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ASSESSMENT OF THE ROLE OF BOTTOMLAND HARDWOODS IN SEDIMENT AND EROSION CONTROL

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ASSESSMENT OF THE ROLE OF BOTTOMLAND HARDWOODS IN SEDIMENT AND EROSION CONTROL

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1. OVERVIEW

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INTRODUCTION

Drainage and clearing of bottomland hardwoods have long been recognized by the U.S. Environmental Protection Agency (EPA) and the U.S. Fish and Wildlife Service (Service) as important impacts of Federal water projects in the lower Mississippi River Valley. More recently, the water quality impacts of such projects (e.g., increases in sediments, nutrients, and pesticides) have also become of concern. In 1984, in an effort to better define problems concerning wetland losses and water degradation, EPA initiated a cooperative project with the Western Energy and Land Use Team (now the National Ecology Research Center) of the Service. Three phases of the project were identified: (1) to collect existing literature and data; (2) to select, develop, and test the utility of methods to quantify the relationships between land use, cover types, soils, hydrology, and water quality (as represented by sediment); and (3) to apply selected methodologies to several sites within the Yazoo Basin of Mississippi to determine the potential effectiveness of various management alternatives to reduce sediment yield, increase sediment deposition, and improve water quality.

Methods development focused on linking a simulation of water and sediment movement to a computerized geographic information system. We had several objectives for the resulting model. We desired that it should (1) estimate the importance of bottomland hardwoods as a cover type that performs the functions of erosion and sediment control, (2) simulate effects of proportions of various cover types and their specific spatial configurations, (3) be applicable to moderately large spatial areas with minimal site-specific calibration, (4) simulate spatial patterns of sediment loss-gain over time, and (5) represent both sediment detachment and transport.

While it was recognized that impacts and management alternatives could be sorted roughly into landscape measures and channel measures, the decision was made to focus study efforts mainly on landscape measures. Landscape measures

include altered drainage and flooding patterns, altered cover types (e.g., conversion of bottomland hardwoods to agricultural crops, reforestation of cropland to bottomland hardwoods, and creation of riparian buffer strips), altered cropping and tillage patterns, altered routing of water, and creation of buffer strips along wetlands and channel margins. Channel measures include vegetative bank stabilization, grade control structures, and regulation of channel water volume and velocity.

During the first year of the study, EPA decided not to fund the third phase of the project. This required considerable rescoping of the project with the result that application of the sediment mobilization, routing, and deposition models to various management alternatives and portions of the Yazoo Basin was somewhat restricted. We believe, however, that this report will provide a good understanding of the various modes of sediment mobilization, transport, and deposition within the Yazoo Basin, as well as of the role of bottomland hardwoods. The model developed in this study could be applied to a variety of management or mitigation alternatives prior to implementation to determine their relative effectiveness. Policy, political, and socio-economic consequences of any proposed management/mitigation practice, however, must ultimately be taken into consideration by those charged with management of water resources within the Yazoo Basin before any practice is implemented. This study makes no effort to judge the feasibility of management alternatives in this regard.

YAZOO BASIN

Several environmental summaries and overviews are available for the Yazoo Basin (Kolb et al. 1976; Howard, Needles, Tammen, and Bergendoff, Inc 1980). This section is drawn largely from that of Kolb et al. (1976). The Yazoo River drains a basin of approximately 13,400 square miles. The Tallahatchie, Coldwater, and Yalobusha Rivers, as well as the Big Sunflower-Steele Bayou system, feed into the Yazoo River, which drains into the Mississippi River at Vicksburg, Mississippi.

Five physiographic provinces compose the Yazoo Basin (Kolb et al. 1976). They are the Pontotoc Ridge, Flatwoods, North Central Hills, Loess Bluffs, and Mississippi Alluvial Plain, also known as the Yazoo Delta (Figure 1.1). The oldest materials, ranging in age from 50 to 100 million years, are located in the northeastern part of the Basin and form the surface of the Pontotoc Ridge, Flatwoods, and North Central Hills. Materials in the Alluvial Plain and Loess Bluffs are recently deposited. The age of materials forming the Loess Bluffs is 10,000 to 25,000 years. Loess consists of wind blown silt that is bound together by calcareous clay. Since wetting quickly breaks the bond between the particles, the bluffs are easily eroded.

The bluffs and rolling hills of the Upland Region were settled in the early 1800's. Land was cleared of virgin forests and planted in cotton. The Upland Region was said to have produced large cotton harvests. Within the Loess Bluffs, early settlers also are reported to have cleared virgin hardwood forests from large flat areas. There is evidence, however, that erosion

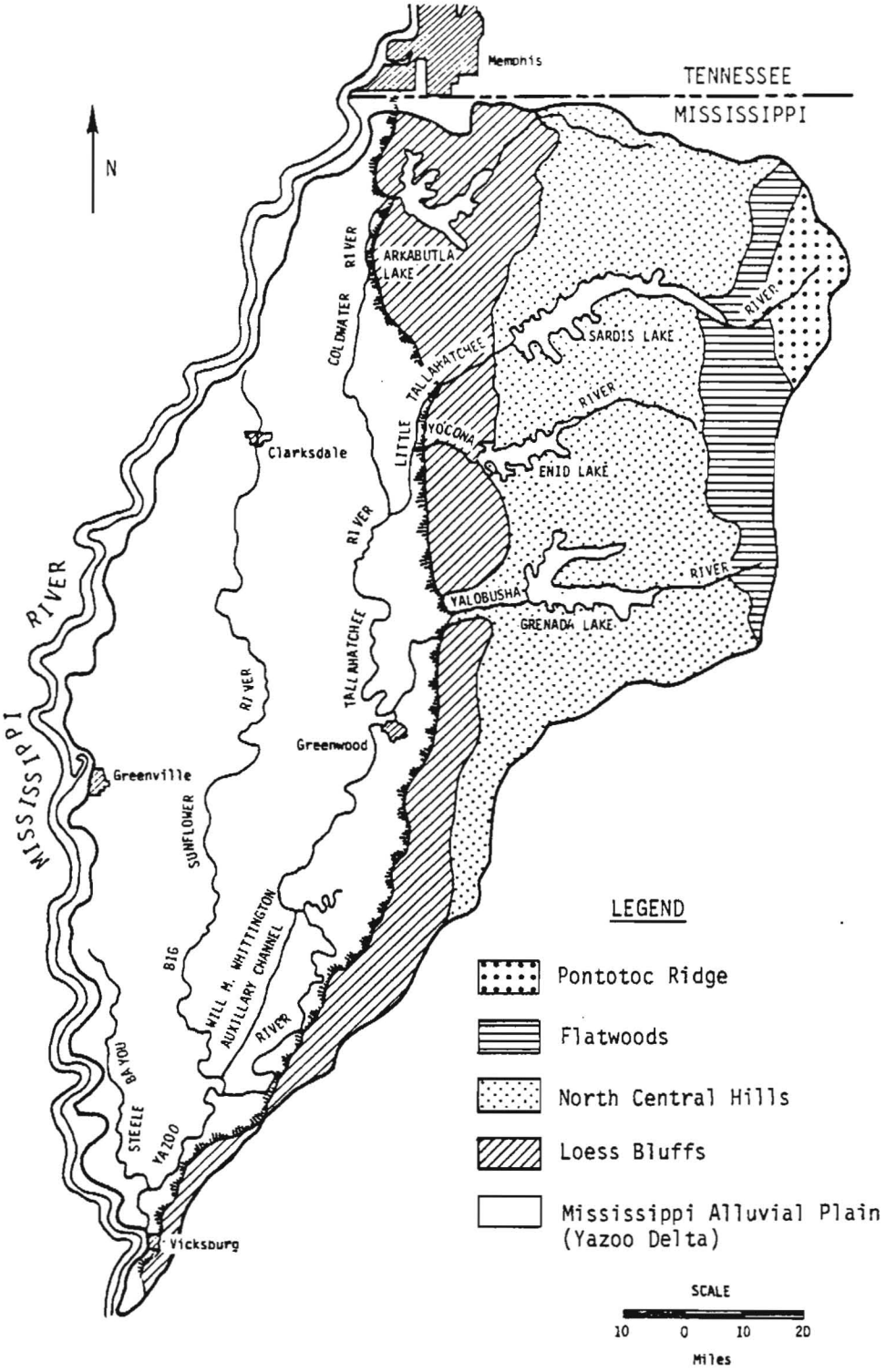

Figure 1.1. Physiographic regions of the Yazoo Basin (redrawn from Kolb et al. 1976).

became so severe with headward growth of gullies that farming in the Loess Bluffs became impractical within a few decades (Kolb et al. 1976), and as cotton farming intensified after the Civil War, the thin layer of topsoil was eroded away in the Upland Region.

Decreasing cotton yields in the Uplands turned the attention of farmers to the Yazoo Delta, also known as the Alluvial Plain. Prior to 1865, the Mississippi River controlled the physiography of the Yazoo Delta. An immense bottomland hardwood forest covered the Alluvial Plain. Since vegetation covered the area and bound the soil, the energy from rainfall and runoff was reduced, and erosion was insignificant (Kolb et al. 1976). The first areas settled in the Alluvial Plain were the broad areas of the natural levees. These lands remained dry during many flooding events and were only inundated a few inches by the larger floods because floodwater could expand over extensive backswamp areas (Kolb et al. 1976). Settlements on the natural levees also were protected from floods by the construction of low levees. As levee construction accelerated, however, levee heights had to be increased to protect against increasing flood stages, because floodwaters were now constricted by the levees.

In the 1880's, increasing demand for cotton resulted in the clearing of bottomland forests surrounding the natural levees. A growing population in the area also required lumber for buildings. Thus, sawmills were moved into the Alluvial Plain, and accessible bottomland hardwood forests were cleared. Farmers often cultivated these cleared areas.

The great floods of 1927 and 1928 resulted in major Federal flood control efforts. Erosion also was recognized as a problem in the Yazoo Basin. The Soil Conservation Service (SCS) has estimated that over 100 million gross tons of sediment were carried annually from the Upland Region to the Alluvial Plain during the 1930's (Kolb et al. 1976). Four large reservoirs were constructed by the U.S. Army Corps of Engineers in the Upland Region, and SCS built numerous small reservoirs. These projects provided increased flood control and resulted in increased sediment retention. In addition, levees were constructed and channels were enlarged and straightened on the Coldwater, Tallahatchie, Yalobusha, and Yazoo Rivers. These actions also made it possible to convert large bottomland hardwood areas, which were formerly too wet, into agriculture. On-farm drainage of the cleared areas then overloaded the downstream channel capacities, prompting additional structural actions to move floodwaters out of the Yazoo Basin.

The conversion of bottomland hardwoods to farmland has increased erosion rates in the Alluvial Plain. MacDonald et al. (1979) have documented land-use changes in the Yazoo Delta; from the 1930's to 1970's, forested bottomlands have decreased from 1.5 million acres to 0.8 million acres. This 47% decrease in bottomland hardwood acreage has been attributed largely to the demand for soybeans (Kolb et al. 1976). The construction of drainage ditches to remove the water from the land as quickly as possible also has enhanced the sediment transport capacity of the water and increased erosion. In contrast, total erosion in the Uplands has decreased. SCS has estimated that only 28 million tons per year of gross erosion was occurring in the Uplands in the 1970's

(Kolb et al. 1976), as compared to 100 million tons per year in the 1930's. This dramatic decrease has been attributed to reforestation and other soil retention practices through projects constructed since the 1930's (Kolb et al. 1976).

In recent times, road construction, residential and commercial development, and mining for sand and gravel have impacted the Loess Bluffs. These activities have increased erosion rates and contributed to the sediment load to the Alluvial Plain.

MODES OF SEDIMENT FLUX

Water and sediment movement in the Yazoo Basin are governed by interrelated processes that exhibit variation in space and time. In the analysis of this complex system, three primary modes of water and sediment movement have been identified: (1) in-channel flow, (2) overbank flooding, (3) overland flow (Figure 1.2). The in-channel flow mode represents movement of water and sediment within the boundaries of a reasonably well-defined channel network; considerable hydrologic and sediment modeling has been conducted in the basin from this perspective. The overbank flooding mode consists of the lateral movement of water and sediment from the channel system out over the landscape during the rising phase of flood events, and potentially back to the channel in the recession phase. The overland flow mode consists of water and sediment movement over the landscape, generated by precipitation. In a network of conveyance channels, a rise in the downstream water surface, due to river confluences and man-made structures, can cause flooding of upstream backwater areas. Such "backwater flooding" can, in some circumstances, involve an upstream direction of water and sediment movement. Overbank and backwater flooding are generally difficult to formulate mathematically and require extensive site-specific model development.

The various modes of water and sediment flows encountered in the Yazoo Basin are not truly distinct. For example, overbank flooding can be considered a special case of in-channel flow, where the water surface elevation is high enough that the channel includes area beyond the banks. Nor can each parcel of land be uniquely associated with a given mode. A bottomland area may be subjected to overland runoff from precipitation at some times and to overbank and backwater flooding from the channel at other times, or all simultaneously.

The general principles relating water and sediment movement are similar for all three modes of transport. For each of the modes, sediment motion can be described by the distinct processes of initiation of motion, transport, and deposition. Initiation of motion is primarily a function of the energy available (e.g., falling raindrops or flowing water) and the nature of the sediment (e.g., more energy being required for bigger particles and soils with well developed root systems being more resistant to detachment). Once the threshold conditions for sediment motion are exceeded, the capacity of flows to transport sediment is primarily a function of velocity, depth of flow, slope, and the size of particles being transported. Other factors of varying importance include viscosity and density of flows, settling velocity, gradation, and shape factor and density of sediment. Scour and deposition

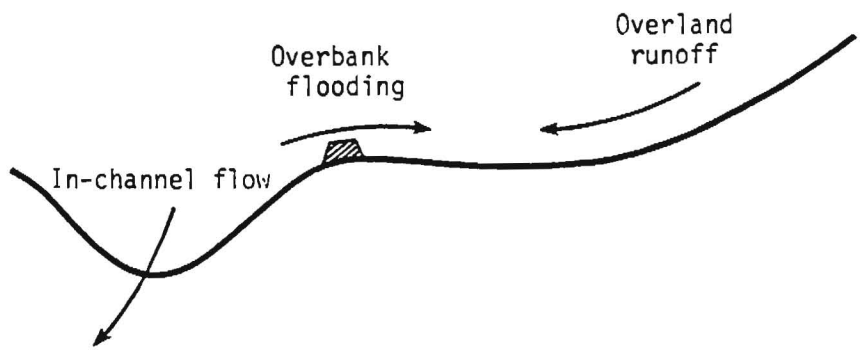

Figure 1.2. Modes of water and sediment movement.

processes can be viewed as adjustments to maintain a balance between the amount of sediment that the flows can carry and the amount of sediment being transported. In the case where the sediment load is in excess of the transport capacity associated with the flow, sediment deposition occurs. For the opposite case, where the sediment transport capacities exceed the amount of sediment being carried, the tendency of flows is to scour the channel bed or banks. The scouring process, however, is also limited by the amount of sediment available to transport and by the sizes of sediments forming the channel bed.

Precise specification of the numerical details is very difficult, but a reasonable general understanding of sediment movement can be obtained by considering how the primary factors affecting initiation of motion, transport, and deposition interact in the modes described above. In the in-channel mode, transport capacity is primarily dictated by velocity and slope. A reduction in velocity (e.g., at a channel expansion or where the gradient is reduced) reduces the transport capacity and can produce deposition. As relatively sediment-laden water in high gradient channels flows from upland areas down into broad, flat floodplains (e.g., at the bluff line in the Yazoo Basin), the gradients, velocities, and transport capacities are sharply reduced, producing alluvial fans of sediment deposition. Similarly, in overbank flooding, water velocities drop sharply as water spreads out of the channel onto the floodplain. The consequent reductions in transport capacity result in deposition. The patterns of this deposition, and the natural levees created, reflect the pattern of reduction in transport capacities coupled with the particle size

distribution of the sediment load. The most rapid reductions of water velocities and transport capacities occur near the channel, producing primary natural levees that are disproportionately composed of heavier, more rapidly settling particles; whereas backswamp deposits further from the channel are disproportionately composed of more slowly settling particles (clay).

Just as the decreases in velocity can result in deposition when the sediment load exceeds the transport capacity, increased velocity can result in erosion when the transport capacity exceeds the sediment load. Such excess transport capacity can be produced by increased gradients, lowered roughness values, and localized areas of increased velocity due to obstructions or channel constrictions. The excess transport capacity may be utilized by the flows to carry additional sediment loads if the excess energy is sufficient to initiate the motion of the available sediment. Many erosion control measures are based on limiting the juxtaposition of excess transport capacity and the presence of sufficient energy to mobilize available sediment. Grade control structures reduce energy slopes and velocities, and numerous stabilization measures (e.g., concrete, riprap) eliminate available sediment and increase the amount of energy required to initiate motion.

In the overland flow mode, detachment is heavily dependent on the energy of raindrops impacting the soil surface. Therefore, detachment is greatly reduced by vegetation or soil cover that absorbs this energy. Detachment is also highly dependent on erodibility, particle sizes, and cohesiveness of the soil. Runoff provides a means for transporting the detached particles. The total transport capacity of the runoff is a function of the gradient, volume of runoff, and the frictional characteristics of the land surface. The type of vegetation has a strong influence on transport capacity; increased roughness (friction) decreases the velocity and hence the transport capacity of the runoff.

In general terms, many changes from natural cover types to man-induced cover types (e.g., from forest to agriculture, vegetated to developed sites) increase the ability of precipitation to detach sediment by reducing interception, increase velocities by decreasing roughness, and change the cohesiveness of the soil. Thus, sediment detachment and transport capacities are increased in the overland runoff mode, and velocities may be increased in the overbank flooding mode. In the Yazoo Basin, land-use changes from presettlement conditions in the Uplands have substantially increased the sediment entering the bottomland or Delta portion of the basin. The role of reservoirs as sediment traps in the Uplands is counter-balanced by the erosion caused by the clearer water releases (excess transport capacity) from the reservoirs. Flood control and drainage improvement projects in the Delta also have had tremendous impacts. Many such projects increase the volume and velocity of water in the channels by shortening channel length, decreasing channel roughness, establishing channels and drainage ditches in areas previously subject more to overland flow, and creating levees that constrain the flow to the channels and limit the general lower velocity overbank flooding mode. These changes have increased sediment transport capacities. To a large extent, the hydrologic objectives of such projects (to limit the spreading out of flood flows over the floodplain and to convey flows quickly through the basin) are fundamentally inconsistent with the role of bottomland areas as sediment traps.

ROLE OF BOTTOMLAND HARDWOODS

Bottomland hardwoods, as considered here, are a wet, forested cover type in the floodplain. They are considered without particular regard to the extent to which they are considered wetlands in a regulatory sense. They serve numerous habitat and food chain support functions for fish and wildlife and also function in erosion and sediment control in several ways. They have well-developed canopy and litter layer structures that absorb the kinetic energy of precipitation (i.e., less energy available to detach sediment). Their root structure and litter layer stabilize the erosive soil (i.e., more energy is required to detach sediment). These surface characteristics lead to high surface roughness coefficients that produce low velocities and low transport capacities. Therefore, the sediment contribution to streams from bottomland hardwood areas is much less than from agricultural cover types.

In terms of the modes of sediment flux identified in Figure 1.2, replacement of bottomland hardwoods with bare ground (the extreme case) produces higher detachment and transport in the overland runoff mode and less deposition in the overbank flooding mode. In other words, such conversions increase the sediment flux to streams, which may have a number of undesirable impacts on the associated aquatic communities. However, the importance of bottomland hardwoods as a cover type in the overbank flooding mode may be reduced in a highly modified floodplain. Much of the velocity reduction (and the consequent reduction of transport capacity) that produces deposition is determined by flood waters spreading out over large flat areas, rather than by the cover-dependent roughness characteristics of these areas. Furthermore, increased channel capacities that limit the extent of overbank flooding constrain the importance of this mode of sediment flux in the floodplain. Therefore, the function of bottomland hardwoods as a cover type contributing to increased deposition or sediment trapping is reduced in the case of highly channelized systems. Basically, bottomland hardwoods can function as sediment detention basins only to the extent that sediment-laden waters flow through these areas. Finally, sediment diversions to bottomland hardwood areas should be designed in such a way as to control the depositional amount and patterns to minimize adverse impacts on the biota, of the areas. The analysis presented in this report on the importance of bottomland hardwoods as a cover type focuses primarily on the overland runoff mode (Sections 3 and 4). Section 2 discusses the possibility of using bottomland hardwood areas as sediment traps in the overbank flooding mode, both from mainstem channels and from tributaries routed through the bottomland hardwood areas.

2. MAINSTEM AND OVERBANK FLOW SEDIMENT MOVEMENT

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INTRODUCTION

The objective of this chapter is to define, qualitatively and quantitatively, general sediment movement within the delta region of the Yazoo Basin, erosion or deposition in the delta during overbank flooding events, and aggradation/degradation within the mainstem and tributaries. An overall schematic of the Yazoo River and tributaries below Arkabutla Dam and above Belzoni, Mississippi is given in Figure 2.1.

This chapter addresses overbank sediment movement on the mainstem, the effects of varying cover types on lands adjacent to the channel, and the use of bottomland hardwood areas for sediment detention areas. A section of Ascalamore Creek has been used as a quantitative example to determine the potential use of bottomland areas for sediment detention.

HYDROLOGY AND GEOMORPHOLOGY

Climate

The climate of the Yazoo Basin is mild and humid with long, hot summers providing a long growing season. The average daily temperature at Greenwood ranges from 44 °F in January to 80 °F in July, with an annual mean of 65 °F. The Yazoo Basin has moderate to heavy rainfall. During the period 1900 to 1973 the annual rainfall at Greenwood ranged from a minimum of 30.16 inches in 1965 to a maximum of 83.33 inches in 1973. Based on the 20-year period from 1954 to 1973 the mean precipitation at Greenwood is 50.87 inches (Table 2.1). The average annual precipitation over the basin is approximately 52 inches. Sixty-seven percent of the rainfall occurs during the months of December through May. The driest period occurs during August through October, but locally intense runoff can occur any time during the year. Major floods are caused by storms of several days duration, commonly with wet antecedent conditions. Major flooding has occurred in 14 of the 45 years from 1931 to 1975 (U.S. Army Corps of Engineers 1975).

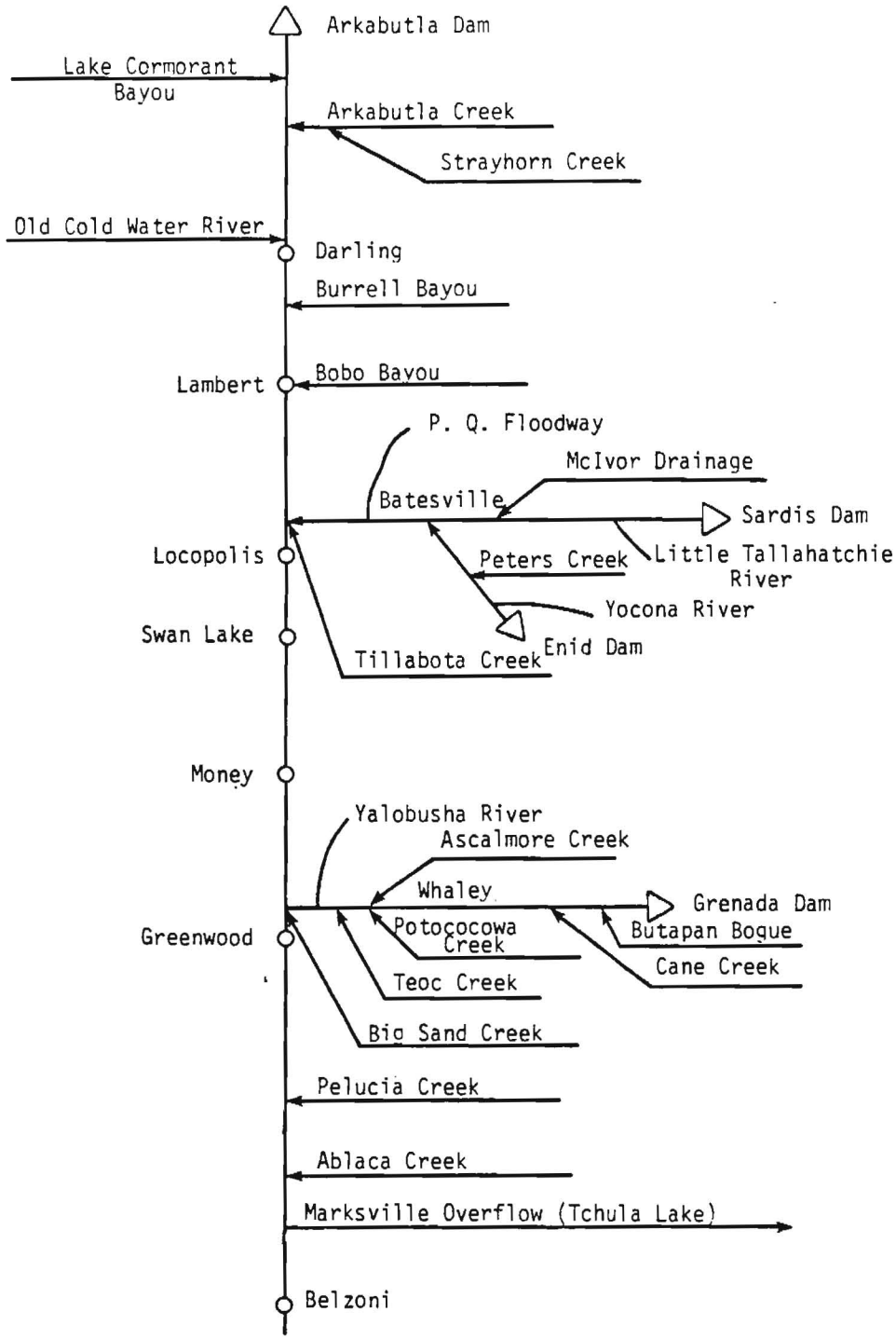

Figure 2.1. Schematic of Yazoo River and tributaries.

Table 2.1. Average rainfall at Greenwood, 1954 - 1973 (after U.S. Army Corps of Engineers 1975).

Month		Rainfall (inches)
January		5.62
February		5.04
March		5.70
April		4.81
May		4.06
June		3.75
July		4.45
August		3.06
September		3.12
October		2.39
November		4.70
December		5.41
	TOTAL	50.87

The U.S. Army Corps of Engineers (1975) reported runoff in the basin to range from 50% to 90% of precipitation, depending on antecedent conditions. They also reported annual runoff of 18 inches in the upper end of the basin to 16 inches at Vicksburg. Watson (1982) presents runoff data for various land uses in northern Mississippi that range from 1.49 inches for pine plantations to 20.00 inches for bare fallow fields (Table 2.2). These data may be low for large watersheds since the study plots were small and would not have measured groundwater return flows.

The U.S. Army Corps of Engineers (reported in Watson 1982) has estimated the change in forested land in the basin (Table 2.3). Significant reforestation has taken place in the hill portion of the basin since 1930. Forested land in the delta part of the basin has generally continued to decline to a low proportion, in large part a result of conversion to agriculture (principally soybeans in recent years).

Table 2.2. Annual runoff for single cover watersheds in upland northern Mississippi (after Watson 1982).

Land use	Annual runoff	
	Average (inches)	Range (inches)
Open Land		
Cultivated	15.39	6.2 - 24.0
Pasture	16.52	12.9 - 23.4
Bare fallow	20.00	10.0 - 30.0
Forest Land		
Abandoned fields	6.65	1.2 - 20.7
Depleted hardwoods	5.94	1.2 - 13.1
Pine and hardwoods	8.74	0.4 - 19.8
Pine plantations	1.49	0.1 - 9.7

Table 2.3. Percent of land in forest (as reported in Watson 1982).

	1800	1860	1880	1900	1930	1940	1950	1980
Delta	100	88	78	72	44	39	35	10
Hills	100	88	78	72	30	36	41	50

Existing Geomorphic Conditions

During the last 7 years, detailed geomorphic analyses have been conducted on selected streams within the basin (Watson 1982; Biedehern 1983). The following is a brief overview of the basin's morphology.

The mainstem of the Yazoo River exhibits a wide variability in slope, sinousity, and shape as it has adjusted to conditions in the Alluvial Plain. Starting in the 1900's channel deterioration became a problem along the mainstem. This then led to flooding problems due to inadequate channel capacity. The reasons for this channel instability, including flooding, are (1) elimination of Mississippi overflows with the final closure of the Yazoo Pass after the 1927 flood, which served to scour the mainstem; (2) clearing of low-lying lands, which was possible due to the elimination of Mississippi overflows; and (3) the channelizing of many bluff line tributaries directly into the mainstem past backswamp areas. These events combined to reduce the channel flows and increase the sediment input. The mainstem experienced a gradual decline in channel capacity.

Starting in the 1930's with projects approved by Congress in 1928, and with subsequent flood control acts, significant flood control features were constructed on the mainstem. With cutoffs, the mainstem was shortened from 366.9 miles in 1939 to 301.4 miles in 1970. This increased the river slope by 22%. Levees were constructed over long reaches such that the river lost much overbank storage. Finally, in 1962 the Will M. Whittington Auxiliary Channel was completed, which added significant flood capacity to the lower Yazoo.

In summary, when compared to conditions at the start of this century, the Yazoo mainstem has (1) higher tributary sediment input, (2) less flow volume and lower peak flows, (3) greater bed slope, (4) smaller cross sectional area, and (5) less channel and overbank storage.

Hydrologic Data Analysis

Selected hydrologic data analysis is summarized here, supporting estimates of sediment movement in later sections.

Tallahatchie River near Swan Lake. Watson (1982) performed specific gage analysis of several stations within the basin, including the station on the Tallahatchie River near Swan Lake. In the records of 1933 to 1973, a degradation trend occurred from about 1937 to 1944 due primarily to the large number of cutoffs made on this reach of the river. This was followed by a period of aggradation from 1944 to 1947, with channel regime appearing fairly stable after this period. The specific gage record for various discharges is given in Figure 2.2, and the stage-discharge relationship is given in Figure 2.3. The daily flow frequency relationships are given in Figure 2.4.

Ascalamore Creek. Stage and discharge data are available at the U.S. Army Corps of Engineers gaging station at Paynes for the period 1964 to date, though data for the earlier years are intermittent. Using the available data, Simons et al. (1978) developed and generated flow statistics for ungaged, or partially gaged, tributaries within the basin.

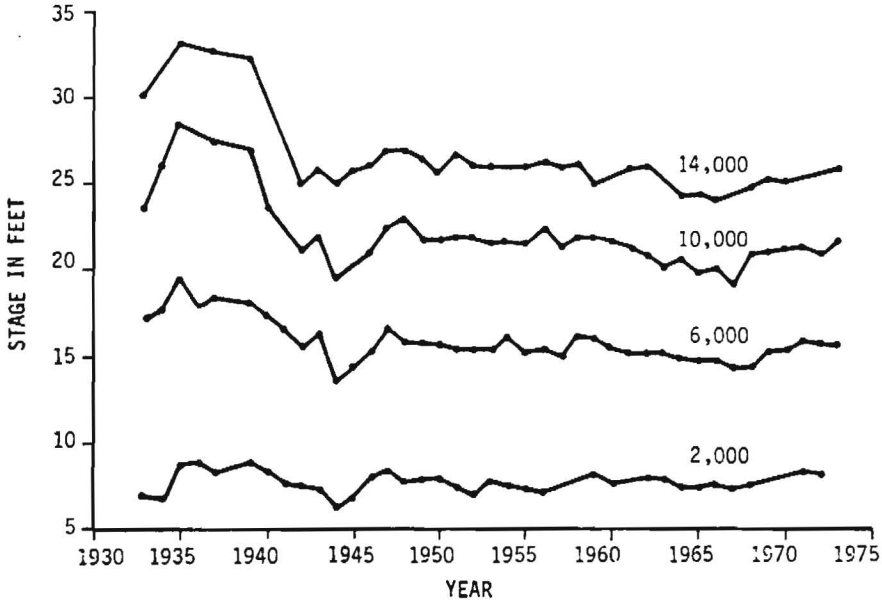

Figure 2.2. Specific gage record for Tallahatchie River at Swan Lake (based on Watson 1982).

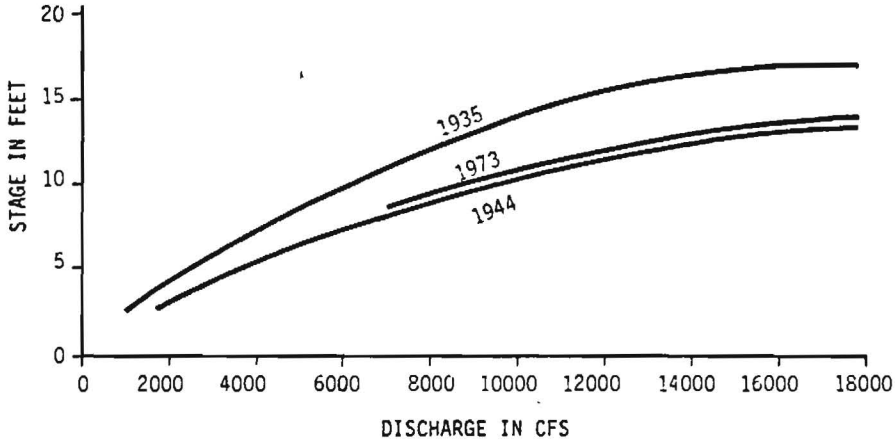

Figure 2.3. Stage-discharge relationship for Tallahatchie River at Swan Lake (based on Simons et al. 1983).

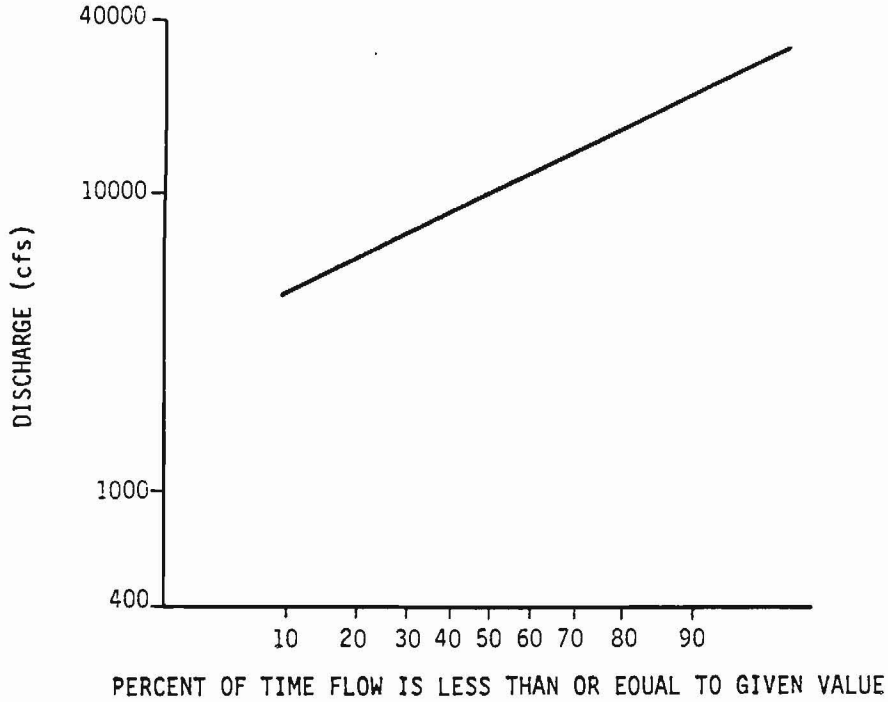

Figure 2.4. Daily flow frequencies for Tallahatchie River near Swan Lake (based on Simons et al. 1978).

Using data from other stations within the basin, stage-discharge relationships for the Yazoo River Basin stations can be expressed by a power function of the form:

$$Q = a(s + c)^b$$

or by a linear equation of the form:

$$Q = (m \cdot s) + k$$

where Q is the discharge, s is the stage, c is a derived value used to transform the stage readings, and a, b, k, and m are empirical values (Simons et al. 1978).

The power function was used to define the in-bank stage discharge relationships. If overbank flow occurred, the linear function was the most representative relationship. For Ascalamore Creek, the respective equations are:

$$Q = 8.492\ (s-1)^{2.615}$$

and

$$Q = 1161\ s - 7339$$

with the break point stage occurring at 7.17 feet. The resulting daily flow frequency curve is given in Figure 2.5 (based on 11 years of daily data).

Hydraulic Properties

The hydraulic properties of the mainstem and tributaries were computed for the single year of 1974 by Simons et al. (1983), with data obtained from discharge measurements taken by the U.S. Army Corps of Engineers. Flow depths on most streams generally exhibited a narrow range for a broad spectrum of discharges, while velocities varied from 0.26 to 4.56 feet per second, with a mean peak velocity of approximately 2.6 feet per second. Peak velocities measured on the Tallahatchie River ranged from 2.50 feet per second at the Fort Pemberton cutoff to 3.17 feet per second at Locopolis. Bank full discharges on Ascalamore Creek had an average velocity of about 2.5 feet per second.

During calibration of a sediment routing model for the Yazoo Basin (Simons et al. 1978), Manning's roughness coefficient (n) varied as a power function of the discharge. The resulting calibrated n values for the Tallahatchie River at Swan Lake are given in Table 2.4.

Cross-sectional data are available for the Swan Lake location; Figure 2.6 is the computer plot of the cross section downstream of the gage. Very little in-field cross-sectional data were obtained for Ascalamore Creek; Figure 2.7 was constructed as representative of sections downstream of Paynes, using known side slopes and the bank full depth and discharge.

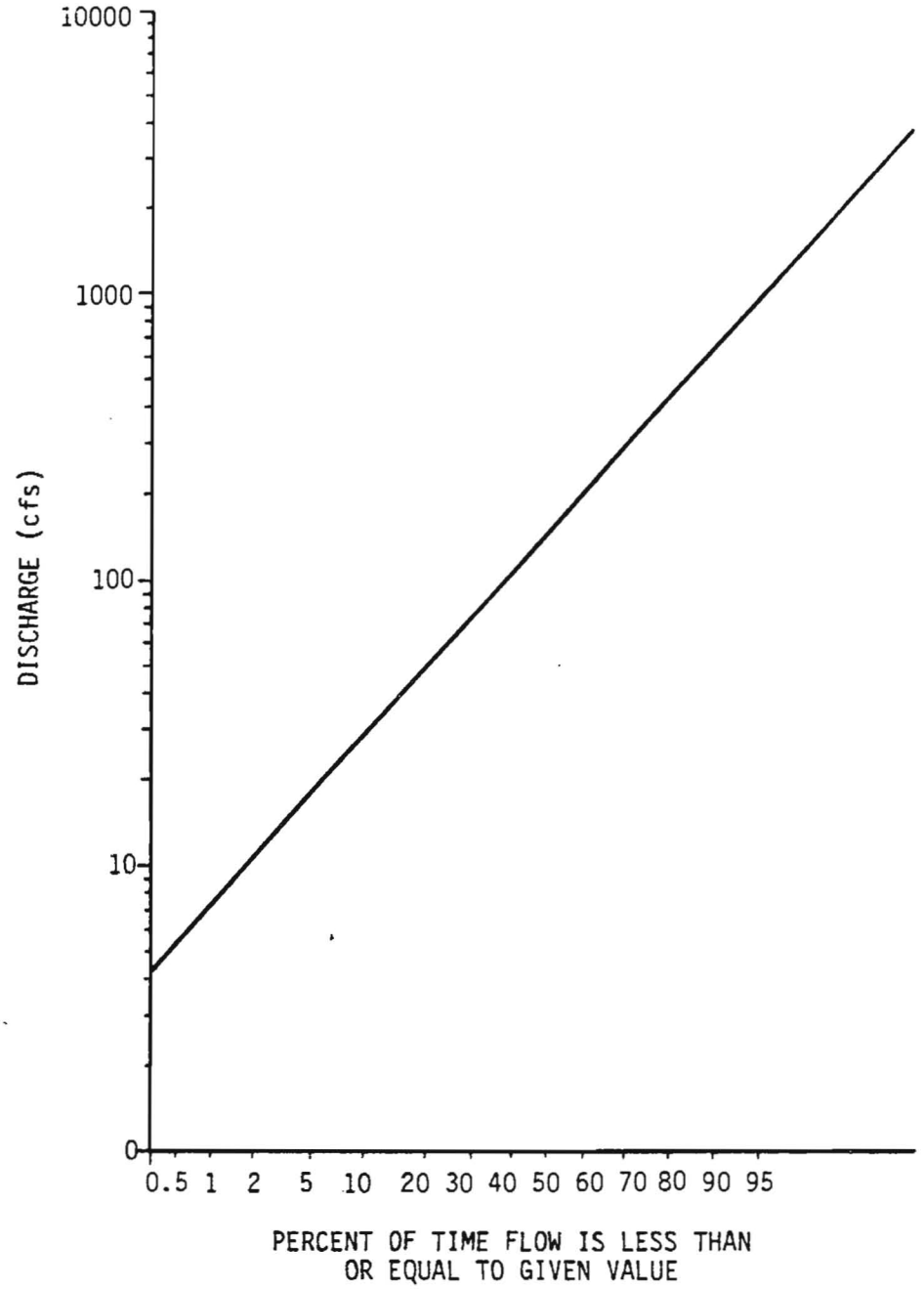

Figure 2.5. Daily flow frequencies for Ascalamore Creek at Paynes.

Table 2.4. Calibrated roughness coefficients for Tallahatchie River at Swan Lake (from Simons et al. 1978).

Discharge at Swan Lake	Roughness coefficient, Manning's n	
	Main channel	Overbank
2,000	0.042	---
10,000	0.035	0.175
35,000	0.020	0.100

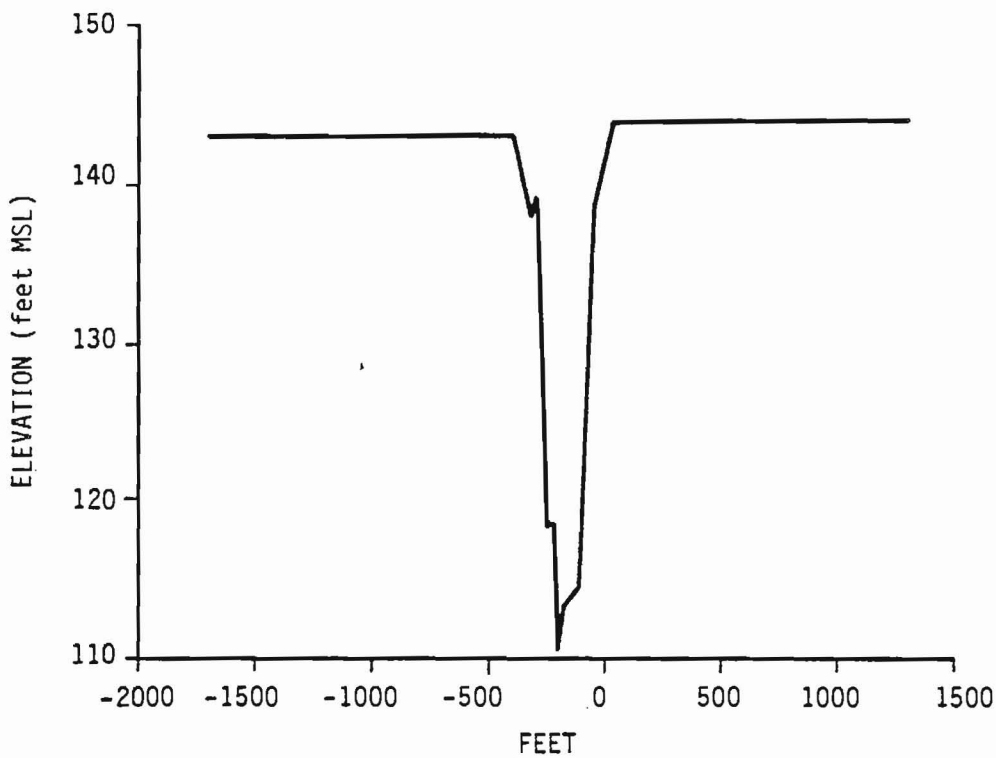

Figure 2.6. Cross section of Tallahatchie River near Swan Lake.

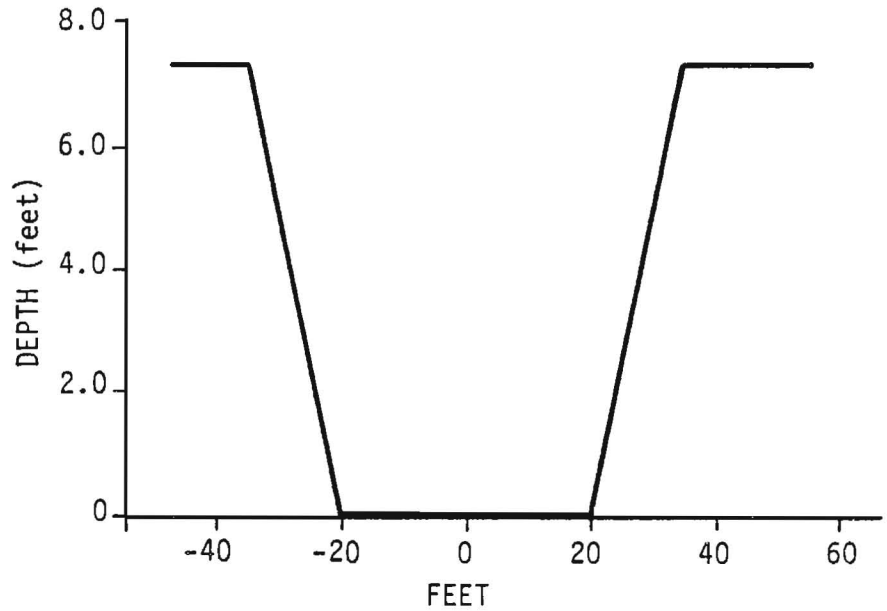

Figure 2.7. Cross section of Ascalamore Creek near Paynes.

MAINSTEM SEDIMENT MOVEMENT

Quantitative Sediment Loss

Previous studies conducted for the U.S. Army Corps of Engineers (Simons et al. 1978; Simons et al. 1983) estimated net degradation and aggradation for the Yazoo Basin and its main tributaries over a 50-year simulation period. Under existing natural conditions, it was estimated that the Tallahatchie River from the Greenwood Bendway to Arkabutla Dam will aggrade at approximately 200,000 cubic yards per year, with a majority of this aggradation occurring between the Greenwood Bendway and the Panola-Quitman (P-Q) Floodway confluence. Above this confluence, the P-Q Floodway-Little Tallahatchie Reach was found to degrade at an average annual rate of approximately 45,000 cubic yards per year, with the P-Q Floodway aggrading and the Little Tallahatchie degrading due to significant bank erosion.

The Upper Yalobusha River was found to degrade at approximately 14,000 cubic yards per year, with the lower reaches remaining comparatively stable over the simulation period. It was estimated that approximately 1.4 million cubic yards of dredging would be required annually on the mainstem channel above Belzoni, Mississippi, to retain the existing channel and bed profile configuration.

Current Sediment Reduction Methods

In the past, the U.S. Army Corps of Engineers has relied heavily upon levees and dredging to keep the mainstem confined to its channel. Construction of cutoffs on the mainstem during the 1940's may have improved channel stability by helping to offset the increased tributary sediment load. Without these cutoffs, the mainstem may have experienced greater aggradation. The results of these cutoffs were a loss of channel and overbank storage and a potential increase in peak discharges. The potential peak discharge increases were not realized, however, due to the construction of regulation reservoirs on the Little Tallahatchie, Yocona, and Yalobusha Rivers.

Numerous sediment and flood control alternatives have been investigated within the basin (U.S. Army Corps of Engineers 1975). These alternatives have included grade control structures (on both the mainstem and tributaries), stepped (or laterally tiered) channels, channel diversion to wetlands, and the use of riparian greenbelts (buffer strips). All of these alternatives have been shown to assist, to varying degrees, the stability of the system. The stepped channel concept and diversion of the tributary flows to detention areas are the two most significant sediment and flood control alternatives.

Mainstem Overbank Flow

During overbank flow events on the mainstem, sediment from the main channel may be deposited on the land adjoining the channel. Whether deposition or erosion occurs on these overbank areas is a function of the adjoining land type, total sediment load, overbank flow depths and velocities, and duration of the overbank inundation (backwater effects). To evaluate the qualitative effects of overbank flow, a reach on the Tallahatchie River is considered below.

Tallahatchie River near Swan Lake. At the Tallahatchie River near Swan Lake (Figure 2.6), overbank flow occurs at approximately 30,000 cubic feet per second. From the flow frequency curve of Figure 2.4, this discharge is exceeded approximately 3% of the time, or 11 days per year. The maximum recorded flow at this location is 36,420 cubic feet per second, and the total sediment load that could be deposited on overbank flow areas, assuming a 100% trap efficiency, would be less than 10% of the total sediment discharge. The use of grade control structures or a synthetic bank low point, however, would increase potential sediment deposition in backwater areas. A more detailed description of potential sediment deposition methods is given in the following section.

SEDIMENT DEPOSITION POTENTIAL

General

Previous studies on tributaries within the Yazoo Basin have shown that natural detention or sediment storage areas effectively trap the heavier sediments from the hill tributaries, and consequently minimize mainstem

aggradation. In a report to the U.S. Army Corps of Engineers, Vicksburg District, Simmons et al. (1983) studied cumulative sediment yields from Abiaca Creek into Matthews Brake, a forested area. A model was developed to evaluate the percentage of material trapped in the Brake. A turbulent settling length concept, as described in Li and Shen (1975), was used to determine the percentage of material settling.

Output from the analysis indicated that initially all but a small percentage of the fine silt and clay sizes would settle out, and the material passing through the Brake would be less than 5% of the inflow (95% trap efficiency). As the Brake continued to fill, the average velocities increased. At the end of the 50-year simulation period, approximately 30% of the material was carried through (70% trap efficiency). During the period of simulation, Abiaca Creek had a mean daily flow of 223 cubic feet per second, and a maximum flow of 4,500 cubic feet per second. Total storage at the end of the simulation period was approximately 2,540 acre feet, which corresponds to an average filling rate of approximately 50 acre feet per year. These results indicate that the average reduction in sediment yield to the mainstem by completely diverting Abiaca Creek through Matthews Brake was approximately 80%.

Overbank Deposition Potential

Agricultural overbank land. On the mainstem and tributaries bordered by cleared and planted land, the potential for net sediment deposition during overbank flow events is minimal. Evaluation of watershed runoff (both water and sediment) from soybean and cotton areas bordering the Tensas River in Louisiana (Water and Environment Consultants 1980a) indicated significant sediment contribution to the tributaries during the recession part of flood hydrographs. Normal agricultural practice in these areas ensures that drainage ditches do not allow ponding or sediment detention during localized storm events or tributary overbank flow.

Buffer strips. In the study described above (Simons et al. 1983), water and sediment routing was conducted on the mainstem to determine the effect of a buffer strip (riparian greenbelt), constructed on overbank areas, on the sediment movement in the mainstem. Manning's roughness coefficient (n) for the floodplain was increased from the calibrated 0.15 value to 0.20 to simulate the effect of increased vegetative structure.

On the reach of the Tallahatchie River below Swan Lake, significant aggradation occurred in the mainstem, compared to the natural conditions, though very little change was noticeable in the maximum water surface elevation. During overbank flow conditions, however, significant increases in the discharge induce only minor changes in stage, with or without bank vegetation. Due to the lower velocities anticipated in the overbank flow portions, some sediment deposition is anticipated within and on the vegetation, although this may be insignificant when compared to the alternative of sediment retention basins. Simulation of the Tallahatchie also revealed that increased bank roughness confines the flow to the channel more than pasture or brush overbanks, and consequently confines more of the sediment movement.

Sediment Detention Ponds

As discussed above, the use of sediment detention ponds or areas is probably the most viable method of controlling aggradation within the tributaries and mainstem. These areas might be vegetated as bottomland hardwoods and thus provide other benefits associated with this cover type (e.g., fish and wildlife habitat). The following subsection considers the possibility of using currently existing wetlands and relatively unproductive agricultural areas for sediment retention within the Ascalamore Creek subbasin.

Ascalamore Creek

Compared to the mainstem, very little data are available for Ascalamore Creek or Tippo Bayou, especially sediment data. Water and Environment Consultants (1977, 1980b) collected and compiled all of the available data for the delta in 1977 and 1980, and these data have been used to determine average annual sediment discharges in Ascalamore Creek. From the hydraulic data given earlier, overbank flow of the creek occurs when the flow depth reaches 7.17 feet downstream of the Paynes gaging station. The maximum range of discharges above 10 cubic feet per second was divided into subranges, and the mean flow within these ranges was used in computing the bed material and wash loads. The respective ranges and mean flows are given in Table 2.5.

Using all available sediment data from the eastern delta tributaries, Simons et al. (1983), conducted a correlation analysis of sediment loads to determine power function relationships for gaged and ungaged tributaries. The resulting relationship between discharge and bed material load for Ascalamore Creek is given by:

$$Q_{sb} = (42.5 \times 10^{-3})\ (Q)^{1.5}$$

where Q_{sb} = bed material in tons/day

Q = discharge in cfs

Limited data from the Yalobusa River tributaries indicate a narrow range of variation in suspended sediment concentrations for varying discharges (Water and Environment Consultants 1977). Assuming a wash load concentration of 300 ppm, and converting to daily sediment load, yields the following equation for wash load:

$$Q_{ss} = 0.81Q$$

where Q_{ss} = wash load in tons/day

Q = discharge in cfs

Table 2.5. Total sediment discharge by flow range for Ascalamore Creek.

Flow range (cfs)	Mean flow (cfs)	Flow depth (ft)	Bed material (Q_{sb} in tons/day)	Wash load (Q_{ss} in tons/day)	Total sediment (Q_s in tons/day)
10 - 20	15	2.24	2	12	14
20 - 50	35	2.72	9	28	37
50 - 100	75	3.30	28	61	89
100 - 250	225	4.50	143	182	325
250 - 750	500	5.75	475	405	880
750 - 1,000	875	6.88	1,100	709	1,809
1,000 - 1,500	1,250	7.40	1,878	1,012	2,890
1,500 - 2,000	1,750	7.83	3,111	1,418	4,529
2,000 - 2,500	2,250	8.26	4,536	1,822	6,358
2,500 - 3,000	2,750	8.69	4,536	1,822	6,358
3,000 - 3,500	3,250	9.12	7,874	2,633	10,507
3,500 - 4,000	3,750	9.55	9,760	3,038	12,798
4,000 - 4,500	4,167	9.91	11,432	3,375	14,807

For each of the mean flows adopted, the daily bed material load, washload, and total sediment load were computed and are given in Table 2.5.

Using the mean flows and the daily flow frequencies from Figure 2.5, the average annual sediment discharge was computed by summing the products of the total number of flow days and the average daily sediment loads. The resulting total load is given in Table 2.6.

Approximately 10% of the bed load material is larger than 0.5 mm (coarse sands). Due to the low, peak flow velocities (approximately 2.5 feet per second), this material has been assumed to constitute bed load. The remaining bed material sediment load will be dispersed through the flow depth, in conjunction with the wash load. In the overbank flow condition, (for discharges greater than 1,000 cubic feet per second), 90% of the bed material load is distributed throughout the flow as a function of the discharge. The resulting overbank flow (for water discharges greater than 1,000) sediment discharge (Q_{so}) is thus given by the relationship:

$$Q_{so} = (0.9)\ (Q_{sb} - 1{,}344) + (Q_{ss} - 810) = (0.9)Q_{sb} + Q_{ss} - 2{,}020 \text{ tons/day}$$

For the mean overbank flow increments and the daily flow frequencies, the average annual overbank flow sediment discharge is given in Table 2.7. The total overbank sediment discharge of 66,000 tons per year constitutes approximately 24% of the total annual sediment discharge of Ascalamore Creek, and is equivalent to approximately 18 acre-feet of deposited sediment with a 100% trap efficiency. If the stage at which overbank flow occurs was reduced by 1.0 feet (to 6.0 feet), approximately 41% of the total sediment load, equivalent to 31 acre-feet, could be diverted.

With the existing stage required for overbank flow and an area with a volume of 10,000 acre feet available for sediment deposition, approximately 550 years of sediment could be deposited. If the entire flow of the Ascalamore Creek were diverted through this area, with a trap efficiency of approximately 70%, approximately 53 acre-feet per year could be deposited, and the useful life for detention in the bottomland area would be approximately 180 years.

SUMMARY AND CONCLUSIONS

During the last 180 years, agricultural and general developmental changes within the Yazoo Basin have increased overall sediment loads in the mainstem and tributaries. In general, degradation has occurred within the eastern hills, and consequent aggradation within the delta streams. The mainstem is now generally confined to a defined channel due to modifications constructed to reduce flooding. Thus, overbank flow on the mainstem, and consequent use of overbank areas for sediment deposition, is probably not a viable method of sediment load reduction, irrespective of overbank vegetation types. Partial or full diversion of tributaries, however, may be a logistically possible and effective method of sediment load reduction.

Table 2.6. Average annual sediment discharge for Ascalamore Creek.

Mean flow (cfs)	Percent of time	Number of days	Average daily sediment load (Q_s in tons/day)	Cumulative sediment load (tons)
15	4.5	61	14	224
35	14.0	51	37	1,887
75	18.0	66	89	5,874
225	25.0	91	325	29,575
500	26.0	95	880	83,600
875	3.6	13	1,809	23,517
1,250	3.5	13	2,890	37,570
1,750	1.4	5	4,529	22,645
2,250	0.9	3	6,358	19,074
3,250	0.3	1	10,507	10,507
3,750	0.2	1	12,798	12,798
4,167	0.1	0.5	14,087	7,403
			Total annual	271,388
				≈ 270,000 tons/year

Table 2.7. Average annual overbank flow sediment discharge for Ascalamore Creek.

Mean flow (cfs)	Overbank stage (ft)	Q_{so} (tons/day)	Number/days	Total overbank Q_{so}
1,250	0.23	682	13	8,866
1,750	0.66	2,198	5	10,990
2,250	1.09	3,884	3	11,652
2,750	1.52	5,724	2	11,448
3,250	1.95	7,700	1	7,700
3,750	2.38	9,802	1	9,802
4,167	2.74	11,644	0.5	5,822
		Total annual		66,280

Previous studies have indicated that, for complete tributary diversions, trap efficiencies of 95% may be attained initially, and long term trap efficiencies of 70% are realistic for the bottomlands of the delta. Diversion of overbank flows on Ascalamore Creek to bottomland hardwood areas functioning as sediment detention ponds could remove a maximum 24% of the total sediment load from the stream. Reduction of the existing overbank height by approximately 1 foot would increase this percentage to approximately 41%. If the entire creek was diverted through this area, it is anticipated that approximately 70% of the total sediment load would be removed during a 50-year period.

Although the source of the sedimentation problems for the delta lies largely in the eastern hills, the use of wetlands (or marginally productive agricultural lands allowed to develop more vegetative structure) or in the Delta as sediment detention areas is a viable method of reducing mainstem sediment loads, while maintaining some of the functions and values of such areas as wildlife habitat.

RECOMMENDATIONS FOR FUTURE STUDIES

This section is based on data collected and collated up to the late 1970's. If specific locations are to be selected for potential bottomland hardwood development, it is recommended that the data base be dated and additional cross-sectional data, reflecting current in-field conditions, be used. A far more precise estimate of sediment detention possibilities could be obtained from channel backwater analysis that considers an entire stream reach rather than individual cross-sections.

3. DESCRIPTION OF LANDSCAPE SEDIMENT MODEL

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INTRODUCTION

This chapter describes a watershed sediment routing model (HEC1WS) that operates on landscape information organized in the MOSS digital Geographic Information System (GIS). The model relates the weight of sediment eroded-deposited per unit area to landscape features (soil type, topography, land use). The MOSS cartographic system (Frosh and Walsh 1983; Lee et al. 1985) is used to develop and modify the areal themes that constitute input to the simulation and to provide spatial display of the simulation output.

The simulation model calculates the movement of water and sediment through complex watersheds. This model is designed for applications for which the sources of data are limited. The water routing is accomplished through the use of U.S. Army Corps of Engineers' (1981) HEC-1 Flood Routing Computer program as a subprogram. Sediment routing, which is coupled with the water routing, utilizes a sediment transport capacity-sediment availability concept.

SEDIMENT ROUTING MODELS FOR WATERSHEDS

Numerous mathematical models are available for estimating sediment yield from watersheds, including stochastic and deterministic models. The first category, stochastic models, use probabilistic formulations. They rely on past sediment yield records and therefore have limited generality. Response to changes in the watershed cannot be readily simulated. The second category, deterministic models, can be further classified into subcategories of: (1) continuous models, and (2) discrete event models. This classification is based on whether the simulated event is broken down into isolated discrete events or not. Continuous models, in their formulations, can treat the events using the methodologies of discrete event models. Finally, discrete event models, depending on their formulation, are grouped either as lumped models or as distributed models.

Lumped models, sometimes referred to as "black box" models, express physical processes in terms of lumped parameters using simplified forms. In lumped models, the parameters involved may or may not represent a specific physical process. These parameters are usually derived from observed field

data or, whenever measured data are not available, from extrapolation. Lumped models are commonly used in applications where limited data are available, or in applications where quick estimations are required. For example, the widely used Universal Soil Loss Equation (USLE) Model of Wischmeier and Smith (1978) falls in this category. In this model, the sediment yield process is expressed in terms of several parameters derived from statistical analysis. This model has been succesfully used to predict annual sediment yields in regions in which its parameters were derived.

Distributed models are physically based. Flow of water and sediment is broken down into different physical processes. These processes can be listed as (1) rainfall, (2) interception, (3) depression storage, (4) evaporation, (5) infiltration, (6) overland surface water flow, (7) interflow, and (8) overland flow sediment routing. For each process, governing equations describing the phenomenon are derived; however, physical parameters relating the variations of the processes to external conditions are needed in the formulations. For example, in the formulation of the Green-Ampt Infiltration Model (Green and Ampt 1911):

$$f = f_c + (f_o - f_c)e^{-kt}$$

the initial infiltration rate (f_o), final infiltration rate (f_c), and exponential decay rate (k) are needed for describing the infiltration rate (f) at time t.

Distributed models accomplish the overland flow sediment routing through satisfying the sediment continuity equation. This equation can be stated as follows. Over a time increment Δt the amount of sediment leaving a control volume is balanced by the sediment entering the control volume, sediment removed or deposited from the control volume, change in suspended sediment concentration over the time step, and lateral sediment inflow. In the application of sediment routing, two variables are considered as limiting factors: (1) availability of sediment, and (2) sediment transport capacity of overland flows. The first variable, availability of sediment, is formulated considering soil detachment by raindrop impact and soil erosion by surface runoff. The relationships defining the rate of erosion due to these processes involve parameters that need calibration by fitting sediment discharge rates to observed data. The second variable, sediment transport capacity of flows, has been the subject of extensive studies. A number of different transport formulas have been derived by either dimensional analysis, regression studies, or flow mechanics. In general, these equations have been derived using limited laboratory or field data and contain optimization coefficients that were obtained by fitting computed sediment discharges to observed data. The majority of these equations relate the sediment transport either to bed shear stress or to shear stress in excess of critical shear stress. Several of these equations follow.

Kilinc Equation (Kilinc 1972, pg. 155)

$$q_s = 2.104[(\tau_o - \tau_c)u]^{1.584}$$

where q_s = sediment discharge (lb/sec/ft of channel width)

τ_o = boundary shear stress, or $\gamma h S_o$ for wide channels (lb/ft²)

τ_c = critical shear stress (lb/ft²)

u = mean velocity (ft/sec)

h = flow depth (ft)

S_o = bed slope (ft/ft)

γ = specific weight of water (62.4 lb/ft³)

Yalin Equation (1963)

$$\phi_k = 0.635\ \theta_k^{3/2}\ [1 - \theta_{ck}/\theta_k]\ [(1/\theta_{ck}) - (1/a\sigma\theta_{ck})\ell n(1 + a\sigma)]$$

where $a = 2.45\ S^{-2/5}\ \theta_{ck}^{1/2}$

$\sigma = (\theta_{50}/\theta_{ck}) - 1 = [u_*^2/\theta_{ck}(S-1)gd_k] - 1$; (dimensionless)

$\phi_k = G_{sk}/(d_k u_*)$; (dimensionless volume transport rate)

θ_k = mobility number based on sediment size, d_k; (dimensionless)

d_k = sediment size (ft)

$\theta_k = u_*^2/(S-1)gd_k$ (dimensionless)

S = specific gravity of sediment (dimensionless)

u_* = bed shear velocity, $= (ghS_o)^{1/2}$; (ft/sec)

S_o = bed slope (ft/ft)

h = flow depth (ft)

G_{sk} = sediment transport rate by volume per unit time (ft³/sec)

g = gravitational acceleration (ft/sec²)

Definition of critical shear stress from Shields Diagram.

Boundary Reynolds Number: $R_e = u_* \, d_k/\upsilon$

where u_* = bed shear velocity, = $(ghS_o)^{1/2}$; (ft/sec)

d_k = sediment size (ft)

υ = kinematic viscosity of water (ft^2/sec)

g = gravitational acceleration (ft/sec^2)

h = flow depth (ft)

S_o = bed slope (ft/ft)

a) If $R_e < 10$ $\tau_c = 0.08\,(S-1)\gamma\, d_k\, R_e^{-0.4}$

b) If $10 \leq R_e \leq 500$ $\tau_c = 0.022\,(S-1)\gamma d_k\, R_e^{-0.16}$

c) If $R_e > 500$ $\tau_c = 0.06\,(S-1)\gamma\, d_k$

where τ_c = critical shear stress (lb/ft^2)

S = specific gravity of sediment (dimensionless)

γ = specific weight of water (62.4 lb/ft^3)

R_e = boundary Reynolds number

d_k = sediment size (ft)

For Laminar Flows

$$h = (K\upsilon/8g)^{1/3}\, q^{1/3} S_o^{-1/3} \quad \text{(Kilinc 1972)}$$

$$u = (8g/K\upsilon) S_o\, h^2$$

where h = flow depth (ft)

g = gravitational acceleration (ft/sec^2)

q = discharge per ft of channel width (ft^2/sec)

S_o = bed slope (ft/ft)

υ = kinematic viscosity of water (ft^2/sec)

$K = 60 + 2{,}500\ GC$ (Hartley 1984)

CG = ground cover fraction

For Turbulent Flows

$$h = (Q \times n/(1.486 \times W \times S_o^{1/2}))^{0.6} \quad \text{(Manning's Equation)}$$

where h = flow depth (ft)

n = Manning's roughness coefficient

W = width of channel (ft)

Q = discharge (ft^3/sec) ($= qW$)

q = discharge per ft of channel width (ft^2/sec)

Distributed models are superior in representing the physical phenomena taking place in watershed sediment transport process. They provide the flexibility of analyzing different best management alternatives for land use, hydrologic conditions, and structural and nonstructural measures for prevention of soil loss. To accomplish these tasks, however, they require site specific parameters for sediment transport capacity, sediment availability, infiltration, evaporation, etc., that can be obtained through field work. In the absence of these data, lumped parameter models are the only viable alternative. The models can be modified for routing water and sediment for discrete events.

DESCRIPTION OF THE HEC1WS MODEL

The HEC1WS computer model, a modification of the HEC-1 water routing model, was developed for this study to route water and sediment through complex watersheds. It has three major components: (1) linkage with MOSS digital GIS and input file generation component, (2) watershed water routing component, and (3) watershed sediment routing component. The components and the files generated in the course of a computer run are shown in Figure 3.1 and are summarized in Tables 3.1 and 3.2.

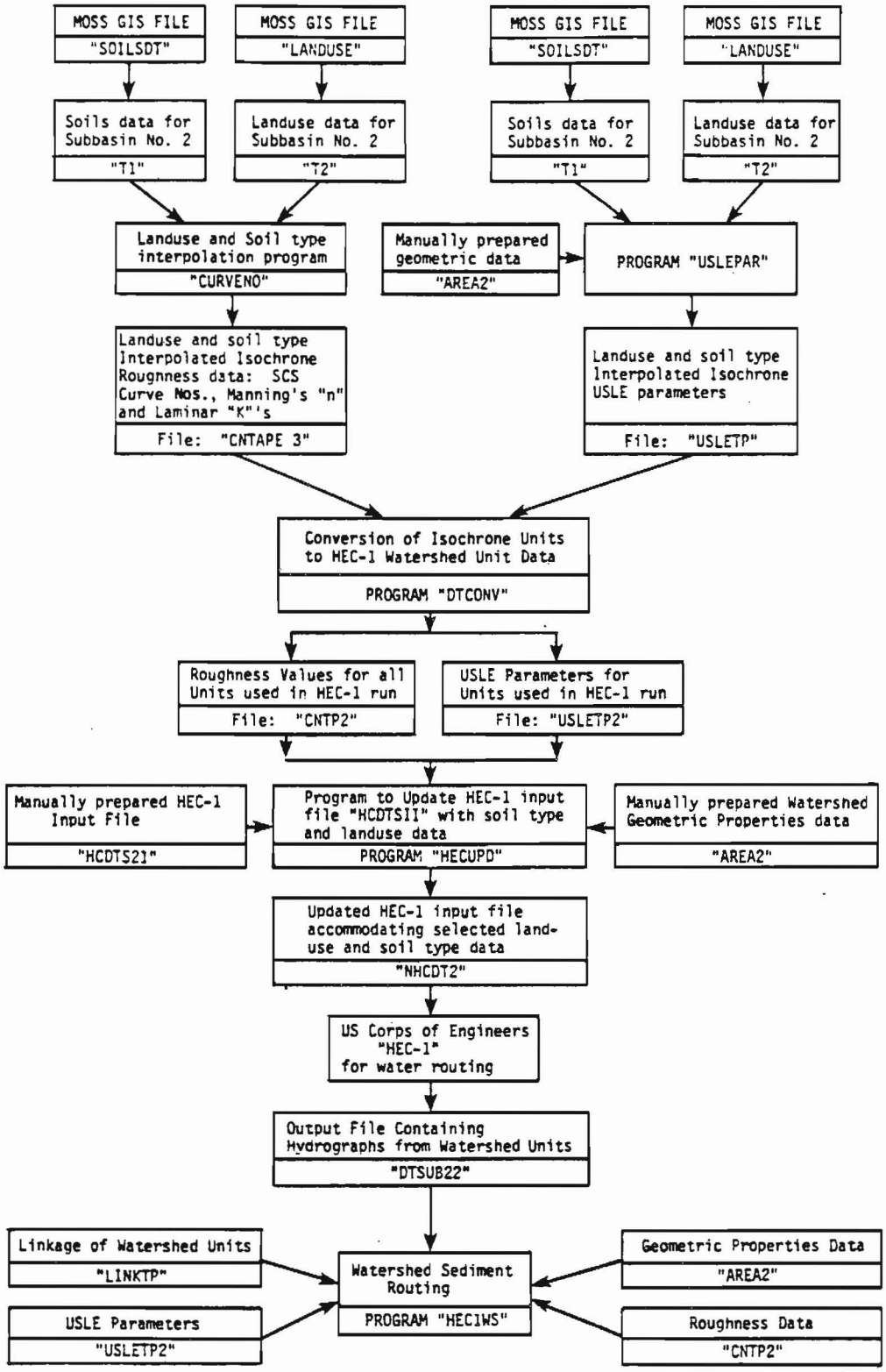

Figure 3.1. Linkage diagram of various data files and programs used.

Table 3.1. List of programs.

	Name	Purpose	Input file(s)	Output file(s)
1.	CURVENO	Interpolate soil type and landuse files for isochrone roughness values	TAPE1=LANDUSE(T1) TAPE2=SOILSDT(T2)	TAPE3=CNTAPE3
2.	USLEPAR	Interpolate soil type and landuse files for isochrone USLE parameters needed for USLE	TAPE1=T1 (Landuse) TAPE2-T2 (Soils)	TAPE3=USLETP
3.	DTCONV	Convert isochrone data for roughness and USLE parameters to watershed units data for HEC-1 run	TAPE4=CNTAPE3 TAPE7=USLETP	TAPE8=USLETP2 TAPE9=CNTP2
4.	HECUPD	Update manually prepared HEC-1 input data HCDTS12 with current landuse, soil type information	TAPE5=HCDTS12 TAPE1=AREA2 TAPE7=CNTP2	TAPE8=NHCDT2
5.	HEC1WS	Watershed sediment routing program using HEC-1 as a "subroutine" for water routing	TAPE1=DTSUB1 TAPE2=LINKTP TAPE3=AREA2 TAPE4=CNTP2 TAPE7=USLETP2	TAPE9=QSTAPE
6.	HEC1	Watershed water routing program developed by U.S. Corps of Engineers	INDATA=NHCDT2	TAPE22=DTSUB2
7.	HYDROGR	Utility program to generate water and sediment hydrograph plots using TEKTRONIX terminals or line printers. Also capable of tabulating these values	TAPE2=DTSUB2	Output is in the form of tables or plots

Table 3.2. List of files.

Name	Contents	Generated by
1. SOILSDT	Soil Associations for isochrones identified for the entire study area	MOSS GIS
2. LANDUSE	Land use data for isochrones identified for the entire study area	MOSS GIS
3. CNTAPE3	Curve numbers, Manning's "n" and Laminar friction coefficients for isochrones	CURVENO (program)
4. USLETP	USLE parameters interpolated for the isochrones identified for the study area	USLEPAR (program)
5. USLETP2	USLE parameters interpolated for the watershed units to be used in HEC-1 run	DTCONV (program)
6. CNTP2	Roughness parameters interpolated for the watershed units to be used in HEC-1 run	DTCONV (program)
7. AREA2	Geometric properties data for the watershed units used in the HEC-1 run	Input file
8. LINKTP	Watershed units linkage data needed for connecting various isochrones, channels, subwatersheds and flow planes	Input file
9. HCDTS12	HEC-1 input file with assumed time of concentration, curve numbers, and roughness values	Input file
10. NHCDT2	HEC-1 input file updated with computed time of concentration, curve numbers, and roughness values	HECUPD (program)

LINKAGE WITH MOSS DIGITAL GIS AND INPUT FILE GENERATION

The MOSS digital Geographic Information System (Lee et al. 1981) is a sophisticated data storage, manipulation, and retrieval system for spatial data. Maps representing soil associations, landuse, topography, and watershed segmentation were digitized and entered into the MOSS system. Through overlays of watershed segmentation with landuse and soil association data, MOSS GIS generates data files containing soil and landuse types for each specified computational watershed unit. These data files are identified as LANDUSE and SOILSDT in Figure 3.1. This information is used to produce area-weighted Soil Conservation Service (SCS) runoff curve numbers, Manning's n values, and laminar friction coefficients in the program CURVENO.

A second program, USLEPAR utilizes the same information to generate area weighted Universal Soil Loss Equation (USLE) Cropping and Management factors, C, and Soil Erodibility factors, K. In addition to C and K parameters, the program USLEPAR utilizes the data file AREA2 to generate EI, LS, and P parameters for individual watershed units. These values are used in computing the amount of sediment available for transport. The data file AREA2 is prepared outside the program from maps generated from the MOSS GIS.

Programs DTCONV and HECUPD are used to convert roughness, curve number, and watershed geometry data into file NHCDT2, in a format suitable for input to the HEC-1 program.

For each different landuse scenario the procedure presented above generates the appropriate input data files for the water and sediment routing components.

WATERSHED WATER ROUTING

The program HEC1WS utilizes three different types of hydrologic units to describe the flow of water and sediment through watersheds: (1) channel units, (2) plane units, and (3) subwatershed units. The subwatershed units are segmented further into isochrone units (Figure 3.2). The definitions of these units, with the exception of isochrone units, are consistent with the segmentation procedure adopted by HEC-1 Flood Routing Program. The isochrone units define sediment movement within a subwatershed unit in greater spatial detail. Plane units define flow planes contributing lateral inflow of water and sediment to channel units. As a group, the plane and subwatershed (including internal isochrones) units are referred to as landscape units for the purposes of reporting and graphing certain results, considering the channel units to be an "output" for sediment flow from the landscape.

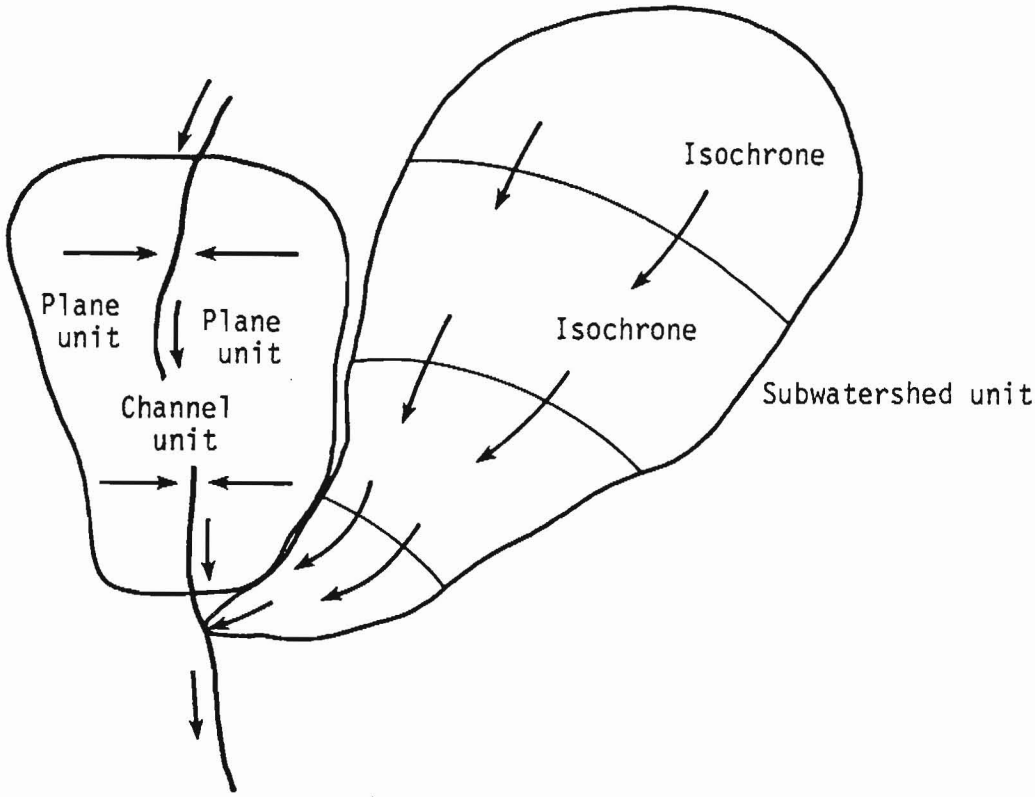

Figure 3.2. Diagram of types of units used to route water and sediment.

Water routing through channel units is accomplished using the kinematic wave routing procedure within HEC-1 (U.S. Army Corps of Engineers 1981). For the other units (individual isochrone and plane units), surface runoff hydrographs are computed by the Soil Conservation Service Runoff Curve Number Option provided in HEC-1 program. The reason for choosing the SCS method for runoff computations is due to its direct estimation of rainfall excess. In this method, the infiltration process is not simulated.

WATERSHED SEDIMENT ROUTING

The sediment routing through different types of watershed units is accomplished by satisfying the sediment continuity equation. Considering each watershed unit as a control volume, the sediment continuity equation can be expressed as:

$$(Q_s)_{out} - (Q_s)_{in} = \text{Change in sediment storage within the unit}$$

In differential form:

$$\rho_s(Q_s + \frac{\partial Q_s}{\partial x} dx)dt - \rho_s(Q_s + q_s dx)dt = -\rho_s(\eta \frac{\partial A_d}{\partial t} + \frac{\partial A_s}{\partial t}) dxdt$$

or

$$\frac{\partial Q_s}{\partial x} = q_s - (\eta \frac{\partial A_d}{\partial t} + \frac{\partial A_s}{\partial t})$$

where Q_s = volumetric sediment discharge

η = one minus porosity

ρ_s = density of the sediment

q_s = lateral sediment inflow per unit length

A_d = volume of sediment deposition per unit length

A_s = volume of sediment in suspension at the cross section per unit length dx

dt = space and time increments

The volumetric sediment discharge, Q_s, is a function of many variables including flow and sediment properties. This quantity can be determined through the use of available sediment transport equations. The model uses the Yalin Equation (Yalin 1963) assuming a single sediment particle size.

At a given instant, the potential sediment transport from a watershed unit is limited by the amount of sediment available within that unit. Flows with predicted transport capacities larger than the available sediment can only carry the amount available for transport.

Sediment availability is determined by a modified version of the Universal Soil Loss Equation:

$$\text{Sediment Available at Time Step "i"} = (EI)(K)(LS)(C)(P) \frac{Q_i}{Q_T}$$

where EI = rainfall factor for the event

K = soil erodibility factor

L = dimensionless slope-length factor

S = slope steepness factor

C = cropping and management factor

P = practices factor

Q_i = runoff discharge at time step "i"

Q_T = total runoff discharge (ΣQ_i)

According to this equation sediment becomes available for transport in proportion to the runoff discharge. Included in the total sediment available for transport is the suspended sediment in storage. This sediment, which was transported into the watershed unit in the previous time steps from upstream units, is assumed to move as a sediment wave front. The velocity of this sediment wave front is assumed to be equal to the flow velocity. This assumption is reasonable for the relatively small sediment concentrations and the fine sediment size used in the study. The sediment supplied to channels from plane units is treated as lateral sediment inflow along the length of channel units, whereas the sediment supply from other watershed and channel units is treated as upstream boundary inflow. For each channel unit the number of units contributing to the sediment supply (lateral and upstream) is limited to nine by the sizes of arrays used in the model.

In the routing procedure at each time step, sediment transport capacities and the amount of sediment available for transport is computed. If sediment transport capacity is smaller than the available sediment, sediment leaving the unit is set equal to transport capacity. The excess available sediment is transferred back to storage for future time steps. If sediment transport capacity is greater than the available sediment the amount of sediment leaving the unit is limited to the available sediment.

4. APPLICATION OF LANDSCAPE SEDIMENT MODEL

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INTRODUCTION

This chapter describes the application of the HEC1WS computer model (see Section 3) to a section of the delta or bottomlands of the Yazoo River Basin in Mississippi. The subbasin used for this application is located in the Phillip Quadrat (33°45' to 34°00' N by 90°00' to 90°15' W) in Tallahatchie County (Figure 4.1). The objectives of this application were to assess the practical aspects of using the model and the general reasonableness of model output and to evaluate the function of bottomland hardwoods in controlling sediment flux from the landscape. To address these objectives, 14 computer runs were performed representing various proportions and spatial configurations of bottomland hardwoods in the landscape. Selected results from these runs are summarized here, followed by a discussion of model verification. More detailed model output is included as Appendix C.

PARAMETER ESTIMATION

Spatial data required by the simulation model were provided from a digital Geographic Information System (GIS) consisting of several data themes derived from a variety of original maps. The sources of original maps and the scheme for combining the resulting digital themes to provide input to the simulation model are summarized in Figure 4.2.

Maps of stream and water features and elevational contours (Figure 4.3) were used to delineate a series of hydrologic units consisting of channel units, plane units, and subwatershed units (subwatershed units being further divided into isochrone units as described in Chapter 3; i.e., Figure 3.2). These hydrologic units are depicted in Figure 4.4 for the test area of application. The hydrologic units are linked in a sequence, reflecting the elevational pattern of the landscape, that defines the flow of water among units (Figure 4.5).

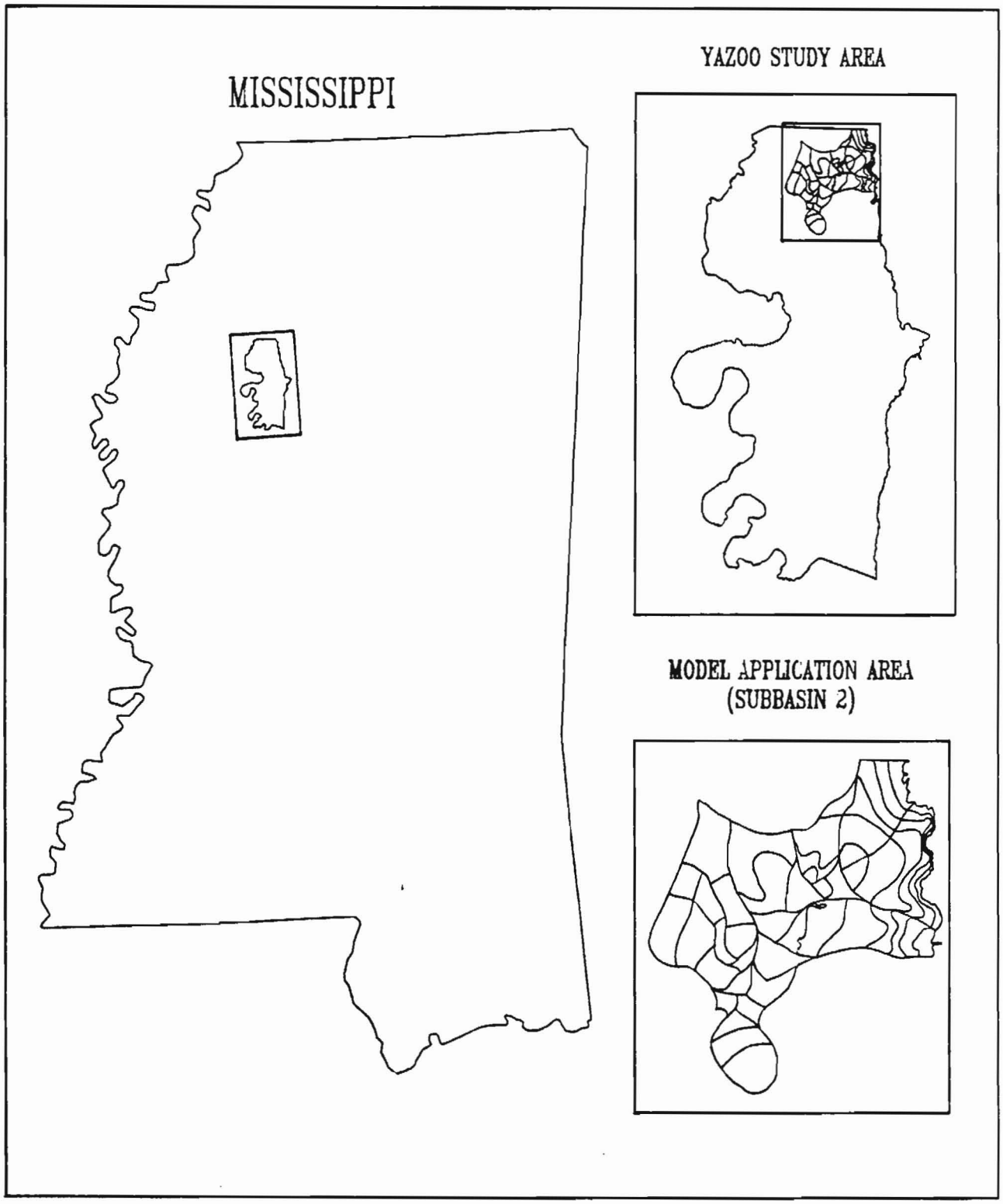

Figure 4.1. Location map of model application area.

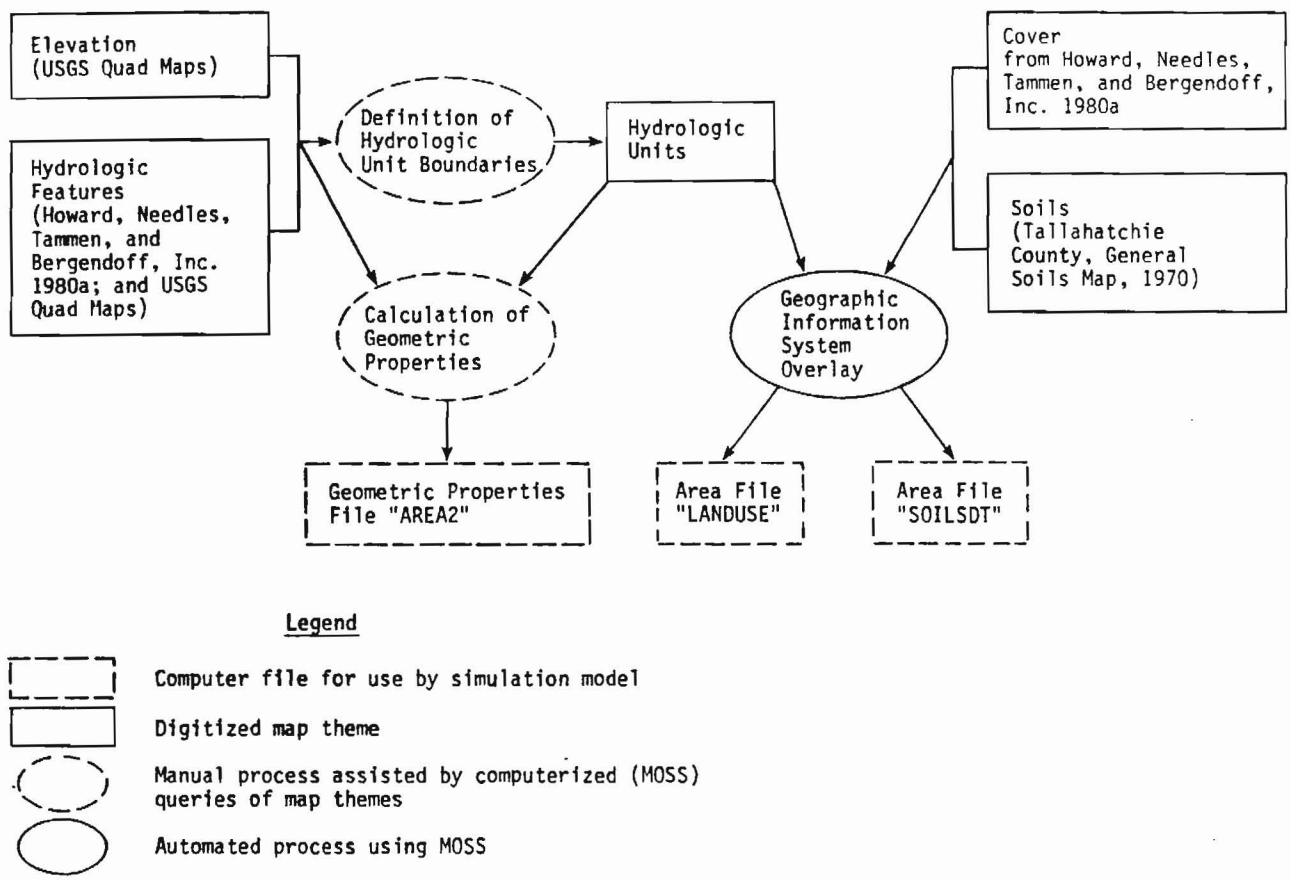

Figure 4.2. Diagram of relationship of map themes to data input required by simulation model.

Two numbering systems are used: a GIS identification number and a computational identification number. Both are indicated on Figure 4.5. The GIS identification numbers are used in files linking the GIS and simulation model. In the computational unit numbering system, channel units are numbered starting from the downstream end of the basin and moving upstream. Channels connecting to the main stem are included in the numbering process. Plane units contributing flows to channel units are numbered starting from the downstream end of the basin and following the same route as channel units. Subwatershed units are connected to the system where appropriate, and numbered sequentially starting from the downstream end of the basin. Where subwatershed units are further subdivided into isochrones only the bottom most isochrone is illustrated on Figure 4.3. The collection of all units except channel units (i.e., plane, subwatershed, and isochrones within subwatersheds) are referred to as landscape units. Many results are reported and plotted for landscape units as a group, considering the channel units as the "sink" for output from the landscape. The relationships between the numbering systems are detailed in Appendix B.

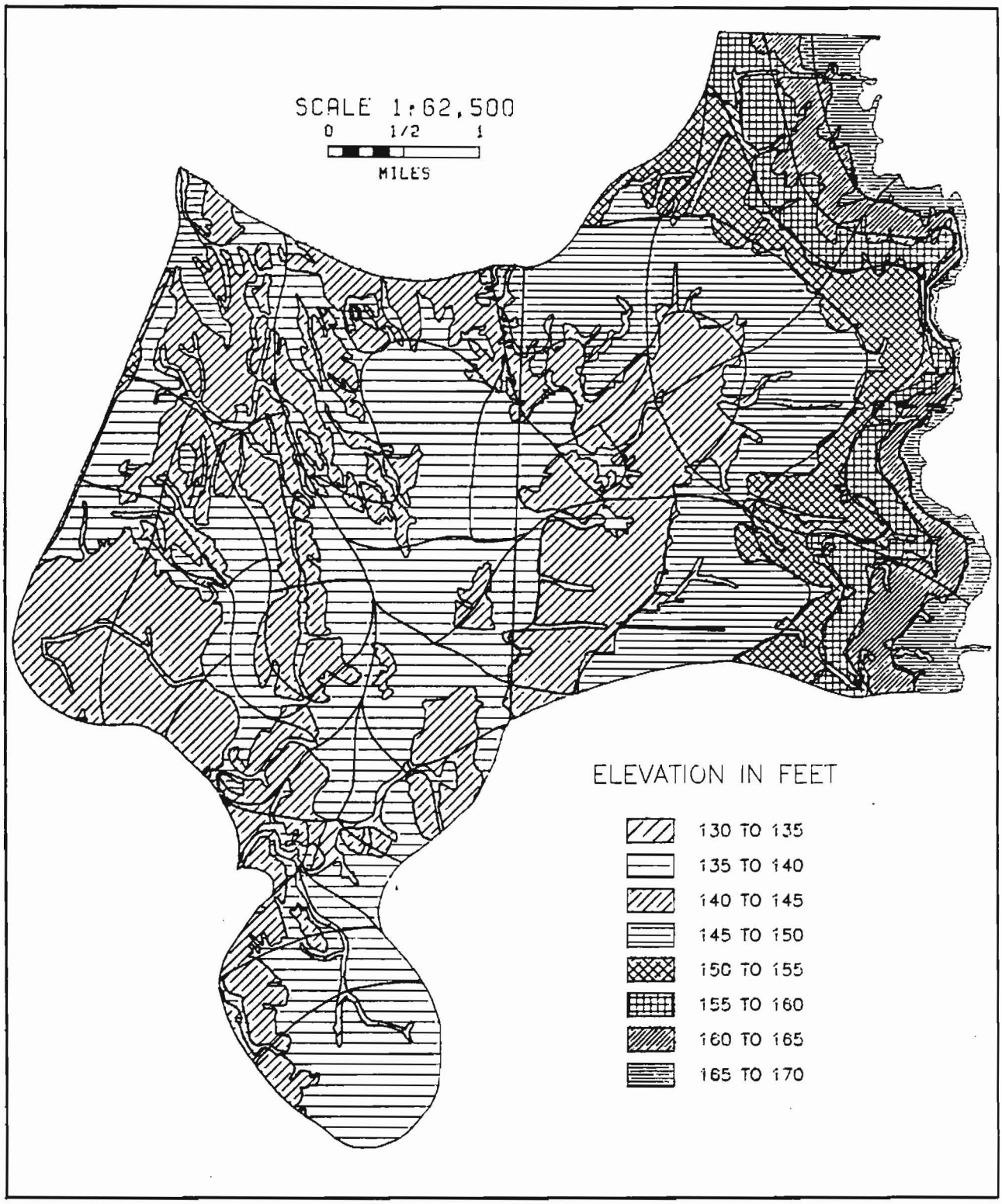

Figure 4.3. Elevation for application area.

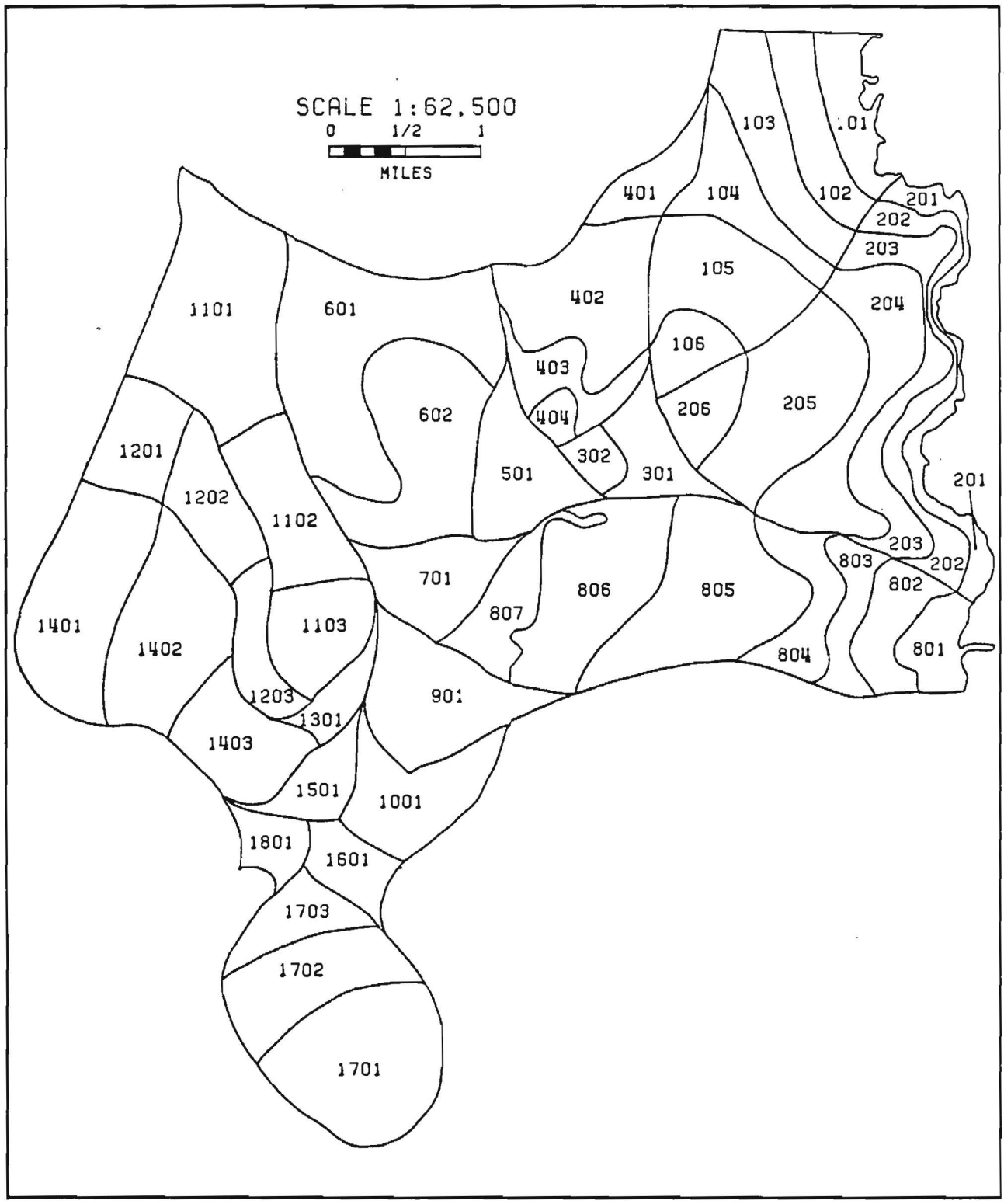

Figure 4.4. Map of landscape hydrologic units used in model application. Refer to Appendix B for more detail on numbering system.

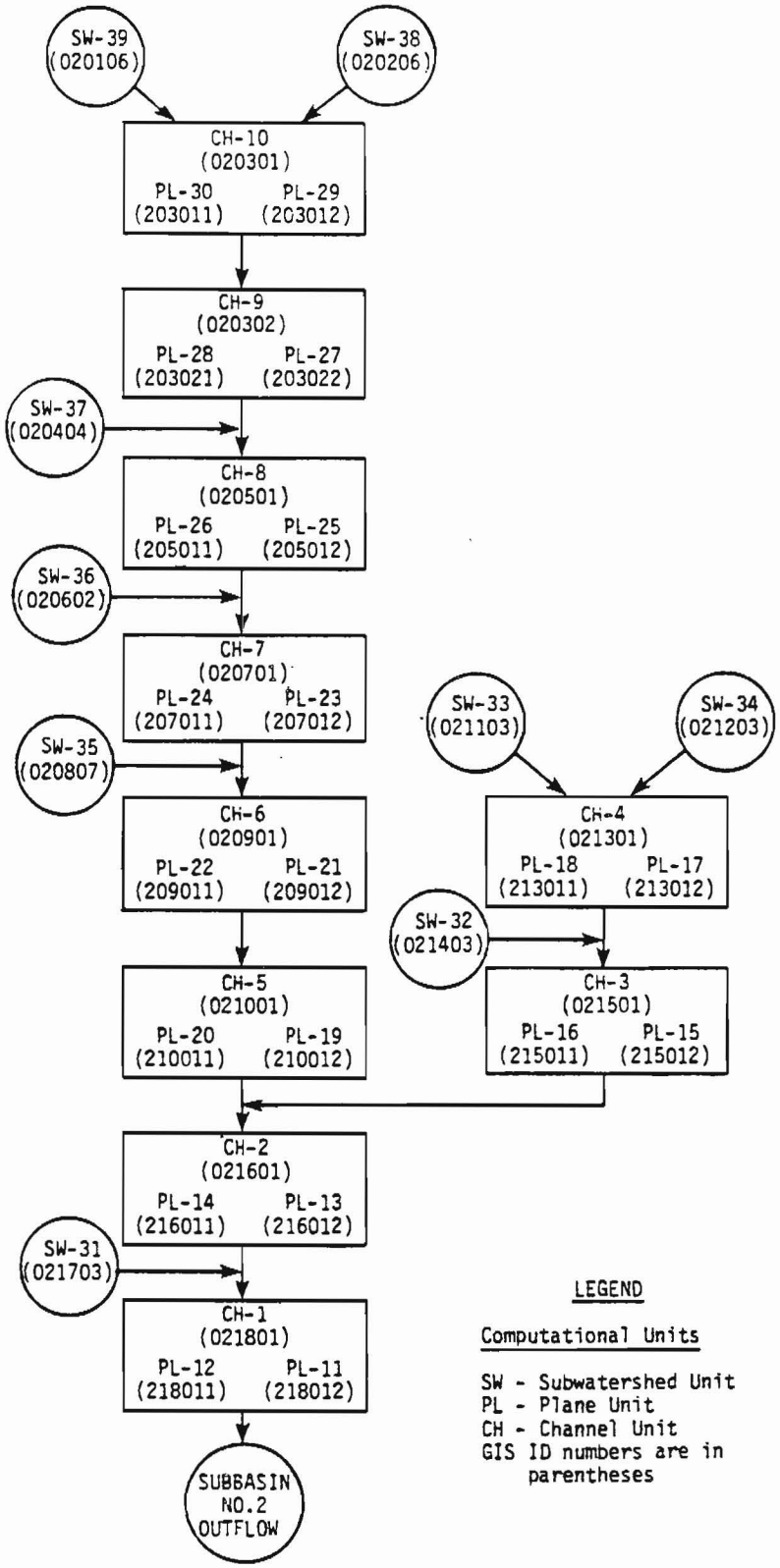

Figure 4.5. Linkage diagram for various hydrologic units in application area.

The hydrologic unit theme is overlain on the themes of cover (Figure 4.6) and soils (Figure 4.7) within the GIS to produce the data files LANDUSE and SOILSDT, which consist of areas of various cover and soil types, respectively, by hydrologic unit. Coefficients for each soil and cover type used by the programs CURVENO and USLEPAR to calculate area-weighted hydrologic and USLE (Universal Soil Loss Equation) parameters for each hydrologic unit are contained in Appendix B. The program USLEPAR also utilizes a data file, AREA2, which contains data on the geometric properties of the hydrologic units.

The cover types (e.g., Figure 4.6) were taken directly from the classification of six types (Agricultural, Cleared Basins and Flats, Open Water, Urban, Bottomland Hardwoods, Woody or Shrub Swamp, and Woody Basins and Flats) used by Howard, Needles, Tammen, and Bergendoff, Inc. (1980a). Parameter values generally consistent with agricultural cover were used for both the Agricultural and Cleared Basins and Flats types, whereas values consistent with forested cover were used for the Bottomland Hardwoods, Woody or Shrub Swamp, and Woody Basins and Flats (Appendix B). This assignment of parameter values demonstrates the capability of the model for treating multiple cover types. However, in a general sense, all the forested types might reasonably be considered "bottomland hardwoods" as both the Agricultural and Cleared Basins and Flats might be considered "agricultural." In the absence of more accurate parameterization and validation studies, results from the model should not be viewed as numerically accurate, but rather indicative of general patterns.

All the runs presented here reflect the response to a standard rainfall event. This synthetic 2-hour rainfall event was constructed based on U.S. Weather Bureau maps and has a total volume of 2.55 inches, an event with a recurrence interval of roughly 2 years. The rainfall sequence for the event is depicted in Figure 4.8. The parameter EI for the storm used in the modification of the USLE is 85.6. This measure of the storm's total erosivity is partitioned into the individual time increments of the total runoff event according to the runoff hydrograph as described in Chapter 3.

MODEL OUTPUT

Nominal Run

Output from the nominal (RUN 1) case is described here in some detail, followed by the results of varying proportions of bottomland hardwoods in the landscape. Conditions for RUN 1 consist of the cover types portrayed in Figure 4.6 and the precipitation event of Figure 4.8. Appendix C contains a detailed summary of the net sediment gain/loss for this event by hydrologic unit with the different types of hydrologic units separated and identified. Figure 4.9 portrays the pattern of sediment loss-gain in the landscape on a unit area basis for the landscape units (plane and watershed units including the individual isochrones, but excluding channel units). Plane units have been averaged on either side of the channel for display in Figure 4.9.

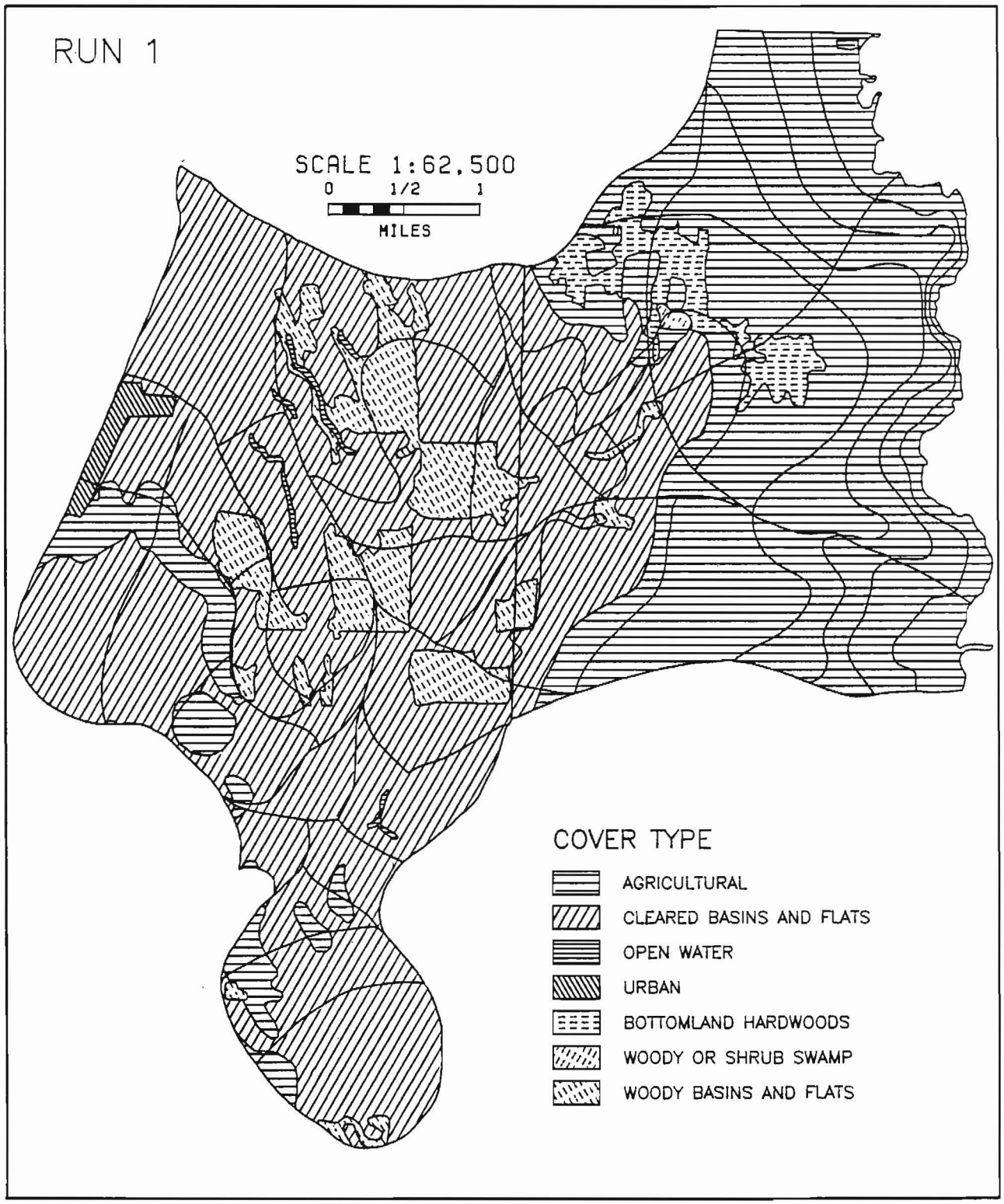

Figure 4.6. Map of cover types used in nominal run (RUN 1).

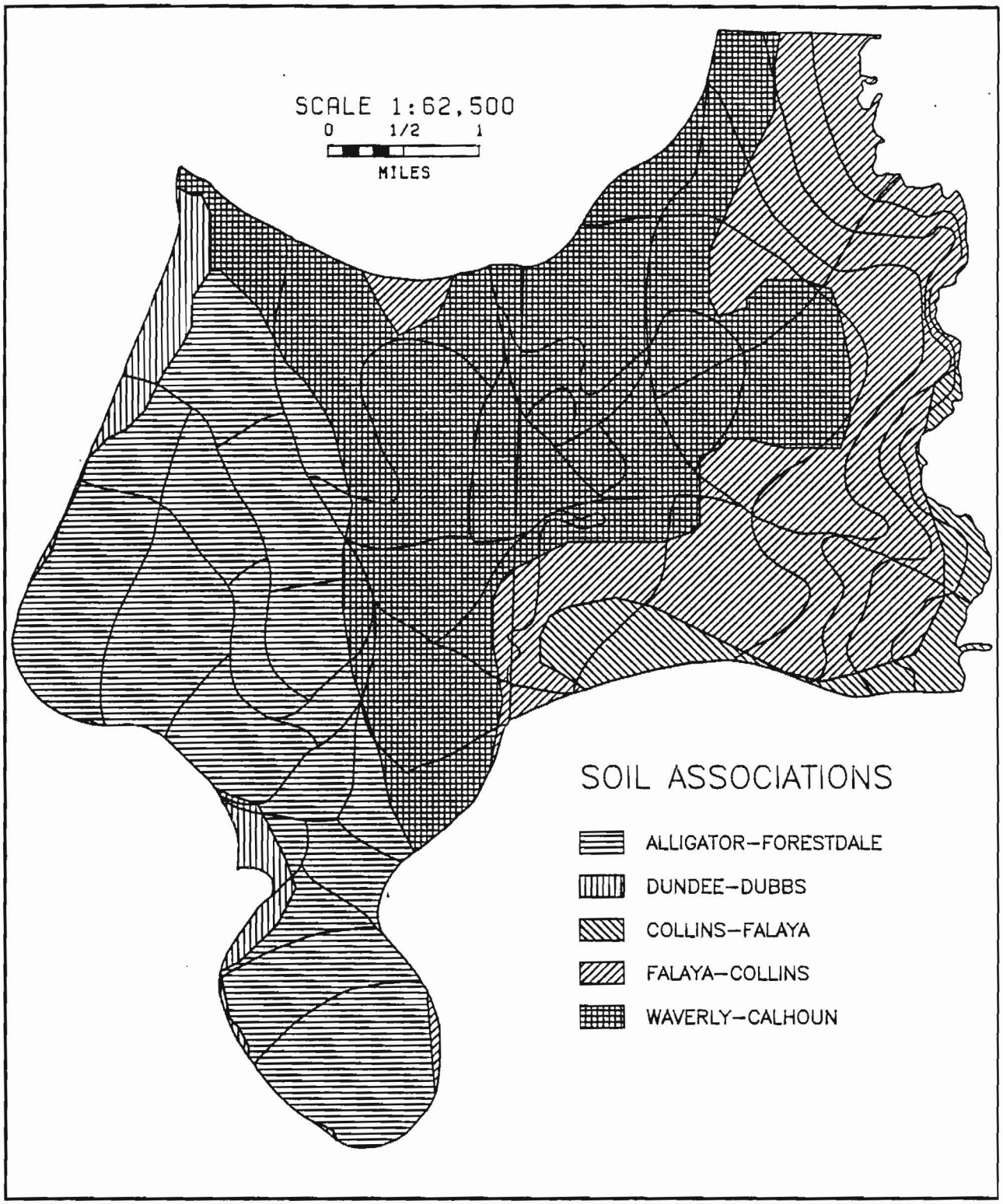

Figure 4.7. Map of soils used in all runs.

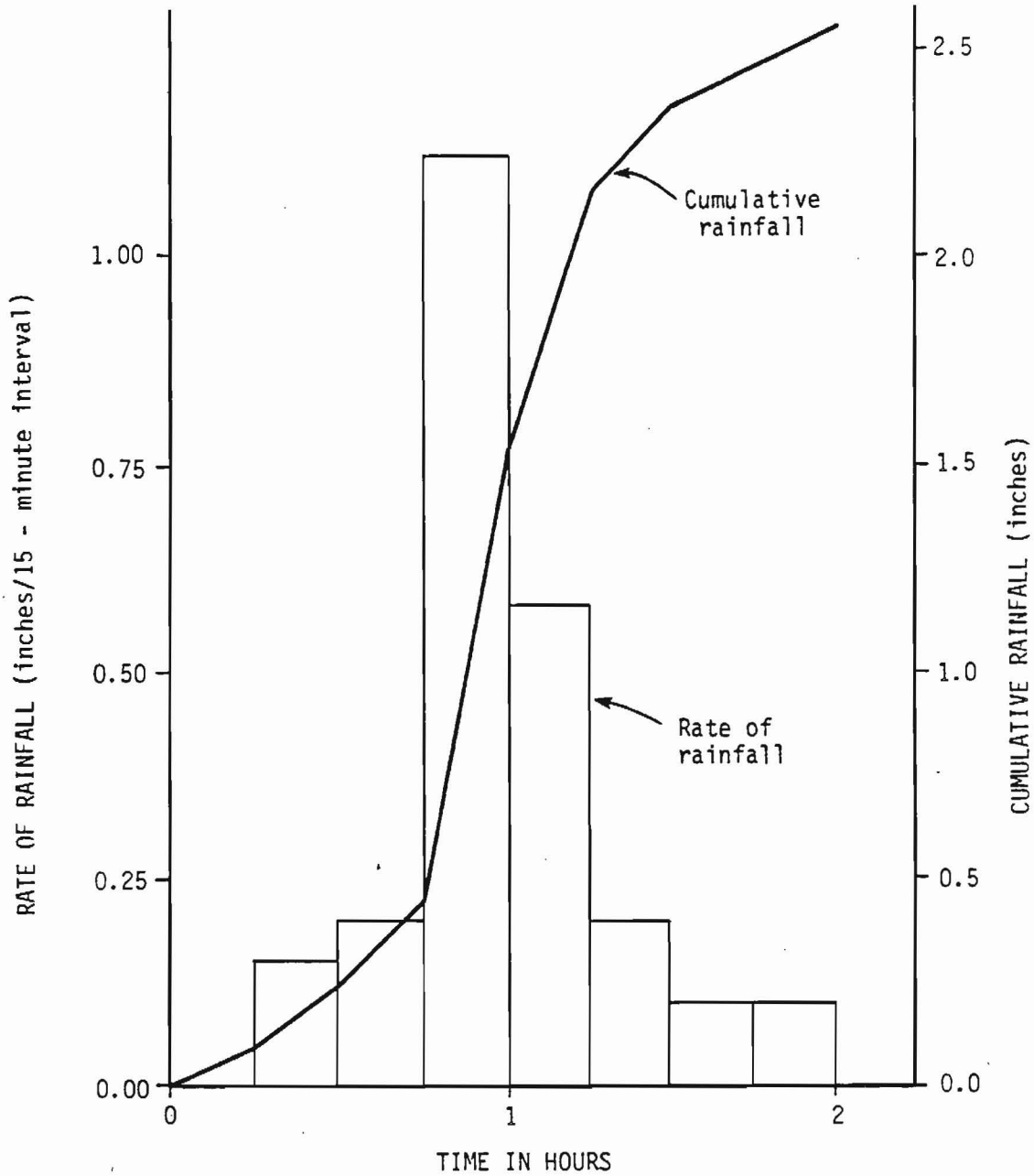

Figure 4.8. Synthetic storm event used for all runs.

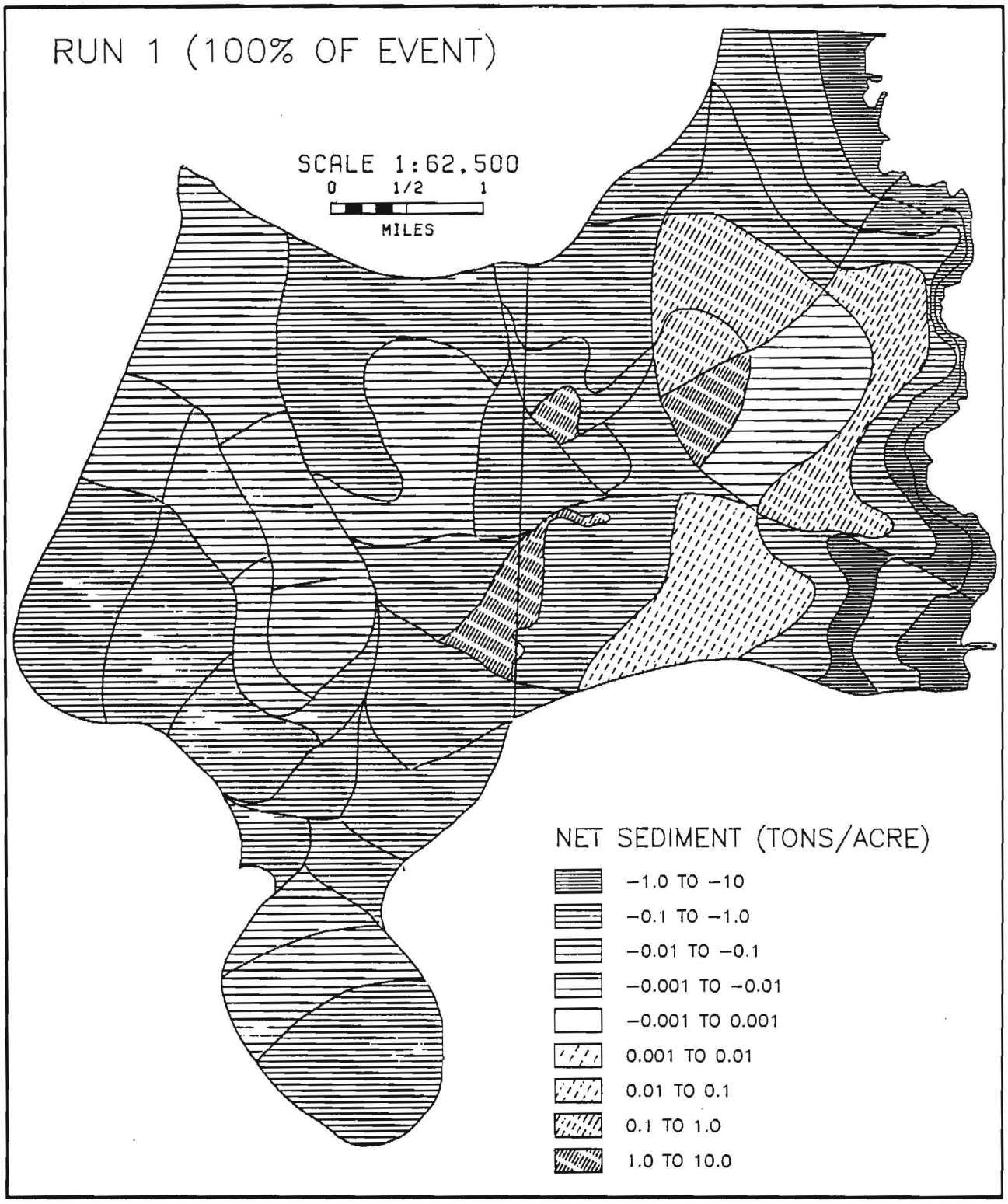

Figure 4.9. Map of sediment loss-gain from landscape units for RUN 1 (100% of event).

Average total overland loss for the whole landscape area for RUN 1 is approximately 2,242 tons or 0.15 tons/acre. This total loss from the landscape is composed of fractions deposited in channel units (1,612 tons or 72%) and discharged from the area as the outflow (630 tons or 28%) from the bottom channel unit (GIS ID 021801). The temporal distribution of sediment discharge from the total area at the bottom channel unit is depicted in Figure 4.10 for RUN 1.

The overland sediment loss is itself a net value and shows wide variation within the landscape, with higher isochrone units experiencing 1.2-1.3 tons/acre loss and lower isochrone units experiencing 1-3 tons/acre of deposition (RUN 1 - 100% table in Appendix C). Figure 4.11 portrays the dynamics of total sediment loss-gain from landscape units during this event by breaking the 9-hour runoff event down into 10% intervals. Figures 4.12, 4.13, 4.14, and 4.15 illustrate the spatial pattern of sediment loss-gain for landscape units at the 10%, 20%, 30%, and 60% intervals, respectively. Output tables listing results from all units (including channel units) for these intervals are given in Appendix C.

The average value of overland sediment erosion of 0.15 tons/acre in RUN 1 is for a storm event with an erosion index (EI) of 85.6. The observed 22-year range for yearly erosion index (EI) for the Mississippi Meridian is 216-820 with 416 being the 50% probability value (Wischmeier and Smith 1978). Based on the observed range of erosion index values, the range of crudely extrapolated overland sediment erosion for the area modeled is 0.4-1.5 tons/acre/year. Note that this represents a value for sediment delivered to the defined channel network by overland flow from the landscape units.

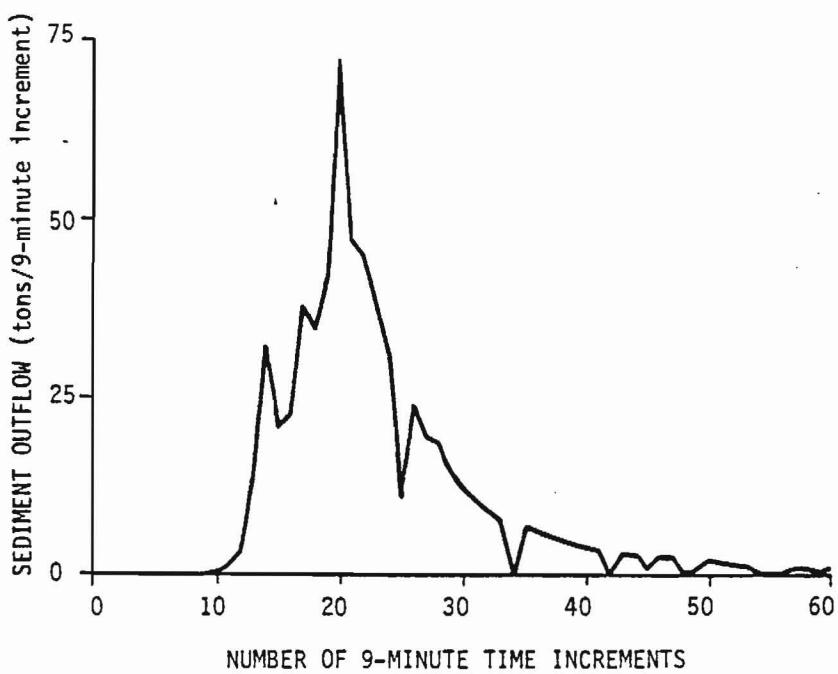

Figure 4.10. Dynamics of sediment discharge from bottom channel unit for RUN 1. Points represent 9 minute intervals throughout event.

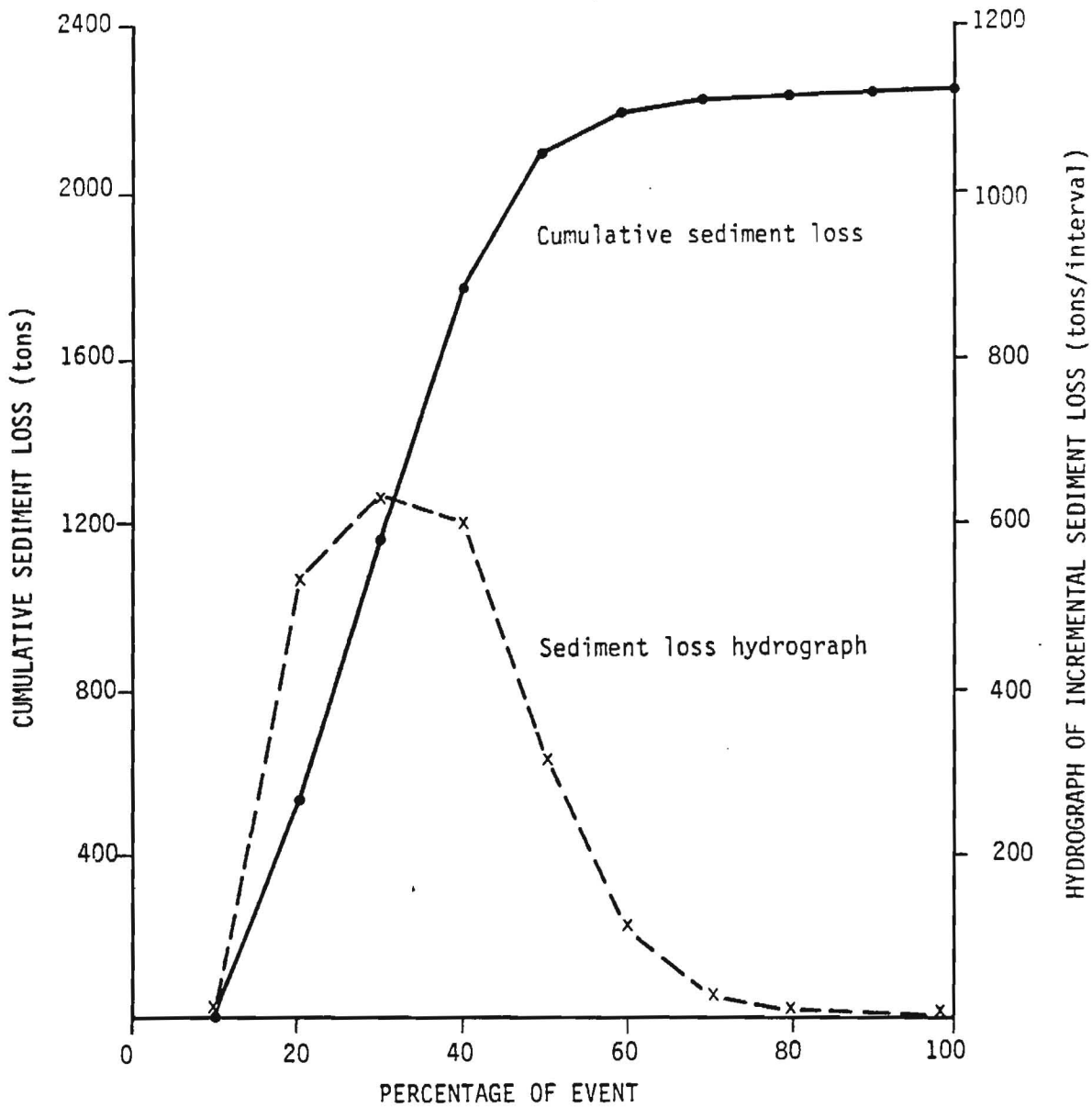

Figure 4.11. Dynamics of net sediment loss from landscape units for RUN 1. Plotted points in sediment loss hydrograph represent preceding intervals of 10% of event.

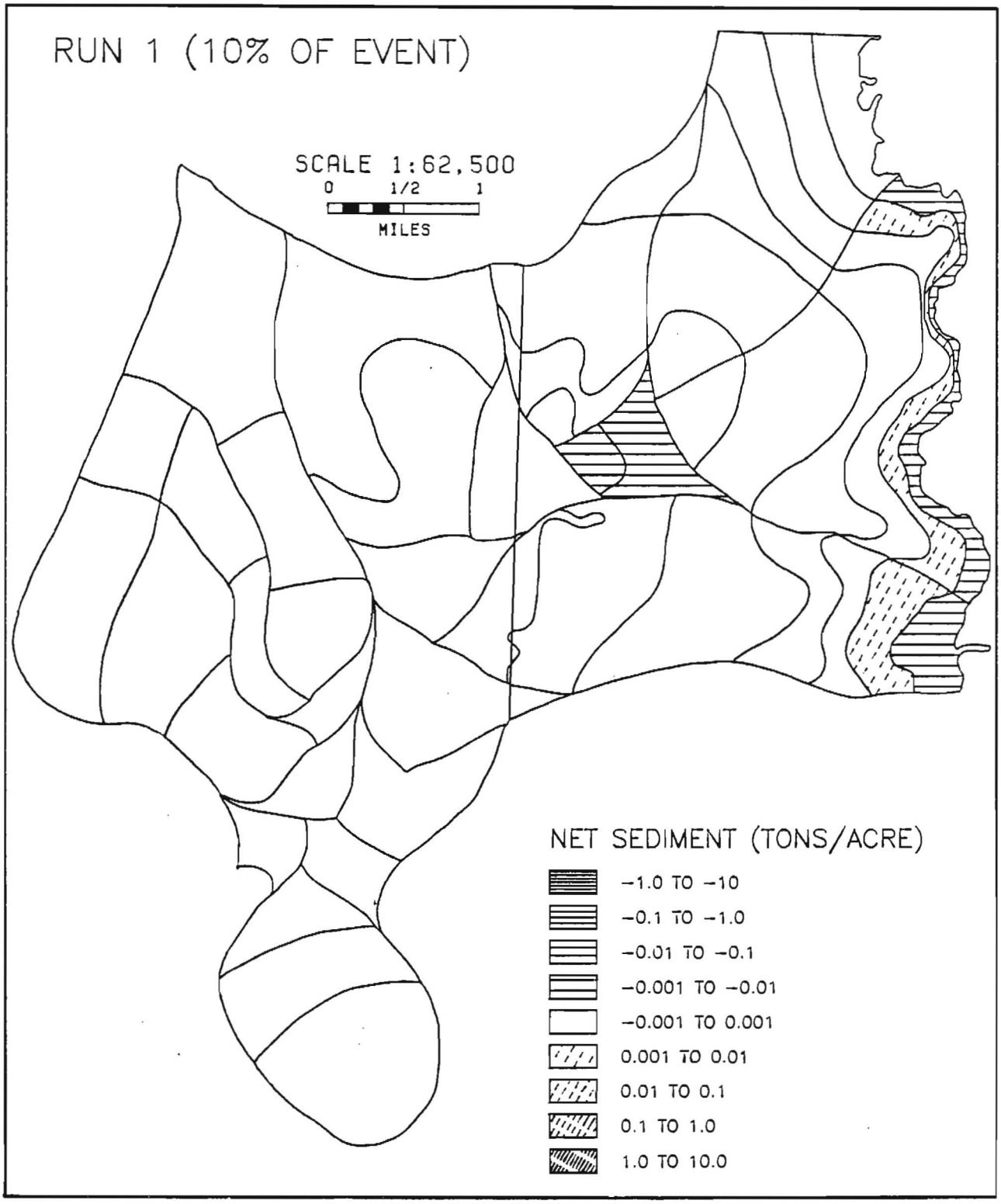

Figure 4.12. Map of sediment loss-gain from landscape units for RUN 1 (10% of event).

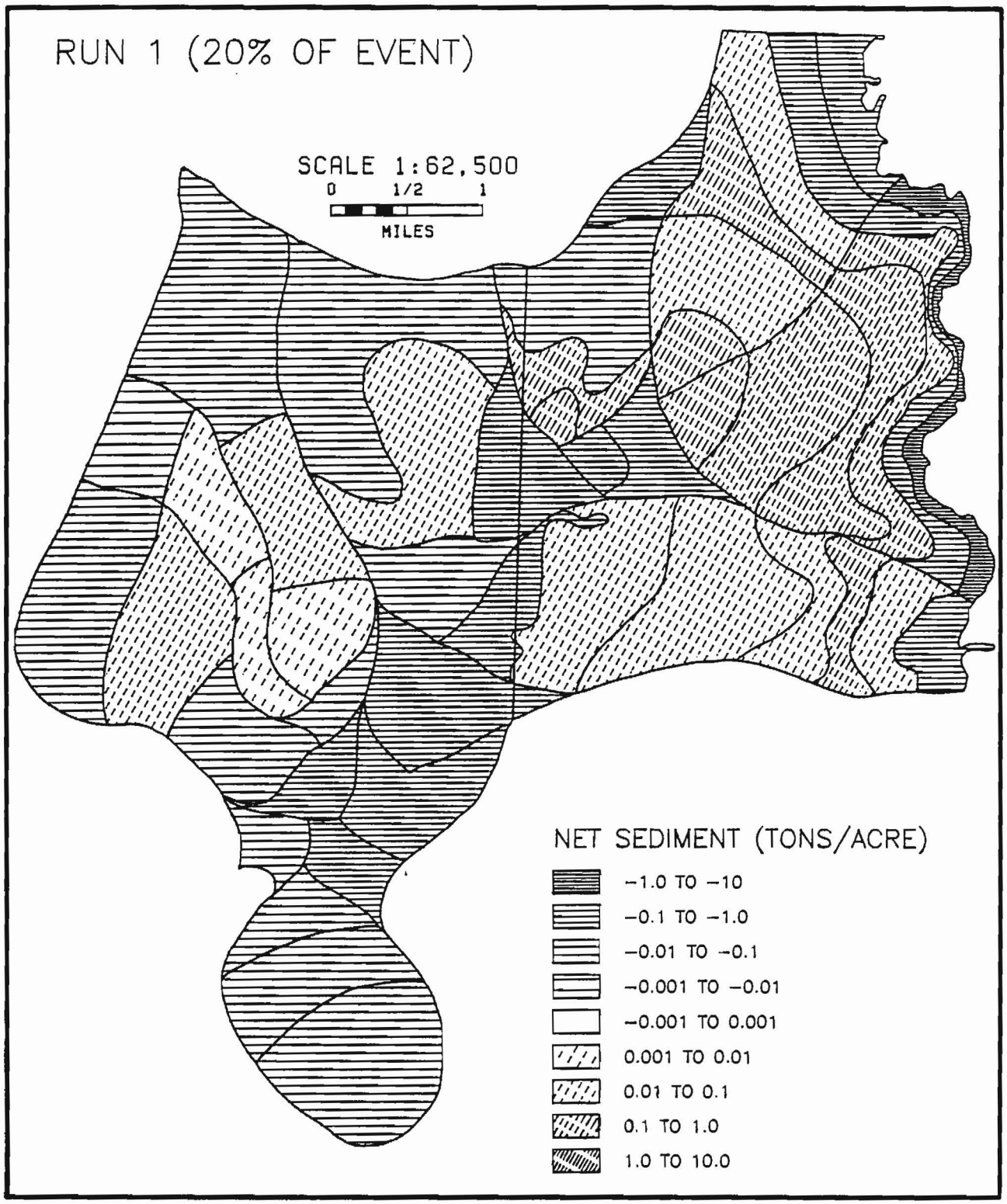

Figure 4.13. Map of sediment loss-gain from landscape units for RUN 1 (20% of event).

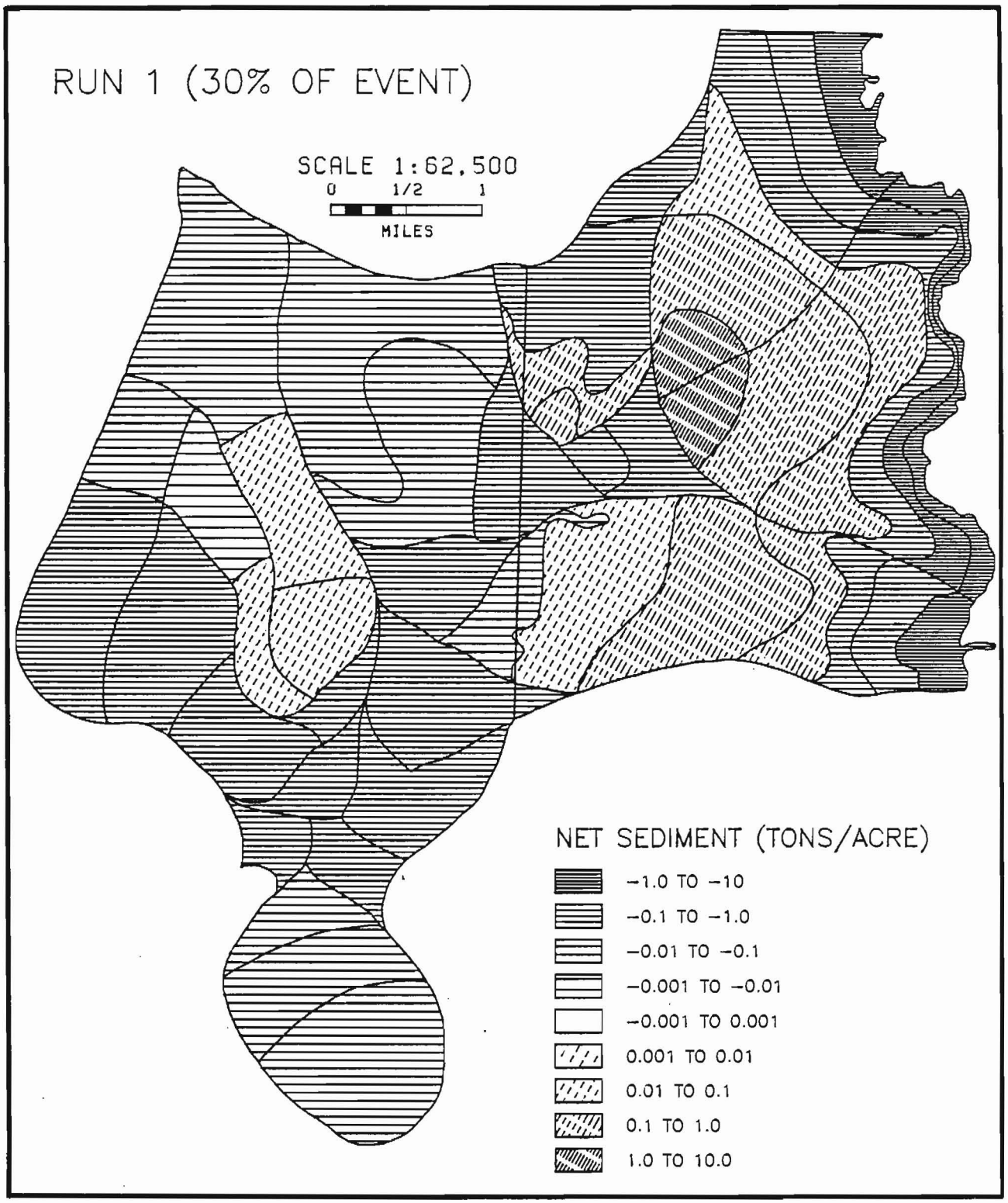

Figure 4.14. Map of sediment loss-gain from landscape units for RUN 1 (30% of event).

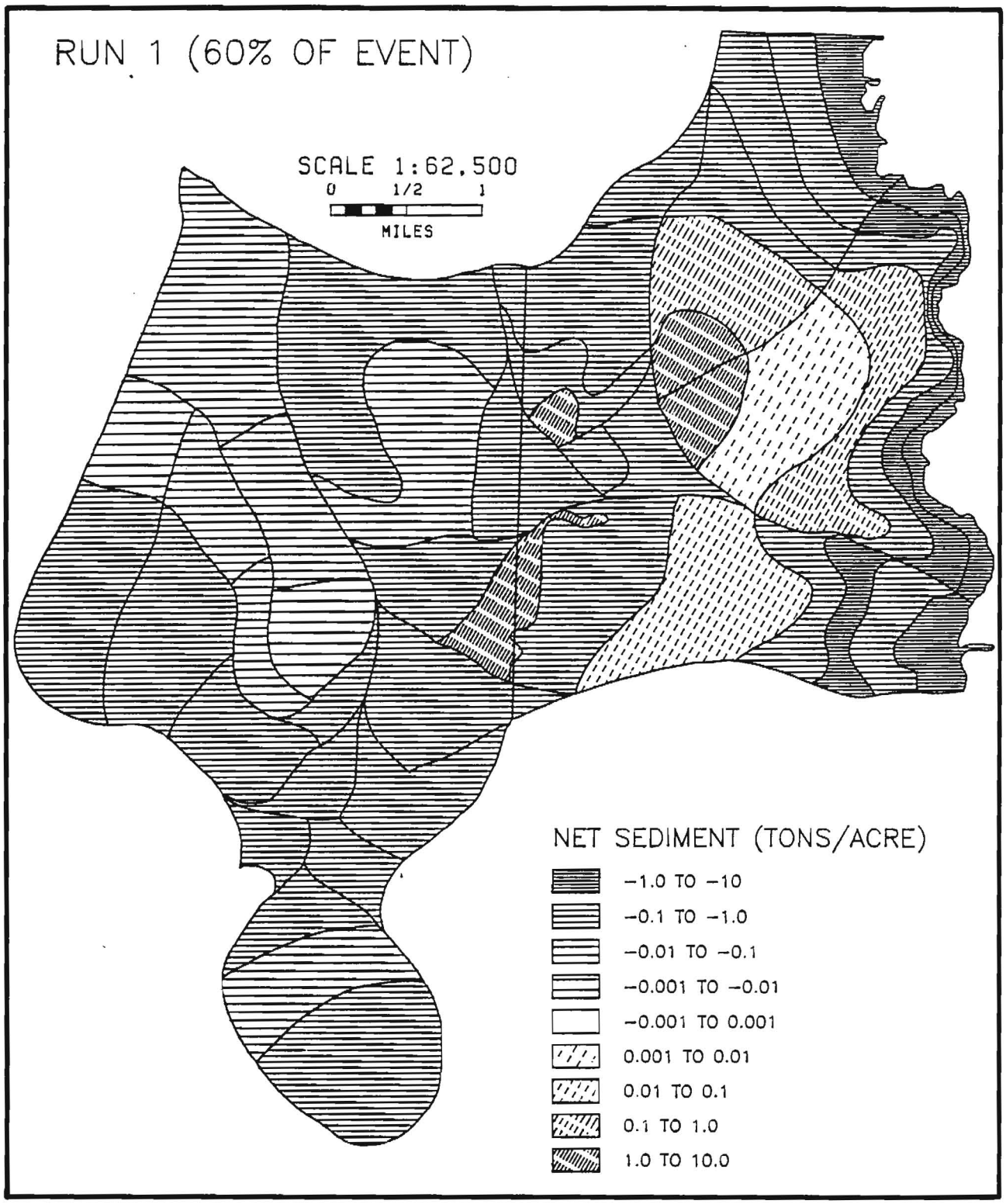

Figure 4.15. Map of sediment loss-gain from landscape units for RUN 1 (60% of event).

Role of Bottomland Hardwoods

Table 4.1 summarizes a series of runs in which the proportions of bottomland hardwoods (BLH) in the landscape are varied. These changes were implemented by increasing the area of the Bottomland Hardwoods cover type (Figure 4.6). As noted in the earlier section concerning parameter estimation, other forested cover types might also be considered as bottomland hardwoods in a general sense and thus results from this preliminary model application should not be interpreted as numerically accurate predictions. Detailed output from these runs is contained in Appendix C. Figure 4.16 portrays the results of increasing the area of BLH by converting from other cover types on total sediment loss from the landscape units. The reduction in sediment loss is an estimate of this function of bottomland hardwoods both as a result of limiting sediment availability and as a result of sediment trapping.

Table 4.1. Summary of computer runs varying proportions of BLH.

Run no.	Total area in BLH (acres)	Percentage of area converted	Total landscape sediment loss per event (tons/event)	Average landscape sediment loss per event (tons/acre/event)
1	388	0	2,242	0.151
2	1,837	10	2,007	0.135
3	3,289	20	1,746	0.117
4	7,642	50	827	0.056
5	11,994	80	155	0.010
6	14,750	99	25	0.002

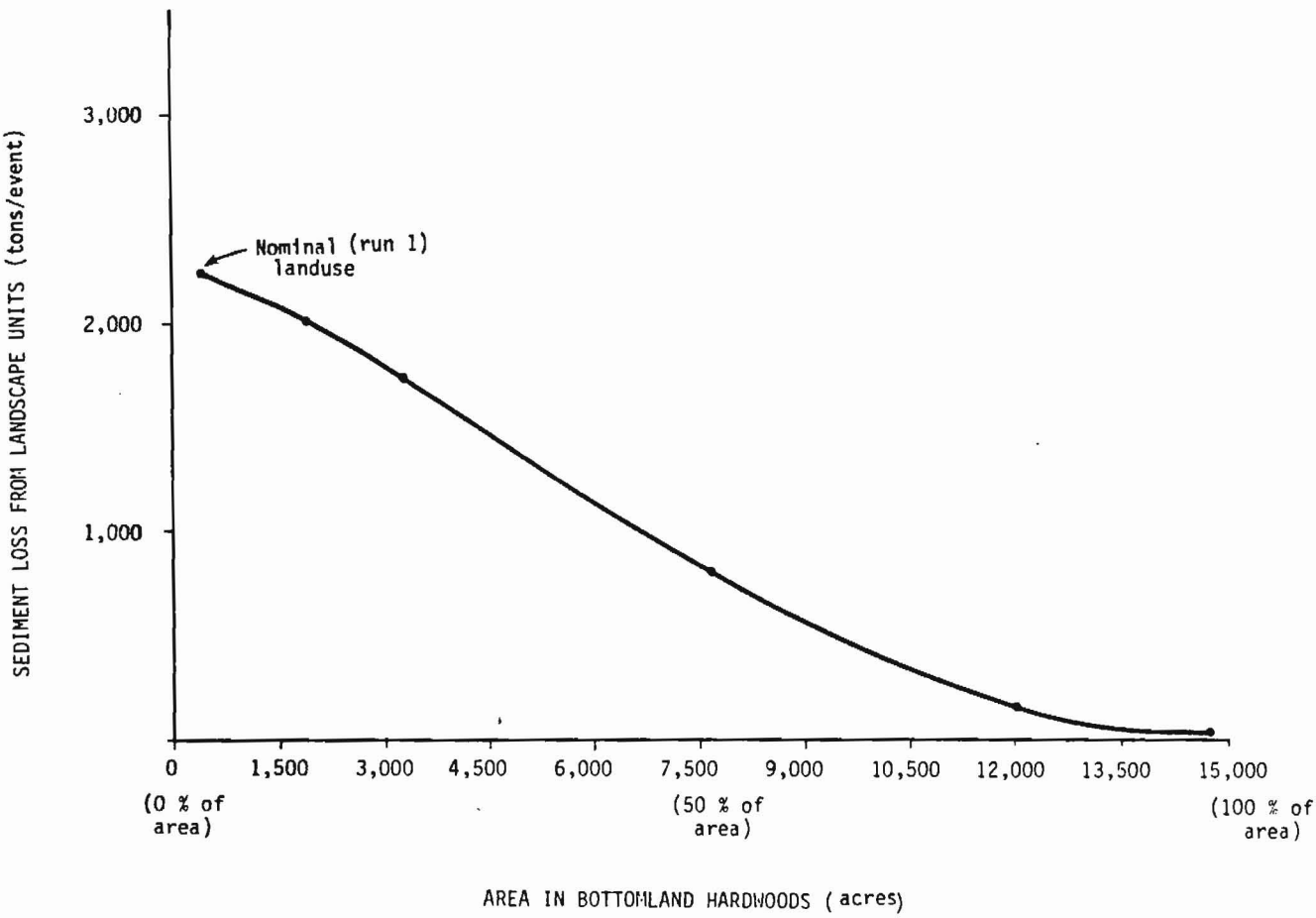

Figure 4.16. Total sediment loss from landscape units as a function of varying proportions of BLH.

Computer RUNS 2 through 6 show the effects of proportional conversion of nominal landuse to the Bottomland Hardwoods cover type from all other cover types. In these runs, the nominal cover types in all watershed computational units have been proportionally converted to BLH by 10, 20, 50, 80, and 99 percent of total area in other cover types. Increasing the total BLH area proportionally across the entire subbasin results in substantial reduction in the overland sediment loss as shown in Figure 4.16. The spatial pattern of sediment loss-gain from landscape units for RUN 6 (essentially complete conversion of the area to BLH) is depicted in Figure 4.17.

Verification. The results generated by the computational algorithms developed for watershed sediment routing were verified at several levels.

1. Input data file generation programs CURVENO and USLEPAR were checked for accuracy in their landuse conversion and the corresponding roughness, curve number, and USLE parameter interpolation computations. Some minor changes to the original versions of CURVENO and USLEPAR programs were made in order to accommodate landuse conversions directly, without extensive use of the MOSS cartographic system. These modifications were checked and corrected throughout by comparisons with hand computations.

2. The HECUPD program to update the U.S. Army Corps of Engineers' HEC-1 program input data file to reflect the changes in various landuse scenarios was checked by hand computations for accuracy.

3. The computational schemes used in the watershed sediment routing program HEC1WS developed for this study were extensively checked by hand calculations. The program was expanded for generating summary tables and for computing net sediment discharges from each hydrologic unit used in the simulation. Some minor errors in the array conversions in channel routing component were found and corrected. The final results were checked manually for satisfying sediment continuity. For the nominal (RUN 1) run the total basin outflow at unit 021801 was computed to be 3,224,569 lbs (see Summary Table for Run No. 1 in Appendix C). The sum of channel sediment deposition and the sediment leaving the application area is 4,483,613 lbs (2241.8 tons). This value is compared against the total sediment loss from the landscape units which is 4,483,609 lbs (2,242 tons). The difference between the two values is only 4 lbs or 0.00009%.

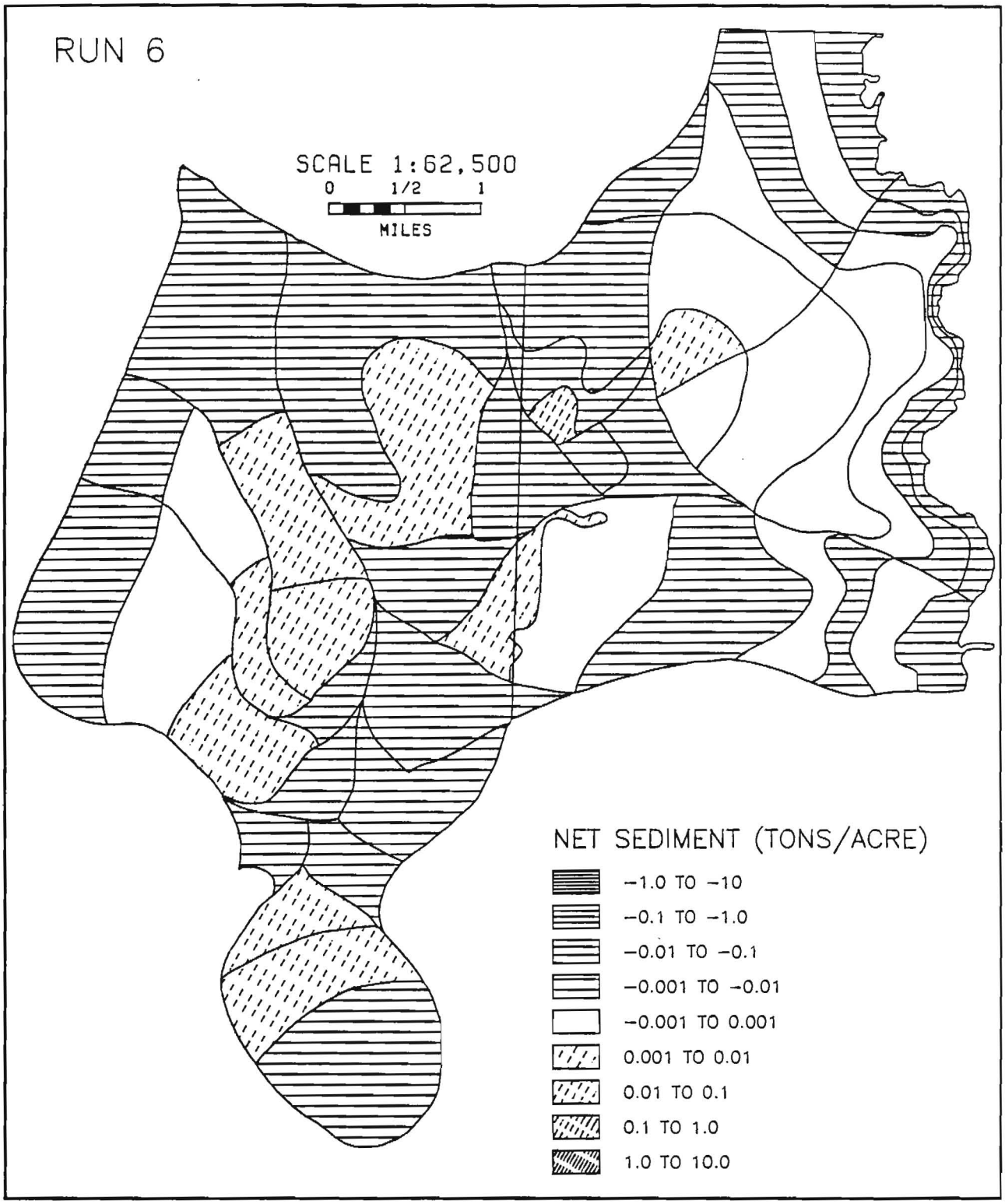

Figure 4.17. Map of sediment loss-gain from landscape units for RUN 6 (essentially all BLH).

5. DISCUSSION

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LANDSCAPE MODEL

Results and Significance

The landscape model, HECWS1, meets the following objectives.

1. Estimate the importance of bottomland hardwoods as a cover type that performs the functions of erosion and sediment control in bottomland systems, focusing on an area representative of the Yazoo Basin in Mississippi.

2. Simulate effects of proportions or total areas in different cover types as well as specific spatial configurations.

3. Simulate spatial patterns of sediment loss-gain over time.

4. Link algorithms for both detachment and transport to represent both the erosion control (limitation of detachment) and sediment control (filtering or trapping function resulting from incoming sediment loads in excess of transport capacity) aspects of the functioning of bottomland hardwoods.

5. Be applicable to medium-large spatial areas with minimal site-specific calibration required to estimate necessary parameters.

The series of runs in which the proportion of bottomland hardwoods is changed produces a quantitative estimate of the role of bottomland hardwoods in water quality improvement in the overland runoff mode. This estimate represents a reduction in sediment loss from the landscape to the channel

system of almost two orders of magnitude, resulting from a potential conversion of essentially all the landscape to bottomland hardwoods (summarized in Figure 4.16). Several factors (e.g., one event to many events, the particular proportions and patterns of nominal cover types, variations in topography, and the likely existence of other defined cover types in a natural floodplain) limit the ability to extrapolate these results. Nonetheless, a crude extrapolation provides some idea of the relative magnitude of this function of bottomland hardwoods. Extrapolating from the single event of the study area (RUN 1) to an annual range based on the 22-year range of Erosivity Index values and to the roughly 6,600 square mile Delta portion of the basin yields a range of approximately 1.6 to 6.1 million tons of sediment loss per year from the Delta landscape to the channel system for the nominal cover condition, compared to 0.02 to 0.08 million tons per year for the cover condition of essentially all bottomland hardwoods. These numbers are significant, although not dominant, compared to the roughly 20 million tons per year of gross erosion estimated to occur in the uplands (see Chapter 1).

Limitations

Scope. The landscape model focuses on the overland flow mode of sediment movement, although some channel routing is incorporated. This preliminary analysis is restricted to a single representative precipitation event. Although this model supports a significant analysis of the relationship between bottomland hardwoods and the sediment component of water quality, several aspects are not represented. A complete model would simulate all the modes of channel, overbank flooding, and overland runoff as they occur over time over the full area of the basin. This is not a viable possibility in any detail for such large areas, given the current state-of-the-art and the tremendous amount of data required. Nonetheless, the scope of HEC1WS could be reasonably extended by treating larger areas, by breaking each area into a larger number of cropland subunits, and by simulating a sequence of precipitation events.

Ease of Use

The landscape model is currently a development version and has several aspects that need to be refined to make it more useable. Several data files are generated manually (e.g., definition of representative length for hydrologic units in the geometric properties file). The definition and linkage of hydrologic units is also left to the user. The computerized geographic information system is used to assist these procedures by generating lengths between specified points and by displaying elevational and stream features; however, the units are not defined automatically by a general algorithm.

The computerized cartographic system, MOSS, is currently running on a minicomputer; whereas the simulation model, HEC1WS, was used on a large mainframe. Linkages between the two (MOSS output files serving as input files for HEC1WS, and HEC1WS output files serving as input files for spatial display of output by MOSS) require some manual transfer and reformatting. These linkages could be streamlined, especially if the whole system were transferred to a single machine. Finally, the whole system is not documented for an end user, although substantial documentation is available for specific elements (e.g., MOSS and HEC1).

Verification and Validation

Verification and validation are the most critical current limitations of the landscape model. The model was designed to minimize requirements for highly site-specific parameterization based on adjusting or "tuning" coefficients to observed data. Verification activities have been restricted to qualitative judgements and comparisons, and to sediment continuity checking (see Chapter 4). A series of validation applications needs to be conducted on the model, as described in the concluding section of this chapter.

POTENTIAL MITIGATIVE ACTIONS

The Yazoo Basin has severe and complex water quality problems including very high levels of sediment. Measures that might improve this situation with respect to sediment fall into the two broad classes of erosion control (i.e., source control) and sediment control (i.e., managing the transport or deposition of sediment once it has been detached). The functioning of all the potential erosion and sediment control measures can be understood in terms of modifying the factors influencing the processes of detachment, transport, and deposition in the three modes of sediment movement (channel, overland runoff, and overbank flooding) described in Section 2.

A large part of the sediment problems in the bottomland or Delta of the Yazoo Basin originate in the uplands. The loading of sediment to the Delta from the uplands has been reduced as land use patterns have shifted from agriculture to forestry in the uplands. As long as upland sediment loading remains high, however, there will continue to be sediment and water quality problems in the Delta.

There are four major reservoirs that intercept and modify a large percentage of the flow passing from the uplands to the Delta. These reservoirs serve as sediment traps. The water released from the dams is relatively clear. As a consequence, reaches immediately downstream of the dams have been subjected to degradation, and then redeposition occurs further downstream. This sequence of degradation followed by aggradation has required extensive dredging and channelization in an attempt to mitigate the associated hydraulic problems. Additional problems are caused by the development of agriculture along the channels; these are related to application of water for supplemental irrigation, increasing high water tables, and significant increases in the instability of the banks.

In order to mitigate the numerous and complex problems in the basin, it is essential to bring the supply of sediment from the uplands under control. To some degree, the four reservoirs accomplish part of the job; however, all uncontrolled tributaries flowing from the upland area should be analyzed. In order to control the sediment from these sources, it would be necessary to study the stability of the streams and the supply of sediment to determine how to bring these streams into some form of equilibrium compatible with their multiple uses.

Having brought the supply of sediment from the uplands under control, the next step would be to look in detail at the numerous streams flowing through the delta. In this regard, it would be essential to identify the prinicipal channels and investigate their geomorphological and hydraulic characteristics, then modify the system to provide more stability (in terms of water and sediment transport) than presently exists. Specifically, the degradation occurring downstream of major dams should be controlled. This may require the flattening of the gradient by structural means or by changing the alignment of the river. The modified system would have the present sediment loads reduced to where most of the sediments could be conveyed in balance. Because the stream profiles of the major tributaries would be changed, it would be essential to consider impacts of these changes on the base level of tributaries. Controls at the mouths of such tributaries may be required in order to prevent erosion through the system yielding unwanted sediments.

Specific mitigative measures that might be taken in the uplands are numerous (e.g., structural and nonstructural bank stabilization, grade control structures, detention areas, and best management practices for agriculture, forestry, and construction) and are described in a number of sources (e.g., Christensen and Wilson 1976; Keown et al. 1977; Goldman et al. 1986). A number of streambank demonstration projects in the Yazoo Basin are analyzed in U.S. Army Corps of Engineers (1978, Appendix G) and Keown and Dardeau (1978).

Assuming a certain level of sediment input from the uplands, what measures can be taken in the delta area to improve water quality with respect to sediment? In its natural configuration, the Delta would have little erosion because of the low slopes and forested cover and would function as a gigantic detention basin. The excess sediment load from the uplands would be deposited in alluvial fans near the bluff line or, in overbank flooding events, spread over large, rough areas with long detention times. The Yazoo Delta, however, is not in a natural configuration. Extensive hydrologic modifications have been and continue to be implemented, with the general objectives of constraining flows to channels, increasing velocities, and decreasing the detention of water on the floodplain. Thus, rather than meandering streams, natural levee deposition, and alluvial fan formation, the situation is one of increased transport capacity. Deposition is counteracted by dredging to maintain channel capacities. A commitment to a hydrologic system in the Delta that achieves some level of flood control and drainage improvement thus fundamentally constrains the potential function of the floodplain in sediment control.

Nonetheless, there is still considerable opportunity for improving the situation by actions within the Delta. The most obvious opportunities involve reducing the role of the Delta landscape as a source of sediment. The landscape model indicated that cover type, the presence of bottomland hardwoods in particular, has substantial effect on the sediment contributed from the Delta landscape. In addition to the importance of the broad scale pattern of cover type demonstrated by the model, localized measures and best management practices in agriculture, forestry, and construction (e.g., tillage practices, sediment traps, edge of field buffer strips, sediment dams) that limit the role of the Delta as a sediment source will improve the situation. This is

true regardless of whether these areas are allowed to function as sediment detention basins on a larger scale to trap channel borne sediment originating elsewhere in the basin.

Measures in the Delta beyond those designed to reduce sediment originating from the Delta--where the value of bottomland hardwoods is clear--generally require a compromise of objectives and efficiencies. There must be a tradeoff between objectives of reduced flooding and rapid drainage versus reduced velocities and deposition over broad areas, for example. An objective of reduced sediment transport from the basin as a whole may be achieved at the cost of low water quality in areas within the basin (e.g., wetlands being used as sediment detention basins). The analysis of Section 2 indicates that bottomland hardwoods can serve to reduce sediment output by functioning as sediment detention basins. Their value in this context, however, may not justify the lower water quality in the bottomland areas nor the long-term degradation as they fill in with sediment. An alternative strategy would be to protect the relatively small areas of wetlands in the Delta by routing sediment-laden water around them, thus maximizing water quality in localized patches while minimizing the opportunity of those patches to reduce the sediment transported downstream. This strategy, however, may cause additional impacts to the extent that hydrologic conditions (i.e., hydroperiod) are altered in the wetlands producting consequent shifts in vegetation and those other features of wetlands that are strongly influenced by soil saturation or inundations.

There are several strategies that represent compromises between the competing hydrologic, water quality, agricultural, and wetland values. Flooding in excess of the design capacity (chosen at a relatively short recurrence interval) of the channel system could be allowed to "overflow" in selected areas. These areas could be reforested to provide for agricultural flood protection outside the overflow area, allow some sediment control by the overflow area functioning as a detention basin, provide other values of bottomland hardwoods (e.g., wildlife habitat) in the overflow area, and potentially reduce costs of modifying and maintaining the channel system (if a smaller design capacity were required). Another hybrid strategy would be to impound or retain water on agricultural fields in the nongrowing season. This offers considerable potential wildlife benefits in terms of "winter water," might still allow agricultural production, and would provide some benefits of sediment detention. The feasibility and sediment benefits may be severely limited, however, because the times when sediment detention is most needed (e.g., spring) are also the times when agricultural flood protection and drainage are most needed.

Compromise channel designs also have potential for meeting multiple objectives. Wide forested floodways bordered by levees and having multitiered channel cross-sections would allow some of the area between the levees to provide both wildlife and water quality improvement (sediment trapping) functions, while also affording flood protection outside the levees and reasonable channel capacity.

FUTURE WORK

Several possibilities for future work are listed below. Clearly, the highest priority in terms of the landscape model is for validation applications. Improving the ease of use and streamlining linkages within the overall model system should probably be deferred until additional validation is completed and would be strongly dependent on the particular hardware environment of potential end users. The current implementation and documentation should be sufficient to support the applications required for validation.

1. Validation studies. Some data are available at the plot level for similar areas (e.g., Murphree et al. 1976; Dendy 1981), which could be used for limited validation. The bottomland hardwoods research site being established by the U.S. Army Corps of Engineers' Waterways Experiment Station may be an excellent possibility for validation runs, because data acquisition is planned for the requisite themes of cover, soils, elevation, and drainage pattern. Essential additional data required for a validation run consist of detailed precipitation record and sediment output, at least for several events, and sediment deposition or flux data at control points within the basin.

2. Model refinement. As mentioned above, the model could be improved by streamlining some linkages between components, as well as made more user friendly by introducing more execution of macros and providing end-user-level documentation for the integrated package. Conversion of the simulation portion of the model to a microcomputer is also feasible, if it would make the model more accessible to end users.

3. Field studies. The modeling and analysis described here is general in nature and has focused on the broad scale. Detailed engineering analyses should be conducted in the context of specific projects. One area of needed field research is the implementation of prototype projects for strategies such as the use of natural bottomland hardwood areas as overflow sediment detention ponds or as buffer strips for overland runoff, and the retention of water on agricultural lands during the nongrowing season. On the broad scale, there may be opportunities to conduct focused surveys on the past functioning of bottomland hardwood areas by using cesium-137 isotope methods for determining sedimentation, coupled with historical vegetation records or with vegetation effects inferred by careful analysis of current composition and age structure of the plant communities. In order to be most meaningful, however, such survey work will need to be focused on areas where past hydrologic and sediment input can be reconstructed, in order to analyze the observed deposition and biological response as a response to specific inputs.

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APPENDIX A: SELECTED PROGRAM LISTINGS

PROGRAM USLEPAR

```
      PROGRAM USLEPAR(INPUT,OUTPUT,TAPE1,TAPE2,TAPE3,TAPE4,
     +TAPE7,TAPE8,TAPE5=INPUT,TAPE6=OUTPUT)
      DIMENSION ASOIL(15),ALUSE(9),AVRSE(300)
      DIMENSION C(300),AREA(300),IDWS(300)
      DIMENSION AT(15),ISPECL(50),NOPR(50)
      DIMENSION COVER(9),SOILERO(15)
      DIMENSION EI(300),P(300),ELES(300)
      DATA (COVER(I),I=1,9)/0.,0.25,0.1,0.001,0.013,0.001,0.003,0.1,0./
      DATA (SOILERO(I),I=1,15)/0.43,0.43,0.37,0.37,0.37,0.32,0.37,0.43
     +,0.37,0.37,0.32,0.39,0.43,0.39,0./
      DATA (ISPECL(I),I=1,2),NSPECL/6H010101,6H010201,0/
      DATA (NOPR(I),I=1,2)/4,5/
      DATA EIFCTR/85.6/
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C     PROGRAM FOR COMPUTING COVER AND MANAGEMENT FACTOR  "C" AND SOIL     C
C     ERODIBILITY FACTOR "K" FOR THE STUDY AREA SOILS AND LAND USE TYPES  C
C************************************************************************C
C                                                                         C
C      LAND USE GROUPS                              FACTOR "C"            C
C************************************************************************C
C  1  OW         OPEN WATER                           0.00                C
C  2  AG         AGRICULTURAL                         0.25                C
C  3  C/BF       CLEARED BASINS AND FLATS             0.10                C
C  4  W/SS       WOODED AND/OR SHRUB SWAMP            0.001               C
C  5  URBAN/DEV  URBAN DEVELOPMENT                    0.013               C
C  6  B H        BOTTOMLAND HARDWOOD                  0.001               C
C  7  W/BF       WOODED BASINS AND FLATS              0.003               C
C  8  CFL        CLEARED FOREST LAND                  0.100               C
C  9  FF         FISH FARM                            0.000               C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C      SOIL ASSOCIATION GROUPS             FACTOR "K"                     C
C*************************************************************************
C  1  ALLIGATOR-FORESTDALE                 0.43                           C
C  2  ALLIGATOR                            0.43                           C
C  3  DUNDEE-DUBBS                         0.37                           C
C  4  COLLINS-FALAYA                       0.37                           C
C  5  FALAYA-COLLINS                       0.37                           C
C  6  MEMPHIS-GULLIED LAND                 0.32                           C
C  7  WAVERLY-CALHOUN                      0.37                           C
C  8  ALLIGATOR-FORESTDALE                 0.43                           C
C  9  WAVERLY-FALAYA-COLLINS               0.37                           C
C 10  FALAYA-COLLINS-WAVERLY               0.37                           C
C 11  MEMPHIS                              0.32                           C
C 12  DUBBS-DUNDEE-FORESDALE               0.39                           C
C 13  ALLIGATOR-DOWLING                    0.43                           C
C 14  COLLINS-FALAYA-HYMON-INA             0.39                           C
C 15  WATER                                0.00                           C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C      TAPE2 CONTAINS SOIL TYPE AND AREAS DATA
C
      K=0
    1 K=K+1
      READ(2,10) ID,ISOIL,AREAI
   10 FORMAT(A6,I3,F10.0)
      IF(EOF(2).NE.0) GOTO 1000
```

```
      IF(K.GT.1) GOTO 2
    4 CONTINUE
      DO 5 I=1,15
      ASOIL(I)=0.
    5 CONTINUE
      ID1=ID
      ASOIL(ISOIL)=AREAI
      GOTO 1
    2 CONTINUE
      IF(ID.NE.ID1) WRITE(4,20) ID1,(ASOIL(J),J=1,15)
C     IF(ID.NE.ID1) WRITE(6,20) ID1,(ASOIL(J),J=1,15)
      IF(ID.NE.ID1) K=1
      IF(ID.NE.ID1) GOTO 4
      ASOIL(ISOIL)=AREAI
      GOTO 1
 1000 CONTINUE
   20 FORMAT(A6,15F8.2)
C
C     TAPE1 CONTAINS LAND USE AND RELATED AREAS DATA
C
      K=0
   11 K=K+1
      READ(1,10) ID,ILUSE,AREALU
      IF(EOF(1).NE.0) GOTO 2000
      IF(K.GT.1) GOTO 12
   14 CONTINUE
      DO 15 I=1,9
      ALUSE(I)=0.
   15 CONTINUE
      ID1=ID
      ALUSE(ILUSE)=ALUSE(ILUSE)+AREALU
      GOTO 11
   12 CONTINUE
      IF(ID.NE.ID1) WRITE(3,20) ID1,(ALUSE(J),J=1,9)
C     IF(ID.NE.ID1) WRITE(6,20) ID1,(ALUSE(J),J=1,9)
      IF(ID.NE.ID1) K=1
      IF(ID.NE.ID1) GOTO 14
      ALUSE(ILUSE)=ALUSE(ILUSE)+AREALU
      GOTO 11
 2000 CONTINUE
C
C     AT THIS POINT BOTH TAPE1 AND TAPE2 ARE READ.
C     START COMPUTATIONS.
C
      REWIND 3
      REWIND 4
  208 CONTINUE
      DO 200 I=1,9
  200 ALUSE(I)=0.
      READ(3,20) IDD,(AT(I),I=1,9)
      IF(EOF(3).NE.0) GOTO 205
      KK=0
  203 KK=KK+1
      IF(KK.GT.NSPECL) GOTO 202
      IF(IDD.NE.ISPECL(KK)) GOTO 203
      NMAX=NOPR(KK)
      DO 206 I=1,NMAX
      ID1=IDD
```

```
      DO 207 J=1,9
  207 ALUSE(J)=ALUSE(J)+AT(J)
      WRITE(8,20) ID1,(ALUSE(M),M=1,9)
C     WRITE(6,20) ID1,(ALUSE(M),M=1,9)
      IF(I.LT.NMAX) READ(3,20) IDD,(AT(M),M=1,9)
  206 CONTINUE
      GOTO 208
  202 CONTINUE
      DO 209 I=1,9
  209 ALUSE(I)=AT(I)
      WRITE(8,20) IDD,(ALUSE(M),M=1,9)
C     WRITE(6,20) IDD,(ALUSE(M),M=1,9)
      GOTO 208
  205 CONTINUE
      REWIND 8
  308 CONTINUE
      DO 300 I=1,15
  300 ASOIL(I)=0.
      READ(4,20) IDD,(AT(I),I=1,15)
      IF(EOF(4).NE.0) GOTO 305
      KK=0
  303 KK=KK+1
      IF(KK.GT.NSPECL) GOTO 302
      IF(IDD.NE.ISPECL(KK)) GOTO 303
      NMAX=NOPR(KK)
      DO 306 I=1,NMAX
      ID1=IDD
      DO 307 J=1,15
  307 ASOIL(J)=ASOIL(J)+AT(J)
      WRITE(7,20) ID1,(ASOIL(M),M=1,15)
C     WRITE(6,20) ID1,(ASOIL(M),M=1,15)
      IF(I.GE.NMAX) GOTO 306
      READ(4,20) IDD,(AT(M),M=1,15)
  306 CONTINUE
      GOTO 308
  302 CONTINUE
      DO 309 I=1,15
  309 ASOIL(I)=AT(I)
      WRITE(7,20) IDD,(ASOIL(M),M=1,15)
C     WRITE(6,20) IDD,(ASOIL(M),M=1,15)
      GOTO 308
  305 CONTINUE
      REWIND 7
C
C     COMPUTE AVERAGE SOIL GROUP FOR EACH ISOCHRONE
C
      K=0
   18 K=K+1
      READ(7,20) ID1,(ASOIL(J),J=1,15)
      IF(EOF(7).NE.0) GOTO 3000
      SUMA=0.
      AVRSE(K)=0.
      DO 21 I=1,15
      SUMA=SUMA+ASOIL(I)
      AVRSE(K)=AVRSE(K)+ASOIL(I)*SOILERO(I)
   21 CONTINUE
      AVRSE(K)=AVRSE(K)/SUMA
      GOTO 18
```

```
 3000 CONTINUE
      KMAX=K-1
C
      K=0
   31 K=K+1
      IF(K.GT.KMAX) GOTO 4000
      READ(8,20) ID1,(ALUSE(J),J=1,9)
      WRITE(6,620)
  620 FORMAT(10X,*LANDUSE ARRAY BEFORE ADJUSTMENTS*)
      WRITE(6,20) ID1,(ALUSE(J),J=1,9)
      WRITE(6,621)
  621 FORMAT(10X,*LANDUSE ARRAY AFTER AJUSTMENTS*)
      SUMARA=0.
      DO 3311 JK=1,9
      IF(JK.EQ.6) GOTO 3311
C     IF(JK.NE.2) GOTO 3311
      SUMARA=SUMARA+ALUSE(JK)
      ALUSE(JK)=1.00*ALUSE(JK)
 3311 CONTINUE
      DELARA=(1.-1.00)*SUMARA
      ALUSE(6)=ALUSE(6)+DELARA
      WRITE(6,20) ID1,(ALUSE(NM),NM=1,9)
      SUMA=0.
      IDWS(K)=ID1
      C(K)=0.
      DO 32 I=1,9
      SUMA=SUMA+ALUSE(I)
      C(K)=C(K)+ALUSE(I)*COVER(I)
   32 CONTINUE
      C(K)=C(K)/SUMA
      AREA(K)=SUMA
      P(K)=1.
      EI(K)=EIFCTR
      GOTO 31
 4000 CONTINUE
C
C.....TAPE5 CONTAINS GEOMETRIC DATA (TAPE5=AREA)
C
      K=0
  121 K=K+1
      READ(5,30) IDU,A,ALEN,SLP,DRP
   30 FORMAT(A6,3X,4F8.0)
      IF(K.GT.47) GOTO 5000
      IF(SLP.GE.0.05) EM=0.5
      IF(0.035.LE.SLP.AND.0.05.GT.SLP) EM=0.4
      IF(0.010.LT.SLP.AND.0.035.GT.SLP) EM=0.3
      IF(SLP.LE.0.01) EM=0.2
      THETA=ATAN(DRP/ALEN)
      X1=SIN(THETA)
      ELES(K)=(ALEN/72.6)**EM*(65.41*X1*X1+4.56*X1+0.065)
      GOTO 121
 5000 CONTINUE
C
C     PRINT THE RESULTS
C
      WRITE(6,52)
      WRITE(6,51)
      REWIND 3
```

```
      DO 41 K=1,KMAX
      WRITE(6,50) K,IDWS(K),EI(K),AVRSE(K),ELES(K),C(K),P(K)
      WRITE(3,*) K,IDWS(K),EI(K),AVRSE(K),ELES(K),C(K),P(K)
   51 FORMAT(5X,* NO.  ID NO.  FACTOR "R"  FACTOR "K"  FACTOR "LS"*,
     +*  FACTOR "C"  FACTOR "P"*,/,5X,
     +73H*****************************************************************
     +**********)
   52 FORMAT(//,5X,73H*****************************************************
     +************************)
   50 FORMAT(5X,I4,2X,A6,4X,F5.1,4X,F8.3,5X,F8.3,5X,F8.3,7X,F4.1)
   41 CONTINUE
      STOP
      END
```

PROGRAM CURVENO

```
      PROGRAM CURVENO(INPUT,OUTPUT,TAPE1,TAPE2,TAPE3,TAPE4,
     +TAPE7,TAPE8,TAPE5=INPUT,TAPE6=OUTPUT)
      DIMENSION TABLE91(9,6),ASOIL(15),ALUSE(9),AVRSG(300)
      DIMENSION RN(300),RK(300),CN(300),AREA(300),IDWS(300)
      DIMENSION AT(15),ISPECL(50),NOPR(50)
      INTEGER SOILS(15),SOILT(15),LANDUSE(9)
      DATA (SOILT(I),I=1,15)/4,4,3,3,3,2,4,4,3,3,2,3,4,3,4/
      DATA (SOILS(I),I=1,15)/1HD,1HD,1HC,1HC,1HC,1HB,1HD,1HD,1HC,1HC,
     +                       1HB,1HC,1HD,1HC,1HD/
      DATA (LANDUSE(I),I=1,9)/10HAG        ,10HB H      ,10HC/BF      ,
     +10HCFL       ,10HFF       ,10HOW       ,10HURBAN/DEV  ,
     +10HW/BF      ,10HW/SS      /
      DATA ((TABLE91(I,J),J=1,6),I=1,9)/100.,100.,100.,100.,0.010,60.,
     +72.,81.,88.,91.,0.040,1060.,
     +68.,79.,86.,89.,0.045,1060.,
     +95.,95.,95.,95.,0.085,2060.,
     +59.,74.,82.,86.,0.045,560.,
     +25.,55.,70.,77.,0.085,1900.,
     +36.,60.,73.,79.,0.075,1560.,
     +49.,69.,79.,84.,0.055,1060.,
     +0.,0.,0.,0.,0.010,60./
      DATA (ISPECL(I),I=1,11),NSPECL/6H010101,6H010201,
     +6H020101,6H020201,6H020401,6H020601,6H020801,6H021401,
     +6H021101,6H021201,6H021701,11/
      DATA (NOPR(I),I=1,11)/4,5,6,6,4,2,7,3,3,3,3/
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C    CURVE NUMBERS FOR DIFFERENT LAND USES AND SOIL TYPES. THE DATA IS  C
C    PARTIALLY TAKEN FROM THE SCS NATIONAL ENGINEERING HANDBOOK.        C
C**********************************************************************C
C                                         SOIL TYPES          MANNING  C
C      LAND USE GROUPS                 A     B     C     D      COEF.  C
C**********************************************************************C
C  1  OW        OPEN WATER            100.  100.  100.  100.    0.010  C
C  2  AG        AGRICULTURAL           72.   81.   88.   91.    0.040  C
C  3  C/BF      CLEARED BASINS AND FLATS 68.  79.   86.   89.    0.045  C
C  4  W/SS      WOODED AND/OR SHRUB SWAMP 95. 95.   95.   95.    0.085  C
C  5  URBAN/DEV URBAN DEVELOPMENT      59.   74.   82.   86.    0.045  C
C  6  B H       BOTTOMLAND HARDWOOD    25.   55.   70.   77.    0.085  C
C  7  W/BF      WOODED BASINS AND FLATS 36.  60.   73.   79.    0.075  C
C  8  CFL       CLEARED FOREST LAND    49.   69.   79.   84.    0.055  C
C  9  FF        FISH FARM               0.    0.    0.    0.    0.010  C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C      TAPE2 CONTAINS SOIL TYPE AND AREAS DATA
C
      K=0
    1 K=K+1
      READ(2,10) ID,ISOIL,AREAI
   10 FORMAT(A6,I3,F10.0)
      IF(EOF(2).NE.0) GOTO 1000
      IF(K.GT.1) GOTO 2
    4 CONTINUE
      DO 5 I=1,15
      ASOIL(I)=0.
    5 CONTINUE
      ID1=ID
```

```
      ASOIL(ISOIL)=AREAI
      GOTO 1
    2 CONTINUE
      IF(ID.NE.ID1) WRITE(4,20) ID1,(ASOIL(J),J=1,15)
      IF(ID.NE.ID1) WRITE(6,20) ID1,(ASOIL(J),J=1,15)
      IF(ID.NE.ID1) K=1
      IF(ID.NE.ID1) GOTO 4
      ASOIL(ISOIL)=AREAI
      GOTO 1
 1000 CONTINUE
   20 FORMAT(A6,15F8.2)
C
C     TAPE1 CONTAINS LAND USE AND RELATED AREAS DATA
C
      K=0
   11 K=K+1
      READ(1,10) ID,ILUSE,AREALU
      IF(EOF(1).NE.0) GOTO 2000
      IF(K.GT.1) GOTO 12
   14 CONTINUE
      DO 15 I=1,9
      ALUSE(I)=0.
   15 CONTINUE
      ID1=ID
      ALUSE(ILUSE)=ALUSE(ILUSE)+AREALU
      GOTO 11
   12 CONTINUE
      IF(ID.EQ.ID1) ALUSE(ILUSE)=ALUSE(ILUSE)+AREALU
      IF(ID.EQ.ID1) GOTO 11
      WRITE(6,620)
  620 FORMAT(10X,*LANDUSE ARRAY BEFORE ADJUSTMENTS*,//)
      WRITE(6,20) ID1,(ALUSE(J),J=1,9)
      SUMARB=0.
      DO 290 M=1,9
      IF(M.EQ.6) GOTO 290
C     IF(M.NE.2) GOTO 290
      SUMARB=SUMARB+ALUSE(M)
      ALUSE(M)=1.00*ALUSE(M)
  290 CONTINUE
      DELAR=(1.-1.00)*SUMARB
      ALUSE(6)=ALUSE(6)+DELAR
      WRITE(6,621)
  621 FORMAT(10X,*LANDUSE ARRAY AFTER AJUSTMENTS*,//)
      WRITE(6,20) ID1,(ALUSE(J),J=1,9)
      WRITE(3,20) ID1,(ALUSE(J),J=1,9)
      K=1
      GOTO 14
 2000 CONTINUE
C.....LAMINAR FRICTION COEFFFICIENTS "RK" ARE COMPUTED ACCORDING TO
C     RK= 60.+2500*GC  ; WHERE GC= PERCENT GROUND COVER.
C     RK VALUES APPLY TO ACTUAL ISOCHRONE AREAS.
      REWIND 3
      N=0
  101 N=N+1
      READ(3,20) IDD,(AT(I),I=1,9)
      IF(EOF(3).NE.0) GOTO 5000
      RK(N)=0.
      SUMA=0.
```

```
      DO 102 I=1,9
      RK(N)=RK(N)+AT(I)*TABLE91(I,6)
      SUMA=SUMA+AT(I)
  102 CONTINUE
      RK(N)=RK(N)/SUMA
      GOTO 101
 5000 CONTINUE
C
C     AT THIS POINT BOTH TAPE1 AND TAPE2 ARE READ.
C     START COMPUTATIONS.
C
      REWIND 3
      REWIND 4
  208 CONTINUE
      DO 200 I=1,9
  200 ALUSE(I)=0.
      READ(3,20) IDD,(AT(I),I=1,9)
      IF(EOF(3).NE.0) GOTO 205
      KK=0
  203 KK=KK+1
      IF(KK.GT.NSPECL) GOTO 202
      IF(IDD.NE.ISPECL(KK)) GOTO 203
      NMAX=NOPR(KK)
      DO 206 I=1,NMAX
      ID1=IDD
      DO 207 J=1,9
  207 ALUSE(J)=ALUSE(J)+AT(J)
      WRITE(8,20) ID1,(ALUSE(M),M=1,9)
      WRITE(6,20) ID1,(ALUSE(M),M=1,9)
      IF(I.LT.NMAX) READ(3,20) IDD,(AT(M),M=1,9)
  206 CONTINUE
      GOTO 208
  202 CONTINUE
      DO 209 I=1,9
  209 ALUSE(I)=AT(I)
 1211 FORMAT(10X,*TOTAL AG AREA=*,F10.3,* ACRES*)
      WRITE(8,20) IDD,(ALUSE(M),M=1,9)
      WRITE(6,20) IDD,(ALUSE(M),M=1,9)
      GOTO 208
  205 CONTINUE
      REWIND 8
  308 CONTINUE
      DO 300 I=1,15
  300 ASOIL(I)=0.
      READ(4,20) IDD,(AT(I),I=1,15)
      IF(EOF(4).NE.0) GOTO 305
      KK=0
  303 KK=KK+1
      IF(KK.GT.NSPECL) GOTO 302
      IF(IDD.NE.ISPECL(KK)) GOTO 303
      NMAX=NOPR(KK)
      DO 306 I=1,NMAX
      ID1=IDD
      DO 307 J=1,15
  307 ASOIL(J)=ASOIL(J)+AT(J)
      WRITE(7,20) ID1,(ASOIL(M),M=1,15)
      WRITE(6,20) ID1,(ASOIL(M),M=1,15)
      IF(I.GE.NMAX) GOTO 306
```

```
      READ(4,20) IDD,(AT(M),M=1,15)
  306 CONTINUE
      GOTO 308
  302 CONTINUE
      DO 309 I=1,15
  309 ASOIL(I)=AT(I)
      WRITE(7,20) IDD,(ASOIL(M),M=1,15)
      WRITE(6,20) IDD,(ASOIL(M),M=1,15)
      GOTO 308
  305 CONTINUE
      REWIND 7
C
C     COMPUTE AVERAGE SOIL GROUP FOR EACH ISOCHRONE
C
      K=0
   18 K=K+1
      READ(7,20) ID1,(ASOIL(J),J=1,15)
      IF(EOF(7).NE.0) GOTO 3000
      SUMA=0.
      AVRSG(K)=0.
      DO 21 I=1,15
      SUMA=SUMA+ASOIL(I)
      AVRSG(K)=AVRSG(K)+ASOIL(I)*SOILT(I)
   21 CONTINUE
      AVRSG(K)=AVRSG(K)/SUMA
      GOTO 18
 3000 CONTINUE
      KMAX=K-1
C
      K=0
   31 K=K+1
      IF(K.GT.KMAX) GOTO 4000
      X=AVRSG(K)
      READ(8,20) ID1,(ALUSE(J),J=1,9)
      KK=0
      CN(K)=0.
      RN(K)=0.
      IDWS(K)=ID1
      ASUM=0.
   32 KK=KK+1
      IF(KK.GT.9) GOTO 33
      IF(ALUSE(KK).LE.0.) GOTO 32
      Y1=TABLE91(KK,2)
      Y2=TABLE91(KK,3)
      Y3=TABLE91(KK,4)
      Y4=TABLE91(KK,5)
C
C     PLOYNOMIAL INTERPOLATION FOR CN
C     CN VALUES ARE AREA WEIGHTED
C
      A=0.5*Y1-Y2+0.5*Y3
      B=-3.5*Y1+6.*Y2-2.5*Y3
      C=6.*Y1-8.*Y2+3.*Y3
C
      YCN=A*X**2+B*X+C
      ASUM=ASUM+ALUSE(KK)
      CN(K)=CN(K)+YCN*ALUSE(KK)
      RN(K)=RN(K)+Y4*ALUSE(KK)
```

```
      GOTO 32
   33 CONTINUE
      AREA(K)=ASUM
      CN(K)=CN(K)/ASUM
      RN(K)=RN(K)/ASUM
      GOTO 31
 4000 CONTINUE
C
C     PRINT THE RESULTS
C
      WRITE(6,52)
      WRITE(6,51)
      REWIND 3
      DO 41 K=1,KMAX
      WRITE(6,50) K,IDWS(K),CN(K),RN(K),RK(K)
      WRITE(3,*) K,IDWS(K),CN(K),RN(K),RK(K),AREA(K)
   52 FORMAT(//,5X,49H*************************************************)
   51 FORMAT(5X,* NO.  ID NO.  CURVE NO.   MANNING N  LAMINAR  K *,/,5X,
     +49H*************************************************  ,//)
   50 FORMAT(5X,I4,2X,A6,4X,F5.1,4X,F8.3,4X,F8.2)
   41 CONTINUE
      STOP
      END
```

PROGRAM DTCONV

```
      PROGRAM DTCONV(INPUT,OUTPUT,TAPE4,TAPE7,TAPE8,TAPE9,TAPE5=INPUT,
     +               TAPE6=OUTPUT)
      COMMON/BLK1/ID(100),R(100),AK(100),ELES(100),C(100),P(100)
      COMMON/BLK2/CN(100),RN(100),RK(100),AA(100)
      REWIND 4
      REWIND 7
      DO 100 K=1,47
      READ(7,*) I,ID(I),R(I),AK(I),ELES(I),C(I),P(I)
      READ(4,*) I,ID(I),CN(I),RN(I),RK(I),AA(I)
  100 CONTINUE
      ID(48)=10H203011
      ID(49)=10H203012
      ID(50)=10H203021
      ID(51)=10H203022
      ID(52)=10H205011
      ID(53)=10H205012
      ID(54)=10H207011
      ID(55)=10H207012
      ID(56)=10H209011
      ID(57)=10H209012
      ID(58)=10H210011
      ID(59)=10H210012
      ID(60)=10H215011
      ID(61)=10H215012
      ID(62)=10H213011
      ID(63)=10H213012
      ID(64)=10H216011
      ID(65)=10H216012
      ID(66)=10H218011
      ID(67)=10H218012
      CALL CONVERT(13,48)
      CALL CONVERT(13,49)
      CALL CONVERT(14,50)
      CALL CONVERT(14,51)
      CALL CONVERT(19,52)
      CALL CONVERT(19,53)
      CALL CONVERT(22,54)
      CALL CONVERT(22,55)
      CALL CONVERT(30,56)
      CALL CONVERT(30,57)
      CALL CONVERT(31,58)
      CALL CONVERT(31,59)
      CALL CONVERT(38,60)
      CALL CONVERT(38,61)
      CALL CONVERT(42,62)
      CALL CONVERT(42,63)
      CALL CONVERT(43,64)
      CALL CONVERT(43,65)
      CALL CONVERT(47,66)
      CALL CONVERT(47,67)
      RN(13)=0.035
      RN(14)=0.035
      RN(19)=0.035
      RN(22)=0.035
      RN(30)=0.035
      RN(31)=0.035
```

```
      RN(38)=0.035
      RN(42)=0.035
      RN(43)=0.035
      RN(47)=0.035
      ELES(48)=0.12978
      ELES(49)=0.14647
       ELES(50)=0.12504
       ELES(51)=0.11896
      ELES(52)=0.13023
      ELES(53)=0.13023
      ELES(54)=0.13023
      ELES(55)=0.13846
      ELES(56)=0.13023
      ELES(57)=0.13846
      ELES(58)=0.13017
      ELES(59)=0.14609
      ELES(60)=0.12742
      ELES(61)=0.12742
      ELES(62)=0.10625
      ELES(63)=0.13229
      ELES(64)=0.13617
      ELES(65)=0.11907
      ELES(66)=0.11528
      ELES(67)=0.11528
      REWIND 8
      REWIND 9
      DO 200 I=1,67
      WRITE(8,*) I,ID(I),R(I),AK(I),ELES(I),C(I),P(I)
      WRITE(9,*) I,ID(I),CN(I),RN(I),RK(I),AA(I)
  200 CONTINUE
      STOP
      END
      SUBROUTINE CONVERT(I1,I2)
      COMMON/BLK1/ID(100),R(100),AK(100),ELES(100),C(100),P(100)
      COMMON/BLK2/CN(100),RN(100),RK(100),AA(100)
      R(I2)=R(I1)
      AK(I2)=AK(I1)
      ELES(I2)=ELES(I1)
      C(I2)=C(I1)
      P(I2)=P(I1)
      CN(I2)=CN(I1)
      RN(I2)=RN(I1)
      RK(I2)=RK(I1)
      RETURN
      END
```

PROGRAM HECUPD

```
      PROGRAM HECUPD(INPUT,OUTPUT,TAPE1,TAPE7,TAPE8,TAPE9,TAPE5=INPUT,
     +               TAPE6=OUTPUT)
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C     PROGRAM TO UPDATE HEC-1 INPUT DATA FILE ,TAPE5, WITH COMPUTED      C
C     SCS CURVE NOS.,ROUGHNESS COEFFICIENTS,AND TIME OF CONCENTRATION    C
C     VALUES. THE UPDATED INPUT FILE IS RETURNED IN TAPE8.               C
C                                                                        C
C     A.    CN VALUES COMPUTED BY PROGRAM CURVENO ARE RETRIEVED FROM     C
C           TAPE7 AND USED IN UPDATING "LS" CARDS.                       C
C                                                                        C
C     B.    MANNING N VALUES COMPUTED BY PROGRAM CURVENO ARE RETRIEVED   C
C           FROM TAPE7  AND USED IN UPDATING "UK" CARDS.
C                                                                        C
C     C.    TIME OF CONCENTRATION VALUES ARE COMPUTED BY USING EITHER    C
C           KIRPITCH, HATHAWAY OR TABLE OF VELOCITY VERSUS LANDUSE VALUES.C
C           THESE TIME OF CONCENTRATION VALUES ARE USED IN UPDATING THE  C
C           "UD" CARDS.  VELOCITY VERSUS LANDUSE TABLES ARE GENERATED BY C
C           PROGRAM CURVENO AND ARE STORED IN TAPE7.                     C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      DIMENSION ID(300),RN(300),AREA(300),VEL(300)
      DIMENSION ALENGTH(300),SLOPE(300),DROP(300)
      INTEGER CN(300)
      DIMENSION TC(300),IOPTLAG(3)
      DATA (IOPTLAG(I),I=1,3)/10HKIRPITCH  ,10HHATHAWAY  ,10HVEL-LUSE  /
      DATA IOPT/10HHATHAWAY  /
      K=0
    1 K=K+1
      READ(7,*) I,ID(I),CURVI,RN(I),RK,AREA(I)
      ENCODE(8,18,ICN) CURVI
   18 FORMAT(F8.2)
      CN(I)=ICN
      DECODE(10,19,ID(I)) IDI
   19 FORMAT(A6,4X)
      ID(I)=IDI
      WRITE(6,10) I,ID(I),CN(I),RN(I),RK,AREA(I)
   10 FORMAT(5X,I4,2X,A6,1X,A8,4X,F8.3,4X,F8.2,F10.2)
      IF(EOF(7).NE.0) GOTO 2
      GOTO 1
    2 CONTINUE
      KM=K-1
C
C.....UPDATE THE CN VALUES IN LS CARDS.
C
      KOUNT=0
   61 KOUNT=KOUNT+1
      READ(5,20) IDC,I1,I2,I3,I4,I5,I6,I7,I8,I9,I10
      IF(EOF(5).NE.0) GOTO 1000
      WRITE(8,20) IDC,I1,I2,I3,I4,I5,I6,I7,I8,I9,I10
      IF(IDC.NE.2HKK) GOTO 61
   20 FORMAT(A2,A6,9A8)
C
C.....SPECIAL CASES
C
      IF(I1.NE.6H010500) GOTO 63
      I2=CN(12)
      I5=CN(13)
```

```
      GOTO 64
C
   63 CONTINUE
      K=0
   62 K=K+1
      IF(K.GT.KM) GOTO 61
      IF(ID(K).NE.I1) GOTO 62
      I2=CN(K)
      I5=CN(K)
   64 CONTINUE
      KOUNT=KOUNT+1
      READ(5,20) IDD,J1,J2,J3,J4,J5,J6,J7,J8,J9,J10
      IF(EOF(5).NE.0) GOTO 1000
      IF(IDD.NE.2HLS) WRITE(8,20) IDD,J1,J2,J3,J4,J5,J6,J7,J8,J9,J10
      IF(IDD.EQ.2HKK) GOTO 61
      IF(IDD.NE.2HLS) GOTO 64
      IF(J5.EQ.8H        ) WRITE(8,20)IDD,J1,I2,J3,J4,J5,J6,J7,J8,J9,J10
      IF(J5.NE.8H        ) WRITE(8,20)IDD,J1,I2,J3,J4,I5,J6,J7,J8,J9,J10
      GOTO 61
 1000 CONTINUE
      REWIND 8
C
C.....UPDATE THE KINEMATIC ROUTING  "UK" CARDS WITH COMPUTED  "N" VALUES.
C
      KOUNT=0
  161 KOUNT=KOUNT+1
      READ(8,20) IDC,I1,I2,I3,I4,I5,I6,I7,I8,I9,I10
      IF(EOF(8).NE.0) GOTO 2000
      WRITE(9,20) IDC,I1,I2,I3,I4,I5,I6,I7,I8,I9,I10
      IF(IDC.NE.2HKK) GOTO 161
      IF(I1.NE.6H010600) GOTO 163
      RNA=(RN(14)*AREA(14)+RN(15)*AREA(15)+RN(16)*AREA(16)+RN(17)*
     +AREA(17))/(AREA(14)+AREA(15)+AREA(16)+AREA(17))
      ENCODE(8,48,I3) RNA
      GOTO 164
  163 CONTINUE
C.....SOME MORE SPECIAL CASES
      IF(I1.EQ.6H010301) RNA=RN(21)
      IF(I1.EQ.6H010500) RNA=(RN(12)*AREA(12)+RN(13)*AREA(13))/
     +(AREA(12)+AREA(13))
      IF(I1.EQ.6H010701) RNA=RN(23)
      IF(I1.EQ.6H010702) RNA=RN(25)
      IF(I1.EQ.6H010703) RNA=RN(27)
      IF(I1.EQ.6H020301) RNA=RN(48)
       IF(I1.EQ.6H020302) RNA=RN(50)
       IF(I1.EQ.6H020501) RNA=RN(52)
       IF(I1.EQ.6H020701) RNA=RN(54)
       IF(I1.EQ.6H020901) RNA=RN(56)
       IF(I1.EQ.6H021001) RNA=RN(58)
       IF(I1.EQ.6H021501) RNA=RN(60)
       IF(I1.EQ.6H021301) RNA=RN(62)
       IF(I1.EQ.6H021601) RNA=RN(64)
       IF(I1.EQ.6H021801) RNA=RN(66)
      ENCODE(8,48,I3) RNA
      K=0
  162 K=K+1
      IF(K.GT.KM) GOTO 161
      IF(ID(K).NE.I1) GOTO 162
```

```
      ENCODE(8,48,I3) RN(K)
C.....SOME MORE SPECIAL CASES
      IF(I1.EQ.6H010301) RNA=RN(21)
      IF(I1.EQ.6H010500) RNA=(RN(12)*AREA(12)+RN(13)*AREA(13))/
     +(AREA(12)+AREA(13))
      IF(I1.EQ.6H010701) RNA=RN(23)
      IF(I1.EQ.6H010702) RNA=RN(25)
      IF(I1.EQ.6H010703) RNA=RN(27)
       IF(I1.EQ.6H020301) RNA=RN(48)
       IF(I1.EQ.6H020302) RNA=RN(50)
       IF(I1.EQ.6H020501) RNA=RN(52)
       IF(I1.EQ.6H020701) RNA=RN(54)
       IF(I1.EQ.6H020901) RNA=RN(56)
       IF(I1.EQ.6H021001) RNA=RN(58)
       IF(I1.EQ.6H021501) RNA=RN(60)
       IF(I1.EQ.6H021301) RNA=RN(62)
       IF(I1.EQ.6H021601) RNA=RN(64)
       IF(I1.EQ.6H021801) RNA=RN(66)
      ENCODE(8,48,I3) RNA
   48 FORMAT(F8.4)
  164 CONTINUE
      KOUNT=KOUNT+1
      READ(8,20) IDD,J1,J2,J3,J4,J5,J6,J7,J8,J9,J10
      IF(EOF(8).NE.0) GOTO 2000
      IF(IDD.NE.2HUK) WRITE(9,20)IDD,J1,J2,J3,J4,J5,J6,J7,J8,J9,J10
      IF(IDD.EQ.2HKK) GOTO 161
      IF(IDD.NE.2HUK) GOTO 164
      IUK=0
  166 IUK=IUK+1
      WRITE(9,20) IDD,J1,J2,I3,J4,J5,J6,J7,J8,J9,J10
      READ(8,20) IDD,J1,J2,J3,J4,J5,J6,J7,J8,J9,J10
      IF(IDD.EQ.2HUK) GOTO 166
      WRITE(9,20) IDD,J1,J2,J3,J4,J5,J6,J7,J8,J9,J10
      GOTO 161
C
 2000 CONTINUE
      REWIND 8
      REWIND 9
C
C.....COMPUTE THE TIME OF CONCENTRATION VALUES AND UPDATE THE "UD" CARDS FOR
C.....LAG TIMES (TLAG=0.6*TC).  STREAM LENGTH,ELEVATION DIFFERENCE, AND SLOPE
C.....OF BASIN DATA ARE READ FROM TAPE1  (ID,AREA,LENGTH,SLOPE,DELTAH,WIDTH)
C
      K=0
  201 K=K+1
      IF(K.GT.3) K=2
      IF(K.GT.3) GOTO 202
      IF(IOPT.NE.IOPTLAG(K)) GOTO 201
      IOPTC=K
  202 CONTINUE
      KK=0
  301 KK=KK+1
      READ(1,30) ID(KK),AREA(KK),ALENGTH(KK),SLOPE(KK),DROP(KK)
   30 FORMAT(A6,3X,4F8.0)
      IF(EOF(1).NE.0) GOTO 360
C     IF(KK.GE.20) GOTO 360
      GOTO 301
  360 CONTINUE
```

```
      DO 364 K=1,KM
C     V=VEL(K)
      DL=ALENGTH(K)
      DELH=DROP(K)
      S=SLOPE(K)
      AN=RN(K)
      GOTO (390,391,392) IOPTC
  390 CONTINUE
C     IOPTC=1.....KIRPITCH EQN: TC=(11.9*L**3/DELH)**0.385/19936  (HRS)
      TC(K)=(11.9*DL**3/DELH)**0.385/19936.
      GOTO 393
  391 CONTINUE
C     IOPTC=2.....HATHAWAY EQN: TC=(0.667*L*N/SQRT(S))**0.467/60.  (HRS)
      TC(K)=(0.66667*DL*AN/SQRT(S))**0.467/60.
C     WRITE(6,1111) K,TC(K)
      GOTO 393
  392 CONTINUE
C     IOPTC=3.....VELOCITY-LANDUSE TABLE (TO BE IMPLEMENTED)
C     TC(K)=DL/V
  393 CONTINUE
      DECODE(6,49,ID(K)) II
   49 FORMAT(A4,2X)
      DECODE(6,44,ID(K)) JJ
   44 FORMAT(4X,I2)
C     WRITE(6,43)II,JJ
   43 FORMAT(5X,A4,I2)
      SUM=0.
C     DO 387 IK=1,JJ
C 387 SUM=SUM+TC(K-IK+1)
      IF(JJ.LE.1.OR.JJ.GT.10) SUM=TC(K)
      IF(JJ.GT.1) SUM=TC(K)+TC(K-1)
C.....SPECIAL CASE FOR 010501 AND 010502
      IF(II.EQ.4H0105) SUM=TC(K)
C.....SPECIAL CASE FOR 106001 AND 106002
      IF(II.EQ.4H1060) SUM=TC(K)
      IF(II.EQ.4H1030) SUM=TC(K)
      IF(II.EQ.4H1070) SUM=TC(K)
      IF(II.EQ.4H2030) SUM=TC(K)
      IF(II.EQ.4H2050) SUM=TC(K)
      IF(II.EQ.4H2070) SUM=TC(K)
      IF(II.EQ.4H2090) SUM=TC(K)
      IF(II.EQ.4H2100) SUM=TC(K)
      IF(II.EQ.4H2180) SUM=TC(K)
      IF(II.EQ.4H2130) SUM=TC(K)
      IF(II.EQ.4H2150) SUM=TC(K)
      IF(II.EQ.4H2160) SUM=TC(K)
      TC(K)=SUM
      WRITE(6,1111) K,TC(K)
  364 CONTINUE
      KOUNT=0
  361 KOUNT=KOUNT+1
      READ(9,20) IDC,I1,I2,I3,I4,I5,I6,I7,I8,I9,I10
      IF(EOF(9).NE.0) GOTO 3000
      WRITE(8,20) IDC,I1,I2,I3,I4,I5,I6,I7,I8,I9,I10
      IF(IDC.NE.2HKK) GOTO 361
  363 CONTINUE
      K=0
  362 K=K+1
```

```
      IF(K.GT.KM) GOTO 361
      IF(ID(K).NE.I1) GOTO 362
      TLAG=TC(K)*0.6
      WRITE(6,1111) K,TLAG
 1111 FORMAT(5X,I4,F10.4)
      ENCODE(6,47,IL) TLAG
   47 FORMAT(F6.2)
  365 CONTINUE
      KOUNT=KOUNT+1
      READ(9,20) IDD,J1,J2,J3,J4,J5,J6,J7,J8,J9,J10
      IF(EOF(9).NE.0) GOTO 3000
      IF(IDD.NE.2HUD) WRITE(8,20) IDD,J1,J2,J3,J4,J5,J6,J7,J8,J9,J10
      IF(IDD.EQ.2HKK) GOTO 361
      IF(IDD.NE.2HUD) GOTO 365
      WRITE(8,20) IDD,IL,J2,J3,J4,J5,J6,J7,J8,J9,J10
      GOTO 361
 3000 CONTINUE
      REWIND 8
      STOP
      END
```

PROGRAM HEC1WS

```
      PROGRAM HEC1WS(INPUT,OUTPUT,TAPE1,TAPE2,TAPE3,TAPE4,TAPE7,TAPE8,
     +               TAPE9,TAPE10,TAPE5=INPUT,TAPE6=OUTPUT)
      COMMON/BLK1/Y(60),IBEG(75),IDTIME(75),IDATEB(75),NPT(75),Q(75,60)
      COMMON/BLK2/NUNITS,NCHNL,NPLANE,NSUBWS,NOISOCH,IDWU(75),ITYPE(75),
     +            ICHNL(75),ISEGMT(75,9),ALPHA(75),BETA(75)
      COMMON/BLK3/DAREA(75),ALENGTH(75),SLOPE(75),DROP(75),ISHAPE(75),
     +            WIDTH(75)
      COMMON/BLK4/RN(75),RK(75),AREA(75)
      COMMON/BLK5/QR(60),QSAVLB(60),QSCAP(60)
      COMMON/BLK6/QWS(10,60),IB(10),IDTM(10),IDAT(10),NPP(10),IDISO(10),
     +            UI(60),XSED(60),ISO(10)
      COMMON/BLK7/EI(75),COEFK(75),COEFC(75),ELES(75),COEFP(75)
      COMMON/BLK8/QSOUT(75,60),ELEV(75,60),QSTPA(75,60)
      COMMON/BLK9/D50,RMU,WTSED
C
C.....READ INPUT DATA FROM FILES:  TAPE1,TAPE2,TAPE3,TAPE4,TAPE7.
C
      CALL INDATA
C
C.....START SEDIMENT ROUTING COMPUTAIONS.
C
      I=0
    1 I=I+1
      IF(I.GT.NUNITS) GOTO 2
      GOTO(3,4,5,1) ITYPE(I)
    3 CONTINUE
C
C.....CHANNEL ELEMENT.  SEDIMENT ROUTING THROUGH CHANNEL ELEMENTS IS
C.....PERFORMED FOLLOWING SEDIMENT COMPUTATIONS FROM PLANE AND OVERLAND
C.....UNITS.
C
      GOTO 1
    4 CONTINUE
C
C.....PLANE UNITS.
C
      CALL PLSED(I)
      GOTO 1
    5 CONTINUE
C
C.....SUBWATERSHED UNITS.
C
      CALL OVRLSED(I)
      GOTO 1
    2 CONTINUE
C
C.....START CHANNEL ROUTING
C
      CALL CHNLR
C
C.....PRINT THE RESULTS
C
      CALL PRINTER(3)
 5000 CONTINUE
      STOP
      END
```

```
      SUBROUTINE INDATA
      COMMON/BLK1/Y(60),IBEG(75),IDTIME(75),IDATEB(75),NPT(75),Q(75,60)
      COMMON/BLK2/NUNITS,NCHNL,NPLANE,NSUBWS,NOISOCH,IDWU(75),ITYPE(75),
     +            ICHNL(75),ISEGMT(75,9),ALPHA(75),BETA(75)
      COMMON/BLK3/DAREA(75),ALENGTH(75),SLOPE(75),DROP(75),ISHAPE(75),
     +            WIDTH(75)
      COMMON/BLK4/RN(75),RK(75),AREA(75)
      COMMON/BLK5/QR(60),QSAVLB(60),QSCAP(60)
      COMMON/BLK6/QWS(10,60),IB(10),IDTM(10),IDAT(10),NPP(10),IDISO(10),
     +            UI(60),XSED(60),ISO(10)
      COMMON/BLK7/EI(75),COEFK(75),COEFC(75),ELES(75),COEFP(75)
      COMMON/BLK8/QSOUT(75,60),ELEV(75,60),QSTPA(75,60)
      COMMON/BLK9/D50,RMU,WTSED
      DATA D50,RMU,WTSED/65.62E-06,0.00001,99.22/
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C     THIS  SUBROUTINE IS TO READ THE INPUT INFORMATION:                C
C                                                                       C
C  1. DERIVED FROM MOSS DIGITAL INFORMATION SYSTEM THROUGH PROGRAMS     C
C     "CURVENO" AND "USLEPAR".
C                                                                       C
C  2. FROM A PRIOR HEC-1 RUN.                                           C
C                                                                       C
C  3. FROM MANUALLY PREPARED GEOMETRIC PROPERTIES DATA                  C
C                                                                       C
C  4. FROM MANUALLY PREPARED CHANNEL LINKAGE DATA                       C
C                                                                       C
C     THE INPUT TAPES CONTAINING THE DATA ARE:                          C
C  1. TAPE1  RESULTS OF PRIOR HEC-1 RUN FOR GENERATING WATERSHED        C
C            OUTFLOW HYDROGRAPHS.
C  2. TAPE2  MANUALLY PREPARED CHANNEL LINKAGE DATA (FILE:LINK)         C
C  3. TAPE3  MANUALLY PEPARED GEOMETRIC PROPERTIES DATA (FILE:AREA)     C
C  4. TAPE4  ROUGHNESS DATA DERIVED FROM MOSS GIS THROUGH "CURVENO".    C
C            (FILE:CNTAPE)                                              C
C  5. TAPE7  USLE PARAMETERS DERIVED FROM MOSS GIS THROUGH "USLEPAR".   C
C            (FILE:USLETAP)                                             C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      REWIND 2
C
C.....TAPE2 CONTAINS CHANNEL LINKAGE DATA
C
      READ(2,10) IDCARD,NCHNL,NPLANE,NSUBWS,NOISOCH
C     WRITE(6,10) IDCARD,NCHNL,NPLANE,NSUBWS,NOISOCH
   10 FORMAT(A2,I6,3I8)
      NUNITS=NCHNL+NPLANE+NSUBWS+NOISOCH
      DO 200 I=1,NUNITS
      READ(2,20) IDCARD,IDWU(I),ITYPE(I)
C     WRITE(6,20) IDCARD,IDWU(I),ITYPE(I)
   20 FORMAT(A2,A6,I8)
  200 CONTINUE
      DO 300 I=1,NCHNL
      READ(2,30) IDCARD,ICHNL(I),ALPHA(I),BETA(I),(ISEGMT(I,J),J=1,9)
C     WRITE(6,30) IDCARD,ICHNL(I),ALPHA(I),BETA(I),(ISEGMT(I,J),J=1,9)
   30 FORMAT(A2,I6,2F10.0,9I4)
  300 CONTINUE
C
C.....AT THIS POINT CHANNEL LINKAGE DATA FROM TAPE2 IS READ IN.
C.....ORDER OF CHANNEL ROUTING COMPUTATIONS IS STORED IN  ICHNL(I),I=1,NCHNL
C.....THE ID OF CHANNEL UNITS ARE STORED IN IDWU(ICHNL(I))
```

```
C.....SEGMENTS CONNECTED TO THE CHANNEL UNITS ARE STORED IN ISEGMT(I,J)
C.....THE ID OF SEGMENTS CONNECTED TO CHANNEL UNIT "I" AT STORED AT
C.....IDWU(ISEGMT(I,J),J=1,9).
C
C.....HEC-1 RUN OUTPUT CONTAINS OUTFLOW HYDROGRAPHS FOR EACH WATERSHED UNIT
C.....INVOLVED IN CHANNEL LINKAGE. USING THIS OUTPUT WHICH IS STORED IN
C.....TAPE1,  TRANSFER THE INFORMATION TO PRESENT PROGRAM.
C
      REWIND 1
  400 CONTINUE
      READ(1,40) IDW,IDT,IBEGIN,IDATE,I1,I2,I3,NDATA
C     WRITE(6,40) IDW,IDT,IBEGIN,IDATE,I1,I2,I3,NDATA
   40 FORMAT(3X,A6,I5,I4,A8,3I2,I4)
      IF(EOF(1).NE.0) GOTO 1000
      NCARD=(NDATA/10)+0.99
      DO 210 NC=1,NCARD
      J1=(NC-1)*10+1
      J2=NC*10
      IF(J2.GT.NDATA) J2=NDATA
      READ(1,50) (Y(J),J=J1,J2)
   50 FORMAT(1X,10F13.0)
  210 CONTINUE
C.....CHECK IF IDW BELONGS TO A WATERSHED UNIT INVOLVED IN CHANNEL LINKAGE.
      I=0
   31 I=I+1
      IF(I.GT.NUNITS) GOTO 400
      IF(IDW.NE.IDWU(I)) GOTO 31
      DO 32 J=1,NDATA
   32 Q(I,J)=Y(J)
      IBEG(I)=IBEGIN
      IDTIME(I)=IDT
      IDATEB(I)=IDATE
      NPT(I)=NDATA
      GOTO 400
 1000 CONTINUE
C
C.....AT THIS POINT ALL HYDROLOGICAL DATA IS READ IN. NEXT, READ CHANNEL
C.....PROPERTIES DATA FROM "TAPE3=AREA" AND MATCH THEM WITH CORRESPONDING
C.....WATERSHED UNITS  IN THE CHANNEL LINKAGE.
C
      REWIND 3
      K=0
  500 K=K+1
      READ(3,60) IDW,A,AL,S,DELH,ITYPWU
C     WRITE(6,60) IDW,A,AL,S,DELH,ITYPWU
      IF(EOF(3).NE.0) GOTO 2000
      W=A/AL
      W=W*43560.
      IF(ITYPWU.EQ.1HT) W=W*2.
   60 FORMAT(A6,3X,4F8.0,A1)
      I=0
   33 I=I+1
      IF(I.GT.NUNITS) GOTO 500
      IF(IDW.NE.IDWU(I)) GOTO 33
C.....WATERSHED UNIT GEOMETRY
      DAREA(I)=A
      ALENGTH(I)=AL
      SLOPE(I)=S
```

```
      DROP(I)=DELH
      ISHAPE(I)=ITYPWU
      WIDTH(I)=W
      GOTO 500
 2000 CONTINUE
C
C.....AT THIS POINT WATERSHED UNIT GEOMETRIES ARE READ IN.
C.....NEXT, READ THE ROUGHNESS DATA FROM "TAPE4=CNTAPE".
C
      REWIND 4
  600 READ(4,*) K,IDD,CN,FRN,FRK,AA
C     WRITE(6,*) K,IDD,CN,FRN,FRK,AA
      IF(EOF(4).NE.0) GOTO 3000
      DECODE(10,80,IDD) IDW
   80 FORMAT(A6,4X)
      I=0
   34 I=I+1
      IF(I.GT.NUNITS) GOTO 600
      IF(IDW.NE.IDWU(I)) GOTO 34
C.....WATERSHED UNIT ROUGHNESS VALUES.
      RN(I)=FRN
      RK(I)=FRK
      AREA(I)=AA
      GOTO 600
 3000 CONTINUE
C
C.....AT THIS POINT WATERSHED UNIT ROUGHNESS COEFFICIENTS FOR BOTH
C.....LAMINAR (RK) AND TURBULENT (RN) FLOWS ARE READ IN.
C.....NEXT, READ IN THE USLE PARAMETERS FOR OVERLAND FLOW PLANES.
C
      REWIND 7
  700 READ(7,*) IJ,IDD,R,AKK,ALS,C,P
C     WRITE(6,*) IJ,IDD,R,AKK,ALS,C,P
      DECODE(10,80,IDD) IDW
      IF(EOF(7).NE.0) GOTO 4000
      I=0
   35 I=I+1
      IF(I.GT.NUNITS) GOTO 700
      IF(IDW.NE.IDWU(I)) GOTO 35
C.....USLE PARAMETERS FOR HE WATERSHED UNIT
      EI(I)=R
      COEFC(I)=C
      COEFK(I)=AKK
      ELES(I)=ALS
      COEFP(I)=P
      GOTO 700
 4000 CONTINUE
C     DO 5001 I=1,NUNITS
C     WRITE(6,5000) I,DAREA(I),ALENGTH(I),SLOPE(I),DROP(I),WIDTH(I),
C    +EI(I),COEFK(I),ELES(I),COEFC(I),COEFP(I),RN(I),RK(I)
 5000 FORMAT(5X,I3,2F10.2,F10.5,2F10.2,7F10.5)
 5001 CONTINUE
      RETURN
      END
      SUBROUTINE PLSED(I)
      COMMON/BLKA/QSNET(75,60)
      COMMON/BLK1/Y(60),IBEG(75),IDTIME(75),IDATEB(75),NPT(75),Q(75,60)
      COMMON/BLK2/NUNITS,NCHNL,NPLANE,NSUBWS,NOISOCH,IDWU(75),ITYPE(75),
```

```
     +           ICHNL(75),ISEGMT(75,9),ALPHA(75),BETA(75)
      COMMON/BLK3/DAREA(75),ALENGTH(75),SLOPE(75),DROP(75),ISHAPE(75),
     +           WIDTH(75)
      COMMON/BLK4/RN(75),RK(75),AREA(75)
      COMMON/BLK5/QR(60),QSAVLB(60),QSCAP(60)
      COMMON/BLK6/QWS(10,60),IB(10),IDTM(10),IDAT(10),NPP(10),IDISO(10),
     +           UI(60),XSED(60),ISO(10)
      COMMON/BLK7/EI(75),COEFK(75),COEFC(75),ELES(75),COEFP(75)
      COMMON/BLK8/QSOUT(75,60),ELEV(75,60),QSTPA(75,60)
      COMMON/BLK9/D50,RMU,WTSED
      COMMON/BLK10/QSUP(60),QDWN(60),QSLAT(60),ISEG(9),VELO(60),
     +            XSEDM(60)
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C     THIS SUBROUTINE IS TO COMPUTE SEDIMENT DISCHARGES AND CHANGES   C
C     IN SOIL SURFACE ELEVATIONS FOR PLANE UNITS. COMPUTATIONS ARE    C
C     CARRIED OUT FOR THE ENTIRE SIMULATION PERIOD.                   C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C.....SEDIMENT AVAILABILITY USING USLE.
C
      ITIMAX=NPT(I)
      DT=IDTIME(I)*60.
      CONVRT=12./(WTSED*43560.)
      SUMQ=0.
      NSTEP=0
      DO 700 IT=1,ITIMAX
C.....CUTOFF POINT FOR WATER RUNOFF HYDROGRAPH IS SET EQUAL TO 5 CFS.
      IF(Q(I,IT).LE.5.) GOTO 700
      NSTEP=NSTEP+1
      SUMQ=SUMQ+Q(I,IT)
  700 CONTINUE
      QAV=SUMQ/NSTEP
      SUMQR=0.
      DO 701 IT=1,ITIMAX
      QR(IT)=Q(I,IT)/QAV
      SUMQR=SUMQR+QR(IT)
  701 CONTINUE
      AS=EI(I)*COEFK(I)*ELES(I)*COEFC(I)*COEFP(I)*DAREA(I)
      AS=AS*2000.
C     WRITE(6,777) I,AS
  777 FORMAT(5X,*SUBROUTINE PLSED ,I,AS= *,I3,E12.7)
      DO 702 IT=1,ITIMAX
      QSAVLB(IT)=(AS/SUMQR)*QR(IT)
  702 CONTINUE
C.....TRANSPORT CAPACITY BY YALIN EQN.
      DO 703 IT=1,ITIMAX
      QSCAP(IT)=0.
      IF(Q(I,IT).LE.0.) GOTO 703
      QQ=Q(I,IT)/WIDTH(I)
      RE=QQ/RMU
      IF(RE.LE.500.) H=(QQ*RK(I)*RMU/(8.*32.2*SLOPE(I)))**0.33333
      IF(RE.GT.500.) H=(QQ*RN(I)/(1.486*SQRT(SLOPE(I))))**0.6
      IF(H.LE.0.) GOTO 703
      U=QQ/H
      TAU0=62.4*H*SLOPE(I)
      USTAR=SQRT(TAU0/1.94)
      CALL YALIN(USTAR,D50,U,H,CT,WS)
      QSCAP(IT)=WS*WIDTH(I)*IDTIME(I)*60.
```

```
  703 CONTINUE
      DO 704 IT=1,ITIMAX
C     WRITE(6,234) IT, QSCAP(IT),QSAVLB(IT)
  234 FORMAT(5X,I3,5X,*QSCAP,QSAVLB=*,2E14.5)
      IF(QSCAP(IT)-QSAVLB(IT)) 705,706,706
  705 CONTINUE
C.....QSCAP LESS THAN QSAVLB. (CAPACITY LIMITED)
      QSOUT(I,IT)=QSCAP(IT)
      IF((IT+1).GT.ITIMAX) GOTO 704
      QSAVLB(IT+1)=QSAVLB(IT+1)+(QSAVLB(IT)-QSCAP(IT))
C.....DEPOSITION DUE TO SETTLING (TO BE IMPLEMENTED IN FUTURE)
      GOTO 704
  706 CONTINUE
      QSOUT(I,IT)=QSAVLB(IT)
  704 CONTINUE
      DO 707 IT=1,ITIMAX
      QSNET(I,IT)=-QSOUT(I,IT)
      IF(IT.EQ.1) ELEV(I,1)=-QSOUT(I,1)*CONVRT/DAREA(I)
      IF(IT.GT.1) ELEV(I,IT)=ELEV(I,IT-1)-QSOUT(I,IT)*CONVRT/DAREA(I)
      QSTPA(I,IT)=QSOUT(I,IT)/(2000.*DAREA(I))
  707 CONTINUE
      RETURN
      END
      SUBROUTINE OVRLSED(I)
      COMMON/BLKA/QSNET(75,60)
      COMMON/BLK1/Y(60),IBEG(75),IDTIME(75),IDATEB(75),NPT(75),Q(75,60)
      COMMON/BLK2/NUNITS,NCHNL,NPLANE,NSUBWS,NOISOCH,IDWU(75),ITYPE(75),
     +            ICHNL(75),ISEGMT(75,9),ALPHA(75),BETA(75)
      COMMON/BLK3/DAREA(75),ALENGTH(75),SLOPE(75),DROP(75),ISHAPE(75),
     +            WIDTH(75)
      COMMON/BLK4/RN(75),RK(75),AREA(75)
      COMMON/BLK5/QR(60),QSAVLB(60),QSCAP(60)
      COMMON/BLK6/QWS(10,60),IB(10),IDTM(10),IDAT(10),NPP(10),IDISO(10),
     +            UI(60),XSED(60),ISO(10)
      COMMON/BLK7/EI(75),COEFK(75),COEFC(75),ELES(75),COEFP(75)
      COMMON/BLK8/QSOUT(75,60),ELEV(75,60),QSTPA(75,60)
      COMMON/BLK9/D50,RMU,WTSED
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C     THIS SUBROUTINE IS TO COMPUTE THE SEDIMENT OUTPUT FROM SUB-
C     WATERSHED UNITS IN THE CHANNEL LINK. THE SEDIMENT IS ROUTED    C
C     THROUGH ISOCHRONES COMPOSING THE SUBWATERSHED OVER TIME.       C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      CONVRT=12./(WTSED*43560.)
      IDU=IDWU(I)
      DECODE(6,42,IDU) NOISO
   42 FORMAT(4X,I2)
      DECODE(6,45,IDU) ISUBW
   45 FORMAT(A4,2X)
C.....FROM HEC-1 OUTPUT OBTAIN OUTFLOW HYDROGRAPHS FOR EACH ISOCHRONE.
C.....J IS ISOCHRONE NO.
      J=0
    1 J=J+1
      IF(J.GT.NOISO) GOTO 1000
      ENCODE(6,46,IDISO(J)) ISUBW,J
   46 FORMAT(A4,1H0,I1)
C
C.....ITERATE IDWU(N), N=1,NUNITS
C.....TO MATCH IDISO(J).
```

```
      N=0
   43 N=N+1
C     WRITE(6,947) N,IDISO(J),IDWU(N)
  947 FORMAT(5X,*N,IDISO,IDWU=*,I4,2A6)
      IF(N.GT.NUNITS) GOTO 100
      IF(IDISO(J).NE.IDWU(N)) GOTO 43
C.....UNIT "N" MATCHES IDISO(J). RETRIEVE NECESSARY FLOW AND GEOM. DATA
C.....HYDROLOGIC DATA
      ISO(J)=N
      IB(J)=IBEG(N)
      IDTM(J)=IDTIME(N)
      IDAT(J)=IDATEB(N)
      NPP(J)=NPT(N)
      NDATA=NPT(N)
      DO 44 IT=1,NDATA
   44 QWS(J,IT)=Q(N,IT)
C.....GEOMETRY
      AR=DAREA(N)
      ALEN=ALENGTH(N)
      SLP=SLOPE(N)
      DRP=DROP(N)
      WDI=WIDTH(N)
      ISHP=ISHAPE(N)
C.....ROUGHNESS COEFFICIENTS
      AN=RN(N)
      AK=RK(N)
C.....USLE PARAMETERS
      EII=EI(N)
      CCI=COEFC(N)
      CKI=COEFK(N)
      ELESI=ELES(N)
      CPI=COEFP(N)
  100 CONTINUE
C
C.....AT THIS POINT ALL PERTINENT DATA FOR ISOCHRONES ARE KNOWN.
C.....SEDIMENT AVAILABILITY BY USLE
C
      NSTEP=0
      SUMQ=0.
      DO 50 IT=1,NDATA
      IF(QWS(J,IT).LE.5.) GOTO 50
      NSTEP=NSTEP+1
      SUMQ=SUMQ+QWS(J,IT)
   50 CONTINUE
      QAV=SUMQ/NSTEP
      SUMQR=0.
      DO 60 IT=1,NDATA
      QR(IT)=QWS(J,IT)/QAV
      SUMQR=SUMQR+QR(IT)
   60 CONTINUE
      AS=EII*CKI*ELESI*CCI*CPI*AR
      AS=AS*2000.
      DO 70 IT=1,NDATA
      QSAVLB(IT)=(AS/SUMQR)*QR(IT)
   70 CONTINUE
C.....TRANSPORT CAPACITY BY YALIN
      DO 80 IT=1,NDATA
      UI(IT)=0.
```

```
      QSCAP(IT)=0.
      IF(QWS(J,IT).LE.0.) GOTO 80
      QQI=QWS(J,IT)/WDI
      REI=QQI/1.0E-05
      IF(REI.LE.500.) H=(QQI*AK*1.0E-05/(8.*32.2*SLP))**0.33333
      IF(REI.GT.500.) H=(QQI*AN/(1.486*SQRT(SLP)))**0.6
      IF(H.LE.0.) GOTO 80
      UI(IT)=QQI/H
      TAU0=62.4*H*SLP
      USTAR=SQRT(TAU0/1.94)
      UUI=UI(IT)
      CALL YALIN(USTAR,D50,UUI,H,CT,WS)
      QSCAP(IT)=WS*WDI*IDTM(J)*60.
   80 CONTINUE
C.....CHECK IF FIRST ISOCHRONE... IF YES, PROCEED WITH SEDIMENT ROUTING
      IF(J.EQ.1) GOTO 2
C.....ISOCHRONE NUMBER THAN GREATER THAN 1... COMPUTE SEDIMENT WAVE FRONT
      NM1=ISO(J-1)
      DO 400 IT=1,NDATA
  400 XSED(IT)=UI(IT)*IDTM(J)*60.
      KOUNT=0
  101 KOUNT=KOUNT+1
      IT=KOUNT-1
      XT=0.
  102 IT=IT+1
      IF(IT.GT.NDATA) GOTO 103
      XT=XT+XSED(IT)
      IF(XT.GT.ALEN) QSAVLB(IT+1)=QSAVLB(IT+1)+QSOUT(NM1,KOUNT)
      IF(XT.GT.ALEN) GOTO 101
      GOTO 102
  103 CONTINUE
    2 CONTINUE
      DO 90 IT=1,NDATA
      IF(QSCAP(IT)-QSAVLB(IT)) 91,92,92
   91 CONTINUE
C.....CAPACITY LIMITED...
      QSOUT(N,IT)=QSCAP(IT)
      IF(IT+1.GT.NDATA) GOTO 90
      QSAVLB(IT+1)=QSAVLB(IT+1)+(QSAVLB(IT)-QSCAP(IT))
      GOTO 90
   92 CONTINUE
C.....AVAILABILITY LIMITED
      QSOUT(N,IT)=QSAVLB(IT)
   90 CONTINUE
      GOTO 1
 1000 CONTINUE
C.....AT THIS POINT ALL SEDIMENT DISCHARGES ALONG ISOCHRONES ARE COMPUTED.
C.....APPLY SEDIMENT CONTINUITY EQN. FOR SCOUR OR DEPOSITION.
      NDATA=NPT(I)
      DO 110 IT=1,NDATA
      DO 111 J=1,NOISO
      N=ISO(J)
      IF(J.GT.1) NM1=ISO(J-1)
      IF(J.GT.1) DQS=QSOUT(N,IT)-QSOUT(NM1,IT)
      IF(J.EQ.1) DQS=QSOUT(N,IT)
      QSNET(N,IT)=-DQS
      QSTPA(N,IT)=DQS/(2000.*DAREA(N))
      IF(IT.EQ.1) ELEV(N,1)=-DQS*CONVRT/DAREA(N)
```

```
      IF(IT.GT.1) ELEV(N,IT)=ELEV(N,IT-1)-DQS*CONVRT/DAREA(N)
  111 CONTINUE
  110 CONTINUE
      RETURN
      END
      SUBROUTINE CHNLR
      COMMON/BLKA/QSNET(75,60)
      COMMON/BLK1/Y(60),IBEG(75),IDTIME(75),IDATEB(75),NPT(75),Q(75,60)
      COMMON/BLK2/NUNITS,NCHNL,NPLANE,NSUBWS,NOISOCH,IDWU(75),ITYPE(75),
     +            ICHNL(75),ISEGMT(75,9),ALPHA(75),BETA(75)
      COMMON/BLK3/DAREA(75),ALENGTH(75),SLOPE(75),DROP(75),ISHAPE(75),
     +            WIDTH(75)
      COMMON/BLK4/RN(75),RK(75),AREA(75)
      COMMON/BLK5/QR(60),QSAVLB(60),QSCAP(60)
      COMMON/BLK6/QWS(10,60),IB(10),IDTM(10),IDAT(10),NPP(10),IDISO(10),
     +            U1(60),XSED(60),ISO(10)
      COMMON/BLK7/EI(75),COEFK(75),COEFC(75),ELES(75),COEFP(75)
      COMMON/BLK8/QSOUT(75,60),ELEV(75,60),QSTPA(75,60)
      COMMON/BLK9/D50,RMU,WTSED
      COMMON/BLK10/QSUP(60),QDWN(60),QSLAT(60),ISEG(9),VELO(60),
     +             XSEDM(60)
C.....CHANNEL UNITS ARE STORED IN VECTOR ICHNL(I),I=1,NCHNL
C.....SEGMENTS CONNECTED TO CHANNEL UNITS ARE STORED IN ARRAY
C.....ISEGMT(I,NSEG)
      I=0
    1 I=I+1
      IF(I.GT.NCHNL) GOTO 1000
      DO 9 NN=1,9
    9 ISEG(NN)=0
      IDCHNL=ICHNL(I)
      ITIMAX=NPT(I)
      DO 10 IT=1,ITIMAX
C.....INITIALIZE
      QSUP(IT)=0.
      QDWN(IT)=0.
      QSLAT(IT)=0.
      QSCAP(IT)=0.
      QSAVLB(IT)=0.
   10 CONTINUE
      NSEG=0
   11 NSEG=NSEG+1
      IF(NSEG.GT.9) GOTO 12
      IF(ISEGMT(I,NSEG).LE.0) GOTO 12
      ISEG(NSEG)=ISEGMT(I,NSEG)
      GOTO 11
   12 CONTINUE
      NMAX=NSEG-1
      N=0
   13 N=N+1
      IF(N.GT.NMAX) GOTO 20
      IJ=ISEG(N)
      IF(ITYPE(IJ).EQ.2) GOTO 15
   14 CONTINUE
C.....CHANNEL OR SUBWATERSHED UNITS CONTRIBUTE TO UPSTREAM SEDIMENT INFLOW
C.....INTO THE REACH.
      DO 16 IT=1,ITIMAX
      QSUP(IT)=QSUP(IT)+QSOUT(IJ,IT)
   16 CONTINUE
```

```
      GOTO 13
   15 CONTINUE
C.....PLANE UNITS CONTRIBUTE TO LATERAL SEDIMENT INFLOW.
      DO 17 IT=1,ITIMAX
      QSLAT(IT)=QSLAT(IT)+QSOUT(IJ,IT)/ALENGTH(IDCHNL)
   17 CONTINUE
      GOTO 13
   20 CONTINUE
      ALP=ALPHA(IDCHNL)
      BET=BETA(IDCHNL)
C.....COMPUTE SEDIMENT TRANSPORT CAPACITY FOR CHANNEL UNIT IDCHNL
      IT=0
   21 IT=IT+1
      IF(IT.GT.ITIMAX) GOTO 22
      QSCAP(IT)=0.
      VELO(IT)=0.
      IF(Q(IDCHNL,IT).LE.0.) GOTO 21
      QQ=Q(IDCHNL,IT)
      XSA=(QQ/ALP)**(1./BET)
      VEL=QQ/XSA
      DD=XSA/WIDTH(IDCHNL)
      TAU0=62.4*DD*SLOPE(IDCHNL)
      USTAR=SQRT(TAU0/1.94)
      VELO(IT)=VEL
      CALL YALIN(USTAR,D50,VEL,DD,CT,WS)
      QSCAP(IT)=WS*WIDTH(IDCHNL)*IDTIME(IDCHNL)*60.
      GOTO 21
   22 CONTINUE
C.....AT THIS POINT SEDIMENT TRANSPORT CAPACITIES AT HE DOWNSTREAM
C.....END OF CHANNEL UNITS ARE KNOWN FOR THE SIMULATION PERIOD.
C.....NEXT, COMPUTE THE AMOUNT OF WASHLOAD AVAILABLE FOR TRANSPORT.
C.....TO ACCOMPLISH THIS COMPUTE THE LOCATION OF SEDIMENT WAVE
C.....FRONT OVER TIME.
C.....UPSTREAM CONTRIBUTION TO AVAILABLE SEDIMENT
      DO 30 IT=1,ITIMAX
   30 XSEDM(IT)=VELO(IT)*IDTIME(IDCHNL)*60.
      KOUNT=0
   31 KOUNT=KOUNT+1
      XT=0.
      IT=KOUNT-1
   32 IT=IT+1
      IF(IT.GT.ITIMAX) GOTO 33
      XT=XT+XSEDM(IT)
      IF(XT.GT.ALENGTH(IDCHNL)) QSAVLB(IT+1)=QSAVLB(IT+1)+QSUP(KOUNT)
      IF(XT.GT.ALENGTH(IDCHNL)) GOTO 31
      GOTO 32
   33 CONTINUE
C.....LATERAL CONTRIBUTION TO AVAILABLE SEDIMENT
      KOUNT=0
   34 KOUNT=KOUNT+1
      XT=0.
      IT=KOUNT-1
   36 IT=IT+1
      IF(IT.GT.ITIMAX) GOTO 37
      XT=XT+XSEDM(IT)
      IF(ALENGTH(IDCHNL)-XT.GT.0.) QSAVLB(IT+1)=QSAVLB(IT+1)+XSEDM(IT)*
     +   QSLAT(KOUNT)
      IF(ALENGTH(IDCHNL)-XT.GT.0.) GOTO 36
```

```
      QSAVLB(IT+1)=QSAVLB(IT+1)+(ALENGTH(IDCHNL)-XT+XSEDM(IT))*
     +QSLAT(KOUNT)
      GOTO 34
   37 CONTINUE
C.....COMPUTE NET SEDIMENT OUTFLOW FROM UNIT "I"
      DO 40 IT=1,ITIMAX
      IF(QSCAP(IT)-QSAVLB(IT)) 41,42,42
   41 CONTINUE
C.....CAPACITY LIMITED
      QSOUT(IDCHNL,IT)=QSCAP(IT)
      IF(IT+1.GT.ITIMAX) GOTO 40
      QSAVLB(IT+1)=QSAVLB(IT+1)+(QSAVLB(IT)-QSCAP(IT))
      GOTO 40
   42 CONTINUE
C.....AVAILABILITY LIMITED
      QSOUT(IDCHNL,IT)=QSAVLB(IT)
   40 CONTINUE
C.....QSOUT IS IN LBS/TIME INCREMENT
C.....COMPUTE NET CHANGE IN SEDIMENT WEIGHT FOR EACH TIME INCREMENT
      CONVRT=12./(WTSED*43560.)
      DO 50 IT=1,ITIMAX
      DQS=QSOUT(IDCHNL,IT)-QSUP(IT)-QSLAT(IT)*ALENGTH(IDCHNL)
      QSNET(IDCHNL,IT)=-DQS
      ARTOP=ALENGTH(IDCHNL)*WIDTH(IDCHNL)
      ARTOP=ARTOP/43560.
      IF(IT.EQ.1) ELEV(IDCHNL,IT)=-DQS*CONVRT/ARTOP
      IF(IT.GT.1) ELEV(IDCHNL,IT)=ELEV(IDCHNL,IT-1)-DQS*CONVRT/ARTOP
      QSTPA(IDCHNL,IT)=DQS/(2000.*ARTOP)
   50 CONTINUE
      GOTO 1
 1000 CONTINUE
      RETURN
      END
      SUBROUTINE YALIN(USTAR,D50,U,H,CT,WS)
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C     THIS SUBROUTINE IS TO COMPUTE THE SEDIMENT CONCENTRATION CT       C
C     USING YALIN'S TRANSPORT FORMULA. (CREAMS MANUAL PP.45)            C
C     NOTE THAT D50 IS IN FEET AND WS IS IN LBS/FT/SEC . CT IS          C
C     DIMENSIONLESS.                                                    C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      S=2.65
      GAMMA=62.4
      G=32.2
      RO=1.94
      CALL SHIELD(USTAR,D50,TAUCR)
      Y=USTAR*USTAR/(1.65*G*D50)
      YCR=TAUCR/(1.65*GAMMA*D50)
      CT=0.
      WS=0.
      IF(U.LE.0. .OR. H.LE.0.) RETURN
      IF(Y.LE.YCR) RETURN
      SIGMA=Y/YCR-1.
      A=2.45*SQRT(YCR/S**0.4)
      A1=1.-ALOG(1.+A*SIGMA)/(A*SIGMA)
      A2=0.635*SIGMA*S*D50*USTAR
      CT=A1*A2/(U*H)
C     WS IS WEIGHT/UNIT LENGTH/UNIT TIME
C     CT IS THE SEDIMENT CONCENTRATION (PPM) BY WEIGTH
```

```
      WS=A1*A2*62.4
      RETURN
      END
      SUBROUTINE SHIELD(USTAR,D50,TAUCR)
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C     SUBROUTINE TO COMPUTE CRITICAL SHEAR STRESS USING SHIELDS FCTS.  C
C     D50 IS IN FEET.                                                  C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      RSTAR=USTAR*D50/1.0E-05
      IF(RSTAR.LE.10.) TAUCR=0.08*1.65*62.4*D50/RSTAR**0.4
      IF(RSTAR.GE.10. .AND. RSTAR.LE.500.)
     +   TAUCR=0.022*1.65*62.4*D50/RSTAR**0.16
      IF(RSTAR.GT.500.) TAUCR=0.06*1.65*62.4*D50
      RETURN
      END
      SUBROUTINE PRINTER(NPRNT)
      COMMON/BLKA/QSNET(75,60)
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C     IF NPRNT=0     NO PRINTOUT IS GENERATED                    C
C     IF NPRNT=1     ONLY THE INPUT DATA IS PRINTED              C
C     IF NPRNT=2     ONLY THE RESULTS ARE PRINTED                C
C     IF NPRNT=3     ALL THE INFORMATION IS PRINTED              C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      COMMON/BLK1/Y(60),IBEG(75),IDTIME(75),IDATEB(75),NPT(75),Q(75,60)
      COMMON/BLK2/NUNITS,NCHNL,NPLANE,NSUBWS,NOISOCH,IDWU(75),ITYPE(75),
     +            ICHNL(75),ISEGMT(75,9),ALPHA(75),BETA(75)
      COMMON/BLK3/DAREA(75),ALENGTH(75),SLOPE(75),DROP(75),ISHAPE(75),
     +            WIDTH(75)
      COMMON/BLK4/RN(75),RK(75),AREA(75)
      COMMON/BLK5/QR(60),QSAVLB(60),QSCAP(60)
      COMMON/BLK6/QWS(10,60),IB(10),IDTM(10),IDAT(10),NPP(10),IDISO(10),
     +            UI(60),XSED(60),ISO(10)
      COMMON/BLK7/EI(75),COEFK(75),COEFC(75),ELES(75),COEFP(75)
      COMMON/BLK8/QSOUT(75,60),ELEV(75,60),QSTPA(75,60)
      COMMON/BLK9/D50,RMU,WTSED
      COMMON/BLK10/QSUP(60),QDWN(60),QSLAT(60),ISEG(9),VELO(60),
     +             XSEDM(60)
      IF(NPRNT.EQ.0) GOTO 2000
      IF(NPRNT.EQ.2) GOTO 1000
      WRITE(6,1)
      WRITE(6,2)
      DO 100 I=1,NUNITS
      WRITE(6,3) IDWU(I),IBEG(I),IDTIME(I),IDATEB(I),NPT(I)
      WRITE(6,4)
      NCARD=(NPT(I)/10)+0.99
      DO 5 NC=1,NCARD
      J1=(NC-1)*10+1
      J2=NC*10
      IF(J2.GT.NPT(I)) J2=NPT(I)
      WRITE(6,6) (Q(I,J),J=J1,J2)
    5 CONTINUE
  100 CONTINUE
      WRITE(6,7)
      DO 200 I=1,NUNITS
      WRITE(6,8) IDWU(I),ITYPE(I)
  200 CONTINUE
      WRITE(6,9)
      WRITE(6,910)
```

```
      DO 300 I=1,NCHNL
      IJ=ICHNL(I)
      WRITE(6,10) IDWU(IJ),ICHNL(I),ALPHA(IJ),BETA(IJ),(ISEGMT(I,J),
     +J=1,9)
  300 CONTINUE
      WRITE(6,11)
      WRITE(6,12)
      DO 400 I=1,NUNITS
      WRITE(6,13) IDWU(I),DAREA(I),ALENGTH(I),SLOPE(I),DROP(I),ISHAPE(I)
     +,            WIDTH(I)
  400 CONTINUE
      WRITE(6,14)
      DO 500 I=1,NUNITS
      WRITE(6,15) IDWU(I),RN(I),RK(I)
  500 CONTINUE
      WRITE(6,16)
      WRITE(6,17)
      I1=NCHNL+1
      DO 600 I=I1,NUNITS
      WRITE(6,18) IDWU(I),EI(I),COEFK(I),ELES(I),COEFC(I),COEFP(I)
  600 CONTINUE
C
C.....END OF INPUT DATA
C
 1000 CONTINUE
      IF(NPRNT.EQ.1) GOTO 2000
      DO 700 I=1,NUNITS
      WRITE(6,19) IDWU(I)
      WRITE(6,20)
      NDATA=NPT(I)
      DO 800 J=1,NDATA
      IF(ITYPE(I).EQ.2) QSOUT(I,J)=QSOUT(I,J)*WIDTH(I)
      IF(J.EQ.1) QSTPA(I,J)=QSOUT(I,J)/(2000.*DAREA(I))
      IF(J.GT.1) QSTPA(I,J)=QSTPA(I,J-1)+QSOUT(I,J)/(2000.*DAREA(I))
      WRITE(6,21) J,QSOUT(I,J),ELEV(I,J),QSTPA(I,J)
  800 CONTINUE
  700 CONTINUE
C     DO 703 IST=1,10
C     NDATA=IST*6
      WRITE(6,22)
       TOTALQS=0.
       TOTALAR=0.
       DO 701 NUNT=1,NUNITS
       SUMQSD=0.
       DO 702 ITM=1,NDATA
       SUMQSD=SUMQSD+QSNET(NUNT,ITM)
  702  CONTINUE
       SUMQSPA=SUMQSD/(DAREA(NUNT)*2000.)
      IF(ITYPE(NUNT).EQ.1) GOTO 710
      TOTALQS=TOTALQS+SUMQSD
        TOTALAR=TOTALAR+DAREA(NUNT)
  710 CONTINUE
       WRITE(6,23) IDWU(NUNT),DAREA(NUNT),SUMQSD,SUMQSPA
  701 CONTINUE
       AVEROS=TOTALQS/(TOTALAR*2000.)
       TOTQST=TOTALQS/2000.
       WRITE(6,24) TOTALQS,TOTQST,TOTALAR,AVEROS
  703 CONTINUE
```

```
 2000 CONTINUE
      REWIND 9
      IDDATA=8H QS DATA
      DO 3000 I=1,NUNITS
      WRITE(9,291) IDWU(I),IDTIME(I),IBEG(I),IDDATA,NPT(I)
  291 FORMAT(2X,A6,I5,I4,A8,6X,I4)
      NDATA=NPT(I)
      NCARD=(NDATA/10)+0.99
      DO 290 K=1,NCARD
      J1=(K-1)*10+1
      J2=K*10
      IF(J2.GT.NDATA) J2=NDATA
      WRITE(9,292) (QSOUT(I,J),J=J1,J2)
  292 FORMAT(2X,10F13.4)
  290 CONTINUE
 3000 CONTINUE
      IDDATA=8H ELEVS.
      DO 4000 I=1,NUNITS
      WRITE(9,291) IDWU(I),IDTIME(I),IBEG(I),IDDATA,NPT(I)
      NDATA=NPT(I)
      NCARD=(NDATA/10)+0.99
      DO 390 K=1,NCARD
      J1=(K-1)*10+1
      J2=K*10
      IF(J2.GT.NDATA) J2=NDATA
      WRITE(9,292) (ELEV(I,J),J=J1,J2)
  390 CONTINUE
 4000 CONTINUE
      IDDATA=8H QS T/A
      DO 5000 I=1,NUNITS
      WRITE(9,291) IDWU(I),IDTIME(I),IBEG(I),IDDATA,NPT(I)
      NDATA=NPT(I)
      NCARD=(NDATA/10)+0.99
      DO 490 K=1,NCARD
      J1=(K-1)*10+1
      J2=K*10
      IF(J2.GT.NDATA) J2=NDATA
      WRITE(9,292) (QSTPA(I,J),J=J1,J2)
  490 CONTINUE
 5000 CONTINUE
      IDDATA=8HNET QS
      DO 6000 I=1,NUNITS
      WRITE(9,291) IDWU(I),IDTIME(I),IBEG(I),IDDATA,NPT(I)
      NDATA=NPT(I)
      NCARD=(NDATA/10)+0.99
      DO 590 K=1,NCARD
      J1=(K-1)*10+1
      J2=K*10
      IF(J2.GT.NDATA) J2=NDATA
      WRITE(9,292) (QSNET(I,J),J=J1,J2)
  590 CONTINUE
 6000 CONTINUE

C
C.....FORMAT STATEMENTS
C
    1 FORMAT(1H1,5X,*INPUT DATA FOR WATERSHED ROUTING*,/,5X,
     +36H*************************************)
```

```
  2 FORMAT(//,15X,*HYDROLOGIC DATA*)
  3 FORMAT(//,5X,*WATERSHED ID: *,A6,/,
   +       5X,*TIME OF START:*,I6,/,
   +       5X,*TIME INCREMENT:*,I5,* MINS.*,/,
   +       5X,*DATE OF EVENT: *,A8,/,
   +       5X,*NO. OF INCRMTS:*,I5,//)
  4 FORMAT(5X,*DISCHARGES OVER SIMULATION PERIOD:*,/)
  6 FORMAT(2X,10F13.1)
  7 FORMAT(//,50X,*LINKAGE DATA*,/)
  8 FORMAT(5X,*UNIT ID: *,A6,*  WATERHED UNIT TYPE:*,I4)
  9 FORMAT(//,5X,*CHANNEL UNITS AND SEGMENTS ATTACHED TO THEM:*,/)
 10 FORMAT(5X,A6,5X,I5,2F10.5,9I4)
910 FORMAT(/,5X,
   +*  ID       UNIT NO.  ALPHA   BETA    CONNECTED UNIT NOS.*,/,5X,
   +55H*******************************************************)
 11 FORMAT(//,50X,*CHANNEL PROPERTIES DATA*,/)
 12 FORMAT(5X,*ID NO.   AREA   LENGTH   SLOPE   DROP   SHAPE   WIDTH*
   +,/,5X,53H*******************************************************,//)
 13 FORMAT(5X,A6,1X,F7.1,F8.1,2F8.4,6X,A1,F10.1)
 14 FORMAT(//,50X,*ROUGHNESS DATA*,/,5X,
   +*ID NO.   MANNING    LAMINAR*,/,14X,
   +         * COEF.    FRCT COEF*,/)
 15 FORMAT(5X,A6,F10.3,F10.2)
 16 FORMAT(//,35X,*USLE PARAMETERS FOR PLANE AND SUBWATERSHED UNITS*)
 17 FORMAT(//,5X,
   +*ID NO.    R    K    LS     C     P  *,/)
 18 FORMAT(5X,A6,2F6.2,F8.4,F6.3,F6.1)
 19 FORMAT(1H1,15X,*COMPUTED SEDIMENT YIELDS FOR UNIT ID: *,A6,/,
   +          15X,44H*********************************************,//)
 20 FORMAT(5X,*TIME INCR.     SEDIMENT DISCH    CHANGE IN    ACC. SED*
   +*MNT*,/,5X,*   NO.         (LBS./INCREM)     ELV. (IN)    LOAD (T*
   +*/A)*,//)
 21 FORMAT(5X,I6,8X,3E14.6)
 22 FORMAT(1H1,11X,*SUMMARY TABLE FOR SUBBASIN SEDIMENT YIELDS FOR*,
   +* WATERSHED UNITS*,/,11X,
   +62H*************************************************************,
   + //,15X,* UNIT      AREA     TOTAL LOSS/GAIN     TOTAL LOSS/GAIN*,
   +/,15X,  *  ID      (ACRE)      (LBS/EVENT)      (TONS/ACRE/EVENT)*
   +,/,15X,56H*************************************************************
   +,//)
 23 FORMAT(15X,A6,4X,F7.0,8X,F10.0,8X,F10.3)
 24 FORMAT(//,15X,*TOTAL SEDIMENT LOSS/GAIN=*,F10.0,* LBS  (*,F8.0,
   +* TONS)*,/,15X,       *TOTAL DRAINAGE AREA     =*,F10.0,* ACRES*
   +,/,15X,       *AVERAGE EROSION RATE    =*,F10.3,* TONS/ACRE/EVENT*
   +)
    RETURN
    END
```

APPENDIX B: SELECTED PARAMETER VALUES AND RELATIONSHIPS BETWEEN NUMBERING SYSTEMS

Table B-1. Description of various soil associations.

ID no.	Name	Soil group	Description
1	Alligator-Forestdale	D	fine textured to moderately fine textured
2	Alligator	D	fine textured throughout
3	Dundee-Dubbs	(C+B) = C	have a medium-textured or moderately fine textured subsoil
4	Collins-Falaya	(C+C) = C	medium textured throughout
5	Falaya-Collins	(C+C) = C	medium textured throughout, formed in silty alluvium on flood plains
6	Memphis-Gullied land	B	formed in loess, have a medium textured to moderately fine textured subsoil
7	Waverly-Calhoun	(B/D+D) = D	medium textured or moderately fine textured throughout. Formed in silty alluvium
8	Alligator-Forestdale	(D+D) = D	fine textured soils formed in old alluvium
9	Waverly-Falaya-Forestdale	(B/D+C+C) = C	silty soils formed in recent alluvium
10	Falaya-Collins-Waverly	(C+C+B/D) = C	silty soils formed in recent alluvium
11	Memphis	B	silty soils
12	Dubbs-Dundee-Forestdale	(B+C+D) = C	predominantly silt loam; some clay
13	Alligator-Dowling	(D+?) = D	predominantly clay; some silty clay and silt loam

Table B-1. (Concluded)

ID no.	Name	Soil group	Description
14	Collins-Falaya-Hymon-Ina	(C+C+?+?) = C	predominantly silt loam; some silty clay
15	Water	N/A	CN = 100

Table B-2. Various soil association groups and the corresponding Soil Erodibility Factor "K" Values.

	Soil association groups	Factor "K"
1	Alligator-Forestdale	0.43
2	Alligator	0.43
3	Dundee-Dubbs	0.37
4	Collins-Falaya	0.37
5	Falaya-Collins	0.37
6	Memphis-Gullied Land	0.32
7	Waverly-Calhoun	0.37
8	Alligator-Forestdale	0.43
9	Waverly-Falaya-Collins	0.37
10	Falaya-Collins-Waverly	0.37
11	Memphis	0.32
12	Dubbs-Dundee-Forestdale	0.39
13	Alligator-Dowling	0.43
14	Collins-Falaya-Hymon-Ina	0.39
15	Water	0.00

Table B-3. Various landuse groups and the corresponding Cover and Management Factor "C" Values.

	Landuse group		Factor "C"
1	OW	Open Water	0.000
2	AG	Agricultural	0.250
3	C/BF	Cleared Basins and Flats	0.100
4	W/SS	Wooded and/or Shrub Swamp	0.001
5	URBAN/DEV	Urban Development	0.013
6	B H	Bottomland Hardwood	0.001
7	W/BF	Wooded Basins and Flats	0.003
8	CFL	Cleared Forest Land	0.100
9	FF	Fish Farm	0.000

Table B-4. Soil Conservation Service runoff curve numbers for different soil types and landuse groups.

CURVE NUMBERS FOR DIFFERENT LAND USES AND SOIL TYPES

Landuse groups			Soil types A	B	C	D	Manning coef.
1	OW	Open Water	100	100	100	100	0.010
2	AG	Agricultural	72	81	88	91	0.040
3	C/BF	Cleared Basins and Flats	68	79	86	89	0.045
4	W/SS	Wooded and/or Shrub Swamp	95	95	95	95	0.085
5	URBAN/DEV	Urban Development	59	74	82	86	0.045
6	B H	Bottomland Hardwood	25	55	70	77	0.085
7	W/BF	Wooded Basins and Flats	36	60	79	84	0.075
8	CFL	Cleared Forest Land	49	69	79	84	0.055
9	FF	Fish Farm	0	0	0	0	0.010

Table B-5. Relationships between numbering systems.

Hydrologic unit type (Figure 3.3)	Computational hydrologic (Figure 4.5)	GIS hydrological unit ID (Appendix C)	Abbreviated GIS codes for landscape hydrologic units (Figure 4.4)
Subwatershed and associated isochrones	SW-39	020106	106
		020105	105
		020104	104
		020103	103
		020102	102
		020101	101
	SW-38	020206	206
		020205	205
		020204	204
		020203	203
		020202	202
		020201	201
	SW-37	020404	404
		020403	403
		020402	402
		020401	401
	SW-36	020602	602
		020601	601
	SW-35	020807	807
		020806	806
		020805	805
		020804	804
		020803	803
		020802	802
		020801	801
	SW-34	021203	1203
		021202	1202
		020201	1201
	SW-33	021103	1103
		021102	1102
		021101	1101
	SW-32	021403	1403
		021402	1402
		021401	1401
	SW-31	021703	1703
		021702	1702
		021701	1701

Table B-5. (Concluded)

Hydrologic unit type (Figure 3.3)	Computational hydrologic (Figure 4.5)	GIS hydrological unit ID (Appendix C)	Abbreviated GIS codes for landscape hydrologic units (Figure 4.4)
Plane units	PL-30	203011	301
	PL-29	203012	301
	PL-28	203021	302
	PL-27	203022	302
	PL-26	205011	501
	PL-25	205012	501
	PL-24	207011	701
	PL-23	207012	701
	PL-22	209011	901
	PL-21	209012	901
	PL-20	210011	1001
	PL-19	210012	1001
	PL-18	213011	1301
	PL-17	213012	1301
	PL-16	215011	1501
	PL-15	215012	1501
	PL-14	216011	1601
	PL-13	216012	1601
	PL-12	218011	1801
	PL-11	218012	1801
Channel units	CH-10	020301	
	CH-9	020302	
	CH-8	020501	
	CH-7	020701	
	CH-6	020901	
	CH-5	021001	
	CH-4	021301	
	CH-3	021501	
	CH-2	021601	
	CH-1	021801	

APPENDIX C: SELECTED MODEL OUTPUT

SUMMARY OF COMPUTER RUN NO. 1 RESULTS

SUMMARY TABLE FOR SUBBASIN SEDIMENT YIELDS FOR WATERSHED UNITS

UNIT ID	AREA (ACRE)	TOTAL LOSS/GAIN (LBS/EVENT)	TOTAL LOSS/GAIN (TONS/ACRE/EVENT)
021801	5.	5128.	.467
021601	4.	2191.	.257
021501	5.	979.	.100
021301	4.	129.	.015
021001	10.	211197.	10.592
020901	14.	363263.	13.002
020701	7.	905616.	62.456
020501	8.	450031.	28.127
020302	4.	346240.	40.260
020301	3.	939795.	138.205
218011	60.	-12540.	-.105
218012	59.	-12633.	-.107
216011	120.	-35075.	-.146
216012	36.	-34589.	-.480
215011	78.	-21750.	-.139
215012	78.	-21750.	-.139
213011	26.	-7549.	-.145
213012	85.	-21549.	-.127
210011	120.	-95695.	-.399
210012	219.	-151219.	-.345
209011	200.	-49889.	-.125
209012	226.	-85909.	-.190
207011	120.	-33481.	-.140
207012	169.	-54333.	-.161
205011	165.	-47910.	-.145
205012	164.	-48000.	-.146
203021	30.	-21663.	-.361
203022	47.	-14161.	-.151
203011	70.	-73929.	-.528
203012	131.	-151400.	-.578
021703	180.	-16748.	-.047
021403	318.	-105813.	-.166
021203	168.	-19224.	-.057
021103	273.	-12493.	-.023
020807	221.	617475.	1.397
020602	610.	-88342.	-.072
020404	55.	397915.	3.617
020206	156.	384191.	1.231
020106	144.	272963.	.948
020101	195.	-452770.	-1.161
020102	248.	-203733.	-.411
020103	341.	-632025.	-.927
020104	261.	-330392.	-.633
020105	420.	567758.	.676
020201	221.	-555636.	-1.257
020202	251.	-592835.	-1.181
020203	333.	-426416.	-.640
020204	480.	253620.	.264
020205	534.	-6142.	-.006
020401	163.	-96943.	-.297
020402	494.	-345031.	-.349
020403	181.	-174836.	-.483
020601	863.	-178912.	-.104
020801	150.	-345104.	-1.150
020802	193.	-118379.	-.307
020803	151.	-342423.	-1.134
020804	222.	-107441.	-.242
020805	631.	104238.	.083
020806	535.	-260610.	-.244
021401	580.	-182559.	-.157
021402	528.	-208343.	-.197
021201	246.	-7484.	-.015
021202	254.	-16783.	-.033
021101	759.	-42716.	-.028
021102	361.	-22550.	-.031
021701	612.	-128009.	-.105
021702	360.	-66057.	-.092

TOTAL SEDIMENT LOSS/GAIN= -4483609. LBS (-2242. TONS)
TOTAL DRAINAGE AREA = 14895. ACRES
AVERAGE EROSION RATE = -.151 TONS/ACRE/EVENT

SUMMARY OF COMPUTER RUN NO. 2 RESULTS

SUMMARY TABLE FOR SUBBASIN SEDIMENT YIELDS FOR WATERSHED UNITS

UNIT ID	AREA (ACRE)	TOTAL LOSS/GAIN (LBS/EVENT)	TOTAL LOSS/GAIN (TONS/ACRE/EVENT)
021801	5.	5509.	.502
021601	4.	2691.	.316
021501	5.	826.	.085
021301	4.	179.	.021
021001	10.	196285.	9.844
020901	14.	334656.	11.978
020701	7.	796636.	54.940
020501	8.	395888.	24.743
020302	4.	295344.	34.342
020301	3.	849107.	124.869
218011	60.	-10932.	-.091
218012	59.	-11016.	-.093
216011	120.	-31684.	-.132
216012	36.	-31246.	-.434
215011	78.	-22022.	-.141
215012	78.	-22022.	-.141
213011	26.	-7688.	-.148
213012	85.	-21864.	-.129
210011	120.	-86605.	-.361
210012	219.	-136951.	-.313
209011	200.	-45022.	-.113
209012	226.	-78433.	-.174
207011	120.	-30373.	-.127
207012	169.	-49353.	-.146
205011	165.	-43410.	-.132
205012	164.	-43496.	-.133
203021	30.	-19572.	-.326
203022	47.	-12853.	-.137
203011	70.	-66777.	-.477
203012	131.	-137287.	-.524
021703	180.	-17952.	-.050
021403	318.	-56054.	-.088
021203	168.	-19071.	-.057
021103	273.	-12536.	-.023
020807	221.	513267.	1.161
020602	610.	-85076.	-.070
020404	55.	358259.	3.257
020206	156.	330381.	1.059
020106	144.	266158.	.924
020101	195.	-408800.	-1.048
020102	248.	-173220.	-.349
020103	341.	-527791.	-.774
020104	261.	-249562.	-.478
020105	420.	431579.	.514
020201	221.	-501679.	-1.135
020202	251.	-525879.	-1.048
020203	333.	-388715.	-.584
020204	480.	265392.	.276
020205	534.	-18407.	-.017
020401	163.	-87105.	-.267
020402	494.	-313908.	-.318
020403	181.	-153546.	-.424
020601	863.	-160788.	-.093
020801	150.	-300085.	-1.000
020802	193.	-113733.	-.295
020803	151.	-303073.	-1.004
020804	222.	-75179.	-.169
020805	631.	104711.	.083
020806	535.	-224176.	-.210
021401	580.	-185609.	-.160
021402	528.	-210279.	-.199
021201	246.	-7560.	-.015
021202	254.	-16893.	-.033
021101	759.	-43409.	-.029
021102	361.	-22327.	-.031
021701	612.	-114724.	-.094
021702	360.	-57422.	-.080

TOTAL SEDIMENT LOSS/GAIN= -4013413. LBS (-2007. TONS)
TOTAL DRAINAGE AREA = 14895. ACRES
AVERAGE EROSION RATE = -.135 TONS/ACRE/EVENT

SUMMARY OF COMPUTER RUN NO. 3 RESULTS

SUMMARY TABLE FOR SUBBASIN SEDIMENT YIELDS FOR WATERSHED UNITS

UNIT ID	AREA (ACRE)	TOTAL LOSS/GAIN (LBS/EVENT)	TOTAL LOSS/GAIN (TONS/ACRE/EVENT)
021801	5.	6332.	.577
021601	4.	3133.	.368
021501	5.	1270.	.130
021301	4.	401.	.047
021001	10.	175558.	8.804
020901	14.	238062.	8.520
020701	7.	817948.	56.410
020501	8.	379327.	23.708
020302	4.	147389.	17.138
020301	3.	764729.	112.460
218011	60.	-13011.	-.108
218012	59.	-13103.	-.111
216011	120.	-36800.	-.153
216012	36.	-22251.	-.309
215011	78.	-22689.	-.145
215012	78.	-22689.	-.145
213011	26.	-7978.	-.153
213012	85.	-22563.	-.133
210011	120.	-67050.	-.279
210012	219.	-135777.	-.318
209011	200.	-50253.	-.126
209012	226.	-86982.	-.192
207011	120.	-34005.	-.142
207012	169.	-55060.	-.163
205011	165.	-48817.	-.148
205012	164.	-48908.	-.149
203021	30.	-13949.	-.232
203022	47.	-14855.	-.158
203011	70.	-47525.	-.339
203012	131.	-100371.	-.383
021703	180.	61809.	.172
021403	318.	82425.	.130
021203	168.	-18537.	-.055
021103	273.	-11935.	-.022
020807	221.	500997.	1.133
020602	610.	-77035.	-.063
020404	55.	340185.	3.093
020206	156.	183559.	.588
020106	144.	166200.	.577
020101	195.	-290441.	-.745
020102	248.	-169583.	-.342
020103	341.	-405924.	-.595
020104	261.	-243241.	-.466
020105	420.	356947.	.425
020201	221.	-356407.	-.806
020202	251.	-372216.	-.741
020203	333.	-417662.	-.627
020204	480.	219108.	.228
020205	534.	2612.	.002
020401	163.	-99334.	-.305
020402	494.	-348119.	-.352
020403	181.	-62598.	-.173
020601	863.	-180801.	-.105
020801	150.	-226238.	-.754
020802	193.	-93420.	-.242
020803	151.	-205764.	-.681
020804	222.	-111704.	-.252
020805	631.	-180366.	-.143
020806	535.	28602.	.027
021401	580.	-192566.	-.166
021402	528.	-214837.	-.203
021201	246.	-7804.	-.016
021202	254.	-16848.	-.033
021101	759.	-44720.	-.029
021102	361.	-21839.	-.030
021701	612.	-132769.	-.108
021702	360.	-67731.	-.094

TOTAL SEDIMENT LOSS/GAIN= -3492636. LBS (-1746. TONS)
TOTAL DRAINAGE AREA = 14895. ACRES
AVERAGE EROSION RATE = -.117 TONS/ACRE/EVENT

SUMMARY OF COMPUTER RUN NO. 4 RESULTS

SUMMARY TABLE FOR SUBBASIN SEDIMENT YIELDS FOR WATERSHED UNITS

UNIT ID	AREA (ACRE)	TOTAL LOSS/GAIN (LBS/EVENT)	TOTAL LOSS/GAIN (TONS/ACRE/EVENT)
021801	5.	7808.	.711
021601	4.	3978.	.467
021501	5.	2133.	.219
021301	4.	950.	.112
021001	10.	61490.	3.084
020901	14.	47844.	1.712
020701	7.	516379.	35.612
020501	8.	82469.	5.154
020302	4.	66240.	7.702
020301	3.	313039.	46.035
218011	60.	-11950.	-.100
218012	59.	-11837.	-.100
216011	120.	-33837.	-.141
216012	36.	-8884.	-.123
215011	78.	-16107.	-.103
215012	78.	-16107.	-.103
213011	26.	-5242.	-.101
213012	85.	-20450.	-.120
210011	120.	-26839.	-.112
210012	219.	-54976.	-.126
209011	200.	-32377.	-.081
209012	226.	-38976.	-.086
207011	120.	-19285.	-.080
207012	169.	-28900.	-.086
205011	165.	-27545.	-.083
205012	164.	-27379.	-.083
203021	30.	-5594.	-.093
203022	47.	-8312.	-.088
203011	70.	-18915.	-.135
203012	131.	-39949.	-.152
021703	180.	45889.	.127
021403	318.	77964.	.123
021203	168.	-11639.	-.035
021103	273.	2973.	.005
020807	221.	231904.	.525
020602	610.	54154.	.044
020404	55.	154160.	1.401
020206	156.	52108.	.167
020106	144.	61519.	.214
020101	195.	-114574.	-.294
020102	248.	-69772.	-.141
020103	341.	-140359.	-.206
020104	261.	-91686.	-.176
020105	420.	84052.	.100
020201	221.	-140576.	-.318
020202	251.	-144084.	-.287
020203	333.	-136041.	-.204
020204	480.	16151.	.017
020205	534.	4831.	.005
020401	163.	-73716.	-.226
020402	494.	-121972.	-.123
020403	181.	-39470.	-.109
020601	863.	-163348.	-.095
020801	150.	-89234.	-.297
020802	193.	-41025.	-.106
020803	151.	-64702.	-.214
020804	222.	-80997.	-.182
020805	631.	-126611.	-.100
020806	535.	60524.	.057
021401	580.	-194152.	-.167
021402	528.	-13046.	-.012
021201	246.	-7716.	-.016
021202	254.	-16162.	-.032
021101	759.	-44657.	-.029
021102	361.	-19915.	-.028
021701	612.	-131986.	-.108
021702	360.	30150.	.042

TOTAL SEDIMENT LOSS/GAIN= -1654523. LBS (-827. TONS)
TOTAL DRAINAGE AREA = 14895. ACRES
AVERAGE EROSION RATE = -.056 TONS/ACRE/EVENT

SUMMARY OF COMPUTER RUN NO. 5 RESULTS

SUMMARY TABLE FOR SUBBASIN SEDIMENT YIELDS FOR WATERSHED UNITS

UNIT ID	AREA (ACRE)	TOTAL LOSS/GAIN (LBS/EVENT)	TOTAL LOSS/GAIN (TONS/ACRE/EVENT)
021801	5.	1979.	.180
021601	4.	1113.	.131
021501	5.	1094.	.112
021301	4.	670.	.079
021001	10.	1102.	.055
020901	14.	1489.	.053
020701	7.	124353.	8.576
020501	8.	26267.	1.642
020302	4.	14511.	1.687
020301	3.	12532.	1.843
218011	60.	-2450.	-.020
218012	59.	-2410.	-.020
216011	120.	-6426.	-.027
216012	36.	-1687.	-.023
215011	78.	-3200.	-.021
215012	78.	-3200.	-.021
213011	26.	-1011.	-.019
213012	85.	-4116.	-.024
210011	120.	-5180.	-.022
210012	219.	-10612.	-.024
209011	200.	-6575.	-.016
209012	226.	-7906.	-.017
207011	120.	-3921.	-.016
207012	169.	-5672.	-.017
205011	165.	-5556.	-.017
205012	164.	-5522.	-.017
203021	30.	-1095.	-.018
203022	47.	-1628.	-.017
203011	70.	-3510.	-.025
203012	131.	-7413.	-.028
021703	180.	9012.	.025
021403	318.	14449.	.023
021203	168.	2833.	.008
021103	273.	5614.	.010
020807	221.	38171.	.086
020602	610.	12114.	.010
020404	55.	18910.	.172
020206	156.	10792.	.035
020106	144.	9977.	.035
020101	195.	-19877.	-.051
020102	248.	-6852.	-.014
020103	341.	-26188.	-.038
020104	261.	-8001.	-.015
020105	420.	6570.	.008
020201	221.	-24359.	-.055
020202	251.	-22455.	-.045
020203	333.	-18125.	-.027
020204	480.	2671.	.003
020205	534.	-7250.	-.007
020401	163.	-12996.	-.040
020402	494.	-22546.	-.023
020403	181.	-4961.	-.014
020601	863.	-34885.	-.020
020801	150.	-15463.	-.052
020802	193.	-4512.	-.012
020803	151.	-12845.	-.043
020804	222.	-5845.	-.013
020805	631.	-30989.	-.025
020806	535.	12113.	.011
021401	580.	-39375.	-.034
021402	528.	1215.	.001
021201	246.	-6987.	-.014
021202	254.	-3524.	-.007
021101	759.	-38505.	-.025
021102	361.	20125.	.028
021701	612.	-36216.	-.030
021702	360.	16719.	.023

TOTAL SEDIMENT LOSS/GAIN= -310758. LBS (-155. TONS)
TOTAL DRAINAGE AREA = 14895. ACRES
AVERAGE EROSION RATE = -.010 TONS/ACRE/EVENT

SUMMARY OF COMPUTER RUN NO. 6 RESULTS

SUMMARY TABLE FOR SUBBASIN SEDIMENT YIELDS FOR WATERSHED UNITS

UNIT ID	AREA (ACRE)	TOTAL LOSS/GAIN (LBS/EVENT)	TOTAL LOSS/GAIN (TONS/ACRE/EVENT)
021801	5.	639.	.058
021601	4.	487.	.057
021501	5.	246.	.025
021301	4.	218.	.026
021001	10.	768.	.039
020901	14.	1318.	.047
020701	7.	20184.	1.392
020501	8.	1288.	.080
020302	4.	853.	.099
020301	3.	447.	.066
218011	60.	-466.	-.004
218012	59.	-459.	-.004
216011	120.	-1215.	-.005
216012	36.	-319.	-.004
215011	78.	-711.	-.005
215012	78.	-711.	-.005
213011	26.	-204.	-.004
213012	85.	-832.	-.005
210011	120.	-1065.	-.004
210012	219.	-2181.	-.005
209011	200.	-1662.	-.004
209012	226.	-1999.	-.004
207011	120.	-996.	-.004
207012	169.	-1492.	-.004
205011	165.	-1370.	-.004
205012	164.	-1362.	-.004
203021	30.	-240.	-.004
203022	47.	-357.	-.004
203011	70.	-583.	-.004
203012	131.	-1231.	-.005
021703	180.	1745.	.005
021403	318.	2353.	.004
021203	168.	774.	.002
021103	273.	1144.	.002
020807	221.	3363.	.008
020602	610.	2534.	.002
020404	55.	3043.	.028
020206	156.	321.	.001
020106	144.	676.	.002
020101	195.	-1884.	-.005
020102	248.	-502.	-.001
020103	341.	-2253.	-.003
020104	261.	-684.	-.001
020105	420.	434.	.001
020201	221.	-2278.	-.005
020202	251.	-2029.	-.004
020203	333.	-702.	-.001
020204	480.	336.	.000
020205	534.	-821.	-.001
020401	163.	-1453.	-.004
020402	494.	-3658.	-.004
020403	181.	-695.	-.002
020601	863.	-8732.	-.005
020801	150.	-1446.	-.005
020802	193.	-422.	-.001
020803	151.	-1034.	-.003
020804	222.	-211.	-.000
020805	631.	-3401.	-.003
020806	535.	983.	.001
021401	580.	-6297.	-.005
021402	528.	286.	.000
021201	246.	-2203.	-.004
021202	254.	-533.	-.001
021101	759.	-8364.	-.006
021102	361.	4380.	.006
021701	612.	-7132.	-.006
021702	360.	3544.	.005

TOTAL SEDIMENT LOSS/GAIN= -50271. LBS (-25. TONS)
TOTAL DRAINAGE AREA = 14895. ACRES
AVERAGE EROSION RATE = -.002 TONS/ACRE/EVENT