilities	Urban runoff
Microbial growth	Mine drainage	Land development
Fire	Spills and releases	Landfills
Saltwater intrusion		Erosion
Density stratification		Atmospheric deposition
		Recreational activities

Adapted from: *Water Quality and Treatment: A Handbook of Community Water Supplies.* 4th ed. (AWWA 1990, p. 193).

Watersheds can be administered at different governmental and/or private levels. The regulatory protection of water supplies is provided by federal environmental programs, and by state and local laws.

The Refuse Act, passed in 1899 was a first basic attempt to regulate water pollution but it wasn't until 1948 that the federal government became really involved in decreasing stream contamination. Federal legislation impulsed the control of water quality discharges (AWWA 1990, pp. 206-209). The Water Quality Act (1965), the Federal Water Pollution Control Act (1966), the Water Improvement Act (1970), and their amendments, the Clean Water Act (CWA) and the Safe Drinking Water Act (SDWA) are some of the laws enacted by Congress in attempts to achieve a decrease in water pollution (Nemerow 1991, pp. 316-19).

Passed by Congress in 1974 and with major amendments in 1986[4], the SDWA contains source water protection provisions. However, public concerns arose as a consequence of incidents like the one which occurred in Milwaukee during the months of March and April of 1993, when an outbreak of *cryptosporidium*[5] resulted in more than 400,000 residents with some degree of illness and more than 40 people dead (Altman 1993; Nash 1993). This incident wasn't isolated and problems with drinking water affecting tens of thousands of people happened in the recent past in Texas, Oregon, Missouri, and Georgia. The issue of watershed management then, assumes more and more importance in order to assure safe drinking water to people, and probably new amendments are needed to the SDWA (Waxman 1995).

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[4]Grizzard, Thomas, Lectures: #1 and #2 of the course Environmental Engineering Design II, Virginia Polytechnic Institute and State University, Northern Virginia Graduate Center, Falls Church, Virginia, January 14 and 21, 1993.

[5]*Cryptosporidium* and *Giardia lamblia* are pathogenic protozoa. They are the cause of life-threatening infections in patients with acquired immune deficiency syndrome (AIDS) and children, elderly people, pregnant women and other groups that may have low immunologic systems (Metcalf & Eddy 1991, pp. 92, 94).

Enacted in 1972 with the objective of rendering water swimmable and fishable, the Clean Water Act established a National Pollutant Discharge Elimination System (NPDES). The NPDES sets numeric limits for specific contaminants and is required by the Clean Water Act for point source discharges. Those limits were extended on September 9, 1992, to storm water discharges[6] (Berube 1995). More than 20 years have passed since the enactment of this act, and whether it was effective to reduce pollution, and render the surfaces waters "fishable and swimmable", as goal established in 1983 by the law, is unclear. Despite the fact that pollution coming from point sources was significantly reduced, large amounts of contaminant are still reaching the streams via runoff from farms, cities and other intensive land uses. Also, better monitoring and reporting reflects that the situation was actually worse of that thought when the CWA was passed. According to the United States Environmental Protection Agency (EPA) pollution controls implemented in 22 industries, since the enactment of the CWA, have reduced the discharge of "priority" toxic organic pollutants by 99 percent (almost 660,000 pounds/day) and by almost 98 percent for toxic metals (1.6 million pounds/day). However, U.S. industries still reported a release, in 1990, of almost 200 million pounds of toxics into surface waters and 450 million pounds into public sewers. The National Water Quality Inventory issued in April 1994 and covering the years 1990 - 1991 demonstrates that even the interim goals proposed in the CWA have not been met yet. About 40 percent of rivers and lakes, and approximately 33 percent of estuaries of the country are not meeting or fully supporting their designated uses (fishing, boating, swimming, drinking water supply, etc.). Therefore, even though the CWA has had a notable impact in reducing water pollution, it is a relative success and the goals have not been entirely accomplished yet. Point source pollution, although considerably reduced, is still causing continuous

[6]57 FR 41236

contamination of water, sediments, fish and wildlife; nonpoint sources are far from being controlled; and the biological health of waters and watersheds seems to be moving in the wrong direction. A new revision and revitalization of the CWA may address these major problems (Adler 1995).

Although federal control provides an equal-level type of regulation, state and local laws and ordinances can more directly affect the protection of local watersheds. Source protection, sanitary regulations, regulation of inland wetland areas, aquifer protection, and water codes, are provided many times in individual state programs. Land use controls and regulation of development activities, provided at the local level, as by municipal ordinances, may provide significant protection of key watershed areas.

In some cases, for watersheds spread over large areas covering several states, Interstate Commissions may provide more comprehensive planning of water resources than individual states. The Interstate Commission on the Potomac River Basin (ICPRB) provides interstate cooperation for pollution control. Being a river whose watershed stretches over 14,670 square miles of the states of Maryland, Pennsylvania, Virginia, West Virginia, and the District of Columbia, during its way from the headwaters to its mouth at the Chesapeake Bay, the Potomac River is used by many consumers. Without proper regulation, misuse of the River in some states may affect the use of the same river downstream by other states (ICPRB 1995). As an example of this kind of cooperative management, the ICPRB comprises five units that work with state and regional agencies and interest groups providing: a) technical services, using modeling and other methods; b) water resources, coordinating management of water and associated land resources; c) living resources, working to improve the health of the basin ecosystems and exchanging biological information; d) public affairs, educating and informing the public, government agencies, and the media about water quality and other basin concerns; and e) Co-op efforts, coordinating cooperative efforts and planning among the basin water utilities. Federal initiatives support this "watershed management approach." Under these provisions states would identify important watersheds, designate watershed management entities, and oversee the development of watershed administration plans (EPA 1994, pp. 30-33). The benefits of this approach include the development of controls enabling the correct functioning of ecosystems, and the increase of recreational opportunities. Other benefits include: cost effective approaches for reducing adverse impacts on water bodies, the use of a proven cooperation system in which voluntary participation of interested parties generally yield more gains than more traditional top-down regulatory approaches.

There are other options for watershed regulation and administration, some of them are specially suited for small watersheds. Nemerow provides an interesting approach for marketing stream resources (Nemerow 1991, pp. 318-29). Since the watershed is small, the beneficiaries are easier to identify and there is a better knowledge of local problems. The stream assimilative capacity can be very well established and then based on that capacity, potential users pay per unit of assimilative capacity used. Local watershed administration may be very effective. Advantages to this approach reside in the desire and concern of people within the watershed to solve regional problems. Even though this type of management is not wide-spread, some cases verify its usefulness in watershed management (Lake Barcroft Watershed Improvement District 1992).

The problems in a watershed and its administration vary depending upon the type of land use and development the watershed has. Therefore, some consideration has to be given to the kind of watershed being studied. The following sections clarify some concepts on urban, forested, grazing land and agricultural watersheds.

b. Urban and Urbanizing Watersheds

Agricultural, forested and other types of rural watersheds have basically pervious surfaces through which water infiltrates at reasonable speeds. Urban watersheds, instead, have large areas covered with impervious surfaces (rooftops, streets, parking lots), and since water cannot infiltrate rapidly, it has to be channeled through a very efficient drainage system. Different from what happens in natural watersheds, where water is slowed down by vegetation, overland flow and infiltration, sewers, pipes and collecting systems in urban areas are characterized by the moving of large amounts of water very fast to nearby bodies of water. City activities produce a vast range of contaminants which are picked up by storm water on its way to the sewers. Oil and grease from roads and parking lots, zinc from automobile tires, nutrients from fertilizers used in city parks and gardens, fallen leaves, particulates and dust fall from industries, heavy metals, and other toxics are all swept by storm water and constitute a serious problem for nearby streams or impoundments.

Management of urban watersheds implies the study of the type of impact that will produce this runoff and its contaminants in the quality of the receiving waters. Control of water quantity is also an important issue[7]. Nonpoint source runoff may constitute a very important origin of pollutants, comparable with point source industrial discharges and sewage from treatment plants. Computer models can be very helpful for administrators, providing an excellent tool for decision making (Huber 1995).

Combined sewers[8] present in many old cities and communities are many times a management problem. After strong rains, what are known as combined sewer overflows (CSOs)

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[7]Actually, that was the primary concern of civil engineers in the mid 1800's, building drainage systems to prevent floodings.

[8]Combined sewers carry both sewage and stormwater runoff (Metcalf & Eddy 1991, p. 1103).

are produced. Many times the drainage system is not designed to carry such large amounts of water and overflows occur. Since combined sewers go directly to the treatment plants, the capacity of treatment may be overcome and large amounts of bacteria, nutrients, solids, BOD, metals, and other contaminants, are released to the receiving bodies of water, violating water quality standards.

This problem may be controlled or at least attenuated with very simple measures, if good management is applied to the impervious watershed. Best management practices (BMPs) may be very helpful in controlling CSOs. Maintenance of drainage systems can improve significantly the quality of combined sewer waters. Curb-side catch basins are designed to capture debris from the street. Their design is such that they can not only capture heavy materials by sedimentation, but also floating materials like oil and greases, which may interfere greatly the sewage plant biological systems. Grassy swales on the sides of roads and parking lots may improve infiltration and retard water movement, reducing peak flows in the system. Perhaps storage of storm water and combined sewage is one of the most effective systems, allowing sedimentation of solids, and the pumping of water to the treatment plants when the large flows have passed.

Urbanizing watersheds are also a challenge for administrative boards. Many watersheds are in the transition process from agricultural or forested watersheds to urban watersheds. These types of situations are very frequently close to expanding metropolitan areas. The Little Seneca Creek watershed is a typical case (Schueler and Sullivan 1983, pp. 221-22). This 20-square mile basin is located approximately 25 miles to the northwest of Washington, D.C., with agricultural lands covering 57 percent of the area and forests occupying 30 percent of the watershed. The construction of a dam created the Little Seneca Lake at the lower end of the basin. This lake serves as an emergency reservoir for the Washington metropolitan area, but it is also an attractive feature for recreational activities that may accelerate the process of urbanization in the area.

Antagonistic interests are raised as a consequence of this type of reservoir in urbanizing areas. On one side, people maintain that recreational use of these lakes should be restricted since they provide a source of drinking water (Ahlgren 1965). On the other side there are opinions that with sufficient controls recreational activities may be allowed (AWWA Journal Roundtable Discussion 1987). However, and just to cite an example, fishing activities are not compatible with copper sulfate additions to control algal growth. A study performed by Lee, Symons and Robeck selected similar watersheds under different conditions of recreational use exposure, to assess the impact of human-use level over water quality. However, no measurable influence could be detected because of the increase of human activity in the different watersheds studied (Lee, Symons and Robeck 1970).

Another example of increased urbanizing activity is the Occoquan Watershed. This watershed is tributary to the Potomac River basin, and occupies the southern periphery of the Washington, D.C., metropolitan area. Parts of Fairfax and Prince Willians counties are included in this basin. These areas are being developed fast, imposing great stress on the Occoquan Reservoir occupying the eastern part of the watershed, as well as on Lake Manassas on the Broad Run Sub-Watershed. To characterize land use and provide tools for management practices some studies have been performed in the area (Weand and Grizzard 1983, pp. 1-2). Large-scale residential development and the construction of new commercial corridors over this area has contributed to a domestic wastewater and stormwater flow increase, affecting water quality.

Some aspects to be considered in the management of urban or urbanizing watersheds are:

- The type and magnitude of potential impacts to surface water in quality and quantity.
- The type of stormwater management control program implemented and how effective it is in mitigating the impacts described in the previous point.
- The investment needed to achieve reasonable levels of water quality in receiving waterbodies.

Problems related to water quantity, historically present in urban watersheds, are now more complex because of considerations of water quality. Collection of data, public information and education, and use of watershed and stormwater models may be of great value for managers in order to take decisions about the health of the basin. However, the analysis of problems caused by urban nonpoint source management has to be integrated with the general watershed administration to provide a careful and responsible management of receiving waters.

c. Forested Watersheds and Riparian Buffers

Forested watersheds constitute a very important source of drinking water for many cities in the United States. About 70 percent of the rain falling in the country is falling on a forest. This fact highlights even more the relevance of forest and water management in drainage basins across the country (McCammon 1995).

Again, conflicting issues make the situation very complex. Many cities and communities depend on the timber industry to survive economically. But water quality is seriously deteriorated by distributed contamination due to road construction and timber harvesting. The change on forest cover generally greatly affects hydrologic processes in the area. Those who use the forests and its waters, including recreationists, fishermen, farmers, ranchers and timber production merchants, are affected by the quality and availability of water. Managers have already observed that costs of treatment increase significantly when water has to be filtrated and processed more and more to meet tougher standards. Managers have also understood that good practices in the administration of forested watersheds imply savings in subsequent water treatment.

Many animal species are dependent for their survival on narrow areas of land and forests protecting stream banks. These areas are known as riparian zones. Buffer strips of trees and vegetation left on stream banks have demonstrated the protection of wildlife living close to or in the streams (Frissell and Bayles 1995). Salmonids, for example, require riparian habitats, clean, cool waters, stable stream channels, woody debris and a continuous path to the ocean. At least 214 salmonid stocks have been identified in 1991 by the American Fisheries Association as at risk of extinction (Gregory 1995). These buffers can nearly eliminate the effects of nonpoint pollution on nearby waterbodies. The Illinois State Natural Survey (ISNS) has developed a computer program (simulation model) that allows decision-makers to study land use changes on riparian zones and examine how these changes modify water quality (Tippet 1993). Beneficial effects may be obtained from good watershed management. Rivers, creeks and other waterways with no bank protection have substantially higher nonpoint source loadings than streams protected with 200 feet of riparian buffers. Also, if BMPs are to be used to reduce water contamination, they will be cost-effectively applied to those zones not protected with riparian buffers. The lack of these protection zones is the reason for landslides and large sediment loadings due to runoff.

Use of BMPs related to silvicultural practices and road engineering, monitoring and feedback of results, cooperative efforts from private owners, land management agencies, and local governments will have a positive effect on the health of forested watersheds, its waters and its wildlife.

d. Management of Grazing Lands and Agricultural Watersheds

Water quality in agricultural watersheds is the result of agricultural practices, with its surface and subsurface pollutant loadings and instream processes affecting contaminant fate and transport.

On the occasion of a three-week workshop on "Integrated Watershed Analysis and Management," sponsored by the Cornell International Institute for Food, Agriculture and Development with the Cornell Center for the Environment, and with the concurrence of 25 representatives from Dominican Republic, Ghana, Honduras, Indonesia, Madagascar and the Philippines, Tim Fahey, associate professor of natural resources, said:

> "In developing countries, the typical conflict is between the use of uplands for subsistence agriculture and the erosion and silting this causes in waterways." (Steele 1995)

The problem is not only for developing or underdeveloped countries, but also for developed countries that practice intensive agriculture. Agricultural cropland is regarded as one of the major sources of sediment and attached nutrients. Average nutrient concentrations from agricultural lands are generally low to moderate; however, the resulting loading of nutrients to streams can be really big because of the large surface covered by crops, and the high volume of runoff produced from those lands. It is estimated that approximately 60 percent of the nitrogen and 42 percent of the phosphorus input to water supplies each year is contributed by agricultural lands (Donigian and Crawford 1976). Also, some pesticides applied to crops and soils do not stay on those sites, but they are transported by runoff to receiving waters. Many of these contaminants, like chlorinated hydrocarbons, are very persistent and even when applied in very small concentrations, they may be applied all year-round, facilitating biological concentration. Other pesticides may be applied during shorter periods in the year, but in higher concentrations, and may constitute a hazard for water pollution on a seasonal basis. Acute toxic levels of contaminants were seen after heavy rainfall following application, accidents or even carelessness in the handling and administration of these chemicals.

Many factors influence the extent of runoff contamination from agricultural lands. Soil and watershed characteristics, climatic conditions and agricultural practices can be very significant in the control of contamination in agricultural watersheds. The two known systems to calibrate and define BMPs for this type of watersheds are: Trial and Error, conducted on small, controlled, and monitored watersheds, and Mathematical Modeling, which probably provides the safest and more practical approach to the problem (Bailey, Swank and Nicholson 1974, pp. 95-96).

Beyond federal, state, and local controls, producer involvement seems to be a key point in the strategy of controlling agricultural runoff. Watershed management implies improved water quality for farmers and producers. Decreasing the levels of nutrient, sediment and pesticides reaching the water bodies has not only been beneficial for watershed health but also for the producer's pocket. The implementation of BMPs and Manure Nutrient Management Plans (MNM Plans) during a three-year project in the Upper Vermilion Watershed, Ohio, resulted in a remarkable improvement in the water quality. Once ranking ninth among the 285 basins in agricultural phosphorus contributions to Lake Erie, MNM Plans resulted in savings on the use of commercial fertilizers of approx. 440,000 pounds of nitrogen, 200,000 pounds of phosphorus and 350,000 pounds of potassium, translating to reduced costs of production for the farmers and additional water quality benefits in the Lake Erie watershed. BMPs applied in this project included: conservation tillage, use of cover crops, animal waste facilities, sediment retention,and erosion and water control structures. These practices saved approximately 10,534 tons of soil (Ward and others 1995).

Rangeland watersheds are composed of three areas: uplands, water, and riparian zones. The last ones (previously described) support a very complex vegetative community. But this wetland type of environment has lost its natural protection due to severe grazing. These grasses are very important for trapping sediments and associated contaminants. Perhaps the most effective measure to make them come back is to limit the seasons in which grazing is allowed in those zones. Preventing grazing before the seasons of high flows, allow them to remain in place where they are more necessary for trapping sediments. This type of management has proved to be not only beneficial to the watershed waters, but also for the ranchers. When cattle is moved away from these zones during early Spring and mid-Summer, the return of high quality grasses improves the riparian buffers and cattle weight (Barrett 1995).

The use of manure as a fertilizer has resulted in a great reduction in contamination from range lands, and economical and environmental savings from the reduction of chemical fertilizers applied to agricultural lands. A combination of BMPs for both land uses constitutes one of the best tools for controlling water contamination in these types of watersheds.

e. Summary for Watershed Management

Robert Hughes, Aquatic Ecologist for Mantech in Corvallis, Oregon, said on the occasion of a watershed seminar held at Oregon State University in Spring, 1993:

> "... relatively clean water seeps through the catchment and emerges carrying the signature of the landscape it has passed through. The health of much of the landscape is deteriorating and water bodies are reflecting this change." (Hughes 1995).

He prefers to call the watershed, "catchment," because he says this word captures a more real concept of water being held, stored and catched within the drainage basin and then being shed to the streams and other waterbodies. The "signature of the landscape" is observed in the health of the land and its waters. In the previous sections, even considering different land uses, a simple deduction may be drawn: economy and environment seem to be on different sides of the scale, but when conscious watershed management is applied that encounter is not that clear. Environmentally sound practices may also be economically positive. Understanding watershed characteristics is important to protect its waters and its populations (including human beings), but not much space is left for trial and error techniques that could have worked many years ago when deteriorating conditions weren't so huge and no other methods were available. The computer era brought new possibilities and tools for watershed management. Now, multiple situations can be simulated in a relatively short period of time, compared with trial and error approaches. Even in very complex systems, where much care has to be taken to avoid underestimation of important parameters, simulation can provide an excellent tool for decision makers.

2. Reasons for the Use of Simulation and Mathematical Models

According to the *Merriam-Webster's Collegiate Dictionary*[9], one of the meanings of the word "simulation" is:

> "**sim·u·la·tion**\ ... **3 a:** the imitative representation of the functioning of one system or process by means of the functioning of another <a computer ~ of an industrial process> **b:** examination of a problem often not subject to direct experimentation by means of a simulating device"

What is to be simulated in this case is a natural process, the routing of waters and the fate and transport of contaminants in a watershed. The "simulating device" is a computer running a code or program frequently called a mathematical model, or simply model. In fact, the complexity of the processes happening in a river basin is such that simple monitoring or measuring of water quality is not enough to accurately describe the system. Models are needed to both describe and predict water quality conditions. Descriptive simulation using computer models is very important because it makes possible the understanding of cause-effect relationships, which in turn facilitate the definition and selection of management alternatives (McCutcheon 1989, p. 1).

Before the use of simulation techniques, and computer power to accomplish them, all the estimates of flow (when no observed data existed) as well as a wide range of hydrologic calculations had to be computed with pencil and paper. The basic concepts of infiltration, water

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[9] *Merriam-Webster's Collegiate Dictionary*. 10th ed. Merriam-Webster, Inc. Springfield, Massachusetts, U.S.A., 1993.

routing to construct runoff hydrographs, and continuous soil moisture accounting were known long before the advent of the computer era. Even though those concepts were developed in the 30's and 40's, there was no way to deal with them in detail if problem solutions were required in a reasonable amount of time. Therefore, all sorts of simplifications were required to obtain results when classical methods were used to solve hydrologic problems.

These simplifications of procedures, approximations, convenient simplifying assumptions and estimations used in classical procedures often resulted in not very accurate results, and sometimes produced big errors (Linsley 1976). The development of computers and models permits more accurate computations. Assumptions of linear relationships to simplify calculations is no longer needed because computers can deal with nonlinear relationships among variables in less time and more precisely. Calculations of runoff, requiring short time steps, used to have not less than 6 hours intervals, being frequently 12 or 24 hours intervals; the use of simulation allows one to reduce those intervals to 1 hour or less, being much more descriptive for infiltration processes in small watersheds.

A model can be defined as a "theoretical construct relating external inputs or forcing functions to system variables responses[10]." Even though it refers to the program as a theoretical construct, many times a model may be based on empirical or semi-empirical relationships. Models simulating watershed processes are composed basically of two parts, the hydrologic model, and the water quality model.

The analysis of hydrologic processes from a practical point of view permits the implementation of mitigating measures, Best Management Practices, to reduce and revert the

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[10]Definition given by Dr. Adil Godrej in lecture #1 of the course Surface Water Quality Modeling, Virginia Polytechnic Institute and State University, Northern Virginia Graduate Center, Falls Church, Virginia, January 25, 1995, and based on a definition given by other authors (Thomann and Mueller 1987, p. 7).

adverse effects of urbanization, chiefly: increase of flood hazard, increase of runoff due to major impervious coverage, and increase of pollution in receiving waters. Urban systems have become more sophisticated and complex; therefore, their study has become accordingly more difficult and has needed a large-scale basin-wide stormwater approach (Dendrou 1982, pp. 219-220). The use of urban storm drainage models has helped to solve practical problems in a much easier way.

Mathematical models simulating agricultural runoff processes are being used to analyze and predict quality and quantity of agricultural land runoff. The goal is to use these types of models to develop BMP Plans. These plans are intended to maintain agricultural productivity at its top while decreasing adverse impacts on the water quality.

The implementation of environmental controls is becoming more and more expensive with time. Tougher standards are making more severe the penalties derived as a consequence of judgement errors; administrators cannot afford to make such mistakes. For these reasons, environmental quality managers require more efficient analytical tools, based on a better understanding and knowledge of the environment and its complex interactions. Simulation models were developed as management and engineering tools, capable of helping in the definition of contamination problems and the finding of their possible solutions, for the achievement of water quality goals.

In brief, computer simulation is more adequate than conventional methods because it involves fewer approximations and, therefore, there is a lower accumulation of errors. Simulation provides a more detailed, useful and complete answer, even when data availability is limited, because the used data is utilized in a more efficient way. The use of computer models is very flexible because it allows parameter adjustments or even complete variations, adapting to changing situations, a capability not found in conventional pencil and paper methods. Even from the cost and time requirements standpoint, computer models have comparable demands if compared with the use of a traditional methods applied in a reliable way, and in the supposed case that cost or time demands for computer models were larger than those for traditional methods, the better quality and comprehensiveness of the results obtained using models is by far more valuable than those procured using conventional techniques.

3. Applications of Simulation

Simulation can be applied to practically any body of water. Rivers and streams; estuaries, bays, and harbors; lakes, reservoirs, and ponds; coastal ocean waters; and even seas and oceans can be simulated for certain aspects. Since this study is specifically concerned with watershed management, the situations that follow will be mostly related to that exclusive context. The previous section stated that the use of computer simulation accelerates the computation of hydrologic calculations giving more reliable results than manual methods. The question then is, in what situations may a mathematical model be applied in the framework of watershed administration? The answer is: basically to any situation in which the help of computer power may improve, speed, and make more efficient the decision making process. Since this is a quite general answer, the following examples will pinpoint some of those situations; however, there are many more contained in the extensive category defined by the answer given above.

a. Hydrologic Simulation

One of the first uses of simulation was to determine continuous streamflow hydrographs at the mouth of a watershed (Crawford 1962). This representation, using computing codes, of the hydrologic cycle, runoff, and water routing, is in fact very helpful in solving one of the classic problems of hydrology: to obtain the best estimates of hydrologic characteristics for a drainage basin, using scarce, incomplete and sometimes inadequate data. Since that beginning of the 60's, hydrologic simulation and analysis have evolved to very sophisticated hydrologic forecast systems, allowing continuous simulation capable of predicting future streamflows based on the existing watershed situation and weather forecasts (Hydrocomp Inc. 1995e).

Hydrologic modeling is useful for deterministic simulation, allowing a better understanding of the hydrologic aspects of a water catchment, and also for some predictive simulation which is almost impossible when using traditional methods. These two types of simulation permit a better planning and design of many hydraulic engineering projects like dams, reservoirs, and generating units, providing at the point of the project: mean annual streamflows, seasonal distribution of runoff, and aspects of flood flows (frequency and magnitude).

Within these types of hydrologic projects some examples may be cited. The optimization of hydroelectric operations may be achieved by integrating water resources management and power scheduling. This integration of power programming and water management is easily achieved and optimized using low cost desktop computing and inexpensive monitoring and data collection, and the effects obtained in efficiency improvement are comparable of those of machinery upgrades (Howard 1995). Also, continuous hydrologic analysis is excellent for answering many of the questions that arise when new hydroelectric projects are in the process of licensing and older hydroelectric systems are studied for re-licensing. Licensing and re-licensing of these types of projects requires comprehensive analysis of operations and their consequences on streamflows, water quality, fisheries, water rights and aquatic ecology (Hydrocomp Inc. 1995b).

Another problem frequently appearing in hydrology is the determination of flood flows at different recurrence intervals, a procedure known as Flood Frequency Analysis. The standard procedure involves the fitting of observed stream flow records to specific probability distributions (Thomann and Mueller 1987, pp. 33-40). However, this traditional method has some requirements. In the first place, the stream flow record has to be sufficiently long to assure and warrant the statistical analysis. And second, the basin has to be not appreciably altered by reservoir regulations, channel improvements, or land use changes. Stream flow records for many drainage basins are rarely available for long periods of time, but meteorologic data for most watersheds in the United States extend between 40 and 70 years. Hydrologic simulation models the rainfall-runoff relationship in the watershed, being a very valuable tool for determination of flood frequencies in ungaged watersheds and in gaged watersheds that have short stream flow records or fall within the category of heavily regulated catchments. Continuous hydrologic simulation may even be useful to check the validity of probabilistic distributions for gaged, unregulated watershed having long stream flow records (Hydrocomp Inc. 1995a).

Finally, hydrologic simulation has proven to be very useful in the calculation of spillway requirements for reservoirs. These requirements have been calculated and sometimes overestimated, since the late 30's, using the probable maximum precipitation (PMP) and probable maximum flood (PMF) concepts developed by the Hydrometeorologic Section of the Hydrologic Services Division of the National Oceanic and Atmospheric Administration (NOAA). It was found that the PMP calculated by maximizing storm characteristics like wind velocities and dewpoint, is many times larger than the maximum historic storm rainfall in the watershed. When hydrologic simulation is calibrated using historic records for the basin, the representation of the response of channel, surface, soil and floodplain characteristics to rainfall and flood flows is more realistic.

This is true because the sensitivity of the watershed not only depends on the storm aspects but also on the watershed situation, previous to the rainfall event. Thus, a watershed may be simulated for different pre-conditions and its reaction to exceptional meteorological events may be established (Hydrocomp Inc. 1995c).

The modeling of runoff quality and quantity for different types of catchments and using different types of watershed models has been studied, compared and reported in a number of papers and articles (Abbott 1978; Bailey, Swank and Nicholson 1974; Dinicola 1990; Lorber and Mulkey 1982; Moore and others 1988).

b. Surface Water Quality

A lot of effort has be put into developing models for the study and understanding of those processes affecting water quality. These models complement, and in some cases form part of those performing hydrologic simulation.

Pollutants may be classified as bacteriological, biological, chemical and/or physical contaminants. They affect water condition in several ways. Table 2 shows what type of problems are caused by different types of pollutants (Thomann and Mueller 1987, p. 2).

Methods for controlling pollutants may be applied easily in calculations concerning point source discharges, like in the allocation of waste load discharges. However, when distributed sources are involved these calculations may be much more complex. For large watersheds it would be impractical to try to determine contaminant levels contributed by nonpoint discharges. In these types of situations, modeling may alleviate considerably the effort in finding those levels of contamination.

Table 2
Types of pollutants affecting water quality

Type of Pollutant	Water Quality Problem	Manifestation
BOD NH_3, org. Nitrogen Organic solids Phytoplankton DO	Low DO (dissolved oxygen)	Fish kills Nuisance odor Radical change in ecosystem
Total coliform bacteria Fecal coliform bacteria Fecal Streptococci Viruses	High bacterial problems	Disease transmission Gastrointestinal disturbances, eye irritation
Nitrogen Phosphorus Phytoplankton	Eutrophication (Excess of nutrients)	Taste and odor problems, aesthetic nuisances, algal mats, unbalanced ecosystems
Metals Radioactive substances Pesticides Herbicides Toxic product chemicals	High toxic chemical levels	Carcinogens in water, fisheries closings, ecosystem upsets, mortality, reproductive impairments.

Source: *Principles of Surface Water Quality Modeling and Control* (Thomann and Mueller 1987, p. 2).

A good example can be found in the evaluation of risks to the environment as a consequence of pesticides and other chemicals used in agricultural practices. The widespread use of pesticides and fertilizers constitute a threat to the environment and a problem for managers of these types of watersheds. Some chemicals undergo degradation reactions becoming relatively innocuous, but some behave in a more conservative way and reach streams and lakes jeopardizing species living in the water or consuming it. These types of compounds can react, be transported, transformed, trapped in sediments, and bioaccumulated. This implies a very complex situation difficult to handle with pencil and paper and for which many nonpoint source models have been developed, tested, and applied with satisfactory results (Mulkey, Carsel, and Smith 1986). Sometimes derivations of risk assessment end up in a cumulative distribution function, but still the problem is to find a solution to the type of equations generated and only mathematical calculus and models can appropriately handle such computations with acceptable margins of error.

Some of these models were reviewed by Novotny. In his article he compares and describes some watershed models like: the Aerial, Nonpoint Source Watershed Environment Response Simulation (ANSWERS), the Agricultural Chemical Transport Model (ACTM), the Hydrologic Simulation Program - Fortran (HSPF), and the Agricultural Runoff Management Model (ARM) (Novotny 1986).

c. Other Uses of Simulation

Simulation may be used in the design and testing of BMPs. For some watersheds with special characteristics the effects of the application of BMPs may not be totally and/or easily understood, and the result of such application may be difficult to predict. The usefulness of models adapted to simulate the BMPs effects has been discussed several times by some authors (Bicknell, Donigian and Barnwell 1985; Donigian and others 1983; Donigian 1986).

> "Mathematical models are being used to analyze and predict the quantity and quality of runoff from agricultural lands. The ultimate goal is to use these models to develop a Best Management Practice (BMP) plan that will maintain agricultural productivity while minimizing adverse water quality impacts." (Bicknell, Donigian and Barnwell 1985, p. 1141).

The simulation of stormwater and the effects of ponds as a management practice was analyzed by Sullivan and Schueler. In their paper they evaluate the pollutant removal performance of wet and dry ponds using data obtained from site monitoring and watershed simulation programs. They concluded that efficiencies were enhanced in ponds where settling and biological processes were active, and that the use of simulation programs is a "valuable addition to watershed management planning" (Sullivan and Schueler 1985).

In addition to BMPs other processes may be simulated on desktop computers to determine the effects those measures may have in a watershed or part of it. Examples of this variety of situations follow.

One possible application of simulation is to study the effects on the surface hydrology due to drainage development and deep aquifer pumping. This type of study was performed previously on the Cypress Creek watershed in Pasco County, Florida, north of Tampa (Hicks, Huber and Heaney 1985). Another similar study performed by Nath, investigated the impacts of extensive groundwater pumpage with irrigation purposes on streamflows on a 2,700 square mile area of the Big Blue River Basin in central Nebraska (Nath 1986).

The results of urbanization processes have already been discussed in section 1, subsection b. Simulation is a very powerful tool for municipal planning, since the effects of road construction and impervious surface covering can be modeled, studied and forecasted, allowing decision makers to decide upon programs to avoid or restrict this type of pollution.

4. Classification and Selection of Mathematical Models

Simulation is an indirect way to investigate the behavior of a system. The three basic types of simulation normally used are:

- physical models
- analog models
- digital models or computer models

Physical models are a representation of a big system by a smaller version of that system. This down-sized scale of the system is then used as a pilot project to conduct experimentation and research that may lead to a better understanding of the original full-scale system. Physical models have been used frequently to represent hydraulic and hydrologic phenomena. A good example of a physical model is the scale representation of the ocean platform including plants and fish populations and a device for wave generation implemented in a water tank that can be seen at the Natural History Museum of Washington D.C. This reduced size model serves to study life in specific stream conditions. The University of the Republic of Uruguay, School of Engineering developed a scale model of the Uruguay River to predict hydraulic behavior after the construction of a dam and power generating plant in Salto Grande, Salto, Uruguay.

Analog models have also been widely used. In this case a mechanical and/or electrical device is constructed having characteristics similar to those of the represented system. If a system can be explained by a mathematical relationship, and the same expression can also represent a different type of system, then one can be built as an analog of the other, since both are depicted by the same set of mathematical equations. For example, the flow of electrons and the flow of water can be described with similar equations[11]. A more extensive analogy can be found in the description of transfer phenomena (Welty, Wicks and Wilson 1984, pp. 675-684). In this field, the differential equations used to describe the phenomena of mass, heat and momentum transfer are very similar. This allow the representation of mass transfer phenomena using heat transfer phenomena, and many equations have been developed on the basis of these analogies to use one system to study another for which data are not available or scarce or experimentation is difficult to perform.

Digital simulation emerged with the arrival of computers. Therefore, it is a relatively new method of study and representation of systems. This type of simulation is based on computer programs. At first glance, computer programs seem to be far away from the representation of a system if compared with physical and analog models. However, these programs are mathematical representations which in turn represent the physical phenomena, turning the computer code into a system model. The major advantages of digital simulation are high speed and lack of dependence

[11]This example and classification of models was extracted from notes of the Surface Water Quality Modeling course given at Virginia Polytechnic Institute and State University, Northern Virginia Graduate Center, Falls Church, Virginia, January 25, 1995.

on hardware[12]. These models are much easier to operate than the physical system they represent and compress the time scale in such a way that years of observations in the original physical system may require just a few minutes of simulation (Crawford and Linsley 1966, pp. 5-6).

Hydrologic simulation models use mathematical equations and can be classified as either theoretical or empirical models. The first group, theoretical models, include a set of general laws and theoretical principles. In fact, if all the physical laws governing the system to be simulated were well known and could be described by equations, the model would be physically based. But models simplify physical systems and frequently include empirical components, so they are called *conceptual models*. The second group, empirical models, exclude any type of theory, principles or general laws, and only constitute data representation, a fit-the-best-curve to experimental data. The processes of construction of a model follow two paths, interconnected at some points, and produce errors for both of them. Theoretical knowledge allows the translation of reality to mathematical equations (usually nonlinear partial differential equations, that are approximated to linear partial differential equations) to allow the construction of computer code (called model structure). These linear differential equations may in turn lead to ordinary differential equations and to a model. The empirical path is based in *a posteriori* measurement knowledge (data), and includes measurement and estimation errors. Models do not generally rely entirely on theoretical knowledge since not all the processes can be physically described in a complete way. Figure 7 shows this process of model construction in a diagram adapted from Eykhoff[13].

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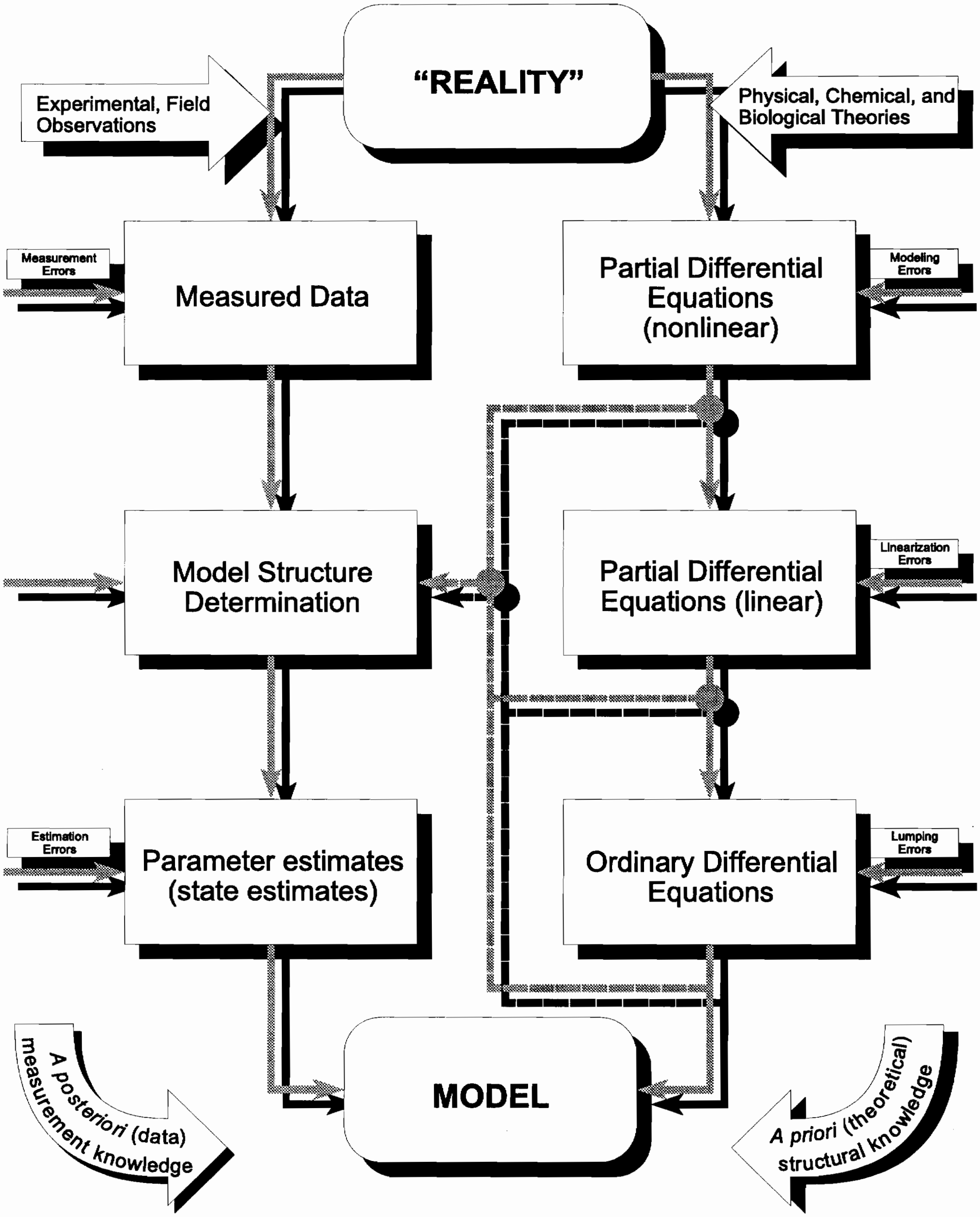
[12]At least other types of hardware different from what is actually known as computer hardware.

[13]Extracted from material handed out on the Surface Water Quality Modeling course given at Virginia Polytechnic Institute and State University, Northern Virginia Graduate Center, Falls Church, Virginia, January 25, 1995.



Adapted from Eykhoff, 1974.

Figure 7: Model Construction Process

Depending on the type of results obtained, models can be further classified as stochastic or deterministic. If one or more variables in the model are regarded as random variables having probability distributions, the model is stochastic. If all the variables are considered free from random alteration and are computed as a direct consequence of the general laws applied, the model is deterministic (Hydrocomp Inc. 1995f).

a. Different Types of Hydrologic Simulation Models

Simulation models can be classified according to dissimilar criteria which in turn may provide a guide for the future selection depending on the required characteristics.

One classification identifies *event models* and *continuous models*. An *event model* is the one that represents a single runoff event occurring over a relatively short period of time (from hours to several days) with relatively short time steps (a few minutes or less) and a more or less detailed schematization of the catchment. The initial conditions of the watershed have to be furnished by the input data and, depending upon how reliable the input is, the accuracy of the results will vary. A *continuous model* performs a representation of the system for a long simulation time, generally several years, using relatively long time steps (one hour) and a more rough outline of the drainage basin. Even though initial conditions have to be supplied for the beginning of the run, their influence becomes less and less important as simulation progresses (Huber 1986).

Examples of *continuous models* are:

- The Storage, Treatment, Overflow, Runoff Model (STORM) designed to be used primarily in planning studies. It is used to evaluate storage and treatment capacity required to reduce pollution from stormwater runoff and CSOs.

- An adaptation of the Hydrologic Engineering Center's computer program, Flood Hydrograph Package (HEC-1C) which performs a simple continuous simulation of basin moisture as a function of precipitation, losses and evapotranspiration.
- The Hydrologic Simulation Program - FORTRAN (HSPF). A very complete package for the synthesis of runoff quality and quantity (Bicknell and others 1993).
- The Streamflow Synthesis and Reservoir Regulation (SSARR) Model designed for continuous simulation and use in river basin system operation.

Examples of *simple event models* are:

- The Storm Water Management Model (SWMM) is one of the most comprehensive models for the analysis of urban storm water runoff. This program also has a module capable of computing the impact of contaminant loadings in the receiving waters.
- The Massachusetts Institute of Technology Catchment Model (MITCAT), very similar to SWMM but without water quality simulation capability.

Depending on the reach of the model it may be regarded as a *comprehensive* or *partial model*. *Comprehensive models* make a complete representation with more or less all details of all significant hydrologic processes affecting runoff, maintaining a water balance and solving in a continuous fashion the equation:

$$\textit{Precipitation} - \textit{Actual Evapotranspiration} \pm \textit{Change in Storage} = \textit{Runoff} \qquad (1)$$

The input is precipitation and other meteorologic data and the output is the catchment hydrograph. The solving of Equation (1) increases the accuracy of the model and constitutes its most important advantage over partial models. *Partial models* represent only a part of the complete runoff process. Compared to comprehensive models they are easier to use.

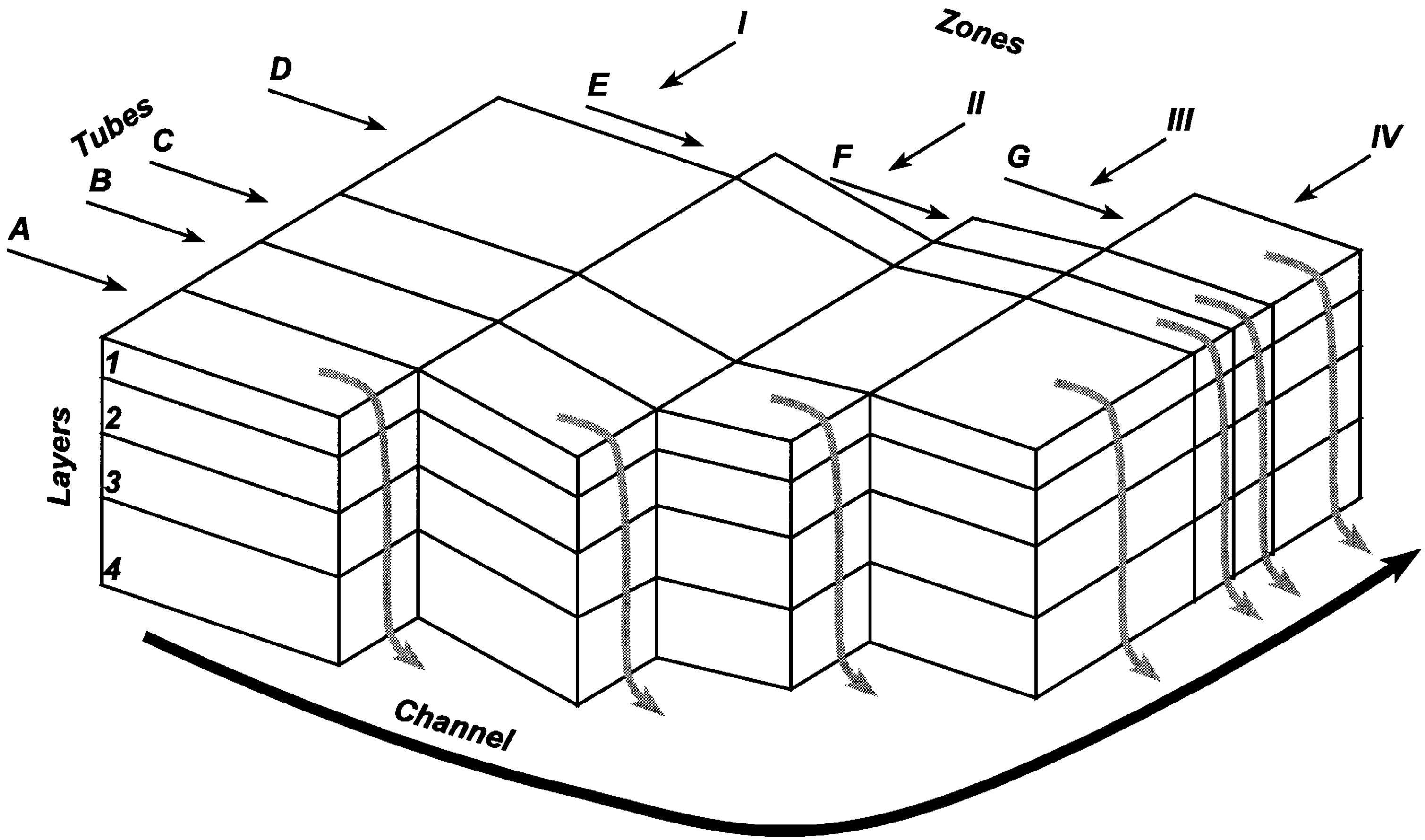
An example of *comprehensive model* is HSPF. Examples of *partial models* or *process oriented models* are:

- The Nonpoint Source Model (NPS) for land areas receiving animal wastes, a model capable of simulating sediment and nitrogen accumulation and losses in runoff from areas receiving manure.
- Models for runoff of pesticides. Bailey and others described in their paper the development of a conceptual model for predicting pesticide runoff from agricultural lands (Bailey, Swank and Nicholson 1974).

Within the input of data for a specific model there are parameters and model coefficients that are needed to perform the different calculations. Those parameters take values given by the user. Depending on the complexity of the model there may be thousands of these parameters. For some models all the parameters have to be calibrated *a priori* using existent data and estimating adequate values. These models are called *calibrated parameter models*. Other models use parameters measured previously by experimental methods or estimated from watershed characteristics or even literature research. They are called *measured parameter models*. Some model coefficients like channel length and cross section, watershed area, and slope can be directly measured using maps or other methods. Other characteristics like soil permeability, chemical rate constants, and sedimentation rates can be experimentally obtained in the laboratory. More difficult parameters can be estimated (channel roughness for example). A model completely using measured parameters is desirable for the simulation of ungaged watersheds. However, no model with such conditions and the characteristics of continuous simulation, acceptable precision and exactness, and applicable for a general situation has yet been developed. Normally a model using a mixture of measured and calibrated parameters is used, in which the calibrated parameters account for the part of the model that allows generality and takes care of any conceptual component of the simulation process. Most models actually used are of this kind.

According to the way in which nonpoint pollution is simulated models can be classified as *lumped* or *distributed* models. Most models fall in the first group while some complex models may have a distributed parameter approach. *Lumped models* are usually coded to utilize average parameter values of drainage basin properties affecting runoff. This averaging of parameters is in some way an averaging of processes occurring in the watershed and when the situation can not be adequately linearized this procedure may lead to significant errors. The watershed is treated as a whole or composed of big areas, in which the characteristics of one of these areas is lumped together, often times using an empirical equation, and the parameter obtained represents the unit as a homogeneous system for that characteristic. A schematic representation of this type of model is shown in Figure 8. *Distributed models* use distributed parameters in which the length, area or volume of the unit is subdivided into small subunits, for which the parameter can be considered as uniform for all the subunits. These subunits, also called elements, are very small compared with the size of the watershed.

The basis for this approach resides in a finite difference representation of the basic differential equation governing the different processes in one, two or three dimensions. While



Adapted from: "Review of Hydrologic and Water Quality Models Used for Simulation of Agricultural Pollution." *Agricultural Nonpoint Source Pollution: Model Selection and Application. Developments in Environmental Modeling.* p. 15. (Novotny 1986).

Figure 8: Lumped Parameter Model Concept

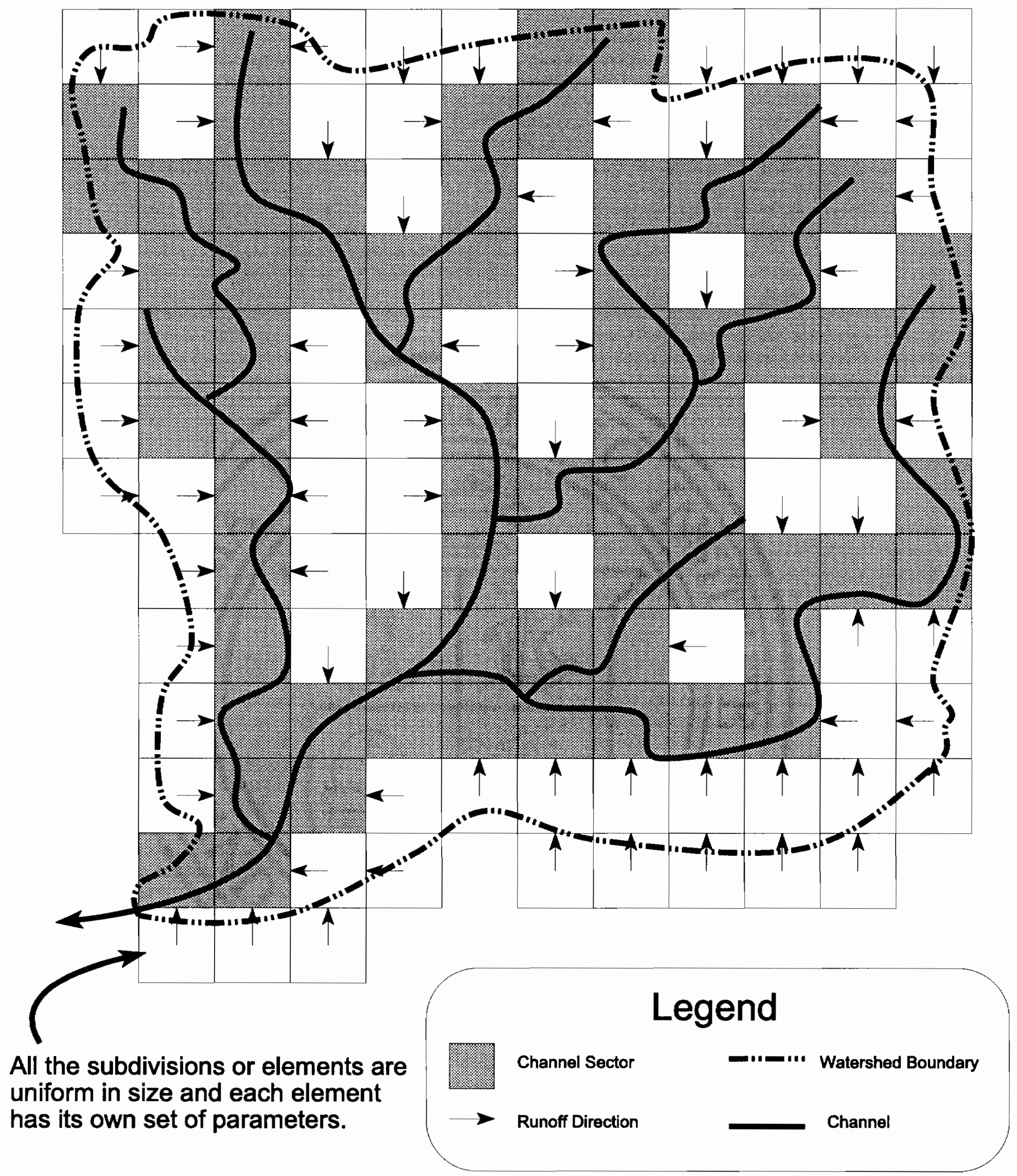
lumped parameter models usually provide one or very few output locations, distributed models can provide output for each finite section. In a lumped model approach, areas located in different parts of the watershed, but sharing similar characteristics, may be considered as a whole. While the output for distributed models can be modeled easily and very effectively, the complexity of these models and their input may preclude their use (Novotny 1986, pp. 12-17). Figure 9 shows the concept of a distributed parameter model.

An example of *distributed parameter model* is:

- The Areal, Nonpoint Source Watershed Environment Response Simulation (ANSWERS), which simulates watershed with primarily agricultural land use. The catchment is divided in square uniform elements. The water motion is provided by the Manning's equation for overland flow. And the outflow of each uniform element is routed to a neighboring element according to the slope of the terrain.

Examples of *lumped parameter models* are:

- The Agricultural Chemical Transport Model (ACTM) designed by the Agricultural Research Service of the U.S. Department of Agriculture. This model contains three submodels that simulate hydrologic response, erosion and chemical transport. The watershed is divided into zones constituted by grouping together areas with similar characteristics for which a lumped parameter is established.
- The Stanford Watershed Model (SWM) developed in the mid 60's at Stanford University to simulate the hydrologic cycle (Crawford and Linsley 1966).



Adapted from: "Review of Hydrologic and Water Quality Models Used for Simulation of Agricultural Pollution." *Agricultural Nonpoint Source Pollution: Model Selection and Application. Developments in Environmental Modeling.* p. 15. (Novotny 1986).

Figure 9: Distributed Parameter Model Concept

There is another classification that divides models into *general* or *special purpose models*. While *general models* are applicable to watersheds of various types and sizes without modifications, just adjusting of parameter values, *special purpose models* are applicable only to a specific type of watershed and they depend on the type of topography, geology and/or land use as well as other characteristics, and if one of them is changed substantial modifications have to be performed in the model in order to make it respond adequately to the variation. These modifications go far beyond parameter calibration.

b. Selection of a Mathematical Model

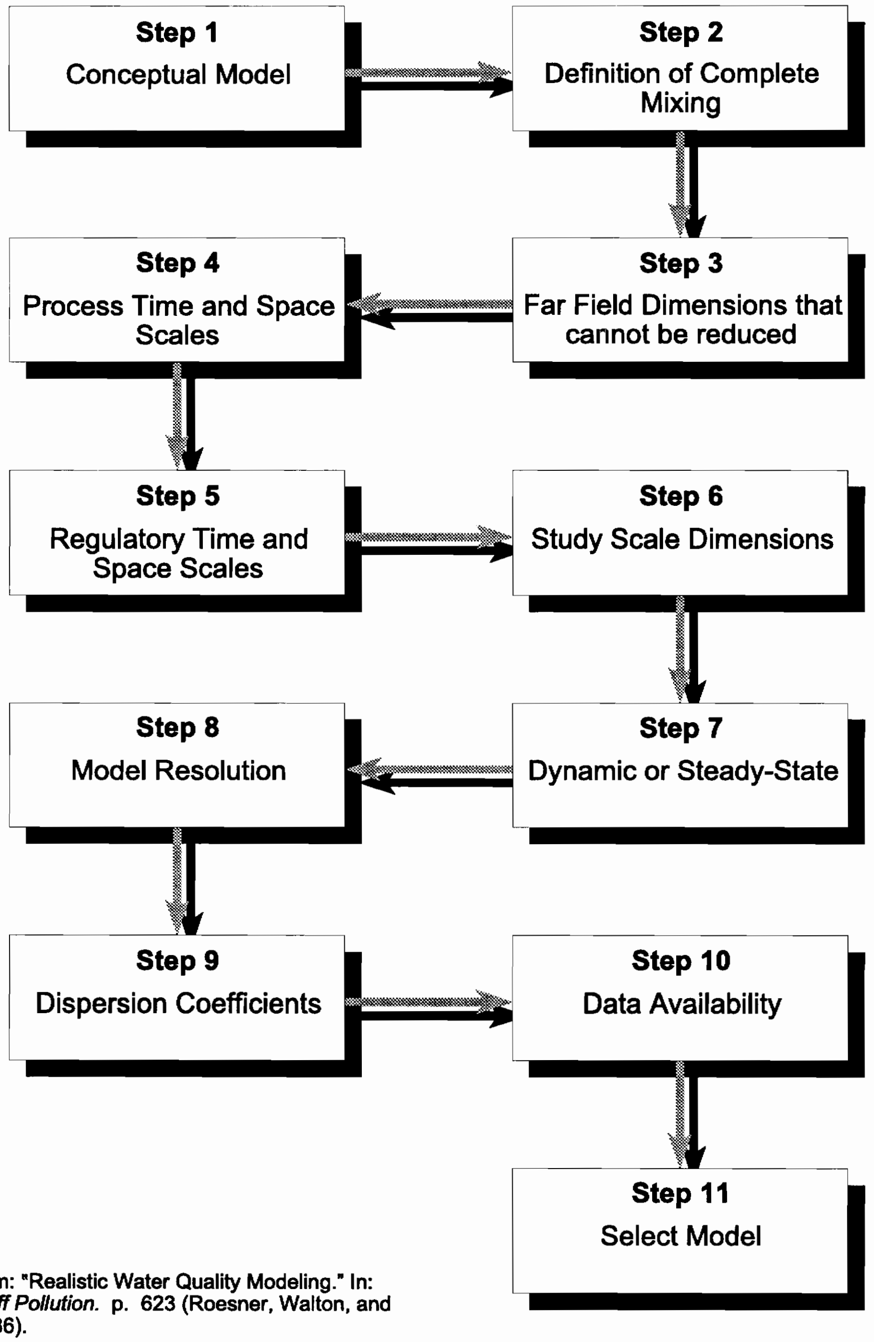
The number of existing models and the lack of documentation makes the task of selection quite difficult, specially for unexperienced modelers. One of the rules that may be applied to model selection should be to select the simplest model that would achieve the purposes traced in the objectives for that modeling effort. However, even this rule may not be totally applicable, since many times objectives may change over the period of model use and some flexibility may be required in order to accommodate new or more sophisticated requirements.

A model may be selected using some or all the classification criteria presented in the previous section (4.a.) or even other classifications. For example models can be chosen based on their sophistication levels (McCutcheon 1989, p. 47). A Level I model used with manual or graphical methods can be used for screening. This type of models is generally based on statistical or deterministic equations and their application requires expertise. A Level II model is usually a simple computer model which may be used for more detailed screening or crude planning. It is used over large areas and long periods of time and is based on deterministic equations, although it is common to use approximations. A Level III model is also computerized but of increased complexity if compared with Level II model. More refined planning can be performed using this type of models. They may be deterministic or stochastic, and the amount of data required is larger. Most operational models fall within Level II and III categories. Finally, a Level IV model is regarded as a very advanced computerized model, based on deterministic equations and used for detailed planning, design and analysis. This type of model is currently in a development and research stage.

Probably the most important criteria for model selection is to base the selection on the objectives of the modeling effort, trying not to choose a too sophisticated or too simple model. This fact has guided many researchers and modelers to develop a selection strategy (Roesner, Walton and Hartigan 1986). A framework for model selection was developed by Roesner and others, with the goal of identifying and evaluating candidate models that can adequately represent the physical, chemical, and biological characteristics of receiving waters. Their process of model selection includes eleven steps, represented in Figure 10, and even though it is mostly oriented to select models for use in estuarine waters, with some modifications it may be used for any receiving waterbody. Table 3 presents a brief discussion of each step.

Other approaches for the task of model selection may be:

- Use models which are readily available to the user or fall within those the user has some experience using.
- Perform a library search for models that may suit the objectives of the modeling effort and reference to bibliographic and/or model specific reports and papers.
- Obtain the advice of experienced modelers.



Adapted from: "Realistic Water Quality Modeling." In: *Urban Runoff Pollution.* p. 623 (Roesner, Walton, and Hartigan 1986).

Figure 10: Model Selection Process

Table 3
Framework for Model Selection

• Step 1: **Develop a Conceptual Model**

The first step is to define the objectives of the water quality modeling effort. Once the objectives have been defined a conceptual model or diagram of the receiving water system can be developed with the purpose of readily visualize all the system's processes. This step has the goal to accumulate and assimilate all the available knowledge of a system so that all major processes and relationships can be included in a numerical model description. From this starting point reductions in complexity can be made systematically to provide adequate representation of the system while meeting the research objectives.

• Step 2: **Definition of Complete Mixing**

For a numerical model, complete mixing is just a theoretical concept. It is necessary to develop a definition of complete mixing over a spatial dimension (length, width and/or depth) providing an acceptable point in which uniformity over that spatial dimension is achieved and that dimension can be neglected.

• Step 3: **Far Field Dimension Reduction**

Using the definition provided in Step 2, a first set of simplifications may be performed trying to reduce the simulation complexity by reducing the number of spatial dimensions to be considered. The approach may be what dimensions can not be neglected in the far field? Considerations here include system stratification and flow reversals.

• Step 4: **Time and Space Scales of Important Processes**

The question of dynamic versus steady-state modeling should begin to be answered in this step. Time and space scales must be compatible with the physical, chemical, and biological processes in study.

• Step 5: **Regulatory Scales**

Many times local/state/federal regulations provide additional time and space scale restrictions and in order to comply with those regulation the model must comply with those restrictions.

• Step 6: **Study Scale Dimension Reduction**

The purpose of this step is, based on the information compiled in the first five steps, determine whether the model can omit spatial dimensions other than the already defined in step 3 and still accomplish the resolution of the processes involved within the regulatory time and space scales.

• Step 7: **Dynamic or Steady-State**

Based on the information provided in steps 1-6, a final decision has to be made about the use of dynamic or steady-state simulation.

• Step 8: **Spatial and Temporal Resolution**

The selection of space and time steps for the numerical model is important in order to provide sufficient resolution for the processes within the prototype. This selection includes considerations of model accuracy and stability.

• Step 9: **Diffusion Coefficients**

The model has to have a reasonable sound basis for its selection of diffusion coefficients. Most dynamic models comply with this requirement.These models are complex, but they are usually well reviewed and many have an agency support what leads to increased confidence. For steady-state models more care should be exercised when selecting appropriate dispersion coefficients.

• Step 10: **Data Availability**

Data is needed for both calibration and verification of the model. If sufficient data is not available, an effort should be done to collect additional supplementary data, if that is not possible, data should be used only for calibration.

• Step 11: **Model Selection**

Once completed steps 1-10, a check list of desired features should be prepared including the conceptual model and several candidate models. This list will allow the evaluation of candidate models and the selection of the best fitted to the simulation objectives.

Source: "Realistic Water Quality Modeling." In: *Urban Runoff Pollution.* pp. 622-645 (Roesner, Walton and Hartigan 1986).

Many times the use of comparative tables describing different models may be useful in selecting an adequate model or at least to discard those not having the features needed to accomplish the primary objectives set. Tables 4 and 5 show a couple of these comparative lists of models.

c. The Hydrologic Simulation Program - FORTRAN (HSPF)

Considering the information presented in Tables 4 and 5 there is a simulation program that presents outstanding capabilities. This computer code is the Hydrologic Simulation Program - FORTRAN (HSPF). In Table 4 it can be seen that only the Water Quality for River-Reservoir Systems (WQRRS) has features similar to those of HSPF, including steady-state and quasi-dynamic simulation. In Table 5 the HSPF model, the Runoff and Routing Model (RROUT) and probably the Minnesota Model for Depressional Watersheds (MMDW) are those that stand out.

Besides, the HSPF has been very well tested and supported by the United States Environmental Protection Agency (EPA). It is an operational model, what means that it has been in use for a relatively long period of time, has been used for people other than the ones that developed the model and has demonstrated good simulation in a number of studies.

Being physically based, models accounting for soil moisture in a continuous way are probably the most accurate models available these days, and HSPF is one of the most comprehensive of them. The HSPF model is proposed to fulfill the goals of this study. Therefore, more information will be provided to describe its characteristics in the following sections.

Table 4
List of Conventional Pollutant Models for Streams and Rivers

MODEL	Spatial domain: Branch. stream	Spatial domain: Segm. stream	Time domain: Steady state	Time domain: Quasi dynamic	Time domain: Dynam.	State variable systems: Hydrau.	Arb. pollut.	BOD/ DO	Nitrog.	Phosp.	Carbon	Solids	Biolog.	Temp.
AUTO-QUAL	✓	✓	✓			✓	✓	✓						
AUTO-QD	✓	✓	✓	✓		✓	✓	✓						
Bauer & Bennett	✓	✓		✓			✓	✓						
DOSAG-I	✓	✓	✓			✓	✓	✓						
DOSAG-III	✓	✓	✓			✓	✓	✓	✓	✓	✓			
DOSCI	✓	✓	✓				✓	✓						
EXPLORE-I	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	
GENQUAL	✓	✓			✓		10							
G475	✓	✓	✓				✓	✓	✓	✓				
HSPF	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
LTM		✓			✓		10							
MIT-DNM	✓	✓			✓	✓	✓		✓					
MIT-DNM (St. Lawrence)	✓	✓			✓	✓	✓	✓	✓	✓			✓	
Overton & Meadows	✓	✓		✓			✓	✓	✓	✓				
PIONEER		✓	✓				✓	✓	✓	✓		✓	✓	
QUAL-I	✓	✓	✓			✓	✓	✓						✓
QUAL-II	✓	✓	✓	✓		✓	✓	✓	✓	✓			✓	✓
RECEIV	✓	✓			✓	✓	✓	✓						
RECEIV-II	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	
RIBAM	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				
RIVSCI	✓	✓	✓		✓	✓	✓	✓	✓	✓			✓	
SNSIM	✓	✓	✓				✓	✓						
SMM	✓	✓	✓				✓	✓	✓	✓				
SSAM-IV	✓	✓	✓				✓	✓	✓	✓			✓	
WASP	✓	✓			✓		19							
WASP/SUISAN	✓	✓			✓		✓	✓	✓	✓			✓	
WIRQAS	✓	✓	✓				✓	✓	✓					
WRECEV	✓	✓			✓	✓	✓	✓						
WQAM	✓	✓	✓				✓	✓	✓	✓				
WQMM	✓	✓			✓	✓	✓	✓	✓				✓	
WQRRS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

A ✓ means that the model includes the attribute heading the list, a number for the "Arbitrary pollutant" column denotes the number of user specified constituents that may include BOD, DO, and other variables listed.

Adapted from McCutcheon 1989, page 48.

Table 5
Model Capabilities Contrast Matrix

MODEL NAME	Continuous or Event	Generally Available or Proprietary	Simulates Snowmelt	Simulates Depressional Wetland Storage	Simulates Surface Drainage Projects	Simulates Sub-surf. Drainage Projects	Open Channel Flow Routing	Spatial Variability of Precipitation	Calculates Water Balance	Reproduces Historic Flows	Compatible with Major Computer Systems
DLBM	Cont.	Prop.	Yes	Implicitly	Yes	Implicitly	Yes	Yes	Yes	Yes	IBM only
HEC-1	Event	Avail.	Yes	No	No	No	Yes	Yes	No	Yes	Yes
HSPF	Cont.	Avail.	Yes	Implicitly	Yes	Implicitly	Yes	Yes	Yes	Yes	Yes
HYMO	Event	Avail.	No	Implicitly	Implicitly	No	Yes	Yes	No	?	Yes
ILLUDAS	Event	Avail.	No	No	Yes	Yes	Yes	No	No	Yes	Yes
MITCAT	Cont. or Event	Prop.	No	Implicitly	Yes	Implicitly	Yes	Yes	?	Yes	Yes
MMDW	Cont.	Avail.	Yes	Yes	Yes	Yes	Yes	?	Yes	Yes (limited)	Yes
RROUT	Cont. or Event	Avail.	Yes	Implicitly	Yes	Implicitly	Yes	Yes	Yes	Yes	Yes
SSARR	Cont.	Avail.	Yes	Implicitly	Implicitly	No	Yes	Yes	No	?	IBM/CDC
STORM	Cont.	Avail.	Yes	Implicitly	No	No	No	Yes	No	No	Yes
TR-20	Event	Avail.	No	Implicitly	Yes	No	Yes	Yes	No	Yes (limited)	Yes
USDAHL	Cont.	Avail.	Implicitly	Implicitly	No	No	No	No	No	Yes (limited)	Yes
USGSRR	Cont.	Avail.	No	Implicitly	Yes	Implicitly	Yes	Yes	Yes	Yes	Yes

Adapted from a Summary Report of the Department of the Army, St. Paul District, Corps of Engineers (CH_2M Hill 1980, pp. 2-5).

5. HSPF: History and Development

HSPF is a comprehensive simulation model for predicting watershed hydrology and water quality. The model uses information from time history of rainfall, temperature, solar radiation, evapotranspiration and other time series, along with land surface characteristics and land-use patterns to simulate the processes that occur in a watershed. In this way flow rate, sediment load, nutrient, pesticide and other water quality constituent concentrations are predicted. Therefore, the output of the simulation is a time history of water quantity and quality. Combining runoff simulation with water routing and instream processes, the program allows for the determination of flows and concentrations at a specific point in the watershed, for example, a lake or reservoir inflow.

HSPF has its origin in the Stanford Watershed Model (SWM) developed by Crawford and Linsley at Stanford University, California, in the mid 60's (Crawford and Linsley 1966). There were a number of studies at Stanford that contributed to the initial development of HSPF (Crawford 1995). Crawford's Ph.D. dissertation (Crawford 1962) also published as a technical report (Crawford and Linsley 1962) provided the first steps in the synthesis of continuous streamflow hydrographs on a computer. The idea was the modeling of the hydrologic cycle, using rainfall and evaporation data to produce simulated streamflow records. Other studies provided further development including snowmelt simulation (Anderson and Crawford 1964) and sediment transport (Negev 1967). The SWM had several modifications, the Kentucky Model being an example. Working for a consulting firm specialized in hydrologic modeling and analysis (Hydrocomp Inc. 1995d), Crawford and Linsley in subsequent development of the Stanford Watershed Model created the Hydrocomp Simulation Program (HSP) in 1969.

In the late 60's and early 70's the need for the development of mathematical models capable of simulating the transport and transformation of pollutants through a watershed was identified by the EPA. The EPA Environmental Research Laboratory in Athens, Georgia, began intensive research aimed at producing a management tool able to help in the anticipation of environmental problems. There were two approaches in this study. One was oriented to the development of a distributed parameter model, the Simulation of Contaminant Reactions and Movement (SCRAM). The other was oriented toward developing a lumped parameter model, the Pesticide Transport and Runoff (PTR) model. Using the first approach, the simulation of a few months of streamflow lasted too long, limiting the distributed parameter model utility as a management tool.

The PTR model applied technology and concepts already present in the SWM and HSP models. In 1973, further development, testing, and modifications of the PTR model resulted in the development of the Agricultural Runoff Management (ARM) model allowing the modeling of pesticides and nutrients in agricultural lands. ARM was developed further to a new version (ARM-II) and became a fully operational tool in the mid 70's. A User's Manual was written (Donigian and Davis 1978) and its refined algorithms for soil moisture, temperature, pesticide degradation, nutrient transformations and plant nutrient uptakes were tested on watersheds in Georgia and Michigan.

During the development of the ARM model the need for a simpler version of the model, using algorithms compatible with current urban models such as SWMM and STORM, was identified. In 1974, the development of the Nonpoint Source (NPS) model began. One of the major differences with existing models were its capability for snowmelt simulation and a refined and more detailed sediment transport algorithm (Donigian and Crawford 1976). The hydrologic algorithms of the NPS model, like those of the ARM model, were based in the SWM and the HSP models. Subsequent testing of the NPS model revealed its ability to simulate nutrient loading in surface runoff from both urban and agricultural watersheds (Donigian and Crawford 1977).

The information provided by models like ARM and NPS is very important for environmental planning. However, management decisions should also consider impacts in aquatic environment. In-stream processes are very important, and they were not considered in the ARM and NPS models. The experience gathered with the HSP model propelled the development of a new model including features of the three simulation packages: ARM, NPS, and HSP. In this way the HSPF project was born in 1976.

Again, two approachs were possible for the construction of the new program. The first could have been to merge the modules of existing software, using interfaces requiring a minimum of new code and alterations to the old programs. Even though this approach was probably the one involving less investment, the shortcomings of the existing models and the possibility of having inconsistency problems among them precluded this strategy of being developed. The second option was the selected one and involved the creation of a completely new code in a structured programming language (FORTRAN) and having the functions and features of the ancestor models (ARM, NPS, and HSP). Information about software development can be found in a couple of papers written by Johanson and Kittle (Johanson 1983, pp. 40-42; Johanson and Kittle 1983, pp. 45-53).

Some features of the Sediment-Radionuclide Transport (SERATRA) model including pesticide fate and sediment transport algorithms were included in 1979 (Onishi 1979). Since its development HSPF has been tested in several applications and presently it is in its 10.10 version with release 11 almost ready. More detailed information about the HSPF development process can be found in some articles written by Barnwell, Johanson, and Kittle (Barnwell 1980; Barnwell and Johanson 1981; Barnwell and Kittle 1984).

6. HSPF: Application in Different Studies

Since the time when its first version was made available, several studies in the United States and around the world have used HSPF for simulation and analysis of different watersheds. Because it is a general or comprehensive program its use ranges from simulation of very small watersheds for very specific studies to simulation of very large watersheds covering a broad spectrum of objectives. For these reasons this section will cover only a selection of these studies.

a. The Four Mile Creek and Iowa River Studies

A series of studies were performed in the Iowa-Cedar rivers watershed in Iowa beginning in 1979. These studies formed part of a comprehensive Field Evaluation Program (FEP) sponsored by the EPA and coordinated by the Environmental Research Laboratory in Athens, Georgia. The objectives of this Program was to evaluate and demonstrate the usefulness of agricultural best management practices to obtain water quality goals, and the application of HSPF as a water quality planning and management tool, in combination with the Chemical Migration and Risk Assessment (CMRA) methodology.

The first step was an extensive field monitoring and data collection program at the Four Mile Creek site, a 52 square kilometers (km^2)(20 square miles (mi^2)) watershed located in an intensively farmed agricultural area in the east-central part of Iowa (Donigian, Imhoff, and Bicknell 1983a; 1983b). The same methodology, using some of the parameters developed for the small watershed were then applied to the 7240 km^2 (2795 mi^2) Iowa River watershed above the Coralville Reservoir. See Figure 11 for the location of these watersheds. These studies demonstrated the applicability of HSPF for large watershed studies and provided the basis for the development of an application guide for the program (Donigian and others 1984). This application demonstrated the value of this simulation program for the modeling of agricultural runoff and resultant water quality in a large basin (Imhoff, Bicknell, and Donigian 1983).

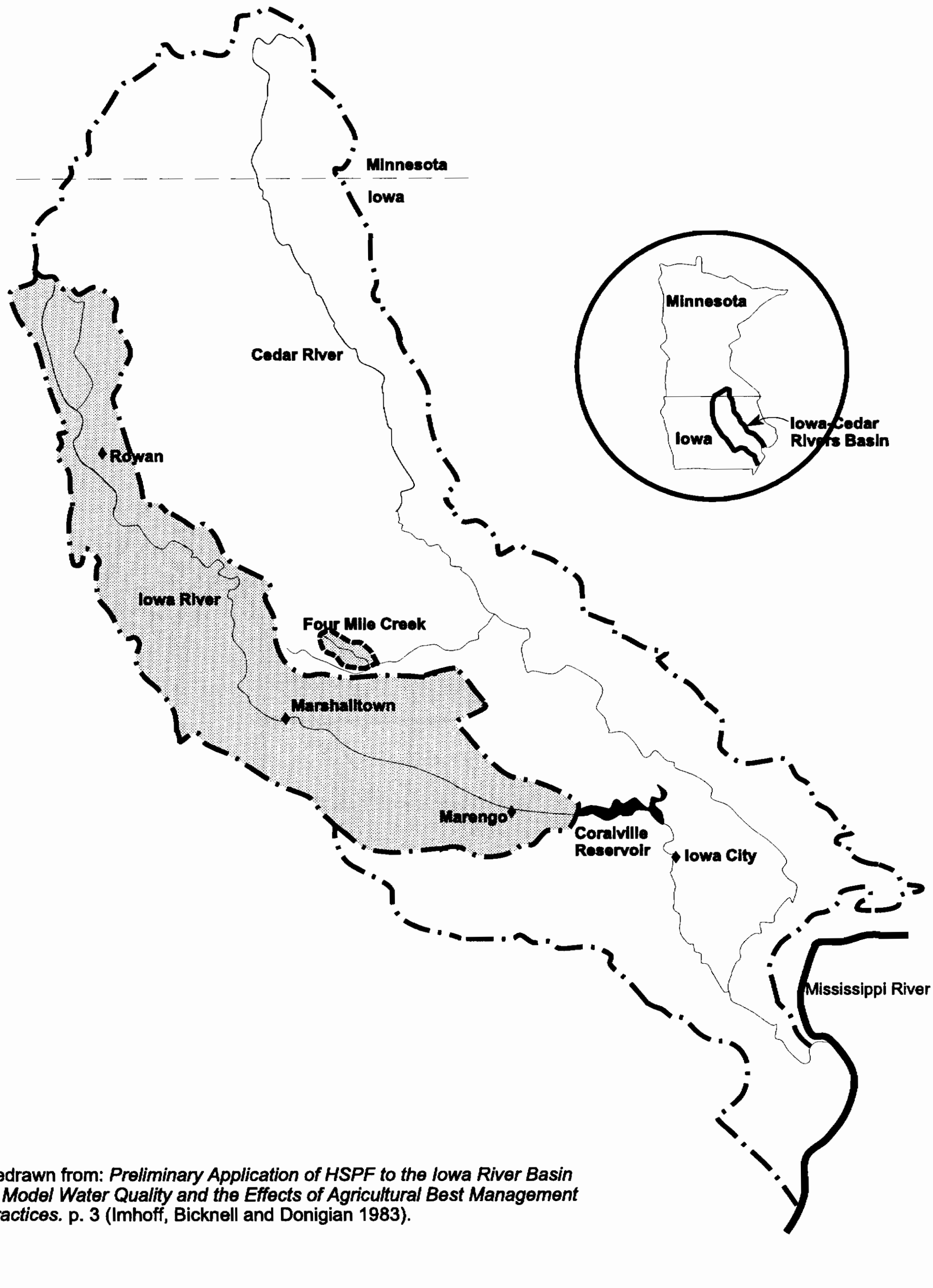
b. The Mgeni River studies in South Africa

As a part of a larger project for the Mgeni River system in South Africa, a catchment of 4000 km^2 (1544 mi^2), HSPF was applied to two drainage basins, one small and highly urbanized, 90 hectares (ha) (0.9 km^2, 0.35 mi^2) in area, and the other much larger and rural, 300 km^2 (116 mi^2) of surface area (Johanson 1989).

An interesting fact in this study, specially for the small watershed, is that for very small watersheds to simulate a storm, it is necessary to have a relatively short time step. However, if a continuous time step of a few minutes is maintained between storms, excessive time is used for computer simulation. The solution was to use the RESUME mode in HSPF, which allows the break down of the simulation period into many consecutive periods, forming an event, inter-event, event, inter-event, etc., sequence. The simulation is done by making several runs, each covering one of these periods, and using the output of one period as an input for the following.

c. The Chesapeake Bay Watershed Model

The Chesapeake Bay Model is formed by two models, the Chesapeake Bay Watershed Model and the Chesapeake Hydrodynamic Water Quality Model. The Chesapeake Bay Watershed



Redrawn from: *Preliminary Application of HSPF to the Iowa River Basin to Model Water Quality and the Effects of Agricultural Best Management Practices.* p. 3 (Imhoff, Bicknell and Donigian 1983).

Figure 11
Location of the Four Mile Creek and Iowa River Watersheds

Model is an adaptation of the HSPF model, with the objective of predicting the delivery of nutrients to the Bay from point and nonpoint sources. The output of HSPF is then used as input for the water quality model of the Bay.

One of the major objectives for the use of the Chesapeake Bay Watershed Model (HSPF), was the evaluation of BMPs in the Bay area. The conclusions obtained during phase II of the project indicated that hydrologic calibration was critical to obtaining an excellent simulation of mean annual flow, and generally a good-to-very-good simulation for the watershed (U.S. Army Corps of Engineers 1994).

d. Other studies

Some studies have examined the interfacing between HSPF and Geographic Information System (GIS) technology. Examples of these studies are: the one performed in the West Wellfield Interim Protection Area, located in west Dade County in south Florida (Tsihrintzis, Fuentes and Gadipudi 1994); and the one performed in the Unity Sub-basin, a 90.1 km^2 (34.8 mi^2) watershed located in the north of the Patuxent River Watershed in Maryland (Fisher 1989). Both studies concluded that the use of GIS in conjunction with HSPF could be highly beneficial. One of the benefits of the combination between GIS and simulation technologies is the identification of critical areas within a watershed, and the promotion of measures like BMPs to control nutrient and pesticide runoff in those areas where it is more necessary.

Another study compiled information for the Patuxent River Basin with the goal of developing a data base for water quality modeling (Fisher and Summers 1987). This study also took advantage of the GIS technology in combination with HSPF. This research provides information about the gathering of data for the use of modeling programs and GIS systems.

In an EPA report presented by Franz and Lieu, the use of remote sensing data for input into HSPF for a study of some sections of the Occoquan Watershed was evaluated (Franz and Lieu 1981). The report concluded that the use of data obtained with the LANDSAT satellite performed at least as well as data obtained by conventional methods. It also concluded that savings between 30 and 50 percent in the costs of set up and operations could be obtained by using LANDSAT data.

Other studies that can be referenced in this section are:

- A study in a big south Florida watershed to simulate the dynamics of phosphorus transport in wetlands (Nichols and Timpe 1985).
- A hydrologic simulation of a 146 km^2 watershed in the north-west of Tennessee to determine agricultural runoff levels (Chew, Moore and Smith 1991).
- The development of an Expert System for the calibration and application of HSPF (Lumb and Kittle 1993).
- The development of an Interactive User Interface for easier data input into HSPF call ANNIE-IDE (Kittle, Hummel and Imhoff 1989).

7. The Occoquan River Watershed

The Occoquan River is one of the major tributaries of the Potomac River. Located at the southwest of the Washington Metropolitan Area, its watershed covers the eastern part of Fauquier County, most of Prince William County, the western part of Fairfax County, and a small triangular area at the south of Loudoun County (See Figure 1). It also includes the cities of

Manassas and Manassas Park. In the late 50's, the Occoquan Dam was constructed just downstream of the point where Hooes Run pours its waters into the Occoquan River. The direct consequence was the formation of the Occoquan Reservoir. The Reservoir has its tailwaters where Bull Run and Occoquan Creek meet. Actually, the Reservoir extends approximately 2.5 miles into each of these two major Occoquan River tributaries. This impoundment has a full-pool capacity of 3.71×10^7 cubic meters (m^3) and constitutes one of the main raw water supplies for the area.

The Watershed has the following channel configuration: the main stem is formed by the Occoquan River (see Figure 12), discharging into the Belmont and Occoquan Bays and in turn to the Potomac River. The Occoquan River receives the waters of the following tributaries (from tailwaters to mouth): Occoquan Creek, which receives the waters of two major tributaries, Cedar Run and Broad Run, and some smaller tributaries including Long Branch, Cabin Run, Purcell Branch, Crooked Creek, and other small streams; Bull Run, which receives the waters of Little Bull Run, Cub Run, and Popes Head Creek and some small streams; and then there are some tributaries discharging into the reservoir, like Wolf Run, Sandy Run, and Hooes Run (almost at the Occoquan Dam point); finally after the Occoquan Dam the river receives the waters of some small streams and Giles Run almost at the point of discharge into Belmont Bay.

Inside the Watershed are located the cities of Manassas and Manassas Park, as well as a small portion of the west of Fairfax City. Part of the north of Woodbridge, and the towns of Brookfield, Greenbriar, and Warrenton are also located inside the Watershed. Besides the Occoquan River Reservoir, Lake Manassas and Lake Jackson are the larger man-made impoundments located in the Watershed. Some other smaller impoundments inside the Occoquan River Basin are: Lake Brittle, Lake Buttle, Silver Lake, Germantown Lake, Warrenton Reservoir, and Dalton Pond.

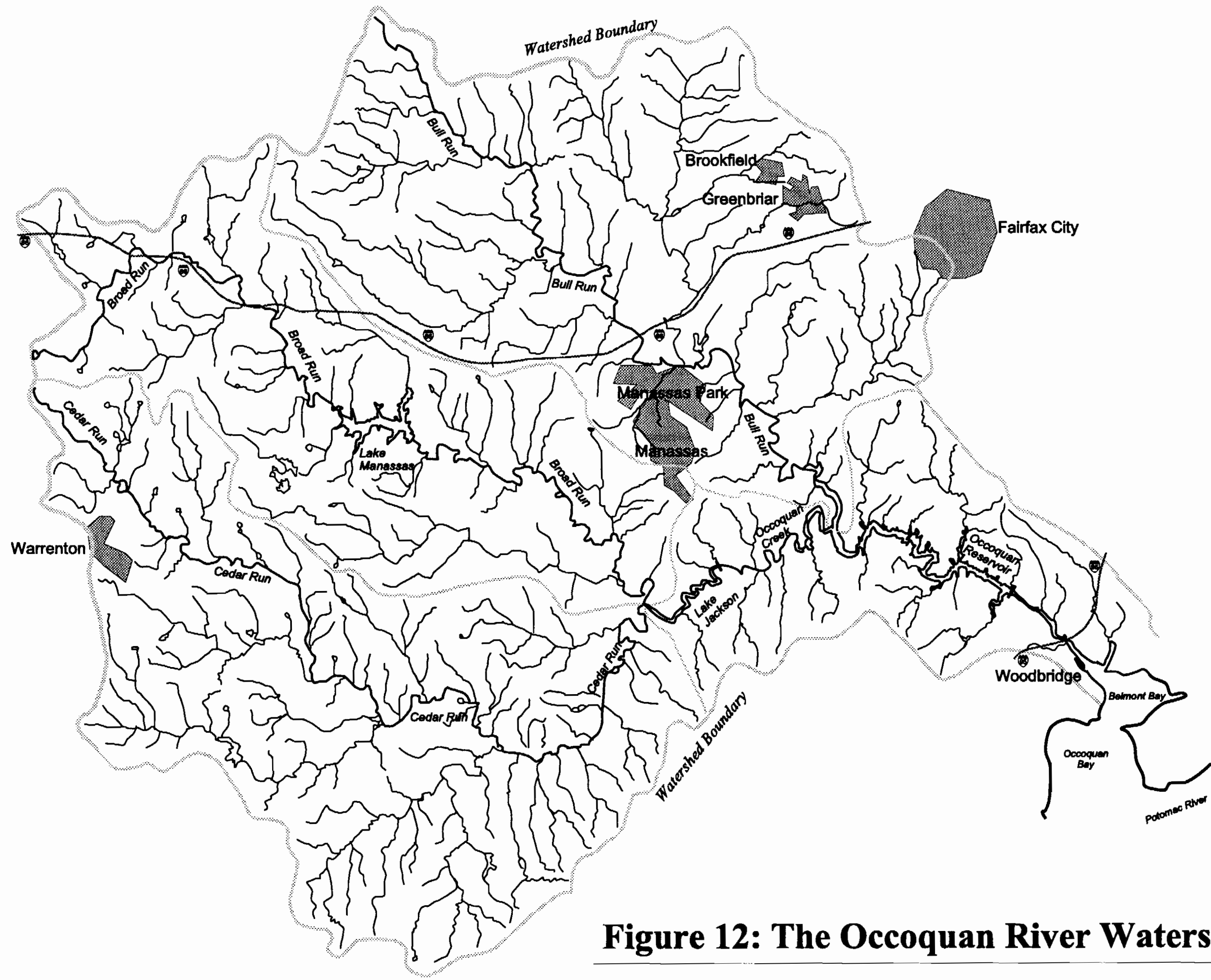


Figure 12: The Occoquan River Watershed

The following description of the soils and geological characteristics was extracted from a paper written by Weand and Grizzard in May 1983 referring to the evaluation of management tools in the Occoquan River Watershed:

> "The basin is situated astride the Coastal Plain and Piedmont physiographic provinces, with the area tributary to the reservoir lying in the latter. For the most part, the soils of the upper basin overlie the Triassic Shales of the Middle Piedmont, and may be generally characterized as sedimentary sandstones and shales." (Weand and Grizzard 1983, p. 1)

Between 55 and 60 percent of the Occoquan River Watershed used to be covered by forests, about 35 percent with agricultural lands and between 5 and 10 percent with urban developments (industrial, commercial and residential). However, in the early 70's a strong urban development process began, which has been accelerating its pace during the 80's and the 90's. As a result, this urbanization caused not only a more intense need for raw water supplies, but also a strong necessity for protection of existing sources. The expansion of impervious surface due to the construction of roads, streets, parking lots, residences, commerce, and industrial parks, caused an increase in the amount of stormwater reaching the streams. Fairfax and Prince William counties have been considered for several decades two of the fastest developing regions in the country. This fact has generated concern for the effects this urbanization could cause in the area and its water bodies. For these reasons this area was selected for a study with the use of a powerful tool such as the HSPF simulation program.

III. MATERIALS AND METHODS

Because of the special characteristics of this study, most of the work was done on a computer. The first section of this chapter will describe those items that might be considered as materials needed for this research and the second section will indicate the methodology applied.

1. Materials

There are basically three groups of materials needed for this study. The first one is computer hardware, the second is computer software, and the third is input data.

a. Computer Hardware

The computer used for this study was a Packard Bell Legend 933® Personal Computer[14] with the following specifications[15]:

- Motherboard with Intel® 80486DX microprocessor with mathematical co-processor, 33 megahertz (MHz) clock speed.
- 8 Megabytes (MB) of Random Access Memory (RAM), 4 MB soldered to the motherboard and 4 MB in Single In-line Memory Modules (SIMMs) added to improve performance.

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[14]Registered marks, trade marks, and brand names are acknowledged when possible. However their mention in this study does not address their preference over others. They were suitable available materials and they were used on that basis.

[15]The specifications given were obtained from the *Packard Bell 486 Personal Computer User's Manual* that came packed with the computer when the latter was bought in 1993. The manual does not have bibliographic information. Specifications for the computer appear in Appendix C of the Manual.

- 8 Kilobytes (KB) of internal cache.
- The computer had the following built-in Input/Outputs: PS/2 type mouse port, keyboard controller and interface, real time clock/calendar, CMOS RAM to maintain system configuration, speaker interface, four AT-compatible expansion slots (one of them occupied with a manual scanner), floppy disk drive controller, IDE interface, serial port, parallel port, extended VGA port, and internal Modem port.
- 3.5", 1.44 MB floppy disk drive (drive A:).
- 5.25", 1.2 MB floppy disk drive (drive B:).
- 170 MB hard disk drive (drive C:).
- 540 MB hard disk drive (drive D:) added to provide additional storage, (more than 300 MB of free space were available at the time of this study).
- Super VGA color monitor (14-inch).
- PS/2 type Mouse.
- Standard keyboard (101 keys).

Connected to the computer were a Hewlett Packard (HP) LaserJet 4L® printer and a Logitech® ScanMan™ manual scanner.

b. Computer Software

The software needed to perform this simulation is listed below:

- Hydrologic Simulation Program - FORTRAN (HSPF) Version 10.10 U.S. EPA Release, November 1993[16].

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[16]Information obtained from the READ.ME file coming with the HSPF software. The HSPF program was obtained from the Center for Exposure Assessment Modeling (CEAM), U.S. Environmental Protection Agency (U.S. EPA), Office of Research and Development, Environmental Research Laboratory, 960 College Station Road, Athens, Georgia 30605-2720. (706)546-3549.

- Microsoft® Disk Operating System (MS-DOS®) version 6.22.
- 386MAX® Memory Manager.
- WordPerfect® 5.1 for DOS.

The following statement lines had to be added to the system CONFIG.SYS file:

```
BREAK=ON
BUFFERS=30
FILES=30
DEVICE=C:\ANSI.SYS
DEVICE=C:\386MAX\386MAX.SYS PRO=C:\386MAX\386MAX.PRO
SHELL=C:\COMMAND.COM C:\ /e:512 /p
```

An updated version of HSPF was obtained. The first versions of the program were produced by Hydrocomp, Inc., a consulting firm in California, and HSP and HSPx were proprietary programs of this company. In the beginning of the 80's, the United States Environmental Protection Agency (US EPA) contracted the company for the development of a comprehensive watershed simulation program and HSPF was created. At the time of this research, HSPF was the property of the US EPA and it was freely distributed either in tape, diskettes or through the Internet.

The release used for this study, version 10.10 of December 1993, was obtained from the Center for Exposure Assessment Modeling at the following address:

Center for Exposure Assessment Modeling
United States Environmental Protection Agency
960 College Station Road
Athens, GA 30605-2720

The program can also be downloaded using file transfer protocol (ftp) from the EPA pages on the Internet. As to November of 1995 the release available using this procedure was version 10.11. Another release with major modifications and improvements (version 11) was expected by late 1995 or the first months of 1996.

The program was installed in the PC following the instructions printed on the label of the first of a set of six disks. Special attention was dedicated to the README files that accompany the program, since they have proved to be very useful in describing the technical characteristics of HSPF, and in detailing important modifications that had to be performed in the system files of the Operating System. Examples on how to run the program, and explanations about the set of test files were also provided in those README files. These User Control Input (UCI) test files had the function of providing training by example and also testing the correct functioning of the program. Since the set of UCI test files came with the corresponding set of OUTPUT files, the program could easily be tested.

The verification of the program's functioning was also explained in the README files and was executed as directed.

c. Input Data

HSPF uses basically two types of data to perform hydrologic and water quality simulation. The first type of data is called time series and consists of meteorological data provided in such a way that there is a value every certain time period called a time step. The second type of data is a group of parameters measured, estimated or used from literature values. Within this type of data, some values can not be obtained and normally they are used as calibration parameters. Time series is a fixed type of data because for a specific moment in time there is one and only one value for a specific condition (temperature, rainfall, humidity, solar radiation, etc.). Selected parameters, instead, may vary during the process of calibration in order to adapt the simulated results to the observed results. Other parameters may vary based on different watershed situations during the period of simulation.

One of the steps, detailed in the following section (2. Methodology), in the process of determining the possible use of this program, was to obtain sufficient data for the simulation input to allow confidence in the modeling results. In fact, modeling results have a better quality when good data are used to run the model.

The information needed for simulation input was not only important for the operation of the model but also for the watershed segmentation process. Meteorological data are available from NOAA weather stations; physical data from the U.S. Geological Survey, U.S. Army Corps of Engineers, U.S. Soil Conservation Service, state geological surveys, state departments of water resources, natural resources councils, forest services, and local universities; water quality parameters can be obtained directly from the HSPF User's Manual (Bicknell and others 1993), the ARM Model User's Manual (Donigian and Davis 1978), CREAMS User's Manual (Knisel 1980), Tetra Tech Report (Zison and others 1978), and some other reports.

Table 6 shows the time series of weather data needed depending upon the modules and sections of HSPF that are used. Table 7 shows the different types and sources of data needed based on the same criteria as those of Table 6.

For the specific case of the Cub Run Watershed study, input data were obtained from diverse sources. The search for data itself constituted one of the longest parts of this research.

Table 6
Meteorological Time Series Requirements Depending on Used Modules and Sections of HSPF

METEOROLOGIC DATA ▾	ACTIVE MODULE SECTIONS										
	PERLND						RCHRES				
	ATEMP	SNOW	PWATER	SEDMNT	PSTEMP	SOIL/ AGROCHEM.	HYDR	HTRCH	GQUAL	OXRX	PLANK
Precipitation	✓	✓	✓	✓		✓[1]	?	?			
Potential Evapo-transpiration			✓	✓[1]		✓[1]	?				
Air Temperature	✓	✓			✓	✓[2]		✓			
Wind Movement		✓						✓	✓[3]	✓[4]	
Solar Radiation		✓						✓			✓
Dewpoint Temperature		✓						✓			
Cloud Cover								✓	✓[5]		

Notes:
- ✓ Required time series
- ? Optional time series
- 1 Required for section PWATER
- 2 Required for section PSTEMP
- 3 Required if volatilization from lake is simulated
- 4 Required if RCHRES is a lake
- 5 Required if photolysis is simulated

Adapted from *Application Guide for Hydrological Simulation Program - FORTRAN (HSPF)* (Donigian and others 1984, p. 28), revised using information from the *Hydrological Simulation Program - FORTRAN: User's Manual for Release 10* (Bicknell and others 1993).

Table 7
Types and Sources of Data
Depending on Used Modules and Sections of HSPF

MODULE PERLND	
SECTION ATEMP	Topographical maps.
SECTION SNOW	Topographical maps, vegetation maps or aerial photos, field observation, ARM User's Manual (Donigian and Davis 1978).
SECTION PWATER	Vegetation maps or aerial photos, soils maps, topographical maps, land use maps, ARM User's Manual, timing of disturbances.
SECTION SEDMNT	Soils maps, data on farming practices, ARM User's Manual.
SECTION PSTEMP	Air temperature data, field soil temperature data.
SECTION PWTGAS	None.
SECTION PQUAL	Local stormwater quality data, NPS User's Manual (Donigian and Crawford 1979).
SECTION MSTLAY	ARM User's Manual.
SECTION PEST	ARM User's Manual, pesticide literature, field data.
SECTION NITR	ARM User's Manual, field application rates, kinetic data, crop life cycle.
SECTION PHOS	ARM User's Manual, field application rates, kinetic data, crop life cycle.
SECTION TRACER	None.
MODULE IMPLND	
SECTION ATEMP	Topographical maps.
SECTION SNOW	Topographical maps, vegetation maps or aerial photos, field observation, ARM User's Manual.
SECTION IWATER	Aerial photos, stormwater management plans, NPS User's Manual.
SECTION SOLIDS	Street cleaning data, land use data, local stormwater quality data, NPS User's Manual.
SECTION IWTGAS	Air temperature data, water temperature data.
SECTION IQUAL	Local stormwater quality data, NPS User's Manual.
MODULE RCHRES	
SECTION HYDR	Channel geometry data, streamflow gage records and rating curves, topographical maps.
SECTION ADCALC	None.
SECTION CONS	None.
SECTION HTRCH	Topographical maps, aerial photos.
SECTION SEDTRN	Bed sediment data, instream sediment loadings data, particle size analysis.
SECTION GQUAL	Laboratory or field kinetic data, literature values for partition coefficients, organic matter content of suspended and bed sediments, environmental conditions (e.g. pH, temperature).
SECTION OXRX	Literature or field kinetic data, channel bottom samples, instream oxygen and BOD data.
SECTION NUTRX	Literature or field kinetic data, instream nutrient data, channel bottom samples.
SECTION PLANK	Literature or field kinetic data, instream biotic data.
SECTION PHCARB	None.

Adapted from *Application Guide for Hydrological Simulation Program - FORTRAN (HSPF)* (Donigian and others 1984, pp. 80-81), revised using information from the *Hydrological Simulation Program - FORTRAN: User's Manual for Release 10* (Bicknell and others 1993).

Since the model was prepared to simulate the hydrological conditions of this Watershed, the number of time series required was reduced to basically three:

- A time series of hourly flow at the downstream limit of the simulated area.
- An hourly rainfall time series for a weather station close to or inside the Watershed.
- A daily evapotranspiration time series for a weather station close to or inside the Watershed.

Some parameters were measured directly from topographical maps, and other were obtained from the mainframe version of the Occoquan Basin Model (NVPDC).

How these time series were obtained and processed will be explained in the Methodology section.

2. Methodology

The use of a comprehensive simulation program to achieve specific goals is a task requiring a considerable amount of effort and time. Large amounts of data are needed. Then these data have to be processed for their input into the simulation program. Finally, large amounts of output data are obtained and they have to be analyzed. The calibration process, itself, constitutes a major investment of effort. For these reasons, and to avoid duplication of work, a meticulous methodology had to be applied.

To have a broad idea of the methodology used for a complete calibration study, a general approach is presented first. Then, the specific adaptation (for the Cub Run study) of this approach will be detailed.

a. A General Approach

The first step in this methodology is to develop a modeling strategy. HSPF requires abundant and significant information to characterize a watershed from the physical, chemical, and biological aspects, including details about land use, soil, meteorology, channel geometry, instream concentrations, streamflow records, and other aspects.

Several factors are involved in the data selection process for the study area. First, general availability of data should be considered. If records from different sources are available, then the selection of the most appropriate ones has to be done. The judgement may be based on the following criteria:

- Specify weather behavior for the study area using a long period of time as a basis.
- Determine the differences between the behavior mentioned in the previous point and long term records from specific weather stations in or close to the study area.
- Determine weather variations depending on the different areas of the Watershed. This is important also for the process of segmentation.
- Review the accuracy and completeness of different weather station records.
- If variability of weather records in different points of the Watershed is large, consider the use of different records for different segments.

Weather data is very important because it is normally used in a preliminary attempt to divide the study area into segments with similar characteristics. The process of data evaluation and selection was described by Donigian and others in the *Application Guide for Hydrological Simulation Program - FORTRAN (HSPF)*, and used in the application of HSPF for extensive studies in the Four Mile Creek and the Iowa River Watersheds in Iowa (Bicknell, Donigian, and

Barnwell 1985, pp. 1141-1153; Donigian and others 1984, pp. 29-38; Donigian, Imhoff, and Bicknell 1983a; Donigian, Imhoff, and Bicknell 1983b; Imhoff, Bicknell, and Donigian 1983).

The particular procedure used for the Iowa studies was generalized and is presented step by step in Table 8. As a rule of thumb, for small watersheds (less than 100 km^2) one weather station record is normally sufficient; for bigger watersheds (more than 100 km^2) generally three or more weather station records may be required. Of course, these are general assumptions and small watersheds with large weather variations may require more than one weather station record and medium or large watersheds with minimum weather variations may be simulated without problem using only one weather station record. Sometimes data availability may restrict the use of more than one weather station record.

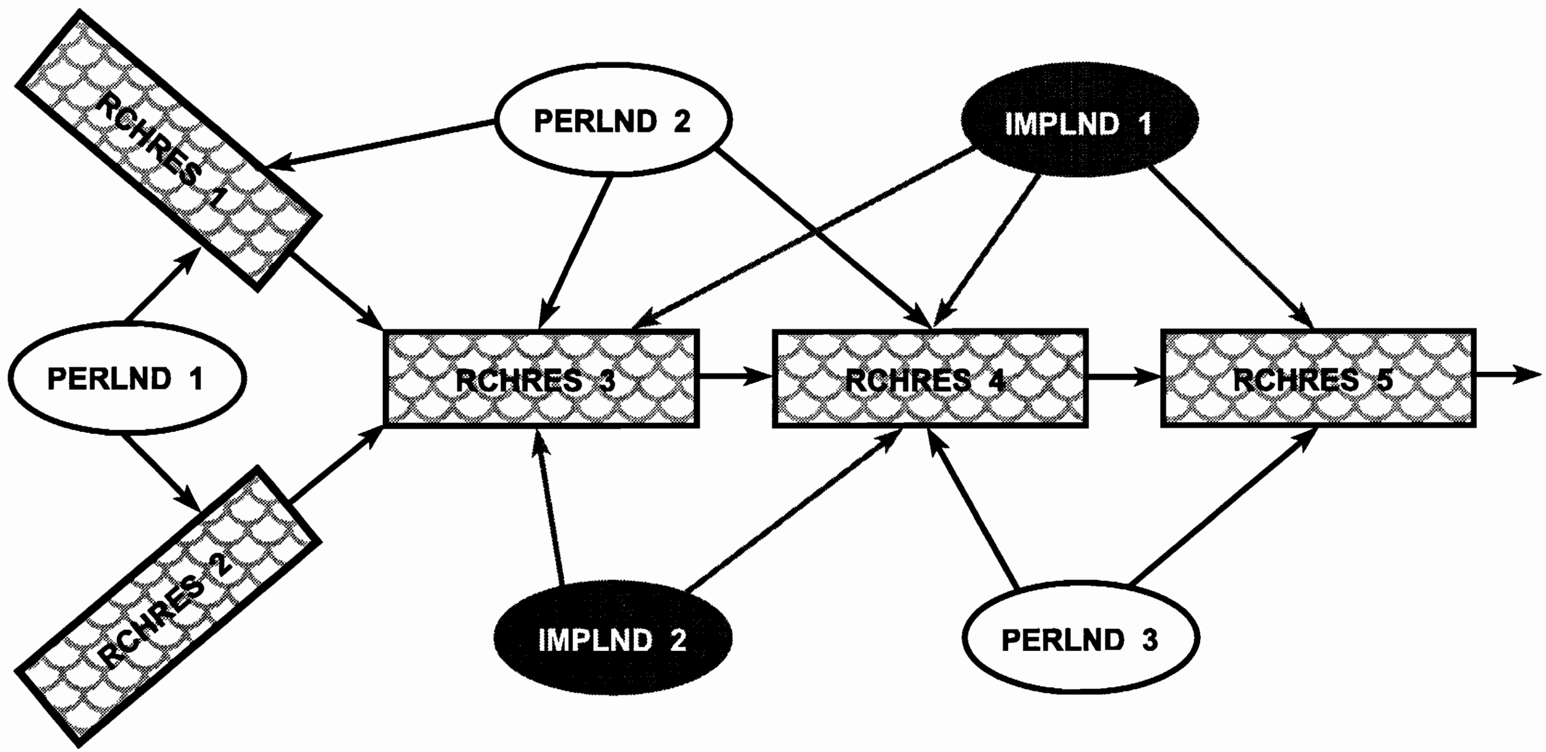
After adequate data have been obtained, the next step would be the division of the watershed into land segments in such a way that each segment can be assumed to produce a homogeneous hydrologic and water quality response. Also, the partition of the channel system into "reaches", each of them with similar hydraulic characteristics, has to be done. The whole drainage basin can be represented by the reach network and the portions of land (segments) draining into each reach. The simulation of any land segment yields runoff and pollutant loads per unit of area entering into the channel system. The runoff and loads calculated per unit of surface are then multiplied by the area of that land segment determining the total runoff and pollutant load discharging into that reach. When these processes are performed in the simulation for every reach, in conjunction with the modeling of instream hydraulics and water quality processes, the result is the simulation of the entire watershed (see Figure 13).

A segment is a portion of land which exhibits a homogeneous hydrologic and water quality response. Therefore, only one set of parameters will be necessary to characterize all the

Table 8
Weather Data Evaluation and Selection Process

◆ **Step 1:**	Mark in a map all the meteorologic stations located inside or near the watershed being studied.
◆ **Step 2:**	Obtain long term weather behavior data and plot them in the form of isopleth maps. These maps will be very valuable to assess the need of preliminary meteorologic segmentation.
◆ **Step 3:**	Based on NOAA summaries for each weather station, tabulate the length of record and mean annual values for each type of weather data to be used in the simulation effort.
◆ **Step 4:**	Using the isopleth maps mark the weather stations and their respective mean values for the different types of weather data. Use this information to determine which weather stations present the most representative data for a particular region within the watershed
◆ **Step 5:**	Assess the availability of streamflow and water quality data. Compare the record period with those for weather data to define the best period of time the calibration effort should use.
◆ **Step 6:**	Specify the type of weather data missing for a particular station for a given period.
◆ **Step 7:**	For the simulation period, study the short term weather trends looking for possible anomalies that may preclude the use of those records as representative for a region or area. An example could be the use of the record from a weather station which registered information for very intense but localized precipitation events. If those records are used for a large area, the results may be oversimulated.
◆ **Step 8:**	If snowmelt is simulated, air temperature data is very important. The comparison of Spring warming timing trends in the air for different stations is important to correlate the observed increases in streamflow at gaging stations.
◆ **Step 9:**	Select the best weather station representing each data type for a region or segment.
◆ **Step 10:**	Fill gaps in the records using those of nearby weather stations.

Adapted from *Application Guide for Hydrological Simulation Program - FORTRAN (HSPF).* pp. 37-38 (Donigian and others 1984).



Adapted from: "Integration of runoff and receiving water models for comprehensive watershed simulation and analysis of agricultural management alternatives" In: *Agricultural Nonpoint Source Pollution: Model Selection and Application Developments in Environmental Modeling.* p. 272 (Donigian 1986).

PERLND: **Pervious Land Segment**
IMPLND: **Impervious Land Segment**
RCHRES: **Stream Channel Segment**

Figure 13: Linkages required for HSPF to simulate a complex watershed

surface considered as a segment. For the purpose of HSPF simulation a segment does not necessarily mean a contiguous surface. In fact, separated portions of land may be considered within one segment as long as they have similar response from the pollution and hydrologic standpoints. The total area in a particular segment has to be known.

The segmentation process aims to subdivide the watershed into parcels of land with similar meteorologic patterns, soil characteristics, and land uses. A preliminary segmentation can be done using meteorologic patterns and soil characteristics. In this preliminary segmentation process, weather data has a key function. This first watershed subdivision will render segment groups. A segment group is a sector of the watershed in which the weather and soil characteristics are uniform for the entire area. Many times, and if it is possible, the borders of these segment groups might approach those of the sub-basins forming the watershed (or the limits of the reach contributing areas). The final step in the segmentation process is the division of the segment groups into pervious land segments and impervious land segments designated by only one type of land use. For example, if three segment groups where obtained in the preliminary subdivision, and each of these segment groups can subsequently be divided into four different types of land use, a total of twelve segments will have to be simulated.

The next step is the channel segmentation and characterization of each reach contributing area. Hydrogeometry is the primary factor for segmentation. To achieve an adequate segmentation the following channel characteristics have to be known:

- length of channel
- average slope of channel
- velocity at mean flow
- flow-through time for mean flow

Three factors provide criteria for channel segmentation:

- *Reach length:* If the flow time through an individual reach approaches the time step for simulation, the HSPF hydraulic routing algorithms will be more accurate. Sometimes for long rivers this criteria may produce a large number of reaches. Thus, when that occurs, the flow time through an individual reach may approach twice the time step, or several times the time step.
- *Slope:* An individual reach should have a reasonably uniform slope. Major drops in bottom elevation due to natural falls and reservoirs should serve as boundaries between reaches.
- *Just above the entry point of a tributary:* HSPF assumes that all local flows enter the reach at the upstream boundary. It is reasonable then to define reaches so that the downstream limit is before the entrance of a tributary flow. The same is applicable for major point source discharges. In this way, any incoming flow enters the reach in the upstream boundary, as assumed by the program.

Gaging stations may also constitute important points for the definition of reach limits for their importance in the calibration process. Segmentation of channels at points where streamflow gages are located is usual. Special studies may require further channel segmentation. One example could be the examination of the effects of a particular point source discharge. In that case the point source has to be the only one in the defined reach.

Table 9 shows a series of steps that have to be performed once an appropriate reach segmentation scheme has been obtained.

Table 9
Steps to Follow after the Channel Segmentation Process

◆ **Step 1:**	In a good topographical map delineate the watershed and the stream channel.
◆ **Step 2:**	Locate and mark reach boundaries on the map.
◆ **Step 3:**	Delineate areas contributing runoff and pollution loads to each of the reaches.
◆ **Step 4:**	Calculate, measure or obtain the best estimate for the areas delineated in the previous step.
◆ **Step 5:**	Based on map contours or other data calculate the average slope for each reach.
◆ **Step 6:**	Determine the possibility of considering the contributing areas limits and the land segments boundaries as only one line. This step aims to a simplification of the modeling effort.
◆ **Step 7:**	Develop tables known as FTABLES for each reach for their use in the HSPF input sequence. These tables have to specify the values of surface area, reach volume, and discharge for a series of selected depths of the water in the reach.
◆ **Step 8:**	Prepare a summary table containing the following information: reach designation number, length, average channel slope, contributing area.

Adapted from *Application Guide for Hydrological Simulation Program - FORTRAN (HSPF)* (Donigian and others 1984, pp. 52-53).

After data gathering and segmentation operations are completed, the calibration procedure can be performed. The methodology followed for this process is the one outlined in Table 10 for land surface calibration and Table 11 for instream calibration, and they are presented in more detail in Section 7 of the *Application Guide for Hydrological Simulation Program - FORTRAN (HSPF)* (Donigian and others 1984, pp. 84-115). The order of calibration —first the hydrologic simulation, then the sediment simulation, and finally the water quality simulation— is due to the way in which HSPF is structured. Sediment simulation depends on the results of hydrologic simulation, and water quality simulation depends on the results of sediment and hydrologic simulations. If sediment simulation were calibrated first, after calibrating the hydrologic simulation the sediment simulation would be out of calibration, because algorithms in the hydrologic simulation influence the sediment processes. The same is valid for water quality calibration. It is important then to know the way in which the program performs the simulation of the different components to avoid duplication of work and waste of efforts. This concept can be seen in other modeling studies (Schafer and others 1982). Figure 14 shows a generalized definition of the calibration process.

b. The Cub Run Study

The Cub Run Subwatershed (called the Watershed or Segment 9), is located over the north central portion of the Occoquan River Drainage Basin. With a surface of little more than 49 square miles, it drains waters from the southern part of Loudoun County and the western part of Fairfax County, in the Northern Virginia area.

Table 10
Land Surface Calibration Steps

These steps are valid for Pervious Land Segments (PERLND) as well as for Impervious Land Segments (IMPLND)

◆ **Step 1:**	Estimate individual values for all type of parameters.
◆ **Step 2:**	Execute hydrologic calibration run.
◆ **Step 3:**	Compare simulated and observed data for monthly and annual runoff volumes.
◆ **Step 4:**	If this comparison results in a good agreement between simulated and observed values, skip step 5 and go to step 6. If the agreement is poor or there is no agreement, adjust hydrologic calibration parameters and initial conditions if necessary and go to step 5.
◆ **Step 5:**	Repeat steps 2 through 4.
◆ **Step 6:**	Perform the comparison of simulated and recorded hydrographs for selected storm events.
◆ **Step 7:**	If this comparison results in a good agreement between simulated and recorded hydrographs, skip step 8 and go to step 9. On the contrary situation, adjust hydrologic calibration parameters to improve storm hydrograph simulation and go to step 8.
◆ **Step 8:**	Execute additional calibration run and repeat steps 6 and 7.
◆ **Step 9:**	Execute sediment calibration run.
◆ **Step 10:**	Compare simulated and observed data for sediment loss, if observed values are available.
◆ **Step 11:**	Compare simulated and recorded values for storm sediment graphs for selected events.
◆ **Step 12:**	If these comparisons yield a good agreement between simulated and recorded values skip step 13 and go to step 14. If there is no agreement or the agreement is poor, adjust sediment calibration parameters to improve simulation of monthly and annual values, and selected storm sediment graphs, and go to step 13.
◆ **Step 13:**	Execute additional calibration run and repeat steps 10 through 12.
◆ **Step 14:**	Execute water quality calibration run.
◆ **Step 15:**	Compare simulated and observed data for water quality component monthly and annual losses, if observed values are available.
◆ **Step 16:**	Evaluate pollutant state variables and compare simulated and observed values, if these are available.
◆ **Step 17:**	Compare simulated and recorded values for pollutant graphs (concentration and/or mass removal) for selected events.
◆ **Step 18:**	If these comparisons yield a good agreement between simulated and recorded values the land surface calibration process is finished. If there is no agreement or the agreement is poor, adjust water quality constituents calibration parameters to improve simulation of monthly and annual losses and pollutant state variables values, as well as selected storm pollutant graphs, and go to step 19.
◆ **Step 19:**	Execute additional calibration run and repeat steps 15 through 18.

Adapted from *Application Guide for Hydrological Simulation Program - FORTRAN (HSPF)* (Donigian and others 1984, pp. 85-86).

Table 11
Instream Calibration Steps

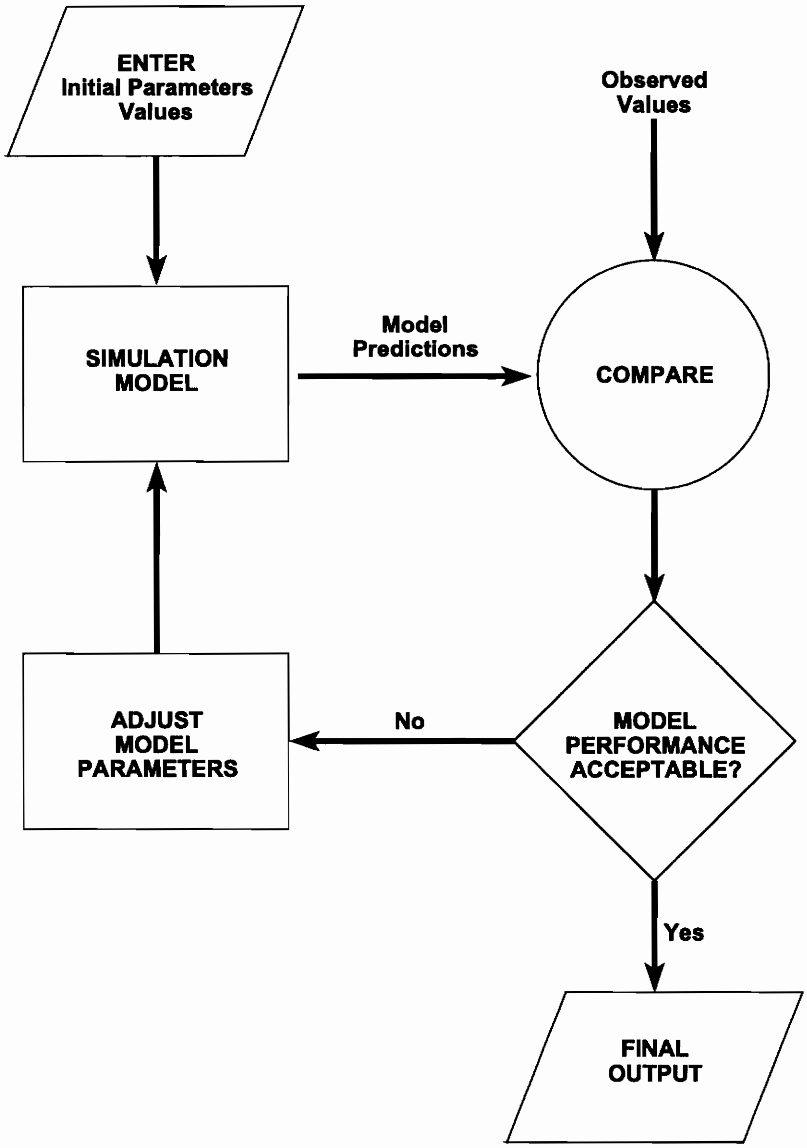
◆ **Step 1:**	Estimate initial values for all type of parameters.
◆ **Step 2:**	Execute hydrologic simulation run.
◆ **Step 3:**	Compare simulated and recorded streamflow values for the calibration period.
◆ **Step 4:**	If this comparison results in a good agreement between simulated and recorded values, skip step 5 and go to step 6. If the agreement is poor, or there is no agreement, adjust the FTABLE values, and the initial conditions if necessary and go to step 5.
◆ **Step 5:**	Execute additional hydrologic simulation run and repeat steps 3 and 4.
◆ **Step 6:**	If water temperature is simulated, execute calibration run for temperature parameters. If water temperature is not simulated skip steps 7, 8, and 9 and go directly to step 10.
◆ **Step 7:**	Compare simulated and recorded values for temperature graphs for the calibration period.
◆ **Step 8:**	If this comparison results in a good agreement between simulated and recorded values, skip step 9 and go to step 10. If the agreement is poor, or there is no agreement, adjust temperature calibration parameters, and go to step 9.
◆ **Step 9:**	Execute additional calibration run for temperature parameters and repeat steps 7 and 8.
◆ **Step 10:**	If sediment is simulated, execute calibration run for sediment parameters, if sediment is not simulated, skip steps 11, 12, 13, 14, and 15 and go directly to step 16.
◆ **Step 11:**	Compare simulated and recorded values for monthly and annual sediment loadings.
◆ **Step 12:**	Compare simulated and recorded values for sediment graphs for selected storm events.
◆ **Step 13:**	Evaluate bed sediment behavior and compare with available data.
◆ **Step 14:**	If these comparisons result in a good agreement between simulated and recorded values, skip step 15 and go to step 16. If the agreement is poor, or there is no agreement, adjust sediment calibration parameters, and go to step 15.
◆ **Step 15:**	Execute additional calibration run for sediment parameters and repeat steps 11 through 14.
◆ **Step 16:**	If a generalized quality constituents (GQUAL) is simulated, execute calibration run for GQUAL parameters, if no GQUAL is simulated, skip steps 17, 18, 19, 20, 21, and 22 and go directly to step 23.
◆ **Step 17:**	Compare simulated and recorded values for monthly and annual GQUAL loadings.
◆ **Step 18:**	Compare simulated and recorded values for GQUAL graphs for selected storm events.
◆ **Step 19:**	Evaluate bed GQUAL behavior and compare with available data.
◆ **Step 20:**	If these comparisons result in a good agreement between simulated and recorded values, skip step 21 and go to step 22. If the agreement is poor, or there is no agreement, adjust GQUAL calibration parameters, and go to step 21.
◆ **Step 21:**	Execute additional calibration run for GQUAL parameters and repeat steps 17 through 20.
◆ **Step 22:**	If an additional GQUAL is simulated repeat steps 16 through 21. If no additional GQUAL is simulated go to step 23.

(Continued)

Table 11 (continued)
Instream Calibration Steps

◆ **Step 23:**	If dissolved oxygen (DO) and biochemical oxygen demand (BOD) are simulated, and nutrients and plankton are not simulated, execute calibration run for DO and BOD parameters and go to step 24. If nutrients are simulated, skip steps 24, 25, 26, 27 and 28 and go directly to step 29.
◆ **Step 24:**	Execute DO and BOD parameters calibration run.
◆ **Step 25:**	Evaluate the effects of these parameters on the DO and BOD simulations with printed output and constituent graphs.
◆ **Step 26:**	Compare simulated and recorded values for these constituents graphs.
◆ **Step 27:**	If these comparisons result in a good agreement between simulated and recorded values, skip step 28 and go to step 39. If the agreement is poor, or there is no agreement, adjust oxygen parameter values to improve both simulations (for DO and BOD) simultaneously, and go to step 28.
◆ **Step 28:**	Execute additional simulation run for DO and BOD parameters and repeat steps 25 through 27.
◆ **Step 29:**	If nutrients are simulated and plankton is not simulated, execute calibration run for nutrient parameters and go to step 30. If plankton is simulated skip steps 30, 31, 32 and 33 and go directly to step 34.
◆ **Step 30:**	Evaluate the effects of these parameters on the DO and nutrient simulations with printed output and constituent graphs.
◆ **Step 31:**	Compare simulated and recorded values for these constituent graphs.
◆ **Step 32:**	If these comparisons result in a good agreement between simulated and recorded values, skip step 33 and go to step 39. If the agreement is poor, or there is no agreement, adjust nutrient parameter values to improve DO simulation (if nitrification is simulated) and nutrients simulations. If adjustments improve nutrients simulations but harm the DO simulation, consider whether adjustment of DO parameters can compensate. Once all adjustments are done go to step 33.
◆ **Step 33:**	Execute additional nutrients and DO calibration run and repeat steps 30 through 32.
◆ **Step 34:**	If plankton is simulated execute calibration run for plankton parameters. If plankton is not simulated skip steps 35, 36, 37, and 38 and go directly to step 39.
◆ **Step 35:**	Evaluate the effects that plankton simulation is having on dissolved oxygen, BOD, nutrients and plankton values, examining printed output and constituent graphs.
◆ **Step 36:**	Compare simulated and recorded values for these constituent graphs.
◆ **Step 37:**	If these comparisons result in a good agreement between simulated and recorded values, skip step 38 and go to step 39. If the agreement is poor, or there is no agreement, adjust plankton parameter values to improve most or all the simulations. Consider the calibration of parameters other than plankton parameters to improve simulations (DO, BOD, and/or nutrient parameters). Once all adjustments are done go to step 38.
◆ **Step 38:**	Execute additional calibration run and repeat steps 35 through 37.
◆ **Step 39:**	If pH and carbon cycle are simulated execute calibration run for pH and carbon parameters. If none are simulated the calibration process is finished.
◆ **Step 40:**	Compare simulated and recorded values for pH and carbon constituents graphs for the calibration period.
◆ **Step 41:**	If this comparison results in a good agreement between simulated and recorded values, skip step 42 and the calibration process is finished. If the agreement is poor, or there is no agreement, adjust pH and carbon cycle calibration parameters, and go to step 42.
◆ **Step 42:**	Execute additional calibration run and repeat steps 40 and 41.

Adapted from *Application Guide for Hydrological Simulation Program - FORTRAN (HSPF)* (Donigian and others 1984, pp. 86-89).



Adapted from: "Calibration and testing of nutrient and pesticide transport models." In: *Agricultural Management and Water Quality* (Young and Alward 1983).

Figure 14
General Model Calibration Process

The main stream is Cub Run and it exhibits a dendritic drainage pattern (Maxey 1964, p. 4-3), the main tributaries are, from tails to mouth: Dead Run, Sand Branch, Cain Branch, Flatlick Branch, Elklick Run and Big Rocky Run (see Figure 3).

Almost all the Watershed is located over the Triassic Lowland, with gentle slopes and generally thin overburden. The drainage basins are poorly defined. Most of the watershed is located in the Triassic bedrock. The characteristics of this bedrock exert great control on the base flow because of the high bulk permeability of the Triassic Sandstones and Shales and their low storage capability. The effects are rapid drainage to streams and very low base flows with the result of many streams going dry during the late summer (Froelich and Zennone 1985; U.S. Department of Agriculture 1960). The geology and soils of the region characterize Segment 9 as natural areas of high runoff.

Main features of the Watershed are: part of the Dulles Airport runways on the northern portion of the watershed, the urban zones of Brookfield and Greenbriar to the east, Route 50 crossing the Watershed from the east to the north-west, on the east the West Ox Road roughly delimits the water divide leaving the intersection of Route 50 and Interstate 66 as well as the Fair Oaks Mall just outside the eastern boundary. The southernmost point may be roughly indicated by the intersection of Compton Road and Interstate 66. The aerial photograph in the attached envelope shows the Cub Run Watershed and the transparent over-layer allows for an easier identification of the main streams and features.

From the geological point of view, the Cub Run Watershed was quite uniform. The same applied to its soil characteristics.

After the first attempts of simulation it was determined that an hourly flow time series at the point where Cub Run is crossed by Compton Road, at the downstream boundary of the watershed, was needed for the calibration procedures. This time series was of primary importance in comparing observed and simulated results, as will be discussed later in the Results and Discussion chapter.

The raw data was obtained in diskette form from the Occoquan Watershed Monitoring Laboratory, in a FoxPro® database format. The information obtained from the Laboratory was for the Gaging Station ST50, located on Compton Road, and the time series were daily for the years 1983 and 1984, and hourly for 1988 and 1989. The calibration of storms (particular events that last normally some hours but no more than a couple of days) required the use of hourly flow information. For that reason, at this point the study focussed on the year 1989. A quality control of the information provided was performed and the database file for 1989 was transformed and corrected in order to obtain an adequate time series. Appendix B shows the transformation process for the flow information, as well as the time series obtained.

The other two time series required were precipitation and evapotranspiration. Climatic data was prepared in sequential format (these formats are presented in the section 4.9 of the HSPF User's Manual and required for the introduction of time series in a time series database called Watershed Data Management) for the National Airport, the weather station at The Plains and for Dulles Airport.

At the beginning of the process of data collection only daily data for Dulles Airport was found (National Oceanic and Atmospheric Administration 1989a). This triggered a study of the differences between the hourly records of The Plains and National Airport and a comparison between the daily records of The Plains, National Airport and Dulles Airport to see if data from the first two weather stations could be used in the simulation of the Cub Run Watershed (National Oceanic and Atmospheric Administration 1989b).

To have an approximate idea of the different weather station's location with respect to the Watershed, Table 12 was constructed.

The study of the precipitation time series for daily records revealed substantial differences between The Plains, National Airport and Dulles Airport (see Appendix C). This stressed even more the need to find the best possible record for the closest weather station.

Therefore, the search for Dulles Airport hourly precipitation records was intensified. Unfortunately only a six-hour time step record for Dulles Airport was found (National Oceanic and Atmospheric Administration 1989c). However this one was considered to be the best available resource for precipitation and was the one finally used.

With respect to evaporation data, it was only available from the Piedmont Research Station, and they produced a seasonal (April to October) evaporation record with daily reports. Further investigation with the National Climatic Data Center (NCDC) in Asheville, North Carolina, revealed the existence of a monthly potential evapotranspiration record for the same station. This record was used to correlate the seasonal daily record for evaporation with potential evapotranspiration and to supplement the months for which the seasonal record was not recorded. Since no apparent simple correlation existed between evaporation and potential evapotranspiration (Veihmeyer 1964), a new sequential file was created disaggregating the monthly evapotranspiration record into daily values.

All the meteorological information was put in sequential file format.

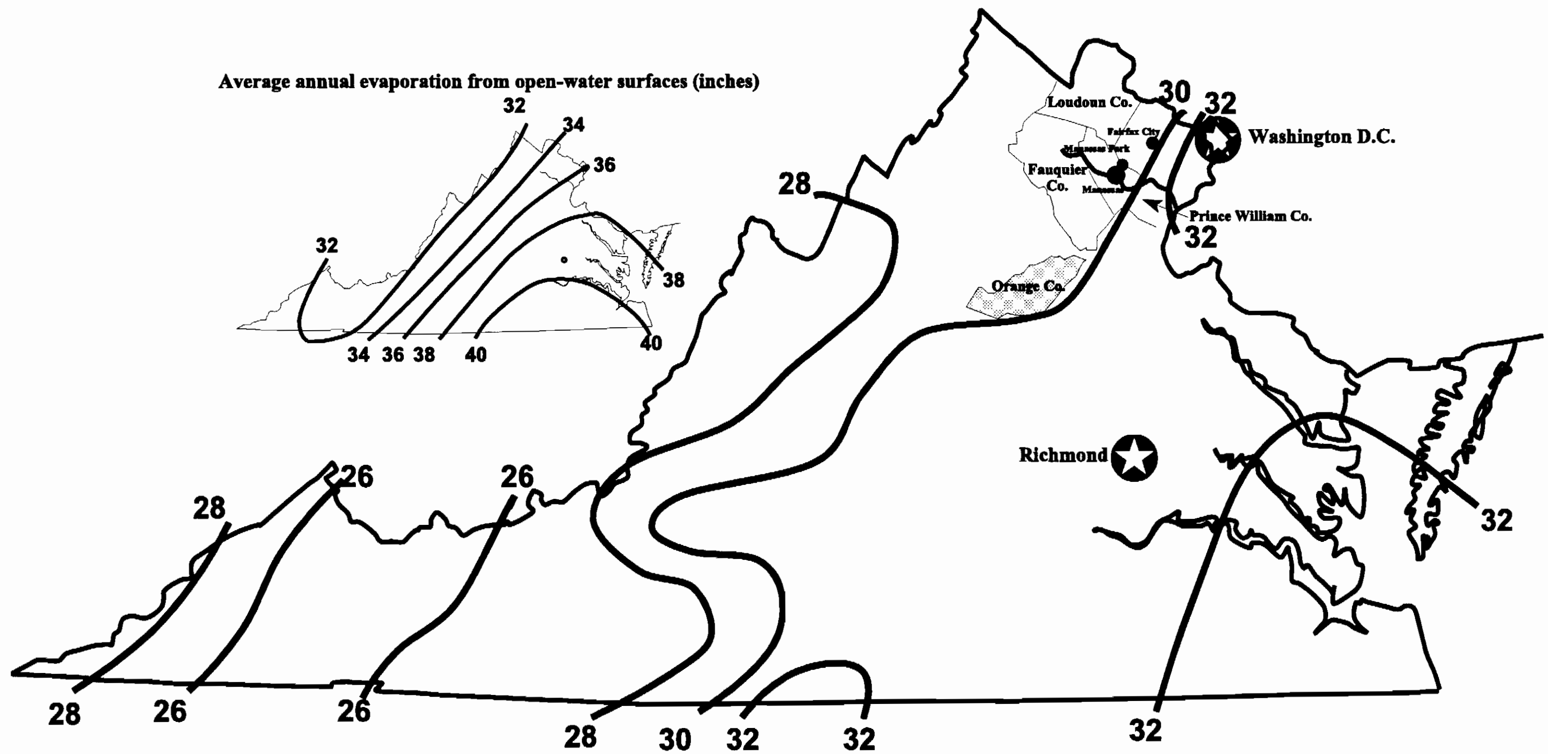
Figure 15 shows a map of Virginia with the different counties and the evapotranspiration zones. This figure shows that the Piedmont Research Station, located in Orange County, and Segment 9, located at the south boundary of Loudoun and Fairfax counties, are approximately placed on the same range of evapotranspiration zones. Therefore, the record of the Piedmont Weather Station could be used as representative of the Watershed.

Table 12
Location of Weather Stations
with Respect to the Cub Run Watershed

Weather Station	Distance* to the closest point	Distance to the approx. center** of the watershed	Distance to the most distant point
Dulles Airport	<0.5 miles	5.5 miles	10.5 miles
The Plains	11.5 miles	17 miles	22.5 miles
National Airport	17.5 miles	22 miles	26.5 miles

* Distances were estimated using a 1:150000 map.

** The approximate center of the watershed was located using the following procedure. A north-south line was traced tangent to the western most boundary point, the same for the eastern most boundary point. The distance between both lines was calculated and a third parallel was traced dividing the watershed in approx. two halves. The middle point of the sector of line formed by the third parallel and the intersections with the northern and southern boundaries was found, this being the point defined as the center of the watershed. All the distances to the center were measured using this point as a reference.



Redrawn from: *Water Atlas of Virginia; Basic Facts about Virginia's Water Resources.* (Van der Leeden 1994)

Figure 15: Potential Evapotranspiration Zones for the State of Virginia (inches)

These sequential files were then processed with HSPF and User Control Input (UCI) files to include them in a Watershed Data Management (WDM) file. The sequential files and the corresponding UCI files used for their processing are presented in Appendix D.

The time series database structure was prepared using another program called ANNIE (Kittle, Hummel and Imhoff 1989) which allows for the management of WDM files.

Some parameters of the model were obtained from a copy of a partially translated version of the Occoquan Basin Model (NVPDC 1995). This file was transformed to obtain the first draft version of the Cub Run Watershed Model. The commented version of this Model is presented in Appendix E. Some of the parameters where changed by values obtained from other sources like the ARM User's Manual (Donigian and Davis 1978).

The analysis of the data input file of the original model, provided by the NVPDC, indicated that 22 different segments were defined for each of the 15 segments into which the Occoquan Watershed was divided. Actually, there were eleven different land use areas, but each segment was defined as pervious and impervious as well, thus doubling the number of segments. A comparison with other models used for the Iowa River, the Patuxent River, Hunting Creek, and Four Mile Creek studies revealed that this is not an usual segmentation technique.

Another point that was noted was that even when these segments were defined as different, the parameters assigned to each of them were identical, making them basically differently named segments with exactly the same characteristics. Based on this analysis a new segmentation scheme was thought necessary, in which each segment effectively represented different characteristics. Another fact in the original model that was different from normal procedures, was that 11 pervious plus 11 impervious segments were defined for each of the 15 reach segments, generating a total of 330 different segments. Therefore, if a pervious segment of type A was defined for reach segment #4 and a pervious segment of the same type A was defined for reach segment #11, they constituted in the model two different operations. This is appropriate when the geologic, meteorologic or edaphic conditions of one segment are different from those of the other. However, and even in the case of reach segments #4 and #11 being apart, if the characteristics of a type A segment in both reaches were similar they could be defined as a unique land segment, thus reducing substantially the complexity and processing time of the model.

The process of segmentation should be considered as a whole for the complete watershed, first looking for segment groups defined by general characteristics and then dividing these segment groups into segments depending on the land use.

A detailed examination of the geologic, edaphic and meteorological conditions for the watershed is needed in order to define segment groups. The first two type of conditions were quite uniform for the Cub Run Drainage Basin and no division was performed using these criteria.

The examination of climatic data suggested great variability for smaller areas. However, an examination of the Watershed and an analysis using the Theissen's Polygons method indicated that the values provided by the Dulles Airport weather station would be representative of the entire area. The *Application Guide for the Hydrologic Simulation Program -FORTRAN (HSPF)* (Donigian and others, 1984) indicates that one set of climatological data should be enough when the area of the watershed is less than 100 km^2 (39 mi^2). The area of the Cub Run Watershed is 121.5 km^2 (49 mi^2). Probably more than one record is necessary, but the Dulles Airport was the only one available and, thus, the one used.

The drainage areas of reach segments were then the only criterion left to define zones in which different parameters could be used. The first runs were performed considering the whole watershed as an unique segment, and then a subdivision into smaller segments was done to analyze how this could affect the quality of the simulation. For this purpose the Watershed was divided into 163 small segments that would provide some basis for groupings with similar characteristics. The segmentation and how the segments were defined are presented in Appendix F.

These small segments were defined to obtain important parameters for the simulation process and not using any particular criteria other than the points of tributary entry to define the downstream boundary.

The measuring of the reach length, the reach slope, the overland flow plane length (LSUR), and the overland flow plane slope (SLSUR) was performed for each of these segments using different techniques. The results are presented in tabular format in Appendix G. The segment name appears in the first column.

On a topographical map, 1:24000 scale, small straight portions of reach segment were transferred using a compass to a straight line and the reach length was measured. The difference between the highest contour and the lowest contour line crossing the stream was computed. The distance between these two points was measured in the same fashion as the reach length, and dividing the height difference by this distance, the reach slope was approximately computed. Since each of the 163 segments where quite small, the slope for each of them can be considered quite uniform and thus a good representation of the real value. This assumption is even more valid when no abrupt falls were found in the streams. The values of reach length and slope appear in columns 2 and 3, respectively, of Appendix G. The reach was then divided into smaller segments. If the reach length was 2000 feet or smaller, no more than 5 divisions where performed, separated by approx. 400 feet. If the reach length was between 2000 and 5000 feet, the reach was divided into six segments (five points), and if the reach was more than 5000 feet long, it was divided every 1000 feet. For each reach a normal to the dividing point was traced, and its length and slope measured. The averages of these lengths and slopes constituted a first approximation to the Overland Flow Plane Length (LSUR) and the Overland Flow Plane Slope (SLSUR). The results of these measurements are given on tabular format in Appendix G, in columns 4 and 5.

However, the comparison between the LSUR values measured with this procedure with values generally observed in the literature indicated that the first ones seemed largely overestimated.

These two parameters are of critical importance for the hydrological simulation because they define the Length-Slope factor used in the universal soil loss equation as well as in many other hydrologic calculations. Since the hydrologic simulation is the basis for all the other simulations in a watershed[17], some research was conducted in order to determine other approaches for the measuring or assessment of those parameters.

The first piece of literature found was a Handbook of Hydrology in which one of the sections dealt with the quantitative geomorphology of drainage basins and channel networks (Strahler 1964). In this article a reference to Horton (Horton 1945) mentioned that the length of the overland plane (LSUR) may be considered approximately equal to one half of the inverse of the drainage density, defining the last one as the length of all the streams on a drainage basin divided by the area of that particular watershed. Therefore, the area of each of the 163 small

[17]In fact to calibrate any other portion of the HSPF simulation program, like sediment or water quality, a good calibration of the hydrologic modules has to be obtained.

divisions was needed and was determined using a planimeter. These values are also provided in column 6 of the Appendix G table.

This procedure for defining the Overland Flow Plane Length was confirmed by another article by Ree, Wimberley and Crow (Ree, Wimberley and Crow 1977). In a study for determining another particularly important parameter, the Manning's Number for the Overland Flow Plane (NSUR) they noted that:

> "... The average length of overland flow was determined by dividing the watershed area by twice the total length of all drainageways.
>
> The delineation of drainageways on a contour map is highly subjective and is the product of the mapmaker's ideas and practices. Yet, the calculated length of the overland flow depends completely on the value of the total drainageway length. Thus describing as exactly as possible how drainageways were determined becomes essential if the results are to be meaningful."

In fact several tries of these procedure were performed for selected segments and still the values of LSUR were overestimated because the length of the reach in the segments was normally smaller than that of the actual drainage ways (see column 7 in Appendix G). To put in practice the idea of extending the drainageways in the map, maps with much higher resolution of the contours would have been required, and since the area of the watershed was considerable the drawing of such drainageways and their measurement would have taken considerable time.

More research was then performed to determine the existence of other methods and techniques to estimate LSUR. A paper by Williams and Berndt was found in which a different methodology was explained (Williams and Berndt 1977). In this methodology the segment area is measured (DA), as well as the difference between the highest and the lowest points for that area (Z). Then, three contour lines at 25, 50 and 75 percent of Z are marked and measured over the map (LC_{25}, LC_{50} and LC_{75} respectively). Then extreme points (EP) are located on the contour lines. Extreme points are defined by Williams and Berndt as follows:

> "...When a channel crosses a contour, the contour comes to a point generally in the direction of the watershed divide ... Because these points are local maximums in an uphill direction, they are called extreme points." (Williams and Berndt 1977, p. 220)

The base lines for these three contours are traced and measured over the map (LB_{25}, LB_{50} and LB_{75} respectively). The base lines are those that represent the contour as if it wasn't crossed by any channels. Once the base lines were traced, it is easier to count the number of extreme points for each contour (EP25, EP50 and EP75 respectively). The parameters LSUR and SLSUR are then calculated using the equations given in Appendix G. This method was faster and as accurate as the previous one. Therefore, it was applied to determine the values of LSUR and SLSUR for 17 segment groups within segment #9.

A total of 17 different groups of the original 163 segments were defined, their area measured and three of their contour lines marked as well as the base lines. This task was executed with the goal of measuring LSUR and SLSUR using the faster approach. The defined segments are shown after the first table in Appendix G. Table 13 shows how the original 163 segments were grouped to form the 17 segment groups. The values of LSUR and SLSUR were

Table 13
Definition of the 17 different segment groups

Group Segment Name	Small Segments from which it is composed
Upper Cub Run	CUB001 - CUB012
Sand Branch	SAN001 - SAN003
Dead Run	DEA001 - DEA005
Middle Upper Cub Run	CUB013 -CUB018
Cain Branch	CAI001 - CAI003
Middle Lower Cub Run	CUB019 - CUB025
Upper Flatlick Branch	FLA001 - FLA012
Middle Flatlick Branch	FLA013 - FLA016
Lower Flatlick Branch	FLA017 - FLA023
Upper Elklick Run	ELK001 - ELK038
Middle Elklick Run	ELK039 - ELK058
Lower Elklick Run	ELK059 - ELK062
Lower Cub Run	CUB026 - CUB037
Upper Big Rocky Run	BIG001 - BIG010
Middle Big Rocky Run	BIG011 - BIG018
Lower Big Rocky Run	BIG019 - BIG029
CUB038	CUB038

obtained using a spreadsheet —shown in Appendix G after the group segments. After obtaining the values of these parameters, the 17 groups were once more grouped into 7 final segments, and the values of LSUR and SLSUR were averaged for each of them using the area weighted values from the 17 group segments defined previously. Table 14 shows how the 17 group segments were grouped into 7 final segments. These segments were used in the last run to compare simulation behavior between a run with just two segments, one pervious and one impervious and a run with 13 segments, 7 pervious and 6 impervious (Elklick Run is mostly agricultural and no impervious segment was defined for that area).

Some parameters used for calibration, like the Lower Zone Nominal Storage and the Interflow-Inflow, were researched to obtain a rough value for them. The maps presented in Figures 16 and 17 were found in the ARM User's Manual (Donigian and Davis 1978, p.56, 62). These maps show the distribution of values for these parameters in the United States.

Table 14
Definition of the final 7 segment groups

New Segment Name	Group Segments from which it is composed
Upper Cub Run	Upper Cub Run Sand Branch Dead Run Middle Upper Cub Run
Middle Cub Run	Cain Branch Middle Lower Cub Run
Flatlick Branch	Upper Flatlick Branch Middle Flatlick Branch Lower Flatlick Branch
Elklick Run	Upper Elklick Run Middle Elklick Run Lower Elklick Run
Lower Cub Run	Lower Cub Run
Big Rocky Run	Upper Big Rocky Run Middle Big Rocky Run Lower Big Rocky Run
CUB038	CUB038

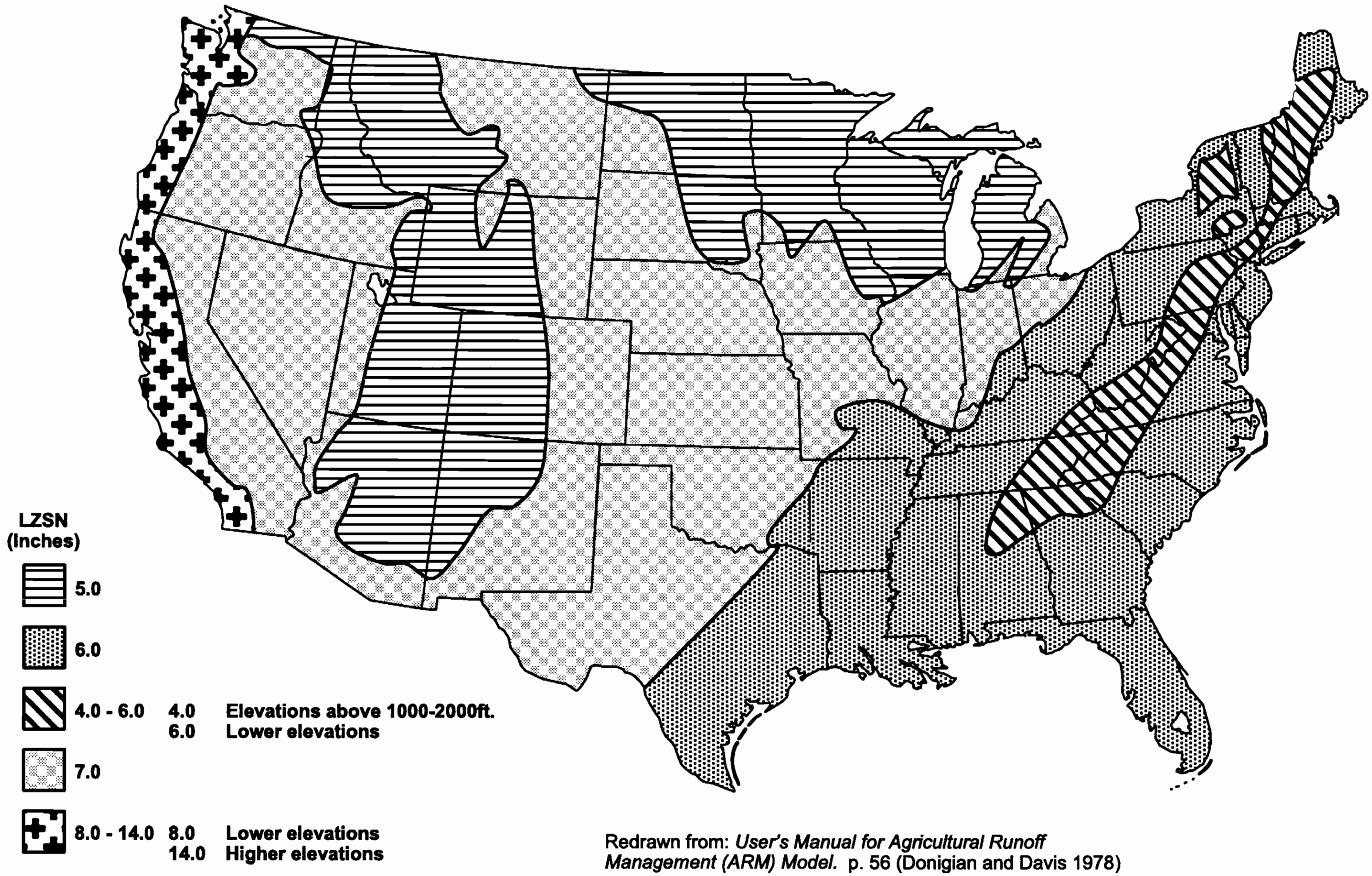


Figure 16: Nominal Lower Zone Soil Moisture (LZSN) Parameter Map

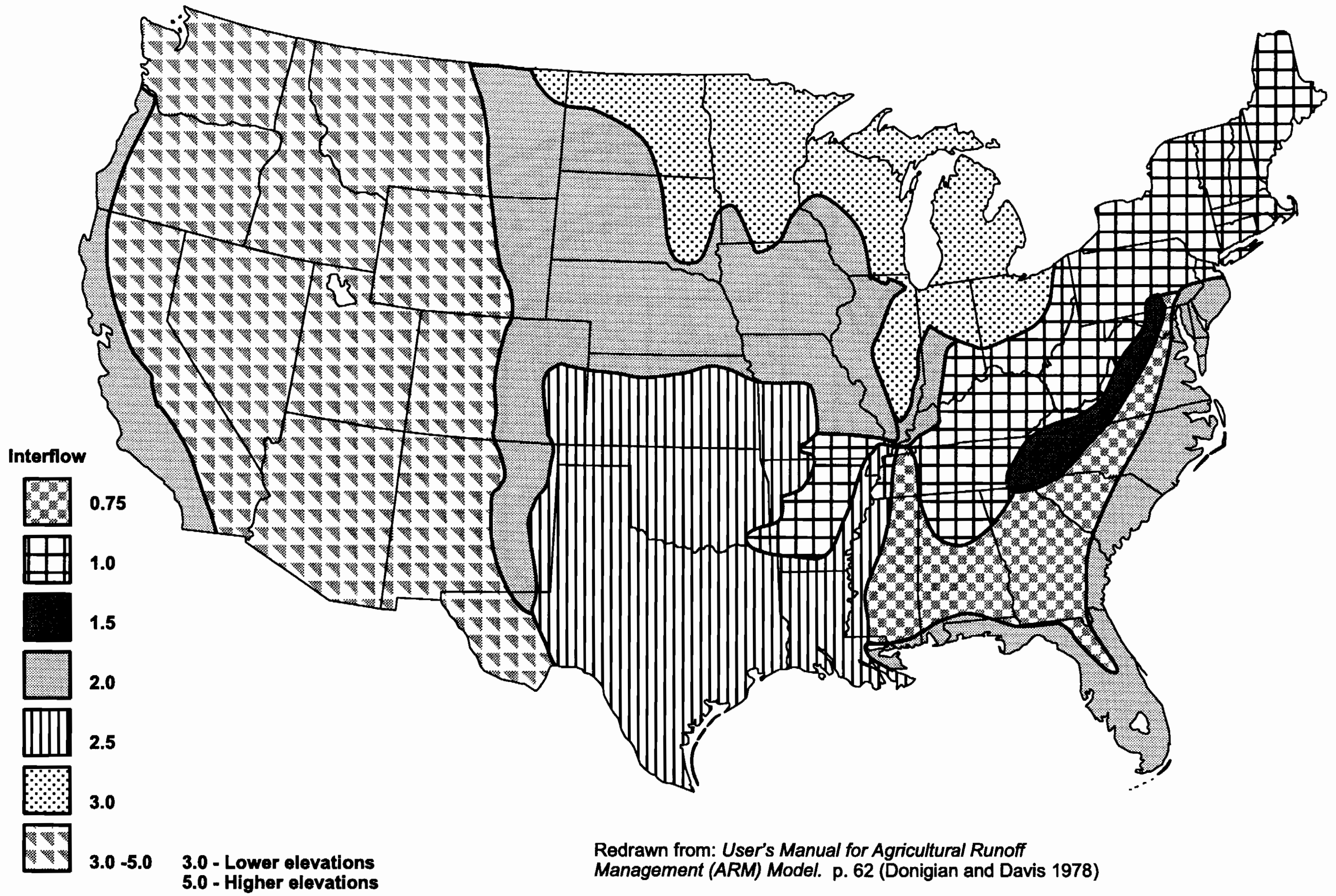


Figure 17: Interflow (INTFW) Parameter Map

IV. RESULTS AND DISCUSSION

A total of eight runs were executed. A description of these runs is presented in Table 15. The first two operative runs, CUBRUN_1.UCI and CUBP&I_1.UCI, were performed to compare the results of a run with only one pervious segment with the results of a run with two segments, one pervious and one impervious. The next five runs, were performed for model calibration, from CUBP&I_2.UCI to CUBP&I_6.UCI, and the last run, CUB13S_1.UCI, was executed to observe if any improvements were obtained when the Watershed was subdivided in smaller segments. In all these runs the simulated outflow from the watershed was stored in a Watershed Data Management file (CUBRUNDT.WDM), and the generated synthetic flow was compared with observed flow at the downsteam watershed boundary, obtained from the gaging station located where Compton Road crosses Cub Run.

1. The Operative Runs

a. First operative UCI file: CUBRUN_1.UCI

The first operative UCI file executed with HSPF contained just one pervious segment the size of the whole Cub Run watershed, 31,620 acres (49.406 mi^2). This file is shown in Appendix H. The hourly flow time series generated by this run was stored in data set #24 of the CUBRUNDT.WDM file. Chart 1 shows a comparison between the monthly observed flow values and the simulated results for this run. A general flow oversimulation could be observed for every month in 1989, except for August.

Table 15
Description of the eight runs

Run #	UCI file name	Number of Impervious Segments	Number of Pervious Segments	Brief Description of the Run	Data set # where the outflow time series was stored
1	CUBRUN_1.UCI	0	1	First operative UCI file	24
2	CUBP&I_1.UCI	1	1	Second operative UCI file	30
3	CUBP&I_2.UCI	1	1	First calibration run	31
4	CUBP&I_3.UCI	1	1	Second calibration run	32
5	CUBP&I_4.UCI	1	1	Third calibration run	33
6	CUBP&I_5.UCI	1	1	First single event calibration run	34
7	CUBP&I_6.UCI	1	1	Second single event calibration run	35
8	CUB13S_1.UCI	6	7	Subdivision of the Watershed into 13 segments	40

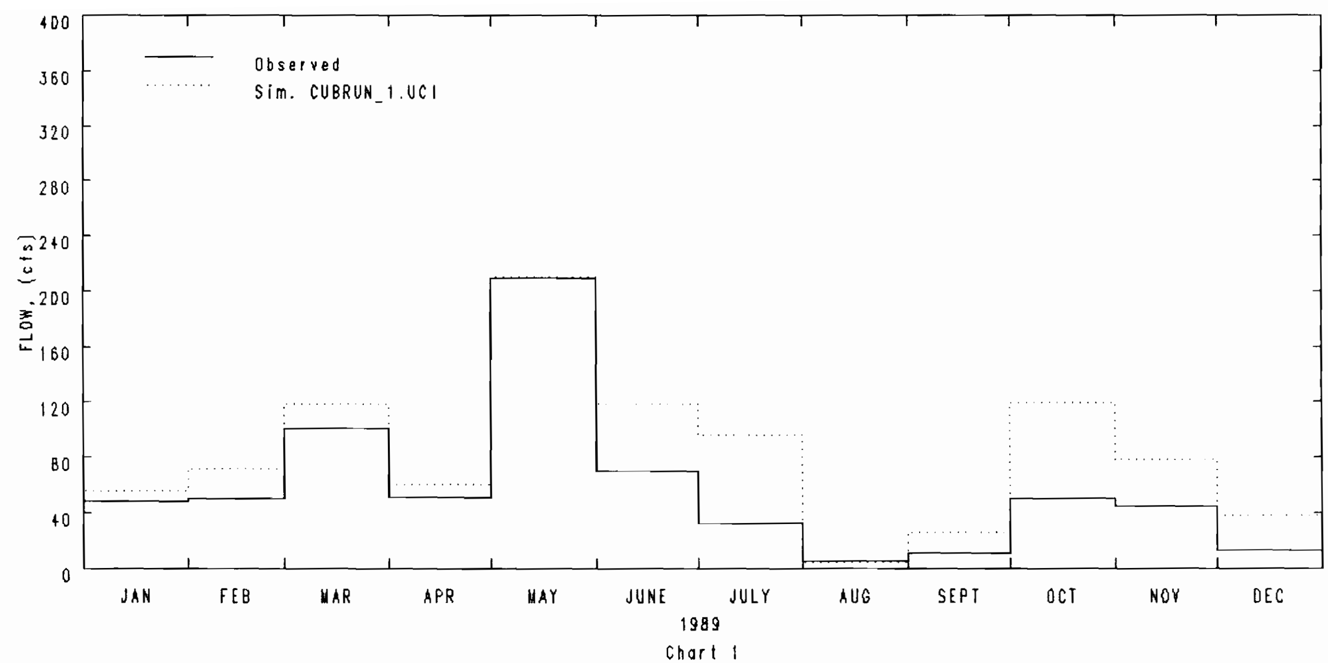


Chart 1: Comparison between the monthly observed flow values and the simulated results for the first operative run (CUBRUN_1.UCI)

b. Second operative UCI file: CUBP&I_1.UCI

For this second run the original pervious segment from the previous run was divided into two segments. This User Control Input file is shown in Appendix H. The hourly flow time series generated by this run was stored in data set #30 of the CUBRUNDT.WDM file. The total area of the impervious segment was 10.18% of the complete watershed area and the size of the pervious segment was reduced to 89.82% of the whole watershed. These percentages were obtained from a spreadsheet file prepared by the Northern Virginia Planning District Commission (NVPDC) (see Appendix I).

A comparison between the monthly observed values and the simulated results for CUBP&I_1.UCI are shown on Chart 2. This run resulted in the flow for every month being oversimulated.

Chart 3 shows a comparison between the monthly simulated values for CUBRUN_1.UCI and CUBP&I_1.UCI. The monthly results for the run considering the two segments, one pervious and one impervious (CUBP&I_1.UCI), were higher than the results for the run with just one pervious segment (CUBRUN_1.UCI). This result could be expected because of the generation of a larger amount of surface runoff due to the presence of the impervious surface and thus less infiltration. Table 16 shows the monthly simulated flow values for CUBRUN_1.UCI and CUBP&I_1.UCI, and the difference expressed as a percentage of the CUBRUN_1.UCI simulated values. This table also displays annual flow averages. These percentages range from 4.53% to 62.21% with an annual difference of 9.44%. Because for some months and for the complete year the difference is appreciable, the inclusion of the impervious segment could not be neglected and the calibration runs executed after this one used, as a basis, the results obtained with the CUBP&I_1.UCI file.

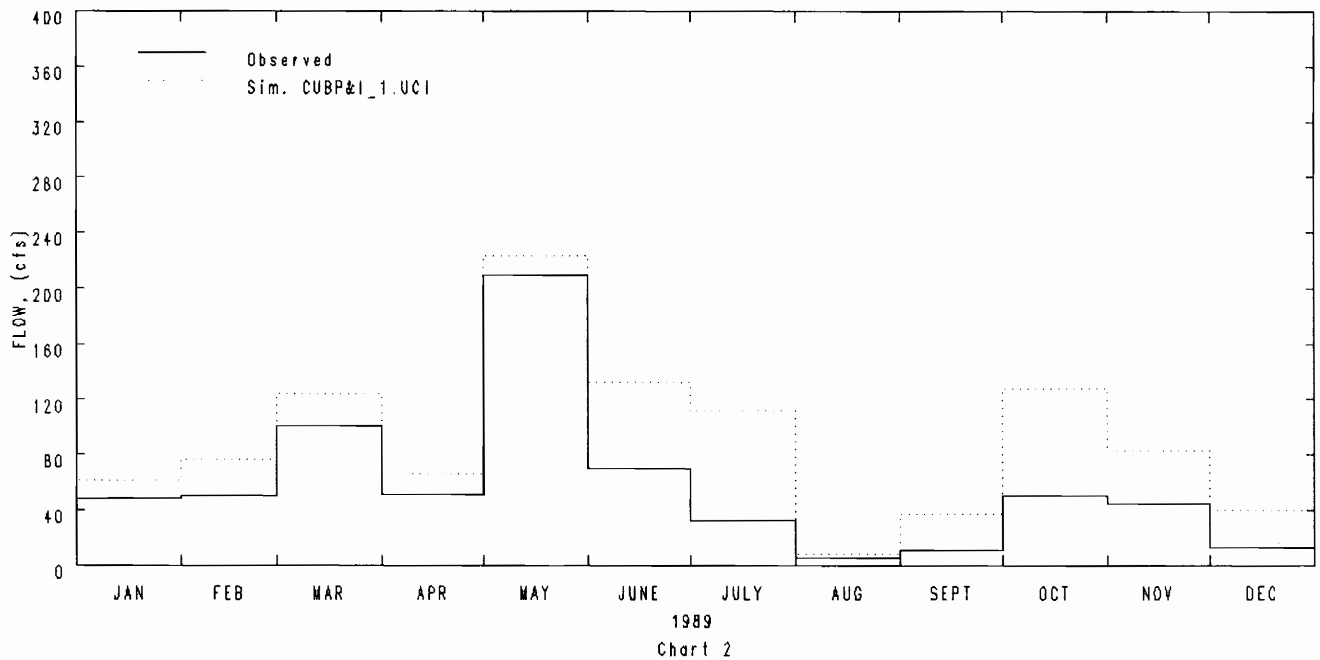


Chart 2: Comparison between the monthly observed flow values and the simulated results for the second operative run (CUBP&I_1.UCI)

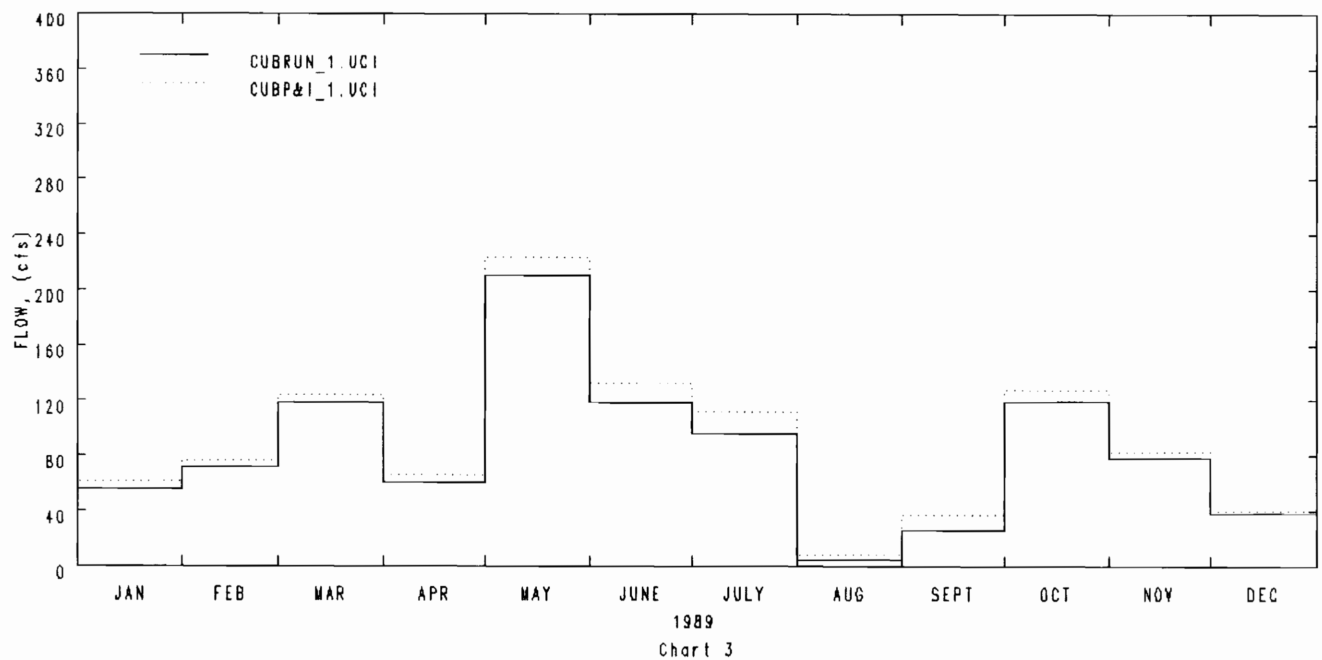


Chart 3: Comparison between the monthly simulated results for the first and the second operative runs (CUBRUN_1.UCI and CUBP&I_1.UCI respectively)

Table 16
Monthly and annual flows for CUBRUN_1.UCI and CUBP&I_1.UCI simulations, and percentage differences

Month	CUBRUN_1.UCI Flow (cfs)	CUBP&I_1.UCI Flow (cfs)	Percent difference
January	55.38	61.39	10.85%
February	71.81	76.57	6.63%
March	118.39	123.76	4.54%
April	60.07	66.39	10.52%
May	210.51	222.92	5.90%
June	118.17	132.19	11.86%
July	96.10	112.40	16.96%
August	4.79	7.77	62.21%
September	25.45	36.88	44.91%
October	119.88	127.88	6.67%
November	78.00	82.79	6.14%
December	38.39	40.13	4.53%
Year: 1989	83.08	90.92	9.44%

Charts 4 to 7 show a comparison between hourly observed data and simulated results for the four quarters of 1989, and Chart 8 shows a comparison between hourly observed values and simulated results for the period from May 1 to May 20, when the largest annual storm occurred. All these charts show an agreement for the location of the storm peaks, though the size of the simulated peaks was normally larger than the peaks generated with observed data.

2. The Calibration Runs

a. First calibration run: CUBP&I_2.UCI

The first calibration effort was aimed at reducing the generated runoff simulated in the CUBP&I_1.UCI run. Examination of Chart 2 indicated that although the results of simulation were always higher than the observed values, that effect was enhanced for the period going from June to November.

In the CUBP&I_1.UCI file no values were assigned for LZETP, a parameter that represents the percentage of evapotranspiration that should be satisfied with lower zone water storage. No table of monthly lower zone evapotranspiration percentages (MON-LZETPARM) was provided either. This parameter is very important for providing an output in the water budget of the watershed, specially during the summer months, when the oversimulation was more noticeable. The monthly balance can be better simulated if a monthly set of LZETP values is provided instead a single annual value. The monthly set of values can provide a more real situation, since larger values of LZETP can be assigned to those months in which the amount of rooted vegetation is larger and when more evapotranspiration is produced.

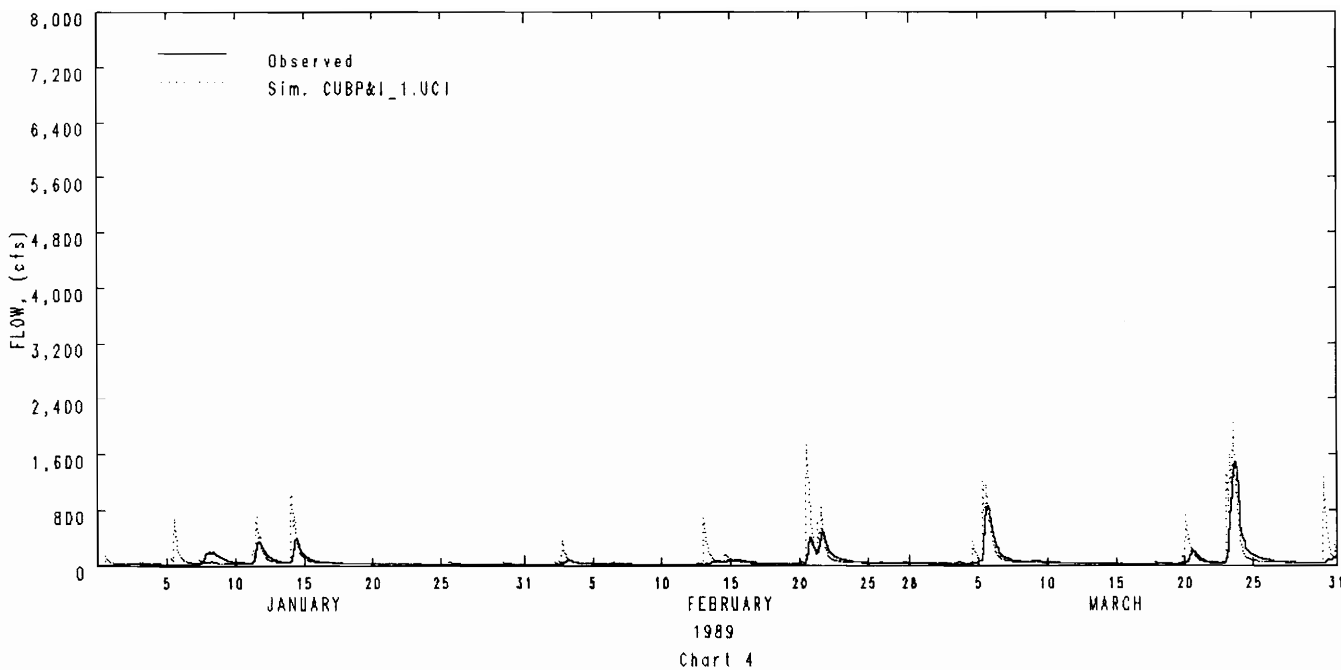


Chart 4: Comparison between hourly observed flow values and simulated results for the second operative run (CUBP&I_1.UCI), for the first Quarter of 1989

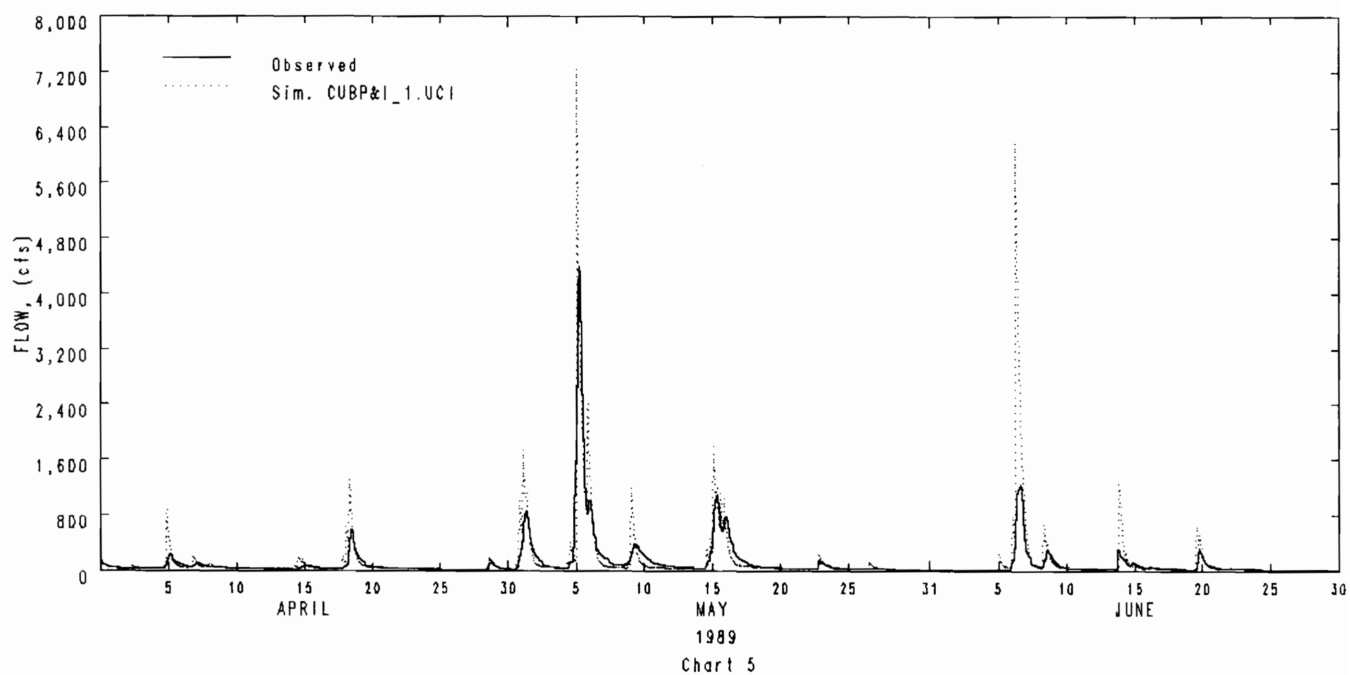


Chart 5: Comparison between hourly observed flow values and simulated results for the second operative run (CUBP&I_1.UCI), for the second Quarter of 1989

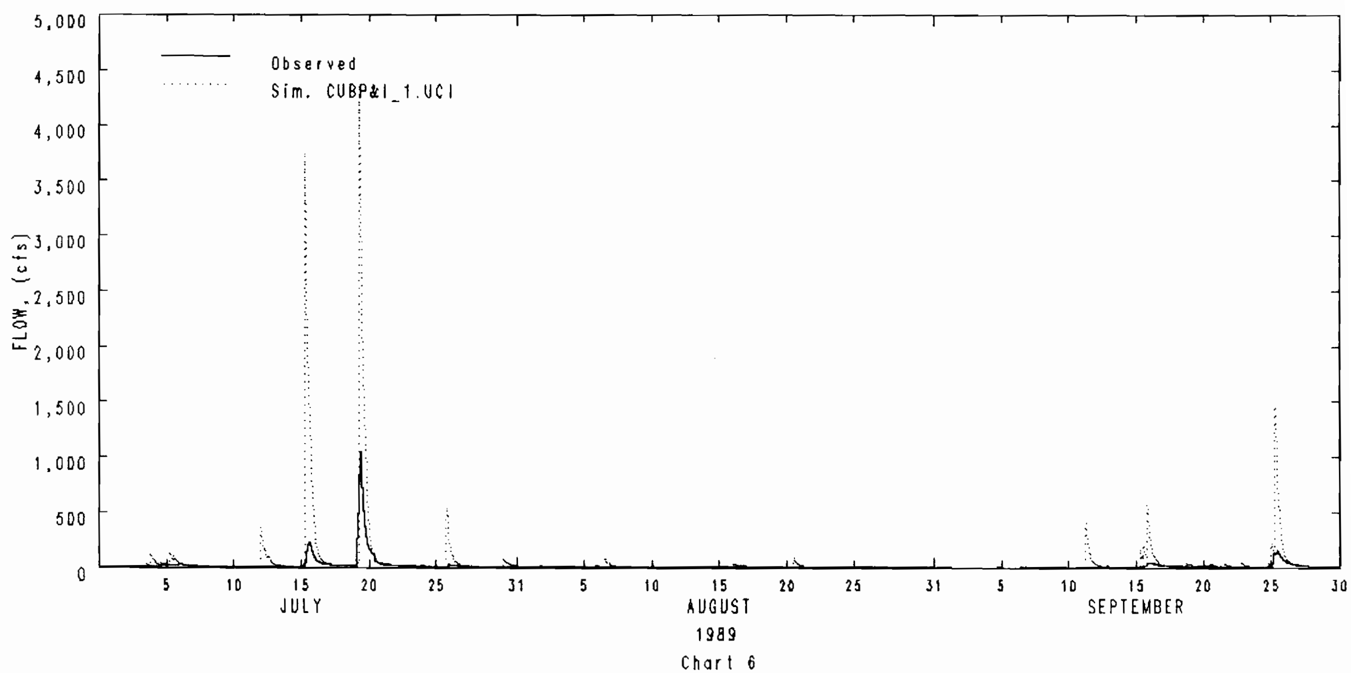


Chart 6: Comparison between hourly observed flow values and simulated results for the second operative run (CUBP&I_1.UCI), for the third Quarter of 1989

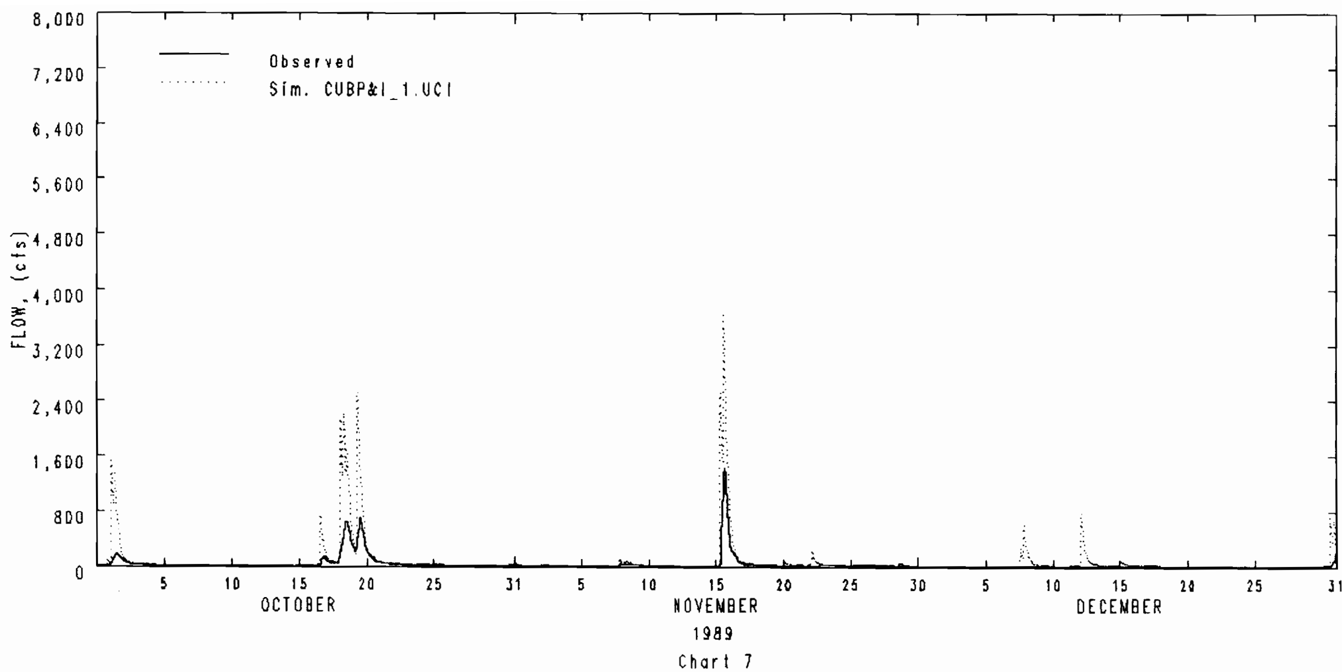


Chart 7: Comparison between hourly observed flow values and simulated results for the second operative run (CUBP&I_1.UCI), for the fourth Quarter of 1989

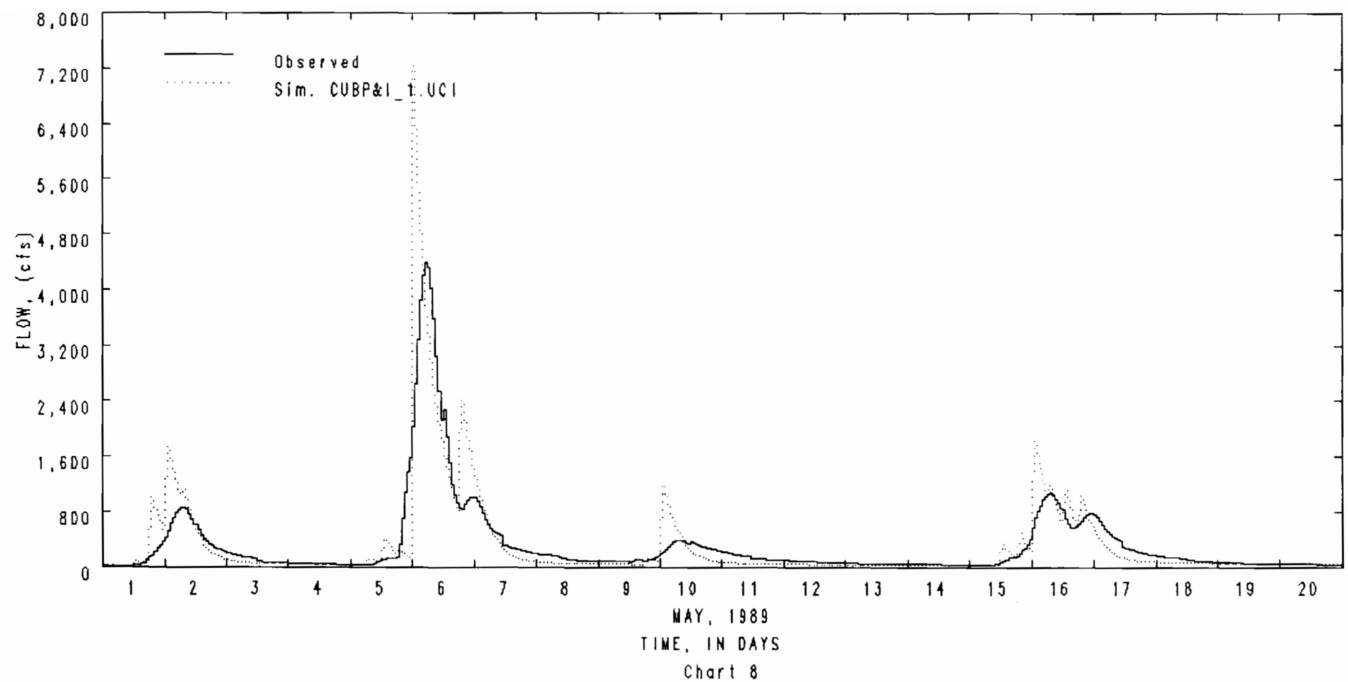


Chart 8: Comparison between hourly observed flow values and simulated results for the second operative run (CUBP&I_1.UCI), for the period from May 1 to May 20 (largest annual storm)

The set of monthly LZETP values used in the first calibration run (CUBP&I_2.UCI) were obtained from a UCI file for Hunting Creek (northern part of the Patuxent River, Maryland). This CUBP&I_2.UCI file with he monthly LZETP table is shown in Appendix H. The hourly flow time series generated by this run was stored in data set #31 of the CUBRUNDT.WDM file.

An analysis of Chart 9, where the monthly values for observed and simulated data are displayed, indicates that better simulation results were produced, specially for the months of July, September, October, November and December. However, June and July values were still far above the observed values. Chart 9 also shows that a general oversimulation for the complete year could be observed. Chart 10 shows the improvement obtained when the original CUBP&I_1.UCI run and the first calibration run (CUBP&I_2.UCI) are compared.

Charts 11 to 14 compare observed and simulated values for the first calibration run for the four quarters of 1989. The peaks for the storms are smaller, specially for the months of July, August, September, October, November and December. Almost no difference could be noted for the period from May 1 to May 20 (Chart 15) and this was due to the fact that the LZETP parameter had more influence during the summer months.

b. Second calibration run: CUBP&I_3.UCI

Chart 9 demonstrated a general oversimulation for all 1989. This required an overall adjustment that had to be performed by increasing the lower zone nominal storage (LZSN). This adjustment provided more capacity for that zone to satisfy the evapotranspiration demand, and then allowed a higher output on the watershed water balance. The LZSN parameter was increased from the original value of 4.270 in. to a value of 6.000 in., and the upper zone nominal storage (UZSN) was accordingly increased from 0.427 in. to 0.600 in.. These changes can be observed

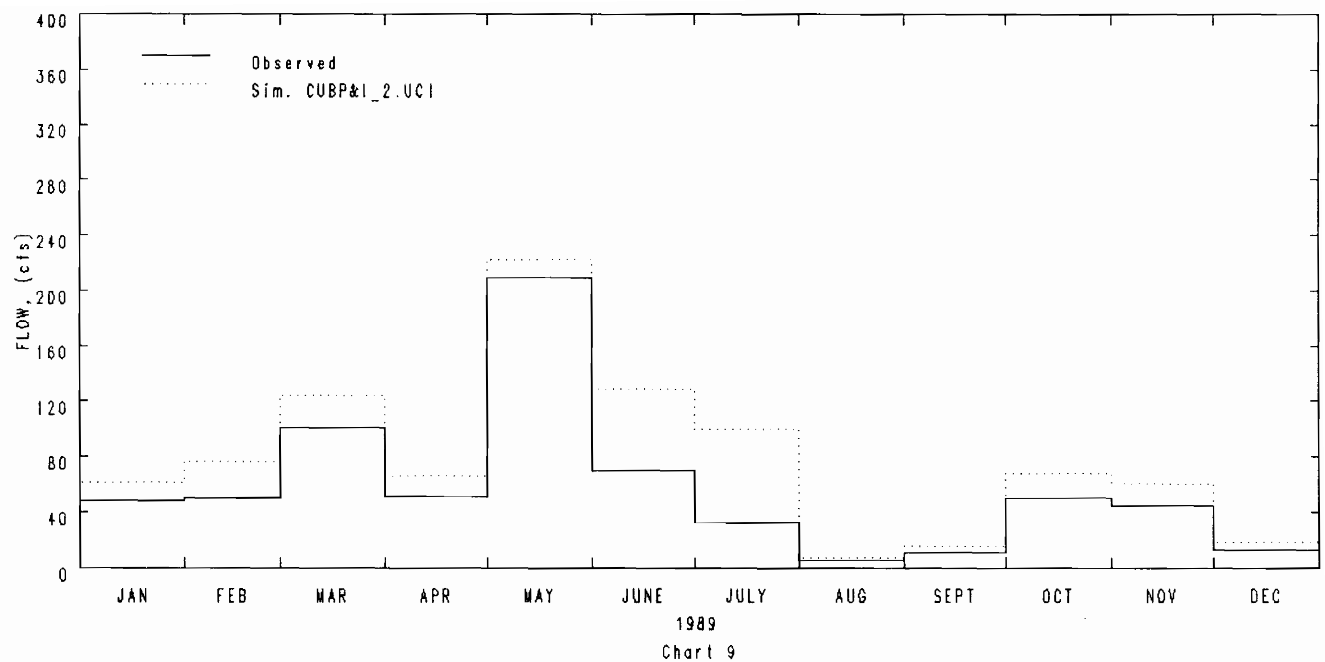


Chart 9: Comparison between the monthly observed flow values and the simulated results for the first calibration run (CUBP&I_2.UCI)

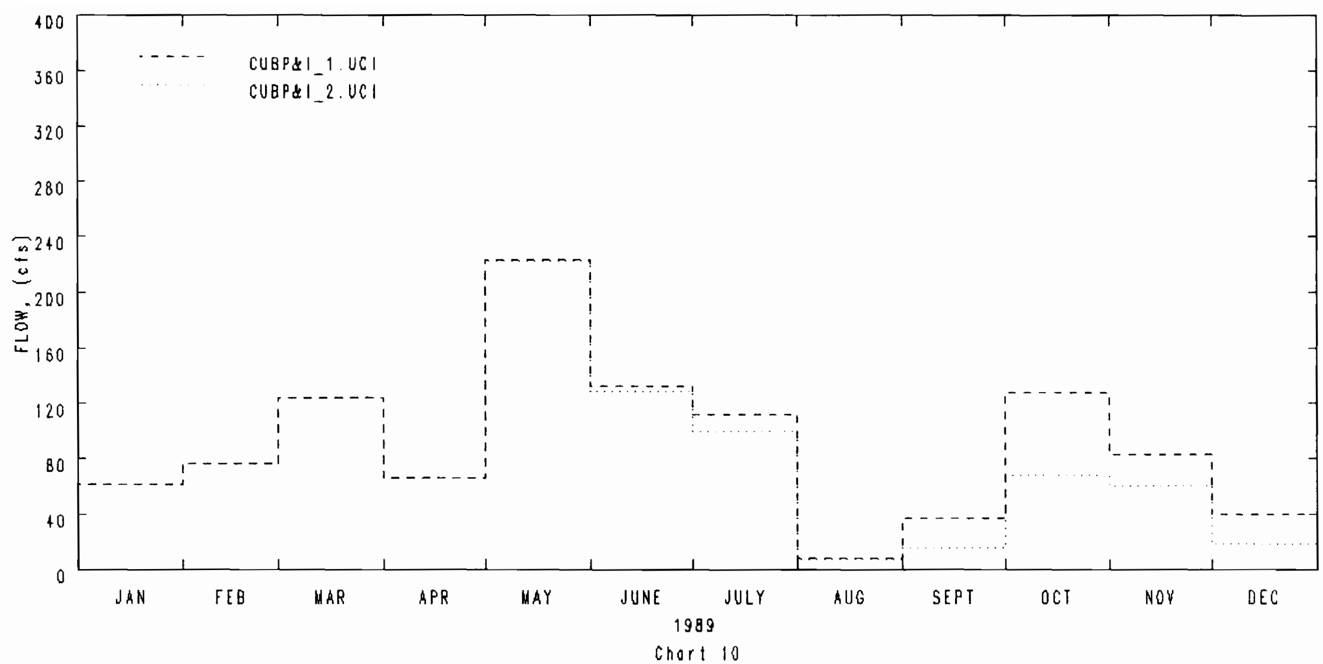


Chart 10: Comparison between the monthly simulated results for the second operative run and the first calibration run (CUBP&I_1.UCI and CUBP&I_2.UCI respectively)

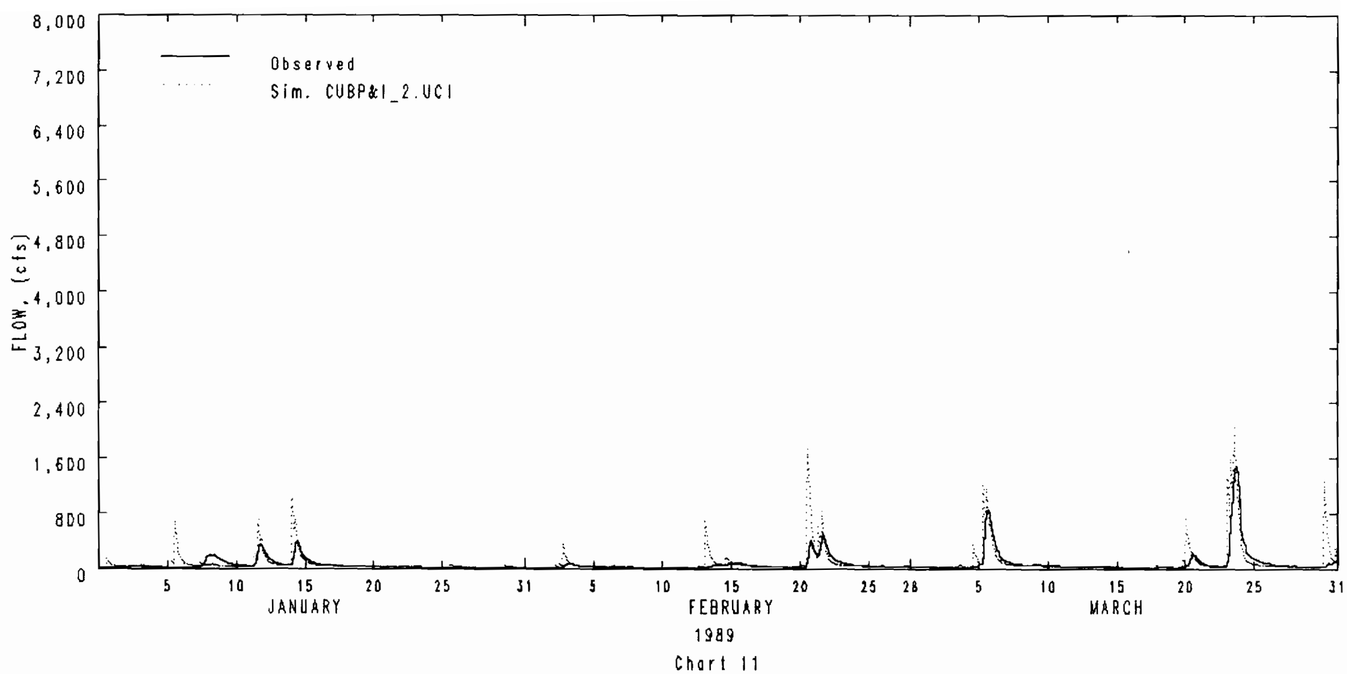


Chart 11: Comparison between hourly observed flow values and simulated results for the first calibration run (CUBP&I_2.UCI), for the first Quarter of 1989

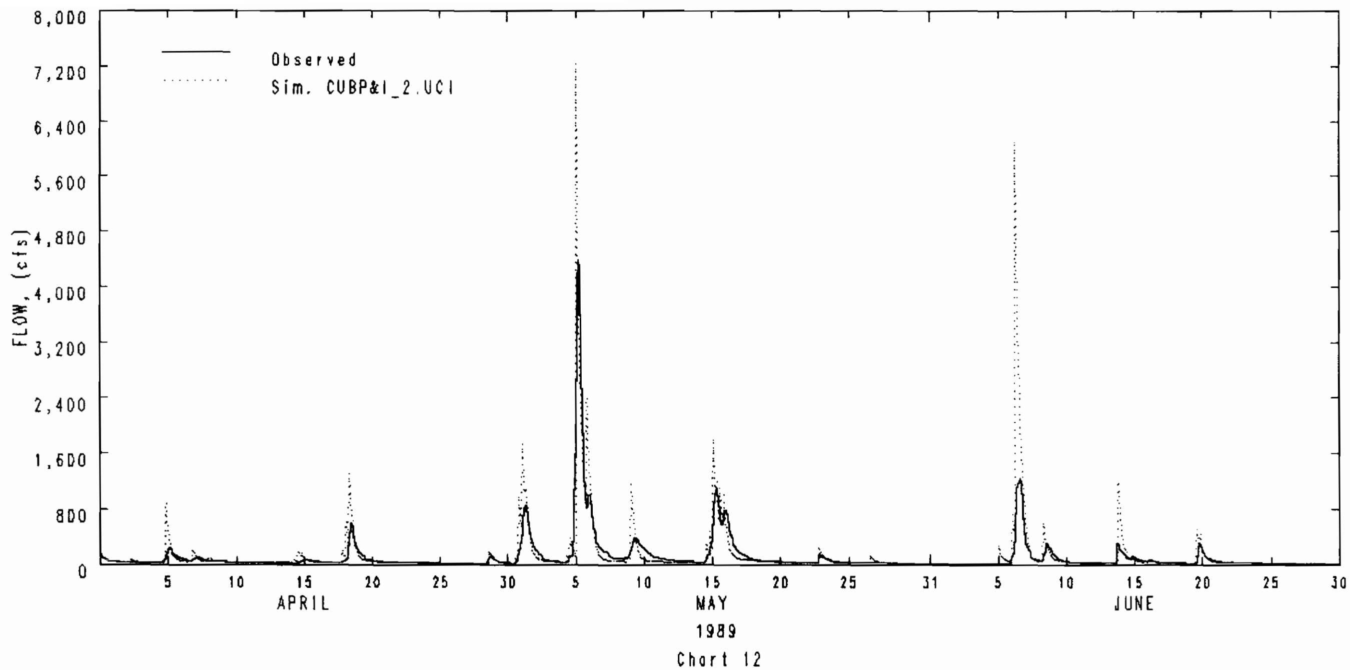


Chart 12: Comparison between hourly observed flow values and simulated results for the first calibration run (CUBP&I_2.UCI), for the second Quarter of 1989

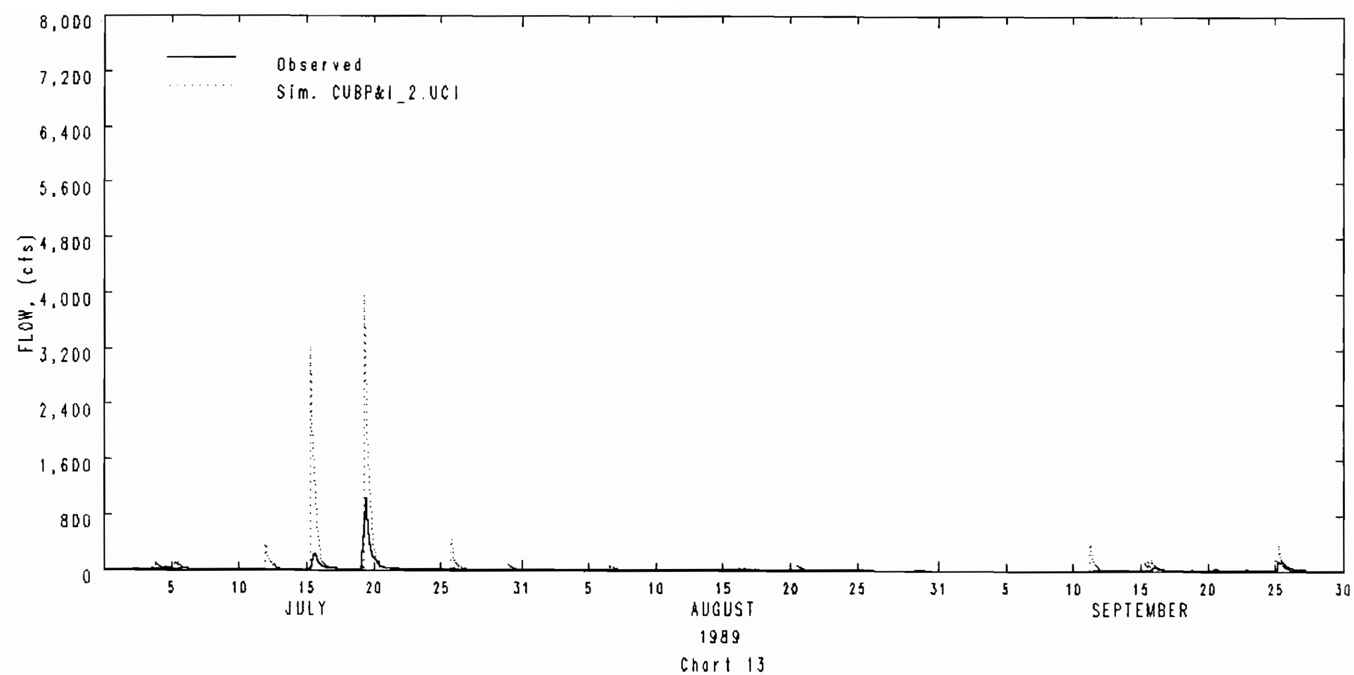


Chart 13: Comparison between hourly observed flow values and simulated results for the first calibration run (CUBP&I_2.UCI), for the third Quarter of 1989

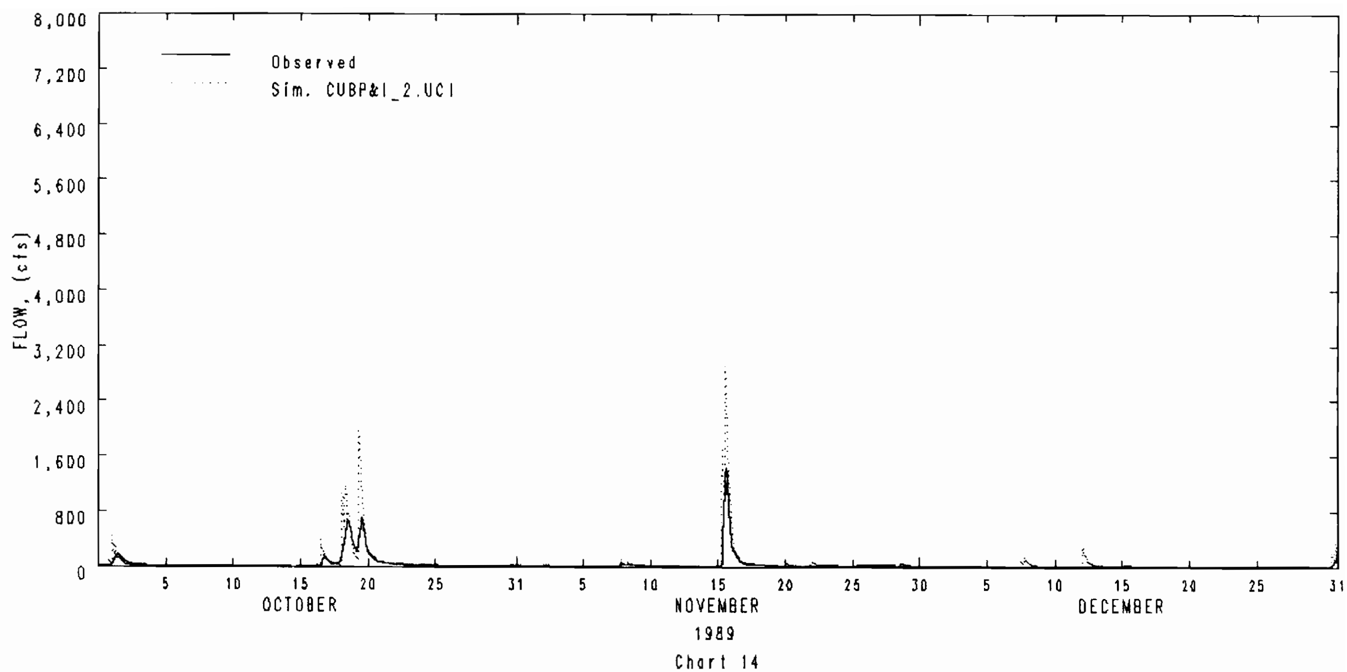


Chart 14: Comparison between hourly observed flow values and simulated results for the first calibration run (CUBP&I_2.UCI), for the fourth Quarter of 1989

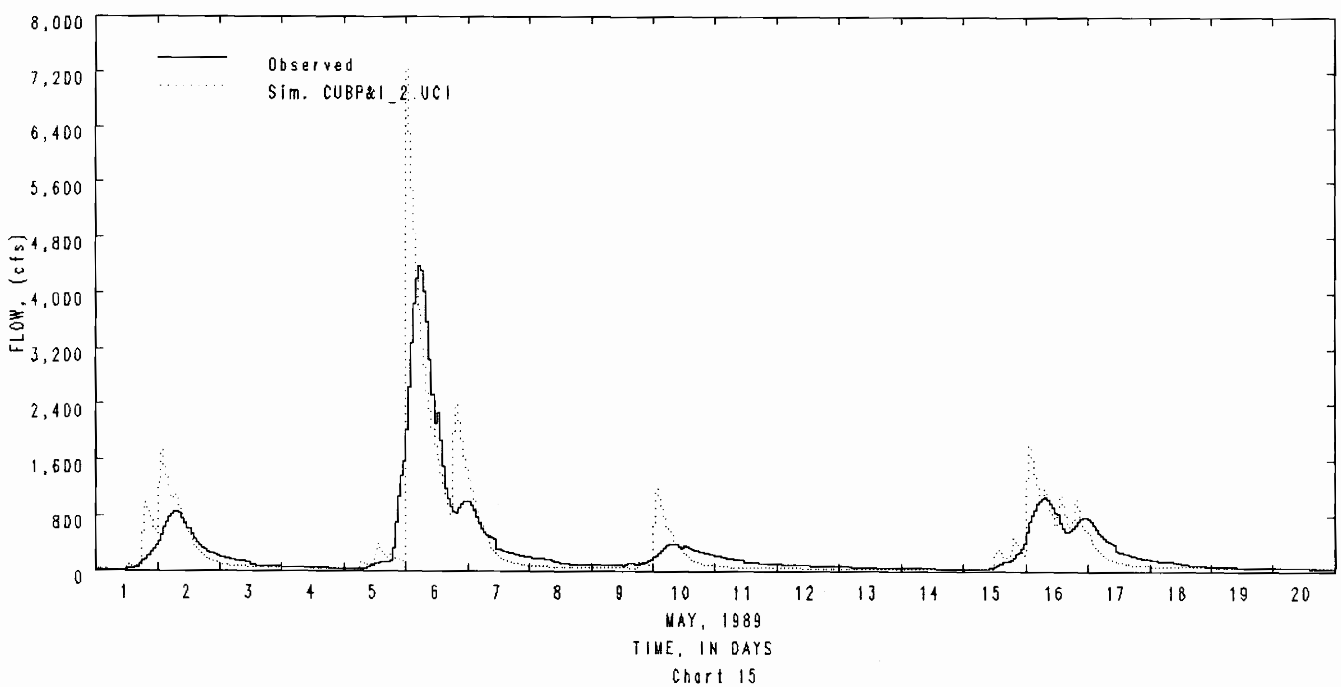


Chart 15: Comparison between hourly observed flow values and simulated results for the first calibration run (CUBP&I_2.UCI), for the period from May 1 to May 20 (largest annual storm)

in the CUBP&I_3.UCI file included in Appendix H. The hourly flow time series generated by this run was stored in data set #32 of the CUBRUNDT.WDM file.

The two adjusted parameters, LZETP and LZSN, were used as calibration parameters, since they were difficult to obtain from measurements. UZSN could be either measured or correlated to the LZSN value, the latter being the approach used.

Chart 16 shows a noticeably better simulation after running this second calibration run for all the months except June and July. The only month in which an undersimulation was noted was January. This might be explained by the fact that January was the first month for this simulation period and was greatly affected by the initial conditions of the watershed. This effect could be corrected by changing the initial values for lower zone storage and upper zone storage. The calibration results for the first month never are expected to be very good and a period of time should have been allowed before that month if those values were really important. Chart 17 displays a comparison of the simulated results for both the first and the second calibration runs. The effect of increasing LZSN can be appreciated. There was a general decrease in the production of runoff.

Charts 18 to 21 show a better adjustment of the simulated values to the observed data specially for the third and fourth quarters of 1989. Chart 22 shows little difference if compared with Chart 8.

c. Third calibration run: CUBP&I_4.UCI

There were two months, however, that were largely oversimulated: June and July. For that reason, a third calibration run was performed by further increasing the values of LZSN and UZSN to 8.000 in. and 0.800 in. respectively. An additional change performed for this calibration run was

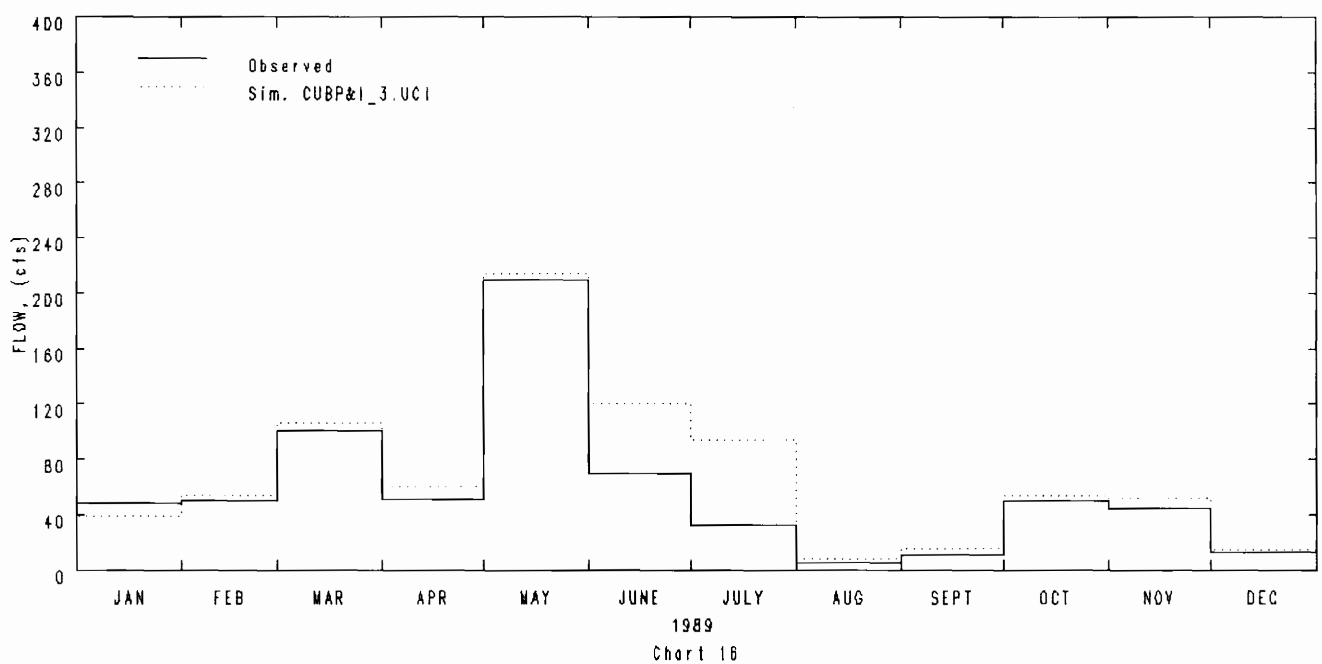


Chart 16: Comparison between the monthly observed flow values and the simulated results for the second calibration run (CUBP&I_3.UCI)

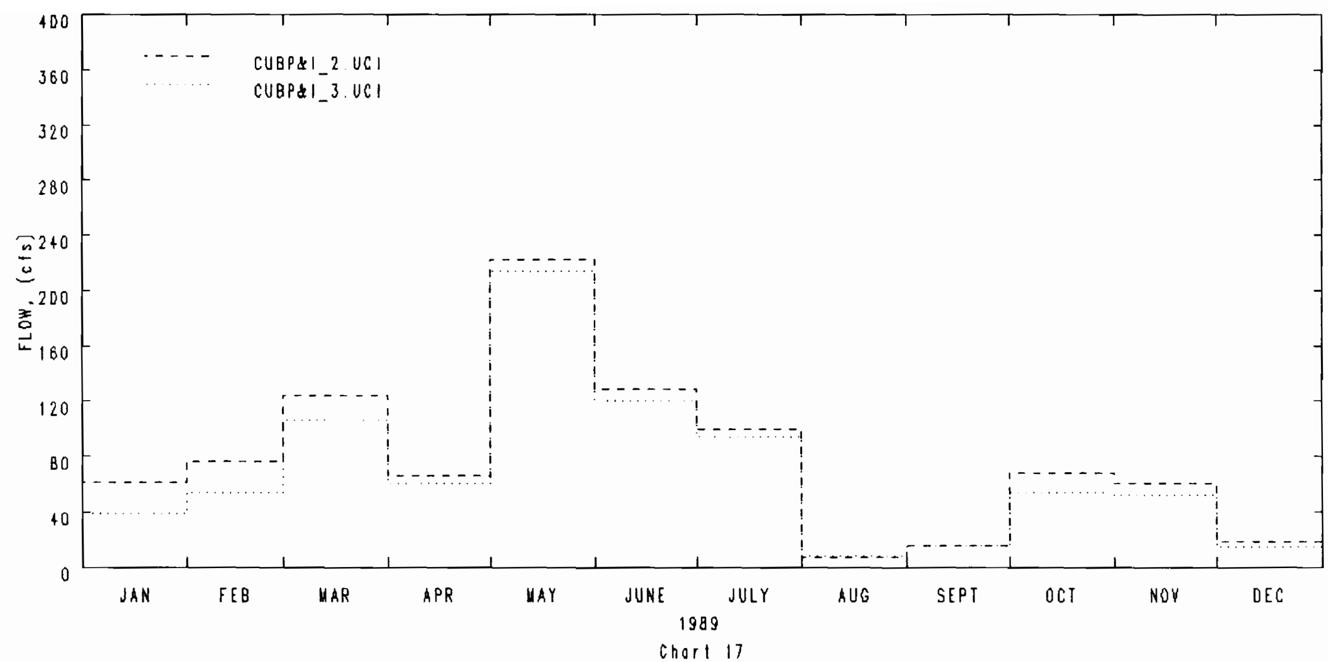


Chart 17: Comparison between the monthly simulated results for the first and the second calibration runs (CUBP&I_2.UCI and CUBP&I_3.UCI respectively)

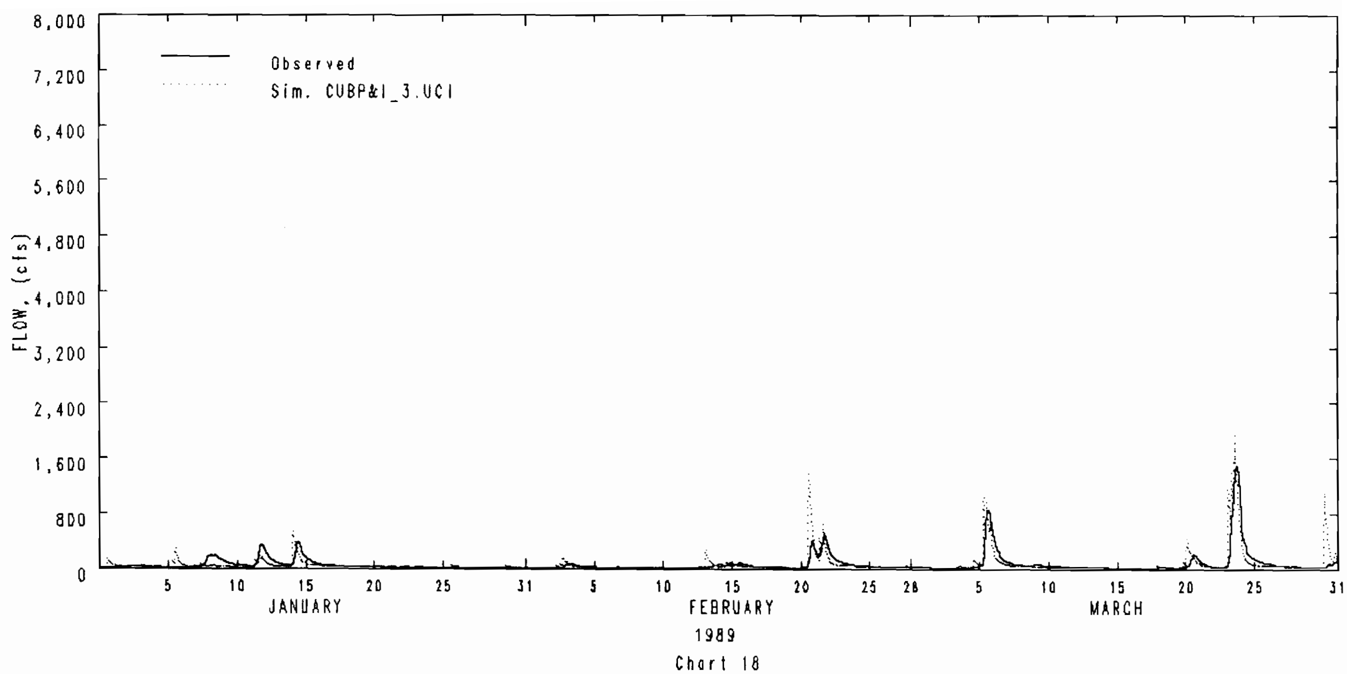


Chart 18: Comparison between hourly observed flow values and simulated results for the second calibration run (CUBP&I_3.UCI), for the first Quarter of 1989

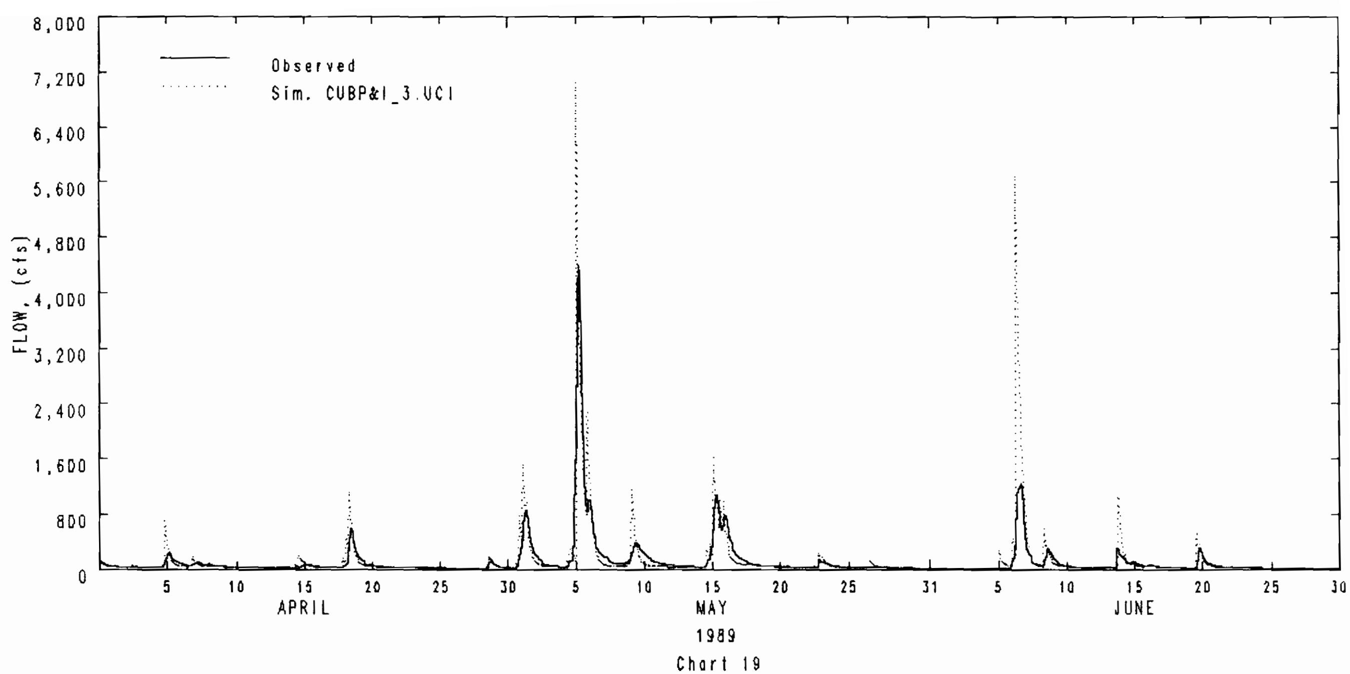


Chart 19: Comparison between hourly observed flow values and simulated results for the second calibration run (CUBP&I_3.UCI), for the second Quarter of 1989

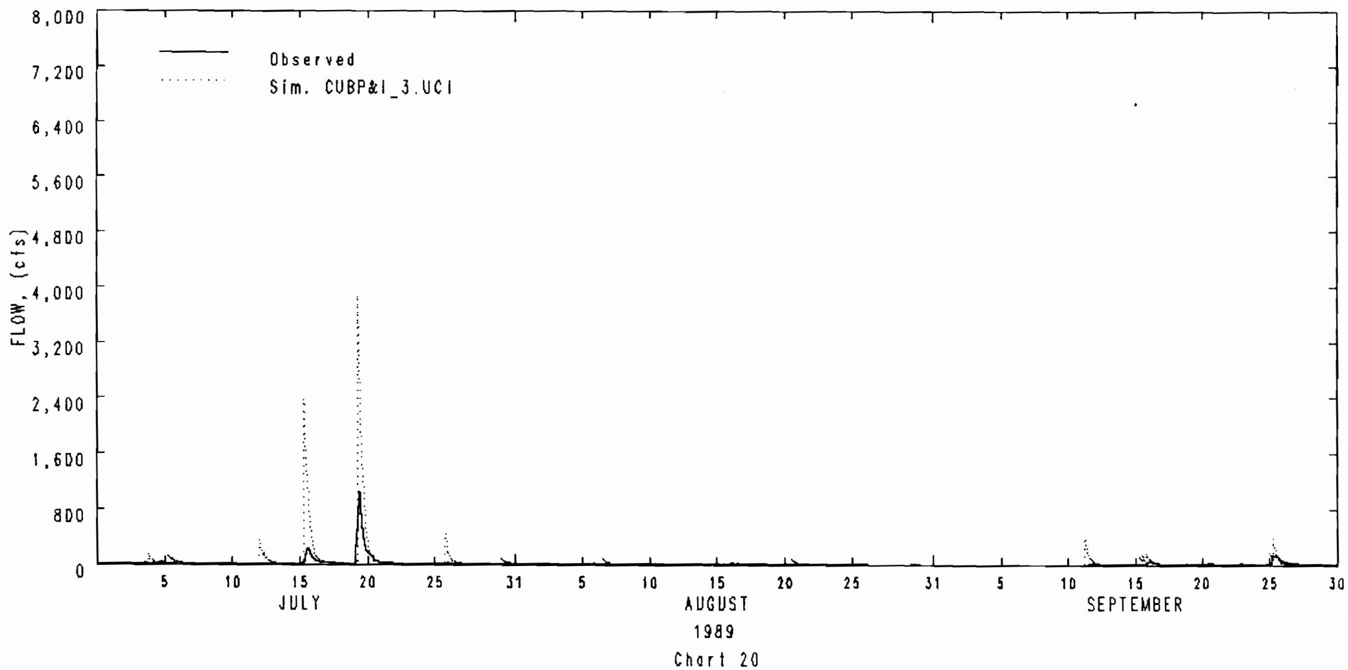


Chart 20: Comparison between hourly observed flow values and simulated results for the second calibration run (CUBP&I_3.UCI), for the third Quarter of 1989

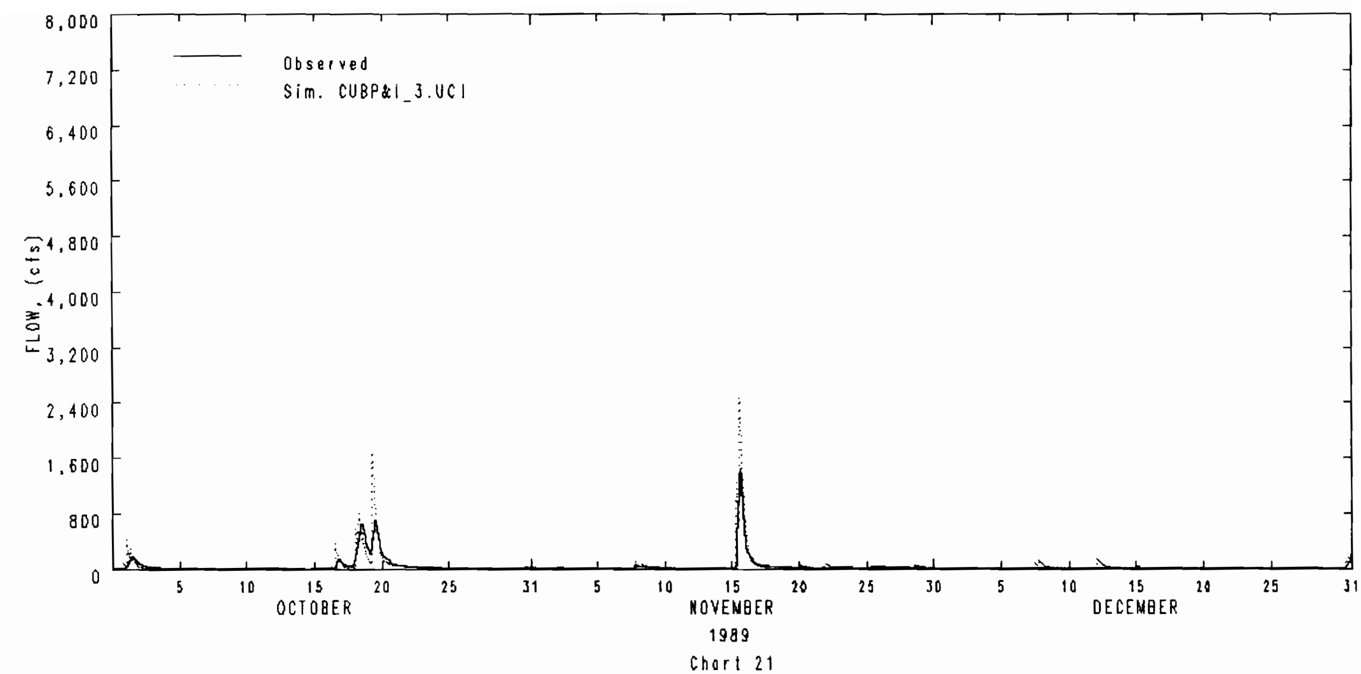


Chart 21: Comparison between hourly observed flow values and simulated results for the second calibration run (CUBP&I_3.UCI), for the fourth Quarter of 1989

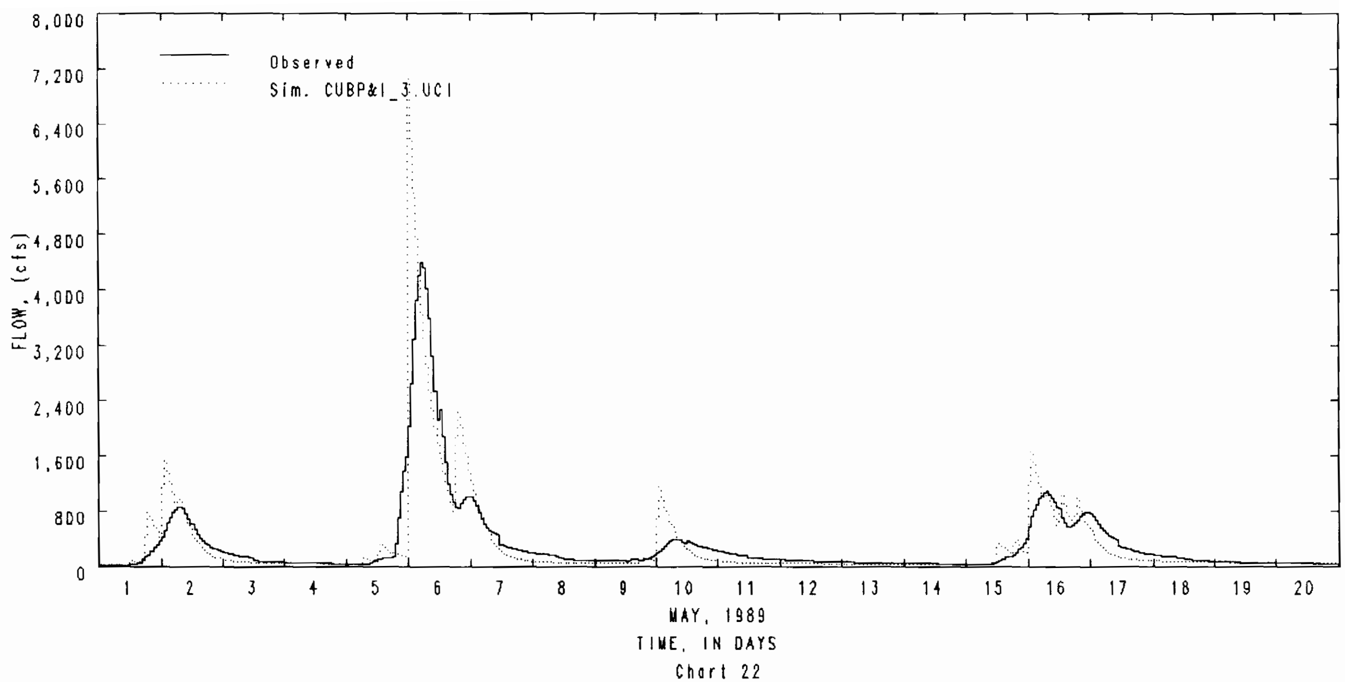


Chart 22: Comparison between hourly observed flow values and simulated results for the second calibration run (CUBP&I_3.UCI), for the period from May 1 to May 20 (largest annual storm)

to include a table of monthly values for the Manning's Number. These changes can be observed in the CUBP&I_4.UCI file included in Appendix H. The hourly flow time series generated by this run was stored in data set #33 of the CUBRUNDT.WDM file.

The analysis of this third calibration run revealed that the annual observed average flow was 57.18 cfs and the annual simulated average flow was 60.84 cfs, 6.4% larger. A general guideline presented in the *Application Guide for Hydrological Simulation Program - FORTRAN (HSPF)* (Donigian *et al.* 1984, p. 114) indicates that for the hydrology/hydraulics simulation, calibration results that differ less than 10% from the observed values are considered very good. They also note that those percent variations apply normally to annual and monthly values and that individual events might show considerably larger differences without having a major impact on the general calibration. However, an analysis of Table 17 and Chart 23, where the monthly comparisons are presented indicated that even though the annual average improved, some months in the first half of 1989 were greatly undersimulated, and that the period going from June to September is largely oversimulated. The reason the annual average is performing well is basically because of a compensation of errors in both directions.

Chart 24 shows the difference between the second and third calibration runs. Almost no difference can be noted from August to December. Charts 25 to 28 show the adjustment of the simulated results to the observed data for the four quarters of 1989 and Chart 29 shows the same for the period going from May 1 to May 20.

The large values of simulated flows observed during the months of June and July can be explained if localized storms took place that were recorded at the precipitation gaging station place at Dulles Airport but not for the whole watershed. This type of precipitation pattern is very characteristic of this zone during the summer months.

Table 17
Monthly and annual flows for observed data (data set #23) and the CUBP&I_4.UCI simulation, and percentage differences

Month	Observed data Flow (cfs)	CUBP&I_4.UCI Flow (cfs)	Percent difference
January	48.65	29.50	-39.36%
February	50.18	35.76	-28.74%
March	100.32	81.24	-19.02%
April	51.43	50.19	-2.41%
May	209.36	198.70	-5.09%
June	69.69	109.45	57.05%
July	32.76	84.03	156.50%
August	5.25	8.98	71.05%
September	11.12	16.53	48.65%
October	49.78	53.04	6.55%
November	44.79	48.83	9.02%
December	12.82	13.79	7.57%
Year: 1989	57.18	60.84	6.40%

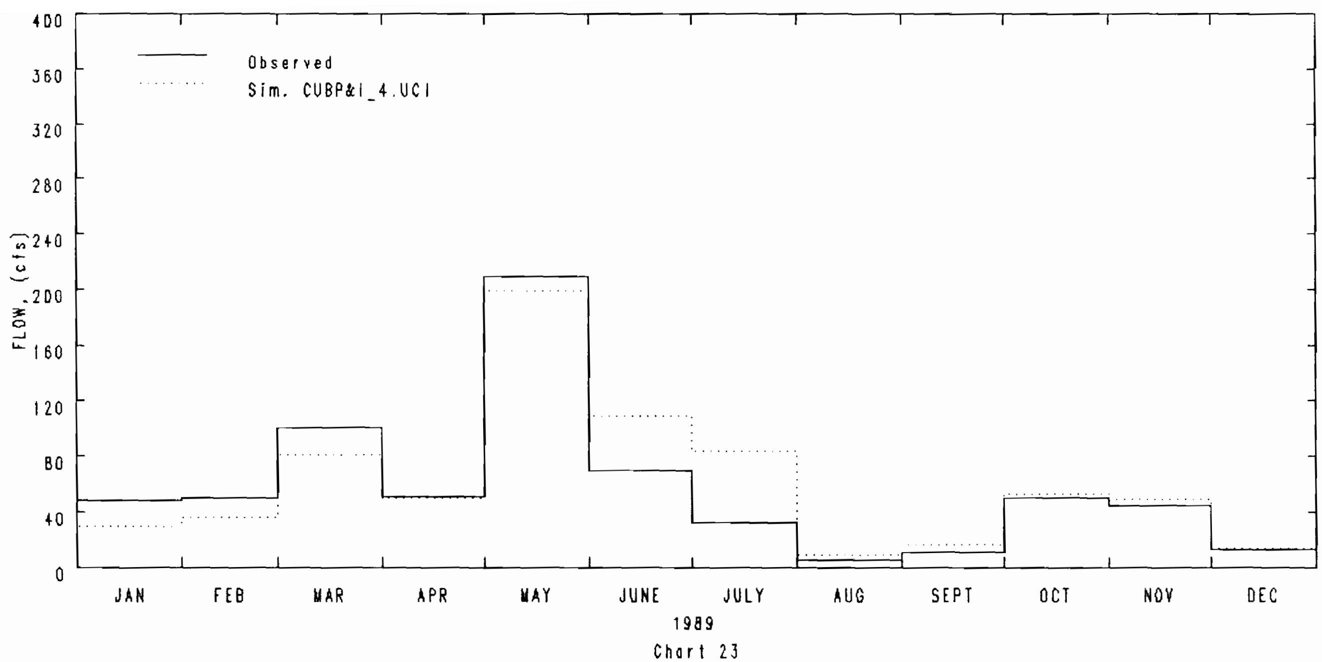


Chart 23: Comparison between the monthly observed flow values and the simulated results for the third calibration run (CUBP&I_4.UCI)

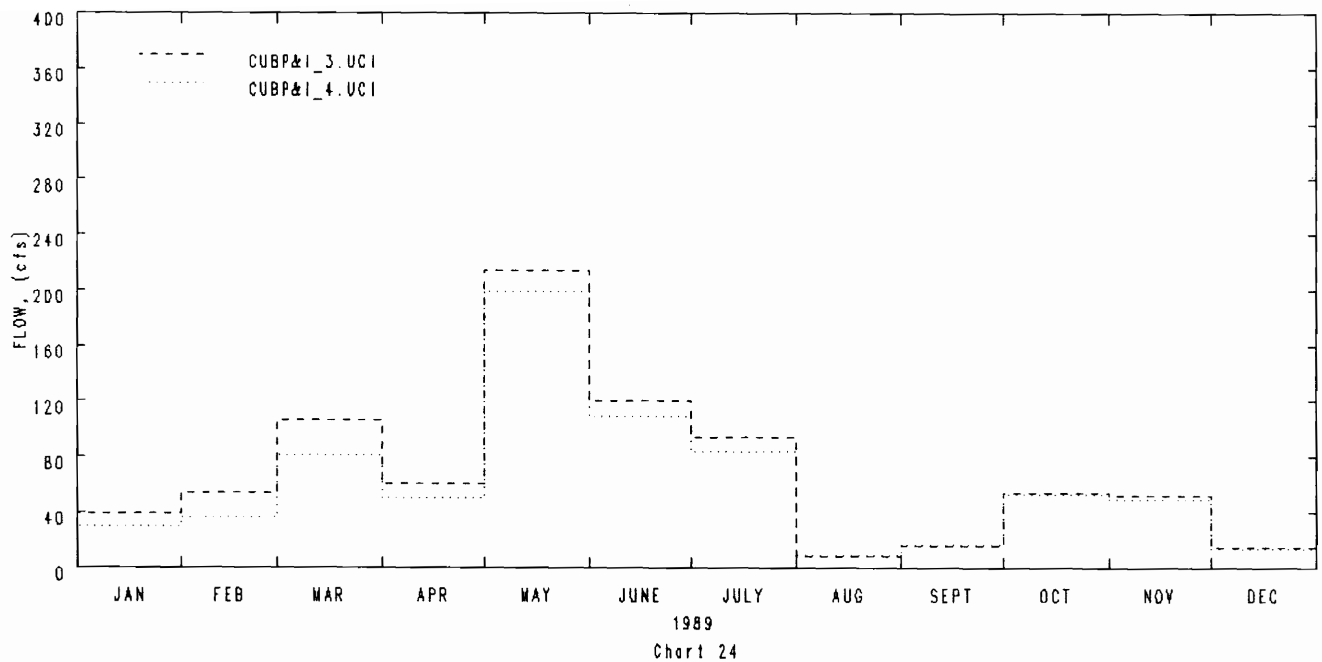


Chart 24: Comparison between the monthly simulated results for the second and the third calibration runs (CUBP&I_3.UCI and CUBP&I_4.UCI respectively)

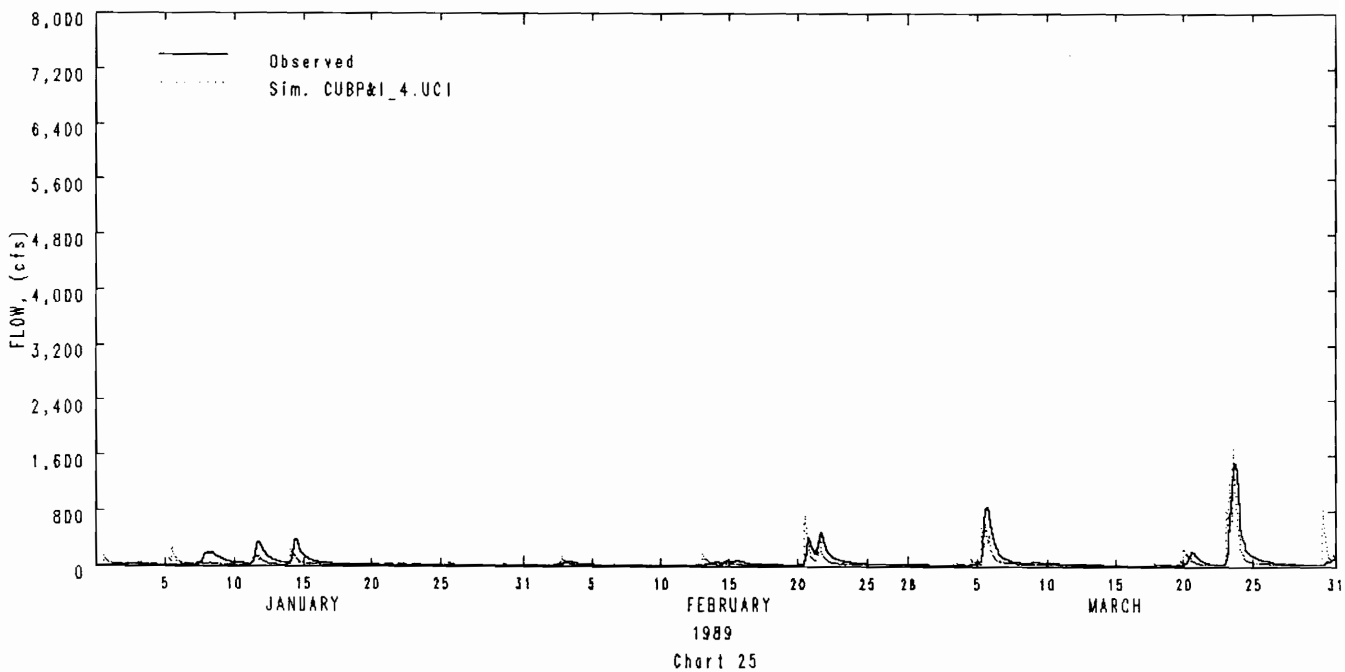


Chart 25: Comparison between hourly observed flow values and simulated results for the third calibration run (CUBP&I_4.UCI), for the first Quarter of 1989

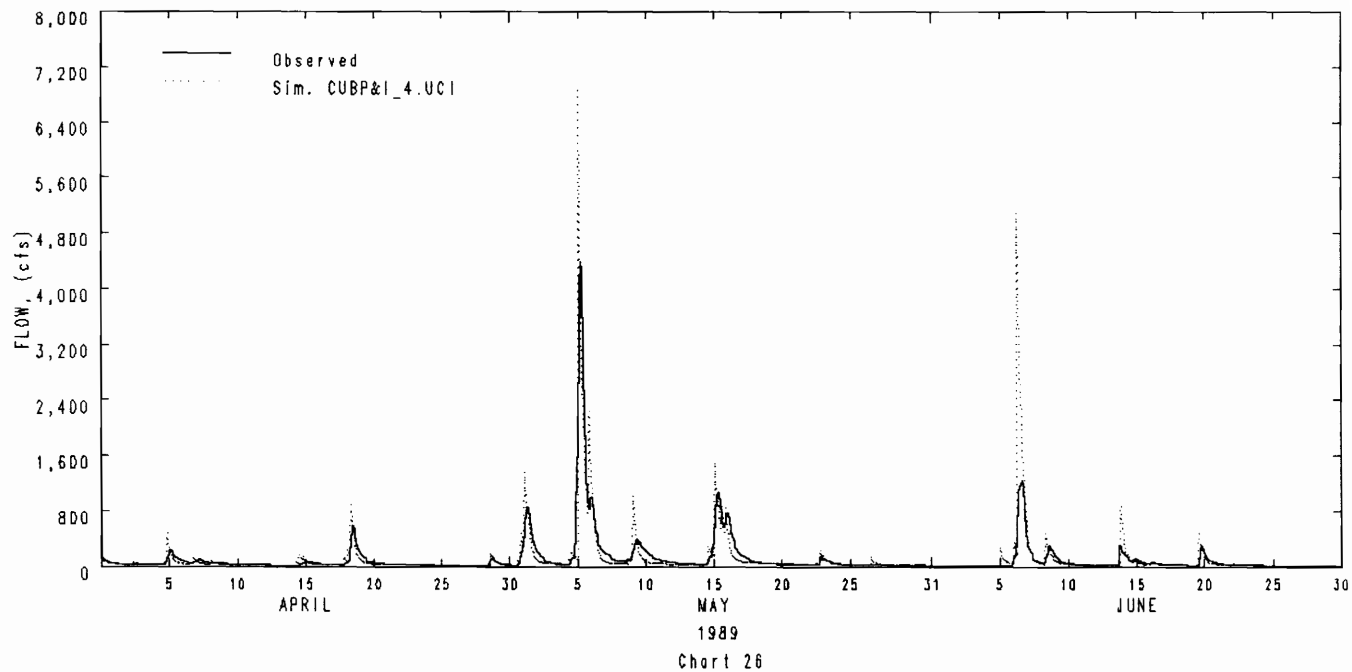


Chart 26: Comparison between hourly observed flow values and simulated results for the third calibration run (CUBP&I_4.UCI), for the second Quarter of 1989

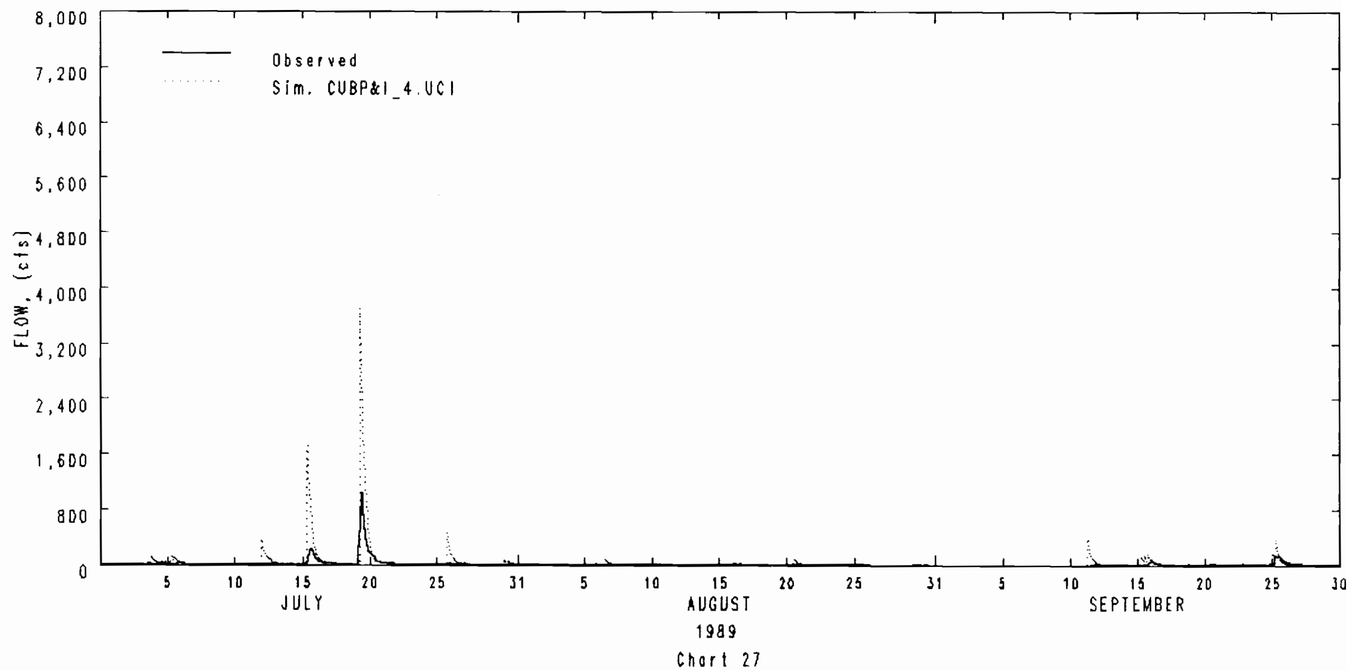


Chart 27: Comparison between hourly observed flow values and simulated results for the third calibration run (CUBP&I_4.UCI), for the third Quarter of 1989

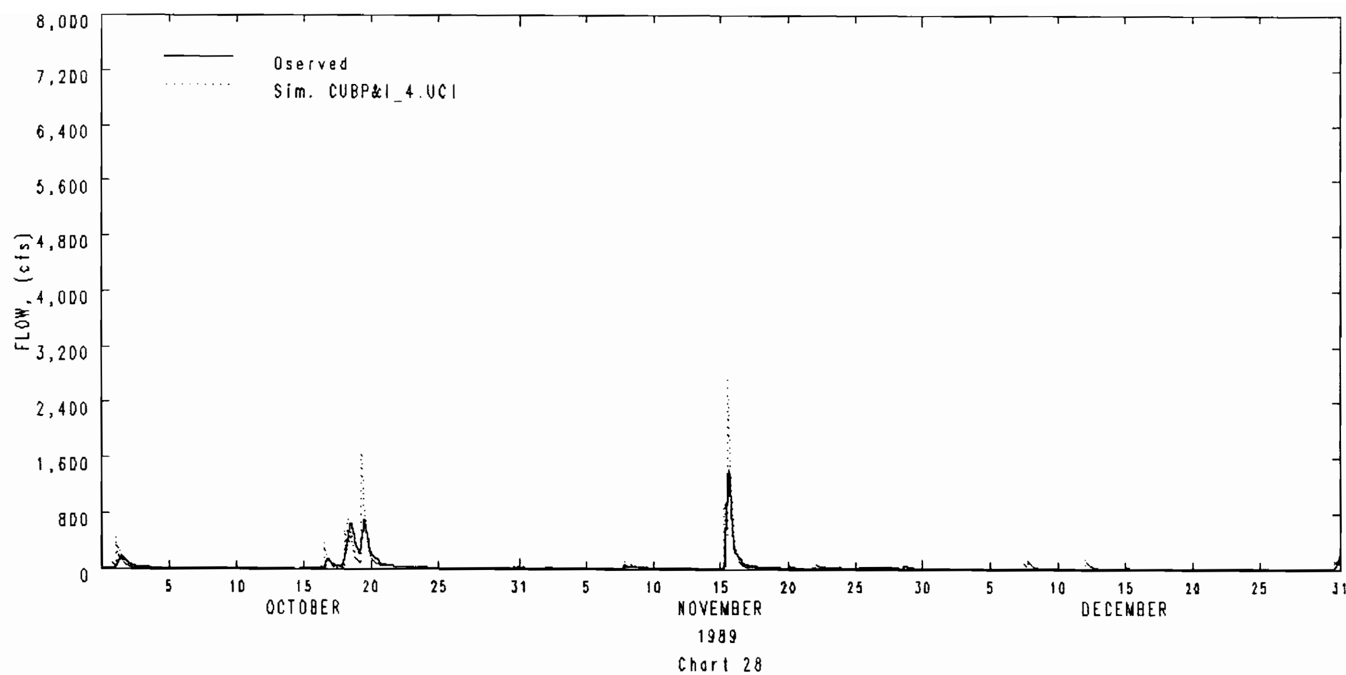


Chart 28: Comparison between hourly observed flow values and simulated results for the third calibration run (CUBP&I_4.UCI), for the fourth Quarter of 1989

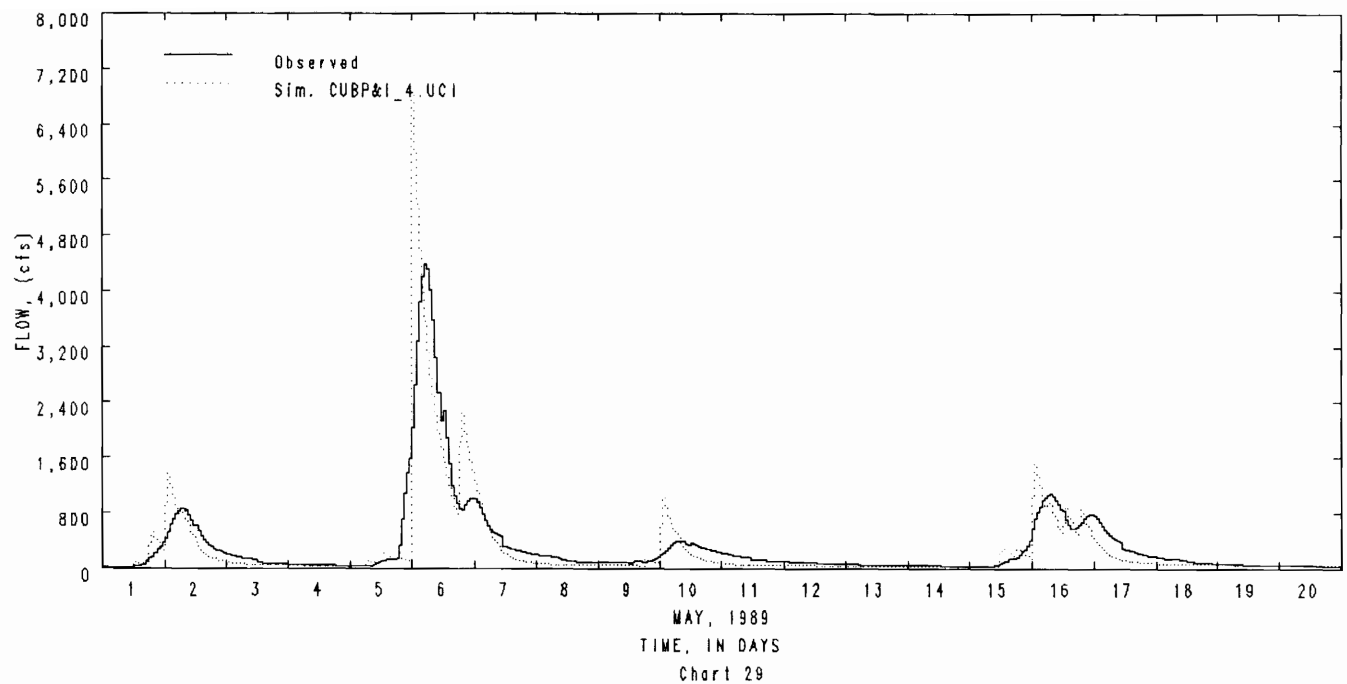
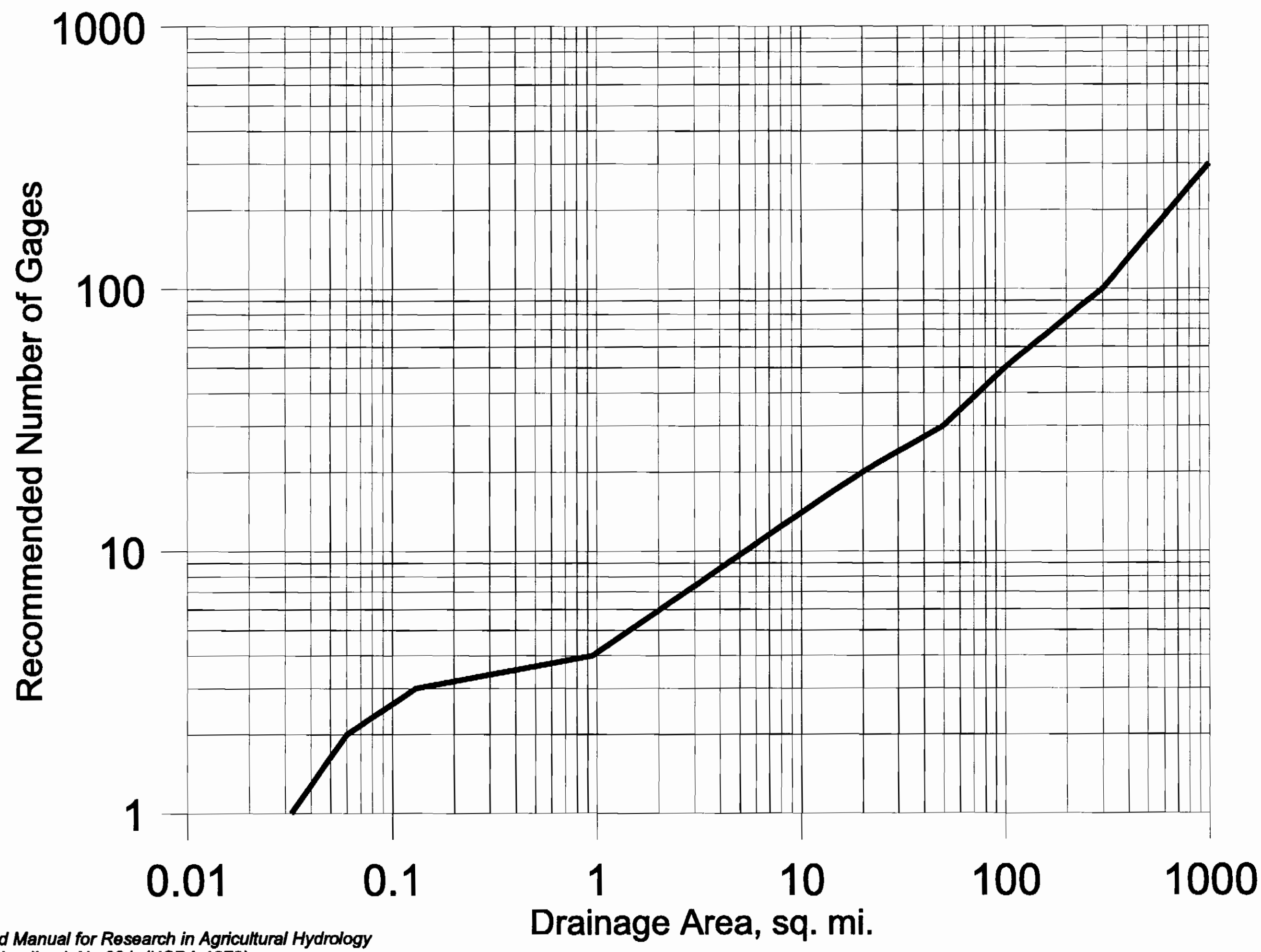


Chart 29: Comparison between hourly observed flow values and simulated results for the third calibration run (CUBP&I_4.UCI), for the period from May 1 to May 20 (largest annual storm)

A comparative analysis of the precipitation records for Dulles Airport, National Airport and The Plains weather station is shown in Appendix C. Major differences can be noted for the months of June, July, August, September, November and December. Even in the case where monthly precipitation records were almost identical for a couple of weather stations, the analysis of daily records indicated substantial differences. Dulles Airport is located between National Airport and The Plains and sometimes large precipitation measurements can be found for National Airport and The Plains without having almost any rainfall at all for Dulles Airport (see the period going from June 20 to June 25 in Chart C-3 in Appendix C), the opposite situation could also be observed for July 16 and 20 on Chart C-4 of Appendix C, when very large values of precipitation were recorded for Dulles Airport while those values were much smaller for The Plains and National Airport.

This situation can be addressed in the future by placing several rainfall gages in different locations of the watershed as recommended in the study *U.S. EPA Clean Lakes Report for the Occoquan Watershed* (NVPDC 1994, pp. 75-77). The recommended rainfall gage placement density can be obtained from Figure 18 which was extracted from the above mentioned report. For a watershed of 49.4 mi^2 the number of recommended gages is 30.

Therefore, the monthly values for June and July were not considered for the effects of the following analysis in which the best calibration run was determined. Table 18 shows the average monthly values from January to May and from August to September and the ten-month average for observed data (data set #23), the second operative UCI file (CUBP&I_1.UCI, data set #30), the first calibration run (CUBP&I_2.UCI, data set #31), the second calibration run (CUBP&I_3.UCI, data set #32), and the third calibration run (CUBP&I_4.UCI, data set #33). The table also shows the percent differences using the observed data as the base.



Source: *Field Manual for Research in Agricultural Hydrology* Agriculture Handbook No.224. (USDA 1979).

Figure 18: Recommended Rain Gage Placement Density

Table 18
Improvements obtained with the calibration runs

Month	Observed data	2nd operative run CUBP&I_1.UCI		1st. calib. run CUBP&I_2.UCI		**2nd. calib. run CUBP&I_3.UCI**		3rd. calib. run CUBP&I_4.UCI	
	Flow (cfs)	Flow (cfs)	Percent	Flow (cfs)	Percent	**Flow (cfs)**	**Percent**	Flow (cfs)	Percent
January	48.65	61.39	26.19%	61.39	26.19%	**39.18**	**-19.47%**	29.50	-39.36%
February	50.18	76.57	52.59%	76.57	52.59%	**54.33**	**8.27%**	35.76	-28.74%
March	100.32	123.76	23.37%	123.72	23.33%	**106.26**	**5.92%**	81.24	-19.02%
April	51.43	66.39	29.09%	66.29	28.89%	**60.54**	**17.71%**	50.19	-2.41%
May	209.36	222.92	6.48%	221.88	5.98%	**213.45**	**1.95%**	198.70	-5.09%
August	5.25	7.77	48.00%	6.95	32.38%	**8.02**	**52.76%**	8.98	71.05%
September	11.12	36.88	231.65%	15.43	38.76%	**15.92**	**43.17%**	16.53	48.65%
October	49.78	127.88	156.89%	67.92	36.44%	**53.79**	**8.05%**	53.04	6.55%
November	44.79	82.79	84.84%	60.28	34.58%	**51.74**	**15.52%**	48.83	9.02%
December	12.82	40.13	213.03%	18.76	46.33%	**14.49**	**13.03%**	13.79	7.57%
10-month period	58.37	84.65	45.02%	71.92	23.21%	**61.77**	**5.82%**	53.66	-8.07%

The original file CUBP&I_1.UCI oversimulated the annual results by 45.02%, the first calibration run reduced the oversimulation to 23.21%, the second calibration run oversimulated the result by just 5.82%, and the third calibration run undersimulated the results by 8.07%. This analysis did not consider the months of June and July for reasons previously explained. The second calibration run (CUBP&I_3.UCI) was the one that better approached the observed results and it was then selected as the basis for the calibration of individual events. The following observations were noted for the simulations for the second calibration run: January, April and November were fair (between 15 and 25%); December was good (between 10 and 15%); February, March, May and October were very good (less than 10%). August and September were months that presented a bad performance for the simulation; however, the absolute difference between the observed and the simulated results were comparable to those for the best months.

d. First single event calibration run: CUBP&I_5.UCI

To reduce the size of the peaks for individual storms and to extend the recession part of the hydrograph, the interflow-inflow parameter (INTFW) was increased from 1.22 to 3.50. This change can be observed in the CUBP&I_5.UCI file included in Appendix H. The hourly flow time series generated by this calibration run was stored in data set #34 of the CUBRUNDT.WDM file.

Chart 30 shows a small improvement for the simulation of the large storm that occurred on May 5 to May 7; however, smaller storms were better simulated than the large storm. Chart 31 shows the monthly flow averages for this run compared with observed data. An important point that has to be noted here, is that the use of six-hour step data as input for HSPF implied the accumulation of precipitation during that period. When that value was processed by the program,

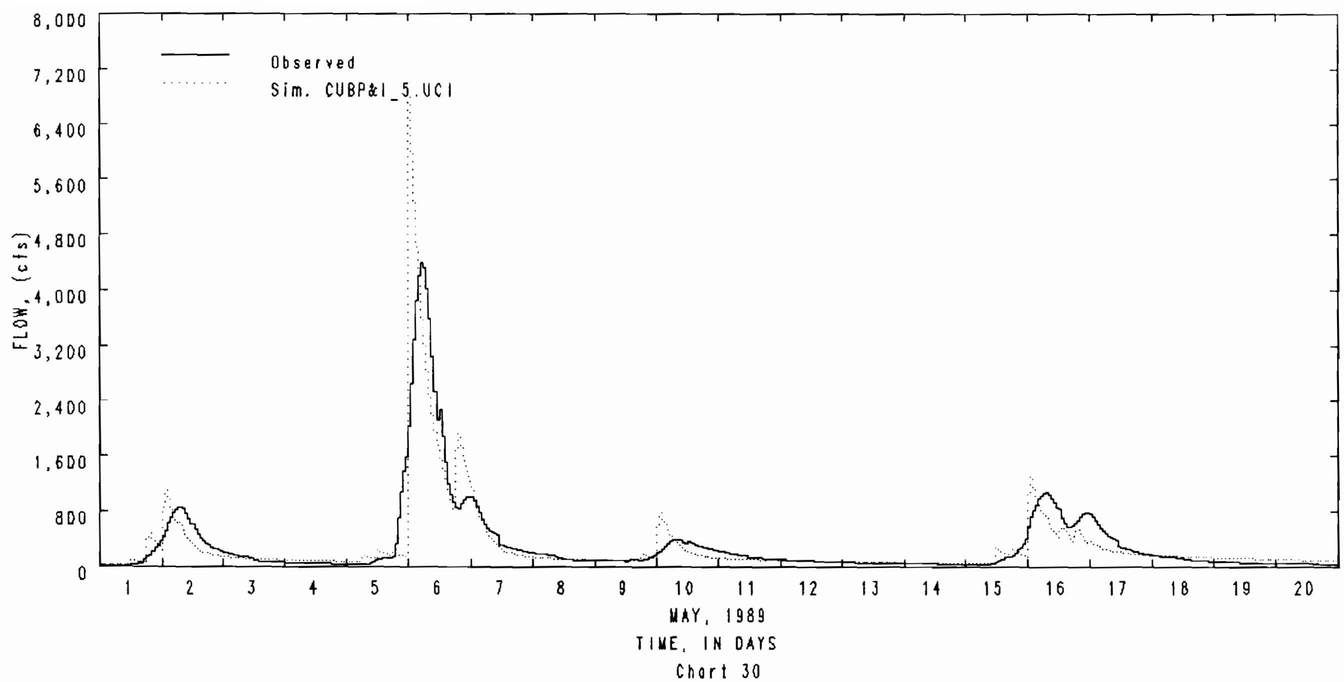


Chart 30: Comparison between hourly observed flow values and simulated results for the first single event calibration run (CUBP&I_5.UCI), for the period from May 1 to May 20 (largest annual storm)

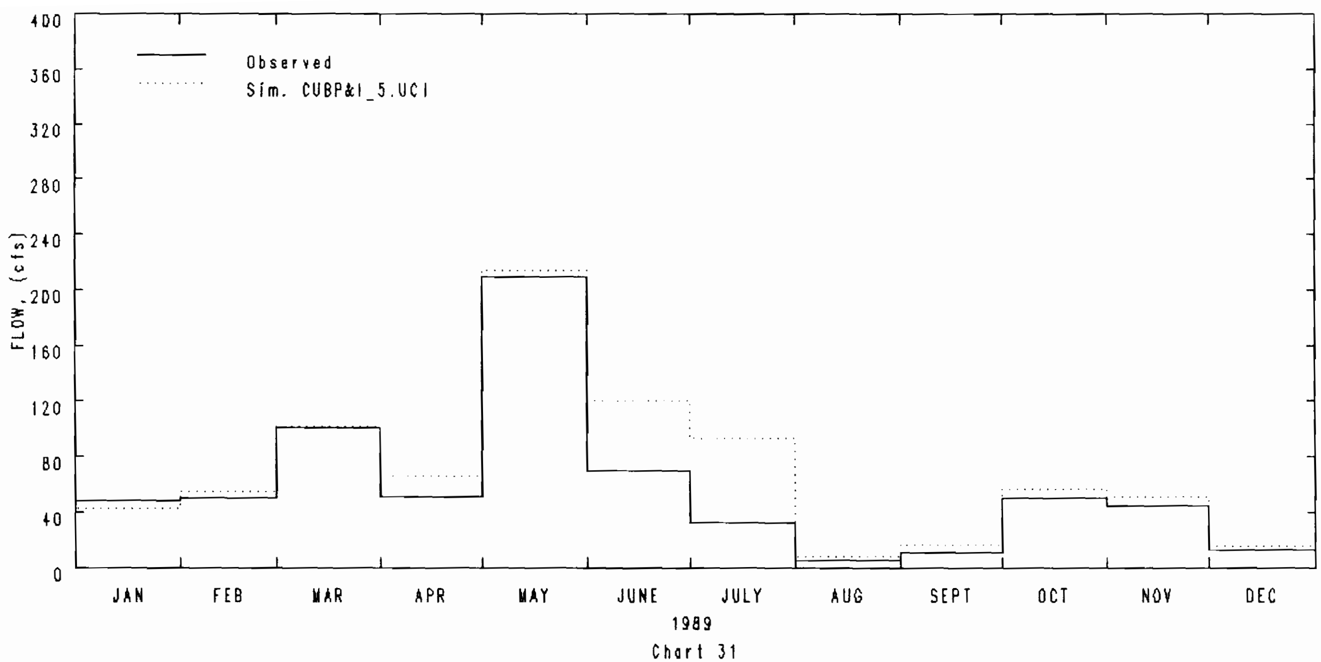


Chart 31: Comparison between the monthly observed flow values and the simulated results for the first single event calibration run (CUBP&I_5.UCI)

a sudden increase appeared in the simulated flow (instead of the gradual increase noted in the observed flow). To better simulate events developed in a few hours (like a storm) the need for hourly data for precipitation appears to be really important. Observation of Chart 30, indicates that the storm peak for the simulated results always appeared some hours before the one for the observed flow. Then the line for the simulated hydrograph crosses the one for the observed one. A compensation of areas indicates that the volume of water for both, simulated and observed hydrographs, were similar.

e. Second single event calibration run: CUBP&I_6.UCI

The value of the interflow-inflow parameter was further increased for this run. The value used was INTFW = 5.50 and the change can be observed in the CUBP&I_6.UCI file included in Appendix H. The hourly flow time series generated by this calibration run was stored in data set #35 of the CUBRUNDT.WDM file.

Charts 32 to 36 show a further decrease in the size of the storm peaks for this calibration run. However, some of the simulated values fall below and some of them are still above the observed values. Chart 37 shows the monthly values obtained with this simulation compared with observed data. Chart 38 and Table 19 show that the monthly values for CUBP&I_5.UCI and CUBP&I_6.UCI showed a decrease in the quality of adjustment already achieved with the second calibration run.

Again, better rainfall records throughout the whole area of the watershed are required if a better simulation and calibration has to be accomplished.

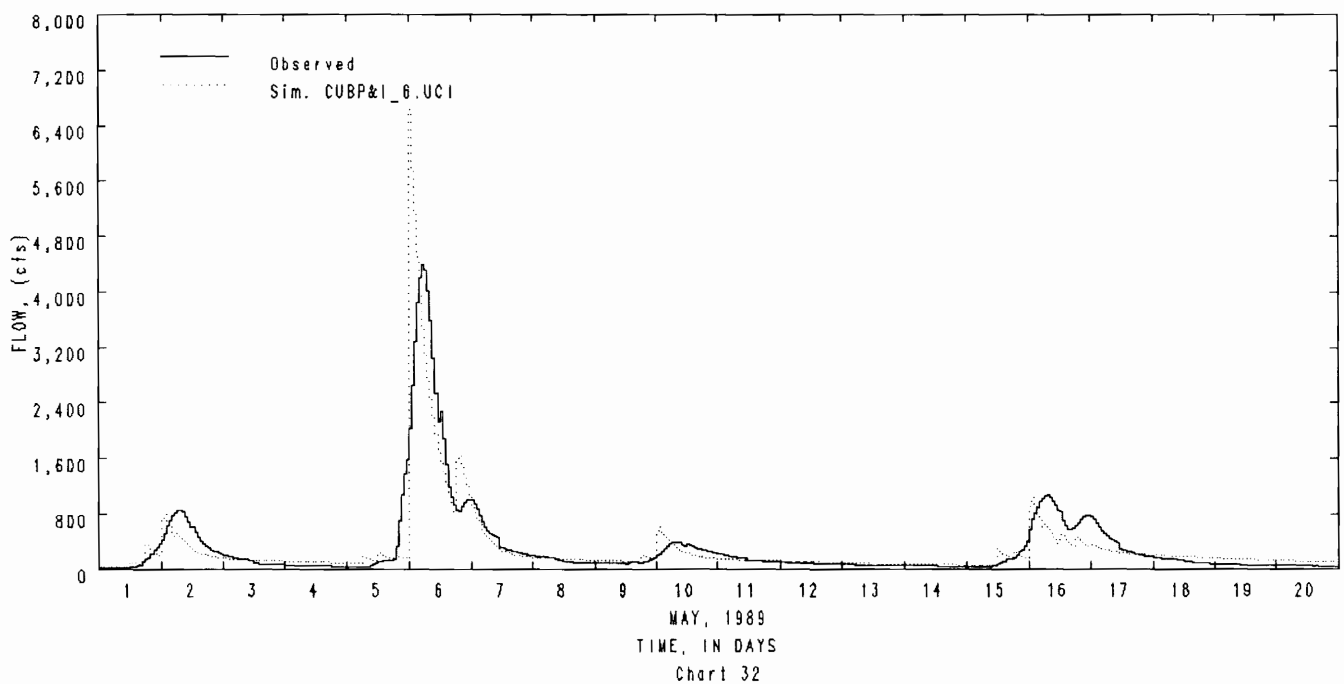


Chart 32: Comparison between hourly observed flow values and simulated results for the second single event calibration run (CUBP&I_6.UCI), for the period from May 1 to May 20 (largest annual storm)

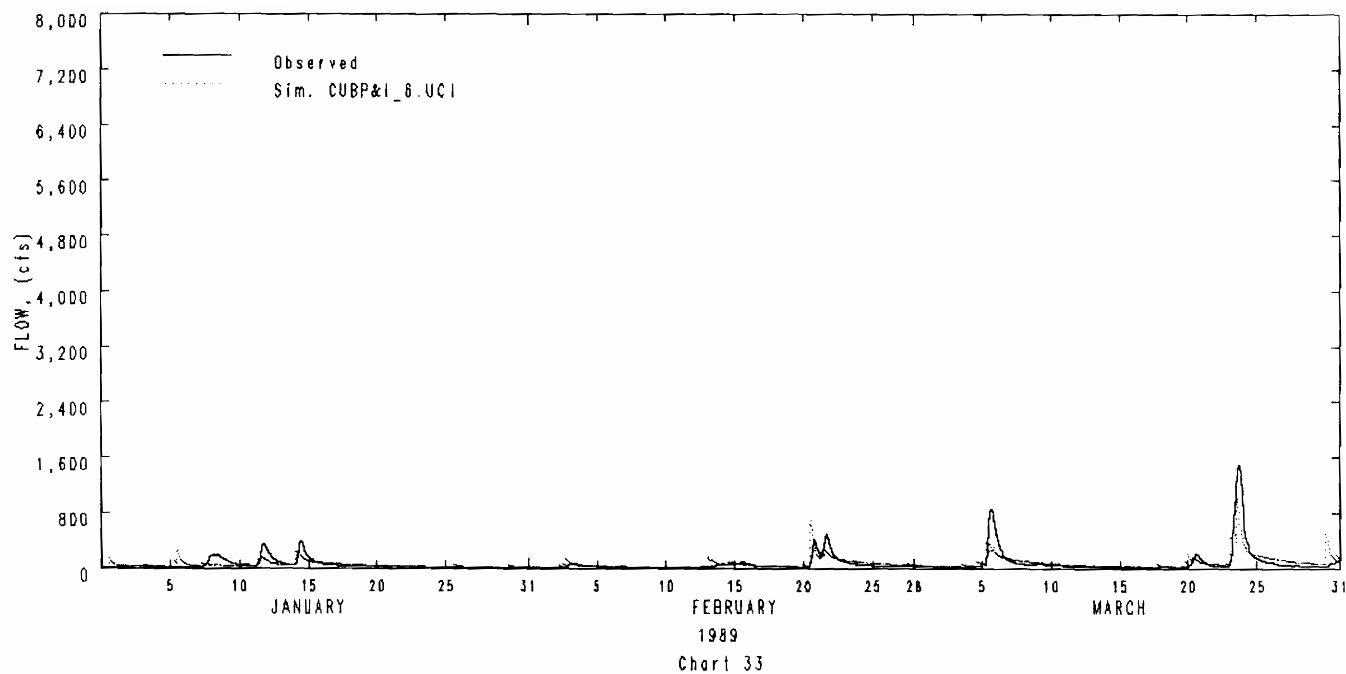


Chart 33: Comparison between hourly observed flow values and simulated results for the second single event calibration run (CUBP&I_6.UCI), for the first Quarter of 1989

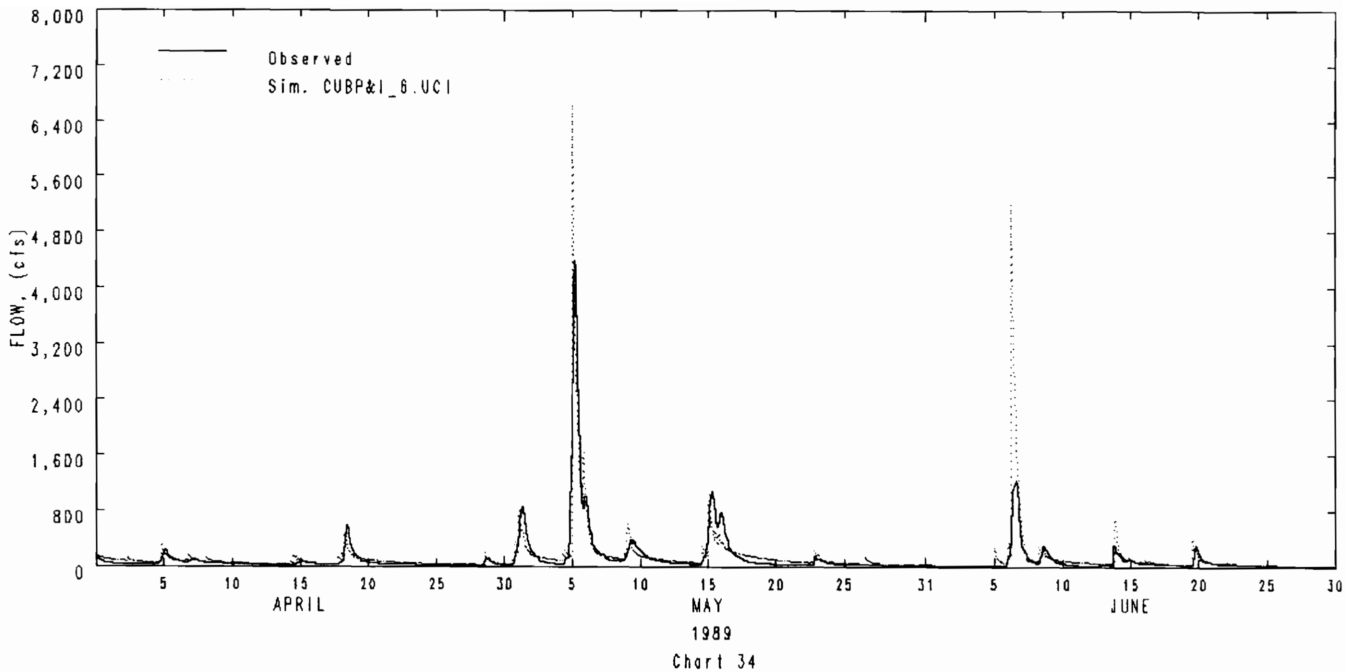


Chart 34: Comparison between hourly observed flow values and simulated results for the second single event calibration run (CUBP&I_6.UCI), for the second Quarter of 1989

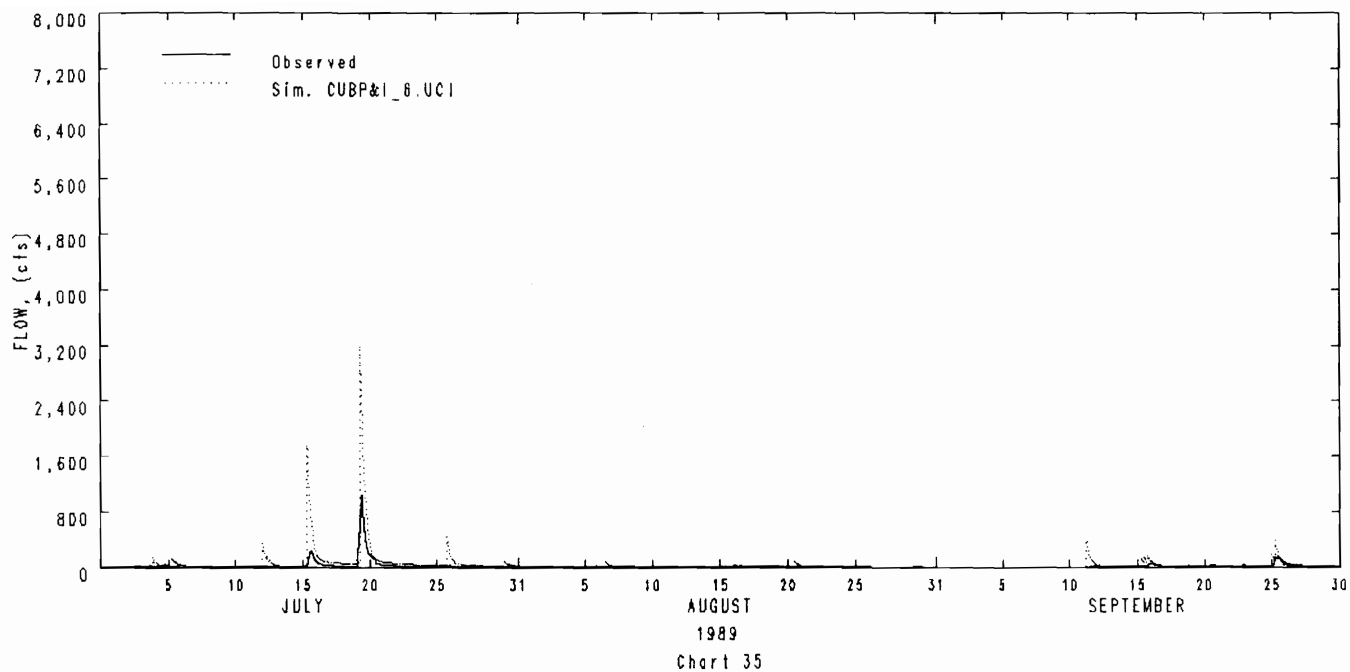


Chart 35: Comparison between hourly observed flow values and simulated results for the second single event calibration run (CUBP&I_6.UCI), for the third Quarter of 1989

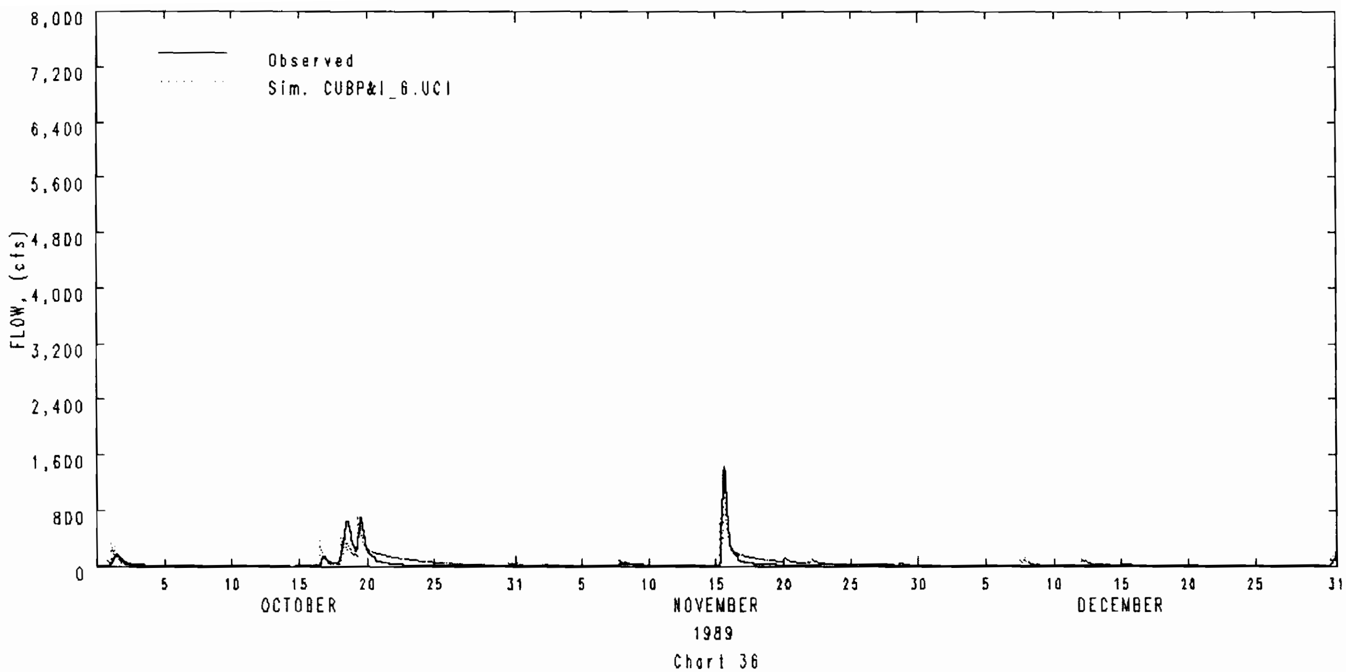


Chart 36: Comparison between hourly observed flow values and simulated results for the second single event calibration run (CUBP&I_6.UCI), for the fourth Quarter of 1989

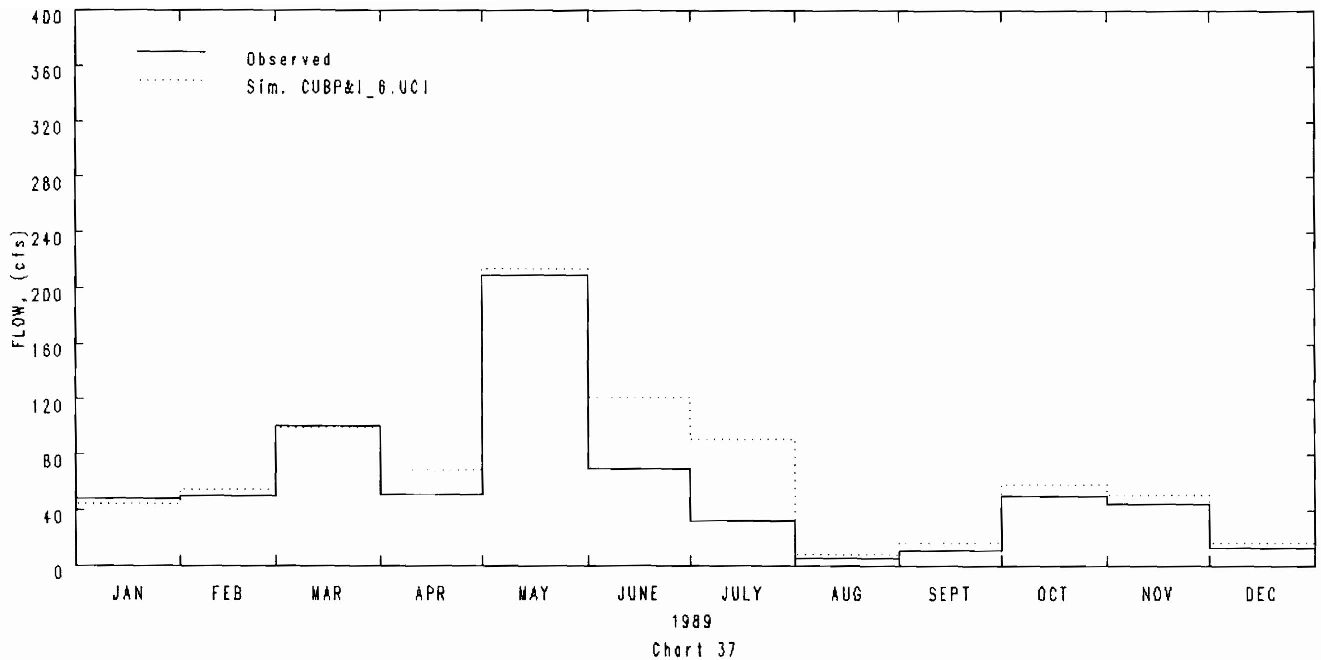


Chart 37: Comparison between the monthly observed flow values and the simulated results for the second single event calibration run (CUBP&I_6.UCI)

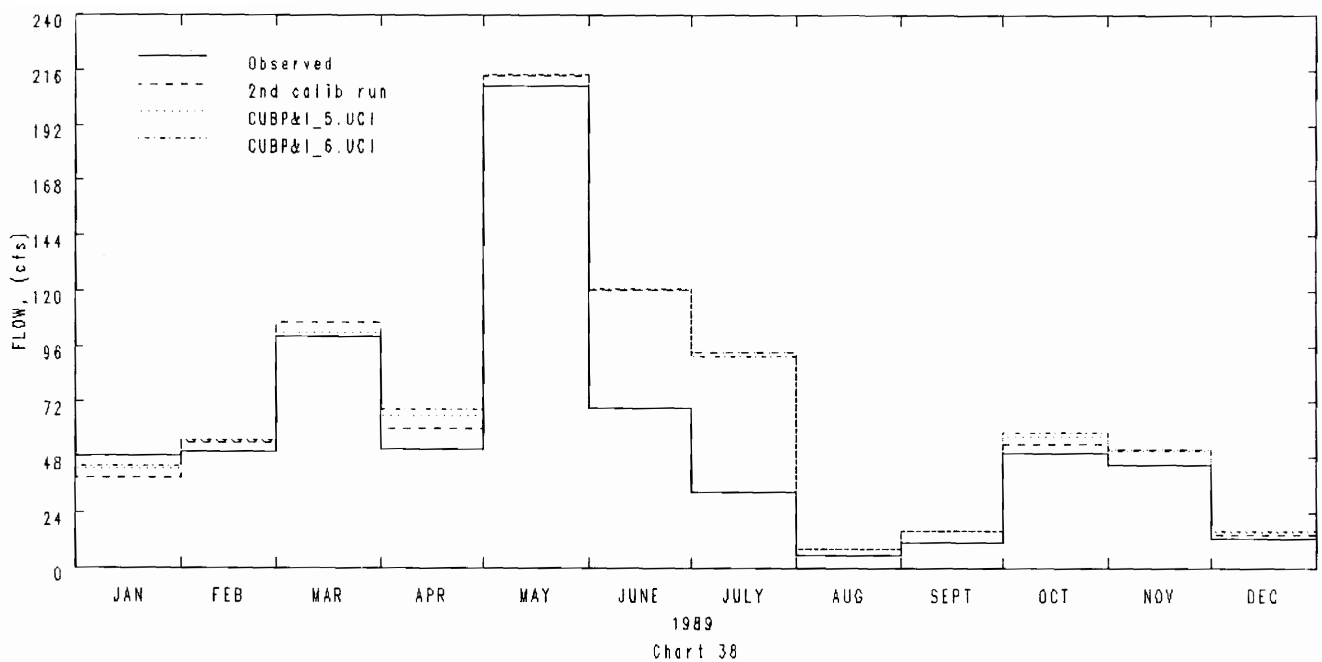


Chart 38: Comparison between the monthly observed flow values and the simulated results for the second calibration run (CUBP&I_3.UCI) and the first and second single event calibration runs (CUBP&I_5.UCI and CUBP&I_6.UCI respectively)

Table 19
Results of the first and second single event calibration runs

Month	Observed data	1st single event cal. run (CUBP&I_5.UCI)		2nd single event cal. run (CUBP&I_6.UCI)		2nd. calib. run (CUBP&I_3.UCI)	
	Flow (cfs)	Flow (cfs)	Percent	Flow (cfs)	Percent	Flow (cfs)	Percent
January	48.65	42.94	-11.74%	44.28	-8.98%	39.18	-19.47%
February	50.18	54.62	8.85%	55.18	9.96%	54.33	8.27%
March	100.32	101.88	1.56%	100.08	-0.24%	106.26	5.92%
April	51.43	66.32	28.95%	69.05	34.26%	60.54	17.71%
May	209.36	214.19	2.31%	214.31	2.36%	213.45	1.95%
June	69.69	120.72	73.22%	120.87	73.44%	120.72	73.22%
July	32.76	93.30	184.80%	91.81	180.25%	93.73	186.11%
August	5.25	8.13	54.86%	8.43	60.57%	8.02	52.76%
September	11.12	16.13	45.05%	16.17	45.41%	15.92	43.17%
October	49.78	57.21	14.93%	58.73	17.98%	53.79	8.05%
November	44.79	51.21	14.33%	50.93	13.71%	51.74	15.52%
December	12.82	15.76	22.93%	16.20	26.37%	14.49	13.03%
Annual (1989)	57.18	70.20	22.77%	70.50	23.29%	69.35	21.28%
10-month period	58.37	62.84	7.66%	63.34	8.51%	61.77	5.82%

3. Subdivision of the watershed in 13 segments: CUB13S_1.UCI

One of the objectives of this study was to determine the effect of further subdivision of the watershed area into smaller segments with different sets of parameters. The only two parameters that could be differentiated for these smaller segments were the overland flow plane length (LSUR) and the overland flow plane slope (SLSUR). These two parameters were carefully determined by different procedures as explained in Chapter III: Materials and Methods.

LSUR and SLSUR are parameters of great significance for the simulation of hydrological conditions. The watershed was divided for this calibration run into thirteen segments: seven pervious and six impervious as detailed in Table 20. This table displays the names of the segments and some of their characteristics and parameters. The seven segment groups are shown in Figure 19.

The layout for the operations performed in this run is shown in Figure 20. The user control input file CUB13S_1.UCI, with the subdivision of the Cub Run Watershed into thirteen segments, is included in Appendix H. The hourly flow time series generated by this run was stored in data set #40 of the CUBRUNDT.WDM file.

Chart 39 shows a comparison between the observed monthly values for flow and the simulated results. The simulation is fairly good with the exception of the months of June and July. Chart 40 compares the monthly simulated results for the second calibration run and the run produced using the CUB13S_1.UCI file. The lines for both files can not be differentiated although a very slight difference can be detected for the months of February and October. The LSUR and SLSUR parameters for the second calibration run were 387.0 and 0.0378 respectively while the LSUR and SLSUR area-weighted averages for the watershed divided in thirteen

Table 20
Name, characteristics and parameters for run CUB13S_1.UCI

Segment name	Perviousness	HSPF segment code	Area (mi^2)	LSUR (ft)	SLSUR (ft/ft)
Upper Cub Run - P.	Pervious	PERLND 1	8.825	299.5	0.0232
Upper Cub Run - I.	Impervious	IMPLND 1	0.933	299.5	0.0232
Middle Cub Run - P.	Pervious	PERLND 2	5.258	302.7	0.0370
Middle Cub Run - I.	Impervious	IMPLND 2	0.546	302.7	0.0370
Flatlick Branch - P.	Pervious	PERLND 3	6.760	288.4	0.0505
Flatlick Branch - I.	Impervious	IMPLND 3	1.191	288.4	0.0505
Elklick Run - P.	Pervious	PERLND 4	11.559	322.9	0.0311
Lower Cub Run - P.	Pervious	PERLND 5	4.052	313.6	0.0415
Lower Cub Run - I.	Impervious	IMPLND 5	0.501	313.6	0.0415
Big Rocky Run - P.	Pervious	PERLND 6	7.592	305.2	0.0557
Big Rocky Run - I.	Impervious	IMPLND 6	1.814	305.2	0.0557
CUB038 - P.	Pervious	PERLND 7	0.329	388.7	0.0749
CUB038 - I.	Impervious	IMPLND 7	0.045	388.7	0.0749

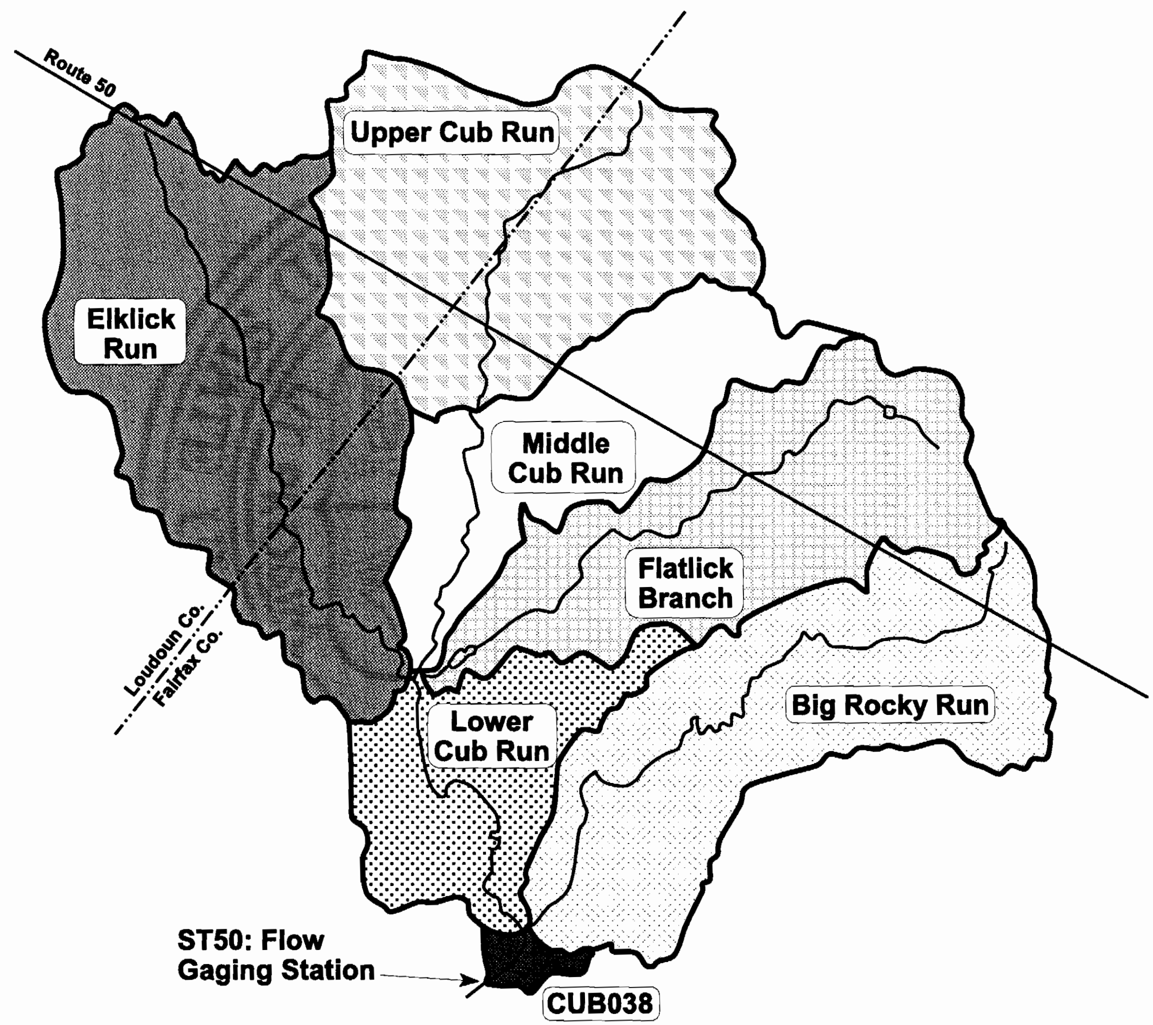


Figure 19: Subwatersheds of the Cub Run Drainage Basin

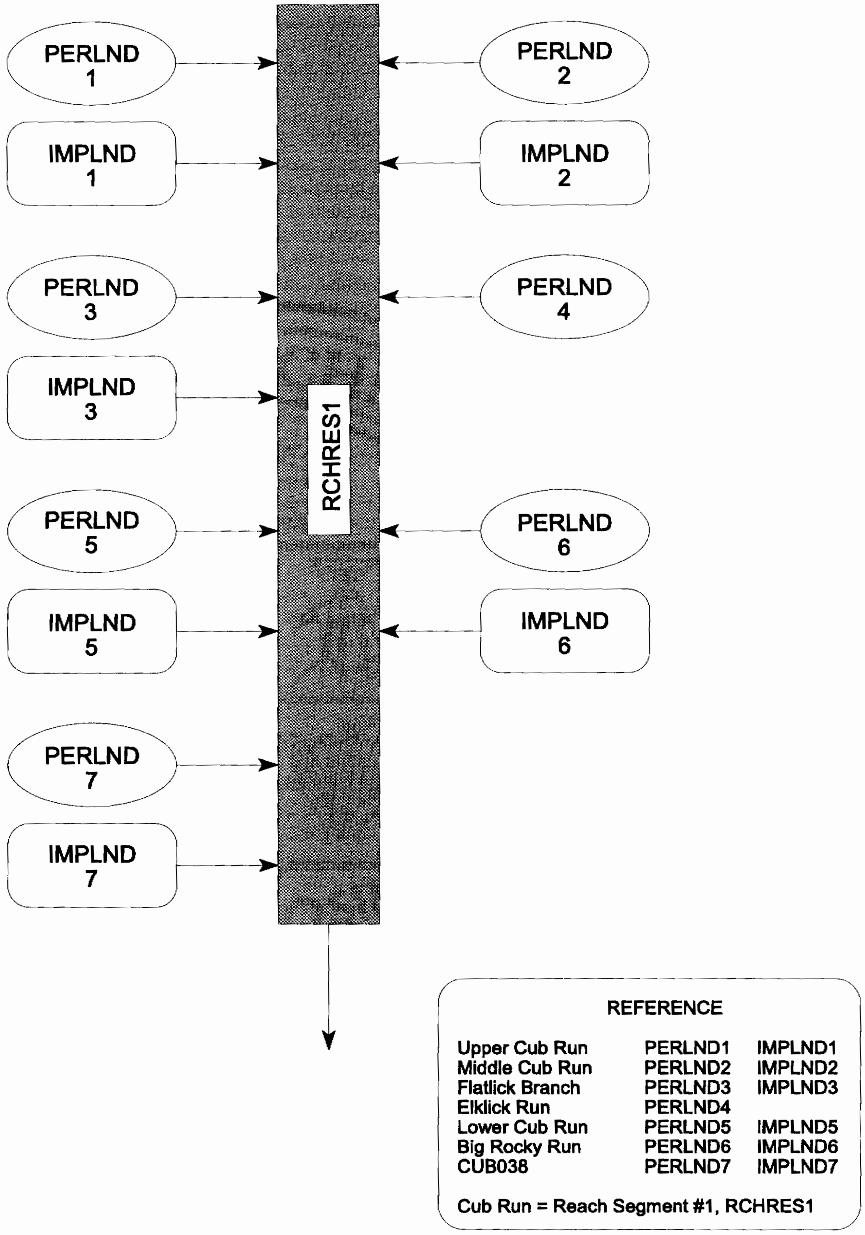


Figure 20
Scheme of Run Operations for Cub Run Watershed Divided into 7 Pervious and 6 Impervious Land Segments

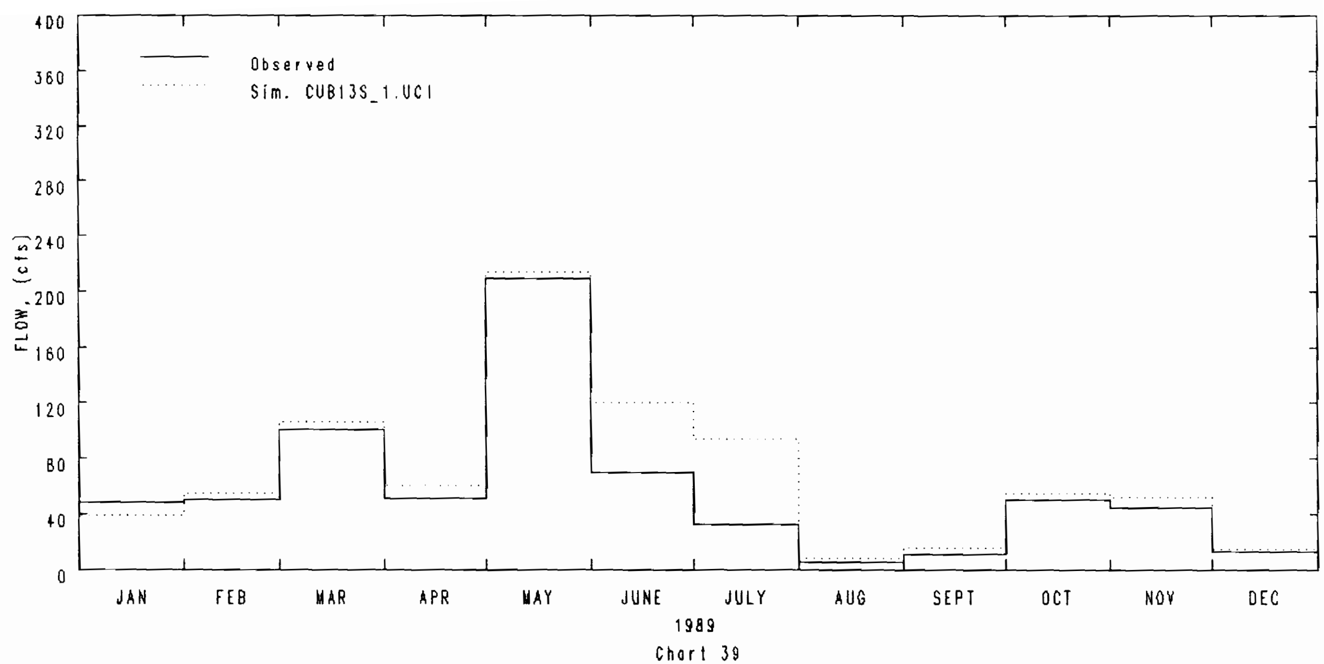


Chart 39: Comparison between the monthly observed flow values and the simulated results for the run considering the Watershed subdivided into 13 different segments (CUB13S_1.UCI)

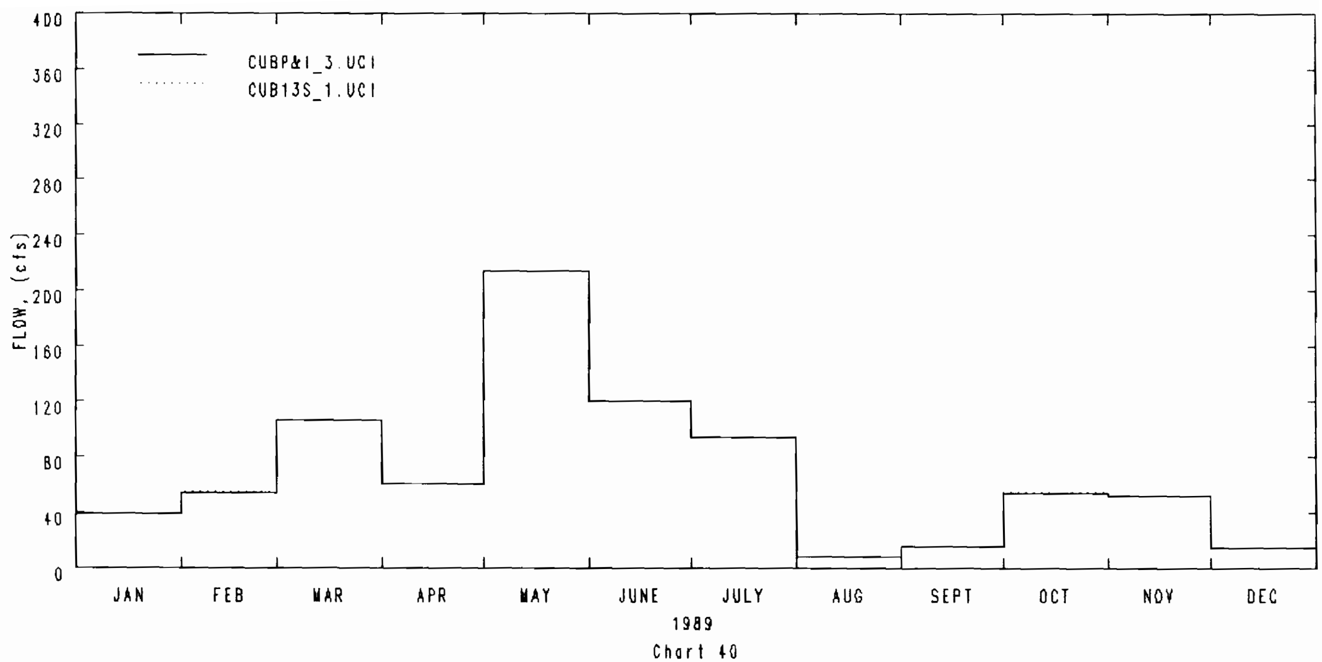


Chart 40: Comparison between the monthly simulated results for the run considering the Watershed subdivided into 13 different segments (CUB13S_1.UCI) and the second calibration run (CUBP&I_3.UCI)

segments were 307.0 and 0.0393. Therefore, there was a significant difference in input parameters between both runs, but just a very small deviation could be noted for a couple of months in the output.

Charts 41 to 44 show the comparisons for the four quarters of 1989 between the second calibration run and the run executed using the CUB13S_1.UCI file. Table 21 displays the differences between the second calibration run, the CUB13S_1.UCI run and the observed values.

The study of Table 21 and charts 39 to 44 indicates that practically there was no difference in the output of the run using the thirteen segment as compared with the second calibration run (using just two segments). This is an indication that the segmentation, at least at this level, did not have a major effect over the output.

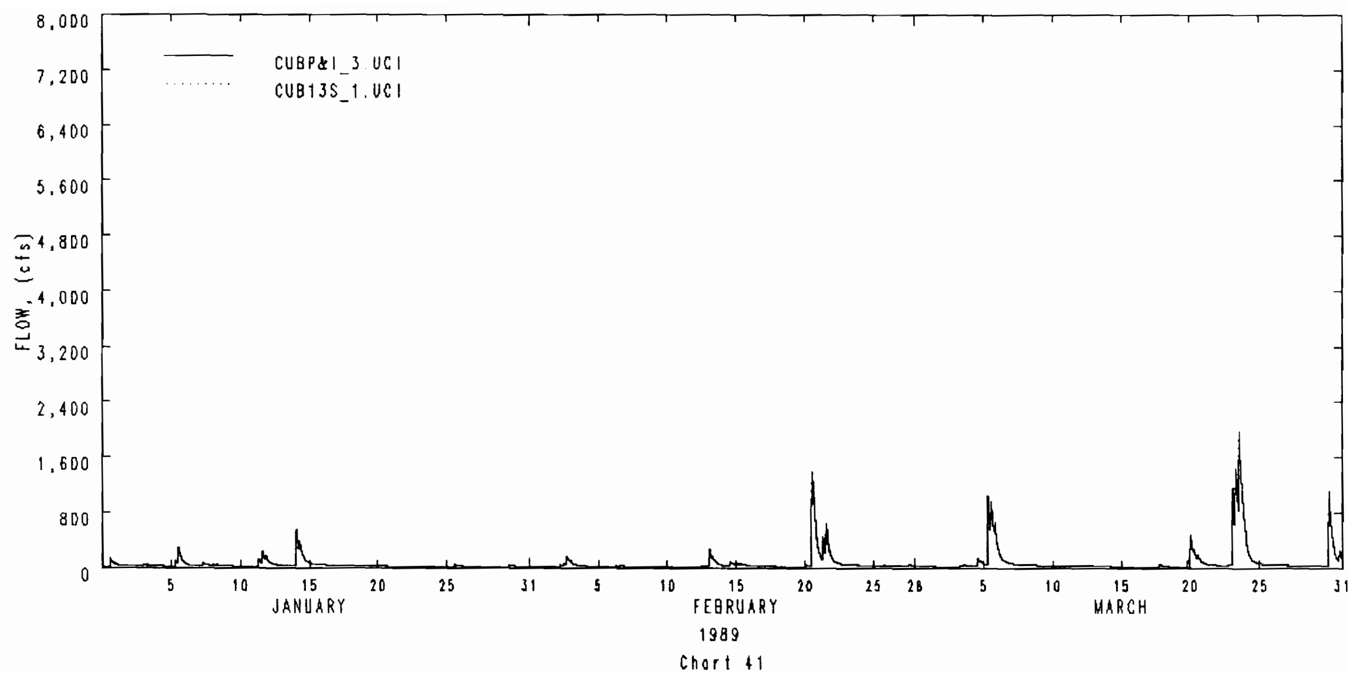


Chart 41: Comparison between hourly observed flow values and simulated results for the run considering the Watershed divided into 13 segments (CUB13S_1.UCI), for the first Quarter of 1989

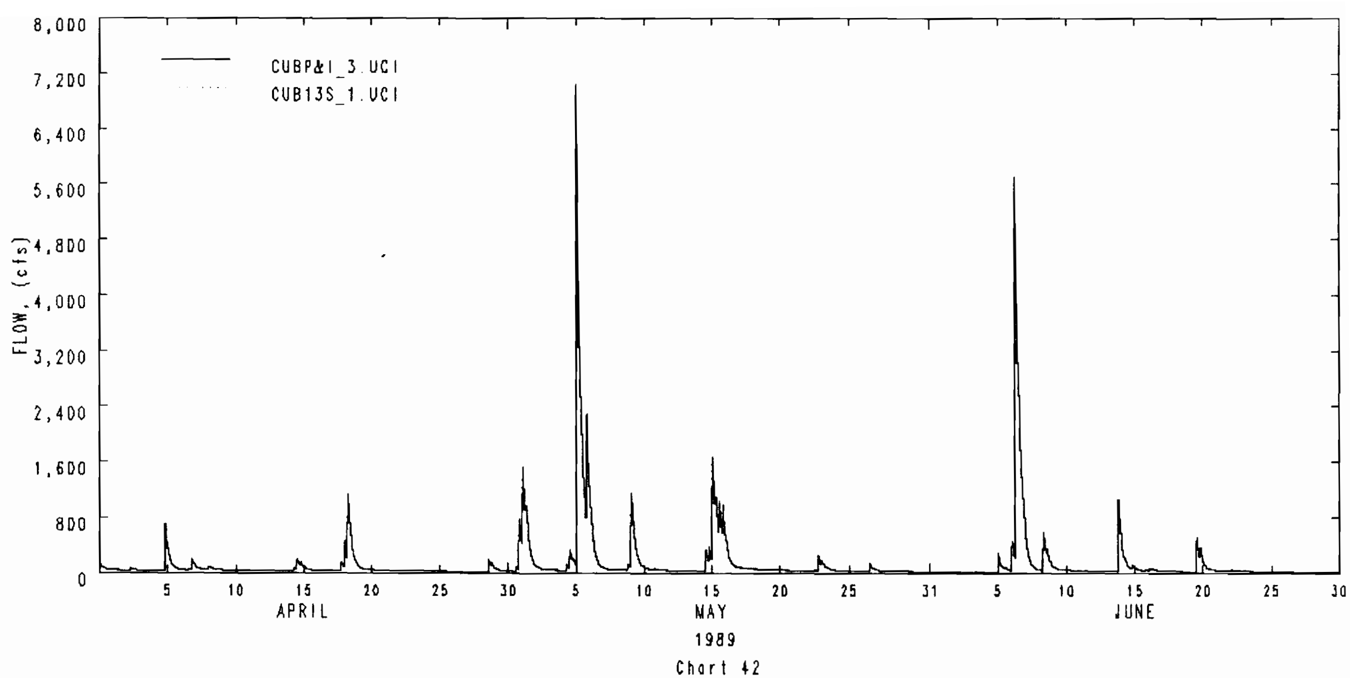


Chart 42: Comparison between hourly observed flow values and simulated results for the run considering the Watershed divided into 13 segments (CUB13S_1.UCI), for the second Quarter of 1989

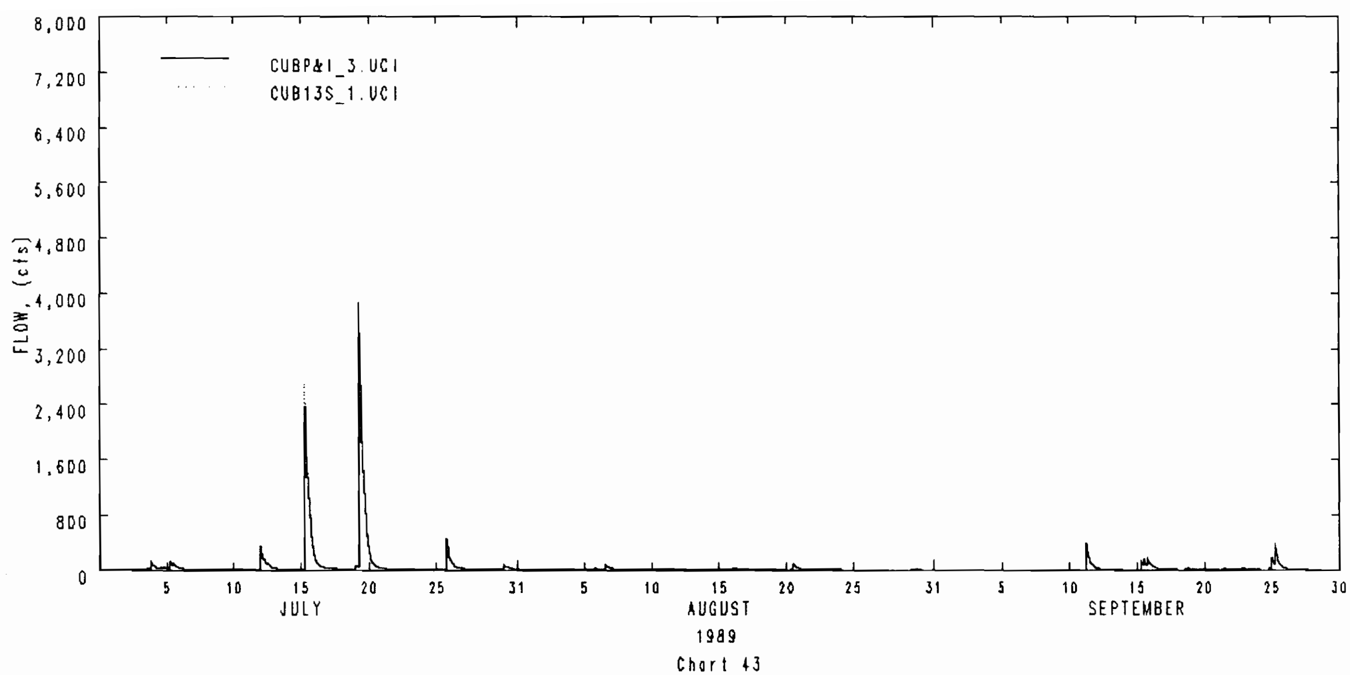


Chart 43: Comparison between hourly observed flow values and simulated results for the run considering the Watershed divided into 13 segments (CUB13S_1.UCI), for the third Quarter of 1989

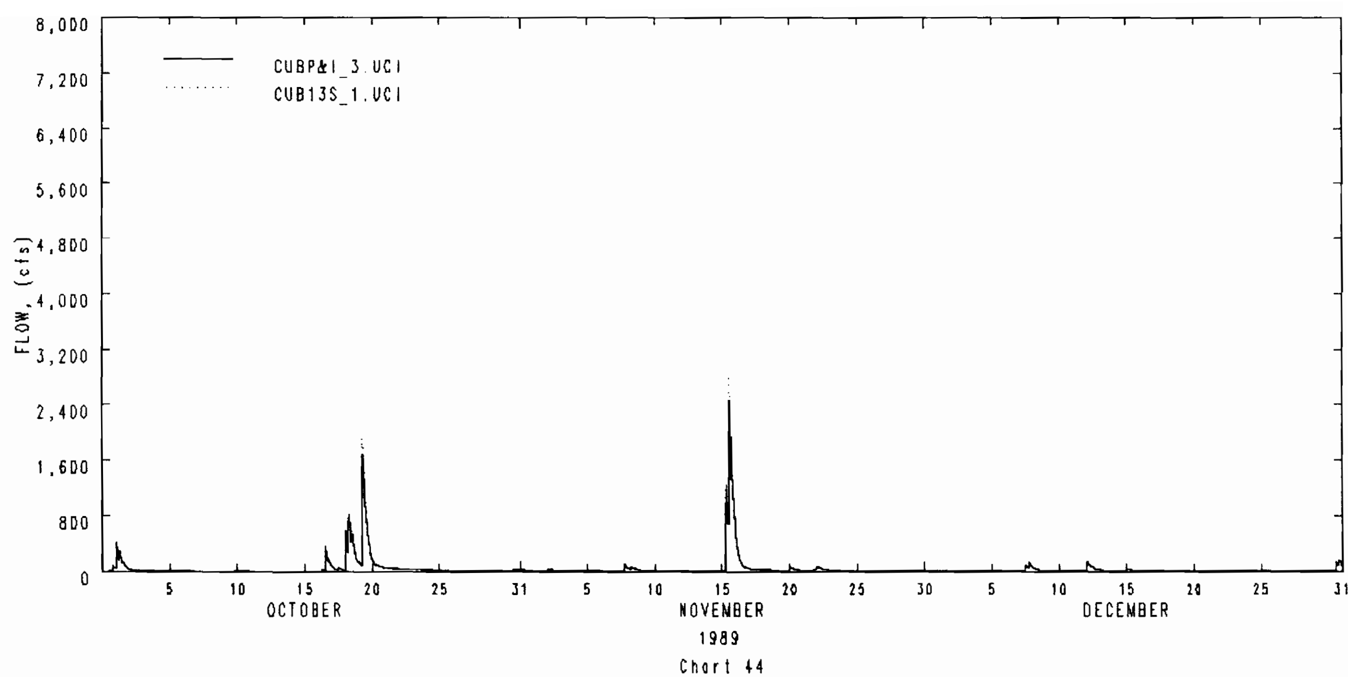


Chart 44: Comparison between hourly observed flow values and simulated results for the run considering the Watershed divided into 13 segments (CUB13S_1.UCI), for the fourth Quarter of 1989

Table 21
Comparative results for the second calibration run and CUB13S_1.UCI

Month	Observed data	Run considering Watershed subdivided into 13 segments (CUB13S_1.UCI)		**2nd. calib. run (CUBP&I_3.UCI)**	
	Flow (cfs)	Flow (cfs)	Percent	**Flow (cfs)**	**Percent**
January	48.65	39.35	-19.11%	**39.18**	**-19.47%**
February	50.18	54.84	9.29%	**54.33**	**8.27%**
March	100.32	106.79	6.45%	**106.26**	**5.92%**
April	51.43	60.48	17.60%	**60.54**	**17.71%**
May	209.36	214.14	2.28%	**213.45**	**1.95%**
June	69.69	120.70	73.20%	**120.72**	**73.22%**
July	32.76	94.42	188.22%	**93.73**	**186.11%**
August	5.25	7.88	50.10%	**8.02**	**52.76%**
September	11.12	15.88	42.81%	**15.92**	**43.17%**
October	49.78	55.35	11.19%	**53.79**	**8.05%**
November	44.79	52.50	17.21%	**51.74**	**15.52%**
December	12.82	14.24	11.08%	**14.49**	**13.03%**
Annual (1989)	57.18	69.71	21.91%	**69.35**	**21.28%**
10-month period	58.37	62.15	6.48%	**61.77**	**5.82%**

V. CONCLUSIONS

This chapter describes the conclusions obtained from this study. At the end some recommendations are listed that could be considered in future studies.

Conclusions:

- The usefulness of the PC version of the Hydrological Simulation Program - FORTRAN was demonstrated on an application of hydrological simulation for the Cub Run Watershed, a sub-watershed of the Occoquan River Drainage Basin. For the selected year, 1989, the best result was obtained with the second calibration run (CUBP&I_3.UCI file), with an annual percent difference of 21.28%, considered a fair result in the literature. If two months, June and July, were excluded, the difference between the simulated and observed results is just 5.82% for the ten-month period. This value, in a range where differences less than 10% are considered Very Good simulation results, could well be qualified as excellent.

- The most time-consuming part of this research was dedicated to the collection of data. However, and even when not all the desired information was found, this effort was worthwhile because the use of good quality data was important in the quality of the simulation results.

- The segmentation of a watershed into smaller segments with similar land use characteristics was not performed due to the lack of land use information. However, this segmentation appeared unnecessary, since the simulation results were fairly good just considering one pervious segment and one impervious segment.

- Including an impervious surface, even in a proportion of 10% of the total area, was important. Notable differences were obtained when the results of the run using a single pervious segment were compared with those of the run which also included an impervious segment.

- From the calibration standpoint, the HSPF simulation program reacted quite logically to changes in the calibration parameters. The changes produced in the simulation results could be predicted. Parameter values used for calibration were similar, at the end, to the values expected for the region.

- The calibration of particular storms did not provide results as expected. Even though parameters could have been changed further to obtain an adequate matching of the observed and simulated results, that effort was not performed since the values required for these calibration parameters were already falling out of the range expected for the area. The results of calibration for particular events were mixed. The need for better weather information was also noted.

- The last run, in which the watershed was segmented into groups with similar geomorphological characteristics, did not provide better results than the runs in which only two segments were considered. Basically, the results were very similar. The conclusion drawn here was that if the lumped value used for a parameter is adequate the need for further segmentation seems unnecessary.

Recommendations:

- At several points during the study, the lack of better information and raw data was evident. The use of the best available weather data can be considered a key issue in the success of the simulation. Only one weather station was located inside the Cub Run Watershed area, while for a drainage basin of this size more gaging stations would be required to obtain even better results. A first set of segment groups could have been established using different weather records from different stations, if they had been available. The occurrence of localized storms seems to be typical for this area, and once again, the problem caused from these types of events could have been solved with the use of distributed weather records for different watershed regions.

- A more detailed study of the watershed would require the collection of rainfall data in different parts of the watershed and the placement of stream flow gages at the points where major tributaries discharge their waters. These two conditions and the collection of some other data, like geometric characteristics of different tributaries, would allow for the calibration of smaller portions of the Watershed.

In summary, with the data that could be collected, the hydrological simulation of the Cub Run Watershed, using the PC version of HSPF was reasonably good. Further segmentation is an unneeded luxury when good results are obtained from a lower level of segmentation. Calibration using the scheme presented in the Methodology Section improved the simulation results, and just a few parameter changes were required to match observed and simulated results fairly well.

VI. REFERENCES

Abbott, Jess. 1978. *Testing of several runoff models on an urban watershed - Technical Memorandum 34.* American Society of Civil Engineers, Water Resources Program. New York.

Adler, Robert. 1995. We have a long way to go. *The Clean Water Act: Has it Worked?* gopher://gopher.epa.gov/00/News/EPAJournal/Summer94/05 (June 14, 1995).

Ahlgren, Clarence L. 1965. Recreational activities on watersheds? *Journal of the New England Water Works Association.* 79:15-17.

Altman, Lawrence K. 1993. Outbreak of disease in Milwaukee undercuts confidence in water. *The New York Times.* April 20, sec. C, p. 3.

American Water Works Association. 1990. *Water Quality and Treatment: A Handbook of Community Water Supplies.* 4th ed. McGraw-Hill, New York.

Anderson, Eric A., and Norman H. Crawford. 1964. *The Synthesis of Continuous Snowmelt Runoff Hydrographs on a Digital Computer.* Department of Civil Engineering, Stanford University, Stanford, CA. Technical Report No. 36.

AWWA Journal Roundtable Discussion. 1987. Debating recreational use. *Journal of the American Water Works Association.* 79(12):10-12.

Bailey, G. W., R. R. Swank, Jr., and H. P. Nicholson. 1974. Predicting pesticide runoff from agricultural land: a conceptual model. *Journal of Environmental Quality.* 3(2):95-102.

Barnwell, Thomas O., Jr. 1980. An overview of the Hydrologic Simulation Program - FORTRAN, a simulation model for chemical transport and aquatic risk assessment. In *Aquatic Toxicology and Hazard Assessment: Proceedings of the Fifth Annual Symposium on Aquatic Toxicology.* ASTM Special Tech. Pub. 766, ASTM, Philadelphia, PA. pp. 291-301.

Barnwell, Thomas O., Jr., and Robert C. Johanson. 1981. HSPF: A comprehensive package for simulation of watershed hydrology and water quality. *Nonpoint Pollution Control - Tools and Techniques for the Future, Proceedings of a Technical Symposium.* Tech. Pub. 81-1. Interstate Commission on the Potomac River Basin, Rockville, MD. pp. 135-153.

Barnwell, Thomas O., Jr., and John L. Kittle, Jr. 1984. Hydrologic Simulation Program - FORTRAN: development, maintenance, and applications. In *Proceedings of the Third International Conference on Urban Storm Drainage.* Chalmers Institute of Technology, Goteborg, Sweden. pp. 1-10.

Barret, Hugh. 1995. *Watershed Management on Grazing Lands.* Seminar held on the Oregon State University in Spring, 1992. ftp://sunsite.unc.edu/pub/academic/agriculture/sustainable_agriculture/permaculture/watershed.management.2 (June 12, 1995).

Berube, Raymond P. 1995. Final NPDES general permits for storm water discharges associated with industrial activity- - TIME CRITICAL: October 1, 1992, deadline. Memo to: distribution. gopher://dewey.tis.inel.gov.2012/00/.egm-sources/cwa.0016 (June 12,1995).

Bicknell, B[rian] R., Anthony S. Donigian, Jr., and T[homas] A. Barnwell. 1985. Modeling water quality and the effects of best managements practices in the Iowa River basin. *Wat. Sci. Tech.* 17:1141-1153.

Bicknell, Brian R., John C. Imhoff, John L. Kittle, Jr., Anthony S. Donigian, Jr., and Robert C. Johanson. 1993. *Hydrological Simulation Program -- FORTRAN. User's Manual for Release 10.* Environmental Research Laboratory, U.S. Environmental Research Laboratory, Athens, Georgia.

CH_2M Hill. 1980. *Analysis of Existing Hydrologic Models, Red River of the North Drainage Basin North Dakota and Minnesota.* Department of the Army, St. Paul District, Corps of Engineers.

Chew, Chee Yen, Larry W. Moore, and Roger H. Smith. 1991. Hydrological simulation of Tennessee's North Reelfoot Creek watershed. *Research Journal of the Water Pollution Control Federation.* 63(1):10-16.

Crawford, Norman H. 1962. The synthesis of continuous streamflow hydrographs on a digital computer. Ph.D. dissertation, Department of Civil Engineering, Stanford University, Stanford, CA.

Crawford, Norman H. 1995. Personal e-mail communication (June 8, 1995).

Crawford, Norman H., and Ray K. Linsley. 1962. *The Synthesis of Continuous Streamflow Hydrographs on a Digital Computer.* Department of Civil Engineering, Stanford University, Stanford, CA. Technical Report No. 12.

Crawford, Norman H., and Ray K. Linsley. 1966. *Digital Simulation in Hydrology: Stanford Watershed Model IV.* Department of Civil Engineering, Stanford University, Stanford, CA. Technical Report No. 39.

Dendrou, Stergios A. 1982. Overview of urban stormwater models. *Urban Stormwater Hydrology.* American Geophysical Union. Washington, D.C. Water Resources Monograph No. 7, pp. 219-247.

Dinicola, R. S. 1990. *Characterization and Simulation of Rainfall-Runoff Relations for Headwater Basins in Western King and Snohomish Counties, Washington.* U.S. Geological Survey, Water-Resources Investigations Report 89-4052.

Donigian, Anthony S., Jr. 1986. Integration of runoff and receiving water models for comprehensive watershed simulation and analysis of agricultural management alternatives. *Agricultural Nonpoint Source Pollution: Model Selection and Application Developments in Environmental Modeling.* 10, Elsevier, New York, 265-275.

Donigian, Anthony S., Jr., James L. Baker, Douglas A. Haith, and Michael F. Walter. 1983. *HSPF Parameter Adjustments to Evaluate the Effects of Agricultural Best Management Practices.* U.S. Environmental Protection Agency, Applications Branch, Environmental Research Laboratory, Athens, Georgia.

Donigian, Anthony S., Jr., and Norman H. Crawford. 1976. *Modeling Nonpoint Pollution from the Land Surface.* U.S. Environmental Protection Agency, Office of Research and Development, Environmental Research Laboratory, Athens, Georgia. EPA/600/3-76/083.

Donigian, Anthony S., Jr., and Norman H. Crawford. 1977. *Simulation of Nutrient Loadings in Surface Runoff with the NPS Model.* U.S. Environmental Protection Agency, Office of Research and Development, Environmental Research Laboratory, Athens, Georgia. EPA/600/3-77/065.

Donigian, Anthony S., Jr., and Norman H. Crawford. 1979. *User's Manual for the Nonpoint Source (NPS) Model.* U.S. Environmental Protection Agency, Office of Research and Development, Environmental Research Laboratory, Athens, Georgia.

Donigian, Anthony S., Jr., and Harley H. Davis, Jr. 1978. *User's Manual for Agricultural Runoff Management (ARM) Model.* U.S. Environmental Protection Agency, Office of Research and Development, Environmental Research Laboratory, Athens, Georgia. EPA/600/3-78/080.

Donigian, Anthony S., Jr., John C. Imhoff, and Brian R. Bicknell. 1983a. *Modeling Water Quality and the Effects of Agricultural Best Management Practices in Four Mile Creek, Iowa.* U.S. Environmental Protection Agency, Office of Research and Development, Environmental Research Laboratory, Athens, Georgia. EPA/600/3-83/067.

Donigian, Anthony S., Jr., John C. Imhoff, and Brian R. Bicknell. 1983b. Predicting water quality resulting from agricultural nonpoint source pollution via simulation - HSPF. *Agricultural Management and Water Quality.* Iowa State University Press, Ames, Iowa, pp. 200-249. EPA Contract No. 68-03-2895.

Donigian, Anthony S., Jr., John C. Imhoff, Brian R. Bicknell, and John L. Kittle, Jr. 1984. *Application Guide for Hydrological Simulation Program - FORTRAN (HSPF).* U.S. Environmental Protection Agency, Office of Research and Development, Environmental Research Laboratory, Athens, Georgia. EPA/600/3-84/065.

Environmental Protection Agency. 1994. *President Clinton's Clean Water Initiative: Analysis of Benefits and Costs.* Office of Water, Environmental Protection Agency, Washington, D.C., EPA/800/R-94/002.

Fisher, Gary T. 1989. Geographic Information System/Watershed Model Interface. In: *Hydraulic Engineering '89 Proceedings, National Conference on Hydraulic Engineering.* HY Div. ASCE, New Orleans, Louisiana, August 14-18. pp. 851-856.

Fisher, Gary T., and Robert M. Summers. 1987. *Development of a Data Base for Water-Quality Modeling of the Patuxent River Basin, Maryland.* United States Geological Survey Open File Report 87-379.

Franz, D. D., and S. M. Lieu. 1981. *Evaluation of Remote Sensing Data for Input into Hydrological Simulation Program - FORTRAN (HSPF).* U.S. Environmental Protection Agency, Office of Research and Development, Environmental Research Laboratory, Athens, Georgia. EPA/600/3-81/037.

Frissell, Chris, and David Bayles. 1995. *Solutions to Watershed Restoration.* Watershed seminar held at Oregon State University, Spring, 1993. ftp://sunsite.unc.edu/pub/academic/agriculture/sustainable_agriculture/permaculture/watershed.management.5 (June 12, 1995).

Froelich, A. J., and Chester Zennone. 1985. *Maps Showing Geologic Terrane, Drainage Basins, Overburden, and Low Flow of Streams in Fairfax County and Vicinity, Virginia.* MAP I-1534 1:48,000, Miscellaneous Investigations Series. Department of Interior. U.S. Geological Survey.

Gregory, Stanley. 1995. *Watersheds and Endangered Salmon.* Watershed seminar held at Oregon State University, Spring, 1993. ftp://sunsite.unc.edu/pub/academic/agriculture/sustainable_agriculture/permaculture/watershed.management.6 (June 12, 1995).

Hicks, C. Nancy, Wayne C. Huber, and James P. Heaney. 1985. Simulation of possible effects of deep pumping on surface hydrology using HSPF. In *Proceedings of Stormwater and Water Quality Model User Group Meeting.* January 31-February 1, 1985. Ed. by Thomas O. Barnwell, Jr. pp. 144-156. EPA/600/9-85/016.

Horton, R. E. 1945. Erosional development of streams and their drainage basins: hydro-physical approach to quantitative morphology. *Bull. Geol. Soc. Am.* 63:275-370.

Howard, Charles D. D. 1995. *Optimal Integrated Scheduling of Reservoirs and Generating Units.* Leading Edge Technology Hydro-Vision Conference. Phoenix, Arizona, August, 1994. http://www.hydrocomp.com/optimal.html (May 10, 1995).

Huber, Wayne. 1986. Deterministic modeling of urban runoff quality. In *Urban Runoff Pollution*. Ed. by Harry C. Torno, Jiri Marsalek, and Michel Desbornes. 10:167-242. Springer-Verlag, New York, NY.

Huber, Wayne. 1995. *Management of Urban Watersheds*. Watershed seminar held at Oregon State University, Spring, 1992. ftp://sunsite.unc.edu/pub/academic/agriculture/sustainable_agriculture/permaculture/watershed.manage ment.1 (June 12, 1995).

Hughes, Robert. 1995. *Assessment of Watershed Health*. Watershed seminar held at Oregon State University, Spring, 1993. ftp://sunsite.unc.edu/pub/academic/agriculture/sustainable_agriculture/permaculture/watershed.manage ment.4 (June 12, 1995).

Hydrocomp, Inc. 1995a. Applications of simulation - flood frequency analysis. *The What and the Why of Simulation*. http://www.hydrocomp.com/ffreq.html (May 10, 1995).

Hydrocomp, Inc. 1995b. Applications of simulation - licensing and re-licensing of hydroelectric projects. *The What and the Why of Simulation*. http://www.hydrocomp.com/licensing.html (May 10, 1995).

Hydrocomp, Inc. 1995c. Applications of simulation - spillway requirements at reservoirs. *The What and the Why of Simulation*. http://www.hydrocomp.com/spillway.html (May 10, 1995).

Hydrocomp, Inc. 1995d. *Corporate Profile*. http://www.hydrocomp.com/companyinfo.html. May 10.

Hydrocomp, Inc. 1995e. The Evolution of Hydrologic Analysis. *The What and the Why of Simulation*. http://www.hydrocomp.com/hydroevolve.html (May 10, 1995).

Hydrocomp, Inc. 1995f. *Hydrologic Simulation Models: An Overview*. http://www.hydrocomp.com/simoverview.html (May 12, 1995).

Imhoff, John C., Brian R. Bicknell, and Anthony S. Donigian, Jr. 1983. *Preliminary Application of HSPF to the Iowa River Basin to Model Water Quality and the Effects of Agricultural Best Management Practices*. U.S. Environmental Protection Agency, Office of Research and Development, Environmental Research Laboratory, Athens, Georgia. EPA/600/3-83/068.

Interstate Commission on the Potomac River Basin. 1995. *Interstate Commission on the Potomac River Basin*. gopher://gopher.gmu.edu:70/00/gophers/biology/bios/info/icprb/about.icprb (June 14, 1995).

Johanson, Robert C. 1983. New mathematical modeling system. *Fate of Chemicals in the Environment: Compartmental and Multimedia Models for Predictions*. American Chemical Society, Washington, D.C. pp. 125-147.

Johanson, Robert C. 1989. Application of the HSPF model to water management in Africa. In: *Proceedings of Stormwater and Water Quality Model Users Group Meeting*. October 3-4, Denver, CO. EPA/600/9-89/001. pp. 102-109.

Johanson, Robert C., and John L. Kittle, Jr. 1983. Design, programming and maintenance of HSPF. *ASCE J. Tech. Topics in Civil Engineering*. 109:41-57.

Kittle, John L., Jr., Paul R. Hummel, and John C. Imhoff. 1989. *ANNIE-IDE, A System for Developing Interactive User Interfaces for Environmental Models (Programmers Guide)*. U.S. Environmental Protection Agency, Office of Research and Development, Environmental Research Laboratory, Athens, Georgia. EPA/600/3-89/034.

Knisel, W. G. 1980. *CREAMS: A Field-Scale Model for Chemicals, Runoff, and Erosion from Agricultural Management Systems*. U.S. Department of Agriculture. Conservation Research Report No. 26.

Lake Barcroft Watershed Improvement District. 1992. *WID Quinquennial Report: A Compendium of 20 Years of Lake Management Ideas.* Lake Barcroft WID, Fairfax County, Virginia.

Lee, Roger D., James M. Symons, and Gordon G. Robeck. 1970. Watershed human-use level and water quality. *Journal of the American Water Works Association.* 62(7):412-422.

Leeden, Frits Van Der. 1994. *Water Atlas of Virginia; Basic Facts about Virginia's Water Resources,* Tennyson Press, Lexington. 105 pp.

Linsley, Ray K. 1976. Why Simulation? *Hydrocomp Simulation Network Newsletter.* September, v. 8, no. 5.

Lorber, Matthew N., and Lee A. Mulkey. 1982. An evaluation of three pesticide runoff loading models. *Journal of Environmental Quality.* 11(3):519-529.

Lumb, Alan M., and John L. Kittle, Jr. 1993. Expert system for calibration and application of watershed models. In: *Proceedings of the Federal Interagency Workshop on Hydrologic Modeling Demands for the 90's.* U.S. Geological Survey Water-Resources Investigation Report 93-4018. pp. 4-1 to 4-7.

Maxey, George B. 1964. Geology. Part I. Hydrogeology. In: *Handbook of Applied Hydrology.* Ed. by V. T. Chow. McGraw-Hill, New York.

McCammon, Bruce P. 1995. *Forested Watershed Issues in Oregon.* Watershed seminar held at Oregon State University, Spring, 1993. ftp://sunsite.unc.edu/pub/academic/agriculture/sustainable_agriculture/permaculture/ watershed.management.3 (June 12, 1995).

McCutcheon, Steve C. 1989. *Transport and Surface Exchange in Rivers.* Water Quality Modeling series. Vol. I. Series ed. Richard H. French. CRC Press, Boca Raton, Florida.

Metcalf & Eddy. 1991. *Wastewater Engineering: Treatment, Disposal, and Reuse.* 3rd. ed. Revised by George Tchobanoglous and Franklin L. Burton. McGraw-Hill Series in Water Resources and Environmental Engineering. McGraw-Hill, New York.

Moore, Larry W., Harvey Matheny, Ted Tyree, David Sabatini, and Stephen J. Klaine. 1988. Agricultural runoff modeling in a small west Tennessee watershed. *Journal Water Pollution Control Federation.* 60(2):242-249.

Mulkey, Lee A., Robert F. Carsel, Charles N. Smith. 1986. Development, testing and applications of nonpoint source models for evaluation of pesticides risk to the environment. *Agricultural Nonpoint Source Pollution: Model Selection and Application. Developments in Environmental Modeling*: 10. Elsevier, New York, pp. 383-397.

Nash, Madeleine J. 1993. The waterworks flu. *Time.* April 19, p. 41.

Nath, Ananta K. 1986. Impact of extensive irrigation pumpage on streamflow by HSPF. In *Proceedings of Stormwater and Water Quality Model Users Group Meeting.* March 24-25, 1986. Ed. by Thomas O. Barnwell, Jr., and Wayne C. Huber. 93-108. EPA/600/9-86/023.

National Oceanic and Atmospheric Administration. 1989a. *Climatological Data. Virginia.* NOAA. National Environmental Satellite, Data and Information Service. National Climatic Data Center. Ashville, North Carolina.

National Oceanic and Atmospheric Administration. 1989b. *Hourly Precipitation Data. Virginia.* NOAA. National Environmental Satellite, Data and Information Service. National Climatic Data Center. Ashville, North Carolina.

National Oceanic and Atmospheric Administration. 1989c. *Local Climatological Data. Virginia.* NOAA. National Environmental Satellite, Data and Information Service. National Climatic Data Center. Ashville, North Carolina.

National Oceanic and Atmospheric Administration. 1995. Computer printout containing Palmer drought monthly analysis for Region 4/Virginia (Dulles), calculated using weather information from the Piedmont Research Station. NOAA. National Environmental Satellite, Data and Information Service. National Climatic Data Center. Ashville, North Carolina (November 9, 1995).

Negev, Moshe. 1967. *A Sediment Model on a Digital Computer*. Department of Civil Engineering, Stanford University, Stanford, CA. Technical Report No. 76.

Nemerow, Nelson L. 1991. *Stream, Lake, Estuary, and Ocean Pollution*. 2nd Ed. Environmental Engineering Series. Van Nostrand Reinhold, New York.

Nichols, James C., and Michael P. Timpe. 1985. Use of HSPF to simulate dynamics of phosphorus in floodplain wetlands over a wide range of hydrologic regimes. In: *Proceedings of Stormwater and Water Quality Model Users Group Meeting*. January 31-February 1. Ed. by Thomas O. Barnwell, Jr. U.S. Environmental Protection Agency, Office of Research and Development, Environmental Research Laboratory, Athens, Georgia. pp 116-132.

Northern Virginia Planning District Commission (NVPDC). 1995. Personal communication with Don Waye and Norm Goulet.

Novotny, Vladimir. 1986. Review of hydrologic and water quality models used for simulation of agricultural pollution. *Agricultural Nonpoint Source Pollution: Model Selection and Application. Developments in Environmental Modeling*. 10, Elsevier, New York, pp. 9-35.

Onishi, Y., and S. E. Wise. 1982. *Mathematical Model, SERATRA, for Sediment Contaminant Transport in Rivers and its Application to Pesticide Transport in Four Mile and Wolf Creeks in Iowa*. U.S. Environmental Protection Agency, Office of Research and Development, Environmental Research Laboratory, Athens, Georgia. EPA/600/3-82/045.

Ree, W. O., F. L. Wimberley, and F. R. Crow. 1977. Manning *n* and the overland flow equation. *Transactions of the ASAE*. 22(1):89-95.

Roesner, Larry A., Raymond Walton, and John P. Hartigan. 1986. Realistic water quality modeling. In *Urban Runoff Pollution*. Ed. by Harry C. Torno, Jiri Marsalek, and Michel Desbornes. 10:629-647. Springer-Verlag, New York, NY.

Schafer, David E., David A. Woodruff, Richard J. Hughto, and G. K[enneth] Young. 1982. Calibration of hydrology and sediment transport on small agricultural watersheds using HSPF. In: *Proceedings of Stormwater and Water Quality Management Modeling Users Group Meeting*. March 25-26, 1982. Washington, D.C. EPA/600/9-82/015. pp. 54-68.

Schueler, Thomas R., and Michael P. Sullivan. 1983. Management of stormwater and water quality in an urbanizing watershed. In *Proceedings of the 1983 International Symposium on Urban Hydrology, Hydraulics and Sediment Control*. University of Kentucky, Lexington, Kentucky. July 25-28.

Steele, William. 1995. Specialists from six nations meet on watershed. *Cornell Chronicle (11/03/94)*. gopher://gopher1.cit.cornell.edu:70/00/.files/CH110394/CH11039409 (June 15, 1995).

Strahler, Arthur N. 1964. Geology. Part II. Quantitative Geomorphology of Drainage Basins and Channel Networks. In: *Handbook of Applied Hydrology*. Ed. by V. T. Chow. McGraw-Hill, New York.

Sullivan, Michael P., and Thomas R. Schueler. 1985. Simulation of the stormwater and water quality attributes of ponds with HSPF. In *Proceedings of Stormwater and Water Quality Model Users Group Meeting*. April 12-13, 1984. Ed. by Thomas O. Barnwell Jr. January 1985. 147-162. EPA/600/9-85/003.

Thomann, Robert V., and John A. Mueller. 1987. *Principles of Surface Water Quality Modeling and Control.* HarperCollinsPublishers, New York, NY.

Tippett, John. 1993. Notes on water quality management. Relating land use and buffer areas to in-stream water quality: the Salt Fork watershed in Illinois. *EPA NPS News-Notes*. Office of Water, Environmental Protection Agency, Washington, D.C. No.26, January-February, pp. 9-10. EPA/841/N-93/001.

Tsihrintzis, Vassilios A., Hector R. Fuentes, and Rao K. Gadipudi. 1994. Interfacing GIS and water quality models for agricultural areas. In: *Proceedings of the 1994 ASCE National Conference on Hydraulic Engineering*. Buffalo, NY. pp. 252-256.

U.S. Army Corps of Engineers. 1994. *Summary Report: Chesapeake Bay Watershed Model Workshop*. 15-16 December 1993. Ed. by Patrick N. Deliman. Waterways Experiment Station, Vicksburg, MS. Final Report. 116 pp.

U.S. Department of Agriculture. 1960. *Soil Survey. Loudoun County, Virginia.* USDA. Soil Conservation Service.

U.S. Department of Agriculture. 1979. *Field Manual for Research in Agricultural Hydrology*. Agriculture Handbook No. 224. USDA, Washington, D.C.

Veihmeyer, Frank J. 1964. Evapotranspiration. In: *Handbook of Applied Hydrology*. Ed. by V. T. Chow. McGraw-Hill, New York.

Ward, Barry W., Mark I. Pittman, Roger Amos, and Gary Bauer. 1995. Producer involvement in watershed management. *Journal of Extension*. December 1994. 32(4): 1-2. gopher://gopher.ext.vt.edu:4070/00/joe/1994december/iw3 (June 15, 1995).

Waxman, Henry. 1995. The outcome is not assured. *Amending the Safe Drinking Water Act: View from Congress*. gopher://gopher.epa.gov:70/00/News/EPAJournal/Summer94/13 (June 12, 1995).

Weand, Barron, and Thomas J. Grizzard. 1983. *Evaluation of Management Tools in the Occoquan Watershed.* Occoquan Watershed Monitoring Laboratory, Department of Civil Engineering, Virginia Polytechnic Institute and State University, Manassas, Virginia. EPA/600/3-83/036.

Welty, James R., Charles E. Wicks, and Robert E. Wilson. 1984. *Fundamentos de Transferencia de Momento, Calor y Masa.* [Fundamentals of Momentum, Heat & Mass Transfer]. Translated by Concepción Calderón Acosta. Revised by José Luis Fernández Zayas. Editorial Limusa, México D.F., México. (page references are to reprint edition of the first spanish edition).

Williams, J. R. and H. D. Berndt. 1977. Determining the universal soil loss equation's length-slope factor for watersheds. In: *Soil Erosion: Prediction and Control.* Ed. G. R. Foster. Soil Conservation Society of American, Ankeny, Iowa. pp. 217-225.

Young, G. Kenneth, and Clayton L. Alward. 1983. Calibration and testing of nutrient and pesticide transport models. In: *Agricultural Management and Water Quality*. Ed. by: F. W. Schaller and G. W. Bailey. Iowa State University Press, Ames, Iowa. pp. 267-277.

Zison, S. W., W. B. Mills, D. Deimer, and C. W. Chen. 1978. *Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling*. U.S. Environmental Protection Agency. Athens, Ga. EPA/600/3-78/105.

APPENDIX A

Selection of the Study Area

The Cub Run Watershed

The guiding principle for selection of the study area was that the study should attempt to produce a model for the hydrologic simulation of a subwatershed located within the Occoquan River drainage basin and that subwatershed should comply with the following requirements:

- It should be one of the segments previously defined by the NVPDC to be comparable with the results of their Occoquan Basin Model. Since the NVPDC had previously divided the Occoquan Basin into 15 segments (see Figure 1), the subwatershed should be identical to one of those 15 segments.

- If possible, the segment should be selected in a manner that contains not only rural lands but also developed lands. This would allow the use of not only the PERLND module of the HSPF program but also the IMPLND module making the study more generic.

- The subwatershed selected should be independent of the input of other segments. This means that no other input but precipitation should be considered in the water budget. The reason for this is quite obvious: if the subwatershed had an input from another segment, then the program would have to be run and calibrated for that segment first, so that the output could be used as an input for the selected subwatershed. Since that output is not available in PC format, the study should deal first with an independent sector.

- The subwatershed had to have a flow gaging station at the very end of the main stream so that the simulated output could be compared with the observed output at that point, and some type of calibration could be performed. The location of the measuring gages is provided in Figure 4.

Table A-1 shows the numbers of the segments defined by the Northern Virginia Planning District Commission (NVPDC) and their approximate locations on the Occoquan River Watershed.

Of all these segments those located over the north of the Occoquan River Drainage Basin (segments 8, 9, 10, 11, and 12) are the ones located on lands that have been developed intensely in the last decades. This statement could be verified by Geographical Information System graphics where urban land use was represented. Of this group only segments 8, 9 and 11 are independent segments. Segment 10 depends on the outputs of segments 8, 9 and 11, and segment 12 depends on the output of segment 10. From the group of independent segments, there was only one, segment 9, that had a gaging station at the downstream boundary. Therefore, segment 9 was the one selected for the study. If an additional requirement for the selection had to be done, that would have been to have a weather station near or inside the segment. This requirement was also met by segment 9. The Dulles Airport Weather Station is near the north boundary of the segment. In fact, a considerable part of the airport runways are located inside the segment.

Table A-1
Segments Defined by the Northern Virginia Planning District Commission

Segment #	Location
1	Drainage area of the upper Cedar Run up to a point approximately one mile downstream of the confluence with Licking Run.
2	Drainage area of the middle Cedar Run from the boundary with segment 1 to a point about half mile below the confluence with Dorrells Run.
3	Drainage area of the lower Cedar Run from the boundary with segment 2 to its mouth at Lake Jackson.
4	Drainage area of the upper Broad Run up to a point approximately one mile upstream from Lake Manassas.
5	Drainage area of Lake Manassas from the boundary with segment 4 to the Dam.
6	Drainage area of Kettle Run from its tail to its mouth (confluence with Broad Run).
7	Drainage area of lower Broad Run from the boundary with segment 5 to its mouth at Lake Jackson.
8	Drainage area of upper Bull Run up to the point of its confluence with Little Bull Run (including its drainage area).
9	Drainage area of Cub Run up to the point where it is crossed by Compton Road.
10	Drainage area of middle Bull Run from its boundary with segment 8 to a point about half mile downstream of the confluence with Cub Run.
11	Drainage area of lower Bull Run from its boundary with segment 10 approximately up to Yates Ford.
12	Drainage area of lower Bull Run from its boundary with segment 11 to the Occoquan Reservoir.
13	Drainage area of Lake Jackson from its boundary with segment 3 and 7 to the Dam.
14	Drainage area of Occoquan Creek from it boundary with segment 13 to its tail.
15	Drainage area of the Occoquan Reservoir.

APPENDIX B

Preparation of Time Series Data to Introduce in the Watershed Data Management File

Flow data

Flow data were obtained from the Occoquan Watershed Monitoring Laboratory, who runs an automated gaging station (ST50) on Cub Run. These data are not evenly spaced. When the flow increases or decreases rapidly, the automated system begins to obtain information every 15 minutes. Irregular intervals of time were also found in the time series, or hours for which no value was assigned. There were two possible approaches to regulate the time step in the time series. The first one was to eliminate any information (values between hours) that was not provided at the hour point, supplementing lacking data with the best criteria available (sometimes interpolation; best professional judgement when the first was not possible) to obtain one-hour time step flow time series. The second approach could have been to supplement the 15 minute intervals for those hours in which the flow was relatively stable with interpolated values and obtain a 15 minute flow time series. Even though the second approach had the advantage of providing a more detailed resolution, it would have taken considerable time to fill the gaps between hours, and even in this case some data would have been removed (because the time interval was not always 15 minutes) and some other added for hour points. Moreover, since the rain information is rarely provided every 15 minutes, or even every hour, to have so much resolution in the flow time series was an unnecesary luxury. Therefore, the one-hour time step approach was selected.

Once the database file was processed to this format, some conversions were performed. The first one was to import the FoxPro format (.dbf) file into a spreadsheet program. Then from that program the file was exported to WordPerfect 5.1 as an ASCII file (.txt). A macro program was written (24hours.wpm) in the WordPerfect macros language to control the data quality of this file and then another macro was created (pasa1.wpm) to put the information in a sequential file format that could be read by HSPF. The macros are presented in the following four pages.

Climatic data

Precipitation and evaporation data were obtained in hard copy format from the NCDC (National Climatic Data Center) and were manually entered in sequential file format. Even though the input of this type of information is quite time consuming, some time savings were obtained by preparing template files, written basically zeroes in all the data positions, and then introducing the hardcopy data only for those days and hours for which the data were different from zero. In the case of precipitation, for which the time series contains large periods without any event, this facilitated the data entry process. For the evaporation, since the data was daily, it was not so time consuming.

24HOURS.WPM December 1, 1995

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APPENDIX C

Comparative Analysis of the Precipitation Records for Dulles and National Airports and The Plains Weather Station

The first graph prepared using ANNIE-IDE (Chart C-1) presents a comparative study for monthly precipitation totals. Months with major differences are June, July, August, September, November and December. Only for one month, June, the record of The Plains and Dulles Airport was almost identical. However if the 2nd quarter graph (Chart C-3) is reviewed in order to see daily differences, there is much bigger rainfall for Dulles Airport during the period going from the 5th to the 9th of June than for The Plains, while for the 21st and 23rd of June there is appreciable precipitation for The Plains while there is almost nothing for Dulles Airport.

Back to the monthly plot for July (Chart C-1), the rainfall total for National is about double of that of The Plains and the one for Dulles is about 80 percent larger than the one for The Plains. In August the situation is reversed. The record for The Plains shows rainfall that is more than twice that for Dulles and that for National about 50 percent larger than that for Dulles. In September the record for National shows rainfall that is approximately twice as large as that for National. When reviewing the daily records even bigger differences can be marked. Good examples of this are the periods from the 11th to the 26th of September (Chart C-4), and the 16th of November to the 31st of December (Chart C-5).

This demonstrates that large differences occur in the precipitation records for these three stations, and that the one closer to the study area is the one that has to be used.

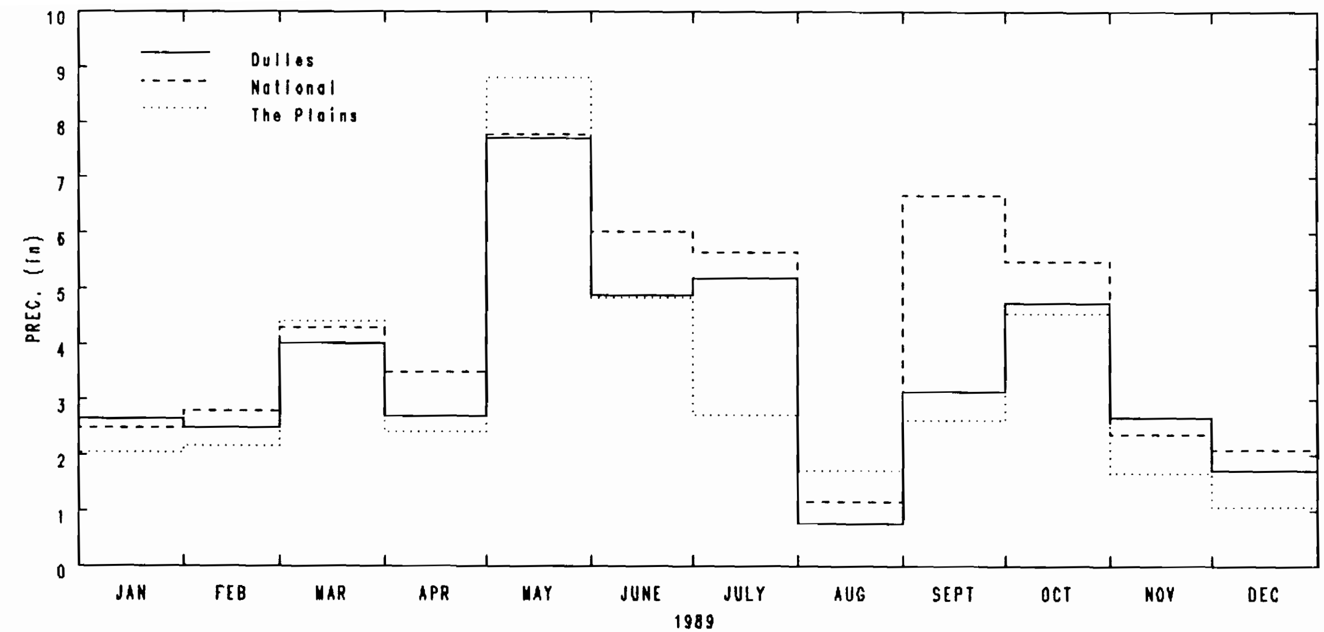

Chart C-1: Comparison between the monthly observed precipitation values for the weather stations at Dulles Airport, National Airport and The Plains

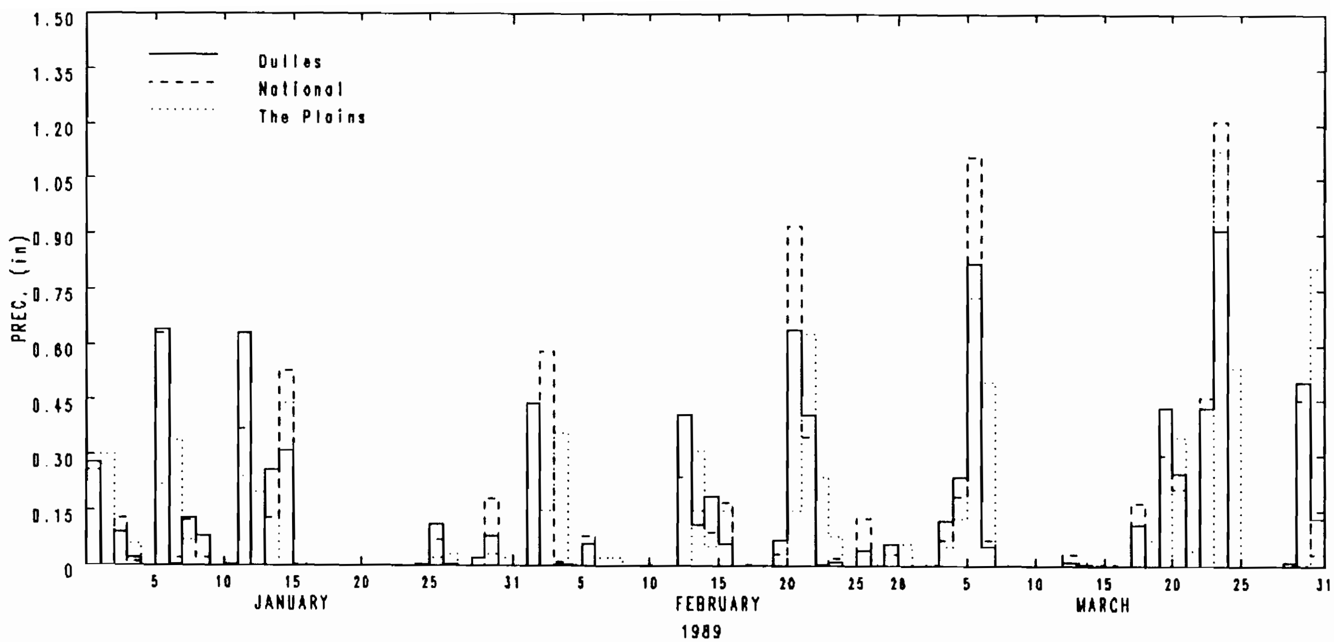

Chart C-2: Comparison between the daily observed precipitation values for the weather stations at Dulles Airport, National Airport and The Plains, first quarter of 1989

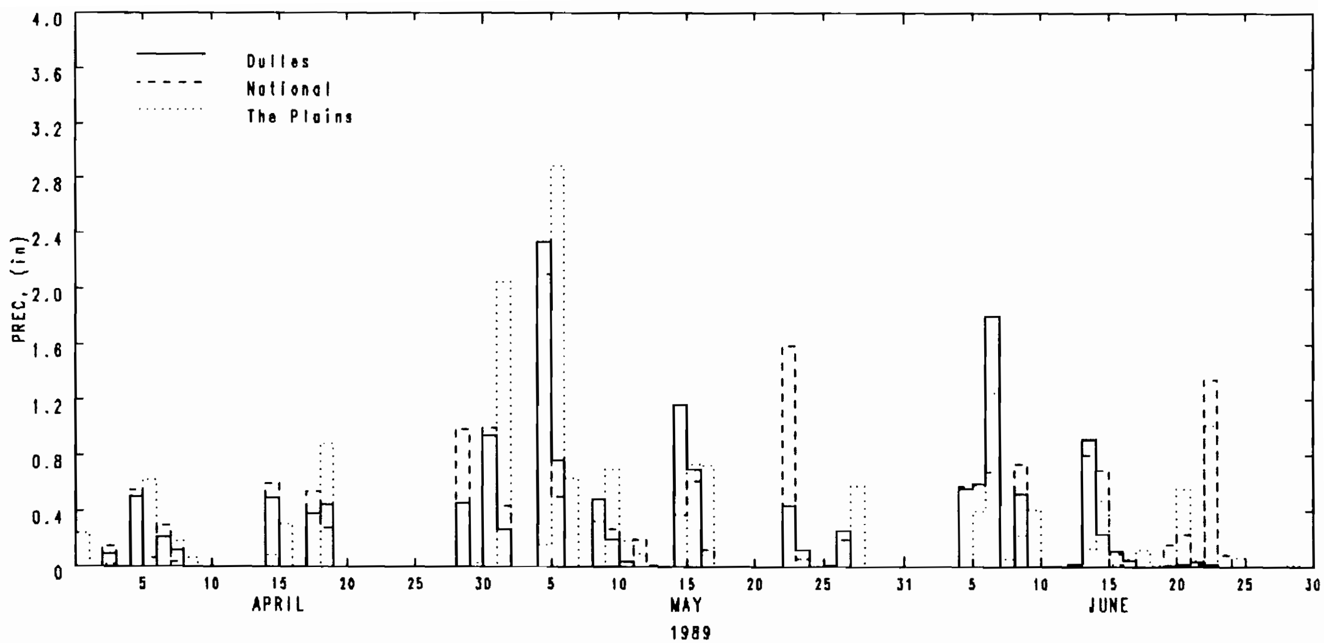

Chart C-3: Comparison between the daily observed precipitation values for the weather stations at Dulles Airport, National Airport and The Plains, second quarter of 1989

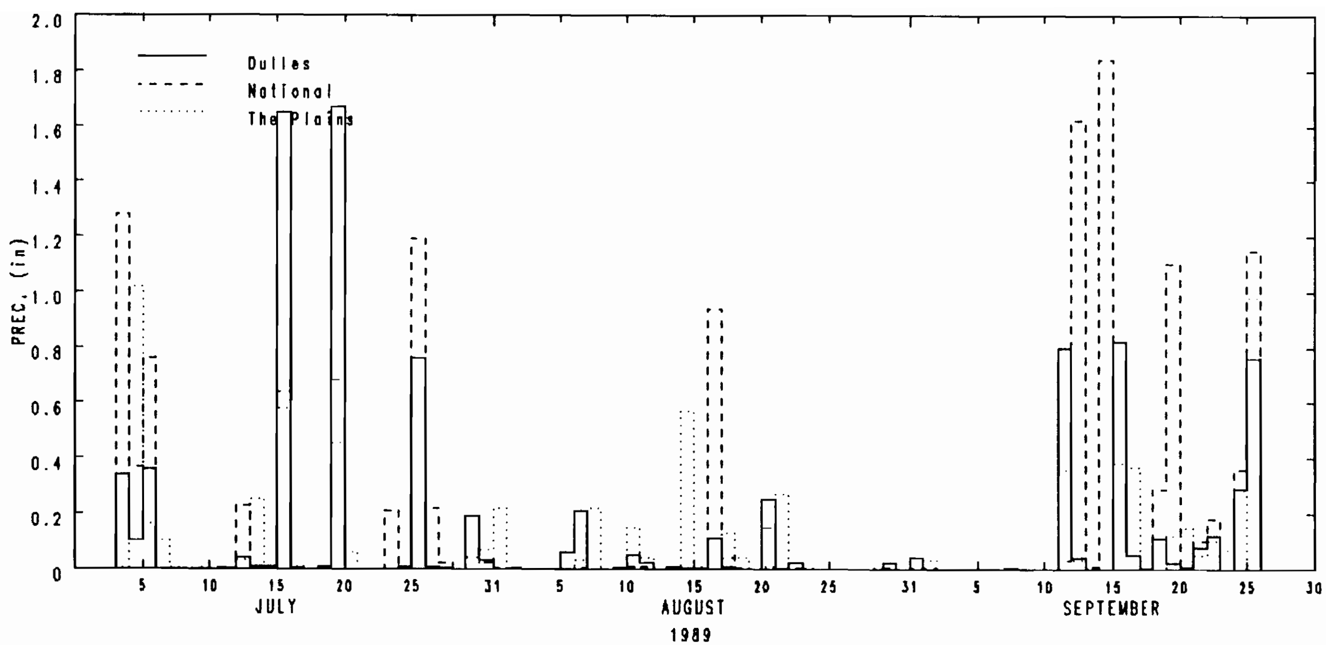

Chart C-4: Comparison between the daily observed precipitation values for the weather stations at Dulles Airport, National Airport and The Plains, third quarter of 1989

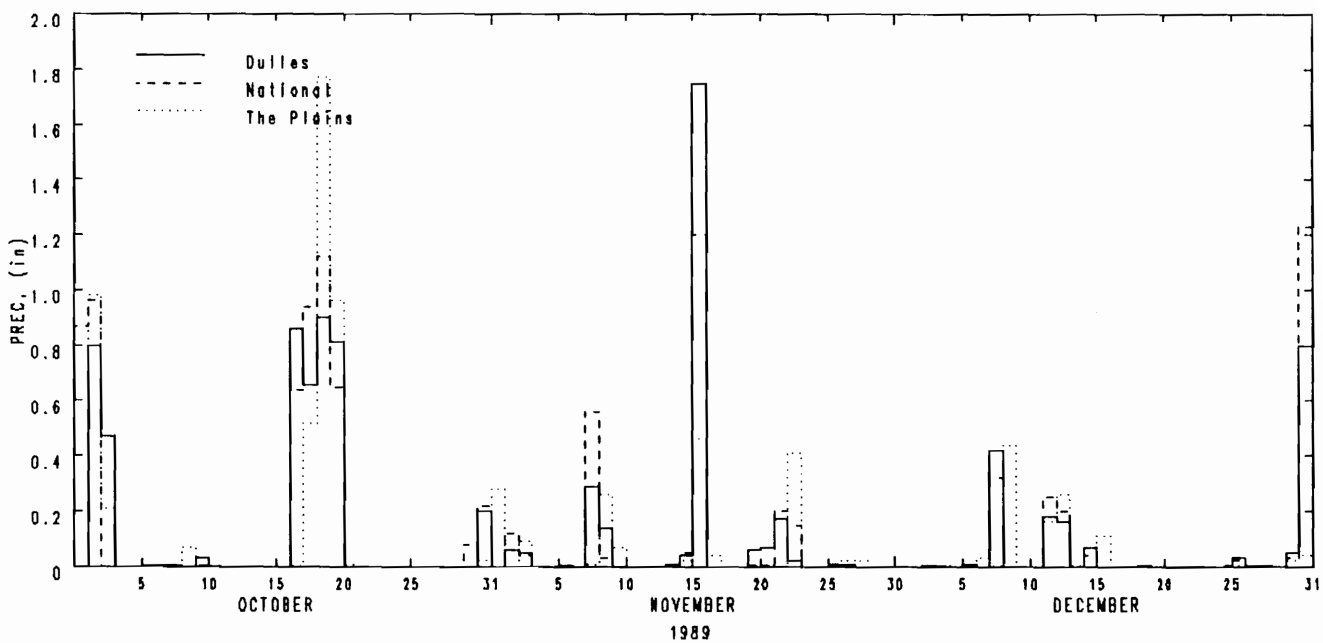

Chart C-5: Comparison between the daily observed precipitation values for the weather stations at Dulles Airport, National Airport and The Plains, fourth quarter of 1989

APPENDIX D

Sequential Files and the UCI Files Used for their Storage in the Watershed Data Management File

Table D-1 gives a description of the sequential files where flow and climatic data were stored, and the corresponding User Control Input files needed for their inclusion in the Watershed Data Management (WDM) file. Only one WDM file is needed to store all the necessary data for running the program. The one used for Cub Run data was named CUBRUNDT.WDM.

Table D-1

Characteristics of Sequential and UCI files						
Name of Sequential file	**Format of Sequential file**	**Type of Data in Sequential file**	**Source of Data**	**Name of UCI file**	**WDM where information was stored**	**Data Set Number in the WDM file**
DAYEVP89.SEQ	HYDDAY	Daily Evaporation	Piedmont Research Station	STORE3.UCI	CUBRUNDT.WDM	71
DYPENV89.SEQ	HYDDAY	Daily Potential Evapo-transpiration	Piedmont Research Station	STORE7.UCI	CUBRUNDT.WDM	76
DYPRDU89.SEQ	HYDDAY	Daily Precipitation	Dulles Airport	STORE4.UCI	CUBRUNDT.WDM	50
DYPRNA89.SEQ	HYDDAY	Daily Precipitation	National Airport	STORE4.UCI	CUBRUNDT.WDM	51
DYPRTP89.SEQ	HYDDAY	Daily Precipitation	The Plains	STORE6.UCI	CUBRUNDT.WDM	53
HRFLOW89.SEQ	HYDHR	Hourly Flow	ST50	HRFLOW89.UCI	CUBRUNDT.WDM	23
DULPRC89.SEQ	HYDHR	Six-Hour Period Precipitation	Dulles Airport	DULPRC89.UCI	CUBRUNDT.WDM	52

File: STORE3.UCI

```
***
*** This file STORE3.UCI was used to include the sequential file information
*** contained in the DAYEVP89.SEQ file into the CUBRUNDT.WDM file as
*** Dataset #71
***

RUN

GLOBAL
  Read daily data from SEQ into WDM file
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  RUN INTERP OUTPUT LEVEL    3
  RESUME     0 RUN     1
END GLOBAL

FILES
<type>  <fun>***<------------fname------------------------------------------->
INFO       21   \hspf10\hspinf.da
ERROR      22   \hspf10\hsperr.da
WARN       23   \hspf10\hspwrn.da
MESSU      24   store3.ech
WDM        25   CUBRUNDT.WDM
           32   DAYEVP89.SEQ

END FILES

OPN SEQUENCE
    INGRP               INDELT 24:00
      COPY          1
    END INGRP
END OPN SEQUENCE

COPY
  TIMESERIES
    # -  #  NPT  NMN ***
    1             1
  END TIMESERIES
END COPY

EXT SOURCES
<-Volume-> <Srcfmt> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   #          tem strg<-factor->strg <Name>   #   #        <Name> # #  ***

SEQ     32 HYDDAY   ENGLZERO               COPY     1     INPUT  MEAN   1

END EXT SOURCES

EXT TARGETS
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Volume-> <Member> Tsys Tgap Amd ***
<Name>   #        <Name> # #<-factor->strg <Name>   # <Name> #  tem strg strg***

COPY     1 OUTPUT MEAN   1            SAME WDM     71 EVAP     ENGL       REPL

END EXT TARGETS

END RUN
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File: DAYEVP89.SEQ

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EVAP     89 12 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
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EVAP     89 41 0.250 0.160 0.250 0.140 0.140 0.140 0.090 0.170 0.170 0.200
EVAP     89 42 0.140 0.170 0.170 0.220 0.170 0.170 0.190 0.320 0.160 0.150
EVAP     89 43 0.230 0.170 0.240 0.210 0.140 0.170 0.120 0.140 0.210 0.000
EVAP     89 51 0.120 0.190 0.320 0.170 0.230 0.200 0.350 0.160 0.120 0.010
EVAP     89 52 0.110 0.070 0.100 0.110 0.140 0.200 0.090 0.090 0.240 0.190
EVAP     89 53 0.200 0.330 0.220 0.120 0.250 0.310 0.190 0.310 0.240 0.390 0.310
EVAP     89 61 0.230 0.260 0.270 0.120 0.330 0.230 0.220 0.230 0.220 0.160
EVAP     89 62 0.260 0.290 0.170 0.170 0.230 0.330 0.070 0.240 0.230 0.260
EVAP     89 63 0.210 0.080 0.130 0.210 0.240 0.280 0.240 0.270 0.160 0.280
EVAP     89 71 0.190 0.230 0.210 0.140 0.110 0.190 0.100 0.240 0.300 0.140
EVAP     89 72 0.280 0.300 0.170 0.130 0.200 0.210 0.130 0.140 0.140 0.160
EVAP     89 73 0.230 0.220 0.220 0.260 0.120 0.200 0.200 0.190 0.320 0.210 0.160
EVAP     89 81 0.030 0.100 0.200 0.220 0.250 0.280 0.240 0.140 0.250 0.170
EVAP     89 82 0.090 0.010 0.100 0.150 0.130 0.120 0.220 0.170 0.040 0.100
EVAP     89 83 0.180 0.040 0.290 0.200 0.100 0.100 0.090 0.110 0.150 0.160 0.280
EVAP     89 91 0.250 0.200 0.240 0.210 0.060 0.100 0.010 0.050 0.160 0.140
EVAP     89 92 0.190 0.120 0.130 0.030 0.160 0.220 0.128 0.100 0.060 0.000
EVAP     89 93 0.129 0.100 0.150 0.150 0.170 0.129 0.120 0.140 0.120 0.100
EVAP     89101 0.000 0.000 0.120 0.150 0.150 0.150 0.000 0.150 0.020 0.080
EVAP     89102 0.040 0.150 0.150 0.100 0.090 0.150 0.030 0.000 0.100 0.050
EVAP     89103 0.040 0.120 0.110 0.090 0.090 0.070 0.070 0.100 0.080 0.090 0.020
EVAP     89111 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
EVAP     89112 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
EVAP     89113 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
EVAP     89121 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
EVAP     89122 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
EVAP     89123 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
```

```
File: STORE7.UCI

***
*** File used to store daily potential evapotranspiration data from the file
*** DYPENV89.SEQ into the CUBRUNDT.WDM file. This file is named STORE7.UCI
*** The data was stored as dataset #76.
***


RUN

GLOBAL
  Read daily data from SEQ and PLTGEN/MUTSIN format into WDM file
  START       1989                 END    1989
  RUN INTERP OUTPUT LEVEL    3
  RESUME     0 RUN     1
END GLOBAL

FILES
<type>  <fun>***<------------fname------------------------------------------->
INFO       21   \hspf10\hspinf.da
ERROR      22   \hspf10\hsperr.da
WARN       23   \hspf10\hspwrn.da
MESSU      24   store7.ech
WDM        25   CUBRUNDT.WDM
           32   DYPENV89.SEQ

END FILES

OPN SEQUENCE
    INGRP              INDELT 24:00
      COPY          1
    END INGRP
END OPN SEQUENCE

COPY
  TIMESERIES
    # -  #  NPT  NMN ***
    1             1
  END TIMESERIES
END COPY

EXT SOURCES
<-Volume-> <Srcfmt> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   #          tem strg<-factor->strg <Name>    #   #        <Name> # #  ***

SEQ      32 HYDDAY   ENGLZERO                COPY      1     INPUT  MEAN   1

END EXT SOURCES

EXT TARGETS
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Volume-> <Member> Tsys Tgap Amd ***
<Name>   #        <Name> # #<-factor->strg <Name>   # <Name> #  tem strg strg***

COPY      1 OUTPUT MEAN   1                WDM      76 PEVT     ENGL      REPL
END EXT TARGETS

END RUN
```

File: DYPENV89.SEQ

```
PRCP    89 110.00650.00650.00650.00650.00650.00650.00650.00650.00650.0065
PRCP    89 120.00650.00650.00650.00650.00650.00650.00650.00650.00650.0065
PRCP    89 130.00650.00650.00650.00650.00650.00650.00650.00650.00650.00650.0065
PRCP    89 210.00320.00320.00320.00320.00320.00320.00320.00320.00320.0032
PRCP    89 220.00320.00320.00320.00320.00320.00320.00320.00320.00320.0032
PRCP    89 230.00320.00320.00320.00320.00320.00320.00320.0032
PRCP    89 310.02130.02130.02130.02130.02130.02130.02130.02130.02130.0213
PRCP    89 320.02130.02130.02130.02130.02130.02130.02130.02130.02130.0213
PRCP    89 330.02130.02130.02130.02130.02130.02130.02130.02130.02130.02130.0213
PRCP    89 410.05670.05670.05670.05670.05670.05670.05670.05670.05670.0567
PRCP    89 420.05670.05670.05670.05670.05670.05670.05670.05670.05670.0567
PRCP    89 430.05670.05670.05670.05670.05670.05670.05670.05670.05670.0567
PRCP    89 510.10390.10390.10390.10390.10390.10390.10390.10390.10390.1039
PRCP    89 520.10390.10390.10390.10390.10390.10390.10390.10390.10390.1039
PRCP    89 530.10390.10390.10390.10390.10390.10390.10390.10390.10390.10390.1039
PRCP    89 610.17200.17200.17200.17200.17200.17200.17200.17200.17200.1720
PRCP    89 620.17200.17200.17200.17200.17200.17200.17200.17200.17200.1720
PRCP    89 630.17200.17200.17200.17200.17200.17200.17200.17200.17200.1720
PRCP    89 710.18060.18060.18060.18060.18060.18060.18060.18060.18060.1806
PRCP    89 720.18060.18060.18060.18060.18060.18060.18060.18060.18060.1806
PRCP    89 730.18060.18060.18060.18060.18060.18060.18060.18060.18060.18060.1806
PRCP    89 810.15610.15610.15610.15610.15610.15610.15610.15610.15610.1561
PRCP    89 820.15610.15610.15610.15610.15610.15610.15610.15610.15610.1561
PRCP    89 830.15610.15610.15610.15610.15610.15610.15610.15610.15610.15610.1561
PRCP    89 910.11730.11730.11730.11730.11730.11730.11730.11730.11730.1173
PRCP    89 920.11730.11730.11730.11730.11730.11730.11730.11730.11730.1173
PRCP    89 930.11730.11730.11730.11730.11730.11730.11730.11730.11730.1173
PRCP    891010.06610.06610.06610.06610.06610.06610.06610.06610.06610.0661
PRCP    891020.06610.06610.06610.06610.06610.06610.06610.06610.06610.0661
PRCP    891030.06610.06610.06610.06610.06610.06610.06610.06610.06610.06610.0661
PRCP    891110.02170.02170.02170.02170.02170.02170.02170.02170.02170.0217
PRCP    891120.02170.02170.02170.02170.02170.02170.02170.02170.02170.0217
PRCP    891130.02170.02170.02170.02170.02170.02170.02170.02170.02170.0217
PRCP    89121 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
PRCP    89122 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
PRCP    89123 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
```

```
File: STORE4.UCI

***
*** This file STORE4.UCI was used to store daily precipitation data from the
*** files DYPRDU89.SEQ (Dulles Airport) and DYPRNA89.SEQ (National Airport)
*** into the CUBRUNDT.WDM file. Data sets stored as: #50 for Dulles Airport
*** and #51 for National Airport.
***


RUN

GLOBAL
  Read daily data from SEQ and PLTGEN/MUTSIN format into WDM file
  START       1989                END     1989
  RUN INTERP OUTPUT LEVEL    3
  RESUME     0 RUN     1
END GLOBAL

FILES
<type>  <fun>***<------------fname--------------------------------------------->
INFO       21   \hspf10\hspinf.da
ERROR      22   \hspf10\hsperr.da
WARN       23   \hspf10\hspwrn.da
MESSU      24   store4.ech
WDM        25   CUBRUNDT.WDM
           32   DYPRDU89.SEQ
           33   DYPRNA89.SEQ

END FILES

OPN SEQUENCE
    INGRP                INDELT 24:00
      COPY         1
      COPY         2
    END INGRP
END OPN SEQUENCE

COPY
  TIMESERIES
    # -  #  NPT  NMN ***
    1              1
    2              1
  END TIMESERIES
END COPY

EXT SOURCES
<-Volume-> <Srcfmt> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   #          tem strg<-factor->strg <Name>   #   #         <Name> # #  ***

SEQ     32 HYDDAY   ENGLZERO               COPY     1     INPUT  MEAN   1
SEQ     33 HYDDAY   ENGLZERO               COPY     2     INPUT  MEAN   1

END EXT SOURCES

EXT TARGETS
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Volume-> <Member> Tsys Tgap Amd ***
<Name>   #        <Name> # #<-factor->strg <Name>   # <Name> #  tem strg strg***

COPY     1 OUTPUT MEAN   1             SAME WDM     50 PREC     ENGL       REPL
COPY     2 OUTPUT MEAN   1             SAME WDM     51 PREC     ENGL       REPL

END EXT TARGETS

END RUN
```

File: DYPRDU89.SEQ

```
PRCP    89 11 0.280 0.000 0.090 0.020 0.000 0.640 0.001 0.130 0.080 0.000
PRCP    89 12 0.001 0.630 0.000 0.260 0.310 0.000 0.000 0.000 0.000 0.000
PRCP    89 13 0.000 0.000 0.000 0.000 0.001 0.110 0.001 0.000 0.020 0.080 0.000
PRCP    89 21 0.000 0.440 0.000 0.001 0.000 0.060 0.000 0.000 0.000 0.000
PRCP    89 22 0.000 0.000 0.410 0.110 0.190 0.060 0.000 0.000 0.000 0.070
PRCP    89 23 0.640 0.410 0.001 0.010 0.000 0.040 0.000 0.060
PRCP    89 31 0.000 0.000 0.000 0.120 0.240 0.820 0.050 0.000 0.000 0.000
PRCP    89 32 0.000 0.000 0.010 0.001 0.000 0.000 0.000 0.110 0.000 0.430
PRCP    89 33 0.250 0.000 0.430 0.910 0.000 0.000 0.000 0.000 0.010 0.500 0.130
PRCP    89 41 0.000 0.000 0.090 0.001 0.500 0.001 0.210 0.120 0.001 0.000
PRCP    89 42 0.000 0.000 0.000 0.000 0.490 0.000 0.000 0.380 0.450 0.000
PRCP    89 43 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.460 0.001
PRCP    89 51 0.940 0.270 0.000 0.000 2.340 0.760 0.001 0.001 0.480 0.190
PRCP    89 52 0.030 0.001 0.001 0.001 1.170 0.700 0.001 0.000 0.000 0.001
PRCP    89 53 0.001 0.000 0.440 0.120 0.001 0.010 0.260 0.000 0.000 0.000 0.000
PRCP    89 61 0.000 0.000 0.000 0.000 0.560 0.600 1.800 0.000 0.520 0.000
PRCP    89 62 0.000 0.001 0.020 0.910 0.230 0.110 0.040 0.000 0.000 0.010
PRCP    89 63 0.020 0.030 0.020 0.001 0.000 0.000 0.000 0.001 0.000 0.000
PRCP    89 71 0.000 0.000 0.000 0.340 0.100 0.360 0.000 0.000 0.000 0.000
PRCP    89 72 0.000 0.001 0.040 0.010 0.010 1.650 0.001 0.000 0.010 1.670
PRCP    89 73 0.000 0.000 0.000 0.000 0.010 0.760 0.010 0.001 0.000 0.190 0.030
PRCP    89 81 0.000 0.001 0.000 0.000 0.000 0.060 0.210 0.000 0.000 0.001
PRCP    89 82 0.050 0.020 0.000 0.010 0.001 0.001 0.110 0.010 0.000 0.000
PRCP    89 83 0.250 0.001 0.020 0.000 0.000 0.000 0.000 0.000 0.000 0.020 0.000
PRCP    89 91 0.040 0.000 0.000 0.000 0.000 0.000 0.000 0.001 0.000 0.000
PRCP    89 92 0.000 0.800 0.040 0.000 0.000 0.820 0.050 0.001 0.110 0.020
PRCP    89 93 0.010 0.080 0.120 0.000 0.290 0.760 0.000 0.000 0.000 0.000
PRCP    89101 0.000 0.800 0.470 0.000 0.000 0.001 0.001 0.001 0.000 0.030
PRCP    89102 0.000 0.000 0.000 0.000 0.000 0.000 0.860 0.660 0.900 0.810
PRCP    89103 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.200
PRCP    89111 0.000 0.060 0.050 0.000 0.000 0.001 0.000 0.290 0.140 0.000
PRCP    89112 0.000 0.000 0.000 0.010 0.040 1.750 0.000 0.000 0.000 0.060
PRCP    89113 0.070 0.170 0.020 0.000 0.000 0.010 0.010 0.000 0.000 0.000
PRCP    89121 0.000 0.000 0.001 0.000 0.000 0.010 0.000 0.420 0.000 0.000
PRCP    89122 0.000 0.180 0.160 0.000 0.070 0.000 0.000 0.000 0.001 0.000
PRCP    89123 0.000 0.000 0.000 0.000 0.000 0.030 0.001 0.001 0.000 0.050 0.800
```

File: DYPRNA89.SEQ

```
PRCP    89 11 0.260 0.000 0.130 0.010 0.000 0.630 0.020 0.120 0.020 0.000
PRCP    89 12 0.000 0.370 0.000 0.130 0.530 0.001 0.000 0.000 0.000 0.000
PRCP    89 13 0.000 0.000 0.000 0.000 0.001 0.070 0.001 0.000 0.020 0.180 0.000
PRCP    89 21 0.000 0.000 0.580 0.010 0.001 0.080 0.000 0.000 0.000 0.000
PRCP    89 22 0.000 0.000 0.240 0.150 0.090 0.170 0.000 0.001 0.000 0.030
PRCP    89 23 0.920 0.350 0.001 0.020 0.000 0.130 0.000 0.030
PRCP    89 31 0.000 0.000 0.001 0.070 0.190 1.110 0.070 0.000 0.000 0.000
PRCP    89 32 0.000 0.000 0.030 0.001 0.001 0.001 0.000 0.170 0.000 0.300
PRCP    89 33 0.210 0.000 0.460 1.210 0.000 0.000 0.000 0.000 0.001 0.450 0.030
PRCP    89 41 0.000 0.000 0.150 0.001 0.550 0.060 0.300 0.030 0.001 0.000
PRCP    89 42 0.000 0.000 0.000 0.000 0.600 0.001 0.000 0.540 0.280 0.000
PRCP    89 43 0.000 0.000 0.000 0.000 0.001 0.000 0.000 0.000 0.990 0.000
pRCP    89 51 1.000 0.440 0.000 0.000 2.100 0.500 0.001 0.001 0.320 0.270
PRCP    89 52 0.001 0.190 0.010 0.001 0.370 0.610 0.120 0.000 0.000 0.001
PRCP    89 53 0.000 0.000 1.590 0.050 0.000 0.010 0.190 0.000 0.000 0.000 0.000
PRCP    89 61 0.000 0.001 0.000 0.000 0.580 0.590 0.680 0.000 0.740 0.000
PRCP    89 62 0.000 0.001 0.020 0.800 0.690 0.090 0.001 0.000 0.001 0.160
PRCP    89 63 0.230 0.020 1.340 0.080 0.000 0.000 0.001 0.001 0.000 0.000
PRCP    89 71 0.000 0.000 0.000 1.280 0.370 0.760 0.000 0.000 0.000 0.000
PRCP    89 72 0.001 0.001 0.230 0.000 0.000 0.640 0.000 0.000 0.000 0.680
PRCP    89 73 0.000 0.000 0.000 0.210 0.000 1.190 0.220 0.020 0.000 0.040 0.020
PRCP    89 81 0.001 0.001 0.000 0.000 0.000 0.000 0.001 0.000 0.000 0.001
PRCP    89 82 0.010 0.010 0.000 0.001 0.001 0.000 0.940 0.040 0.001 0.000
PRCP    89 83 0.150 0.001 0.001 0.000 0.000 0.000 0.000 0.000 0.000 0.001 0.000
PRCP    89 91 0.001 0.001 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
PRCP    89 92 0.000 0.030 1.620 0.010 1.840 0.000 0.000 0.000 0.290 1.100
PRCP    89 93 0.001 0.100 0.180 0.000 0.360 1.150 0.000 0.000 0.000 0.000
PRCP    89101 0.870 0.960 0.000 0.000 0.000 0.001 0.001 0.001 0.000 0.001
PRCP    89102 0.000 0.000 0.000 0.000 0.000 0.000 0.640 0.940 1.120 0.650
PRCP    89103 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.080 0.220
PRCP    89111 0.000 0.120 0.040 0.000 0.000 0.001 0.000 0.560 0.030 0.000
PRCP    89112 0.000 0.000 0.000 0.010 0.050 1.200 0.000 0.000 0.000 0.001
PRCP    89113 0.001 0.200 0.150 0.000 0.000 0.001 0.010 0.000 0.000 0.000
PRCP    89121 0.000 0.000 0.000 0.001 0.000 0.010 0.000 0.320 0.000 0.000
PRCP    89122 0.000 0.250 0.200 0.000 0.040 0.000 0.000 0.000 0.001 0.000
PRCP    89123 0.000 0.000 0.000 0.000 0.001 0.020 0.001 0.000 0.000 0.030 1.230
```

```
File: STORE6.UCI

***
*** This file STORE6.UCI was used to store daily precipitation data from the
*** file DYPRTP89.UCI (The Plains) into the CUBRUNDT.WDM file. The set was
*** stored with # 53.
***

RUN

GLOBAL
  Read daily data from SEQ into WDM file
  START     ' 1989              END    1989
  RUN INTERP OUTPUT LEVEL    3
  RESUME     0 RUN     1
END GLOBAL

FILES
<type>  <fun>***<------------fname------------------------------------------------>
INFO       21   \hspf10\hspinf.da
ERROR      22   \hspf10\hsperr.da
WARN       23   \hspf10\hspwrn.da
MESSU      24   store4.ech
WDM        25   CUBRUNDT.WDM
           32   DYPRTP89.SEQ

END FILES

OPN SEQUENCE
    INGRP              INDELT 24:00
      COPY          1
    END INGRP
END OPN SEQUENCE

COPY
  TIMESERIES
    # -  #  NPT  NMN ***
    1             1
  END TIMESERIES
END COPY

EXT SOURCES
<-Volume-> <Srcfmt> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   #          tem strg<-factor->strg <Name>   #   #        <Name> # #  ***

SEQ     32 HYDDAY   ENGLZERO               COPY     1     INPUT  MEAN   1

END EXT SOURCES

EXT TARGETS
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Volume-> <Member> Tsys Tgap Amd ***
<Name>   #        <Name> # #<-factor->strg <Name>   # <Name> #  tem strg strg***

COPY     1 OUTPUT MEAN   1            SAME WDM     53 PREC     ENGL      REPL

END EXT TARGETS

END RUN
```

File: DYPRTP89.SEQ

```
PRCP     89 11 0.000 0.300 0.000 0.060 0.000 0.220 0.340 0.070 0.080 0.000
PRCP     89 12 0.000 0.240 0.200 0.000 0.440 0.000 0.000 0.000 0.000 0.000
PRCP     89 13 0.000 0.000 0.000 0.000 0.001 0.020 0.030 0.000 0.000 0.030 0.020
PRCP     89 21 0.000 0.000 0.150 0.360 0.001 0.000 0.020 0.020 0.000 0.000
PRCP     89 22 0.000 0.000 0.000 0.310 0.050 0.150 0.000 0.000 0.000 0.000
PRCP     89 23 0.150 0.630 0.240 0.080 0.000 0.000 0.001 0.000
PRCP     89 31 0.060 0.000 0.000 0.050 0.130 0.730 0.500 0.001 0.000 0.000
PRCP     89 32 0.000 0.000 0.000 0.010 0.001 0.000 0.000 0.000 0.070 0.000
PRCP     89 33 0.350 0.040 0.000 1.130 0.540 0.000 0.000 0.000 0.000 0.001 0.810
PRCP     89 41 0.240 0.000 0.020 0.000 0.000 0.620 0.000 0.180 0.060 0.000
PRCP     89 42 0.000 0.000 0.000 0.000 0.080 0.310 0.000 0.000 0.890 0.000
PRCP     89 43 0.000 0.000 0.000 0.000 0.000 0.001 0.000 0.001 0.001 0.029
PRCP     89 51 0.000 2.050 0.000 0.000 0.160 2.890 0.630 0.000 0.000 0.700
PRCP     89 52 0.180 0.090 0.000 0.000 0.000 0.740 0.730 0.000 0.000 0.000
PRCP     89 53 0.001 0.000 0.001 0.050 0.000 0.000 0.001 0.580 0.000 0.000 0.000
PRCP     89 61 0.000 0.000 0.001 0.000 0.000 0.400 1.250 0.050 0.220 0.410
PRCP     89 62 0.000 0.000 0.020 0.130 0.470 0.020 0.050 0.120 0.010 0.000
PRCP     89 63 0.560 0.040 1.020 0.001 0.060 0.000 0.000 0.000 0.010 0.000
PRCP     89 71 0.000 0.000 0.000 0.001 1.020 0.160 0.100 0.001 0.000 0.001
PRCP     89 72 0.000 0.000 0.030 0.250 0.000 0.580 0.010 0.000 0.000 0.450
PRCP     89 73 0.060 0.000 0.000 0.000 0.000 0.000 0.001 0.000 0.000 0.000 0.070
PRCP     89 81 0.220 0.001 0.000 0.000 0.000 0.000 0.030 0.220 0.000 0.000
PRCP     89 82 0.150 0.040 0.000 0.000 0.570 0.010 0.000 0.130 0.040 0.000
PRCP     89 83 0.010 0.270 0.020 0.001 0.000 0.000 0.000 0.000 0.001 0.000 0.000
PRCP     89 91 0.000 0.030 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
PRCP     89 92 0.000 0.360 0.030 0.001 0.000 0.380 0.370 0.000 0.000 0.120
PRCP     89 93 0.150 0.050 0.100 0.070 0.000 0.980 0.000 0.000 0.000 0.000
PRCP     89101 0.000 0.980 0.210 0.000 0.000 0.000 0.000 0.000 0.070 0.000
PRCP     89102 0.001 0.000 0.000 0.000 0.000 0.000 0.001 0.520 1.770 0.960
PRCP     89103 0.010 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.020
PRCP     89111 0.280 0.000 0.090 0.000 0.000 0.000 0.000 0.010 0.260 0.070
PRCP     89112 0.000 0.000 0.000 0.000 0.020 0.460 0.040 0.000 0.000 0.000
PRCP     89113 0.001 0.000 0.410 0.000 0.000 0.000 0.020 0.020 0.000 0.000
PRCP     89121 0.000 0.000 0.001 0.001 0.000 0.000 0.030 0.001 0.440 0.000
PRCP     89122 0.000 0.160 0.260 0.001 0.000 0.110 0.000 0.000 0.000 0.000
PRCP     89123 0.000 0.000 0.000 0.000 0.000 0.001 0.000 0.001 0.000 0.020 0.040
```

File: HRFLOW89.UCI

```
***
*** This UCI file: HRFLOW89.UCI was used to include the information of the
*** sequential file HRFLOW89.SEQ in the Watershed Data Management file named
*** CUBRUNDT.WDM
***

RUN

GLOBAL
  Read hourly flow '89 data from SEQ format into WDM file
  START       1989                END     1989
  RUN INTERP OUTPUT LEVEL    3
  RESUME      0 RUN     1
END GLOBAL

FILES
<type>  <fun>***<------------fname------------------------------------------->
INFO       21   \hspf10\hspinf.da
ERROR      22   \hspf10\hsperr.da
WARN       23   \hspf10\hspwrn.da
MESSU      24   hrflow89.ech
WDM        25   cubrundt.wdm
           31   hrflow89.seq
END FILES

OPN SEQUENCE
      COPY          1   INDELT 01:00
END OPN SEQUENCE

COPY
  TIMESERIES
    # -  #  NPT  NMN ***
    1              1
  END TIMESERIES
END COPY

EXT SOURCES
<-Volume-> <Srcfmt> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   #          tem strg<-factor->strg <Name>   #   #         <Name> # #  ***

SEQ     31 HYDHR    ENGLZERO                COPY     1     INPUT  MEAN   1

END EXT SOURCES

EXT TARGETS
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Volume-> <Member> Tsys Tgap Amd ***
<Name>   #        <Name> # #<-factor->strg <Name>   # <Name> #  tem strg strg***

COPY     1 OUTPUT MEAN   1             SAME WDM     23 FLOW     ENGL      REPL

END EXT TARGETS

END RUN
```

File: HRFLOW89.SEQ

```
89  1  1 19.8009.8009.8009.8009.8009.8009.8009.8009.8009.8009.8009.800
89  1  1 29.80010.2010.2011.1211.5812.0412.0412.0412.5012.5012.5012.96
89  1  2 114.3414.8014.8014.8014.8014.8014.8015.2815.7615.7616.2416.72
89  1  2 216.7216.7216.7216.7216.7216.7216.7216.7216.7217.2017.2017.68
89  1  3 118.1619.1220.1021.1022.1022.6024.1025.6826.2226.7626.7626.76
89  1  3 227.3026.7626.7626.2225.6825.1425.1424.6024.1024.1023.6023.60
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File: DULPRC89.UCI

```
***
*** This is the UCI file (DULPRC89.UCI) that was used to store 6-hour time step
*** precipitation information in the sequential file DULPRC89.SEQ into the
*** CUBRUNDT.WDM file. The information is in data set # 52
***

RUN

GLOBAL
  Read hourly precipitation data from SEQ format into WDM file
  START       1989              END    1989
  RUN INTERP OUTPUT LEVEL    3
  RESUME     0 RUN     1
END GLOBAL

FILES
<type>  <fun>***<------------fname------------------------------------------->
INFO       21   \hspf10\hspinf.da
ERROR      22   \hspf10\hsperr.da
WARN       23   \hspf10\hspwrn.da
MESSU      24   dulprc89.ech
WDM        25   cubrundt.wdm
           31   DULPRC89.SEQ
END FILES

OPN SEQUENCE
      COPY         1   INDELT 01:00
END OPN SEQUENCE

COPY
  TIMESERIES
    # -  #  NPT  NMN ***
    1              1
  END TIMESERIES
END COPY

EXT SOURCES
<-Volume-> <Srcfmt> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   #          tem strg<-factor->strg <Name>   #   #        <Name> # #  ***

SEQ     31 HYDHR    ENGLZERO               COPY     1     INPUT  MEAN   1

END EXT SOURCES

EXT TARGETS
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Volume-> <Member> Tsys Tgap Amd ***
<Name>   #        <Name> # #<-factor->strg <Name>   # <Name> #  tem strg strg***

COPY     1 OUTPUT MEAN   1            SAME WDM     52 PREC     ENGL      REPL

END EXT TARGETS

END RUN
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File: DULPRC89.SEQ

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89  1 20 2 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
89  1 21 1 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
89  1 21 2 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
89  1 22 1 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
89  1 22 2 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
89  1 23 1 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
89  1 23 2 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
89  1 24 1 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
89  1 24 2 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
89  1 25 1 0.00 0.00 0.00 0.00 0.00 0.000.001 0.00 0.00 0.00 0.00 0.00
89  1 25 2 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
89  1 26 1 0.00 0.00 0.00 0.00 0.00 0.000.001 0.00 0.00 0.00 0.00 0.00
89  1 26 2 0.11 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
89  1 27 10.001 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
89  1 27 2 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
89  1 28 1 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
89  1 28 2 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
89  1 29 1 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
89  1 29 2 0.01 0.00 0.00 0.00 0.00 0.00 0.01 0.00 0.00 0.00 0.00 0.00
89  1 30 1 0.00 0.00 0.00 0.00 0.00 0.000.001 0.00 0.00 0.00 0.00 0.00
89  1 30 2 0.08 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
89  1 31 1 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
89  1 31 2 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
89  2  1 1 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
89  2  1 2 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
89  2  2 1 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
89  2  2 2 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
```

89	2	3	1	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00
89	2	3	2	0.09	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.00	0.00	0.00
89	2	4	1	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	2	4	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	2	5	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	2	5	2	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	2	6	1	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	2	6	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	2	7	1	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
89	2	7	2	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	2	8	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	2	8	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	2	9	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	2	9	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	2	10	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	2	10	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	2	11	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	2	11	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	2	12	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	2	12	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	2	13	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	2	13	2	0.05	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00
89	2	14	1	0.33	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00
89	2	14	2	0.02	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	2	15	1	0.001	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
89	2	15	2	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	2	16	1	0.05	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00
89	2	16	2	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	2	17	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	2	17	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	2	18	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	2	18	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	2	19	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	2	19	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	2	20	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	2	20	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	2	21	1	0.07	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
89	2	21	2	0.60	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
89	2	22	1	0.02	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.00
89	2	22	2	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	2	23	1	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	2	23	2	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	2	24	1	0.001	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
89	2	24	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	2	25	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	2	25	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	2	26	1	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	2	26	2	0.01	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
89	2	27	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	2	27	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	2	28	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	2	28	2	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	1	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	1	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	2	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	2	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	3	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	3	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	4	1	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
89	3	4	2	0.08	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	3	5	1	0.01	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	3	5	2	0.20	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00
89	3	6	1	0.001	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00
89	3	6	2	0.24	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.00
89	3	7	1	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
89	3	7	2	0.03	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	3	8	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	8	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

89	3	9	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	9	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	10	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	10	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	11	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	11	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	12	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	12	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	13	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	13	2	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	3	14	1	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	14	2	0.001	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	3	15	1	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	15	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	16	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	16	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	17	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	17	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	18	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	18	2	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00
89	3	19	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	19	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	20	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	20	2	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.00
89	3	21	1	0.28	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00
89	3	21	2	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	22	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	22	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	23	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	23	2	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00
89	3	24	1	0.43	0.00	0.00	0.00	0.00	0.00	0.36	0.00	0.00	0.00	0.00	0.00
89	3	24	2	0.47	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00
89	3	25	1	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	25	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	26	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	26	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	27	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	27	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	28	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	28	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	29	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	29	2	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
89	3	30	1	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	3	30	2	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	3	31	1	0.50	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	3	31	2	0.01	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00
89	4	1	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	1	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	2	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	2	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	3	1	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00
89	4	3	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	4	1	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	4	4	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	5	1	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	5	2	0.02	0.00	0.00	0.00	0.00	0.00	0.41	0.00	0.00	0.00	0.00	0.00
89	4	6	1	0.07	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	4	6	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	7	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	7	2	0.05	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.00
89	4	8	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	8	2	0.001	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
89	4	9	1	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	9	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	10	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	10	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	11	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	11	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

89	4	12	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	12	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	13	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	13	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	14	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	14	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	15	1	0.001	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00
89	4	15	2	0.24	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00
89	4	16	1	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	16	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	17	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	17	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	18	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	18	2	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00
89	4	19	1	0.22	0.00	0.00	0.00	0.00	0.00	0.36	0.00	0.00	0.00	0.00	0.00
89	4	19	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	20	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	20	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	21	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	21	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	22	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	22	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	23	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	23	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	24	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	24	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	25	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	25	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	26	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	26	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	27	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	27	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	28	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	28	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	29	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	4	29	2	0.37	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00
89	4	30	1	0.001	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	4	30	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	1	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	1	2	0.17	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00
89	5	2	1	0.47	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00
89	5	2	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	3	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	3	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	4	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	4	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	5	1	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.00
89	5	5	2	0.22	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00
89	5	6	1	1.98	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	5	6	2	0.00	0.00	0.00	0.00	0.00	0.00	0.63	0.00	0.00	0.00	0.00	0.00
89	5	7	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	7	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	8	1	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	8	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	9	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	9	2	0.001	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.00
89	5	10	1	0.41	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00
89	5	10	2	0.02	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	5	11	1	0.001	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	5	11	2	0.001	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
89	5	12	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	12	2	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	5	13	1	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	13	2	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	5	14	1	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	5	14	2	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	15	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	15	2	0.42	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00

89	5	16	1	0.56	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.00
89	5	16	2	0.23	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.00	0.00	0.00
89	5	17	1	0.06	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	5	17	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	18	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	18	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	19	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	19	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	20	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	20	2	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	5	21	1	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	21	2	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	22	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	22	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	23	1	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	5	23	2	0.03	0.00	0.00	0.00	0.00	0.00	0.39	0.00	0.00	0.00	0.00	0.00
89	5	24	1	0.12	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
89	5	24	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	25	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	25	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	26	1	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	26	2	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	27	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	27	2	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	28	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	28	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	29	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	29	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	30	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	30	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	31	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	5	31	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	6	1	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	6	1	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	6	2	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	6	2	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	6	3	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	6	3	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	6	4	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	6	4	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	6	5	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	6	5	2	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	6	6	1	0.56	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	6	6	2	0.08	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	6	7	1	0.55	0.00	0.00	0.00	0.00	0.00	1.68	0.00	0.00	0.00	0.00	0.00
89	6	7	2	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	6	8	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	6	8	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	6	9	1	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.00	0.00	0.00	0.00	0.00
89	6	9	2	0.14	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
89	6	10	1	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	6	10	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	6	11	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	6	11	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	6	12	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	6	12	2	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	6	13	1	0.001	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	6	13	2	0.001	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
89	6	14	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	6	14	2	0.01	0.00	0.00	0.00	0.00	0.00	0.90	0.00	0.00	0.00	0.00	0.00
89	6	15	1	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00
89	6	15	2	0.001	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00
89	6	16	1	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	6	16	2	0.001	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00
89	6	17	1	0.07	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00
89	6	17	2	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	6	18	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	6	18	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

89	6	19	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	6	19	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	6	20	1	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	6	20	2	0.63	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.00
89	6	21	1	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	6	21	2	0.02	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	6	22	1	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	6	22	2	0.001	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	6	23	1	0.05	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	6	23	2	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	6	24	1	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	6	24	2	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	6	25	1	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	6	25	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	6	26	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	6	26	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	6	27	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	6	27	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	6	28	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	6	28	2	0.001	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	6	29	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	6	29	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	6	30	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	6	30	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	1	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	1	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	2	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	2	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	3	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	3	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	4	1	0.001	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	7	4	2	0.06	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00	0.00	0.00	0.00
89	7	5	1	0.01	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	7	5	2	0.06	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00
89	7	6	1	0.001	0.00	0.00	0.00	0.00	0.00	0.26	0.00	0.00	0.00	0.00	0.00
89	7	6	2	0.10	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	7	7	1	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	7	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	8	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	8	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	9	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	9	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	10	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	10	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	11	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	11	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	12	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	12	2	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	13	1	0.70	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00
89	7	13	2	0.06	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	7	14	1	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
89	7	14	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	15	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	15	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	16	1	0.01	0.00	0.00	0.00	0.00	0.00	1.52	0.00	0.00	0.00	0.00	0.00
89	7	16	2	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	17	1	0.001	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	7	17	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	18	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	18	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	19	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	19	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	20	1	0.14	0.00	0.00	0.00	0.00	0.00	1.54	0.00	0.00	0.00	0.00	0.00
89	7	20	2	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	7	21	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	21	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	22	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	22	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

89	7	23	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	23	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	24	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	24	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	25	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	25	2	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
89	7	26	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	26	2	0.00	0.00	0.00	0.00	0.00	0.00	0.76	0.00	0.00	0.00	0.00	0.00
89	7	27	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	27	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	28	1	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	28	2	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	7	29	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	29	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	30	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	7	30	2	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
89	7	31	1	0.19	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
89	7	31	2	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	1	1	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	1	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	2	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	2	2	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	3	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	3	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	4	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	4	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	5	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	5	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	6	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	6	2	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00
89	8	7	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	7	2	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	8	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	8	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	9	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	9	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	10	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	10	2	0.001	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	8	11	1	0.05	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	8	11	2	0.001	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	8	12	1	0.001	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
89	8	12	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	13	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	13	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	14	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	14	2	0.001	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	8	15	1	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	15	2	0.001	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	8	16	1	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	16	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	17	1	0.11	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	8	17	2	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	8	18	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	18	2	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	19	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	19	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	20	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	20	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	21	1	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00
89	8	21	2	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	22	1	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	8	22	2	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	8	23	1	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	8	23	2	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	24	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	24	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	25	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	25	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

89	8	26	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	26	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	27	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	27	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	28	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	28	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	29	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	29	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	30	1	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
89	8	30	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	31	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	8	31	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	1	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	1	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	2	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	2	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	3	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	3	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	4	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	4	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	5	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	5	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	6	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	6	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	7	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	7	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	8	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	8	2	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	9	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	9	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	10	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	10	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	11	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	11	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	12	1	0.00	0.00	0.00	0.00	0.00	0.00	0.79	0.00	0.00	0.00	0.00	0.00
89	9	12	2	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	13	1	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	9	13	2	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00
89	9	14	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	14	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	15	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	15	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	16	1	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.00
89	9	16	2	0.20	0.00	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.00
89	9	17	1	0.05	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
89	9	17	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	18	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	18	2	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	9	19	1	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	9	19	2	0.02	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00
89	9	20	1	0.02	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	9	20	2	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	9	21	1	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
89	9	21	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	22	1	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
89	9	22	2	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	23	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	23	2	0.001	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00
89	9	24	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	24	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	25	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	25	2	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00
89	9	26	1	0.37	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.00	0.00	0.00
89	9	26	2	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	27	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	27	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	28	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	28	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

89	9	29	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	29	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	30	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	9	30	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	1	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	1	2	0.02	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.00
89	10	2	1	0.70	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00	0.00	0.00	0.00
89	10	2	2	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	3	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	3	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	4	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	4	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	5	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	5	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	6	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	6	2	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	10	7	1	0.001	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	10	7	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	8	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	8	2	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	10	9	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	9	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	10	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	10	2	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
89	10	11	1	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	11	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	12	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	12	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	13	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	13	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	14	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	14	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	15	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	15	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	16	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	16	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	17	1	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00
89	10	17	2	0.68	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00
89	10	18	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	18	2	0.10	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	10	19	1	0.70	0.00	0.00	0.00	0.00	0.00	0.44	0.00	0.00	0.00	0.00	0.00
89	10	19	2	0.25	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
89	10	20	1	0.04	0.00	0.00	0.00	0.00	0.00	0.72	0.00	0.00	0.00	0.00	0.00
89	10	20	2	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	21	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	21	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	22	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	22	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	23	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	23	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	24	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	24	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	25	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	25	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	26	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	26	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	27	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	27	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	28	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	28	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	29	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	29	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	30	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	30	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	10	31	1	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	10	31	2	0.08	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00
89	11	1	1	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	1	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

89	11	2	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	2	2	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
89	11	3	1	0.07	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
89	11	3	2	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	4	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	4	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	5	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	5	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	6	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	6	2	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	7	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	7	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	8	1	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	11	8	2	0.03	0.00	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.00
89	11	9	1	0.02	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00
89	11	9	2	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	10	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	10	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	11	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	11	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	12	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	12	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	13	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	13	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	14	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	14	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	15	1	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
89	11	15	2	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	11	16	1	0.01	0.00	0.00	0.00	0.00	0.00	0.97	0.00	0.00	0.00	0.00	0.00
89	11	16	2	0.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	17	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	17	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	18	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	18	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	19	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	19	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	20	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	20	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	21	1	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	21	2	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	22	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	22	2	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00
89	11	23	1	0.13	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
89	11	23	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	24	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	24	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	25	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	25	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	26	1	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
89	11	26	2	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	27	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	27	2	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
89	11	28	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	28	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	29	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	29	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	30	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	11	30	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	1	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	1	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	2	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	2	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	3	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	3	2	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	12	4	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	4	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	5	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	5	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

89	12	6	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	6	2	0.01	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	12	7	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	7	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	8	1	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	12	8	2	0.23	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.00
89	12	9	1	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	9	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	10	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	10	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	11	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	11	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	12	1	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
89	12	12	2	0.03	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	12	13	1	0.25	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00
89	12	13	2	0.001	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	12	14	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	14	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	15	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	15	2	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	12	16	1	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	16	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	17	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	17	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	18	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	18	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	19	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	19	2	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	12	20	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	20	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	21	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	21	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	22	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	22	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	23	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	23	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	24	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	24	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	25	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	25	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	26	1	0.001	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
89	12	26	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	27	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	27	2	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00
89	12	28	1	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	28	2	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	29	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	29	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	30	1	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
89	12	30	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	12	31	1	0.04	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
89	12	31	2	0.25	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.00

APPENDIX E

Commented Version of the Cub Run Watershed Model

This Appendix contains a commented UCI file for the Cub Run Watershed. Even though many parameters were changed, some remain as in the original file. This file was not prepared to be run but to help in the understanding of the different portions of the hydrologic User Control Input process. The files that were actually executed with the HSPF program are presented in Appendix H.

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*******************************************************************************
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***                                                                         ***
***     Hydrologic Run for calibration of the Cub Run Subwatershed using:   ***
***                          HSPF Version 10.10                             ***
***                            September 1995                               ***
***                                                                         ***
*******************************************************************************
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***                                                                         ***
***  This file is the User Control Input for the Cub Run Subwatershed model. ***
***  It is based on one of the 15 idealized subbasins defined by the NVPDC,  ***
***  specifically the number 9, including the Cub Run Basin until the        ***
***  confluence with the Big Rocky Run. This UCI file will contain only      ***
***  those parameters afecting hydrologic and hydraulic behavior. Snow will  ***
***  not be simulated, nor will sediments or quality constituents. This run  ***
***  is intended only for hydrologic and hydraulic calibration.              ***
***                                                                         ***
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***  Since the NVPDC defined the Cub Run Subbasin as Segment 9 and the       ***
***  corresponding reach segment as Reach 90, those numbers will be          ***
***  maintained for reference with the NVPDC study.                          ***
***                                                                         ***
***  This file will be documented as much as possible to make it             ***
***  easily understood in future studies.                                    ***
***                                                                         ***
***  The file is based on the following files:                               ***
***                                                                         ***
***         HUNT_HY.UCI   from the Hunting Creek Hydrology Run               ***
***         TEST07.UCI    from the test files packed with the HSPF program   ***
***         TEST12.UCI    from the test files packed with the HSPF program   ***
***     and OCC_86DW.UCI  prepared by Don Waye from the mainframe Occoquan   ***
***                       Watershed Model and the Hunting Creek Studies.     ***
***                                                                         ***
***  Page numbers refer normally to those of the Hydrological Simulation     ***
***  Program - FORTRAN, User's Manual for Release 10. If they refer to       ***
***  another publication it will be noted appropriately.                     ***
***                                                                         ***
***  Lines with three or more consecutive "*" are comment lines and will not ***
***  be considered by the program when executing the run. The three *** may  ***
***  appear in any place in the line, they do not necessarily have to be at  ***
***  the beginning of the line. Blank lines will not be considered by the    ***
***  program either.                                                         ***
***                                                                         ***
***                                                Daniel R. Vilariño       ***
***                                                September, 1995          ***
***                                                                         ***
***                                                                         ***
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*******************************************************************************
***                                                                         ***
***  WDM File Documentation:                                                 ***
***                                                                         ***
***  In addition to the model inputs defined in this "UCI" file, the model   ***
***  also accesses data from a "WDM" file. The WDM file is a data base file  ***
***  in binary format, created by the ANNIE program. It consists of a number ***
***  of different data sets that are all time series-dependent. The name of  ***
***  the WDM file is defined in the "FILES" module as D:\HSPF10\CUBRUNDT.WDM ***
***                                                                         ***
***  The data sets in the WDM file are as follows:                           ***
***  DS#  Description                                                        ***
***  ===  ============================================                       ***
```

```
***    71   Evaporation                                                       ***
***    52   Precipitation                                                     ***
***    76   Potential Evapotranspiration                                      ***
***    23   Observed Flow                                                     ***
***                                                                           ***
*********************************************************************************
*********************************************************************************
***                                                                           ***
***  A HSPF Run always begins with the word "RUN" and ends with the words    ***
***   "END RUN".                                                              ***
***                                                                           ***
*********************************************************************************
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*********************************************************************************
***                                                                           ***
***   Beginning of the Hydrologic Calibration Run No. 001 for Segment 9.     ***
***                                                                           ***
*********************************************************************************
*********************************************************************************
*********************************************************************************
RUN

*********************************************************************************
*********************************************************************************
***   Beginning of GLOBAL block                                               ***
*********************************************************************************
*********************************************************************************
GLOBAL

*********************************************************************************
*** Inputs for the GLOBAL block are explained on pp. 275 - 276.               ***
*********************************************************************************
*** Title of HSPF Run listed here (up to 78 characters):                      ***
*********************************************************************************

  CUB RUN SUB-BASIN HYDROLOGIC RUN
  START       1983 10  1  0  0  END    1984 12 31 24  0
  RUN INTERP OUTPUT LEVEL    7
  RESUME     0 RUN     1
*********************************************************************************
*** The RESUME feature is not implemented in this version of HSPF. For that  ***
*** reason the RESMFG (RESUME FLAG) must be set to 0. The RUNFG (RUN FLAG)   ***
*** is set to 1 because we want to have the program to interpret and execute ***
*** the RUN, If we wanted only to interpret the RUN it should have been set  ***
*** to 0.                                                                     ***
*********************************************************************************

END GLOBAL
*********************************************************************************
*********************************************************************************
***   End of the GLOBAL Block.                                                ***
*********************************************************************************
*********************************************************************************

*********************************************************************************
*********************************************************************************
***   Beginning of FILES block                                                ***
*********************************************************************************
*********************************************************************************
FILES

*********************************************************************************
*** All the files that will be accessed by this input data set are defined   ***
```

```
*** here. The two-digit numbers are the Fortran unit numbers that are user-  ***
*** defined. The primary output from this run will be directed to two files  ***
*** #80 & #82. File #80 will contain land segment runoff results (from       ***
*** PERLND and IMPLND), and File #82 will contain in-stream (RCHRES) results.***
*** See pp. 277 - 278 for more info.                                         ***
********************************************************************************
<type>  <Fu#>***<------------fname------------------------------------------->
INFO      21    \HSPF10\HSPINF.DA
ERROR     22    \HSPF10\HSPERR.DA
WARN      23    \HSPF10\HSPWRN.DA
MESSU     25    \OCC\OCC-94dW.ECH
WDM       30    \OCC\OCC-A.WDM
ANNMES    32    \OCC\OCC-A.MSG
          80    \OCC\OCC_WQ_L.OUT
          82    \OCC\OCC_WQ_R.OUT

END FILES
********************************************************************************
********************************************************************************
***   End of the FILES Block.                                                ***
********************************************************************************
********************************************************************************

********************************************************************************
********************************************************************************
***   Beginning of OPN SEQUENCE Block.                                       ***
********************************************************************************
********************************************************************************
OPN SEQUENCE

********************************************************************************
*** OPN SEQUENCE stands for "Operations Sequence" module.  Inputs for        ***
*** this module are documented on pp. 279 - 283.                             ***
***                                                                          ***
*** One (1) hour time step is used for entire HSPF simulation (INDELT).      ***
*** For that reason, in the Internal Group Scratch Pad the INDELT is set to  ***
*** 1:00.                                                                    ***
********************************************************************************
    INGRP              INDELT 1:00
********************************************************************************
*** Eleven (11) pervious land use categories are specified here for each of  ***
*** RCHRES drainage segments. The PERLND categories are numbered from 901 to ***
*** 911 for Reach 90. See "GEN-INFO" in the PERLND module input for more     ***
*** details. Use "I3" format for element numbers (cols 18-20).               ***
********************************************************************************
*** PERLNDs #901 through #911 represent the eleven land uses that drain to   ***
*** RCHRES Segment 90 (Cub Run).                                             ***
********************************************************************************
      PERLND     901
      PERLND     902
      PERLND     903
      PERLND     904
      PERLND     905
      PERLND     906
      PERLND     907
      PERLND     908
      PERLND     909
      PERLND     910
      PERLND     911
********************************************************************************
*** Eleven (11) impervious land use categories are specified here for each of***
*** RCHRES drainage segments. The IMPLND categories are numbered from 901 to ***
*** 911 for Reach 90. See "GEN-INFO" in the PERLND module input for more     ***
*** details. Use "I3" format for element numbers (cols 18-20).               ***
********************************************************************************
*** IMPLNDs #901 through #911 represent the eleven land uses that drain to   ***
*** RCHRES Segment 90 (Cub Run).                                             ***
```

```
********************************************************************************
      IMPLND     901
      IMPLND     902
      IMPLND     903
      IMPLND     904
      IMPLND     905
      IMPLND     906
      IMPLND     907
      IMPLND     908
      IMPLND     909
      IMPLND     910
      IMPLND     911
********************************************************************************
*** The following is the definition of reaches for this run.                 ***
********************************************************************************
*** Reach #90 represents Cub Run.                                             ***
********************************************************************************

      RCHRES      90

*** Begin Utility Blocks
      GENER        1     *** INACTIVE
      GENER        2     *** INACTIVE
      GENER        3     *** INACTIVE
      COPY        10     *** INACTIVE
    END INGRP
END OPN SEQUENCE
********************************************************************************
********************************************************************************
***   End of the OPN SEQUENCE Block.                                          ***
********************************************************************************
********************************************************************************


********************************************************************************
********************************************************************************
***   Beginning of PERLND block                                               ***
********************************************************************************
********************************************************************************
PERLND

********************************************************************************
*** PERLND stands for "Pervious Land Segments" module.  Inputs for this       ***
*** module are documented on pages 284 - 402.                                 ***
********************************************************************************

********************************************************************************
***   Beginning of the table-type ACTIVITY                                    ***
********************************************************************************
  ACTIVITY
    <PLS >    Active Sections (1 = Active; 0 = Inactive. p. 286)        ***
    # -  # ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC ***
  901  911    0    0    1    0    0    0    0    0    0    0    0    0

********************************************************************************
*** The following PERLND sub-modules are activated:                           ***
***                                                                           ***
*** PWAT (PWATER)  - Simulates the water budget                               ***
********************************************************************************

  END ACTIVITY
********************************************************************************
***   End of the table-type ACTIVITY                                          ***
********************************************************************************

********************************************************************************
***   Beginning of the table-type PRINT-INFO                                  ***
```

```
********************************************************************************
  PRINT-INFO
     <PLS> ******************** Print-flags ************************ PIVL  PYR
    # -   # ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC *********
  901  911    0    0    4    0    0    0    0    0    0    0    0    0    0   12

********************************************************************************
*** A value "4" means information printed every month                        ***
********************************************************************************

  END PRINT-INFO
********************************************************************************
***   End of the table-type PRINT-INFO                                       ***
********************************************************************************

********************************************************************************
***   Beginning of the table-type GEN-INFO                                   ***
********************************************************************************
  GEN-INFO

********************************************************************************
*** Cub Run-specific land use categories for each PERLND are listed below.   ***
********************************************************************************
*** <PLS ><---Description----><---->< Unit-systems>< Printer>
*** # -   #      Name                User  t-series Engl Metr
***                            NBLKS        in  out
  901     Forest        Seg.90     1     1    1    1   80    0
  902     Idle Land     Seg.90     1     1    1    1   80    0
  903     Hi-Till Crop  Seg.90     1     1    1    1   80    0
  904     Lo-Till Crop  Seg.90     1     1    1    1   80    0
  905     Pasture       Seg.90     1     1    1    1   80    0
  906     Lg. Lot Res.  Seg.90     1     1    1    1   80    0
  907     Med.Dens.Res.Seg.90      1     1    1    1   80    0
  908     Thse/Grdn.AptSeg.90      1     1    1    1   80    0
  909     Commercial    Seg.90     1     1    1    1   80    0
  910     Industrial    Seg.90     1     1    1    1   80    0
  911     InstitutionalSeg.90      1     1    1    1   80    0

  END GEN-INFO
********************************************************************************
***   End of the table-type GEN-INFO                                         ***
********************************************************************************

********************************************************************************
***************************************HYDROLOGY********************************
********************************************************************************

********************************************************************************
***   Beginning of the table-type PWAT-PARM1. 1st group of PWATER parms (fgs)***
********************************************************************************
  PWAT-PARM1
***
*** <PLS >                Flags
*** x -   x CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE
  901  911    0    1    0    1    0    0    0    0    0

********************************************************************************
*** Explanation of PWAT-PARM1 flags (see pp. 301 - 302):                     ***
***                                                                          ***
*** RTOP (RTOPFG) = 1; Routing of overland flow is computed in the same way  ***
***                    as the method used in HSPX, ARM, & NPS.               ***
*** UZFG (UZFG)   = 0; Uses an algorithm less sensitive to DELT changes for  ***
***                    the computation of Upper Zone inflow.                 ***
*** VCS  (VCSFG)  = 1; Vary interception storage capacity monthly. Table type***
***                    MON-INTERCEP will have to appear after PWAR-PARM4 set ***
********************************************************************************
```

```
  END PWAT-PARM1
********************************************************************************
***   End of the table-type PWAT-PARM1.                                      ***
********************************************************************************
********************************************************************************
***   Beginning of the table-type PWAT-PARM2. 2nd group of PWATER parms (fgs)***
********************************************************************************
  PWAT-PARM2
***  <PLS>    FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
*** x -  x                (in)   (in/hr)      (ft)             (1/in)   (1/day)
  901  911       0.0     4.270     0.015     387.0    0.0378       0.0      0.96

********************************************************************************
*** Table PWAT-PARM2 is explained on pp. 303 - 304.                          ***
***                                                                          ***
*** FOREST always = 0.0 if snow is not simulated.                            ***
*** LZSN is the lower (groundwater) zone nominal storage. Varies by RCHRES   ***
***       segment drainage. Values taken from "LZSN" in NPS 16 liner L1 card.***
*** INFILT is an index to the soil's infiltration capacity. Varies by RCHRES ***
***       segment drainage. Values taken from "INFIL" in NPS 16 liner L1 card***
*** LSUR is the length of overland flow (upslope of any concentrated flow).  ***
***       Varies by RCHRES segment drainage. Values taken from "L" in NPS    ***
***       16 liner L2 card.                                                  ***
*** SLSUR is the overland slope. Varies by RCHRES segment drainage. Values   ***
***       taken from "SS" in NPS 16 liner L2 card.                           ***
*** KVARY affects groundwater recession flow. Use default of 0.0.            ***
*** AGWRC groundwater recession rate. Varies by RCHRES segment drainage.     ***
***       values taken from "KK24" in NPS 16 liner L3 card.                  ***
********************************************************************************

  END PWAT-PARM2
********************************************************************************
***   End of the table-type PWAT-PARM2.                                      ***
********************************************************************************

********************************************************************************
***   Beginning of the table-type PWAT-PARM3. 3rd group of PWATER parms (fgs)***
********************************************************************************
  PWAT-PARM3

***  <PLS>    PETMAX    PETMIN    INFEXP    INFILD    DEEPFR    BASETP    AGWETP
*** x -  x   (deg F)   (deg F)
  901  911      40.0      35.0       2.0       2.0       0.0       0.0       0.0

********************************************************************************
*** See pp. 305 - 306 for more info on PWAT-PARM3 Table.                     ***
***                                                                          ***
*** PETMAX & PETMIN values are ignored if snow is not simulated.             ***
*** INFEXP is the infiltration exponent. Since there does not appear to be   ***
***        a similar variable in the NPS files, use the HSPF default of 2.0. ***
*** INFILD is the ratio of max to mean infilt. capacities w/in PERLNDs.      ***
***        Since there does not appear to be a similar variable in the NPS   ***
***        files, use the HSPF default of 2.0.                               ***
*** DEEPFR is the fraction of groundwater inflow lost to deep groundwater.   ***
***        This constant value of 0.0 is taken from "K24L" in NPS 16 liner   ***
***        L3 card.                                                          ***
*** BASETP is the fraction of potential evapo-transpiration available from   ***
***        groundwater outflow (baseflow). Since there does not appear to be ***
***        a similar variable in the NPS files, use the HSPF default of 0.0. ***
*** AGWETP is the fraction of potential E-T available from active ground-    ***
***        water storage. Since there does not appear to be a similar        ***
***        variable in the NPS files, use the HSPF default of 0.0.           ***
********************************************************************************

  END PWAT-PARM3
********************************************************************************
***   End of the table-type PWAT-PARM3.                                      ***
```

```
********************************************************************************

********************************************************************************
***   Beginning of the table-type PWAT-PARM4. 4th group of PWATER parms (fgs)***
********************************************************************************
  PWAT-PARM4

*** <PLS >     CEPSC      UZSN      NSUR     INTFW       IRC     LZETP
*** x  -  x     (in)      (in)                        (1/day)
  901  911       0.0     0.427      0.30      1.22      0.75       0.0

********************************************************************************
*** See pp. 306 - 307 for more info on PWAT-PARM4 Table.                     ***
***                                                                          ***
*** CEPSC is the interception storage capacity. Since storage capacity varies***
***       per month (as specified by "EPXM" in the NPS 16 liner L4 card),    ***
***       this value is ignored, and values in Table MON-INTERCEP are used   ***
***       instead.                                                           ***
*** UZSN is the upper (groundwater) zone nominal storage. Varies by RCHRES   ***
***       segment drainage. Values taken from UZSN in the NPS 16 liner L1    ***
***       card.                                                              ***
*** NSUR is the Manning's n for overland flow. This constant value of 0.30   ***
***       is taken from "NN" in the NPS 16 liner L2 card. Realistically,     ***
***       this parameter SHOULD be a function of land use, since well-       ***
***       manicured lawns will have a lower Manning's n value than forest    ***
***       or idle areas. An even better improvement would be to vary this    ***
***       parameter monthly using the MON-MANNING Table.                     ***
*** INTFW is the interflow inflow parameter. It is taken from "INTER" in the ***
***       NPS 16 liner L1 card.                                              ***
*** IRC is the interflow recession parameter. It is taken from "IRC" in the  ***
***       NPS 16 liner L1 card.                                              ***
*** LZETP is the lower zone evapo-transpiration parameter. Since its value is***
***       a function of deep-rooted vegetation, it SHOULD be dependent upon  ***
***       land use. (e.g., FOREST deciduous trees have deep tap roots, thus  ***
***       FOREST land use PERLNDs should have non-zero LZETP values.)        ***
***                                                                          ***
********************************************************************************

  END PWAT-PARM4
********************************************************************************
***   End of the table-type PWAT-PARM4.                                      ***
********************************************************************************

********************************************************************************
***   Beginning of the table-type MON-INTERCEP                               ***
********************************************************************************
  MON-INTERCEP

*** <PLS >  Interception storage capacity at start of each month (in inches)
*** x  -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
*********=====*****=====*****=====*****=====*****=====*****=====*****
  901  911 0.07 0.07 0.09 0.09 0.11 0.11 0.11 0.11 0.11 0.09 0.07 0.07

********************************************************************************
*** This Table is explained on p. 308.                                       ***
*** This data comes directly from "EPXM" variable in the NPS 16 liner L4     ***
*** card. There is a slight difference, however. Whereas the NPS variable    ***
*** "EXPM" represents the maximum interception storage for each month,       ***
*** values in this table represent the interception storage at the START     ***
*** of each month. This difference should NOT be noticed for simulation      ***
*** periods of a year or longer (specified in the GLOBAL block), and should  ***
*** be negligible for most intervals longer than a month or so.              ***
********************************************************************************

  END MON-INTERCEP
********************************************************************************
***   End of the table-type MON-INTERCEP                                     ***
```

```
******************************************************************************

******************************************************************************
***   Beginning of the table-type PWAT-STATE1. For PERLND Block            ***
******************************************************************************
  PWAT-STATE1

***  <PLS>  PWATER state variables (in)
*** x -  x      CEPS      SURS       UZS      IFWS       LZS      AGWS      GWVS
  901  911       0.0       0.0     0.286       0.0     2.861       0.5       0.0

******************************************************************************
*** This Table is explained on pp. 314 - 315.                              ***
*** These PWATER state variables represent the initial water storages.     ***
*** Presumably, these would vary depending upon the start date of the      ***
*** simulation, specified in the GLOBAL block.                             ***
***                                                                        ***
*** CEPS is the initial interception storage. There is no equivalent variable***
***      in the NPS/HSP input, so leave this = 0.0 (default).              ***
*** SURS is the initial surface storage. There is no equivalent variable in ***
***      the NPS/HSP input, so leave this = 0.0 (default).                 ***
*** UZS is the initial upper (groundwater) zone storage. Values are taken  ***
***     from "UZS" in the NPS 16 liner L5 card.                            ***
*** IFWS is the initial interflow storage. There is no equivalent variable  ***
***      in the NPS/HSP input, so leave this = 0.0 (default).              ***
*** LZS is the initial lower (groundwater) zone storage. Values are taken  ***
***     from "LZS" in the NPS 16 liner L5 card.                            ***
*** AGWS is the initial active groundwater storage. Values are taken from  ***
***     SGW in the NPS 16 liner L5 card.                                   ***
*** GWVS is the index to groundwater slope (a measure of antecedent ground- ***
***     water inflow). Since there is no equivalent variable in the NPS/HSP ***
***     input, leave this = 0.0 (default).                                 ***
******************************************************************************

  END PWAT-STATE1
******************************************************************************
***   End of the table-type PWAT-STATE1 for PERLND Block.                  ***
******************************************************************************

END PERLND
******************************************************************************
******************************************************************************
***   End of the PERLND Block.                                             ***
******************************************************************************
******************************************************************************


******************************************************************************
******************************************************************************
***   Beginning of IMPLND block                                            ***
******************************************************************************
******************************************************************************
IMPLND

******************************************************************************
*** IMPLND stands for "Impervious Land Segments" module.  Inputs for this  ***
*** module are documented on pages 403 - 432.                              ***
******************************************************************************

******************************************************************************
***   Beginning of the table-type ACTIVITY for IMPLND Block.               ***
******************************************************************************
  ACTIVITY
    # -  # ATMP SNOW IWAT  SLD  IWG IQAL   ***
  901  911    0    0    1    0    0    0

  END ACTIVITY
```

```
********************************************************************************
***   End of the table-type ACTIVITY for IMPLND Block.                       ***
********************************************************************************

********************************************************************************
***   Beginning of the table-type PRINT-INFO for IMPLND Block.               ***
********************************************************************************
  PRINT-INFO

    # -  # ATMP SNOW IWAT  SLD  IWG IQAL PIVL  PYR  ***
  901  911    0    0    4    0    0    0    0   12
********************************************************************************

*** A Print Flag of "4" means "print monthly summaries".                     ***
********************************************************************************

  END PRINT-INFO
********************************************************************************
***   End of the table-type PRINT-INFO for IMPLND Block.                     ***
********************************************************************************


********************************************************************************
***   Beginning of the table-type GEN-INFO for IMPLND Block.                 ***
********************************************************************************
  GEN-INFO

*** <ILS >      Name              Unit-systems   Printer
*** <ILS >                      User  t-series Engl Metr
*** x -  x                             in  out
***
  901     Forest        Seg.90     1    1    1   80    0
  902     Idle Land     Seg.90     1    1    1   80    0
  903     Hi-Till Crop  Seg.90     1    1    1   80    0
  904     Lo-Till Crop  Seg.90     1    1    1   80    0
  905     Pasture       Seg.90     1    1    1   80    0
  906     Lg. Lot Res.  Seg.90     1    1    1   80    0
  907     Med.Dens.Res. Seg.90     1    1    1   80    0
  908     Thse/Grdn.AptSeg.90      1    1    1   80    0
  909     Commercial    Seg.90     1    1    1   80    0
  910     Industrial    Seg.90     1    1    1   80    0
  911     InstitutionalSeg.90      1    1    1   80    0
  END GEN-INFO
********************************************************************************
***   End of the table-type GEN-INFO for IMPLND Block.                       ***
********************************************************************************

********************************************************************************
***************************************HYDROLOGY********************************
********************************************************************************

********************************************************************************
***   Beginning of the table-type IWAT-PARM1. 1st group of IWATER parms (fgs)***
********************************************************************************
  IWAT-PARM1

*** <ILS >        Flags
*** x -  x CSNO RTOP  VRS  VNN RTLI
  901  911    0    1    0    0    0

********************************************************************************
*** Explanation of IWAT-PARM1 flags (see pp. 409 - 410):                     ***
***                                                                          ***
*** CSNO (CSNOFG) = 0; Do NOT consider SNOW budget in Section IWATER.        ***
*** RTOP (RTOPFG) = 1; Routing of overland flow is computed in the same way  ***
***                    as the method used in NPS.                            ***
*** VRS (VRSFG)   = 0; Do NOT vary retention storage capacity monthly.       ***
```

```
*** VNN (VNNFG)    = 0; Do NOT vary Manning's n for overland flow.          ***
*** RTLI (RTLIFG) = 0; Do NOT subject lateral surface inflow to retention   ***
***                    storage.                                              ***
*****************************************************************************

  END IWAT-PARM1
*****************************************************************************
***   End of the table-type IWAT-PARM1                                      ***
*****************************************************************************

*****************************************************************************
***   Beginning of the table-type IWAT-PARM2. 2nd group of IWATER parms (fgs)***
*****************************************************************************
  IWAT-PARM2

*** <ILS >      LSUR     SLSUR      NSUR     RETSC
*** x -  x      (ft)                           (ft)
  901  911     387.0    0.0378     0.014       0.0

*****************************************************************************
*** Table IWAT-PARM2 is explained on p. 411.                                ***
***                                                                         ***
*** LSUR is the length of overland flow (upslope of any concentrated flow). ***
***       Varies by RCHRES segment drainage. Values taken from "L" in NPS   ***
***       16 liner L2 card.                                                 ***
*** SLSUR is the overland slope. Varies by RCHRES segment drainage. Values  ***
***       taken from "SS" in NPS 16 liner L2 card.                          ***
*** RETSC (= 0.0) is the retention storage capacity of the surface.         ***
*** Note:  I do not agree with this assumption.  RETSC should be some very  ***
***        small positive number (say 0.08 inches) to account for surface   ***
***        ponding from various sources, including curb & gutter, but the   ***
***        mainframe model did not account for any retention storage on     ***
***        impervious surfaces.                                             ***
*****************************************************************************

  END IWAT-PARM2
*****************************************************************************
***   End of the table-type IWAT-PARM2                                      ***
*****************************************************************************

*****************************************************************************
***   Beginning of the table-type IWAT-STATE1. For IMPLND Block.            ***
*****************************************************************************
  IWAT-STATE1

*** <ILS >  IWATER state variables (inches)
*** x -  x      RETS      SURS
  901  911       0.0       0.0

  END IWAT-STATE1
*****************************************************************************
***   End of the table-type IWAT-STATE1. For the IMPLND Block.              ***
*****************************************************************************

END IMPLND
*****************************************************************************
*****************************************************************************
***   End of the IMPLND Block.                                              ***
*****************************************************************************
*****************************************************************************

*****************************************************************************
*****************************************************************************
***   Beginning of RCHRES block                                             ***
*****************************************************************************
*****************************************************************************
RCHRES
```

```
******************************************************************************
***   Beginning of the table-type ACTIVITY for RCHRES Block.              ***
******************************************************************************
  ACTIVITY

******************************************************************************
*** RCHRES  Active sections (See p. 434 for more info.)                    ***
******************************************************************************
*** x -  x HYFG ADFG CNFG HTFG SDFG GQFG OXFG NUFG PKFG PHFG
   90         1    0    0    0    0    0    0    0    0    0

******************************************************************************
*** HYFG (HYDR Flag)   - Simulates hydraulic behavior (ACTIVE)             ***
******************************************************************************

  END ACTIVITY
******************************************************************************
***   End of the table-type ACTIVITY for RCHRES Block.                     ***
******************************************************************************

******************************************************************************
***   Beginning of the table-type PRINT-INFO for RCHRES Block.            ***
******************************************************************************
  PRINT-INFO

******************************************************************************
*** RCHRES  Printout level flags (pp. 435 - 436)                           ***
******************************************************************************
*** x -  x HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK PHCB PIVL  PYR
   90         4    0    0    0    0    0    0    0    0    0    1   12
******************************************************************************

*** A Print Flag of "4" means "print monthly summaries".                   ***
******************************************************************************

  END PRINT-INFO
******************************************************************************
***   End of the table-type PRINT-INFO for RCHRES Block.                   ***
******************************************************************************

******************************************************************************
***   Beginning of the table-type GEN-INFO for RCHRES Block.              ***
******************************************************************************
  GEN-INFO

***              Name          Nexits   Unit Systems   Printer
*** RCHRES                              user t-series  Engl Metr LKFG
*** x -  x                                    in  out
   90     CUB RUN                     1    1    1    1   82    0    0

******************************************************************************
*** All RCHRES output will be directed to file #82.  See "FILES" module near ***
*** top of this input file for output file name.                           ***
*** LKFG:  Flags for lakes: 0 = stream/river; 1 = lake.                    ***
******************************************************************************

  END GEN-INFO
******************************************************************************
***   End of the table-type GEN-INFO for RCHRES Block.                     ***
******************************************************************************

******************************************************************************
***   Beginning of the table-type HYDR-PARM1. 1st group of HYDR Parms (fgs)  ***
******************************************************************************
  HYDR-PARM1

******************************************************************************
```

```
***         Flags for HYDR section (pp. 439 - 440)                               ***
************************************************************************************

    RCHRES  VC A1 A2 A3  ODFVFG for each *** ODGTFG for each     FUNCT  for each
    x -  x  FG FG FG FG  possible   exit *** possible   exit     possible   exit
   90        0  1  1  1    4  0  0  0  0       0  0  0  0  0       1  1  1  1  1

************************************************************************************
*** A1, A2, and A3 must all = 1 for flow, DO, BOD, and sediment simulation.    ***
************************************************************************************

  END HYDR-PARM1
************************************************************************************
***   End of the table-type HYDR-PARM1. 1st group of HYDR Parms (fgs)          ***
************************************************************************************

************************************************************************************
***   Beginning of the table-type HYDR-PARM2. 2ND group of HYDR Parms (fgs)    ***
************************************************************************************
  HYDR-PARM2

************************************************************************************
*** See pp. 441 - 442 for more info.                                            ***
************************************************************************************

*** RCHRES FDSN F-T#        LEN      DELTH      STCOR          KS       DB50
*** x -  x             (miles)       (ft)       (ft)                    (in)
*****=====*****=====**********=========*********==========**********
   90          0   90     13.84      157.0        0.0          0.5       0.01


************************************************************************************
*** FDSN   = 0 means RCHRES F-TABLE (aka RCHTAB; see p. 127) is supplied in    ***
***          THIS file; NOT in the WDM file.                                   ***
*** F-T#   = F-TABLE Number that represents the geometric & hydraulic          ***
***          characteristics of this channel.                                  ***
*** LEN    = Reach/Reservoir length in miles.                                  ***
*** DELTH = Drop in water elevation from upstream end to downstream end in     ***
***          feet.  Values derived from NETWORK section of old HSP model.      ***
*** STCOR = Stage Correction - Correction (feet) to the RCHRES depth to        ***
***          calculate stage.                                                  ***
*** KS     = Weighting factor for hydraulic routing.  Affects accuracy AND     ***
***          stability of flow routing (p. 123).                               ***
*** DB50   = Mean diameter of the bed sediment.                                ***
************************************************************************************

  END HYDR-PARM2
************************************************************************************
***   End of the table-type HYDR-PARM2. 2nd group of HYDR Parms (fgs)          ***
************************************************************************************

************************************************************************************
***   Beginning of the table-type HYDR-INIT.                                   ***
************************************************************************************
  HYDR-INIT

*** No Occoquan data input yet...
***         Initial conditions for HYDR section
*** RCHRES       VOL     Initial  value  of COLIND    initial  value  of OUTDGT
***  x - x      ac-ft    for each  possible   exit  for each possible exit,ft3
   90           ?0.0?      4.0  4.0  4.0  4.0  4.0        0.0  0.0  0.0  0.0  0.0

  END HYDR-INIT
************************************************************************************
***   End of the table-type HYDR-INIT.                                         ***
************************************************************************************
```

```
END RCHRES
******************************************************************************
******************************************************************************
***   End of the RCHRES Block.                                            ***
******************************************************************************
******************************************************************************
*** Until the next remark, data in these sections are from the Hunting       ***
*** Creek Hydrologic Run, and were not modified in this commented file, DRV. ***
******************************************************************************
******************************************************************************

EXT SOURCES
<-Volume-> <Member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   x <Name> x tem strg<-factor->strg <Name>   x   x        <Name> x x  ***
*** Meteorological data
WDM     106 HPCP  10 ENGL                  PERLND 302 315 EXTNL  PREC
WDM     111 EVAP  10 ENGL          0.8     PERLND 302 315 EXTNL  PETINP
WDM     123 ATMP  10 ENGL                  PERLND 302 315 EXTNL  GATMP
WDM     106 HPCP  10 ENGL                  IMPLND 301 306 EXTNL  PREC
WDM     111 EVAP  10 ENGL          0.8     IMPLND 301 306 EXTNL  PETINP
WDM     123 ATMP  10 ENGL                  IMPLND 301 306 EXTNL  GATMP
WDM     106 HPCP  10 ENGL                  RCHRES  30  40 EXTNL  PREC
WDM     123 ATMP  10 ENGL                  RCHRES  30  40 EXTNL  GATMP
WDM     131 CLDC  10 ENGL             SAME RCHRES  30  40 EXTNL  CLOUD
WDM     141 WIND  10 ENGL             DIV  RCHRES  30  40 EXTNL  WIND
WDM     151 DEWP  10 ENGL             SAME RCHRES  30  40 EXTNL  DEWTMP
WDM     161 SOLR  10 ENGL                  RCHRES  30  40 EXTNL  SOLRAD
END EXT SOURCES

NETWORK
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   x        <Name> x x<-factor->strg <Name>   x   x        <Name> x x  ***
*** Results for calibration
    PARTICULATE N (ADSORBED NH3 + ORG N) ***
RCHRES  30 NUTRX  RSNH4  4                 GENER    1     INPUT  ONE
RCHRES  30 HYDR   VOL                      GENER    1     INPUT  TWO
GENER    1 OUTPUT TIMSER       0.368       COPY    10     INPUT  MEAN   1
RCHRES  30 PLANK  PKST3  4                 COPY    10     INPUT  MEAN   1
    TOTAL N (NO3 + DISSOLVED NH3 + PARTICULATE N) ***
RCHRES  30 NUTRX  DNUST  1                 COPY    10     INPUT  MEAN   2
RCHRES  30 NUTRX  DNUST  2                 COPY    10     INPUT  MEAN   2
GENER    1 OUTPUT TIMSER       0.368       COPY    10     INPUT  MEAN   2
RCHRES  30 PLANK  PKST3  4                 COPY    10     INPUT  MEAN   2
    PARTICULATE P (ADSORBED PO4 + ORG P) ***
RCHRES  30 NUTRX  RSPO4  4                 GENER    2     INPUT  ONE
RCHRES  30 HYDR   VOL                      GENER    2     INPUT  TWO
GENER    2 OUTPUT TIMSER       0.368       COPY    10     INPUT  MEAN   3
RCHRES  30 PLANK  PKST3  5                 COPY    10     INPUT  MEAN   3
    TOTAL P (DISSOLVED PO4 + PARTICULATE P) ***
RCHRES  30 NUTRX  DNUST  4                 COPY    10     INPUT  MEAN   4
GENER    2 OUTPUT TIMSER       0.368       COPY    10     INPUT  MEAN   4
RCHRES  30 PLANK  PKST3  5                 COPY    10     INPUT  MEAN   4
    WATER TEMPERATURE ***
RCHRES  30 HTRCH  TW                       GENER    3     INPUT  ONE

END NETWORK

EXT TARGETS
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Volume-> <Member> Tsys Aggr Amd ***
<Name>   x        <Name> x x<-factor->strg <Name>   x <Name>qf  tem strg strg***
*** Results for Calibration
  Hunting Creek ***
    Flow ***
RCHRES  30 HYDR   RO                  AVER WDM   1281 FLOW     ENGL AGGR REPL
    NO3 ***
RCHRES  30 NUTRX  DNUST  1            AVER WDM   1282 NO3X     ENGL AGGR REPL
    Dissolved NH3 ***
```

```
RCHRES  30 NUTRX  DNUST  2            AVER WDM   1283 NH4X     ENGL AGGR REPL
     Particulate N (adsorbed NH3 + ORG N) ***
COPY    10 OUTPUT MEAN   1            AVER WDM   1284 ORGN     ENGL AGGR REPL
     Total N (N03 + dissolved NH3 + particulate N) ***
COPY    10 OUTPUT MEAN   2            AVER WDM   1285 TOTN     ENGL AGGR REPL
     Dissolved PO4 ***
RCHRES  30 NUTRX  DNUST  4            AVER WDM   1286 PO4X     ENGL AGGR REPL
     Particulate P (adsorbed PO4 + ORG P) ***
COPY    10 OUTPUT MEAN   3            AVER WDM   1287 ORGP     ENGL AGGR REPL
     Total P (dissolved PO4 + particulate P) ***
COPY    10 OUTPUT MEAN   4            AVER WDM   1288 TPXX     ENGL AGGR REPL
     Total organic carbon ***
RCHRES  30 PLANK  PKST3  6            AVER WDM   1289 TOCX     ENGL AGGR REPL
     BOD ***
RCHRES  30 OXRX   BOD                 AVER WDM   1290 BOD5     ENGL AGGR REPL
     DO ***
RCHRES  30 OXRX   DOX                 AVER WDM   1291 DOXX     ENGL AGGR REPL
     Sediment ***
RCHRES  30 SEDTRN SSED   4            AVER WDM   1292 SEDC     ENGL AGGR REPL
     Water temperature ***
GENER    3 OUTPUT TIMSER      .55555  AVER WDM   1293 WTMP     ENGL AGGR REPL
     Chlorophyll-a ***
RCHRES  30 PLANK  PHYCLA              AVER WDM   1294 CHLA     ENGL AGGR REPL
END EXT TARGETS
***
********************************************************************************


********************************************************************************
*** Remark: Here begins again data related to the Cub Run Study, DRV
********************************************************************************
********************************************************************************
********************************************************************************
***   Beginning of SCHEMATIC Block.                                          ***
********************************************************************************
********************************************************************************
SCHEMATIC

********************************************************************************
*** There are 11 land uses.  Column numbers in the table below refer to      ***
*** old 3-liner data sets (Mainframe NPS model).  These area values are      ***
*** also provided as the last three lines of the old 19-liner NPS files,     ***
*** specifically, Line 02 for PERLND + IMPLND and Line 03 for the IMPLND     ***
*** fraction.  Refer to the spreadsheet file "C:\OCC\OCC-LU-1.WB1" for       ***
*** more details.                                                            ***
***                                                                          ***
*** Col. #'s   Element #'s   Land Use Categories                             ***
*** ========   ===========  ==================================               ***
***  1  -  7    PERLND  1    Forest                                          ***
***  8  - 14    PERLND  2    Idle Land                                       ***
***  15 - 21    PERLND  3    High Till Cropland                              ***
***  22 - 28    PERLND  4    Low Till Cropland                               ***
***  29 - 35    PERLND  5    Pasture                                         ***
***  36 - 42    PERLND  6    Large Lot Residential                           ***
***  43 - 49    PERLND  7    Medium Density Residential                      ***
***  50 - 56    PERLND  8    Townhouse/Garden Apt. Residential               ***
***  57 - 63    PERLND  9    Commercial                                      ***
***  64 - 70    PERLND 10    Industrial                                      ***
***  71 - 77    PERLND 11    Institutional                                   ***
***                                                                          ***
***                                                                          ***
***  The SCHEMATIC block specifies the structure of the watershed. It        ***
***  defines how much of each land use drains to each stream reach or        ***
***  reservoir.  Source numbers in this section refer to land use types      ***
***  specified in "GEN-INFO" tables found in the PERLND and IMPLND           ***
***  sections.  The area factors were derived from a Quattro Pro for         ***
***  Windows spreadsheet called "C:\OCC\OCC-LU-1.WB1", and are in ACRES.     ***
```

```
***   See pp. 574 - 578 for more info.                                      ***
***                                                                         ***
***   The data set below represents land use conditions as they existed in  ***
***   1989.  Since NPS pollution is greatly influenced by land use, and is  ***
***   of primary concern in the Occoquan basin, is it necessary to update   ***
***   this section of the UCI file for long calibration runs of more than   ***
***   two or three years?  Should separate UCI files be created for individual***
***   years?  For model calibration &/or production runs involving the recent ***
***   years (1990 - 1998), should the model use more recent land use inputs? ***
***                                                                         ***
***   This refinement (land use values that changes yearly) could be        ***
***   accomodated by expanding the Quattro Pro land use spreadsheet file to ***
***   interpolate yearly land use conditions based on known conditions during ***
***   1984, 1989,and (presumably) 1994.  New SCHEMATIC sections could be    ***
***   swapped in and out as needed.                                         ***
***                                                                         ***
***   Note: All multiplication factors here are areas in acres.            ***
***         If Acres = 0.0, there are no loadings for that PERLND,         ***
***         and the line is "commented out" with "***".                    ***
***         Conversion factors, where applicable, are in Mass-Link.        ***
*******************************************************************************

<-Source-><---Dummy Info---><Area, Ac.>    <-Target->   <ML>  ***
<Name>   #<---(Not Read)---><--factor->    <Name>   #     #  ***
======****XXXXXXXXXXXXXXXXXX==========XXXXX======****XXX====  ***
***
*** Pervious land use loading factors for Cub Run drainage.
PERLND 901                     12679.2     RCHRES  90      1
PERLND 902                      1791.4     RCHRES  90      1
PERLND 903                      1038.1     RCHRES  90      1
PERLND 904                      4272.8     RCHRES  90      1
PERLND 905                      4298.1     RCHRES  90      1
PERLND 906                      1816.6     RCHRES  90      1
PERLND 907                      1651.3     RCHRES  90      1
PERLND 908                       207.4     RCHRES  90      1
PERLND 909                        18.6     RCHRES  90      1
PERLND 910                       798.8     RCHRES  90      1
PERLND 911                       120.6     RCHRES  90      1
***
***
<-Source-><---Dummy Info---><Area, Ac.>    <-Target->   <ML>  ***
<Name>   #<---(Not Read)---><--factor->    <Name>   #     #  ***
======****XXXXXXXXXXXXXXXXXX==========XXXXX======****XXX====  ***
***
*** Impervious land cover loading factors for Cub Run Run drainage.
IMPLND 901                       141.0     RCHRES  90      3
IMPLND 902                        19.9     RCHRES  90      3
IMPLND 903                        11.5     RCHRES  90      3
IMPLND 904                        47.5     RCHRES  90      3
IMPLND 905                        47.8     RCHRES  90      3
IMPLND 906                       199.6     RCHRES  90      3
IMPLND 907                       550.4     RCHRES  90      3
IMPLND 908                       138.3     RCHRES  90      3
IMPLND 909                       167.1     RCHRES  90      3
IMPLND 910                      1863.8     RCHRES  90      3
IMPLND 911                        65.0     RCHRES  90      3

END SCHEMATIC
*******************************************************************************
*******************************************************************************
***    End of SCHEMATIC Block.                                              ***
*******************************************************************************
*******************************************************************************


*******************************************************************************
*******************************************************************************
```

```
***   Beginning of MASS-LINK Block.                                          ***
********************************************************************************
********************************************************************************
MASS-LINK

  MASS-LINK        1
<Srce>      <-Grp> <-Member-><--Mult-->     <Targ>         <-Grp> <-Member-> ***
<Name>      <Name> <Name> # #<-factor->     <Name>         <Name> <Name> # # ***
PERLND      PWATER PERO        0.0833333    RCHRES         INFLOW IVOL
  END MASS-LINK    1

  MASS-LINK        3
<Srce>      <-Grp> <-Member-><--Mult-->     <Targ>         <-Grp> <-Member-> ***
<Name>      <Name> <Name> # #<-factor->     <Name>         <Name> <Name> # # ***
IMPLND      IWATER SURO        0.0833333    RCHRES         INFLOW IVOL
  END MASS-LINK    3

END MASS-LINK
********************************************************************************
********************************************************************************
***   Beginning of SCHEMATIC Block.                                          ***
********************************************************************************
********************************************************************************

********************************************************************************
********************************************************************************
***   Beginning of FTABLES Block.                                            ***
********************************************************************************
********************************************************************************
FTABLES

********************************************************************************
*** F-TABLES are explained on pp. 565 - 568. See also pp. 126 - 127.         ***
********************************************************************************
***                                                                          ***
*** These F-TABLES define the geometric and hydraulic properties of the      ***
*** channels specified in the Table HYDR-PARM2 in the RCHRES Module.  They   ***
*** are based directly on the mainframe HSP model NETWORK Section.  The      ***
*** F-TABLES were derived by inputting the HSP NETWORK data into a stand-    ***
*** alone HSPF companion program called XSECT.  (The HSP NETWORK data were   ***
*** formatted into an XSECT input format as a file called C:\OCC\OCC-RCH1.   ***
*** INP.)  The output file (called C:\OCC\OCC-RCH1.OUT) generated by XSECT   ***
*** consists of the F-TABLES for the following RCHRES elements:  10, 20,     ***
*** 30, 40, 60, 65, 70, 80, 90, 100, 110, & 140.  Input data from the HSP    ***
*** NETWORK Section (and the XSECT input file) are provided below:           ***
***                XSECT INPUT FORMAT: (I5,9F8.0)                            ***
***                                                                          ***
********************************************************************************
RCHNM  LENGTH    ELUP  ELDOWN *** W1      W2       H     SFP     NCH     NFP
*****=======*******=======*******=======*******=======*******=======*******=======
   90   13.84   295.0   138.0 *** 4.0    60.0     5.2   0.023   0.053   0.170
RCHNM  *** REACH NUMBER
LENGTH *** REACH LENGTH (MILES)
ELUP   *** UPSTREAM ELEVATION (FT)
ELDOWN *** DOWNSTREAM ELEVATION (FT)
W1     *** CHANNEL BOTTOM WIDTH (FT)
W2     *** CHANNEL BANKFULL WIDTH (FT)
H      *** CHANNEL HEIGHT (FT)
SFP    *** SLOPE OF FLOOD PLAIN (-)
NCH    *** MANNINGS N FOR THE CHANNEL
NFP    *** MANNINGS N FOR THE FLOOD PLAIN
***
*** Note   :  The fifth column in each F-TABLE (generated by the XSECT
***           program) is ignored by HSPF, which is only instructed to read
***           a 15-row by 4-column matrix.  This fifth column, entitled
***           "FLO-THRU (MIN)" represents the time (in minutes) needed to
***           completely drain the RCHRES at each specified flow depth.
```

```
***             [Take (VOLUME * 43,560 ft/ac) / (DISCH * 60 s/min)]
***


  FTABLE     90
*** Cub Run (Upper Cub Run to just below junction w/ Big Rocky Run)
 ROWS COLS ***
   15    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      0.00       0.0       0.0       0.0        0.
      0.43      14.5       4.6       1.7     2025.
      0.87      22.4      12.6       6.6     1381.
      1.30      30.2      24.0      15.8     1099.
      1.73      38.0      38.8      30.2      931.
      2.17      45.9      56.9      50.6      817.
      2.60      53.7      78.5      77.8      733.
      3.47      69.3     131.8     155.6      615.
      4.33      85.0     198.7     269.1      536.
      5.20     100.7     279.1     423.7      478.
      6.93     353.5     672.8    1000.0      488.
      8.67     606.4    1504.6     1944.      562.
     10.40     859.2    2774.8     3367.      598.
     12.13    1112.1    4483.2     5365.      607.
     13.87    1364.9    6629.9     8025.      600.
  END FTABLE 90

END FTABLES
********************************************************************************
********************************************************************************
***    End of FTABLES Block.                                                 ***
********************************************************************************
********************************************************************************


END RUN
********************************************************************************
********************************************************************************
********************************************************************************
***                                                                          ***
***    End of the Hydrologic Calibration Run No. 001 for Segment 9.          ***
***                                                                          ***
********************************************************************************
********************************************************************************
********************************************************************************
```

APPENDIX F

Segmentation of the Cub Run Watershed in Reach Segments

The first step was to precisely define the area of study on a good topographical map. The USGS quadrangle maps at 1:24000 scale were found to be both practical and with enough resolution to perform this task. For Segment 9 the USGS quadrangles for Arcola, Gainesville, Herndon, Manassas, Vienna and Fairfax at 1:24000 scale were pasted together. These topographical maps have 10 feet contour lines so the topological characteristics of the area could be determined quite precisely. The watershed boundary for the Cub Run Watershed was defined tracing lines for the water divide. The total area of the watershed was measured using a 1:24000 scale grid with squares of 0.1 inches per side representing areas of 40000 square feet. The area of the whole watershed was found to be 49.0 square miles.

The method for the measuring was as follows: the grid was prepared in a graphic program so that when printed it produced lines with 1/10 of an inch of separation. Then, it was printed over transparency paper, and a sufficient number of these papers where carefully pasted together so that the complete area of the watershed marked on the topographical map was covered. The map boundary was transferred to the transparency paper and the squares inside the water divide where counted. Squares appearing over the water divide that were not totally included inside the boundary where counted using fractions as precisely as possible and added to the previous value. The total # of squares was multiplied by the surface of one of them (40000 sq. ft.).

The area of the watershed was then divided into very small reach segments, defined so that each segment was formed by a portion of stream with no tributaries. In fact, tributary entry points where considered criteria for defining a new reach segment, so these points were always located at the conjunction of at least three reach segments: the one downstream from the tributary entrance, the one upstream and the one formed by the tributary itself. Sometimes, when two tributaries poured their waters at approximately the same point in the main stream, four segments defined the point. Using this technique 163 segments were defined and they where cataloged using the first three letters of the main tributary stream (when this one had a name in the USGS map), plus a three digit number increasing from the tail to the mouth of the main tributary. If the reach did not have a proper name, the three first letters of the main stream with a proper name to which the tributary poured its waters were the ones used.

This system generated:

62 segments for Elklick Run cataloged from ELK001 to ELK062

3 segments for Sandy Branch cataloged from SAN001 to SAN003

3 segments for Cain Branch cataloged from CAI001 to CAI003

5 segments for Dead Run cataloged from DEA001 to DEA005

23 segments for Flatlick Branch cataloged from FLA001 to FLA023

29 segments for Big Rocky Run cataloged from BIG001 to BIG029

38 segments for Cub Run cataloged from CUB001 to CUB038

The 163 segments are shown on a map of the Watershed included in the attached envelope.

APPENDIX G

Determining Geomorphological Parameters

for the 163 Defined Segments

A Table containing the following columns is presented: Segment Code Name, Reach Length in ft, Reach Slope in ft/ft, Length of the Overland Flow Plane measured from the map (LSUR), Slope of the Overland Flow Plane measured from the map (SLSUR), Area of the segment in millions of square feet, and the Calculated LSUR using Horton's Equation.

Then, 17 segment groups are shown with the measurements in feet of three contour lines at 25, 50 and 75% of the height difference, and the base lines for those contours.

Finally, a table prepared in a spreadsheet is presented. In this table, the new values of LSUR and SLSUR were obtained using the following equations:

$$LSUR = \frac{(LC * LB)}{(2EP\sqrt{LC^2 - LB^2})} \quad (2)$$

$$SLSUR = \frac{0.25Z(LC_{25} + LC_{50} + LC_{75})}{DA} \quad (3)$$

where LC is the contour line length, LB is the base line length, EP is the number of extreme points, Z is the difference between the highest and the lowest points of the watershed, and DA is the drainage area. For the LSUR parameter the values were calculated at 25, 50, and 75 percent of the height and then they were averaged weighing the numbers based on half of the sum of the contour line and the base line. The seven final segments values were obtained using a weighted area average.

Segment #9 Data

Segment Code Name	RLENGTH (ft)	R. Slope	LSUR (ft)	SLSUR	Area (millions of sqft.)	Calc. LSUR Area/2RLength
	Elklick Run Subwatershed					
ELK001	1780	0.01205	340	0.01205	2.71711	763
ELK002	3040	0.01408	692	0.02684	5.54605	912
ELK003	2040	0.00617	492	0.01299	3.38816	830
ELK004	6160	0.01178	564	0.03381	8.43421	685
ELK005	1620	0.00472	1250	0.01136	3.94737	1218
ELK006	1480	0.01064	455	0.02222	3.84868	1300
ELK007	200	0.01064	140	0.02222	0.05241	131
ELK008	2860	0.01119	460	0.02360	5.73183	1002
ELK009	920	0.00472	690	0.02490	2.09294	1137
ELK010	2560	0.01563	584	0.03215	3.81249	745
ELK011	2060	0.01111	1048	0.02264	7.30399	1773
ELK012	4940	0.00750	1126	0.02233	13.36991	1353
ELK013	1780	0.00472	550	0.03174	2.31238	650
ELK014	3080	0.01230	476	0.03954	3.41945	555
ELK015	1700	0.01923	238	0.03571	1.092	321
ELK016	1060	0.01577	360	0.04007	0.76774	362
ELK017	1660	0.00463	453	0.09103	1.46735	442
ELK018	5280	0.01131	898	0.02584	11.62743	1101
ELK019	2120	0.01333	856	0.02629	6.39672	1509
ELK020	660	0.00806	440	0.02798	0.57777	438
ELK021	5660	0.01245	628	0.05278	7.46776	660
ELK022	1100	0.00901	665	0.04861	4.21863	1918
ELK023	960	0.01807	140	0.06667	0.53992	281
ELK024	740	0.01807	430	0.06667	1.0535	712
ELK025	2120	0.00588	1268	0.03716	5.82716	1374
ELK026	1460	0.01087	610	0.02874	5.18189	1775
ELK027	3500	0.00781	1080	0.02709	11.23292	1605
ELK028	5080	0.00670	714	0.03497	7.37449	726
ELK029	2700	0.00291	838	0.04332	4.60905	854
ELK030	1580	0.01613	753	0.04861	6.14979	1946
ELK031	500	0.00291	120	0.04861	0.14025	140
ELK032	2980	0.02459	766	0.02708	6.80165	1141
ELK033	1200	0.01852	505	0.03348	3.63457	1514
ELK034	1500	0.01000	343	0.05333	1.19835	399
ELK035	1960	0.02083	636	0.04107	2.77202	707
ELK036	320	0.01000	80	0.05333	0.61893	967
ELK037	560	0.02273	180	0.05000	2.07565	1853
ELK038	2860	0.00990	592	0.04557	3.40844	596
ELK039	4660	0.00140	1088	0.04079	11.23146	1205
ELK040	4880	0.00739	552	0.04218	6.50225	666
ELK041	2600	0.00140	690	0.02573	3.18558	613
ELK042	1960	0.01053	556	0.04437	3.51331	896
ELK043	2620	0.02101	860	0.04120	7.95084	1517
ELK044	460	0.00746	380	0.02778	0.54404	591
ELK045	4560	0.01208	1188	0.02753	8.03605	881
ELK046	1180	0.00746	680	0.02968	2.60877	1105
ELK047	2660	0.01802	298	0.04432	2.26325	425
ELK048	1700	0.00725	723	0.03897	2.89212	851
ELK049	2540	0.01770	404	0.04940	3.37359	664
ELK050	660	0.00725	495	0.04431	0.72057	546
ELK051	2600	0.01563	1050	0.02571	5.45998	1050
ELK052	2680	0.00455	560	0.03877	2.41392	450
ELK053	360	0.00140	480	0.02222	0.28823	400
ELK054	2880	0.01200	902	0.02735	6.67185	1158
ELK055	1040	0.00154	330	0.04533	0.60921	293
ELK056	6920	0.00685	776	0.03260	13.66469	987
ELK057	4820	0.00893	1722	0.02910	22.08884	2291
ELK058	2880	0.00485	506	0.03221	3.74043	649

Segment Code Name	RLENGTH (ft)	R. Slope	LSUR (ft)	SLSUR	Area (millions of sqft.)	Calc. LSUR Area/2RLength
ELK059	3760	0.02000	942	0.03097	10.91341	1451
ELK060	3740	0.00154	976	0.05783	11.98772	1603
ELK061	3180	0.01020	638	0.04993	6.01351	946
ELK062	7760	0.00166	1897	0.04103	23.37277	1506

Dead Run Subwatershed

DEA001	11000	0.00731	1201	0.03091	33.15947	1507
DEA002	2420	0.00588	826	0.04542	7.8346	1619
DEA003	2840	0.00316	1178	0.04456	6.78649	1195
DEA004	6420	0.00828	820	0.04474	9.69171	755
DEA005	3200	0.00313	716	0.04072	4.36274	682

Cain Branch Subwatershed

CAI001	3600	0.01103	712	0.04786	10.85432	1508
CAI002	9540	0.00888	1527	0.04637	29.32675	1537
CAI003	9340	0.00326	1208	0.03433	16.87243	903

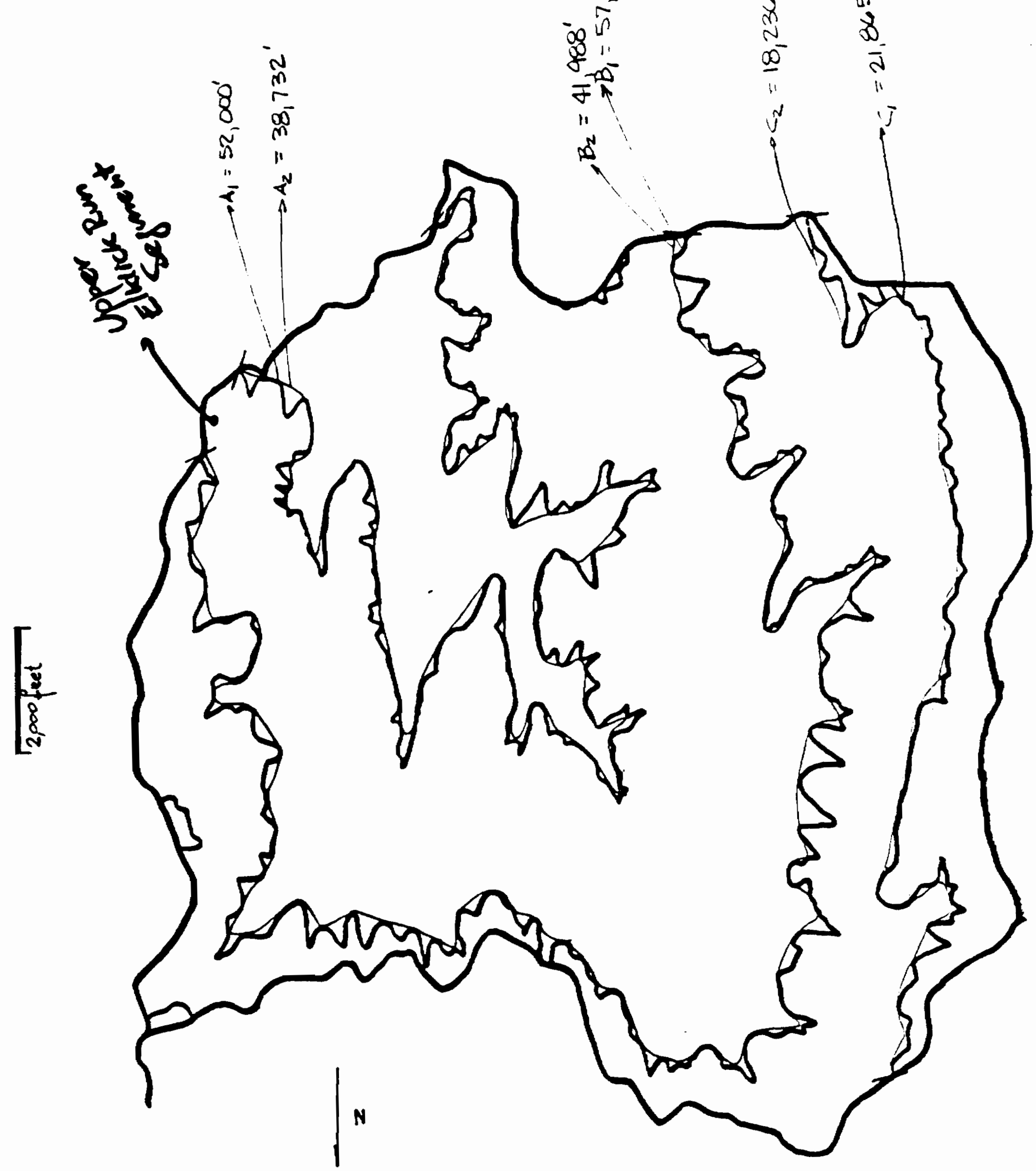
Flatlick Branch Subwatershed

FLA001	2940	0.01681	864	0.03913	8.72428	1484
FLA002	1260	0.01613	400	0.09859	5.28724	2098
FLA003	3340	0.01075	1020	0.04949	7.60494	1138
FLA004	1960	0.02083	895	0.06810	5.84691	1492
FLA005	1620	0.00769	633	0.07677	2.06749	638
FLA006	5680	0.01613	522	0.06742	7.11111	626
FLA007	1920	0.01124	658	0.08488	2.74239	714
FLA008	2700	0.02119	735	0.13109	5.95885	1103
FLA009	600	0.00476	410	0.06905	0.50041	417
FLA010	3800	0.01875	722	0.06986	7.73663	1018
FLA011	4900	0.01741	834	0.06684	9.80412	1000
FLA012	7600	0.00898	1690	0.05898	21.49136	1414
FLA013	3500	0.00476	1748	0.05364	15.30206	2186
FLA014	3980	0.01623	592	0.03991	6.12346	769
FLA015	3220	0.00331	1386	0.06131	9.97531	1549
FLA016	7300	0.01176	1829	0.05212	31.11111	2131
FLA017	6960	0.00383	2495	0.05693	31.93498	2294
FLA018	2960	0.01835	672	0.05674	7.06502	1193
FLA019	1380	0.00383	587	0.11952	1.69547	614
FLA020	2480	0.01754	504	0.08163	5.36626	1082
FLA021	880	0.00154	1175	0.09093	3.50288	1990
FLA022	3060	0.01504	528	0.07875	4.65514	761
FLA023	7040	0.00154	1239	0.05556	19.06173	1354

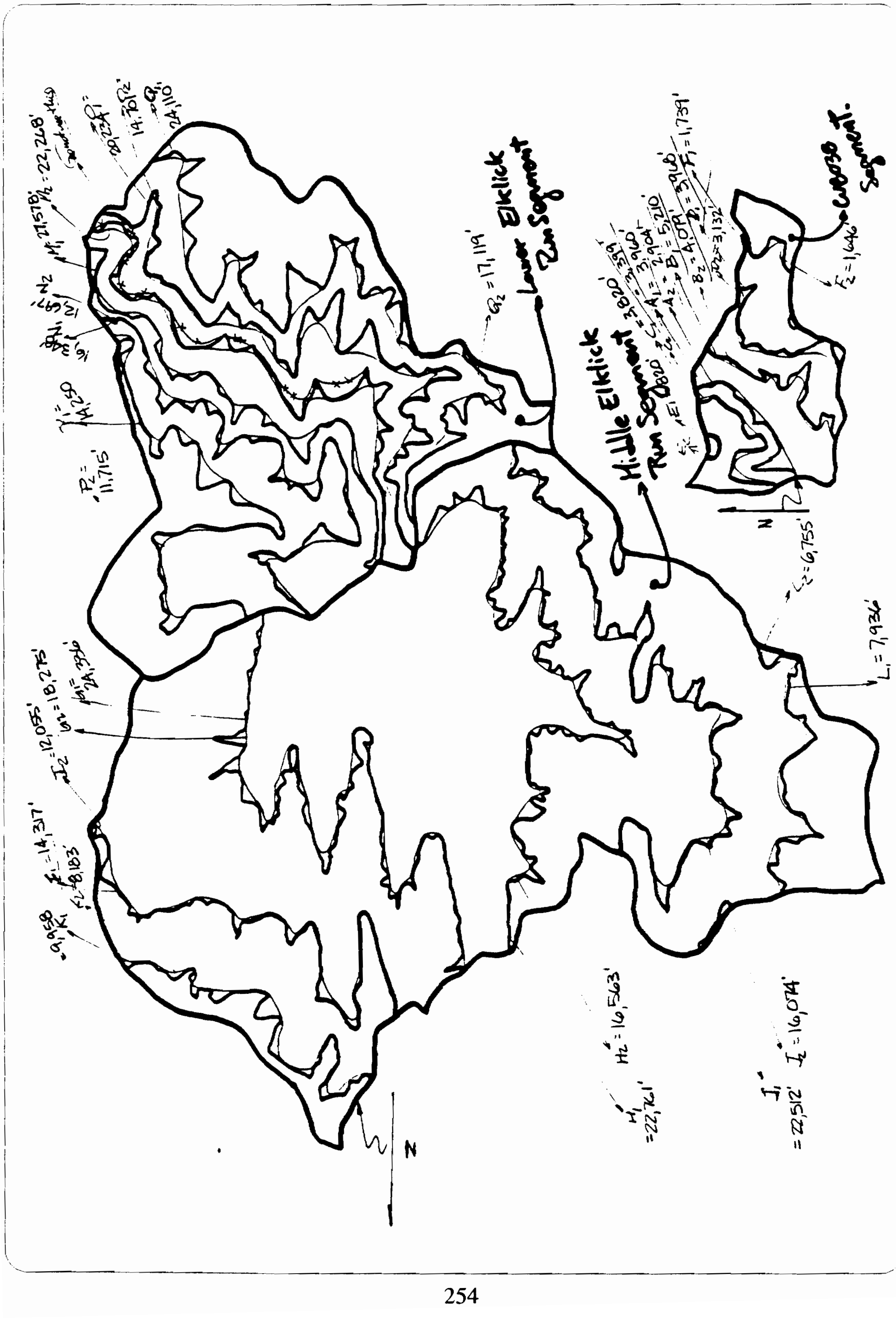
Segment Code Name	RLENGTH (ft)	R. Slope	LSUR (ft)	SLSUR	Area (millions of sqft.)	Calc. LSUR Area/2RLength
	Sand Branch Subwatershed					
SAN001	5660	0.01185	822	0.03185	14.81481	1309
SAN002	4860	0.01244	1198	0.03008	10.69959	1101
SAN003	3140	0.00735	666	0.02311	10.15309	1617
	Big Rocky Run Subwatershed					
BIG001	4100	0.01955	1088	0.05384	8.93498	1090
BIG002	3020	0.01770	878	0.07415	7.23621	1198
BIG003	3360	0.01020	974	0.08007	8.11523	1208
BIG004	1980	0.01695	468	0.07367	4.99095	1260
BIG005	3080	0.01678	1172	0.05083	9.79095	1589
BIG006	3220	0.00840	1006	0.08345	9.65926	1500
BIG007	2640	0.02604	593	0.08445	4.27325	809
BIG008	1780	0.00422	610	0.09557	1.61646	454
BIG009	3400	0.00422	1496	0.05266	20.33909	2991
BIG010	5020	0.01464	1130	0.06539	12.13498	1209
BIG011	8860	0.00799	1563	0.05413	28.53004	1610
BIG012	4620	0.01942	716	0.03756	8.4609	916
BIG013	5240	0.02200	520	0.04630	6.23539	595
BIG014	1680	0.00568	538	0.06761	1.84033	548
BIG015	1200	0.00568	307	0.18624	0.6716	280
BIG016	3040	0.02212	1036	0.04157	10.04115	1652
BIG017	5740	0.00718	1234	0.07694	12.38519	1079
BIG018	3840	0.02601	1120	0.08127	12.20741	1590
BIG019	900	0.00718	430	0.11346	1.21811	677
BIG020	2860	0.04054	1062	0.11115	9.62634	1683
BIG021	9740	0.00213	1920	0.07083	32.91523	1690
BIG022	2680	0.02913	852	0.07390	7.55885	1410
BIG023	2640	0.02885	450	0.12200	4.42469	838
BIG024	2420	0.02344	748	0.10801	4.54979	940
BIG025	1480	0.00365	988	0.05467	5.51111	1862
BIG026	3280	0.02667	544	0.07569	5.84033	890
BIG027	2580	0.03097	1026	0.09128	9.58025	1857
BIG028	1960	0.01220	1052	0.05667	5.33992	1362
BIG029	3340	0.01515	1184	0.07978	8.19095	1226

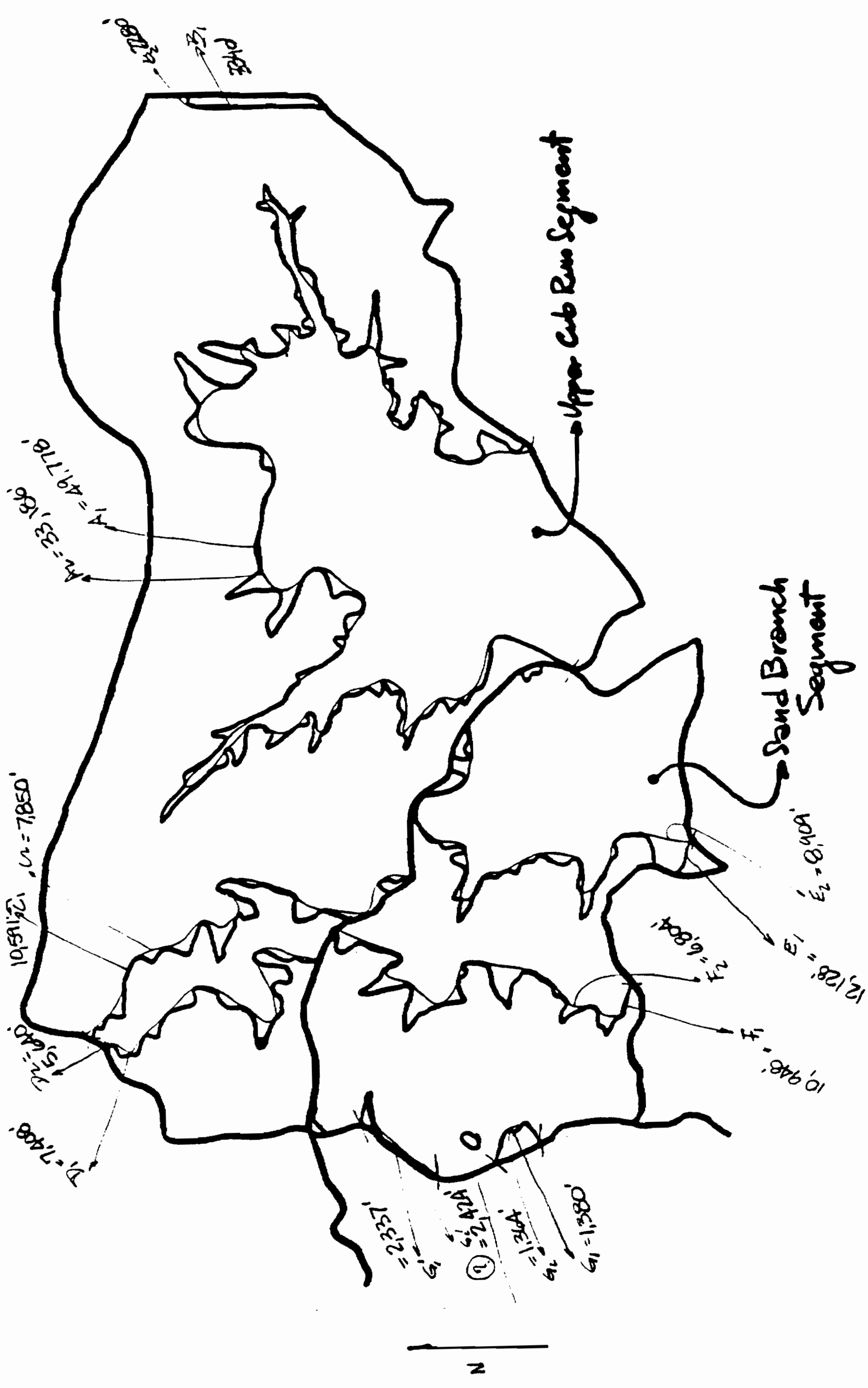
Segment Code Name	RLENGTH (ft)	R. Slope	LSUR (ft)	SLSUR	Area (millions of sqft.)	Calc. LSUR Area/2RLength
	Cub Run Subwatershed					
CUB001	5020	0.00508	1008	0.04844	10.83786	1079
CUB002	4000	0.00365	902	0.01636	10.28477	1286
CUB003	2900	0.00800	708	0.04601	5.57037	960
CUB004	2820	0.00370	722	0.02599	4.0823	724
CUB005	1800	0.00990	968	0.02607	10.87737	3021
CUB006	4340	0.00633	432	0.05891	4.34568	501
CUB007	1080	0.00990	593	0.02849	1.73827	805
CUB008	1620	0.00245	883	0.02243	3.30535	1020
CUB009	8740	0.00677	1335	0.02580	30.59753	1750
CUB010	3660	0.00754	580	0.02470	7.67078	1048
CUB011	1900	0.00276	978	0.01857	4.13498	1088
CUB012	2660	0.00188	924	0.01988	4.49053	844
CUB013	1100	0.00132	765	0.01778	1.74156	792
CUB014	3340	0.00132	1390	0.01376	15.5786	2332
CUB015	8080	0.00794	1281	0.00990	18.6535	1154
CUB016	1700	0.00132	970	0.01092	4.18107	1230
CUB017	8200	0.00901	1519	0.02462	28.7572	1753
CUB018	1940	0.00128	1825	0.01710	7.69053	1982
CUB019	2220	0.00128	704	0.04333	3.34486	753
CUB020	9380	0.00768	1596	0.02148	31.31523	1669
CUB021	4280	0.00789	618	0.03892	6.37366	745
CUB022	2820	0.00400	1210	0.03919	11.1177	1971
CUB023	2740	0.00128	825	0.07152	8.55967	1562
CUB024	2360	0.01829	620	0.05247	9.38272	1988
CUB025	11080	0.00143	1919	0.04492	34.67325	1565
CUB026	700	0.00143	320	0.11836	0.46749	334
CUB027	5920	0.00109	1842	0.03830	23.90782	2019
CUB028	3920	0.01944	613	0.05312	6.1893	789
CUB029	3420	0.00075	1186	0.02653	14.28148	2088
CUB030	11980	0.00996	1054	0.04735	25.8107	1077
CUB031	800	0.00870	715	0.02653	14.98601	9366
CUB032	1580	0.00318	463	0.02653	1.65267	523
CUB033	1180	0.00075	850	0.01890	2.48889	1055
CUB034	3040	0.01119	726	0.04128	5.78107	951
CUB035	960	0.00075	1443	0.07588	5.44527	2836
CUB036	6000	0.01168	1018	0.02213	15.07819	1257
CUB037	6860	0.00631	926	0.07396	10.84444	790
CUB038	3700	0.00694	1204	0.08753	10.41646	1408

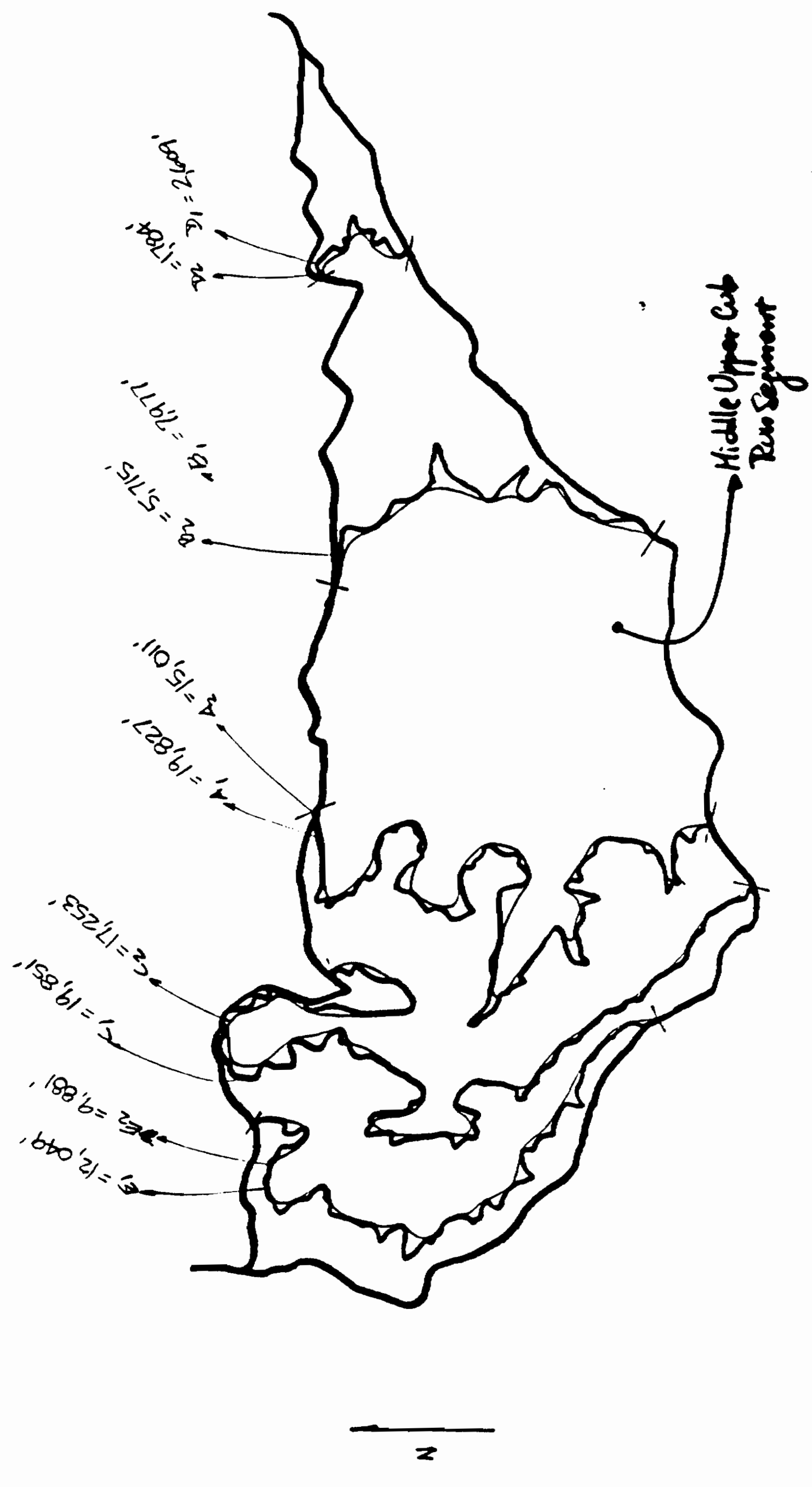
Cub Run length: 58980 11.17miles



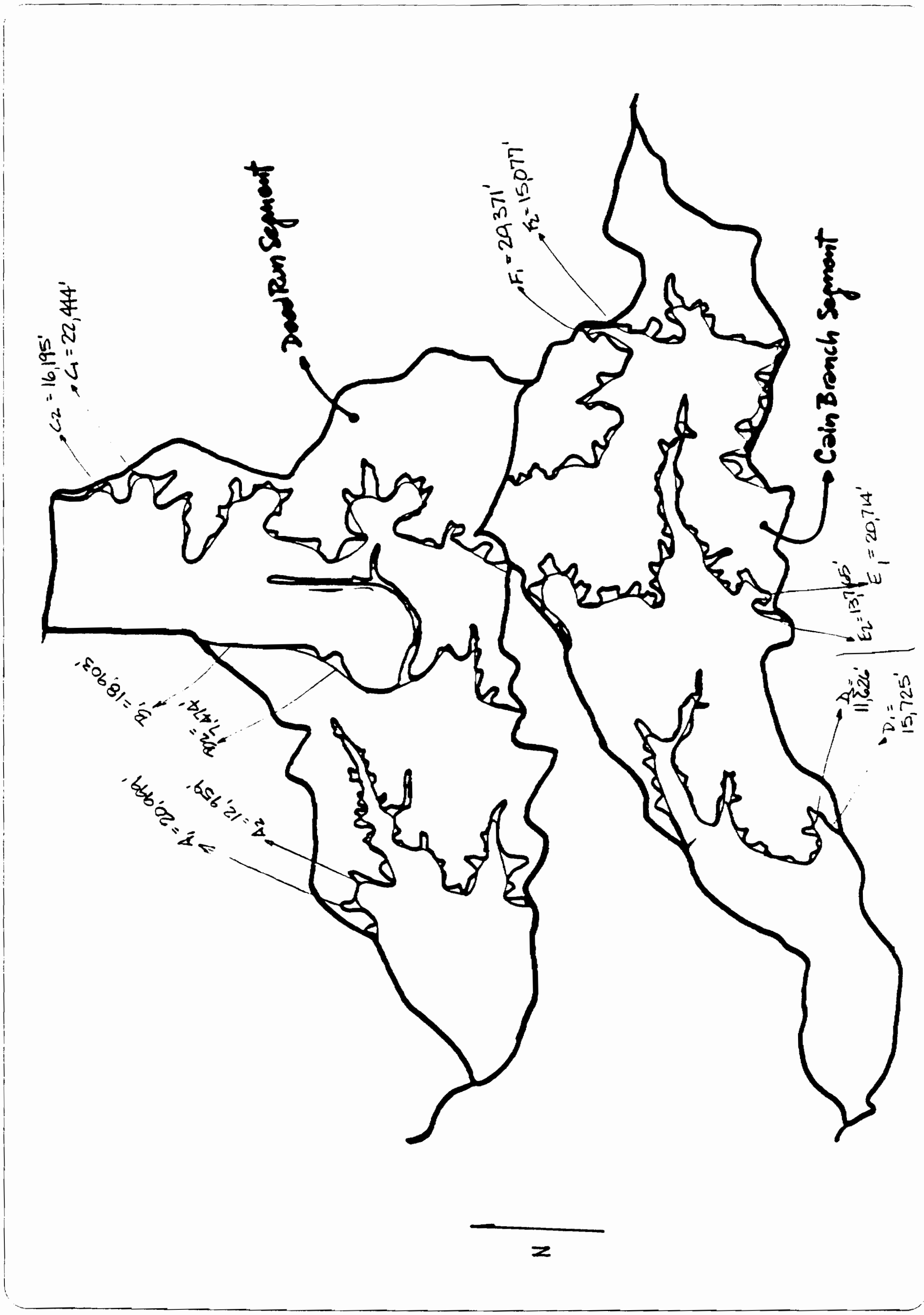
A_1 = 52,000'
A_2 = 38,732'
B_2 = 41,988'
B_1 = 57,048'
C_2 = 18,236'
C_1 = 21,865'
2000 feet
N


Lower Elklick Run Segment
Middle Elklick Run Segment
N
N

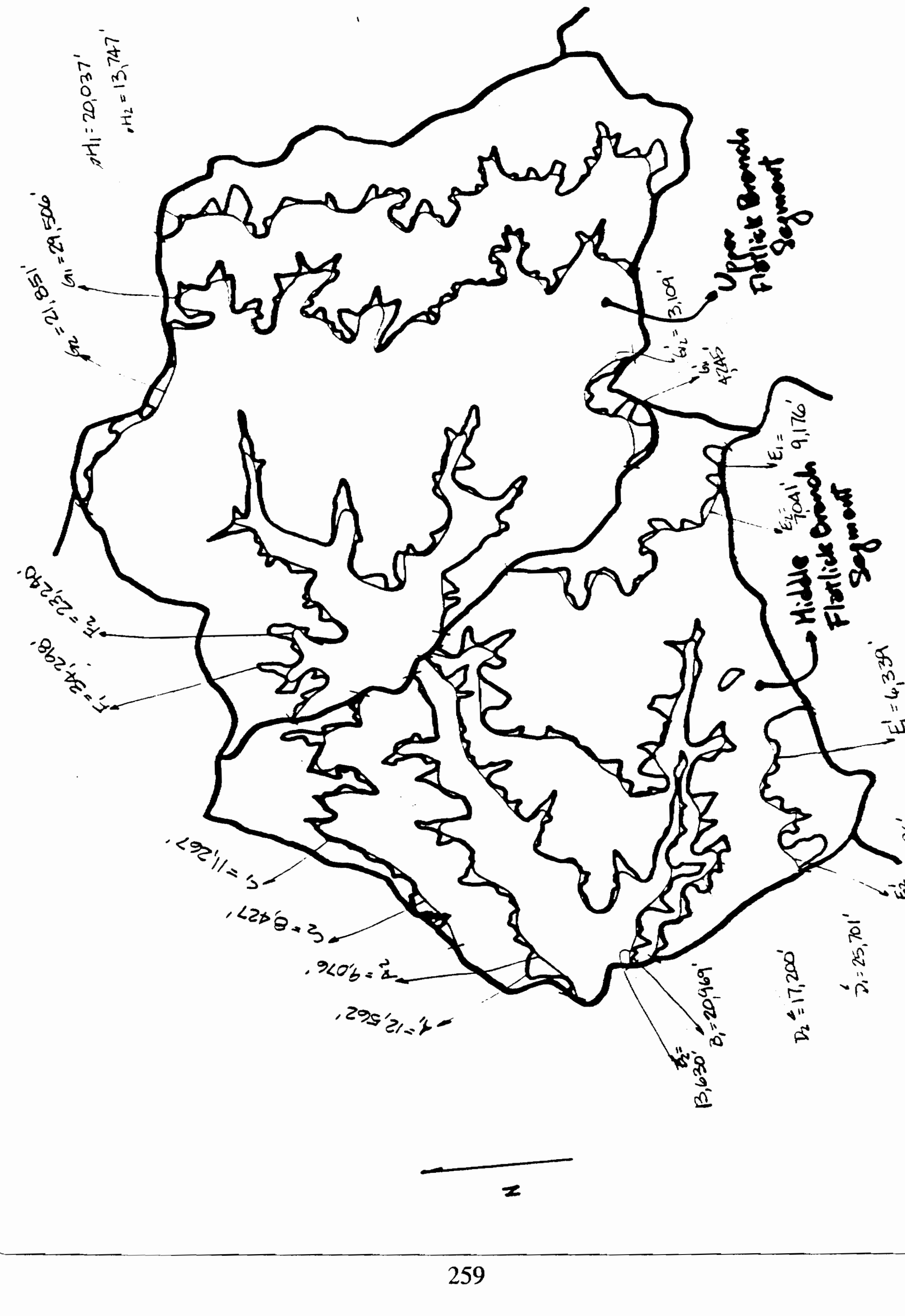

Upper Cub Run Segment
Sand Branch Segment

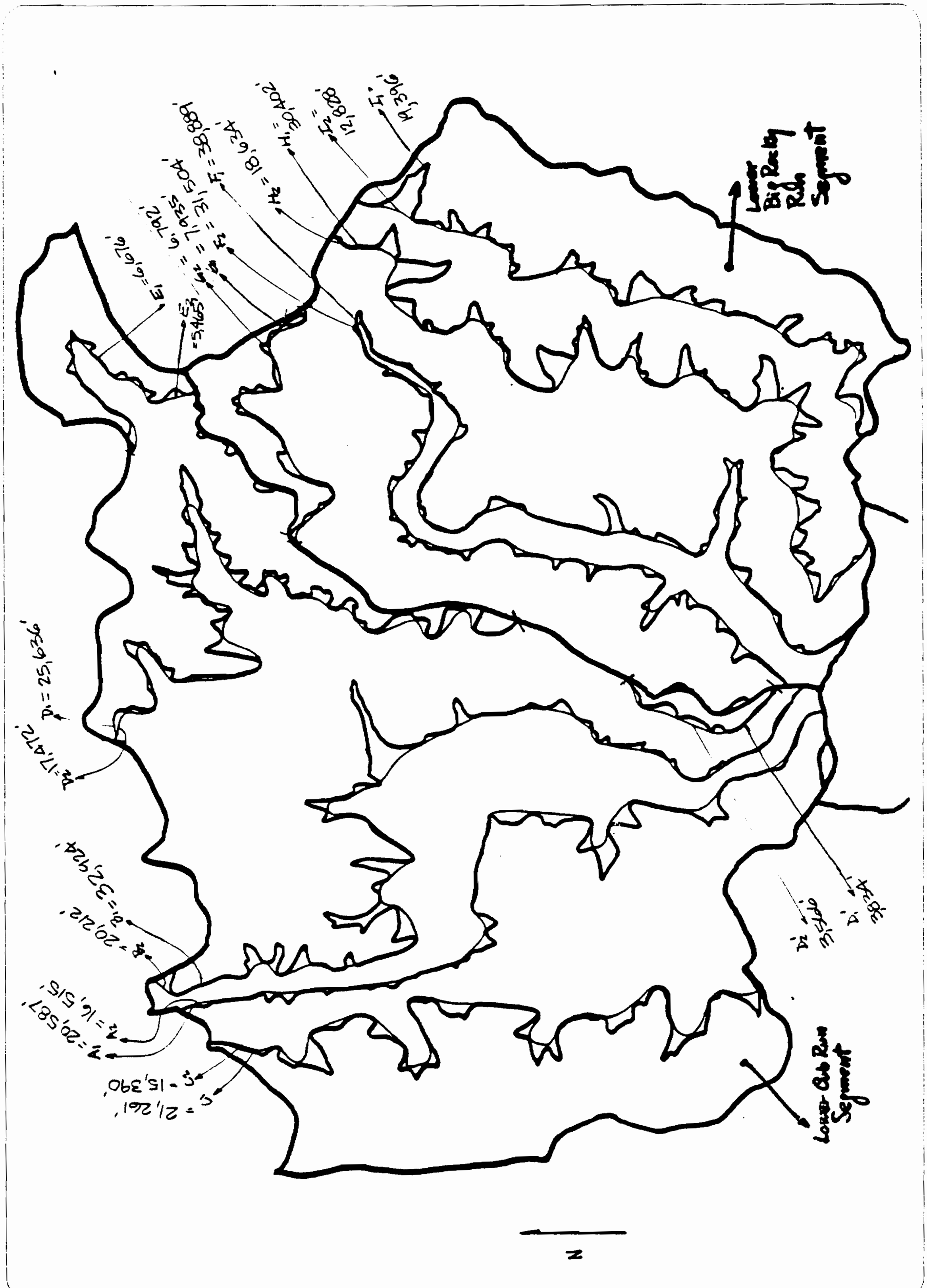


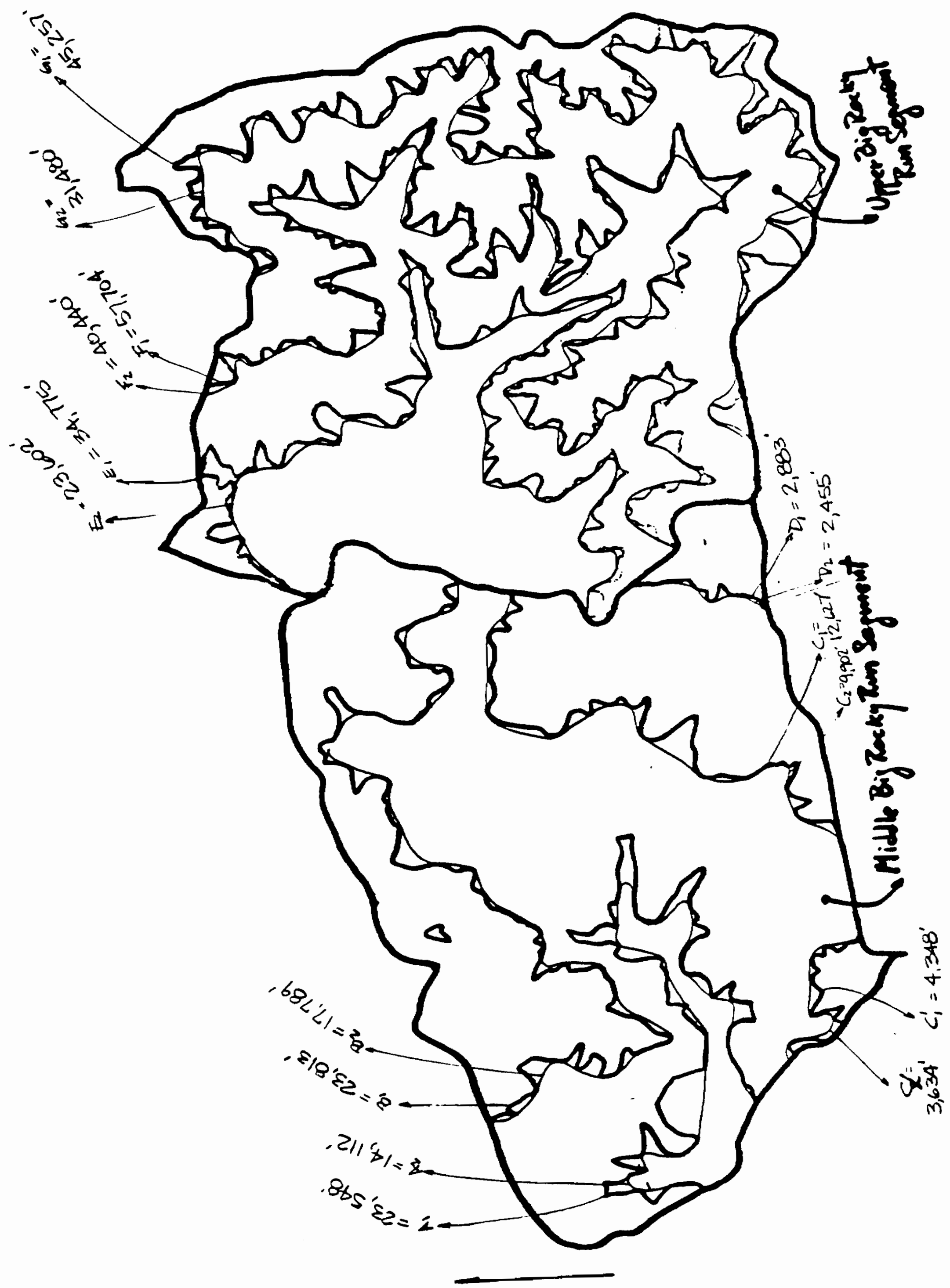
Middle Upper Cub Run Segment
D1 = 2,609'
D2 = 1784'
B1 = 7,977'
B2 = 5,715'
A2 = 15,011'
A1 = 19,827'
C2 = 17,253'
C1 = 19,851'
E2 = 9,881'
E1 = 12,049'
N


Dead Run Segment
Cain Branch Segment
C2 = 16,195'
C1 = 22,444'
F1 = 29,371'
F2 = 15,077'
E1 = 20,714'
D1 = 15,725'
N


J1 = 25,715'
J2 = 17,465'
K2 = 4,204'
K1 = 5,642'
N


Upper Flatlick Branch Segment
Middle Flatlick Branch Segment
H1 = 20,037'
H2 = 13,747'
G1 = 29,506'
G2 = 21,851'
G2 = 3,109'
F2 = 23,240'
F1 = 34,298'
E1 = 9,176'
E2 = 7041'
E1 = 4,339'
E2 = 4,296'
C1 = 11,267'
C2 = 8,427'
A2 = 9,076'
A1 = 12,562'
B1 = 20,969'
B2 = 13,630'
D2 = 17,200'
D1 = 25,701'
N




Upper Big Rocky Run Segment
Middle Big Rocky Run Segment
D1 = 2,883'
D2 = 2,455'
C1 = 4,348'
N

Computation of LSUR and SLSUR using geomorphologic methods

Segment Name	Area	Z	LC25	LC50	LC75	LB25	LB50	LB75	EP25	EP50	EP75	LSUR25	LSUR50	LSUR75	LSUR	SLSUR	LSUR*A	SLSUR*A
Upper Big Rocky Run	87091360	160	34775	57704	45257	23602	40440	31480	62	98	85	259.1722	289.24	257.7459	271	0.06326	23632600116	5509440
Middle Big Rocky Run	80372010	210	23548	40788	2883	14112	31325	2455	35	70	8	251.8317	349.3609	292.6611	315	0.04391	25303011133	3528997.5
Lower Big Rocky Run	94755570	230	38889	38337	19396	31504	25426	12828	61	68	36	440.446	249.8003	237.5376	328	0.05863	31087858031	5555765
Lower Cub Run	126933330	190	53511	50731	6676	36727	36428	5465	80	85	14	315.6211	307.8861	339.8202	314	0.04151	39808105762	5268605
Upper Flatlick Branch	84875730	190	34298	33751	20037	23240	24960	13747	52	61	40	303.8477	303.9433	236.1945	289	0.04930	24499475324	4184085
Middle Flatlick Branch	62511940	140	33531	36968	15515	22706	25627	11337	61	63	30	252.9311	282.2004	276.7745	270	0.04816	16872085316	3010490
Lower Flatlick Branch	74281480	160	50607	43729	5642	35082	31508	4204	74	81	12	328.8932	280.4828	262.6487	304	0.05384	22562676762	3999120
Middle Lower Cub Run	104767090	135	40117	61557	12666	32977	46191	9304	73	110	30	396.6402	317.6341	228.5304	336	0.03683	35249494696	3858975
Cain Branch	57053600	150	15725	20714	20371	11626	13765	15077	33	44	44	261.6083	209.324	254.775	241	0.03734	13726313627	2130375
Dead Run	61835010	110	20999	18903	22444	12959	7474	16195	41	17	43	200.8432	239.325	271.9973	239	0.02773	14770962086	1714515
Middle Upper Cub Run	76602460	120	27804	22460	12049	20726	19037	9881	46	43	25	337.9672	417.1555	345.3289	369	0.02440	28247957388	1869390
Sand Branch	35667490	140	12128	10948	1380	8909	6804	1364	23	18	7	285.4365	241.2476	641.6724	290	0.02400	10346588980	855960
Upper Cub Run	97935790	110	49778	10591	7408	33186	7850	5640	79	19	15	281.8	307.7346	289.9651	287	0.01903	28098711391	1863867.5
Upper Elklick Run	162210960	150	52000	57048	21865	38732	41988	18236	96	105	40	302.3354	295.3502	413.1597	319	0.03026	51690050049	4909237.5
Middle Elklick Run	107758980	120	47097	36829	17894	34838	28129	14938	100	63	42	258.8536	345.8579	323.0128	302	0.02835	32545379150	3054600
Lower Elklick Run	52287410	80	27578	36582	38360	22268	27398	28834	46	58	58	410.2926	356.4431	376.8816	379	0.03921	19809500249	2050400
Cub038	10416460	160	9170	7788	2559	6983	6531	2466	17	16	7	316.8703	374.6551	659.3649	389	0.07495	4048501348	780680
																	422299271409	54144502.5

Total Area (sqft)	1377356570
Total Area (sq miles)	49.41
Total Impervious Area	140214899
Total Pervious Area	1237141671

CUB RUN WATERSHED AVERAGES

LSUR	SLSUR
307	0.03931

Segment Name	Areas		PERCENT	Areas in acres		Multiplication factors for Network Module		
	IMPLND	PERLND		IMP	PER	IMPLND	PERLND	
Upper Big Rocky Run	87091360	17679546.1	69411813.9	0.203	405.8665308	1593.47599	33.8	132.8
Middle Big Rocky Run	80372010	16315518	64056492	0.203	374.5527555	1470.53471	31.2	122.5
Lower Big Rocky Run	94755570	16582224.7	78173345.3	0.175	380.6754993	1794.61307	31.7	149.6
Lower Cub Run	126933330	13962666.3	112970664	0.11	320.5387121	2593.44958	26.7	216.1
Upper Flatlick Branch	84875730	16975146	67900584	0.2	389.69573	1558.78292	32.5	129.9
Middle Flatlick Branch	62511940	12502388	50009552	0.2	287.0153352	1148.06134	23.9	95.7
Lower Flatlick Branch	74281480	3721502.15	70559977.9	0.0501	85.43393361	1619.8342	7.1	135.0
Middle Lower Cub Run	104767090	5238354.5	99528735.5	0.05	120.2560721	2284.86537	10.0	190.4
Cain Branch	57053500	9984362.5	47069137.5	0.175	229.2094238	1080.55871	19.1	90.0
Dead Run	61835010	6801851.1	55033158.9	0.11	156.1490152	1263.38749	13.0	105.3
Middle Upper Cub Run	76602460	8426270.6	68176189.4	0.11	193.4405556	1565.10995	16.1	130.4
Sand Branch	35667490	0	35667490	0	0	818.812902	0.0	68.2
Upper Cub Run	97935790	10772936.9	87162853.1	0.11	247.312601	2000.98377	20.6	166.7
Upper Elklick Run	162210960	0	162210960	0	0	3723.85124	0.0	310.3
Middle Elklick Run	107758980	0	107758980	0	0	2473.80579	0.0	206.2
Lower Elklick Run	52287410	0	52287410	0	0	1200.35376	0.0	100.0
Cub038	10416460	1252058.49	9164401.51	0.1202	28.7433079	210.38571	2.4	17.5
Totals	1377356570	140214825	1237141745				268.2	2366.7	2634.98
control		73							

Definition of Impervious and Pervious Segments and Parameters for new Calibration Run (CUB13S_1.UCI)

Segment Name		Areas IMPLND	PERLND	PERCENT	Areas in acres IMP	PER	Multiplication factors for Network Module IMPLND	PERLND	LSUR	SLSUR
Upper Cub Run	272040750	26001058.6	246039691	0.096	596.9021717	5648.29411	49.7	470.7	299.5	0.0232
Middle Cub Run	161820590	15222717	146597873	0.094	349.4654959	3365.42408	29.1	280.5	302.7	0.0370
Flatlick Branch	221669150	33199036.1	188470114	0.150	762.1449988	4326.67846	63.5	360.6	288.4	0.0505
Elklick Run	322257350	0	322257350	0.000	0	7398.01079	0.0	616.5	322.9	0.0311
Lower Cub Run	126933330	13962666.3	112970664	0.110	320.5387121	2593.44958	26.7	216.1	313.6	0.0415
Big Rocky Run	262218940	50577288.9	211641651	0.193	1161.094786	4858.62376	96.8	404.9	305.2	0.0557
CUB038	10416460	1252058.49	9164401.51	0.120	28.7433079	210.38571	2.4	17.5	388.7	0.0749

APPENDIX H

HSPF User Control Input (UCI) Files

CUBRUN_1.UCI
First Operative UCI file
1 Pervious Segment of 49.406 mi^2

```
****************************************************************************
*** THIS IS A HSPF HYDROLOGIC RUN FOR THE CUB RUN SUB-WATERSHED INCLUDING    ***
*** ONLY ONE PERVIOUS SEGMENT WITH AN AREA EQUAL TO THE WHOLE WATERSHED.     ***
*** THE VALUES OF THE MAIN CALIBRATION PARAMETERS USED ARE:                  ***
*** LZSN=4.27, INFILT=0.015, LSUR=387.0, SLSUR= 0.0378, NSUR=0.3, UZSN=0.427 ***
*** INTFW=1.22                                                               ***
****************************************************************************

RUN

GLOBAL
  CUB RUN SUB-BASIN HYDROLOGIC RUN
  START       1989 01 01  0  0  END    1989 12 31 24  0
  RUN INTERP OUTPUT LEVEL    7
  RESUME     0 RUN     1
END GLOBAL

FILES
<FILE>  <UN#>***<----FILE NAME------------------------------------------------->
WDM       21    CUBRUNDT.WDM
MESSU     22    CUBRUN_1.ECH
INFO      23    HSPINF.DA
ERROR     24    HSPERR.DA
WARN      25    HSPWRN.DA
END FILES

OPN SEQUENCE
    INGRP              INDELT 01:00
      PERLND       1
      RCHRES       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              1
  END ACTIVITY

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

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

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

  PWAT-PARM2
    <PLS > ***  PWATER input info: Part 2
    # -  # ***FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
    1            0.0     4.270     0.015     387.0    0.0378       0.0      0.96
  END PWAT-PARM2

  PWAT-PARM3
    <PLS > ***  PWATER input info: Part 3
    # -  # ***PETMAX    PETMIN    INFEXP    INFILD    DEEPFR    BASETP    AGWETP
    1            40.       35.       2.0       2.0      0.00       0.0      0.00
  END PWAT-PARM3

  PWAT-PARM4
    <PLS >      PWATER input info: Part 4                                  ***
    # -  #      CEPSC      UZSN      NSUR     INTFW       IRC     LZETP ***
    1                     0.427       0.3      1.22      0.75       0.0
  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      0.07 0.07 0.09 0.09 0.11 0.11 0.11 0.11 0.11 0.09 0.07 0.07
  END MON-INTERCEP

  PWAT-STATE1
    <PLS > *** Initial conditions at start of simulation
    # -  # ***  CEPS      SURS       UZS      IFWS       LZS      AGWS      GWVS
    1           0.05       0.0     0.286       0.0     2.861      0.50      0.00
  END PWAT-STATE1
END PERLND

RCHRES
  ACTIVITY
    RCHRES  Active Sections (1=Active; 0=Inactive)           ***
    # -  # HYFG ADFG CNFG HTFG SDFG GQFG OXFG NUFG PKFG PHFG ***
    1         1
  END ACTIVITY

  PRINT-INFO
            Print-flags                                                ***
    # -  # HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK   PH      PYR ***
    1         4                                                    12
  END PRINT-INFO

  GEN-INFO
    RCHRES<-------Name------->Nexit   Unit Systems   Printer      ***
    # -  #                          User t-series  Engl Metr LKFG ***
                                          in  out                 ***
    1       CUB RUN             1    1    1    1    1    0
  END GEN-INFO
```

```
  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        0  1  1  1    4  0  0  0  0       0  0  0  0  0        1  1  1  1  1
  END HYDR-PARM1

  HYDR-PARM2
    RCHRES ***
    # -  #  DSN FTBN       LEN      DELTH      STCOR        KS ***
    1         0    1     11.17      148.0        0.0       0.5
  END HYDR-PARM2

  HYDR-INIT
    RCHRES  Initial conditions for HYDR                    ***
    # -  #        VOL     Initial  value  of COLIND *** Initial  value  of OUTDGT
             (ac-ft)      for  each  possible  exit *** for  each  possible  exit
                            EX1  EX2  EX3  EX4  EX5 ***   EX1  EX2  EX3  EX4  EX5
    1            12.9       4.0
  END HYDR-INIT
END RCHRES

FTABLES
  FTABLE      1
 ROWS COLS ***
   15    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      0.00       0.0       0.0       0.0        0.
      0.43      11.7       3.7       1.8     1512.
      0.87      18.1      10.2       7.2     1032.
      1.30      24.4      19.4      17.1      821.
      1.73      30.7      31.3      32.7      695.
      2.17      37.0      46.0      54.7      610.
      2.60      43.3      63.4      84.1      547.
      3.47      56.0     106.4     168.1      459.
      4.33      68.6     160.4     290.9      400.
      5.20      81.2     225.3     457.9      357.
      6.93     285.3     543.0     1081.      365.
      8.67     489.4    1214.4     2100.      420.
     10.40     693.5    2239.5     3639.      447.
     12.13     897.5    3618.3     5798.      453.
     13.87    1101.6    5350.9     8673.      448.
  END FTABLE  1
END FTABLES

EXT SOURCES
<-Volume-> <Member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->    ***
<Name>   # <Name> # tem strg<-factor->strg <Name>   #   #        <Name> # #    ***
WDM     52 PREC     ENGLZERO          SAME PERLND   1     EXTNL  PREC
WDM     52 PREC     ENGLZERO          SAME RCHRES   1     EXTNL  PREC
WDM     76 PEVT     ENGL              DIV  PERLND   1     EXTNL  PETINP
WDM     76 PEVT     ENGL              DIV  RCHRES   1     EXTNL  POTEV
END EXT SOURCES

NETWORK
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->    ***
<Name>   #        <Name> # #<-factor->strg <Name>   #   #        <Name> # #    ***
PERLND   1 PWATER PERO           2635.  SAME RCHRES   1     EXTNL  IVOL
END NETWORK

EXT TARGETS
```

```
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Volume-> <Member> Tsys Aggr Amd ***
<Name>   x        <Name> x x<-factor->strg <Name>    x <Name>qf  tem strg strg***
*** Results for Calibration
RCHRES   1 HYDR   RO                       WDM      24 FLOW     ENGL      REPL

END EXT TARGETS

END RUN
```

CUBP&I_1.UCI
Second Operative UCI file
1 Pervious Segment of 44.376 mi^2
1 Impervious Segment of 5.030 mi^2

```
*******************************************************************************
*** THIS IS A HSPF HYDROLOGIC RUN FOR THE CUB RUN SUB-WATERSHED INCLUDING     ***
*** ONE PERVIOUS AND ONE INPERVIOUS SEGMENTS WITH TOTAL AREA EQUAL TO THE ONE***
*** OF THE WATERSHED.                                                         ***
*** THE VALUES OF THE MAIN CALIBRATION PARAMETERS USED ARE:                   ***
*** LZSN=4.27, INFILT=0.015, LSUR=387.0, SLSUR= 0.0378, NSUR=0.3, UZSN=0.427 ***
*** INTFW=1.22                                                                ***
*******************************************************************************

RUN

GLOBAL
  CUB RUN SUB-BASIN HYDROLOGIC RUN
  START       1989 01 01  0  0  END    1989 12 31 24  0
  RUN INTERP OUTPUT LEVEL    7
  RESUME     0 RUN     1
END GLOBAL

FILES
<FILE>  <UN#>***<----FILE NAME------------------------------------------------->
WDM        21    CUBRUNDT.WDM
MESSU      22    CUBP&I_1.ECH
           01    CUBP&I_1.OUT
           65    test12.d65  ***
           93    test12.p93  ***
INFO       23    HSPINF.DA
ERROR      24    HSPERR.DA
WARN       25    HSPWRN.DA
END FILES

OPN SEQUENCE
    INGRP              INDELT 01:00
      PERLND       1
      IMPLND       1
      RCHRES       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                 1
  END ACTIVITY

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

```
  GEN-INFO
    <PLS ><-------Name------->NBLKS   Unit-systems   Printer ***
    # -  #                          User  t-series Engl Metr ***
                                           in  out           ***
    1      CUBRUN Pervious  9      1    1    1    1    1    0
  END GEN-INFO

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

  PWAT-PARM2
    <PLS > ***  PWATER input info: Part 2
    # -  # ***FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
    1            0.0     4.270     0.015     387.0    0.0378       0.0      0.96
  END PWAT-PARM2

  PWAT-PARM3
    <PLS > ***  PWATER input info: Part 3
    # -  # ***PETMAX    PETMIN    INFEXP    INFILD    DEEPFR    BASETP    AGWETP
    1            40.       35.       2.0       2.0      0.00       0.0      0.00
  END PWAT-PARM3

  PWAT-PARM4
    <PLS >     PWATER input info: Part 4                                   ***
    # -  #     CEPSC      UZSN      NSUR     INTFW       IRC     LZETP ***
    1                    0.427       0.3      1.22      0.75       0.0
  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      0.07 0.07 0.09 0.09 0.11 0.11 0.11 0.11 0.11 0.09 0.07 0.07
  END MON-INTERCEP

  PWAT-STATE1
    <PLS > *** Initial conditions at start of simulation
    # -  # ***  CEPS      SURS       UZS      IFWS       LZS      AGWS      GWVS
    1           0.05       0.0     0.286       0.0     2.861      0.50      0.00
  END PWAT-STATE1
END PERLND

IMPLND

  ACTIVITY
    # -  # ATMP SNOW IWAT  SLD  IWG IQAL   ***
    1         0    0    1    0    0    0
  END ACTIVITY

  PRINT-INFO
    # -  # ATMP SNOW IWAT  SLD  IWG IQAL PIVL  PYR   ***
    1         0    0    4    0    0    0    0   12
  END PRINT-INFO
```

```
  GEN-INFO
*** <ILS >      Name             Unit-systems   Printer
*** <ILS >                     User  t-series Engl Metr
*** x -  x                             in   out
   1     CUBRUN Impervious 9      1     1     1     1     0
  END GEN-INFO

  IWAT-PARM1
*** <ILS >          Flags
*** x -  x CSNO RTOP  VRS  VNN RTLI
   1        0    1     0    0    0
  END IWAT-PARM1

  IWAT-PARM2
*** <ILS >      LSUR      SLSUR      NSUR      RETSC
*** x -  x      (ft)                            (ft)
   1          387.0     0.0378     0.014        0.0
  END IWAT-PARM2

  IWAT-STATE1
*** <ILS >  IWATER state variables (inches)
*** x -  x      RETS       SURS
   1             0.0        0.0
  END IWAT-STATE1

END IMPLND

RCHRES
  ACTIVITY
    RCHRES  Active Sections (1=Active; 0=Inactive)          ***
    # -  # HYFG ADFG CNFG HTFG SDFG GQFG OXFG NUFG PKFG PHFG ***
    1         1
  END ACTIVITY

  PRINT-INFO
            Print-flags                                           ***
    # -  # HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK   PH      PYR ***
    1         4                                                   12
  END PRINT-INFO

  GEN-INFO
    RCHRES<-------Name------->Nexit  Unit Systems   Printer      ***
    # -  #                          User t-series  Engl Metr LKFG ***
                                           in  out                ***
    1      CUB RUN                 1    1    1    1    1    0
  END GEN-INFO

  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        0  1   1  1    4  0  0  0  0       0  0  0  0  0       1  1  1  1  1
  END HYDR-PARM1

  HYDR-PARM2
    RCHRES ***
    # -  #  DSN FTBN      LEN     DELTH      STCOR        KS ***
    1         0    1    11.17     148.0        0.0       0.5
  END HYDR-PARM2
```

```
  HYDR-INIT
    RCHRES  Initial conditions for HYDR            ***
    # - #        VOL     Initial  value  of COLIND *** Initial  value  of OUTDGT
             (ac-ft)     for  each  possible  exit *** for  each  possible  exit
                           EX1  EX2  EX3  EX4  EX5 ***   EX1  EX2  EX3  EX4  EX5
    1           12.9       4.0
  END HYDR-INIT
END RCHRES

FTABLES
  FTABLE      1
 ROWS COLS ***
   15    4
     DEPTH      AREA    VOLUME      DISCH  FLO-THRU ***
      (FT)   (ACRES)  (AC-FT)       (CFS)     (MIN) ***
      0.00       0.0       0.0        0.0        0.
      0.43      11.7       3.7        1.8     1512.
      0.87      18.1      10.2        7.2     1032.
      1.30      24.4      19.4       17.1      821.
      1.73      30.7      31.3       32.7      695.
      2.17      37.0      46.0       54.7      610.
      2.60      43.3      63.4       84.1      547.
      3.47      56.0     106.4      168.1      459.
      4.33      68.6     160.4      290.9      400.
      5.20      81.2     225.3      457.9      357.
      6.93     285.3     543.0      1081.      365.
      8.67     489.4    1214.4      2100.      420.
     10.40     693.5    2239.5      3639.      447.
     12.13     897.5    3618.3      5798.      453.
     13.87    1101.6    5350.9      8673.      448.
  END FTABLE  1
END FTABLES

EXT SOURCES
<-Volume-> <Member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   # <Name> # tem strg<-factor->strg <Name>    #  #        <Name> # #  ***
WDM     52 PREC     ENGLZERO          SAME PERLND    1     EXTNL  PREC
WDM     52 PREC     ENGLZERO          SAME IMPLND    1     EXTNL  PREC
WDM     52 PREC     ENGLZERO          SAME RCHRES    1     EXTNL  PREC
WDM     76 PEVT     ENGL              DIV  PERLND    1     EXTNL  PETINP
WDM     76 PEVT     ENGL              DIV  IMPLND    1     EXTNL  PETINP
WDM     76 PEVT     ENGL              DIV  RCHRES    1     EXTNL  POTEV
END EXT SOURCES
NETWORK
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   #        <Name> # #<-factor->strg <Name>    #  #        <Name> # #  ***
PERLND   1 PWATER PERO          2367.  SAME RCHRES    1     EXTNL  IVOL
IMPLND   1 IWATER SURO           268.  SAME RCHRES    1     EXTNL  IVOL
END NETWORK
***Impervious surface is approx. 10.18% of the total (Total is 2635)***

EXT TARGETS
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Volume-> <Member> Tsys Aggr Amd ***
<Name>   x        <Name> x x<-factor->strg <Name>   x <Name>qf  tem strg strg***
*** Results for Calibration
RCHRES   1 HYDR   RO                       WDM     30 FLOW     ENGL      REPL

END EXT TARGETS

END RUN
```

CUBP&I_2.UCI
First Calibration Run
1 Pervious Segment of 44.376 mi^2
1 Impervious Segment of 5.030 mi^2

```
*******************************************************************************
*******************************************************************************
*******************************************************************************
***                                                                         ***
***                               CUBP&I_2.UCI                              ***
***                                                                         ***
*******************************************************************************
*******************************************************************************
*******************************************************************************


*******************************************************************************
*** THIS IS A HSPF HYDROLOGIC RUN FOR THE CUB RUN SUB-WATERSHED INCLUDING    ***
*** ONE PERVIOUS AND ONE INPERVIOUS SEGMENTS WITH TOTAL AREA EQUAL TO THE ONE***
*** OF THE WATERSHED.                                                       ***
*** THE VALUES OF THE MAIN CALIBRATION PARAMETERS USED ARE:                 ***
*** LZSN=4.27, INFILT=0.015, LSUR=387.0, SLSUR= 0.0378, NSUR=0.3, UZSN=0.427 ***
*** INTFW=1.22, with monthly table of values for LZETP                      ***
*******************************************************************************

RUN

GLOBAL
  CUB RUN SUB-BASIN HYDROLOGIC RUN
  START       1989 01 01  0  0  END    1989 12 31 24  0
  RUN INTERP OUTPUT LEVEL    7
  RESUME     0 RUN     1
END GLOBAL

FILES
<FILE>  <UN#>***<----FILE NAME------------------------------------------------>
WDM         21   CUBRUNDT.WDM
MESSU       22   CUBP&I_2.ECH
INFO        23   HSPINF.DA
ERROR       24   HSPERR.DA
WARN        25   HSPWRN.DA
END FILES

OPN SEQUENCE
    INGRP              INDELT 01:00
      PERLND       1
      IMPLND       1
      RCHRES       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                   1
  END ACTIVITY
```

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

GEN-INFO
  <PLS ><-------Name------->NBLKS   Unit-systems   Printer ***
  # - #                         User  t-series Engl Metr ***
                                      in  out            ***
  1     CUBRUN Pervious  9      1    1    1    1    1    0
END GEN-INFO

********************************************************************************
********************************************************************************
*** The flag VLE had to be activated (value 1) to consider monthly set of    ***
*** values for the parameter LZETP                                            ***
********************************************************************************
********************************************************************************

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

PWAT-PARM2
  <PLS > ***  PWATER input info: Part 2
  # - # ***FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
  1           0.0     4.270     0.015     387.0    0.0378       0.0      0.96
END PWAT-PARM2

PWAT-PARM3
  <PLS > ***  PWATER input info: Part 3
  # - # ***PETMAX    PETMIN    INFEXP    INFILD    DEEPFR    BASETP    AGWETP
  1           40.       35.       2.0       2.0      0.00       0.0      0.00
END PWAT-PARM3

PWAT-PARM4
  <PLS >     PWATER input info: Part 4                                ***
  # - #     CEPSC      UZSN      NSUR     INTFW       IRC     LZETP ***
  1                   0.427       0.3      1.22      0.75
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      0.07 0.07 0.09 0.09 0.11 0.11 0.11 0.11 0.11 0.09 0.07 0.07
END MON-INTERCEP

********************************************************************************
*** The following table was not present on the original run when CUBP&I_1.UCI***
*** was executed. The parameter LZETP was 0.0 for that run and that could    ***
*** account for the bad simulation of the June to November when rooted       ***
*** vegetation produces more actual evapotranspiration the reducing the      ***
*** amount of runoff generated.                                               ***
*** The monthly values were extracted from similar watershed on the northern ***
*** Patuxent River.                                                           ***
********************************************************************************
```

```
  MON-LZETPARM
*** <PLS >  Lower zone evapotransp parameter at start of each month
*** x -   x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
    1        0.3  0.3  0.3  0.4  0.7  0.7  0.7  0.7  0.6  0.5  0.4  0.3
  END MON-LZETPARM

********************************************************************************
********************************************************************************


  PWAT-STATE1
    <PLS > *** Initial conditions at start of simulation
    # -  # ***  CEPS      SURS       UZS       IFWS       LZS       AGWS      GWVS
    1           0.05       0.0      0.286       0.0      2.861      0.50      0.00
  END PWAT-STATE1
END PERLND

IMPLND

  ACTIVITY
    # -  # ATMP SNOW IWAT  SLD  IWG IQAL  ***
    1         0    0    1    0    0    0
  END ACTIVITY

  PRINT-INFO
    # -  # ATMP SNOW IWAT  SLD  IWG IQAL PIVL  PYR  ***
    1         0    0    4    0    0    0    0   12
  END PRINT-INFO

  GEN-INFO
*** <ILS >      Name              Unit-systems   Printer
*** <ILS >                      User  t-series Engl Metr
*** x -  x                             in  out
    1      CUBRUN Impervious 9     1    1    1    1    0
  END GEN-INFO

  IWAT-PARM1
*** <ILS >          Flags
*** x -   x CSNO RTOP  VRS  VNN RTLI
    1         0    1    0    0    0
  END IWAT-PARM1

  IWAT-PARM2
*** <ILS >      LSUR     SLSUR      NSUR      RETSC
*** x -  x      (ft)                           (ft)
    1          387.0    0.0378     0.014       0.0
  END IWAT-PARM2

  IWAT-STATE1
*** <ILS >  IWATER state variables (inches)
*** x -  x      RETS      SURS
    1            0.0       0.0
  END IWAT-STATE1

END IMPLND
```

```
RCHRES
  ACTIVITY
    RCHRES  Active Sections (1=Active; 0=Inactive)           ***
    # -  # HYFG ADFG CNFG HTFG SDFG GQFG OXFG NUFG PKFG PHFG ***
    1         1
  END ACTIVITY

  PRINT-INFO
            Print-flags                                                ***
    # -  # HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK   PH       PYR ***
    1         4                                                    12
  END PRINT-INFO

  GEN-INFO
    RCHRES<-------Name------->Nexit   Unit Systems   Printer      ***
    # -  #                          User t-series  Engl Metr LKFG ***
                                           in  out                ***
    1      CUB RUN                  1    1    1    1    1    0
  END GEN-INFO

  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        0  1  1  1    4  0  0  0  0       0  0  0  0  0       1  1  1  1  1
  END HYDR-PARM1

  HYDR-PARM2
    RCHRES ***
    # -  #  DSN FTBN      LEN     DELTH     STCOR        KS ***
    1         0    1    11.17     148.0       0.0       0.5
  END HYDR-PARM2

  HYDR-INIT
    RCHRES  Initial conditions for HYDR                ***
    # -  #       VOL     Initial  value  of COLIND *** Initial  value  of OUTDGT
               (ac-ft)   for  each  possible  exit *** for  each  possible  exit
                           EX1  EX2  EX3  EX4  EX5 ***   EX1  EX2  EX3  EX4  EX5
    1           12.9       4.0
  END HYDR-INIT
END RCHRES

FTABLES
  FTABLE      1
 ROWS COLS ***
   15    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      0.00       0.0       0.0       0.0        0.
      0.43      11.7       3.7       1.8     1512.
      0.87      18.1      10.2       7.2     1032.
      1.30      24.4      19.4      17.1      821.
      1.73      30.7      31.3      32.7      695.
      2.17      37.0      46.0      54.7      610.
      2.60      43.3      63.4      84.1      547.
      3.47      56.0     106.4     168.1      459.
      4.33      68.6     160.4     290.9      400.
      5.20      81.2     225.3     457.9      357.
      6.93     285.3     543.0     1081.      365.
      8.67     489.4    1214.4     2100.      420.
     10.40     693.5    2239.5     3639.      447.
     12.13     897.5    3618.3     5798.      453.
     13.87    1101.6    5350.9     8673.      448.
```

```
  END FTABLE  1
END FTABLES

EXT SOURCES
<-Volume-> <Member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   # <Name> # tem strg<-factor->strg <Name>   #   #        <Name> # #  ***
WDM     52 PREC     ENGLZERO          SAME PERLND   1     EXTNL  PREC
WDM     52 PREC     ENGLZERO          SAME IMPLND   1     EXTNL  PREC
WDM     52 PREC     ENGLZERO          SAME RCHRES   1     EXTNL  PREC
WDM     76 PEVT     ENGL              DIV  PERLND   1     EXTNL  PETINP
WDM     76 PEVT     ENGL              DIV  IMPLND   1     EXTNL  PETINP
WDM     76 PEVT     ENGL              DIV  RCHRES   1     EXTNL  POTEV
END EXT SOURCES

NETWORK
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   #        <Name> # #<-factor->strg <Name>   #   #        <Name> # #  ***
PERLND   1 PWATER PERO          2367.  SAME RCHRES   1     EXTNL  IVOL
IMPLND   1 IWATER SURO           268.  SAME RCHRES   1     EXTNL  IVOL
END NETWORK

***Impervious surface is approx. 10.18% of the total (Total is 2635)***

EXT TARGETS

<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Volume-> <Member> Tsys Aggr Amd ***
<Name>   x        <Name> x x<-factor->strg <Name>   x <Name>qf  tem strg strg***
*** Results for Calibration
RCHRES   1 HYDR   RO                       WDM     31 FLOW     ENGL      REPL

END EXT TARGETS

END RUN
```

CUBP&I_3.UCI
Second Calibration Run
1 Pervious Segment of 44.376 mi^2
1 Impervious Segment of 5.030 mi^2

```
*****************************************************************************
*****************************************************************************
*****************************************************************************
***                                                                       ***
***                          CUBP&I_3.UCI                                 ***
***                                                                       ***
*****************************************************************************
*****************************************************************************
*****************************************************************************


*****************************************************************************
*** THIS IS A HSPF HYDROLOGIC RUN FOR THE CUB RUN SUB-WATERSHED INCLUDING   ***
*** ONE PERVIOUS AND ONE INPERVIOUS SEGMENTS WITH TOTAL AREA EQUAL TO THE ONE***
*** OF THE WATERSHED.                                                     ***
*** THE VALUES OF THE MAIN CALIBRATION PARAMETERS USED ARE:               ***
*** LZSN=6.00, INFILT=0.015, LSUR=387.0, SLSUR= 0.0378, NSUR=0.3, UZSN=0.600 ***
*** INTFW=1.22, with monthly table of values for LZETP                    ***
*****************************************************************************

RUN

GLOBAL
  CUB RUN SUB-BASIN HYDROLOGIC RUN
  START       1989 01 01  0  0  END    1989 12 31 24  0
  RUN INTERP OUTPUT LEVEL    7
  RESUME     0 RUN     1
END GLOBAL

FILES
<FILE>  <UN#>***<----FILE NAME------------------------------------------->
WDM        21   CUBRUNDT.WDM
MESSU      22   CUBP&I_3.ECH
INFO       23   HSPINF.DA
ERROR      24   HSPERR.DA
WARN       25   HSPWRN.DA
END FILES

OPN SEQUENCE
    INGRP              INDELT 01:00
      PERLND       1
      IMPLND       1
      RCHRES       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                 1
  END ACTIVITY
```

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

GEN-INFO
  <PLS ><-------Name------->NBLKS   Unit-systems   Printer ***
  # -  #                        User  t-series Engl Metr ***
                                       in  out           ***
  1     CUBRUN Pervious  9      1    1    1    1    1    0
END GEN-INFO

********************************************************************************
********************************************************************************
*** The flag VLE had to be activated (value 1) to consider monthly set of    ***
*** values for the parameter LZETP                                           ***
********************************************************************************
********************************************************************************

PWAT-PARM1
  <PLS >  PWATER variable monthly parameter value flags ***
  # -  # CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE    ***
  1         0    1    0    1    0    0    0    0    1
END PWAT-PARM1
********************************************************************************
********************************************************************************
*** Value of LZSN increased to 6.000                                         ***
********************************************************************************
********************************************************************************

PWAT-PARM2
  <PLS > ***  PWATER input info: Part 2
  # -  # ***FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
  1            0.0     6.000     0.015     387.0    0.0378       0.0      0.96
END PWAT-PARM2

PWAT-PARM3
  <PLS > ***  PWATER input info: Part 3
  # -  # ***PETMAX    PETMIN    INFEXP    INFILD    DEEPFR    BASETP    AGWETP
  1            40.       35.       2.0       2.0      0.00       0.0      0.00
END PWAT-PARM3
********************************************************************************
********************************************************************************
*** Value of UZSN increased to 0.600                                         ***
********************************************************************************
********************************************************************************

PWAT-PARM4
  <PLS >     PWATER input info: Part 4                                ***
  # -  #     CEPSC      UZSN      NSUR     INTFW       IRC     LZETP ***
  1                    0.600       0.3      1.22      0.75
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       0.07 0.07 0.09 0.09 0.11 0.11 0.11 0.11 0.11 0.09 0.07 0.07
END MON-INTERCEP

********************************************************************************
********************************************************************************
```

```
*******************************************************************************
*** The following table was not present on the original run when CUBP&I_1.UCI***
*** was executed. The parameter LZETP was 0.0 for that run and that could    ***
*** account for the bad simulation of the June to November when rooted       ***
*** vegetation produces more actual evapotranspiration the reducing the      ***
*** amount of runoff generated.                                              ***
*** The monthly values were extracted from similar watershed on the northern ***
*** Patuxent River.                                                          ***
*******************************************************************************
*******************************************************************************
*******************************************************************************

  MON-LZETPARM
*** <PLS >  Lower zone evapotransp parameter at start of each month
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
    1       0.3  0.3  0.3  0.4  0.7  0.7  0.7  0.7  0.6  0.5  0.4  0.3
  END MON-LZETPARM

*******************************************************************************
*******************************************************************************


  PWAT-STATE1
    <PLS > *** Initial conditions at start of simulation
    # -  # ***  CEPS      SURS       UZS      IFWS       LZS      AGWS      GWVS
    1           0.05       0.0     0.286       0.0     2.861      0.50      0.00
  END PWAT-STATE1
END PERLND

IMPLND
  ACTIVITY
    # -  # ATMP SNOW IWAT  SLD  IWG IQAL  ***
    1         0    0    1    0    0    0
  END ACTIVITY

  PRINT-INFO
    # -  # ATMP SNOW IWAT  SLD  IWG IQAL PIVL  PYR  ***
    1         0    0    4    0    0    0    0   12
  END PRINT-INFO

  GEN-INFO
*** <ILS >      Name             Unit-systems   Printer
*** <ILS >                     User  t-series Engl Metr
*** x -  x                            in  out
    1     CUBRUN Impervious 9     1    1    1    1    0
  END GEN-INFO

  IWAT-PARM1
*** <ILS >        Flags
*** x -  x CSNO RTOP  VRS  VNN RTLI
    1         0    1    0    0    0
  END IWAT-PARM1

  IWAT-PARM2
*** <ILS >      LSUR     SLSUR      NSUR     RETSC
*** x -  x      (ft)                          (ft)
    1          387.0    0.0378     0.014       0.0
  END IWAT-PARM2
  IWAT-STATE1
*** <ILS >  IWATER state variables (inches)
*** x -  x      RETS      SURS
    1            0.0       0.0
  END IWAT-STATE1
```

```
END IMPLND

RCHRES
  ACTIVITY
    RCHRES  Active Sections (1=Active; 0=Inactive)           ***
    # -  # HYFG ADFG CNFG HTFG SDFG GQFG OXFG NUFG PKFG PHFG ***
    1        1
  END ACTIVITY

  PRINT-INFO
            Print-flags                                                ***
    # -  # HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK   PH       PYR ***
    1        4                                                      12
  END PRINT-INFO

  GEN-INFO
    RCHRES<-------Name------->Nexit   Unit Systems   Printer      ***
    # -  #                          User t-series  Engl Metr LKFG ***
                                           in  out                ***
    1       CUB RUN                 1    1    1    1    1    0
  END GEN-INFO

  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        0  1  1  1    4  0  0  0  0       0  0  0  0  0       1  1  1  1  1
  END HYDR-PARM1

  HYDR-PARM2
    RCHRES ***
    # -  #  DSN FTBN      LEN     DELTH     STCOR        KS ***
    1        0    1     11.17     148.0       0.0       0.5
  END HYDR-PARM2

  HYDR-INIT
    RCHRES  Initial conditions for HYDR                ***
    # -  #       VOL     Initial  value  of COLIND *** Initial  value  of OUTDGT
               (ac-ft)   for  each  possible  exit *** for  each  possible  exit
                           EX1  EX2  EX3  EX4  EX5 ***   EX1  EX2  EX3  EX4  EX5
    1           12.9       4.0
  END HYDR-INIT
END RCHRES

FTABLES
  FTABLE      1
 ROWS COLS ***
   15    4
    DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
     0.00       0.0       0.0       0.0        0.
     0.43      11.7       3.7       1.8     1512.
     0.87      18.1      10.2       7.2     1032.
     1.30      24.4      19.4      17.1      821.
     1.73      30.7      31.3      32.7      695.
     2.17      37.0      46.0      54.7      610.
     2.60      43.3      63.4      84.1      547.
     3.47      56.0     106.4     168.1      459.
     4.33      68.6     160.4     290.9      400.
     5.20      81.2     225.3     457.9      357.
     6.93     285.3     543.0     1081.      365.
     8.67     489.4    1214.4     2100.      420.
    10.40     693.5    2239.5     3639.      447.
```

```
     12.13     897.5    3618.3     5798.      453.
     13.87    1101.6    5350.9     8673.      448.
  END FTABLE  1
END FTABLES

EXT SOURCES
<-Volume-> <Member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   # <Name> # tem strg<-factor->strg <Name>   #   #        <Name> # #  ***
WDM     52 PREC     ENGLZERO          SAME PERLND   1      EXTNL  PREC
WDM     52 PREC     ENGLZERO          SAME IMPLND   1      EXTNL  PREC
WDM     52 PREC     ENGLZERO          SAME RCHRES   1      EXTNL  PREC
WDM     76 PEVT     ENGL              DIV  PERLND   1      EXTNL  PETINP
WDM     76 PEVT     ENGL              DIV  IMPLND   1      EXTNL  PETINP
WDM     76 PEVT     ENGL              DIV  RCHRES   1      EXTNL  POTEV
END EXT SOURCES

NETWORK
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   #        <Name> # #<-factor->strg <Name>   #   #        <Name> # #  ***
PERLND   1 PWATER PERO          2367.  SAME RCHRES   1      EXTNL  IVOL
IMPLND   1 IWATER SURO           268.  SAME RCHRES   1      EXTNL  IVOL
END NETWORK

***Impervious surface is approx. 10.18% of the total (Total is 2635)***

EXT TARGETS

<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Volume-> <Member> Tsys Aggr Amd ***
<Name>   x        <Name> x x<-factor->strg <Name>   x <Name>qf  tem strg strg***
*** Results for Calibration
RCHRES   1 HYDR   RO                       WDM     32 FLOW     ENGL      REPL

END EXT TARGETS

END RUN
```

CUBP&I_4.UCI
Third Calibration Run
1 Pervious Segment of 44.376 mi^2
1 Impervious Segment of 5.030 mi^2

```
*********************************************************************************
*********************************************************************************
*********************************************************************************
***                                                                           ***
***                               CUBP&I_4.UCI                                ***
***                                                                           ***
*********************************************************************************
*********************************************************************************
*********************************************************************************

*********************************************************************************
*** THIS IS A HSPF HYDROLOGIC RUN FOR THE CUB RUN SUB-WATERSHED INCLUDING     ***
*** ONE PERVIOUS AND ONE INPERVIOUS SEGMENTS WITH TOTAL AREA EQUAL TO THE ONE***
*** OF THE WATERSHED.                                                         ***
*** THE VALUES OF THE MAIN CALIBRATION PARAMETERS USED ARE:                   ***
*** LZSN=6.00, INFILT=0.015, LSUR=387.0, SLSUR= 0.0378, NSUR=0.3, UZSN=0.600 ***
*** INTFW=1.22, with monthly table of values for LZETP,                       ***
*** with monthly table of values for Manning, modifying interception values  ***
*** Increasing more LZSN to a value of 8.00 and UZSN to 0.800                 ***
*********************************************************************************

RUN

GLOBAL
  CUB RUN SUB-BASIN HYDROLOGIC RUN
  START       1989 01 01  0  0  END    1989 12 31 24  0
  RUN INTERP OUTPUT LEVEL    7
  RESUME     0 RUN     1
END GLOBAL

FILES
<FILE>  <UN#>***<----FILE NAME------------------------------------------------->
WDM        21   CUBRUNDT.WDM
MESSU      22   CUBP&I_4.ECH
INFO       23   HSPINF.DA
ERROR      24   HSPERR.DA
WARN       25   HSPWRN.DA
END FILES

OPN SEQUENCE
    INGRP              INDELT 01:00
      PERLND      1
      IMPLND      1
      RCHRES      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              1
  END ACTIVITY
```

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

  GEN-INFO
    <PLS ><-------Name------->NBLKS  Unit-systems   Printer ***
    # -  #                          User  t-series Engl Metr ***
                                           in  out           ***
    1     CUBRUN Pervious  9      1    1    1    1    1    0
  END GEN-INFO

*******************************************************************************
*******************************************************************************
*** The flag VLE had to be activated (value 1) to consider monthly set of   ***
*** values for the parameter LZETP                                          ***
*******************************************************************************
*******************************************************************************

  PWAT-PARM1
    <PLS >  PWATER variable monthly parameter value flags ***
    # -  # CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE    ***
    1         0    1    0    1    0    1    0    0    1
  END PWAT-PARM1
*******************************************************************************
*******************************************************************************
*** Value of LZSN increased to 8.000                                        ***
*******************************************************************************
*******************************************************************************

  PWAT-PARM2
    <PLS > ***  PWATER input info: Part 2
    # -  # ***FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
    1            0.0     8.000     0.015     387.0    0.0378       0.0      0.96
  END PWAT-PARM2

  PWAT-PARM3
    <PLS > ***  PWATER input info: Part 3
    # -  # ***PETMAX    PETMIN    INFEXP    INFILD    DEEPFR    BASETP    AGWETP
    1            40.       35.       2.0       2.0      0.00       0.0      0.00
  END PWAT-PARM3
*******************************************************************************
*******************************************************************************
*** Value of UZSN increased to 0.800                                        ***
*******************************************************************************
*******************************************************************************
  PWAT-PARM4
    <PLS >     PWATER input info: Part 4                                ***
    # -  #     CEPSC      UZSN      NSUR     INTFW       IRC     LZETP ***
    1                    0.800                1.22      0.75
  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      0.07 0.07 0.09 0.11 0.13 0.16 0.16 0.13 0.11 0.09 0.07 0.07
  END MON-INTERCEP

*******************************************************************************
*******************************************************************************
*******************************************************************************
*** The following table was not present on the original run when CUBP&I_1.UCI***
```

```
*** was executed. The parameter LZETP was 0.0 for that run and that could     ***
*** account for the bad simulation of the June to November when rooted       ***
*** vegetation produces more actual evapotranspiration the reducing the       ***
*** amount of runoff generated.                                               ***
*** The monthly values were extracted from similar watershed on the northern ***
*** Patuxent River.                                                           ***
*********************************************************************************
*********************************************************************************
*********************************************************************************

  MON-LZETPARM
*** <PLS >  Lower zone evapotransp parameter at start of each month
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
    1       0.3  0.3  0.3  0.4  0.7  0.7  0.7  0.7  0.6  0.5  0.4  0.3
  END MON-LZETPARM

*********************************************************************************
*********************************************************************************
*** including table of variable manning's number.                             ***
*********************************************************************************
*********************************************************************************

  MON-MANNING
*** <PLS >  Lower zone evapotransp parameter at start of each month
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
    1      0.20 0.20 0.25 0.25 0.30 0.35 0.35 0.30 0.30 0.30 0.25 0.20
  END MON-MANNING


  PWAT-STATE1
    <PLS > *** Initial conditions at start of simulation
    # -  # ***  CEPS      SURS       UZS      IFWS       LZS      AGWS      GWVS
    1           0.05       0.0     0.286       0.0     2.861      0.50      0.00
  END PWAT-STATE1
END PERLND

IMPLND

  ACTIVITY
    # -  # ATMP SNOW IWAT  SLD  IWG IQAL   ***
    1         0    0    1    0    0    0
  END ACTIVITY

  PRINT-INFO
    # -  # ATMP SNOW IWAT  SLD  IWG IQAL PIVL  PYR   ***
    1         0    0    4    0    0    0    0   12
  END PRINT-INFO

  GEN-INFO
*** <ILS >      Name            Unit-systems   Printer
*** <ILS >                    User  t-series Engl Metr
*** x -  x                           in  out
    1     CUBRUN Impervious 9    1    1    1    1    0
  END GEN-INFO
```

```
  IWAT-PARM1
*** <ILS >         Flags
*** x -  x CSNO RTOP  VRS  VNN RTLI
    1        0    1    0    0    0
  END IWAT-PARM1

  IWAT-PARM2
*** <ILS >      LSUR     SLSUR      NSUR     RETSC
*** x -  x      (ft)                          (ft)
    1          387.0    0.0378     0.014       0.0
  END IWAT-PARM2

  IWAT-STATE1
*** <ILS >  IWATER state variables (inches)
*** x -  x      RETS      SURS
    1            0.0       0.0
  END IWAT-STATE1

END IMPLND

RCHRES
  ACTIVITY
    RCHRES  Active Sections (1=Active; 0=Inactive)           ***
    # -  # HYFG ADFG CNFG HTFG SDFG GQFG OXFG NUFG PKFG PHFG ***
    1        1
  END ACTIVITY

  PRINT-INFO
            Print-flags                                               ***
    # -  # HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK   PH       PYR ***
    1        4                                                      12
  END PRINT-INFO

  GEN-INFO
    RCHRES<-------Name------->Nexit  Unit Systems   Printer      ***
    # -  #                         User t-series  Engl Metr LKFG ***
                                          in  out                ***
    1      CUB RUN                 1    1    1    1    1    0
  END GEN-INFO

  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        0  1  1  1    4  0  0  0  0       0  0  0  0  0       1  1  1  1  1
  END HYDR-PARM1

  HYDR-PARM2
    RCHRES ***
    # -  #  DSN FTBN       LEN     DELTH     STCOR        KS ***
    1         0    1     11.17     148.0       0.0       0.5
  END HYDR-PARM2
  HYDR-INIT
    RCHRES  Initial conditions for HYDR                ***
    # -  #         VOL     Initial  value  of COLIND *** Initial  value  of OUTDGT
              (ac-ft)      for  each  possible  exit *** for  each  possible  exit
                             EX1  EX2  EX3  EX4  EX5 ***   EX1  EX2  EX3  EX4  EX5
    1             12.9       4.0
  END HYDR-INIT
END RCHRES

FTABLES
  FTABLE      1
```

```
 ROWS COLS ***
   15    4
     DEPTH      AREA     VOLUME      DISCH  FLO-THRU ***
      (FT)   (ACRES)    (AC-FT)      (CFS)     (MIN) ***
      0.00       0.0        0.0        0.0        0.
      0.43      11.7        3.7        1.8     1512.
      0.87      18.1       10.2        7.2     1032.
      1.30      24.4       19.4       17.1      821.
      1.73      30.7       31.3       32.7      695.
      2.17      37.0       46.0       54.7      610.
      2.60      43.3       63.4       84.1      547.
      3.47      56.0      106.4      168.1      459.
      4.33      68.6      160.4      290.9      400.
      5.20      81.2      225.3      457.9      357.
      6.93     285.3      543.0      1081.      365.
      8.67     489.4     1214.4      2100.      420.
     10.40     693.5     2239.5      3639.      447.
     12.13     897.5     3618.3      5798.      453.
     13.87    1101.6     5350.9      8673.      448.
  END FTABLE  1
END FTABLES

EXT SOURCES
<-Volume-> <Member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   # <Name> # tem strg<-factor->strg <Name>   #   #        <Name> # #  ***
WDM     52 PREC     ENGLZERO          SAME PERLND   1     EXTNL  PREC
WDM     52 PREC     ENGLZERO          SAME IMPLND   1     EXTNL  PREC
WDM     52 PREC     ENGLZERO          SAME RCHRES   1     EXTNL  PREC
WDM     76 PEVT     ENGL              DIV  PERLND   1     EXTNL  PETINP
WDM     76 PEVT     ENGL              DIV  IMPLND   1     EXTNL  PETINP
WDM     76 PEVT     ENGL              DIV  RCHRES   1     EXTNL  POTEV
END EXT SOURCES

NETWORK
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   #        <Name> # #<-factor->strg <Name>   #   #        <Name> # #  ***
PERLND   1 PWATER PERO          2367.  SAME RCHRES   1     EXTNL  IVOL
IMPLND   1 IWATER SURO           268.  SAME RCHRES   1     EXTNL  IVOL
END NETWORK

***Impervious surface is approx. 10.18% of the total (Total is 2635)***

EXT TARGETS

<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Volume-> <Member> Tsys Aggr Amd ***
<Name>   x        <Name> x x<-factor->strg <Name>   x <Name>qf  tem strg strg***
*** Results for Calibration
RCHRES   1 HYDR   RO                       WDM     33 FLOW     ENGL      REPL

END EXT TARGETS

END RUN
```

CUBP&I_5.UCI
First Single Event Calibration Run
1 Pervious Segment of 44.376 mi²
1 Impervious Segment of 5.030 mi²

```
*******************************************************************************
*******************************************************************************
*******************************************************************************
***                                                                         ***
***                              CUBP&I_5.UCI                               ***
***                                                                         ***
*******************************************************************************
*******************************************************************************
*******************************************************************************


*******************************************************************************
*** THIS IS A HSPF HYDROLOGIC RUN FOR THE CUB RUN SUB-WATERSHED INCLUDING    ***
*** ONE PERVIOUS AND ONE INPERVIOUS SEGMENTS WITH TOTAL AREA EQUAL TO THE ONE***
*** OF THE WATERSHED.                                                        ***
*** THE VALUES OF THE MAIN CALIBRATION PARAMETERS USED ARE:                  ***
*** LZSN=6.00, INFILT=0.015, LSUR=387.0, SLSUR= 0.0378, NSUR=0.3, UZSN=0.600 ***
*** INTFW=3.50, with monthly table of values for LZETP                       ***
*******************************************************************************

RUN

GLOBAL
  CUB RUN SUB-BASIN HYDROLOGIC RUN
  START       1989 01 01  0  0  END    1989 12 31 24  0
  RUN INTERP OUTPUT LEVEL    7
  RESUME     0 RUN     1
END GLOBAL

FILES
<FILE>  <UN#>***<----FILE NAME------------------------------------------------>
WDM        21   CUBRUNDT.WDM
MESSU      22   CUBP&I_5.ECH
INFO       23   HSPINF.DA
ERROR      24   HSPERR.DA
WARN       25   HSPWRN.DA
END FILES

OPN SEQUENCE
    INGRP              INDELT 01:00
      PERLND       1
      IMPLND       1
      RCHRES       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              1
  END ACTIVITY
```

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

  GEN-INFO
    <PLS ><-------Name------->NBLKS  Unit-systems  Printer ***
    # -  #                       User  t-series Engl Metr ***
                                       in  out           ***
    1     CUBRUN Pervious  9      1    1    1    1    1    0
  END GEN-INFO

*********************************************************************************
*********************************************************************************
*** The flag VLE had to be activated (value 1) to consider monthly set of    ***
*** values for the parameter LZETP                                           ***
*********************************************************************************
*********************************************************************************

  PWAT-PARM1
    <PLS >  PWATER variable monthly parameter value flags ***
    # -  # CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE    ***
    1         0    1    0    1    0    0    0    0    1
  END PWAT-PARM1
*********************************************************************************
*********************************************************************************
*** Value of LZSN increased to 6.000                                         ***
*********************************************************************************
*********************************************************************************

  PWAT-PARM2
    <PLS > ***  PWATER input info: Part 2
    # -  # ***FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
    1            0.0     6.000     0.015     387.0    0.0378       0.0      0.96
  END PWAT-PARM2

  PWAT-PARM3
    <PLS > ***  PWATER input info: Part 3
    # -  # ***PETMAX    PETMIN    INFEXP    INFILD    DEEPFR    BASETP    AGWETP
    1            40.       35.       2.0       2.0      0.00       0.0      0.00
  END PWAT-PARM3

*********************************************************************************
*********************************************************************************
*** Value of UZSN increased to 0.600. INTFW increased to 3.50                ***
*********************************************************************************
*********************************************************************************

  PWAT-PARM4
    <PLS >     PWATER input info: Part 4                                  ***
    # -  #     CEPSC      UZSN      NSUR     INTFW       IRC     LZETP ***
    1                    0.600       0.3      3.50      0.75
  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      0.07 0.07 0.09 0.09 0.11 0.11 0.11 0.11 0.11 0.09 0.07 0.07
  END MON-INTERCEP

*********************************************************************************
*********************************************************************************
```

```
*******************************************************************************
*** The following table was not present on the original run when CUBP&I_1.UCI***
*** was executed. The parameter LZETP was 0.0 for that run and that could     ***
*** account for the bad simulation of the June to November when rooted        ***
*** vegetation produces more actual evapotranspiration the reducing the       ***
*** amount of runoff generated.                                               ***
*** The monthly values were extracted from similar watershed on the northern ***
*** Patuxent River.                                                           ***
*******************************************************************************
*******************************************************************************
*******************************************************************************

  MON-LZETPARM
*** <PLS >  Lower zone evapotransp parameter at start of each month
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
    1       0.3  0.3  0.3  0.4  0.7  0.7  0.7  0.7  0.6  0.5  0.4  0.3
  END MON-LZETPARM

*******************************************************************************
*******************************************************************************


  PWAT-STATE1
    <PLS > *** Initial conditions at start of simulation
    # -  # ***  CEPS      SURS       UZS      IFWS       LZS      AGWS      GWVS
    1           0.05       0.0     0.286       0.0     2.861      0.50      0.00
  END PWAT-STATE1
END PERLND

IMPLND
  ACTIVITY
    # -  # ATMP SNOW IWAT  SLD  IWG IQAL   ***
    1         0    0    1    0    0    0
  END ACTIVITY

  PRINT-INFO
    # -  # ATMP SNOW IWAT  SLD  IWG IQAL PIVL  PYR   ***
    1         0    0    4    0    0    0    0   12
  END PRINT-INFO

  GEN-INFO
*** <ILS >      Name             Unit-systems   Printer
*** <ILS >                     User  t-series Engl Metr
*** x -  x                             in  out
    1     CUBRUN Impervious 9     1     1    1    1    0
  END GEN-INFO

  IWAT-PARM1
*** <ILS >        Flags
*** x -  x CSNO RTOP  VRS  VNN RTLI
    1         0    1    0    0    0
  END IWAT-PARM1

  IWAT-PARM2
*** <ILS >      LSUR     SLSUR      NSUR     RETSC
*** x -  x      (ft)                          (ft)
    1          387.0    0.0378     0.014       0.0
  END IWAT-PARM2
  IWAT-STATE1
*** <ILS >  IWATER state variables (inches)
*** x -  x      RETS      SURS
    1            0.0       0.0
  END IWAT-STATE1
```

```
END IMPLND

RCHRES
  ACTIVITY
    RCHRES  Active Sections (1=Active; 0=Inactive)           ***
    # -  # HYFG ADFG CNFG HTFG SDFG GQFG OXFG NUFG PKFG PHFG ***
    1        1
  END ACTIVITY

  PRINT-INFO
            Print-flags                                                ***
    # -  # HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK   PH       PYR ***
    1        4                                                      12
  END PRINT-INFO

  GEN-INFO
    RCHRES<-------Name------->Nexit   Unit Systems   Printer      ***
    # -  #                          User t-series  Engl Metr LKFG ***
                                           in  out                ***
    1      CUB RUN                  1    1    1    1    1    0
  END GEN-INFO

  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        0  1  1  1    4  0  0  0  0       0  0  0  0  0        1  1  1  1  1
  END HYDR-PARM1

  HYDR-PARM2
    RCHRES ***
    # -  #  DSN FTBN       LEN     DELTH     STCOR         KS ***
    1         0    1     11.17     148.0       0.0        0.5
  END HYDR-PARM2

  HYDR-INIT
    RCHRES  Initial conditions for HYDR                ***
    # -  #         VOL     Initial  value  of COLIND *** Initial  value  of OUTDGT
             (ac-ft)     for  each  possible  exit *** for  each  possible  exit
                           EX1  EX2  EX3  EX4  EX5 ***   EX1  EX2  EX3  EX4  EX5
    1            12.9      4.0
  END HYDR-INIT
END RCHRES

FTABLES
  FTABLE      1
 ROWS COLS ***
   15    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      0.00       0.0       0.0       0.0        0.
      0.43      11.7       3.7       1.8     1512.
      0.87      18.1      10.2       7.2     1032.
      1.30      24.4      19.4      17.1      821.
      1.73      30.7      31.3      32.7      695.
      2.17      37.0      46.0      54.7      610.
      2.60      43.3      63.4      84.1      547.
      3.47      56.0     106.4     168.1      459.
      4.33      68.6     160.4     290.9      400.
      5.20      81.2     225.3     457.9      357.
      6.93     285.3     543.0     1081.      365.
      8.67     489.4    1214.4     2100.      420.
     10.40     693.5    2239.5     3639.      447.
```

```
     12.13     897.5    3618.3     5798.      453.
     13.87    1101.6    5350.9     8673.      448.
  END FTABLE  1
END FTABLES

EXT SOURCES
<-Volume-> <Member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   # <Name> # tem strg<-factor->strg <Name>   #   #        <Name> # #  ***
WDM     52 PREC     ENGLZERO          SAME PERLND   1     EXTNL  PREC
WDM     52 PREC     ENGLZERO          SAME IMPLND   1     EXTNL  PREC
WDM     52 PREC     ENGLZERO          SAME RCHRES   1     EXTNL  PREC
WDM     76 PEVT     ENGL              DIV  PERLND   1     EXTNL  PETINP
WDM     76 PEVT     ENGL              DIV  IMPLND   1     EXTNL  PETINP
WDM     76 PEVT     ENGL              DIV  RCHRES   1     EXTNL  POTEV
END EXT SOURCES

NETWORK
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   #        <Name> # #<-factor->strg <Name>   #   #        <Name> # #  ***
PERLND   1 PWATER PERO          2367.  SAME RCHRES   1     EXTNL  IVOL
IMPLND   1 IWATER SURO           268.  SAME RCHRES   1     EXTNL  IVOL
END NETWORK

***Impervious surface is approx. 10.18% of the total (Total is 2635)***

EXT TARGETS

<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Volume-> <Member> Tsys Aggr Amd ***
<Name>   x        <Name> x x<-factor->strg <Name>   x <Name>qf  tem strg strg***
*** Results for Calibration
RCHRES   1 HYDR   RO                       WDM     34 FLOW     ENGL      REPL

END EXT TARGETS

END RUN
```

CUBP&I_6.UCI
Second Single Event Calibration Run
1 Pervious Segment of 44.376 mi^2
1 Impervious Segment of 5.030 mi^2

```
*******************************************************************************
*******************************************************************************
*******************************************************************************
***                                                                         ***
***                              CUBP&I_6.UCI                               ***
***                                                                         ***
*******************************************************************************
*******************************************************************************
*******************************************************************************


*******************************************************************************
*** THIS IS A HSPF HYDROLOGIC RUN FOR THE CUB RUN SUB-WATERSHED INCLUDING     ***
*** ONE PERVIOUS AND ONE INPERVIOUS SEGMENTS WITH TOTAL AREA EQUAL TO THE ONE***
*** OF THE WATERSHED.                                                       ***
*** THE VALUES OF THE MAIN CALIBRATION PARAMETERS USED ARE:                 ***
*** LZSN=6.00, INFILT=0.015, LSUR=387.0, SLSUR= 0.0378, NSUR=0.3, UZSN=0.600 ***
*** INTFW=5.50, with monthly table of values for LZETP                      ***
*******************************************************************************

RUN

GLOBAL
  CUB RUN SUB-BASIN HYDROLOGIC RUN
  START       1989 01 01  0  0  END    1989 12 31 24  0
  RUN INTERP OUTPUT LEVEL    7
  RESUME     0 RUN     1
END GLOBAL

FILES
<FILE>  <UN#>***<----FILE NAME------------------------------------------------->
WDM        21   CUBRUNDT.WDM
MESSU      22   CUBP&I_6.ECH
INFO       23   HSPINF.DA
ERROR      24   HSPERR.DA
WARN       25   HSPWRN.DA
END FILES

OPN SEQUENCE
    INGRP              INDELT 01:00
      PERLND       1
      IMPLND       1
      RCHRES       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                 1
  END ACTIVITY
```

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

GEN-INFO
  <PLS ><-------Name------->NBLKS  Unit-systems   Printer ***
  # -  #                       User  t-series Engl Metr ***
                                       in  out            ***
  1     CUBRUN Pervious  9      1    1    1    1    1    0
END GEN-INFO

*******************************************************************************
*******************************************************************************
*** The flag VLE had to be activated (value 1) to consider monthly set of   ***
*** values for the parameter LZETP                                          ***
*******************************************************************************
*******************************************************************************

PWAT-PARM1
  <PLS >  PWATER variable monthly parameter value flags ***
  # -  # CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE   ***
  1         0    1    0    1    0    0    0    0    1
END PWAT-PARM1
*******************************************************************************
*******************************************************************************
*** Value of LZSN increased to 6.000                                        ***
*******************************************************************************
*******************************************************************************

PWAT-PARM2
  <PLS > ***  PWATER input info: Part 2
  # -  # ***FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
  1            0.0     6.000     0.015     387.0    0.0378       0.0      0.96
END PWAT-PARM2

PWAT-PARM3
  <PLS > ***  PWATER input info: Part 3
  # -  # ***PETMAX    PETMIN    INFEXP    INFILD    DEEPFR    BASETP    AGWETP
  1            40.       35.       2.0       2.0      0.00       0.0      0.00
END PWAT-PARM3

*******************************************************************************
*******************************************************************************
*** Value of UZSN increased to 0.600. INTFW increased to 5.50               ***
*******************************************************************************
PWAT-PARM4
  <PLS >     PWATER input info: Part 4                                  ***
  # -  #     CEPSC      UZSN      NSUR     INTFW       IRC     LZETP ***
  1                    0.600       0.3      5.50      0.75
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      0.07 0.07 0.09 0.09 0.11 0.11 0.11 0.11 0.11 0.09 0.07 0.07
END MON-INTERCEP

*******************************************************************************
*******************************************************************************
*******************************************************************************
```

```
*** The following table was not present on the original run when CUBP&I_1.UCI***
*** was executed. The parameter LZETP was 0.0 for that run and that could    ***
*** account for the bad simulation of the June to November when rooted       ***
*** vegetation produces more actual evapotranspiration the reducing the       ***
*** amount of runoff generated.                                               ***
*** The monthly values were extracted from similar watershed on the northern ***
*** Patuxent River.                                                           ***
********************************************************************************
********************************************************************************
********************************************************************************

  MON-LZETPARM
*** <PLS >  Lower zone evapotransp parameter at start of each month
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
    1       0.3  0.3  0.3  0.4  0.7  0.7  0.7  0.7  0.6  0.5  0.4  0.3
  END MON-LZETPARM

********************************************************************************
********************************************************************************


  PWAT-STATE1
    <PLS > *** Initial conditions at start of simulation
    # -  # ***  CEPS      SURS       UZS      IFWS       LZS      AGWS      GWVS
    1           0.05       0.0     0.286       0.0     2.861      0.50      0.00
  END PWAT-STATE1
END PERLND

IMPLND
  ACTIVITY
    # -  # ATMP SNOW IWAT  SLD  IWG IQAL   ***
    1          0    0    1    0    0    0
  END ACTIVITY

  PRINT-INFO
    # -  # ATMP SNOW IWAT  SLD  IWG IQAL PIVL  PYR   ***
    1          0    0    4    0    0    0    0   12
  END PRINT-INFO

  GEN-INFO
*** <ILS >      Name              Unit-systems   Printer
*** <ILS >                      User  t-series Engl Metr
*** x -  x                             in  out
    1     CUBRUN Impervious 9      1    1    1    1    0
  END GEN-INFO

  IWAT-PARM1
*** <ILS >        Flags
*** x -  x CSNO RTOP  VRS  VNN RTLI
    1          0    1    0    0    0
  END IWAT-PARM1

  IWAT-PARM2
*** <ILS >      LSUR     SLSUR       NSUR      RETSC
*** x -  x      (ft)                            (ft)
    1          387.0    0.0378      0.014       0.0
  END IWAT-PARM2
```

```
  IWAT-STATE1
*** <ILS >  IWATER state variables (inches)
*** x -  x       RETS      SURS
    1            0.0       0.0
  END IWAT-STATE1

END IMPLND

RCHRES
  ACTIVITY
    RCHRES  Active Sections (1=Active; 0=Inactive)           ***
    # -  # HYFG ADFG CNFG HTFG SDFG GQFG OXFG NUFG PKFG PHFG ***
    1       1
  END ACTIVITY

  PRINT-INFO
            Print-flags                                              ***
    # -  # HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK   PH      PYR ***
    1       4                                                     12
  END PRINT-INFO

  GEN-INFO
    RCHRES<-------Name------->Nexit   Unit Systems   Printer      ***
    # -  #                          User t-series  Engl Metr LKFG ***
                                           in  out                ***
    1      CUB RUN                  1    1    1    1    1    0
  END GEN-INFO

  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        0  1  1  1    4  0  0  0  0       0  0  0  0  0       1  1  1  1  1
  END HYDR-PARM1

  HYDR-PARM2
    RCHRES ***
    # -  #  DSN FTBN       LEN      DELTH       STCOR        KS ***
    1         0    1     11.17      148.0         0.0       0.5
  END HYDR-PARM2

  HYDR-INIT
    RCHRES  Initial conditions for HYDR                 ***
    # -  #       VOL     Initial  value  of COLIND *** Initial  value  of OUTDGT
               (ac-ft)   for  each  possible  exit *** for  each  possible  exit
                           EX1  EX2  EX3  EX4  EX5 ***    EX1  EX2  EX3  EX4  EX5
    1           12.9       4.0
  END HYDR-INIT
END RCHRES

FTABLES
  FTABLE      1
 ROWS COLS ***
   15    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      0.00       0.0       0.0       0.0        0.
      0.43      11.7       3.7       1.8     1512.
      0.87      18.1      10.2       7.2     1032.
      1.30      24.4      19.4      17.1      821.
      1.73      30.7      31.3      32.7      695.
      2.17      37.0      46.0      54.7      610.
      2.60      43.3      63.4      84.1      547.
```

```
      3.47       56.0      106.4      168.1       459.
      4.33       68.6      160.4      290.9       400.
      5.20       81.2      225.3      457.9       357.
      6.93      285.3      543.0      1081.       365.
      8.67      489.4     1214.4      2100.       420.
     10.40      693.5     2239.5      3639.       447.
     12.13      897.5     3618.3      5798.       453.
     13.87     1101.6     5350.9      8673.       448.
  END FTABLE  1
END FTABLES

EXT SOURCES
<-Volume-> <Member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   # <Name> # tem strg<-factor->strg <Name>   #   #        <Name> # #  ***
WDM     52 PREC     ENGLZERO          SAME PERLND   1     EXTNL  PREC
WDM     52 PREC     ENGLZERO          SAME IMPLND   1     EXTNL  PREC
WDM     52 PREC     ENGLZERO          SAME RCHRES   1     EXTNL  PREC
WDM     76 PEVT     ENGL              DIV  PERLND   1     EXTNL  PETINP
WDM     76 PEVT     ENGL              DIV  IMPLND   1     EXTNL  PETINP
WDM     76 PEVT     ENGL              DIV  RCHRES   1     EXTNL  POTEV
END EXT SOURCES

NETWORK
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   #        <Name> # #<-factor->strg <Name>   #   #        <Name> # #  ***
PERLND   1 PWATER PERO          2367.  SAME RCHRES   1     EXTNL  IVOL
IMPLND   1 IWATER SURO           268.  SAME RCHRES   1     EXTNL  IVOL
END NETWORK

***Impervious surface is approx. 10.18% of the total (Total is 2635)***

EXT TARGETS

<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Volume-> <Member> Tsys Aggr Amd ***
<Name>   x        <Name> x x<-factor->strg <Name>   x <Name>qf  tem strg strg***
*** Results for Calibration
RCHRES   1 HYDR   RO                       WDM     35 FLOW     ENGL      REPL

END EXT TARGETS

END RUN
```

CUB13S_1.UCI
Run for Subdivided Watershed
7 Pervious Segments
6 Impervious Segments

Upper Cub Run:	**1 Pervious Segment of 8.825 mi^2**
	1 Impervious Segment of 0.933 mi^2
Middle Cub Run:	**1 Pervious Segment of 5.258 mi^2**
	1 Impervious Segment of 0.546 mi^2
Flatlick Branch:	**1 Pervious Segment of 6.760 mi^2**
	1 Impervious Segment of 1.191 mi^2
Elklick Run:	**1 Pervious Segment of 11.559 mi^2**
Lower Cub Run:	**1 Pervious Segment of 4.052 mi^2**
	1 Impervious Segment of 0.501 mi^2
Big Rocky Run:	**1 Pervious Segment of 7.592 mi^2**
	1 Impervious Segment of 1.814 mi^2
CUB038:	**1 Pervious Segment of 0.329 mi^2**
	1 Impervious Segment of 0.045 mi^2

```
*********************************************************************************
*********************************************************************************
*********************************************************************************
***                                                                           ***
***                              CUB13S_1.UCI                                 ***
***                                                                           ***
*********************************************************************************
*********************************************************************************
*********************************************************************************


*********************************************************************************
*** THIS IS A HSPF HYDROLOGIC RUN FOR THE CUB RUN SUB-WATERSHED INCLUDING    ***
*** 7   PERVIOUS AND 6   INPERVIOUS SEGMENTS WITH TOTAL AREA EQUAL TO THE ONE***
*** OF THE WATERSHED.                                                        ***
*** THE VALUES OF THE MAIN CALIBRATION PARAMETERS USED ARE:                  ***
*** LZSN=6.00, INFILT=0.015, LSUR=var.,  SLSUR= var.,   NSUR=0.3, UZSN=0.600 ***
*** INTFW=1.22, with monthly table of values for LZETP                       ***
*********************************************************************************

RUN

GLOBAL
```

```
  CUB RUN SUB-BASIN HYDROLOGIC RUN
  START       1989 01 01  0  0  END    1989 12 31 24  0
  RUN INTERP OUTPUT LEVEL    7
  RESUME     0 RUN     1
END GLOBAL

FILES
<FILE>  <UN#>***<----FILE NAME------------------------------------------------->
WDM        21    CUBRUNDT.WDM
MESSU      22    CUB13S_1.ECH
INFO       23    HSPINF.DA
ERROR      24    HSPERR.DA
WARN       25    HSPWRN.DA
END FILES

OPN SEQUENCE
    INGRP              INDELT 01:00
      PERLND       1
      IMPLND       1
      PERLND       2
      IMPLND       2
      PERLND       3
      IMPLND       3
      PERLND       4
      PERLND       5
      IMPLND       5
      PERLND       6
      IMPLND       6
      PERLND       7
      IMPLND       7
      RCHRES       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    7            1
  END ACTIVITY

  PRINT-INFO
    <PLS >          Print-flags                                    *** PIVL  PYR
    # -  # ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC       ***
    1    7            4                                                     12
  END PRINT-INFO

  GEN-INFO
    <PLS ><-------Name------->NBLKS   Unit-systems   Printer ***
    # -  #                          User  t-series Engl Metr ***
                                          in   out           ***
    1     Upper Cub Run Perv.     1    1    1    1    1    0
    2     Middle Cub Run Perv.    1    1    1    1    1    0
    3     Flatlick Branch Prv.    1    1    1    1    1    0
    4     Elklick Run Pervious    1    1    1    1    1    0
    5     Lower Cub Run Perv.     1    1    1    1    1    0
    6     Big Rocky Run Perv.     1    1    1    1    1    0
    7     CUB038 Pervious         1    1    1    1    1    0
  END GEN-INFO

********************************************************************************
********************************************************************************
*** The flag VLE had to be activated (value 1) to consider monthly set of    ***
```

```
*** values for the parameter LZETP                                          ***
********************************************************************************
********************************************************************************
PWAT-PARM1
    <PLS >  PWATER variable monthly parameter value flags ***
    # -   # CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE    ***
    1    7    0    1    0    1    0    0    0    0    1
  END PWAT-PARM1
********************************************************************************
********************************************************************************
*** Value of LZSN increased to 6.000                                        ***
********************************************************************************
********************************************************************************

  PWAT-PARM2
    <PLS > ***  PWATER input info: Part 2
    # -   # ***FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
    1            0.0     6.000     0.015     299.5    0.0232       0.0      0.96
    2            0.0     6.000     0.015     302.7    0.0370       0.0      0.96
    3            0.0     6.000     0.015     288.4    0.0505       0.0      0.96
    4            0.0     6.000     0.015     322.9    0.0311       0.0      0.96
    5            0.0     6.000     0.015     313.6    0.0415       0.0      0.96
    6            0.0     6.000     0.015     305.2    0.0557       0.0      0.96
    7            0.0     6.000     0.015     388.7    0.0749       0.0      0.96
  END PWAT-PARM2

  PWAT-PARM3
    <PLS > ***  PWATER input info: Part 3
    # -   # ***PETMAX    PETMIN    INFEXP    INFILD    DEEPFR    BASETP    AGWETP
    1    7       40.       35.       2.0       2.0      0.00       0.0      0.00
  END PWAT-PARM3

********************************************************************************
********************************************************************************
*** Value of UZSN increased to 0.600                                        ***
********************************************************************************
********************************************************************************

  PWAT-PARM4
    <PLS >     PWATER input info: Part 4                                  ***
    # -   #     CEPSC      UZSN      NSUR     INTFW       IRC     LZETP ***
    1    7               0.600       0.3      1.22      0.75
  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    7 0.07 0.07 0.09 0.09 0.11 0.11 0.11 0.11 0.11 0.09 0.07 0.07
  END MON-INTERCEP

********************************************************************************
********************************************************************************
********************************************************************************
*** The following table was not present on the original run when CUBP&I_1.UCI***
*** was executed. The parameter LZETP was 0.0 for that run and that could    ***
*** account for the bad simulation of the June to November when rooted       ***
*** vegetation produces more actual evapotranspiration the reducing the      ***
*** amount of runoff generated.                                              ***
*** The monthly values were extracted from similar watershed on the northern ***
*** Patuxent River.                                                          ***
********************************************************************************
********************************************************************************
```

```
*******************************************************************************
  MON-LZETPARM
*** <PLS >  Lower zone evapotransp parameter at start of each month
*** x -   x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
    1     7  0.3  0.3  0.3  0.4  0.7  0.7  0.7  0.7  0.6  0.5  0.4  0.3
  END MON-LZETPARM

*******************************************************************************
*******************************************************************************
  PWAT-STATE1
    <PLS > *** Initial conditions at start of simulation
    # -  # ***  CEPS      SURS       UZS      IFWS       LZS      AGWS      GWVS
    1    7      0.05       0.0     0.286       0.0     2.861      0.50      0.00
  END PWAT-STATE1
END PERLND

IMPLND

  ACTIVITY
    # -  # ATMP SNOW IWAT  SLD  IWG IQAL   ***
    1         0    0    1    0    0    0
    2         0    0    1    0    0    0
    3         0    0    1    0    0    0
    5         0    0    1    0    0    0
    6         0    0    1    0    0    0
    7         0    0    1    0    0    0
  END ACTIVITY

  PRINT-INFO
    # -  # ATMP SNOW IWAT  SLD  IWG IQAL PIVL  PYR   ***
    1         0    0    4    0    0    0    0   12
    2         0    0    4    0    0    0    0   12
    3         0    0    4    0    0    0    0   12
    5         0    0    4    0    0    0    0   12
    6         0    0    4    0    0    0    0   12
    7         0    0    4    0    0    0    0   12
  END PRINT-INFO

  GEN-INFO
*** <ILS >      Name              Unit-systems   Printer
*** <ILS >                      User  t-series Engl Metr
*** x -  x                             in  out
    1     Up. Cub Run Imperv.      1    1    1    1    0
    2     Mid. Cub Run Imprv.      1    1    1    1    0
    3     Flatlick Br. Imprv.      1    1    1    1    0
    5     Lo. Cub Run Imperv.      1    1    1    1    0
    6     Big Rocky Run Imp.       1    1    1    1    0
    7     CUB038 Impervious        1    1    1    1    0
  END GEN-INFO

  IWAT-PARM1
*** <ILS >        Flags
*** x -  x CSNO RTOP  VRS  VNN RTLI
    1         0    1    0    0    0
    2         0    1    0    0    0
    3         0    1    0    0    0
    5         0    1    0    0    0
    6         0    1    0    0    0
    7         0    1    0    0    0
  END IWAT-PARM1

  IWAT-PARM2
*** <ILS >      LSUR      SLSUR      NSUR      RETSC
```

```
*** x -  x       (ft)                               (ft)
    1           299.5     0.0232      0.014        0.0
    2           302.7     0.0370      0.014        0.0
    3           288.4     0.0505      0.014        0.0
    5           313.6     0.0415      0.014        0.0
    6           305.2     0.0557      0.014        0.0
    7           388.7     0.0749      0.014        0.0
  END IWAT-PARM2

  IWAT-STATE1
*** <ILS >  IWATER state variables (inches)
*** x -  x       RETS       SURS
    1             0.0        0.0
    2             0.0        0.0
    3             0.0        0.0
    5             0.0        0.0
    6             0.0        0.0
    7             0.0        0.0
  END IWAT-STATE1

END IMPLND

RCHRES
  ACTIVITY
    RCHRES  Active Sections (1=Active; 0=Inactive)           ***
    # -  # HYFG ADFG CNFG HTFG SDFG GQFG OXFG NUFG PKFG PHFG ***
    1         1
  END ACTIVITY

  PRINT-INFO
            Print-flags                                               ***
    # -  # HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK   PH      PYR ***
    1         4                                                    12
  END PRINT-INFO

  GEN-INFO
    RCHRES<-------Name------->Nexit   Unit Systems   Printer      ***
    # -  #                          User t-series  Engl Metr LKFG ***
                                           in  out                ***
    1       CUB RUN                 1    1    1    1    1    0
  END GEN-INFO

  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        0  1  1  1    4  0  0  0  0       0  0  0  0  0       1  1  1  1  1
  END HYDR-PARM1

  HYDR-PARM2
    RCHRES ***
    # -  #  DSN FTBN       LEN      DELTH      STCOR        KS ***
    1         0    1     11.17      148.0        0.0       0.5
  END HYDR-PARM2

  HYDR-INIT
    RCHRES  Initial conditions for HYDR                ***
    # -  #       VOL     Initial  value  of COLIND *** Initial  value  of OUTDGT
               (ac-ft)     for  each  possible  exit *** for  each  possible  exit
                           EX1  EX2  EX3  EX4  EX5 ***    EX1  EX2  EX3  EX4  EX5
    1           12.9       4.0
  END HYDR-INIT
END RCHRES
```

```
FTABLES
  FTABLE      1
 ROWS COLS ***
   15    4
     DEPTH      AREA    VOLUME      DISCH  FLO-THRU ***
      (FT)    (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      0.00       0.0       0.0       0.0        0.
      0.43      11.7       3.7       1.8     1512.
      0.87      18.1      10.2       7.2     1032.
      1.30      24.4      19.4      17.1      821.
      1.73      30.7      31.3      32.7      695.
      2.17      37.0      46.0      54.7      610.
      2.60      43.3      63.4      84.1      547.
      3.47      56.0     106.4     168.1      459.
      4.33      68.6     160.4     290.9      400.
      5.20      81.2     225.3     457.9      357.
      6.93     285.3     543.0     1081.      365.
      8.67     489.4    1214.4     2100.      420.
     10.40     693.5    2239.5     3639.      447.
     12.13     897.5    3618.3     5798.      453.
     13.87    1101.6    5350.9     8673.      448.
  END FTABLE  1
END FTABLES

EXT SOURCES
<-Volume-> <Member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   # <Name> # tem strg<-factor->strg <Name>   #   #        <Name> # #  ***
WDM     52 PREC      ENGLZERO          SAME PERLND   1      EXTNL  PREC
WDM     52 PREC      ENGLZERO          SAME IMPLND   1      EXTNL  PREC
WDM     52 PREC      ENGLZERO          SAME PERLND   2      EXTNL  PREC
WDM     52 PREC      ENGLZERO          SAME IMPLND   2      EXTNL  PREC
WDM     52 PREC      ENGLZERO          SAME PERLND   3      EXTNL  PREC
WDM     52 PREC      ENGLZERO          SAME IMPLND   3      EXTNL  PREC
WDM     52 PREC      ENGLZERO          SAME PERLND   4      EXTNL  PREC
WDM     52 PREC      ENGLZERO          SAME PERLND   5      EXTNL  PREC
WDM     52 PREC      ENGLZERO          SAME IMPLND   5      EXTNL  PREC
WDM     52 PREC      ENGLZERO          SAME PERLND   6      EXTNL  PREC
WDM     52 PREC      ENGLZERO          SAME IMPLND   6      EXTNL  PREC
WDM     52 PREC      ENGLZERO          SAME PERLND   7      EXTNL  PREC
WDM     52 PREC      ENGLZERO          SAME IMPLND   7      EXTNL  PREC
WDM     52 PREC      ENGLZERO          SAME RCHRES   1      EXTNL  PREC
WDM     76 PEVT      ENGL              DIV  PERLND   1      EXTNL  PETINP
WDM     76 PEVT      ENGL              DIV  IMPLND   1      EXTNL  PETINP
WDM     76 PEVT      ENGL              DIV  PERLND   2      EXTNL  PETINP
WDM     76 PEVT      ENGL              DIV  IMPLND   2      EXTNL  PETINP
WDM     76 PEVT      ENGL              DIV  PERLND   3      EXTNL  PETINP
WDM     76 PEVT      ENGL              DIV  IMPLND   3      EXTNL  PETINP
WDM     76 PEVT      ENGL              DIV  PERLND   4      EXTNL  PETINP
WDM     76 PEVT      ENGL              DIV  PERLND   5      EXTNL  PETINP
WDM     76 PEVT      ENGL              DIV  IMPLND   5      EXTNL  PETINP
WDM     76 PEVT      ENGL              DIV  PERLND   6      EXTNL  PETINP
WDM     76 PEVT      ENGL              DIV  IMPLND   6      EXTNL  PETINP
WDM     76 PEVT      ENGL              DIV  PERLND   7      EXTNL  PETINP
WDM     76 PEVT      ENGL              DIV  IMPLND   7      EXTNL  PETINP
WDM     76 PEVT      ENGL              DIV  RCHRES   1      EXTNL  POTEV
END EXT SOURCES

NETWORK
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   #        <Name> # #<-factor->strg <Name>   #   #        <Name> # #  ***
PERLND   1 PWATER PERO           470.7  SAME RCHRES   1      EXTNL  IVOL
PERLND   2 PWATER PERO           280.5  SAME RCHRES   1      EXTNL  IVOL
PERLND   3 PWATER PERO           360.6  SAME RCHRES   1      EXTNL  IVOL
```

```
PERLND   4 PWATER PERO          616.5  SAME RCHRES   1     EXTNL  IVOL
PERLND   5 PWATER PERO          216.1  SAME RCHRES   1     EXTNL  IVOL
PERLND   6 PWATER PERO          404.9  SAME RCHRES   1     EXTNL  IVOL
PERLND   7 PWATER PERO           17.5  SAME RCHRES   1     EXTNL  IVOL
IMPLND   1 IWATER SURO           49.7  SAME RCHRES   1     EXTNL  IVOL
IMPLND   2 IWATER SURO           29.1  SAME RCHRES   1     EXTNL  IVOL
IMPLND   3 IWATER SURO           63.5  SAME RCHRES   1     EXTNL  IVOL
IMPLND   5 IWATER SURO           26.7  SAME RCHRES   1     EXTNL  IVOL
IMPLND   6 IWATER SURO           96.8  SAME RCHRES   1     EXTNL  IVOL
IMPLND   7 IWATER SURO            2.4  SAME RCHRES   1     EXTNL  IVOL
END NETWORK

***Impervious surface is approx. 10.18% of the total (Total is 2635)***

EXT TARGETS

<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Volume-> <Member> Tsys Aggr Amd ***
<Name>   x        <Name> x x<-factor->strg <Name>   x <Name>qf  tem strg strg***
*** Results for Calibration
RCHRES   1 HYDR   RO                       WDM     40 FLOW     ENGL      REPL

END EXT TARGETS

END RUN
```

APPENDIX I

Information on Land Use for Segment 9

Land Use Spreadsheet for the Occoquan Model

Data from the last three lines of 19-liner files for 1986 revision (1984 land use).

	Segment 90, Cub Run
Total Acres (given):	31,945
Total Square Miles:	49.91406

	Segment 90, Cub Run					Acres		Check
Land Use Type	Proportion (Given)	Proportio (Percent)	***Acres***	Square Miles	Imperv. Factors, Percent	Pervious Fraction	Impervious Fraction	Against Col. E - ***"Acres"***
Forest	20.03	40.13%	***12,820***	20.03	1.1%	**12,679.2**	**141.0**	**12,820**
Idle	2.83	5.67%	***1,811***	2.83	1.1%	**1,791.4**	**19.9**	**1,811**
Hi-Till Crop	1.64	3.29%	***1,050***	1.64	1.1%	**1,038.1**	**11.5**	**1,050**
Lo-Till Crop	6.75	13.52%	***4,320***	6.75	1.1%	**4,272.8**	**47.5**	**4,320**
Pasture	6.79	13.60%	***4,346***	6.79	1.1%	**4,298.1**	**47.8**	**4,346**
Large Lot Resid.	3.15	6.31%	***2,016***	3.15	9.9%	**1,816.6**	**199.6**	**2,016**
Medium Density Resid.	3.44	6.89%	***2,202***	3.44	25.0%	**1,651.3**	**550.4**	**2,202**
Townhouse/Garden Apts.	0.54	1.08%	***346***	0.54	40.0%	**207.4**	**138.3**	**346**
Commercial	0.29	0.58%	***186***	0.29	90.0%	**18.6**	**167.1**	**186**
Industrial	4.16	8.34%	***2,663***	4.16	70.0%	**798.8**	**1,863.8**	**2,663**
Institutional	0.29	0.58%	***186***	0.29	35.0%	**120.6**	**65.0**	**186**
Total:	49.91	100.00%	***31,945***	49.91		**28,693.0**	**3,252.0**	**31,945**

VITA

Daniel Vilariño was born in Montevideo, Uruguay, on the 15th of April, 1963.

In 1981 he obtained a Degree in Business Administration from the Universidad del Trabajo de Uruguay (Polytechnic University of Uruguay).

In 1982 he was admitted to the School of Chemistry of the University of the Republic of Uruguay.

In 1984 he began working for Industria Sulfúrica Sociedad Anónima (ISUSA) as a chemistry technician, and later as a chief technician. ISUSA is an industrial complex dedicated to the production of sulfuric acid and inorganic fertilizer. Performing tasks as a chemical engineer, he realized the importance of pollution control and care for the environment.

In 1985 he obtained his Bachelor of Science in Chemistry and entered the School of Engineering from which he obtained a Chemical Engineering Degree in 1990.

In 1987 he married Adriana Vilar and in 1989 his son, Martín, was born.

In 1992 he was accepted by the Virginia Polytechnic Institute and State University (Virginia Tech) and enrolled in the Graduate Program to pursue a Master of Science in Environmental Engineering. That year he moved to Vienna, Virginia, in the United States of America and began his studies in the Northern Virginia Graduate Center of Virginia Tech at Telestar, Falls Church.

From 1992 he has worked for the Organization of American States in Washington, D.C.

In 1996 he presented this document in partial fulfillment of the requirement for the Degree of Master of Science in Environmental Engineering and he presented the defense of his Thesis to the Advisory Committee.