PREDICTING SEDIMENT DETACHMENT AND CHANNEL SCOUR IN THE PROCESS-BASED PLANNING MODEL ANSWERS-2000

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Abstract

ANSWERS-2000, a continuous simulation, distributed parameter nonpoint source model for simulating runoff, sediment, and nutrients from disturbed watersheds was updated to include a critical-shear rill detachment subroutine, an improved interrill detachment subroutine, and a channel scour subroutine. The existing version of ANSWERS-2000 did not simulate channel scour. The original detachment equations used in the model were developed through regression analysis of data from a northeast Indiana watershed, and were not directly applicable to other watersheds. The new detachment equations are based on process-oriented equations developed for the WEPP model and they can be applied to ungaged watersheds with a wide variety of soils and land use conditions.

The new model (ANSWERS-2000) was evaluated on three watersheds and its predictions were compared with the previous version of ANSWERS. On the largest watershed (2070 hectares), both models appeared to predict sediment loss adequately. On the second watershed (1053 hectares), ANSWERS-2000 improved sediment yield predictions compared to the original model. Neither model adequately described sediment loss from the smallest watershed (1.2 ha) used for validation. The sediment prediction errors were caused by errors in runoff prediction, despite an attempt to increase runoff prediction accuracy by calibration. The channel scour subroutine was evaluated by comparison with observed channel erosion data from the largest watershed. The new model appeared to consistently over predict scoured depth. However, more research is required to determine if the channel scour component is flawed or if the uncertainty in the observed channel scour data was large as suspected. Ultimately, the erosion prediction accuracy of the

ANSWERS-2000 model was improved in two of the three upland evaluation data sets. The channel scour data set was not successfully validated. Model input parameter requirements increased significantly as a result of the new erosion and channel scour submodels.

DEDICATION

This work is dedicated to my parents, John and Sarah Byne, for their selfless devotion to my education. Without their support, foresight, and attention to detail, attaining this degree would not have been possible.

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1 INTRODUCTION

Nonpoint source (NPS) pollution is variable in time and space, tied to precipitation events, and difficult to predict with accuracy. NPS pollution was characterized by Novotny and Olem (1994) as a subset of diffuse pollution, with the following characteristics:

- Diffuse discharges enter receiving surface waters in a diffuse manner at intermittent intervals that are related mostly to the occurrence of meteorological events.
- Waste generation (pollution) arises over an extensive area of land and is in transit overland before it reaches surface waters or infiltrates into shallow aquifers.
- Diffuse sources are difficult or impossible to monitor at the point of origin.
- Unlike traditional point sources, where treatment is the most effective method of pollution control, abatement of diffuse pollution is focused on land and runoff management practices.
- The most important waste constituents from diffuse sources subject to management and control are suspended solids, nutrients, and toxic compounds.

Runoff from agricultural lands may be characterized as diffuse NPS pollution according to these characteristics. Agricultural runoff can contain macronutrients, micronutrients, pesticides, sediment, organic matter, and pathogens. Of these pollutants, sediment is of particular concern because erosion degrades the quality of the land and has the potential to impair the quality of surface water. Soil loss reduces agricultural productivity by removing nutrients and reducing the depth of topsoil. Sediment in surface water increases turbidity and transports nutrients, promoting eutrophication. Sediment can also transport adsorbed contaminants to surface waters. It is estimated that 60% of the water quality impairment in the United States is attributable to agricultural NPS pollution (Shirmohammadi et al., 1997).

Because of the negative effects of nonpoint sediment pollution, it is important to determine areas that can and will contribute sediment during precipitation events. This can be done by monitoring, which records and analyzes historical data to determine trends of pollution generation, or it can be done by modeling, which simulates a natural system by establishing relationships between forces acting upon the system and the system's response to these stimuli. Nonpoint source pollution models may be process-based, empirically-based, or a combination of the two. Process-based models are derived from principles that govern the system, and parameters in the model can be estimated from physical properties of the system or measured directly in the field. Empirically-based models are derived from statistical analysis of large quantities of data obtained from monitoring the system, and parameters in the model may or may not represent a property that can be measured directly. Models are also classified according to their intended usage, as management or research models. Management models are intended to predict the effects of varying management, cultural, or structural practices on the pollution generated from a catchment, while research models are generally more complex than management models and are constructed to investigate physical processes that occur in the field.

Process-based models are important because they allow for simulation of conditions that are new or undocumented. Evaluation of new best management practices using an empirical model requires field research to verify the performance of the practice. With a process-based model, the underlying physical phenomena can be described and used to predict the performance of the practice without extensive field research beforehand. This allows new practices or combinations of practices to be evaluated for effectiveness prior to implementation.

1.1 Research Objectives

The overall goal of this research was to incorporate new process-oriented sediment detachment and channel scour submodels into ANSWERS-2000 and to determine if the process-oriented approach improved sediment yield predictions compared to the existing version of the model. The developed sediment detachment model is intended for use by planners in estimating the impacts of spatially variable land management practices on upland sediment yield and channel erosion. This overall objective was subdivided into three minor objectives:

1. To develop and incorporate a new process-oriented sediment detachment submodel into ANSWERS-2000.
2. To develop and incorporate a process-oriented channel scour submodel into ANSWERS-2000.
3. To determine if the new process-based sediment detachment and channel scour submodels improve the ability of ANSWERS-2000 to predict sediment loss at the watershed scale.

2 LITERATURE REVIEW

2.1 Introduction

In order to determine the process-based erosion theories in use and how they might fit into the structure of ANSWERS-2000, a review of literature concerning NPS models was conducted. First, ANSWERS-2000 (or in early incarnations as ANSWERS) was reviewed to determine the general framework of the model and how it has been used in recent studies. Second, other watershed-scale NPS models were reviewed to determine general structure including the nature of their erosion submodels. Third, erosion theory was reviewed in the component forms of rill, interrill, and channel contributions so that different methods could be compared. Finally, methods of parameter estimation for these erosion theories were reviewed in order to determine the relative difficulty of obtaining input information.

2.2 Watershed Scale NPS Models

Several prominent watershed-scale NPS models include SWRRB-WQ, SWAT, AnnAGNPS, HSPF, WEPP, SHE, and ANSWERS-2000. All of these are continuous simulation, process-based models that simulate runoff, nutrients, and sediment movement from large watersheds. For a more exhaustive list of watershed-scale, urban NPS models, the reader is referred to Shoemaker et al. (1997).

2.2.1 ANSWERS-2000

2.2.1.1 Overview

ANSWERS-2000 (Beasley and Huggins, 1981; Bouraoui, 1994) is a continuous simulation, distributed parameter model. It was developed upon the hypothesis that at every point in a watershed there exists a relationship between water flow rates and the factors that govern them, and that these can be related to processes in the watershed such as erosion or chemical movement. The point concept is relaxed to square cells of uniform size, for which arbitrary changes of parameter values for a single element have a negligible influence upon the response of the watershed. Parameter values may vary in an unrestricted fashion so that any degree of spatial variability may be represented. The individual elements act together as a composite system because their hydrology is interrelated, and the outflow from one element becomes the inflow to another. A flowchart (Fig. 1) of the overall ANSWERS-2000 model shows the interactions between the different components of the model.

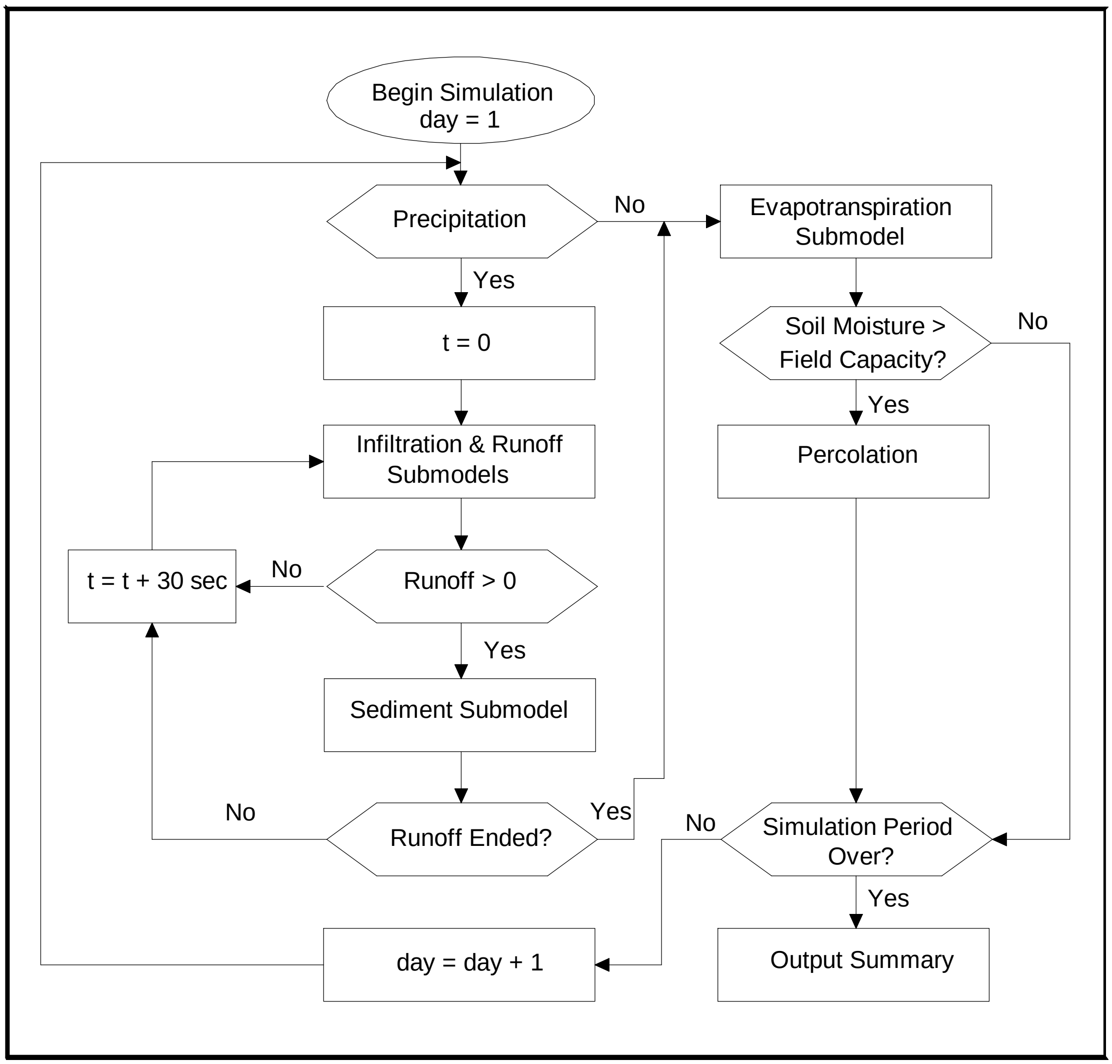

Figure 1. ANSWERS-2000 model flowchart

2.2.1.2 Hydrology

After rainfall begins, a portion is intercepted by vegetal canopy until the interception storage is met. When the rainfall rate exceeds the interception rate, infiltration into the soil begins. As the rainfall proceeds, the infiltration capacity decreases until it reaches the rainfall rate and storage in surface micro-depressions begins. Once the storage capacity of the micro-depressions is satisfied, surface runoff begins. When rainfall ceases, water in surface detention decreases until runoff ceases. Infiltration continues until all depressional water infiltrates. Infiltration is modeled using the Green-Ampt infiltration equations (Bouraoui, 1994). Between rainfall events, the model simulates evapotranspiration using Ritchie's method (Ritchie, 1972) with a 24-hour time step.

The net rainfall rate reaching the ground surface is dependent on user specified pluviograph(s) and interception. The rainfall characteristics of each cell are specified by a rain gage identifier that specifies the pluviograph for a particular cell. The model allows a maximum of 8 rain gages.

Mathematically, each element's hydraulic response is calculated as a function of time by an explicit, backward difference solution of the continuity equation:

$$I - Q = \frac{dS}{dt} \qquad (1)$$

where I = inflow rate to an element from rainfall and adjacent elements ($m^3\ s^{-1}$), Q = outflow rate ($m^3\ s^{-1}$), S = volume of water stored in an element (m^3), and t = time (s). This equation is combined with a stage-discharge relationship and solved for overland and channel flow rates. The stage-discharge relationship used is Manning's equation. The hydraulic radius in Manning's equation is assumed equal to the detention depth on an element.

2.2.1.3 Sediment Model

Soil erosion in the ANSWERS model is viewed as a two-stage process. The first is sediment detachment and the second is sediment transport. Sediment detachment in upland areas is a function of raindrop impact and of flowing water. Detachment of soil particles by rainfall is assumed to be a function of the kinetic energy of the rainfall, and is described by Meyer and Wischmeier (1969) as:

$$DETR = 0.108 * CDR * SKDR * A_i * R^2 \quad \text{..(2)}$$

where *DETR* = detachment by rainfall (kg min^{-1}), *CDR* = cropping and management factor, *C* (from USLE), *SKDR* = soil erodibility factor, *K* (from USLE), A_i = area increment (m^2), and *R* = rainfall intensity during time interval (mm min^{-1}). Detachment of soil particles by overland flow is described by the work of Meyer and Wischmeier (1969) as modified by Foster (1976):

$$DETF = 0.90 * CDR * SKDR * A_i * SL * Q \quad \text{..(3)}$$

where *DETF* = detachment by flowing water (kg min^{-1}), *SL* = slope steepness, and *Q* = flow rate per unit width (m^2 min^{-1}). Once a soil particle has been detached, sufficient energy must be available for transport or the particle will be deposited. Transport by overland flow is self-regulating in that soil particle detachment by overland flow does not occur unless there is excess energy available in addition to the amount required to transport suspended sediments. Detachment by rainfall occurs independent of transport capacity. If sufficient transport capacity exists to transport the detached sediment, then sediment is apportioned to adjacent cells based upon flow partitioning. If a channel element exists within a cell, then all flow and detached sediment is directed to that channel element.

Once detachment is known, the transport capacity is calculated. The earliest version of ANSWERS (Beasley and Huggins, 1981) assumed a two-stage transport capacity dependent upon whether flow is in the laminar or turbulent regions. The laminar region transport assumes that transport is proportional to the square root of flow, while the turbulent region transport assumes that transport is proportional to the square of flow. The equations and their regions of application are:

$$TF = 161 * SL * Q^{0.5} \quad \text{.. for } Q <= 0.046 \text{ m}^2 \text{ min}^{-1}\text{: ....(4)}$$

$$TF = 16{,}320 * SL * Q^2 \quad \text{.. for } Q > 0.046 \text{ m}^2 \text{ min}^{-1}\text{:................(5)}$$

and where *TF* = transport capacity (kg m^{-1} min^{-1}). The transport equations in the latest version of ANSWERS (Dillaha and Beasley, 1983) allow for differential detachment and transport of various particle size classes. This version of the model is discussed in detail by Dillaha and Beasley (1983), and in the ANSWERS User's Manual (Beasley and Huggins, 1981).

Sediment transport occurs in two related forms in overland flow: bedload and suspended load. Bedload is that portion of the load, which moves along the bottom of the flow by saltation, rolling, and sliding. Bedload is generally composed of the larger soil particles, and is highly transport dependent. A decrease in transport capacity causes immediate deposition of the excess bedload.

Suspended load is much more uniformly distributed throughout the flow depth than bedload. A decrease in transport capacity will not result in the immediate deposition of suspended sediment due to the small fall velocities. Some particle size classes have such small velocities that they are effectively in permanent suspension and are termed washload. In the current version of ANSWERS-2000, particles less than 10 microns in diameter are defined as washload and are not allowed to deposit unless the overland flow rate is zero. Their yield is therefore determined by their weight fraction in the original soil mass and the total amount of detachment.

The fraction of particles larger than 10 microns that is deposited when there is a transport capacity deficit is calculated using relationships developed to describe the settling efficiency of particles in water (Dillaha and Beasley, 1983):

$$RE_i = \left(\frac{FV_i A}{Q}\right) \text{.................................. } (IF\ RE_i > 1.,\ then\ RE_i = 1.) \text{ ....} (6)$$

where RE_i = removal efficiency of particle size i, FV_i = fall velocity (m s^{-1}) of particle size i. This equation assumes that settling occurs under quiescent conditions, flow is steady, the concentration of suspended particles of each size is initially uniformly distributed throughout the flow, and that deposited particles are not resuspended.

Transport capacity is calculated using a modified form of Yalin's equation (Yalin, 1963), which is an expression for the bedload transport of uniform, cohesionless grains over a moveable bed for steady, uniform flow of a viscous fluid. The derivation is based on dimensional analysis and the mechanics of average motion of a grain. The Yalin equation is (Dillaha and Beasley, 1983):

$$TF = P_s S_g \, r_w \, g d V_* \text{ ....}(7)$$

where:

$$P_s = 0.635 \, d \left[1 - \frac{\ln(1+s)}{s} \right] \text{ ....}(8)$$

$$s = 2.45 \, S_g^{-0.4} \, Y_{cr}^{0.5} \, d \text{ ....}(9)$$

$$d = \left(\frac{Y}{Y_{cr}} \right) - 1 \text{ .... } (if\ Y \pounds Y_{cr},\ d = 0.) \text{ ....}(10)$$

$$Y = \frac{V_*^2}{\left[(S_g - 1) \, g \, d \right]} \text{ ....}(11)$$

and *TF* = transport capacity (kg s^{-1}), P_s = number of particles in transport, r_w = mass density of the fluid (kg m^{3}), Y_{cr} = critical shear stress from the Shield's diagram (Pa), V_* = $(g\ R\ S)^{0.5}$ = the shear velocity (m s^{-1}), S_g = particle specific gravity (kg m^{-3}), *S* = slope of the energy gradeline, *R* = hydraulic radius which is assumed to equal the flow depth (m), *d* = diameter of particle (m), and *g* = acceleration due to gravity (m s^{-2}).

Foster and Meyer (1972) developed a method by which Yalin's equation could be used to predict the transport capacity of each particle size class in a mixed sediment by assuming that the number of particles of a particle size class is proportional to the excess of the shear stress caused by the flowing water. Yalin assumed that the number of particles in transport was equal to a linear function of δ, the dimensionless excess of the tractive force. Foster and Meyer assumed that for a mixture, the number of particles of size i is proportional to δ_i. Values of δ_i for each particle class were summed to give the total transportability, T.

$$T = \sum_{i=1}^{n} d_i \text{ ....}(12)$$

where n is the number of particle size classes and δ_i is the δ defined by Equation (10) for particle class i.

The number of transported particles of class i in a mixture, $(N_e)_i$ was taken to be:

$$(N_e)_i = N_i \frac{d_i}{T} \qquad (13)$$

where N_i is the number of particles transported in a uniform sediment for a δ_i.

In a similar manner, $(P_s)_i$ was assumed to be proportional to δ_i so:

$$(P_e)_i = (P_s)_i \frac{d_i}{T} \qquad (14)$$

where $(P_e)_i$ is the effective P_s for particle class i in a mixture and $(P_s)_i$ = the P_s calculated for a uniform sediment of class i. The actual transport rate TF_i of each particle class in a mixture can then be expressed as (Dillaha and Beasley, 1983):

$$TF_i = (P_e)_i (S_g)_i \, r_w g d_i V_* \qquad (15)$$

The assumptions of the current ANSWERS-2000 sediment transport model is as follows:

1. The particle size distribution of detached sediment is the same as the weight fractions of the soil particles in the original soil mass (no enrichment during detachment).
2. Rainfall detachment is not limited by the transport capacity of the flow.
3. Flow detachment occurs only if there is excess transport capacity and can never exceed the transport capacity excess.
4. Deposition and flow detachment never occur at the same time for the same particle.
5. Washload transport is independent of the transport capacity of the flow and does not influence the transport of larger particles.
6. Deposited sediment requires the same amount of energy as in the original detachment to become redetached.
7. The deposition process controls enrichment.
8. The rate at which a particle will deposit is proportional to its fall velocity.
9. Channel erosion is limited to the amount of sediment deposited, if any, in the channel during the current storm.
10. Subsurface or tile drainage produces no sediment.

A flow chart of the expanded sediment transport model (Fig. 2) illustrates the logical flow of the extended sediment transport module.

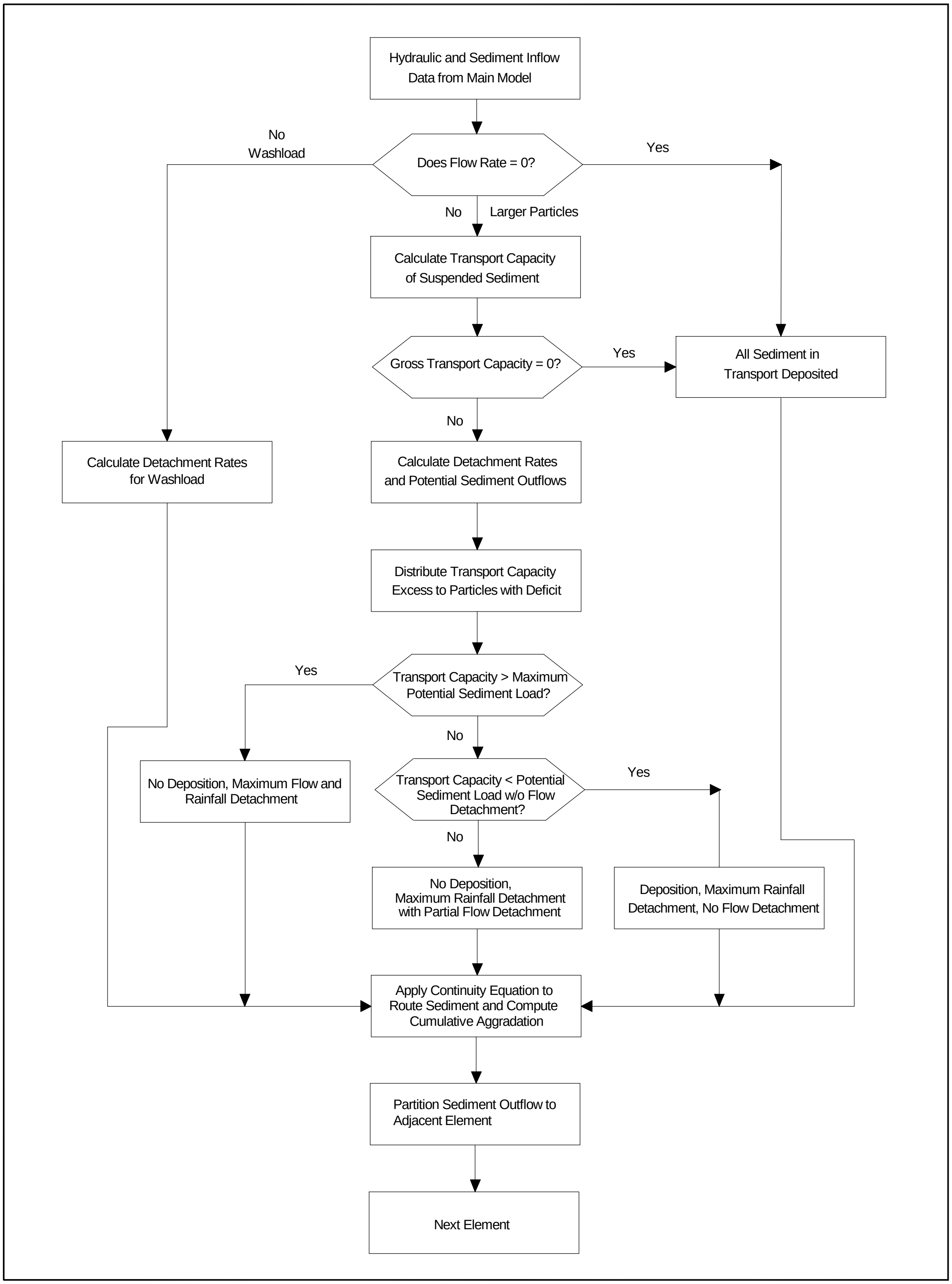

Figure 2. ANSWERS-2000 extended sediment detachment and transport model flowchart.

2.2.1.4 ANSWERS-2000 applications

In recent years, the event-based ANSWERS model has been evaluated extensively. Breve et al. (1989) tested it on a small upland watershed on the Georgia Coastal Plain and attempted to develop a method to optimize its application to larger watersheds in the same physiographic region. They found that the model underestimated runoff and soil erosion values. DeRoo and Walling (1994) evaluated it using cesium-137 and found that the model did not predict hydrology correctly, however the erosion prediction component was adequate. They attributed the poor hydrologic prediction to the model's use of Hortonian runoff generation. They incorporated variable contributing areas into the model and improved its prediction accuracy marginally. Sharma and Singh (1995) predicted runoff and soil loss from three agricultural watersheds in the arid zone of India, and found that the model predicted hydrographs acceptably, but that it under predicted soil loss by a factor of 2.6 to 3.6. They theorized that the under prediction occurred because the model did not allow for resuspension of deposited particles after rainfall ceased, and that the model was sensitive to discretization of the rainfall intensities.

The continuous simulation version of ANSWERS, known as ANSWERS-2000, has undergone limited evaluation in recent years. Connolly and Silburn (1995) tested the continuous-simulation version of ANSWERS using data from two rainfall simulator plots and three small catchments. They found that the model predicted runoff accurately, and a linear regression explained 93% and 81% of the variation in peak runoff rate and runoff volume, respectively, between predicted and measured values. They also found that processes controlling runoff from the catchments were realistically described, and the parameters could be derived independently of runoff and therefore the model could be expanded to larger catchments without distortion or optimization. Recently, Bouraoui et al. (1997) modified ANSWERS-2000 to include the simulation of water transport in the vadose and saturated zones. The model was tested at the local scale by comparing model output to measured data at a grid scale for three different soil covers over a three-year period. The model was evaluated at the watershed scale for the same watershed over the same three-year period. After this initial evaluation, the model simulated conditions for eighteen months, and the authors concluded that the model accurately predicted drainage below the root zone, and evapotranspiration from different soil covers. At the watershed scale, they concluded that the model reproduced piezometric levels and trends of variation well.

2.2.2 SWRRB-WQ

SWRRB-WQ is the Simulator for Water Resources in Rural Basins-Water Quality (Arnold et al., 1989), developed and maintained by the USDA-ARS at the Texas A&M Blacklands Research Station. The following description is taken from the SWRRB-WQ website at Texas A&M (http://www.brc.tamus.edu/swat). SWRRB-WQ is a basin-scale, continuous simulation model that operates on a daily time step. The model allows discretization of a catchment into ten sub basins, and is an adaptation of the CREAMS (Chemicals, Runoff, Erosion from Agricultural Management Systems) model (Knisel, 1980). The model allows simultaneous, continuous computations on several sub basins to predict basin water yield. SWRRB-WQ incorporates a flow component, a reservoir storage component for farm ponds and reservoirs, a weather simulation module, a crop growth module, a simple flood routing component, a channel transmission loss component, the GLEAMS (Groundwater Loading Effects from Agricultural Management Systems) model pesticide fate component (Knisel et al., 1993), the Soil Conservation Service (SCS) technology for estimating peak runoff rates, and the Hydro-Geomorphic Universal Soil Loss Equation (HUSLE). In the late 1980s, it became necessary to link many sub basins, and the ROTO (Routing Outputs to Outlets) adaptation was included. The ROTO module was considered difficult to operate, and the next generation of SWRRB-WQ was incorporated into the SWAT model (Arnold et al., 1993). The SWRRB-WQ model uses the Hydrologic Unit / Water Quality (HU/WQ) interface.

2.2.3 SWAT

SWAT is the Soil and Water Assessment Tool (Arnold et al., 1993). The following information was taken from the Texas A&M SWAT website (http://www.brc.tamus.edu/swat). SWAT incorporates SWRRB-WQ and is a basin-scale, continuous simulation (daily time step) model designed to evaluate the long-term impacts of agricultural management. The model can simulate reservoir sedimentation over 50 to

100 years, and crop parameters and pesticide applications during a year. The model utilizes the Modified Universal Soil Loss Equation (MUSLE) (Williams, 1975). Runoff volume is calculated using the SCS Curve Number method and peak runoff predictions are based upon a modification of the rational formula. Watershed time of concentration is estimated using Manning's formula considering both overland and channel flow, and potential evapotranspiration is calculated using one of three methods: Hargreaves' (Hargreaves and Samani, 1985), Priestley-Taylor (Priestley and Taylor, 1972), or Penman-Monteith (Monteith, 1965). Evapotranspiration is calculated using Ritchie's equation (Ritchie, 1972), while crop growth is calculated by estimating the energy interception of a crop and then assuming that the potential increase in biomass for a day is the product of this energy and a crop parameter for converting energy to biomass. The model simulates nutrients and pesticides, and utilizes the stream power concept for channel erosion.

2.2.4 AnnAGNPS

AnnAGNPS stands for the Annualized Agricultural Nonpoint Source Model (http://www.sedlab.olemiss.edu/AGNPS98.html). The model is a distributed parameter, watershed-scale, and continuous simulation tool. It is integrated with the CONCEPTS receiving water model (Alonso et al., 1995) for analyzing channel hydraulics, morphology, and transport of sediment and contaminants. TOPAGNPS (Bingner et al., 1998) is integrated into the model framework to assist in the development of flow routings, and the model utilizes the Revised Universal Soil Loss Equation (RUSLE) (Renard et al., 1991) to predict annual sediment loadings. The model simulates winter conditions, pesticides, nutrients, and organic carbon cycles, as well as nutrient concentrations from feedlots and other point sources.

2.2.5 HSPF

HSPF (Hydrologic Simulation Program Fortran) "is a comprehensive package developed by EPA for simulating water quantity and quality for a wide range of organic and inorganic pollutants from complex watersheds (Bicknell et al., 1993). The model uses continuous simulations of water balance and pollutant generation, transformation, and transport. Time series of the runoff flow rate, sediment yield, and user-specified pollutant concentrations can be generated at any point in the watershed. The model also includes instream quality components for nutrient fate and transport, biochemical oxygen demand (BOD), dissolved oxygen (DO), pH, phytoplankton, zooplankton, and benthic algae. Data requirements for HSPF are extensive, and calibration and validation are recommended." (Shoemaker et al., 1997)

2.2.6 WEPP

WEPP (Water Erosion Prediction Project) is a continuous simulation, field or watershed scale model that incorporates new erosion prediction technology developed by the USDA (Shoemaker et al. 1997). "The model requires inputs for rainfall amounts and intensity; soil textural qualities; plant growth parameters; residue decomposition parameters; effects of tillage implements on soil properties and residue amounts; slope shape, steepness, and orientation; and soil erodibility parameters. Parameters used for predicting erosion, including soil roughness, surface residue cover, canopy height, canopy cover, and soil moisture are updated on a daily basis. The basic output from WEPP consists of runoff and erosion summary information, which can be produced on a storm-by-storm, monthly, annual, or average annual basis. The time-integrated estimates of runoff, erosion, sediment delivery, and sediment enrichment are contained in this output, as well as the spatial distribution of erosion." (Shoemaker et al., 1997) The watershed version of WEPP routes runoff and sediment from fields and incorporates channel scour based on the work of Foster and Meyer (1972), Knisel (1980), and Williams (1995).

In the WEPP model, a baseline soil erodibility is calculated for rill and interrill areas based upon the fractions of sand, silt, clay, very fine sand, and organic matter of a soil. This baseline erodibility is then adjusted for plant height and canopy, ground cover, live and dead root biomass, surface sealing and consolidation, ground freeze and thaw, buried residue in the upper soil layer, and local variation from a uniform slope profile. These adjusted erodibilities (rill and interrill) are used to calculate soil detachment potential during a rainfall event. Transport capacity is calculated using a simplified transport capacity equation. The detachment potential of flowing water is then adjusted to account for sediment already in transport using the Duboy's sediment transport equation (Foster et al., 1995). The detachment potential of rainfall is adjusted to account for the interrill runoff rate, and random roughness affects that will lower sediment delivery from interrill areas.

2.2.7 SHE

2.2.7.1 Overview

SHE (Systeme Hydrologique Europeen), Wicks et al., (1992) "was developed jointly by the Danish Hydraulic Institute, the Institute of Hydrology (England), and the French consulting company SOGREAH in a program supported by the Commission of the European Communities. Subsequent U.K. activity has been concentrated at the Natural Environment Research Council's Water Resource Systems Research Unit (WRSRU) located within the University of Newcastle upon Tyne. Within SHE, spatial distribution of catchment parameters, rainfall input, and hydrological response is achieved in the horizontal through representation of the basin on an orthogonal grid network and in the vertical by a column of layers at each grid square. Each of the major hydrological processes of water movement (snowmelt, canopy interception, evapotranspiration, overland and channel flow, and unsaturated and saturated subsurface flow) is modeled, either by finite difference representations of the partial differential equations of mass, momentum, and energy conservation or by empirical equations derived from independent experimental research." (Wicks et al. 1992).

2.2.7.2 SHESED

SHESED (Wicks and Bathurst, 1996) is the sediment component of the SHE model, developed at the University of Newcastle upon Tyne. The component accounts for soil erosion by raindrop impact, leaf-drip impact, and overland flow, and for sediment transport by overland and channel flow. For channels, the component simulates the erosion of bed material and the downstream transport of this material together with that supplied by overland flow. In the channel sediment routine it is assumed that the flow can carry any available load of fine sediments (less than 0.062 mm in diameter), but for coarser sediments the load is limited by the calculated transport capacity of the flow. The channel component also allows for bed armoring.

2.3 Upland Erosion

It is generally accepted that erosion from upland areas can be divided between rill and interrill contributions. Historically, a rill has been defined as a small channel that can be obliterated by tillage operations. Soil detachment in a rill is assumed to be due to flowing water and not raindrop impact (Watson and Laflen, 1986). Rill erosion is difficult to predict due to the uncertainty of predicting the location and formation of rills. Although their formation is assumed to be associated with microtopography and slope, the actual mechanisms associated with rill development are generally unknown (Owoputi and Stolte, 1995). Interrill areas are the areas between rills, and detachment of soil in interrill areas is assumed to be due to raindrop impact and not flowing water (Watson and Laflen, 1986). Although raindrop impact increases the turbulence and sediment transport capacity in interrill areas, the effect of raindrop impact is generally neglected in transport and interrill transport is assumed to occur by shallow sheet flow.

2.3.1 Rill Erosion

2.3.1.1 Critical Shear Theory

Erosion in rills has been attributed to component processes including scour, headcutting, sidewall sloughing, and slaking (incipient failure, or mass erosion). Equations that describe rill erosion have generally been limited to describing the scouring process through relation of flow, shear, and slope. The equations attempt to predict either the detachment rate of sediment-laden water or the detachment capacity of clear water flowing without sediment load. The critical shear stress equation predicts the sediment detachment capacity of flowing water (Elliot and Laflen, 1993):

$$D_c = K_r (Bt - t_c)^a \qquad (16)$$

where D_c = the detachment capacity of sediment (g m^{-2} s^{-1}), K_r = sediment erodibility coefficient (g m^{-2} s^{-1}), t = hydraulic shear in the rill (Pa), t_c = critical hydraulic shear below which no erosion occurs (Pa), a = an exponent, and B = a constant of proportionality. The detachment capacity for clear water is related to the detachment rate of sediment-laden water through the equation developed by Foster and Meyer (1972):

$$\left(\frac{D_r}{D_c}\right)+\left(\frac{G_r}{T_c}\right)=1 \quad (17)$$

where D_r = actual detachment rate (kg s^{-1}), G_r = flow sediment load (kg s^{-1}), and T_c = flow sediment transport capacity (kg s^{-1}). Foster et al. (1995) utilized the critical shear-stress concept in the WEPP model, assuming values of B and a equal to 1. Shear stress in WEPP is calculated from the Darcy-Weisbach uniform flow equation and the assumption that discharge varies linearly with distance downslope (Foster et al., 1995):

$$t = g\left[\left(\frac{P_r}{C}\right)xs\right]^{0.67} \quad (18)$$

where γ = specific weight of water (kg m^{-2} s^{-2}), P_r = peak runoff rate (m s^{-1}), C = Chezy discharge coefficient = $\left(\frac{8g}{f_c}\right)^{0.5}$, x = distance downslope (m), and s = slope (m m^{-1}).

Foster and Meyer (1972) presented a simplified form of the critical shear concept:

$$D_c = K_r t^{\frac{3}{2}}{}_{ave} \quad (19)$$

where t_{ave} = an average shear stress exerted by the flowing water. .

Wicks and Bathurst (1996) presented another form of the critical shear equation for the SHE model:

$$D_{SHE} = k_f\left(\left(\frac{t_{SHE}}{t_c}\right)-1\right) \quad (20)$$

where D_{SHE} = overland flow detachment (kg m^{-2} s^{-1}), t_{SHE} = $r\ g\ h\ S$ (Pa), and t_c is taken from the Mantz extension of the Shield's curve (Wicks and Bathurst, 1996), and k_f = combined erodibility constant (kg m^{-2} s^{-1}). Sheet and rill flow erosion processes are not separated in the SHE model, and the value of k_f will differ from values used in other models.

Hirschi and Barfield (1988) proposed a critical shear stress equation for the KYERMO model, where the shear stress is calculated using the area method of Lundgren and Jonsson (1964):

$$t_{ij} = \left(\frac{g \Delta A_{ij} \; n_i \; \sin\Theta}{100 \; l_i} \right) \qquad (21)$$

where DA_{ij} = the area of water applying shear stress to subsegment j of segment i, cm^2, n_i = the number of subsegments on segment *i*, and l_i = the slope length of segment *i* (m). The critical shear stress is determined using the Shield's diagram and the relation proposed by Smerdon and Beasley (1961):

$$t_c = (0.493)10^{0.0183 clay} \qquad (22)$$

The values of *B* and *a* in the KYERMO model are input by the user. The balance equation of Foster and Meyer (1972) can be used to account for conditions where detachment is not equal to transport capacity. KYERMO differentiates between erosion of deposited and bed material by incorporating different critical shear stress values and the fractional amount of a bed covered by deposited material. The model accounts for erosion of deposited material by multiplying the detachment equation by the fraction of material covering the bed and utilizing a value of critical shear stress for deposited material. The erosion of bed (matrix) material is accounted for by multiplying the detachment equation by a value of one minus the fraction of bed covered while utilizing a value of critical shear stress for matrix material.

2.3.1.2 Unit Stream Power Theory

Misra and Rose (1996) presented a form of the stream power equation used in the GUEST model. Stream power is defined as the runoff-energy available per unit area and is estimated as the product of the shear stress and stream velocity. Erosion of sediment is assumed to occur only when stream power exceeds a certain threshold value. In the GUEST model, rill erosion for steady-state conditions takes the form:

$$r_{ei} = \frac{(1 - H)F(\Omega - \Omega_O)\, I}{J} \qquad (23)$$

where r_{ei} = entrainment of sediment (kg m^{-2} s^{-1}), *H* = fraction of the surface covered by the deposited layer, *F* = a constant relating to the fraction of the excess stream power that is effective in re-entrainment of sediments (taken as 0.1), Ω = stream power (Pa m s^{-1}), Ω_O = critical stream power below which no detachment occurs (Pa m s^{-1}), I = number of particle size classes, and J = specific energy of entrainment (J kg^{-1}).

Elliot and Laflen (1993) presented a stream power equation of the form:

$$D_c = K_r\left[\left(\frac{gQs}{w_r}\right) - \Omega_O\right] \qquad (24)$$

where Q = volumetric flow rate of water (m^3 s^{-1}), and w_r = rill width (m). Elliot and Laflen found that the equation predicted best when the critical unit stream power at incipient motion was treated as a constant for shallow flows.

Moore and Burch (1986) applied unit stream power theory to rill and sheet flow and used the resulting equations to predict sediment transport capacity. They determined that the unit stream power for rill flow was:

$$\Omega = \left(\frac{Q}{J}\right)0.25\left(\frac{s^{1.375}}{n^{0.75}}\right)W \qquad (25)$$

where J = number of rills crossing the contour element, n = Manning's roughness coefficient, and W = a rill shape factor dependent upon rill geometry. Sediment transport capacity then becomes:

$$\log T_c = z + b\left[\frac{(\Omega - \Omega_O)}{w}\right] \qquad (26)$$

where z and b are functions of sediment properties:

$$z = 5.435 - 0.286\log\left(\frac{w\,d}{n}\right) - 0.457\log\left(\frac{U^*}{w}\right) \qquad (27)$$

$$b = 1.799 - 0.409\log\left(\frac{w\,d}{n}\right) - 0.314\log\left(\frac{U^*}{w}\right) \qquad (28)$$

where w = sediment terminal fall velocity in water (m s^{-1}), d = median particle size diameter of the bed material (m), n = kinematic viscosity of water(m^2 s), and U^* = average shear velocity (m s^{-1}) = (g y s)$^{0.5}$.

2.3.1.3 Other Theories

Wilson (1993) developed a fundamentally based detachment model by summing the moment forces on a particle:

$$e_i = \frac{\Delta FF_i}{K_e} r_s k_r \sqrt{\frac{gd\left(K_n t^* - m_f\right)}{k_d}} \times \{1 - \exp[\exp(-x_e)]\} \quad if \quad K_n t^* \geq m_f \text{ ....(29)}$$

where e_I = detachment rate (kg m^2 s^{-1}) for a particle of size d, DFF_I = fraction of bed material finer than particle diameter d, K_e = parameter expressing the time required to expose underlying particles, r_s = particle density (kg m^{-1}), k_r = ratio of the constants of soil particle area and volume relationships, g = acceleration due to gravity (m s^{-1}), d = equivalent particle diameter (m), K_n = a combination of particle and fluid factors, t^* = dimensionless critical shear known as the Shield's parameter, m_f = coefficient of friction, k_d = proportionality constant, and x_e = upper exceedance probability limit. This derivation indicates that a small value of critical shear exists, and thus the model demonstrates a smooth transition of detachment rates for shear values. The model predicts a linear response of detachment rate for median values of shear, and for large values of shear, the detachment rate increases with the square root of shear stress (Wilson, 1993).

Blau et al. (1988) presented the rill erosion component of Shirley and Lane (1978) as incorporated into the KINEROS model:

$$D_f = K_r\left(\left(\frac{B}{k}\right)q - cq\right) \text{ ....(30)}$$

where D_f = the rill erosion rate (g m^{-2} s^{-1}), B = a sediment transport parameter, k = a slope resistance parameter, q = discharge per unit width (m^3 s^{-1} m^{-1}), and c = sediment concentration (g m^{-1}). The model is based on the partial differential equations for kinematic flow, includes rainfall and runoff detachment, and has been shown to provide reasonable results of erosion from upland areas of the Southwest (Blau et al., 1988).

2.3.2 Interrill Erosion

Interrill soil detachment is generally attributed to raindrop impact while interrill transport is generally attributed to shallow overland flow and raindrop splash. Detachment by raindrop impact is considered a function of depth of flow, and the resulting erosion has been linked to rainfall characteristics such as rainfall intensity, drop diameter, impact velocity, and rainfall kinetic energy (Owoputi and Stolte, 1995). Gilley et al. (1985) derived a set of equations for predicting detachment by a single raindrop while considering transport of detached sediment by raindrop splash to be negligible. The equation has the form:

$$D_s = 0.2\, K_d\, r\, \cos^2 \Theta\, a_i\, V_i^2 \left(\frac{d_i}{y} \right)^{1.83} \qquad (31)$$

where D_s = soil detachment (kg m^{-2} s^{-1}), K_d = soil detachment factor (s m^{-1}), Θ = slope angle, a_i = number of drops in the i^{th} class, V_i = velocity of drops (m s^{-1}) with diameter i, d_I = mean drop diameter of class i (m), and y = depth of overland flow (m). The depth of overland flow was determined from the Darcy-Weisbach equation:

$$y = \left[\frac{\left(bI^c + k_w \right)\left(u\, I\, x \right)}{8gS} \right]^{\frac{1}{3}} \qquad (32)$$

where I = rainfall intensity (m s^{-1}), b, and c are regression constants, k_w = 24 for laminar flow over smooth surfaces, u = kinematic viscosity of water (mm^2 s^{-1}), x = distance in the main flow direction (m), and S = channel bottom slope (assumed equal to friction slope). A transport capacity equation was then developed:

$$T_o = K_t\,(g y_o S) V_{fo} \qquad (33)$$

where T_o = normalized sediment transport capacity (kg m^{-2} s^{-1}), K_t = sediment transport factor (s^2 m^2), y_o = normalized depth of flow (m), and V_{fo} = normalized runoff velocity (m s^{-1}). The development of these equations assumed that all sediment available for transport was provided by raindrop impact, and that sediment detachment by runoff was insignificant in interrill areas. The sediment transport equation does not take into account differences in particle size distribution. The sediment transport factor, K_t, was empirically derived from rainfall simulator experiments. The equations were tested on a Nunn clay loam and found to predict reasonably well.

Watson and Laflen (1986) presented an equation of the form:

$$D_i = A\, t_a^{\,B} I^C S \qquad (34)$$

where t_a = soil shear strength after rainfall (Pa), and A, B, and C are constants. It was determined that shear strength of the soil measured after rainfall provided a better indicator of interrill erodibility than did the soil compressive strength. It was also found that equations that included rainfall intensity, soil shear strength, and slope variables provided good estimates of soil erosion. Finally, it was found that rainfall intensity was the most important variable for predicting interrill erosion, followed by soil shear strength and slope.

Schultz et al. (1985) investigated changes in soil splashed from raindrops impacting a fallow soil as affected by changes in the shear strength of the soil, depth of ponded water, and time. They calculated soil shear strength to be:

$$t = 3.22 + 15.4^{e-2.68t} \quad for \;\; t \le t_p \qquad (35)$$

where t_p = time to initial ponding = 1.5 minutes in this study. The soil splash rate before ponding was:

$$\ln(SR) = 4.27 - 0.339\ln(t - 3.22) \quad for \;\; t \le t_p \qquad (36)$$

where SR = soil splash rate, (kg ha^{-1} min^{-1}). The splash rate after ponding was:

$$\ln(SR) = 17.2\ln(10.3 - D) - 35.0 \quad for \;\; t > t_p \qquad (37)$$

where D = depth of ponded water, mm. They subsequently found that at a ponded water depth of approximately 1.88 times the drop diameter stopped soil splash from their experimental apparatus, and a ponded depth of 3.75 times the drop diameter effectively stopped soil detachment for raindrops of 1.6 mm diameter.

Guy et al. (1987) developed a set of equations for differentiating between runoff and rainfall sediment transport capacity, and found that rainfall greatly increased sediment transport capacity. Unfortunately, the equations developed were site specific and could not be generalized.

Wicks and Bathurst (1996) presented the equation for soil detached by raindrop impact in the SHE model as:

$$D_R = k_r F_w (1 - C_G)[(1 - C_C) M_R + M_D] \quad (38)$$

where D_R = soil detached by raindrop impact (kg m^{-2} s^{-1}), F_W = water depth correction factor, C_G = proportion of soil covered by ground cover, C_C = proportion of soil covered by canopy cover, M_R = momentum squared for rain $= a I^b$ ((kg m s^{-1})^2 m^{-2} s^{-1}), where α and β are regression constants, and M_D = momentum squared for leaf drip:

$$M_D = \frac{\left(\frac{V r p D^3}{6}\right)^2 DRIP\%DRAIN}{\left(\frac{p D^3}{6}\right)} \quad (39)$$

where V = leaf drip fall velocity (m s^{-1}), r = density of water (kg m^{-1}), D = leaf drip diameter, $DRIP\%$ = proportion of drainage which falls as leaf drip, and $DRAIN$ = canopy drainage (m s^{-1}). Values of k_r were determined by applying equation (38) to measured data sets and solving for k_r. The results are presented for different soil textural classes.

Misra and Rose (1996) presented a rainfall detachment rate equation for the GUEST model as:

$$e_i = \frac{(1 - H) a P}{I} \quad (40)$$

where e_i = rate of rainfall detachment of sediment of settling class i (kg m^{-2} s^{-1}), a = rainfall detachability (kg m^{-1}), P = rainfall rate (m s^{-1}), and I = number of classes of sediments. To solve for a, H is approximated as unity, and a is solved relative to its maximum potential value.

Foster et al. (1995) estimated sediment delivery from interrill areas as:

$$D_i = K_{iadj} I_e s_{IR} SDR_{RR} \left[\frac{R_s}{w}\right] \quad (41)$$

where K_{iadj} = interrill erodibility adjusted for consolidating effects (kg s m^{-4}), I_e = effective rainfall intensity (m s^{-1}):

$$I_e = \frac{\int I\,dt}{t_e} \quad \text{...(42)}$$

where I = breakpoint rainfall intensity (m s^{-1}), t_e = total time during which the rainfall rate exceeds infiltration rate (s), s_{IR} = interrill runoff rate (m s^{-1}), SDR_{RR} = a sediment delivery ratio, R_S = rill spacing (m), and w = rill width (m). The sediment delivery ratio, SDR_{RR}, associated with the interrill erosion rate is taken from the work of Foster (1982). The delivery ratio is a function of the random roughness of the soil surface and particle size distribution in the eroding sediment. The ratio is used to selectively reduce the detachment rate of particles based upon the random roughness of the soil in the interrill area. Roughness factors are calculated for seven different surface descriptions ranging from large-scale roughness to smooth surface, and the fraction of the original load removed for each particle size class is calculated. The remaining fraction is the sediment delivery ratio, and is used to scale the sediment delivery from the interrill area. This information is taken from Tables 8.4 and 8.5 in Foster (1982).

Hirschi and Barfield (1988) presented the soil detached by raindrop impact as used in the KYERMO model as:

$$SSR = CR^{e1}E^{e2}P_{cl}^{e3}S^{e4} \quad \text{..(43)}$$

where SSR = soil splash, g cm^{-2} during Δt; C = an empirical coefficient, R = rainfall rate, cm hr^{-1}; $e1$, $e2$, $e3$, and e4 are exponents; E = applied energy during Δt, in j cm^{-2}; and P_{cl} = percent clay of the surface layer. Raindrop impact is considered to have a negligible impact when the depth of surface water exceeds 3 times the drop diameter, and ponded water and sheet flow are handled separately by incorporating different energy factors. Finally, detachment rate is determined by multiplying the plot increment area by the detachment equation and dividing by the time increment.

Blau et al. (1988) presented the equations for interrill flow in the erosion model of Shirley and Lane (1978) as incorporated into the KINEROS model:

$$E_i = K_i R \quad \text{...(44)}$$

where E_i = interrill erosion rate (kg m^{-2} s^{-1}), K_i = interrill erodibility factor (kg m^{-3}), and R = rainfall excess rate (m s^{-1}).

Moore and Burch (1986) applied the unit stream power theory to sheet flow and determined that its value was:

$$P = \left(\frac{Q}{b}\right)^{0.4}\left(\frac{s^{0.3}}{n^{0.6}}\right) \quad (45)$$

where b = length of contour element. This value of unit stream power was then used in equation (26) to predict sediment transport capacity. Both the rill and interrill flow unit stream power equations were found to predict sediment transport capacity well for shallow overland flow.

2.4 Channel Erosion

Channel erosion, associated with vegetated or bare-earth channels, can be thought to result from several components: hydraulic stresses, boundary geometry, and properties of the material being eroded (Hanson, 1991). Hanson (1988) described the erosion process in terms of three regions. In Region I, slow-rate erosion occurs at stresses below the critical shear stress. In Region II, erosion is a surface phenomenon and there exists a linear relationship between stress and erosion rate. The transition from Region I to Region II stress is referred to as the critical shear stress, and is considered the force below which no substantial erosion occurs. Region III is referred to as the region of mass erosion. This is where the tractive forces exceed the forces that hold the bed together, and mass failure occurs. Hanson presents a critical shear stress model for predicting channel erosion in Region II of the form:

$$e = K(t_e - t_c)^a \quad (46)$$

where e = erosion rate in volume of soil per unit time per unit area (cm^3 h^{-1} cm^{-2}) t_e = effective shear stress for cohesive material in wide channels (Pa). Using a slope partitioning approach to explain stress partitioning between grain roughness and bed form roughness, the equation for effective shear stress is:

$$t_e = \gamma D S \left(\frac{n_s}{n}\right)^2 \quad (47)$$

where D = flow depth (cm), and n_s = Manning's roughness coefficient associated with the soil grain roughness. Also, Hanson (1988) presented evidence for an equation for erosion rate that was the product of the erodibility coefficient and effective local stress. The effective local stress equation was generalized so that the exponent on the ratio of stresses varied between 4/3 and 2. Through regression analysis on four different soils, erodibility coefficient K was determined by plotting cumulative erosion versus a summation of a stress-time product. Unfortunately the conditions of the test do not allow the results to be generalized. In Hanson (1991), an in-situ water-jet scouring device was developed to determine an index related to the soil erodibility parameter.

Temple (1985) investigated the use of the slope-partitioning method on grass lined channels and recommended an equation for effective local shear stress:

$$t_e = \gamma D S (1 - C_F) \left(\frac{n_s}{n}\right)^2 \quad (48)$$

where C_F = an empirical vegetal cover factor. He then used the critical shear stress equation to evaluate a data set from grass-lined open channels, and found that major trends in the data were explained using the slope-partitioning approach and the linear erosion model. Applying the method to comparable channels in mowed and unmowed conditions suggested that mowing the channels had little effect on the vegetal cover factor.

Novak (1985) derived simple equations to predict long-term soil loss by rills and channel erosion. He used these equations to calculate the time required for the area of interest to reach equilibrium with the maximum overland flow. His results indicated that the time varied between 5 and 500 years and were applicable to relatively undisturbed areas where rill and channel erosion can occur.

Wang et al. (1992) found that boundary shear stress in erodible channels varied exponentially with depth to a maximum at the bed centerline in channels with a width to depth ratio greater than one. They also found that the maximum shear stress varies exponentially with width-depth ratios and approaches the average shear stress as the channel becomes infinitely wide. They found that the maximum shear stress was approximately 1.42 times the average shear stress and occurred when the width to depth ratio was approximately 2.8.

Coleman (1986) studied the effect of suspended sediment on the velocity distribution in open-channels and concluded that suspended sediment loading decreased the logarithmic portion of the velocity profile relative to clear water flows. He showed that the Karman coefficient did not vary significantly with increasing sediment concentration, however, the wake strength coefficient, a measure of deviation from the logarithmic equation in the wake region, varied significantly with increased sediment concentration.

Dawdy and Vanoni (1986) presented several alluvial channel models. They presented two approaches to modeling armoring: one dictating the probability of a grain in the top layer remaining immobile, as a function of the critical shear stress, grain diameter, and an empirical coefficient; and the other dictating the probability of grain movement as a function of the submerged specific gravity of the sediment, the volumetric bed load discharge per unit width, hydraulic radius, and energy slope.

Wicks and Bathurst (1996) used the one-dimensional partial differential equation for conservation of sediment mass:

$$\frac{\partial (Ac)}{\partial t} + (1 - l)W\frac{\partial z}{\partial t} + \frac{\partial (AcV_s)}{\partial x} = \frac{\partial}{\partial x}\left(A \in \frac{\partial c}{\partial x}\right) + g_s \quad \text{...(49)}$$

where A = flow cross-sectional area (m^2), l = bed porosity, W = active bed width for which there is transport (m), z = channel bed elevation (m), V_s = longitudinal sediment velocity (m s^{-1}), $\hat{I}$ = longitudinal dispersion coefficient (m^2 s^{-1}), g_s = overland flow sediment input to the channel (m^3 s^{-1} m^{-1}), t = time (s), and x = distance along the channel (m). The equation is solved for each sediment size in turn. The transport equation is either the Ackers-White or the Englund-Hansen total load equation, depending on the user's choice (Wicks and Bathurst, 1996). To simulate armoring, the model assumes a simplified two layer vertical variation in the bed material. The upper layer is assumed to be of a smaller diameter than the lower layer, and to entrain until the particle sizes exposed are too large for the flow to move.

Foster (1982) presented a form of the critical shear equation for erosion occurring in a channel:

$$E_{ch} = W_{eq} K_{ch} (1.35\bar{t} - t_c)^{1.05} \qquad (50)$$

where E_{ch} = channel erosion rate (kg s^{-1}), W_{eq} = channel equilibrium width (m), K_{ch} = channel erosion parameter, and $\bar{t}$ = average channel shear stress (Pa), assumed maximum at the channel midsection. This model assumes that the channel bottom is eroding downward at a constant rate. After the channel bottom hits a non-erodible surface, the downward erosion ceases and the channel begins to widen according to:

$$E_{ch} = 2K_{ch}(t_b - t_c)^{1.05} d_{ne} \qquad (51)$$

where t_b = shear stress at normalized position x* along the channel perimeter (Pa), and d_{ne} = depth to the non-erodible layer (m). The channel continues to widen until the depth of flow is insufficient to cause the flow shear to exceed the critical shear.

Ascough et al. (1995) presented the form of the channel erosion equations used in the WEPP model. The model uses the critical shear erosion rate equation of Foster et al. (1980):

$$E_{ch} = W_{eq}\, k_{ch}(t_b - t_c) \qquad (52)$$

Average shear stress is calculated assuming stress partitioning between bare soil and vegetation on the surface. Average shear stress on bare soil is:

$$t_b = gR_s S_f \qquad (53)$$

$$R_s = \left[\frac{V_c n_{bch}}{1.49 S_f^{\,0.5}}\right]^{\frac{3}{2}} \qquad (54)$$

where R_s = hydraulic radius (ft), V_c = channel velocity (ft s^{-1}), n_{bch} = Manning's roughness of the bare channel soil, and S_f = a normalized friction slope based upon the work of Foster et al. (1980). Average shear stress of flow acting on vegetation in the channel is calculated by:

$$t_{\text{cov}} = gS_f \left[\frac{V_c (n_t - n_{bch})}{1.49 S_f^{0.5}} \right]^{\frac{3}{2}} \qquad (55)$$

where n_t = Manning's roughness factor for the vegetated surface. If t_{cov} exceeds the shear stress at which the cover starts to move, the cover fails and more stress is shifted to the bare soil. Shear stress is assumed to be triangularly distributed in time over the duration of runoff in order to estimate the time that the shear stress is greater than the critical shear stress. During this time, the shear is assumed constant and equal to peak shear stress for the precipitation event, and the duration of runoff is shortened to that required by the water mass balance. After the erosion rate and sediment inflow are calculated, transport is calculated using Yalin's equation. If capacity exceeds transport, then the model assumes that the sediment load is at capacity at the end of the channel reach. Because the transport capacity and sediment load are dependent, the solution is iterated until the potential load is within 1 percent of transport capacity or until 20 iterations have been performed.

2.5 Inconsistencies of the critical shear stress approach

Lavelle and Mofjeld (1987) contested the theory of a critical shear stress value for incipient motion for a bed of particles. They argued that instantaneous stresses have magnitudes that fluctuate about the mean stress, and that any mean stress level will have instantaneous stress levels that will exceed the critical shear threshold for some particles. As evidence, they presented situations where small fluxes of sediment occur over long time periods (up to and greater than 70 hours) while the dimensionless Shield's stress value is less than 0.6. Below the value of 0.6, it is implied that there is no motion. They also presented evidence of at least four different definitions of critical shear stress, and argued that combination plots of these values on a single diagram are inconsistent. While these results may be appropriate for long time periods of flow, such as those that occur in erodible channels, they are not as relevant in the case of overland flow or rill erosion events where the hydrologic response is often intense and of short duration. The work of

Wilson (1993) and Meyer et al. (1975) also seem to support the concept of critical shear. Unfortunately, the differing definitions of critical shear stress remains an issue that is yet to be resolved.

2.6 Effects of Consolidation

Describing the change in soil strength over time is important if a model is to predict long-term erodibility of soils accurately. Nearing et al. (1988) developed a model to predict consolidation effects on rill erodibility. They indicated that the primary factors that influence soil stability include effective stress and time, with surface sealing and crusting being important in interrill areas. The main destabilizing forces in soils include tillage and freeze/thaw cycles. They indicated that when a soil is subjected to suction for a period of time and then resaturated, the soil retains some of its strength gain, and that the magnitude of stabilization is proportional to the maximum magnitude of this stress.

Alberts et al. (1995) presented equations used in the WEPP project to estimate the changes in rill and interrill erosion rate due to consolidation. This is done by adjusting the erodibility coefficients, K_r and K_i, and the critical shear stress, t_c, for consolidation effects. The adjusted rill erodibility and critical shear stress are then used to calculate rill detachment based on equations (16) and (17). The adjusted interrill erodibility is used to calculate interrill detachment based on equations (41) and (42). The adjusted rill erodibility for variations in soil properties and seasonal weather factors:

$$K_{radj} = K_{rb}(CK_{rbr})(CK_{rdr})(CK_{rlr})(CK_{rsc})(CK_{rft}) \qquad (56)$$

where K_{radj} = baseline rill erodibility adjusted for effects (s m^{-1}), and K_{rb} = baseline rill erodibility (s m^{-1}):

$$K_{rb} = 0.00197 + 0.030\,vfs + 0.03863e^{-184OM} \quad \text{for } sand > 0.30 \qquad (57)$$

$$K_{rb} = 0.0069 + 0.134e^{-20clay} \quad \text{for } sand \le 0.30 \qquad (58)$$

where *vfs* = fraction of very fine sand in the surface soil, *OM* = fraction of organic matter in the surface soil, *sand* = fraction of sand in the surface soil, *clay* = fraction of clay in the surface soil. CK_{rbr} = a buried residue adjustment factor = $e^{-0.4br}$, *br* = mass of buried residue (kg m^{-2}) within the 0 to 0.15 m zone of the soil. CK_{rdr} = dead root adjustment factor = $e^{-2.2dr}$, *dr* = mass of dead roots (kg m^{-2}) in the 0 to 0.15 m soil zone, CK_{rlr} = live root adjustment factor = $e^{-3.5lr}$, *lr* = mass of live roots (kg m^{-2}) in the 0 to 0.15 m zone, and CK_{rsc} = sealing and crusting adjustment factor:

$$CK_{rsc} = \left[\left(\frac{K_{rcons}}{K_{rb}}\right) + \left(1 - \frac{K_{rcons}}{K_{rb}}\right)\right] e^{-r_c daydis} \qquad (59)$$

where K_{rcons} = consolidated rill erodibility:

$$K_{rcons} = 0.00035 - 0.0014\Theta_{fc} + 0.00068silt + 0.0049M_{cf} \qquad (60)$$

where θ_{fc} = volumetric water at field capacity, *silt* = fraction of silt in the upper soil layer, M_{cf} = coarse fragment content by weight (fraction), ρ_c = soil bulk density at 0.033 MPa, daydis = cumulative number of days since total soil disturbance, CK_{rft} = freeze and thaw adjustment factor = $2.0(0.933)^{\Psi_{surf}}$, and Ψ_{surf} = matrix potential of the soil surface in kPa.

Critical shear stress in WEPP is estimated using the equation:

$$t_{cadj} = t_{cb}(Ct_{rr})(Ct_{sc})(Ct_{ft}) \qquad (61)$$

where t_{cadj} = baseline critical shear adjusted for effects (Pa), and t_{cb} = baseline critical shear (Pa). For cropland soils:

$$t_{cb} = 2.67 + 6.5clay - 5.8vfs \quad \text{if } sand > 0.3 \qquad (62)$$

$$t_{cb} = 3.5 \quad \text{if } sand \le 0.3 \qquad (63)$$

$$t_{cb} = 0.35 + 6.5clay \quad \text{if } vfs \le 0.4 \qquad (64)$$

$$t_{cb} = 5.27 - 5.8vfs \quad \text{if } clay > 0.4 \qquad (65)$$

Ct_{rr} = random roughness adjustment factor = $1.0 + 8.0(RR_t - 0.006)$, RR_t = random roughness in m, Ct_{sc} = sealing and crusting adjustment factor:

$$Ct_{sc} = \left(\frac{t_{cons}}{t_c}\right) + \left[1 - \left(\frac{t_{cons}}{t_c}\right)\right] e^{-r_c daydis} \qquad (66)$$

where t_{cons} = consolidated shear stress:

$$t_{cons} = 8.37 - 11.8\Theta_{fc} - 4.9sand \qquad (67)$$

and Ct_{ft} = freeze and thaw adjustment factor $= 0.875 + 0.543\ln(\Psi_{surf})$.

Alberts et al. (1995) presented the adjusted interrill erodibility factor as:

$$K_{iadj} = K_{ib}(CK_{ican})(CK_{igc})(CK_{idr})(CK_{ilr})(CK_{isc})(CK_{isl})(CK_{ift}) \qquad (68)$$

K_{ib} = interrill adjusted erodibility:

$$K_{ib} = 5{,}300{,}000 \quad kg\ s\ m^{-4} \text{ .... default value} \qquad (69)$$

$$K_{ib} = 2{,}728{,}000 + 19{,}210{,}000 vfs \text{ .... } sand > 0.30 \qquad (70)$$

$$K_{ib} = 10{,}412{,}000 \text{ .... } sand > 0.30,\ vfs > 0.40 \qquad (71)$$

$$K_{ib} = 6{,}054{,}000 - 5{,}513{,}000 clay \text{ .... } sand \le 0.30 \qquad (72)$$

$$K_{ib} = 5{,}502{,}700 \text{ .... } sand \le 0.30,\ \text{clay} \le 0.10 \qquad (73)$$

CK_{ican} = canopy height adjustment factor:

$$CK_{ican} = 1 - 2.941\left(\frac{can\text{cov}}{h}\right)\left(1 - e^{-0.34h}\right) \qquad (74)$$

h = canopy height in meters, $cancov$ = fraction of soil covered by canopy cover, CK_{igc} = ground cover adjustment factor:

$$CK_{igc} = e^{-2.5 inr\text{cov}} \qquad (75)$$

where $inrcov$ = fraction of interrill area covered by ground cover, $CK_{idr} = e^{-0.56dr}$, dead roots within 0 to 0.15 m soil zone factor, $Ck_{ilr} = e^{-0.56lr}$, live roots within 0 to 0.15 m soil zone factor, CK_{isc} = sealing and crusting adjustment factor:

$$CK_{isc} = \frac{K_{icons}}{K_{ib}} + \left[1 - \frac{K_{icons}}{K_{ib}}\right] e^{-r_c daydis} \qquad (76)$$

where K_{icons} = consolidated interrill erodibility:

$$K_{icons} = 10^3 (3042 - 3166\, sand - 8816\, orgmat - 2477\, \Theta_{fc}) \qquad (77)$$

Lyle and Smerdon (1965) related compaction to erosion resistance of soils and found that critical shear stress increased linearly with compaction as indicated by a decrease in the void ratio. Using regression analysis to analyze critical shear force versus void ratio on several soils in an attempt to correlate shear force to other soil properties, they concluded that different soils do not react the same to compaction and that erosion resistance does not increase or decrease at the same rate for every soil as a result of compaction. Kemper and Rosenau (1984) attempted to describe soil cohesion as a function of time and water content. They found that the moduli of rupture of soils increase with time, and that cohesive forces due to water are large enough to significantly explain cohesion in soils, except in clay soils whose cohesion increase as they dry. Brown et al. (1989) investigated the effects of incorporated crop residue and seasonal consolidation on rill erosion. They found that surface application of crop residue is more effective in reducing soil loss than incorporation of crop residues, unless a critical discharge or slope length is exceeded, or massive rilling occurs beneath the residue. They also state that antecedent soil moisture is important in determining seasonal erodibility of a soil, and found that residue plays an important part in stabilizing sand-sized aggregates. They developed an empirical factor based upon the condition that subsequent runoff rates did not exceed the initial runoff rate, which produced the rill of interest:

$$D_c = K_r\, e^{(-b_4 RIR)} e^{(b_5 DAYS)} (t - t_c) \qquad (78)$$

where D_c = detachment capacity of flowing water (kg m^{-2} s^{-1}), RIR = residue incorporation rate (kg ha^{-1}), and $DAYS$ = the number of days after the first erosion event on freshly tilled conditions.

2.7 Seepage

Stolte et al. (1990) studied the effect of seepage on a sandy loam and a sandy soil. They found that seepage had no effect on the erodibility of the loam and concluded that temporal variation of erodibility depends upon soil type and other conditions. For the sandy soil, they found that during low rainfall rates, sediment concentration in rills increased as infiltration was reduced to zero, and that seepage through the rill walls served to destabilize the rills and cause sloughing. At high rainfall rates, erodibility was not enhanced by increased return flow.

2.8 Canopy and Surface Cover Effects

Canopy or mulch cover effects on soil erodibility require accurate prediction if a model is to predict seasonal variation of erosion accurately. Khan et al. (1988) simulated crop canopy cover, canopy height, and straw mulch cover in a laboratory and found that runoff was significantly reduced by increased mulch cover but was unaffected by canopy cover or canopy height. They also found that soil loss was significantly reduced by increased mulch cover and by canopy cover when the canopy was less than one meter above the soil surface. At a canopy height of one meter, they found that soil loss was nearly the same as having no canopy at all. They also found that mulch is not as effective in reducing erosion when canopy cover is present as when it is absent, and that equations that neglect the interaction between these two terms may overestimate erosion reduction. Subsequently they developed empirical equations for estimating erosion reduction by breaking the USLE C-factor into subfactors:

$$C = PLU\ CC\ RC\ SR \quad (79)$$

where *PLU* = prior landuse subfactor, *CC* = crop canopy subfactor, *RC* = residue or mulch cover subfactor, and *SR* = surface residue subfactor. The subfactors *CC* and *RC* were determined by regression. Meyer et al. (1975) investigated the effect of flow rate and canopy cover on rill erosion and found that a simulated canopy dissipated raindrop impact, increasing the flow rate at which rill erosion began. They found that a canopy had little effect on rill velocity, and that the rate of increase in rill erosion with increased flow rate was about halved when protected by a canopy. Alberts et al. (1995) presented equations used in the WEPP project to estimate changes in interrill erosion rate due to canopy and ground cover as equations (68) through (77).

2.9 Parameter Estimation

One of the most difficult tasks when using any model is parameter estimation. This is due to the spatial variability of soil characteristics and the inability to correlate bulk soil properties to measures of erodibility. Stein and Nett (1997) developed an impinging jet apparatus that allowed separation of the subprocesses of sediment detachment and transport. Their device was a clear-water impinging jet that produced detachment without transport at the site of maximum scour. They measured scour depth versus time for six different soils in a saturated, disturbed condition, and then used statistical analysis to determine the optimum values for the soil erodibility coefficient and critical shear stress. Their results were similar to those obtained by field calibration studies. Nearing et al. (1988) developed a calibration technique for estimating the model parameters of interrill erodibility, rill erodibility, and critical shear stress. They optimized parameter values and plotted a least squares error function for combinations of the parameters to construct a response surface for the parameter combinations. They found that the parameters exhibited no identifiability, interdependence, or insensitivity problems. They then used the optimized parameter values to predict sediment losses and compared these to field data, and found that the model represented the data accurately.

Blau et al. (1988) optimized a rill erosion parameter and a sediment transport parameter and found that errors introduced by an implicit finite difference solution had little effect on the least squares error function, but that the model exhibited parameter insensitivity. They examined the effect of errors in the data on parameter identifiability, or the ability to obtain consistent parameter estimates given data from a set of experimental runs on the same erosion plot. They found that when dependent and independent errors were added, the only effect was to increase the magnitude of the error function in areas close to the true parameter values. They stated that this was significant because noise in optimization schemes often contributes to their failure.

Gilley and Finkner (1992) used random roughness data to predict the Darcy-Weisbach hydraulic roughness coefficient and Manning's hydraulic roughness factor. They found that the Darcy-Weisbach coefficient was:

$$f = \left(\frac{6.30 RR_o 1.75}{R_n^{0.661}} \right) \quad (80)$$

where RR_o = random roughness immediately after tillage, ranging from 6 to 32 mm, and R_n = Reynold's number ranging from 20 to 6000. They found that linear regression analysis of predicted versus measured hydraulic roughness coefficients yielded a coefficient of determination, r^2, of 0.898. They then found that the Manning's roughness coefficient was:

$$n = \left(\frac{0.172 RR_o^{0.742}}{R_n^{0.282}} \right) \quad (81)$$

for the variables within the range previously mentioned. They stated that the random roughness after rainfall should be substituted for the random roughness after tillage if rainfall has occurred since the last tillage event. Linear regression analysis yielded a coefficient of determination of 0.727.

Foster (1982) proposed a technique to determine rill widths from a conveyance function and plots of erosion rates at various discharges based upon data for 16 rills. The equation takes the form:

$$g(x_c) = \left[\frac{Qn}{s^{0.5}}\right]^{\frac{3}{8}} \frac{gs}{t_c} \qquad (82)$$

Given a value of $g(x_c)$, x_c (m) is read from a graph of the data and a non-dimensional wetted perimeter and hydraulic radius are calculated using this value. Equilibrium rill width is then calculated using the equation:

$$W_{eq} = \left(\frac{Qn}{s^{0.5}}\right)^{\frac{3}{8}} \frac{W_*}{R_*^{\frac{5}{8}}} \qquad (83)$$

Lane and Foster (1980) found that 95 percent of the variation in measured rill widths could be explained by regression analysis with the equation:

$$w = aQ^m \qquad (84)$$

where a, and m are constants that vary according to soil conditions and time of consolidation.

McIsaac and Mitchell (1991) compared the effect of two tillage treatments, a moldboard plow versus no-till, on rill morphology in an attempt to describe variation in rill geometry. They concluded that between 52 and 81 percent of the variation in estimated average rill width could be explained by the non-linear equations with rill discharge rate. They found that for the moldboard plow treatment, non-linear regression explained 52 percent of the variation but that the exponent of discharge was not significantly different from 0. For the no-till treatment, the non-linear regression explained 81 percent of the variation in estimated rill widths but that the parameters were not significantly different from the results of the moldboard plow treatment, or from a similar study by Gilley et al. (1990). McIsaac and Mitchell then found that linear regression using the cube root of discharge as the independent variable explained 52 percent of the variation of estimated rill width for the moldboard plow treatment, and that the coefficient was significantly different from 0. Similar analysis of the no-till treatment indicated that the linear model could explain 76 percent of the variation in rill width, and that the coefficient was statistically different from the moldboard plow treatment. This indicated that rills in the no-till system were significantly wider than for the moldboard system for a given discharge, however they cautioned that because of the uncertainty in the actual discharge and width per rill, that their results should not be taken as conclusive proof that tillage practices affect rill width.

2.10 Summary

A review of literature indicated that there are approximately seven watershed-scale NPS models that can be used to quantify the effects of changing landuse. These models are SWRRB-WQ, SWAT, AnnAGNPS, HSPF, WEPP, SHE, and ANSWERS-2000. These are all continuous simulation, process-based (to varying degrees) planning tools. SWRRB-WQ, SWAT, and AnnAGNPS utilize different versions of the USLE to predict sediment detachment in a watershed. The USLE's parameters have no physical basis with respect to detachment, routing, or transport of sediment, however, they do recognize the different factors that govern soil erosion by water. Although the USLE is considered a good method for estimating long-term average annual soil loss from homogeneous fields, the model cannot simulate temporal and spatial variability required by an effective planning model (Owoputi and Stolte, 1995). The sediment module in HSPF generally requires extensive calibration and was therefore considered unacceptable to use in ungaged watersheds. The erosion module used in SHE is a form of the critical shear equation, however sheet and rill erosion are lumped together. The erosion module in WEPP utilizes the critical shear concept, separating rill, interrill, and channel contributions. The erosion module in ANSWERS-2000 is a site-specific module developed for watersheds in Indiana, and is generally unacceptable for generalization to other watersheds.

A review of erosion theory indicated that there are two process-based theories used to describe rill erosion. The first is critical shear theory and the second is unit stream power theory. Interrill erosion is generally assumed to be a function of rainfall intensity, and is adjusted for canopy and ground cover effects and soil consolidation. Channel erosion is generally assumed to be a function of excess shear stress and soil erodibility, sometimes taking separation of shear stress between cover and bare soil into account. In the case of the SHE model, channel erosion is predicted by the one-dimensional partial differential equation for conservation of sediment mass.

Parameter estimation in NPS models is difficult due to the spatial and temporal variability of the input parameters. Much research has been done in the area of parameter estimation, however many methods require regression analysis on data sets before they can be applied. This has limited the applicability of some erosion theory to research plots. Methods have been defined for obtaining parameters for several models and development will likely continue as modeling becomes a tool for landuse planning.

3 MODEL DEVELOPMENT

3.1 Introduction

Model development consists of formulating and dictating the methods and equations used to describe a physical phenomenon. The rationale for the method selection is discussed, and the equations used in the updated ANSWERS-2000 model are presented. The equations are presented as closely as possible to the equations in the model code for convenience, consistency, and clarity. Due to the complexity of the input file and the model code, several simplifying assumptions were made in the model development: (1) Primarily, the plant growth parameters were assumed to be linear functions that were constrained to maximum and minimum values by the user. (2) Plant canopy height and cover, and live and dead root mass are considered to be linear functions. (3) An armoring fraction incorporated into the channel erosion submodel represents nonerodible bed material.

3.2 Existing Methods

The existing ANSWERS-2000 model uses empirical detachment coefficients for rainfall and flow detachment that are based on the work of Meyer and Wischmeier (1969), using empirical relations of the cropping and management (C) factor and the soil erodibility (K) factor coefficients from the Universal Soil Loss Equation (Wischmeier and Smith, 1978). In addition, Beasley and Huggins (1981) inserted several arbitrary calibration factors that were required to improve estimates of sediment detachment for Indiana watersheds where the model was originally evaluated. In the continuous simulation version of ANSWERS-2000 (Bouraoui and Dillaha, 1996) the C factor is allowed to vary seasonally based upon the leaf area index. While the USLE and its subfactors are useful for predicting average annual soil loss, they lack the ability to accurately represent seasonal variation of the factors that govern soil erodibility.

Recently, several new approaches to rill erosion have been developed. These approaches have attempted to predict soil erosion based upon observed physical processes. The unit stream power theory and the critical shear theory are the two most prominent approaches. The Water Erosion Prediction Project (Alberts et al., 1995) generated documentation concerning seasonal changes in soil erodibility due to plant canopy height and cover, plant root density, soil consolidation, and roughness effects caused by tillage implements. Because of the documentation, the method was considered attractive. These parameters can be assumed constant over a uniform area, allowing integration into the cellular structure of ANSWERS-2000. Inspection of the unit stream power theories indicated that some of the parameters were either more difficult to estimate or were less suitable for implementation into the ANSWERS-2000 model. The GUEST model utilizes a parameter that is the fraction of soil covered by deposited sediment at a given time. This variable would require estimation on a thirty-second time step, and no direct method was available for calculating its value. Other versions of the unit stream power theory, such as that suggested by Elliot and Laflen (1993) (Eq. 24) do not offer a method for calculating soil erodibility or critical unit stream power. The method suggested by Moore and Burch (1986) (eqs. (25) through (28)) lacks a method for estimating the rill shape factor, and the resulting equations are used to estimate sediment transport capacity instead of sediment detachment. Because parameters can be estimated for the critical shear methodology used by the WEPP model, and because the method lends itself to implementation in ANSWERS-2000, this method was chosen to replace the rill detachment equations according to equations (16) and (17). Because the WEPP interrill and channel components followed the same parameter set as the rill erosion submodel and were suitable for implementation into ANSWERS-2000, they were chosen to replace the existing detachment equations for both interrill (Eq. 41) and channel erosion (eqs. (16) and (17)). Their selection was based on simplicity of the data set (to implement as an input file), consistency of method, and because of the documentation that was available for parameter estimation. The ANSWERS-2000 source code in Fortran 77 format is included as Appendix A.

3.3 Interrill Erodibility

Interrill erodibility is modeled using the equations developed for the WEPP model. Baseline interrill erodibility is calculated based upon the percentage of sand, silt, clay, and very fine sand present in the parent soil using equations (68) through (73), and baseline erodibility is adjusted for crop canopy height using equation (74). Interrill cover is modeled using equation (75) and sealing and crusting using equations (76) and (77). Crop height and canopy cover at maturity are inputs to the model, and height and canopy cover are calculated on a daily basis as:

$$HEIGHT = HGTFACT * DAYDIFF \quad (85)$$

where *HEIGHT* = canopy height at a specific day (m), *HGTFACT* = height growth factor:

$$HGTFACT = \left(\frac{MAXHEIGHT}{GROWTHFACTOR * LDATE} \right) \quad (86)$$

where *MAXHEIGHT* = maximum plant height (m), and *GROWTHFACTOR* = percentage of crop growth period required for plant to reach maturity, *LDATE* = crop growth period (days), and *DAYDIFF* = number of days since planting. The daily plant height is not allowed to exceed the maximum input value.

The area covered by canopy on a specific day (fraction), *CANOPY*, is expressed as:

$$CANOPY = AUCFACT * DAYDIFF \quad (87)$$

where *AUCFACT* = area under the canopy factor:

$$AUCFACT = \left(\frac{\left(\frac{AC}{100} \right)}{GROWTHFACTOR * LDATE} \right) \quad (88)$$

where *AC* = cell area covered by the canopy at plant maturity (%). Canopy cover is not allowed to exceed maximum input values. *DAYDIFF* is calculated from the planting date.

The live root biomass is calculated on a daily basis according to:

$$LIVEROOT = LVROOTFAC * DAYDIFF \quad (89)$$

where *LIVEROOT* = root biomass in upper 15 cm of soil horizon (kg m^{-2}), *LVROOTFAC* = live root growth factor:

$$LVROOTFAC = \left(\frac{MXLVROOT}{GROWTHFACTOR * LDATE} \right) \quad (90)$$

where *MXLVROOT* = maximum root biomass in the upper 15 cm of the soil (kg m^2), which is an input.

The dead root biomass is calculated on a daily basis according to:

$$DEADROOT = DDROOTFAC * DAYDIFF \quad \text{.........} (91)$$

where *DEADROOT* = dead root mass in the upper 15 cm of the soil (kg m^{-2}) at a given day, and *DDROOTFAC* = dead root factor:

$$DDROOTFAC = \left(\frac{DDROOTF - DDROOTI}{LDATE} \right) \quad \text{.........} (92)$$

where *DDROOTF* = dead root biomass in the upper 15 cm of the soil surface at the end of the crop growth period (kg m^{-2}), and *DDROOTI* = dead root biomass in the upper 15 cm of the soil surface at the beginning of the crop growth period (kg m^{-2}). The dead root biomass is therefore allowed to decrease linearly from a given initial value to a given final value. The dead root biomass is not allowed to increase during a crop growth period.

Interrill cover is calculated on a given day using:

$$INRCOV = INRCOVI + (INCOVFAC * DAYDIFF) \quad \text{.........} (93)$$

where *INRCOV* = interrill area covered by ground cover on a specific day, *INRCOVI* = fraction of interrill area with ground cover at the beginning of the crop growth period, and INCOVFAC = interrill cover factor:

$$INCOVFAC = \frac{(INCOVF - INCOVI)}{LDATE} \quad \text{.........} (94)$$

where *INCOVF* = fraction of interrill area with ground cover at end of the crop growth period. Interrill cover can increase or decrease during a growing season, however it can never exceed INCOVF.

3.4 Rill Erodibility

Rill erodibility in the ANSWERS-2000 model is calculated according to equations (56) through (60) from the WEPP model. Rill erodibility is not adjusted for freeze and thaw effects. The mass of buried residue within the upper 15 cm of the soil profile (kg m^{-2}) is calculated based upon the work of Brown et al. (1989), who found that the mass of buried residue was reduced by about 60% over a 90 day period. The buried residue on a specific day is calculated as:

$$BURRES = BR * e^{(-0.010181 * DAYDIFF)} \quad \text{.......(95)}$$

where *BURRES* = mass of buried residue within the upper 15 cm of the soil (kg m^{-2}) on a specific day, and BR = mass of buried residue within the upper 15 cm of the soil (kg m^{-2}) at the beginning of the crop growth period. Live root and dead root biomasses are the same for rill and interrill areas, however root biomass adjustments are calculated differently for rill and interrill areas.

3.5 Channel Erodibility

Channel erodibility in the ANSWERS-2000 model is calculated using the rill erodibility equations (56) through (60) developed for WEPP. The channel erodibility submodel does not incorporate live root adjustments, dead root adjustments, or freeze and thaw effects, but it does include soil consolidation effects due to time, allowing the soil to always remain in a consolidated state. The channel soil consolidation factor is calculated according to:

$$CK_{rsc} = \frac{(K_{rcons})}{K_{rb}} \quad \text{.......(96)}$$

3.6 Critical Shear

Critical shear in the rill area in the ANSWERS-2000 model is calculated using equations (61) through (67) from the WEPP model, but it does not incorporate freeze and thaw effects. Critical shear in channels is calculated using the same equations but adjustments due to freeze and thaw, and random roughness caused by tillage effects are not considered. Tillage is not allowed in channels.

3.7 Interrill Detachment

Interrill detachment is also simulated using the WEPP approach, according to equation (41) on a 30-second time step:

$$DIINT = \frac{(K_{iadj} * XR * RNOFIR * SEDDR)}{AREA} \quad \text{.......(97)}$$

where *DIINT* = interrill detachment (kg s^{-1}), K_{iadj} = the adjusted interrill erodibility (kg s m^{-4}), *XR* = net rainfall rate (m s^{-1}), *RNOFIR* = interrill runoff rate (m s^{-1}) per rill contributing area:

$$RNOFIR = \frac{QEFF}{(DX * RILLSPC)} \quad \text{.......(98)}$$

where *QEFF* = flow rate per rill contributing area (m^3 s^{-1}), *DX* = cell width (m), *RILLSPC* = spacing between rills (m), *SEDDR* = a sediment delivery ratio, *AREA* = area of each cell (m^2). Rill spacing is an input to the model and is generally taken as 1.0 meter according to Gilley et al. (1990). The sediment delivery ratio is taken from Foster (1982) (Table 1) based on the assumption that random roughness affects sediment delivery.

Table 1: Sediment Delivery Ratio (adapted from Foster, 1982).

	Particle Diameter (mm)				
Random Roughness (mm)	<0.002	0.002 to 0.05	0.05 to 0.25	0.25 to 1.0	>1.00
>150	0.91	0.79	0.37	0.00	0.00
70 to 100	1.00	0.99	0.98	0.07	0.17
50 to 70	1.00	1.00	0.99	0.32	0.46
20 to 50	1.00	1.00	0.99	0.58	0.69
5 to 20	1.00	1.00	1.00	0.78	0.84
0 to 5	1.00	1.00	1.00	1.00	1.00

Interrill detachment is calculated on a per unit area basis for an entire cell as:

$$DIINT = DIINT * ((DX * DX) - (NORILLS * RILLWID * DX)) \quad \text{.......(99)}$$

where *NORILLS* = the number of rills per cell, and *RILLWID* = rill width (m). In this manner, rill contributing areas are removed from interrill contributing areas.

3.8 Rill Detachment

Rill detachment in ANSWERS-2000 is calculated by according to equations (16) and (17), assuming uniform rill density across a cell, and an excess shear stress exponent (a) equal to 1, as in WEPP. The effective flow rate per rill is calculated by:

$$QEFF = \left(\frac{Q}{NORILLS}\right) \quad \text{.......(100)}$$

where Q = flow rate on the cell ($m^3\ s^{-1}$). The rill width is calculated using the approach of Gilley (1990):

$$RILLWID = 1.13\ QEFF^{\ 0.303} \qquad (101)$$

where *RILLWID* = rill width in meters. The rill width is tracked to ensure that rills widen during the growing season according to flow rate, and then rill width is reset to zero after a tillage event. Depth of flow in a rill is calculated using the Darcy-Weisbach friction factor equation solved for the hydraulic radius, set equal to hydraulic radius, and solved for flow depth. The Darcy-Weisbach friction factor, *f*, is calculated at each time step as (Gilley and Finkner, 1992):

$$f = \left(\frac{n^2 * 8g}{R_{i-1}^{\ 0.333}} \right) \qquad (102)$$

where g = acceleration due to gravity ($m\ s^{-2}$), and R_{i-1} = hydraulic radius (m^{-1}) at the previous time step. The depth of flow is:

$$\mathrm{FLOWDEP} = \mathrm{FLDEPOLD} - \left(\frac{f(D) * f'(D)}{f'(D)^2 - f(D) * f''(D)} \right) \qquad (103)$$

where *FLOWDEP* = depth of flow at this time step (m), *FLDEPOLD* = depth of flow at the previous time step (m), f(D) = flow depth function:

$$f(D) = (FLOWDEP^3 * RILLWID^3 * 8 * 9.80665 * SL) - (f * QEFF^2 * 2 * FLOWDEP) - (f * QEFF^2 * RILLWID) \qquad (104)$$

where *SL* = element slope (tenths of a percent), f'(D) = first derivative of the flow depth function:

$$f'(D) = (3 * FLOWDEP^2 * RILLWID^3 * 8 * 9.80665 * SL) - (f * QEFF^2 * 2) \qquad (105)$$

and f''(D) =second derivative of flow depth function:

$$f''(D) = (6 * FLOWDEP * RILLWID^3 * 8 * 9.80665 * SL) \qquad (106)$$

The depth of flow equation is solved using the Newton-Raphson method for multiple roots (Chapra and Canale, 1988), and an incremental technique that allows the program to search for the initial guess values in the solution of the equation. After the flow depth is solved, the effective shear stress is found using:

$$TAUEFF = 9806.65 * SL * HYDRAD * \left(\frac{MNSOIL^2}{MNTOT^2} \right) \qquad (107)$$

TAUEFF = effective shear stress, 9806.65 = specific weight of water (kg m^{-2} s^{-2}), *MNSOIL* = Manning's n for bare soil, and *MNTOT* = Manning's n for bare soil and vegetated cover. If the effective shear stress exceeds the adjusted critical shear, then the detachment capacity in the rill is calculated using:

$$DCAP = K_{radj} * (TAUEFF - TAUCADJ) * (NORILLS * RILLWID * DX) \qquad (108)$$

where *DCAP* = detachment capacity (kg s^{-1}), and *TAUCADJ* = adjusted critical shear stress. The actual rill detachment is then calculated using:

$$DACT = DCAP * \left(1 - \left(\frac{SST_{i-1}}{TF} \right) \right) \qquad (109)$$

where *DACT* = actual detachment rate (kg s^{-1}), SST_{i-1} = sediment in transport at the previous time step (kg s^{-1}), and *TF* = transport capacity (kg s^{-1}).

3.9 Channel Detachment

Channel detachment is calculated using the rill detachment methodology (eqs. (16) and (17)), and an excess shear stress exponent, *a*, equal to 1. The effective flow rate in the channel is assumed equal to the cumulative flow from upslope contributing channels and the overland flow rate of the cell containing the channel. A channel cell is assumed rectangular, and the channel bottom is considered erodible. The model adjusts for nonerodible surfaces in channels by use of a nonerodible fraction. The detachment capacity in a channel cell is calculated in the same manner as for rill erosion, and is then multiplied by the fraction of the channel cell that is erodible. Bottom scour is calculated by multiplying the adjusted channel erodibility times the shear stress excess and the erodible fraction and dividing by the soil bulk density (kg m^{-3}):

$$DOWNRATE = K_{radj} * \left(\frac{TAUEFF - TAUCADJ}{BULKDENS} \right) * (1 - ARMOUR) \qquad (110)$$

where *DOWNRATE* = downward erosion rate of the channel bottom (m s^{-1}), *BULKDENS* = soil bulk density (kg m^{-3}), and *ARMOUR* = non-erodible fraction of the parent soil. Eroded depth is calculated by multiplying the bottom erosion rate by a time increment. If transport capacity is insufficient to transport all eroded material, then the deposition rate is tracked and the eroded depth is adjusted for deposited material. If the channel bottom has a nonerodible layer (input to the model), bottom erosion ceases at this depth and scour switches to the channel walls. Channel widening is calculated by assuming that the shear stress is uniform along the walls and that the wall erosion rate is the same as the bottom erosion rate. The detachment capacity is recalculated assuming that all erosion occurs along the channel walls:

$$DCAP = K_{radj} * (TAUEFF - TAUCADJ) * (2 * FLOWDEP * DX) \qquad (111)$$

where DCAP = detachment capacity in kg s^{-1}. The detachment capacity is then multiplied by the erodible percentage of the channel soil.

The ANSWERS-2000 model calculates flow in a cell based upon a stage-discharge relationship utilizing Manning's equation. If channel widening occurs, then the conveyance in the channel cell is adjusted according to the new channel width. In this manner, as channel width increases, channel flow rate per unit width decreases, and subsequently flow depth and shear stress decrease.

3.10 Strengths and Weaknesses

The new erosion submodels have several strengths and weaknesses. The strengths of the new erosion submodels are that they are process-based and represent conditions that occur in the field. This helps to overcome limitations associated with purely empirical regression models, that do not simulate how erodibility varies with porosity, soil type, and crop growth-stage. Using this technique it is possible to predict how combinations of these factors influence sediment detachment. New or untested BMPs may also be evaluated using the new submodel without preliminary performance data for calibration. The weaknesses associated with this technique are the increased data requirements for the model, and some of the required parameters such as rill spacing or critical-shear are difficult to estimate. While the theory of critical shear stress is process-oriented, many of the sub-parameters are obtained through empirical means such as regression on data plots. To date, no method has been developed to correlate a single index such as bulk density or porosity to either erodibility or critical shear stress. Also, the assumption of a linear plant growth function throughout the growing season is a significant limitation. This assumption was made to lessen the input requirements at the expense of some level of accuracy. In an eroding channel, mass erosion is controlled by factors other than the shear stress of flowing water. Bank sloughing, bed failure, and the complex hydraulics of meandering in a natural system affect channel erosion and are not considered here. Finally, inclusion of the new detachment routines requires considerable additional memory and computational time.

3.11 Variables

A complete list of variables in ANSWERS-2000 model is included as Appendix B. An input variable selection guide for the new ANSWERS-2000 model is include as Appendix C. A sample input file that corresponds to the input guide is included as Appendix D.

4 SENSITIVITY ANALYSIS

4.1 Overview

Model sensitivity is defined as the change in model output per a change in parameter input. Sensitivity analysis describes how model output varies over a range of a given input variable. While this definition is useful, it does not allow comparisons of sensitivity values, and it is therefore practical to define the relative sensitivity of a parameter:

$$S_r = \left(\frac{\frac{\partial O}{O}}{\frac{\partial P}{P}} \right) \qquad (112)$$

where S_r = relative sensitivity, O = output, P = input. In discrete terms, this may be written as:

$$S_r = \left(\frac{O - O_b}{P - P_b} \right) \left(\frac{P_b}{O_b} \right) \qquad (113)$$

where the subscript b represents a base value. The sensitivity values are thus normalized and can be compared to determine a level of importance. Negative values of relative sensitivity indicate inverse correlation with the parameter, while positive values indicate direct correlation with the parameter. Absolute values greater than 1 indicate exaggerated model response, while absolute values of relative sensitivity less than 1 indicate damped model response. Model parameters that have high sensitivity must be chosen with care because small variations in their values can cause large variations in model output, and therefore it is important to ensure that the parameter value is the best possible estimate. Model parameters that have low sensitivity do not require as much scrutiny in their selection because small changes in their values do not cause large changes in model output. Finally, due to the complexity ANSWERS-2000, the model may not respond in the same manner to every dataset and the general nature of this analysis should be realized. While this exercise indicates response of the model to inputs, in some instances the model may be sensitive to parameters other than the ones indicated.

4.2 Procedure

A data file of the NWJFINA farm was used in the sensitivity analysis. The farm is part of a data set of the work of Jose Collado, a doctoral student at Virginia Tech studying the impact of varying management plans on surface water quality. The number of soil, crop, and channel types were reduced from 2 to 1, 7 to 1, and 6 to 1, respectively, to simplify the sensitivity analysis. All new variables in the detachment model were included in the analysis. All variables, except for the 'no tillage' flag and 'no erosion' flag, were varied by -25%, -10%, 10%, and 25% from their baseline values. The 'no tillage' and 'no erosion' flags were varied from 0 to 1. A value of 0 indicates a conventional tillage crop or an erodible surface, respectively, while a value of 1 indicates a no-till crop or a non-erodible surface, respectively. In a no-till crop, rills are not obliterated during a crop change as they would be during conventional tillage. The output variables of interest were runoff (mm) and sediment yield (kg ha^{-1}) at the watershed outlet, and the simulation period was one year. The parameters included in the analysis, along with their baseline values, adjusted values, and relative sensitivities are included as Appendix E.

4.3 Results and Discussion

The relative sensitivity analysis demonstrated that the model was most sensitive to the parameters found in Table 2. The sediment submodel was very sensitive, as expected to the NOEROS parameter, which turned erosion on and off. The results presented in Table 2 indicate that the sediment submodel was most sensitive to the sand content, final interrill cover, and soil porosity. The submodel was approximately three times as sensitive to the sand content as to the final interrill cover, and approximately twice as sensitive as to the soil porosity. This was because the sand content was used to calculate soil erodibility and to calculate transport capacity of suspended flow. Sand particles were considered to be of the largest nominal size, and these fractions require more transport capacity. Therefore, as the fraction of sand increased, sediment delivered from the watershed decreased. The sediment submodel showed an exaggerated inverse relationship with sand fraction.

Table 2: Relative sensitivity of ANSWERS-2000.

Parameter		Parameter Value	Runoff (mm)	Runoff Relative Sensitivity	Sediment Yield (kg/ha)	Sediment Relative Sensitivity
Sand Content	Baseline	58.00	82.60		7374.00	
	-25%	43.50	77.80	0.23	13183.00	-3.15
	-10%	52.20	79.30	0.40	9661.10	-3.10
	10%	63.80	83.80	0.15	4797.10	-3.49
		72.50	81.20	-0.07	1068.30	-3.42
Final Interrill	Baseline	75.00	82.60		7374.00	
Cover	-25%	56.25	82.60	0.00	10005.40	-1.43
	-10%	67.50	82.60	0.00	8296.60	-1.25
	+10%	82.50	82.60	0.00	6590.40	-1.06
	+25%+	93.75	82.60	0.00	5626.10	-0.95
Soil Porosity	Baseline	0.50	82.60		7374.00	
	-25%	0.38	104.20	-1.05	10223.50	-1.55
	-10%	0.45	92.60	-1.21	8628.80	-1.70
	10%	0.55	72.60	-1.21	5950.40	-1.93
	+25%+	0.63	56.40	-1.27	3809.90	-1.93
Area Under	Baseline	50.00	82.60		7374.00	
Canopy	-25%	37.50	97.10	-0.70	8920.10	-0.84
	-10%	45.00	86.40	-0.46	7956.40	-0.79
	10%	55.00	79.90	-0.33	6812.20	-0.76
	+25%+	62.50	76.60	-0.29	6008.50	-0.74
Clay Content	Baseline	21.00	82.60		7374.00	
	-25%	15.75	74.10	0.41	6732.00	0.35
	-10%	18.90	77.90	0.57	7047.20	0.44
	10%	23.10	86.30	0.45	7567.40	0.26
	+25%+	26.25	87.80	0.25	7641.30	0.14

The hydrology submodel also showed some damped sensitivity to the parameter, and the response was nonlinear. The model was sensitive to the final interrill cover, as this variable affected rainfall detachment towards the end of the simulation period. The sediment submodel showed a moderately exaggerated inverse response to the final interrill cover. This variable may not be as important in a watershed where most of the storms occur early in the season. The soil porosity was the third most important parameter, with the sediment submodel showing an exaggerated inverse sensitivity. This was probably due to an erodibility calculation made using a field capacity parameter that was calculated using the soil porosity.

The hydrology submodel was the most sensitive to the soil porosity, showing an slightly exaggerated inverse relationship. This was because the soil porosity affected the rate of infiltration, and therefore directly affected runoff. The next most sensitive parameter was the area under the canopy, which showed a damped inverse relationship. As area under the canopy increased, runoff decreased. This was due to the use of the area under the crop canopy in calculating a canopy factor that was used in the infiltration submodel. The canopy factor was assumed constant during the growing season. The hydrology submodel was also sensitive to the clay content of the soil, showing a damped direct relationship that was nonlinear. As the clay content increased, the runoff increased, but at different rates. This was probably due to the use of clay content in the infiltration submodel. The sediment submodel also showed a damped direct relationship to the clay content that was nonlinear.

4.4 Summary

A sensitivity analysis was performed on the ANSWERS-2000 model using a data set with the crop, soil, and channel variables reduced to one type. The parameters associated with the new detachment submodel were then varied by -25%, -10%, 10%, 25%, and the resulting sediment loads at the outlet of the watershed were compared to determine the relative impact of the variations. The analysis revealed that the sediment submodel was most sensitive to the sand content of the soil. The next most sensitive parameters were the soil porosity and the final interrill cover. These parameters affected not only the soil erodibility calculations, but also the sediment transport capacity requirements of the sediment load. The hydrology submodel was most sensitive to the soil porosity, and then to the area under the canopy and the clay content of the soil. These variables are used in the infiltration submodel.

5 MODEL EVALUATION

5.1 Introduction

Model evaluation is the process of comparing model output predictions to measured values. Evaluation determines how closely a model represents actual conditions. Data sets from the P2 watershed in Watkinsville, Georgia (Smith et al., 1978) and the Owl Run watershed (Mostaghimi, 1989) in Fauquier County, Virginia were used to validate the upland erosion module. The P2 and Owl Run watersheds were chosen because they were readily available data sets that had been used for evaluation of previous versions of ANSWERS-2000. The existing data sets also allowed for comprehensive debugging during evaluation, as discrepancies between versions could be detected. A data set from the Goodwin Creek watershed (Blackmarr, 1995) in Panola County, Mississippi was used to evaluate the model in highly erodible watersheds. Goodwin Creek was chosen because it is a highly instrumented research watershed with significant channel erosion, which made it attractive for evaluation of the newly implemented channel scour component. In this discussion, the ANSWERS code with the new sediment routine is referred to as ANSWERS-2000, while the ANSWERS code with the old sediment routine is referred to as ANSWERS.

Model output from each watershed was compared to observed data from each watershed in three ways. The first was percent error:

$$Error = \left(\frac{pred - obs}{obs}\right) * 100 \qquad (114)$$

where *Error* = error for a prediction (%), *obs* = observed value of an event, and *pred* = predicted value for an event. Positive values indicate overprediction by the model, and negative values indicate under prediction by the model. The second technique used was regression of the best-fit line of predicted versus observed data points, and comparison to a line with slope equal to one and an intercept of 0, which implies a perfect fit. The regression was performed using a spreadsheet that performed a least-squares fit for a line represented by $y=mx+b$, where m is the slope and b is the intercept (Microsoft, 1996). The intercept was forced to zero, and subsequently slope values of less than 1.0 indicate under prediction of the model, while values greater than 1.0 indicate overprediction by the model. The coefficient of determination (R^2) gives an indication of the quality of the fit of the data, with values of R^2 of 1.0 indicating perfect fit, and lesser values indicating less agreement of the data. The third technique used to evaluate model error was the Nash-Sutcliffe model efficiency (Risse, 1999):

$$E = 1 - \frac{\Sigma(Y_t - O_t)^2}{\Sigma(Y_t - y_{ave-t})^2} \qquad (115)$$

where E = model efficiency, Y_t = observed data of event t, O_t = predicted data of event t, and y_{ave-t} = the average of observed values of output. This efficiency is similar to the coefficient of determination, except that the residual variation (or the numerator) is calculated from the actual predicted values rather than the line of best fit between observed and predicted values (Risse, 1999). The implications of this are that if the model results are highly correlated but biased, then the model efficiency will be lower than the coefficient of determination, and if its value is less than zero it indicates that the average value of the output is a better estimate than the model prediction (Risse, 1999). As with the coefficient of determination, values of one indicate perfect agreement between measured and observed, and lesser values indicate less agreement.

5.2 Evaluation Criteria

Validation is the endpoint of evaluation, because when evaluation is finished, the modeler should know whether the model was a valid or an invalid application to a dataset. Knowing when evaluation is successful is difficult. Zacharias et al. (1996) discussed evaluation of pesticide transport models and concluded that model evaluation should be based on both graphical displays and quantitative techniques. Graphical analysis detects anomalies between observed and predicted values and differences between model predictions. Quantitative techniques provide an objective measurement of model performance by determining the difference between observed and predicted values. Some studies have examined whether pesticide concentrations fall within a factor of two of observed data for site-specific applications, which was suggested by the Workshop on Field Applicability Testing of Chemical Exposure Models sponsored by the U.S. EPA (Parrish and Smith, 1990). Parrish and Smith state that comparing simulated values to the data distribution is appropriate when the output variable is highly variable. Because sediment yield over a landscape is a highly variable phenomenon, this evaluation guideline was assumed for this study. If predicted values fall within a factor of two of observed values, then evaluation will be considered successful, and application of the model to the dataset will be valid. Regression analysis of predicted versus observed plots also indicates quality of model fit.

5.3 C.P.I.D.S.

The Crop Parameter Intelligent Database System (CPIDS) (http://topsoil.nserl.purdue.edu/weppmain/cpids.html) was used to parameterize input files for the three data sets used to evaluate the ANSWERS-2000 model. CPIDS was designed and developed by the USDA for parameter estimation of the RUSLE and WEPP models. It is a database of articles that contain parameter values for row and vegetable crops. The database contains parameters such as maximum live root biomass, canopy height, canopy density, and yield, which were used in the ANSWERS-2000 validation runs.

5.4 P2 Watershed

5.4.1 Introduction

The P2 watershed is a 1.29 hectare, field-scale watershed at the Southern Piedmont Conservation Research Center in Watkinsville, Georgia. Average annual temperature ranges from 14 to 18°C and annual precipitation ranges from 115 to 140 cm. Soils in the watershed include Cecil sandy loam (62%), Cecil sandy clay loam (28%), and Cecil loam (10%) (Bouraoui, 1994). In the early 1970's, a study was conducted on the P2 watershed and three accompanying watersheds to determine the effect of pesticide application techniques on movement from fields. The study documented runoff, sediment, nutrient, and residual pesticides in runoff over a three-year period. For a full description of the experiment, see Smith et al. (1978).

5.4.2 Simulation

The P2 watershed was simulated for the three-year time period of 1973 – 1975. As soil temperature data were not available, soil temperature was assumed to equal air temperature (Bouraoui, 1994). Values for plant root mass were taken from recommended values from the CPIDS database. Where the crop was an annual or data were not available, a root biomass value of 1 kg m^{-2} was assumed as recommended by CPIDS. Random roughness values caused by tillage operations were taken from Alberts et al. (1995). Rill spacing was taken from a study by Gilley et al. (1990), which suggested a rill density of 1.0 rills per meter. The watershed was discretized into 89 square cells with 12.5 meter sides, and illustrates the general flow patterns shown in Figure 3. Row-cropping produces the general flow directions indicated, and the watershed drains to a central draw, which exits at row 13, column 3.

Although ANSWERS-2000 is not intended to be calibrated, the original "best guess" values of parameter inputs did not produce accurate runoff results. Because sediment movement is dependent on runoff, the sediment output from P2 were not as accurate as possible. Therefore, runoff from the watershed was calibrated by manipulation of the soil porosity until the output approximated measured values. Soil porosity was chosen because the hydrology was most sensitive to this parameter. The soil porosity values were increased in increments of 5% until the daily runoff predictions approximated the daily measured totals. The final calibrated soil porosity value was within the range suggested for that soil type.

5.4.3 Results and discussion

5.4.3.1 Calibrated Hydrology

Comparisons of predicted and observed runoff using percent error, along with corresponding rainfall amounts, are included as Table 3. Missing months indicate measured data values of 0.0. The line of best-fit equation, coefficient of determination, and the model efficiency are presented as Table 4. The model tended to under predict runoff for the months of May, June and July, with percent errors of –48.9%, -88.9%, and

–81.1%, respectively. The prediction accuracy improved for September and December for 1973, with percent errors of –21.8% and 22.7%, respectively. In May, almost all of the rainfall fell during a 24-hour period immediately after tillage and the model was unable to accurately represent the conditions.

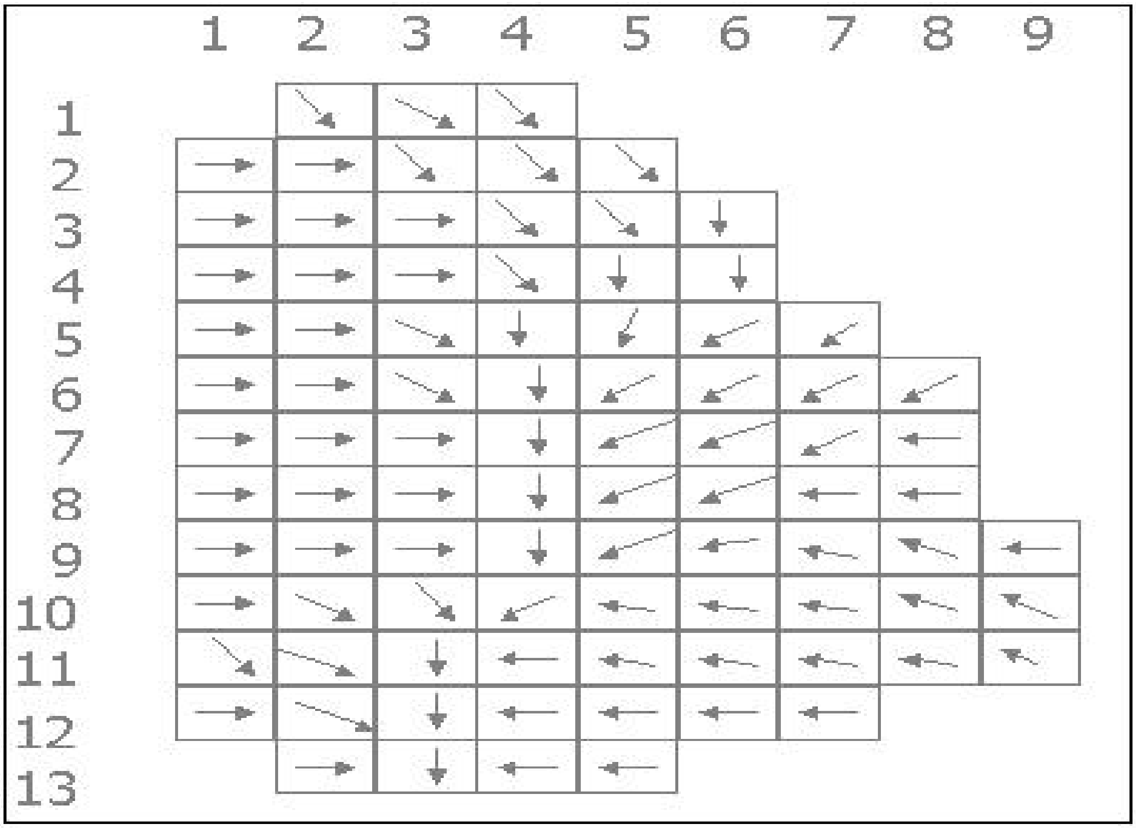

Figure 3: Image of P2 watershed showing cell discretization and flow directions (actual cells are square).

In June and July of 1973, the total runoff predicted was approximately 11% and 19% of runoff observed, respectively. During September and December of 1973 the observed runoff was lower than during the previous months of record, and the model's prediction improved significantly. The only month during 1973 where the model over predicted runoff was December. Overall for 1973 the percent error was –54.8%. Regression analysis of the 1973 data indicated that the hydrology model did a fair job (R^2=0.71) of approximating observed events. The optimized least-squares fit and the coefficient of determination suggest that the model under predicted runoff. The slope value of less than unity indicates that the hydrology model tended to under predict runoff in 1973. The low model efficiency (E=0.53) also indicates this under prediction.

Table 3: Runoff predicted from the P2 watershed.

Date	Rainfall Observed (mm)	Runoff Observed (mm)	ANSWERS[1] Runoff Predicted (mm)	Percent Error (%)
May 73	140.0	80.0	40.9	-48.9
June 73	127.0	35.0	3.9	-88.9
July 73	91.0	19.0	3.6	-81.1
Sept 73	127.0	11.0	8.6	-21.8
Dec 73	175.0	11.0	13.5	22.7
1973 Total	660.0	156.0	70.5	-54.8
Jan 74	66.0	*	0.0	-
Feb 74	105.0	2.0	2.3	15.0
Mar 74	50.0	*	0.4	-
Apr 74	66.0	7.0	9.4	34.3
May 74	139.0	7.0	12.0	71.4
June 74	134.0	42.0	49.2	17.1
July 74	106.0	46.0	46.6	1.3
Aug 74	147.0	10.1	13.8	36.6
1974 Total	813.0	114.1	133.7	17.2
Jan 75	76.0	*	2.9	-
Feb 75	110.0	0.8	9.5	1087.5
Mar 75	133.0	4.7	27.1	476.6
May 75	36.0	0.4	5.3	1225.0
Jun 75	77.0	4.1	30.8	651.2
Jul 75	70.0	3.2	11.5	259.4
1975 Total	502.0	13.2	87.1	559.8
1973-1975 Total	1975.0	283.3	291.3	2.8

[1] - The hydrology portion of both models is identical.
* Measured runoff < = 1 mm, and percent error not calculated (divide by 0)

Table 4: Runoff regression analysis from the P2 watershed.

Year	Best Fit Equation y=mx	R^2	Efficiency[1]
1973	0.45x	0.71	0.53
1974	1.10x	0.98	0.96
1975	6.06x	0.75	-90.65
1973-1975	0.69x	0.29	0.46
1 Nash-Sutcliffe Model Efficiency			
2 Hydrology of both models is identical			

During 1974, the model predictions improved, although the model tended to slightly over predict runoff on average for all months. The percent errors in 1974 ranged from 1.3% in July to 71.4% in May. The percent errors did not follow a particular trend, except that months that showed increased rainfall showed increased error. The two months that had the highest rainfall were August and May, with rainfall of 147mm and 139mm, respectively. These two months had the highest percent error in runoff prediction of 36.6% and 71.4%, respectively. The next highest error was 34.3%, occurring in April when 66mm of rainfall fell. This result tended to undermine the relationship between increased rainfall and increased error in runoff prediction. During January and March, no runoff was measured and therefore the results could not be compared. Overall for 1974 the model error was 17.2%. Regression analysis for 1974 indicated that the model did a much better job of predicting runoff than in 1973, as the line of best-fit and coefficient of determination indicate (R^2 = 0.98). The slope of greater than unity indicates that the model tended to over predict values. The model efficiency was high (E=0.96), indicating minor bias in the model.

In 1975, the model greatly over predicted runoff on average, with percent errors ranging from 259.4% in July to 1225.0% in May. During 1975, summer precipitation (183 mm) during May, June, and July was approximately half of that during 1973 (358 mm) and 1974 (379 mm). The model may not be able to predict the lower moisture contents of the soil in 1975. The cumulative observed runoff from 1975 was 13.2 mm, compared to 156.0 mm and 114.1 mm in 1973 and 1975, respectively. The overall percent error for

1975 was 559.8%. The regression analysis from 1975 indicate consistent overprediction by the model (y=6.06x). The model efficiency from 1975 was very large and negative (E=–90.65), indicating that the average of the measured output were a better prediction tool than the model.

The overall error during the simulation time period was 2.8%, showing that over the long-term of the simulation, the model only slightly over predicted cumulative runoff. This compared with -54.8% in 1973, 17.2% in 1974, and 559.8% in 1975, and tended to indicate that the model was better at predicting long-term averages rather than annual runoff for years. The large percent error from 1975 is slightly misleading, due to the small runoff amounts observed during the year. The regression analysis from the 3-year simulation time period indicate that the line of best-fit of predicted versus observed values was $y=0.69x$, with a $R^2=0.29$. This value suggests that the model could not consistently over or under predict runoff, and that there were significant scatter to the data when analyzed over the entire three-year period. The model efficiency was 0.46, indicating that model performance was slightly better than the coefficient of determination suggests.

5.4.3.2 Sediment

Table 5 contains sediment predictions and observations from the P2 watershed. Table 6 contains regression calculations and model efficiency. The erosion predictions in 1973 indicated that ANSWERS-2000 under predicted sediment in all months, as does the ANSWERS model. Percent errors ranged from –30.8% to –98.4% for ANSWERS-2000 and –94.9% to –98.3% for ANSWERS. The greatest under prediction for both models occurred in May, June, and July, and tended to follow the under prediction of runoff as expected. During May 1973, the majority of the total monthly rainfall fell in 24 hours on the freshly tilled watershed, resulting in the large sediment movement observed. As mentioned previously, the model was unable to accurately represent the runoff during this time, and subsequently the sediment predictions suffered. The ANSWERS-2000 model under predicted sediment for the last two months, however, as the runoff prediction accuracy increased, the sediment yield prediction accuracy increased. The ANSWERS model predictions did not increase with increased runoff prediction accuracy. The percent errors for the ANSWERS-2000 model ranged from -30.8% to -98.4% while the percent errors for the ANSWERS model ranged from –94.9% to –98.3%. The cumulative error for 1973 was –94.8% for ANSWERS-2000 and –96.1% for ANSWERS. The regression equation for ANSWERS-2000 for 1973 indicated that the model greatly under predicted sediment loss. The model efficiency was negative (E=–2.01), suggesting that the average of the measured output was a better predictor for P2 in 1973 than was the ANSWERS-2000 model. The regression equation of predicted versus observed data for ANSWERS for 1973 also indicated that the ANSWERS greatly under predicted sediment loss. The large negative model efficiency (E=-13.92) indicates that the ANSWERS model was ineffective at predicting sediment loss from P2 in 1973.

During 1974, both models tended to follow measured predictions well, with percent errors ranging from –0.7% in July to –100.0% in January for ANSWERS-2000 and –56.1% in May to –100% in January and March for ANSWERS. Although the hydrology subroutine of the model tended to over predict runoff, ANSWERS-2000 tended to under predict sediment. The ANSWERS model also tended to under predict sediment, although the magnitude of under prediction was greater than the ANSWERS-2000 model. In January, February, and March, the sediment movement observed was smaller than typical (0.8kg ha^{-1}, 0.0kg ha^{-1}, 0.9kg ha^{-1}, respectively).

During this period the absolute error was very small, but the percent error was large because of the low sediment loss. In February, because 0.0kg ha^{-1} was observed, the error calculation was not performed. The overall error during 1974 was –17.4% for ANSWERS-2000 and –83.6% for ANSWERS. The regression equation for ANSWERS-2000 for 1974 was y=0.82x, with a $R^2=0.97$, indicating that the model was performing much better than during 1973 at predicting sediment yield. The model efficiency was 0.93 for 1974, also indicating a high degree of correlation. The older version of ANSWERS did not perform as well in 1974, with the regression equation of y=0.18x, with a degree of correlation of 0.65. The negative model efficiency (-0.002) indicates that ANSWERS did a poor job of predicting sediment in 1974.

Table 5: Sediment yield predicted from the P2 watershed.

Date	Sediment Observed (kg/ha)	ANSWERS -2000 Sediment Predicted (kg/ha)	ANSWERS -2000 Percent Error (%)	ANSW ERS Sediment Predicted (kg/ha)	ANSW ERS Percent Error (%)
May 73	8953.4	476.9	-94.7	389.0	-95.7
June 73	1855.3	29.1	-98.4	32.0	-98.3
July 73	424.2	17.4	-95.9	21.6	-94.9
Sept 73	57.0	30.7	-46.1	1.6	-97.2
Dec 73	57.5	39.8	-30.8	2.6	-95.5
1973 Total	11347.4	593.9	-94.8	446.8	-96.1
Jan 74	0.8	0.0	-100.0	0.0	-100.0
Feb 74	0.0	0.0	-	0.2	-
Mar 74	0.9	0.4	-55.6	0.0	-100.0
Apr 74	24.1	19.4	-19.5	1.9	-92.1
May 74	102.1	77.5	-24.1	44.8	-56.1
June 74	967.9	716.7	-26.0	245.2	-74.7
July 74	684.7	680.0	-0.7	14.6	-97.9
Aug 74	104.4	62.2	-40.4	2.2	-97.9
1974 Total	1884.9	1556.2	-17.4	308.9	-83.6
Jan 75	3.4	3.7	8.8	0.3	-91.2
Feb 75	13.3	22.5	69.2	2.1	-84.2
Mar 75	59.4	100.8	69.7	8.1	-86.4
May 75	215.9	22.8	-89.4	22.3	-89.7
Jun 75	4124.6	203.3	-95.1	150.4	-96.4
Jul 75	748.5	28.7	-96.2	40.4	-94.6
1975 Total	5165.1	381.8	-92.6	223.6	-95.7
1973-1975	18397.4	2531.9	-86.2	979.3	-94.7

- Indicates no measured value.

During 1975, the sediment predictions for the ANSWERS-2000 model were greater than measured for January, February, and March, while they were less than measured for May, June and July. The percent errors ranged from 8.8% in January to –96.2% in July. The ANSWERS model performed equally poorly during the 1975 cropping season, with percent errors ranging from –84.2% to –96.4%. The regression equation for ANSWERS-2000 for 1975 was y=0.05x, with a coefficient of determination of 0.65, and indicating gross under prediction of sediment yield. The negative model efficiency indicates that the

Table 6: Sediment regression analysis from the P2 watershed.

Year	Model	Equation	R^2	Efficiency[1]
1973	ANSWERS-2000	0.05x	0.96	-2.01
	ANSWERS	0.04x	0.98	-13.92
1974	ANSWERS-2000	0.82	0.97	0.93
	ANSWERS	0.18x	0.65	-0.002
1975	ANSWERS-2000	0.05x	0.65	-0.17
	ANSWERS	0.04x	0.98	-0.2
Simulation	ANSWERS-2000	0.06x	0.06	-0.07
	ANSWERS	0.04x	0.75	-0.11

1 Nash-Sutcliffe Model Efficiency
2 Hydrology routine of both models is identical

model was incapable of accurately predicting sediment yield in 1975. The older ANSWERS model had a regression value of y=0.04x, with a $R^2=0.90$. The negative model efficiency also indicates the ANSWERS model's inability to accurately predict sediment movement during 1975. While the sediment numbers tend to follow observed for the first three records, the overprediction of runoff during this period emphasizes that the numbers are merely similar and do not correlate. The discrepancy during 1975 can be attributed to either gross parameterization error or model failure.

The percent error for sediment prediction over the three-year period was –86.2% for ANSWERS-2000 and –94.7% for ANSWERS. This compared to –94.8%, -17.4%, and -92.6% for ANSWERS-2000 in 1973, 1974, and 1975, respectively, and –96.1%, -83.6%, and –95.7% for ANSWERS in 1973, 1974, and 1975, respectively. Except for ANSWERS-2000 in 1974, all results indicate unsuccessful validation for the simulation period. The errors show that both models under predict sediment movement on average for the entire period, while the hydrology subroutine under predicted runoff in 1973, and over predicted runoff in 1974 and 1975. Regression analysis from the simulation period indicate that the ANSWERS-2000 model greatly under predicted sediment, with an equation of y=0.06x and a $R^2=0.06$. This small coefficient of determination tends to suggest that not only did the numbers not correlate, but they had significant scatter to suggest that the model was ineffective. The negative efficiency also indicates the same conclusion. The regression analysis for ANSWERS show that it performed worse than ANSWERS-2000, with an equation of $y=0.04x$, however unlike ANSWERS-2000, the R^2 was higher at 0.75. This tended to indicate that ANSWERS consistently under predicted sediment yield. The negative model efficiency also indicates that the model performed poorly, and that the average of the measured output values was a better indicator of sediment yield than this model for this period of interest.

5.4.4 Summary

Neither model was decisively better at predicting erosion from the small (1.29 ha) P2 watershed. The predicted runoff did not compare with the measured runoff well in 1973 and 1975. This could have been due to poor parameterization or data collection error. Another probable cause of model error resulted from the use of a constant canopy factor in the infiltration submodel, which subsequently controls runoff. The canopy factor is calculated using the covered area underneath and outside the canopy at maturity, however, this factor is not adjusted throughout the season to simulate canopy growth. A final possible source of error was the rain gage data from the watershed. Prior to May 21, 1974 rain data for P2 were taken from either the P1 gage or a gage about 300 meters south of P2. Between May 21, 1974 and April 30, 1975 a continuous recording rain gage was installed, however, after this time the gage was deemed unreliable and was removed. The P1 watershed is approximately 0.6 km from the P2 watershed. The ANSWERS-2000 sediment model performed poorly in 1973 and 1975, as did ANSWERS. During the 1974 growing season, the model performed better at predicting runoff, and the sediment prediction accuracy of ANSWERS-2000 and ANSWERS increased. The data show that during the three-year simulation period, the ANSWERS-2000 model tended to be a better predictor of erosion then the older ANSWERS model, however, evaluation of both models indicated that neither were very accurate in predicting runoff and sediment yield from the P2 watershed. The evaluation criteria was not met as total sediment yield predictions were not within a factor of two of observed data. Future research should investigate the soil moisture levels during the simulation to observed values to determine if the evapotranspiration module is adequate or if the error lies in another submodel such as the infiltration module.

5.5 Owl Run Watershed

5.5.1 Introduction

The Owl Run watershed is located in Fauquier County, Virginia and encompasses 1153 hectares. The following description of the watershed is taken from Bouraoui (1994). Owl Run is a mixed land-use watershed (Table 7), and non-agricultural activities cover less than 30% of the watershed. The primary crops are corn, hay, and pasture. The watershed has a humid continental climate with an average annual precipitation of 104 cm. The watershed soils are mainly silt loam, with the predominant soil being Penn silt loam, comprising 40% of the watershed. It is characterized by moderate permeability with slopes ranging from 2 to 14%. Buck silt loam is the second most abundant soil, 16.3% of the watershed, and has moderate permeability and slopes ranging from 2 to 7 %. Montalto soils are the third most abundant, comprise 14.4% of the watershed, and have moderate permeability and slopes ranging from 2 to 14%. The Owl Run watershed contains four water quality monitoring stations, QOA, QOB, QOC, QOD. The main station QOA is located at the watershed outlet and drains approximately 1153 hectares. Additional information on the Owl Run monitoring project is found in Mostaghimi et al. (1989).

5.5.2 Simulation

The Owl Run watershed was simulated for a full corn growing season from May 1991 to September 1991. The simulation included 23 soil types, and 20 crops. Crop root mass was taken from the CPIDS database, and was assumed to equal 1 kg m^{-2} if the crop was an annual. Random roughness caused by tillage implements were taken from Alberts et al. (1995), and rill spacing was assumed to equal 1.0 rill per meter according to Gilley et al. (1990). Approximately 85% of the channels in Owl Run were estimated to be nonerodible because of heavy armoring and the presence of exposed shale.

As with the P2 dataset, the hydrology of the model did not produce results that were as accurate as were desired. Because of this, the soil porosity of all soils with porosity less than 50% was raised to 50%. This was an arbitrary change that affected 13 of the 22 soils in the simulation. Most values were increased by 3% or less, while two porosities were increased by 8% and one soil was increased by 9%. This change reduced runoff from the watershed.

Table 7: Owl Run watershed landuse in 1991 (Bouraoui, 1994).

Landuse	Percent of watershed
Conventional-till corn	8.2
No-till corn	2.3
Small grain	7.0
Hayland	20.1
Pasture	15.9
Homesite	6.7
Forest	26.0
Corn contour-strip cropping	2.3
Idled pasture	6.1
Alfalfa	0.6
Farmstead	1.4
Loafing lot	1.8
Wetland	0.2

5.5.3 Results and discussion

5.5.3.1 Calibrated Hydrology

Table 8 contains measured and predicted runoff, along with corresponding prediction error. Table 9 contains the best-fit regression equation, coefficient of determination, and model efficiency. The observed runoff and sediment yields were reported by Bouraoui (1994). The record for the Owl Run watershed from the 1991 cropping season included only 5 events, and the percent errors of runoff prediction ranged from 12.9% to –94.4%. The worst prediction occurred on day 267, which corresponded to the smallest storm of the period. The overall prediction error was –2.6%, indicating a slight under prediction from runoff during the simulation period. Regression analysis indicated that the hydrology model did a good job of predicting runoff (y=1.09x). The R^2 was 0.94, and the model efficiency was 0.89. The high coefficient of determination indicated that the model consistently over predicted runoff, and the lower efficiency indicated some degree of bias.

Table 8: Predicted runoff from the Owl Run watershed.

Julian Day Year 1991	Rainfall Observed (mm)	Runoff Observed (mm)	ANSWERS Runoff Predicted (mm)	Percent Error (%)
207	59	1.2	0.8	-33.3
221	103	18.6	21.0	12.9
247	80	3.8	2.7	-28.9
261	61	3.8	5.5	44.7
267	41	3.6	0.2	-94.4
Total	344	31.0	30.2	-2.6

Table 9: Runoff regression analysis from the Owl Run watershed.

Best Fit Equation y=mx	R^2	Efficiency[1]
1.09x	0.94	0.89

1 Nash-Sutcliffe Model Efficiency

5.5.3.2 Sediment

Table 10 contains observed and predicted sediment yield, along with corresponding percent errors for the ANSWERS-2000 and ANSWERS model predictions. Table 11 contains the best-fit regression equations, coefficients of determination, and model efficiencies. The sediment predictions from the ANSWERS-2000 model tended to follow the runoff predictions during the simulation period. The model generally predicted sediment well, and percent errors ranged from –98.3% to 48.1%. The original ANSWERS model did not predict sediment yield as well, and percent errors ranged from 23.7% to over 7000%. The cumulative error from the simulation period shows that the

ANSWERS-2000 model had a percent error of 9.0%, while the ANSWERS model had an error of 4286.8%. The results indicate successful validation of the ANSWERS-2000 model, as total predictions averaged over the watershed area were within a factor of two of observed values. The ANSWERS model did not meet this criterion, and was not considered a valid model for this dataset. The line of best-fit between predicted and observed was $y=1.31x$ for ANSWERS-2000, with a $R^2=0.84$. The model efficiency, however was much lower at 0.24, and indicated bias in the overprediction of the model. The regression equation for ANSWERS was extremely large ($y=60.58x$), with a moderately high coefficient of determination ($R^2=0.76$), and a large negative model efficiency (–11,282). This large value indicated that the model grossly over predicted sediment yield, and that the average of the measured output was a better predictor of sediment yield than the ANSWERS model prediction.

Table 10: Sediment yield predicted from the Owl Run watershed.

		ANSWERS -2000		ANSW ERS	
Julian Day Year 1991	Sediment Observed (kg/ha)	Sediment Predicted (kg/ha)	Percent Error (%)	Sediment Predicted (kg/ha)	Percent Error (%)
207	4.0	1.3	-67.5	64.1	1502.5
221	38.9	57.6	48.1	2975.6	7549.4
247	15.1	3.7	-75.5	156.9	939.1
261	15.1	23.4	55.0	261.7	1633.1
267	5.9	0.1	-98.3	7.3	23.7
Total	79.0	86.1	9.0	3465.6	4286.8

Table 11: Sediment regression analysis from the Owl Run watershed.

Model	Best Fit Equation y=mx	R^2	Efficiency[1]
ANSWERS-2000	1.31x	0.84	0.24
ANSWERS	60.58x	0.76	-11282.09

1 Nash-Sutcliffe Model Efficiency
2 Hydrology routine of both models is identical

5.5.4 Summary

The ability of ANSWERS-2000 and the older ANSWERS models to predict sediment yield were compared on the Owl Run watershed, which is a mixed land-use watershed in Virginia. The hydrology predictions were acceptable after calibration, and the error, regression, and model efficiency indicated good agreement between predicted and observed values. The total runoff values summed over the simulation period were within a factor of two of observed values, thus meeting the requirement for successful model validation. The ANSWERS-2000 model predicted sediment yield much better than the older ANSWERS model, as indicated by the percent error, regression, and model efficiency. All measures of fit indicate that the ANSWERS-2000 model slightly over predicted sediment yield during the period, while the ANSWERS model tended to greatly over predict sediment yield. The results also indicated that the ANSWERS-2000 model was a better predictor of soil loss over the simulation period than on any specific day. The sediment submodel also followed the daily trends of the hydrology submodel, over predicting sediment yield when runoff was over predicted and under predicting yield when runoff was under predicted. The cumulative analysis showed that the hydrology model slightly under predicted runoff while sediment was slightly over predicted. The ANSWERS model did not tend to follow this trend. The evaluation criteria of total predicted sediment yield being within a factor of two of observed was met by ANSWERS-2000, but not by ANSWERS.

5.6 Goodwin Creek

5.6.1 Introduction

The National Sedimentation Laboratory in Oxford, Mississippi conducts an extensive, ongoing research project on the Goodwin Creek watershed. The work is part of an effort to document channel erosion processes in a watershed that is highly susceptible to channel erosion. Breakpoint rainfall and runoff and sediment yield data, along with surveys of the main channel cross section are available for download at their ftp site (ftp:\\ftp.sedlab.olemiss.edu). The following discussion of Goodwin Creek is taken from Blackmarr (1995).

Goodwin Creek is located in an area known as the Bluff Hills (or Loess Hills), a strip of land from 32.19 km (20 miles) to 64.37 km (40 miles) wide, east to west, stretching from the Tennessee state line near Memphis, along the eastern edge of the Mississippi Alluvial Plain (locally called the Delta), to near Vicksburg and then along the Mississippi River to the Louisiana state line. The western edge of this region is generally well-defined with the loess hills dropping abruptly to the alluvial plain. The loess surface mantle thins to the east where it blends into the North Central Hills. The depth of loess in places is close to 30 m, although the deposits in the deeper areas are generally 9 m to 15 m in depth. The significance of this area for sediment research lies in the high erodibility of the loess material when stripped of cover. Erosion of the material, Holocene valley sediments, has produced deeply incised channels in the tributaries, which have dissected the landscape of the Bluff Hills. Most of the channels have steep sides, which are unstable, contributing additional sediment and causing loss of adjacent agricultural land and habitat. The two dominant soil associations of Panola County are the Loring-Grenada-Memphis soils of the uplands and the Collins-Falaya-Grenada-Calloway soils of the valleys, which cover most of the county.

The Goodwin Creek Watershed is divided into fourteen nested subcatchments from which runoff is monitored. The drainage areas above these stream gaging sites range from 1.6 km^2 to 21.4 km^2. Twenty-nine standard recording rain gages are uniformly located within and just outside the watershed. Instrumentation at each gaging site includes an electronic data acquisition system, which consists of a VHF-radio telemetry system with microcomputer. This system collects, temporarily stores and transmits the data at predetermined intervals to a central computer at the National Sedimentation Laboratory.

The climate of the watershed is humid, hot in summer and mild in winter. The average annual rainfall during 1982-1992 from all storms was 144 cm, and the mean annual runoff measured at the watershed outlet was 14.5 cm per year. The 21.4 km^2 watershed flows from northeast to southwest with the outlet at latitude 89 54' 50" and longitude 34 13' 55". Elevation ranges from 71 m to 128 m above mean sea level, with an average channel slope of 0.004. The Goodwin Creek watershed is largely free of active land management activities with 13 percent of its total area being under cultivation and the rest classified as idle, pasture and forest land. Periodic acquisition of aerial photography and satellite data contribute to complete aerial coverage of land use and surface conditions.

Measurements collected at each site include water stage, sediment yield, air and water temperature, and precipitation. Manual sampling of total sediment loads is also carried out during storm events at stations 1 and 2 using bedload and depth-integrating suspended sediment samplers. Surveys of channel geometry, bed material, bank geotechnical properties, and channel migration are conducted at periodic intervals to keep track of channel morphological changes. Additional details on the Goodwin Creek Watershed monitoring project are available from Blackmarr (1995).

5.6.2 Simulation

The Goodwin Creek watershed was simulated for a seven-month period from May 2, 1986 to November 25, 1986. Soil temperatures were assumed equal to air temperature, and plant root mass values were taken from the CPIDS database. The watershed contained four landuses: forest, cropland, idle, and pasture. The cropland was assumed to be small grains, and random roughness values were taken from Alberts et al. (1995). Rill spacing was assumed to be 1.0 rill per meter according to Gilley et al. (1990). The stream network in the watershed was generated from a hydrological modeling tool in Arc/Info assuming a critical source area of 7.08 hectares. The critical source area is the minimum area required to establish channel flow in a watershed. Tarboton et al. (1991) provide a good description of the technique used for the extraction of channel networks from digital elevation models. Soil parameters for the watershed were taken from the SOILS5 database (ftp://soils.ecn.purdue.edu/pub/wepp/soildata/). Flow direction, stream locations, soils identification, channel slopes, channel widths, rain gage locations, and landuses were extracted from a GIS of the watershed provided by the National Sedimentation Laboratory (NSL). An image of the Goodwin Creek watershed showing its general drainage pattern was created from the digital elevation data provided by the NSL (Fig. 4).

The updated erosion components of the ANSWERS-2000 model code include a routine that predicts channel scour in channel bottoms by estimating mass erosion, and dividing by soil bulk density to determine scour depth. ANSWERS-2000 calculates the channel scour on a cell-by-cell basis and includes this information in the channel output file. The channel network for the Goodwin Creek simulation was generated from a DEM, while the channel cross-section locations were calculated from state-plane coordinates.

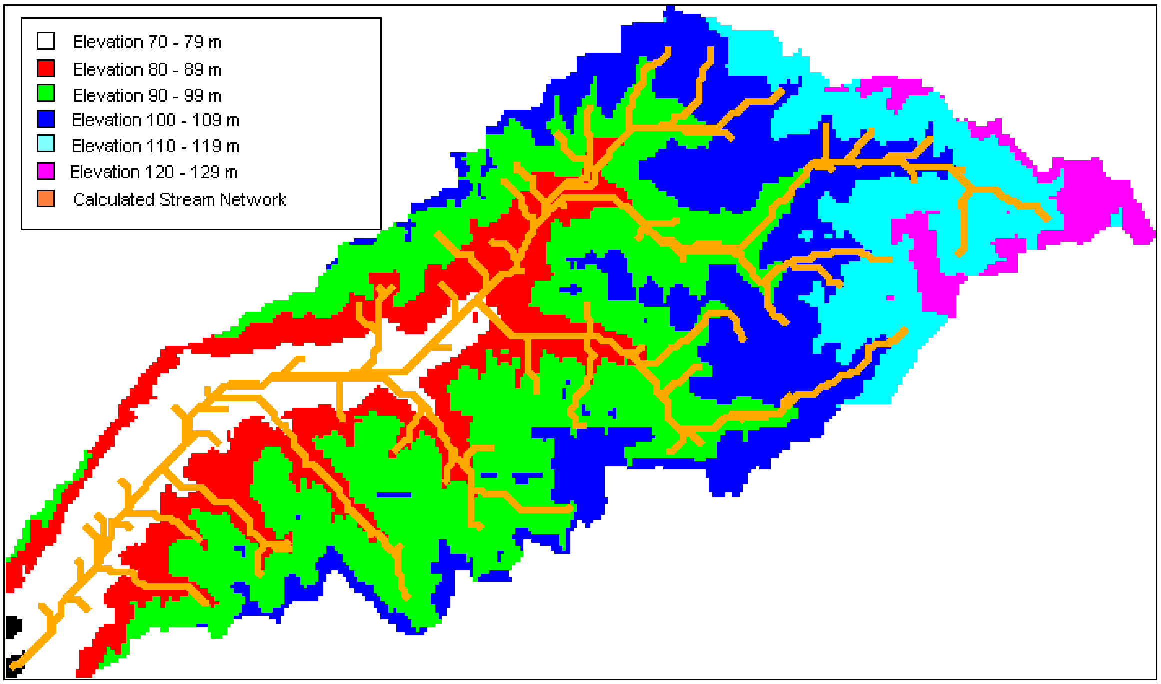

Figure 4: Image of Goodwin Creek watershed showing general drainage patterns.

Because of this, the calculated channel location did not always correspond to the location of the measured channel cross-sections, and some judgment was involved in determining which channel cells were representative of specific cross-sections. Typically, if the location of a cross-section was within three cells (90 meters), either horizontally, vertically, or diagonally, then the values were compared. In situations where the calculated channel was not close enough to be considered representative, the comparison of calculated and measured channel scour was not performed, and therefore not all measured cross-sections were compared to predictions. In the instances where the nearest channel cell was assumed to be representative of the cross-section, the calculated scour depth was compared to measured scour depth. The measured scour depth was obtained from channel surveys of the watershed that occurred from June 23, 1986 to September 29, 1986. While this time period was shorter than the simulation time period, the time periods were considered close enough for comparison. Scour depths during this time period were calculated by obtaining the area under the curve for each survey, then subtracting the previous area from the latter value and dividing by the average channel width as presented in Blackmarr (1995). The area under the curve was calculated by summing the area of sequential trapezoids whose height was taken as the horizontal distance between survey points and whose bases were assumed to be the height of the elevation points minus some base value. For all points in the survey, the base value was assumed to be 67.0 m (220 ft), which was lower than the minimum elevation value. An example cross-section (Fig. 5) is included to illustrate the method. Appendix F indicates the relative position of the points to the outlet of the watershed. Values are given in UTM zone 16 meters.

5.6.3 Results and discussion

5.6.3.1 Hydrology

Table 12 contains the observed and measured runoff, and the corresponding percent error from Goodwin Creek for the simulation period. Table 13 contains the regression equation, coefficient of determination, and model efficiency of the hydrology subroutine. The model did a good job of representing runoff from the Goodwin Creek watershed, however it tended to under predict runoff. Percent errors ranged from –100% on day 228 to 66.7% on day 226. The model under predicted runoff significantly on days 160 and 179 with percent error of –63.5%, and –45.3%, respectively. The reason for the large under prediction is unknown. Other differences are generally small despite the large percent errors. An example of this is day 228, with -100% error, while the absolute difference between the observed and predicted runoff is only 0.7mm. The cumulative analysis shows that predicted runoff was 40.8 mm while observed runoff was 69.4 mm, resulting in a percent error of –41.2%. The line of best-fit between predicted and observed values for Goodwin Creek was y=0.52x, with a R^2=0.75, and a model efficiency of 0.50. This shows that the model under predicted runoff consistently, and that there may have been some systematic bias in the predictions.

5.6.3.2 Sediment

Table 14 contains observed and predicted sediment yield, and corresponding percent error from Goodwin Creek for the simulation period. Table 15 contains information about the regression and model efficiency for ANSWERS-2000 and ANSWERS. The sediment prediction for ANSWERS-2000 tended to follow the trend of runoff prediction better than ANSWERS, which sometimes over predicted sediment yield when runoff was under predicted, especially on days 179, and 183. ANSWERS-2000 predicted sediment yield as well or better than ANSWERS except on days 199 and 228 Percent errors for ANSWERS-2000 ranged from –100% on day 228 to 291.2% on day 226. The large under prediction on day 228 corresponds to a situation where the model did not accurately predict runoff and subsequently did not accurately predict sediment yield. On day 226, the large overprediction of the ANSWERS-2000 code corresponds to an overprediction of runoff on that day (2.0 predicted versus 1.2mm observed).

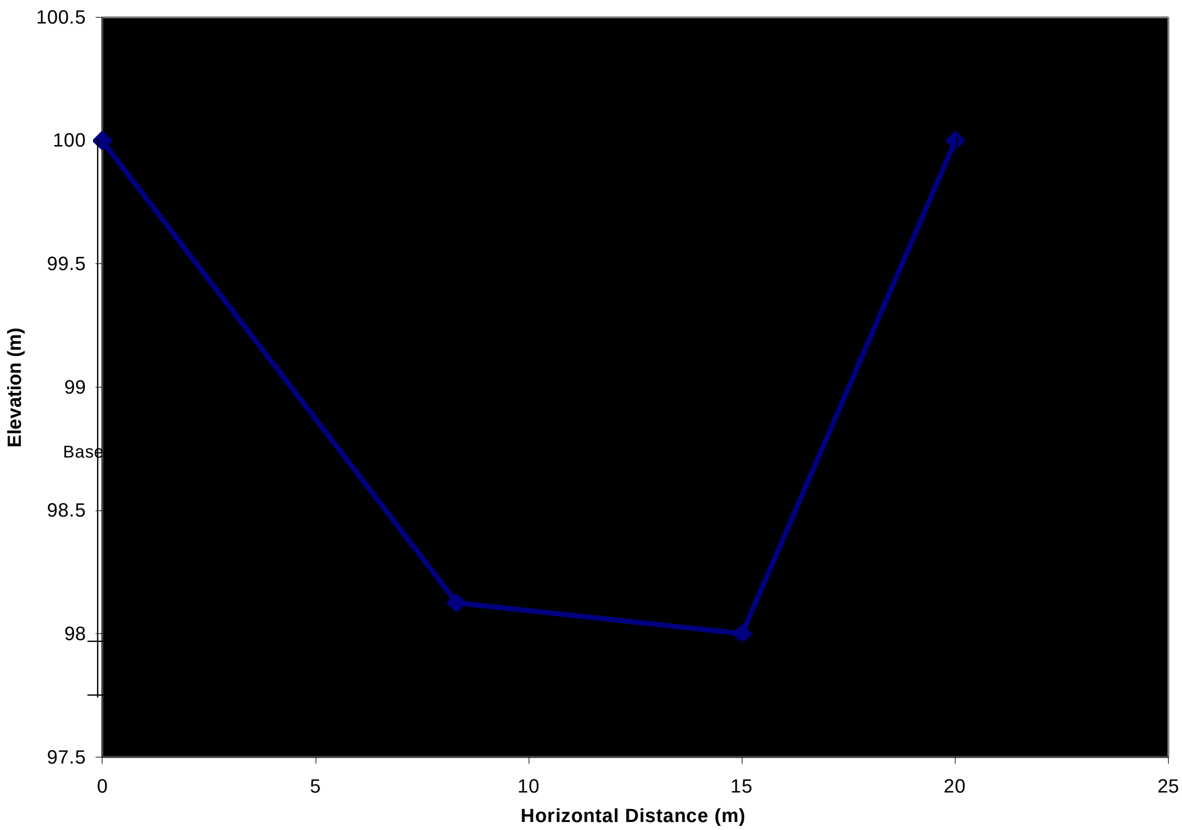

Figure 5: Example trapezoidal representation of channel cross-section.

The error for ANSWERS ranged from –50.0% on day 228 to 616.1% on day 226, however the model tended almost always over predicted yield. The cumulative percent error for ANSWERS-2000 was –24.9% compared to 52.0% for ANSWERS for the simulation period. Both models met the validation criterion of being within a factor of

Table 12: Runoff predicted from Goodwin Creek.

	ANSWERS -2000		ANSWERS	
Julian Day Year 1985	Rainfall Observed (mm)	Runoff Observed (mm)	Runoff Predicted (mm)	Percent Error (%)
156	75.0	4.9	7.2	46.6
160	36.0	16.2	5.9	-63.5
162	19.0	6.2	1.3	-79.0
179	81.0	24.3	13.3	-45.3
183	22.0	1.6	1.0	-37.50
199	35.0	3.9	2.4	-38.5
226	35.0	1.2	2.0	66.7
228	18.0	0.7	0.0	-100.0
239	53.0	9.3	6.2	-33.3
248	20.0	1.1	1.5	36.4
Total	394.0	69.4	40.8	-41.2

Table 13: Runoff regression analysis from Goodwin Creek.

Best Fit Equation y=mx	R[2]	Efficiency[1]
0.52x	0.75	0.50

1 Nash-Sutcliffe Model Efficiency

2 Hydrology routine of both models is identical.

two for this watershed. The line of best-fit for ANSWERS-2000 indicated under prediction with relatively high coefficient of determination (y=0.72x, R^2=0.89), and a relatively high model efficiency (0.81). The line of best-fit for ANSWERS indicated overprediction and relatively high coefficient of determination (y=1.36x, R^2=0.79), and a much lower model efficiency (0.38) indicating systematic overprediction. The results show that ANSWERS-2000 tended to under predict sediment yield, while ANSWERS tended to over predict sediment yield and may have had some systematic bias in its estimates. The coefficient of determination and the model efficiency of ANSWERS-2000 were similar.

Table 14: Sediment yield predicted from Goodwin Creek.

Julian Day Year 1985	Sediment Observed (kg/ha)	ANSWERS-2000 Sediment Predicted (kg/ha)	ANSWERS-2000 Percent Error (%)	ANSWERS Sediment Predicted (kg/ha)	ANSWERS Percent Error (%)
156	101.2	217.0	114.4	520.3	414.0
160	349.6	198.3	-43.3	507.2	45.1
162	128.5	22.0	-82.9	82.3	-36.0
179	778.2	586.6	-24.6	1104.2	41.9
183	10.4	10.2	-1.9	58.1	458.7
199	141.4	67.0	-52.6	168.7	19.3
226	13.7	53.6	291.2	98.1	616.1
228	1.8	0.0	-100.0	0.9	-50.0
239	326.4	230.2	-29.5	234.0	-28.3
248	11.9	15.1	26.9	58.0	387.4
Total	1863.1	1400.0	-24.9	2831.8	52.0

Table 15: Sediment regression analysis from Goodwin Creek.

Model	Equation	R^2	Efficiency[1]
ANSWERS-2000	0.72x	0.89	0.81
ANSWERS	1.36x	0.79	0.38

1 Nash-Sutcliffe Model Efficiency
2 Hydrology routine of both models is identical

5.6.3.3 Channel scour

Table 16 contains the measured cross-section ID, calculated scour depth, predicted scour depth, along with percent error and actual difference between values. Negative values of scour indicate eroded depth, while positive values indicate deposition. The data indicate that the ANSWERS-2000 model was not very good at predicting channel scour at specific locations in the watershed. Most of the time, the model did not predict enough scoured depth to be significant to three decimal places. The percent error for these predictions is 100%, while percent error for significant predictions ranged from -45% to -1660%. Calculated scour depths during the time period were generally quite small, never exceeding –0.041 meters. The largest value during the period occurred at cross-section C45-1, which showed a deposited sediment depth of 0.604 meters. ANSWERS-2000 never predicted deposition during the simulated time period. The difference between calculated and predicted values could be explained by the approximate nature of the comparison, including the assumption of rectangular channels in the model and the assumption of the location of the channel cross-sections.

Table 16: Predicted channel scour in the Goodwin Creek watershed.

Cross-Section ID	Measured Erosion[1] (m)	Predicted Erosion (m)	Percent Error (%)	Difference (m)
C4-8	-0.013	-0.175	-1287	-0.16
C4-17	-0.007	-0.123	-1660	-0.12
C5-2	-0.041	-0.059	-45	-0.02
C5-6	0.074	-0.016	121	-0.09
C5-10	-0.006	-0.016	-149	-0.01
C6-6	0.011	0.000	100	-0.01
C7-4	0.053	0.000	100	-0.05
C8-5	0.000	0.000	100	-0.00
C10-1	-0.014	0.000	100	0.01
C41-3	0.018	0.000	100	-0.02
GC-50	0.007	0.000	100	-0.01
C43-2	0.018	0.000	100	-0.02
C45-1	0.604	0.000	100	-0.60
C46-1	-0.018	0.000	100	0.02
C47-2	-0.007	-0.066	-831	-0.06
C50-1	0.009	0.000	100	-0.01
T1-1	0.086	0.000	100	-0.08
T2-2	-0.028	0.000	100	0.03
T3-5	-0.003	0.000	100	0.00
GC-100	-0.024	0.000	100	0.02
T14-6	-0.027	0.000	100	0.03
T64-2	-0.039	0.000	100	0.04

[1] Negative values indicate erosion, while positive values indicate deposition.

5.6.4 Summary

The ANSWERS-2000 and ANSWERS models were compared on the Goodwin Creek watershed in Panola County, Mississippi. The watershed is highly erodible, and extensive data have been gathered on the catchment. The hydrology portion of the model predicted runoff well. Runoff depth from the watershed was typically small for a given event or day, and this resulted in large percent errors in situations where absolute runoff predictions were typically close. Sediment predictions from the watershed indicated that the ANSWERS-2000 model followed the runoff trend better than the ANSWERS model. ANSWERS-2000 tended to under predict sediment while ANSWERS tended to over predict sediment. The Nash-Sutcliffe model efficiency analysis indicated systematic overprediction by the ANSWERS model, and under prediction by ANSWERS-2000. Results indicated that both models met the validation criterion (within a factor of two of observed values) on the larger 2140 ha Goodwin Creek watershed. Channel scour comparisons on the Goodwin Creek watershed indicated that the channel scour portion of the ANSWERS-2000 model was not able to approximate measured data, however this may have been due to uncertainty in the observed scour. Future research should analyze several time periods in order to obtain more comparative data.

5.7 Evaluation Summary

A process-oriented soil detachment subroutine was added to ANSWERS-2000 in an effort to improve the ability of the model to predict soil loss. The model was tested on three different watersheds to determine how well the model predicted measured conditions and whether new versions of the model increased prediction accuracy over the older ANSWERS. Predicted hydrology and sediment yield were compared to measured data and predictions from the older versions of ANSWERS. The P2 watershed was field-scale (1.29 ha), while Owl Run (1053 ha) and Goodwin Creek (2140 ha) were larger. Goodwin Creek exhibited significant channel erosion. On the smaller P2 watershed, neither model accurately predicted erosion due to inaccurate runoff predictions, although an attempt was made to improve hydrology predictions by calibration of soil porosity. The runoff error could have been due to the lack of seasonal variability of the crop canopy factor, which controlled infiltration and subsequently runoff, or inaccurate prediction of evapotranspiration during the simulation period. The error could also be attributed to data collection, as rain data from 1973, part of 1974, and 1975 were taken from a rain gage outside of the watershed. On P2, the second year had more accurate runoff predictions, and during this year ANSWERS-2000 tended to predict sediment movement better than the ANSWERS. Validation was unsuccessful on the P2 watershed for both models.

On the larger Owl Run watershed, the hydrology subroutine of both models did a good job of predicting runoff, after calibration by manipulating soil porosity. ANSWERS-2000 predicted sediment yield better than ANSWERS. ANSWERS-2000 was successfully validated on the Owl Run watershed while ANSWERS was not according to the validation criterion of a factor of two of observed values. In the Goodwin Creek watershed, ANSWERS-2000 predicted sediment yield better than the older version of ANSWERS, and both models were successfully validated. Analysis of the channel scour component of the model indicated that the model did not accurately predict the observed channel scour. This could have been due to either model inaccuracy or to the assumptions made to relate channel cross-sections to the generated channel network in the model. Overall, the ANSWERS-2000 erosion model performed better than ANSWERS in predicting sediment yield. The findings also suggest that the new detachment submodel and ANSWERS-2000 in general is more applicable to larger watersheds (that it was developed for) than smaller watersheds. This could be because the small watersheds require more accurate information than do large watersheds in order to accurately predict response. Parameter error in a small watershed will likely be seen in the output, while the same error in a large watershed may be offset by other errors in the opposite direction and thus produce some dampening of the watershed's response to error.

6 SUMMARY

A process-based sediment detachment submodel based on the WEPP model was added to ANSWERS-2000 to improve sediment yield predictions of the model. The new detachment submodel was tested for sensitivity to model input parameters. The sensitivity analysis indicated that the model was most sensitive to parameters that affected sediment yield, and runoff. The sediment submodel was most sensitive to sand fraction, while the hydrology submodel was most sensitive to soil porosity. To validate the model, predictions were compared with observed runoff and sediment yields from three different watersheds. Validation was considered successful if the predicted cumulative runoff and sediment yield were within a factor of two of measured output. The model was unable to accurately represent runoff and subsequent sediment yield on the smallest watershed (P2, 1.29 ha). Attempts to calibrate the hydrology by manipulation of soil porosity were unsuccessful. The hydrology predictions of the model were poor. Runoff was under predicted the first year, and over predicted the third year. During the second year, runoff predictions followed measured, and sediment predictions of ANSWERS-2000 were better than predictions by ANSWERS. Validation was not successful on this small watershed. On the larger Owl Run watershed (1053 hectares), the runoff was calibrated by increasing soil porosity values. After calibration, the runoff predictions compared favorably with the observed runoff, and comparisons of sediment yield over a 5 month corn growing season (5 runoff events) indicated that the modified ANSWERS-2000 model predicted sediment yield much better than previous version of ANSWERS. Validation of ANSWERS-2000 was successful while validation of ANSWERS was not. On the Goodwin Creek watershed, (2040 hectares), the hydrology submodel accurately simulated runoff without calibration. The sediment yield predictions of ANSWERS-2000 over a seven-month simulation period tended to follow runoff predictions, while the sediment predictions of ANSWERS did not. Both models met the validation criteria of cumulative runoff and sediment yield being within a factor of two of measured data.

7 CONCLUSIONS

- A process-based sediment detachment submodel based on WEPP model research was incorporated into ANSWERS-2000.
- Care must be taken in the selection of sand fraction and soil porosity, as the sediment submodel and the hydrology submodel are most sensitive to these parameters, respectively.
- The sediment submodel was evaluated in three different size watersheds, and found to work best with large watersheds (>1000 ha).
- ANSWERS-2000 predicted sediment yield better than the ANSWERS model, except in one instance where it performed as well. In all instances, ANSWERS-2000 sediment predictions tended to follow runoff trends better than ANSWERS.
- The sediment detachment submodel appears to be more applicable to larger watersheds than smaller watersheds.
- Parameter inputs increased significantly for ANSWERS-2000, but the increased predictive ability justified the increased input requirements.
- Increasing the parameter inputs by increasing the detail of crop input data would eliminate the dependence on a linear crop growth model for sediment detachment.
- The channel scour submodel did not accurately predict channel scour in a highly erodible watershed, and more testing is required to evaluate its accuracy.
- ANSWERS-2000 can be used in a planning role to meet water quality goals based on sediment yield.

8 RECOMMENDATIONS FOR RESEARCH AND MODEL IMPROVEMENT

While ANSWERS-2000 is a state-of-the-art research model, there are several areas that need improvement. These areas are listed below along with reasons for their recommendation.

- Input file construction could be made easier by improving the usability of the FARMSCALE interface (FARMSCALE, 1994) by converting it to operation in ArcView® and Windows NT®, and incorporating databases to facilitate selection of the new input erosion and channel parameters.

- Test datasets could be developed and maintained for evaluation of future revisions to the ANSWERS model. The Goodwin Creek watershed is an excellent dataset that requires extensive GIS manipulation to create an ANSWERS-2000 dataset. Duplication of the effort required to assemble the information from the watershed is a substantial waste of time. Also, the use of a GIS would allow for more exhaustive error-checking of the input files.

- Develop an improved channel evolution model to more accurately represent processes in perennial streams. The existing ANSWERS-2000 model utilizes a simple channel routing method. In watershed-scale simulations, the channel network may have a complex floodplain, a non-rectangular shape, or some degree of sinuosity. Improving the channel portion of the ANSWERS-2000 model would also include representation of in-stream processes such as nutrient dynamics and fate that may be necessary to simulate water quality in larger watersheds.

- Working with the ANSWERS-2000 model code revealed that the infiltration time step should be fixed at 30 seconds due to an non-linear and unusual response of the model to simultaneously varying the model calculation time step and the infiltration time step. This should be investigated further and corrected if time steps other than 30 seconds are to be used.

- The final and probably most pressing area of the model that could use improvement is the structure of the model code. Although the model is written in modular format to facilitate easy subroutine replacement, the various integrations of model components have spilled over into the main model code and should be rewritten. It is inevitable in large applications of model code that there are errors. Although most of these will eventually be corrected as the model evolves, rewriting the model code in ANSI FORTRAN 90 would facilitate debugging and would remove the danger of obsolescent command calls in the FORTRAN 77 framework. Also, rewriting the model in FORTRAN 90 would allow dynamic array sizing, which would eliminate the need for a separate versions of the model for simulating large watersheds.

- At the present time, if a watershed outlet exists in the first column of the cellular representation, then this condition generates a run-time array overflow error. This problem is remedied at present by shifting the watershed to the right one column.

- An error late in the evaluation process of ANSWERS-2000 revealed the need for an echo of all information in the input file. Ideally, this copy of the input file should be automatically compared with the original input file parameters to ensure that there are no read-in errors by the model.

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APPENDICES

Appendix A: ANSWERS-2000 Source Code in FORTRAN 77 format.

```
!WB  THIS IS THE LATEST VERSION AS OF 19 AUG 1999 FWB
!WB  THIS VERSION INCLUDES CRITICAL SHEAR DETACHMENT COMPONENTS FOR
!WB  FLOW DETACHMENT, AN UPDATED RAINFALL DETACHMENT COMPONENT, AND
!WB  A CHANNEL EROSION COMPONENT.  30 SOIL TYPES ARE AVAILABLE TO
!WB  ACCOMODATE THE INCLUSION OF CHANNEL SOILS.
*
!WB        19 AUG 1999 UPDATES THE HYDROGRAPH TO INCLUDE ALL NUTRIENT
!WB        SPECIES IN SEDIMENT-BOUND AND DISSOLVED FORM, OUTPUT IN PPM.
*
!WB        14 AUG 1999 REINSTATES THE HYDROGRAPH PRINT OPTION.
!WB        ALSO, THE MODEL DOES NOT WORK CORRECTLY WHEN MULTIPLE CHANNEL
!WB        OUTLETS ARE INCLUDED BECAUSE THE CONV VARIABLE DOES NOT
!WB        ACCOUNT FOR SUBWATERSHED SIZE, WHILE THE QI VARIABLE
!WB        (AND OTHERS) USE CONV TO CONVERT THEIR VALUES TO OTHER
!WB        OTHER UNITS FOR OUTPUT
*
!WB        8 AUG 1999 FIXES THE FOLLOWING LINE (LINE # 1817 AT THE TIME)
!WB        IF(FIL.LT.0) FIL=0.0, THE LINE ORIGINALLY STATED THAT IF
!WB        (FIL.LT.O), OR LT THE LETTER O
!WB        ALSO, IN SUBROUTINE RAINFA, THE NCHAN VAR WASN'T DEFINED
!WB        BEFORE IT WAS USED, AND SO THE ARGUMENT NCHAN WAS ADDED TO
!WB        THE SUBROUTINE CALL
*
*
!WB        27 JULY 1999 FIXES THE RILLWID GT RILLSPACING ERROR MESSAGE
!WB        PREVIOUSLY IT DIDN'T CONTAIN THE CELL #, RILLWID, RILLSPACING
*
!WB  7/14/99 RELEASE FIXES A LT/GE ERROR IN THE SDR CALCULATION
!WB  FOR PARTICLES LT 0.002 AND RR GT 150
*
*
*THIS VERSION INCLUDES SEDIMENT BOUND ORGANIC NITROGEN
* AND SEDIMENT BOUND AND SOLUBLE AMMONIUM

** NRZ (7/22/94)
*  THIS VERSION ELIMINATES P,PH,RALPHA,RBETA, AND RGAMA FROM THE INPUT
*  FILE.  P(20), RALPHA(20), AND RGAMA(20) ARE ALSO REMOVED FROM THEIR
*  RESPECTIVE COMMON STATEMENTS. RBETA IS STILL USED.
*
*  9/11/94
*  THIS VERSION HAS THE ABILITY TO ACCEPT MULTIPLE CHANNEL NETWORKS
*  IN THE INPUT FILE AND PRODUCES AN OUTPUT FILE FOR EACH CHANNEL.
*
*  (11/3/94)
*  THIS VERSION CONTAINS AN OPTION TO ENTER SATURATED HYDRAULIC
*  CONDUCTIVITY AS AN INDEPENDENT INPUT.  THE INPUT FILE HAS BEEN
*  REVISED TO ACCOMODATE THIS FEATURE.
*
*  THIS VERSION UTILIZES A SEPARATE INPUT FILE FOR FERTILIZER
*  APPLICATIONS.  AN ADDITIONAL INPUT FILE HAS BEEN ADDED AND THE MAIN
*  INPUT FILE HAS BEEN MODIFIED.
*
*  A MODIFIED SCREEN OUTPUT INDICATES CALENDAR MONTH AND DAY, RAIN
*  EVENTS, AND FERTILIZER APPLICATIONS
*
*  10/12/94
*  THIS VERSION CONTAINS A CORRECTION TO THE NITRIFICATION ALGORITHM
*  TO ACCOUNT FOR FERTILIZER APPLICATIONS LESS THAN 20 DAYS BEFORE A
*  ROTATION.
*
*  THIS VERSION CONTAINS AN OPTION TO PLACE AN IMPOUNDMENT AT THE END
*  OF ANY CHANNEL NETWORK.  THE NECESSARY STRUCTURAL DATA MUST BE
*  INCLUDED IN THE INPUT FILE.
*
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*  THIS VERSION ALLOWS THE USER TO ENTER A MEASURED VALUE OF SATURATED
*  HYDRAULIC CONDUCTIVITY.
*
*  7/29/95
*  THIS VERSION ADDS THE CAPABILITY TO INCLUDE 28 ROTATION END DATES AS
*  OPPOSED TO THE PREVIOUS 20
*

C************************************************************************
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C*****                                                            ******
C*****                                                            ******
C*****                  A N S W E R S                             ******
C*****                                                            ******
C*****          (AREAL NONPOINT SOURCE WATERSHED                  ******
C*****          ENVIRONMENT RESPONSE SIMULATION)                  ******
C*****                                                            ******
C*****                                                            ******
C*****  DISTRIBUTED PARAMETER MATHEMATICAL MODEL OF A RAINFALL    ******
C*****  EVENT ON A CATCHMENT, WITH EROSION AND DEPOSITION AS A    ******
C*****  FUNCTION OF  PARTICLE SIZE.                               ******
C*****                                                            ******
C*****                                                            ******
C*****  AUTHORS:  D. B. BEASLEY, L. F. HUGGINS, AND J. R. BURNEY  ******
C*****                                                            ******
C*****   AGRICULTURAL ENGINEERING DEPARTMENT, PURDUE UNIVERSITY   ******
C*****          WEST LAFAYETTE, INDIANA  47907                    ******
C*****                                                            ******
C*****                                                            ******
C*****  AUTHORS: THEO DILLAHA                                     ******
C*****         DEVELOPMENT OF EXTENDED SEDIMENT MODEL             ******
C*****         LAST MODIFY DATE: SEPTEMBER 1, 1981                ******
C*****                                                            ******
C*****         INCORPORATION OF EXTENDED SEDIMENT MODEL BY        ******
C*****         DILLAHA INTO CURRENT ANSWERS MODEL FOR FORTRAN     ******
C*****         77 COMPILER FOR VIRGINIA TECH SYSTEM.              ******
C*****         FEBURARY 17, 1986.                                 ******
C*****                                                            ******
C*****    AGRICULTURAL ENGINEERING DEPARTMENT, VIRGINIA TECH      ******
C*****         BLACKSBURG, VIRGINIA  24061  540-961-6813          ******
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C*****                                                            ******
C*****                                                            ******
C************************************************************************
C************************************************************************
C************************************************************************
C*****                                                            ******
C*****                                                            ******
C*****                                                            ******
C*****   THIS VERSION OF ANSWERS CONTAINS:                        ******
C*****                                                            ******
C*****   1) MEMORY CONSERVATION EQUIVALENCING                     ******
C*****   2) 3-PER-PASS ALGORITHM                                  ******
C*****   3) IMPROVED DATA VERIFICATION DIAGNOSTICS                ******
C*****   4) STRUCTURAL PRACTICES                                  ******
C*****   5) MODIFIED INPUT FORMATS (SEE USER'S MANUAL)            ******
C*****   6) MODIFIED DETACHMENT AND TRANSPORT RELATIONSHIPS       ******
C*****   7) MODIFIED OUTPUT FORMATS                               ******
C*****                                                            ******
C************************************************************************
C************************************************************************
C
C
C ****** DISTRIBUTED PARAMETER MATHEMATICAL MODEL OF A RAINFALL
C ****** EVENT ON A CATCHMENT, WITH EROSION AND DEPOSITION.
C
      IMPLICIT DOUBLE PRECISION A-H,O-Z
C
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C **** MAXIMUM NUMBER OF SOIL TYPES IS 30.
C
      COMMON /CSOIL/ A(30),FC(30),GWC(30)
      COMMON /GRAMPT/ CL(30),SA(30),ST(30),OM(30),AC(30)
     & ,AO(30),BC(30),BO(30),PHI(30),VCF(30),WCF(30),CFC(30),
     &  CEC(30),EAC(30),PHIC(30),XF(30),PSIF(30),CBF(30),
     &  THETAR(30),KS(30),CF(30),Z(30),LF(30),CS(30),SCF(30),
     &  CRC(30),KE(30,30),ZC(30),BD(30)
      DOUBLE PRECISION KS,LF,KE
!     COMMON /ETPES/LAI(20,11),ESU(30),LAI1(20),POTLAI(20),EDX(20)
!     &,SUMLAI(20)
      COMMON /ETPES/LAI(20,11),ESU(30),LAI1(20),POTLAI(20)
     &,SUMLAI(20)
              COMMON /EDX/ EDX(30)
      DIMENSION S1EP(2000),S2EP(2000),TTIME(2000),PEP(2000),ES(2000)
      DOUBLE PRECISION LAI,LAI1
      COMMON /ASMF/ ASMBF(30),FCAP1(30),TP1(30),RESWAT(30),DF1(30)
              INTEGER DAYBEG,SIMDUR,TEMPC,SOITEM,RADI,RAITES,YERBEG,RNUT

      COMMON /ROT/ IROT1,IROT(20,57)
      INTEGER IROT1,IROT

C *** NRZ 9/15/94
C *** CHANGED DIMENSION OF SOME VARIABLES TO CORRESPOND WITH
C *** NMAX+ISTRUC+1+NCHAN

      COMMON /PHOS1/ P0SOIL(2000),SSA(30,8),SSAT(30),EDI(2000),
     & P0(2000,8),ERP(8),STOLD(2000,8),SEDNEW(2000,8),PPT(2000,8),
     & PI(2030,8),PSEL(2000),STNEW(8),P2(8),PCELL(2000,8)
     & ,DRFT(8)
      COMMON /PHOS2/PE(8)

      COMMON/NITRO1/ A0SOIL(2000),ANPT(2000,8),ANI(2020,8),
     & ANSEL(2000),AN2(8),ANCELL(2000,8),ANE(8),AN0(2000,8)
     & ,CNH4(2000)


      COMMON/NITRO2/ O0SOIL(2000),ONPT(2000,8),ONI(2020,8),
     & ONSEL(2000),ON2(8),ONCELL(2000,8),ONE(8),ON0(2000,8)

C *** NRZ 9/15/94

      COMMON /PLANTN/DATPLA(20),DATHAR(20),CP1(20),CP2(20),DMY(20)
     &   ,YP(20),ROTMAX(20),ROTDAY(20),RLAIMX(20)
     &   ,RES(20),RES20(20),RES90(20)
      INTEGER DATPLA,DATHAR,ROTMAX,ROTDAY

C **** NRZ 9/14/94
C **** CHANGE DIMENSIONS TO ACCOMODATE MULTIPLE OUTLETS
C **** AND DIMENSION OTHERS

       DIMENSION PSSI(101,10),SPSSI(101,10),ANSSI(101,10),ONSSI(101,10)
     & ,ANH4SI(101,10),ANO3SI(101,10)
       DIMENSION SIG(10),VOL(10),PSIG(10),ANSIG(10),ONSIG(10),XS(10),
     & VOL1F(10),VOL1X(10),RNO3(10),RNH4S(10),RNH4SE(10),RPHOS(10),
     & RORGN(10),RSEDP(10),SPT(10),PSPT(10)

C **** NRZ 9/14/94

      COMMON /CUMIN/ CUMIN1(2000),rbit0(2000),testi(2000)
     & ,timpon(2000),tpon(2000)

C **** NRZ 9/15/94
C **** CHANGED DIMENSIONS OF SOME VARIABLES TO CORRESPOND WITH
C **** NMAX+ISTRUC+1+NCHAN

      COMMON /SOLUB/ SP2(2000),PEXT(2000),PK(30)
     & ,RBETA(30),SPI(2020),CGEN1(2000)
     & ,T13(2000),SPSP(2000)
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      COMMON/WATNH4/VOLSZ(2000),SZNH4(2000),AINH4(2020),STONH4(2000)
     & ,OUTNH4(2000),EDINH4(2000),VOLSZ1(2000),VOLSOI(2000)

      COMMON/NO3/SZNO3(2000),AINO3(2020),STONO3(2000),OUTNO3(2000)
     & ,CNO3(2000),EDINO3(2000),CLENO3(2000)

C **** NRZ 9/15/94

      COMMON/OUT/SUMSED(2000),SUMNO3(2000),SUMNHW(2000),SUMNHS(2000)
     & ,SUMTKN(2000),SUMPO4(2000),NO3SEL(2000),NHWSEL(2000),NHSSEL(2000)
     & ,TKNSEL(2000),PO4SEL(2000)
       DOUBLE PRECISION NO3SEL,NHWSEL,NHSSEL
C
C **** MAXIMUM NUMBER OF SURFACE AND CROP TYPES IS 20.
C
      COMMON /CROUGH/ ROUGH(20),HU(20),DIR(21),PIT(8,20),PER(20)
C
C **** MAXIMUM NUMBER OF RAINGAGES IS 8 WITH 35 VALUES PER GAGE.
C
      COMMON /CRGAGE/ RC(8,35),TC(8,35),R(8,21),FRA(8),JTR(8),RATE(8),SR
     1(8),NF(8)
C
C .... PARAMETERS USED IN THE EXTENDED SED SUBROUTINE
C
      COMMON /ZSEDI/ NPART,NWASH,NWASH1
      COMMON /ZSEDR/ VISCOS,AGRAV,SWH2O,YALCON,SE(8),VS(2000),DIA(8),
     1SG(8),FV(8),CY1(8),CY2(8),CY4(8),DIAMM(8),EQSDIA(8),EDMM(8),
     2F(30,8),CE1,CE2,CE3,CE4,CE5,CE6
!WB        Changed F(10,8) to F(30,8) to accomodate 30 soil types
C
C **** MAXIMUM NUMBER OF OVERLAND ELEMENTS PLUS CHANNEL ELEMENTS
C **** IS 2000 = NMAX.


C ****** NRZ 9/15/94
C ****** DUE TO ADDITION OF MULTIPLE OUTLETS, SI AND QI (AS WELL AS
C ****** OTHER ARRAYS ORIGINALLY USING THE VARIABLE NN AS AN ELEMENT
C ****** OF THE ARRAY) MUST BE DIMENSIONED TO NMAX+ISTRUC+1+NCHAN

      COMMON /CFLOW/ Q(2000),RFL(2000),FLINS(2000),SS(2000),PIV(2000),B(
     12000),NR(2000),NC(2000),DR(2000),S(2000),SL(2000),SEL(2000),SI(202
     20,8),QI(2020),DIN(2000),SST(2000,8),PIVTMP(2000),SSTMP(2000)

C *** NRZ
C *** ADD COMMON BLOCK FOR PERCENTAGE OF CELL AREA "LEAKING" OUTSIDE THE
C *** WATERSHED

      COMMON /LEAKY/ OUTSID

C *** NRZ 9/15/94
C
C ****** ARRAYS SI AND QI MUST BE DIMENSIONED TO A SIZE = NMAX+ISTRUC+2
C ****** TO HOLD, IN ORDER, SEDIMENT AND FLOW FROM THE WATERSHED OUTLET
C ****** ELEMENT, STRUCTURAL PRACTICES AND ANY "LEAKY" ELEMENTS.
C
      DIMENSION FILTS(2000), CWID(2000),CWIDTMP(2000)
      COMMON /CSURF/ SUR(2000),RANE(2000),SOIL(2000)
      INTEGER SUR,TIAL(2000),RANE,SOIL
      DIMENSION ASMVOL(2000),ASMLIM(30),XMOI(2000),SOIVOL(30)
     & ,FCVOL(30),WP(30),RATEMX(30)
c            fert array changed from 20 to 99: JLCollado, oct-97
!WB        CHANGED REMAINING VARIABLES TO ACCOUNT FOR 30 SOIL TYPES
      DIMENSION RNUTNI(99),RNUTAM(99),RNUTP(99)

C *** NRZ 9/12/94
C *** ADD VARIABLES FOR FERTILIZER FILE
c     dimension changed from 20 to 99
      COMMON /FERT/ IFERT
      DIMENSION TMPNI(99),TMPAM(99),TMPP(99)
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C *** ADD COMMON BLOCK FOR NITRIFICATION CORRECTION

      COMMON /YEAR/ LDYEAR

C *** ADD COMMON BLOCK FOR EXTRA OUTPUT OPTIONS

      COMMON /XPRINT/ NSBS,NPDAY(10)
      CHARACTER*7 XPFIL(10)

C *** NRZ 9/12/94

      COMMON /ASMP/ASMPER(2000)
      COMMON /TRANSF/POTMIN(2000),SOILN(2000),XMIN(2000),AMON(2000)
     & ,NIT(2000),DNI(2000),UPNH4(2000),UPNO3(2000),TDMN2(2000),
     & ROTR(2000),RFON(2000)
      DOUBLE PRECISION XMIN,NIT
      COMMON /TRAP/PMINP(2000),SOILP(2000),MINP(2000),PLAB(2000),
     &  UPPHOS(2000),TDMP2(2000),SORGP(2000),PSOL(2000),EDILAB(2000)
      DOUBLE PRECISION MINP
      COMMON /PARTITION/PKDA(30),PKDP(30),PSP(30)
!WB          CHANGED ARRAY SIZES TO 30
C
C **** NUMBER OF PRINT AND PLOT POINTS IS 101 MAXIMUM.
C
C **** NRZ 9/14/94
C **** CHANGE DIMENSION OF CERTAIN VARIABLES TO ACCOUNT FOR MULTIPLE
C **** CHANNEL OUTLETS

      DIMENSION T(101),Q1(101,10),RW(101,10),SSI(101,10),
     & SSCON(101,10),ER(8)

C **** ADDED VARIABLES FOR CHANNEL NETWORKS

      COMMON /OUTLET/ NCHAN,NIOUT(9),NJOUT(9),MOUT(9),CHNUM(2000),
     &               CHOUT(9),NCELLS(9),CHNUMBER(2000)
      INTEGER CHNUM,CHOUT,CHNUMBER

C **** NRZ 9/14/94



      DIMENSION PP(14), QA(300), TT(20)
      CHARACTER*4 PP, TT
      DATA PP(1),PP(2),PP(3),PP(4),PP(5),PP(6),PP(7),PP(8),PP(9),PP(10),
     1PP(11),PP(12),PP(13),PP(14)/' IN.','/HR.',' AC.',' FT.',' LB.',
     2' PPM','/AC ','  MM','/H  ',' HA ',' M  ','  KG','MG/L','/HA '/

C **** NRZ (8/29/94)
C **** NEW VARIABLES AND COMMON BLOCKS FOR IMPOUNDMENT MODEL

      COMMON /IMPDIM/ BASE,WIDTH,SLOPE,ORIF,CI,FI,MAXHGT,NIMP
      DOUBLE PRECISION BASE(10),WIDTH(10),SLOPE(10),ORIF(10),CI(10),
     &FI(10),MAXHGT(10)

      COMMON /FWATER/ AFWEV,DFWEV

      DIMENSION SEDG(10,8),SEDH(10,101,8)

      DOUBLE PRECISION ONSEDG(10,8),ONSEDH(10,101,8),ONSEDI(10,8),
     &ONSEDO(10,8),ONSEDT(10)

      DIMENSION PSEDG(10,8),PSEDH(10,101,8),PSEDI(10,8),
     &PSEDO(10,8),PSEDT(10)

      DIMENSION ANSEDG(10,8),ANSEDH(10,101,8),ANSEDI(10,8),
     &ANSEDO(10,8),ANSEDT(10)

      DIMENSION SEDOR(10,8),SEDOT(10,8),SEDWT(10,8),DIAM(8),TSEDI(10,8)
     &,TSEDO(10,8),TTSEDO(10)
      DIMENSION DANSED(10),DNO3O(10),DNH4O(10),DONSED(10),DPHOSO(10)
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     &,DPSED(10),DTSEDO(10),RUNO(10),TNO3O(10),TNH4O(10),TPHOSO(10)
     &,TRUNO(10),TRUNOM(10),RUNVOL(10),RUNOM(10)

      DIMENSION SEDZO(10,8),SEDZOT(10,8)


C **** NRZ (8/29/94)
!WB************************************************
!WB************************************************
!WB*****
!WB***** When the comment indicator is !WB
!WB***** it indicates that the comment was
!WB***** inserted by Wes Byne in FALL 1998,
!WB*****  or SPRING 1999.
!WB*****
!WB************************************************
!WB************************************************

!WB      BEGINNING OF NEW VARIABLES FOR NEW DETACHMENT ROUTINES
!WB      soil variables:
         COMMON/SOILVAR/CLAY(30),SAND(30),SILT(30),VFSPER(30),VFS(30),
         1ORGMAT(30),MASSCF(30),RANROU(30),RANROUM(30)
         DOUBLE PRECISION MASSCF

!WB      rill erodibility variables:
         COMMON/RILLVARS/KRBASE(2000),KRBR(2000),BR(20),BURRES(20),
         1KRADJHLD(2000),KRCONS(2000),KRSC(2000),KRADJ(2000)
         DOUBLE PRECISION KRBASE,KRBR,KRADJHLD,KRCONS,KRSC,KRADJ

!WB      critical shear variables:
         COMMON/CRTSHEAR/TAUCB(2000),TAURR(2000),TAUCHLD(2000),TAUCONS
         1(2000),TAUSC(2000),TAUCADJ(2000),TAUEFF

!WB      interrill erodibility variables:
         COMMON/IRILLVARS/KIBASE(2000),KICAN(2000),KIGRCOV(2000),KICONS
         1(2000),KISC(2000),KIADJ(2000),CANOPY(20),AUCFACT(20),HEIGHT(20),
     2MAXPLHGT(20),HGTFACT(20),GROWFACT(20)
         DOUBLE PRECISION KIBASE,KICAN,KIGRCOV,KICONS,KISC,KIADJ,MAXPLHGT

!WB      interrill cover common block:
         COMMON /IRILLCOV/ INRCOV(20),INRCOVI(20),INRCOVF(20),INRFACT(20),
         1LROOT(21),DROOT(21),KDROOTI(2000),KLROOTI(2000),DDROOTI(21),
         2DDROOTF(21),DDRTFAC(21),LRFAC(21),LIVEROOT(21),KDROOTR(2000),
         3KLROOTR(2000)

         DOUBLE PRECISION INRCOV,INRCOVI,INRCOVF,INRFACT,LROOT,KDROOTI,
         1KLROOTI,LRFAC,LIVEROOT,KDROOTR,KLROOTR

!WB      rill erosion variables:
         COMMON/RILLEROS/NORILLS,RILLSPC(20),QEFF,RILLWID,MNSOIL(21),
     1MNTOT(21),FLOWDEP,HYDRAD,DCAP,FCFRAC(30),FOFD,FPOFD,FDPOFD,
         2FLDEPOLD,MNCHNSL(2000),MNCHNTOT(2000),MNCS(10),MNCT(10),MNCSTMP
         3(2000),MNCTTMP(2000),MAXWID,NOTILL(21),NOEROS(21),DWSOIL,
         4HYDRADOLD(2000)
         DOUBLE PRECISION MNSOIL,MNTOT,MNCHNSL,MNCHNTOT,MNCS,MNCT,MNCSTMP,
         1MNCTTMP,NORILLS,MAXWID

!WB      interrill erosion variables
         COMMON /IRILLEROS/RNOFIR,SEDDR(2000,8),DIINT(2000,8),DETR(8)
         1,DETF(8),DACT(2000,8)

!WB      PLANT GROWTH VARIABLES
         COMMON /PLANTS/ DAYNOW(2000),YEARNOW(2000),DYYRNOW
         1(2000),DAYTHEN(2000),YEARTHEN(2000),DYYRTHEN(2000),DAYDIFF(2000),
         2BEGROTDT(2000)

!WB      CHANNEL BOTTOM EROSION VARIABLES
         COMMON /CHANEROS/WIDINC(2000),DOWNRATE(2000),
         1DEPTHINC(2000),IMPERM(10),ROCKBOT(2000),RBTEMP(2000),BULKDENS(30),
         2CHNSOIL(2000),CHNSL(2000),CHNSLTMP(2000),DEPRATE(2000)
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   3,DEPPREV(2000),CONSTHLD(2000),XHOLD(2000),CONSTTMP(2000)
   4,XTMP(2000),ARMOUR(2000),NOERODE(2000),NERODTMP(2000)

!WB        HYDROGRAPH PLOT VARIABLES
           COMMON /HYPLT/PRINHYD,IMPFLAG,QHYP(101,10),PHYP(101,10)
           1,DPHYP(101,10),A4SHYP(101,10),A4DHYP(101,10),ONHYP(101,10)
           2,A3HYP(101,10)
           CHARACTER(11) HYPNAM(10)

           DOUBLE PRECISION DIFF,RGTSID,LFTSID,IMPERM,NOERODE,NERODTMP

           INTEGER CNT,CNTER,CNTFLAG,NOTILL,INIT,NOEROS,CHNSL,CHNSOIL,
           1CHNSLTMP,PRINHYD

!WB        Sediment Erosion routine information:  Some equations and
!WB        calculations in the sediment subroutine are not placed in the
!WB        location that will allow optimal calculation efficiency.  This is
!WB        recognized, and was done in order to ease understanding of the
!WB        methodology at the cost of computational efficiency.

!WB        END OF NEW VARIABLES FOR NEW DETACHMENT ROUTINES


C **** OPENING INPUT FILE--ANSWERS.INP
     OPEN (UNIT=1, FILE='ANSWERS.INP', STATUS='OLD')
     OPEN (UNIT=8, FILE='WEATHER.INP', STATUS='OLD')

C**    WDB 5/23/94
C**    OPEN A SEPARATE FILE FOR AVERAGE ANNUAL OUTPUT SENT BACK TO GIS
           OPEN (UNIT=5, FILE='ANSWGRID.OUT', STATUS='OLD')
C**    WDB 5/23/94


C **** OPENING OUPUT FILE--ANSWERS.OUT
     OPEN (UNIT=2, FILE='ANSWERS.OUT', STATUS='OLD')

!WB        OPENING RILL OUTPUT FILE
            OPEN (UNIT=101,FILE='RILL.OUT',STATUS='UNKNOWN')
!WB        OPENING SCRATCH INTERRILL OUTPUT FILE
     OPEN (UNIT=102,FILE='IRILL.OUT',STATUS='UNKNOWN')
*****************************************************************
!WB ****  CE6 IS A CONSTANT ASSOCIATED WITH THE OLD EROSION EQNS,
!WB                    BUT WAS NOT REMOVED B/C IT IS USED IN SEVERAL SUBROUTINES
    CE6=62.3174

    READ (1,280) (TT(I),I=1,19)
!WB        Reads first line in input file
    WRITE (2,290) (TT(I),I=1,19)
!WB        Writes first line in input file to output file


***********RILL & IRILL FILE HEADER*****
    WRITE (101,*) 'LDAY','    SED ',' JK ','DAYDIFF','  KRBASE',
           1'  TAUCB','   TAURR',' TAUCHLD'
    WRITE (101,*) '      KRCONS','  KRSC',' KRBR','   KRADJ',
           1'   TAUCONS',' TAUSC',' TAUCADJ',' SOIL'
           WRITE (101,*) '      KDROOTR',' KLROOTR'
           WRITE (102,*) 'LDAY ',' SED ','    JK',' DAYDIFF',' KIBASE',
           1' HEIGHT','   CANOPY',' KICAN'
    WRITE (102,*)'          INRCOV',' KIGRCOV',' KICONS',
   1' KISC','      LROOT',' DROOT'
    WRITE (102,*)'          KLROOT',' KDROOT','  KIADJ',' SOIL'
!WB        END OF OUTPUT HEADERS TO RILL/IRILL OUTPUTS


C
C **** READ, TRANSFORM AND RETURN INPUT INFORMATION.
C
    CALL XDATA (NDT,KPR,N,CONV,CU,SF,IT,NN,ICR,NFI,CU2,ISTRUC,SB,TMIN,
```

```
   &TMAX,NRG,DX,GRF,NEXP,DC,PP,FILTS,CWID,AREA,AREA2,DT,NMAX,CU1,
   &DAYBEG,SIMDUR,ISR,YERBEG,CLAYAV)

!WB       NDT = # lines hydrograph input, KPR = # time increment routings
!WB       between print lines, N = number of overland flow cells,
!WB       CONV = catchment conversion, CU = conversion, SF = segment factor
!WB        = max. projected catchment discharge, IT = unknown,
!WB       NN = # overland flow + channel elements + 1, ICR = # cropping
!WB       practices, NFI = max # of time increments b/t infiltration
!WB       recalc.'s, CU2 = conversion, ISTRUC = counter for structural
!WB       practices, SB = ave. overland flow conveyance coeff., TMIN = min.
!WB       time value in any hyetograph, TMAX = maximum time, NRG = # rain
!WB        gages, DX = element width, GRF = fractional rate of baseflow
!WB       release, NEXP = unknown,  DC = tile drainage coeff.,
!WB       PP = alphanumeric unit descrip., FILTS = infil. cap. for
!WB       element i, CWID = width of channel seg. i, AREA = catchment area
!WB       as sum of element areas, AREA2 = element or channel area,
!WB       DT = time increment, NMAX = max. # of elements,
!WB       CU1 = conversion, DAYBEG = beginning day of simulation, SIMDUR =
!WB        simulation duration, ISR = # of soil types,
!WB       YERBEG = beg. year of the simulation, CLAYAV = unknown

    CONFAY=DX*DX/10000.
!WB        (element width)^2 / 10000
    DO 5550 J=1,N
!WB       do this loop from J = counter to # overland flow el's
    K=SOIL(J)/256
!WB        = soil type / 256
    ASMVOL(J)=ASMBF(K)*(TP1(K)/CU1)
!WB       ASMBF = ASM(I)
    ASMPER(J)=ASMBF(K)

          ASMLIM(K)=(FCAP1(K)-FC(K))*(TP1(K)/CU1)*0.25+FC(K)*(TP1(K)/CU1)
!WB         ASMLIM(K) = (field cap of soil K - wilting point) * (TP1 / conv.)
!WB                      * 0.25 + wilt pt * TP1 / conv.
    WP(K)=FC(K)*TP1(K)/CU1
!WB        = wilt pt * porosity / conversion
    FCVOL(K)=FCAP1(K)*(TP1(K)/CU1)
!WB        field cap (mm) = field cap as fraction of pore space *
!WB                   (porosity / conv)
          SOIVOL(K)=DF1(K)*DX*DX*BD(K)
!WB        soil mass of layer = depth of horizon * side length*side length
!WB                    * bulk density of soil
    VOLSZ1(J)=EDI(J)*PHI(K)
!WB        = effective depth of interaction * porosity
    VOLSOI(J)=EDI(J)*BD(K)
!WB        = EDI * bulk density
    VOLSZ(J)=EDI(J)*0.001*DX*DX*PHI(K)
!WB    = EDI * 0.001 * side length * side length * porosit
 5550 CONTINUE
*MAX RATE OF NITRIFICATION IS 100MG/KG/WEEK

    DO 5551 J=1,ISR
!WB        do this loop from counter J=1 to # of soil types
    RATEMX(J)=0.0001*SOIVOL(J)/7.
!WB       max nit. rate = 0.0001 * soil mass of soil layer / 7.
 5551 CONTINUE


     DO 5532 JK=1,ICR
!WB        do this loop from counter JK=1 to # of cropping practices
          IF(DATPLA(JK).GT.DATHAR(JK)) DATHAR(JK)=DATHAR(JK)+365
!WB       if plant date > harvest date, then harvest date moves to next year
          LDATE=(DATHAR(JK)-DATPLA(JK))+1
!WB       growth duration = (harvest date - plant date) +1
          RLENGT=(DATHAR(JK)-DATPLA(JK)+1)/10.
!WB       unknown = ((harv. date - plant date) +1) / 10
          DO 5531 LL1=1,10
!WB       do this loop 10 times?
*LDATE REPRESENT GROWTH DURATION
```

```
          POTLAI(JK)=(LAI(JK,LL1+1)+LAI(JK,LL1))*0.5*RLENGT
   &        +POTLAI(JK)
!WB       sum of potential lai from planting to harvest =
!WB                 (lai (crop practice, next count step) +
!WB                 lai (crop practice, this count step))  * 0.5 *
!WB                 ((harv date - plant date) + 1) / 10 + potential
!WB                 lai from crop practice
 5531   CONTINUE
 5532  CONTINUE

!WB       RESET CHANNEL WIDTH INCREASE AT THE BEGINNING OF THE SIMULATION
          N2=NN-1
          DO LL1=N+1,N2
          WIDINC(LL1)=0.
          DEPTHINC(LL1)=0.
          DEPRATE(LL1)=0.
          DEPPREV(LL1)=0.
          INIT=0
!WB       INIT IS A FLAG/COUNTER THAT ALLOWS THE SED INITIALIZATION TO
!WB       ONLY OCCUR ONCE, AS REDOING THE LOOP MULTIPLE TIMES CAUSES ERRORS
          IMPFLAG=0
!WB       IMPOUNDMENT FLAG, FOR HYDROGRAPH PRINT OPTION.  IF THIS FLAG IS 1, THEN
!WB       THERE ARE IMPOUNDMENTS AND THE HYDROGRAPH OUTPUT WILL NOT PRINT AND A
!WB       SINGLE OUTPUT STATEMENT WILL PRINT.  WITHOUT THIS STATEMENT, THE STATEMENT
!WB       WILL PRINT OVER AND OVER AGAIN.
          END DO

     DO 5555 IDATE=1,SIMDUR
!WB       do this loop from day of simulation up to simulation duration

*         print *,' DAY OF SIMULATION IS ',IDATE
*get leaf area index and interpolate for a specific date
*LDAY REPRESENT THE CURRRENT DAY IN JULIAN CALENDAR
C *** NRZ
C *** ADDED CORRECTION FOR LEAP YEAR

          IF(LDAY.GE.365 .AND. MOD(YERBEG,4).NE.0.) THEN
           YERBEG=YERBEG+1
           DAYBEG=DAYBEG-365
      ELSEIF (LDAY.GE.366 .AND. MOD(YERBEG,4).EQ.0) THEN
       YERBEG=YERBEG+1
       DAYBEG=DAYBEG-366
          ENDIF

C *** NRZ END

          LDAY=IDATE+DAYBEG-1
!WB       current day = date counter + beg. day -1

      DO 5580 JK=1,ICR
!WB        do this loop from the counter JK=1 to # cropping practices
*LDATE REPRESENT GROWTH DURATION
          LDATE=(DATHAR(JK)-DATPLA(JK))+1
!WB       growth duration = (harvest date of cropping practice
!WB                  - plant date of cropping practice) +1
          RLENGT=(DATHAR(JK)-DATPLA(JK))/10.
!WB       unknown = (harv. date of crop practice -
!WB                 plant date of crop practice) / 10
!WB       This same line is defined differently a few lines above.
          LMODE=IDINT(((DBLE(LDAY)-DBLE(DATPLA(JK))+1)/DBLE(LDATE))*10)+1
          IF(LMODE.GT.11) GOTO 5580
          RMODE=((DBLE(LDAY)-DBLE(DATPLA(JK))+1)/DBLE(LDATE))*10.+1.
          IF(RMODE.LT.0.) THEN
           LMODE=IDINT(((DBLE(LDAY)-DBLE(DATPLA(JK))+366)/DBLE(LDATE))*10)+1
           RMODE=((DBLE(LDAY)-DBLE(DATPLA(JK))+366)/DBLE(LDATE))*10.+1.
          ENDIF
          IF(LMODE.GT.10) GOTO 5580
          IF(RMODE.LT.1) GOTO 5580
!WB       LINE ADDED 1/19/99 TO PREVENT A NEGATIVE LAI1 WHEN LDAY IS LT
!WB       DATPLA.  AT THE BEG OF A ROTATION, THIS CAUSES FLOAT ERRORS.
```

```
          LAI1(JK)=(LAI(JK,LMODE+1)-LAI(JK,LMODE))*(RMODE-LMODE)
   &      +LAI(JK,LMODE)
*COMPUTING THE ROOT DEPTH FOR A GIVEN DAY
          RDAYL=DBLE(LDAY)-DBLE(DATPLA(JK))+1.
!WB        = (current date - plant date) + 1
          RDAYM=DBLE(DATHAR(JK))-DBLE(DATPLA(JK))+1.
!WB        = harvest date - plant date +1

          ROTDAY(JK)=ROTMAX(JK)*(0.5+0.5*SIN(3.03*(RDAYL/RDAYM)-1.47))
!WB       root depth for crop practice = max root depth for crop *
!WB                 (0.5 + 0.5*sin(3.03*(fraction of root growth)-1.47))

!WB       ***** SEDIMENT SUBROUTINE HEIGHT & CANOPY FACTORS ****************
    IF (LDATE.GT.365) THEN
!WB       A GENERAL ERROR CHECK FOR LONG ROTATIONS, WHICH AREN'T HANDLED
!WB       BY THE PLANT GROWTH MODEL IN THE SEDIMENT ROUTINE
                    WRITE (*,2595)
            PAUSE
            ENDIF
          HGTFACT(JK)=MAXPLHGT(JK)/(GROWFACT(JK)*LDATE)
!WB       This is the canopy growth factor, used in the Kican factor in the
!WB       sed submodel.  It assumes linear growth of plant height and canopy,
!WB       during the first half of the growing period, then is equal to
!WB       the max height during the last half of the growth period.
!WB       maxPLhgt=maximum canopy height for a crop.
          AUCFACT(JK)=(AC(JK)/100)/(GROWFACT(JK)*LDATE)
!WB       This is the Area Under Canopy factor, used in the Kican factor in
!WB       the sed submodel.  It assumes linear growth of plant canopy, and
!WB       that max canopy is obtained at halfway through the growth period.
!WB       ERROR MESSAGES
          DDRTFAC(JK)=(DDROOTF(JK)-DDROOTI(JK))/(LDATE)
          LRFAC(JK)=(LIVEROOT(JK)/(GROWFACT(JK)*LDATE))
          INRFACT(JK)=(INRCOVF(JK)-INRCOVI(JK))/(LDATE)
          IF ((DDRTFAC(JK).LT.-1).OR.(DDRTFAC(JK).GT.1)) THEN
          WRITE (2,3050) DDRTFAC(JK), JK
          WRITE (*,2592)
          PAUSE
          STOP
          ENDIF
          IF ((LRFAC(JK).LT.0).OR.(LRFAC(JK).GT.1)) THEN
          WRITE (2,3052) LRFAC(JK),JK
          WRITE (*,2592)
          PAUSE
          STOP
          ENDIF
          IF ((GROWFACT(JK).LT.0).OR.(GROWFACT(JK).GT.1)) THEN
          WRITE (2,2582) GROWFACT(JK)
          WRITE (*,2592)
          STOP
          ENDIF
          IF ((MAXPLHGT(JK).LT.0).OR.(MAXPLHGT(JK).GT.3.0)) THEN
          WRITE (2,2584) MAXPLHGT(JK)
          WRITE (*,2592)
          STOP
          ENDIF
          IF ((HGTFACT(JK).LT.0).OR.(HGTFACT(JK).GT.1)) THEN
          WRITE (2,2586) HGTFACT(JK)
          WRITE (*,2592)
          STOP
          ENDIF
          IF (((AC(JK)/100).LT.0).OR.((AC(JK)/100).GT.1)) THEN
          WRITE (2,2588) AC(JK)
          WRITE (*,2592)
          STOP
          ENDIF
          IF ((AUCFACT(JK).LT.0).OR.(AUCFACT(JK).GT.1)) THEN
          WRITE (2,2590) AUCFACT(JK)
          WRITE (*,2592)
          STOP
          ENDIF
```

```
!WB         END ERROR MESSAGES
!WB         ***** END SEDIMENT SUBROUTINE HEIGHT & CANOPY FACTOR ***************

 5580   CONTINUE
    RAITES=0
!WB         raintest flag, 0 = false, no storm
    RNUT=0
!WB         nutrient application flag, 0 = no nutrient app
    DO 5581 JK1=1,ICR
!WB         do this loop from counter JK1 up to # of cropping practices
    RNUTNI(JK1)=0.
!WB         nitrate fertilizer applied to cropping practice
    RNUTAM(JK1)=0.
!WB         ammonium fertilizer applied to cropping practice
    RNUTP(JK1)=0.
!WB         P fert applied to cropping practice
 5581 CONTINUE
C *** NRZ 9/12/94
C *** MODIFIED FERTILIZER INPUT

!WB****this is where raites is read, see if-then loop #699***********

    READ(8,5560) TEMPC,SOITEM,RADI,RAITES
!WB          TEMPC = air temp, SOITEM = soil temp, RADI = daily radiation,
!WB                        RAITES = raintest flag
    IF ((IDATE.EQ.1).AND.(IFERT.EQ.1)) THEN
!WB         if day = first day and fert. app = 1, then
            READ (9,*)
!WB         read from fertilizer.inp file
            READ (9,*)
            READ (9,6010) NFYEAR,NFDAY,NICR,TMPNI(NICR),
   &             TMPAM(NICR),TMPP(NICR)
!WB          NFYEAR = year of fert. app., NFDAY = day of fertilizer app.,
!WB         NICR = crop # to which fert is app'ed., TMPNI = amt of NO3
!WB         aplied to crop i, TMPAN = amount of NH4 fert app to crop i,
!WB         TMPP = amt of P fert app'ed to crop i,
 5583 ENDIF
 5584 IF ((NFYEAR.EQ.YERBEG).AND.(NFDAY.EQ.LDAY)) THEN
!WB          if year of fert app equals beginning year and fert app day =
!WB          today, then
      NFPR = 1
!WB          unknown
            RNUTNI(NICR)=TMPNI(NICR)*CONFAY
!WB         nitrate applied to crop i = amt NO3 app'ed to crop i *
!WB                     DX^2 / 10000
            RNUTAM(NICR)=TMPAM(NICR)*CONFAY
!WB         NH4 applied to crop i = amt of NH4 app'ed to crop i *
!WB                     DX^2 / 10000
            RNUTP(NICR)=TMPP(NICR)*CONFAY
!WB         P applied to crop i = amt of P app'ed to crop i * DX^2 / 10000
            READ (9,6010,END=5585) NFYEAR,NFDAY,NICR,TMPNI(NICR),
   &             TMPAM(NICR),TMPP(NICR)
!WB         The END statement in the read command above says to return
!WB         control to the executable statement when the end of file record
!WB         is reached, otherwise the program will return an error message.
!WB         This one says to read all the fert app data.
              GOTO 5584
    ENDIF
C *** NRZ 9/12/94

 5585 PREMOI=0.
!WB          unknown
    PREPIV=0.
!WB     unknown

*CHOOSE THE CORRECT COVER FOR THE GIVEN DAY

     LDYEAR=YERBEG*1000+LDAY
!WB          = beginning year of sim * 1000 + the day #
             DO 5588 J=1,N
```

```
!WB          do this loop from the counter J until the number of overland
!WB                        flow elements
      K=MOD(SOIL(J),256)
!WB          K = soil - INT(SOIL / 256) * 256, this is the rotation # for
!WB                        the overland flow element
             DO 5587 J1111=3,29,2
!WB          DO 5587 J1111=3,21,2 !changed count to 29 b/c 28 rotation dates
!WB          J1111 is a count from 3 to 21 by 2
              IF(LDYEAR.LE.IROT(K,J1111)) THEN
!WB         If the LDYEAR variable is less than or equal to the end date for
!WB   cover for a specific rotation (surf. type, J1111 matrix)
               INTI=IROT(K,J1111-1)
!WB         INTI = cover for rotation at beginning of rotation period
               SUR(J)=K*256+IROT(K,J1111-1)
!WB         surf. type = rotation # of current element * 256 + cover for
!WB                        beginning of rotation period
                           DAYNOW(J)=MOD(LDYEAR,1000)
!WB         THE JULIAN DAY TODAY=LDYEAR-INT(LDYEAR/1000)*1000
                           YEARNOW(J)=INT(LDYEAR/1000)
!WB         THE YEAR NOW=INTEGER(LDYEAR/1000)
                           DYYRNOW(J)=(YEARNOW(J)*365+DAYNOW(J))
!WB         THE # OF DAYS=YEAR # * 365 (DAYS/YEAR) + DAY # NOW
                           IF (J1111.GT.3) THEN
!WB         IF THIS IS NOT THE FIRST INPUT ROTATION
                           BEGROTDT(J)=IROT(K,J1111-2)+1
!WB         THE END DATE OF THE PREVIOUS ROTATION (=BEG DATE OF THIS ROTATION)
                           DAYTHEN(J)=MOD(BEGROTDT(J),1000.)
!WB         THE DAY # AT THE BEGINNING OF THIS CROP/COVER
                           YEARTHEN(J)=INT(BEGROTDT(J)/1000.)
!WB         THE YEAR # AT THE BEGINNING OF THIS CROP/COVER
                           ELSE
                           DAYTHEN(J)=DATPLA(INTI)
                           IF (DAYNOW(J).GE.DATPLA(INTI)) THEN
                           YEARTHEN(J)=YEARNOW(J)
                           ELSE
                           YEARTHEN(J)=YEARNOW(J)-1
                           ENDIF
                           ENDIF
                           DYYRTHEN(J)=(YEARTHEN(J)*365+DAYTHEN(J))
!WB         THE # OF DAYS AT THE BEGINNING OF THIS CROP/COVER
                           DAYDIFF(J)=DYYRNOW(J)-DYYRTHEN(J)
!WB         THE DIFFERENCE IN # OF DAYS (NOW-BEGINNING DATE OF CROP/COVER)
                           IF (DAYDIFF(J).GT.10000) DAYDIFF(J)=0.
!WB         THIS MAKES MAXIMUM ROTATION LENGTH FOR A SINGLE CROP
!WB         = 27 YEARS, 145 DAYS, BUT IS INTENDED TO PREVENT AN ERROR
!WB         OCCURRING WHEN THE FIRST ROTATION PARAMETER IS READ
                           IF (DAYDIFF(J).LT.0) THEN
                           WRITE (*,2594)
                           STOP
                           ENDIF
              GOTO 5588
              ENDIF
 5587    CONTINUE

 5588  CONTINUE

             DO 6001 J=1,N
!WB          do this one from the counter J=1 to # of overland flow elements
      K=MOD(SOIL(J),256)
!WB          rotation # for current element = soil type for element i -
!WB                        INT(soil type for i / 256) * 256
             DO 6001 J1111=3,27,2
!WB     DO 6001 J1111=3,19,2 changed count to 27 to represent 28 end dates
!WB          J1111 is a count from 3 to 19 by 2
              IF(LDYEAR.EQ.(IROT(K,J1111)+1))  THEN
!WB                        if the LDYEAR formula equals 1st day of the next period
!WB                         of sim/cover
                           SUMLAI(IROT(K,J1111+1))=0.
!WB                        sum of LAI for the next (from J1111) cover/period is reset to 0
                LAI1(IROT(K,J1111+1))=0.
```

```
!WB                     LAI of the next (from J1111) cover/period = 0
                        INTI=IROT(K,J1111+1)
!WB                      initial cover = cover at next (from J1111) period
                        INTPREV=IROT(K,J1111-1)
!WB                      previous cover = cover at previous (from J1111) period
                        RES(INTI)=DMY(INTPREV)*YP(INTPREV)*CP1(INTPREV)
            1           *0.25/100.*CONFAY
!WB                     nitrogen in residue at beg of cover period =
!WB                     dry matter ratio * yield potential * exponent for nitrogen
!WB                     content * 0.25 / 100 * DX^2 / 10000
              RES20(INTI)=RES(INTI)*0.80
!WB                     = nitrogen in residue at rotation at end of period
!WB                      * 0.80
              RES90(INTI)=RES(INTI)*0.10
!WB                     = nitrogen in residue at rotation at end of period
!WB                      * 0.10
!WB           INTI=IROT(K,J1111+1)-1
!WB           RES(INTI+1)=DMY(INTI)*YP(INTI)*CP1(INTI)*0.25/100.*CONFAY
!WB           RES20(INTI+1)=RES(INTI+1)*0.80
!WB           RES90(INTI+1)=RES(INTI+1)*0.10
!WB         THE PREVIOUS 4 LINES WERE REMOVED 1/6/99 AND REPLACED BY THE LINES
!WB         ABOVE.  THEY WERE REPLACED BECAUSE WHEN THE COVER # WAS A 1, THE
!WB         INTI VARIABLE RETURNED A 0, AND THE RES VARIABLE EXCEEDED ARRAY
!WB         BOUNDARIES IN THE CALCULATION.  I BELIEVE THE COVER CHOICE TO BE
!WB         ERRONEOUS AS PREVIOUSLY WRITTEN BECUASE IT DIDN'T CALCULATE RES AT
!WB         THE PREVIOUS COVER, IT CALCULATED IT FOR CURRENT COVER # MINUS 1.
              GOTO 6002
             ENDIF
 6001    CONTINUE

 6002  J=MOD(SUR(19),256)
!WB                     J = surface type on element 19 - INT (same / 256) * 256
     JAD=MOD(LDAY,60)  !THIS LINE IS USED NOWHERE-FWB
!WB             = Day # - INT (Day # / 60) * 60
C      IF(JAD.EQ.0) WRITE(6,*) 'SIMULATING ', YERBEG,LDAY

C **** NRZ (11/4/94)
C **** NEW SCREEN OUTPUT

     CALL XDATE (LDAY,YERBEG,IDATE,SIMDUR,RAITES,NFPR)
!WB                     LDAY = day #, YERBEG = beginning year of simulation,
!WB                     IDATE = date of simulation, SIMDUR = simulation duration,
!WB                     RAITES = raintest flag, NFPR = unknown
C **** NRZ 11/4/94)

!WB         ****** BEGINNING OF NEW SEDIMENT INITIALIZATION SCHEME **********
            IF (INIT.EQ.0) THEN
!WB         THIS LOOP IS A PAGE OR SO LONG, AND THE INIT=0 VARIABLE IS INITIAL-
!WB         IZED ABOVE WITH WIDINC & DEPTHINC.  IT IS DESIGNED TO ONLY ALLOW
!WB         THE BASELINE VALUES TO INITIALIZE ONCE.
!WB         THE ROUTINE MUST BE PLACED HERE B/C IT RELIES ON CORRECT CHOICE OF
!WB         COVER CONDITIONS FOR CALCULATION OF OTHER VAR'S.
            INIT=1
!WB         The following do loop converts the soil parameters from percentage
!WB         quantities to fractional quantities.
            DO 9200 CNT=1,ISR
            CLAY(CNT)=CL(CNT)/100
            SAND(CNT)=SA(CNT)/100
            SILT(CNT)=ST(CNT)/100
            ORGMAT(CNT)=OM(CNT)/100
            MASSCF(CNT)=WCF(CNT)/100
            VFS(CNT)=VFSPER(CNT)/100
            BULKDENS(CNT)=BD(CNT)*1000
!WB         BULKDENS=SOIL BULK DENSITY IN KG*M-3
            IF ((CLAY(CNT).LT.0).OR.(SAND(CNT).LT.0).OR.(SILT(CNT).LT.0).OR.
            1(ORGMAT(CNT).LT.0).OR.(MASSCF(CNT).LT.0).OR.(BULKDENS(CNT).LT.0)
    2.OR.(VFS(CNT).LT.0))
            3 THEN
            WRITE (2,2596) CLAY(CNT),SAND(CNT),SILT(CNT),VFS(CNT),ORGMAT
            1(CNT),MASSCF(CNT),BULKDENS(CNT),CNT
```

```
      WRITE (*,2592)
      STOP
      ENDIF
      IF ((CLAY(CNT).GT.1).OR.(SAND(CNT).GT.1).OR.(SILT(CNT).GT.1).OR.
      1(ORGMAT(CNT).GT.1).OR.(MASSCF(CNT).GT.1).OR.(VFS(CNT).GT.1).OR.
   2(BULKDENS(CNT).GT.5000)) THEN
      WRITE (2,2596) CLAY(CNT),SAND(CNT),SILT(CNT),VFS(CNT),ORGMAT
      1(CNT),MASSCF(CNT),BULKDENS(CNT),CNT
      WRITE (*,2592)
      STOP
      ENDIF
 9200 END DO

      N2=NN-1
      DO 9210 CNT=1,N2
      K=SOIL(CNT)/256
!WB   THIS EXTRACTS THE SOIL TYPE
      JK=MOD(SUR(CNT),256)
!WB   jk extracts the crop descriptor #
      HYDRADOLD(CNT)=0.1
!WB   INITIALIZE A VAR HOLDER FOR HYDRAULIC RADIUS.  SEE SUB SED
      IF (CNT.GT.N) THEN
      JK=21
      NOTILL(JK)=1.
      ENDIF
      IF (SAND(K).GE.0.30) THEN
!WB   sand(K)=fraction of sand in upper soil layer, VFS = fraction of
!WB   very fine sand in upper soil layer (very fine sand in WEPP
!WB   documentation)
!WB   orgmat=fraction of organic matter in upper soil layer, clay =
!WB   fraction of clay in the upper soil layer
            IF (VFS(K).LT.0.40) THEN
            VFSCALC=0.40
            ELSE
            VFSCALC=VFS(K)
            ENDIF
            IF (ORGMAT(K).LT.0.0035) THEN
            OMCALC=0.0035
            ELSE
            OMCALC=ORGMAT(K)
        ENDIF
            KRBASE(CNT)=0.00197+0.030*VFSCALC+0.03863*
      1     exp(-184*OMCALC)
!WB   Krbase = baseline rill erodibility
            IF (CLAY(K).GE.0.40) THEN
            CLAYCALC=0.40
            ELSE
            CLAYCALC=CLAY(K)
            ENDIF
            TAUCB(CNT)=2.67+6.5*CLAYCALC-5.8*VFSCALC
!WB   taucb = baseline critical shear
      ENDIF
      IF (SAND(K).LT.0.30) THEN
            IF (CLAY(K).LT.0.10) THEN
            CLAYCALC=0.10
            ELSE
            CLAYCALC=CLAY(K)
            ENDIF
            KRBASE(CNT)=0.0069+0.134*exp(-20*CLAYCALC)
            TAUCB(CNT)=3.5
      ENDIF
      IF (KRBASE(CNT).GT.0.05) THEN
!WB   THESE ARE LIMITS SUGGESTED BY WEPP DOCUMENTATION
      WRITE (*,2598) CNT,KRBASE(CNT)
      WRITE (2,2598) CNT,KRBASE(CNT)
      KRBASE(CNT)=0.05
      PAUSE
      ENDIF
      IF (KRBASE(CNT).LT.0.002) THEN
      WRITE (*,3000) CNT,KRBASE(CNT)
```

```
        WRITE (2,3000) CNT,KRBASE(CNT)
        KRBASE(CNT)=0.002
        PAUSE
        ENDIF

        IF (TAUCB(CNT).GT.7.0) THEN
!WB     LIMITS SUGGESTED BY WEPP
        WRITE (*,3002) CNT,TAUCB(CNT)
        WRITE (2,3002) CNT,TAUCB(CNT)
        TAUCB(CNT)=7.0
        PAUSE
        ENDIF
        IF (TAUCB(CNT).LT.0.3) THEN
        WRITE (*,3004) CNT,TAUCB(CNT)
        WRITE (2,3004) CNT,TAUCB(CNT)
        TAUCB(CNT)=0.3
        PAUSE
        ENDIF

        IF (CNT.LE.N) THEN
!WB     SKIP THE RANDOM ROUGHNESS ADJUSTMENT IF ITS A CHANNEL CELL, B/C
!WB     THE RANROU IS A FUNCTION OF TILLAGE PROP'S
        IF ((RANROUM(JK).LT.0.00099).AND.(RANROUM(JK).NE.0)) THEN
!WB     'RANROU INPUT IN METERS' ERROR STATEMENT
        WRITE (2,3006) RANROUM(JK)
        WRITE (*,3006) RANROUM(JK), JK
        PAUSE
        ENDIF

        IF (RANROUM(JK).LE.0.006) RANROUM(JK)=0.006
!WB     INPUT A VALUE OF 0 FOR A PASTURE SITUATION WILL RESULT IN TAURR = 1
        TAURR(CNT)=1.0+8.0*(RANROUM(JK)-0.006)
!WB     taurr=random roughness adjustment, where ranroum = random roughness
!WB     in m
        IF (TAURR(CNT).GT.2.552) THEN
!WB     This corresponds to a random roughness in excess of 200 mm.
        WRITE (2,3008) TAURR(CNT),CNT
        WRITE (*,3008) TAURR(CNT),CNT
        PAUSE
        ENDIF
        ELSE
!WB     ELSE GOES WITH THE IF CNT.LE.N; IF ITS A CHANNEL CELL, TAURR=1
        TAURR(CNT)=1
        ENDIF
        TAUCHLD(CNT)=TAUCB(CNT)*TAURR(CNT)
!WB     tauchld(M) is a variable to "hold" the adjusted critical shear,
!WB     where taucb is calculated
!WB     above.  This doesn't incorporate the sealing and crusting factor
!WB     for the same reason given for Kradj above, both are calculated on
!WB     a day to day basis
        IF (CNT.GT.N) GO TO 9205
!WB     SKIP THE BASELINE INTERRILL ERODIBILITY CALC IF THIS IS A CHANNEL
!wb     CELL
!WB     Calculate the baseline interrill erodibility parameter, Kibase
        IF (SAND(K).GE.0.30) THEN
                IF (VFS(K).GE.0.40) THEN
                VFSCALC=0.40
                ELSE
                VFSCALC=VFS(K)
                ENDIF
                KIBASE(CNT)=2728000+19210000*VFSCALC
!WB     BASELINE INTERRILL ERODIBILITY
        ENDIF
        IF (SAND(K).LT.0.30) THEN
                IF (CLAY(K).LT.0.10) THEN
                CLAYCALC=0.10
                ELSE
                CLAYCALC=CLAY(K)
                ENDIF
                KIBASE(CNT)=6054000-5513000*CLAYCALC
```

```
        ENDIF
!WB     The adjusted interrill erodibility parameter is:
!WB     Kiadj=Kibase*Kican*Kigrcov*Kisc where Kibase = baseline interrill
!WB     erodibility, Kican = canopy height adjustment, Kigrcov = ground
!WB     ground cover adjustment, Kisc = sealing and crusting adjustment.
!WB     Because these variables are expected to change throughout the season,
!WB     they are calculated on a daily basis.

        IF (KIBASE(CNT).GE.12000000) THEN
!WB     LIMITS SUGGESTED BY WEPP
        WRITE (*,3010) CNT,KIBASE(CNT)
        WRITE (2,3010) CNT,KIBASE(CNT)
        KIBASE(CNT)=12000000
        PAUSE
        ENDIF
        IF (KIBASE(CNT).LT.500000) THEN
        WRITE (*,3012) CNT,KIBASE(CNT)
        WRITE (2,3012) CNT,KIBASE(CNT)
        KIBASE(CNT)=500000
        PAUSE
        ENDIF

 9205 CONTINUE
 9210   ENDDO
        ENDIF
!WB     END OF INIT=0 'LOOP'
!WB     ******* END OF NEW SED SUBROUTINE INITIALIZATION ***************

***********************if then loop #699************************

    IF (RAITES.EQ.1) THEN
!WB     this if then loop goes for several pages, look for program
!WB                 marker # 2610

!WB     ******* BEGIN SEDIMENT SUBROUTINE DAILY CALC'S **************

!WB     The # of days since last soil disturbance is approximated by
!WB     DAYDIFF, which is the current day - the planting day
!WB     for the crop in the current rotation.
        DO 9305 CNT=1,N2
        K=SOIL(CNT)/256
!wb     K extracts the soil type #
        JK=MOD(SUR(CNT),256)
!WB     jk extracts the crop descriptor #
        IF (CNT.GT.N) THEN
        JK=21
        NOTILL(JK)=1
        LRFAC(JK)=0.
        DDROOTI(JK)=0.
        DDRTFAC(JK)=0.
        ENDIF

        IF (CNT.LE.N) THEN
!WB     SKIP THIS SECTION IF IT'S A CHANNEL CELL
        IF (DAYDIFF(CNT).EQ.0) THEN
        IF (NOTILL(JK).EQ.0)            MAXWID=0.0000001
        ENDIF
        ENDIF
!WB     THIS SAYS THAT IF THE DAYDIFF=0,  A ROTATION HAS JUST BEEN CHANGED,
!WB     AND THEREFORE PREVIOUS RILLS HAVE BEEN DESTROYED, AND NEW RILLS
!WB     MUST BE TRACKED.

        KRCONS(CNT)=0.00035-0.0014*FCFRAC(K)+0.00068*SILT(K)
        1+0.0049*MASSCF(K)
!WB     This is a soil consolidation factor for use in the sealing and
!WB     crusting adjustment equation.
```

```
      IF (FCFRAC(K).GT.1) THEN
      WRITE (2,3014) FCFRAC(K),K
      WRITE (*,2592)
      STOP
      ENDIF
      IF ((KRCONS(CNT).LT.0.).OR.(KRCONS(CNT).GT.1.)) THEN
      WRITE (2,3016) KRCONS(CNT),CNT
      WRITE (*,2592)
      STOP
      ENDIF
      IF ((CNT.GT.N).OR.(NOTILL(JK).EQ.1)) THEN
      KRSC(CNT)=(KRCONS(CNT)/KRBASE(CNT))
      ELSE
      KRSC(CNT)=(KRCONS(CNT)/KRBASE(CNT))+(1-(KRCONS(CNT)/KRBASE(CNT)))*
      1exp(-BD(K)*DAYDIFF(CNT))
!WB   Krsc=sealing and crusting adjustment for rill erodibility.  It is
!WB   dependent upon the # of days since soil disturbance.  The quantity
!WB   (DAYDIFF(CNT)) is the # of days since planting, which will be
!WB   the last assumed day of disturbance.
      ENDIF
      IF ((KRSC(CNT).LT.0).OR.(KRSC(CNT).GT.1)) THEN
      WRITE (2,3018) KRSC(CNT),CNT
      WRITE (2,2592)
      STOP
      ENDIF
      IF ((CNT.LE.N).OR.(NOTILL(JK).EQ.0)) THEN
!WB   IF ITS A O.F. CELL OR A CONV TILLAGE, CALC BURIED RES ADJUSTMENT
      BURRES(JK)=BR(JK)*exp(-0.010181*DAYDIFF(CNT))
!WB   THIS FACTOR BASED ON THE WORK OF BROWN, FOSTER, BEASLEY, 60%
!WB   REDUCTION OVER 90 DAY PERIOD LN 0.4 / -90 = 0.010181
      KRBR(CNT)=exp(-0.4*BURRES(JK))
!WB   Krbr = adjustment for buried residue, where br(M) is the
!WB   mass of buried residue (kg m-2) w/in 0 to 0.15 m of the soil zone
      ENDIF
      IF ((CNT.GT.N).OR.(NOTILL(JK).EQ.1)) THEN
!WB   IF CHANNEL CELL OR NOTILL COVER, SET THE BURIED RESIDUE FACTOR=1.
      KRBR(CNT)=1.
      ENDIF
      IF ((KRBR(CNT).LT.0).OR.(KRBR(CNT).GT.1)) THEN
      WRITE (2,3005) KRBR(CNT)
      WRITE (*,2592)
      STOP
      ENDIF

      TAUCONS(CNT)=8.37-11.8*FCFRAC(K)-4.9*SAND(K)
!WB   This is a consolidation adjustment for the baseline critical shear.
      IF ((CNT.GT.N).OR.(NOTILL(JK).EQ.1)) THEN
      TAUSC(CNT)=(TAUCONS(CNT)/TAUCB(CNT))
      ELSE
      TAUSC(CNT)=(TAUCONS(CNT)/TAUCB(CNT))+(1-(TAUCONS(CNT)/TAUCB(CNT)))
      1*exp(-BD(K)*DAYDIFF(CNT))
!WB   tausc=sealing and crusting adjustment for critical shear.
      END IF

      TAUCADJ(CNT)=TAUCHLD(CNT)*TAUSC(CNT)
!WB   taucadj=adjusted critical shear calculated in the initialization of
!WB   the program * sealing and crusting adjustment.
  IF ((TAUCONS(CNT).LT.0.).OR.(TAUCADJ(CNT).GT.15)) THEN
      WRITE (*,3030) CNT
      WRITE (2,3030) CNT
      STOP
      ENDIF
      IF (CNT.GT.N) GO TO 9300
!WB   THIS SKIPS THE INTERRILL CALCS IF YOU ARE CALCULATING CHANNEL
!WB   EROSION.
      HEIGHT(JK)=HGTFACT(JK)*(DAYDIFF(CNT)+1)
!WB   the height at this day = the height factor * the # of days since
!WB   planting.  The daydiff +1 is added to avoid a div by 0 error below.
      CANOPY(JK)=AUCFACT(JK)*(DAYDIFF(CNT)+1)
!WB   the canopy area at this day = canopy factor * the # of days since
```

```
!WB        planting
           IF (HEIGHT(JK).GT.MAXPLHGT(JK)) HEIGHT(JK)=MAXPLHGT(JK)
           IF (CANOPY(JK).GT.(AC(JK)/100)) CANOPY(JK)=(AC(JK)/100)
     IF ((HEIGHT(JK).GT.3.0).OR.(CANOPY(JK).GT.1.)) THEN
           WRITE (*,3032) CNT
           WRITE (2,3032) CNT
           PAUSE
           ENDIF
!WB        IF THE HEIGHT EXCEEDS THE MAXIMUM PLANT HEIGHT, OR CANOPY EXCEEDS
!WB        ITS INPUT MAX VALUE, THEN
!WB        height=maximum height and canopy=maximum canopy
           IF (HEIGHT(JK).NE.0) THEN
!WB        ADDED TO ELIMINATE DIV BY 0
           KICAN(CNT)=1-2.941*(CANOPY(JK)/HEIGHT(JK))*
           1(1-exp(-0.34*HEIGHT(JK)))
!WB        Kican=canopy height adjustment factor.  CANOPY IS THE FRACTION OF
!WB        GROUND COVERED BY CANOPY AT THIS DAY, HEIGHT IS PLANT HEIGHT AT
!WB        THIS DAY.  CANOPY & HEIGHT ARE LINEAR FUNCTIONS OF THEIR MAX VALUES.
           ELSE
           KICAN(CNT)=1
           ENDIF

           IF ((KICAN(CNT).LT.0).OR.(KICAN(CNT).GT.1)) THEN
           IF (KICAN(CNT).LT.0) THEN
           WRITE (2,3034) KICAN(CNT),CNT
           WRITE (*,2592)
           STOP
           ELSE
           IF (KICAN(CNT).GT.1) THEN
           WRITE (2,3034) KICAN(CNT),CNT
           WRITE (*,3034) KICAN(CNT),CNT
           PAUSE
           ENDIF
           ENDIF
           ENDIF

           INRCOV(JK)=INRCOVI(JK)+(INRFACT(JK)*(DAYDIFF(CNT)+1))
!WB        inrcov=fraction of interrill area covered by ground cover
           IF (INRFACT(JK).GT.0) THEN
!WB        IF COVER INCREASES
           IF (INRCOV(JK).GT.INRCOVF(JK)) INRCOV(JK)=INRCOVF(JK)
!WB        IF THE CALC INT COV EXCEEDS THE FINAL VALUE INPUT, SET THEM EQUAL
           ELSE
!WB        IF COVER DECREASES
           IF (INRCOV(JK).LT.INRCOVF(JK)) INRCOV(JK)=INRCOVF(JK)
!WB        IF THE COVER DROPS BELOW THE FINAL VALUE, SET THEM EQUAL
           ENDIF
           IF (INRCOV(JK).GT.1) THEN
           INRCOV(JK)=1.
           WRITE (2,3036) INRCOV(JK),JK
           WRITE (*,2592) INRCOV(JK),JK
           PAUSE
           ENDIF

           IF (INRCOV(JK).LT.0) THEN
           WRITE (2,3049) INRCOV(JK), JK
           WRITE (*,2592)
           PAUSE
           STOP
           ENDIF


           KIGRCOV(CNT)=exp(-2.5*INRCOV(JK))
!WB        kigrcov=ground cover adjustment factor, which is a function of crop
!WB        crop properties.  Inrcov is the fraction of interrill area covered
!WB        by ground cover.
     IF ((KIGRCOV(CNT).LT.0).OR.(KIGRCOV(CNT).GT.1)) THEN
           IF (KIGRCOV(CNT).LT.0) THEN
           WRITE (2,3038) KIGRCOV(CNT),CNT
           WRITE (*,2592)
```

```
        STOP
        ELSE
        IF (KIGRCOV(CNT).GT.1) THEN
        WRITE (2,3038) KIGRCOV(CNT),CNT
        WRITE (*,3038) KIGRCOV(CNT),CNT
        PAUSE
        ENDIF
        ENDIF
        ENDIF

        KICONS(CNT)=1000*(3042-3166*SAND(K)-8816*ORGMAT(K)-2477*
        1FCFRAC(K))
!WB     Kicons=consolidation adjustment for sealing and crusting adjustment
!WB     to the interrill erodibility.
        IF (KICONS(CNT).LT.0) THEN
        WRITE (2,3040) SAND(K),ORGMAT(K),FCFRAC(K)
        WRITE (*,2592)
        STOP
        ENDIF
        IF (NOTILL(JK).EQ.1) THEN
        KISC(CNT)=(KICONS(CNT)/KIBASE(CNT))
        ELSE
        KISC(CNT)=(KICONS(CNT)/KIBASE(CNT))+(1-(KICONS(CNT)/KIBASE(CNT)))
        1*exp(-BD(K)*DAYDIFF(CNT))
!WB     Kisc=interill sealing and crusting adjustment.  DAYDIFF(CNT) is
!WB     the # of days since disturbance.
        ENDIF
        IF ((KISC(CNT).LT.0).OR.(KISC(CNT).GT.1)) THEN
        IF (KISC(CNT).LT.0) THEN
        WRITE (2,3042) KISC(CNT),CNT
        WRITE (*,2592)
        STOP
        ELSE
        IF (KISC(CNT).GT.1) THEN
        WRITE (2,3042) KISC(CNT),CNT
        WRITE (*,3042) KISC(CNT),CNT
        PAUSE
        ENDIF
        ENDIF
        ENDIF

 9300   CONTINUE
!WB     AFTER THE INCLUSION OF THE DEAD AND LIVE ROOT FACTORS FOR
!WB     RILL AND INTERRILL ERODIBILITY ADJUSTMENT, THE ADJUSTED
!WB     RILL ERODIBILITY HAD TO BE CALCULATED HERE, BECAUSE
!WB     THE LIVE AND DEAD ROOT FACTORS ARE CALCULATED HERE.
!WB     AN IF-THEN STATEMENT SKIPS THE INTERRILL ERODIBILITY ADJUSTMENT
        LROOT(JK)=LRFAC(JK)*(DAYDIFF(CNT)+1)
        IF (LROOT(JK).GT.LIVEROOT(JK)) LROOT(JK)=LIVEROOT(JK)
        KLROOTI(CNT)=EXP(-0.56*LROOT(JK))
        IF ((KLROOTI(CNT).LT.0).OR.(KLROOTI(CNT).GT.1)) THEN
        WRITE (2,3058) KLROOTI(CNT),JK,CNT
        WRITE (*,2592)
        PAUSE
        STOP
        ENDIF

        DROOT(JK)=DDROOTI(JK)+DDRTFAC(JK)*(DAYDIFF(CNT)+1)
        IF (DROOT(JK).LT.DDROOTF(JK)) THEN
        DROOT(JK)=DDROOTF(JK)
        ENDIF
        KDROOTI(CNT)=EXP(-0.56*DROOT(JK))
        IF ((KDROOTI(CNT).LT.0).OR.(KDROOTI(CNT).GT.1)) THEN
        WRITE (2,3060) KDROOTI(CNT),JK,CNT
        WRITE (*,2592)
        PAUSE
        STOP
        ENDIF

        IF (CNT.LE.N) THEN
```

```
!WB     IF IT'S AN O.F. CELL, DO THE KIADJ CALC
        KIADJ(CNT)=KIBASE(CNT)*KICAN(CNT)*KIGRCOV(CNT)*KISC(CNT)
        1*KLROOTI(CNT)*KDROOTI(CNT)
!WB     Kiadj=adjusted interrill erodibility parameter.
   IF (KIADJ(CNT).LT.0) THEN
        WRITE (2,3044) KIADJ(CNT),CNT
        WRITE (*,2592)
        STOP
        ENDIF
        ENDIF

        KLROOTR(CNT)=EXP(-3.5*LROOT(JK))
        IF ((KLROOTR(CNT).LT.0).OR.(KLROOTR(CNT).GT.1)) THEN
        WRITE (2,3054) KLROOTR(CNT),JK,CNT
        WRITE (*,2595)
        PAUSE
        STOP
        ENDIF

        KDROOTR(CNT)=EXP(-2.2*DROOT(JK))
        IF ((KDROOTR(CNT).LT.0).OR.(KDROOTR(CNT).GT.1)) THEN
        WRITE (2,3056) KDROOTR(CNT),JK,CNT
        WRITE (*,2592)
        PAUSE
        STOP
        ENDIF

        KRADJ(CNT)=KRBASE(CNT)*KRSC(CNT)*KRBR(CNT)*KLROOTR(CNT)
        1*KDROOTR(CNT)
!WB     This is the adjusted rill erodibility parameter, which is
!WB     initialized previously and recalculated here to include
!WB     consolidation with time.
   IF ((KRADJ(CNT).LT.0.).OR.(KRADJ(CNT).GT.1)) THEN
        IF (KRADJ(CNT).LT.0) THEN
        WRITE (2,3020) KRADJ(CNT),CNT
        WRITE (*,2592)
        STOP
        ELSE
        WRITE (2,3022) KRADJ(CNT),CNT
        WRITE (*,3022) KRADJ(CNT),CNT
        PAUSE
        ENDIF
        ENDIF




 9305   END DO

!WB     ******* END OF SEDIMENT SUBROUTINE DAILY CALC'S **************

!WB***************do loop # 717*************************
         DO 6000 J=1,N
!WB      do from counter J to # of overland flow elements
   K=SOIL(J)/256
!WB      soil factor for element
   PIV(J)=(1.-(ASMVOL(J)+RESWAT(K))*CU1/TP1(K))*TP1(K)/DT
!WB                Volume of air filled pore space in upper layer =
!WB        (1 - (ASMVOL(flow element)+res. water as a fraction of
!WB                soil porosity) * conversion-mm to m^3 / soil porosity )
!WB        * porosity / time increment
          ASMPER(J)=ASMVOL(J)*CU1/TP1(K)
!WB       unknown
   PREMOI=ASMPER(J)+PREMOI
!WB      unknown
   PREPIV=PREPIV+PIV(J)
!WB      unknown
```

```
 6000  CONTINUE
!WB***************end do loop # 717**********************
      PREMOI=PREMOI/N
!WB          unknown
      PREPIV=PREPIV/N
!WB          unknown
 5570 CALL RAINFA(NRG,FILTS,PP,N,CU1,CU2,CU,DT,TMIN,TMAX,KPR,NDT,
    1 ISTRUC,NMAX,ICR,NN,NCHAN)
!WB                        NRG = # of raingage, FILTS = infiltration cap., PP =
!WB                        alphanumeric unit descriptor, N = # overland flow elements,
!WB                        CU1 = conv. mm to m^3, CU2 = twice m^3, CU = mm/h to m^3 / s,
!WB                        DT = time increment, TMIN = min time value of hyetograph,
!WB                        TMAX = max time value of hyetograph, KPR = # of time
!WB                        increment routings b/t print lines, NDT = # of lines of
!WB                        hydrograph print, ISTRUC = structural practice counter
!WB                        NMAX = maximum # of cells, ICR = # of cropping practices,
!WB                        NN = N2 +1 (# of channel + # of overland flow elements + 1)
C
C **** COMPUTE THE PIECE-WISE LINEAR SEGMENTS FOR USE IN MANNING'S
C **** EQUATION.
C
     SC=((SF*CONV/SB)**.6)/300.
!WB          depth incr. for segmented curve = [[seg. factor = max projected
!WB          catchment discharge * (conv mm/h to m/s / ave. overland flow
!WB          conveyance coefficient) ] ^0.6 ] / 300
     D=0.
!WB          depth increment = 0
!WB*************************do loop # 760********************
     DO 10 I=1,300
     QA(I)=D**1.66667
!WB          incremental depth power values
  10 D=D+SC
!WB          depth = depth + segmented curve depth increment
!WB*************************end do loop # 760****************
     SC=1./SC
!WB          depth increment = inverse of depth increment

*--*
      DX2=DX*DX
!WB        = length of side * length of side
*--*
C
C **** INITIALIZE VARIABLES.
C **** SET RAINFALL INITIAL VALUES.
C
!WB*********************do loop # 778***********************
     DO 20 I=1,NRG
!WB          do from counter I = 1 to number of rain gages
     JTR(I)=1
!WB          current rainfall intensity histogram period for rain gage i
     IF (TC(I,2).EQ.TMIN) JTR(I)=2
!WB          if time of jth histogram period for gage i = min. time ,
!WB          current rainfall int. histogram period = 2
     SR(I)=0.
!WB          rainfall rate from prev. calculation
  20 NF(I)=NFI
!WB          down counter = max # of time increments b/t infiltration recalculations
!WB*********************end do loop # 778********************
     N1=N+1
!WB          N1 = number of elements + 1
     N2=NN-1
!WB          reset N2 to # overland flow + # channel elements
     CHN=N2-N
!WB           # channel seg's = above - # of o.f. elements
C
C **** EROSION CONSTANTS.
C
     IF (IT.LE.0) GO TO 30
!WB          unknown
C
```

```
C **** METRIC UNITS.
C

!WB                  These can all be removed, 9/29/98

* CE1 and CE2 were not corrected because they are not
* used anymore
!     CE1=9.66155E+5
!     CE2=2.0847E+1
!     CE3=6.53864E+6
*these correction are made according to the Wisconsin
*department of Natural resources, EPA final report (1986)

!WB                  This can be removed also, 9/29/98

C **** NRZ 8/5/95
C **** CE3 was divided by 20. in order to examine difference in sediment
C **** output.

!     CE3=CE3/20.

!     CE4=5.25545E+1
!     CE4=CE4
!     CE5=7.7419E-4
      CE6=1.E+3
C
C **** INITIALIZE VALUES.
C
C **** NRZ 9/14/94
C **** ADD DIMENSIONS FOR MULTIPLE CHANNEL OUTLETS

!WB******************do loop # 836*********************
   30 DO 25 NCH=1,NCHAN+1
!WB    NCH is a channel counter, do from that until you equal the # of
!WB         channels + 1
            VOL(NCH)=0.
!WB         accumulated runoff depth
            SSI(1,NCH)=0.
!WB         accumulated loss at print line i
            PSSI(1,NCH)=0.0
!WB         accumulated sediment bound P-loss, line i for a given storm
            SPSSI(1,NCH)=0.
!WB         accum dissolved P loss
            ANSSI(1,NCH)=0.
!WB         accum sed-bound ammonium loss
            ANH4SI(1,NCH)=0.
!WB         accum dissolved ammonium loss
            ONSSI(1,NCH)=0.
!WB         accum sed. bound TKN loss
            ANO3SI(1,NCH)=0.
!WB         accum dissolved nitrate loss
            SSCON(1,NCH)=0.
!WB         sed conc at print line i
            RW(1,NCH)=0.
!WB         average rainfall intensity over catchment
            Q1(1,NCH)=0.
!WB         discharge from catchment at i
   25 CONTINUE
!WB*************************end do loop # 836**********************
      SDR=0.
!WB         accum groundwater storage
      CHDR=0.
!WB         groundwater discharge into a channel segment
      RMAX=0.
!WB         MAX RAINFALL INTENSITY?
      QMAX=0.
!WB         MAX FLOW?
      CMAX=0.
!WB         MAX SEDIMENT?
      PREC=0.
```

```
!WB         accum depth of precip
    DTM=DT/60.
!WB         sim. time increment in minutes
    T(1)=TMIN
!WB         = min time value on hyetograph

C **** NRZ 9/14/94

C
C .... INITILIZATION OF DATA EXTENDED SED SUBROUTINE
C
    ERG=0.
!WB         sum of all particle size classes leaving watershed
!WB********************do loop # 888*********************
    DO 31 I1=1,8
!WB         do this for the number of particle size classes?
  31 ER(I1)=0.
!WB    amount of particle type i leaving watershed
!WB********************end do loop # 888*****************
    YALCON=0.635
!WB         Yalin's constant = 0.635

*
* INITIALIZE VARIABLES FOR THE PHOSHORUS COMPONENT
*
*
    TESPLA=0.
!WB         unknown
    TESNH4=0.
!WB         unknown
    TESNO3=0.
!WB         unknown
!WB********************do loop # 907************************
    DO 32 M=1,N
!WB         do from element # counter, M, to the # of overland flow elements
     ISOIL= SOIL(M)/256
!WB          ISOIL = soil type of element M - INT (same / 256) * 256

            PSSA=P0SOIL(M)/SSAT(ISOIL)
!WB         ? = original P mass? / total specific surface area
*
* AMMONIUM AND ORGANIC N SEDIMENT BOUND ORIGINAL CONCENTRATION
*A0SOIL IS EXPRESSED IN KG
            ANPSSA=A0SOIL(M)/SSAT(ISOIL)
!WB         = sed. bound ammonium soil conc. ?
            ONPSSA=O0SOIL(M)/SSAT(ISOIL)
!WB         = sed. bound org-N conc. ?

!WB*******************do loop # 923*************************
            DO 33 IC=1,NPART
!WB         do from counter NC = 1 to # of particle size classes
            P0(M,IC)=SSA(ISOIL,IC)*PSSA/F(ISOIL,IC)
!WB         unknown
            AN0(M,IC)=SSA(ISOIL,IC)*ANPSSA/F(ISOIL,IC)
!WB         unknown
            ON0(M,IC)=SSA(ISOIL,IC)*ONPSSA/F(ISOIL,IC)
!WB         unknown
            ERP(IC)=0.
!WB         unknown
            STOLD(M,IC)=0.
!WB         SEDIMENT STORAGE AT PREVIOUS TIME STEP
            STNEW(IC)=0.
!WB         SEDIMENT STORAGE AT THIS TIME STEP

** NRZ 9/23/94
** CORRECTION
** ADD ONPT AND ONI TO THESE INITIALIZATIONS


            ANPT(M,IC)=0.
```

```
!WB         unknown
            PPT(M,IC)=0.
!WB         unknown
            ONPT(M,IC)=0.
!WB         unknown


            ANI(M,IC)=0.
!WB         unknown
            PI(M,IC)=0.
!WB         unknown
            ONI(M,IC)=0.
!WB         unknown

** NRZ 9/23/94

  33     CONTINUE
!WB***********************end do loop # 923***************
            T12=0.0
            T13(M)=0.0

    KK=SOIL(M)/256
!WB         soil type of current element =

    rbit0(m)=0.
!WB         unknown
    tpon(m)=0.
!WB         equiv. time to ponding, time to infiltrate cum. ponding under
!WB         ponded conditions
    timpon(m)=0.
!WB         time to ponding (min)
    testi(m)=0.
!WB         flag indicating ponding
    TESPLA=EDILAB(M)+TESPLA
!WB         ? = labile P in the EDI + ?
    TESNH4=EDINH4(M)+TESNH4
!WB         ? = NH4 in the EDI + ?
    TESNO3=TESNO3+EDINO3(M)
!WB    ? = NO3 in the EDI + ?


 32    CONTINUE
!WB**********************end do loop # 907***********************
           TESPLA=TESPLA/N
!WB         ? = ? / # of overland flow elements
           TESNO3=TESNO3/N
!WB         ? = ? / # of overland flow elements
           TESNH4=TESNH4/N
!WB         ? = ? / # of overland flow elements

C
C
C
C **** START COMPUTATION FOR EACH HYDROGRAPH PRINT LINE AT DT*KPR.
!WB ***DT = time incr, KPR = # of time increment routings b/t print lines
C
***************************do loop 972***************************
    DO 220 L=2,NDT
!WB         do from counter L = 2 to # of lines of hydrograph print
    LM1=L-1
!WB         unknown
    T(L)=T(LM1)
!WB         real time at counter = time at L-1
C
C **** CONTINUITY EQUATION FOR TIME INCREMENTS DT.
C
***************************do loop 982***************************
    DO 170 J=1,KPR
!WB         do from J = 1 to # of time increment routings b/t print lines
```

```
C *** NRZ 9/15/94
C *** MODIFY ELEMENTS OF PI AND SI TO REPRESENT MULTIPLE OUTLETS
*************************do loop #988****************************
    DO 37 NCH=1,NCHAN+1
!WB         do from NCH counter to # of channels + 1

    SPT(NCH)=0.
!WB         accum sed. loss at previous time
*
* PSPT ACCUMULATED SEDIMENT-BOUND PHOSPHORUS LOSS
    PSPT(NCH)=0.
    DO 35 IC=1,NPART
    PSPT(NCH)=PSPT(NCH)+PI(CHOUT(NCH),IC)
!WB         ? = ? + inflow of P
  35 SPT(NCH)=SPT(NCH)+SI(CHOUT(NCH),IC)
!WB    accum sed loss previous time = same + sed. inflow
  37 CONTINUE
***************************end do loop #988******************************
C *** NRZ 9/15/94

    T(L)=T(L)+DTM
!WB         time = time + time increment in minutes
C
C **** CALCULATE NET RAINFALL FOR EACH GAGE AND SURFACE CONDITION AND
C **** UPDATE INFILTRATION CAPACITIES WITHIN GAGE AREA ON TIME OR NET
C **** RAINFALL CHANGE.
C
***************************do loop 1014***************************
    DO 90 JJ=1,NRG
!WB         do from counter JJ = 1 to # of rain gages
    NF(JJ)=NF(JJ)-1
!WB         down counter from NFI = max # of time increments b/t infil.
!WB         recalc.'s
    ITR=JTR(JJ)
!WB         rainfall histogram counter = current rainfall intensity histogram
!WB         for rain gage i
    ITRM1=ITR-1
    IF (T(L)-TC(JJ,ITR)) 60,60,40
!WB         if time - jth time of rain gage i is < = > 0,
!WB         then go to 60, 60, 40, respectively
  40 IF (T(L)-TMAX) 50,230,230
!WB         if time - max time in hyetograph < = > 0, then go
!WB         to 50, 230, 230, respectively.
C
C **** NEW RAINFALL RATE, ALLOW FOR DTM BRIDGING TC VALUE.
C
  50 DI=T(L)-TC(JJ,ITR)
!WB          = sim time - rainfall histogram change time
    ITRP1=ITR+1
!WB         RAINFALL HIST CNTER PLUS 1 = RAINFALL HIST CNTR + 1
    RATE(JJ)=CU*(RC(JJ,ITRP1)*DI+RC(JJ,ITR)*(DTM-DI))/DTM
!WB                     gage rainfall rate at gage i = conv mm/h to m^3/s *
!WB                     (rainfall intensity * time increment + prev rainfall
!WB                     intensity * (sim time increment - histogram change time))
!WB                      / sim time increment
    JTR(JJ)=JTR(JJ)+1
!WB         current rainfall intensity histogram period for rain gage i =
!WB         same + 1
    ITR=ITRP1
!WB         rainfall histogram counter = SAME + 1
C
C **** ADD WHOLE HISTOGRAM BLOCK TO TOTAL PRECIPITATION IN
C **** PROPORTION TO WATERSHED AREA COVERED.
C
    PREC=PREC+RC(JJ,ITR)*(TC(JJ,ITR)-TC(JJ,ITR-1))*FRA(JJ)/60.
!WB         accum depth of precip = same + rainfall intensity *
!WB          (time of jth histogram for period i - same, prev period) *
!WB         fraction of catchment area covered by i / 60
C
C **** CALCULATE NET RAINFALL FOR EACH COVER.
```

```
C
************************do loop #1058**************************************
  60 DO 70 I=1,ICR
!WB         do from counter I = 1 to # of cropping practices
    R(JJ,I)=RAIN(RATE(JJ),PIT(JJ,I),PER(I))
!WB         Net rainfall rate, gage i, surface j = effective rainfall
!WB         rate (rate, interception storage, fraction of area covered
!WB         by foliage for surface type i)
    IF (R(JJ,I).EQ.SR(JJ).AND.NF(JJ).GT.0) GO TO 70
!WB         if net rate = previous rate & down counter > 0
    SR(JJ)=R(JJ,I)
!WB         prev rate = net rate
    NF(JJ)=-NFI
!WB         down counter = - max of time increments b/t infil recalc.'s
  70 CONTINUE
*************************end do loop #1058********************************
    RATE(JJ)=RC(JJ,ITR)*CU
!WB         gage rate = intensity * conversion
    IF (NF(JJ).GT.0) GO TO 90
!WB         if downcounter > 0, go to 90
C
C **** CALCULATION OF INFILTRATION CAPACITY FOR EACH OVERLAND ELEMENT.
C
****************************do loop #1080**********************************
    DO 80 M=1,N
!WB         do from overland flow element counter M = 1 to # of overland
!WB         flow elements
    IF (MOD(RANE(M),256).NE.JJ) GO TO 80
!WB          (# of rain gage applicable to i - INT (same / 256) * 256)
!WB         NE raingage # counter
    K=MOD(SUR(M),256)
!WB          K=COVER?
!WB         INT(same/256)*256
    KK=SOIL(M)/256
!WB         soil type of i = soil type of i / 256
    FILTS(M)=FILT(PIV(M),FCAP1(KK),GWC(KK),DR(M),S(M),R(JJ,K)
   1,CU2,ROUGH(K),HU(K),NEXP,ASMPER(M),KE(KK,K),PSIF(KK),PHIC(KK),T(L)
   1,CU,LF(KK),KS(KK),K,kk,M,CUMIN1(M),rbit0(m),testi(m),timpon(m),
   & TPON(M),FILTS(M),DT,CU1,TP1(KK),A(KK))
!WB         FILTS = infil cap of element M, PIV = vol of air filled pore
!WB         space, FCAP1 = field cap as fraction of pore space?, GWC = vol
!WB         of air filled pore space at field cap., DR = vert. drain loss,
!WB         S = storage at start of incr. i, R = net rainfall rate, CU2 =
!WB         conv, ROUGH = surf. storage depth param for i, HU = max ht diff
!WB         on soil surface, NEXP = ?, ASMPER = ?, KE = eff. hydr.
!WB         conductivity, PSIF = cap. pot. at infil. wetting front, PHIC =
!WB         corrected effective porosity, T = real time, CU = conversion,
!WB         LF = depth to wetting front, KS = sat hyd conductivity,
!WB         K = counter?variable?, kk = soil type, M = element no., CUMIN1 =
!WB         cum. infiltration, rbit = ?, testi = ponding flag,
!WB         timpon = time to ponding, TPON = equil. time to ponding, FILTS =
!WB         infil cap, DT = sim time incr (sec), CU1 = conversion, TP1 =
!WB         porosity, A = ratio of sat. hydr. cond top layer & sat. hyd.
!WB         cond. for underlying soil
  80 CONTINUE
*************************end do loop #1080*****************************
    NF(JJ)=NFI
!WB         down counter = max # of time increments
  90 CONTINUE
****************************end do loop 1014**************************
C
C **** CONTINUITY EQUATION EXPLICIT SOLUTION FOR EACH ELEMENT DURING
C **** TIME INCREMENT, DT.
C
****************************do loop # 1121****************************
    DO 170 M=1,N2
!WB          # of overland flow + channel elements
    SSTOR=S(M)+SS(M)
!WB         storage on element at end of time inc = storage at start +
!WB         incremental increase in storage
```

```
      IF (SSTOR.LT.0.) SSTOR=0.
!WB           avail. supply for infil. < 0

     IF (M.GT.N) GO TO 100
!WB          if element counter greater than # of overland flow elements
C
C **** OVERLAND ELEMENT.
C
     I=MOD(RANE(M),256)
!WB           = # of rain gage applicable to i - INT(same/256) * 256
     K=MOD(SUR(M),256)
!WB           = surface type on element i - INT(same/256) * 256
     KK=SOIL(M)/256
!WB          soil type of i = soil type of i / 256
     SUPP=.5*SSTOR+QI(M)+R(I,K)
!WB          avail. supply for infil = = 0.5*(end stor + inflow + net rainfall)

     FIL=FILTS(M)
!WB          infil = infil cap
     IF (FIL.GT.SUPP) FIL=SUPP
!WB          if infil > supply, then set them equal
     IF(FIL.LT.0) FIL=0.0
!WB          if infil < 0, then set infil = 0
      if (dr(m).lt.0.) dr(m)=0.
!WB           if vert. drain<0, then set = 0
      CUMIN1(M)=CUMIN1(M)+(FIL/CU)*(DT/3600.)
!WB           cum infil = same + (infil/conv) * (time inc / 3600(sec / hr?))
     CNO3(M)=CNO3(M)+(DR(M)/CU)*(DT/3600)
!WB          accum perc during infil = same + (vert drain / conv) *
!WB           ( time inc / 3600)
     PIV(M)=PIV(M)+DR(M)-FIL
!WB          vol airspace = same + vert drain - infil
     SDR=SDR+DR(M)
!WB          accum ground H2O storage = accum groun H2O storage + vert drain
     FLIN=QI(M)+R(I,K)-FIL
!WB          net rate of flow into an element less losses = inflow + net
!WB          rainfall - infil
     GO TO 110
C
C **** CHANNEL ELEMENT.
C
  100 K=21
     FLIN=QI(M)+CHDR+DIN(M)
!WB          net rate of flow into an element less losses = inflow + ground
!WB          water discharge + accum tile drainage rate
C
C **** COMBINE INITIAL INFLOW, OUTFLOW AND STORAGE WITH ACCUMULATED
C **** INFLOW.
C
  110 FHS=FLINS(M)+FLIN
!WB          FHS = (storage, inflow + outflow) + net rate of flow into a
!WB          channel element (less losses)
     IF (SSTOR.GT.DIR(K)) GO TO 130
!WB          storage on element at end of time increment > ret. depth
C
C **** NO RUNOFF FROM ELEMENT.
C
  120 S(M)=FHS
!WB          storage = combined water
     SS(M)=0.
!WB          incremental increase in storage = 0
     FLINS(M)=FLIN+FHS
!WB          storage, inflow, and outflow = net inflow rate + total from above
     IF (Q(M).EQ.0.) GO TO 170
!WB          if outflow > 0
     D=-Q(M)
!WB          depth increment in seg. curve = - outflow
     Q(M)=0.
!WB          outflow = 0
     GO TO 150
```

```
C
C **** DIRECT SOLUTION OF CONTINUITY EQUATION BY LINEARIZATION.
C
 130 Y=SC*(SSTOR-DIR(K))
!WB        seg. number on depth value = depth inc. on seg.
!WB        curve*(storage at end of time increment - ret. depth)
   IY=Y+1.
!WB        seg # on discharge curve
   IF (IY.LT.300) GO TO 140
!WB        this and next 2 lines are the formulation of an error
   WRITE (2,330) M
   STOP
 140 Y=IY-1
!WB        Y = incremented Y -1

   IF (M.GT.N) THEN
           CHWID=CWID(M)+WIDINC(M)
!WB        THE CHANNEL WIDTH IS EQUAL TO ORIGINAL WIDTH + ANY WIDTH INCREASE THAT OCCURS
!WB        DURING SIMULATION.  SEE SUBROUTINE SED FOR INFO ON THIS VARIABLE
!WB        THE CHWID VARIABLE IS ONLY USED HERE AND THEREFORE ISN'T DECLARED IN
!WB        THE COMMON BLOCKS
           B(M)=CONSTHLD(M)/MNCHNTOT(M)/XHOLD(M)*(DX/CHWID/XHOLD(M))**0.6667
           1*DSQRT(SL(M))
!WB        ADJUST CHANNEL CONVEYANCE TO ACCOMODATE CHANNEL WIDENING
           ENDIF

   QL=B(M)*QA(IY)
!WB        discharge at lower end of seg IY on discharge curve =
!WB        conveyance in Manning's eqn * incr. depth power value
   QD=B(M)*(QA(IY+1)-QA(IY))
!WB        differential = conveyance (difference)
   SSTOR=(FHS-QL+QD*(Y+DIR(K)*SC))/(1.+QD*SC)
!WB    storage = (combined water - curve lower discharge +
!WB        discharge differential*(seg. # + ret. depth for crop practice i
!WB         * depth incr) / (1+discharge differential*depth incr)
            IF (SSTOR.LE.DIR(K)) GO TO 120
!WB         if storage at end of time increment < ret. depth
   Q2=QL+QD*((SSTOR-DIR(K))*SC-Y)
!WB        outflow at end of time increment = discharge at lower end +
!WB        differential ((storage - ret) * depth incr. - seg. depth)
   D=Q2-Q(M)
!WB        depth increment in seg. depth curve = outflow from at end of
!WB        time increment - outflow in segment
   Q(M)=Q2
!WB        set em equal
   SS(M)=SSTOR-S(M)
!WB        increase in storage = storage - storage at start
   S(M)=SSTOR
!WB        reset storage at beginning equal to storage at end of increment
   FLINS(M)=FLIN+SSTOR-Q2
!WB        storage, inflow + outflow = net inflow less losses + storage -
!WB        outflow at end of time incre
C
C.....SEDIMENT CALCULATION.....
C
 150 IF (M.LE.N) GO TO 156
!WB        if element # less than # of overland flow elements, JUMP DOWN TO
!WB        DO O.F. CALCULATIONS
C
C......COMPUTE TRANSPORT/DEPOSITION FOR CHANNEL FLOW
C
           KK=SOIL(M)/256
!WB        ADDED FOR PROPER SELECTION OF CHANNEL SOIL TYPE
           CALL SED(CWID(M),0.,DT,0.,M,N,KK,DX,N2)
!WB        calculate sediment movement in channel, JUMP DOWN TO THE NEXT
!WB        CALL SED STATMENT FOR DEFINITIONS OF WHAT'S BEING PASSED.
   CALL PBOUND(NPART,M)
   CALL SOLUBP(DX2,KK,M,I,K,DT,T12,L,T11,SSTOR,FIL,SE,N
  & ,CUMIN1,CU,NPART)
   CALL AMMON(NPART,M)
```

```
    CALL WATNH(SSTOR,FIL,M,DT,N,CUMIN1,CU,KK,NPART)
    CALL NO3Z(SSTOR,FIL,M,DT,N,CUMIN1,CU)
    CALL ORGN(NPART,M)

    DO 151 IC=1,NPART
!WB         do from this counter to the # of particles
    SI(M,IC)=0.0
!WB         set sediment inflow back to 0
 151  CONTINUE
C
C......REMEMBER ALL CHANNEL FLOW MOVES WITH ITS "COLUMN" DESIGNATOR
C
    K=NC(M)
!WB         set K = # of element receiving outflow from element i in a
!WB         column direction
    QI(K)=QI(K)+D
!WB         inflow = inflow + depth increment

    SPI(K)=SPI(K)+SP2(M)
!WB         inflow of dissolved P = same + outflow

    AINH4(K)=AINH4(K)+OUTNH4(M)
!WB         inflow of dissolved NH4 = same + outflow of dissolved NH4
    AINO3(K)=AINO3(K)+OUTNO3(M)
!WB         inflow of nitrate = same + outflow of NO3
********************************do loop #1276************************
            DO 152 IC=1,NPART
!WB         do from counter IC=1 to # of particles
            PI(K,IC)=PI(K,IC)+PE(IC)
!WB         inflow of sed. bound P = same + outflow
            ANI(K,IC)=ANI(K,IC)+ANE(IC)
!WB          ?
            ONI(K,IC)=ONI(K,IC)+ONE(IC)
!WB     ?
            SI(K,IC)=SI(K,IC)+SE(IC)
!WB         rate of sed. inflow = inflow + outflow


  152 CONTINUE
********************************end do loop #1276*******************
    IF(M.NE.N2) GO TO 170
!WB         if element counter # does not equal total # of elements + channels
********************************do loop #1293**************************
    DO 154 IC=1,NPART
!WB         do from counter IC=1 to # of particles
            ER(IC)=ER(IC)+SE(IC)
!WB         amt of particle size i leaving watershed = same + movement from
!WB         element
  154 CONTINUE
********************************end do loop #1293**********************
    GO TO 170
C
C.....COMPUTE TRANSPORT/DEPOSITION FOR OVERLAND FLOW
C
  156 CONTINUE
    CALL SED(DX,R(I,K),DT,DIR(K),M,N,KK,DX,N2)
!WB                     DX = cell width, R = net rainfall, DT=TIME INCREMENT,
!WB           DIR= ret. depth, M = element counter, N = # of overland flow
!WB           elements, KK = soil type for current element, DX = cell width
!WB                     N2=# OF O.F. + CHANNEL CELLS
            CALL PBOUND(NPART,M)
    CALL SOLUBP(DX2,KK,M,I,K,DT,T12,L,T11,SSTOR,FIL,SE,N
   & ,CUMIN1,CU,NPART)
    CALL AMMON(NPART,M)
    CALL WATNH(SSTOR,FIL,M,DT,N,CUMIN1,CU,KK,NPART)
    CALL NO3Z(SSTOR,FIL,M,DT,N,CUMIN1,CU)
    CALL ORGN(NPART,M)

********************************do loop #1319**************************
    DO 157 IC=1,NPART
```

```
!WB         do from counter IC = 1 to # of particles
    SI(M,IC)=0.
!WB         sediment inflow = 0
 157  CONTINUE
******************************** end do loop #1319*********************
C
C......PROPORTION OUTFLOW AND SEDIMENT TO DOWNSLOPE ADJACENT ROW
C............AND COLUMN ELEMENTS.....
C
    IF(M.LT.N2) GO TO 160
!WB         if el # < # overland flow + channel elements
********************************do loop #1332**************************
    DO 158 IC=1,NPART
!WB         do from counter IC =1 to # of particles
            ER(IC)=ER(IC)+SE(IC)
!WB         amt of part. type i leaving watershed = same + sed. exiting
!WB         the element
  158 CONTINUE
****************************end do loop #1332*************************
  160 CONTINUE

    DRA=D*RFL(M)
!WB         incremental increase in outflow = depth increment * fraction
!WB         of discharge in row dir
    I=NR(M)
!WB          # of element receiving outflow from element I in row dir.
    K=NC(M)
!WB          # of element receiving outflow from element I in col. dir.
    QI(I)=QI(I)+DRA
!WB         inflow to row element i = same + incremental increase in outflow

    QI(K)=QI(K)+D-DRA
!WB         inflow to column element i = same + depth increment - increase
!WB         in outflow, row direction

    PSIRA=SP2(M)*RFL(M)
!WB          = outflow of dissol. P * fraction of discharge from element
!WB          flowing in row direction
    SPI(I)=SPI(I)+PSIRA
!WB          inflow of dissolved P from adjacent cells (row dir) = same +
!WB          above
    SPI(K)=SPI(K)+SP2(M)-PSIRA
!WB          inflow of dissol P (column dir) = same + outflow dissolv P -
!WB          fraction in row dir

    AINH4(I)=AINH4(I)+OUTNH4(M)*RFL(M)
!WB         inflow dissol NH4 (row dir) = same + outflow from M * fraction
!WB         of discharge
    AINH4(K)=AINH4(K)+OUTNH4(M)-OUTNH4(M)*RFL(M)
!WB         inflow diss NH4 (col dir) = same + outflow col dir -
!WB         outflow col dir * fraction

    AINO3(I)=AINO3(I)+OUTNO3(M)*RFL(M)
!WB         inflow dissol NO3 (row dir) = same + outflow * rel fraction
    AINO3(K)=AINO3(K)+OUTNO3(M)-OUTNO3(M)*RFL(M)
!WB         inflow dissol NO3 (col dir) = same + outflow - outflow * rel fract
********************************do loop #1380**************************
    DO 162 IC=1,NPART
!WB         do this loop from counter IC=1 to # of particle size classes
C *** NRZ
C *** CHANNEL CORRECTION
            PRA=PE(IC)*RFL(M)
!WB          = outflow of sed. bound P * fraction of discharge from el
!WB         flowing in row dir
            ANRA=ANE(IC)*RFL(M)
!WB          = outflow of sed. bound NH4 for particle class i * fraction
!WB         of discharge
            ONRA=ONE(IC)*RFL(M)
!WB          = outflow of sed. bound org. N * fractional flow discharge
!WB         in row dir
```

```
          SRA=SE(IC)*RFL(M)
!WB        portion of sed. leaving and flowing in row dir = sed. exiting *
!WB        flow in row dir

          PI(I,IC)=PI(I,IC)+PRA
!WB        = inflow of sed bound P (row, part. size class) + above
          PI(K,IC)=PI(K,IC)+PE(IC)-PRA
!WB        = inflow of sed bound P (col, part. size class) + above

          ANI(I,IC)=ANI(I,IC)+ANRA
!WB       see above
          ANI(K,IC)=ANI(K,IC)+ANE(IC)-ANRA
!WB       see above

          ONI(I,IC)=ONI(I,IC)+ONRA
!WB       see above
          ONI(K,IC)=ONI(K,IC)+ONE(IC)-ONRA
!WB       see above

          SI(I,IC)=SI(I,IC)+SRA
!WB       see above
          SI(K,IC)=SI(K,IC)+SE(IC)-SRA
!WB       see above
  162 CONTINUE
***************************end do loop #1380***************************
C *** NRZ END
  170  CONTINUE
***************************end do loop 982***************************
***************************end do loop 1121***************************

    IF (CHN.LT.1..OR.SDR.EQ.0.) GO TO 180
!WB       if # of channel seg's < 1 or accum groundH2O storage = 0
C
C **** CALCULATE TILE DRAINAGE AND GROUNDWATER CONTRIBUTION.
C
    XPR=KPR
!WB        = # of time increment routings b/t print lines
    CALL DRAIN (DR,DC,DIN,N,N1,N2,STD,TIAL,RFL,NR,NC)
!WB       DR = vert. drain loss, DC = tile drain. coeff, DIN = accum
!WB       tile drain, N = # overland flow el's, N1 = N + 1, N2 = # overland
!WB       flow + # channel el's, STD = total inflow to tile lines, TIAL =
!WB       flag, RFL = fraction of discharge in row dir, NR = # el receiving
!WB       flow in row dir, NC = # el receiving flow in col dir

    SDR=SDR-STD*XPR
!WB       groundwater storage = same - total inflow * # time increment
!WB       routings
    CHDR=SDR*GRF/XPR/CHN
!WB       groundH2O discharge into element = groundwater storage *
!WB       fractional rate of baseflow release / XPR / # of channel segments
    SDR=SDR*(1.-GRF)
!WB       groundwater storage = same * (1 - release fraction)

C
C **** OUTPUT PRINT SECTION.
C **** NRZ 9/14/94
C **** ADD EXTRA DIMENSION TO KEEP TRACK OF EACH CHANNEL OUTLET
C 180 Q1(L)=QI(NN)/CONV
****************************do loop #1453***************************
  180 DO 219 NCH=1,NCHAN+1
!WB       do from channel counter NCH = 1 to # of channels + 1
          Q1(L,NCH)=QI(CHOUT(NCH))/CONV
!WB       discharge from catchment at ith hydrograph line = inflow
!WB       to el i / catchment conversion
          SIG(NCH)=0.
!WB       sum of sediment inflow values for all particle size clases

C *** NRZ
C *** CHANNEL ADDITION
```

```
C *** ACCUMULATE KG OF SEDIMENT FOR EACH PARTICLE CLASS
****************************do loop #1465**************************
          DO 185 IC=1,NPART
!WB       do from counter IC=1 to # of particle size classes
      SEDG(NCH,IC)=0.
!WB                 sed of particle class i draining from a channel for a
!WB                 given print line
      SIG(NCH)=SIG(NCH)+SI(CHOUT(NCH),IC)
!WB                 sum of sediment for all particle size classes = same +
!WB                 sed inflow (channel outlet cell, particle size class)
      SEDG(NCH,IC)=SEDG(NCH,IC)+SI(CHOUT(NCH),IC)
!WB                 sed drainage = same + sed. inflow (channel outlet cell,
!WB                 part size class)
 185  CONTINUE
************************end do loop #1465**************************
****************************do loop #1479**************************
     DO 187 IC=1,NPART
!WB        do from counter IC=1 to # of particle size classes
      SEDH(NCH,L,IC)=SEDG(NCH,IC)*DT
!WB                 sed from catchment of particle class i at hydrograph line
!WB                 L = channel out * time increment
!WB                 SEDH IS USED FOR THE IMPOUNDMENT MODEL
 187  CONTINUE
************************end do loop #1479**************************
C *** NRZ END

          SSI(L,NCH)=SIG(NCH)*DT
!WB       accum sed out of catchment for a given storm = sum of all sed
!WB       size classes * time increment
          QHYP(L,NCH)=QI(CHOUT(NCH))*DT
!WB       FLOW RATE USED IN HYDROGRAPH PLOTTING OF NUTRIENT VARIABLES QI (M3/S) * DT (S)=M3
          IF (QI(CHOUT(NCH)).GT.0.) GO TO 190
!WB       if discharge from catchment > 0 , then
          SSCON(L,NCH)=0.
!WB       sed conc at print line L of hydrograph for outlet i = 0
          GO TO 200
 190  SSCON(L,NCH)=(SIG(NCH)-SPT(NCH))/(SIG(NCH)-SPT(NCH)+
   &        QI(CHOUT(NCH))*CE6)*1000000.
!WB                 sed. conc at print line L of hydrograph for outlet i =
!WB                 (sed accum - sed accum prev time step + Qinflow)*CE6)*1000000
 200  IF (Q1(L,NCH).GT.QMAX) QMAX=Q1(L,NCH)
!WB        if flow out of catchment > qmax, qmax = outflow
          IF (SSCON(L,NCH).GT.CMAX) CMAX=SSCON(L,NCH)
!WB       if sed conc > ?max
          VOL(NCH)=VOL(NCH)+Q1(L,NCH)
!WB       runoff depth for outlet i = same + flow out
          RW(L,NCH)=0.
!WB       average rainfall intensity = 0
****************************do loop #1509**************************
          DO 210 I=1,NRG
!WB       do from counter I = 1 to # of rain gages
           J=JTR(I)
!WB        current rainfall intensity histogram period for rain gage
 210    RW(L,NCH)=RW(L,NCH)+RC(I,J)*FRA(I)
!WB          ave rainfall intensity = same + rainfall intensity for
!WB                 gage i * fraction of catchment covered by gage
************************end do loop #1509**************************
          IF (RW(L,NCH).GT.RMAX) RMAX=RW(L,NCH)
!WB       if ave intensity > rmax, rmax = ave intensity

*
*DETERMINE PHOSPHORUS OUTPUT
*

     PSIG(NCH)=0.
!WB       accum sed bound P loss for all particle size classes draining
!WB       to outlet i = 0

** NRZ (8/31/94)
** ACCUMULATE KG OF SEDIMENT BOUND P FOR EACH PARTICLE CLASS
```

```
*****************************do loop #1531***************************
    DO 215 IC=1,NPART
!WB         do from counter IC = 1 to # of particle size classes
      PSEDG(NCH,IC)=0.
!WB           sed bound P from channel = 0
      PSIG(NCH)=PSIG(NCH)+PI(CHOUT(NCH),IC)
!WB           sum of sed bound P to outlet = same + inflow of sed. bound
!WB           P from adj cells
      PSEDG(NCH,IC)=PSEDG(NCH,IC)+PI(CHOUT(NCH),IC)
!WB           sed bound P from channel = same + inflow from channel out
 215  CONTINUE
*************************end do loop #1531***************************
*****************************do loop #1543***************************
    DO 216 IC=1,NPART
!WB         do from counter IC = 1 to # of particle size classes
     PSEDH(NCH,L,IC)=PSEDG(NCH,IC)*DT*1000.
!WB          sed bound P leaving catchment = sed bound P leaving channel *
!WB          time incr * 1000
 216  CONTINUE
*************************end do loop #1543***************************
** NRZ (8/31/94)

    PSSI(L,NCH)=PSIG(NCH)*DT*1.E+3
!WB         sum of sed. bound P loss from catchment = sum of sed bound P
!WB         draining to outlet * time inc * 1000
    SPSSI(L,NCH)=SPI(CHOUT(NCH))*DT*1000.
!WB         sum of dissol P loss from catchment to outlet i = inflow of
!WB         dissol P * time inc * 1000

*
*DETERMINE NITROGEN OUTPUT
*

    ANSIG(NCH)=0.
!WB         sum of sed bound NH4 loss to outlet i for all part size classes
    ONSIG(NCH)=0.
!WB         sum of sed bound TKN loss to outlet i for all part size classes

** NRZ (8/31/94)
** ACCUMULATE KG OF SEDIMENT BOUND NH4 AND TKN FOR EACH PARTICLE
** CLASS
*****************************do loop #1572***************************
    DO 217 IC=1,NPART
!WB         do from counter IC = 1 to # of particle size classes
      ANSEDG(NCH,IC)=0.
!WB           Sediment bound NH4 for particle class i draining from channel
!WB           for a given hydrograph print line (kg/sec) = 0
      ONSEDG(NCH,IC)=0.
!WB           Sediment bound TKN for particle class i draining from channel
!WB           for a given hydrograph print line (kg/sec) = 0
      ANSIG(NCH)=ANSIG(NCH)+ANI(CHOUT(NCH),IC)
!WB           sum of sed bound NH4 loss to outlet i for all part size
!WB                       classes = same + ?
      ANSEDG(NCH,IC)=ANSEDG(NCH,IC)+ANI(CHOUT(NCH),IC)
!WB                       Sediment bound NH4 for particle class i draining from channel
!WB                       for a given hydrograph print line (kg/sec) = same + ?
                           ONSIG(NCH)=ONSIG(NCH)+ONI(CHOUT(NCH),IC)
!WB                       sum of sed bound TKN loss to outlet i for all particle size
!WB                       classes = same + ?
                           ONSEDG(NCH,IC)=ONSEDG(NCH,IC)+ONI(CHOUT(NCH),IC)
!WB                       Sediment bound TKN for particle class i draining from channel
!WB                       for a given hydrograph print line (kg/sec) = same + ?

 217  CONTINUE
*************************end do loop #1572***************************
*****************************do loop #1596***************************
    DO 218 IC=1,NPART
!WB         do from counter IC = 1 to # of particle size classes
      ANSEDH(NCH,L,IC)=ANSEDG(NCH,IC)*DT*1000.
!WB           Sediment bound NH4 for particle class i and hydrograph line L
```

```
!WB                  leaving catchment (kg) = Sediment bound NH4 for particle
!WB                  class i draining from channel for a given hydrograph print
!WB                  line (kg/sec) * time increment * 1000
                      ONSEDH(NCH,L,IC)=ONSEDG(NCH,IC)*DT*1000.
!WB                   Sediment bound TKN for particle class i and hydrograph line L
!WB                  leaving catchment (kg) = Sediment bound NH4 for particle class
!WB                  i draining from channel for a given hydrograph print line
!WB                  (kg/sec) * time incr * 1000
 218  CONTINUE
************************end do loop #1596**************************
** NRZ (8/31/94)

     ANSSI(L,NCH)=ANSIG(NCH)*DT*1.E+3
!WB        Accumulated sediment-bound ammonium loss from catchment draining
!WB        to outlet i at hydrograph line L for a given storm(g) =
!WB        Accumulated sediment-bound ammonium loss for all particle size
!WB        classes draining to outlet i for a given hydrograph print
!WB        line (kg/sec) * time increment * 1000
     ONSSI(L,NCH)=ONSIG(NCH)*DT*1.E+3
!WB        Accumulated sediment-bound TKN loss from catchment draining to
!WB        outlet i at hydrograph line L for a given storm (g) =
!WB        Accumulated sediment-bound TKN loss for all particle size classes
!WB        draining to outlet i for a given hydrograph print line (kg/sec) *
!WB        time incr * 1000

C    CONVERTING NITROGEN OUTPUT FROM KG TO G

     ANH4SI(L,NCH)=AINH4(CHOUT(NCH))*1000.*DT
!WB        Accumulated dissolved ammonium loss from catchment draining to
!WB        outlet i at hydrograph line L for a given storm (g) =
!WB        Inflow of dissolved ammonium from adjacent cells (kg/s) * 1000 *
!WB        time increment
     ANO3SI(L,NCH)=AINO3(CHOUT(NCH))*1000.*DT
!WB        Accumulated dissolved nitrate loss from catchment draining to
!WB        outlet i at hydrograph line L for a given storm (g) =
!WB        Inflow of dissolved NO3 from adjacent cells (kg/s) * 1000 * time
!WB        increment
  219 CONTINUE
************************end do loop #1453**************************
C **** NRZ 9/14/94

C
C **** PRINT ONE HYDROGRAPH LINE.....
C
  220 CONTINUE
*******************************end do loop #972********************
  222   FORMAT(1X,F7.1,5(1X,F12.4))
!WB this is used nowhere.  try to find 222
C
C **** END OF HYDROGRAPH.  PRINT TOTAL RUNOFF AND RAINFALL.
C
     L=NDT+1
!WB        Number of last element in row and a counter = Number of lines of
!WB        hydrograph print + 1

!WB*************************do loop # 1684********************
  230 DO 228 NCH=1,NCHAN+1
!WB     do from channel counter = 1 to # of channels + 1

C **** NRZ 9/10/94
C **** ACCUMULATE RAINFALL AMOUNT

     IF (NCH.EQ.1) TPREC=TPREC+PREC
!WB        if channel counter = 1, then Accumulated rainfall for
!WB        simulation (mm) = same + Accumulated depth of precipitation (mm)

C **** NRZ END

     VOL(NCH)=(VOL(NCH)-.5*Q1(L-1,NCH))*DT*DBLE(KPR)/3600.
!WB        Runoff depth for outlet i for a given storm (mm) = same - 0.5 *
```

```
!WB         Flow out of catchment draining to outlet i at hydrograph line
!WB         L (mm/h) * time increment * Number of time increment routings
!WB         between print lines / 3600
C *** THE NUMBER OF CELLS DRAINING INTO EACH CHANNEL NETWORK IS COMPUTED FROM
C *** ARC-INFO, AND THIS IS CONVERTED TO AREA BY MULTIPLYING THE NUMBER OF
C *** CELLS BY THE AREA OF EACH CELL IN HA.  IF THIS IS THE SEDIMENT COMING
C *** FROM THE "LEAKY CELLS", THE AREA IS COMPUTED BY MULTIPLYING THE
C *** PERCENTAGE OF CELL AREA LEAKING BY THE AREA OF EACH CELL.
C    X=SSI(L-1)/AREA
    IF (NCH.LE.NCHAN) THEN
!WB         if channel counter is less than number of channels
      XS(NCH)=SSI(L-1,NCH)/(DBLE(NCELLS(NCH))*AREA2)
!WB                   Accumulated sediment loss out of catchment for outlet i for
!WB                   a given storm (kg/ha) = Accumulated sediment loss out of
!WB                   catchment at print line L of hydrograph for outlet i for a
!WB                   given storm (kg) / (Number of cells in channel network i
!WB                   (entered in input file) * Element or channel area (m2))
    ELSE
C *** NRZ 7/29/95
C *** ADDED "IF OUTSID.GT.0" IN ORDER TO ELIMINATE 0/0 WHEN NO CELLS LEAK
      IF (OUTSID.GT.0) XS(NCH)=SSI(L-1,NCH)/(OUTSID*AREA2)
!WB         IF Area of watershed border elements which drain outside of
!WB         watershed > 0, then Accumulated sediment loss out of catchment
!WB         for outlet i for a given storm (kg/ha) = Accumulated sediment loss
!WB         out of catchment at print line L of hydrograph for outlet i for a
!WB         given storm (kg) / (Area of watershed border elements which drain
!WB         outside of watershed * Element or channel area (m2))
          ENDIF

    CONFAC=AREA*10000.
!WB          = Catchment area as sum of element areas, ha * 10000
    CONFA1=CONFAC/1000.
!WB          = Catchment area as sum of element areas, ha * 10000 / 1000
    VOL1F(NCH)=VOL1F(NCH)+VOL(NCH)
!WB         Accumulated runoff depth for outlet i for the simulation (mm) =
!WB         same + Runoff depth for outlet i for a given storm (mm)
    VOL1X(NCH)=VOL1X(NCH)+XS(NCH)
!WB         Accumulated sediment loss out of catchment for outlet i for
!WB         the simulation (kg/ha) = same + XS (NCH) from above

    NUNIT=NCH+10
!WB          = channel counter + 10
         IF(YEAR0.NE.YERBEG) THEN
!WB         if year0? does not equal the beginning year of the simulation
      DO 9902 NZ=0,NCHAN
!WB          do from counter NZ = 0 to # of channels
 9902    WRITE(NUNIT+NZ,*) YERBEG
!WB                   write to the channel file #(nunit+nz) the beg. year of sim
      YEAR0=YERBEG
!WB          reset the year0 var to the beginning year of the simulation
    ENDIF
!WB         put your finger on the side of your head and scratch, scratch
!WB         and say "hmmmmmmm".  I have no idea what the previous lines
!WB         are used for  10/15/98
    RNO3(NCH)=RNO3(NCH)+ANO3SI(L-1,NCH)
!WB         Accumulated dissolved nitrate loss from catchment draining to
!WB         outlet i for the simulation (g) = same + Accumulated dissolved
!WB         nitrate loss from catchment draining to outlet i at hydrograph
!WB         line L for a given storm (g)
    RNH4S(NCH)=RNH4S(NCH)+ANH4SI(L-1,NCH)
!WB         Accumulated dissolved NH4 loss from catchment draining to outlet
!WB         i for the simulation (g)= same + Accumulated dissolved ammonium
!WB         loss from catchment draining to outlet i at hydrograph line L
!WB         for a given storm (g)
    RNH4SE(NCH)=RNH4SE(NCH)+ANSSI(L-1,NCH)
!WB         Accumulated sediment-bound ammonium loss from catchment draining
!WB         to outlet i for the simulation (g) = same + Accumulated
!WB         sediment-bound ammonium loss from catchment draining to outlet i
!WB         at hydrograph line L for a given storm(g)
    RPHOS(NCH)=RPHOS(NCH)+SPSSI(L-1,NCH)
```

```
!WB       Accumulated dissolved P loss from catchment draining to outlet i
!WB       for the simulation (g) = same + Accumulated dissolved P loss from
!WB       catchment draining to outlet i at hydrograph print line L for a
!WB       given storm (g)
     RORGN(NCH)=RORGN(NCH)+ONSSI(L-1,NCH)
!WB       Accumulated sediment-bound TKN loss from catchment draining to
!WB       outlet i for the simulation (g) = same + Accumulated sediment-bound
!WB       TKN loss from catchment draining to outlet i at hydrograph line L
!WB       for a given storm (g)
     RSEDP(NCH)=RSEDP(NCH)+PSSI(L-1,NCH)
!WB       Accumulated sediment-bound P loss from catchment draining to outlet
!WB       i for the simulation (g) = same + Accumulated sediment-bound P loss
!WB       from catchment draining to outlet i at hydrograph line L for a given
!WB       storm (g)

          IF (NCH.LT.NCHAN+1) THEN
          IF (NSBS.EQ.1)THEN
          DO JKK=1,20
          CNT2=0
          do CNT=1,NN-1
          JK=MOD(SUR(CNT),256)
          KKX=(SOIL(CNT)/256)
          if (jk.eq.jkk) then
          IF (CNT2.EQ.1) GOTO 3451
          CNT2=1
          WRITE (101,3450) LDAY,XS(NCH),JK,DAYDIFF(CNT),
          1KRBASE(CNT),TAUCB(CNT),TAURR(CNT),TAUCHLD(CNT),KRCONS(CNT),
    2KRSC(CNT),KRBR(CNT),KRADJ(CNT),TAUCONS(CNT),TAUSC(CNT),
    3TAUCADJ(CNT),KKX,KDROOTR(CNT),KLROOTR(CNT),CNT
     WRITE (102,3452) LDAY,XS(NCH),JK,DAYDIFF(CNT),KIBASE(CNT),
          1HEIGHT(JK),CANOPY(JK),KICAN(CNT),INRCOV(JK),KIGRCOV(CNT),
    2KICONS(CNT),KISC(CNT),LROOT(JK),DROOT(JK),KLROOTI(CNT),
    3KDROOTI(CNT),KIADJ(CNT),KKX,CNT
          endif
 3451     end do
          END DO
          ENDIF

 3450 FORMAT (1X,I3,1X,F8.2,3X,I2,1X,F6.0,2X,F5.3,3X,F4.2,4X,F4.2,2X,
          1F4.2,/,
    27X,F6.4,1X,F4.2,1X,F4.2,4X,F6.4,2X,F4.2,4X,F4.2,2X,F4.2,2X,I3,/,
    37X,F6.4,1X,F6.4,' CELL: ',I4)
 3452 FORMAT (1X,I3,1X,F9.2,1X,I2,1X,F6.0,F10.0,1X,F4.2,5X,F5.3,
          12X,F4.2,/,
    113X,F4.2,2X,F4.2,2X,F9.0,1X,F4.2,5X,F4.2,3X,F4.2,/
    2,13X,F4.2,2X,F4.2,3X,F8.0,2X,I3,' CELL: ',I4)
          END IF

C **** THE FOLLOWING PRODUCES DAILY OUTPUT
     IF (NSBS.EQ.1)
!WB       if NSBS? (I believe this reads the flag for storm by
!WB       storm output) equals 1
    &WRITE(NUNIT,229) LDAY,PREC,VOL(NCH),XS(NCH),ANO3SI(L-1,NCH)/1000.,
    &ANH4SI(L-1,NCH)/1000.,ANSSI(L-1,NCH)/1000.,SPSSI(L-1,NCH)/1000.,
    &PSSI(L-1,NCH)/1000.,ONSSI(L-1,NCH)/1000.
!WB       write to channel out file: LDAY = day of sim?, PREC = accumulated
!WB       depth of precipitation (mm), VOL(NCH) = Runoff depth for outlet i
!WB       for a given storm (mm), XS (NCH) = Accumulated sediment loss out
!WB       of catchment for outlet i for a given storm (kg/ha), ANO3SI =
!WB       accumulated dissolved nitrate loss from catchment draining to
!WB       outlet i at hydrograph line L for a given storm (g) / 1000,
!WB       and same for dissolve NH4, sed bound NH4 loss, dissolved P loss,
!WB       sed bound P loss, sed bound TKN loss


C ****THE FOLLOWING PRODUCES CUMULATIVE OUTPUT ON A SPECIFIED DAY
          DO 9903 NZ=1,10
 9903 IF (LDYEAR.EQ.NPDAY(NZ))
    &WRITE(NUNIT,229) LDAY,PREC,VOL(NCH),XS(NCH),ANO3SI(L-1,NCH)/1000.,
```

```
   &ANH4SI(L-1,NCH)/1000.,ANSSI(L-1,NCH)/1000.,SPSSI(L-1,NCH)/1000.,
   &PSSI(L-1,NCH)/1000.,ONSSI(L-1,NCH)/1000.
!WB        THIS PRINT LINE ADDED 1/15/99 TO PRODUCE STORM OUTPUT ALONG
!WB        WITH CUMULATIVE OUTPUT
           DO 9901 NZ=1,10
 9901 IF (LDYEAR.EQ.NPDAY(NZ))
!WB        if yerbeg+1000 equals an input print option
   &WRITE(NUNIT,229) LDAY,TPREC,VOL1F(NCH),VOL1X(NCH),RNO3(NCH)/1000.,
   & RNH4S(NCH)/1000.,RNH4SE(NCH)/1000.,RPHOS(NCH)/1000.,
   & RSEDP(NCH)/1000.,RORGN(NCH)/1000.

!WB        write LDAY = day of sim, TPREC = accum rainfall for sim., see
!WB        above for remaining printout stuff


C *** CONTINUE LOOP FOR EACH CHANNEL OUTLET
  228 CONTINUE
!WB*************************end do loop # 1684**************

  229 FORMAT(1X,I3,1X,F5.0,1X,F6.1,1X,F9.1,5(1X,F7.1),F10.0)


C *** NRZ END
C
C **** INDIVIDUAL ELEMENT SEDIMENT LOSS (-) OR GAIN (+).
C
            X=10000./DX/DX
!WB         overland flow width across overland flow element
            IF (IT.EQ.0) X=X*4.356
!WB         if IT flag = 0, then multiply flow width * 4.356

C
C **** OUTPUT INDIVIDUAL ELEMENT NET SEDIMENTATION AMOUNTS AND GROSS
C **** STATISTICAL VALUES.
C
    SPAERO=0.
!WB        min. elemental aggradation value (kg/ha)
    SPADEP=0.
!WB        max. elemental aggrad. value (kg/ha)
    SPASUM=0.
!WB        sum of sel values used to calculate SPASD
    SPASS=0.
!WB        variable used in determining SPASD
C
C **** COMPUTE STATISTICS ON OVERLAND FLOW ELEMENTAL SEDIMENT YIELDS.
C
            DO 250 I=1,N
            SEL(I)=SEL(I)*DT*X
!WB         accum sed aggrad. in element i for a given storm (kg/s)
!WB         where dt is the time increment and x is the area of a cell in 1/ha
            NO3SEL(I)=NO3SEL(I)*X*DT
!WB         accum NO3 loss in ele i for a given storm (kg/s)
            NHWSEL(I)=NHWSEL(I)*X*DT
!WB         accum dissol NH4 loss in el i for a given storm (kg/s)
            NHSSEL(I)=NHSSEL(I)*X*DT
!WB         accum sed.-bound NH4 loss in el i for a given storm (kg/s)
            TKNSEL(I)=TKNSEL(I)*X*DT
!WB         accum sed.bound TKN loss in el i for a given storm (kg/s)
            PO4SEL(I)=PO4SEL(I)*X*DT
!WB         accum dissol P loss in el i for a given storm (kg/s)
            SUMSED(I)=SUMSED(I)+SEL(I)
!WB         accum sed. loss for cell i for the entire length of the sim (kg)
            SUMNO3(I)=SUMNO3(I)+NO3SEL(I)
!WB         accum dissol. NO3 loss for cell i for the entire length of sim (kg)
            SUMNHW(I)=SUMNHW(I)+NHWSEL(I)
!WB         accum dissol. NH4 loss for cell i for the entire length of sim (kg)
            SUMNHS(I)=SUMNHS(I)+NHSSEL(I)
!WB         accum sed. bound NH4 loss for cell i for the entire length
!WB                 of sim (kg)
            SUMTKN(I)=SUMTKN(I)+TKNSEL(I)
```

```
!WB          accum sed. bound TKN loss for cell I for the entire length
!WB                        of sim (kg)
             SUMPO4(I)=SUMPO4(I)+PO4SEL(I)
!WB          accum dissol P loss for cell i for entire length of the sim. (kg)

  250    CONTINUE

C
C **** NOW, OUTPUT NET DEPOSITION FOR CHANNEL AREAS.
C

     J=N+1
!WB          J = # overland flow cells + 1
     DO 260 I=J,N2
!WB          do from #overland flow cells + 1 to # overland flow cells +
!WB           # channel flow cells
  260 SEL(I)=SEL(I)*DT
!WB          accum sed aggradation in element i for a given storm (kg/s) *
!WB          time increment

C
C **** PLOTTING SECTION.  THIS SECTION OF CODE WILL CREATE THE INPUT
C **** FILE FOR SUBROUTINE HYPLT ON DEVICE 8.  SOME OF THE COMMANDS
C **** ARE MACHINE DEPENDENT AND ALL ARE PRESENTLY DISABLED.  TO USE,
C **** SIMPLY REMOVE THE C IN COLUMN 1, ADD SUBROUTINE HYPLT TO THE
C **** PROGRAM, AND APPEND THE CALCOMP LIBRARY TO THE INPUT FILE.
C **** THERE ARE TWO FORMAT STATEMENTS (380 AND 390) THAT MUST ALSO
C **** HAVE THE COMMENT DESIGNATION REMOVED!
C
C    L=L-1
C    REWIND 8
C    WRITE (8,380) L1,RMAX,QMAX,CMAX,IT,PP
C
C **** COPY HYDROGRAPH TO STORAGE TAPE.
C
C    DO 270 I=1,L
C 270 WRITE (8,390) T(I),RW(I),Q1(I),SSCON(I)
C    CALL HYPLT (L1,T,RW,Q1,SSCON,RMAX,QMAX,CMAX,IT,PP)

             IF (PRINHYD.EQ.1) THEN
             DO NCH=1,NCHAN
             WRITE (HYPNAM(NCH),3070) 'HYPLOT',NCH,'.OUT'
 3070 FORMAT (A6,I1,A4)
             OPEN (UNIT=NCH+20,FILE=HYPNAM(NCH))
             PRINHYD=2
             ENDDO
             ENDIF

             DO NCH=1,NCHAN
             DO I=2,L-1
!WB          DO FROM: 2 B/C BELOW SETS 1 = 0, AND TO: L-1 B/C L=NDT+1
             IF ((PSSI(I,NCH).EQ.0).AND.(PSSI(I-1,NCH).EQ.0)) THEN
             PHYP(I,NCH)=0
             ELSE
             PHYP(I,NCH)=
    2((PSSI(I,NCH)-PSSI(I-1,NCH))/(PSSI(I,NCH)-PSSI(I-1,NCH)
    3+QHYP(I,NCH)*1000000.))*1000000.
!WB          PSSI=SED BOUND P (G - G)/(G-G+M3*(E6G/M3)) * 1000000 = PPM
!WB          THESE VALUES WILL NEVER BE LT 0 B/C THEY ARE CUMULATIVE VALUES
!WB          AT WORST, THE DIFFERENCE WILL BE 0.
             ENDIF

             IF ((SPSSI(I,NCH).EQ.0).AND.(SPSSI(I-1,NCH).EQ.0)) THEN
             DPHYP(I,NCH)=0
             ELSE
     DPHYP(I,NCH)=((SPSSI(I,NCH)-SPSSI(I-1,NCH))/
    5(SPSSI(I,NCH)-SPSSI(I-1,NCH)
    6+QHYP(I,NCH)*1000000.))*1000000.
!WB          SPSSI=DISSOL P
             ENDIF
```

```
            IF ((ANSSI(I,NCH).EQ.0).AND.(ANSSI(I-1,NCH).EQ.0)) THEN
            A4SHYP(I,NCH)=0
      ELSE
            A4SHYP(I,NCH)=((ANSSI(I,NCH)-ANSSI(I-1,NCH))/
     7(ANSSI(I,NCH)-ANSSI(I-1,NCH)
     8+QHYP(I,NCH)*1000000.))*1000000.
            ENDIF
!WB         ANSSI=SED BOUND NH4

            IF ((ANH4SI(I,NCH).EQ.0).AND.(ANH4SI(I-1,NCH).EQ.0)) THEN
            A4DHYP(I,NCH)=0
            ELSE
      A4DHYP(I,NCH)=((ANH4SI(I,NCH)-ANH4SI(I-1,NCH))/
     9(ANH4SI(I,NCH)-ANH4SI(I-1,NCH)
     1+QHYP(I,NCH)*1000000.))*1000000.
!WB         ANH4SI=DISSOL NH4
            ENDIF

            IF ((ONSSI(I,NCH).EQ.0).AND.(ONSSI(I-1,NCH).EQ.0)) THEN
            ONHYP(I,NCH)=0
            ELSE
      ONHYP(I,NCH)=((ONSSI(I,NCH)-ONSSI(I-1,NCH))/
            2(ONSSI(I,NCH)-ONSSI(I-1,NCH)
     3+QHYP(I,NCH)*1000000.))*1000000.
!WB         ONSSI=SED BOUND TKN
            ENDIF

            IF ((ANO3SI(I,NCH).EQ.0).AND.(ANO3SI(I-1,NCH).EQ.0)) THEN
            A3HYP(I,NCH)=0
            ELSE
            A3HYP(I,NCH)=((ANO3SI(I,NCH)-ANO3SI(I-1,NCH))/
            3(ANO3SI(I,NCH)-ANO3SI(I-1,NCH)
     4+QHYP(I,NCH)*1000000.))*1000000.
!WB         ANO3SI=DISSOL NO3
            ENDIF

            ENDDO
            ENDDO

            IF (PRINHYD.NE.0) THEN
            IF (NIMP.GT.0) THEN
            IF (IMPFLAG.EQ.1) THEN
            WRITE (2,*) 'INPUT INDICATES IMPOUNDMENTS, HYDROGRAPH(S) WILL NOT
            1 PRINT FOR THIS SIMULATION'
            IMPFLAG=1
            ENDIF
            ELSE
            DO NCH=1,NCHAN
            WRITE (NCH+20,3080) 'STORM DATE = ',LDYEAR
            WRITE (NCH+20,3090)
            DO I=1,L-1
            IF (I.EQ.1) WRITE (NCH+20,3100) T(I),RW(I,NCH),Q1(I,NCH)
            1,Q1(I,NCH)*CONV,SSCON(I,NCH),0,0,0,0,0,0
            IF (I.GT.1) WRITE (NCH+20,3100) T(I),RW(I,NCH),Q1(I,NCH)
            1,Q1(I,NCH)*CONV
!WB         T(I)=TIME (MIN), RW=RAINFALL INTENS,MM/HR,Q1=FLOW MM/HR
!WB         Q1*CONV = FLOW M3/S (CHECK THE CONVERSION TO Q1)
            1,SSCON(I,NCH),PHYP(I,NCH),DPHYP(I,NCH),A4SHYP(I,NCH)
            2,A4DHYP(I,NCH),ONHYP(I,NCH),A3HYP(I,NCH)
!WB         SSCON IS SED CONC IN PPM (THE KG/S UNITS CANCEL), SEE ABOVE
!WB         PHYP = PSSI = SED BOUND P
!WB         DPHYP = SPSSI=DISSOL P
!WB         A4SHYP = ANSSI=SED BOUND NH4
!WB         A4DHYP = ANH4SI=DISSOL NH4
!WB         ONHYP = ONSSI=SED BOUND TKN
!WB         A3HYP = ANO3SI=DISSOL NO3
            END DO
            WRITE (NCH+20,*)
            WRITE (NCH+20,*)
```

```
            END DO
            ENDIF
            ENDIF




*COMPUTE NEW SOIL MOISTURE AFTER EVERY RAINFALL EVENT
*
            DO 6003 J=1,N
!WB         resets J and goes back to counting for every cell
            K=SOIL(J)/256
!WB         # of values in rainfall hyetograph and surface type of
!WB         current element = soil type for element i / 256

            ASMVOL(J)=(1.-PIV(J)*DT/TP1(K))*TP1(K)/CU1-RESWAT(K)
!WB          = (1-vol of air filled pore space in upper soil layer in el
!WB          i * time increment / porosity for soil type i ?) * porosity for
!WB         soil type i / (convert mm to m3) - residual water as a fraction
!WB         of soil porosity
            ASMPER(J)=ASMVOL(J)*CU1/TP1(K)
!WB          = above * (convert mm to m3) / porosity for soil type i ?
 6003   CONTINUE

** NRZ 8/24/94
** CONVERSIONS FOR IMPOUNDMENT MODEL
** SUM SEDIMENT BOUND NUTRIENTS FOR EACH PARTICLE SIZE CLASS

    DO 2610 NCH=1,NCHAN
    DO 261 IC=1,NPART
      SEDWT(NCH,IC)=SEDH(NCH,L-1,IC)
!WB          sed of part class i leaving catchment and entering impoundment
!WB                      for a single rainfall event (kg) = sed of part class i and
!WB                      hydr line L leaving catchment (kg)
      TSEDI(NCH,IC)=TSEDI(NCH,IC)+SEDWT(NCH,IC)
!WB          accum sed of part class i leaving catchment and entering
!WB                      impoundment for sim (kg) = same + above
      PSEDI(NCH,IC)=PSEDI(NCH,IC)+PSEDH(NCH,L-1,IC)
!WB          accum sed bound P for part class i leaving catchment &
!WB                      entering impoundment for the sim (kg) = same + sed bound P
!WB                      for part class i and hydr line L leaving catchment (kg)
      ANSEDI(NCH,IC)=ANSEDI(NCH,IC)+ANSEDH(NCH,L-1,IC)
!WB          accum total sed. bound NH4 for part class i leaving catchment
!WB                      & entering impoundment for the sim (kg) = same + sed bound
!WB                      NH4 for part class i and hydr line L leaving catchment
      ONSEDI(NCH,IC)=ONSEDI(NCH,IC)+ONSEDH(NCH,L-1,IC)
!WB          accum sed. bound TKN for part class i leaving catchment and
!WB                      entering impond. for the sim (kg) = same + sed. bound TKN
!WB                      for part class i and hydr line L leaving catchment (kg)
 261  CONTINUE
 2610 RUNVOL(NCH)=VOL(NCH)/1000.*(AREA2*DBLE(NCELLS(NCH)))*10000.
!WB         runoff leaving catchment and entering impoundment for a single
!WB         rainfall event (m^3) (calc from depth of runoff * area drained
!WB         by network)
    DFWEV=0.0
!WB         daily free water evap for impoundment (m)

** NRZ 8/24/94


*THE FOLLOWING ENDIF INDICATES THE END OF THE IF RAITES=1
    ENDIF
*******************end if then loop #699************************
** NRZ 8/29/94
** CALL FREE WATER EVAPORATION SUBROUTINE IF IMPOUNDMENT IS PRESENT

    IF (RAITES.EQ.0. .AND. NIMP.GE.1) CALL EVAPFW(LDAY)
!WB         if raintest flag equals 0 and # of impoundments greater
!WB         than or equal to 1
```

```
** CALL IMPOUNDMENT MODEL FOR A CHANNEL IF STRUCTURE IS PRESENT AT
** THE END OF THAT CHANNEL

      IF (NIMP.GE.1) THEN

C *** CONVERT PARTICLE DIAMETER FROM MM TO M

      DO 262 ID=1,NPART
        DIAM(ID)=DIAMM(ID)*0.001
!WB            diameter of sed. part. size i (m) = part dia (mm) * 0.001
 262  CONTINUE

      DO 10000 NCH=1,NCHAN
        IF (BASE(NCH).NE.0.) THEN
!WB            BASE(NCH)? DOES NOT EQUAL 0
        NUNIT=10+NCH
!WB            reset the nunit variable to equal 10 + nch counter

** SET DAILY SEDIMENT AND NUTRIENT ACCUMULATORS TO ZERO
        RUNO(NCH)=0.0
!WB            daily runoff leaving impoundment (m^3) = 0
        DTSEDO(NCH)=0.0
!WB            daily total of sediment leaving impoundment = 0
        DPSED(NCH)=0.0
!WB            daily total of sed. bound P leaving impound = 0
        DANSED(NCH)=0.0
!WB            daily totalof sed bound NH4 leavin impound = 0
        DONSED(NCH)=0.0
!WB            daily total of sed bound TKN leaving impound = 0
        DNO3O(NCH)=0.0
!WB            daily total of dissol. NO3 leaving impound = 0
        DNH4O(NCH)=0.0
!WB            daily total of dissolv NH4 leaving impound = 0
        DPHOSO(NCH)=0.0
!WB            daily total of soluble P leaving impound = 0

        CALL IMPOND(IDATE,RAITES,NPART,DIAM,SG,RUNVOL,SEDWT,DFWEV,
     &             SEDOT,SEDOR,RUNO,NCH)
!WB          IDATE = date of sim, RAITES = raintest flag (1 = rain),
!WB          NPART = # of particle size classes, DIAM = diam of sediment
!WB          particle size i (m), SG = spec. gravity of particle type i,
!WB          RUNVOL = runoff leaving catchment & entering impoundment,
!WB          SEDWT = sed of part class i leaving catchment and !WB                    entering
!WB          impoundment for a singl rainfall event (kg), DFWEV = daily
!WB          free water evap for impound (m), SEDOT = sed for part class
!WB          i overtopping impound !WB          for a single rainfal event,
!WB          SEDOR = sed of particle class i passing through impound
!WB          orifice for a single rainfall event (kg), RUNO = daily runoff
!WB          leaving impoundment (m^3), NCH = counter for # of channel
!WB          networks, or denotes which channel network
** ACCUMULATE RUNOFF FROM IMPOUNDMENT OVER SIMULATION
        TRUNO(NCH)=TRUNO(NCH)+RUNO(NCH)
!WB            cum. runoff leaving impound (m^3) = same + daily runoff
!WB                        leaving impundment (m^3)

** CALCULATE THE TOTAL SEDIMENT DISTRIBUTION LEAVING THE IMPOUNDMENT
        DO 263 ID=1,NPART
          TSEDO(NCH,ID) = TSEDO(NCH,ID) + SEDOT(NCH,ID) + SEDOR(NCH,ID)
!WB          sed of part class i leaving catchment & entering impond =
!WB          same + sed for part class i overtopping impound + sed of
!WB          particle class i passing through impound orifice for a single
!WB          rainfall event (kg)
          SEDZO(NCH,ID) = SEDZO(NCH,ID) + SEDOR(NCH,ID)
!WB          accum sed of particle class i passing through impond for sim =
!WB          same + sed of particle class i passing through impound orifice
!WB          for a single rainfall event (kg)
          SEDZOT(NCH,ID) = SEDZOT(NCH,ID) + SEDOT(NCH,ID)
!WB          total sed for part class i overtopping impound? = same +
!WB          sed for part class i overtopping impound
```

```
** CALCULATE THE TOTAL MASS OF SEDIMENT LEAVING THE IMPOUNDMENT
** DAILY AND OVER THE ENTIRE SIMULATION
       DTSEDO(NCH) = DTSEDO(NCH) + SEDOT(NCH,ID) + SEDOR(NCH,ID)
!WB         daily total of sed leaving impound = same + above + above
                         TTSEDO(NCH) = TTSEDO(NCH) + SEDOT(NCH,ID) + SEDOR(NCH,ID)
!WB         accum sed leaving impound = same + above + above

** CALCULATE NUTRIENT REDUCTION DUE TO SETTLING OF SEDIMENT BOUND
** SPECIES (BASED ON A RATIO OF SEDIMENT SETTLED/TOTAL SEDIMENT)
** COMPUTE DAILY AND CUMULATIVE TOTALS
** NOTE: IF SEDIMENT LEAVES THE IMPOUNDMENT ON A DAY WITH NO RAINFALL,
** SEDWT,PSEDI,ANSEDI, AND ONSEDI ARE EQUAL TO THE VALUES COMPUTED FOR
** THE LAST RAINFALL EVENT

      IF (SEDWT(NCH,ID).GT.0.) THEN
!WB         SEDWT = sed of part class i leaving catchment and entering
!WB         impoundment for a single rainfall event (kg)
       PSEDO(NCH,ID)=(SEDOT(NCH,ID)+SEDOR(NCH,ID))/SEDWT(NCH,ID)*
    &           PSEDH(NCH,L-1,ID)/1000.
!WB         accum sed bound P for part class i leaving impoundment for
!WB         sim (kg) = above
       DPSED(NCH)=DPSED(NCH)+PSEDO(NCH,ID)
!WB         daily total of sed bound P leaving impound (kg) = same +
!WB         accum sed bound P for part class i leaving impond for sim (kg)
       PSEDT(NCH)=PSEDT(NCH)+PSEDO(NCH,ID)
!WB         accum sed bound P for all classes ? = same + accum sed bound
!WB         P for particle class i leaving impond for sim (kg)
       ANSEDO(NCH,ID)=(SEDOT(NCH,ID)+SEDOR(NCH,ID))/SEDWT(NCH,ID)*
    &           ANSEDH(NCH,L-1,ID)/1000.
!WB         accum sed bound NH4 leaving impond on part size i for sim (kg)
       DANSED(NCH)=DANSED(NCH)+ANSEDO(NCH,ID)
!WB         daily total of sed bound NH4 leaving impound (kg) =
       ANSEDT(NCH)=ANSEDT(NCH)+ANSEDO(NCH,ID)
!WB         sim total sed bound NH4 leaving impond =
       ONSEDO(NCH,ID)=(SEDOT(NCH,ID)+SEDOR(NCH,ID))/SEDWT(NCH,ID)*
    &           ONSEDH(NCH,L-1,ID)/1000.
!WB         accum sed bound TKN for part class i
                         DONSED(NCH)=DONSED(NCH)+ONSEDO(NCH,ID)
!WB         daily total of sed bound TKN leaving impound
       ONSEDT(NCH)=ONSEDT(NCH)+ONSEDO(NCH,ID)
!WB         sim total sed bound TKN for part class i ?
      ENDIF
  263  CONTINUE
     IF (RUNVOL(NCH).GT.0.) THEN
!WB          runoff entering impoundment (depth * area)
      DNO3O(NCH)=RUNO(NCH)/RUNVOL(NCH)*ANO3SI(L-1,NCH)
!WB         daily total of dissolved NO3 leaving impound = daily runoff
!WB         leaving impound / runoff entering * accum dissol NO3 loss at
!WB         outlet i
      TNO3O(NCH)=TNO3O(NCH)+DNO3O(NCH)
!WB         accum dissol NO3 leaving impond for si = same + daily
!WB         dissolved NO3
      DNH4O(NCH)=RUNO(NCH)/RUNVOL(NCH)*ANH4SI(L-1,NCH)
!WB         daily NH4 leaving impound = daily runoff leaving impound /
!WB         runoff entering impound * accum dissol NH4 at outlet i
      TNH4O(NCH)=TNH4O(NCH)+DNH4O(NCH)
!WB         accum dissol NH4 leaving impound for sim = same + daily
!WB         dissolved NH4
      DPHOSO(NCH)=RUNO(NCH)/RUNVOL(NCH)*SPSSI(L-1,NCH)
!WB         daily total soluble P = volume exiting impound / volume
!WB         entering impound * accum dissolved P loss from catchment
!WB         draining to outlet i for a given storm
                        TPHOSO(NCH)=TPHOSO(NCH)+DPHOSO(NCH)
!WB         accum soluble P leaving impound for sim = same + daily
!WB         soluble P leaving impound
     ENDIF

** PRINT DAILY OUTPUT FOR IMPOUNDMENT
```

```
      IF ((RAITES.EQ.1).OR.(DTSEDO(NCH).GT.0.)) THEN
!WB          if raintest = 1 (rain) or daily total of sed leaving impound > 0

** THE FOLLOWING PRODUCES CUMULATIVE OUTPUT
       TRUNOM(NCH)=TRUNO(NCH)/(10000.*(AREA2*DBLE(NCELLS(NCH))))*1000.
!WB          total runoff leaving impoundment = cum runoff leaving impound /
!WB           (10000 * (area of element*# cells in the channel))*1000

** THE FOLLOWING PRODUCES DAILY OUTPUT
       RUNOM(NCH)=RUNO(NCH)/(10000.*(AREA2*DBLE(NCELLS(NCH))))*1000.
!WB          total daily runoff leaving impound = daily runoff leaving
!WB          impound / (10000 ( area of cell * (# of cells))*1000

      ENDIF

 2290 FORMAT(1X,6F9.1)
 6012 FORMAT(1X,10X,F6.1,2X,F7.1,5(1X,F7.3),F10.3,/)

  265   IF (IDATE.EQ.SIMDUR) THEN
!WB          If date of sim equals the duration of the simulation

        WRITE(NUNIT,*)
        WRITE(NUNIT,*) 'THE FINAL SEDIMENT DISTRIBUTION ENTERING THE',
     &   ' IMPOUNDMENT FOLLOWS:'
        WRITE(NUNIT,*)
        WRITE(NUNIT,*) 'CLASS    DIAM(MM)   SEDIMENT(KG/HA)'
        DO 267 NSD=1,NPART
  267      WRITE(NUNIT,6014) NSD,DIAMM(NSD),TSEDI(NCH,NSD)/
     &                              (AREA2*DBLE(NCELLS(NCH)))
        WRITE(NUNIT,*)
        WRITE(NUNIT,*) 'THE FINAL SEDIMENT DISTRIBUTION LEAVING THE',
     &   ' OUTLET OF THE IMPOUNDMENT FOLLOWS:'
        WRITE(NUNIT,*)
        WRITE(NUNIT,*) 'CLASS    DIAM(MM)   SEDIMENT(KG/HA)'
        DO 268 NSD=1,NPART
          WRITE(NUNIT,6014) NSD,DIAMM(NSD),TSEDO(NCH,NSD)/
     &                              (AREA2*DBLE(NCELLS(NCH)))
  268   CONTINUE
        WRITE(NUNIT,*)
        WRITE(NUNIT,*) 'THE FINAL SEDIMENT DISTRIBUTION LEAVING THE',
     &   ' ORIFICE:'
        WRITE(NUNIT,*)
        WRITE(NUNIT,*) 'CLASS    DIAM(MM)   SEDIMENT(KG/HA)'
        DO 269 NSD=1,NPART
          WRITE(NUNIT,6014) NSD,DIAMM(NSD),SEDZO(NCH,NSD)/
     &                              (AREA2*DBLE(NCELLS(NCH)))
  269   CONTINUE
        WRITE(NUNIT,*)
        WRITE(NUNIT,*) 'THE FINAL SEDIMENT DISTRIBUTION',
     &   ' OVERTOPPING:'
        WRITE(NUNIT,*)
        WRITE(NUNIT,*) 'CLASS    DIAM(MM)   SEDIMENT(KG/HA)'
        DO 271 NSD=1,NPART
          WRITE(NUNIT,6014) NSD,DIAMM(NSD),SEDZOT(NCH,NSD)/
     &                              (AREA2*DBLE(NCELLS(NCH)))
  271   CONTINUE
 6014      FORMAT(3X,I1,6X,F5.3,6X,F7.1)
        WRITE(NUNIT,*)
        WRITE(NUNIT,*) 'THE TOTAL OUTPUTS FROM THE IMPOUNDMENT ARE ',
     &          'AS FOLLOWS:'
        WRITE(NUNIT,*)
       WRITE(NUNIT,*) 'DAY  RAIN  RUNOFF SEDIMENT   NO3   DIS-NH4'
     &          ,' SED-NH4 DIS-PO4 SED-PO4 SED-TKN'
       WRITE(NUNIT,*) '      MM     MM     KG/HA    KG      KG'
     &          ,'     KG      KG      KG       KG'
       WRITE(NUNIT,229) LDAY,TPREC,TRUNOM(NCH),TTSEDO(NCH)/
     &  (AREA2*DBLE(NCELLS(NCH))),TNO3O(NCH)/1000.,
     &  TNH4O(NCH)/1000.,ANSEDT(NCH),TPHOSO(NCH)/1000.,
     &  PSEDT(NCH),ONSEDT(NCH)
```

```
** THE FOLLOWING ENDIF INDICATES THE END OF THE IF (IDATE.EQ.SIMDUR)

      ENDIF

** THE FOLLOWING ENDIF INDICATES THE END OF THE IF (BASE(NCH).NE.0)
      ENDIF
10000 CONTINUE

** THE FOLLOWING ENDIF INDICATES THE END OF THE IF (NIMP.GE.1)
      ENDIF

** NRZ 9/10/94
** PRINT FINAL OUTPUTS FROM THE CATCHMENT

      DO 11000 NCH=1,NCHAN+1
        NUNIT=10+NCH
      IF (IDATE.EQ.SIMDUR) THEN
        WRITE(NUNIT,*)
        WRITE(NUNIT,*) 'THE TOTAL OUTPUTS FROM THIS AREA ARE ',
     &        'AS FOLLOWS:'
        WRITE(NUNIT,*)
        WRITE(NUNIT,*) 'DAY  RAIN  RUNOFF SEDIMENT   NO3   DIS-NH4'
     &        ,' SED-NH4 DIS-PO4 SED-PO4 SED-TKN'
        WRITE(NUNIT,*) '      MM     MM     KG/HA     KG      KG'
     &        ,'     KG      KG      KG       KG'
        WRITE(NUNIT,229) LDAY,TPREC,VOL1F(NCH),VOL1X(NCH),
     &  RNO3(NCH)/1000.,RNH4S(NCH)/1000.,RNH4SE(NCH)/1000.,
     &  RPHOS(NCH)/1000.,RSEDP(NCH)/1000.,RORGN(NCH)/1000.

!WB        PRINT NEW CHANNEL WIDTHS CALCULATED BY NEW SED ROUTINE
           IF (NCH.LT.NCHAN+1) THEN
           WRITE (NUNIT,*)
           WRITE (NUNIT,*) 'THE FINAL WIDTHS FOR THIS CHANNEL ARE:'
           DO JKL=N+1,N2
           KKJ=SOIL(JKL)/256
                      IF (CHNUMBER(JKL-N).EQ.NCH) THEN
                      IF (CWID(JKL).GT.0) THEN
                      WRITE (NUNIT,*)
                      WRITE (NUNIT,3046) JKL,KKJ,CWID(JKL)+WIDINC(JKL)
                      IF (DEPTHINC(JKL).GE.0) THEN
                      WRITE (NUNIT,3047) DEPTHINC(JKL)
!WB        IF THE DEPTHINC IS GREATER THAN 0, IT INDICATES BOTTOM EROSION
!WB        AS THIS IS TRACKED AS A POSITIVE NUMBER.
                      ELSE
                      WRITE (NUNIT,3048) -1*DEPTHINC(JKL)
!WB        IF THE DEPTHINC IS NEGATIVE, IT INDICATES DEPOSITION, SO PRINT
!WB        NET DEPOSITION MASS
                      ENDIF
                      ELSE
                      WRITE (NUNIT,*)
                      WRITE (NUNIT,*) 'CHANNEL WIDTH = 0.'
           ENDIF
           ENDIF
      ENDDO
           ENDIF
           ENDIF
!WB        END OF PRINT NEW CHANNEL WIDTHS CALCULATED BY NEW SED ROUTINE

11000 CONTINUE
** NRZ 9/10/94


      CALL ETP11(TEMPC,RADI,ETPMM)
           TETPPR=0.
!WB        TETPPR = unknown
           TOTPER=0.
!WB        TOTPER = unknown
*      TOTES=0.
*      TOTEP=0.
           TOTXMO=0.
```

```
!WB        TOTXMO = unknown
           DO 5590 J11=1,N

           K=MOD(SUR(J11),256)
!WB        K = # of values in rainfall hyetograph and surface type
!WB        of current element
!WB          = surface type - INT (same / 256) * 256
           KK=SOIL(J11)/256
!WB        KK = soil type for current element
           CALL EVAPO(LAI1(K),S1EP(J11),ESU(KK),TTIME(J11),S2EP(J11)
     & ,ETPMM,TETP,PEP(J11),ES(J11),CUMIN1(J11))
!WB        LAI1 =  LAI + 1?, S1EP = accum stage 1 soil evap (mm),
!WB        ESU = Upper limit of stage 1 of soil evap (mm day-0.5),
!WB        TTIME = time since stage 2 evap started (days), S2EP =
!WB        accum stage 2 soil evap (mm), ETPMM = Pot ET (mm),
!WB        TETP = Sum of ES and PEP (mm), PEP = plant transpiration (mm),
!WB        ES = soil evap (mm), CUMIN1 = cum infil (mm)

*INITIALIZING THE INITIAL CUMULATIVE INFILTRATION TO ZERO
           CUMIN1(J11)=0.
!WB        cum infil = 0
           XMOI(J11)=ASMVOL(J11)+RESWAT(KK)*TP1(KK)/CU1
!WB        soil moisture = ASMVOL? + residual water as a fraction of
!WB        soil porosity * porosity + 1? / (conv mm to m3)
*EDX REPRESENTS THE MAXIMUM EVAPORATIVE DEPTH
           RRATIO=(EDX(KK)/DF1(KK))*(XMOI(J11)-WP(KK))
!WB        RRATIO? = (max soil evap depth / depth of soil horizon +1)*
!WB         (soil moisture - WP?)
           IF(ES(J11).GT.RRATIO) ES(J11)=RRATIO
!WB        If soil evaporation greater than RRATIO?, set em equal
*REDUCE THE PLANT EVAPORATION ACCORDING TO THE ROOT DEPTH
           IF(ROTDAY(K).GT.DF1(KK)) THEN
!WB        if root depth at a specific day is greater than depth of
!WB        soil horizon
             ROTRAT=DEXP(-3.065*DF1(KK)/ROTDAY(K))
!WB        ROTRAT? = (-3.065 * depth of soil horizon) / root depth
!WB        at a specific day
             ROTR(J11)=(1.-ROTRAT)/(1.-EXP(-3.065))
!WB        Ratio that reduces evap according to root depth =
!WB         (1-root ratio?) / (1-exp(-3.065)
             PEP(J11)=PEP(J11)*ROTR(J11)
!WB        plant transpiration = same * root depth ratio
           ELSE
             ROTR(J11)=1.
!WB        reset root ratio equal to 1
           ENDIF

           CNH4(J11)=0.
!WB        fraction of water leaching = 0
*SOIL MOISTURE LIMITING
           IF(XMOI(J11).LT.WP(KK)) xmoi(j11)=wp(kk)
!WB        if soil moisture is less than wilting point?
           IF(XMOI(J11).LT.ASMLIM(KK)) THEN
!WB        if soil moisture is less ASMLIM?
            PEP(J11)=PEP(J11)*XMOI(J11)/ASMLIM(KK)
!WB        plant transpiration = same * soil moisture / ASMLIM ?
            TETP=PEP(J11)+ES(J11)
!WB        TETP = plant transpiration + soil evaporation
             IF((XMOI(J11)-WP(KK)).GT.TETP) THEN
!WB        if soil moisture - wilting point? is greater than plant
!WB        trans + soil evap
               ASMVOL(J11)=ASMVOL(J11)-TETP
!WB        ASMVOL = same - (plant trans + soil evap)
               TETPPR=TETPPR+TETP
!WB        TETPPR ? = same + (plant trans + soil evap)
             ELSEIF (XMOI(J11).EQ.WP(KK)) THEN
!WB        elseif soil moisture equal to wilting point (we set
!WB        it equal earlier if it's less than)
               ES(J11)=0.
!WB        soil evapo = 0
```

```
              PEP(J11)=0
!WB         plant trans = 0
             ELSE
              TETP=XMOI(J11)-WP(KK)
!WB          (plant trans + soil evap) = soil moisture - wilting point?
!WB          (wilt point*porosity / conversion)
              PEP(J11)=PEP(J11)*TETP/(PEP(J11)+ES(J11))
!WB         plant trans = same * (soil moisture - wilt point) / (plant
!WB         trans + soil evap)
              ES(J11)=ES(J11)*TETP/(PEP(J11)+ES(J11))
!WB         soil evap = same*(soil moisture - wilt point) / (plant
!WB         trans + soil evap)
              ASMVOL(J11)=ASMVOL(J11)-TETP
!WB         ASMVOL ? = same - (soil moisture - wilting point)
              TETPPR=TETPPR+TETP
!WB         TETPPR ? = same + (soil moisture - wilting point)
             ENDIF

            TOTES=TOTES+ES(J11)
!WB         TOTES? = same + soil evap
            TOTEP=TOTEP+PEP(J11)
!WB         TOTEP? = same + plant trans
            GOTO 5590
            ENDIF


*SOIL MOISTURE NOT LIMITING
            IF (XMOI(J11).GT.FCVOL(KK)) THEN
!WB         if soil moisture greater than field capacity
             XMOI2=XMOI(J11)*CU1/TP1(KK)
!WB         soil moisture var #2 = soil moisture * (conv mm to m3) / porosity?
             PERCOL=0.
!WB         percolation amount (mm) = 0

            IF(XMOI(J11).LT.WP(KK)) xmoi(j11)=wp(kk)
!WB         if soil moisture is less than wilting point?
!WB         THIS LINE ADDED TO ALL CALL STATEMENTS DUE TO FLOAT OVERFLOWS AND
!WB         DOMAIN ERRORS ASSOCIATED WITH XMOI DROPPING BELOW WP 1/19/99
             CALL PERCO(XMOI(J11),KS(KK),FCVOL(KK),CU,PERCOL,FCAP1(KK)
    &   ,XMOI2,TMAX,RAITES,A(KK))
!WB         XMOI = soil moisture, KS = sat hyd conductivity (mm/hr),
!WB         FCVOL = field cap, PERCOL = percolation amount, FCAP1 =
!WB         field cap ?, XMOI2 = soil moisture,            converted and divided
!WB         by porosity, TMAX = max time on hyetograph, RAITES=
!WB         raintest flag, A = ratio of KS of top layer to KS for
!WB         underlying layer
            ASMVOL(J11) = ASMVOL(J11)-TETP-PERCOL
!WB         ASMVOL? = same - (soil moisture - wilting point) - percolation
!WB         amount
            XMOI(J11)=ASMVOL(J11)+RESWAT(KK)*TP1(KK)/CU1
!WB         soil moisture = ASMVOL? + residual water as a fraction of
!WB         soil porosity * porosity / (conv mm to m3)

*CNH4 REPRESENTS THE LEACHING FRACTION OF NITROGEN
            CNH4(J11)=(PERCOL+CNO3(J11))/(XMOI(J11)+TETP+PERCOL+CNO3(J11))
!WB         leaching frac of N = (perc amt + accum perc during infil
!WB          (mm)) / (soil moisture + (soil moisture - wilting point) +
!WB         perc amt + accum perc during infil)
            CNO3(J11)=0.
!WB         reset accum perc =0
            TETPPR=TETPPR+TETP
!WB         TETPPR? = same + (soil moisture - wilting point)
            TOTPER=TOTPER+PERCOL
!WB         total percolation? = same + perc amount
            TOTES=TOTES+ES(J11)
!WB         total soil evap? = same + soil evap
            TOTEP=TOTEP+PEP(J11)
!WB         total plant evap? = same + plant evap
            PERCOL=0.
!WB         set perc amount = 0
```

```
            GOTO 5590
            ENDIF

             IF((XMOI(J11)-WP(KK)).GT.TETP) THEN
!WB         soil moisture - wilt point greater than (soil moisture - wilt point)
!WB         this may be using a different def of TETP, as it is redefined above
              ASMVOL(J11)=ASMVOL(J11)-TETP
              TETPPR=TETPPR+TETP
             ELSEIF (XMOI(J11).EQ.WP(KK)) THEN
              ES(J11)=0.
              PEP(J11)=0
             ELSE
              TETP=XMOI(J11)-WP(KK)
              PEP(J11)=PEP(J11)*TETP/(PEP(J11)+ES(J11))
              ES(J11)=ES(J11)*TETP/(PEP(J11)+ES(J11))
              ASMVOL(J11)=ASMVOL(J11)-TETP
              TETPPR=TETPPR+TETP
             ENDIF
             TOTES=TOTES+ES(J11)
             TOTEP=TOTEP+PEP(J11)
             TOTXMO=TOTXMO+XMOI(J11)
 5590   CONTINUE

 5591   FORMAT(1X,5(F10.5,1X))

            CALL NITRAN(ES,FCVOL,SOIVOL,XMOI,PEP,WP,N,TEMPC,ICR,
   &          RATEMX,CU1,SOITEM,RNUTNI,RNUTAM,RNUTP,DF1,TP1)

     IF(IDATE.EQ.SIMDUR) THEN
      XCOR=365./SIMDUR

             WRITE(2,301)
             WRITE(2,302)
             WRITE(2,303)
 301  FORMAT(///,1X,75('*'))
 302  FORMAT(///,30X,25H****  ANNUAL OUTPUT  ****)
 303  FORMAT(30X,25H**** ON A CELL BASIS ****,///)

             WRITE(2,309)
             WRITE(2,308)

            DO 5554 I=1,N
             WRITE (2,360) I,SUMSED(I)*XCOR,SUMNO3(I)*XCOR,SUMNHW(I)*XCOR,
   &  SUMNHS(I)*XCOR,SUMTKN(I)*XCOR,SUMPO4(I)*XCOR,CLENO3(I)*XCOR

 5554 CONTINUE

C***  WDB 5/23/94
C***  Added by Bill Batchelor to send annual output to new file
             DO 9876 I=1,N
             WRITE (5,360) I,SUMSED(I)*XCOR,SUMNO3(I)*XCOR,SUMNHW(I)*XCOR,
   &  SUMNHS(I)*XCOR,SUMTKN(I)*XCOR,SUMPO4(I)*XCOR,CLENO3(I)*XCOR
 9876 CONTINUE

C**   WDB 5/23/94
     ENDIF

C *** NRZ
C *** PRINT CELLULAR OUTPUT FILE IF REQUESTED FOR A CERTAIN DAY

     DO 9877 NZ=1,10
       IF (LDYEAR.EQ.NPDAY(NZ)) THEN
        XCOR = 365./DBLE(IDATE)
             NFUNIT=30+NZ
             WRITE(XPFIL(NZ),9900) NPDAY(NZ)
 9900     FORMAT (I7)
             OPEN (NFUNIT,FILE=XPFIL(NZ))

        DO 9878 I=1,N
         WRITE (NFUNIT,360) I,SUMSED(I)*XCOR,SUMNO3(I)*XCOR,SUMNHW(I)
```

```
     &     *XCOR,SUMNHS(I)*XCOR,SUMTKN(I)*XCOR,SUMPO4(I)*XCOR,CLENO3(I)
     &     *XCOR
 9878     CONTINUE
        CLOSE (NFUNIT)
       ENDIF
 9877 CONTINUE

 5555 CONTINUE

      CLOSE(5)

C *** SET IEEE ARITHMETIC FLAG TO 0 FOR SUN-OS FORTRAN 77 COMPILER
*      ieeer=ieee_flags('clear', 'exception', 'all', out)

C
C **** FORMATS.
C
  280 FORMAT (19A4)
  290 FORMAT (1X,52H DISTRIBUTED HYDROLOGIC AND WATER QUALITY SIMULATION
     1,/10X,37HBY ANSWERS VER 19 AUG 99 BETA RELEASE/19A4)
  300 FORMAT (/,15X,'OUTLET HYDROGRAPHS--VER 4.940001',/,31X,'YIELD',9X,
     1'CONCENTRATIONS -',A4,/,2X,' TIME',2X,'RAINFALL',2X,'RUNOFF',4X,'S
     2EDIMENT',3X,'SEDIMENT  PHOSPHORUS   SOLPHOS',/,1X,'  MIN.',2X,2A4,
     31X,2A4,5X,A4,18X,'(MG)',6X,'(G)')
* 309 FORMAT(5X,'TIME',5X,'SEDIMENT',5X,'SOLUBLE',6X,'SEDIMENT')
* 308 FORMAT(13X,'BOUND NH4',7X,'NH4',7X,'BOUND ORG-N',5X,'NITRATE')
* 307 FORMAT(5X,'(MN)',6X,'(G)',10X,'(G)',10X,'(G)',11X,'G')
C *** NRZ
C *** SIGNIFIED DISSOLVED PO4 IN CELLULAR OUTPUT ("DIS-PO4", NOT "PO4")
  309 FORMAT(1X,7HELE NO ,1X,9H SEDIMENT,1X,9H   NO3   ,1X,9H SOL-NH4 ,
     &1X,9H SED-NH4 ,1X,9H SED-TKN ,1X,9H DIS-PO4 ,10H NO3 LEACH )
  308 FORMAT(1X,7H       ,1X,9H   KG/HA ,1X,9H KG/HA   ,1X,9H  KG/HA  ,
     &1X,9H   KG/HA ,1X,9H  KG/HA  ,1X,9H  KG/HA  ,9H   KG/HA )
  310 FORMAT (1X,F7.1,F8.2,F10.4,2F11.0,1X,F12.3,1X,F12.5)
  311 FORMAT(1X,F7.1,1X,F12.4,1X,F12.4,1X,F12.4,2X,F12.4)
  320 FORMAT (4X,28HRUNOFF VOLUME PREDICTED FROM,F7.2,A4,14H OF RAINFALL
     1 =,F7.3,A4/15X,19HAVERAGE SOIL LOSS =,F7.0,1X,2A4)
  330 FORMAT (///5X,48HMEAN FLOW DEPTH GREATER THAN EXPECTED AT ELEMENT,
     1I5/56H CONDITION OCCURRED BECAUSE THIS ELEMENT'S SLOPE IS MUCH,31H
     2 LESS THAN WATERSHED AVERAGE OR,/,28H CIRCULAR FLOW PATTERNS ARE ,
     358H PRESENT IN THIS VICINITY.  RECOMMENDED CORRECTIVE ACTION:,/'
     4 INCREASE EXPECTED PEAK RUNOFF VALUE (SF) IN SUBROUTINE DATA',10H
     5OR MODIFY,/,24HELEMENT FLOW DIRECTIONS.)
  340 FORMAT (//19X,36HINDIVIDUAL ELEMENT NET SEDIMENTATION/1X,4(2X,16HE
     1LEMENT SEDIMENT)/1X,4(4X,3HNO.,3X,2A4))
  350 FORMAT (1X,'MAX EROSION RATE =',F7.0,2A4,2X,'MAX DEPOSITION RATE =
     1',F7.0,2A4,/,23X,'STD. DEV. =',F7.0,2A4,//,24X,'CHANNEL DEPOSITION
     2 --',A4,/,4(4X,'NO.     AMOUNT'))
  360 FORMAT (I7,1X,F9.0,6(1X,F9.3))
  370 FORMAT (21H  STRUCTURAL PRACTICE,I3,32H REDUCED TOTAL SEDIMENT YIE
     1LD BY,F9.0,A4)
C 380 FORMAT (I4,2F7.2,F7.0,I3/12A4)
  390 FORMAT (3(F10.2,1X),F10.0)
  405 FORMAT(/20X,26HPARTICLE SIZE DISTRIBUTION/
     *24X,18HOF ERODED SEDIMENT/)
  410 FORMAT(17X,15HPARTICLE CLASS ,I1,2H =,F6.2,8H PERCENT)
C
 5560 FORMAT(1X,I4,1X,I4,1X,I4,1X,I1,1X,I1)

C *** NRZ 9/12/94
C *** MODIFY FORMAT LINE FOR FERTILIZER INPUT
C 6010 FORMAT (1X,F9.4,1X,F9.4,1X,F9.4)
 6010 FORMAT (1X,I4,1X,I3,1X,I5,3(1X,F9.4))
C *** NRZ 9/12/94

 2570 FORMAT(2X,I4,1X,I3,3X,F7.2,2X,F7.3,2X,F7.0,3X,F7.4,2X,F7.4,5X,
     &F7.4,3X,F7.4,/,55X,F7.4,5X,F7.4)
 2580 FORMAT(2X,I4,1X,I3,3X,F7.2,2X,F7.3,2X,F7.0,3X,F7.3,2X,F7.3,5X,
     &F7.3,3X,F7.3,/,55X,F7.3,5X,F7.3)
!WB          BEGIN NEW SED ROUTINE ERROR MESSAGES
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2582 FORMAT ('GROWTH FACTOR IS < 0 OR >1',F5.2)
2584 FORMAT ('MAXIMUM PLANT HEIGHT <0 OR > 3.0 M',F5.2)
2586 FORMAT ('THE HEIGHT FACTOR IS <0 OR >1',F5.2,/,'PLEASE CHECK THE
  1GROWTH FACTOR AND MAXIMUM PLANT HEIGHT')
2588 FORMAT ('THE AREA UNDER THE CANOPY IS EITHER < 0 OR > 100%',
         1F6.2)
2590     FORMAT ('THE AREA UNDER TEH CANOPY FACTOR IS <0 OR >1',F5.2,/,
  1'PLEASE CHECK THE GROWTH FACTOR AND AREA UNDER CANOPY')
2592 FORMAT ('AN ERROR HAS OCCURRED.  PLEASE CHECK THE PRIMARY'
         1,/,'OUTPUT FILE.')
2594 FORMAT ('ERROR IN ROUTINE THAT CALCULATES THE COVER
         1 FOR THE ',/,'CURRENT DAY.  PLEASE CHECK YOUR ROTATION
         2 PARAMETERS.')
2595 FORMAT ('THE ROTATION LENGTH IS GREATER THAN ONE YEAR.  THIS ',/,
  1'MAY CAUSE ERRORS IN THE PLANT GROWTH SCHEME.  PLEASE LIMIT',/,
         2' ROTATIONS TO LESS THAN ONE YEAR IN LENGTH.')
2596 FORMAT ('ONE OF THE SOIL VARIABLES IS < 0, >1 (>100%), OR BULK'
  1,/,' DENSITY IS INPUT IN KG/M3 INSTEAD OF G/CM3',/,'IT IS
         2CLAY =',F5.2,' SAND =',F5.2,' SILT=',F5.2,' VFS =',F5.2,
  3' ORGMAT=',/,'MASS OF C.F. BY WEIGHT =',F5.2,' BULK DENSITY ='
  4,F5.2,/,'IT OCCURRED AT CELL # ',I3)

2598 FORMAT ('KRBASE GT 0.05',' CNT =',I3,' KRBASE= ',F8.4,
         1/,' AND HAS BEEN SET EQUAL TO 0.05.')
3000 FORMAT ('KRBASE LT 0.002',' CNT =',I3,' KRBASE= ',F8.4,
         1/,' AND HAS BEEN SET EQUAL TO 0.002.')
3002     FORMAT ('TAUCB GT 7.0',' CNT =',I3,' TAUCB= ',F8.4,
         1/,' AND HAS BEEN SET TO 7.0')
3004 FORMAT ('TAUCB LT 0.3',' CNT =',I3,' TAUCB= ',F8.4,
         1/,' AND HAS BEEN SET TO 0.3')
3005 FORMAT ('THE BURIED RESIDUE ADJUSTMENT IS <0 OR >1, AND THIS',/,
         1'INDICATES THAT A PROGRAM ERROR HAS OCCURRED.  KRBR = ',F5.2,/,
  2' AT CELL # ',I3)
3006 FORMAT ('THE RANDOM ROUGHNESS APPEARS TO BE INPUT IN M.',/,
         1' THE RANDOM ROUGHNESS IS (IN METERS):',F10.5,/,
  2' THE CROP SERIES # IS: ',I3,/,' PLEASE BE
         2 CERTAIN THAT THE ROUGHNESS IS INPUT IN MM.')
3008 FORMAT ('THE RANDOM ROUGHNESS ADJUSTMENT FACTOR INDICATES THAT',/,
         1' RANDOM ROUGHNESS EXCEEDS 200 MM, OR IS INPUT IN METERS.',/,
  2' PLEASE CHANGE THIS.',/,
         3' RR ADJUSTMENT =',F5.2,' THE CELL IS: ',I4)
3010 FORMAT ('KIBASE GT 12,000,000 AT CELL:',' CNT =',I4,'
         1KIBASE = ',F8.4,/,' AND HAS BEEN SET TO 12,000,000.')
3012 FORMAT ('KIBASE LT 500,000 AT CELL:',' CNT =',I4,'
         1KIBASE =',F8.4,/,' AND HAS BEEN SET TO 500,000.')
3014     FORMAT ('FIELD CAPACITY TIMES POROSITY (FCFRAC) IS GT 1.'
  1,/,' THE VALUE IS: ',F5.3,' AND IT OCCURRED FOR SOIL #: ',I4)
3016     FORMAT ('THE SOIL CONSOLIDATION FACTOR KRCONS IS LT 0 OR GT 1.'
         1,/,' ITS VALUE IS: ',F6.3,' AT CELL #: ',I4)
3018     FORMAT ('THE SEALING AND CRUSTING FACTOR IS LT 0 OR GT 1.'
         1,/,' ITS VALUE IS: ',F6.3,' AT CELL #: ',I4)
3020     FORMAT ('THE ADJUSTED RILL ERODIBILITY IS LT 0.'
         1,/,' ITS VALUE IS: ',F6.3,' AT CELL #: ',I4)
3022 FORMAT ('THE ADJUSTED RILL ERODIBILITY IS GT 1.'
         1,/,'ITS VALUES IS: ',F6.3,' AT CELL #: ',I4)
3030 FORMAT ('TAUCONS LT 0, OR TAUCADJ GT 15.',/,' TAUCONS: ',F10.5,/,
         1' CELL #: ',I4)
3032 FORMAT ('HEIGHT GT 3.0 M, OR CANOPY FACTOR GT 1.0',/,'
  1 CELL #: ',I4)
3034     FORMAT ('THE INTERRILL CANOPY FACTOR IS LT 0 OR IS GT 1.'
  1,/,' THE VALUE IS: ',F5.3,' AND IT OCCURRED FOR CELL #: ',I4)
3036     FORMAT ('THE FRACTION OF INTERRILL AREA COVERED BY GROUND
  1 COVER IS 0 OR IS GT 1.',/,' AND IT HAS BEEN SET TO 0 OR 1 '
  2,/,' THE VALUE IS: ',F5.3,' AND IT OCCURRED FOR SOIL #: ',I3)
3038 FORMAT ('THE INTERRILL COVER FACTOR IS LT 0 OR IS GT 1.'
  1,/,' THE VALUE IS: ',F5.3,' AND IT OCCURRED FOR CELL #: ',I4)

3040 FORMAT ('THE VARIABLES BELOW HAVE CAUSED THE INTERRILL CONSOLI
         1DATION',/,' FACTOR TO BE NEGATIVE, PLEASE CHECK THEM.',/,
         21X,14HSAND FRACTION=,1X,F5.3,3X,24HORGANIC MATTER FRACTION=
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   3,1X,F5.3,/,1X,15HFIELD CAPACITY=,1X,F5.3)
 3042 FORMAT ('THE INTERRILL SEALING AND CRUSTING FACTOR '
           1,/,' IS LT 0 OR IS GT 1.'
   2,/,' THE VALUE IS: ',F5.3,' AND IT OCCURRED FOR CELL #: ',I4)
 3044 FORMAT ('THE ADJUSTED INTERRILL ERODIBILITY FACTOR IS LT 0.'
   1,/,' THE VALUE IS: ',F5.3,' AND IT OCCURRED FOR CELL #: ',I4)
 3046 FORMAT (11HCELL NO. = ,I5,2X,12HSOIL TYPE = ,I2,2X,
   114HFINAL WIDTH = ,F6.3)
 3047 FORMAT (14HERODED DEPTH =,2X,F7.4)
 3048 FORMAT (17HDEPOSITED DEPTH =,2X,F7.4)
 3049 FORMAT ('THE INTERILL COVER IS LESS THAN 0.'
           1,/,'  ITS VALUE IS ',F6.3,' FOR CROP # :',I3)

 3050 FORMAT ('THE DEAD ROOT FACTOR IS LESS THAN -1, OR GT 1'
           1,/,'  ITS VALUE IS ',F6.3,' FOR CROP # :',I3)
 3052 FORMAT ('THE LIVE ROOT FACTOR IS LESS THAN 0, OR GT 1'
           1,/,'  ITS VALUE IS ',F6.3,' FOR CROP # :',I3)
 3054 FORMAT ('KLROOTR LT 0 OR GT 1 :',F6.3,3X,'FOR CROP #',3X,I3
           1,' AT CELL # ',3X,I4)
 3056 FORMAT ('KDROOTR LT 0 OR GT 1 :',F6.3,3X,'FOR CROP #',3X,I3
           1,' AT CELL # ',3X,I4)
 3058 FORMAT ('KLROOTI LT 0 OR GT 1 :',F6.3,3X,'FOR CROP #',3X,I3
           1,' AT CELL # ',3X,I4)
 3060 FORMAT ('KDROOTI LT 0 OR GT 1 :',F6.3,3X,'FOR CROP #',3X,I3
           1,' AT CELL # ',3X,I4)
 3080 FORMAT (A13,I8)
 3090 FORMAT (12X, 'RAINFALL', 22X, 'SEDIMENT', 2X,/, 6X
   1,'TIME', 1X, 'INTENSITY', 6X, 'FLOW', 6X, 'FLOW', 5X, 'CONC.'
   2,3X,'SED-PO4',3X,'DIS-PO4',3X,'SED-NH4',3X,'DIS-NH4',3X
   3,'SED-TKN',3X,'DIS-NO3',/, 6X, 'MIN.', 5X, 'MM/HR', 5X, 'MM/HR'
   4,7X,'CMS', 7X, 'PPM',7X,'PPM',7X,'PPM',7X,'PPM',7X,'PPM',7X,'PPM'
   5,7X,'PPM')
 3100 FORMAT (11(1X,F9.2))
 9000 END

C **** NRZ 7/23/95
C **** ADD IEEE HANDLER
*     integer function handler(sig,code,context)
*     integer sig, code, context(5)
*     write (*, '("exception at pc", I5 )' ) context(5)
*     end

      SUBROUTINE XDATA (NDT,KPR,N,CONV,CU,SF,IT,NN,ICR,NFI,CU2,ISTRUC,
     &SB,TMIN,TMAX,NRG,DX,GRF,NEXP,DC,PP,FILTS,CWID,AREA,AREA2,DT,NMAX,
     &CU1,DAYBEG,SIMDUR,ISR,YERBEG,CLAYAV)
      IMPLICIT DOUBLE PRECISION A-H,O-Z
C
C ****** SUBROUTINE TO INPUT WATERSHED DATA.
C
C *** NRZ 9/12/94
C *** ADD VARIABLES FOR FERTILIZER INPUT

      COMMON /FERT/ IFERT

C *** NRZ 9/12/94

      COMMON /ZSEDI/ NPART,NWASH,NWASH1
      COMMON /ZSEDR/ VISCOS,AGRAV,SWH2O,YALCON,SE(8),VS(2000),DIA(8),
     1SG(8),FV(8),CY1(8),CY2(8),CY4(8),DIAMM(8),EQSDIA(8),EDMM(8),
     2F(30,8),CE1,CE2,CE3,CE4,CE5,CE6
!WB       Changed F(10,8) to F(30,8) to accomodate 30 soil types
      COMMON /CUMIN/ CUMIN1(2000),rbit0(2000),testi(2000),timpon(2000),
     & tpon(2000)
C
C **** MAXIMUM NUMBER OF SOIL TYPES IS 30.
C
      COMMON /CSOIL/ A(30),FC(30),GWC(30)
      COMMON /GRAMPT/ CL(30),SA(30),ST(30),OM(30),AC(30)
     & ,AO(30),BC(30),BO(30),PHI(30),VCF(30),WCF(30),CFC(30),
     &  CEC(30),EAC(30),PHIC(30),XF(30),PSIF(30),CBF(30),
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     &  THETAR(30),KS(30),CF(30),Z(30),LF(30),CS(30),SCF(30),
     &  CRC(30),KE(30,30),ZC(30),BD(30)


C **** NRZ 9/12/94
C **** ADD VARIABLES TO ENTER SATURATED HYDRAULIC CONDUCTIVITY

      DIMENSION SK(30),KOPT(30)

C **** NRZ 9/12/94


      COMMON /ETPES/LAI(20,11),ESU(30),LAI1(20),POTLAI(20)
     &,SUMLAI(20)
              COMMON /EDX/ EDX(30)
      COMMON /ROT/ IROT1,IROT(20,57)
      INTEGER IROT1,IROT
       DOUBLE PRECISION KS,KE,LF,LAI,LAI1

C *** NRZ 9/15/94
C *** CHANGE DIMENSION OF SOME VARIABLES TO CORRESPOND WITH
C *** NMAX+ISTRUC+1+NCHAN

      COMMON /PHOS1/ P0SOIL(2000),SSA(30,8),SSAT(30),EDI(2000),
     & P0(2000,8),ERP(8),STOLD(2000,8),SEDNEW(2000,8),PPT(2000,8),
     & PI(2030,8),PSEL(2000),STNEW(8),P2(8),PCELL(2000,8)
     & ,DRFT(8)
      COMMON /PHOS2/PE(8)

      COMMON/NITRO1/ A0SOIL(2000),ANPT(2000,8),ANI(2030,8),
     & ANSEL(2000),AN2(8),ANCELL(2000,8),ANE(8),AN0(2000,8)
     & ,CNH4(2000)


      COMMON/NITRO2/ O0SOIL(2000),ONPT(2000,8),ONI(2030,8),
     & ONSEL(2000),ON2(8),ONCELL(2000,8),ONE(8),ON0(2000,8)

      COMMON /SOLUB/ SP2(2000),PEXT(2000),PK(30)
     & ,RBETA(30),SPI(2030),CGEN1(2000)
     & ,T13(2000),SPSP(2000)

      COMMON/WATNH4/VOLSZ(2000),SZNH4(2000),AINH4(2020),STONH4(2000)
     & ,OUTNH4(2000),EDINH4(2000),VOLSZ1(2000),VOLSOI(2000)

      COMMON /TRANSF/POTMIN(2000),SOILN(2000),XMIN(2000),AMON(2000)
     & ,NIT(2000),DNI(2000),UPNH4(2000),UPNO3(2000),TDMN2(2000)
     & ,ROTR(2000),RFON(2000)
      DOUBLE PRECISION XMIN,NIT
      COMMON /TRAP/PMINP(2000),SOILP(2000),MINP(2000),PLAB(2000),
     &  UPPHOS(2000),TDMP2(2000),SORGP(2000),PSOL(2000),EDILAB(2000)
      DOUBLE PRECISION MINP

      COMMON/NO3/SZNO3(2000),AINO3(2020),STONO3(2000),OUTNO3(2000)
     & ,CNO3(2000),EDINO3(2000),CLENO3(2000)

C *** NRZ 9/15/94
      COMMON /ASMF/ ASMBF(30),FCAP1(30),TP1(30),RESWAT(30),DF1(30)
       DIMENSION TP(30), DF(30), ASM(30), FCAP(30)
C
C **** MAXIMUM NUMBER OF SURFACE AND CROP TYPES IS 20.
C
      COMMON /CROUGH/ ROUGH(20),HU(20),DIR(21),PIT(8,20),PER(20)
!WB       I'm not sure if the below is still true.
C
C **** MAXIMUM NUMBER OF OVERLAND ELEMENTS PLUS CHANNEL ELEMENTS
C **** IS 50.
!WB       below is no longer true becuase they aren't equivalenced anymore
C ****** IT IS EXPECTED THAT ARRAY "IEL" (IN SUBROUTINE DATA) WILL
C ****** BE OF SUCH A SIZE THAT IT WILL OVERLAY (BE EQUIVALENCED TO)
C ****** THE SPACE IN ARRAYS SI AND QI TOGETHER.  THEREFORE IT IS
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C ****** NECESSARY THAT THESE TWO ARRAYS BE KEPT ADJACENT IN THEIR
C ****** COMMON BLOCK.  NOTE: THE ACTUAL NUMBER OF ELEMENTS THAT
C ****** CAN BE DIMENSIONED IN IEL WILL DEPEND ON THE WORD LENGTH
C ****** OF THE MACHINE BEING USED, E.G. ON A MACHINE WHICH USES
C ****** A SINGLE WORD INTEGER AND A DOUBLE WORD REAL, THE NUMBER
C ****** OF ELEMENTS IN IEL CAN BE FOUR TIMES THE NUMBER OF ELEMENTS
C ****** IN ARRAY SI.
C
C ****** NRZ 9/15/94
C ****** DIMENSIONS OF SI AND QI ARE CHANGED TO CORRESPOND WITH
C ****** NMAX+ISTRUC+1+NCHAN
C
      COMMON /CFLOW/ Q(2000),RFL(2000),FLINS(2000),SS(2000),PIV(2000),B(
     12000),NR(2000),NC(2000),DR(2000),S(2000),SL(2000),SEL(2000),SI(202
     20,8),QI(2020),DIN(2000),SST(2000,8),PIVTMP(2000),SSTMP(2000)

C *** NRZ
C *** ADD COMMON BLOCK FOR PERCENTAGE OF CELL AREA "LEAKING" OUTSIDE THE
C *** WATERSHED

      COMMON /LEAKY/ OUTSID


C *** NRZ END
!WB         I'm not so sure that the below is still true.  See above
C
C ****** ARRAYS SI AND QI MUST BE DIMENSIONED TO A SIZE = NMAX+ISTRUC+2
C ****** TO HOLD, IN ORDER, SEDIMENT AND FLOW FROM THE WATERSHED OUTLET
C ****** ELEMENT, STRUCTURAL PRACTICES AND ANY "LEAKY" ELEMENTS.
C
      DIMENSION CROP(20,2), RN(20), DIRM(20), CBAR(20), SPER(30), NSTRUC
     1(4), STRNAM(3,4)

      COMMON / CROPAD/  DIRM2(20)
C
C **** MAXIMUM NUMBER OF RAINGAGES IS 4 WITH 35 VALUES PER GAGE.
C
      COMMON /CRGAGE/ RC(8,35),TC(8,35),R(8,21),FRA(8),JTR(8),RATE(8),SR
     1(8),NF(8)
      DIMENSION  IRR(8),IG(8),XDATE(2)

      DIMENSION IEL(3,103,20), ITEMP(20)
      DIMENSION IELC(3,103,2), ITEMPC(2)
      DIMENSION FILTS(2000), CWID(2000),CWIDTMP(2000)

            COMMON /CSURF/ SUR(2000),RANE(2000),SOIL(2000)
            COMMON /PARTITION/PKDA(30),PKDP(30),PSP(30)
      COMMON /PLANTN/DATPLA(20),DATHAR(20),CP1(20),CP2(20),DMY(20)
     &  ,YP(20),ROTMAX(20),ROTDAY(20),RLAIMX(20)
     &  ,RES(20),RES20(20),RES90(20)

** NRZ (8/29/94)
** ADD COMMON STATEMENT FOR IMPOUNDMENT DIMENSIONS

      COMMON /IMPDIM/ BASE,WIDTH,SLOPE,ORIF,CI,FI,MAXHGT,NIMP
      DOUBLE PRECISION BASE(10),WIDTH(10),SLOPE(10),ORIF(10),CI(10),
     &FI(10),MAXHGT(10)

      COMMON /FWATER/ AFWEV,DFWEV

C *** ADD COMMON BLOCK FOR EXTRA OUTPUT OPTIONS

      COMMON /XPRINT/ NSBS,NPDAY(10)

** NRZ (8/29/94)

            INTEGER SUR,SOIL,TIAL(2000),RANE,CHAN(2000),DATPLA,DATHAR


C NRZ 9/5/94
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C ADDED VARIABLES FOR CHANNEL NETWORKS

      COMMON /OUTLET/ NCHAN,NIOUT(9),NJOUT(9),MOUT(9),CHNUM(2000),
     &           CHOUT(9),NCELLS(9),CHNUMBER(2000)


      INTEGER CHNUM,CHOUT,CHNUMBER
      CHARACTER*13 OUTFIL(10)
      DIMENSION LCC(2000),LCR(2000)


C NRZ 9/5/94

      INTEGER DAYBEG,SIMDUR,YERBEG,ROTMAX,ROTDAY
C
C **** MAXIMUM NUMBER OF CHANNEL TYPES IS 10.
C
!WB        BEGINNING OF NEW VARIABLES FOR NEW DETACHMENT ROUTINES
!WB        soil variables:
           COMMON/SOILVAR/CLAY(30),SAND(30),SILT(30),VFSPER(30),VFS(30),
           1ORGMAT(30),MASSCF(30),RANROU(30),RANROUM(30)
           DOUBLE PRECISION MASSCF

!WB        rill erodibility variables:
           COMMON/RILLVARS/KRBASE(2000),KRBR(2000),BR(20),BURRES(20),
           1KRADJHLD(2000),KRCONS(2000),KRSC(2000),KRADJ(2000)
           DOUBLE PRECISION KRBASE,KRBR,KRADJHLD,KRCONS,KRSC,KRADJ

!WB        critical shear variables:
           COMMON/CRTSHEAR/TAUCB(2000),TAURR(2000),TAUCHLD(2000),TAUCONS
           1(2000),TAUSC(2000),TAUCADJ(2000),TAUEFF

!WB        interrill erodibility variables:
           COMMON/IRILLVARS/KIBASE(2000),KICAN(2000),KIGRCOV(2000),KICONS
           1(2000),KISC(2000),KIADJ(2000),CANOPY(20),AUCFACT(20),HEIGHT(20),
     2MAXPLHGT(20),HGTFACT(20),GROWFACT(20)
           DOUBLE PRECISION KIBASE,KICAN,KIGRCOV,KICONS,KISC,KIADJ,MAXPLHGT

!WB        interrill cover common block:
           COMMON /IRILLCOV/ INRCOV(20),INRCOVI(20),INRCOVF(20),INRFACT(20),
           1LROOT(21),DROOT(21),KDROOTI(2000),KLROOTI(2000),DDROOTI(21),
           2DDROOTF(21),DDRTFAC(21),LRFAC(21),LIVEROOT(21),KDROOTR(2000),
           3KLROOTR(2000)

           DOUBLE PRECISION INRCOV,INRCOVI,INRCOVF,INRFACT,LROOT,KDROOTI,
           1KLROOTI,LRFAC,LIVEROOT,KDROOTR,KLROOTR

!WB        rill erosion variables:
           COMMON/RILLEROS/NORILLS,RILLSPC(20),QEFF,RILLWID,MNSOIL(21),
     1MNTOT(21),FLOWDEP,HYDRAD,DCAP,FCFRAC(30),FOFD,FPOFD,FDPOFD,
           2FLDEPOLD,MNCHNSL(2000),MNCHNTOT(2000),MNCS(10),MNCT(10),MNCSTMP
           3(2000),MNCTTMP(2000),MAXWID,NOTILL(21),NOEROS(21),DWSOIL,
           4HYDRADOLD(2000)
           DOUBLE PRECISION MNSOIL,MNTOT,MNCHNSL,MNCHNTOT,MNCS,MNCT,MNCSTMP,
           1MNCTTMP,NORILLS,MAXWID

!WB        interrill erosion variables
           COMMON /IRILLEROS/RNOFIR,SEDDR(2000,8),DIINT(2000,8),DETR(8)
           1,DETF(8),DACT(2000,8)

!WB        PLANT GROWTH VARIABLES
           COMMON /PLANTS/ DAYNOW(2000),YEARNOW(2000),DYYRNOW
           1(2000),DAYTHEN(2000),YEARTHEN(2000),DYYRTHEN(2000),DAYDIFF(2000),
           2BEGROTDT(2000)

!WB        CHANNEL BOTTOM EROSION VARIABLES
           COMMON /CHANEROS/WIDINC(2000),DOWNRATE(2000),
           1DEPTHINC(2000),IMPERM(10),ROCKBOT(2000),RBTEMP(2000),BULKDENS(30),
           2CHNSOIL(2000),CHNSL(2000),CHNSLTMP(2000),DEPRATE(2000)
     3,DEPPREV(2000),CONSTHLD(2000),XHOLD(2000),CONSTTMP(2000)
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     4,XTMP(2000),ARMOUR(2000),NOERODE(2000),NERODTMP(2000)

!WB        HYDROGRAPH PLOT VARIABLES
           COMMON /HYPLT/PRINHYD,IMPFLAG,QHYP(101,10),PHYP(101,10)
           1,DPHYP(101,10),A4SHYP(101,10),A4DHYP(101,10),ONHYP(101,10)
           2,A3HYP(101,10)
           CHARACTER(11) HYPNAM(10)

           DOUBLE PRECISION DIFF,RGTSID,LFTSID,IMPERM,NOERODE,NERODTMP

           INTEGER CNT,CNTER,CNTFLAG,NOTILL,INIT,NOEROS,CHNSL,CHNSOIL,
           1CHNSLTMP,PRINHYD

!WB        Sediment Erosion routine information:  Some equations and
!WB        calculations in the sediment subroutine are not placed in the
!WB        location that will allow optimal calculation efficiency.  This is
!WB        recognized, and was done in order to ease understanding of the
!WB        methodology at the cost of computational efficiency.

!WB        END OF NEW VARIABLES FOR NEW DETACHMENT ROUTINES



      DIMENSION WID(10), CN(10), PP(14), TITLE(11)
      LOGICAL STRUC
      CHARACTER*4 C1, C2, C3, C4, C5, C6, PRI, UN, UNITS, PR, TEST
      CHARACTER*4 PP, TITLE, STRNAM, XDATE
      CHARACTER*2 IG, IELC, ITEMPC, ISTL

      DATA C1,C2,C3,C4,C5,C6,PRI,UN/' RAI',' SI',' SO',' SU',' CH',
     1' EL','PRIN','METR'/
      DATA ISTL/'TI'/
C
C **** NOW, STORE THE NAMES OF THE STRUCTURAL PRACTICES.
C
      DATA STRNAM/'PTO ','TERR','ACES','POND','S, L','AKES','G. W',
           1'ATER','WAYS','FIEL','D BO','RDER'/
      STRUC=.FALSE.


C
C ****** NUMBER OF STRUCTURAL PRACTICES PERMITTED.  ARRAYS STRNAM AND
C ****** NSTRUC MUST BE REDIMENSIONED IF ISTRUC IS MODIFIED.  ALSO, THE
C ****** ADITIONAL STRUCTURE NAMES MUST BE ADDED TO THE DATA STATEMENT.
C
      ISTRUC=4
!WB   # of structural practices
      IT=0
!WB   this appears to be a place holder for an array named PP
      OUTSID=0.
!WB        the number of cells flowing outside the watershed
      TMAX=0.
!WB        maximum time of the hydrograph
      TMIN=1.E+10
!WB        minimum time of the hydrograph.  It's big for a reason, that
!WB        is it is reset later to a smaller value.
C
C **** INPUT UNITS USED IN SIMULATION AND OUTPUT PRINT CONTROL.
C
      READ (1,800) UNITS,PR
!WB        read the units and print flags
C
C **** NRZ
C **** INPUT OUTPUT PRINT OPTIONS

      READ (1,801) NSBS
!WB        read the storm by storm output flag
      READ (1,801) (NPDAY(NZ),NZ=1,10)
!WB        read the additional days according to the above flag, up to 10 days
  801 FORMAT (24X,10(1X,I7))
```

```
C
C **** INPUT NUMBER OF RAINGAGES AND DATE OF EVENT.
C
    READ (1,802) PRINHYD
!WB         FLAG TO INDICATE WHETHER TO PRINT HYDROGRAPHS.  ADDED 14 AUG 1999
  802 FORMAT (21X,I2)
            READ (1,810) TEST,NRG,XDATE
!WB         read the test (=' rai'), # of rain gages, not sure about xdate
    IF (NRG.GT.8) GO TO 540
    IF (TEST.NE.C1) GO TO 580
!WB         C1 equals ' rai'
            READ (1,1666) DAYBEG,YERBEG
!WB         read the beginning day and year of simulation
    READ (1,1667) SIMDUR
!WB         read the simulation duration
    DO 20 I=1,NRG
    READ(1,830) IG(I)
!WB         read from 1 to # of rain gages, the descriptor of each rain gage
  20  CONTINUE
C
C ****** DEFINE DEFAULT SIMULATION REQUIREMENTS.  MAXIMUM NUMBER OF
C ****** HYDROGRAPH PRINT POINTS IS 101 (THIS IS THE NUMBER THAT WILL BE
C ****** OUTPUT).  NORMAL TIME STEP IS 60 SECONDS AND NORMAL TIME STEP
C ****** FOR INFILTRATION IS 180 SECONDS.  MAXIMUM EXPECTED RUNOFF RATE
C ****** IS 2 INCHES (50.8 MM) PER HOUR.  IF A SEGMENTED CURVE ERROR
C ****** OCCURS DURING SIMULATION, INCREASE SF BY 50 PERCENT UNTIL THAT
C ****** PROBLEM CEASES (IT MAY NOT BE THE ONLY PROBLEM, THOUGH).
C ****** FOR WATERSHEDS WITH LARGE ELEMENTS (GREATER THAN 5 ACRES),
C ****** MILD TOPOGRAPHY (LESS THAN 1 PERCENT AVERAGE SLOPES), OR
C ****** MANY ELEMENTS (MORE THAN 1000), THE SIMULATION TIME STEP, DT,
C ****** SHOULD BE INCREASED TO NO MORE THAN 300 SECONDS (5 MINUTES).
C ****** SIMILARLY, FOR SMALL ELEMENTS (LESS THAN 1 ACRE), SEVERE
C ****** TOPOGRAPHY, OR WATERSHEDS WITH ONLY A FEW ELEMENTS, THE
C ****** SIMULATION TIME STEP SHOULD BE DECREASED TO 15 - 30 SECONDS.
C
C.... INPUT SIMULATION REQUIREMENTS
C
    READ (1,810) TEST
    IF (TEST.NE.C2) GOTO 580
!WB         C2 = ' si'
            READ (1,1030) NDT,DT,NFI,SF
!WB         # of lines of hydrograph print,sim time increment ,max # of
!WB         time increments b/t infil recalc's, segment factor
    IF (UNITS.EQ.UN) IT=7
!WB         UN = 'metr'
    IF (PRI.EQ.PR) WRITE(2,630) DT,NFI,SF,PP(IT+1),PP(IT+2),NRG
    NFI=NFI/IFIX(SNGL(DT))
!WB         NFI = same / DT as an integer (IFIX converts by truncating)
C
C **** INPUT INFILTRATION AND SOIL DATA.
C
    READ (1,810) TEST
    IF (TEST.NE.C3) GO TO 580
!WB         C3 = ' so'
    READ (1,780) ISR
!WB         ISR = # of soil types
            IF (PRI.EQ.PR) WRITE (2,750) PP(IT+1),PP(IT+2),PP(IT+1)
    IF (ISR.GT.30) GO TO 530
    ASMBAR=0.
    FPBAR=0.
!WB         I'm guessing that these are average values
    DO 60 I=1,ISR
!WB         do from i=1 to # of soil types
    READ (1,790) TP(I),FCAP(I),FC(I),A(I),DF(I),ASM(I)
!WB         read TP=porosity for soil type i, FCAP=field cap for soil i as a
!WB         fraction of pore space, FC=wilting point for soil it as a fraction
!WB         of pore space, A=ratio of sat hyd cond of the top layer and sat hyd
!WB         cond for underlying layer for soil i, DF=depth of soil horizon,
!WB         ASM=antecedent soil moisture as a fraction of pore space for soil i,
```

```
C *** NRZ 9/12/94
C *** ADD LINE TO READ SATURATED HYDRAULIC CONDUCTIVITY FROM INPUT FILE

      READ (1,791) KOPT(I),SK(I)
!WB         I'm not really sure, but i'm guessing hydraulic conductivity?
C *** NRZ 9/12/94
            FCFRAC(I)=FCAP(I)*TP(I)
!WB         THE FIELD CAPACITY ON A VOLUME BASIS = FIELD CAP AS A FRACTION OF
!WB         PORE SPACE * FRACTIONAL PORE SPACE
!WB         NOTE TO SELF, THIS VARIABLE WAS CHECKED AND IS CORRECT!  MANY MANY TIMES.
      ASMBF(I)=ASM(I)
!WB         antecedent soil moisture as a fraction of pore space
      FCAP1(I)=FCAP(I)
!WB         field capacity as a fraction of pore space
      DF1(I)=DF(I)
!WB         depth of soil horizon
      SPER(I)=0.
!WB         steady state infiltration rate (mm/h)
      READ(1,795) CL(I),SA(I),ST(I),OM(I),WCF(I),VFSPER(I)
!WB         CL = clay content of the soil, SA = sand content of the soil (%),
!WB         ST = silt content of the soil (%), OM = organic matter content (%)
!WB         WCF = weight of the coarse fragment (%),VFSPER = percent of very
!WB         fine sand in the soil.
*PK REPRESENT SOIL PH
C----
      BD(I)=2.65*(1.-TP(I))
!WB         bulk density g/cm3

C
CC.....WATER TEMPERATURE ASSUMED TO BE 20 DEG.C. (68 DEG.F.).....
CC..........AT OTHER TEMPERATURES ADJUST VISCOS AND SWH2O..........
C
      AGRAV=32.174
!WB         acceleration due to gravity
      VISCOS=0.0000108
!WB         water viscosity
      SWH2O=62.32
!WB         specific weight of water
      IF(UNITS.NE.UN) GO TO 58
!WB         UN = 'METR' , so if its not metric, jump on down
      AGRAV=9.8066352
      VISCOS=0.000001003352832
C     SWH2O=9789.69088
      SWH2O=999.1677535
   58 CONTINUE
   60 CONTINUE
C
      DO 57 I=1,ISR
****************************************************
*ADDING THE CRUST THICKNESS ASSUMED TO BE 0.005M
      ZC(I)=0.5
****************************************************


******************************
***POROSITY
***************


      PHI(I)=TP(I)
!WB         porosity = porosity
****VOLUME OF COARSE FRAGMENT (>2MM)
             VCF(I)=100.*(WCF(I)/2.65)/(100.-(WCF(I)/BD(I))+(WCF(I)/2.65))
* WHERE WCF IS THE WEIGHT OF COARSE FRAGMENT (%)
****CORRECTION FACTOR FOR COARSE FRAGMENT
             CFC(I)=1.0-(VCF(I)/100.0)
****CATION EXCHANGE CAPACITY/%CLAY
             CEC(I)=(0.0059*CL(I)+0.041)/(.6*CL(I))
             IF(CEC(I).LT.0.15) CEC(I)=0.15
****CORRECTION FOR ENTRAPPED AIR
```

```
          EAC(I)=1.0-(3.8+0.00019*CL(I)**2.-0.0337*SA(I)+0.126*CEC(I)
     &  *CL(I)+OM(I)*(SA(I)/200.)**2.)/100.

**************************
****EFFECTIVE POROSITY
           PHIC(I)=PHI(I)*CFC(I)*EAC(I)
**************************

****************************
****CAPILLARY FRONT POTENTIAL
******************************
      XF(I)=6.531-7.33*PHIC(I)+.001583*CL(I)**2.0+3.81*PHIC(I)**2.0
     & -.0498*SA(I)*PHIC(I)-.000799*SA(I)**2.0*PHIC(I)
     &-.0000140*SA(I)**2.0*CL(I)-.00348*CL(I)**2.0*PHIC(I)
     &  +.00034*CL(I)*SA(I)+.0016*CL(I)**2.0*PHIC(I)**2.0
     &  +.00161*SA(I)**2.0*PHIC(I)**2.0

************************
          PSIF(I)=DEXP(XF(I))
****************************************
!WB       PSIF = cap potential at the infil wetting front (mm)
*CONVERTING PSIF TO MM
          PSIF(I)=10.*PSIF(I)
************************

******CONSTANT C USED TO COMPUTE THE SATURATED HYDRAULIC CONDUCTIVITY

          CBF(I)=-0.17+0.181*CL(I)-0.00000069*SA(I)**2.0*CL(I)**2.0
     &    -.00000041*SA(I)**2.0*ST(I)**2.0+0.000118*SA(I)**2.0*BD(I)**2.
     &    +0.00069*CL(I)**2.0*BD(I)**2.0+0.000049*SA(I)**2.0*CL(I)
     &    -0.000085*ST(I)*CL(I)**2.0

****RESIDUAL SOIL WATER
           THETAR(I)=(0.2+0.1*OM(I)+0.25*CL(I)*CEC(I)**0.45)*(BD(I)/100)
     &  *EAC(I)*CFC(I)
           asmbf(i)=asmbf(i)-(thetar(i)/tp(i))
            RESWAT(I)=THETAR(I)/TP(I)

****
* UPPER STAGE OF SOIL EVAPORATION (MM DAY ** -0.5)

**      ESU(I)= 9.*((4.165+0.02456*SA(I)-0.01703*CL(I)-0.0004*SA(I)
**   1       *SA(I))-3.)**0.42
           ESU(I)=9.*(3.5-3.)**0.42
*COMPUTE THE MAXIMUM EVAPORATIVE DEPTH
           EDX(I)=90.-0.77*CL(I)+0.006*SA(I)*SA(I)
************************************
****SATURATED HYDRAULIC CONDUCTIVITY
            KS(I)=((PHIC(I)-THETAR(I))**3.0/(1-PHIC(I))**2.0)
     &      *(BD(I)/THETAR(I))**2.0*0.0002*CBF(I)**2.0
************************************
****MACROPOROSITY FACTOR
          Z(I)=DEXP(0.96-.032*SA(I)+.04*CL(I)-0.032*BD(I))
          IF(Z(I).LE.0.4) Z(I)=0.4
* SEE WEPP MANUAL
****CRUST FACTOR
          ZC(I)=1.
          SCF(I)=0.0099+.0721*ZC(I)+0.0000068*SA(I)**2.+.0000212*SA(I)
     &     **2.0*ZC(I)+.0003151*SA(I)*ZC(I)**2.0
****DEPTH TO WETTING FRONT
*** DEPTH TO WETTING FRONT MUST BE GREATER THAN CRUST DEPTH (1CM)

          LF(I)=14.7-(0.0015*SA(I)**2.)-0.3*CL(I)*BD(I)
          IF(LF(I).LE.ZC(I)) LF(I)=ZC(I)

****CORRECTION FACTOR FOR PARTIAL SATURATION OF THE SUBCRUST SOIL
          CS(I)=0.74+0.0019*SA(I)
****CRUST REDUCTION FACTOR
          CRC(I)=LF(I)/((LF(I)-ZC(I))/CS(I)+ZC(I)/SCF(I))
```

```
*CONVERTING KE TO CM/HR TO MM/HR
     KS(I)=KS(I)*10.

C *** NRZ 9/12/94
C *** ASSIGN USER ENTERED VALUE OF SATURATED HYDRAULIC CONDUCTIVITY

     IF (KOPT(I).EQ.1) KS(I) = SK(I)
!WB         KOPT must be a flag for the K option,
C *** NRZ 9/12/94

     LF(I)=LF(I)*10.
* this is the depth of the first soil layer
*      DF(I)= 250.
*COMPUTING PARTITION FACTOR FOR DISSOLVED AND ADSORBED AMMONIUM
      PKDA(I)=1.34+0.083*CL(I)
*COMPUTING PARTITION COEFFICIENT FOR PHOSPHORUS
      PKDP(I)=100.+2.5*CL(I)
*      PKDP(I)=5.1+2.2*CL(I)+26.4*(PK(I)-6.)*(PK(I)-6.)
*      WRITE(6,*) PK(I),PKDP(I)
      PSP(I)=0.46-0.0916*DLOG(CL(I))
      IF(PSP(I).LT.0.05)PSP(I)=0.05
      IF(PSP(I).GT.0.75) PSP(I)=0.75
!WB         phosphorus sorption coefficient
C----
     IF (PRI.EQ.PR) WRITE (2,640) I,TP(I),FCAP(I),FC(I),KS(I),DF(I)
    1,ASM(I)
!WB         I = counter to # of soil types, TP = porosity for soil type i,
!WB         FCAP = field cap, FC = wilting point, KS = sat hydr cond, DF =
!WB         depth of soil horizon, ASM = antecedent soil moisture
  57    CONTINUE


C
C .... ADDITIONAL CALCULATIONS FOR EXTENDED SEDIMENT MODEL
C
     WRITE(2,1040)
     READ(1,1050)NPART,NWASH
!WB         NPART = # of particle size classes, NWASH = # of washload particles
     WRITE(2,1060)NPART,NWASH
     NWASH1=NWASH+1
     IF(NWASH.EQ.NPART) NWASH1=1
     VISCOS=1./VISCOS
!WB         VISCOS = kinematic viscosity of water (m2/s)
     READ(1,1070)(DIAMM(IC),SG(IC),FV(IC),IC=1,NPART)
!WB         DIAMM = particle diameter (MM), SG = spec grav, FV = fall velocity
     DO 70 IC=1,NPART
             IF(UNITS.EQ.UN) GO TO 61
             DIA(IC)=DIAMM(IC)*.0032808399
!WB         particle diameter (m)
             GO TO 62
   61   DIA(IC)=DIAMM(IC)*0.001
   62   IF(FV(IC).LE.0.00000001) GO TO 63
             GO TO 70
C
CC.........CALCULATION OF PARTICLE FALL VELOCITIES..........
C
   63   FV(IC)=AGRAV*(SG(IC)-1.)*VISCOS*DIA(IC)**2/18.
             X1=DIA(IC)*VISCOS
             REYN=FV(IC)*X1
!WB         particle reynold's #
             IF(REYN.LE.0.1) GO TO 70
             X2=DSQRT(4.*AGRAV*(SG(IC)-1.)*DIA(IC)/3.)
             DO 69 I=1,10
               CD=24./REYN+3./DSQRT(REYN)+.34
!WB         CD = drag coeff. used in determining particle fall velocity
               FV(IC)=X2/DSQRT(CD)
               REYN=FV(IC)*X1
   69   CONTINUE
   70 CONTINUE
C
```

```
CC.........CALCULATION OF EQUIVALENT SAND DIAMETERS.........
C
      DO 78 IC=1,NPART
            IF(SG(IC).GT.2.645) GO TO 77
!WB         if spec gravity of particle size gt 2.645
            X4=FV(IC)*VISCOS
!WB         X4 = fall velocity * kin viscos of water
            DS=DSQRT(10.90909091*FV(IC)/(AGRAV*VISCOS))
!WB         sand diameter? because its not the rate of sed inflow
            REYN=X4*DS
!WB         reynolds # = X4 * sand diameter
            IF(REYN.LE.0.1) GO TO 76
            X3=FV(IC)**2/(AGRAV*2.2)
            DO 75 II=1,20
             DS=X3*(24./REYN+3./DSQRT(REYN)+.34)
             REYN=X4*DS
   75   CONTINUE
   76   EQSDIA(IC)=DS
!WB         equivalent sand diameter of particle i (m)
            GO TO 78
   77   EQSDIA(IC)=DIA(IC)
   78 CONTINUE
      X3=304.8
      IF(UNITS.EQ.UN) X3=1000.
      DO 79 IC=1,NPART
   79 EDMM(IC)=EQSDIA(IC)*X3
      WRITE(2,1080)PP(IT+4)
      WRITE(2,1090)(IC,DIAMM(IC),EDMM(IC),SG(IC),FV(IC),IC=1,NPART)
      WRITE(2,1100)
      DO 85 J=1,ISR
      READ(1,1110)(F(J,I),I=1,NPART)
!WB         fraction of particles of type i in original soil
  85  WRITE(2,1120)J,(F(J,I),I=1,NPART)

************************************************************************
* INPUT SPECIFIC SURFACE AREA FOR PHOSPHORUS COMPONENT
* SPECIFIC SURFACE AREA MUST BE IN M^2/G

       WRITE(2,*)'SPECIFIC AREA FOR DIFFERENT PARTICLE SIZE'
       DO 86 J=1,ISR
       READ(1,1111) SSAT(J),(SSA(J,I),I=1,NPART)
!WB         SSA = spec surf area for part class j for soil type i, SSAT = total
!WB         SSA for soil type i
       WRITE(2,1111) SSAT(J),(SSA(J,I),I=1,NPART)
 86    CONTINUE

       DO 81 J=1,ISR
       SASA=0.
!WB         SASA = unknown
            DO 88 I=1,NPART
             SSA(J,I)=SSA(J,I)*F(J,I)
             SASA=SASA+SSA(J,I)
 88     CONTINUE
            DO 82 I=1,NPART
             SSA(J,I)=SSA(J,I)*SSAT(J)/SASA
 82     CONTINUE
 81    CONTINUE
************************************************************************

C
C **** NRZ 9/12/94
C **** MODIFY INPUT LINE TO INCLUDE FERTILIZER FILE FLAG
C **** INPUT DRAINAGE AND GROUNDWATER CONSTANTS.
C
C     READ (1,980) NEXP,DC,GRF
      READ (1,980) NEXP,DC,GRF,IFERT
!WB         NEXP = ? , DC = tile drainage coefficient, GRF = fractional
!WB         rate of baseflow release, IFERT = fert app flag
      IF (PRI.EQ.PR) WRITE (2,990) NEXP,DC,PP(IT+1),GRF
      IF (IFERT.EQ.1) OPEN (9,FILE='FERTILIZER.INP',STATUS='OLD')
```

```
C **** NRZ 9/12/94
** NRZ (8/29/94)
** ADDED IMPOUNDMENT INPUT STATEMENT
C
C **** INPUT IMPOUNDMENT DATA

     READ (1,981) NIMP
     WRITE(2,*) 'THE NUMBER OF IMPOUNDMENTS IS ',NIMP
     IF (NIMP.GT.0) THEN
       READ(1,*)
       READ(1,*)
     ENDIF
     DO 12000 NCHC=1,NIMP
       READ (1,982) NCH,BASE(NCH),WIDTH(NCH),SLOPE(NCH),ORIF(NCH),
    &  MAXHGT(NCH),CI(NCH),FI(NCH),AFWEV
!WB          See the input variable guide for a description of this subroutine.
12000 CONTINUE

** NRZ (8/29/94)

C
C **** INPUT CROP AND SURFACE ROUGHNESS DATA.
C
     READ (1,810) TEST
     IF (TEST.NE.C4) GO TO 580
!WB          C4 = ' SU'
     READ (1,940) ICR
     WRITE(2,*) 'THE NUMBER OF CROPS IS',ICR
     IF (PRI.EQ.PR) WRITE (2,950) PP(IT+1),PP(IT+1),PP(IT+1)
     IF (ICR.GT.20) GO TO 550
     DO 87 I=1,ICR
     CBAR(I)=0.
!WB          percent of watershed in crop i
     READ (1,620) CROP(I,1),CROP(I,2),PIT(1,I),PER(I),ROUGH(I),HU(I),
    1DIRM(I)
!WB          CROP(I,1),CROP(I,2) = alphanumeric name of crop i
!WB          PIT(1,I) = interception storage for cover for surface type i (mm)
!WB          PER(I) = fraction of element area covered by foliage for surface type i
!WB          ROUGH(I) = surface depth-storage parameter for surface i
!WB          HU(I) = maximum height differential on soil surface (mm)
!WB          DIRM(I) = maximum physical retention depth for cropping practice i
     DIRM2(I)=DIRM(I)
!WB          max physical ret depth for crop practice i = same
     READ(1,623) AC(I),AO(I),BC(I),BO(I),INRCOVI(I),INRCOVF(I),
             1LIVEROOT(I),DDROOTI(I),DDROOTF(I)
!WB          AC(I) = canopy area (%)
!WB          AO(I) = area outside canopy (%)
!WB          BC(I) = bare area under canopy (%)
!WB          BO(I) = bare area outside canopy (%)
!WB          INRCOVI(I) = INTERRILL AREA COVERED BY GROUND COVER AT BEG OF SEASON
!WB          INRCOVF(I)=INTERRILL AREA COVERED BY GROUND COVER AT END OF SEASON
!WB          LIVEROOT(I)=MASS OF LIVE ROOTS IN THE 0 TO 0.15 M OF THE SOIL SURFACE
!WB          IN KG/M^2
!WB          DDROOTI(I) = MASS OF DEAD ROOTS AT THE BEG OF THE COVER PERIOD IN THE
!WB          0 TO 0.15 M OF THE SOIL        SURFACE IN KG/M^2
!WB          DDROOTF(I) = MASS OF DEAD ROOTS AT THE END OF THE COVER PERIOD IN THE
!WB          0 TO 0.15 M OF THE SOIL SURFACE.
     IF (DDROOTI(I).LT.DDROOTF(I)) THEN
             WRITE (*,1962) DDROOTI(I),DDROOTF(I)
             PAUSE
             STOP
             ENDIF
             INRCOVI(I)=INRCOVI(I)/100.
             INRCOVF(I)=INRCOVF(I)/100.
             READ(1,624) (LAI(I,I111),I111=1,11)
!WB          leaf area index
     READ(1,625)DATPLA(I),DATHAR(I),CP1(I),CP2(I),DMY(I),YP(I)
    & ,ROTMAX(I),RLAIMX(I)
!WB          DATPLA(I) = planting date
```

```
!WB      DATHAR(I) = harvest date
!WB      CP1(I) = exponent for nitrogen content
!WB      CP2(I) = exponent for nitrogen content
!WB      DMY(I) = dry matter ratio
!WB      YP(I) = yield potential (kg/ha)
!WB      ROTMAX(I) = maximum rooting depth for crop i (mm)
!WB      RLAIMX(I) = maximum lai

!WB      ***** READ IN THE PARAMETERS FOR THE NEW SED ROUTINE *********
         READ(1,626) RANROU(I),BR(I),MAXPLHGT(I),GROWFACT(I),RILLSPC(I),
         1MNSOIL(I),MNTOT(I),NOTILL(I),NOEROS(I)

!WB      RANROU=RANDOM ROUGHNESS OF THE SOIL SURFACE(MM), BR=BURIED RESIDUE
!WB      W/IN 0 TO 0.15 M OF THE SOIL SURFACE (KG/HA), MAXPLHGT=MAXIMUM
!WB      PLANT CANOPY HEIGHT (M), GROWFACT=FRACTION OF GROWTH PERIOD
!WB      REQUIRED FOR THIS CROP TO REACH MATURITY, RILLSPC=RILL SPACING
!WB  (M OR M/RILL WHICH SAYS M B/T RILLS), MNSOIL=MANNING'S N
!WB  FRICTION FACTOR FOR THE        BARE SOIL, MNTOT=MANNING'S N FRICTION
!WB  FACTOR FOR THE SURFACE WITH COVER.  NOTILL=A TILLAGE FLAG THAT
!WB      INDICATES THE CROP COVER IS A NO-TILL CROP.  THIS AFFECTS THE
!WB      RILL WIDTH CALCULATION.  NOEROS=A FLAG INDICATING THAT A CROP
!WB      IS A NON-ERODIBLE PRACTICE (I.E.-POND, COMMERCE)
         RN(I)=MNTOT(I)
!WB      RN(I) = manning's n for surface type 1, I MOVED THIS FROM WHERE
!WB      IT WAS READ ORIGINALLY DUE TO SOME LAST MINUTE CHANGES.

         RANROUM(I)=RANROU(I)/1000
!WB      CONVERT RANDOM ROUGHNESS TO MM FROM M
!WB      ERROR CHECKS
         IF (MNSOIL(I).GT.MNTOT(I)) THEN
         WRITE (2,1950) MNSOIL(I),MNTOT(I),I
         WRITE (*,1950) MNSOIL(I),MNTOT(I),I
         STOP
         ENDIF
         IF (NOTILL(I).NE.0) THEN
         IF (NOTILL(I).NE.1) THEN
         WRITE (*,1952)
         WRITE (2,1952)
         PAUSE
         STOP
         ENDIF
         ENDIF
         IF (NOEROS(I).NE.0) THEN
         IF (NOEROS(I).NE.1) THEN
         WRITE (*,1954)
         WRITE (2,1954)
         PAUSE
         STOP
         ENDIF
         ENDIF
         IF (BR(I).GT.1) THEN
         WRITE (*,1956)
         WRITE (2,1956)
         PAUSE
         ENDIF
!WB      ERROR CHECKS
**********************************************************************
* COMPUTE A EFFECTIVE HYDRAULIC CONDUCTVITY FOR EACH SOIL
* CROP COMBINATION)

****CANOPY FACTOR
         CF(I)=1.+AC(I)/(AC(I)+AO(I))
!WB      CF = 1+canopy area / (canopy area + area outside of canopy)

   DO 84 KKK=1,ISR


************************************
****EFFECTIVE HYDRAULIC CONDUCTIVITY
```

```
** SEARCHING FOR THE CORRECT HYDRAULIC CONDUCTIVITY
*************************************************************
***********************************************************

          KE(KKK,I)= KS(KKK)*
   &       ( CF(I)*(AC(I)/100.)
   &      *(BC(I)*CRC(KKK)/AC(I)+Z(KKK)*(1-BC(I)/AC(I)))
   &      +(AO(I)/100.)
   &      *(BO(I)*CRC(KKK)/AO(I)+Z(KKK)*(1-BO(I)/AO(I))))
*****************************************************************

 84   CONTINUE

     IF (ROUGH(I).GT.1.0.OR.ROUGH(I).LE.0.) GO TO 590
     IF (PRI.EQ.PR) WRITE (2,960) I,CROP(I,1),CROP(I,2),PIT(1,I),PER(I)
    1,ROUGH(I),HU(I),DIRM(I)


  87 CONTINUE
!WB   ******* PRINT SECTION FOR NEW SEDIMENT VARIABLES *******
     DO I=1,ICR
          IF (PRI.EQ.PR) THEN
          IF (I.EQ.1) WRITE (2,975)
          WRITE (2,976) I,RANROU(I),BR(I),MAXPLHGT(I),GROWFACT(I)
    1,RILLSPC(I)
          END IF
          END DO
          DO I=1,ICR
          IF (PRI.EQ.PR) THEN
          IF (I.EQ.1) WRITE (2,977)
          WRITE (2,978) I,MNSOIL(I),MNTOT(I),NOTILL(I),NOEROS(I)
          ENDIF
          END DO
          DO I=1,ICR
          IF (PRI.EQ.PR) THEN
          IF (I.EQ.1) WRITE (2,1958)
          WRITE (2,1960) I,INRCOVI(I),INRCOVF(I),LIVEROOT(I),DDROOTI(I),
          1DDROOTF(I)
          ENDIF
          END DO
          WRITE (2,*)
!WB ***** END OF PRINT SECTION FOR NEW SEDIMENT VARIABLES *****

C **** RWC
C     INPUT ROTATION DESCRIPTION
      READ(1,940) IROT1
      DO 89 I=1,IROT1
       WRITE(2,*) 'READING IN THE ROTATION PARAMETERS FOR',I

C **** NRZ 7/20/95
C **** MODIFIED ROTATION INPUT TO ALLOW 8 ADDITIONAL END DATES
C         READ(1,1800) IROT(I,1),(IROT(I,I1111),I1111=2,41)
          READ(1,1800) IROT(I,1),(IROT(I,I1111),I1111=2,57)
  89  CONTINUE

C
C **** INPUT CHANNEL DATA.
C
     READ (1,810) TEST
     IF (TEST.EQ.C6) GO TO 80
!WB        ' EL'
!WB        if there are no channel elements, then they are overland
!WB        elements, jump down to 80 to read those
     IF (TEST.NE.C5) GO TO 580
!WB        ' CH', if the flag doesn't equal el or ch, then something
!WB        is wrong, so jump down and stop the program
C **** NRZ 9/11/94
C **** ADD INPUT FOR NUMBER OF CHANNEL NETWORKS
```

```
      READ (1,920) NCHAN

C **** NRZ 9/11/94

      READ (1,920) M
!WB        M = # of types of channels
      IF (M.GT.10) GO TO 510
!WB        if there are more than 10 types of channels, then jump down
!WB        and stop the program !!!!!shouldn't there be only 9 channel
!WB        types?
      READ (1,760) (WID(I),MNCS(I),CN(I),IMPERM(I),ARMOUR(I),I=1,M)
!WB        WID = width of channel type, CN = manning's n for channel type i
!WB        MNCS=MANNING'S N FRICTION FACTOR FOR BARE SOIL FOR THE CHANNEL,
!WB        MNCT=MANNING'S N FF FOR SOIL+VEGETATION IN CHANNEL, IMPERM=
!WB        DEPTH TO IMPERMEABLE LAYER IN THE CHANNEL, ARMOUR = FRACTION
!WB        OF CHANNEL SOIL THAT IS UNERODIBLE, OR EROSION RESISTANT

           DO I=1,M
           MNCT(I)=CN(I)
!WB        SET THE MANNING'S N CHANNEL SOIL + VEG VARIABLE EQUAL TO CN (SAME)
           ENDDO
           IF (MNCS(I).GT.MNCT(I)) THEN
           WRITE (*,1950) MNCS(I),MNCT(I),'CHAN ',I
           STOP
           ENDIF
           IF (PRI.EQ.PR) WRITE (2,650) PP(IT+4),(I,WID(I),MNCS(I),
           1MNCT(I),IMPERM(I),ARMOUR(I),I=1,M)
C
C **** INPUT OUTFLOW ELEMENT POSITION.
C
      READ (1,820) TEST,TITLE
!WB        why read test and title of the farm
      IF (TEST.NE.C6) GO TO 580
!WB        C6 = '  EL'
C **** NRZ 9/11/94

C **** OPEN A SCRATCH OUTPUT FILE FOR EACH CHANNEL OUTLET AND THE "LEAKY"
C **** CELLS

      DO 91 NCH=1,NCHAN+1
           NUNIT=10+NCH
           IF (NCH.LE.NCHAN) THEN
            WRITE(OUTFIL(NCH),301) 'CHANNEL',NCH,'.OUT'
  301    FORMAT (A7,I1,A4)
           ELSE
            WRITE(OUTFIL(NCH),302) 'LEAKYCELL.OUT'
  302    FORMAT (A13)
           ENDIF
           OPEN (NUNIT,FILE=OUTFIL(NCH))
!WB        I feel as though this should be above the if then loop, but
!WB        this seems to work.  Something to look into.  I commented this
!WB        line out and the program wrote the proper file anyway.
   91 CONTINUE

C **** MODIFY INPUT LINE TO ACCEPT MULTIPLE OUTLETS

C  80 READ (1,610) DX,NIOUT,NJOUT
C *** NRZ
C *** The length of the side of each square element is DX
   80 READ (1,609) DX
      READ (1,610) (NIOUT(NCH),NJOUT(NCH),NCELLS(NCH),NCH=1,NCHAN)
!WB        NIOUT = row # of catchment outflow element, NJOUT = column #
!WB        of outlet cell for channel network i, NCELLS = # of cells in
!WB        channel network i (entered as input)

C **** NRZ 9/11/94
C
C **** EVALUATE CONSTANTS FOR USE WITH METRIC OR ENGLISH UNITS.
C **** METRIC UNITS.
C
```

```
      DX2=DX*DX

C *** NRZ
C *** The area of each cell (in ha) is computed here
      AREA2=DX2/1.E+4
!WB         area2 is supposed to be element or channel area, but instead it
!WB         looks like area in ha
      CU1=DX2/1.E+3
!WB         conversion from mm to m3
      CU2=DT/DX2*500.
!WB         conversion for twice m3?, looks like time increment / (cell
!WB         size in m2 * 500)
      CU=DX2/3.6E+6
!WB         conv from mm/h to m3/s? = cell area in m2 / 3.6E6
      CONST=DX/(2./DT*DX2)**1.6667
!WB         flow depth units conversion factor = cell width / (2./cell
!WB         width * cell area in m2) ^1.6667
      IF (UNITS.EQ.UN) GO TO 90
!WB         jump over the next section if the units are metric
C
C **** CONVERT TO ENGLISH UNITS.
C
      CU1=CU1/.012
      CU=CU/.012
      CU2=CU2*.012
      CONST=1.486*CONST
      AREA2=AREA2/4.3560
C
C **** INPUT INDIVIDUAL ELEMENT TOPOGRAPHICAL DATA.
C
* CHANGING ORIGINAL VALUR OF NPAR AND NPAR2 FROM 13 & 11 TO 20,18
   90  NPAR=22
      NPAR2=20
!WB         NPAR and NPAR2 are counters for the # of parameters, and are
!WB         used for data manipulation
C
C **** CHANGE DIMENSION STATEMENT BELOW IF JMAX IS CHANGED.
C
      JMAX=103
!WB         max # of columns
      NMAX=2000
!WB   max # of cells, overland flow + channel segments
      N=0
!WB         probably a counter reset
      II=0
!WB         II is a counter / place holder
      SCMIN=9.
!WB         minimum slope value, probably in channels
      SCMAX=0.
!WB         max value of slope, probably in channels
      SCBAR=0.
!WB         average value of slope, probably in channels
      SMIN=9.
!WB         min elemental and channel slope in watershed
      SMAX=0.
!WB         final accum sed loss from catchment (kg)? maybe max slope
      SBAR=0.
!WB         average catchment slope
      TBAR=0.
!WB         percent of elements tiled
      DO 100 J=1,JMAX
  100 IEL(3,J,3)=0
!WB         make sure you reset the last element flag of element counter flag
!WB         to 0 for all elements
C
C **** INPUT FIRST ROW OF ELEMENTAL DATA.
C
* ADDED PHOSPHORUS INPUT ITEMP(12,13)

      READ (1,680) (ITEMP(K),K=1,7),(ITEMPC(L),L=1,2),(ITEMP(K),K=8,16)
```

```
      READ (1,681) (ITEMP(K),K=17,20)
!WB          ITEMP(1) = element #
!WB          ITEMP(2) = column # of last watershed element in the row
!WB   ITEMP(3) = 9 in this column indicates last element in list
!WB   ITEMP(4) = slope steepness in tenths of a percent (2.9% = 29)
!WB   ITEMP(5) = direction of steepest slope, in c!WB degrees from r-horizon
!WB   ITEMP(6) = channel network designator
!WB   ITEMP(7) = I1 = rotation #
!WB   ITEMPC(1) = rain gauge designator
!WB   ITEMPC(2) = tile drainage designator
!WB   ITEMP(8) = SS(I) = channel slope
!WB   ITEMP(9) = PRACT = # of structural practice type (BMP practice?)
!WB   ITEMP(10) = TRAP = trapping efficiency of ponds / bmps
!WB   ITEMP(11) = CHAN = channel # perhaps?
!WB   ITEMP(12) = SORGP = soil organic P (kg/ha)
!WB   ITEMP(13) = EDI = effective depth of interaction (mm)
!WB   ITEMP(14) = PMINP = active mineral P (kg/ha)
!WB   ITEMP(15) = SOILP = stable soil P (kg/ha)
!WB   ITEMP(16) = PLAB = labile P (kg/ha)
!WB   ITEMP(17) = POTMIN = potentially mineralizable soil N (kg/ha)
!WB   ITEMP(18) = AMON = total NH4 present in soil (kg/ha)
!WB   ITEMP(19) = SOILN = stable soil organic N (kg/ha)
!WB   ITEMP(20) = SZNO3 = nitrate present in soil (kg/ha)
C **** NRZ 9/11/94
C **** MODIFIED CALL FOR MULTIPLE OUTLETS
!WB          the input cell data is read in to the itemp arrays, and then
!WB          you jump down to the subroutine relem and roll 2 into 1 and
!WB          then 3 into 2.  Then, in relem, you move the itemp array
!WB          elements into the third row.  Then you are returned.  You go
!WB          through this twice because the first time you roll the data
!WB          into lines 2 and 1 when they are originally empty.  Then you
!WB          go through again, roll 2 into 1, 3 into 2 and then itemp into
!WB          line 3.  In relem, you read all the column elements in a row
!WB          before being returned to the xdata subroutine.
!WB          Then you can do calculations (2&3 have data in them).
!WB   The elements of IEL
!WB          are put in as (i,j,k) where i = row #, j = column #,
!WB          k = parameter value, except for 3 (i,j,3) which is reset
!WB          to an element 3 counter, and (i,1,2) which is set to
!WB   the column # of the last element in that row

      CALL RELEM (IEL,ITEMP,N,ISR,ICR,NMAX,JMAX,NPAR,IELC,ITEMPC,
     1NPAR2)
C
C **** PUT WATERSHED ELEMENTAL DATA INTO SINGLE DIMENSIONED ARRAYS.
C

C **** MODIFIED CALL FOR MULTIPLE OUTLETS

  110 CALL RELEM (IEL,ITEMP,N,ISR,ICR,NMAX,JMAX,NPAR,IELC,ITEMPC,
     1NPAR2)
C 110 CALL RELEM (IEL,ITEMP,N,MOUT,NIOUT,NJOUT,ISR,ICR,NMAX,JMAX,NPAR,
C    1IELC,ITEMPC,NPAR2)

C **** NRZ 9/11/94
      JS=IEL(2,1,2)
!WB          column # for last column on current element row which is set in
!WB          the relem subroutine.
!WB**************************************************
!WB          beginning of do loop for the current row's calculations
!WB**************************************************
      DO 270 J=1,JS
!WB          do this for the # of columns?
      JM1=J-1
      I=IEL(2,J,3)
!WB          I is reset to an element # counter (it holds the # counter)
!WB          in the relem subroutine.  Also, mout(nch) is set equal to niout
!WB          and njout in the relem subroutine.
      IF (I.EQ.0) GO TO 270
!WB          if the element counter = 0, jump out of this loop, but I'm
```

```
!WB         not sure when this would be true.
     SL(I)=DBLE(IEL(2,J,4))/1000.
!WB         overland element slope
     IF (SL(I).LT.SMIN) SMIN=SL(I)
     IF (SL(I).GT.SMAX) SMAX=SL(I)
     SBAR=SBAR+SL(I)

C **** NRZ 9/5/94
C **** COMPUTE CHANNEL NETWORK DESIGNATOR AND CHANNEL WIDTH NUMBER
C **** FROM 5-DIGIT NUMBER IEL(2,J,6)

     CHNUM(I)=IEL(2,J,6)/1000000
!WB         chnum is the channel # designator
     CHAN(I)=MOD(IEL(2,J,6),1000000)/10000
!WB         chan(I) = (IEL(2,J,6)-int(IEL(2,J,6)/10000)*10000)/100
!WB         so this is the 3rd number in decimal form of the channel #
!WB         designator (for ex: CHAN(I) of 10201 is 2.01), CHAN(I) is
!WB         the width designator for the channel (it's a type 1 or 2, etc)
            IF (CHAN(I).GT.0) THEN
     CHNSL(I)=(MOD(MOD(IEL(2,J,6),1000000),10000))/100
!WB         CHNSL(I)= SOIL TYPE # OF CHANNEL CELL
            IF (CHNSL(I).GT.ISR) THEN
            WRITE (2,865) CHNSL(I),I,ISR
            WRITE (*,865) CHNSL(I),I,ISR
            PAUSE
            STOP
            ENDIF
            ENDIF
C **** NRZ 9/5/94

     IF (CHAN(I).GT.10) WRITE (2,1020) CHAN(I),I
!WB         if the channel # is greater than 10, then write it
!WB         I feel like this should be an error statement, or should
!WB         do something aside from simply writing the cell width & #
     SS(I)=DBLE(IEL(2,J,8))/1000.
!WB         SS is channel slope / 1000
*******************************************************************
* PUT PHOSPHORUS AND NITROGEN INPUT VALUE INTO DIMMENSIONED ARRAYS
* P0SOIL=INITIAL PHOSPHORUS CONTENT OF SOIL
* EDI EFFECTIVE DEPTH OF INTERACTION
* INPUT ARE DONE IN KG/HA
* CONVERT EVERYTHING TO KG
*******************************************************************
      CONFAY=DX*DX/10000.
!WB         confay = (area in ha)
      SORGP(I)=IEL(2,J,12)
!WB    SORGP = soil organic P (kg/ha)
      SORGP(I)=SORGP(I)*CONFAY
      EDI(I)=IEL(2,J,13)
!WB   ITEMP(13) = EDI = effective depth of interaction
      PMINP(I)=IEL(2,J,14)
!WB   ITEMP(14) = PMINP = active mineral P (kg/ha)
      PMINP(I)=PMINP(I)*CONFAY
      SOILP(I)=IEL(2,J,15)
!WB   ITEMP(15) = SOILP = stable soil P (kg/ha)
      SOILP(I)=SOILP(I)*CONFAY
      PLAB(I)=IEL(2,J,16)
!WB   ITEMP(16) = PLAB = labile P (kg/ha)
      PLAB(I)=PLAB(I)*CONFAY
      POTMIN(I)=IEL(2,J,17)
!WB   ITEMP(17) = POTMIN = potentially mineralizable soil N (kg/ha)
      POTMIN(I)=POTMIN(I)*CONFAY
      AMON(I)=IEL(2,J,18)
!WB   ITEMP(18) = AMON = total NH4 present in soil (kg/ha)
      AMON(I)=AMON(I)*CONFAY
      SOILN(I)=IEL(2,J,19)
!WB   ITEMP(19) = SOILN = stable soil organic N (kg/ha)
      SOILN(I)=SOILN(I)*CONFAY
      SZNO3(I)=IEL(2,J,20)
!WB   ITEMP(20) = SZNO3 = nitrate present in soil (kg/ha)
```

```
      SZNO3(I)=SZNO3(I)*CONFAY
C
C **** IF CHANNEL SLOPE NOT SPECIFIED, ASSUME IT'S HALF OVERLAND SLOPE.
C
      IF (SS(I).LE.0.) SS(I)=.50*SL(I)
      TIAL(I)=0
!WB         tile drainage flag = false
      IF (IELC(2,J,2).NE.ISTL) GO TO 120
!WB         ISTL = 'TI'
      TIAL(I)=256
!WB         this is supposed to be the tile drainage flag
      TBAR=TBAR+1.
!WB         TBAR = percent of elements tiled?
  120 M=DBLE(IEL(2,J,5))/90.+1.
!WB         the prev line reads the flow angle, divides it by 90 and adds 1,
!WB         and then rounds the number, it tells the quad #
      MM1=M-1
!WB         this is set up to tell how many quads come before M
C
C **** EVALUATE OUTFLOW PROPORTIONS TO ADJACENT COLUMN AND ROW ELEMENTS.
C
      ANG=(DBLE(IEL(2,J,5))-90.*DBLE(MM1))*.01745329
!WB         the ang calculates the angular difference from the nearest
!WB         horizontal or vertical axis, in rads
      X=SIN(ANG)+COS(ANG)
!WB         not really sure what this is for yet
!WB         this is opposite/hyp + adj / hyp = opp+adj / (2hyp)
      IX=CHAN(I)
!WB         IX is the width #
      IF (IX.EQ.0) GO TO 130
!WB         if the channel width/type is 0, go to 130
!WB         and skip over the channel conveyance calculations
C
C **** EVALUATE CONVEYANCE FOR CHANNEL ELEMENTS.
C
!WB         this section appears to create a separate counter that keeps
!WB         track of channel segments.  As this loop goes through performing
!WB         calculations, if there is a channel segment it is recorded here
!WB         and its width, slope (which may be a little awry), and
!WB         conveyance are calculated (which uses the variable PIV).
      II=II+1
!WB         II appears to be a counter, and it only works if the element
!WB         has a channel element in it
            CHNUMBER(II)=CHNUM(I)
!WB         THIS DESIGNATES THAT THE CHANNEL DESIGNATOR # OF ELEMENT II IS EQUAL
!WB         TO THE CHANNEL DESIGNATOR # OF THE CURRENT ELEMENT.  THIS IS USED
!WB         TO EXTRACT CWID,SS,PIV LATER.
      CHNSOIL(II)=CHNSL(I)
!WB         CHNSOIL(II)=CHANNEL SOIL TYPE
            MNCHNSL(II)=MNCS(IX)
!WB         MNCHNSL=MANNING'S N FRIC FACT. FOR THIS CHANNEL SOIL, INPUT ABOVE
            MNCHNTOT(II)=MNCT(IX)
!WB         MNCHNTOT=MANNING'S N FRIC FACT. FOR THIS CHANNEL SOIL + VEG
            CWID(II)=WID(IX)
!WB         width of segment i = width of identifier IX
      ROCKBOT(II)=IMPERM(IX)
!WB         ROCKBOT = DEPTH TO IMPERMEABLE LAYER
            NOERODE(II)=ARMOUR(IX)
!WB         NOERODE = THE FRACTION OF THE CHANNEL CELL THAT IS NONERODIBLE,
!WB         OR ARMORED.  THIS IS USED TO ADJUST DETACHMENT IN THE CHANNEL
!WB         EROSION MODULE.
            SS(II)=SS(I)
!WB         channel slope for element is equal to slope for channel, I is
!WB         reclassified to be the # of the element
      IF (SS(I).LT.SCMIN) SCMIN=SS(I)
      IF (SS(I).GT.SCMAX) SCMAX=SS(I)
!WB         these set the slope in the channel cell.
      SCBAR=SCBAR+SS(I)
!WB         average slope?
      PIV(II)=CONST/CN(IX)/X*(DX/WID(IX)/X)**0.6667*DSQRT(SS(I))
```

```
!WB        PIV is used to record conveyance = flow depth conversion /
!WB         (manning's N for channel width
!WB         #) / (sin ang + cos ang) * (cell width / width / (sin ang + cos ang)
!WB         ^0.6667*sqrt(element slope))
           CONSTHLD(II)=CONST
           XHOLD(II)=X
!WB        THE ABOVE VARIABLES ARE USED TO HOLD PLACES SO THAT CONVEYANCE
!WB        CAN BE CALCULATED FOR EACH TIME STEP WHEN ITS RAINING AND THE
!WB        PROPER FLOW CAN BE EXTRACTED AND ADJUSTED FOR CHANNEL WIDENING
C
C **** NOW DETERMINE THE ELEMENT(S) THAT RECEIVE OUTFLOW FROM THE
C **** CURRENT ELEMENT.  NOTE:  IT IS LEGAL FOR AN ELEMENT WITH A
C **** SHADOW CHANNEL ELEMENT TO SHOW FLOW, AT THIS TEST POINT, THAT
C **** WOULD OTHERWISE BE OUTSIDE THE CATCHMENT.
C
C **** NRZ 9/11/94
C **** THIS SECTION HAS BEEN MODIFIED TO ACCEPT MULTIPLE OUTLETS
C **** LINE 130 FINDS THE APPROPRIATE ERROR CHECK BASED ON THE QUADRANT
C **** THAT THE OUTFLOW IS DIRECTED FROM

    NOUTFL=0
!WB        flow out of watershed flag
 130 GO TO (140,150,150,140,140), M
!WB        If M is equal to 1,2,3,4,5 then the
!WB        program is directed in that manner.
 140 DO 141 NCH=1,NCHAN
!WB        do from 1 to the # of channels
    IF (NOUTFL.EQ.1) GOTO 142
!WB        if the flow out of the watershed flag = true, then goto 142
    IF ((J.GE.JMAX.OR.IEL(2,J+1,3).EQ.0).AND.CHAN(I).EQ.0.AND.
   1IEL(2,J,5).NE.270.AND.I.NE.MOUT(NCH)) THEN
!WB        if the column # of the element is ge the max # of columns or if
!WB        the element # of the next column equal 0 and the channel width
!WB        designator equals 0 and the flow direction doesn't equal 270
!WB        and the element counter # ne the outlet cell of the channel.
!WB        shouldn't the first message be an error message?
           WRITE (2,770) IEL(2,J,1),J
!WB        write element # row, column, flows out of the watershed
           NOUTFL=1
!WB        set the outflow flag equal to 1
    ENDIF
 141 CONTINUE
 142 NR(I)=IEL(2,J+1,3)
!WB        element # receiving flow from element i in the row direction
    NOUTFL=0
!WB        reset the outflow flag to 0
    GO TO (160,160,170,170,160), M
!WB        still not really sure what this is supposed to do
 150 DO 151 NCH=1,NCHAN
!WB        do from 1 to # of channels
    IF (NOUTFL.EQ.1) GOTO 152
!WB        if the outflow flag = 1, goto 152
    IF ((J.LE.1.OR.IEL(2,JM1,3).EQ.0).AND.CHAN(I).EQ.0.AND.
   1IEL(2,J,5).NE.90.AND.I.NE.MOUT(NCH)) THEN
!WB        if the column # of the current element le 1 or if the element
!WB   # of the previous column equals 0 and the channel width # equals
!WB        to 0 and the flow direction ne 90 and the element # ne the outlet
           WRITE (2,770) IEL(2,J,1),J
!WB        write that this cell flows out of the watershed at its row and
!WB        column
           NOUTFL=1
!WB        reset the leaky cell flag to 1 and continue
    ENDIF
 151 CONTINUE
 152 NR(I)=IEL(2,JM1,3)
!WB        the element # receiving flow from this cell in the row direction
!WB        is the previous cell #
    GO TO (160,160,170,170,160), M
!WB        directing flow based on the value of M (1,2,3,4,5? or 1,2,3,4,0?)
 160 DO 161 NCH=1,NCHAN
```

```
    IF (NOUTFL.EQ.1) GOTO 162
    IF (IEL(1,J,3).EQ.0.AND.IEL(2,J,5).NE.0.AND.CHAN(I).EQ.0.AND.
   1IEL(2,J,5).NE.360.AND.I.NE.MOUT(NCH)) THEN
!WB        if the element number of the cell above this one equals 0 and
!WB        the slope ne 0 and channel width # equal 0 and slope ne 360 and
!WB        the element # ne the outlet of a channel
           WRITE (2,770) IEL(2,J,1),J
!WB        write that this cell leaks
           NOUTFL=1
    ENDIF
 161 CONTINUE
 162 NC(I)=IEL(1,J,3)
!WB        mark the element # receiving flow from this cell in the column
!WB        direction equal to element # above it
    GO TO 180
!WB        jump over the next section
 170 DO 171 NCH=1,NCHAN
    IF (NOUTFL.EQ.1) GOTO 172
    IF (IEL(3,J,3).EQ.0.AND.IEL(2,J,5).NE.180.AND.I.NE.MOUT(NCH).AND.
   1CHAN(I).EQ.0) THEN
!WB        if the element # below this cell equals 0 and the slope doesn't
!WB        equal 180 and the element # ne a channel outlet and the chan width
!WB   # equals 0
           WRITE (2,770) IEL(2,J,1),J
!WB        write that this cell leaks
           NOUTFL=1
!WB        set the outflow flag = 1
    ENDIF
 171 CONTINUE
C *** NRZ 9/11/94

 172 NC(I)=IEL(3,J,3)
!WB        route the flow in column direction to the cell below it
 180 IF (ANG.GT..78539816) GO TO 190
!WB        if angle from the axis is greater than 45 degrees
    RFL(I)=.5*SIN(ANG)/COS(ANG)
!WB        fraction of discharge from element flowing in row direction
!WB        is equal to 0.5 (opposite/hyp) / (adjacent/hyp) = 0.5 (opp/adj)
!WB        angles less than 45 degrees will always be within 45 degrees of
!WB        a major axis, on the plus side (ex: 90+45, 180+45, etc)
    GO TO 200
 190 RFL(I)=1.-.5*SIN(1.5707963-ANG)/COS(1.5707963-ANG)
!WB        fraction of discharge from element flowing in row direction =
!WB        1-0.5*sin(90-ang)/cos(90-ang)
 200 GO TO (210,220,210,220,210), M
!WB        M is the quadrant #
 210 RFL(I)=1.-RFL(I)
!WB        fraction of flow in row direction equals 1-the above calculation
C
C **** ELIMINATE FALSE RECEIVING ELEMENTS WHICH MAY CAUSE OUT-OF-RANGE
C **** SUBSCRIPTS FOR SOME BOUNDARY ELEMENTS.
C
 220 IF (RFL(I).LT.0.01) NR(I)=NC(I)
!WB        if the fraction of discharge from element in row direction is
!WB        less than 0.01, then the number of the element receiving flow in
!WB        the row direction is equal to the number of the element receiving
!WB        flow in the column direction
    IF (RFL(I).GT.0.99) NC(I)=NR(I)
!WB        similar to above, but other direction
C
C **** "LEAKY" ELEMENTS (THOSE WITH PARTIAL FLOW OUTSIDE THE WATERSHED)
C **** MUST DIVERT THAT PARTIAL FLOW INTO A SPECIAL PSUEDO ELEMENT.
C
C **** NRZ 9/11/94
C **** MODIFY CHECK FOR ALL OUTLETS
    DO 223 NCH=1,NCHAN
           IF (NC(I).GT.0.OR.I.EQ.MOUT(NCH)) GO TO 230
!WB        if the number of element receiving flow from this element in the
!WB        column direction gt 0 or the element # is a an outlet, goto 230.
!WB        This says that the element isn't a leaky element or it's a
```

```
!WB       channel outlet.
  223 CONTINUE
C
C **** THIS ELEMENT LEAKS, DIVERT IT INTO SPECIAL "BOTTOMLESS PIT".
C **** MARK THIS CELL AS LEAKY IN THE COLUMN DIRECTION WITH FLAG ARRAY
C **** LCC

      NC(I)=NMAX+ISTRUC+2
!WB       the element # receiving flow from this element is equal to the
!WB       max # of cells + # of structures + 2
!WB       shouldn't this be equal to NMAX + ISTRUC + NCHAN + 2 ?
      LCC(I)=1
!WB       LCC = flag indicating cell leaks
C
C **** ADD TO TOTAL NON-CONTRIBUTING AREA.
C
      OUTSID=OUTSID+1.-RFL(I)
!WB       the flow to outside the watershed = same + column flow from this
!WB       element
C **** NRZ
C **** MODIFY CHECK FOR ALL OUTLETS
C  230 IF (NR(I).GT.0.OR.I.EQ.MOUT) GO TO 240
  230 DO 233 NCH=1,NCHAN
          IF (NR(I).GT.0.OR.I.EQ.MOUT(NCH)) GO TO 240
!WB       if the element # receiving flow from this element in the row
!WB       direction is gt 0 or the element # is equal to a channel outlet
!WB       this and the above statement say that if the receiving element
!WB       is numbered 0 and is not a channel outlet then its a leaky cell
  233 CONTINUE

C **** NRZ
C **** MARK THIS CELL AS LEAKY IN THE ROW DIRECTION WITH FLAG ARRAY
C **** LCR
C
     NR(I)=NMAX+ISTRUC+2
!WB       the element # receiving flow in the row direction is equal to
!WB       the max # of overland cells+# of structures+2
!WB       shouldn't this equal NMAX + ISTRUC + NCHAN + 2 ?
     LCR(I)=1
!WB       flag it as leaky in the row direction
     OUTSID=OUTSID+RFL(I)
!WB       add its contribution to flow outside the watershed
C **** NRZ 9/15/94
C
C **** GET CROP/MGMT NUMBER.
C
  240 I1=IEL(2,J,7)
!WB       I1 is the rotation #
     CBAR(I1)=CBAR(I1)+1.
!WB       CBAR is supposed to be percent of watershed in crop i
!WB       Each time that you go through this loop, you add 1 (a cell)
!WB       of each crop type to the percent of watershed in crop i.
C
C **** PUT CROP/MANAGEMENT NUMBER IN LOW BYTE AND SOIL TYPE NUMBER IN
C **** NEXT BYTE OF (SOIL:SUR).
C **** NRZ 3/26/95
C **** CROP/MANAGEMENT NUMBER IS THE ROTATION NUMBER - NOT CROP NUMBER
C
C **** NRZ 9/5/94
C **** DIVIDE IEL(2,J,6) BY 10000 TO ACCOUNT FOR ADDITION OF CHANNEL
C **** NETWORK DESIGNATOR

C     K=MOD(IEL(2,J,6),100)
     K=MOD(MOD(MOD(IEL(2,J,6),1000000),10000),100)
!WB       K = SOIL TYPE # OF OVERLAND FLOW CELL
C **** NRZ 9/5/94

     SPER(K)=SPER(K)+1.
!WB       steady state infiltration rate for the soil type = same +1
!WB       so every time you go through and this soil type is present,
```

```
!WB         you add 1 to that value.  Maybe its a percent of the
!WB         watershed with that ss infil rate?
    SOIL(I)=(K*256)+I1
!WB         soil type for element i = (soil type # * 256) + rot #
C **** NRZ 3/26/95
C **** FAYCAL MADE THIS CHANGE, THIS IS MY COMMENT
C **** IROT(I1,2) IS THE CROP # FOR THE FIRST CROP IN ROTATION I1
!WB         CORRECT COVER CHOSEN IN MAIN ROUTINE
*     SUR(I)=(K*256)+IROT(1,2)
    SUR(I)=I1*256+IROT(I1,2)
!WB   surface type on element i = (rot # * 256) + first crop in rot I1
C **** NRZ 3/26/95

    ASMBAR=ASMBAR+ASM(K)
!WB         average ASM = same + asm of soil type #
    FPBAR=FPBAR+FCAP(K)
!WB         the variable list says that this isn't used
C **** NRZ 8/5/95
C **** RN(I1) SHOULD BE MANNING'S N FOR THE CROP # OF THE CROP IN THE CURRENT
C **** ROTATION.  AS CODED BEFORE, IT WAS MANNING'S N FOR THE ROTATION #, WHICH
C **** MAY NOT HAVE BEEN DEFINED IF THERE WERE MORE ROTATIONS THAN CROPS.
!WB         actually, RN(IROT(I1,2)) is manning's n of the first crop in the
!WB         rotation #, so this may not be correct
*     B(I)=CONST*DSQRT(SL(I))*X/RN(I1)
    B(I)=CONST*DSQRT(SL(I))*X/RN(IROT(I1,2))
!WB         conveyance B(I) = depth conversion * sqrt (slope of element) *
!WB         sin(ang) + cos(ang) / manning's n of 1st crop in the rotation
C
C **** MAKE SPECIAL ADJUSTMENTS TO ACCOUNT FOR STRUCTURAL PRACTICES,
C **** BUT FIRST SEE IF ANY ARE PRESENT IN THIS ELEMENT.
C
    IF (IEL(2,J,9).NE.0) CALL STRUCT (I,J,NC(I),NR(I),RFL(I),IEL,JMAX,
   1NPAR,NMAX,STRUC,NSTRUC,ISTRUC,X,DX,WID,SS(II+1),SS(I),PIV(II+1),CN
   2,CWID(II+1),CHAN(I),CONST,SL(I),II,SCMIN,SCMAX,SCBAR,ANG,IELC,NPAR
   32)
!WB         if the structural flag ne 0, then a structure is present and the
!WB         appropriate subroutine needs to be called.
    DO 250 K=1,NRG
    IF (IELC(2,J,1).EQ.IG(K)) GO TO 260
!WB         if the element of the array equals the raingage designator name
  250 CONTINUE
    WRITE (2,600) IELC(2,J,1),IEL(2,J,1),J,IG(1)
    K=1
!WB         this says that if the IELC doesn't equal the raingage designator
!WB         name, then write that the raingage identifier is missing
C
C **** PUT RAINGAGE NUMBER IN LOW BYTE AND TILE NUMBER IN NEXT BYTE
C **** OF (TIAL:RANE).
C
  260 RANE(I)=TIAL(I)+K
!WB         number of rain gage applicable to element i = tile flag + (K=1)
!WB         should rane(I) be dimensioned to 2000 also?
  270 CONTINUE
!WB***************************************************
!WB                       end of do loop for doing the current row's calculations
!WB***************************************************
    JS=IEL(3,1,2)
!WB         this is the last column # of the third row I think
    IF (ITEMP(3).NE.999.AND.IEL(3,JS,1).NE.ITEMP(1)) GO TO 110
!WB         if the last element in a row flag ne 999 (its only supposed to
!WB         be a 9) and the row number of the last column in the IEL array
!WB         ne the row # currently read in the itemp(1) array, then go back
!WB         to the top to redo subroutine relem
    ITEMP(3)=999
!WB         okay, you set itemp(3) equal to 999, which flags the program
!WB         that you are on the last row in the watershed
    IF (JS.NE.JMAX) GO TO 110
!WB         if the last column # of the row ne the maximum column #, go back
!WB         to the top and redo subroutine relem
    IF (N+II.GT.NMAX) GO TO 520
```

```
!WB        if the # overland flow cells + channel segments is greater than
!WB        the max # of cells, then jump down and stop the program
      X=N
      ASMBAR=ASMBAR/X
      FPBAR=FPBAR/X
      SB=AREA2
      AREA=AREA2*(X-OUTSID)
      CONV=CU*(X-OUTSID)
      SBAR=SBAR/X
!WB        I guess that this is part of the statistical output from the
!WB        watershed
      IF (II.GT.0) SCBAR=SCBAR/DBLE(II)
      NN=N+1
!WB        this says that if the II counter (for channels) is gt 0, then
!WB        relabel NN to be the low counter for the channel networks
C
C **** OUTPUT STATISTICAL SUMMARY OF WATERSHED CHARACTERISTICS.
C
      TBAR=TBAR/X

* NRZ 9/11/94
* CHANGE OUTPUT PRINT LINE TO PRINT MULTIPLE OUTLET CELLS
C     WRITE (2,690) TITLE,SB,PP(IT+3),N,II,AREA,PP(IT+3),SMIN,SBAR,SMAX,
C    1SCMIN,SCBAR,SCMAX,TBAR,DC,PP(IT+1),ASMBAR,FPBAR,GRF,MOUT,NIOUT,NJO
C    2UT
      WRITE (2,690) TITLE,SB,PP(IT+3),N,II,AREA,PP(IT+3),SMIN,SBAR,SMAX,
     1SCMIN,SCBAR,SCMAX,TBAR,DC,PP(IT+1),ASMBAR,FPBAR,GRF
      WRITE (2,695) (NCH,MOUT(NCH),NIOUT(NCH),NJOUT(NCH),NCH=1,NCHAN)
      WRITE (2,*)
* NRZ 9/11/94

      WRITE (2,700) PP(IT+1),PP(IT+2)
      DC=DC*CU/24.
!WB        tile drainage coefficient = same * (mm/h to m3/s) / 24
      SB=CONST*DSQRT(SBAR)/RN(1)
!WB        SB = average overland flow conveyance coeff
!WB        SB=depth conversion*sqrt(average catchment slope)/reynold's #
!WB        for surface type 1
!WB        check the Reynold's # for accurate selection
      J=0
      DO 330 I=1,ICR
!WB        ICR = # of cropping practices
      IF (CBAR(I).LE.0..AND.I.LT.ICR) GO TO 330
!WB        cbar is the percent of watershed in crop i, I is the # of
!WB        cropping practices
      CBAR(I)=CBAR(I)/X
!WB        X is the # of overland flow cells
      IF (J.GE.ISR) GO TO 320
!WB        this seems to be an imbedded count/do-while loop is greater
!WB        than # of soil types, when the # of cropping practices exceeds
!WB        the # of soil types, jump down to 320
  280 J=J+1
      DO 300 JJ=J,ISR
!WB        do to # of soil types
      IF (SPER(JJ).LE.0.) GO TO 300
!WB        if steady-state infiltration rate less than or equal 0
      CLAYAV=CLAYAV+CL(JJ)*SPER(JJ)/100.
!WB        average clay = same + clay content of soil type * steady-state
!WB        infil rate / 100
*FC REPRESENT THE WILTING POINT
      FPBAR=FC(JJ)
!WB        the notes say that FPBAR is not used = wilting point
      SPER(JJ)=SPER(JJ)/X
!WB        steady-state infil rate = same / # of cells?  Represents
!WB        percent of watershed in that rate?
      IF (CBAR(I).LE.0.) GO TO 290
!WB        if the percent of watershed in crop practice i is le 0, skip the
!WB        write statement
      WRITE (2,710) CROP(I,1),CROP(I,2),CBAR(I),PER(I),RN(I),JJ,S
     1PER(JJ),KS(JJ),DF(JJ)
```

```
      CBAR(I)=0.
!WB          reset the % of watershed in crop i to 0.  It gets set above.
      GO TO 310
  290 WRITE (2,720) JJ,SPER(JJ),KS(JJ),DF(JJ)
      GO TO 310

  300 CONTINUE
      J=ISR
      GO TO 320
  310 J=JJ
      IF (I.LT.ICR) GO TO 330
!WB          if the cropping practice counter # is lt # of cropping practices
!WB          then jump down to 330 and go back to the top (b/c 330 is end of loop)
      IF (J.LT.ISR) GO TO 280
!WB          if the J counter in this loop is lt # soil types, go back to
!WB          the top and redo the soil properties loop
  320 IF (CBAR(I).GT.0.) WRITE (2,730) CROP(I,1),CROP(I,2),CBAR(I),PER(I
     1),RN(I)
  330 CONTINUE
!WB          end of this loop
C *** NRZ 9/15/94
C *** PRINT OUTPUT HEADER TO ALL OUTPUT FILES

      DO 332 NCH=1,NCHAN+1
              NUNIT=NCH+10
              WRITE(NUNIT,1700)
              WRITE(NUNIT,*) ' DAY  RAIN  RUNOFF SEDIMENT   NO3   DIS-NH4'
     &,' SED-NH4 DIS-PO4 SED-PO4 SED-TKN'
              WRITE(NUNIT,*) '      MM     MM     KG/HA     KG      KG'
     &,'     KG      KG      KG       KG'
  332 CONTINUE

C *** ASSIGN AN OUTLET CELL FOR EACH CHANNEL NETWORK OUTLET

      DO 335 NCH=1,NCHAN+1
            IF (NCH.LE.NCHAN) THEN
              CHOUT(NCH)=N+II+NCH
              NR(MOUT(NCH))=CHOUT(NCH)
              NC(MOUT(NCH))=CHOUT(NCH)
!WB          these set the element # receiving the flow from the outlet
!WB          cell equal to the channel out #
!WB          what about ISTRUC?
            ELSE
              CHOUT(NCH)=N+II+NCH
!WB          This is used to track the leakycell.out a couple of lines down.
!WB          chout is dimensioned to 9!!!!

            ENDIF
  335 CONTINUE

!WB          THE NEXT SECTION RENUMBERS THE CHANNEL CELLS NUMBERED N+1 UP TO
!WB          II.  THEY ARE ORIGINALLY NUMBERED LINEARLY ACCORDING TO WHETHER
!WB          OR NOT THEY HAVE A CHANNEL CELL IN THEM.  IN THE ABOVE SECTION,
!WB          THEY ARE EXTRACTED FROM THE LINEAR ORDER.  BELOW, THE VALUES ARE
!WB          ATTRIBUTED TO THEM, HOWEVER THE VALUES ARE NOT RENUMBERED ACCORDING
!WB          TO THE CHANNEL SERIES TO WHICH THEY BELONG (THEY ARE STILL IN
!WB          LINEAR ORDER), SO THIS ROUTINE RENUMBERS THEM INTO ORDER BY
!WB          CHANNEL SEG TO WHICH THEY BELONG.

!WB          BEGIN RENUMBER CHANNEL SEGMENTS
            IF (II.NE.0) THEN
            I1=1
      DO NCH=1,NCHAN
      DO CNT=1,II
                        IF (CHNUMBER(CNT).EQ.NCH) THEN     !SHOULD BE CHANNEL IDENTIFIER
                        PIVTMP(I1)=PIV(CNT)
                        CWIDTMP(I1)=CWID(CNT)
                        SSTMP(I1)=SS(CNT)
                        MNCSTMP(I1)=MNCHNSL(CNT)
                        MNCTTMP(I1)=MNCHNTOT(CNT)
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```
                    RBTEMP(I1)=ROCKBOT(CNT)
                    CHNSLTMP(I1)=CHNSOIL(CNT)
                    CONSTTMP(I1)=CONSTHLD(CNT)
                    XTMP(I1)=XHOLD(CNT)
                    NERODTMP(I1)=NOERODE(CNT)
                    I1=I1+1
                    ENDIF
                    END DO
          END DO
          ENDIF
!WB       END RENUMBER CHANNEL SEGMENTS


C *** NRZ 9/15/94

* CHECK TO SEE IF THERE ARE ANY CHANNEL SEGMENTS
   IF (II.NE.0) GO TO 340
   N2=N
!WB       if there are no channel segments, set the high N equal to the
!WB       # of overland flow cells, and jump over the continuity section
   GO TO 410
C
C **** DETERMINE SHADOW ELEMENT CONTINUITY.
C **** FIND CHANNEL SEGMENTS.
C
C **** NRZ 9/5/94
C **** REPEAT CHANNEL SEGMENT CONTINUITY CHECK FOR EACH CHANNEL
C **** NETWORK ON THE FARM

  340 DO 405 NCH=1,NCHAN+1
   DO 350 J=1,N
C **** IF CELLS LEAK, ROUTE THEM TO THE LEAKY CELL OUTLET CELL
          IF (NCH.EQ.NCHAN+1) THEN
           IF (LCC(J).EQ.1) NC(J)=CHOUT(NCH)
!WB       if the leaky cell column direction flag = 1, then the # of the
!WB       element receiving flow in the column direction = the outlet cell
!WB   for the channel

           IF (LCR(J).EQ.1) NR(J)=CHOUT(NCH)
!WB       if the leaky cell in the row direction flag = 1, then the
!WB       number of the element receiving flow in the row direction is
!WB       equal to the outlet cell of the channel
          ENDIF
   IF ((CHAN(J).EQ.0).OR.(CHNUM(J).NE.NCH)) GO TO 350
!WB       if channel width # = 0 or channel # designator ne the
!WB       channel counter, so if there is no channel in this cell or
!WB       if the channel # of the loop isn't the same as the channel
!WB       in this cell.  This extracts all channel cells of one type.
C
C **** USE THE ROW FLOW POINTER TO REMEMBER ORIGINAL ELEMENT NUMBER
C **** OF THIS CHANNEL ELEMENT, SINCE THE FLOW COMPONENT IN THE ROW
C **** DIRECTION IS 0.
C
   NR(NN)=J
!WB       the original overland flow cell # is equal to
!WB       the element counter #, is originally set to n+1
!WB       NN is another counter used to track channel cells
   NN=NN+1
  350 CONTINUE
   IF (NCH.EQ.NCHAN+1) GOTO 405
!WB       if the channel counter equals the leakycell place holder, goto 405
C
C **** MOVE CHANNEL PARAMETERS TO END OF ARRAYS.

C **** NRZ
C **** CHANGE LOWER BOUND (N1) OF CHANNEL CELL SECTION OF ARRAY TO
C **** ACCOUNT FOR NEXT CHANNEL NETWORK

   IF (NCH.NE.1) THEN
          NLOW=N2+1
```

```
      ELSE
              NLOW=N+1
      ENDIF

      N1=NLOW

C **** NRZ

      N2=NN-1

      DO 390 I=N1,N2

C **** NRZ 3/25/95
C **** I1 IS THE NUMBER OF THE CHANNEL SEGMENT IN THIS NETWORK (i.e. IF
C **** THIS IS NETWORK #2 AND NETWORK #2 HAS 10 CHANNEL SEGMENTS, I1 WILL
C **** RANGE FROM 1-10)
      I1=I-N

      B(I)=PIVTMP(I1)
!WB          this is conveyance? = the PIV variable is set equal to the
!WB          channel conveyance (I believe) in previous lines
      CWID(I)=CWIDTMP(I1)
!WB          channel width of this cell is equal to the channel width of the
!WB          segment
             SL(I)=SSTMP(I1)
!WB          slope of the overland cell = slope of the channel segment
             MNCHNSL(I)=MNCSTMP(I1)
!WB          THIS IS THE MANNING'S N FOR BARE CHANNEL SOIL.
             MNCHNTOT(I)=MNCTTMP(I1)
!WB          THIS IS THE MANNING'S N FOR CHANNEL SOIL + VEG.
             ROCKBOT(I)=RBTEMP(I1)
!WB          DEPTH TO IMPERMEABLE LAYER FOR CHANNEL CELL
             CHNSOIL(I)=CHNSLTMP(I1)
!WB          CHNSOIL = SOIL TYPE FOR CHANNEL CELL
             SOIL(I)=CHNSOIL(I)*256
!WB          THIS SETS THE SOIL TYPE IN THE CHANNEL CELL INTO THE SOIL ARRAY
             CONSTHLD(I)=CONSTTMP(I1)
             XHOLD(I)=XTMP(I1)
!WB          THE PREVIOUS TWO VALUES HOLD PLACE FOR CONVEYANCE CALCULATIONS IN THE MAIN
!WB          ROUTINE
             ARMOUR(I)=NERODTMP(I1)
!WB          FRACTION OF THE CHANNEL SOIL THAT IS NONERODIBLE
C **** NRZ 3/25/95
C **** NR(I) IS THE ORIGINAL OVERLAND FLOW CELL #, NOT "NUMBER RECEIVING
C **** ROW FLOW FROM (I)"

      J=NR(I)
!WB          recall J, which is an element with a channel series.  The series
!WB          of the channel depends on how many times you've been through the
!WB          outer loop

      I1=NC(J)
!WB          I1 is equal to the element # that receives flow in the column
!WB          direction from the overland flow element
      I2=NR(J)
!WB          I2 is equal to the element # that receives flow in the row
!WB          direction from the overland flow element that contains a channel
!WB          of type that depends on the counter
C
C **** IF CERTAIN STRUCTURES ARE PRESENT IN AN ELEMENT WITH A SHADOW
C **** ELEMENT, IT IS LIKELY THAT THE RECEIVING CHANNEL ELEMENT WILL
C **** NOT BE GETTING THE MAJOR OUTFLOW.
C
      IF (I1.GT.NMAX) GO TO 360
!WB          If the # of the element that receives flow from the marker used
!WB          to designate a channel in an element exceeds the max # of cells,
!WB          then it implies that a structural element lies on the boundary
!WB          of this cell which contains a channel.  Jump down to 360, set
!WB          the receiving element column # equal to the receiving element
!WB          row #, which means set the column flow equal to row flow.  I would
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!WB         think that this one should also point to 380.
      IF (I2.GT.NMAX) GO TO 380
!WB         if the # of the element that receives flow from the marker used
!WB         to designate a channel in an element exceeds the max # of cells,
!WB         then it implies that a structural element resides on the
!WB         boundaries of this marker cell, and that you should check to see
!WB         if the receiving cell from this marker cell contains a channel
!WB         or if the marker cell is an outlet cell.  If not it stops the
!WB         program.
C
C **** THIS ELEMENT DOES NOT CONTAIN A STRUCTURE; THEREFORE, THE
C **** RECEIVING CHANNEL ELEMENT SHOULD BE IN THE DIRECTION OF THE
C **** PREDOMINANT FLOW COMPONENT.
C
      IF (RFL(J).LT.0.207107) GO TO 380
!WB         flow in the row direction from the marker cell is
!WB         predominantly column
      IF (RFL(J).GT.0.792893) GO TO 360
!WB         flow in the row direction from the marker cell is
!WB         predominantly row
C
C ****** FLOW DIRECTION IS PREDOMINANTLY DIAGONAL.
C ****** IF ROW FLOW DESTINATION NUMBER IS LESS THAN CURRENT ELEMENT
C ****** NUMBER, THE DIAGONAL POINTS TO THE LEFT AND THE DIAGONAL
C ****** DESTINATION ELEMENT CAN BE COMPUTED BY SUBTRACTING ONE FROM
C ****** THE CONVENTIONAL OVERLAND FLOW COLUMN DESTINATION NUMBER.
C
      IF (I2.LT.J) GO TO 370
      I1=I1+1
      GO TO 380
  360 I1=I2
!WB         element # that receives flow in the col direction from the
!WB         marker element = element
!WB   # that receives flow in the row direction from the marker cell.
      GO TO 380
  370 I1=I1-1
!WB         if the element # receiving row flow from J (marker cell)
!WB         is less than the marker element J #, then
!WB         the element # that receives flow from the marker cell is equal
!WB         to the # that it originally was, subtract 1.  This is legitimate
!WB         because the o.f. routings do not calculate diagonal flow, and
!WB         therefore you will never be more than 1 column away from this
!WB         element
C
C **** MAKE CERTAIN THE RECEIVING ELEMENT IS A CHANNEL ELEMENT.
C
C **** NRZ 9/11/94
C **** THE FOLLOWING CHECK FOR DISCONTINUOUS CHANNELS IS PERFORMED FOR
C **** EACH POSSIBLE OUTLET OF THE CHANNEL NETWORKS


C NRZ 3/5/95
  380 IF (CHAN(I1).LT.1.AND.J.NE.MOUT(NCH)) GO TO 560
!WB         if the channel width lt 1 and the element counter # ne the outlet
!WB         cell, goto 560 and stop the program
C **** NRZ 9/11/94
C
C **** TEMPORARILY ASSIGN THE ORIGINAL OVERLAND FLOW ELEMENT
!WB*** destination NUMBER
C **** AS THE DESTINATION FOR THE SHADOW OUTFLOW.  THIS IS NECESSARY
C **** UNTIL NEW NUMBERS ARE ASSIGNED TO ALL SHADOW ELEMENTS.
C
      NC(I)=I1
!WB         the element # receiving flow in the column direction from this
!WB         channel cell (I from N1 to N2) is equal to the calculated
!WB         column receiving # derived from the original o.f. cell
C
C **** MAKE ALL OVERLAND FLOW FROM THIS ELEMENT GO INTO ITS SHADOW
C **** ELEMENT, UNLESS IT CONTAINS A STRUCTURAL PRACTICE.
C
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      NR(J)=I
!WB          the element # that receives flow from this marker element in the
!WB          row direction is equal to the number of this channel element
      NC(J)=I
!WB          the element # that receives flow from this marker element in the
!WB          column direction is equal to the number of this channel seg.
  390 CONTINUE
C
C **** FIND REAL CHANNEL SEGMENT NUMBER INTO WHICH EACH CHANNEL
C **** SEGMENT FLOWS.
C
      DO 400 J=N1,N2
      I=NC(J)
!WB          set I equal to the element # receiving flow from this element
!WB          in the column direction.  This is equal to I1 from a few lines
!WB          above, it says to recall the outflow element # for the channel
!WB          segment.
      NC(J)=NR(I)
!WB          set the element # receiving flow in the column direction equal
!WB          to the element # receiving flow in the row direction
!WB          from the original overland flow cell
C
C **** IF THIS ELEMENT CONTAINS A STRUCTURAL MEASURE, ITS CORRECT
C **** CHANNEL ELEMENT NUMBER MAY BE PRESENT ONLY IN ARRAY NC.
C
C     IF (NC(J).GT.NMAX) NC(J)=NC(I)
C
C **** FORCE ALL CHANNEL FLOW TO USE ONLY COLUMN FLOW DIRECTIONS.
C
C **** NRZ 9/5/94
C **** INCORPORATE EXTRA OUTLETS AND DIRECT FLOW TO CORRECT FINAL
C **** RECEIVING ELEMENT

  400 RFL(J)=0.
!WB          set the fraction of flow in the row direction equal to 0

      J=NR(MOUT(NCH))
!WB          set the # J equal the element # receiving flow in the row
!WB          direction from the outlet cell #
      NC(J)=CHOUT(NCH)
!WB          set the element # receiving flow in the column direction from
!WB          the row element # above equal to the channel out variable for
!WB          the channel #
C **** END OF MULTIPLE CHANNEL LOOP AND REASSIGN LOW VALUE OF CHANNEL
C **** ELEMENT ARRAY

  405 CONTINUE
      N1=N+1

C **** NRZ 9/5/94
C
C **** OUTPUT DATA CONCERNING ANY STRUCTURAL PRACTICES.
C
!WB          you are sent here to 410 if there are no channel segments
  410 IF (.NOT.STRUC) GO TO 430
!WB          the .struc flag must be set to 'true' if there are any practices
      WRITE (2,1000)
      DO 420 I=1,ISTRUC
      IF (NSTRUC(I).NE.0) WRITE (2,1010) I,(STRNAM(J,I),J=1,3),NSTRUC(I)
  420 CONTINUE
C
C **** EVALUATE INITIAL CONDITIONS.
C
  430 DO 440 I=1,N2
      S(I)=0.
!WB          storage at start of time increment for element I is equal to 0
  440 FLINS(I)=0.
!WB          infiltration into the element is equal to 0
C
C **** CONVERT SOIL CONSTANTS.
```

```
C
      DO 450 I=1,ISR
!WB          do from 1 to # of soil types
      TP(I)=TP(I)*CU1*DF(I)
!WB          porosity = same * conv * depth of soil horizon
      TP1(I)=TP(I)
*     A(I)=CU*A(I)*(DT/TP(I))**P(I)
  450 GWC(I)=(1.-FCAP(I))*TP(I)/DT
!WB          volume of air filled pore space at field capacity for soil i
C
C **** INITIALIZE VALUES SPECIFIC TO INDIVIDUAL ELEMENTS.
C
      Y=1./X
!WB          y = the inverse of the # of overland flow cells?
      DO 460 I=1,N
      K=2
      IS=SOIL(I)/256
      IC=MOD(SUR(I),256)
      PIV(I)=(1.-ASM(IS))*TP(IS)/DT
  460 CONTINUE

C
C **** CONTINUE FOR SURFACE INITIAL CONDITION.
C
C
CC....CALCULATION OF COEFFICIENTS FOR YALINS EQUATION........
C
      DO 505 IC=1,NPART
             CY1(IC)=EQSDIA(IC)*VISCOS
!WB          CY1 = equiv sand diameter of particle * kinematic viscosity of water
             CY2(IC)=1.65*AGRAV*EQSDIA(IC)
!WB          CY2 = 1.65 * acceleration due to gravity * equiv sand diam
             CY4(IC)=2.65*EQSDIA(IC)*SWH2O
!WB          CY4 = 2.65 * equiv sand diam * spec wght of water
  505 CONTINUE
      SGD2=DSQRT(AGRAV*.5)
!WB          SGD2 = sqrt(accel due to gravity * 0.5)
      DO 506 IC=1,N
             K=MOD(SUR(IC),256)
!WB          K = surface type of element - INT(same / 256) * 256
             VS(IC)=SGD2*DSQRT(SL(IC)*DT/DX2)
!WB          VS = SGD2*sqrt(slope*time increment / area of cell)
  506 CONTINUE
      IF(N2.EQ.N) GO TO 508
!WB          if there are no channels, go to 508
      DO 507 IC=N1,N2
             VS(IC)=SGD2*DSQRT(SL(IC)*DT/(DX*CWID(IC)))
!WB          VS = SGD2 * sqrt (slope * time increment / (cell width * chan width))
  507 CONTINUE
  508 CONTINUE
      RETURN
C
C **** ERROR MESSAGES.
C
  510 WRITE (2,930)
      STOP
  520 WRITE (2,840)
      STOP
  530 WRITE (2,860)
      STOP
  540 WRITE (2,850)
      STOP
  550 WRITE (2,870)
      STOP
  560 WRITE (2,890) J
      STOP
  570 WRITE (2,900) NRG,J
      STOP
  580 WRITE (2,910) TEST
      STOP
```

```
 590 WRITE (2,970) ROUGH(I),CROP(I,1),CROP(I,2)
     STOP
C
C **** FORMATS.
C
 600 FORMAT (1X,'RAIN DATA MISSING FOR GAGE ',A2,12H, AT ELEMENT,I4,1H
    1,,I4,7H: GAGE ,A2,' DATA USED')

** NRZ 9/11/94
** MODIFIED INPUT FORMAT TO INCLUDE MULTIPLE CHANNELS
C 610 FORMAT (16X,F7.2/17X,I4,8X,I4)
 609 FORMAT (16X,F7.2)
 610 FORMAT (27X,I4,8X,I4,5X,I4)
** NRZ 9/11/94

 620 FORMAT (11X,2A4,6X,F3.2,6X,F3.2,5X,F3.2,4X,F4.2,4X,F5.3)
 623 FORMAT(1X,6(F4.1,1X),3(F4.2,1X))
!WB      ADDED INTERRILL COVER FACTORS
 624 FORMAT(1X,11(F4.2,1X))
 625 FORMAT(1X, I3, 1X, I3, 1X, F4.2, 1X, F6.3, 1X, F5.2, 1X, F7.1,
    + 1X, I3, 1X, F4.2)
 626 FORMAT(1X,F5.1,1X,F5.3,1X,F5.2,1X,F5.2,1X,F5.2,1X,F5.3,1X,F5.3,
    11X,I2,1X,I2)
!WB      READ IN THE NEW SEDIMENT ROUTINE VARIABLES
 630 FORMAT (/1X,27HSIMULATION TIME INCREMENT =,F6.1,8H SECONDS/1X,
    *38HINFILTRATION CAPACITY CALCULATED EVERY,I5,8H SECONDS/1X,
    *22HEXPECTED RUNOFF PEAK =,F5.1,2A4,/,1X,20HNUMBER OF RAIN GAGES,
    *3X,'= ',I4)
 640 FORMAT (I4,2PF9.1,F11.1,0PF11.2,8X,F7.2,F9.1,2PF10.1,0PF9.2)
 650 FORMAT (/1X,18HCHANNEL PROPERTIES/1X,4HTYPE,3X,5HWIDTH,3X,
         111HMANN N SOIL,4X,10HMANN N TOT,4X,7HIMPERM.,2X,7HPERCENT
    2,/,9X,A4,32X,5HDEPTH,4X,6HARMOUR,/,(I4,F8.1,4X,F5.3,10X,
    3F5.3,9X,F5.3,4X,F4.2))
!WB      FORMAT STATEMENT 650 EDITED TO INCLUDE MAN. OUTPUT, IMPERM LAYER
 660 FORMAT (//5X,33HRAINFALL HYETOGRAPH FOR EVENT OF ,2A4)
 670 FORMAT (/5X,12HGAGE NUMBER ,A2/5X,11HTIME - MIN.,7X,15HRAINFALL RA
    1TE -,2A4/(F14.1,F24.2))

C NRZ 9/5/94
C CHANGED FORMAT STATEMENT TO INCLUDE AN EXTRA 2 DIGITS FOR THE CHANNEL
C NETWORK NUMBER

C 680 FORMAT (2I3,I2,I3,3I4,3X,A2,1X,A2,2X,I4,I3,2I4,I6,I2,I5,I5,I5)
!WB  680 FORMAT (2I3,I2,I3,I4,1X,I5,I4,3X,A2,1X,A2,2X,I4,I3,2I4,I6,I2,I5,I5
!WB    &,I5)
 680 FORMAT (2I3,I2,I3,I4,1X,I7,I4,3X,A2,1X,A2,2X,I4,I3,2I4,I6,I2,I5,I5
    &,I5)

C NRZ 9/5/94
C

 681 FORMAT(3I5,I6)

C *** NRZ 9/11/94
C *** MODIFY OUTPUT FOR MULTIPLE CHANNEL NETWORKS
C 690 FORMAT (/,5X,11A4,/,5X,'WATERSHED CHARACTERISTICS',/,' NUMBER OF',
C    1F6.2,A4,' OVERLAND FLOW ELEMENTS =',I5,/,1X,'NUMBER OF CHANNEL SEG
C    2MENTS = ',I3,/,1X,'AREA OF CATCHMENT =',F8.1,A4,/,1X,'CATCHMENT SL
C    3OPE: MIN =',2PF7.2,'  AVE =',F7.2,'  MAX =',F7.2,' PERCENT',/,1X,'
C    4CHANNEL SLOPE:   MIN =',F7.2,'  AVE =',F7.2,'  MAX =',F7.2,' PERCE
C    5NT',/,1X,'PERCENT OF AREA TILED =',F6.1,' WITH A D.C. OF',0PF5.2,A
C    64,'/24H',/,' MEAN ANTECEDENT SOIL MOISTURE =',2PF4.0,', FIELD CAPA
C    7CITY =',F4.0,' PERCENT SATURATION',/,' GROUNDWATER RELEASE FRACTIO
C    8N =',0PF7.4,/,1X,'OUTLET IS ELEMENT',I5,' AT ROW',I4,' COL',I4)
 690 FORMAT (/,5X,11A4,/,5X,'WATERSHED CHARACTERISTICS',/,' NUMBER OF',
    1F6.2,A4,' OVERLAND FLOW ELEMENTS =',I5,/,1X,'NUMBER OF CHANNEL SEG
    2MENTS = ',I3,/,1X,'AREA OF CATCHMENT =',F8.1,A4,/,1X,'CATCHMENT SL
    3OPE: MIN =',2PF7.2,'  AVE =',F7.2,'  MAX =',F7.2,' PERCENT',/,1X,'
    4CHANNEL SLOPE:   MIN =',F7.2,'  AVE =',F7.2,'  MAX =',F7.2,' PERCE
    5NT',/,1X,'PERCENT OF AREA TILED =',F6.1,' WITH A D.C. OF',0PF5.2,A
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    64,'/24H',/,' MEAN ANTECEDENT SOIL MOISTURE =',2PF4.0,', FIELD CAPA
    7CITY =',F4.0,' PERCENT SATURATION',/,' GROUNDWATER RELEASE FRACTIO
    8N =',0PF7.4)
  695 FORMAT (1X,'OUTLET ',I2,' IS ELEMENT',I5,' AT ROW',I4,' COL',I4)
C *** NRZ 9/11/94

  700 FORMAT (/,' SURFACE COVER/MANAGEMENT CONDITIONS',8X,'SOIL ASSOCIAT
    1ION PROPERTIES',/,3X,'CROP  PERCENT PERCENT     N',14X,'NO. PER
    2CENT   KS',4X,'  CONTROL  ',/,9X,'PRESENT  COVER',25X,'PRE
    3SENT',2A4,2X,'DEPTH MM')
  710 FORMAT (1X, 2a4, 2P, F6.1, F7.0, 0P, 4X, F6.3, 10X, I4, 2P,
    + F7.1, 2X, 0P, F7.2, 2X, F8.1)
  720 FORMAT (I46,2PF7.1,1X,0PF7.2,8X,F8.1)
  730 FORMAT (1X, 2A4, 2P, F6.1, F7.0, 4X, 0P, F6.3)
  740 FORMAT (A1,F9.0,F10.0)
  750 FORMAT (//1X,15HSOIL PROPERTIES/1X,4HSOIL,2X,8HPOROSITY,2X,10HFIEL
    1D CAP.,2X,22HWILT. POINT  HYDRAULIC,2X,7HCONTROL,2X,10HANTECEDENT,
    21X,/7X,8H(PERCENT,3X,8H(PERCENT,3X,8H(PERCENT,4X,7HCONDUC
    3.,5X,4HZONE,5X,8HMOISTURE,3X,/9X,5HVOL.),6X,5HSAT.),
    47X,5HSAT.),6X,2A4,3X,A4,3X,13H(PERCENT SAT))
  760 FORMAT (13X,F4.1,14X,F6.3,9X,F6.3,1X,F4.2,1X,F4.2)
!WB          760 MODIFIED TO INCLUDE MANNING F.F. FOR CHANNEL SOILS,IMPERM LAYER
  770 FORMAT (8H ELEMENT,I4,1H,,I4,27H FLOWS OUT OF THE WATERSHED)
  780 FORMAT (18X,I4)
  790 FORMAT (10X,F3.2,6X,F3.2,6X,F5.2,5X,F5.3,6X,F5.1,7X,F3.2)

C *** NRZ 9/12/94
C *** ADD FORMAT LINE TO ENTER SATURATED HYDRAULIC CONDUCTIVITY

  791 FORMAT (23X,I1,9X,F5.2)

C *** NRZ 9/12/94

  795 FORMAT (1X,F4.1,1X,F4.1,1X,F4.1,1X,F4.2,1X,F4.1,1X,F4.1)
  797 FORMAT (1X,4(F7.5,1X))
  800 FORMAT (1X,A4,52X,A4)
  810 FORMAT (A4,15X,I1,25X,2A4)
  820 FORMAT (A4,24X,11A4)
  830 FORMAT (16X,A2)
  840 FORMAT (' NUMBER OF SHED+CHAN ELEMENTS EXCEEDS,10H DIMENSION')
  850 FORMAT (' RAINFALL DATA EXCEEDS DIMENSION')
  860 FORMAT (' NO. OF SOILS EXCEEDS DIMENSION')
  865 FORMAT (' CHANNEL SOIL ',I3,' AT CELL ',I5,' EXCEEDS DIMENSION
    1 OF TOTAL SOIL TYPES')
!WB          ADDED IN CASE CHANNEL SOIL PROPERTIES EXCEED DIMENSION
  870 FORMAT (' NO. OF CROPS EXCEEDS DIMENSION SPEC')
  890 FORMAT (39HCHANNELS DISCONTINUOUS NEAR ELEMENT NO.,I5)
  900 FORMAT (1X,'HYETOGRAPH DATA MISSING OR INCORRECT',24H FIRST COLU
    1MN NOT 0 OR 1/I4,40H GAGES REQUESTED. BAD LINE BEGINS WITH: ,A2)
  910 FORMAT ('INCORRECT INPUT SEQUENCE',36H OR HEADER CARD.  CARD BEGI
    1NS WITH: ,A4)
  920 FORMAT (30X,I3)
  930 FORMAT (' NO. OF CHANNEL TYPES EXCEEDS DIMENSION')
  940 FORMAT (31X,I3)
  950 FORMAT (/7H COVER /20HMANAGEMENT PRACTICES/3X,4HCROP,6X,
    19HMAX. POT.,3X,7HPERCENT,2X,6HROUGH.,2X,6HROUGH.
    2,2X,9HMAX. RET.,2X,/11X,12HINTERCEPTION,
    33X,5HCOVER,3X,6HCOEFF.,2X,6HHEIGHT,2X,5HDEPTH,5X,
    4/14X,A4,23X,A4,4X,A4)
  960 FORMAT (1X,I2,1X,2A4,F7.2,2PF12.0,0PF8.2,F8.1,F10.3,F10.2)
  970 FORMAT (20H ROUGHNESS COEFF. OF,F8.2,27H IS OUT OF RANGE FOR CROP:
    1 ,2A4)
  975 FORMAT (/,1X,4HCROP,3X,6HRANDOM,6X,6HBURIED,3X,9HMAX PLANT,3X,
    16HGROWTH,3X,4HRILL,/,1X,1H#,6X,9HROUGHNESS,3X,
    27HRESIDUE,2X,6HHEIGHT,6X,6HFACTOR,3X,7HSPACING,3X,/,8X,4H(MM),8X,
    38H(KG/M^2),1X,3H(M),18X,8H(M/RILL))
  976 FORMAT (1X,I2,F11.2,1X,F11.2,F7.2,8X,F4.2,5X,F4.2)
  977 FORMAT (/,1X,4HCROP,3X,11HMANNING'S N,3X,11HMANNING'S N,3X,
    110HNO-TILLAGE,3X,7HNO-EROS,/,8X,4HSOIL,10X,5HTOTAL,9X,
    24HFLAG,9X,4HFLAG)
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  978 FORMAT (1X,I2,5X,F5.3,9X,F5.3,8X,I2,11X,I2)
 1958 FORMAT (/,1X,4HCROP,3X,9HINTERRILL,3X,9HINTERRILL,3X,9HLIVE ROOT,
              13X,9HDEAD ROOT,3X,9HDEAD ROOT,/,1X,1H#,6X,9HCOVER INI,3X,
     29HCOVER FIN,3X,4HMASS,8X,9HMASS INIT,3X,10HMASS FINAL)
 1960 FORMAT (1X,I3,4X,F4.2,8X,F4.2,8X,F4.2,8X,F4.2,8X,F4.2)
!WB          ADDED 1958 AND 1960 TO PRINT THE COVER EROS PARAMETERS
C *** NRZ 9/12/94
C *** MODIFY FORMAT LINE TO INCLUDE FERTILIZER FILE FLAG
C 980 FORMAT (20X,I2/39X,F5.2/31X,E10.3)
  980 FORMAT (20X,I2/39X,F5.2/31X,E10.3,/21X,I2)
C *** NRZ 9/12/94
C *** NRZ (8/29/94)
C *** ADDED FORMAT STATEMENTS FOR IMPOUNDMENT DATA

  981 FORMAT (/,1X,25X,I2)
  982 FORMAT (1X,I7,3(1X,F6.1),2(1X,F7.1),1X,F6.1,1X,F5.3,1X,F11.3)

C *** NRZ (8/29/94)

  990 FORMAT (/1X,19HDRAINAGE EXPONENT =,I2/1X,22HTILE DRAINAGE COEFF. =
     1,F5.2,A4,4H/24H/1X,30HGROUNDWATER RELEASE FRACTION =,E10.3)
 1000 FORMAT (/3X,28HSTRUCTURAL MEASURES INCLUDED,/10X,4HTYPE,9X,6HNUMBE
     1R)
 1010 FORMAT (I7,2X,3A4,I6)
 1020 FORMAT (1X,11HCHANNEL NO.,I5,15H AT ELEMENT NO.,I5)
 1030 FORMAT (39X,I4/17X,F5.1/39X,I5/23X,F5.2)
 1040 FORMAT(/20X,'PARTICLE SIZE DISTRIBUTION DATA'/)
 1050 FORMAT(/36X,I2/36X,I2/)
 1060 FORMAT(14X,37H    NUMBER OF PARTICLE SIZE CLASSES =,I2/
     *14X,37H    NUMBER OF WASHLOAD CLASSES      =,I2)
 1070 FORMAT(1X,F15.8,F15.3,F15.7)
 1080 FORMAT(3X,5HCLASS,3X,6HDIA,MM,7X,9HEQSAND,MM,10X,2HSG,3X,
     *14HFALL VELOCITY,,A4,2H/S)
 1090 FORMAT(5X,I1,4X,F6.3,2F15.3,F15.7)
 1110 FORMAT(1X,8F6.3)
 1100 FORMAT(1X,47HPARTICLE SIZE DISTRIBUTION OF SOILS AS DETACHED/
     *2X,52HCLASS    1     2     3     4     5     6     7     8)
 1120 FORMAT(1X,4HSOIL,I2,8F6.3)
 1111 FORMAT(1X,9F8.4)
 1666 FORMAT(1X,35X,I3,1X,I4)
 1667 FORMAT(1X,28X,I4)
 1700 FORMAT(///,30X,22H**** DAILY OUTPUT ****,///)
 1710 FORMAT(2X,4HYEAR,1X,3HJUL,3X,8HRAINFALL,2X,6HRUNOFF,2X,8HSEDIMENT
     &,2X,8H NITRATE,2X,8HDIS. NH4,2X,8H SED.NH4,2X,8HSED.ORGN/
     &,7X,3HDAY,6X,2HMM,7X,2HMM,6X,5HKG/HA,5X,4HMG/L,5X,4HMG/L,7X
     &,4HG/HA,5X,4HG/HA,/,56X,6HSED. P,6X,6HSOL. P,/,58X,4HG/HA,7X,
     &4HMG/L)

C *** NRZ 7/29/95
C *** MODIFIED FORMAT LINE TO INCLUDE 7 ROTATION END DATES PER LINE
C1800 FORMAT(1X,I2,1X,5(I2,1X,I7,1X)/4X,5(I2,1X,I7,1X)/4X,5(I2,1X,I7,1X)
C    & /4X,5(I2,1X,I7,1X))
 1800 FORMAT(1X,I2,1X,7(I2,1X,I7,1X)/4X,7(I2,1X,I7,1X)/4X,7(I2,1X,I7,1X)
     & /4X,7(I2,1X,I7,1X))
 1950 FORMAT (1X,'THE FRICTION FACTOR FOR SOIL',F6.3,' EXCEEDS THE '
              1,/,' COMBINED FRICTION FACTOR:',F6.3,' FOR SOIL #: ',I3
     2,/,' PLEASE CHANGE THIS.')
 1952 FORMAT ('THE NOTILL FLAG IS NOT A 0 OR A 1.  PLEASE CHECK'
              1,/,'THE MAIN INPUT FILE.  THE PROGRAM HAS STOPPED.')
 1954 FORMAT ( 'THE NO EROSSION FLAG IS NOT A 0 OR A 1.  PLEASE'
              1,/,' CHECK THE MAIN INPUT FILE.  THE PROGRAM HAS STOPPED.')
 1956 FORMAT ('THE BURIED RESIDUE FACTOR APPEARS TO BE INPUT
     1IMPROPERLY'
     2,/,' AS ITS VALUE EXCEEDS 1 KG/M2, OR 10,000 KG/HA.')
 1962 FORMAT ('THE DEAD ROOT MASS AT THE END OF THE CROP/COVER: ',
              1F6.3,/,' EXCEEDS THE INITIAL DEAD ROOT MASS FOR THE
     2CROP/COVER: ',F6.3,' FOR COVER # ', I3,/,' AND THE PROGRAM
     3 HAS TERMINATED')
C
      END
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```
      SUBROUTINE STRUCT (I,J,NC,NR,RFL,IEL,JMAX,NPAR,NMAX,STRUC,NSTRUC,I
     1STRUC,X,DX,WID,SSII,SSI,PIV,CN,CWID,CHAN,CONST,SL,II,SCMIN,SCMAX,S
     2CBAR,ANG,IELC,NPAR2)
      IMPLICIT DOUBLE PRECISION A-H,O-Z
C
C ****** SUBROUTINE TO ADJUST PARAMETERS TO REFLECT STRUCTURAL PRACTICES
C ****** INSTALLED WITHIN AN ELEMENT.
C
      DIMENSION IEL(3,JMAX,NPAR2), NSTRUC(ISTRUC), WID(10), CN(10)
      DIMENSION IELC(3,JMAX,2)
      INTEGER CHAN,PRACT
      LOGICAL STRUC
      CHARACTER*2 IELC
C
C **** SWITCH TO APPROPRIATE HANDLER FOR EACH STRUCTURAL TYPE.
C
      PRACT=IEL(2,J,9)
      IF (PRACT.GT.ISTRUC.OR.PRACT.LT.0) GO TO 90
      STRUC=.TRUE.
      NSTRUC(PRACT)=NSTRUC(PRACT)+1
      GO TO (10,60,70,80), PRACT
C
C **** HANDLE PONDS AND TILE-OUTLET TERRACES BY USING A TRAP EFFICIENCY
C **** APPROACH, FOR BOTH SEDIMENT AND WATER.
C
C **** CASE 1 IS FOR A PTO.
C
   10 TRAP=.90
C
C **** CHECK FOR A POSSIBLE SHADOW CHANNEL ELEMENT.
C
   20 IF (CHAN.EQ.0) GO TO 40
C
C **** IT'S A CHANNEL ELEMENT, DOES IT REQUIRE DIAGONAL FLOW?
C
      IF (ANG.LT..3926991.OR.ANG.GT.1.178097) GO TO 40
C
C **** FLOW IS DIAGONAL, CHANGE DESTINATION ELEMENT NUMBERS.
C
      IF (NR.LT.I) GO TO 30
      NR=NC+1
      NC=NC+1
      GO TO 40
   30 NR=NC-1
      NC=NC-1
C
C **** THE PREDOMINANT OVERLAND DIRECTION IS MAINTAINED AND THAT
C **** ELEMENT WILL RECEIVE THE UNTRAPPED FLOW AND SEDIMENT.
C
   40 IF (RFL.GT..5) GO TO 50
      RFL=TRAP
      NR=NMAX+1+PRACT
      RETURN
   50 RFL=1.-TRAP
      NC=NMAX+1+PRACT
      RETURN
C
C **** PONDS ARE SIMILAR TO PTO'S, BUT HAVE A HIGHER TRAP EFFICIENCY.
C
   60 TRAP=.95
      GO TO 20
C
C **** GRASSED WATERWAYS DIRECTLY AFFECT ONLY THE VEGETAGED AREA OF
C **** THE ELEMENT IN WHICH THEY ARE LOCATED, BUT THEY MUST ALSO ASSURE
C **** THAT THIS ELEMENT HAS A SHADOW CHANNEL ELEMENT.
C
   70 IF (CHAN.NE.0) GO TO 80
C
C **** CURRENT ELEMENT DOES NOT HAVE A SHADOW CHANNEL ELEMENT, MAKE ONE.
C
```

```
      CHAN=IEL(2,J,11)
      IF (CHAN.EQ.0) CHAN=1
      II=II+1
      CWID=WID(CHAN)
      PIV=CONST/CN(CHAN)/X*(DX/CWID/X)**.6667*DSQRT(SSI)
      SSII=SSI
      IF (SSI.LT.SCMIN) SCMIN=SSI
      IF (SSI.GT.SCMAX) SCMAX=SSI
      SCBAR=SCBAR+SSI
C
C **** NOW ACCOUNT FOR VEGETATED AREA BY REDUCING THE SEDIMENT
C **** DETACHMENT BY FLOW FOR THIS ELEMENT BY AN AMOUNT PROPORTIONAL
C **** TO THE VEGETATED AREA.  SINCE FLOW DETACHMENT IS DIRECTLY
C **** PROPORTIONAL TO THE OVERLAND SLOPE, ADJUST THAT PARAMETER.
C
C **** FIELD BORDERS HAVE A SIMILAR EFFECT TO THE VEGETATED AREA
C **** OF GRASSED WATERWAYS.
C
   80 TRAP=DBLE(IEL(2,J,10))/DX
      IF (TRAP.GT..5) TRAP=.5
      SL=SL*(1.-TRAP)
      RETURN
C
C **** CHECK TO SEE IF IT'S A MANAGEMENT PRACTICE BEFORE SPOUTING OFF.
C
   90 IF (PRACT.GT.10.AND.PRACT.LT.13) RETURN
      WRITE (2,100) IEL(2,J,9),IEL(2,J,1),J
      RETURN
C
  100 FORMAT (14H  PRACTICE NO.,I3,7H IN ROW,I4,5H, COL,I4,20H ILLEGAL A
     1ND IGNORED)
C
      END
      SUBROUTINE DRAIN (DR,DC,DIN,N,N1,N2,STD,TIAL,RFL,NR,NC)
      IMPLICIT DOUBLE PRECISION A-H,O-Z
C
C ****** SUBROUTINE FOR SUBSURFACE DRAINAGE.
C
      DIMENSION DR(2000), DIN(2000), RFL(2000)
      INTEGER NR(2000),NC(2000),TIAL(2000)
C
C **** SET ALL CHANNEL INFLOWS TO ZERO.
C
      DO 10 I=N1,N2
   10 DIN(I)=0.
      STD=0.
C
C **** ROUTE DRAINAGE FROM TILES.
C
      DO 50 I=1,N
      DRANE=0.
      IF (TIAL(I).LT.256) GO TO 40
      IF (DR(I).GT.DC) GO TO 20
      DRANE=DR(I)
      GO TO 30
   20 DRANE=DC
   30 STD=STD+DRANE
   40 DRANE=DRANE+DIN(I)
      DD=RFL(I)*DRANE
      J=NR(I)
      K=NC(I)
      DIN(J)=DIN(J)+DD
      DIN(K)=DIN(K)-DD+DRANE
   50 DIN(I)=0.
      RETURN
C
      END
      FUNCTION FILT(PIV,FCAP1,GWC,DR,S,R,CU2,ROUGH,HU,NEXP,ASMPER,
     & KE,PSIF,PHIC,T,CU,LF,KS,K,kk,M,CUMIN1,rbit0,testi,timpon,
     & TPON,FILTS,DT,CU1,TP1,AZRAT)
```

```
      IMPLICIT DOUBLE PRECISION A-H,O-Z
      DOUBLE PRECISION NS,KE,KS,LF
C
C **** POTENTIAL INFILTRATION CAPACITY -- WHOLE SURFACE COVERED.
C     IF (T.LE.O.) GOTO 50
C
C **** UNSATURATED INFILTRATION ZONE.
C
*************************************
*********************************
******EFFECTIVE MATRIX POTENTIAL
             NS=PHIC*(1.0-ASMPER)*PSIF
****************************************



**DETERMINE THE CUMULATIVE INFILTRATION USING THE NEWTON ITERATION
**TECHNIQUE
**KE*T=F-NS*LN(1+F/NS); G=(F-KE*T)-NS*LN((NS+F)/NS)
** DG/DF= 1-NS/(F+NS)=F/F+NS
** F2=F1-G1/(DG/DF1)
*      if(m.eq.503)write(6,*) filts/cu
*     if(R.lt.0.) stop

      if (t.eq.0.) then
              fmax=r
              testi=0
              test1=10
              goto 2
      endif
       T2=T
       rbit=r/cu

               if ((r.eq.0.).and.(testi.eq.1).and.(s.lt.0)) then
               fmax=filts
               testi=0
               goto 2
               endif

       if((ke.gt.rbit).and.(testi.eq.1).and.(s.gt.0)) then
               testi=1
               goto 8
       else
              if((ke.gt.rbit).and.(testi.eq.1).and.(s.lt.0)) then
               testi=0
               goto 2
             endif
       endif

      if(rbit0.eq.r) goto 111


      if((ke.le.rbit).and.(testi.eq.1)) then
                          testi=1
                         test1=13
                          goto 8
      endif


       if((ke.gt.rbit).and.(testi.eq.0)) then
               fmax=filts
               if(r.gt.0.)fmax=r
               testi=0
               goto 2
             endif

               if ((r.eq.0.).and.(testi.eq.1).and.(s.lt.0)) then
               fmax=filts
               testi=0
               goto 2
```

```
                 endif




      cumpon=ns/((rbit/ke)-1.)

              if((cumpon-cumin1).lt.0.) then
                   timpon=t2
                   Tpon=60*((cumin1)-NS*DLOG(1.0+(cumin1)/NS))/KE
                   goto 112
              endif

      timpon=(cumpon-cumin1)*60./rbit+t2
      Tpon=60*((cumpon)-NS*DLOG(1.0+(cumpon)/NS))/KE
               test1=15

      goto 112

111    continue

      if(testi.eq.1) goto 8

      if ((ke.ge.rbit).and.(testi.eq.0.)) then
                fmax=filts
                if(r.gt.0) fmax=r
                testi=0.
                timpon=0.
                tpon=0.
              test1=16
                goto 2
      endif


 112  if(t2.lt.timpon) then
                fmax=r
                testi=0
*        test1=17
                goto 2
      endif


  8    t1=t2-timpon+tpon
      if(t1.lt.0.) then
              fmax=filts
              goto 2
      endif
      testi=1.
 77    if(cumin1.gt.0) then
                           cumf=cumin1
      else
                           cumf=0.1
      endif
 88     ZU1=(T1/60.)*KE-(CUMF-NS*DLOG(1.0+CUMF/NS))
              DEL=CUMF/(NS+CUMF)
              TEST=ZU1/DEL
              XX=CUMF+TEST
              IF(ABS(TEST).GT.0.000001) THEN
              CUMF=XX
      GOTO 88
      ENDIF
      CUMINF=CUMF

   7    CONTINUE
              FMAX=KE*(1+NS/CUMINF)*CU
              ZXA=FMAX/CU
              FILT=FMAX

*  2    rbit0 = rbit
   2    FILT=FMAX
```

```
*       if (m.eq.76) write(5,888)ke,r/cu,t,timpon,tpon,fmax/cu,testi,
*     & cumin1,cumpon,filts/cu,s/cu,t2
 888   format(12(f10.4,1x),f3.1,5(f10.4,1x))
      rbit0=r
      cumpon=0.
      test1=0.
      IF (PIV) 30,40,10

 10   IF (PIV.LT.GWC) GO TO 20
     DR=0.
     RETURN

********************************
 20    CONTINUE
             RKFC=KS*AZRAT*(1-PIV*DT/TP1)**(-2.655/DLOG10(FCAP1))
             TI=(((1-PIV*DT/TP1)-FCAP1)*TP1/CU1)/RKFC
*       computing drainage for one hour
     ZFAY=1./TI
     IF(ZFAY.GT.75.) TI=1./75.

             DR=(((1-PIV*DT/TP1)-FCAP1)*TP1/CU1)*(1.-DEXP(-1/(TI)))*CU
             ASMFI=(1-PIV*DT/TP1)*TP1/CU1

             RETURN
********************************
C
C **** INFILTRATION ZONE SATURATED.
C
  30  PIV=0.
  40  RKFC=KS*AZRAT*(1-PIV*DT/TP1)**(-2.655/DLOG10(FCAP1))
     TI=(((1-PIV*DT/TP1)-FCAP1)*TP1/CU1)/RKFC
     ZFAY=1./TI
     IF(ZFAY.GT.75.) TI=1./75.
             DR=(((1-PIV*DT/TP1)-FCAP1)*TP1/CU1)*(1.-DEXP(-1./(TI)))*CU

     FMAX=DR
     FILT=FMAX
      testi=1
     RETURN
C
     END
     FUNCTION RAIN(RATE,PIT,PER)
     IMPLICIT DOUBLE PRECISION A-H,O-Z
C
C ****** DETERMINATION OF NET RAINFALL RATE.
C
     IF (PIT) 40,50,10
   10 RIT=PER*RATE
     IF (RIT-PIT) 20,30,30
   20 RAIN=RATE-RIT
     PIT=PIT-RIT
     RETURN
   30 RAIN=RATE-PIT
     PIT=0.
     RETURN
   40 PIT=0.
   50 RAIN=RATE
     RETURN
     END
C
C
CC.......SHIELDS DIAGRAM EXTENDED BY MANTZ (1977)................
C
     FUNCTION SHIELD(REYN)
     IMPLICIT DOUBLE PRECISION A-H,O-Z
     IF(REYN.LE.  1. ) GO TO 30
     IF(REYN.LE.  6.0) GO TO 40
     IF(REYN.LE. 20. ) GO TO 50
     IF(REYN.LE.450. ) GO TO 20
  10  CONTINUE
```

```
      SHIELD=.06
      RETURN
   20  SHIELD=DEXP(-3.9793+.19212*DLOG(REYN))
      RETURN
   30  SHIELD=.1*REYN**(-.3)
      RETURN
   40  SHIELD=DEXP(-2.3026-.5546*DLOG(REYN))
      RETURN
   50  SHIELD=0.033
      RETURN
      END
C
      SUBROUTINE SED(XZW,XR,DT,XDIR,M,N,KK,DX,N2)
!WB         XZW = element or channel width, XR = net rainfall rate for raingage
!WB         i on surface type j, DT=TIME INCREMENT, XDIR = retention depth
!WB         for cropping practice i, M = element # counter, N = # overland flow
!WB         elements, KK = soil type for current element, DX = length of side
!WB         of square element,N2=# OF O.F. CELLS + CHANNEL CELLS
            IMPLICIT DOUBLE PRECISION A-H,O-Z
C

C *** NRZ 9/15/94
C *** VARIABLES ARE CHANGED TO REFLECT NMAX+ISTRUC+1+NCHAN
!WB         NMAX = max # of cells, ISTRUC = counter for structural practices(+1)
!WB         NCHAN = # channels


      COMMON /PHOS1/ P0SOIL(2000),SSA(30,8),SSAT(30),EDI(2000),
     & P0(2000,8),ERP(8),STOLD(2000,8),SEDNEW(2000,8),PPT(2000,8),
     & PI(2030,8),PSEL(2000),STNEW(8),P2(8),PCELL(2000,8)
     & ,DRFT(8)
      COMMON /PHOS2/PE(8)

            COMMON /ZSEDI/ NPART,NWASH,NWASH1
      COMMON /ZSEDR/ VISCOS,AGRAV,SWH2O,YALCON,SE(8),VS(2000),DIA(8),
     1SG(8),FV(8),CY1(8),CY2(8),CY4(8),DIAMM(8),EQSDIA(8),EDMM(8),
     2F(30,8),CE1,CE2,CE3,CE4,CE5,CE6
!WB         Changed F(10,8) to F(30,8) to accomodate 30 soil types
C
      COMMON /CFLOW/ Q(2000),RFL(2000),FLINS(2000),SS(2000),PIV(2000),B(
     12000),NR(2000),NC(2000),DR(2000),S(2000),SL(2000),SEL(2000),SI(202
     20,8),QI(2020),DIN(2000),SST(2000,8)

C
C *** NRZ 9/15/94
C NRZ 9/5/94
C ADDED VARIABLES FOR CHANNEL NETWORKS

      COMMON /OUTLET/ NCHAN,NIOUT(9),NJOUT(9),MOUT(9),CHNUM(2000),
     &          CHOUT(9),NCELLS(9),CHNUMBER(2000)
            INTEGER CHNUM,CHOUT,CHNUMBER

C NRZ 9/5/94

      DIMENSION SE1(8),SE2(8),DELTA(8),PS(8),TF(8),TFMSE2(8)
     *,DS1(8),DS2(8),S22(8)

!WB         THE NEXT 4 LINES WERE ADDED/INCLUDED FOR THE NEW
!WB         SEDIMENT SUBROUTINE
      DIMENSION FILTS(2000), CWID(2000),CWIDTMP(2000)
      COMMON /CSURF/ SUR(2000),RANE(2000),SOIL(2000)
      INTEGER SUR,TIAL(2000),RANE,SOIL


!WB         BEGINNING OF NEW VARIABLES FOR NEW DETACHMENT ROUTINES
!WB         soil variables:
            COMMON/SOILVAR/CLAY(30),SAND(30),SILT(30),VFSPER(30),VFS(30),
            1ORGMAT(30),MASSCF(30),RANROU(30),RANROUM(30)
            DOUBLE PRECISION MASSCF
```

```
!WB     rill erodibility variables:
        COMMON/RILLVARS/KRBASE(2000),KRBR(2000),BR(20),BURRES(20),
        1KRADJHLD(2000),KRCONS(2000),KRSC(2000),KRADJ(2000)
        DOUBLE PRECISION KRBASE,KRBR,KRADJHLD,KRCONS,KRSC,KRADJ

!WB     critical shear variables:
        COMMON/CRTSHEAR/TAUCB(2000),TAURR(2000),TAUCHLD(2000),TAUCONS
        1(2000),TAUSC(2000),TAUCADJ(2000),TAUEFF

!WB     interrill erodibility variables:
        COMMON/IRILLVARS/KIBASE(2000),KICAN(2000),KIGRCOV(2000),KICONS
        1(2000),KISC(2000),KIADJ(2000),CANOPY(20),AUCFACT(20),HEIGHT(20),
  2MAXPLHGT(20),HGTFACT(20),GROWFACT(20)
        DOUBLE PRECISION KIBASE,KICAN,KIGRCOV,KICONS,KISC,KIADJ,MAXPLHGT

!WB     interrill cover common block:
        COMMON /IRILLCOV/ INRCOV(20),INRCOVI(20),INRCOVF(20),INRFACT(20),
        1LROOT(21),DROOT(21),KDROOTI(2000),KLROOTI(2000),DDROOTI(21),
        2DDROOTF(21),DDRTFAC(21),LRFAC(21),LIVEROOT(21),KDROOTR(2000),
        3KLROOTR(2000)

        DOUBLE PRECISION INRCOV,INRCOVI,INRCOVF,INRFACT,LROOT,KDROOTI,
        1KLROOTI,LRFAC,LIVEROOT,KDROOTR,KLROOTR

!WB     rill erosion variables:
        COMMON/RILLEROS/NORILLS,RILLSPC(20),QEFF,RILLWID,MNSOIL(21),
  1MNTOT(21),FLOWDEP,HYDRAD,DCAP,FCFRAC(30),FOFD,FPOFD,FDPOFD,
        2FLDEPOLD,MNCHNSL(2000),MNCHNTOT(2000),MNCS(10),MNCT(10),MNCSTMP
        3(2000),MNCTTMP(2000),MAXWID,NOTILL(21),NOEROS(21),DWSOIL,
        4HYDRADOLD(2000)
        DOUBLE PRECISION MNSOIL,MNTOT,MNCHNSL,MNCHNTOT,MNCS,MNCT,MNCSTMP,
        1MNCTTMP,NORILLS,MAXWID

!WB     interrill erosion variables
        COMMON /IRILLEROS/RNOFIR,SEDDR(2000,8),DIINT(2000,8),DETR(8)
        1,DETF(8),DACT(2000,8)

!WB     PLANT GROWTH VARIABLES
        COMMON /PLANTS/ DAYNOW(2000),YEARNOW(2000),DYYRNOW
        1(2000),DAYTHEN(2000),YEARTHEN(2000),DYYRTHEN(2000),DAYDIFF(2000),
        2BEGROTDT(2000)

!WB     CHANNEL BOTTOM EROSION VARIABLES
        COMMON /CHANEROS/WIDINC(2000),DOWNRATE(2000),
        1DEPTHINC(2000),IMPERM(10),ROCKBOT(2000),RBTEMP(2000),BULKDENS(30),
        2CHNSOIL(2000),CHNSL(2000),CHNSLTMP(2000),DEPRATE(2000)
  3,DEPPREV(2000),CONSTHLD(2000),XHOLD(2000),CONSTTMP(2000)
  4,XTMP(2000),ARMOUR(2000),NOERODE(2000),NERODTMP(2000)

!WB     HYDROGRAPH PLOT VARIABLES
        COMMON /HYPLT/PRINHYD,IMPFLAG,QHYP(101,10),PHYP(101,10)
        1,DPHYP(101,10),A4SHYP(101,10),A4DHYP(101,10),ONHYP(101,10)
        2,A3HYP(101,10)
        CHARACTER(11) HYPNAM(10)

        DOUBLE PRECISION DIFF,RGTSID,LFTSID,IMPERM,NOERODE,NERODTMP

        INTEGER CNT,CNTER,CNTFLAG,NOTILL,INIT,NOEROS,CHNSL,CHNSOIL,
        1CHNSLTMP,PRINHYD

!WB     Sediment Erosion routine information:  Some equations and
!WB     calculations in the sediment subroutine are not placed in the
!WB     location that will allow optimal calculation efficiency.  This is
!WB     recognized, and was done in order to ease understanding of the
!WB     methodology at the cost of computational efficiency.

!WB     END OF NEW VARIABLES FOR NEW DETACHMENT ROUTINES
```

```
          NP=1

    IF(Q(M).GT.0.) GO TO 30
!WB       if the outflow from element i at start of time increment is
!WB       greater than 0, then jump on down to 30

C
C.......NO OUTFLOW, ALL SEDIMENT ASSUMED DEPOSITED............
C
    GO TO 10

  5 NP=NWASH1
!WB       you are sent to line 5 after line 50 if the summation of deltas
!WB       is less than 0

 10 CONTINUE
    DO 20 IC=NP,NPART
!WB       the first time through, the IC=NP is =1, so this loop is performed
!WB       from 1 until the # of particle size classes
          SEL(M)=SEL(M)+.5*(SST(M,IC)+SI(M,IC))
!WB       accum sed in el i for a storm = same + 0.5*(sum of initial values in
!WB       sedi. continuity eqn + rate of sediment inflow into el i from
!WB       adjacent elements)
          SST(M,IC)=SI(M,IC)
!WB       sum of initial values in sediment continuity equation is equal to
!WB       the rate of sediment inflow into element i from adjacent elements
!WB       the M, IC denotes the element # we are going through and the particle
!WB       size class #
!WB       the previous two lines indicate that the sed accum in an element is
!WB       equal to the accum sed from the previous time step + 0.5 (the sed
!WB       inflow from the prev time step + sed inflow at current time step)
*DETERMINING THE NEWLY GENERATED SEDIMENT

          SEDNEW(M,IC)=0.
!WB       rate of new erosion occurring in cell for a particle class i (kg/sec)
!WB       and M,IC is element #, particle size class #
          STNEW(IC)=0.
!WB       soil storage for particle class i

C *** NRZ
C *** CHANNEL ADDITION
          SE(IC)=0.
!WB       rate of sediment movement from an element for this particle size
!WB       (kg/s) class is equal to 0

C *** NRZ END
 20 CONTINUE
!WB       this is the end of the first section loop that sets the sediment
!WB       continuity equation for the cells equal to the sediment inflow
!WB       and then sets the new sed generated in cell equal to 0

    IF(NP.EQ.NWASH1.AND.NWASH.NE.0) GO TO 65
!WB       NWASH = # washload particle size classes, NWASH1 = NWASH+1
!WB       NWASH1 is a counter for particle size classes that are settleable
!WB       (remember that washload particles (NWASH) are not settleable unless
!WB       flow is 0), so if there are for example 5 particle size classes,
!WB       and two of those are settleable, then NWASH1 to NPART is a count
!WB       of settleable particles
!WB       this sends you down to do washload calculations
    RETURN
C
C.......OUTFLOW...............................................
C
 30 CONTINUE
    SMDIR=S(M)-XDIR
!WB        = storage at start of time increment for el i - ret. depth for
!WB       cropping practice i (m3/s)
!WB       I think that this says that the amount of storage at the start
!WB       of the time increment minus the ret depth, so this tells if there
!WB       is water available to runoff
```

```
      IF(SMDIR.LE.0.) GO TO 10
!WB          if the above var is less than or equal to 0, then jump back up
!WB          and redo the intialization of the cont eqn, sed gen var.'s
!WB          so, from above, if there is no runoff, you jump back up and calc.
!WB          the sediment inflow into a cell, and reset the continuity eqn
!WB          equal to inflow to the cell

C
C.......CALCULATE TRANSPORT CAPACITY FOR EACH ...........
C................PARTICLE SIZE CLASS.....................
C
      SDEL=0.
!WB          summation of delta = 0
!WB          essentially, delta is the dimensionless excess of the tractive
!WB          force, and Yalin made the assumption that the # of particles in
!WB          transport was equal to a linear function of delta
      VSTAR=VS(M)*DSQRT(SMDIR)
!WB          shear velocity = simplification var * sqrt(storage-ret. depth)
!WB          in the text, Vstar = (g R S)^0.5, where g is gravity, R is
!WB          hydraulic radius assumed equal to flow depth, S is slope of
!WB          the energy gradeline
!WB
      CY5=VSTAR*XZW
!WB          simplifying constant = shear vel * element or channel width
!WB
      DO 50 IC=NWASH1,NPART
!WB
             REYN=CY1(IC)*VSTAR
!WB          constant(NWASH1)*shear velocity
!WB          this appears to be the Reynold's # calculation for the particle size
!WB          class
             YCR=SHIELD(REYN)
!WB          dimensionless critical shear = shields function of reynolds #

             DELTA(IC)=VSTAR**2/(CY2(IC)*YCR)-1.0
!WB          variable = shear vel^2 / [const(NWASH1)*dimensionless crit shear)-1
!WB          dimensionless excess of the tractive force = shear velocity^2 /
!WB          simplifying constant (particle size class) * dimensionless critical
!WB          shear) - 1.0
             IF(DELTA(IC).LE.0) GO TO 45
!WB          if the dimensionless critical shear is less than or equal to 0
!WB          then jump down to line 45 because there is no transport
             SIGMA=1.65908*DELTA(IC)*DSQRT(YCR)
!WB          sigma = 1.65098*delta(NWASH1)*DSQRT(dimensionless crit shear)
!WB          sigma is unnamed, and this equation differs from the paper by the
!WB          factor 2.45*particle spec grav^-0.4, whereas this equation has the
!WB          constant 1.65098
             PS(IC)=YALCON*DELTA(IC)*(1.-DLOG(1.+SIGMA)/SIGMA)
!WB          variable = Yalin's constant*delta*(1-natural log(1+sigma)/sigma)
!WB          PS is unnamed, however this is used in the trans cap equation
!WB          from the paper
             SDEL=SDEL+DELTA(IC)
!WB          summation of delta = sum + delta
!WB          this is important because it is assumed that for a mixture, the #
!WB          of particles of a size i in transport is proportional to delta i
             GO TO 50
   45    CONTINUE
             DELTA(IC)=0.
!WB          this one is where you are sent if Y<= Ycr (shear stress < crit value)
             PS(IC)=0.
!WB          essentially sets the transport capacity equal to 0
   50  CONTINUE
      IF(SDEL.LE.0.) GO TO 5
!WB          if the summation of delta is <= 0, go on back to the top to
!WB          reapportion inflow and sum the sediment continuity eqn
      DO 60 IC=NWASH1,NPART
!WB          reset the count variable IC equal to the NWASH1 variable, and add
!WB          it up to number of particle size classes
             TF(IC)=PS(IC)*DELTA(IC)/SDEL*CY5*CY4(IC)
!WB          transport cap = var * delta / sum delta * const * const
```

```
!WB      this says that the transp cap is a function of the ratio of the
!WB      amount of dimensionless critical shear of this particle size class
!WB      to the summed delta of all particle size classes.
 60  CONTINUE
C
 65  CONTINUE
!WB      you are sent here from above if nwash not equal 0 and NP
!WB      equals NWASH1
    AREA=DX*XZW
!WB      area = length of size * el or channel width
!    IF(M.GT.N) GO TO 70
!WB      if element # counter > # overland flow el's, THIS ORIGINALLY RESET
!WB      THE FLOW AND RAINFALL DETACHMENT EQUAL TO 0.  NOW, THE RAIN-
!WB      FALL DETACHMENT IS RESET TO 0, WHILE FLOW DETACHMENT IS CALCULATED
!WB      FOR CHANNEL CELLS.
C
CC....CALCULATE RAINFALL DETACHMENT & POTENTIAL FLOW DETACHMENT....
C
!WB      ************* NEW SEDIMENT DETACHMENT ROUTINE *****************
!WB      ********************* flow detachment *************************
         JK=MOD(SUR(M),256)
!WB      jk extracts the crop descriptor #
         IF (M.GT.N) GO TO 9400
!WB      THIS SKIPS THE RILL WIDTH CALCULATION IF THE CELL IS A CHANNEL CELL.
         IF (RILLSPC(JK).EQ.0) RILLSPC(JK)=1.
!WB      ADDED 1/6/99 AS A DEFAULT.
         NORILLS=DX/RILLSPC(JK)
!WB      norills=the number of rills per cell.
         QEFF=Q(M)/(NORILLS)
!WB      effective flow = total flow on cell / # of rills per cell,
!WB      this should be flow per rill contributing area (the rill plus
!WB      the interrill area that contributes flow to the rill)
         RILLWID=1.13*QEFF**0.303
!WB      rillwid=rill width, see 1995 WEPP documentation, eqn 10.7.1
         IF (RILLWID.GT.MAXWID) THEN
!WB      THE MAX WIDTH IS SET EQUAL TO A VERY SMALL # RIGHT AFTER
!WB      A CROPPING ROTATION CHANGES (INDICATING OBLITERATION OF RILLS)
!WB      AND CONTINUES TO WIDEN DURING THE CROP GROWTH PERIOD.
         MAXWID=RILLWID
!WB      IF THE CURRENT RILLWID EXCEEDS THE MAXWID, THEN SET MAX = CURRENT
         ELSE
         RILLWID=MAXWID
!WB      IF A PREVIOUS WIDTH IS GREATER, THEN SET CURRENT = MAX WIDTH
         ENDIF
         IF (RILLWID.GT.RILLSPC(JK)) THEN
!WB      THIS IS A FLAG TO INDICATE THAT THE RILL WIDTH OF AN O.F. CELL IS
!WB      GREATER THAN RILL SPACING (I.E.-MORE
!WB      RILL THAN YOU HAVE SPACE.)
         WRITE (2,1000) M,RILLWID,RILLSPC(JK)
         WRITE (*,1000) M,RILLWID,RILLSPC(JK)
         PAUSE
         ENDIF
 9400 CONTINUE
         IF (M.GT.N) THEN
         QEFF=Q(M)
         RILLWID=XZW+WIDINC(M)
         JK=21
         MNSOIL(JK)=MNCHNSL(M)
         MNTOT(JK)=MNCHNTOT(M)
         NORILLS=1.
         IF (MNSOIL(JK).GT.MNTOT(JK)) THEN
         WRITE (2,1002)
         WRITE (*,1002)
         STOP
         ENDIF
!WB      IF THE CELL IS A CHANNEL CELL, THEN SET THE QEFF EQUAL TO FLOW
!WB      RATE, AND RILLWID=CWID (PASSED AS XZW IN THE SUBROUTINE CALL),
!WB      IF THE CELL IS DESIGNATED NOEROS THEN SET THE WIDTH INCREASE = 0
!WB      THEN SET JK=21, WHICH IS THE LAST POSITION
!WB      IN THE ARRAY MNSOIL, AND USE THIS POSITION TO HOLD THE FRICTION
```

```
!WB        FACTOR FOR EACH CHANNEL CELL.  SAME GOES FOR MNTOT.  FINALLY, THERE'S
!WB        AN ERROR STATEMENT IF MNSOIL EXCEEDS MNTOT.
           ENDIF
           DIFF=1.
           FLDEPOLD=1.0
           FLOWDEP=1.0
           CNTER=0
           CNTFLAG=100
           DEPINIT=0
           DWSOIL=(MNTOT(JK)*MNTOT(JK)*8*9.80665)/(HYDRADOLD(M)**0.33333333)
           IF (DWSOIL.GT.10) THEN
           DWSOIL=10
           ENDIF
           IF (DWSOIL.LT.0.1) THEN
           DWSOIL=0.1
           ENDIF
!WB        SET THE INITIAL CONDITIONS FOR THE ITERATION.  THE ITERATION IS
!WB        THE NEWTON-RAPHSON METHOD FOR MULTIPLE ROOTS PER 'NUMERICAL
!WB        METHODS FOR ENGINEERS, 2ND ED.' BY CHAPRA AND CANALE, 1988,
!WB        MC-GRAW HILL.
!WB        THE EQUATION IS THE DARCY-WEISBACH FRICTION FACTOR EQN, SOLVED
!WB        FOR THE HYD RAD, AND THEN SET EQUAL TO THE DEFN OF HYD RAD AND
!WB        SOLVED FOR FLOW DEPTH.  AN INITIAL GUESS OF DWSOIL IS REQUIRED.
!WB        IT HAS BEEN ARBITRARILY SET TO = 0.1.  IT IS THEN CALCULATED
!WB        BASED ON THE MANNING'S N AND HYD RADIUS.
           IF (QEFF.LT.0.00001) THEN
           QEFF=0
           FLOWDEP=0
           GOTO 9005
           ENDIF
!WB        THIS WAS ADDED 1/5/99 AFTER SOME DIFFICULTIES IN THE SOLUTION
!WB        TECHNIQUE IN SOLVING FLOWDEPTH FOR CHANNELS WITH VERY LOW QEFF
!WB        (LESS THAN 1e-8).  THE EXACT PROBLEM WAS UNDETERMINED, HOWEVER
!WB        THE SOLUTION TECHNIQUE WAS PROVEN FOR THE SAME PARAMETER VALUES
!WB        THAT CAUSED THE ERROR USING A SPREADSHEET WITH THE SAME ITERATION,
!WB        SO THE ERROR IS LIKELY DUE TO ROUNDING.
 9001      DO WHILE ((DIFF.GT.0.00001).OR.(FLOWDEP.LT.0))
!WB        DO THIS WHILE THE DIFFERENCE IN FLOW DEPTH B/T THIS CALC AND
!WB        THE PREVIOUS CALCULATION IS GT 0.0001, AND WHILE THE FLOWDEPTH
!WB        IS NEGATIVE.  THE SECOND PART IS NECESSARY B/C THIS TECHNIQUE WILL
!WB        SOMETIMES PRODUCE NEGATIVE VALUES IN THE FIRST FEW ITERATIONS.
           IF (CNTER.EQ.0) THEN
!WB        THIS SECTION SAVES THE INITIAL VALUES IN CASE THE ITERATION DOESN'T
!WB        CONVERGE.  IF AFTER 100,200,300,500 ITERATIONS W/O CONVERGENCE, THE
!WB        ITERATION IS RETRIED WITH DIFFERENT INITIAL CONDITIONS.  IF, AFTER
!WB   10,000 ITERATIONS, THERE IS NO CONVERGENCE, THE PROGRAM CALLS AN
!WB        ERROR MESSAGE AND STOPS.
           FLDEP=FLOWDEP
           RLWID=RILLWID
           DIF=DIFF
           FLDOLD=FLDEPOLD
           ENDIF
           FOFD=((FLOWDEP**3)*(RILLWID**3)*8*9.80665*SL(M))-(DWSOIL
           1*(QEFF**2)*2*FLOWDEP)-(DWSOIL*(QEFF**2)*RILLWID)
!WB        FOFD=f(FLOWDEP)
           FPOFD=(3*(FLOWDEP**2)*(RILLWID**3)*8*9.80665*SL(M))-(DWSOIL*
           1(QEFF**2)*2)
!WB        FPOFD=f'(FLOWDEP)
           FDPOFD=(6*FLOWDEP*(RILLWID**3)*8*9.80665*SL(M))
!WB        FDPOFD=f''(FLOWDEP)
           FLOWDEP=FLDEPOLD-((FOFD*FPOFD)/((FPOFD**2)-FOFD*FDPOFD))
!WB        Xi+1=Xi-((f(D)*f'(D))/(f'(D)^2-f(D)*f''(D))) WHERE D = FLOWDEPTH
           DIFF=ABS(FLOWDEP-FLDEPOLD)
!WB        DIFF=TEST VARIABLE FOR THE LOOP.
           FLDEPOLD=FLOWDEP
!WB        SET THE FLDEPOLD=FLOWDEP FOR THIS CALCULATION.
           CNTER=CNTER+1

           IF (CNTER.GT.10000) THEN
!WB        THIS DISPLAYS AN ERROR MESSAGE IF, AFTER 10000 ITERATIONS,
```

```
!WB         THE EQUATION DOES NOT CONVERGE.
            WRITE (2,1004) M,QEFF,RILLWID,SL(M),DWSOIL,FLDEPOLD
            WRITE (*,1004) M,QEFF,RILLWID,SL(M),DWSOIL,FLDEPOLD
            STOP
            ENDIF

            IF (CNTER.EQ.CNTFLAG) THEN
!WB         THIS RESTARTS THE CALCULATION WITH DIFFERENT INITIAL CONDITIONS
            DEPINIT=DEPINIT+0.10
            FLOWDEP=DEPINIT
            RILLWID=RLWID
            DIFF=DIF
            FLDEPOLD=DEPINIT
            CNTFLAG=CNTFLAG+100
            GO TO 9001
            ENDIF
            END DO

            IF (FLOWDEP.LT.0) THEN
!WB         FLOWDEPTH CALCULATION ERROR MESSAGE, WHICH IS LIKELY DUE TO PROGRAM
!WB   ERROR, SUCH AS AN ARRAY THAT HAS "OVER-FLOW'ED".
            WRITE (2,1006) M,FOFD,FPOFD,FDPOFD,FLOWDEP,FLDEPOLD,RILLWID,QEFF,
            1SL(M),DWSOIL,DIFF
            WRITE (*,1006) M,FOFD,FPOFD,FDPOFD,FLOWDEP,FLDEPOLD,RILLWID,QEFF,
            1SL(M),DWSOIL,DIFF
            STOP
            ENDIF
 9005       CONTINUE
            HYDRAD=(FLOWDEP*RILLWID)/(2*FLOWDEP+RILLWID)
!WB         hydrad= hydraulic radius
            HYDRADOLD(M)=HYDRAD
!WB         SAVE THE HYDRAD FOR THE DWSOIL CALC THE NEXT TIME STEP
      IF (HYDRADOLD(M).EQ.0) HYDRADOLD(M)=0.1
!WB         IF QEFF = 0 , HYDRAD = 0, & DWSOIL IS DIV BY 0, SO RESET HYDRADOLD=0.1
            TAUEFF=9806.65*SL(M)*HYDRAD*((MNSOIL(JK)*MNSOIL(JK))
            1/(MNTOT(JK)*MNTOT(JK)))
!WB         taueff = effective shear stress,9806.65 (kg*m-2*s-2) =
!WB         specific weight of water
!WB         sl(M) is the element slope in m/m
!WB         degrees.  MNSOIL is the manning's n friction factor for
!WB         the bare soil, while MNTOT includes the factor for cover.
            IF (TAUEFF.GT.TAUCADJ(M)) THEN
            DCAP=KRADJ(M)*(TAUEFF-TAUCADJ(M))*(NORILLS*RILLWID*DX)
!WB         THE ABOVE LINE SAYS THAT RILL DETACHMENT EQUALS THE DETACHMENT
!WB         CAPACITY TIMES THE RILL CONTRIBUTING AREA
            IF (M.GT.N) THEN
            DCAP=DCAP*(1-ARMOUR(M))
!WB         DETACHMENT CAPACITY IN A CHANNEL IS EQUAL TO DETACHMENT
!WB         CAPACITY TIMES THE AMOUNT OF THE CHANNEL SOIL THAT IS
!WB         ERODIBLE (ARMOUR IS THE NONERODIBLE PERCENTAGE)
            DOWNRATE(M)=(KRADJ(M)*(TAUEFF-TAUCADJ(M))/BULKDENS(KK))*
            1(1-ARMOUR(M))
!WB         DOWNRATE=RATE OF EROSION OF THE CHANNEL BOTTOM (M/S)
            DEPRATE(M)=(DEPPREV(M)/BULKDENS(KK))/XZW
!WB         THIS IS THE DEPOSITION RATE AT THE PREVIOUS TIME STEP, USED
!WB         TO ADJUST THE DEPTHINC VAR FOR DEPOSITION.  THE CALCULATION IS:
!WB         ((KG/S)/(KG/M^3)) / M WIDTH, ASSUMED 1 METER LENGTH ALONG
!WB         CHANNEL BOTTOM, YIELDS UNITS M/S
            DEPTHINC(M)=DEPTHINC(M)+(DOWNRATE(M)*DT)-(DEPRATE(M)*DT)
!WB         DEPTHINC=DEPTH THAT THE CHANNEL BOTTOM HAS ERODED (METERS)
            IF (DEPTHINC(M).GT.ROCKBOT(M)) DEPTHINC(M)=ROCKBOT(M)
!WB         IF THE ERODED DEPTH IS GREATER THAN THE NONERODIBLE BOUNDARY,
!WB         THEN BOTTOM EROSION IS RESET EQUAL TO THE NONERODIBLE DEPTH,
!WB   THIS ALLOWS FOR DEPOSITION TO LESSEN THE ERODED DEPTH
!WB   "INCREMENT".  IF DEPTHINC > NONERODIBLE DEPTH, EROSION
!WB         SWITCHES TO THE WALLS
            DEPRATE(M)=0.
!WB         THIS MAKES SURE THAT AN 'OLD' VALUE OF DEPOSITION DOESN'T
!WB         AFFECT CALCULATIONS
            IF (DEPTHINC(M).GE.ROCKBOT(M)) THEN
```

```
!WB     IF THE ERODED DEPTH IS G.E. THE DISTANCE TO AN IMPERMEABLE LAYER
        WIDINC(M)=WIDINC(M)+DOWNRATE(M)*DT
!WB     WIDINC=WIDTH THAT THE CHANNEL HAS ERODED.  NOTE THAT THE EROSION
!WB     RATE IS THE SAME FOR DOWNWARD MOVEMENT AS FOR LATERAL MOVEMENT.
        DCAP=KRADJ(M)*(TAUEFF-TAUCADJ(M))*(2*FLOWDEP*DX)
!WB     BECAUSE THE CHANNEL BOTTOM IS CONSIDERED UNERODIBLE, DETACHMENT
!WB     CAPACITY IS CALCULATED ALONG THE CHANNEL WALLS,AND NORILLS=1.
!WB     RATE IS (KG/S)
        DCAP=DCAP*(1-ARMOUR(M))
!WB     DETACHMENT CAPCACITY TIMES THE ERODIBLE FRACTION OF SOIL (THIS
!WB     WAS INCLUDED FOR WALL EROSION TO SIMULATE LOWERED ERODIBILITY
!WB     OF CHANNEL SOIL)
        ENDIF
        ENDIF
        ELSE
        DCAP=0.
!WB     IF THE EFFECTIVE SHEAR STRESS DOESN'T EXCEED THE BASELINE, THERE
!WB     IS NO RILL DETACHMENT.
        ENDIF
        DO IC=1,NPART
        IF ((SST(M,IC).GT.TF(IC)).OR.((SST(M,IC).GE.0).AND.
        1(TF(IC).LE.0))) THEN
!WB     IF THE SED IN TRANSPORT IS GT TRANS CAP, YOU WILL HAVE
!WB     A NEGATIVE DCAP, SO SET DACT=0
        DACT(M,IC)=0
        ELSE
        DACT(M,IC)=DCAP*(1-(SST(M,IC)/TF(IC)))
        ENDIF
        IF (DACT(M,IC).GT.DCAP) THEN
!WB     THIS WOULD OCCUR IF THERE WAS A PROGRAM ERROR, FOR INSTANCE IF AN
!WB     ARRAY OVERFLOWED.
        WRITE (2,1008) DACT(M,IC),M,IC,DCAP
        WRITE (*,1008) DACT(M,IC),M,IC,DCAP
        STOP
        ENDIF
        END DO
        IF (DACT(M,IC).GT.10) THEN
!WB     JUST A GENERAL ERROR CHECK, DACT IS IN KG/S
        WRITE (*,*) 'DACT(M,IC) GT 10',DACT(M,IC),M,IC
        PAUSE
        ENDIF
        IF (M.GT.N) GO TO 9405
!WB     IF ITS A CHANNEL CELL, THEN JUMP DOWN TO CHANNEL DETACHMENT
!WB     **************** Rainfall detachment **********************
        RNOFIR=QEFF/(DX*RILLSPC(JK))
        IF (RNOFIR.GT.1) THEN
!WB     GENERAL ERROR CHECK
        WRITE (*,*) 'RNOFIR EXCEEDS 1'
        PAUSE
        ENDIF
!WB     rnofir=interrill runoff rate, assumed equal to the effective runoff
!WB     rate per rill / (flow length*distance b/t rills).  This equals the
!WB     flowdepth at present time
!WB     ******** sediment delivery ratio calculation *******
!WB     This information comes from table 8.4 and 8.5 by Foster, ASAE
!WB     monograph # 5.  The roughness factor range for the last two
!WB     categories were changed to give a quantifiable category for
!WB     a smooth surface (see table 8.4).

        DO IC=1,NPART
        IF (RANROU(JK).GE.150) THEN
!WB     rghfact(M)=0.3, read table 8.5 for this roughness factor
        IF (DIAMM(IC).LT.0.002) SEDDR(M,IC)=0.91
        IF (DIAMM(IC).GE.0.002.AND.DIAMM(IC).lt.0.050) SEDDR(M,IC)=0.79
        IF (DIAMM(IC).GE.0.050.AND.DIAMM(IC).lt.0.250) SEDDR(M,IC)=0.37
        IF (DIAMM(IC).GE.0.250.AND.DIAMM(IC).lt.1.000) SEDDR(M,IC)=0.00
        IF (DIAMM(IC).GE.1.000) SEDDR(M,IC)=0.00
        ENDIF
        IF (RANROU(JK).GE.100.AND.RANROU(JK).LT.150) THEN
!WB     rghfact(M)=0.5, read table 8.5 for this roughness factor
```

```
        IF (DIAMM(IC).LT.0.002) SEDDR(M,IC)=0.97
        IF (DIAMM(IC).GE.0.002.AND.DIAMM(IC).LT.0.050) SEDDR(M,IC)=0.93
        IF (DIAMM(IC).GE.0.050.AND.DIAMM(IC).LT.0.250) SEDDR(M,IC)=0.75
        IF (DIAMM(IC).GE.0.250.AND.DIAMM(IC).LT.1.000) SEDDR(M,IC)=0.00
        IF (DIAMM(IC).GE.1.000) SEDDR(M,IC)=0.00
        ENDIF
        IF (RANROU(JK).GE.70.AND.RANROU(JK).LT.100) THEN
!WB     rghfact(M)=0.65, read table 8.5 for this roughness factor
        IF (DIAMM(IC).LT.0.002) SEDDR(M,IC)=1.00
        IF (DIAMM(IC).GE.0.002.AND.DIAMM(IC).LT.0.050) SEDDR(M,IC)=0.99
        IF (DIAMM(IC).GE.0.050.AND.DIAMM(IC).LT.0.250) SEDDR(M,IC)=0.98
        IF (DIAMM(IC).GE.0.250.AND.DIAMM(IC).LT.1.000) SEDDR(M,IC)=0.07
        IF (DIAMM(IC).GE.1.000) SEDDR(M,IC)=0.17
        ENDIF
        IF (RANROU(JK).GE.50.AND.RANROU(JK).LT.70) THEN
!WB     rghfact(M)=0.75, read table 8.5 for this roughness factor
        IF (DIAMM(IC).LT.0.002) SEDDR(M,IC)=1.00
        IF (DIAMM(IC).GE.0.002.AND.DIAMM(IC).LT.0.050) SEDDR(M,IC)=1.00
        IF (DIAMM(IC).GE.0.050.AND.DIAMM(IC).LT.0.250) SEDDR(M,IC)=0.99
        IF (DIAMM(IC).GE.0.250.AND.DIAMM(IC).LT.1.000) SEDDR(M,IC)=0.32
        IF (DIAMM(IC).GE.1.000) SEDDR(M,IC)=0.46
        ENDIF
        IF (RANROU(JK).GE.20.AND.RANROU(JK).LT.50) THEN
!WB     rghfact(M)=0.85, read table 8.5 for this roughness factor
        IF (DIAMM(IC).LT.0.002) SEDDR(M,IC)=1.00
        IF (DIAMM(IC).GE.0.002.AND.DIAMM(IC).LT.0.050) SEDDR(M,IC)=1.00
        IF (DIAMM(IC).GE.0.050.AND.DIAMM(IC).LT.0.250) SEDDR(M,IC)=0.99
        IF (DIAMM(IC).GE.0.250.AND.DIAMM(IC).LT.1.000) SEDDR(M,IC)=0.58
        IF (DIAMM(IC).GE.1.000) SEDDR(M,IC)=0.69
        ENDIF
        IF (RANROU(JK).GE.5.AND.RANROU(JK).LT.20) THEN
!WB     rghfact(M)=0.92, read table 8.5 for this roughness factor
        IF (DIAMM(IC).LT.0.002) SEDDR(M,IC)=1.00
        IF (DIAMM(IC).GE.0.002.AND.DIAMM(IC).LT.0.050) SEDDR(M,IC)=1.00
        IF (DIAMM(IC).GE.0.050.AND.DIAMM(IC).LT.0.250) SEDDR(M,IC)=1.00
        IF (DIAMM(IC).GE.0.250.AND.DIAMM(IC).LT.1.000) SEDDR(M,IC)=0.78
        IF (DIAMM(IC).GE.1.000) SEDDR(M,IC)=0.84
        ENDIF
        IF (RANROU(JK).GE.0.AND.RANROU(JK).LT.5) THEN
!WB     rghfact(M)=1.00, read table 8.5 for this roughness factor
        IF (DIAMM(IC).LT.0.002) SEDDR(M,IC)=1.00
        IF (DIAMM(IC).GE.0.002.AND.DIAMM(IC).LT.0.050) SEDDR(M,IC)=1.00
        IF (DIAMM(IC).GE.0.050.AND.DIAMM(IC).LT.0.250) SEDDR(M,IC)=1.00
        IF (DIAMM(IC).GE.0.250.AND.DIAMM(IC).LT.1.000) SEDDR(M,IC)=1.00
        IF (DIAMM(IC).GE.1.000) SEDDR(M,IC)=1.00
        ENDIF
        END DO
        DO 9500 IC=1,NPART
        DIINT(M,IC)=(KIADJ(M)*XR*RNOFIR*SEDDR(M,IC)/AREA)
!WB     DIINT=INTERRILL DETACHMENT, KIADJ=ADJUSTED INTERRILL ERODIBILITY,
!WB     XR=NET RAINFALL RATE CONVERTED TO M3/S,
!WB     RNOFIR=INTERRILL RUNOFF RATE,SEDDR=SED DELIVERY
!WB     RATIO, AREA=AREA OF CELL OR CHANNEL, USED TO ADJUST THE RAINFALL
!WB     RATE TO A UNIT AREA BASIS, AND THEN THE DETACHMENT IS MULTIPLIED
!WB     BY AREA BELOW.
        IF (DIINT(M,IC).GT.100) THEN
!WB     GENERAL ERROR CHECK
        WRITE (*,*) 'DIINT EXCEEDS 100'
        STOP
        ENDIF
        DIINT(M,IC)=DIINT(M,IC)*((DX*DX)-(NORILLS*RILLWID*DX))
!WB     THIS SAYS THAT THE INTERRILL CONTRIBUTION IN KG/S*M2 SHOULD BE
!WB     MULTIPLIED BY THE INTERRILL AREA, WHICH EQUALS THE CELL AREA
!WB     MINUS THE RILL AREA
 9500   END DO
        DO IC=1,NPART
   DETR(IC)=DIINT(M,IC)
!WB     rainfall detachment (kg/s) =
   DETF(IC)=DACT(M,IC)
```

```
!WB       flow detachment (kg/s) =
          IF (NOEROS(JK).EQ.1) THEN
!WB       THIS IS A FLAG THAT INDICATES A COVER CONDITION THAT DOES NOT INCUR
!WB       EROSION, SUCH AS A PARKING LOT OR POND
          DETR(IC)=0.
          DETF(IC)=0.
          ENDIF
          END DO

    GO TO 75

 9405 CONTINUE
  70  DO IC=1,NPART
          DETR(IC)=0.
!WB       reset rainfall detach to 0
    DETF(IC)=DACT(M,IC)
!WB       you are sent here to reset flow and rainfall detachment if the
!WB       element is a channel cell
!WB       IF AN ELEMENT HAS A NOEROS FLAG, IT DOES NOT AFFECT EROSION IN A
!WB       CHANNEL CELL OF THAT ELEMENT.
          END DO

  75  CONTINUE
!WB       you skip the reset of the rainfall and flow detachments to 0 if
!WB       you are still doing calculations on overland flow cells
    DO IC=1,NPART
          DRFT(IC)=DETR(IC)+DETF(IC)
!WB       sum of rainfall & flow detach (kg/s)
          END DO
    X1=Q(M)/S(M)
!WB       X1 = flow / water storage on element
!WB       (it's a volumetric flow/volum storage)
    X2=1./(1.+X1)
!WB       X2 = 1 / (1+flow/storage)
!WB       this is also:  storage/(storage+flow)
    IF(NP.EQ.NWASH1.AND.NWASH.NE.0) GO TO 310
!WB       if np equals NWASH + 1 and # of washload particles doesn't equal 0
!WB       line 310 is the beginning of the washload particle calculations
    X3=X1*X2
!WB       X3 = (flow / storage) * (1 / (1+flow/storage))
!WB       this is also flow/(flow+storage
    X4=1./X1
!WB       X4 = storage / flow
    DO 80 IC=NWASH1,NPART
!WB       do from counter IC = # washload particles + 1 up to # of particles
          DS1(IC)=SI(M,IC)+F(KK,IC)*DETR(IC)
!WB       max rate of sed. inflow & erosion in element with only rainfall
!WB       detach (kg/s) = sed. inflow + fraction of particles of type i in
!WB       original soil * detach rate for rainfall
          DS2(IC)=DS1(IC)+F(KK,IC)*DETF(IC)
!WB       max rate of sed inflow & erosion in element with rainfall &
!WB       flow detachment (kg/s) = above + fraction of particles of type i in
!WB       original soil (soil type of current element, particle size class)
!WB        * flow detachment (kg/s)
          S22(IC)=(SST(M,IC)+DS2(IC))*X2
!WB       S22 = (sum of initial values in sed. cont eqn (kg/s) +
!WB       max rate sed inflow & erosion w/ rainfall & flow detach (kg/s)) *
!WB        (1/(1+(flow/storage)))
          SE1(IC)=(SST(M,IC)+DS1(IC))*X3
!WB       SE1 (rate of sed movement w/o flow detachment
!WB        = (sum of initial values in sed cont eqn +
!WB       max rate of sed. movement w/ rainfall detach) * X3
          SE2(IC)=S22(IC)*X1
!WB       SE2 (rate of sed movement w/ rainfall and flow detachment
!WB        = sed cont eqn + erosion w/rainfall & flow detach * (1/1+
!WB        (flow/storage)) * flow/storage
  80  CONTINUE
!WB       you are sent here after completing the last loop for the # of
!WB       settleable size classes
C
```

```
C.........APPORTION ANY TRANSPORT EXCESS TO DEFICITS..........
C
      NPM=NPART-NWASH
!WB         NPM = # of particle size classes - # of washload size classes
!WB         this is equal to the # of settleable size classes
 90  I1=0
!WB         counter
!WB         you are sent here from later in the prog
      I2=0
!WB         counter
      I3=0
!WB         counter
      SDEL=0.
!WB         sum of delta
      TFXCES=0.
!WB         trans cap excess

!WB********calculate transport capacity excess ******************
      DO 150 IC=NWASH1,NPART
!WB         do from nwashload part's + 1 to # particle size classes
            TFMSE2(IC)=TF(IC)-SE2(IC)
!WB          = trans cap - sediment w/ rainfall and flow detach
            IF(TFMSE2(IC))130,140,110
!WB         if above var < = > 0, then go to 130, 140, 110, respectively
!WB         this says, is trans cap less than sediment erosion
!WB         capacity with rainfall and flow detachment, or equal to or
!WB         greater than
C
C............TRANSPORT > SE2........................
C
!WB         this says that the transport capacity exceeds the detachment
!WB         rate with rainfall and flow detachment
 110    I1=I1+1
!WB         count
            TFXCES=TFXCES+TFMSE2(IC)
!WB         trans cap excess = excess + (cap - no flow detachment)
!WB         this says that the excess is equal to the previous excess + the
!WB         definition of trans cap excess
            TF(IC)=SE2(IC)
!WB         trans cap = rate of sed movement w/ rainfall and flow detach
!WB         set trans cap equal to the detachment rate if you have an excess
!WB         of t.c.
      GO TO 150
C
C............TRANSPORT < SE2........................
C
!WB         this says that if the transport capacity is less than the
!WB         detachment rate
 130    I3=I3+1
!WB         count
            SDEL=SDEL+DELTA(IC)
!WB         summ of delta = same + delta (= dimensionless crit shear)
 140    I2=I2+1
!WB         count.  You are sent here if the t.c. excess is equal to the
!WB         detachment rate.
 150  CONTINUE
!WB         you are sent here to skip the I3 counter and the sum of delta
!WB         for the condition of t.c. < detachment rate (or equal to det.
!WB         rate), and the I2 counter
      IF(SDEL.LE.0.) GO TO 200
!WB         sum of delta less than or equal to 0.  You get here if t.c.
!WB         exceeds SE2 for all particle size classes, or if t.c. is
!WB         equal to SE2 for all particle size classes
      IF(I1.EQ.NPM.OR.I2.EQ.NPM.OR.I3.EQ.NPM) GO TO 200
!WB         if the count equals the # of settleable particle size classes or
!WB         if count I2 or if count I3 equals the same, then go to 200
!WB         this says that if you have gone through the loop the same #
!WB         of times as the # of settleable particle size classes, then skip
!WB         the reapportionment of trans capacity
!WB********end of transport capacity excess loop/section********
```

```
!WB       ***********reapportion the transport capacity************
!WB       I believe that this loop is done until T.C < SE2
    DO 160 IC=NWASH1,NPART
!WB       do from the counter that represents the # of particle size classes
!WB       that are settleable up to the # of particles
          IF(TFMSE2(IC).GE.0..OR.DELTA(IC).LE.0.) GO TO 160
!WB       if trans cap excess > 0 or delta (= excess tractive force) < 0
          TF(IC)=TF(IC)+TFXCES*DELTA(IC)/SDEL
!WB       trans cap = same + accum trans cap excess * delta / sum of deltas
          IF(I3.EQ.1) GO TO 170
!WB       if the I3 counter equals 1, which occurs when t.c. is lt se2,
!WB       and there won't be sufficient energy for transport, and then
  160 CONTINUE
    GO TO 90
!WB       this sends you back to the top to redo the calculations on trans
!WB       capacity.  you are sent here if trans cap excess is greater than
!WB       or equal to 0 or if the excess tractive force = 0
  170 IF(TF(IC).GT.SE2(IC)) TF(IC)=SE2(IC)
!WB       if the trans cap > detach rate, then trans cap =
!WB       detachment rate
!WB       you get here if the I3 counter is = 1, which means that t.c. < det
!WB       rate
C
C.........SOLVE CONTINUITY EQUATION FOR SEDIMENT TRANSPORT.....
C
 200  CONTINUE
!WB       you are sent here if any of the counters equals to the # of
!WB       settleable particle classes
    DO 300 IC=NWASH1,NPART
!WB       do from # washload particles + 1 up to # particles size classes
!WB       I believe that the NWASH1 var is used to keep count of the same
!WB       thing as NPM
          IF(TF(IC).LT.SE1(IC)) GO TO 240
!WB       if trans cap < rainfall detach
          IF(TF(IC).LT.SE2(IC)) GO TO 220
!WB       if trans cap < max detach rate with rainfall & flow
!WB       so you jump over the next section if the trans cap is not equal
!WB       to maximum, and you're directed according to the amt of detachment
C
C..........MAXIMUM RAINFALL AND FLOW DETACHMENT...............
C..................NO DEPOSITION............................
C
!WB       this is the section for t.c.>SE2 and so all detachment can be
!WB       transported
          SST(M,IC)=DS2(IC)-SE2(IC)+S22(IC)
!WB       SST = (detachment rate w/rainfall & flow detach + sed inflow prev
!WB       time step) -
!WB       [(sed cont eqn prev time step +
!WB    detachment w/ rainfall & flow detach)*(1/1+
!WB        (flow/storage)) * flow/storage] *
!WB       (flow/storage) + [sed cont eqn prev time step +
!WB    detachment w/ rainfall & flow detach)*(1/(1+(flow/storage)))]

C *** NRZ
C *** CHANNEL ADDITION
          SE(IC)=SE2(IC)
!WB       sediment movement from a cell is equal to max detach rate
!WB       with rainfall & flow
C *** NRZ END
          SEL(M)=SEL(M)-F(KK,IC)*DRFT(IC)
!WB       sed accum = sed accum (per storm) - fraction of particles in
!WB       class i * sum of rainfall & detachment

*DETERMING THE NEWLY GENERATED SEDIMENT
          SEDNEW(M,IC)=F(KK,IC)*DRFT(IC)
!WB       sednew = fraction of particles in class i * sum of rainfall &
!WB       detach
          STNEW(IC)=S22(IC)/2.
!WB       new soil storage
```

```
!WB        this says that the new soil storage is equal to:
!WB         [sed cont eqn + erosion w/rainfall & flow detach * (1/1+
!WB         (flow/storage))] / 2
           GO TO 290
!WB        this sends you down to the section on washload particle calculation
!WB        and then out the bottom of this subroutine
C
C..........MAXIMUM RAINFALL, PARTIAL FLOW DETACHMENT..........
C....................NO DEPOSITION..........................
C
!WB        This is the section for when t.c.<detach cap, but not < rain detach

  220 ZI2=TF(IC)*(1.+X4)-SST(M,IC)
!WB         = trans cap * (1+storage/flow by volume) - sum of values
!WB        in cont eqn
           SEL(M)=SEL(M)+SI(M,IC)-ZI2
!WB         = sed accum + sed inflow - (rate of sed inflow + erosion at
!WB        end of time increment)
           SST(M,IC)=ZI2+TF(IC)*(X4-1.)
!WB         cont eqn = (sed inflow + erosion) + t.c.(storage/flow -1)
C *** NRZ
C *** CHANNEL ADDITION
           SE(IC)=TF(IC)
!WB        rate of sed movement from element = t.c.
C *** NRZ END

*DETERMING THE NEWLY GENERATED SEDIMENT
           SEDNEW(M,IC)=ZI2-SI(M,IC)
!WB        this newly generated sediment is equal to the transport capacity
!WB        times a scaling factor according to the flow minus the values
!WB        in the sed. cont eqn minus the value of sed inflow
           STNEW(IC)=TF(IC)*X4/2.
!WB        this appears to say that the new soil storage is equal to the
!WB        transport capacity times (storage / flow) / 2
           GO TO 290
!WB        this sends you down to the section on washload particle calculation
!WB        and then out the bottom of this subroutine
C
C..........DEPOSITION, NO FLOW DETACHMENT.....................
C
!WB        this is the section for when t.c.<SE1, and therefore there is
!WB        deposition
 240    RE=FV(IC)*AREA/Q(M)
!WB        partial removal eff. during dep = fall velocity * area / flow
!WB        this says that the partial removal variable is equal to the
!WB        fall velocity of the particle size class * catchment AREA
!WB        as a sum of element areas, ha / outflow from element i at start
!WB        of time increments (m3/s)
           IF(RE.GT.1.) RE=1.
!WB        if that removal efficiency is greater than 1 (more than
!WB        everything deposits), then set it equal to total removal

      DP=RE*(SE1(IC)-TF(IC))
!WB        dep rate = remov eff (rainfall detachment - t.c.)
           DEPPREV(M)=DP
!WB        IF THERE IS DEPOSITION IN A CHANNEL CELL, THEN THIS VARIABLE IS
!WB        USED TO ADJUST THE ERODED DEPTH INCREMENT.  SEE DEPTHINC ABOVE
C *** NRZ
C *** CHANNEL ADDITION
           SE(IC)=SE1(IC)-DP
!WB        sed movement from cell = rainfall detachment - deposition rate
           ZI2=SE(IC)*(1.+X4)-SST(M,IC)
!WB        sed. inflow & erosion = sed. movement * (1+storage/flow) - cont eqn
           IF(ZI2.LT.0.) ZI2=0.
           SEL(M)=SEL(M)+SI(M,IC)-ZI2
!WB        sed accum = accum + sed inflow - inflow + erosion
           SST(M,IC)=ZI2+SE(IC)*(X4-1.)
!WB        cont eqn = sed. inflow & erosion + sed. movement *
!WB         (storage/flow - 1)
```

```
*DETERMING THE NEWLY GENERATED SEDIMENT
            SEDNEW(M,IC)=F(KK,IC)*DETR(IC)
!WB          = fraction in size class * det. rate by rainfall
            STNEW(IC)=SE(IC)*X4/2.
!WB         new soil in storage = sed movement * (storage / 2*flow)
C *** NRZ END



C *** NRZ
C *** CHANNEL ADDITION
 290    IF(SE(IC).LT.0.) SE(IC)=0.
!WB         if sediment exiting less than 0, set it = 0
C *** NRZ END
            IF(SST(M,IC).LT.0.) SST(M,IC)=0.
!WB         if cont eqn < 0 , it = 0

 300  CONTINUE
     IF(NWASH.EQ.0) GO TO 410
!WB          # of particles in washload equals 0
C
C....WASH LOAD CALCULATIONS..................................
C
  310 CONTINUE
     DO 400 IC=1,NWASH
            DS=SI(M,IC)+F(KK,IC)*DRFT(IC)
!WB         max rate of inflow & erosion in an element = sed. inflow + size
!WB         fraction * (sum of flow & rainfall detach)

            S2=(SST(M,IC)+DS)*X2
!WB          = (cont eqn + max inflow & erosion) * ( 1/(1+flow/storage))
C *** NRZ
C *** CHANNEL ADDITION
            SE(IC)=S2*X1
!WB         sed movement = S2 * flow / storage
            SST(M,IC)=DS-SE(IC)+S2
!WB         cont eqn = max inflow & erosion - sed leaving + S2
            IF(SST(M,IC).LT.0.)SST(M,IC)=0.
!WB         if cont eqn < 0, then set it = 0
            SEL(M)=SEL(M)-F(KK,IC)*(DETR(IC)+DETF(IC))
!WB         sed accum = sed accum - size fraction * (rainfall + flow detach)
*DETERMING THE NEWLY GENERATED SEDIMENT
            SEDNEW(M,IC)=F(KK,IC)*DRFT(IC)
!WB         sednew = size fraction * total detach
            STNEW(IC)=S2/2.
!WB         STORAGE new = S2/2



  400 CONTINUE
  410 CONTINUE
 1000 FORMAT ('RILL WIDTH EXCEEDS RILL SPACING AT: ',/,
    1I4,' RILL WIDTH ',F5.3,' RILLSPACING ',F5.3
    2,/,'  PLEASE CHANGE THE RILL SPACING.')
 1002 FORMAT ('THE MANNINGS N FOR CHANNEL SOILS EXCEEDS'
            1,/,' THE VALUE FOR SOIL + VEGETATION.  PLEASE CHANGE THIS.')
 1004 FORMAT ('FLOW-DEPTH CALCULATED MORE THAN 10,000 TIMES AND'
            1,/,' DOES NOT APPEAR TO CONVERGE.  PLEASE CONTACT ANSWERS'
            2,/,' ASSISTANCE FOR HELP.  THE ERROR OCCURRED AT:'
            3,/,' CELL #: ',I5,' QEFF =',F12.8,' RILLWID =',F6.3,' SL(M)=',
            4F5.3,/,' DWSOIL =',F5.3,' FLDEPOLD =',F6.3)
 1006 FORMAT ('THE FLOWDEPTH IS NEGATIVE.',' M =',I3,' FOFD =',F11.6
            1,/,' FPOFD =',F11.6,' FDPOFD =',F11.6,' FLOWDEP =',F11.6
    2,/,' FLOWDEPOLD =',F11.6,' RILLWID =',F11.6,'QEFF=',F11.6
    3,/,' SL =',F5.3,' DWSOIL =',F6.3,' DIFF = ',F11.6
            4,/,' IF YOU RECEIVE THIS MESSAGE, PLEASE CONTACT ANSWERS'
            5,/,' SUPPORT AND PROVIDE THE INFORMATION ON THIS SCREEN.')
 1008       FORMAT ('AN ERROR HAS OCCURRED AND THE PROGRAM HAS STOPPED'
            1,/,' ACTUAL RILL DETACHMENT EXCEEDS CAPACITY'
            2,/,' ACTUAL DETACHMENT =',F11.7,' AT CELL: ',I3,' FOR PARTICLE'
```

```
            3,/,' CLASS :',I3,' WHILE CAPACITY EQUALS: ',F11.7)


      RETURN
      END

C NRZ 9/11/94
C MODIFIED CALL FOR MULTIPLE OUTLETS
      SUBROUTINE RELEM (IEL,ITEMP,N,ISR,ICR,NMAX,JMAX,NPAR,IELC,
     1ITEMPC,NPAR2)
C NRZ 9/11/94

      IMPLICIT DOUBLE PRECISION A-H,O-Z

C NRZ 9/5/94
C ADDED VARIABLES FOR CHANNEL NETWORKS

      COMMON /OUTLET/ NCHAN,NIOUT(9),NJOUT(9),MOUT(9),CHNUM(2000),
     &              CHOUT(9),NCELLS(9),CHNUMBER(2000)
      INTEGER CHNUM,CHOUT,CHNUMBER

C NRZ 9/5/94

C *** NRZ 3/26/95
C *** ADD COMMON BLOCK FOR IROT TO MAKE CHECKS

      COMMON /ROT/ IROT1,IROT(20,57)
      INTEGER IROT1,IROT

C *** NRZ 3/26/95

C
C ******  SUBROUTINE TO SET UP NEXT ROW OF WATERSHED ELEMENTAL DATA.
C **** INTO THE PROPER POSITION OF THE "3-ROW PER PASS" ARRAY.
C
      DIMENSION IEL(3,JMAX,NPAR2), ITEMP(NPAR2) !(3,103,20)
      DIMENSION IELC(3,JMAX,2), ITEMPC(2)
      CHARACTER*2 IELC, ITEMPC
C
C **** "RIPPLE" ROW 2 INTO ROW 1 AND ROW 3 INTO ROW 2, THEN ZERO
C **** THE THIRD ROW.
C
      DO 20 J=1,JMAX
      NZZ=NPAR-2
!WB         NPAR = 22
      DO 10 I=1,NZZ
      IEL(1,J,I)=IEL(2,J,I)
   10 IEL(2,J,I)=IEL(3,J,I)
   20 IEL(3,J,3)=0
      DO 25 J=1,JMAX
      DO 23 I=1,2
      IELC(1,J,I)=IELC(2,J,I)
   23 IELC(2,J,I)=IELC(3,J,I)
   25 CONTINUE
C
C **** SET UP POSSIBLE LAST ROW TEST FLAG.
C
      IEL(3,1,2)=JMAX
      IF (ITEMP(3).EQ.999) RETURN
!WB         ITEMP(3) should equal 9, but is set equal to 999 near the
!WB         end of the data subroutine
C
C **** NOW TRANSFER CURRENT WATERSHED ELEMENTAL DATA INTO THE THIRD
C **** ROW OF THE "3-ROW PER PASS" ARRAY.
C
C ****** IEL(I,J,3) CONTAINS THE POSITION NUMBER FOR THAT ELEMENT IN
C ****** THE SINGLE DIMENSION ARRAYS USED FOR SIMULATION ANALYSIS.
C ****** IEL(I,1,2) CONTAINS THE COLUMN NUMBER OF THE LAST WATERSHED
C ****** ELEMENT IN THE ROW.
```

```
C
  30 J=ITEMP(2)
C NRZ 9/5/94
C MODIFY COMPUTATION OF K TO ACCOUNT FOR 5-DIGIT ITEMP(6)

C     K=MOD(ITEMP(6),100)
      K=MOD(MOD(MOD(ITEMP(6),1000000),10000),100)
!WB          K = SOIL TYPE OF OVERLAND FLOW CELL

C NRZ 9/5/94

      IF (K.LE.0.OR.K.GT.ISR) GO TO 80
C RWC  3/2/95
C THE LAST VARIABLE IN THE STATEMENT WAS CHANGED FROM THE TOTAL NUMBER OF CROPS
C IN THE SIMULATION (ICR) TO THE TOTAL NUMBER OF ROTATIONS (IROT1) DUE TO
C *** NRZ 3/26/95
C *** THE FACT THAT ITEMP(7) IS NOW EQUAL TO ROTATION # - NOT CROP NUMBER
C
C      IF (ITEMP(7).LE.0.OR.ITEMP(7).GT.ICR) GO TO 90
      IF (ITEMP(7).LE.0.OR.ITEMP(7).GT.IROT1) GO TO 90

C *** ALSO MAKE ORIGINAL INTENDED CHECK FOR UNDEFINED CROP NUMBER

      DO 35 NRZ=2,40,2
       IF (IROT(ITEMP(7),NRZ).GT.ICR) THEN
        ICRERR=IROT(ITEMP(7),NRZ)
        GOTO 91
       ENDIF
  35 CONTINUE

C *** NRZ 3/26/95

      IF (J.GT.JMAX) GO TO 50
C
C **** TRANSFER PARAMETER DATA FROM A SINGLE ELEMENT.
C
      NZZ=NPAR-2
      DO 40 I=1,NZZ
  40 IEL(3,J,I)=ITEMP(I)
      DO 45 I=1,2
  45 IELC(3,J,I)=ITEMPC(I)
C
C **** REMEMBER AS POSSIBLE LAST ELEMENT IN CURRENT ROW.
C
      IEL(3,1,2)=J
C
C **** REMEMBER ROW NUMBER OF THIS ELEMENT.
C
      IC=ITEMP(1)
C
C **** SAVE ELEMENT'S SEQUENCE NUMBER.
C
      N=N+1
      IF (N.GT.NMAX) GO TO 60
      IEL(3,J,3)=N

C **** NRZ 9/11/94
C **** CHECK FOR ANY POSSIBLE OUTLET CELLS AND ASSIGN OUTLET NUMBER
      DO 47 NCH=1,NCHAN
            IF (ITEMP(1).EQ.NIOUT(NCH).AND.J.EQ.NJOUT(NCH)) MOUT(NCH)=N
  47 CONTINUE
C **** NRZ 9/11/94

            IF (ITEMP(3).NE.0) RETURN
C
C **** NOW READ PARAMETERS FOR NEXT ELEMENT.
C
      READ (1,100) (ITEMP(K),K=1,7),(ITEMPC(L),L=1,2),(ITEMP(K),K=8,16)
      READ(1,101) (ITEMP(K),K=17,20)
!WB ??     if((itemp(1).eq.32).and.(itemp(2).eq.35)) write(6,*) 'n',n
```

```
!WB ??     if((itemp(1).eq.33).and.(itemp(2).eq.34)) write(6,*) 'n',n
!WB ??     if((itemp(1).eq.39).and.(itemp(2).eq.55)) write(6,*) 'n',n
!WB ??     if((itemp(1).eq.41).and.(itemp(2).eq.55)) write(6,*) 'n',n
      IF (ITEMP(1).LT.IC.OR.ITEMP(1).GT.IC+1.OR.(ITEMP(2).LE.J.AND.ITEMP
     1(1).EQ.IC)) GO TO 70
      IF (ITEMP(1).EQ.IC) GO TO 30
      RETURN
   50 WRITE (2,110) ITEMP(1),J
      STOP
C
C **** ERROR MESSAGES.
C
   60 WRITE (2,120) ITEMP(1),J
      STOP
   70 WRITE (2,130) ITEMP(1),ITEMP(2)
      STOP
   80 WRITE (2,140) K,ITEMP(1),J
      STOP
   90 WRITE (2,150) ITEMP(7),ITEMP(1),J
      WRITE (2,*) 'IROT1 = ',IROT1
      STOP

C *** NRZ 3/26/95
C *** ADDED MESSAGE FOR UNDEFINED CROP NUMBER

   91 WRITE (2,151) ICRERR,ITEMP(1),J
      STOP


C
C NRZ 9/5/94
C CHANGED FORMAT STATEMENT TO INCLUDE AN EXTRA 2 DIGITS FOR THE CHANNEL
C NETWORK NUMBER

C 100 FORMAT (2I3,I2,I3,3I4,3X,A2,1X,A2,2X,I4,I3,2I4,I6,I2,I5,I5,I5)
  100 FORMAT (2I3,I2,I3,I4,1X,I7,I4,3X,A2,1X,A2,2X,I4,I3,2I4,I6,I2,I5,I5
     &,I5)

C NRZ 9/5/94
C
  101 FORMAT(3I5,I6)
  110 FORMAT (23H COLUMN NO. FOR ELEMENT,I4,1H,,I4,24H EXCEEDS IEL() DIM
     1ENSION)
  120 FORMAT (' NO. OF ELEMENTS EXCEEDS DIMENSION AT ELEMENT',I4,1H,,I4
     1)
  130 FORMAT (' ELEMENT DATA OUT OF SEQUENCE AT ELEMENT',I4,1H,,I4)
  140 FORMAT (1X,'SOIL TYPE',I4,22H SPECIFIED FOR ELEMENT,I4,1H,,I4,
     114HIS NOT DEFINED)

C *** NRZ 3/26/95
C *** CHANGED ERROR STATEMENT TO REFLECT CROP #/ROTATION # CHANGE
C  150 FORMAT (1X,9HCROP TYPE,I4,22H SPECIFIED FOR ELEMENT,I4,1H,,I4,15H
C     1IS NOT DEFINED)
  150 FORMAT (1X,9HROTATION ,I4,22H SPECIFIED FOR ELEMENT,I4,1H,,I4,
     114HIS NOT DEFINED)

C *** AND ADDED STATEMENT FOR UNDEFINED CROP AGAIN
  151 FORMAT (1X,'CROP TYPE',I4,22H SPECIFIED FOR ELEMENT,I4,1H,,I4,
     &14HIS NOT DEFINED)
C *** 3/26/95


C

      END
* SUBROUTINE TO DETERMINE SEDIMENT BOUND PHOSPHORUS

      SUBROUTINE PBOUND(NPART,M)
*
      IMPLICIT DOUBLE PRECISION A-H,O-Z
```

```
* THIS SUBROUTINE DETERMINE SEDIMENT BOUND PHOSPHORUS USING
* A CONSERVATION OF MASS APPROACH

C *** NRZ 9/15/94
C *** CHANGE VARIABLES TO REFLECT NMAX+ISTRUC+1+NCHAN

      COMMON /PHOS1/ P0SOIL(2000),SSA(30,8),SSAT(30),EDI(2000),
     & P0(2000,8),ERP(8),STOLD(2000,8),SEDNEW(2000,8),PPT(2000,8),
     & PI(2030,8),PSEL(2000),STNEW(8),P2(8),PCELL(2000,8)
     & ,DRFT(8)
      COMMON /PHOS2/PE(8)

      COMMON /CFLOW/ Q(2000),RFL(2000),FLINS(2000),SS(2000),PIV(2000),B(
     12000),NR(2000),NC(2000),DR(2000),S(2000),SL(2000),SEL(2000),SI(202
     20,8),QI(2020),DIN(2000),SST(2000,8)

C *** NRZ 9/15/94

C **** ADDED VARIABLES FOR CHANNEL NETWORKS

      COMMON /OUTLET/ NCHAN,NIOUT(9),NJOUT(9),MOUT(9),CHNUM(2000),
     &                CHOUT(9),NCELLS(9),CHNUMBER(2000)
      INTEGER CHNUM,CHOUT,CHNUMBER

C **** NRZ 9/14/94


* OUTFLOW LARGER THAN ZERO, THERE IS POTENTIAL FOR SEDIMENT
* DETACHMENT

      IF (Q(M).LE.0.) GOTO 30
* DETERMINING THE NEWLY GENERATED SEDIMENT BOUND PHOSPHORUS

      X1=Q(M)/S(M)

      DO 10 IC=1,NPART
*       IF (SI(M,IC).LE.0..AND.STOLD(M,IC)
*      & .LE.0..AND.SEDNEW(M,IC).LE.0.) THEN
*         P2(IC)=0.
*         GOTO 10
*       ENDIF
       IF (SI(M,IC).EQ.0.) PI(M,IC)=0.

      PCELL(M,IC)=P0(M,IC)*SEDNEW(M,IC)
      P2(IC)=(PPT(M,IC)+PI(M,IC)+PCELL(M,IC))/
     & (X1+1.)
C *** NRZ 11/21/94
C *** CHANNEL CORRECTION
      PE(IC)=P2(IC)*X1
C *** NRZ END
*       PSEL(M)=PSEL(M)-PCELL(M,IC)+P2(IC)
      PPT(M,IC)=PI(M,IC)+PCELL(M,IC)-P2(IC)*X1
     & +P2(IC)
       PSEL(M)=SEDNEW(M,IC)+PSEL(M)
 10   CONTINUE
      GO TO 40

* NO OUTFLOW

30    DO 20 IC=1,NPART
*         IF(SI(M,IC).LE.0..AND.STOLD(M,IC).LE.0.) THEN
*           P2(IC)=0.
*           GOTO 20
*         ENDIF

       IF (SI(M,IC).EQ.0.) PI(M,IC)=0.

       P2(IC)=(PPT(M,IC)+PI(M,IC))/2.
C *** NRZ 11/21/94
C *** CHANNEL CORRECTION
```

```
      PE(IC)=0.0
C *** NRZ END
*       PSEL(M)=PSEL(M)+P2(IC)
       PPT(M,IC)=PI(M,IC)
 20   CONTINUE
      GOTO 40


40    CONTINUE
      DO 50 IC=1,NPART
      PI(M,IC)=0.
 50   CONTINUE
      RETURN
      END


*     THIS SUBROUTINE IS USED TO DETERMINE SOLUBLE PHOSPHORUS

      SUBROUTINE SOLUBP(DX2,KK,M,I,K,DT,T12,L,T11,SSTOR,FIL,SE,N
     & ,CUMIN1,CU,NPART)

*     THIS SUBROUTINE USES SIMPLE AVERAGES

      IMPLICIT DOUBLE PRECISION A-H,O-Z

*      DOUBLE PRECISION R(8,20)

C *** NRZ 9/15/94
C *** DIMENSION VARIABLES TO REFLECT NMAX+ISTRUC+1+NCHAN

      COMMON/WATNH4/VOLSZ(2000),SZNH4(2000),AINH4(2020),STONH4(2000)
     & ,OUTNH4(2000),EDINH4(2000),VOLSZ1(2000),VOLSOI(2000)

C
C **** MAXIMUM NUMBER OF SOIL TYPES IS 30.
C
      COMMON /CSOIL/ A(30),FC(30),GWC(30)
      COMMON /GRAMPT/ CL(30),SA(30),ST(30),OM(30),AC(30)
     & ,AO(30),BC(30),BO(30),PHI(30),VCF(30),WCF(30),CFC(30),
     &  CEC(30),EAC(30),PHIC(30),XF(30),PSIF(30),CBF(30),
     &  THETAR(30),KS(30),CF(30),Z(30),LF(30),CS(30),SCF(30),
     &  CRC(30),KE(30,30),ZC(30),BD(30)
      DOUBLE PRECISION KS,LF,KE

      COMMON /PHOS1/ P0SOIL(2000),SSA(30,8),SSAT(30),EDI(2000),
     & P0(2000,8),ERP(8),STOLD(2000,8),SEDNEW(2000,8),PPT(2000,8),
     & PI(2030,8),PSEL(2000),STNEW(8),P2(8),PCELL(2000,8)
     & ,DRFT(8)
      COMMON /PHOS2/PE(8)

      COMMON /CFLOW/ Q(2000),RFL(2000),FLINS(2000),SS(2000),PIV(2000),B(
     12000),NR(2000),NC(2000),DR(2000),S(2000),SL(2000),SEL(2000),SI(202
     20,8),QI(2020),DIN(2000),SST(2000,8)

      COMMON /SOLUB/ SP2(2000),PEXT(2000),PK(30)
     & ,RBETA(30),SPI(2030),CGEN1(2000)
     & ,T13(2000),SPSP(2000)

C *** NRZ 9/15/94

      COMMON /TRAP/PMINP(2000),SOILP(2000),MINP(2000),PLAB(2000),
     &  UPPHOS(2000),TDMP2(2000),SORGP(2000),PSOL(2000),EDILAB(2000)

      COMMON /PARTITION/PKDA(30),PKDP(30),PSP(30)

      COMMON/OUT/SUMSED(2000),SUMNO3(2000),SUMNHW(2000),SUMNHS(2000)
     & ,SUMTKN(2000),SUMPO4(2000),NO3SEL(2000),NHWSEL(2000),NHSSEL(2000)
     & ,TKNSEL(2000),PO4SEL(2000)
      DOUBLE PRECISION NO3SEL,NHWSEL,NHSSEL
      DOUBLE PRECISION MINP
```

```
      X11=(Q(M)+FIL)/S(M)
      X21=Q(M)/S(M)

      IF(M.GT.N) GOTO 5

      X12=(Q(M)+FIL+S(M))/((VOLSZ1(M)+(10-VOLSZ1(M))*2.6*PKDP(KK))
     & *CU*3600/DT)

      X1=(Q(M)+FIL)/(S(M)+VOLSZ1(M)*CU*3600/DT)
      X2=Q(M)/(S(M)+VOLSZ1(M)*CU*3600/DT)
      X3=(Q(M)+FIL)/((10-VOLSZ1(M))*2.6*CU*3600/DT)

      SSTOR1=S(M)
      IF(SSTOR1.LT.0) SSTOR1=0.

      IF((Q(M).EQ.0.0).AND.(FIL.EQ.0.0)
     & .AND.(SSTOR1.EQ.0.0)) GOTO 20

*EDINH4(M0 REPRESENT THE CONCENTRATION OF DISSOLVED
*AMMONIUM IN EDI



 5    IF (M.GT.N) THEN
            SP=(SPI(M)+SPSP(M))/(X11+1)
            SP2(M)=SP*X21
            SPSP(M)=SPI(M)+SP*(1-X11)
            IF(SPSP(M).LE.0.) SPSP(M)=0.
            GOTO 20
      ENDIF

       IF((Q(M).EQ.0).AND.(FIL.EQ.0).OR.(CUMIN1.EQ.0.)) THEN
       SP=(SPSP(M)+SPI(M))/2.
       SP2(M)=0.0
       SPSP(M)=SPI(M)
       GOTO 20
       ENDIF


      EXTFAC=DEXP(-X12)*(0.1/(1+0.1*PKDP(KK)))

       DO 10 IC=1,NPART
       OUPO4=OUPO4+PCELL(M,IC)*DT
 10    CONTINUE

      SP=(SPI(M)+SPSP(M)+EDILAB(M)*EXTFAC*X3/DT)/(1.+X1)
      IF(SP.LT.EXP(-50.)) THEN
       SP2(M)=0.
       GOTO 20
      ENDIF
      SP2(M)=SP*X2
      SPSP(M)=SPI(M)+EDILAB(M)*EXTFAC*X3/DT+SP*(1.-X1)
            IF(SPSP(M).LE.0.) SPSP(M)=0.
      IF (PSOL(M).LT.0.) PSOL(M)=0.
      EDILAB(M)=EDILAB(M)*(1-EXTFAC*X3-OUPO4)
           GOTO 20



 20   CONTINUE
      PO4SEL(M)=PO4SEL(M)+SP2(M)
      SPI(M)=0.0
      OUPO4=0.
      RETURN
      END


* SUBROUTINE TO DETERMINE SEDIMENT BOUND AMMONIUM
```

```
      SUBROUTINE AMMON(NPART,M)
*
      IMPLICIT DOUBLE PRECISION A-H,O-Z
* THIS SUBROUTINE DETERMINE SEDIMENT BOUND NITROGEN USING
* A CONSERVATION OF MASS APPROACH

C *** NRZ 9/15/94
C *** DIMENSION VARIABLES TO REFLECT NMAX+ISTRUC+1+NCHAN

      COMMON /PHOS1/ P0SOIL(2000),SSA(30,8),SSAT(30),EDI(2000),
     & P0(2000,8),ERP(8),STOLD(2000,8),SEDNEW(2000,8),PPT(2000,8),
     & PI(2030,8),PSEL(2000),STNEW(8),P2(8),PCELL(2000,8)
     & ,DRFT(8)
      COMMON /PHOS2/PE(8)

      COMMON/NITRO1/ A0SOIL(2000),ANPT(2000,8),ANI(2020,8),
     & ANSEL(2000),AN2(8),ANCELL(2000,8),ANE(8),AN0(2000,8)
     & ,CNH4(2000)

      COMMON /CFLOW/ Q(2000),RFL(2000),FLINS(2000),SS(2000),PIV(2000),B(
     12000),NR(2000),NC(2000),DR(2000),S(2000),SL(2000),SEL(2000),SI(202
     20,8),QI(2020),DIN(2000),SST(2000,8)

C *** NRZ 9/15/94

C **** ADDED VARIABLES FOR CHANNEL NETWORKS

      COMMON /OUTLET/ NCHAN,NIOUT(9),NJOUT(9),MOUT(9),CHNUM(2000),
     &          CHOUT(9),NCELLS(9),CHNUMBER(2000)
      INTEGER CHNUM,CHOUT,CHNUMBER

C **** NRZ 9/14/94


      COMMON/OUT/SUMSED(2000),SUMNO3(2000),SUMNHW(2000),SUMNHS(2000)
     & ,SUMTKN(2000),SUMPO4(2000),NO3SEL(2000),NHWSEL(2000),NHSSEL(2000)
     & ,TKNSEL(2000),PO4SEL(2000)
       DOUBLE PRECISION NO3SEL,NHWSEL,NHSSEL


* OUTFLOW LARGER THAN ZERO, THERE IS POTENTIAL FOR SEDIMENT
* DETACHMENT

      IF (Q(M).LE.0.) GOTO 30
* DETERMINING THE NEWLY GENERATED SEDIMENT BOUND PHOSPHORUS

      X1=Q(M)/S(M)

      DO 10 IC=1,NPART

      IF (SI(M,IC).EQ.0.) ANI(M,IC)=0.

      ANCELL(M,IC)=AN0(M,IC)*SEDNEW(M,IC)
      AN2(IC)=(ANPT(M,IC)+ANI(M,IC)+ANCELL(M,IC))/
     & (X1+1.)
C *** NRZ
C *** CHANNEL CORRECTION
      ANE(IC)=AN2(IC)*X1
C *** NRZ END
      ANSEL(M)=ANSEL(M)-ANCELL(M,IC)+AN2(IC)
      ANPT(M,IC)=ANI(M,IC)+ANCELL(M,IC)-AN2(IC)*X1
     & +AN2(IC)

 10   CONTINUE
      GO TO 40

* NO OUTFLOW

30    DO 20 IC=1,NPART
```

```
      IF (SI(M,IC).EQ.0.) ANI(M,IC)=0.

      AN2(IC)=(ANPT(M,IC)+ANI(M,IC))/2.
C *** NRZ
C *** CHANNEL CORRECTION
      ANE(IC)=0.0
C *** NRZ END
      ANSEL(M)=ANSEL(M)+AN2(IC)
      ANPT(M,IC)=ANI(M,IC)
 20   CONTINUE
     GOTO 40


40    CONTINUE
     DO 50 IC=1,NPART
     ANI(M,IC)=0.
C *** NRZ
C *** CHANNEL ADDITION
     NHSSEL(M)=NHSSEL(M)+ANE(IC)
C *** NRZ END
 50   CONTINUE
     RETURN
     END


* SUBROUTINE TO DETERMINE SEDIMENT BOUND ORGANIC NITROGEN (AZOTE)

     SUBROUTINE ORGN(NPART,M)
*
     IMPLICIT DOUBLE PRECISION A-H,O-Z

* THIS SUBROUTINE DETERMINE SEDIMENT BOUND ORGANIC N USING
* A CONSERVATION OF MASS APPROACH

C *** NRZ 9/15/94
C *** DIMENSION VARIABLES TO REFLECT NMAX+ISTRUC+1+NCHAN

     COMMON /PHOS1/ P0SOIL(2000),SSA(30,8),SSAT(30),EDI(2000),
    & P0(2000,8),ERP(8),STOLD(2000,8),SEDNEW(2000,8),PPT(2000,8),
    & PI(2030,8),PSEL(2000),STNEW(8),P2(8),PCELL(2000,8)
    & ,DRFT(8)
     COMMON /PHOS2/PE(8)

     COMMON/NITRO2/ O0SOIL(2000),ONPT(2000,8),ONI(2020,8),
    & ONSEL(2000),ON2(8),ONCELL(2000,8),ONE(8),ON0(2000,8)

     COMMON /CFLOW/ Q(2000),RFL(2000),FLINS(2000),SS(2000),PIV(2000),B(
    12000),NR(2000),NC(2000),DR(2000),S(2000),SL(2000),SEL(2000),SI(202
    20,8),QI(2020),DIN(2000),SST(2000,8)

C *** NRZ 9/15/94

C **** ADDED VARIABLES FOR CHANNEL NETWORKS

     COMMON /OUTLET/ NCHAN,NIOUT(9),NJOUT(9),MOUT(9),CHNUM(2000),
    &                CHOUT(9),NCELLS(9),CHNUMBER(2000)
     INTEGER CHNUM,CHOUT,CHNUMBER

C **** NRZ 9/14/94


     COMMON/OUT/SUMSED(2000),SUMNO3(2000),SUMNHW(2000),SUMNHS(2000)
    & ,SUMTKN(2000),SUMPO4(2000),NO3SEL(2000),NHWSEL(2000),NHSSEL(2000)
    & ,TKNSEL(2000),PO4SEL(2000)
      DOUBLE PRECISION NO3SEL,NHWSEL,NHSSEL


* OUTFLOW LARGER THAN ZERO, THERE IS POTENTIAL FOR SEDIMENT
* DETACHMENT
```

```
      IF (Q(M).LE.0.) GOTO 30
* DETERMINING THE NEWLY GENERATED SEDIMENT BOUND PHOSPHORUS

      X1=Q(M)/S(M)

      DO 10 IC=1,NPART

      IF (SI(M,IC).EQ.0.) ONI(M,IC)=0.

      ONCELL(M,IC)=ON0(M,IC)*SEDNEW(M,IC)
      ON2(IC)=(ONPT(M,IC)+ONI(M,IC)+ONCELL(M,IC))/
     & (X1+1.)
C *** NRZ
C *** CHANNEL CORRECTION
      ONE(IC)=ON2(IC)*X1
C *** NRZ END
      ONSEL(M)=ONSEL(M)-ONCELL(M,IC)+ON2(IC)
      ONPT(M,IC)=ONI(M,IC)+ONCELL(M,IC)-ON2(IC)*X1
     & +ON2(IC)

 10   CONTINUE
      GO TO 40

* NO OUTFLOW

30     DO 20 IC=1,NPART

       IF (SI(M,IC).EQ.0.) ONI(M,IC)=0.

       ON2(IC)=(ONPT(M,IC)+ONI(M,IC))/2.
C *** NRZ
C *** CHANNEL CORRECTION
      ONE(IC)=0.0
C *** NRZ END
       ONSEL(M)=ONSEL(M)+ON2(IC)
       ONPT(M,IC)=ONI(M,IC)
 20   CONTINUE
      GOTO 40


40    CONTINUE
      DO 50 IC=1,NPART
      ONI(M,IC)=0.
C *** NRZ
C *** CHANNEL CORRECTION
      TKNSEL(M)=TKNSEL(M)+ONE(IC)
C *** NRZ END
 50   CONTINUE
      RETURN
      END



      SUBROUTINE WATNH(SSTOR,FIL,M,DT,N,CUMIN1,CU,KK,NPART)


      IMPLICIT DOUBLE PRECISION A-H,O-Z


* THIS SUBROUTINE DETERMINES DISSOLVED AMMONIUM CONCENTRATION
* IT USES AN EXTRACTION FACTOR
* DEVELOPPED BY KNISEL (1980, SEE CREAMS MANUAL).

C *** NRZ 9/15/94
C *** DIMENSION VARIABLES TO REFLECT NMAX+ISTRUC+1+NCHAN

      COMMON /CFLOW/ Q(2000),RFL(2000),FLINS(2000),SS(2000),PIV(2000),B(
     12000),NR(2000),NC(2000),DR(2000),S(2000),SL(2000),SEL(2000),SI(202
     20,8),QI(2020),DIN(2000),SST(2000,8)
```

```
      COMMON/WATNH4/VOLSZ(2000),SZNH4(2000),AINH4(2020),STONH4(2000)
     & ,OUTNH4(2000),EDINH4(2000),VOLSZ1(2000),VOLSOI(2000)

      COMMON/NO3/SZNO3(2000),AINO3(2020),STONO3(2000),OUTNO3(2000)
     & ,CNO3(2000),EDINO3(2000),CLENO3(2000)

C *** NRZ 9/15/94

      COMMON /PARTITION/PKDA(30),PKDP(30),PSP(30)

C *** NRZ 9/15/94
C *** DIMENSION VARIABLES TO REFLECT NMAX+ISTRUC+1+NCHAN

      COMMON/NITRO1/ A0SOIL(2000),ANPT(2000,8),ANI(2020,8),
     & ANSEL(2000),AN2(8),ANCELL(2000,8),ANE(8),AN0(2000,8)
     & ,CNH4(2000)

C *** NRZ 9/15/94

      COMMON/OUT/SUMSED(2000),SUMNO3(2000),SUMNHW(2000),SUMNHS(2000)
     & ,SUMTKN(2000),SUMPO4(2000),NO3SEL(2000),NHWSEL(2000),NHSSEL(2000)
     & ,TKNSEL(2000),PO4SEL(2000)
       DOUBLE PRECISION NO3SEL,NHWSEL,NHSSEL

       RBETA=0.598*DEXP(-0.179*PKDA(KK))

      X11=(Q(M)+FIL)/S(M)
      X21=Q(M)/S(M)

       IF((Q(M).EQ.0).AND.(FIL.EQ.0).OR.(CUMIN1.EQ.0.)) THEN
       SPNH4=(STONH4(M)+AINH4(M))/2.
       OUTNH4(M)=0.0
       STONH4(M)=AINH4(M)
       GOTO 20
       ENDIF

      IF(M.GT.N) GOTO 5

      IF((Q(M).EQ.0.0).AND.(FIL.EQ.0.0)
     & .AND.(SSTOR1.EQ.0.0)) GOTO 20

      X12=(Q(M)+FIL+S(M))/((VOLSZ1(M)+(10-VOLSZ1(M))*2.6*PKDA(KK))
     & *CU*3600/DT)
      X1=(Q(M)+FIL)/(S(M)+VOLSZ1(M)*CU*3600/DT)
      X2=Q(M)/(S(M)+VOLSZ1(M)*CU*3600/DT)
      X3=(Q(M)+FIL)/((10-VOLSZ1(M))*2.6*CU*3600/DT)

      SSTOR1=S(M)
      IF(SSTOR1.LT.0) SSTOR1=0.


*EDINH4(M0 REPRESENT THE CONCENTRATION OF DISSOLVED
*AMMONIUM IN EDI


 5    IF (M.GT.N) THEN
            SPNH4=(AINH4(M)+STONH4(M))/(X11+1)
            OUTNH4(M)=SPNH4*X21
            STONH4(M)=AINH4(M)+SPNH4*(1-X11)
            IF(STONH4(M).LE.0.) STONH4(M)=0.
            IF(OUTNH4(M).LE.0.) OUTNH4(M)=0.
            GOTO 20
      ENDIF
```

```
      EXTFAC=DEXP(-X12)*RBETA/(1+RBETA*PKDA(KK))
      DO 10 IC=1,NPART
      OUNH4=OUNH4+ANCELL(M,IC)*DT
 10   CONTINUE

      SPNH4=(STONH4(M)+AINH4(M)+EDINH4(M)*EXTFAC*X3/DT)/(1.+X1)
      IF(SPNH4.LT.EXP(-50.)) THEN
            OUTNH4(M)=0.
            GOTO 20
      ENDIF
      OUTNH4(M)=SPNH4*X2
      STONH4(M)=AINH4(M)+EDINH4(M)*EXTFAC*X3/DT+SPNH4*(1.-X1)
             IF(STONH4(M).LE.0.) STONH4(M)=0.
      IF (SZNH4(M).LT.0.) SZNH4(M)=0.
      EDINH4(M)=EDINH4(M)*(1-EXTFAC*X3-OUNH4)
      IF (EDINH4(M).LT.0.) EDINH4(M)=0.
      GOTO 20

 20   CONTINUE

      NHWSEL(M)=NHWSEL(M)+OUTNH4(M)
      OUNH4=0
      AINH4(M)=0.0
      RETURN
      END

      SUBROUTINE NO3Z(SSTOR,FIL,M,DT,N,CUMIN1,CU)


      IMPLICIT DOUBLE PRECISION A-H,O-Z


* THIS SUBROUTINE DETERMINES NITRATE CONCENTRATION
* IT USES AN EXTRACTION FACTOR
* DEVELOPPED BY KNISEL (1980, SEE CREAMS MANUAL).

C *** NRZ 9/15/94
C *** DIMENSION VARIABLES TO REFLECT NMAX+ISTRUC+1+NCHAN

      COMMON /CFLOW/ Q(2000),RFL(2000),FLINS(2000),SS(2000),PIV(2000),B(
     12000),NR(2000),NC(2000),DR(2000),S(2000),SL(2000),SEL(2000),SI(202
     20,8),QI(2020),DIN(2000),SST(2000,8)

      COMMON/WATNH4/VOLSZ(2000),SZNH4(2000),AINH4(2020),STONH4(2000)
     & ,OUTNH4(2000),EDINH4(2000),VOLSZ1(2000),VOLSOI(2000)

      COMMON/NO3/SZNO3(2000),AINO3(2020),STONO3(2000),OUTNO3(2000)
     & ,CNO3(2000),EDINO3(2000),CLENO3(2000)

C *** NRZ 9/15/94

      COMMON/OUT/SUMSED(2000),SUMNO3(2000),SUMNHW(2000),SUMNHS(2000)
     & ,SUMTKN(2000),SUMPO4(2000),NO3SEL(2000),NHWSEL(2000),NHSSEL(2000)
     & ,TKNSEL(2000),PO4SEL(2000)
      DOUBLE PRECISION NO3SEL,NHWSEL,NHSSEL


      X11=(Q(M)+FIL)/S(M)
      X21=Q(M)/S(M)

      IF(M.GT.N) GOTO 5

      IF(SSTOR1.LT.0) THEN
      SSTOR1=0.
      OUTNO3(M)=0.
      STONO3(M)=AINO3(M)
      GOTO 20
      ENDIF
```

```
      IF((Q(M).EQ.0.0).AND.(FIL.EQ.0.0)
     & .AND.(SSTOR1.EQ.0.0)) GOTO 20

       IF((Q(M).EQ.0).AND.(FIL.EQ.0).OR.(CUMIN1.EQ.0.)) THEN
       SPNO3=(STONO3(M)+AINO3(M))/2.
       OUTNO3(M)=0.0
       STONO3(M)=AINO3(M)
       GOTO 20
       ENDIF

      X1=(Q(M)+FIL)/(S(M)+VOLSZ1(M)*CU*3600/DT)
      X2=Q(M)/(S(M)+VOLSZ1(M)*CU*3600/DT)
      X12=(Q(M)+FIL+S(M))/(VOLSZ1(M)*CU*3600/DT)
      SSTOR1=S(M)
      X3=(Q(M)+FIL)/((10-VOLSZ1(M))*2.6*CU*3600/DT)




 5    IF (M.GT.N) THEN
             SPNO3=(AINO3(M)+STONO3(M))/(X11+1)
             OUTNO3(M)=SPNO3*X21
             STONO3(M)=AINO3(M)+SPNO3*(1-X11)
             IF(STONO3(M).LE.0.) STONO3(M)=0.
             IF(OUTNO3(M).LE.0.) OUTNO3(M)=0.
             GOTO 20
      ENDIF



       EXTFAC=DEXP(-X12)*0.5
      SPNO3=(STONO3(M)+AINO3(M)+EDINO3(M)*X3*EXTFAC/DT)/(1.+X1)
      IF(SPNO3.LT.EXP(-50.)) THEN
       OUTNO3(M)=0.
       GOTO 20
      ENDIF
      OUTNO3(M)=SPNO3*X2
      STONO3(M)=AINO3(M)+EDINO3(M)*EXTFAC*X3/DT+SPNO3*(1.-X1)
             IF(STONO3(M).LE.0.) STONO3(M)=0.
      EDINO3(M)=EDINO3(M)*(1-EXTFAC*X3)
      IF(EDINO3(M).LT.0.)EDINO3(M)=0.
      GOTO 20

 20   CONTINUE
      NO3SEL(M)=NO3SEL(M)+OUTNO3(M)
      AINO3(M)=0.0
      RETURN
      END

       SUBROUTINE ETP11(TEMPC,RADI,ETPMM)
      IMPLICIT DOUBLE PRECISION A-H,O-Z
      INTEGER TEMPC,RADI
      DATA ALBED,GAM/0.23,0.68/

       TEMPK = TEMPC + 273
       TEMPR = 5304./TEMPK

* COMPUTING THE POTENTIAL ET ACCORDING TO RITCHIE'S EQUATION

       DELTA = (TEMPR/TEMPK)*DEXP(21.25-TEMPR)

       ETPM = 0.00128*(RADI*(1-ALBED)/58.3)*(DELTA/(DELTA+GAM))
       ETPMM = ETPM*1000.

      RETURN
      END
```

```
      SUBROUTINE EVAPO(LAI1,S1EP,ESU,TTIME,S2EP,ETPMM,TETP,PEP,ES
     & ,CUMINF)
      IMPLICIT DOUBLE PRECISION A-H, O-Z

* COMPUTING SOIL EVAPORATION IN TWO STAGES
* FIRST STAGE ONLY ENERGY IS LIMITING, AND SOIL EVAPORATION
* IS EQUAL TO POTENTIAL SOIL EVAPORATION
*
*  POTENTIAL SOIL EVAPORATION
      DOUBLE PRECISION LAI1
      PSEP = ETPMM * DEXP(-0.4*LAI1)

* IF CUMULATIVE SOIL EVAPORATION IS LESS THAN UPPER LIMIT OF
* STAGE 1 (ESU), SOIL EP = POTENTIAL SOIL EP, ELSE STAGE 2 SOIL EP
* STARTS.  DAY2 REPRESENTS THE NUMBER OF DAY SINCE STAGE 2 STARTED


      IF (S1EP.LT.ESU) THEN
            S1EP=DMAX1(0.0D0,S1EP-CUMINF)
            S1EP=S1EP+PSEP

            IF(S1EP.GT.ESU) THEN
             ES=PSEP-0.4*(S1EP-ESU)
             S2EP=0.6*(S1EP-ESU)
             TTIME=(S2EP/3.5)**2.
             GOTO 10
            ELSE
             ES=PSEP
             GOTO 10
            ENDIF

      ELSE

       SB=CUMINF-S2EP
            IF (SB.LT.0.) THEN
             TTIME=TTIME+1.
             ES=3.5*DSQRT(TTIME)-S2EP

             IF (CUMINF.GT.0.) THEN
              ESX=0.8*CUMINF
               IF(ESX.LE.ES) ESX=CUMINF+ES
               IF(ESX.GT.PSEP) ESX=PSEP
              ES=ESX
             ELSEIF (ES.GT.PSEP) THEN
              ES=PSEP
             ENDIF

             S2EP=S2EP+ES-CUMINF
             TTIME=(S2EP/3.5)**2.

       ELSE
*        CUMINF=SB
            S1EP=ESU-SB
            TTIME=0.0
            S1EP=DMAX1(S1EP,0.0D0)

       S1EP=S1EP+PSEP

            IF(S1EP.GT.ESU) THEN
             ES=PSEP-0.4*(S1EP-ESU)
             S2EP=0.6*(S1EP-ESU)
             TTIME=(S2EP/3.5)**2.
            ELSE
             ES=PSEP
            ENDIF
       ENDIF
      ENDIF

 10   ES=DMAX1(ES,0.0D0)
* COMPUTING PLANT TRANSPIRATION
```

```
      IF (LAI1.LT.3.) THEN
              PEP = ETPMM*LAI1/3.
      ELSE
              PEP = ETPMM
      ENDIF

      TETP=ES+PEP
      IF(ETPMM.LT.TETP) THEN
       TETP=ETPMM
       ES=TETP-PEP
      ENDIF

      RETURN
      END

              SUBROUTINE PERCO(XMOI,KS,FCVOL,CU,PERCOL,FCAP1,XMOI2
     &  ,TMAX,RAITES,AZRAT)
      IMPLICIT DOUBLE PRECISION A-H,O-Z
      DOUBLE PRECISION KS,TMAX,TDAY,FCVOL
      INTEGER RAITES

              RKFC=KS*AZRAT*XMOI2**(-2.655/DLOG10(FCAP1))
              XMOI1=XMOI-FCVOL
              TI=XMOI1/RKFC
*       computing drainage for 24 hour
              TDAY=24.
              IF(RAITES.EQ.1) TDAY=DMAX1(0.0D0,TDAY-TMAX/60.)
              ZFAY=TDAY/TI
              IF(ZFAY.GT.75.) ZFAY=75.
              PERCOL=XMOI1*(1.-DEXP(-ZFAY))

              RETURN
              END


      SUBROUTINE RAINFA(NRG,FILTS,PP,N,CU1,CU2,CU,DT,TMIN,TMAX
     1 ,KPR,NDT,ISTRUC,NMAX,ICR,NN,NCHAN)
      IMPLICIT DOUBLE PRECISION A-H,O-Z

      COMMON /CSOIL/ A(30),FC(30),GWC(30)
      COMMON /CRGAGE/ RC(8,35),TC(8,35),R(8,21),FRA(8),JTR(8),RATE(8),SR
     1(8),NF(8)

C *** NRZ 9/15/94
C *** DIMENSION VARIABLES TO REFLECT NMAX+ISTRUC+1+NCHAN

      COMMON /CFLOW/ Q(2000),RFL(2000),FLINS(2000),SS(2000),PIV(2000),B(
     12000),NR(2000),NC(2000),DR(2000),S(2000),SL(2000),SEL(2000),SI(202
     20,8),QI(2020),DIN(2000),SST(2000,8)

C *** NRZ 9/15/94

      COMMON /CROUGH/ ROUGH(20),HU(20),DIR(21),PIT(8,20),PER(20)
      COMMON /CSURF/ SUR(2000),RANE(2000),SOIL(2000)
      COMMON /CUMIN/ CUMIN1(2000),rbit0(2000),testi(2000),timpon(2000),
     & tpon(2000)
C
C **** MAXIMUM NUMBER OF SOIL TYPES IS 30.
C
      COMMON /GRAMPT/ CL(30),SA(30),ST(30),OM(30),AC(30)
     & ,AO(30),BC(30),BO(30),PHI(30),VCF(30),WCF(30),CFC(30),
     &  CEC(30),EAC(30),PHIC(30),XF(30),PSIF(30),CBF(30),
     &  THETAR(30),KS(30),CF(30),Z(30),LF(30),CS(30),SCF(30),
     &  CRC(30),KE(30,30),ZC(30),BD(30)
      DOUBLE PRECISION LF


      DIMENSION IRR(8), IG(8), PP(14)
      DIMENSION FILTS(2000), CWID(2000),CWIDTMP(2000)
```

```
      COMMON / CROPAD/  DIRM2(20)
      COMMON /ZSEDI/ NPART,NWASH,NWASH1
      COMMON /ASMF/ ASMBF(30) ,FCAP1(30),TP1(30),RESWAT(30),DF1(30)
      COMMON /ASMP/ASMPER(2000)
      CHARACTER*2 IG
      CHARACTER*4 PP
      CHARACTER JBEG
      INTEGER SUR,SOIL,RANE
      DOUBLE PRECISION KS,KE

C *** NRZ 9/15/94
C *** DIMENSION VARIABLES TO REFLECT NMAX+ISTRUC+1+NCHAN

      COMMON /PHOS1/ P0SOIL(2000),SSA(30,8),SSAT(30),EDI(2000),
     & P0(2000,8),ERP(8),STOLD(2000,8),SEDNEW(2000,8),PPT(2000,8),
     & PI(2030,8),PSEL(2000),STNEW(8),P2(8),PCELL(2000,8)
     & ,DRFT(8)
      COMMON /PHOS2/PE(8)

      COMMON/NITRO1/ A0SOIL(2000),ANPT(2000,8),ANI(2020,8),
     & ANSEL(2000),AN2(8),ANCELL(2000,8),ANE(8),AN0(2000,8)
     & ,CNH4(2000)


      COMMON/NITRO2/ O0SOIL(2000),ONPT(2000,8),ONI(2020,8),
     & ONSEL(2000),ON2(8),ONCELL(2000,8),ONE(8),ON0(2000,8)

      COMMON/WATNH4/VOLSZ(2000),SZNH4(2000),AINH4(2020),STONH4(2000)
     & ,OUTNH4(2000),EDINH4(2000),VOLSZ1(2000),VOLSOI(2000)

      COMMON/NO3/SZNO3(2000),AINO3(2020),STONO3(2000),OUTNO3(2000)
     & ,CNO3(2000),EDINO3(2000),CLENO3(2000)

      COMMON /SOLUB/ SP2(2000),PEXT(2000),PK(30)
     & ,RBETA(30),SPI(2020),CGEN1(2000)
     & ,T13(2000),SPSP(2000)

C *** NRZ 9/15/94

      COMMON/OUT/SUMSED(2000),SUMNO3(2000),SUMNHW(2000),SUMNHS(2000)
     & ,SUMTKN(2000),SUMPO4(2000),NO3SEL(2000),NHWSEL(2000),NHSSEL(2000)
     & ,TKNSEL(2000),PO4SEL(2000)
       DOUBLE PRECISION NO3SEL,NHWSEL,NHSSEL

!WB        THIS IS READ IN THE MAIN ROUTINE.
!WB     READ(8,5560) TEMPC,SOITEM,RADI,RAITES
!WB          TEMPC = air temp, SOITEM = soil temp, RADI = daily radiation,
!WB                        RAITES = raintest flag

C
C **** INPUT SEPARATE RAINFALL HYETOGRAPHS FOR EACH RAINGAGE.
C
      TMAX=0.
!WB        MAX TIME VALUE GIVEN IN ANY HYETOGRAPH
      TMIN=1.E+10
!WB        MIN TIME VALUE GIVEN IN ANY HYETOGRAPH
      DTMIN=900.
!WB        Minimum time increment in any hyetograph
      TINT=DTMIN
!WB        Time interval in hyetograph
      DO 20 I=1,NRG
!WB        DO FROM 1 TO # OF RAIN GAGES
      FRA(I)=0.
!WB        Fraction of catchment area covered by rain gauge i
      READ (8,830) IG(I)
!WB        Alphanumeric number for rain gauge
      K=2
      KM1=1
   10 READ (8,740) JBEG,TC(I,K),RC(I,K)
!WB        READ JBEG?,TC=Time of jth histogram period for rain gauge i,
```

```
!WB         Rainfall intensity for gauge i, histogram period j (mm/hr)
    IF (K.GT.2) TINT=TC(I,K)-TC(I,KM1)
!WB         IF K.GT.2, THEN TINT=CURRENT TIME-TIME BEFORE THIS
    IF (TINT.LT.DTMIN) DTMIN=TINT
!WB         IF THE TIME INTERVAL LT THE MIN INTERVAL, SET THEM EQUAL
    K=K+1
!WB         INCREASE K BY 1
    KM1=K-1
!WB         INCREASE KM1 COUNTER TO BE ONE LESS THAN K
    IF (JBEG.EQ.' '.OR.JBEG.EQ.'0') GO TO 10
!WB         IF THE JBEG FLAG IS BLANK OR 0, READ THE NEXT RAINFALL LINE
    IF (JBEG.NE.'1') GO TO 570
!WB         IF THE JBEG FLAG IS ANYTHING OTHER THAN 1, GO TO 570 AND WRITE
!WB         THE RAINGAGE & J, WHICH DOESN'T APPEAR TO BE DEFINED HERE, BUT IS
!WB         SUPPOSED TO BE THE LINE #
    IF (K.GT.35) GO TO 540
!WB         IF THE COUNTER IS GREATER THAN 35, THEN WRITE 'RAINFALL DATA
!WB         EXCEEDS DIMENSION' AND STOP THE PROGRAM.
    IF (TC(I,2).LT.TMIN) TMIN=TC(I,2)
!WB         Time FOR rain gauge i,HISTOGRAM PERIOD 2 IS LT TMIN, SET TMIN
!WB         EQUAL TO THIS VALUE.
    IF (TC(I,KM1).GT.TMAX) TMAX=TC(I,KM1)
!WB         IF THE TIME FOR RAINGAGE I, HISTOGRAM PERIOD K-1, IS GT TMAX, THEN
!WB         SET TMAX EQUAL TO THIS VALUE.
  20 IRR(I)=K
!WB         LAST LINE IN THIS LOOP, Number of rainfall intensity readings for
!WB         rain gauge i IS EQUAL TO K.

C
C **** INSERT SAME START AND FINISH TIME FOR EACH RAINGAGE RECORD.
C
    DO 30 I=1,NRG
    K=IRR(I)
!WB         RECALL THE # OF RAINFALL INTENSITY READINGS (BREAKPOINT INTERVALS)
!WB         FOR RAIN GAGE I
    KM1=K-1
!WB         SET KM1=K-1
    TC(I,1)=TMIN
!WB         THE TIME INTERVAL FOR GAGE I, HISTOGRAM PERIOD 1=TMIN
    RC(I,1)=0.
!WB         THE RAINFALL INTENSITY FOR GAGE I, HISTOGRAM PERIOD 1 =0
    IF (TC(I,KM1).EQ.TMAX) IRR(I)=IRR(I)-1
!WB         IF THE TIME INTERVAL FOR GAGE I, HISTOGRAM PERIOD (K-1) EQUALS
!WB         TMAX, THE # OF INTERVALS FOR GAGE I = SAME - 1
    TC(I,K)=TMAX
!WB         TIME INTERVAL FOR GAGE I, HISTOGRAM PERIOD K = MAX TIME INTERVAL
  30 RC(I,K)=0.
!WB         RAINFALL INTENSITY FOR GAGE I, HISTOGRAM PERIOD K = 0

    IT=7
!WB         THIS IS A FLAG USED TO MANIPULATE AROUND THE PP ARRAY?
    DO 40 I=1,NRG
!WB         DO FROM 1 TO # OF RAIN GAGES
    L=IRR(I)
!WB         RECALL THE # OF HISTOGRAM INTERVALS FOR GAGE I
  40 CONTINUE
***    WRITE (2,670) IG(I),PP(IT+1),PP(IT+2),(TC(I,K),RC(I,K),K=2,L)
C **** RENUMBER RAINGAGES TO 1,2,..,NRG IN ORDER OF HYETOGRAPH INPUTS.
C
  50 IF (DT.GT.DTMIN*60.) WRITE (2,880)
!WB         WRITE 'ANALYSIS IS NOT CORRECT IF RAINFALL INTENSITY INTERVALS
!WB         ARE LESS THAN DT'
    KPR=(TMAX-TMIN)/DT/DBLE(NDT)*60.+1.
!WB         Number of time increment routings between print lines =
!WB         (MAX TIME - MIN TIME) / (DT = Simulation time increment in (s)) /
!WB         # OF LINES OF HYDROGRAPH PRINT * 60 + 1
    N2=NN-1
 430 DO 440 I=1,N2
!WB         DO FROM 1 TO # OF O.F. CELLS + CHANNEL CELLS
    S(I)=0.
```

```
!WB         Storage at start of time increment for element i (m3/s)
  440 FLINS(I)=0.
!WB         Storage, inflow and outflow for element i at start of time
!WB         increment (m3/s),
    X=N
    Y=1./X
    DO 460 I=1,N
!WB         DO FROM 1 TO # OF O.F. ELEMENTS
    K=2
    IS=SOIL(I)/256
!WB         SOIL TYPE FOR ELEMENT I
    IC=MOD(SUR(I),256)
!WB         CROP COVERAGE FOR THIS CELL
    J=MOD(RANE(I),256)
!WB         RAIN GAGE # FOR THIS CELL
    IF (TC(J,2).LT.(TMIN+1.1)) K=3
!WB         IF THE TIME INTERVAL FOR RAIN GAGE J FOR THIS CELL, HISTOGRAM
!WB         PERIOD 2 IS LESS THAN MIN TIME FOR ANY HYETOGRAPH + 1.1, THEN K=3
    FRA(J)=FRA(J)+Y
!WB         FRACTION OF WATERSHED IN GAGE J = SAME + INVERSE OF # OF O.F. CELLS
    SUPP=RC(J,K)*(1.-PER(IC))*CU
!WB         Available supply for infiltration during time increment = RAINFALL
!WB         INTENSITY, GAGE J, PERIOD K * (1-Fraction of element area covered
!WB         by foliage for surface type i FOR THIS CROP) * CONVERT MM/H TO M3/S
    X=FILT(PIV(I),FCAP1(IS),GWC(IS),DR(I),S(I),SUPP,CU2,ROUGH
   1(IC),HU(IC),NEXP,ASMPER(I),KE(IS,IC),PSIF(IS),PHIC(IS),T,CU,LF(IS)
   2,KS(IS),IC,is,I,CUMIN1(I),rbit0(i),testi(i),timpon(i),tpon(i),
   3 FILTS(I),DT,CU1,TP1(IS),A(IS))
!WB         FILTS = A FUNCTION IN SUBROUTINE DRAIN
            FILTS(I)=X
!WB         INFIL CAP FOR ELEMENT I (M3*S-1) = FUNCTION FILTS
    IF (X.GT.SUPP) X=SUPP
!WB         IF INFIL CAP GT. SUPPLY, THEN INFIL CAP = SUPPLY
  460 FLINS(I)=SUPP-X
!WB         Storage, inflow and outflow for element i at start of time
!WB   increment (m3/s) = SUPPLY - INFIL CAP.
C
C **** CONVERT SURFACE VALUES.
C
    DO 480 I=1,ICR
!WB         DO FROM 1 TO # OF CROPS IN ROTATION
    DIRM2(I)=0.10*HU(I)
!WB         DIRM2 FOR CROP I = 0.10 * MAX HEIGHT DIFFERENTIAL ON SOIL SURFACE
    DO 470 J=1,NRG
!WB         DO FROM 1 TO # OF RAIN GAGES
  470 PIT(J,I)=PIT(1,I)*CU1/DT
!WB         Interception storage for cover for surface type i (mm) FOR GAGE J,
!WB         CROP # I = SAME FOR GAGE 1, CROP # I * (MM TO M3) / SIM TIME INCR
    ADIR=HU(I)*ROUGH(I)*(DIRM2(I)/HU(I))**(1./ROUGH(I))
!WB         ADIR=MAX HGT DIFF * SURF. DEPTH-STORAGE PARAM * ((0.10*HU)/HU)
!WB         ^(1/SURF. DEPTH-STORAGE PARAM)
  480 DIR(I)=ADIR*2.*CU1/DT
!WB         Retention depth for cropping practice i (m3/s) = ADIR * 2 * MM TO
!WB         M3 / SIM TIME INCREMENT
C
C **** SET CHANNEL RETENTION TO ZERO.
C
    DIR(21)=0.

C *** NRZ 9/22/94
C *** CHANGE BOUNDS TO INCLUDE EXTRA CHANNEL OUTLETS
    J=NMAX+ISTRUC+1+NCHAN
C *** NRZ 9/22/94
!WB         THE NEXT 3 SECTIONS RESET VARS TO 0.
    DO 500 I=1,J
    IF (I.GT.NMAX) GO TO 490
    Q(I)=0.
    SS(I)=0.
    SEL(I)=0.
    NO3SEL(I)=0.
```

```
      NHWSEL(I)=0.
      NHSSEL(I)=0.
      TKNSEL(I)=0.
      PO4SEL(I)=0.
      PSEL(I)=0.

C **** NRZ 9/23/94
C **** CORRECTION
C **** MOVE LINE INDICATOR 484 TO INCLUDE PPT, ANPT, AND ONPT

      DO 484 IZ=1,NPART
      SST(I,IZ)=0.
      PPT(I,IZ)=0.
      ANPT(I,IZ)=0.
  484 ONPT(I,IZ)=0.

C **** NRZ 9/23/94

      DIN(I)=0.
  490 QI(I)=0.
      AINO3(I)=0.
      AINH4(I)=0.
      SPI(I)=0.
      DO 494 IZ=1,NPART
      SI(I,IZ)=0.
      PI(I,IZ)=0.
      ANI(I,IZ)=0.
  494 ONI(I,IZ)=0.
  500 CONTINUE
      RETURN


  540 WRITE (2,850)
      STOP
  570 WRITE (2,900) NRG,J
      STOP
C
C **** FORMATS.
C
  600 FORMAT (1X,'RAIN DATA MISSING FOR GAGE ',A2,12H, AT ELEMENT,I4,1H
     1,,I4,7H: GAGE ,A2,' DATA USED')
  670 FORMAT (/5X,12HGAGE NUMBER ,A2/5X,11HTIME - MIN.,7X,15HRAINFALL RA
     1TE -,2A4/(F14.1,F24.2))
  730 FORMAT (1X,2A4,2PF6.1,F7.0,0PF6.3,F6.2)
  740 FORMAT (A1,F8.0,F10.0)
  830 FORMAT (16X,A2)
  850 FORMAT (' RAINFALL DATA EXCEEDS DIMENSION')
  880 FORMAT (' ANALYSIS IS NOT ACCURATE IF RAINFALL INTENSITY',28H INT
     1ERVALS ARE LESS THAN DT.)
  900 FORMAT (1X,'HYETOGRAPH DATA MISSING OR INCORRECT',24H FIRST COLU
     1MN NOT 0 OR 1/I4,40H GAGES REQUESTED. BAD LINE BEGINS WITH: ,A2)

      END

      SUBROUTINE NITRAN(ES,FCVOL,SOIVOL,XMOI,PEP,WP,N,TEMPC,ICR,
     &  RATEMX,CU1,SOITEM,RNUTNI,RNUTAM,RNUTP,DF1,TP1)
      IMPLICIT DOUBLE PRECISION A-H,O-Z

*THIS SUBROUTINE INCLUDES NITROGEN TRANSFORMATION
* COMPUTING SOIL WATER COEFFICIENTS (SW)
* CALLING WP WILTING POINT WHICH MUST BE INPUT

      COMMON /TRANSF/POTMIN(2000),SOILN(2000),XMIN(2000),AMON(2000)
     & ,NIT(2000),DNI(2000),UPNH4(2000),UPNO3(2000),TDMN2(2000)
     & ,ROTR(2000),RFON(2000)
      DOUBLE PRECISION NIT,XMIN

      COMMON /TRAP/PMINP(2000),SOILP(2000),MINP(2000),PLAB(2000),
     &  UPPHOS(2000),TDMP2(2000),SORGP(2000),PSOL(2000),EDILAB(2000)
      DOUBLE PRECISION MINP
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C *** NRZ 9/15/94
C *** DIMENSION VARIABLES TO REFLECT NMAX+ISTRUC+1+NCHAN

      COMMON /PHOS1/ P0SOIL(2000),SSA(30,8),SSAT(30),EDI(2000),
     & P0(2000,8),ERP(8),STOLD(2000,8),SEDNEW(2000,8),PPT(2000,8),
     & PI(2030,8),PSEL(2000),STNEW(8),P2(8),PCELL(2000,8)
     & ,DRFT(8)
      COMMON /PHOS2/PE(8)

      COMMON/WATNH4/VOLSZ(2000),SZNH4(2000),AINH4(2020),STONH4(2000)
     & ,OUTNH4(2000),EDINH4(2000),VOLSZ1(2000),VOLSOI(2000)

      COMMON/NITRO1/ A0SOIL(2000),ANPT(2000,8),ANI(2020,8),
     & ANSEL(2000),AN2(8),ANCELL(2000,8),ANE(8),AN0(2000,8)
     & ,CNH4(2000)

      COMMON/NITRO2/ O0SOIL(2000),ONPT(2000,8),ONI(2020,8),
     & ONSEL(2000),ON2(8),ONCELL(2000,8),ONE(8),ON0(2000,8)

      COMMON/NO3/SZNO3(2000),AINO3(2020),STONO3(2000),OUTNO3(2000)
     & ,CNO3(2000),EDINO3(2000),CLENO3(2000)

C *** NRZ 9/15/94

      COMMON /CSURF/ SUR(2000),RANE(2000),SOIL(2000)
C
C **** MAXIMUM NUMBER OF SOIL TYPES IS 30.
C
      COMMON /GRAMPT/ CL(30),SA(30),ST(30),OM(30),AC(30)
     & ,AO(30),BC(30),BO(30),PHI(30),VCF(30),WCF(30),CFC(30),
     &  CEC(30),EAC(30),PHIC(30),XF(30),PSIF(30),CBF(30),
     &  THETAR(30),KS(30),CF(30),Z(30),LF(30),CS(30),SCF(30),
     &  CRC(30),KE(30,30),ZC(30),BD(30)
      DOUBLE PRECISION KS,LF,KE

        COMMON /ETPES/LAI(20,11),ESU(30),LAI1(20),POTLAI(20)
     &,SUMLAI(20)
              COMMON /EDX/ EDX(30)
      DOUBLE PRECISION LAI,LAI1

      COMMON /PARTITION/PKDA(30),PKDP(30),PSP(30)

      COMMON /PLANTN/DATPLA(20),DATHAR(20),CP1(20),CP2(20),DMY(20)
     &  ,YP(20),ROTMAX(20),ROTDAY(20),RLAIMX(20)
     &  ,RES(20),RES20(20),RES90(20)
      INTEGER DATPLA,DATHAR,TEMPC,SOITEM,ROTMAX,ROTDAY

      DIMENSION FCVOL(30),SOIVOL(30),TP1(30),
     & XMOI(2000),PEP(2000),WP(30),ES(2000),RATEMX(30),DF1(30)
c     fert array changed to 99: oct-97 JLCollado
      DIMENSION RNUTNI(99),RNUTAM(99),RNUTP(99),ILAI(20)
      DIMENSION RNUTZ(20),ICOUN1(20)
      INTEGER SUR,SOIL,RANE

** NRZ (10/12/94)
** ADD COMMON BLOCKS FOR NITRIFICATION CORRECTION

      COMMON /ROT/ IROT1,IROT(20,57)
      INTEGER IROT1,IROT
      COMMON /YEAR/ LDYEAR

** NRZ (10/12/94)

*NOTE CU1=DX2/1000 CU1/10 WOULD CONVERTG KG TO KG/HA
      CONFAY=CU1/10.
      DX2=CU1*1000.
*COMPUTE TEMPERATURE COEFFICIENT
      IF(SOITEM.LE.0.) THEN
              TEMPFA=0.
```

```
      ELSE
       TEMPFA=(DBLE(SOITEM)/(DBLE(SOITEM)+
     &        DEXP(9.93-0.312*DBLE(SOITEM))))
      ENDIF

*     IF(SOITEM.LT.0.) THEN
*      TEMPFN=0.
*     ELSEIF (SOITEM.LT.10.) THEN
*      TEMPFN=0.496*DBLE(SOITEM)
*     ELSE
*      TEMPFN=DEXP(22.64-5956.4/DBLE(SOITEM+273))
*     ENDIF

      DO 9 I=1,ICR
       ILAI(I)=0
  9   CONTINUE

      DO 11 I=1,N
      MIC=MOD(SUR(I),256)
      ILAI(MIC)=1
 11   CONTINUE

      DO 20 I=1,ICR
       SUMLAI(I)=SUMLAI(I)+LAI1(I)*ILAI(I)
 20   CONTINUE

*ASSUME THAT NITRIFCATION OF AMMONIUM FERTILIZER TAKES 20 DAYS

      DO 2222 I=1,ICR
      IF(RNUTAM(I).GT.0) THEN
            RNUTZ(I)=RNUTAM(I)*0.8/20.
            ICOUN1(I)=20
      ENDIF

** NRZ (10/12/94)
** CORRECTION - MODIFY RNUTZ CALCULATION TO ACCOUNT FOR FERTILIZER
** APPLICATIONS < 20 DAYS BEFORE A ROTATION OCCURS.  ICOUN1(I+1)
** AND RNUTZ(I+1) TRANSFER NITRIFYING NH4 TO NEXT CROP IN ROTATION

      IF(ICOUN1(I).GT.0) THEN
        ICOUN1(I)=ICOUN1(I)-1
        DO 2221 K=1,20
          IF (LDYEAR.EQ.IROT(K,2*I+1)) THEN
            ICOUN1(I+1)=ICOUN1(I)+1
            RNUTZ(I+1)=RNUTZ(I)
          ENDIF
 2221   CONTINUE
      ELSE
        RNUTZ(I)=0.
      ENDIF
 2222 CONTINUE

*COMPUTE TRANSFORMATION
*CMN=MINERALIZATION CONSTANT=0.000KG/HA/D,POTMIN IS IN KG/HA
      CMN=0.0003
*BKN IS A RATE CONSTANT =0.0003KG/HA/DAY
      BKN=0.00001
      DO 1000 I=1,N

      MIC=MOD(SUR(I),256)
      MIS=SOIL(I)/256

            IF(XMOI(I).LT.WP(MIS)) THEN
            xmoi(I)=wp(MIS)
            ENDIF
!WB         if soil moisture is less than wilting point
!WB         THIS LINE ADDED TO ALL CALL STATEMENTS DUE TO FLOAT OVERFLOWS AND
!WB         DOMAIN ERRORS ASSOCIATED WITH XMOI DROPPING BELOW WP 1/19/99
```

```
      IF(XMOI(I).GT.FCVOL(MIS)) THEN
               SWFA=0.
      ELSE
       SWFA=(XMOI(I)-WP(MIS))/(FCVOL(MIS)-WP(MIS))
      ENDIF

      IF(XMOI(I).LT.WP(MIS)) THEN
       SWFN=0.
      ELSEIF(XMOI(I).LT.FCVOL(MIS)) THEN
       SWFN=(XMOI(I)-WP(MIS))/(FCVOL(MIS)-WP(MIS))
      ELSEIF(XMOI(I).LT.TP1(MIS)/CU1) THEN
       SWFN=1.-(XMOI(I)-FCVOL(MIS))/(TP1(MIS)/CU1-FCVOL(MIS))
      ELSE
       SWFN=0.
      ENDIF

      AMON(I)=AMON(I)+EDINH4(I)
      SZNO3(I)=SZNO3(I)+EDINO3(I)
*ADD NUTRIENTS IF PRESENT
      AMON(I)=AMON(I)+RNUTAM(MIC)
      SZNO3(I)=SZNO3(I)+RNUTNI(MIC)
      PLAB(I)=PLAB(I)+RNUTP(MIC)

      CP11=5.0
*COMPUTE RESIDUE MINERALIZATION

*COMPUTE RESIDUE MINERALIZATION
      IF(RES(MIC).GT.0.) THEN
      RFON(I)=RFON(I)+RES(MIC)
      ENDIF


               POTMIN(I)=POTMIN(I)+RES(MIC)
               SORGP(I)=SORGP(I)+RES(MIC)/CP11


   21   CONTINUE
*COMPUTE  FLOW BETWEEN ACTIVE AND STABLE POOL
      RTN=POTMIN(I)/(POTMIN(I)+SOILN(I))
      POTSO=BKN*(POTMIN(I)*RTN-SOILN(I))
       IF(POTSO.GT.POTMIN(I)) POTSO=POTMIN(I)
       IF(-POTSO.GT.SOILN(I)) POTSO=-SOILN(I)
       POTMIN(I)=POTMIN(I)-POTSO
       SOILN(I)=SOILN(I)+POTSO
*AMMONIFICATION

       IF(POTMIN(I).LT.(0.01*CONFAY))  THEN
               SOILN(I)=SOILN(I)+POTMIN(I)
               POTMIN(I)=0.0
               XMIN(I)=0.0
       ELSE

               XMIN(I)=CMN*POTMIN(I)*(SWFA*TEMPFA)**0.5
       ENDIF
       IF(XMIN(I).GT.POTMIN(I)) XMIN(I)=POTMIN(I)
       POTMIN(I)=POTMIN(I)-XMIN(I)
       AMON(I)=XMIN(I)+AMON(I)

*NITRIFICATION

       IF(AMON(I).LT.(0.01*CONFAY)) THEN
               IF(AMON(I).GT.0.) SZNO3(I)=SZNO3(I)+AMON(I)
               AMON(I)=0.
               NIT(I)=0.
       ELSE

               IF(RNUTZ(MIC).GT.0) THEN
                NIT(I)=RNUTZ(MIC)
               ELSE
                NIT(I)=0.1*SOIVOL(MIS)/1000000.
```

```
*       NIT(I)=0.1*TEMPFA*SWFN*SOIVOL(MIS)/1000000.
              ENDIF
*THE MAX RATEMX IS 100MG/KG SOIL/WEEK
              IF(NIT(I).GT.RATEMX(MIS)) NIT(I)=RATEMX(MIS)

              IF(NIT(I).GT.AMON(I)) THEN
               NIT(I)=AMON(I)
              ENDIF
              AMON(I)=AMON(I)-NIT(I)

              IF(AMON(I).LT.(0.01*CONFAY)) THEN
               IF(AMON(I).GT.0.) SZNO3(I)=SZNO3(I)+AMON(I)
               AMON(I)=0.
              ENDIF
       ENDIF

       SZNO3(I)=SZNO3(I)+NIT(I)

* compute denitrification in case moisture content is higher
* than field capacity
      RFCV=FCVOL(MIS)+0.10*(TP1(MIS)/CU1-FCVOL(MIS))

      IF((XMOI(I)+PEP(I)+ES(I)).GT.RFCV) THEN
       SC=18.*POTMIN(I)/(SOIVOL(MIS)/1000.)
*DAILY DECAY RATE
       DK=24.*(0.0022*SC+0.0042)
       TFDN=DBLE(SOITEM)/(DBLE(SOITEM)+DEXP(9.93-0.321*DBLE(SOITEM)))
      SWFDN=((XMOI(I)+PEP(I)+ES(I))-RFCV)/(TP1(MIS)/CU1-RFCV)
*DENITTRFICATION
       DNI(I)=SZNO3(I)*(1-DEXP(-DK*TFDN*SWFDN))
       IF(DNI(I).LT.0.) DNI(I)=0.
       IF(SZNO3(I).LT.DNI(I)) THEN
              DNI(I)=SZNO3(I)
              SZNO3(I)=0.0
       ELSE
              SZNO3(I)=SZNO3(I)-DNI(I)
       ENDIF
      ELSE
       DNI(I)=0.
      ENDIF
*DISTRIBUTE AMMONIUM BETWEEN ADSORBED AND DISSOLVED AMMONIUM
*THE EQUILIBRIUM CONSTANT IS BASED ON CLAY CONTENT ECNH4
* ALL COMPUTATION ARE BASED ON MASSES NOT ON CONCENTRATION
      WATVOL=XMOI(I)*CU1*1000.
      WATVO1=FCVOL(MIS)*CU1*1000.
      SZNH4(I)=AMON(I)/(1+PKDA(MIS)*SOIVOL(MIS)/WATVOL)
      A0SOIL(I)=AMON(I)-SZNH4(I)
*COMPUTING PLANT UPTAKE
*COMPUTE INTO SUBROUTINE DATA SUMALI AND POTLAI
      PGRT=SUMLAI(MIC)/POTLAI(MIC)
*CONCENTRATION OF PLANT N IS IN PERCENT
      IF(SUMLAI(MIC).EQ.0.) THEN
       CN=0.
       CP=0.
       GOTO 22
      ENDIF
      CN=CP1(MIC)*PGRT**CP2(MIC)
      CP=CN/CP11
*COMPUTING THE DRY MATTER CONTENT
 22   DM=PGRT*YP(MIC)*DMY(MIC)

      TDMN1=0.01*CN*DM
      TDMN=TDMN1-TDMN2(I)
      TDMP1=0.01*CP*DM
      TDMP=TDMP1-TDMP2(I)

      IF (TDMN.LT.0.) TDMN=0.
      IF (TDMP.LT.0.) TDMP=0.
```

```
      TDMN2(I)=TDMN1
      TDMP2(I)=TDMP1

      UPNH4(I)=PEP(I)*CU1*1000.*SZNH4(I)/WATVOL
      UPNO3(I)=PEP(I)*CU1*1000.*SZNO3(I)/WATVOL

      TUPTN=UPNH4(I)+UPNO3(I)
      IF(TUPTN.GT.0.) THEN
            DEMFAC=TDMN*CONFAY*ROTR(I)/TUPTN
            UPNH4(I)=UPNH4(I)*DEMFAC

             IF(UPNH4(I).GT.SZNH4(I)) THEN
               UPNH4(I)=SZNH4(I)
               SZNH4(I)=0.
               AMON(I)=AMON(I)-UPNH4(I)
             ELSE
              AMON(I)=AMON(I)-UPNH4(I)
              SZNH4(I)=SZNH4(I)-UPNH4(I)
             ENDIF

            UPNO3(I)=UPNO3(I)*DEMFAC

             IF(UPNO3(I).GT.SZNO3(I)) THEN
               UPNO3(I)=SZNO3(I)
               SZNO3(I)=0.
             ELSE
              SZNO3(I)=SZNO3(I)-UPNO3(I)
             ENDIF

           ENDIF

*COMPUTE THE AMOUNT OF NITRATE LOST THROUGH LEACHING
* THE ACTUAL CONCENTRATION OF NITRATE THUS THE FRACTION OF NITRATE
*LOST THROUGH LEACHING IS ASSUMING COMPLETE MIXING
           CNO3(I)=SZNO3(I)*CNH4(I)
           CLENO3(I)=CLENO3(I)+CNO3(I)
           SZNO3(I)=SZNO3(I)*(1.-CNH4(I))
*HERE SEDIMENT BOUND NITROGEN IS EXPRESSED IN KG P/KG SOIL
            A0SOIL(I)=5.0*A0SOIL(I)/SOIVOL(MIS)

            EDINO3(I)=SZNO3(I)*(VOLSZ(I)/PHI(MIS))*BD(MIS)*1000.
   &         /SOIVOL(MIS)
            SZNO3(I)=SZNO3(I)-EDINO3(I)
            SZNH4(I)=AMON(I)/(1.+PKDA(MIS)*SOIVOL(MIS)/WATVOL)

            RBETA=0.598*DEXP(-0.179*PKDA(MIS))

            EDINH4(I)=AMON(I)*(VOLSZ(I)/PHI(MIS))*BD(MIS)*1000.
   &         /SOIVOL(MIS)
            AMON(I)=AMON(I)-EDINH4(I)

            O0SOIL(I)=5.0*(AMON(I)+POTMIN(I)+SOILN(I))/SOIVOL(MIS)

            PLAB(I)=PLAB(I)+EDILAB(I)
*PHOSPHORUS TRANSFORMATION

      IF(SORGP(I).LE.0.01) THEN
           PLAB(I)=PLAB(I)+SORGP(I)
           MINP(I)=0.
           SORGP(I)=0.
      ELSE
           MINP(I)=CMN*RTN*SORGP(I)*(SWFA*TEMPFA)**0.5
           IF(MINP(I).GT.SORGP(I)) MINP(I)=SORGP(I)
           SORGP(I)=SORGP(I)-MINP(I)
           PLAB(I)=PLAB(I)+MINP(I)
      ENDIF

      PTRANS=0.1*SWFA*DEXP(DBLE(0.115*SOITEM-2.88))*
     & (PLAB(I)-PMINP(I)*(PSP(MIS)/(1-PSP(MIS))))
      IF(PTRANS.GT.PLAB(I)) PTRANS=PLAB(I)
```

```
      PLAB(I)=PLAB(I)-PTRANS
      IF(PLAB(I).LE.0) PLAB(I)=0.
      IF(PMINP(I).LE.0.) PMINP(I)=0.
      PMINP(I)=PMINP(I)+PTRANS
*COMPUTING THE TRANSFER BETWEEN STABLE AND ACTIVE P POOLS
      TRANP=DEXP(-1.77*PSP(MIS)-7.05)
     &      *(4.*PMINP(I)-SOILP(I))
      IF(TRANP.GT.0.) THEN
            IF(TRANP.GT.PMINP(I)) TRANP=PMINP(I)
      ELSE
            IF(-TRANP.GT.SOILP(I)) TRANP=-SOILP(I)
      ENDIF

      SOILP(I)=SOILP(I)+TRANP
      PMINP(I)=PMINP(I)-TRANP



*DISTRIBUTE PLAB BETWEEN SEDIMENT BOUND AND DISSOLVED PHASE
      PSOL(I)=PLAB(I)/(1+PKDP(MIS)*SOIVOL(MIS)/WATVOL)
      P0SOIL(I)=PLAB(I)-PSOL(I)

      UPPHOS(I)=PEP(I)*CU1*1000.*PSOL(I)/WATVOL

            IF(UPPHOS(I).GT.0.) THEN
             DEMFAC=TDMP*CONFAY*ROTR(I)/UPPHOS(I)
             UPPHOS(I)=UPPHOS(I)*DEMFAC

              IF(UPPHOS(I).GT.PSOL(I)) THEN
                UPPHOS(I)=PSOL(I)
                PSOL(I)=0.
                PLAB(I)=PLAB(I)-UPPHOS(I)
              ELSE
               PLAB(I)=PLAB(I)-UPPHOS(I)
               PSOL(I)=PSOL(I)-UPPHOS(I)
              ENDIF
            ENDIF

             PLAB(I)=PSOL(I)+P0SOIL(I)
             PSOL(I)=PLAB(I)/(1.+PKDP(MIS)*SOIVOL(MIS)/WATVOL)
             P0SOIL(I)=PLAB(I)-PSOL(I)

      EDILAB(I)=PLAB(I)*(VOLSZ(I)/PHI(MIS))*BD(MIS)*1000.
     &            /SOIVOL(MIS)
             P0SOIL(I)=5.*P0SOIL(I)/SOIVOL(MIS)
             PLAB(I)=PLAB(I)-EDILAB(I)

      CNO3(I)=0.
 1000  CONTINUE

      DO 1010 I=1,ICR
             RES(I)=0
 1010  CONTINUE

2000   FORMAT( 7(1X,F10.4))
      END

C **** NRZ 10/11/94
C **** THE FOLLOWING SUBROUTINES AND FUNCTIONS WERE ADDED TO SIMULATE
C **** IMPOUNDMENTS FOR EACH CHANNEL

      SUBROUTINE IMPOND(IDATE,RAITES,N,DIAM,SPEC,VOLUME,MASSIN,EVAP,
     &                MLOST,MASTOT,DVOLO,NCH)

      COMMON /IMPDIM/ BASE,WIDTH,SLOPE,ORIF,CI,FI,MAXHGT,NIMP
      DOUBLE PRECISION BASE(10),WIDTH(10),SLOPE(10),ORIF(10),CI(10),
     &FI(10),MAXHGT(10)

      DOUBLE PRECISION  DIAM(N),SPEC(N),MASSIN(10,N),
     $EVAP, MLOST(10,N), MASTOT(10,N),VEL(10), MASREM(10,10),H(10,10),
```

```
     $RHO(10,10), MAXVOL(10),INFIL(10),DEPAVG(10),LOST(10),NDEPTH(10),
     $HAVG(10),STORAG(10),DELTIM, MASS(10,10),VOLUME(10),DVOLO(10),
     $DEPTH(10),RATE(10),HEAD(10),VOLOUT(10),XROOT,VOL
      INTEGER I,RAITES

C *** DELTIM MUST EVENLY DIVIDE 86400 - THE NUMBER OF SECONDS IN A DAY -
C ***  IF A NEW TIME STEP IS SELECTED.  THE STEP MUST BE IN SECONDS!

      DELTIM = 900.0

C *** ESTABLISHES INITIAL CONDITIONS AT SIMULATION START ***
C ***
C *** MAKE SURE SEDIMENT AND RUNOFF ENTERING ARE ZERO ON DAYS WITH NO
C *** RAINFALL EVENT

      IF (RAITES.EQ.0) THEN
        DO 5 I=1,N
          MASSIN(NCH,I)=0.0
 5      CONTINUE
      VOLUME(NCH)=0.0
      LOST(NCH)=0.0
      ENDIF
C *** SET SEDIMENT OUTFLOW TO ZERO
      DO 10 I=1,N
        MLOST(NCH,I) = 0.0
        MASTOT(NCH,I) = 0.0
10    CONTINUE
      IF (IDATE.NE.1) GOTO 15
       CALL SETTLE(DIAM, SPEC, VEL, N)
       MAXVOL(NCH) = VOL(MAXHGT(NCH), BASE(NCH), WIDTH(NCH),
     &              SLOPE(NCH))
       DO 55 I = 1, N
        MASREM(NCH,I) = 0.0
        MASTOT(NCH,I) = 0.0
55        H(NCH,I) = 0.0
       STORAG(NCH) = 0.0

C *** ESTABLISHES CONDITIONS AT START OF EACH SIMULATED DAY ***
15    IF (VOLUME(NCH) .LE. 0.01) GOTO 29
      STORAG(NCH) = STORAG(NCH) + VOLUME(NCH)
      IF (STORAG(NCH) .GT. MAXVOL(NCH)) THEN
       LOST(NCH) = STORAG(NCH) - MAXVOL(NCH)
       STORAG(NCH) = MAXVOL(NCH) - 0.1
        DO 44 I = 1, N
        MLOST(NCH,I) = (LOST(NCH)/VOLUME(NCH))*MASSIN(NCH,I)
44        MASS(NCH,I) = MASSIN(NCH,I) - MLOST(NCH,I)
      ELSE
        DO 45 I=1,N
45        MASS(NCH,I) = MASSIN(NCH,I)
      ENDIF
      DEPTH(NCH) = XROOT(STORAG(NCH),BASE(NCH),WIDTH(NCH),SLOPE(NCH),
     &            MAXHGT(NCH))
C     WRITE(*,*) DEPTH(NCH)
C *** ESTABLISHES PARTICLE CLASS DENSITY ***
      DO 7 I = 1, N
       RHO(NCH,I) = (MASREM(NCH,I) + MASS(NCH,I))/STORAG(NCH)
       H(NCH,I) = DEPTH(NCH)
7     CONTINUE

C *** SIMULATES IMPOUNDMENT PERFORMANCE GIVEN DAILY INPUTS ***

29    DO 77 I = 1, 86400/DELTIM
C *** ESTABLISHES DEPTH OF WATER IN IMPOUNDMENT ***

      HEAD(NCH) = DEPTH(NCH) - ORIF(NCH)
            INFIL(NCH) = DEPTH(NCH)*0.001/24.0

      IF (DEPTH(NCH) .GT. ORIF(NCH)) THEN
!WB   THIS LINE ADDED BY SEAN AND WES BUT NOT IN USLE MODEL
            RATE(NCH) = CI(NCH)*HEAD(NCH)**FI(NCH)/3600
```

```
      VOLOUT(NCH) = RATE(NCH)*DELTIM
              ENDIF
      IF (DEPTH(NCH) .LE. ORIF(NCH)) VOLOUT(NCH) = 0.0
      STORAG(NCH) = STORAG(NCH) - VOLOUT(NCH)

      IF (STORAG(NCH) .LE. 0.0) GOTO 99
      NDEPTH(NCH) = XROOT(STORAG(NCH),BASE(NCH),WIDTH(NCH),SLOPE(NCH),
     &                   MAXHGT(NCH))
     $- EVAP/24.0 - INFIL(NCH)
      IF (NDEPTH(NCH) .LT. 0.0) THEN
        NDEPTH(NCH) = 0.0
        DO 98 J = 1, N
98        H(NCH,J) = 0.0
        GOTO 99
      ENDIF
      IF (DEPTH(NCH) .GT. ORIF(NCH) .AND. NDEPTH(NCH) .LT. ORIF(NCH))
     & NDEPTH(NCH) = ORIF(NCH)
      DEPAVG(NCH) = (DEPTH(NCH) + NDEPTH(NCH))/2.0

      DO 27 K = 1, N
C *** TRACKS HEIGHT OF EACH DISCRETE PARTICLE CLASS IN IMPOUNDMENT ***

      IF (H(NCH,K) .LE. 0.0) GOTO 27
       HOLD = H(NCH,K)
       H(NCH,K) = H(NCH,K) - (DEPTH(NCH) - NDEPTH(NCH)) - VEL(K)*DELTIM
       HAVG(NCH) = (H(NCH,K) + HOLD)/2.0
      IF (HAVG(NCH) .LT. 0.0) HAVG(NCH) = HOLD/2.0
      IF (HOLD .GT. ORIF(NCH) .AND. HAVG(NCH) .LT. ORIF(NCH))
     & HAVG(NCH) = (HOLD +  ORIF(NCH))/2.0

C *** CALCULATES MASS LOST THROUGH DRAIN PIPE ***
      IF (HAVG(NCH) .GT. ORIF(NCH)) THEN
C        WRITE(*,*) HAVG(NCH), DEPAVG(NCH), RHO(NCH)1)
        PROP = (HAVG(NCH) - ORIF(NCH))/(DEPAVG(NCH) - ORIF(NCH)) *
     &          VOLOUT(NCH) * RHO(NCH,K)
        MASTOT(NCH,K) = PROP + MASTOT(NCH,K)
      ENDIF

      IF (H(NCH,K) .LE. 0.0) H(NCH,K) = 0.0
27    CONTINUE
      DEPTH(NCH) = NDEPTH(NCH)

** NRZ
** ACCUMULATE VOLUME OF RUNOFF OUT OF IMPOUNDMENT FOR EACH DAY
      DVOLO(NCH) = DVOLO(NCH) + VOLOUT(NCH)


77    CONTINUE
      DVOLO(NCH) = DVOLO(NCH) + LOST(NCH)

** MAKE SURE VOLUME OUT IS NOT GREATER THAN VOLUME IN
      IF (DVOLO(NCH).GT.VOLUME(NCH)) DVOLO(NCH)=VOLUME(NCH)
** NRZ

      DO 87 I = 1, N
87      MASREM(NCH,I) = RHO(NCH,I)*VOL(H(NCH,I), BASE(NCH),
     &                WIDTH(NCH),SLOPE(NCH))
99    RETURN
      END

      SUBROUTINE SETTLE(DIAM, SPEC, VEL, N)
      DOUBLE PRECISION DIAM(N), VEL(N), VCHECK, RN, CDH, SPEC(N),
     &                RE,CD
      DO 17 I = 1,N
      VEL(I) = (SPEC(I) - 1.0)*999.0*9.81/(18.0*1.002*10**(-3.0))
     $*DIAM(I)**2
19    RN = RE(VEL, DIAM, N, I)
      IF (RN.LT.1.0) GOTO 17
      CDH = CD(RN)
      VCHECK = DSQRT(DIAM(I)*(SPEC(I)-1.0)*9.81*4.0/(3.0*CDH))
```

```
      IF (ABS((VEL(I) - VCHECK)/VEL(I)) .GT. 0.05) THEN
      VEL(I) = VCHECK
      GOTO 19
      ENDIF
17    CONTINUE
      RETURN
      END

      FUNCTION CD(RN)
      DOUBLE PRECISION CD, RN
      IF (RN .GT. 10000) THEN
      CD = 0.4
      ELSEIF (RN .LT. 10000 .AND. RN .GE. 1.0) THEN
      CD = 24.0/RN + 3.0/DSQRT(RN) + 0.34
      ELSE
      CD = 24.0/RN
      ENDIF
      RETURN
      END

      FUNCTION RE(VEL, DIAM, N, I)
      DOUBLE PRECISION VEL(N), DIAM(N), RE
      INTEGER I
      RE = VEL(I)*DIAM(I)*997006.0
      RETURN
      END

      FUNCTION XROOT(VOL,BA,W,S,MAXHGT)
      DOUBLE PRECISION  X,W,S,A,B,VOL,XERROR,MID,XROOT,F,BA,MAXHGT
      F(X) = BA*W*X + (X**2.)*S*(BA+W) + (4.0/3.0)*(S**2.)*(X**3.)-VOL
      XERROR = 0.05
      A = 0.0
      B = MAXHGT
      DO 20 I = 1,30
      MID = (A + B)/2.
      IF (F(A) * F(MID) .LT. 0.0) THEN
      B = MID
      IF ( (B-A) .LE. XERROR) THEN
      XROOT = (A+B)/2.
      GOTO 23
      ENDIF
      ELSE
      A = MID
      ENDIF
20    CONTINUE
23    RETURN
      END

      FUNCTION VOL(X, BASE, WIDTH, SLOPE)
      DOUBLE PRECISION X, BASE, WIDTH, SLOPE, VOL
      VOL = X*BASE*WIDTH + X**2*(BASE+WIDTH)*SLOPE + 4.0/3.0*SLOPE**2*
     $X**3
      RETURN
      END

      SUBROUTINE EVAPFW(LDAY)

      COMMON /FWATER/ AFWEV,DFWEV
      DOUBLE PRECISION AFWEV,DFWEV

***** THIS SUBROUTINE CALCULATES THE DAILY EVAPORATION FROM A FREE WATER
***** SURFACE BASED ON THE MEAN ANNUAL FREE WATER SURFACE EVAPORATION
***** AND JULIAN CALENDAR DATE.  MONTHLY SOLAR RADIATION VALUES ARE USED
***** TO PROPORTION THE ANNUAL EVAPORATIVE DEPTH INTO REASONABLE ESTIMATES
***** FOR EACH MONTH AND DAY OF THE YEAR.  EVAPORATION RATES ARE CONSIDERED
***** CONSTANT IN ANY ONE MONTH.

      IF ((LDAY.GE.1).AND.(LDAY.LE.31)) THEN
        DFWEV = 0.050*AFWEV/31.
      ELSEIF ((LDAY.GE.32).AND.(LDAY.LE.59)) THEN
```

```
        DFWEV = 0.065*AFWEV/28.
      ELSEIF ((LDAY.GE.60).AND.(LDAY.LE.90)) THEN
        DFWEV = 0.082*AFWEV/31.
      ELSEIF ((LDAY.GE.91).AND.(LDAY.LE.120)) THEN
        DFWEV = 0.099*AFWEV/30.
      ELSEIF ((LDAY.GE.121).AND.(LDAY.LE.151)) THEN
        DFWEV = 0.110*AFWEV/31.
      ELSEIF ((LDAY.GE.152).AND.(LDAY.LE.181)) THEN
        DFWEV = 0.115*AFWEV/30.
      ELSEIF ((LDAY.GE.182).AND.(LDAY.LE.212)) THEN
        DFWEV = 0.112*AFWEV/31.
      ELSEIF ((LDAY.GE.213).AND.(LDAY.LE.243)) THEN
        DFWEV = 0.104*AFWEV/31.
      ELSEIF ((LDAY.GE.244).AND.(LDAY.LE.273)) THEN
        DFWEV = 0.089*AFWEV/30.
      ELSEIF ((LDAY.GE.274).AND.(LDAY.LE.304)) THEN
        DFWEV = 0.071*AFWEV/31.
      ELSEIF ((LDAY.GE.305).AND.(LDAY.LE.334)) THEN
        DFWEV = 0.055*AFWEV/30.
      ELSEIF ((LDAY.GE.335).AND.(LDAY.LE.365)) THEN
        DFWEV = 0.046*AFWEV/31.
      ENDIF

      END

C **** NRZ 10/11/94

C **** NRZ 11/4/94
C **** THIS SUBROUTINE WAS ADDED FOR CONSOLE DISPLAY PURPOSES
C **** IT PRINTS THE CALENDAR MONTH AND DAY, AND INDICATES A STORM
C **** OR FERTILIZATION DAY

      SUBROUTINE XDATE (LDAY,YERBEG,IDATE,SIMDUR,RAITES,NFPR)

      CHARACTER*3 MONTH
      INTEGER LDAY,DAYMON,YERBEG,SIMDUR,RAITES

      RDATE=REAL(IDATE)
      RSIM=REAL(SIMDUR)

      IF (MOD(YERBEG,4).NE.0) THEN
        IF ((LDAY.GE.1).AND.(LDAY.LE.31)) THEN
          MONTH='JAN'
          NDB=0
        ELSEIF ((LDAY.GE.32).AND.(LDAY.LE.59)) THEN
          MONTH='FEB'
          NDB=31
        ELSEIF ((LDAY.GE.60).AND.(LDAY.LE.90)) THEN
          MONTH='MAR'
          NDB=59
        ELSEIF ((LDAY.GE.91).AND.(LDAY.LE.120)) THEN
          MONTH='APR'
          NDB=90
        ELSEIF ((LDAY.GE.121).AND.(LDAY.LE.151)) THEN
          MONTH='MAY'
          NDB=120
        ELSEIF ((LDAY.GE.152).AND.(LDAY.LE.181)) THEN
          MONTH='JUN'
          NDB=151
        ELSEIF ((LDAY.GE.182).AND.(LDAY.LE.212)) THEN
          MONTH='JUL'
          NDB=181
        ELSEIF ((LDAY.GE.213).AND.(LDAY.LE.243)) THEN
          MONTH='AUG'
          NDB=212
        ELSEIF ((LDAY.GE.244).AND.(LDAY.LE.273)) THEN
          MONTH='SEP'
          NDB=243
        ELSEIF ((LDAY.GE.274).AND.(LDAY.LE.304)) THEN
          MONTH='OCT'
```

```
    NDB=273
  ELSEIF ((LDAY.GE.305).AND.(LDAY.LE.334)) THEN
    MONTH='NOV'
    NDB=304
  ELSEIF ((LDAY.GE.335).AND.(LDAY.LE.365)) THEN
    MONTH='DEC'
    NDB=334
  ENDIF
ELSE
  IF ((LDAY.GE.1).AND.(LDAY.LE.31)) THEN
    MONTH='JAN'
    NDB=0
  ELSEIF ((LDAY.GE.32).AND.(LDAY.LE.60)) THEN
    MONTH='FEB'
    NDB=31
  ELSEIF ((LDAY.GE.61).AND.(LDAY.LE.91)) THEN
    MONTH='MAR'
    NDB=60
  ELSEIF ((LDAY.GE.92).AND.(LDAY.LE.121)) THEN
    MONTH='APR'
    NDB=91
  ELSEIF ((LDAY.GE.122).AND.(LDAY.LE.152)) THEN
    MONTH='MAY'
    NDB=121
  ELSEIF ((LDAY.GE.153).AND.(LDAY.LE.182)) THEN
    MONTH='JUN'
    NDB=152
  ELSEIF ((LDAY.GE.183).AND.(LDAY.LE.213)) THEN
    MONTH='JUL'
    NDB=182
  ELSEIF ((LDAY.GE.214).AND.(LDAY.LE.244)) THEN
    MONTH='AUG'
    NDB=213
  ELSEIF ((LDAY.GE.245).AND.(LDAY.LE.274)) THEN
    MONTH='SEP'
    NDB=244
  ELSEIF ((LDAY.GE.275).AND.(LDAY.LE.305)) THEN
    MONTH='OCT'
    NDB=274
  ELSEIF ((LDAY.GE.306).AND.(LDAY.LE.335)) THEN
    MONTH='NOV'
    NDB=305
  ELSEIF ((LDAY.GE.336).AND.(LDAY.LE.366)) THEN
    MONTH='DEC'
    NDB=335
  ENDIF
ENDIF

DAYMON=LDAY-NDB
PC=(RDATE/RSIM)*100.

IF (IDATE.EQ.1) THEN
  WRITE (*,*)
  WRITE (*,*)
  WRITE (*,*) '**************************** ANSWERS ',
&          'INITIALIZED **************************'
  WRITE (*,*)
  WRITE (*,*)
ENDIF

IF (MOD(LDAY,20).EQ.0) THEN
  WRITE (*,10) 'SIMULATING ',MONTH,DAYMON,YERBEG,
&           'SIMULATION ',INT(PC),'% COMPLETE'
ELSE
  WRITE (*,10) 'SIMULATING ',MONTH,DAYMON,YERBEG
ENDIF

IF (RAITES.EQ.1) THEN
  WRITE (*,*) ' ...Raining'
  WRITE (*,*)
```

```
      ENDIF

      IF (NFPR.EQ.1) THEN
        WRITE (*,*) '  ...Fertilizing'
        WRITE (*,*)
        NFPR = 0
      ENDIF

      IF (IDATE.EQ.SIMDUR) THEN
        WRITE (*,*)
        WRITE (*,*)
        WRITE (*,*) '***************************  SIMULATION ',
     &             'COMPLETE  ***************************'
        WRITE (*,*)
        WRITE (*,*)
      ENDIF

   10 FORMAT (1X,A11,A3,1X,I2,1X,I4,11X,A11,I4,1X,A10)
      RETURN
      END

C **** NRZ 11/4/94
```

Appendix B: Complete list of variables included in ANSWERS-2000.

A	Ratio of saturated hydraulic conductivity of the top layer and saturated hydraulic conductivity for underlying layer for soil i.
A0SOIL	Sediment-bound ammonium soil concentration (µg/g).
AC	Canopy area (%).
ADIR	Retention depth on volume per unit area (m).
AFWEV	Annual free water evaporation for all impoundments (m).
AGRAV	Acceleration of gravity (m^2).
AINH4	Inflow of dissolved ammonium from adjacent cells (kg/s).
AINO3	Inflow of nitrate from adjacent cells (kg/s).
ALBED	Albedo.
AMON	Total ammonium present in the soil layer (kg/ha).
AMON	Ammonium present in soil (kg/ha).
AN2	Sediment-bound ammonium in storage for particle class i (kg/s).
ANCELL	Newly added sediment-bound ammonium for particle class i (kg/s).
ANE	Outflow of sediment-bound ammonium for particle class i (kg/s).
ANG	Slope direction of element in degrees counter-clockwise from positive row axis.
ANH4SI	Accumulated dissolved ammonium loss from catchment at print line i for a given storm.
ANH4SI(L,i)	Accumulated dissolved ammonium loss from catchment draining to outlet i at hydrograph line L for a given storm (g).
ANO3SI	Accumulated dissolved nitrate loss from catchment at print line i for a given storm.
ANO3SI(L,i)	Accumulated dissolved nitrate loss from catchment draining to outlet i at hydrograph line L for a given storm (g).
ANSEDG(NCH,i)	Sediment bound NH4 for particle class i draining from channel for a given hydrograph print line (g/s).
ANSEDH(NCH,i,L)	Sediment bound NH4 for particle class i and hydrograph line L leaving catchment (kg).
ANSEDI(NCH,i)	Accumulated total sediment bound NH4 for particle class i leaving catchment and entering impoundment for the simulation(kg) .
ANSEDO(NCH,i)	Accumulated sediment bound NH4 leaving impoundment on particle size i for simulation (kg).
ANSEDT(NCH)	Simulation total sediment bound NH4 leaving impoundment (kg).
ANSIG(i)	Accumulated sediment-bound ammonium loss for all particle size classes draining to outlet i for a given hydrograph print line (kg/s).
ANSSI	Accumulated sediment-bound ammonium loss from catchment at print line i.
ANSSI(L,i)	Accumulated sediment-bound ammonium loss from catchment draining to outlet i at hydrograph line L for a given storm(g).
AO	Area outside canopy (%).
AREA	Catchment area as sum of element areas, (ha).
AREA2	Element or channel area (m^2).

ARMOUR	Fraction of channel cell that is nonerodible, or armored (different than depth to nonerodible layer).
ARMOUR	Fraction of channel cell that is nonerodible, or armored (different than depth to nonerodible layer).
ASLIM	Soil moisture beyond which plant transpiration is being reduced (mm).
ASM	Antecedent soil moisture as a fraction of pore space for soil i.
ASMBAR	Average ASM.
ASPECT	Slope direction.
AUCFACT	This is the Area Under Canopy factor, used in the KICAN factor in the sediment submodel. It assumes linear growth of plant canopy, and that max canopy is obtained at halfway through the growth period.
AZRAT	Same as A.
B	Conveyance in Manning's equation.
BC	Bare area under canopy (%).
BD	Soil bulk density in g/cm^3.
BEGROTDT	The end date of the previous rotation (= beginning date of this rotation).
BKN	Rate constant used in the determination of flux between stable and active organic N pools.
BO	Bare area outside canopy (%).
BR	Mass of buried residue (kg/m^2) w/in 0 to 0.15 m of the soil zone (initial)
BULKDENS	Soil bulk density in kg/m^3.
BURRES	mass of buried residue (kg/m^2) w/in 0 to 0.15 meter of the soil zone on a specific day.
C1-6	Product of CDR and SKDR for element.
CANOPY	Fraction of ground covered by canopy at this day.
CBAR	Percent of watershed in crop i.
CBF	Soil texture coefficient.
CD	Drag coefficient used in determining particle fall velocity.
CDR	Erosion parameter for crop management practice i.
CDRFAL	Erosion parameter for crop management practice i at planting day.
CE3-6	Constants in erosion equations.
CEC	Cation exchange capacity.
CELL	Counter for number of cells in a basin.
CF	Canopy factor.
CFC	Correction factor for coarse fragment.
CHAN	Constant indicating presence of absence of channel in an element.
CHDR	Groundwater discharge into a channel segment.
CHN	Number of channel segments.
CHNSL	Channel soil type.
CHNSLTMP	Temporarily holds channel soil type for reordering in XDATA.
CHNSOIL	Channel soil type.
CHNUM(j)	Number of the channel network to which cell j belongs.
CHNUMBER	Designates that the channel designator number of element II is equal to the channel designator number of the current element. It is used to extract CWID, SS, PIV, in subroutine XDATA.
CHOUT(i)	Number of the outlet cell for channel network i.

CL	Clay content of the soil (%).
CLAY	Fraction of clay in upper soil surface.
CLAYCALC	Holds a value of CLAY in order to make calculations in the erodibility section.
CMN	mineralization constant (kg/ha/day).
CN	Manning's "n" for channel type i.
CN	concentration of nitrogen (% of plant biomass).
CNH4	Fraction of water leaching.
CNO3	Accumulative percolation during infiltration (mm).
CNT	A count variable.
CNTER	A counter that tracks the number of times the flow-depth calculation has been performed.
CNTFLAG	Counter flag.
CONST	Flow depth units conversion factor.
CONSTHLD	Holds a constant in the channel conveyance daily calculation.
CONSTTMP	Temporarily holds CONSTHLD for reordering in XDATA.
CONV	Catchment conversion constant for mm/h to m/s.
CP	concentration of phosphorus (% of plant biomass).
CP1	Exponent for nitrogen content.
CP11	Ratio of nitrogen to phosphorus.
CP2	Exponent for nitrogen content.
CRC	Crust reduction factor.
CRCOEF	Roughness coefficient of channel type i.
CROP	Alphanumeric name of crop i.
CSIZE(1-4)	Cell Size.
CU	Element conversions constant for mm/h to m^3/s.
CU1	Element conversion constant for mm to m^3.
CU2	Element conversion constant for twice m^3.
CUMIN1	Cumulative infiltration (mm).
CUMINF	Same as CUMIN1.
CUMPON	Cumulative depth of ponding (mm).
CWID	Width of channel segment i.
CWIDTH	Width of channel type i
CY1-5	Simplifying constants used in transport equation.
D	Depth increment in segmented depth curve.
DACT	Actual detachment capacity of sediment-laden flow (kg/s).
DANSED(NCH)	Daily total of sediment bound NH4 leaving impoundment (kg).
DATE	Date of event being simulated.
DATHAR	Date of harvest (Julian calendar).
DATPLA	Date of planting (Julian calendar).
DAYBEG	Beginning day of simulation.
DAYDIFF	The difference in days between planting and today in the simulation.
DAYNOW	The Julian day today in the simulation.
DAYTHEN	The day number at the beginning of a crop/cover condition.
DC	Tile drainage coefficient.
DCAP	Detachment capacity for rill flow (kg/s).

DD	Portion of tile drainage flowing in a row direction.
DDROOTF	Mass of dead roots within top 15 cm of soil at the end of the rotation (kg/m^2).
DDROOTFAC	Rate of change of dead root mass during the rotation period.
DDROOTI	Mass of dead roots within top 15 cm of soil at the beginning of the rotation (kg/m^2).
DELTA	Variable in transport equation.
DELTA	Slope of the saturated vapor pressure at mean air temperature.
DEMFAC	Demand factor used in the uptake of nitrogen.
DENOM	Denominator used in proportioning soluble nutrients to outflow and storage in mass balance procedure.
DEP	Storage depth on element in volume per unit area (m).
DEPINIT	An incremental variable used in calculating flow depth.
DEPPREV	Bulk soil deposition (kg/m^3).
DEPRATE	Deposition rate (kg/s).
DEPTHINC	Depth that the channel bottom has eroded (m).
DETF	Rainfall detachment (kg/s).
DETR	Rainfall detachment (kg/s).
DF	Depth of soil horizon (mm).
DFWEV	Daily free water evaporation for impoundment (m).
DI	Simulation time minus rainfall histogram change time (s).
DIA	Particle diameter (m).
DIAM(i)	Diameter of sediment particle size i (m).
DIAMM	Particle diameter (mm).
DIF, DIFF	A value calculated as the test condition for the depth of flow in a rill calculation.
DIINT	Interrill detachment capacity of clear water (kg/s).
DIN	Accumulated tile drainage rate in element i (m).
DIR	Retention depth for cropping practice i (m^3/s).
DIRM	Maximum physical retention depth for cropping practice i.
DK	Daily decay rate.
DMY	Dry matter ratio.
DNH4O(NCH)	Daily total of dissolved NH4 leaving impoundment (kg).
DNI	Denitrification (kg).
DNO3O(NCH)	Daily total of dissolved NO3 leaving impoundment (kg).
DONSED(NCH)	Daily total of sediment bound TKN leaving impoundment (kg).
DOWNRATE	Rate of erosion of the channel bottom (m/s).
DP	Deposition rate (kg/s).
DPHOSO(NCH)	Daily total of soluble P leaving impoundment (kg).
DPSED(NCH)	Daily total of sediment bound P leaving impoundment (kg).
DR	Vertical drainage loss from control zone of element i.
DRA	Incremental increase in outflow from element in row direction.
DRANE	Rate of tile drainage in element (m^3/s).
DRFT	Sum of rainfall and flow detachment (kg/s).
DROOT	Mass of dead roots within top 15 cm of soil at a specific day (kg/m^2).
DS	Maximum rate of sediment inflow and erosion in element (kg/s).

DS1	DS with only rainfall detachment (kg/s).
DS2	DS with rainfall and flow detachment (kg/s).
DT	Simulation time increment in (s).
DTM	Simulation time increment in (min).
DTMIN	Minimum time increment in any hyetograph.
DTSEDO(NCH)	Daily total of sediment leaving impoundment(kg).
DWSOIL	Darcy-Weisbach friction factor, used to calculate flow depth.
DX	Length of side of square element (m).
DX2	Area of element (^{m2}).
DYYRNOW	The number of days = Year number * 365 (days/year) + day number today.
DYYRTHEN	The number of days at the beginning of this crop/cover.
EAC	Correction factor for entrapped air.
EDI	Effective depth of interaction (mm).
EDI	Effective depth of interaction (mm).
EDILAB	Labile P in the EDI (kg).
EDINH4	Ammonium in the EDI (kg).
EDINO3	Nitrate in the EDI (kg).
EDMM	Equivalent sand diameter of particle i (mm).
EDX	Maximum soil evaporative depth (mm).
ELMSIZE	Size of element.
EQSDIA	Equivalent sand diameter of particle i (m).
ER	Amount of particle type i leaving watershed (kg/s).
ERG	Sum of ER for all particle classes (kg/s).
ES	Soil evaporation (mm).
ESU	Upper limit of stage 1 of soil evaporation (mm day-0.5).
ETP	Potential evapotranspiration (m).
ETPMM	Potential evapotranspiration (mm).
EXTFAC	Extraction factor used in the soluble nutrient submodel.
F	Fraction of particles of type i in original soil.
FC	Wilting point for soil i as a fraction of pore space.
FCAP	Field capacity for soil i as a fraction of pore space.
FCFRAC	Field capacity on a volumetric basis.
FCVOL	Field capacity (mm).
FDPOFD	Second derivative of flow depth function.
FH	Maximum physical water depth in element (m).
FHS	FLINS plus FLIN.
FIL	Infiltration into element during time increment (m^3/s).
FILTS	Infiltration capacity for element i (m^3/s).
FLDEP	Initial value of flow depth.
FLDEPOLD	Flow depth from the previous iteration.
FLDOLD	FLDEPOLD, used to hold the original value of flow depth in case the calculation has to be restarted.
FLIN	Net rate of flow into an element less losses (m^3/s).
FLINS	Storage, inflow and outflow for element i at start of time increment (m^3/s).
FLODEP	Depth of flow in element or channel (m).

FLOWDEP Depth of flow in a rill.
FMAX Maximum infiltration capacity, surface inundated (m^3/s).
FOFD Used to solve for depth of flow.
FPBAR Not used.
FPOFD First derivative of flow depth.
FRA Fraction of catchment area covered by rain gauge i.
FV Fall velocity of particle type i (m/s).
FWA Fraction of surface area of element covered by water.
GAM Coefficient used in the Ritchie's equation.
GRF Fractional rate of baseflow release.
GROWFACT Time required for the crop to reach full size, as a fraction of its growth period.
GWC Volume of air filled pore space at field capacity for soil i (m).
HEIGHT Height of the canopy at current day (m).
HGTFACT Canopy growth factor, used in the KICAN factor in the sediment submodel.
HU Maximum height differential on soil surface (mm).
HYDRAD Hydraulic Radius (m^{-1}).
I1-3 Counter.
IASPEC Slope direction.
IBASIN Basin code for all (NROWS x NCOLS) cells.
ICHSZE Channel size category for each overland flow element.
ICR Number of cropping practices.
ICTYPE Channel type code corresponding to each NCHANN.
IDSOIL Soil ID number id for element (I,J) with slope >-9999.
IEBSN Basin code for each element (cell) if cell is considered part of stream network.
IEL Array for data manipulation.
IFERT Flag indicating that fertilizer applications were made during this simulation (integer).
IFLDIR Flow direction (1,2,4,8,16,32,64,128).
IFLOW Flow direction in degrees (0,45,90,...315).
IFLWAC Flow accumulation info.
IG Alphanumeric number for rain gauge.
IHDRPT Value used to determine position in SOILHDR array so that header-id is used to access the soil nutrient information rather than soils number.
II Number of channel segments.
IMBSN Basin code for each overland flow elem.
IMPERM Depth to non-erodible layer in the channel (m).
INIT Initialization variable of the sediment subroutine.
INRCOV Fraction of interrill area covered by ground cover at a specific day.
INRCOVF Fraction of interrill area covered by ground cover at the end of the rotation.
INRCOVI Fraction of interrill area covered by ground cover at the beginning of the crop cover.
INRFACT Interrill cover change rate.

IROT	IROT(2i) represents the cover for a specific rotation, IROT(2i+1) represents the end of IROT(2i) (YearDay) for instance 2 1973123 represents cover number 2 until Julian day 123 for the year 1973.
IROT1	Number of all possible rotations.
IRR	Number of rainfall intensity readings for rain gauge i.
IS	Soil type for current element.
ISLOPE	Slope (tenths of %).
ISOIL	Soil id for each row-col element .
ISOILPT	Value used to determine position in arrays that store soil nutrient information.
ISR	Number of soil types.
ISTL	Comparator for sensing presence of drain tile in element.
ISTREM	Stream network code.
ISTRUC	Counter for structural practices.
ISTYPE	Soil id number corresponding to each NSOL.
ITEMP	Array for input data manipulation.
ITMP(1-3)	Dummy variables.
ITR	Rainfall histogram counter.
IX	Constant to indicate presence of a channel in an element.
IY	Segment number on segmented discharge curve.
J1-3	Counters.
JJ, JK	Counters.
JMAX	Dimension in IEL.
JS	Column number for last column on current element row plus 1.
JTR	Current rainfall intensity histogram period for rain gauge i.
K	Number of values in rainfall hyetograph and surface type of current element.
K1	Counter.
KDROOTI	Interrill dead root adjustment (fraction).
KDROOTR	Rill dead root adjustment (fraction).
KE	Effective saturated hydraulic conductivity (mm/hr).
KIADJ	Adjusted interrill erodibility parameter.
KIBASE	Baseline interrill ($kg*s*m^{-4}$).
KICAN	Canopy height adjustment factor (fraction).
KICONS	Consolidation factor for sealing and crusting adjustment (fraction).
KIGRCOV	Ground cover adjustment factor (fraction).
KISC	Interrill sealing and crusting adjustment.
KK	Soil type for current element.
KLROOTI	Interrill live root adjustment (fraction).
KLROOTR	Rill live root adjustment (fraction).
KPR	Number of time increment routings between print lines.
KRADJ	Adjusted rill erodibility parameter.
KRADJHLD	Adjusted rill erodibility parameter. This doesn't incorporate the sealing and crusting factor because that factor is dependent on days since a tillage operation, which is calculated on a daily basis.
KRBASE	Baseline rill erodibility (s/m).

KRBR	Adjustment for buried residue.
KRCONS	A soil consolidation factor used in the sealing and crusting adjustment equation.
KRSC	Sealing and crusting adjustment for rill erodibility.
KS	Saturated hydraulic conductivity (mm/hr).
L	Number of last element in row and a counter.
LAI	Leaf area index.
LCC(j)	Flag indicating overland flow cell j leaks in a column direction.
LCR(j)	Flag indicating overland flow cell j leaks in a row direction.
LF	Depth to the wetting front (mm).
LIVEROOT	Mass of live roots in top 15 cm of soil (kg/m^2) at plant maturity.
LRFAC	Rate of change of live root mass during rotation period.
LROOT	Mass of live roots in top 15 cm of soil (kg/m^2) at a specific day.
M	Element number counter and slope direction quadrant.
MASSCF	Fractional weight of the coarse fraction of material in the upper soil surface.
MAXPLHGT	Maximum canopy height for a crop (m).
MAXWID	Maximum calculated rill width (m).
MIN	Mineralized N (kg).
MNCHNSL	Manning's n for bare channel soil.
MNCHNTOT	Manning's n for channel with vegetation.
MNCS	Manning's n for bare channel soil, equal to MNCHNSL.
MNCSTMP	Manning's n for bare channel soil, used to hold place for reordering scheme in DATA.
MNCT	Manning's n for channel with vegetation, equal to MNCHNTOT.
MNCTTMP	Manning's n for channel with vegetation, used for reordering scheme in DATA.
MNSOIL	Manning's n for bare upland soil.
MNTOT	Manning's n for upland soil with vegetation (total friction factor).
MOUT	Catchment outflow overland flow element number.
MOUT(i)	Number of the last overland flow cell in channel network i
MXSOILHDR	total number of soil header id's in a coverage.
N	Number of overland flow elements.
N1	N + 1.
N2	Number of overland flow plus channel elements.
NBASIN	Counter for number of basins.
NBNCEL	Number of cells draining into basin i.
NC	Number of element receiving outflow from element i in a column direction.
NCELLS(i)	Number of cells in channel network i (entered in input file).
NCH	Counter for number of channel networks.
NCH	denotes for which channel network.
NCHAN	Number of channel networks (NIOUT and NJOUT are entered in the input file).
NCHANN	Counter for number of channel types.
NCHCEL	Number of cells considered as channel elements.

NCOLS(1-4)	Number of columns .
NDT	Number of lines of hydrograph print.
NERODTMP	Same as ARMOUR, used in XDATA to reorder channel data.
NETCOL	Column designation of flow outlet of NNth stream.
NETFLW	Flow accumulation value for NNth stream.
NETROW	Row designation of flow outlet of NNth stream.
NF	Down-Counter from NFI.
NFDAY	Julian day of fertilizer application.
NFI	Maximum number of time increments between infiltration recalculations.
NFYEAR	Year of fertilizer application.
NHDR	Number of soils with different soils information.
NHSSEL	Accumulated sediment-bound ammonium loss in element i for a given storm (kg/s).
NHWSEL	Accumulated dissolved ammonium loss in element i for a given storm (kg/s).
NICR	Crop number to which fertilizer is applied.
NIMP	number of impoundments to be simulated.
NIOUT	Row number of catchment outflow element.
NIOUT(i)	Row number of outlet cell for channel network i.
NIT	Nitrified ammonium (kg).
NJOUT	Column number of catchment outflow element.
NJOUT(i)	Column number of outlet cell for channel network i
NLOW	Temporary lower bound of channel network portion of cell array.
NMAX	Maximum number of elements.
NN	N2 + 1.
NN	Number of overland flow + channel elements + 1.
NN	Actual number of basins.
NNCHAN	NN + (number of channel networks - 1).
NNN	Actual number of channel types.
NO3SEL	Accumulated nitrate loss in element i for a given storm (kg/s).
NODATA(1-3)	No data.
NOERODE	Same as Armour, fraction of channel cell that is nonerodible.
NOEROS	Flag indicating a nonerodible cover condition (asphalt, etc).
NOFCEL	Number of overland flow cells; NOFCEL is less than NROWS x NCOLS.
NORILLS	The number of rills per cell.
NOTILL	Flag indicating a no-till crop rotation.
NOUTFL	Flag signifying that a cell flows out of the watershed.
NPAR	Dimension of IEL and ITEMP.
NPART	Number of particle size classes.
NPM	NPART - NWASH1.
NR	Number of element receiving outflow from element i in a row direction.
NRG	Number of rain gauges.
NRGAGE	Number of rain gages.
NROWS(1-4)	Number of rows.
NSOILS	Number of soils in a coverage.
NSOL	Counter for number of soil types.

NSTRUC	Type of structural practice.
NWASH1	NWASH + 1.
O0SOIL	Sediment-bound organic N concentration (μg/g).
OMCALC	Holds a value of organic matter used to make calculations in the erodibility section.
ON2	Sediment-bound organic N in storage for particle class i (kg/s).
ONCELL	Newly added sediment-bound organic N for particle class i (kg/s).
ONE	Outflow of sediment-bound organic N for particle class i (kg/s).
ONNI	Inflow of sediment-bound organic N for particle class i (kg/s).
ONSEDG(NCH,i)	Sediment bound TKN for particle class i draining from channel for a given hydrograph print line (kg/s).
ONSEDH(NCH,L,i)	Sediment bound TKN for particle class i and hydrograph line L leaving catchment (kg).
ONSEDI(NCH,i)	Accumulated sediment-bound TKN for particle class i leaving catchment and entering impoundment for the simulation (kg).
ONSEDO(NCH,i)	Accumulated sediment bound TKN for particle class i leaving impoundment for simulation (kg).
ONSIG(i)	Accumulated sediment-bound TKN loss for all particle size classes draining to outlet i for a given hydrograph print line (kg/s).
ONSSI	Accumulated sediment-bound TKN loss from catchment at print line i for a given storm.
ONSSI(L,i)	Accumulated sediment-bound TKN loss from catchment draining to outlet i at hydrograph line L for a given storm (g).
ORGMAT	Fraction of organic matter in upper soil surface.
OUTCOL	Column designation of flow outlet.
OUTFIL(i+1)	Character string for the name of the output file for channel network i and the leaky cells output.
OUTLET	Flow accumulation value of flow outlet.
OUTNH4	Outflow of dissolved ammonium (kg/s).
OUTNO3	Outflow of nitrate (kg/s).
OUTROW	Row designation of flow outlet.
OUTSID	Area of watershed border elements, which drain outside of watershed.
PCELL	Newly generated sediment-bound P for particle size i (kg/s).
PE	Outflow of sediment-bound P for particle class i (kg/s).
PEP	Plant transpiration (mm).
PER	Fraction of element area covered by foliage for surface type i.
PERCOL	Percolation amount (mm).
PGRT	Plant growth ratio.
PHI	Porosity (mm/mm).
PHIC	Corrected effective porosity (mm/mm).
PI	Inflow of sediment-bound P from adjacent cells for particle size i (kg/s).
PIT	Interception storage for cover for surface type i (mm).
PIV	Volume of air filled pore space in upper soil layer in element i.
PIV2	Same as PIV.
PKDA	Partition coefficient for ammonium.
PKDP	Partition coefficient for phosphorus.

PLAB	Labile P (kg/ha).
PLAB	Labile phosphorous (kg/ha).
PMINP	Active mineral P (kg/ha).
PMINP	Active mineral phosphorous (kg/ha).
PO4SEL	Accumulated dissolved P loss in element i for a given storm (kg/s).
POTLAI	Summation of potential leaf area index from planting day to harvest day.
POTMIN	Potentially mineralizable N (kg-N/ha).
POTMIN	Potentially mineralizable soil nitrogen (kg/ha).
PP	Alphanumeric unit description.
PRACT	Counter for structural practices.
PREC	Accumulated depth of precipitation (mm).
PRI	PR comparator for print of hyetograph(s).
PS	Variable in transport equation.
PSEDG(NCH,i)	Sediment bound P for particle class i draining from channel for a given hydrograph print line (kg/s).
PSEDH(NCH,L,i)	Sediment bound P for particle class i and hydrograph line L leaving catchment (kg).
PSEDI(NCH,i)	Accumulated sediment bound P for particle class i leaving catchment and entering impoundment for the simulation (kg).
PSEDO(NCH,i)	Accumulated sediment bound P for particle class i leaving impoundment for the simulation (kg).
PSEP	Potential soil evaporation (mm).
PSIF	Capillary potential at the infiltration wetting front (mm).
PSIG(i)	Accumulated sediment-bound P loss for all particle size classes draining to outlet i for a given hydrograph print line (kg/s).
PSP	Phosphorus sorption coefficient.
PSPT(i)	Accumulated inflow of sediment-bound P from adjacent cells for outlet i (kg/s).
PSSI	Accumulated sediment-bound P loss from catchment at print line i for a given storm.
PSSI(L,i)	Accumulated sediment-bound P loss from catchment draining to outlet i at hydrograph line L for a given storm (g).
Q	Outflow from element i at start of time increments (m^3/s).
Q1	Discharge from catchment at ith hydrograph line (mm/h).
Q1(L,i)	Flow out of catchment draining to outlet i at hydrograph line L (mm/h).
Q1M1	Q1(i-1).
Q2	Outflow from element at end of time increment (m^3/s).
QA	Incremental depth power values for segmented curve.
QD	Differential in discharge on curve segment.
QEFF	Flow per rill contributing area (m^3/s).
QI	Inflow to element i from adjacent elements (m^3/s).
QL	Discharge at lower end of segment IY on discharge curve.
R	Net rainfall rate for rain gauge i on surface type j (m^3/s).
RADI	Daily solar radiation (langley).
RAIN	Effective rainfall rate (m^3/s).
RAITES	Flag indicator of storm occurrence.

RANE	Number of rain gauge applicable to element i.
RANROU	Random roughness of the soil surface (mm).
RANROUM	Random roughness of the soil surface in meters (m).
RATE	Gauge rainfall rate at rainfall gauge i (m^3/s).
RATEMX	Maximum nitrification rate (µg/g/day).
RBETA	Extraction coefficient for ammonium.
RBTEMP	Temporary variable that holds ROCKBOT for reordering in subroutine XDATA.
RBTEMP	temporary variable that holds depth to nonerodible layer (m).
RC	Rainfall intensity for gauge i, histogram period j (m^3/s).
RE	Particle removal efficiency during deposition.
RES	Nitrogen in residue (kg/ha).
RESWAT	Residual water as a fraction of soil porosity.
REYN	Particle Reynolds number.
RFL	Fraction of discharge from element flowing in a row direction.
RILLSPC	Rill spacing in meters, or meters between rills.
RILLWID	Rill width (m).
RIT	Interception during time increment (m^3/s).
RLAIMX	Maximum leaf area index.
RLWID	RILLWID, used to hold the original rill width in case the flow-depth calculation has to be restarted.
RN	Manning's "n" for surface type 1.
RNH4S(i)	Accumulated dissolved ammonium loss from catchment draining to outlet i for the simulation (g).
RNH4SE(i)	Accumulated sediment-bound ammonium loss from catchment draining to outlet i for the simulation (g).
RNO3(i)	Accumulated dissolved nitrate loss from catchment draining to outlet i for the simulation (g).
RNOFIR	Interrill runoff rate (m/s), assumed equal to change in depth per unit time.
RNUT	Flag indicating the application of nutrient.
RNUTAM	Ammonium fertilizer applied (kg/ha).
RNUTNI	Nitrate fertilizer applied (kg/ha).
RNUTP	P fertilizer applied (kg/ha).
ROCKBOT	Same as IMPERM: depth to non-erodible layer (m).
RORGN(i)	Accumulated sediment-bound TKN loss from catchment draining to outlet i for the simulation (g).
ROTDAY	Root depth at a specific day (mm).
ROTMAX	Maximum rooting depth for crop i (mm).
ROTR	Ratio used to reduce evaporation according to the root depth.
ROUGH	Surface depth-storage parameter for surface i.
RPHOS(i)	Accumulated dissolved P loss from catchment draining to outlet i for the simulation (g).
RSEDP(i)	Accumulated sediment-bound P loss from catchment draining to outlet i for the simulation (g).
RUNO(NCH)	Daily runoff leaving impoundment (m^3).

RUNVOL(NCH)	Runoff leaving catchment and entering impoundment for a single rainfall event (m^3) (calculated from depth of runoff*Area drained by network).
RW	Average rainfall intensity over catchment at ith hydrograph print time.
RW(L,i)	Average rainfall intensity over catchment draining to outlet i at hydrograph print line L.
S	Storage at start of time increment for element i (m^3/s).
S1EP	Accumulative stage 1 soil evaporation (mm).
S2EP	Accumulative stage 2 soil evaporation (mm).
SA	Sand content of the soil (%).
SAND	Fraction of sand in upper soil surface.
SB	Average overland flow conveyance coefficient.
SBAR	Average catchment slope.
SC	Depth increment for segmented curve.
SCBAR	Variable used for determining mean value of SS and SSI.
SCF	Crust factor.
SCMAX	Maximum value of SS and SSI.
SCMIN	Minimum value of SS and SSI.
SDEL	Summation of DELTA.
SDR	Accumulated groundwater storage (m^3/s).
SE	Rate of sediment movement from element (kg/s).
SE1-2	Rate of sediment movement from element with and without flow detachment (kg/s).
SEDDR	Sediment delivery ratio from interrill areas.
SEDG(NCH,i)	Sediment of particle class i draining from channel for a given hydrograph print line (kg/s).
SEDH(NCH,L,i)	Sediment of particle class i and hydrograph line L leaving catchment (kg).
SEDNEW	Rate of new erosion occurring in a cell for particle class i (kg/s).
SEDOR(NCH,i)	Sediment of particle class i passing through impoundment orifice for a single rainfall event (kg).
SEDOT(NCH,i)	Sediment of particle class i overtopping impoundment for a single rainfall event (kg).
SEDWT(NCH,i)	Sediment of particle class i leaving catchment and entering impoundment for a single rainfall event (kg).
SEDZO(NCH,j)	Accumulated sediment of particle class i passing through impoundment for simulation (kg).
SEL	Accumulated sediment aggradation in element i for a given storm (kg/s).
SF	Segment factor. Maximum projected catchment discharge.
SG	Specific gravity of particle type i.
SGD2	SQRT (AGRAV/2).
SI	Rate of sediment inflow into element i from adjacent elements (kg/s).
SIG	Sum of SI values for all particle classes (kg/s).
SIG(i)	Sum of sediment in values for all particle sizes for outlet i.
SIGMA	Coefficient in transport equation.
SILT	Fraction of silt in upper soil surface.
SIMDUR	Simulation duration (days).
SKDR	Erosion parameter for soil type i.

SL	Slope of overland flow element or channel segment i.
SLOPE	Slope.
SMAX	Final accumulated sediment loss from catchment (kg).
SMDIR	S-DIR.
SMIN	Minimum elemental and channel slope in watershed.
SOIL	Soil type for element i.
SOILHDR	Header-id value for each soil polygon in a given coverage.
SOILN	Stable organic N (kg/ha).
SOILN	Stable soil organic nitrogen (kg/ha).
SOILP	Stable soil phosphorus (kg/ha).
SOILP	Stable soil phosphorous (kg/ha).
SOITEMP	Soil temperature (^{o}C).
SOIVOL	Soil mass of the soil layer (kg).
SORGP	Soil organic phosphorus (kg/ha).
SORGP	Soil Organic Phosphorous (kg/ha).
SP2	Outflow of dissolved P (kg/s).
SPADEP	Maximum elemental aggradation value (kg/ha).
SPAERO	Minimum elemental aggradation value (kg/ha).
SPASD	Variable used in determining SPASD.
SPASUM	Sum of SEL values used to calculate SPASD.
SPER	Steady state infiltration rate (mm/h).
SPI	Inflow of dissolved phosphorus from adjacent cells (kg/s).
SPSSI	Accumulated dissolved P loss from catchment at print line i.
SPSSI(L,i)	Accumulated dissolved P loss from catchment draining to outlet i at hydrograph print line L for a given storm (g).
SPT	Accumulated sediment loss from catchment at previous time (kg).
SPT(i)	Accumulated sediment loss from catchment draining to outlet i at previous time step (kg).
SR	Rainfall rate from previous calculation (m^3/s).
SRA	Portion of sediment leaving element and flowing in a row direction.
SS	Incremental increase in storage on element i.
SS1M1	SSI at previous time step.
SSA	Specific surface area for particle size class j for soil type i (^{m2}/g).
SSAT	Total specific surface area for soil type i (^{m2}/g).
SSCON	Sediment concentration at print line i (mg/l).
SSCON(L,i)	Sediment concentration at print line L of hydrograph for outlet i
SSI	Accumulated sediment loss from catchment at print line i.
SSI(L,i)	Accumulated sediment loss out of catchment at print line L of hydrograph for outlet i for a given storm (kg).
SSII	Same as SSI.
SST	Sum of initial values in sediment continuity equation (kg/s).
SSTOR	Storage on element at end of time increment (m^3/s).
ST	Silt content of the soil (%).
STD	Total inflow into tile lines during DT.
STRUC	Flag for existence of structure.
SUMLAI	Summation of the leaf area index from planting day to the current day.

SUMNHS	Accumulated sediment-bound ammonium loss for cell i for the entire length of the simulation (kg).
SUMNHW	Accumulated dissolved ammonium loss for cell i for the entire length of the simulation (kg).
SUMNO3	Accumulated dissolved nitrate loss for cell i for the entire length of the simulation (kg).
SUMPO4	Accumulated dissolved P loss for cell i for the entire length of the simulation (kg).
SUMSED	Accumulated sediment loss for cell i for the entire length of the simulation (kg).
SUMTKN	Accumulated sediment-bound TKN loss for cell i for the entire length of the simulation (kg).
SUPP	Available supply for infiltration during time increment.
SUR	Surface type on element i.
SWFA	Soil water factor for ammonification.
SWFDN	Soil water factor for denitrification.
SWH20	Specific weight water (kg/m^3).
SZNO3	Nitrate present in soil matrix (kg/ha).
T	Real time.
TAUCADJ	Adjusted critical shear.
TAUCB	Baseline critical shear (Pa).
TAUCHLD	"HOLDS" the adjusted critical shear. This doesn't incorporate the sealing and crusting factor for the same reason given for KRADJ above, both are calculated on a day to day basis.
TAUCONS	Consolidation adjustment for baseline critical shear.
TAUEFF	Effective shear stress in a rill ($kg*m^{-2}*s^{-2}$).
TAURR	Random roughness adjustment.
TAUSC	Sealing and crusting adjustment for critical shear.
TBAR	Percent of elements tiled.
TC	Time of j^{th} histogram period for rain gauge i.
TDMN2	Total dry matter N (kg/ha).
TDMP2	Total dry matter P (kg/ha).
TEMPC	Air temperature (^oC).
TEMPFA	Temperature factor for ammonification.
TEMPK	Air temperature (?K).
TEST	Comparison for correct data input check.
TESTI	Flag indicating occurrence of ponding.
TETP	Sum of ES and PEP (mm).
TF	Sediment transport capacity (kg/s).
TFDN	Temperature factor for denitrification.
TFMSE2	TF-SE2.
TFXCES	Transport capacity excess (kg/s).
THETAR	Residual water (mm).
TIAL	Value of 1 denotes element is tile drained.
TIMPON	Time ponding (min).
TINT	Time interval in hyetograph.

TITLE	Simulation title.
TKNSEL	Accumulated sediment-bound TKN loss in element i for a
TMAX	Maximum time value given in any hyetograph.
TMIN	Minimum tine value given in any hyetograph.
TMPAM(i)	Amount of NH4 fertilizer applied to crop i (kg/ha).
TMPNI(i)	Amount of NO3 fertilizer applied to crop i (kg/ha).
TMPP(i)	Amount of P fertilizer applied to crop i (kg/ha).
TNH4O(NCH)	Accumulated dissolved NH4 leaving impoundment for simulation (kg).
TNO3O(NCH)	Accumulated dissolved NO3 leaving impoundment for simulation (kg).
TP	Porosity for soil type i.
TPHOSO(NCH)	Accumulated soluble P leaving impoundment for simulation (kg).
TPON	Equivalent time of ponding, represents the time it would take to infiltrate CUMPON under ponded conditions (min).
TPREC	Accumulated rainfall for simulation (mm).
TRANP	Phosphorus transfer between active and mineral P pools (kg).
TRAP	Trap efficiency of ponds.
TRUNO(NCH)	Cumulative runoff leaving impoundment (m^3).
TRUNOM(NCH)	Total runoff leaving impoundment (mm).
TSEDI(NCH,i)	Accumulated sediment of particle class i leaving catchment and entering impoundment for simulation (kg).
TSEDO(NCH,i)	Sediment of particle class i leaving catchment and entering impoundment for a given rainfall event (kg).
TTIME	Time since stage 2 evaporation started (days).
TTSEDO(NCH)	Accumulated sediment leaving impoundment (kg).
TUPTN	Total uptake of N (kg).
UN	Comparison for units.
UNITS	Type of input-output units.
UPNH4	Uptake of ammonium (kg/ha).
UPNO3	Uptake of nitrate (kg/ha).
UPPHOS	Uptake of P (kg/ha).
VFS	Fraction of very fine sand in the soil (fraction).
VFSCALC	Holds a value of VFS in order to make calculations in the erodibility section.
VISCOS	Kinematic viscosity of water (^{m2}/s).
VOL	Accumulated runoff depth from catchment.
VOL(i)	Runoff depth for outlet i for a given storm (mm).
VOL1F(i)	Accumulated runoff depth for outlet i for the simulation (mm).
VOL1X(i)	Accumulated sediment loss out of catchment for outlet i for the simulation (kg/ha).
VS	Simplification variable used in transport equation.
VSFPER	Percentage of very fine sand in the soil (%).
VSTAR	Shear velocity (m/s).
WATVOL	Water present in the soil layer (L).
WID	Width of type 1 channel (m).
WIDINC	Width that the channel has eroded.
X	Overland flow width across overland flow element (m).

X1-4	Simplifying variables used in SUBROUTINE SED.
XDIR	Same of DIR.
XF	Variable used in the calculation of the capillary front potential.
XHOLD	Holds the variable X for the daily channel conveyance calculation.
XMOI	Soil moisture (mm).
XPR	Real value of KPR.
XR	Same as R.
XS(i)	Accumulated sediment loss out of catchment for outlet i for a given storm (kg/ha).
XTMP	Holds the XHOLD variable for reordering in XDATA.
XZW	Element or channel width (m).
Y	Number of appropriate increment on segmented discharge.
YALCON	Yalin's Constant.
YCR	Dimensionless critical shear stress from Shield's diagram.
YEARNOW	Current year in the simulation.
YEARTHEN	First year of the simulation.
YERBEG	Beginning year of the simulation.
YP	Yield potential (kg/ha).
Z	Macroporosity factor.
Z12	Rate of sediment inflow plus erosion at end of time increment.
ZC	Crust thickness, assumed to be 10 mm.

Appendix C: Input Variable Guide

Although every effort has been made to ensure that this input variable guide is correct, this guide is a **DRAFT** guide. If a variable or input looks suspicious, check it out further. The existing version of ANSWERS is distributed parameter, continuous simulation model that utilizes Ritchie's equation to predict evapotranspiration and Green-Ampt to predict infiltration. Sediment detachment is based on the work of the Water Erosion Prediction Project, and the nutrient routines are based on the GLEAMS model. The model can accomodate approximately 30,000 combined upland and channel cells. The upland cells are constrained to 1.0 hectare. The model can accomodate 9 separate channel networks, and 10 separate channel width/roughness combinations. The model can accomodate 30 soil types, 40 rain gages with up to 100 values per storm event, and 20 crop/cover combinations with 28 rotation end dates. There is a ArcView GIS interface known as FARMSCALE that assists in data file construction. At present time, the interface is being converted to run under Windows NT 4.

This variable guide is constructed as a reference line number and then a description of that line. The line number refers to the example data file that lists inputs and the read format of the model. All entries except for text and titles are right justified.

001 The first line is read in entirety, and is a title for the file.

002 The units flag is read. Although the model was originally used either in English or SI units, it current accepts only SI units. The PRINT variable determines whether or not the program will 'echo' input variables to the output file. If the variable is present, the input data is echoed to the output file.

003 If this value is a 1, the program will print output for every storm event. The output generated here is a value for that day.

004 This line is used to designate days that daily output will be generated. If there is not a rain event on these days, then the program will not generate output. The output generated here is a daily value and then a cumulative total to that day.

004b This is the hydrograph print option. A value of 1 indicates that hydrographs should be printed. The file will be titled HYPLOT1.OUT, where the number corresponds to the outlet from the watershed.

005 This line designates the number of rain gages. The maximum value is 8, with 35 values per gage.

006 This is the beginning day of the simulation.

007 The simulation duration, in days.

008 This line contains a two-letter designator for each rain gage If there are multiple rain gages, then include this line for each rain gage consecutively.

009 The first two letters of this line are read to ensure that the input file is in the proper order.

010 This designates the number of lines that the hydrograph will be divided into for printing purposes. Currently the model does not produce hydrograph output because the subroutine is machine dependent. The maximum number of lines of output is 101.

011 This designates the time increment between calculations during a rain event. The recommended time step is 30 seconds. This shouldn't be changed or model accuracy will decrease.

012 This designates the time step on which the infiltration capacity is calculated. This value should be 30 seconds and should not be changed.

013 This designates the maximum expected runoff rate. Recommended value is 50.8 mm/hr (2 in./hr).

014 The first two characters of this line are read to ensure that the input file is constructed properly.

015 This is the number of soil types in the simulation. The program does not consider spatial variation of soil properties with depth. The soil properties for each soil are considered 'average' values for that soil layer / type.

016 These are the soil properties. They are, in order:
S 1=Soil descriptor (usually S1, S2, S3, etc.)
TP=total porosity (percent volume) for soil type i.
FCAP=field cap for soil i as a fraction of total porosity (fraction of saturation).
WP=wilting point for soil i as a fraction of total porosity.
A=ratio of sat hyd cond of the top layer and sat hyd cond for underlying layer for soil I.
DF=depth of soil horizon.
ASM=antecedent soil moisture as a fraction of total porosity space for soil i, (percent saturation).

Total Porosity (TP): The total porosity is defined as: TP = 100 - (BD / PD) * 100, where TP = total porosity, percent, BD = bulk density (g/cm^3), particle density (g/cm^3),(assumed 2.65). Recommended values are included in Table 1. (Adapted from Beasley and Huggins, 1981).

Field Capacity (FCAP): As the moisture content of the soil is increased, a point is reached when water begins to drain due to gravitational forces. Another way of describing this phenomenon is to say that the moisture holding tension within the soil becomes less than 1/3 atmosphere. Field capacity (FP) is expressed as a fraction of saturation. Saturation occurs when the total pore space is filled with water. Thus, a soil with a total porosity of 50 percent and a field capacity of 70 percent (FCAP=0.70) contains 35 percent water (by volume) at field capacity. Although some surveys contain information about the actual field capacity of the individual soil types, most soil surveys

only state what the available water capacity of the soil is. Using the information in Table 1 and the available water capacity of the individual soils (A horizon), the modeler can easily estimate the field capacity (percent saturation) when that information is not available. By definition, the available water capacity of a soil is that water held within the pores between field capacity (tension of 1/3 atmospheres) and the wilting point (tension of 15 atmospheres). In addition, the assumption is made that approximately one-half of the water in the soil is unavailable. Thus, if the available water is listed as 0.15 mm/mm (15 % by volume), the field capacity of the soil is twice that amount or 0.30 mm/mm (30 percent by volume). Further, if the total porosity has been listed as 50 percent, that means that the field capacity of the soil is 30 percent divided by 50 percent or 60 percent of saturation (FCAP = 0.60).
(Taken from Beasley and Huggins, 1981).

Wilting Point (WP): Wilting point is the soil moisture at 15 atmospheres of pressure, as a fraction of pore space/saturation.

Depth of the horizon (DF): This was originally a parameter that represented the depth of soil that controlled the infiltration rate of the soil. Now it is the depth of the soil horizon for which the properties are uniform (horizon A).

Antecedent Soil Moisture (ASM): The infiltration equations in ANSWERS-2000 use this value to calculate an initial soil moisture in the system, and to calculate residual soil water. Since the infiltration rate will be much greater when the soil is ‘dry’ rather than ‘wet’, it is critical that a reasonable antecedent soil moisture content be used when simulating single events or short periods. (Taken from Beasley and Huggins, 1981).

Table 1:

Soil Texture	Bulk Density (g/cm^3)	Total Porosity (% saturation)	Field Capacity (% saturation)	Wilting Point (% saturation)
Sandy	1.65 (1.55-1.80)	38 (32-42)	39 (31-47)	17 (10-24)
Sandy Loam	1.50 (1.40-1.60)	43 (40-47)	49 (38-57)	21 (15-26)
Loam	1.40 (1.35-1.50)	47 (43-49)	66 (59-74)	30 (26-34)
Clay Loam	1.35 (1.30-1.40)	49 (47-51)	74 (66-82)	36 (32-40)
Silty Clay	1.30 (1.25-1.35)	51 (49-53)	79 (72-86)	38 (34-42)
Clay	1.25 (1.20-1.30)	53 (51-55)	83 (76-89)	40 (37-43)

Numbers in parentheses indicate normal range. (Table 1 taken from Beasley and Huggins, 1981).

017 To input hydraulic conductivity, make this value a 1, and then place the appropriate value according to the format listed (cm/hr). If the conductivity option is a 0, ANSWERS will calculate the value for the user.

018 This line contains soil property information, in order:
CL = clay content of the soil (%)
SA = sand content of the soil (%)
ST = silt content of the soil (%)
OM = organic matter content (%)
WCF = weight of the coarse fragment (%)
VFS = very fine sand content of the soil (%).

Lines 16,17,18 are repeated for each different soil type, up to a maximum of 30.

Soil Properties: Due to the variability of soil properties, the user is referred to a USDA soil survey or the USDA Soils5 soils database for information on the description of soils by clay, sand, silt, organic matter, and very fine sand.

019 This line is skipped by the program, but is required for proper formatting of the file.

020 This line reads the number of particle size classes.

021 This line reads the number of wash load classes, which is a subset of particle size classes. A washload particle is a particle of diameter < 10 microns, and it is assumed to be in suspension until there is no flow from an element.

022 This line is skipped by the program, but is required for proper formatting of the file.

023 This reads, in order:
Particle Diameter, mm.
Specific gravity of the particle.
Fall velocity of the particle, (m/s). If the fall velocity is input as 0, the model will calculate a value assuming spherical particles and Stokes Law.

026 This is the fraction of each soil category in each size class. The numbers 1 & 2 are read, but are not used. They are for user reference.

027 This is the specific surface area information for soil series #1. The line reads total specific surface area, then surface area for size class 1,2,3. From CREAMS manual, page 211: The total specific surface area is equal to clay*20 + sand*0.05 + silt*4. This information is used in the phosphorus transport subroutine.

Table 2 contains information on particle type and recommended values.

Particle Type	Size (mm)	Specific Gravity	Fall Velocity (mm/s)	Time to Settle 1.0 mm
Primary Clay	0.002	2.65	0.003	5. min
Primary Silt	0.01	2.65	0.08	13 sec
Small Aggregate	0.03	1.80	0.35	3 sec
Primary Sand	0.20	2.65	24.00	0.04 sec
Large Aggregate	0.50	1.60	40.00	0.03 sec

(Table 2 taken from Beasley and Huggins, 1981).

Please note that the fall velocity values in this table are in mm/s, but that model input is in m/s.
Lines 24, 25 are diameter, specific gravity, and fall velocity for each additional soil size classification (up to a maximum of 8 size classes).

028 The drainage exponent, a calibration factor for the soil drainage when soil moisture exceeds field
capacity. A value of 3 is recommended.

029 This line reads the design coefficient for tile drains, in mm/24 hr, for areas having tile drainage. Suggested values are between 6.4 and 12.7 mm / 24 hr.

030 This calibration factor is the fraction of groundwater released to streams and channels as baseflow at each time step. Recommended values are between 0 and 0.01.

031 This is the fertilizer application flag. If the value is 1, then the program looks for a separate input file titled <fertilizer.inp>, which must reside in the same directory as the main input file. The format for the fertilizer input file is included below.

032 The impoundment specifications allow for inclusion of an impoundment at the end of a channel. This line is skipped by the program, but must be included for proper file structure.

033 Here, the number of impoundments is specified. If this number is 0, then the surface and crop constants follow. If the value is 1 or greater (up to the # of channel networks, a maximum of 9), the impoundment specifications must follow.

If there are impoundments, the read format is:
(1X,I7,3(1X,F6.1),2(1X,F7.1),1X,F6.1,1X,F5.3,1X,F11.3)

The impoundment specifications must be included for each channel network that has an impoundment at the end.

```
  IMPOUNDMENT SPECIFICATIONS FOLLOW
 NUMBER OF IMPOUNDMENTS = 2    .
```

CHANNEL	LENGTH	WIDTH	SLOPE	ORIFICE HEIGHT	MAXIMUM HEIGHT	ORIFICE COEF C	F	ANNUAL FREE WATER EVAP
1	5.0	3.0	2.0	4.0	5.5	25.0	0.560	0.965
3	2.0	1.0	2.0	2.0	3.5	25.0	0.560	0.965

FREE WATER SURFACE EVAPORATION SUBROUTINE (EVAPFW)This subroutine calculates the daily evaporation from a free water surface based on the mean annual free water surface evaporation and Julian calendar date. Monthly solar radiation values are used to proportion the given annual evaporative depth into reasonable estimates for each month and day of the year. The mean monthly radiation in any one month is based on a location at 35 degrees north latitude (The proportions do not change drastically for locations within the central United States). Evaporation rates are considered constant in any one month. The proportion of radiation in any month is taken from a table in: Gray, D.M. 1970. Handbook on the Principles of Hydrology. National Research Council of Canada, Saskatchewan, Canada, p. 3.8, Section III. Estimates of average lake evaporation can be taken from a map contained in: Hjelmfelt, A.T. Jr, and J.J. Cassidy. 1975. Hydrology for Engineers and Planners. Iowa State University Press, Ames, Iowa, p. 170.

OPERATION OF THE IMPOUNDMENT MODEL (This is intended as an explanation of how the model interacts with ANSWERS). If no rainfall event occurs on any one day, the daily free water evaporation is computed. It is assumed that no evaporation occurs on a day when there is a rainfall event. After a rainfall event:

1) The mass of each sediment bound nutrient attached to each particle size class is computed.
2) The mass of eroded sediment of each particle size is computed.
3) The runoff volume is computed by multiplying the depth of runoff by the area drained by the channel network feeding the impoundment.
4) The impoundment model is called.
5) The amount of nutrient reduction for sediment bound nutrients is computed based on a ratio of the sediment settled for each particle size class to the total sediment eroded of that particle size class.
6) The amount of nutrient reduction for soluble nutrients is computed based on a ratio of the runoff leaving the impoundment to the runoff entering the impoundment.
7) At the end of the simulation, the following is printed in the channel output file if an impoundment was present:
    a) sediment distribution entering the impoundment
    b) sediment distribution leaving the impoundment
    c) sediment distribution leaving the orifice of the impoundment
    d) sediment distribution, which overtopped the impoundment
    e) cumulative runoff, sediment, and nutrients leaving the impoundment

(Impoundment information taken from notes by Zahradka, N R., 1994).

034 The first two characters of this line are read to ensure proper file structure.

035 This reads the total number of crops, or surfaces if the crop is fallow ground or pasture, etc.

036 This reads crop properties. They are, in order:
CROP,CROP = alphanumeric name of crop i
PIT = interception storage for cover for surface type i (mm)
PER = fraction of element area covered by foliage for surface type i
ROUGH = surface depth-storage parameter for surface I (fractional shape factor. See notes below).
HU = maximum height differential on soil surface (mm)
DIRM = maximum physical retention depth for cropping practice i

Interception Parameters (PIT and PER): A certain amount of the precipitation during any event never reaches the soil surface. Contact with and storage on vegetation accounts for this removal and is called interception. The potential interception volume (PIT) describes the volume of moisture that could be removed if the area were completely covered by that crop or land use. The actual percentage of cover (PER) assumes the non-covered area has no interception. Some recommended values are included below as Table 3. (Taken from Beasley and Huggins, 1981).

Table 3: Typical PIT values for various crops.

Crop	PIT (mm)
Oats	0.5 - 1.0
Corn	0.3 - 1.3
Grass	0.5 - 1.0
Pasture and meadow	0.3-0.5
Wheat, Rye and Barley	0.3 - 1.0
Beans, Potatoes, and Cabbage	0.5 - 1.5
Woods	1.0 - 2.5

Table 3 taken from Beasley and Huggins (1981).

Surface Storage Descriptors (HU and ROUGH): The ANSWERS model uses the maximum roughness height (HU) and a roughness coefficient (ROUGH) to describe the surface storage characteristics and the ponded surface area. The roughness coefficient is essentially a shape factor that describes the frequency and severity of the roughness. The maximum roughness height (HU) is used to establish the upper limits of surface roughness and is physically measurable. Recommended values are included as Table 4 and Table 5. (Taken from Beasley and Huggins (1981)). See Figure 1 below for a graphic representation of the HU parameter.

```
                        _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _
                             .``.              ^
            \               /   \      /       |
   soil      \             /     \    /        | HU
 surface---> \      ~\   _/       `--\/        |
              \   /  \_-/                      |
               \_/ _ _ _ _ _ _ _ _ _ _ _ _ v_ _ _ _ _ _ DATUM
```

Figure 1: Graphic representation of a soil surface to describe the HU variable. (Taken from Beasley and Huggins, 1991: ANSWERS User's Manual, 2nd edition).

Table 4: Typical surface storage coefficients.

Surface Condition	**HU (mm)**	**ROUGH**
Plowed Ground:		
Spring - smooth	100	0.53
Spring - normal	130	0.48
Spring - rough	130	0.59
Fall - smooth	60	0.37
Fall - normal	70	0.33
Fall - rough	130	0.45
Disked and Harrowed:		
Very smooth	30	0.42
Rather rough	60	0.43
Corn Stubble	110	0.59

(Table 4 taken from Beasley and Huggins, 1981).

037 This reads, in order:

AC(I) = canopy area (%)
AO(I) = area outside canopy (%)
BC(I) = bare area under canopy (%)
BO(I) = bare area outside canopy (%)
INRCOVI(I) = Interrill cover at the beginning of the rotation (% of area covered)
INRCOVF(I) = Interrill cover at the end of the rotation (% of area covered)
LIVEROOT(I) = live root mass in the soil at the end of the rotation (kg / m^2 in the upper 15 cm of the soil surface, used in the erosion module, and not the infiltration module).
DEADROOTI(I) = dead root mass in the soil at the beginning of the rotation (kg/m^2 in the upper 15 cm of the soil surface, used in the erosion module)
DEADROOTF(I) = dead root mass in the soil at the end of the rotation (kg/m^2 in the upper 15 cm of the soil surface, used in the erosion module)
Note: The dead root factor CANNOT increase during the rotation period, as this will create erroneous results.

The canopy area factors (AC, AO, BC, BO) are used to adjust infiltration in the model. The canopy area factor in the erosion module is also calculated from the area under the canopy. This factor is assumed to be 0 at the beginning of a rotation, and to increase until a maximum value of AC is reached. The interrill cover factors, and live and dead root adjustments are used in the erosion subroutines and do not affect infiltration.

Table 5: Quick Guide for Determining Roughness Parameters for Use in the ANSWERS Model

Land Use or Cover	**RC* (inches)**		**Manning's n**		**HU (inches)**	
	Range	**Default**	**Range**	**Default**	**Range**	**Default**
Row Crop						
Turn Plowed						
Smooth	0.40-0.50	0.45	0.070-0.100	0.085	10.0-30.0	10.5
Cultivated	0.45-0.60	0.52	0.090-0.120	0.110	10.5-40.0	20.5
Chisel Plowed						
Smooth	0.45-0.60	0.52	0.080-0.120	0.100	10.0-40.0	20.0
Cultivated	0.55-0.65	0.60	0.100-0.140	0.120	20.0-50.0	30.0
No-Till						
Normal Residue	0.55-0.65	0.60	0.100-0.150	0.120	10.0-40.0	20.0
Heavy Residue	0.60-0.70	0.65	0.130-0.170	0.150	20.0-50.0	30.0
Grass or Pasture**						
Poor Cover	0.35-0.45	0.40	0.065-0.100	0.080	00.5-20.0	10.0
Average Cover	0.40-0.50	0.45	0.090-0.120	0.100	10.0-30.0	10.5
Good Cover	0.45-0.55	0.50	0.100-0.140	0.120	10.0-30.0	10.5
Small Grains						
Residue Removed	0.40-0.50	0.45	0.090-0.120	0.100	10.0-30.0	10.5
Incorporated Residue	0.60-0.55	0.110-0.140	0.120	10.5-40.0	20.5	0.50
Forests or Wooded Areas**						
Light Woods	0.45-0.60	0.55	0.120-0.180	0.150	10.5-50.0	20.5
Heavy Woods	0.55-0.65	0.60	0.150-0.250	0.200	20.0-60.0	30.0
Plowed Ground						
Turn Plowed						
Smooth	0.25-0.35	0.30	0.01-0.05	0.035	10.0-30.0	10.5
Rough	0.65-0.80	0.75	0.25-0.50	0.350	20.0-120.0	60.0
Chisel Plowed						
Smooth	0.35-0.45	0.40	0.03-0.08	0.050	10.5-40.0	20.5
Rough	0.60-0.70	0.65	0.15-0.50	0.250	20.0-80.0	40.0
Disked						
Smooth	0.30-0.40	0.35	0.03-0.07	0.040	10.0-30.0	10.5
Rough	0.50-0.60	0.55	0.10-0.40	0.200	20.0-50.0	30.5

* The RC parameter is an exponent that describes the frequency of the surface roughness. The number varies from around 0.28 to 0.8. The larger the number, the more sinuous the surface profile (greater frequency).

**The additional cover afforded in the average or good categories also has an impact on the infiltration characteristics of the soil. This is due to prevention of crusting and to enhancement of soil surface organic matter contents.';'
(Taken from Beasley and Huggins, 1991: ANSWERS user's manual, 2nd edition).

Maximum physical retention depth (DIRM): The maximum physical retention depth

038 These are leaf area index (ratio of plant leaf area to surface area m^2/m^2) data for the crop. The program requires input for the growth stage divided into tenths (therefore there are eleven entries when you include the entry for growth stage 0.0). A good reference to obtain this information is the GLEAMS manual, Table H-7. Table H-7 has been reproduced below as table 6.

Table 6a: Idealized leaf area index (m^2/m^2) for representative crops under excellent management.

Fraction of Growing Season	Corn	Corn	Corn	Corn	Winter Small Grain	Winter Small Grain	Winter Small Grain
	Grain	Pop	Silage	Sweet	Barley	Oats	Rye
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.10	0.09	0.09	0.09	0.09	0.44	0.42	0.47
0.20	0.19	0.18	0.20	0.18	0.88	0.84	0.90
0.30	0.23	0.22	0.32	0.22	0.90	0.90	0.90
0.40	0.49	0.40	0.55	0.40	0.90	0.90	0.90
0.50	1.16	1.05	1.30	1.05	1.58	0.98	0.90
0.60	2.97	2.80	3.00	2.80	3.00	2.62	1.75
0.70	3.00	2.85	3.00	2.85	3.00	3.00	3.00
0.80	2.72	2.80	2.90	2.90	3.00	3.00	3.00
0.90	1.83	1.80	2.00	1.80	2.14	3.00	3.00
1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

039 DATPLA = planting date (day #)
DATHAR = harvest date (day #)
CP1 = exponent for nitrogen content
CP2 = exponent for nitrogen content
DMY = dry matter ratio
YP = yield potential (kg/ha)
ROTMAX = maximum rooting depth for crop i (mm)
RLAIMX = maximum LAI (m^2/m^2)

Table 7 contains recommended values for the C1 & C2 nitrogen exponents, Dry matter ratio, yield potential, and root depth.

Table 6-b: Idealized leaf area index (m^2/m^2) for representative crops under excellent management.

Fraction of Growing Season		Spring Small Grain	Spring Small Grain	Spring Small Grain	Sorghum	Sorghum
	Winter Wheat	Barley	Oats	Wheat	Grain	Forage
0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.10	0.47	0.34	0.32	0.37	0.09	0.10
0.20	0.90	0.58	0.54	0.60	0.19	0.30
0.30	0.90	0.90	0.90	0.90	0.23	0.80
0.40	0.90	1.25	1.20	1.28	0.54	1.50
0.50	0.90	1.80	1.60	1.70	1.35	2.80
0.60	1.62	2.50	2.30	2.30	2.98	3.00
0.70	3.00	3.00	3.00	3.00	3.00	3.00
0.80	3.00	3.00	3.00	3.00	2.72	3.00
0.90	3.00	2.25	2.90	3.00	1.84	2.80
1.00	0.00	0.00	0.00	0.00	1.00	2.00

Table 6-c: Idealized leaf area index (m^2/m^2) for representative crops under excellent management.

Fraction of Growing Season	Millet	Millet	Peanuts	Peanuts	Soybean	Soybean	Cotton
	Row	Bdcst.	2-row	4-row	Row	Bdcst.	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.10	0.16	0.20	0.15	0.20	0.15	0.19	0.13
0.20	0.45	0.60	0.42	0.55	0.40	0.48	0.28
0.30	1.20	1.50	1.80	2.00	1.90	2.10	1.05
0.40	2.10	2.25	2.80	2.95	2.60	2.70	2.15
0.50	2.90	3.00	3.00	3.00	3.00	3.00	2.96
0.60	3.00	3.00	3.00	3.00	2.96	3.00	3.00
0.70	3.00	3.00	3.00	3.00	2.92	2.95	2.96
0.80	2.95	2.96	3.00	3.00	2.30	2.35	2.92
0.90	2.30	2.45	2.80	2.85	1.15	1.25	1.78
1.00	1.80	1.85	2.60	2.65	0.50	0.50	1.00

Table 6-d: Idealized leaf area index (m^2/m^2) for representative crops under excellent management.

Fraction of Growing Season	Tobacco	Squash	Cabbage	Mustard	Onions	Potato	Tomato	Snap Beans
0.00	0.03	0.00	0.02	0.00	0.02	0.00	0.04	0.00
0.10	0.18	0.07	0.08	0.15	0.15	0.10	0.30	0.09
0.20	0.40	0.30	0.18	0.40	0.45	0.25	0.60	0.40
0.30	1.50	1.00	0.30	1.00	1.00	0.43	1.20	1.00
0.40	2.00	1.80	0.60	1.80	1.75	0.63	2.30	2.00
0.50	3.00	2.20	1.00	2.45	1.90	2.23	3.00	2.50
0.60	3.00	2.40	1.35	2.85	2.00	2.62	3.00	2.80
0.70	2.90	2.50	1.60	3.00	1.96	3.00	2.70	3.00
0.80	2.70	2.45	1.80	3.00	1.50	2.76	2.00	2.70
0.90	1.50	2.30	1.95	2.65	1.10	2.48	1.50	2.00
1.00	0.20	1.80	2.00	2.20	0.70	2.15	0.90	1.10

Table 6-e: Idealized leaf area index (m^2/m^2) for representative crops under excellent management.

Fraction of Growing Season	Southern Peas	Spin-ach	Leaf Lettuce	Head Lettuce	Cucu-mbers	Water-melon	Cantaloupe	Alfalfa
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
0.10	0.15	0.15	0.10	0.09	0.05	0.05	0.05	0.15
0.20	0.45	0.40	0.40	0.25	0.10	0.10	0.10	0.40
0.30	1.80	1.00	1.00	0.45	0.35	0.30	0.30	1.00
0.40	2.85	1.80	1.80	0.75	0.95	0.90	0.95	1.70
0.50	3.00	2.45	2.45	1.15	1.45	1.25	1.35	2.50
0.60	2.95	2.85	2.85	1.50	2.10	2.00	2.05	3.00
0.70	2.80	3.00	3.00	2.00	2.80	2.70	2.75	3.00
0.80	2.20	3.00	3.00	2.20	2.90	2.80	2.80	3.00
0.90	1.30	2.65	2.75	2.30	2.50	2.00	2.40	2.90
1.00	0.80	2.20	2.40	2.40	2.20	1.00	1.20	2.70

040 These are, in order:

RR=Random roughness of the soil surface (mm). See the WEPP documentation (1995), table 7.5.1 for recommended values of random roughness caused by different tillage implements.

BR=Buried residue within 0 to 0.15 meters of the soil surface (kg/m^2). Although there is no recommended value for this variable, the two studies from which this parameter was developed did not incorporate greater than 5,000 kg/ha.

PLHT=Maximum plant canopy height (m). This is limited to 3.0 meters in the program. If the plant height exceeds 3 meters, the model code must be altered.

GROWFACT = The amount of the crop's growth period required for the crop to reach full size and canopy. A recommended value is 0.5.

RSPC= Rill spacing (m or m/rill which equals meters between rills). Recommended value is 1.0 rill / meter. If the user inputs a 0, then a default value of 1 rill / meter will be used.

Table 6-f: Idealized leaf area index (m^2/m^2) for representative crops under excellent management.

Fraction of Growing Season	Bell Pepper	Carrots	Egg Plant	Sugar Beets	Turnips	Broccoli	Cauliflower	Sweet Potato
0.00	0.04	0.00	0.05	0.00	0.00	0.04	0.04	0.02
0.10	0.15	0.09	0.18	0.10	0.15	0.12	0.10	0.08
0.20	0.45	0.15	0.60	0.25	0.40	0.30	0.25	0.20
0.30	1.10	0.35	1.50	0.50	1.00	0.75	0.65	0.45
0.40	1.90	0.60	2.10	1.95	1.80	1.25	1.10	2.00
0.50	2.50	1.20	2.80	2.30	2.45	1.80	1.60	2.80
0.60	3.00	1.80	3.00	2.80	2.85	2.25	2.00	3.00
0.70	3.00	2.10	3.00	3.00	3.00	2.45	2.40	3.00
0.80	3.00	2.15	2.95	3.00	3.00	3.00	2.55	3.00
0.90	2.80	1.95	2.80	2.95	2.65	2.90	2.70	2.85
1.00	2.20	1.85	2.25	2.40	2.20	2.00	2.20	1.90

Table 6-g: Idealized leaf area index (m^2/m^2) for representative crops under excellent management.

Fraction of Growing Season	Rice	Winter Rape	Pasture	Conifer	Hard-wood	Conifer & Hard-wood
0.00	0.00	0.00	0.00	5.50	0.50	2.50
0.10	0.10	0.25	0.70	5.50	0.50	2.50
0.20	0.30	0.40	1.80	5.50	4.00	4.50
0.30	0.80	0.80	3.00	5.50	4.00	4.50
0.40	1.20	0.80	3.00	5.50	4.00	4.50
0.50	1.75	1.10	3.00	5.50	4.00	4.50
0.60	2.50	1.80	2.90	5.50	4.00	4.50
0.70	2.90	2.45	2.70	5.50	4.00	4.50
0.80	3.00	2.90	1.96	5.50	4.00	4.50
0.90	3.00	2.90	0.90	5.50	0.50	2.50
1.00	2.80	2.40	0.50	5.50	0.50	2.50

Tables 6-a through 6-g are taken from GLEAMS user's manual (Knisel et al., 1992).

MNSL= Manning's n for the bare soil.

MNTOT=Manning's n for the surface & cover.

NOTILL= 1 indicates a no-till or a conservation tillage condition where tillage will not obliterate rills that have been formed. 0 indicates conventional tillage and rill obliteration during plowing.

NOEROS = 0 a situation where erosion occurs. 1 = a situation where erosion does not occur (as in industrial land or parking lot). This variable became necessary when simulating large watersheds that contain areas where erosion generally does not occur. Setting this variable = 1 sets the rainfall and flow detachment variables equal to 0. during the simulation for that any cell that uses that cover. This does not set channel detachment to 0.

Manning's n total (MNTOT): The measure of surface roughness or flow retardance used in the flow equation in ANSWERS is Manning's n. This information, when combined with element slopes, rainfall, interception, infiltration, and routing considerations, helps yield the solution to the continuity equation, which is the basis of ANSWERS. There are numerous sources for obtaining reasonable values of n for channel and overland flow situations. (Taken from Beasley and Huggins, 1981).

036-040 These lines are repeated for additional crops/surfaces, up to 20 different entries.

041 The number of rotations used in the simulation.

042-045 Crop rotation information:

Rotation number, crop/surface descriptor number, end date for the rotation. The program will allow 28 rotation end dates, and a maximum of 20 rotations. If the rotation does not have 28 end dates, it must contain blank lines to accomodate the read order of the program. Note that the end dates for the crops correspond to harvest dates input for the crops. The harvest date of the previous crop and the plant date of the current crop cannot overlap. If there is a fallow condition, it must be input as a cropping practice.

042-045 The rotation information is repeated for each crop / surface.

046 The first two characters of this line are read to ensure proper file structure.

047 The maximum number of channel networks is 9.

048 The maximum number of channel types is 10.

049 This reads the width of channel type 1, in meters, Manning's n for bare soil in the channel, Manning's n for soil & vegetation in the channel, and depth to a non-erodible layer. The Manning's roughness coefficient for soil & vegetation is used to calculate conveyance for the channel, and to partition shear stress for vegetation in the channel. The depth to a non-erodible layer is used to calculate channel widening when a non-

erodible layer is reached. Until this layer is reached, all erosion is assumed to occur on the channel bottom. If there is no non-erodible layer, simply make this value a 1 or greater. The non-erodible depth variable is input in meters.

Table 7: Recommended inputs for the C1 & C2 nitrogen exponents, Dry matter ratio, yield potential, and root depth.

Crop	C1	C2	Dry Matter Ratio	Yield Potential (kg/ha)	Root Depth (mm)
Alfalfa-seed	2.8	-0.165	5	900	
Alfalfa-hay	2.8	-0.165	1	4,500	
Winter Barley-grain	1.15	-0.296	2.5	2,150	
Winter Barley-gr + straw	1.15	-0.296	1.35	4,390	
Spring Barley-grain	1.15	-0.296	2.5	1,880	
Spring Barley -gr + straw	1.15	-0.296	1.35	4,200	
Beans-dry	1	-0.350	2.5	1,950	300
Beans-snap	1.26	-0.299	2	6,720	300
Beets	0.3	-0.562	1.2	33,600	300
Bermuda Grass	1.25	-0.278	1.35	17,920	
Bluegrass	1.5	-0.239	1.35	4,480	
Broccoli	0.89	-0.352	2.5	7,392	300
Bromegrass	0.89	-0.352	1.35	11,200	
Brussel Sprouts	0.87	-0.357	2.5	10,752	300
Cabbage	0.38	-0.537	1.5	44,800	300
Cantaloupes	0.34	-0.535	2	22,400	450
Carrots	0.35	-0.529	1.2	33,600	300
Cauliflower	0.38	-0.537	1.5	16,800	300
Clover	3	-0.151	1.35	4,480	
Corn-grain	1.3	-0.264	2.5	9,400	
Corn-pop	1.3	-0.264	2.5	3,760	450
Corn-silage	0.4	-0.548	1.35	44,800	
Corn-sweet	1.5	-0.213	2.5	9,400	450
Cotton	2.6	-0.119	2.5	2,240	
Cowpeas-hay	3	-0.151	1.35	4,480	600
Cucumbers	0.34	-0.535	2	13,440	300
Eggplant	0.4	-0.548	2	28,000	450
Lettuce-leaf	0.17	-0.657	1.5	33,600	300
Lettuce-head	0.17	-0.657	1.5	44,800	300
Lespedeza	2.05	-0.214	1.35	4,480	
Millet, row-grain	1.3	-0.264	5	3,000	
Millet, row-gr+forage	1.3	-0.264	1.35	11,200	
Millet, bdcast-grain	1.3	-0.264	5	3,000	
Millet, bdcast-gr+for	1.3	-0.264	1.35	13,000	
Mustard greens	0.36	-0.494	1.35	22,400	300

Winter Oats-grain	1.3	-0.244	3	3,200	
Winter Oats -gr+straw	1.3	-0.244	1.35	7,680	
Spring Oats -grain	1.3	-0.244	3	2,800	
Spring Oats -gr+straw	1.3	-0.244	1.35	7,000	
Onions	0.29	-0.570	1.2	44,800	300
Orchardgrass	2.5	-0.128	1.35	13,440	
Peas	1.12	-0.325	2.25	6,720	300
Pepper, bell	0.31	-0.555	2	22,400	300
Peanuts, 2-row	3.66	-0.107	2.2	4,480	450
Peanuts + hay, 2-row	3.66	-0.107	1.1	8,960	450
Peanuts, 4-row	3.66	-0.107	2.2	5,040	450
Peanuts + hay, 4-row	3.66	-0.107	1.1	9,800	450
Potatoes - Irish	0.43	-0.484	1.25	39,200	300
Rape seed	0.36	-0.494	3	3,000	
Rice	1.37	-0.258	2.5	4,540	
Winter Rye - grain	1.05	-0.290	3	1,880	
Winter Rye - gr + straw	1.05	-0.290	1.35	5,240	
Spring Rye - grain	1.05	-0.290	3	1,700	
Spring Rye - gr + straw	1.05	-0.290	1.35	5,000	
Safflower	1.2	-0.261	3	1,120	
Sorghum - grain	1.67	-0.190	3	5,000	
Sorghum -forage	1.4	-0.228	1.35	11,200	
Soybeans, row	2.3	-0.208	2.25	3,020	
Soybeans, broadcast	2.3	-0.208	2.25	3,200	
Spinach	0.36	-0.494	1.35	22,400	300
Squash	0.34	-0.535	2	33,600	300
Sugarbeets	0.3	-0.562	1.8	44,800	600
Sugarcane	0.17	-0.686	1.8	67,200	
Sunflower	1.2	-0.261	3	2,240	
Sweet potatoes	0.42	-0.489	1.3	22,400	600
Timothy grass	1.2	-0.261	1.35	5,600	
Tobacco	3.84	-0.034	2	3,360	
Tomatoes	0.27	-0.556	1.45	56,000	600
Turnips	0.36	-0.494	1.1	36,300	300
Watermelon	0.34	-0.535	1.5	22,400	600
Winter Wheat -grain	1	-0.301	2.5	3,360	
Winter Wheat -gr + straw	1	0.301	1.35	6,720	
Spring Wheat -grain	1	-0.301	2.5	3,000	
Spring Wheat -gr + straw	1	-0.301	1.35	6,000	
Weeds	1.1	-0.264	0	1,000	

Table 7 taken from GLEAMS user's manual (Knisel et al., 1992)

050- This is the descriptive info for channel #2.

051 This reads the title for the element specifications and uses it for an output heading.

052 This reads the size of each overland flow element (m). The maximum permitted value is 100m. The cell size is square.

053 This reads the row and column number of the outlet of channel network #1, and then the number of cells in the watershed that contribute to this channel network. The number of cells is calculated by a GIS, and may be difficult to calculate by hand for large watersheds.

053- Outlet cell specifications are repeated for the remaining channel networks.

054 This begins the input of elemental specifications.

a b c d e f g h i j k l m n o p q r s
t u v w

(Note: the letters may not line up exactly as the input data should align. Please check the input format for proper alignment).

a: This is the row number of the element.
b: This is the column number of the element.
c: THIS COLUMN IS BLANK: A '9' in this column indicates last element in list.
d: This is the slope steepness in tenths of a percent (2.9% = 29)
e: This is the aspect of the cell, or the direction of steepest slope in counter-clockwise degrees from a horizontal line from the center of the element and directed to the right.
f: The channel network or soil type designator. If there is a channel cell in this cell, then it is described using a 7 digit number such as: 1020304, where 1 is the channel network to which this channel cell belongs, 02 is the channel type of this channel (to determine width), 03 is the soil type of this channel cell, and 04 is the soil type of the parent overland flow cell. If there is not a channel cell in this cell, then this number represents the soil type of this cell (04).
g: This is the rotation # for the cell.
h: This is the rain gage designator for this cell.
i: If there is tile drainage in this cell, indicate this by the letters 'TI'. Any other combination represents no tile drainage.
j: This is the channel slope in tenths of a percent. If there is a channel cell present, and this value is not specified, the channel slope will be assumed to equal one-half of the overland flow slope.
k: This is the number of any BMP structural practice type (see Table 8 and the BMP description section below).
l: This contains the trapping efficiency of ponds / BMPs if they are present. See BMP description section below.
m: This is the BMP width # if a structural BMP is present and this input is required. See BMP description section and Table 8 below.
n: SORGP = soil organic P (kg/ha)
o: EDI = effective depth of interaction (mm)

p: active mineral P (kg/ha)
q: stable soil P (kg/ha)
r: labile P (kg/ha)
s: potentially mineralizable soil N (kg/ha), also known as organic nitrogen (kg/ha).
t: total NH4 present in soil (kg/ha)
u: stable soil organic N (kg/ha)
v: nitrate present in soil (kg/ha)

BMP description section: ANSWERS handles BMPs in two different ways. Practices, which are strictly tillage-oriented, are described in both the soils and land use sections. This is due to the fact that tillage-based management changes can affect both the infiltration response and the surface condition of the soil. On the other hand, those BMPs which are structural in nature or which require a change in land use (row crop to grass for waterways or field borders, for example) are described in the individual element data file. The primary tillage based BMPs considered by ANSWERS are:

1. Change from conventional tillage (fall turning plow) to chisel plowing,
2. Change from conventional tillage to minimum tillage,
3. Change from conventional tillage to no-till.

Each of these has similar effects, but to a different degree upon both the soils and land use (surface) descriptors. This necessitates describing both 'new' soils and land uses. When conventional tillage is replaced by chisel plowing (#1), the infiltration components (A & FC) should be increased approximately 20 percent. At the same time, the surface descriptors (HU and RN) should be increased by approximately 15 percent. In changing from conventional tillage to minimum tillage techniques (#2), the infiltration and surface parameters should be increased by approximately 25 % and 20 %, respectively. The change from conventional to no-till (#3) requires increases of approximately 25 % for both infiltration and surface parameters. Table 8 lists the BMP codes, which are based upon structures or land-use changes, and assumptions made for each BMP. (BMP info taken from Beasley and Huggins, 1981).

Table 8: Structural and Land Use Change BMP Descriptions.

BMP	Code No.	Additional Information	Assumptions
Tile Outlet Terraces	1		a) Sediment trapping efficiency of 90% b) Only lowermost terraces are described
Sedimentation Pond	2		a) Trap efficiency of 95% b) Only ponds in upland areas should be defined, instream structures are treated differently.
Grassed Waterways	3	Width	Decreases erodibility
Field Borders	4	Total Width	Decreases erodibility

(Table 8 taken from Beasley and Huggins, 1981).

055- Remaining cellular input data.
END

Fertilizer Input File

001 This line isn't read, but is for description.
002 This line isn't read, but is for description.
003 This reads:

- a) Year of application
- b) Day of application
- c) Crop # of application.
- d) Nitrate present in fertilizer (kg/ha)
- e) Ammonium present in fertilizer (kg/ha)
- f) Phosphate present in fertilizer (kg/ha)

This is read until the end of the file is reached, and then control is returned to the main program. The model does not simulate the application of organic fertilizers.

Weather Input File

001 This reads:

- a) Air temp (^oC)
- b) Soil temp (^oC)
- c) daily radiation (Langleys)
- d) rain flag (1 indicates a rain event is about to occur)

(The numbers after this are used for bookkeeping by the user.)

002-006 Data for subsequent days. When the number 1 is read in the fourth column of line 006, it signals that a rain event is about to occur.

007 This is the rain gage alphanumeric descriptor. If there is more than one rain gage, the input file will read the name of the first, then the storm information, and then the name of the second and the storm information for gage number 2, up to the total # of rain gages (maximum of 8 with 35 values per gage). Note that more than 35 values per rain gage will result in a run-time error.

008 This reads:

- a) flag (0=rain, 1 = no-rain)
- b) time in minutes
- c) rainfall intensity (mm/h)

Note that this means that the rainfall intensity in column c occurs to the time in minutes listed in column 2 from the time listed in column 2 in the previous lines entry.

This is repeated until the end of the file.

Appendix D: Example Input File.

The first line is input, the second is read format.

```
EXAMPLE DATA FILE ..........................................................................................001
          19A4
 METRIC  UNITS ARE USED ON INPUT/OUTPUT ........... PRINT.........................002
          1X,A4,52X,A4
 STORM BY STORM OUTPUT = 0 ............................................................................003
          24X,10(1X,I7)
 EXTRA OUTPUT ON DAYS  = 1950365 1950298 ....................................................004
          24X,10(1X,I7)
 PRINT HYDROGRAPHS = 1 .........................................................................004b
          24X,I2
 RAINFALL DATA FOR 1 RAINGAUGES ...............................................................005
          A4,15X,I1,25X,2A4
 BEGINNING JULIAN DAY OF SIMULATION 001 1999.......................................006
          1X,35X,I3,1X,I4
 DURATION OF SIMULATION DAYS 0365 .............................................................007
          1X,28X,I4
 GAUGE NUMBER   R1..............................................................................................008
          16X,A2
  SIMULATION CONSTANTS FOLLOW...................................................................009
          A4,15X,I1,25X,2A4
 NUMBER OF LINES OF HYDROGRAPH OUTPUT = 101.....................................010
          39X,I4/
 TIME INCREMENT =  60. SEC.........................................................................011
          17X,F5.1/
 INFILTRATION CAPACITY CALCULATED EVERY 180. SECONDS..................012
          39X,I5/
 EXPECTED RUNOFF PEAK =850. MM/HR .............................................................013
          23X,F5.2
  SOIL INFILTRATION, DRAINAGE AND GROUNDWATER CONSTANTS FOLLOW
          014
          A4,15X,I1,25X,2A4
 NUMBER OF SOILS =  1 .............................................................................015
          18X,I4
 S 1, TP =.50, FP =.43, WP =  .21, A =1.000, DF =228.0, ASM =.43...........................016
          10X,F3.2,6X,F3.2,6X,F5.2,5X,F5.3,6X,F5.1,7X,F3.2
 CONDUCTIVITY OPTION = 0.........................................................................017
          23X,I1,9X,F5.2
 21.  58.  21.  2.0  5.5 4.5     ..........................................................................018
          1X,F4.1,1X,F4.1,1X,F4.1,1X,F4.2,1X,F4.1,1X,F4.1
  PARTICLE SIZE AND TRANSPORT DATA FOLLOWS .......................................019
          /
 NUMBER OF PARTICLE SIZE CLASSES  = 3 .......................................................020
          36X,I2/
```

```
NUMBER OF WASH LOAD CLASSES      = 0.........................................................021
          36X,I2
  SIZE  SPECIFIC GRAVITY  FALL VELOCITY.....................................................022
          /
0.002          2.65          0.000003 .....................................................................023
          1X,F15.8,F15.3,F15.7
0.010          2.65          0.000080 .....................................................................024
0.200          2.65          0.024000 .....................................................................025
0.210 0.210 0.580  1..............................................................................026
          1X,8F6.3
 5.0690 20.0000  4.0000  0.0500 ......................................................................027
          1X,9F8.4
DRAINAGE EXPONENT = 3,.........................................................................028
          20X,I2/
DRAINAGE COEFFICIENT FOR TILE DRAINS = 0.00 MM/24HR.......................029
          39X,F5.2/
GROUNDWATER RELEASE FRACTION =   0.000 ...............................................030
          31X,E10.3
FERTILIZER APPLIED = 1.........................................................................031
          21X,I2
 IMPOUNDMENT SPECIFICATIONS FOLLOW.....................................................032
          /
NUMBER OF IMPOUNDMENTS = 0.........................................................................033
          1X,25X,I2
 SURFACE ROUGHNESS AND CROP CONSTANTS FOLLOWS..........................034
          A4,15X,I1,25X,2A4
NUMBER OF CROPS AND SURFACES =  7 ..........................................................035
          31X,I3
C 1,      alfalfa ,    0.40     0.05    0.75    60.0       1.00 .................................................036
          11X,2A4,6X,F3.2,6X,F3.2,5X,F3.2,4X,F4.2,4X,F5.3
50.0  50.0 50.0 50.0 25.0 75.0 0.14 0.14 0.07.............................................................037
          1X,6(F4.1,1X),3(F4.2,1X)
0.05 0.15 0.40 1.00 1.70 2.50 3.00 3.00 3.00 2.70 .......................................................038
          1X,11(F4.2,1X)
279 151 2.80 -0.165  1.00   9000  100 3.00.................................................................039
          1X, I3, 1X, I3, 1X, F4.2, 1X, F6.3, 1X, F5.2, 1X, F7.1, 1X, I3, 1X, F4.2
 51.0  0.14  1.00  0.50  1.00  0.03  0.08  0  0................................................................040
          1X,F5.1,1X,F5.3,1X,F5.2,1X,F5.2,1X,F5.2,1X,F5.3,1X,F5.3,11X,I2,1X,I2
NUMBER OF ALL ROTATIONS      =  1.................................................................041
          31X,I3
 1  6 1950151  3 1950278  6 1951151  3 1951278  6 1952151  3 1952278  6 1953151.042
 3 1953278  6 1954151  3 1954278  6 1955151  3 1955278  6 1956151  .....................043
           044
          045
          1X,I2,1X,7(I2,1X,I7,1X)/4X,7(I2,1X,I7,1X)/4X,7(I2,1X,I7,1X),/,4X,7(I2,1X,I7,1X)
```

```
  CHANNEL SPECIFICATIONS FOLLOW ..............................................................046
          A4,15X,I1,25X,2A4
 NUMBER OF CHANNEL NETWORKS  =  1, ........................................................047
          30X,I3
 NUMBER OF TYPES OF CHANNELS =  2,............................................................048
          30X,I3
CHAN 1 WID = 2.5  M., SOIL N = 0.040 CHAN N = 0.100 0.15 0.62........................050
          13X,F4.1,14X,F6.3,9X,F6.3,1X,F4.2,1X,F4.2
  ELEMENT SPECIFICATIONS FOR EXAMPLE FARM ........................................051
          A4,24X,11A4
 EACH ELEMENT IS  50.00  m. SQUARE................................................................052
          16X,F7.2
NETWORK 1 OUTFLOW FROM ROW  12  COLUMN   5       50 ............................053
          27X,I4,8X,I4,5X,I4
2  5 0  4 315      1   1   R1       0  0   0   0   24210   16   63   59     ................................054
          2I3,I2,I3,I4,1X,I7,I4,3X,A2,1X,A2,2X,I4,I3,2I4,I6,I2,I5,I5,I5
262    6  595    16 ..........................................................................................055
          3I5,I6
  a  b c  d   f     g   h    j  k    i  l   m   n     o p    q    r    s
    t    u    v     w
  2  6 0 15 315      1   1   R1       0  0   0   0   24210   16   63   59     ............................056
  262    6  595    16
  3  6 0 22 360      1   1   R1       0  0   0   0   24210   16   63   59
  262    6  595    16
  3  7 0 23 360      1   1   R1       0  0   0   0   24210   16   63   59
  262    6  595    16
  4  6 0 16 360      1   1   R1       0  0   0   0   24210   16   63   59
  262    6  595    16
  4  7 0 22 360      1   1   R1       0  0   0   0   24210   16   63   59
  262    6  595    16
  5  6 0  8  45      1   1   R1       0  0   0   0   24210   16   63   59
  262    6  595    16
  5  7 0  5  90      1   1   R1       0  0   0   0   24210   16   63   59
  262    6  595    16
  6  3 0  4 315      1   1   R1       0  0   0   0   24210   16   63   59
  262    6  595    16
  6  4 0 14 315      1   1   R1       0  0   0   0   24210   16   63   59
  262    6  595    16
  6  5 0 11 270      1   1   R1       0  0   0   0   24210   16   63   59
  262    6  595    16
  6  6 0 18 315      1   1   R1       0  0   0   0   24210   16   63   59
  262    6  595    16
  6  7 0 19 270      1   1   R1       0  0   0   0   24210   16   63   59
  262    6  595    16
  7  3 0 22 315      1   1   R1       0  0   0   0   24210   16   63   59
  262    6  595    16
```

7 4 0 33 315 1 1 R1 0 0 0 0 24210 16 63 59
262 6 595 16
7 5 0 32 270 1 1 R1 0 0 0 0 24210 16 63 59
262 6 595 16
7 6 0 30 270 1 1 R1 0 0 0 0 24210 16 63 59
262 6 595 16
7 7 0 25 360 1 1 R1 0 0 0 0 24210 16 63 59
262 6 595 16
8 3 0 19 315 1 1 R1 0 0 0 0 24210 16 63 59
262 6 595 16
8 4 0 39 315 1 1 R1 0 0 0 0 24210 16 63 59
262 6 595 16
8 5 0 36 270 1 1 R1 0 0 0 0 24210 16 63 59
262 6 595 16
8 6 0 30 225 1 1 R1 0 0 0 0 24210 16 63 59
262 6 595 16
8 7 0 18 270 1 1 R1 0 0 0 0 24210 16 63 59
262 6 595 16
9 2 0 18 315 1 1 R1 0 0 0 0 24210 16 63 59
262 6 595 16
9 3 0 36 270 1 1 R1 0 0 0 0 24210 16 63 59
262 6 595 16
9 4 0 39 270 1 1 R1 0 0 0 0 24210 16 63 59
262 6 595 16
9 5 0 24 315 1 1 R1 0 0 0 0 24210 16 63 59
262 6 595 16
9 6 0 29 315 1 1 R1 0 0 0 0 24210 16 63 59
262 6 595 16
9 7 0 32 270 1 1 R1 0 0 0 0 24210 16 63 59
262 6 595 16
10 2 0 29 360 1 1 R1 0 0 0 0 24210 16 63 59
262 6 595 16
10 3 0 50 315 1010101 1 R1 0 0 0 0 24210 16 63 59
262 6 595 16
10 4 0 40 270 1010101 1 R1 0 0 0 0 24210 16 63 59
262 6 595 16
10 5 0 28 270 1 1 R1 0 0 0 0 24210 16 63 59
262 6 595 16
10 6 0 33 360 1 1 R1 0 0 0 0 24210 16 63 59
262 6 595 16
10 7 0 36 360 1 1 R1 0 0 0 0 24210 16 63 59
262 6 595 16
11 2 0 43 360 1 1 R1 0 0 0 0 24210 16 63 59
262 6 595 16
11 3 0 47 315 1 1 R1 0 0 0 0 24210 16 63 59
262 6 595 16

11 4 0 37 315 1010101 1 R1 0 0 0 0 24210 16 63 59
262 6 595 16
11 5 0 48 270 1 1 R1 0 0 0 0 24210 16 63 59
262 6 595 16
11 6 0 41 225 1 1 R1 0 0 0 0 24210 16 63 59
262 6 595 16
11 7 0 22 270 1 1 R1 0 0 0 0 24210 16 63 59
262 6 595 16
12 1 0 21 360 1 1 R1 0 0 0 0 24210 16 63 59
262 6 595 16
12 2 0 38 360 1 1 R1 0 0 0 0 24210 16 63 59
262 6 595 16
12 3 0 38 360 1010101 1 R1 0 0 0 0 24210 16 63 59
262 6 595 16
12 4 0 30 360 1010101 1 R1 0 0 0 0 24210 16 63 59
262 6 595 16
12 5 0 40 270 1010101 1 R1 0 0 0 0 24210 16 63 59
262 6 595 16
12 6 0 35 315 1 1 R1 0 0 0 0 24210 16 63 59
262 6 595 16
12 7 0 32 270 1 1 R1 0 0 0 0 24210 16 63 59
262 6 595 16
13 6 0 13 360 1 1 R1 0 0 0 0 24210 16 63 59
262 6 595 16
13 7 9 22 360 1 1 R1 0 0 0 0 24210 16 63 59
262 6 595 16 ....

```
*******************FERTILIZER INPUT FILE**********************

 FERTILIZER INPUTS FOR ANSWERS SIMULATION........................................ 001
*
 YEAR|DAY|CROP#|---NO3---|---NH4---|---PO4---| ................................................ 002
*
 1950 152   2     135.        0.       34.................................................................. 003
         1X,I4,1X,I3,1X,I5,3(1X,F9.4)
THIS IS READ UNTIL THE END OF THE FILE
******************END FERTILIZER INPUT FILE*******************

***************WEATHER INPUT FILE************************
   17   17  585 0   152...................................................................................... 001
         1X,I4,1X,I4,1X,I4,1X,I1,1X,I1
   20   20  418 0   153...................................................................................... 002
   18   18  523 0   154...................................................................................... 003
   15   15  510 0   155...................................................................................... 004
   18   18  673 0   156...................................................................................... 005
   16   16  521 1   157...................................................................................... 006
 GAUGE NUMBER   R1 ........................................................................................ 007
         16X,A2
0      0.       27.              ........................................................................... 008
         A1,F8.0,F10.0
0      6.      408.              ........................................................................... 009
......(etc., until the end of the file)
***************END WEATHER INPUT FILE****************
```

Appendix E: Sensitivity Analysis Parameters.

VARIABLE	BASE VALUE	SIMULATED VALUE	SEDIMENT RELATIVE SENSITIVITY	RUNOFF RELATIVE SENSITIVITY
TP	0.5	0.38	-1.546	-1.046
TP	0.5	0.45	-1.702	-1.211
TP	0.5	0.55	-1.931	-1.211
TP	0.5	0.63	-1.933	-1.269
FP	0.43	0.32	-1.005	0.048
FP	0.43	0.39	-0.923	0.036
FP	0.43	0.47	-0.932	0.036
FP	0.43	0.54	-1.028	0.044
CL	21	15.8	0.348	0.412
CL	21	18.9	0.443	0.569
CL	21	23.1	0.262	0.448
CL	21	26.3	0.145	0.252
SA	58	43.5	-3.151	0.232
SA	58	52.2	-3.102	0.400
SA	58	63.8	-3.495	0.145
SA	58	72.5	-3.421	-0.068
ST	21	15.8	0.112	0.107
ST	21	18.9	0.092	0.121
ST	21	23.1	0.104	0.145
ST	21	26.3	0.111	0.160
OM	2	1.5	-0.319	0.034
OM	2	1.8	-0.320	0.024
OM	2	2.2	-0.324	0.036
OM	2	2.5	-0.321	0.034
WCF	5.5	4.1	0.021	0.010
WCF	5.5	5.0	0.020	0.000
WCF	5.5	6.1	0.020	0.012
WCF	5.5	6.9	0.020	0.010
VFS	4.5	3.4	0.001	0.000
VFS	4.5	4.1	0.001	0.000
VFS	4.5	5.0	0.001	0.000
VFS	4.5	5.6	0.001	0.000
RR	43	32.3	-0.008	0.000
RR	43	38.7	-0.008	0.000
RR	43	47.3	-0.007	0.000
RR	43	53.8	-0.007	0.000
BR	0.04	0.03	0.000	0.000
BR	0.04	0.036	0.000	0.000
BR	0.04	0.044	0.000	0.000
BR	0.04	0.05	0.000	0.000
MAXPLHGT	1	0.75	0.084	0.000

VARIABLE	BASE VALUE	SIMULATED VALUE	SEDIMENT RELATIVE SENSITIVITY	RUNOFF RELATIVE SENSITIVITY
MAXPLHGT	1	0.9	0.082	0.000
MAXPLHGT	1	1.1	0.080	0.000
MAXPLHGT	1	1.25	0.079	0.000
GROWFACT	0.5	0.38	0.016	0.000
GROWFACT	0.5	0.45	0.016	0.000
GROWFACT	0.5	0.55	0.013	0.000
GROWFACT	0.5	0.62	0.013	0.000
RILLSPC	1	0.75	0.655	0.000
RILLSPC	1	0.9	0.562	0.000
RILLSPC	1	1.1	0.474	0.000
RILLSPC	1	1.25	0.426	0.000
MANNSOIL	0.03	0.023	0.041	0.000
MANNSOIL	0.03	0.027	0.064	0.000
MANNSOIL	0.03	0.033	0.092	0.000
MANNSOIL	0.03	0.038	0.126	0.000
MANNTOT	0.08	0.060	-0.855	-0.097
MANNTOT	0.08	0.072	-0.709	-0.097
MANNTOT	0.08	0.088	-0.659	-0.048
MANNTOT	0.08	0.100	-0.587	-0.082
NOTILL[1]	0	1	0.000	0.000
NOEROS[1]	0	1	0.000	0.000
MANNCHAN	0.04	0.030	0.040	0.000
MANNCHAN	0.04	0.036	0.046	0.000
MANNCHAN	0.04	0.044	0.054	0.000
MANNCHAN	0.04	0.050	0.059	0.000
MANNTOT	0.1	0.075	-0.056	0.063
MANNTOT	0.1	0.090	-0.043	0.048
MANNTOT	0.1	0.110	-0.033	0.048
MANNTOT	0.1	0.125	-0.028	0.039
CHANWID	2.5	1.9	0.010	0.039
CHANWID	2.5	2.3	0.012	0.048
CHANWID	2.5	2.8	0.010	0.036
CHANWID	2.5	3.1	0.007	0.024
AC	50	37.50	-0.839	-0.702
AC	50	45.00	-0.790	-0.460
AC	50	55.00	-0.762	-0.327
AC	50	62.50	-0.741	-0.291
AO	50	37.50	-0.170	-0.324
AO	50	45.00	-0.156	-0.242
AO	50	55.00	-0.149	-0.206
AO	50	62.50	-0.142	-0.184
BC	50	37.50	0.165	0.213

VARIABLE	BASE VALUE	SIMULATED VALUE	SEDIMENT RELATIVE SENSITIVITY	RUNOFF RELATIVE SENSITIVITY
BC	50	45.00	0.177	0.230
BC	50	55.00	0.193	0.303
BC	50	62.50	0.214	0.421
BO	50	37.50	0.114	0.150
BO	50	45.00	0.118	0.157
BO	50	55.00	0.126	0.194
BO	50	62.50	0.134	0.237
INRCOVI	25	18.8	-0.233	0.000
INRCOVI	25	22.5	-0.226	0.000
INRCOVI	25	27.5	-0.216	0.000
INRCOVI	25	31.3	-0.207	0.000
INRCOVF	75	56.3	-1.427	0.000
INRCOVF	75	67.5	-1.251	0.000
INRCOVF	75	82.5	-1.063	0.000
INRCOVF	75	93.8	-0.948	0.000
LIVEROOT	0.14	0.11	-0.053	0.000
LIVEROOT	0.14	0.13	-0.044	0.000
LIVEROOT	0.14	0.15	-0.043	0.000
LIVEROOT	0.14	0.18	-0.068	0.000
DDROOTI	0.14	0.11	-0.024	0.000
DDROOTI	0.14	0.13	-0.020	0.000
DDROOTI	0.14	0.15	-0.020	0.000
DDROOTI	0.14	0.18	-0.032	0.000
DDROOTF	0.07	0.05	-0.029	0.000
DDROOTF	0.07	0.06	-0.037	0.000
DDROOTF	0.07	0.08	-0.036	0.000
DDROOTF	0.07	0.09	-0.029	0.000
ARMOUR	0.5	0.38	-0.016	0.000
ARMOUR	0.5	0.45	-0.016	0.000
ARMOUR	0.5	0.55	-0.016	0.000
ARMOUR	0.5	0.62	-0.016	0.000

1. Value actually > 0, see text.

Appendix F: Relative location of survey points in the Goodwin Creek watershed.

Cross-Section ID	Easting[1] (m)	Northing[1] (m)
C4-8	231664	3791560
C4-17	231752	3791598
C5-2	231810	3791642
C5-6	231846	3791700
C5-10	231864	3791750
C6-6	231900	3791838
C7-4	231953	3791896
C8-5	232023	3792009
C10-1	232118	3792101
C41-3	232201	3792232
GC-50	232293	3792349
C43-2	232297	3792480
C45-1	232319	3792478
C46-1	232429	3792594
C47-2	232444	3792677
C50-1	232536	3792800
T1-1	232735	3793018
T2-2	232847	3793126
T3-5	232943	3793229
GC-100	233034	3793315
T14-6	233735	3793805
T64-2	234403	3793863
Outlet[2]	231765	3791505

[1] Values are UTM Zone 16 meters.
[2] Calculated outlet.

VITA

Wes Byne was born in Augusta, Georgia on January 2, 1974 to John and Sarah Byne. He graduated from the University of Georgia in June 1997 with a B.S. in Agricultural Engineering. Currently he is employed by the Biological and Agricultural Engineering Department at the University of Georgia as a Research Engineer.