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Environmental Protection Technology Series

MODELING PESTICIDES AND NUTRIENTS ON AGRICULTURAL LANDS

Environmental Research Laboratory
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MODELING PESTICIDES AND NUTRIENTS ON AGRICULTURAL LANDS

by

Anthony S. Donigian, Jr.
Norman H. Crawford

Hydrocomp, Incorporated
Palo Alto, California 94304

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Project Officer

George W. Bailey
Environmental Research Laboratory
U.S. Environmental Protection Agency
Athens, Georgia 30601

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF RESEARCH AND DEVELOPMENT
ENVIRONMENTAL RESEARCH LABORATORY
ATHENS, GEORGIA 30601

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ABSTRACT

Modifications, testing, and further development of the Pesticide Transport and Runoff (PTR) Model have produced the Agricultural Runoff Management (ARM) Model presented in this report. The ARM Model simulates runoff, snow accumulation and melt, sediment loss, pesticide-soil interactions, and soil nutrient transformations. The Model is capable of simulating sediment, pesticide, and nutrient content of runoff from small agricultural watersheds. The report discusses the major modifications to and differences between the PTR and the ARM Models. Detailed presentation of an energy-balance method of snow simulation, and a first-order transformation approach to nutrient modeling are included. Due to lack of data, the nutrient model was not tested with observed data; testing and refinement are expected to begin in the near future.

Instrumented watersheds in Georgia provided data for testing and refinement of the runoff, sediment and pesticide portions of the ARM Model. Comparison of simulated and recorded values indicated good agreement for runoff and sediment loss, and fair to good agreement for pesticide loss. Pesticides which are transported only by sediment particles were simulated considerably better than pesticides which move both in solution and on sediment. These results indicate the need for further study of methods to simulate those pesticides which are transported by both mechanisms. A sensitivity analysis of the ARM Model parameters demonstrated that soil moisture and infiltration, land surface sediment transport, pesticide-soil interactions, and pesticide degradation are the critical mechanisms in simulating pesticide loss from agricultural watersheds. Recommendations are included for (1) additional research on these mechanisms, (2) modification of the ARM Model to simplify application and use, and (3) demonstration of the use of the ARM Model in agricultural land planning and management.

This report was submitted in fulfillment of Research Grant No. R803116-01-0 by Hydrocomp, Incorporated under the sponsorship of the Environmental Protection Agency. Work completed as of September 1975.

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ACKNOWLEDGEMENTS

Many people and organizations were instrumental to the successful completion of this project. Dr. George W. Bailey, and his staff at the EPA Environmental Research Laboratory in Athens, Georgia (ERL-Athens), provided coordination, data, and assistance critical to the project work. The ERL-Athens sponsored cooperative agreements for data collection and analysis programs with the USDA Southern Piedmont Conservation Research Center (SPCRC) in Watkinsville, Georgia and the Michigan State University Departments of Crop and Soil Science, and Entomology in East Lansing, Michigan. Dr. Ralph Leonard and his staff at the SPCRC were responsible for the watershed instrumentation and runoff sampling program in Georgia, and provided assistance for hydrologic and sediment data analysis and interpretation. The Michigan program was operated by Dr. Boyd G. Ellis and his staff at MSU who supplied watershed information, meteorologic data, and historical data for calibration purposes. The individual staff members of all these supporting programs are too numerous to mention without the possibility of omission; their dedication to the program and their assistance to Hydrocomp is gratefully acknowledged.

Numerous individuals at Hydrocomp contributed to this project throughout its duration. Dr. Norman H. Crawford, as principal investigator, provided the general direction of the research effort. Mr. Anthony Donigian, Jr., project manager, supervised the project work and the final report. Calibration, model development, and programming were ably performed by Mr. Douglas C. Beyerlein and Mr. James Hunt; Mr. Hunt was singularly responsible for the nutrient model development and wrote the corresponding section of the final report. Data analysis and technical assistance were provided by Mr. Howard Yamaguchi, Mr. John C. Imhoff, and Ms. Danielle Wellander. Mrs. Margaret Muller patiently performed artistic and graphical consultation, and supplied drafting expertise. Clerical assistance and support throughout the project was provided by Ms. Suzi Cummins and Ms. Donna D'Onofrio.

SECTION I

CONCLUSIONS

(1) The Agricultural Runoff Management (ARM) Model has been used successfully for simulating runoff, sediment, and pesticide loss from small agricultural watersheds. Model testing for sediment and pesticide loss has been performed on watersheds in the Southern Piedmont and is presently underway on watersheds in the Great Lakes region.

(2) The simulation of surface runoff with the ARM Model has been verified by split-sample testing for the Southern Piedmont watersheds. The hydrology parameters calibrated on six months of 1972 data allowed the Model to simulate 1973 data with reasonable accuracy. Past experience with the hydrologic simulation methodology indicates that similar accuracy can be expected in other geographical regions.

(3) The method of snowmelt simulation presented in this report has been employed successfully on watersheds across the United States. Although its use on small agricultural watersheds has been limited, the methodology of energy balance calculations is conceptually valid. Calibration and testing is presently underway on watersheds in the Great Lakes region.

(4) Tillage operations and practices have a significant impact on both surface runoff and sediment loss from watersheds in the Southern Piedmont. The effect is relatively greater on sediment loss than on surface runoff and tends to decrease with time since the last tillage operation. Both total sediment loss and peak sediment concentrations are increased by frequent tillage operations while peak runoff is generally reduced and delayed in time.

(5) The ARM Model simulation of sediment production is relatively accurate except for storms immediately following tillage operations. In general, monthly sediment loss and storm concentrations are close to observed values when the hydrologic simulation is accurate. The sediment simulation methodology allows for the inclusion of tillage operations, but further testing and calibration are needed to more reliably quantify tillage effects.

(6) Simulation of pesticide loss from the Southern Piedmont watersheds with the ARM Model indicates the following:

a. Simulation results are good for pesticides like paraquat that are completely adsorbed onto sediment particles. In these cases, the accuracy of the pesticide simulation is directly dependent upon the accuracy of the sediment simulation.

b. Simulation of pesticides that move both in water and on sediment is dependent upon the partitioning between the two phases (water and sediment) as specified by the adsorption/desorption function. Simulation results for this type of pesticide (e.g. diphenamid) using laboratory isotherm data is fair to poor. Initial comparison of simulation results from single-valued (SV) and non-single-valued (NSV) adsorption/desorption functions is inconclusive. The SV function appears to simulate some storms better than the NSV function, but the reverse is true for other storms. Further comparisons and evaluations are warranted.

c. Pesticide attenuation processes are critical to the simulation of pesticide loss since they determine the amount of pesticide available for transport from the land surface. Storms, even minor ones, occurring immediately or soon after pesticide application are the major events for pesticide loss. The applied pesticide has not attenuated to a significant extent; thus, it is highly susceptible to transport. The first order degradation rate presently used in the ARM Model appears to underestimate attenuation at the beginning of the growing season and overestimate it at the middle and end of the growing season. Accurate simulation of pesticide attenuation would provide a more valid base for the evaluation of adsorption/desorption functions and improvement of the overall pesticide simulation.

(7) The ARM Model provides a structure for simulating the transport and soil transformations of plant nutrients. Testing and comparison of simulated and observed results will provide a basis for modification and refinement of the nutrient algorithms presented in this report. Data from the Southern Piedmont and Great Lakes watersheds is expected to be available for nutrient model testing in the near future.

(8) A sensitivity analysis of the ARM Model parameters for hydrology, sediment production, and pesticide loss indicates that the most sensitive parameters are related to soil moisture and infiltration, land surface sediment transport, pesticide-soil interactions, and pesticide degradation. These mechanisms are the critical ones for the accurate simulation of pesticide loss from agricultural watersheds.

SECTION II

RECOMMENDATIONS

(1) Application and testing of the ARM Model on watersheds in different regions of the country is of primary concern at this time. The hydrologic methodology of the ARM Model has demonstrated its general applicability from the results of testing on hundreds of watersheds; similar testing is needed for the sediment production methodology. In this way, the simulation of the transport mechanisms (runoff and sediment loss) for agricultural pollutants can be tested, refined, and verified for general application. Moreover, the relationship of the ARM Model parameters to climatic and edaphic characteristics could be investigated.

(2) Testing of the nutrient model is crucial to the reliable simulation of plant nutrients. Although a nutrient model has been developed, only testing and comparison with observed data can indicate the validity of the model assumptions and the need for model refinements.

(3) The impacts of different agricultural management techniques on the transport mechanisms of runoff and sediment loss need to be further investigated. Since the ARM Model will be applied to managed agricultural lands, the relationships between land management techniques and the ARM Model parameters must be established. This is a necessity if the Model is to be used for evaluating the efficacy of land and agricultural management plans. Also, for widespread use, the Model must accommodate practices employed in different agricultural regions of the country.

(4) Pesticide-soil interactions and pesticide attenuation processes must be further investigated in order to improve the accuracy and reliability of the pesticide simulation. Both the single-valued and non-single-valued adsorption/desorption functions warrant further investigation, in addition to a kinetic, or non-equilibruim, approach to the pesticide-soil interaction processes. First-order pesticide degradation should be replaced with a more sophisticated degradation model. Various candidate approaches are presently under investigation. Environmental conditions (e.g. soil temperature, soil moisture, and oxygen content) need to be included where they are significant.

(5) To promote the general use of the ARM Model for investigation, evaluation, and management of agricultural runoff, the following recommendations are extended:

a. The ARM Model structure should be modified to allow a more user-oriented method of application. The acceptance and use of the ARM Model by the user community is contingent upon the ease of Model application, calibration, parameter evaluation, data management, and output interpretation. To date, Model development has concentrated on the testing and evaluation of algorithms to simulate the physical processes. Efforts should now be directed to the goal of making the Model more amenable for use by potential users.

b. The use of the ARM Model as a tool for the planning and evaluation of agricultural management techniques for the control of sediment, pesticides, and nutrients should be demonstrated. It is insufficient to develop and document a model like the ARM Model without a clear demonstration of its potential application in the planning and management process. In addition, recommendations, guidelines, and a proposed methodology should be developed to insure the effective use and to avoid misuse of the ARM Model.

SECTION III

INTRODUCTION

MODELING PROGRAM

The development of models to simulate the water quality impact of nonpoint source pollutants is receiving considerable attention by the engineering and scientific community. One of the major reasons for this interest was the passage of the Federal Water Pollution Control Act Amendments of 1972, specifically requiring the evaluation of the contribution of nonpoint source pollution to overall water quality. This report describes a modeling effort whose goal is the simulation of water quality resulting from agricultural lands. The beginnings of this research modeling effort date from 1971 when the U.S. Environmental Protection Agency, through the direction of the Environmental Research Laboratory in Athens, Georgia (ERL-Athens), sponsored the development and initial testing of the Pesticide Transport and Runoff (PTR) Model.[1] The Agricultural Runoff Management (ARM) Model presented in this report is the combined result of further model testing and refinement, algorithm modifications, and inclusion of additional capabilities not present in the PTR Model. Moreover, the ultimate goal of the continuing ARM Model development effort is the establishment of a methodology and a tool for the evaluation of the efficacy of management practices to control the loss of sediment, pesticides, nutrients, and other nonpoint pollutants from agricultural lands. The present version of the Model, presented in this report, is a 'snapshot' of the ARM Model in its testing and refinement process. When recommended for public use, the final ARM Model will be a tool for evaluating the water quality impact of agricultural management practices.

MODELING PHILOSOPHY

The guiding philosophy of the modeling effort is to represent, in mathematical form, the physical processes occurring in the transport of nonpoint source pollutants. The hydrologic and water quality related processes occurring on the land surface (and in the soil profile) are continuous in nature; hence, continuous simulation is critical to the accurate representation of these physical processes. Although nonpoint source pollution from the land surface takes place only during runoff-producing events, the status of the soil moisture and the pollutant prior to the event is a major determinant of the amount of runoff and pollutants that can reach the stream during the event. In turn, the soil moisture and pollutant status prior to the event is the result of processes which occur between events. Cultivation and tillage practices, pesticide and fertilizer applications, pesticide degradation and nutrient transformations, all critically affect the mass of pollutant that can enter the aquatic environment during a runoff-producing event. Models that simulate only single events cannot accurately evaluate agricultural land management practices since between-event processes are ignored. Although all between-event processes cannot be quantitatively described at the present state of technology, continuous simulation provides a sound framework for their approximation and for further research into their quantification.

When modeling nonpoint source pollution, the above stated philosophy is joined by the fact that the transport mechanisms of such pollutants are universal. Whether the pollutants originate from pervious or impervious lands, from agricultural or urban areas, or from natural or developed lands, the major transport modes of runoff and sediment loss are operative. (Wind transport may be significant in some areas, but its importance relative to runoff and sediment loss is usually small.) In this way, the simulation of nonpoint source pollution is analogous to a three-layered pyramid. The basic foundation of the pyramid is the hydrology of the watershed. Without accurate simulation of runoff, modeling nonpoint pollutants is practically impossible. Sediment loss simulation, the second layer of the pyramid, follows in sequence the hydrologic modeling. Although highly complex and variable in nature, sediment modeling provides the other critical transport mechanism. The pinnacle or final layer of the pyramid is the interaction of various pollutants with sediment loss and runoff, resulting in the overall transport simulation of nonpoint source pollutants.

The general goals of the research effort described in this report are (1) to utilize the most advanced state of present technology in the simulation of nonpoint source pollutants, and (2) to delineate critical areas for further research and investigation. In addition, the final version of the ARM Model will be designed for general applicability throughout the United States and for use by state and local agencies for the water quality evaluation of agricultural land management practices.

REPORT CONTENTS AND FORMAT

As stated previously, this report describes the progress of the continuing ARM Model development work. Further testing and refinement of Model algorithms is in progress at the present time; thus, this report provides a detailed look at the existing version of the Model and a glimpse at projected future modifications. The major differences between the present ARM Model and its predecessor, the PTR Model, are as follows:

(1) Modifications of the input and output (I/O) procedures
(2) Modifications to the sediment model, SEDT, algorithms
(3) Option to utilize non-single-valued adsorption-desorption function
(4) Simulation capability for snow accumulation and melt
(5) Simulation capability for plant nutrients (not tested on observed data).

In order to prevent a duplication of material presented in the PTR Model report,[1] this report will be restricted to an explanation of the major modifications listed above and a presentation of the results of testing the ARM Model on new data. However, some duplication is necessary in order to provide a cohesive presentation. The reader will be referred to the PTR Model report for elaboration of material summarized here.

Modifications to the I/O procedures will be described in the User Manual (Appendix A) along with a complete explanation of Model operation and use. Section IV provides a brief description of the overall ARM Model structure, including modifications to the sediment model and the addition of the non-single-valued adsorption/desorption option. Since major efforts were devoted to addition of the snow accumulation and melt routine and development of the plant nutrient model, Section V and Section VI describe the respective physical processes and algorithms. Following a brief presentation of the companion data collection programs in Section VII, the results of Model testing are presented in Section VIII. A sensitivity analysis of Model parameters is reported in Section IX. Finally, Section X summarizes the overall conclusions and recommendations. The appendices include a brief user manual, a sample input listing, and a source code of the ARM Model.

SECTION IV

THE AGRICULTURAL RUNOFF MANAGEMENT (ARM) MODEL

The ARM Model simulates runoff (including snow accumulation and melt), sediment, pesticides, and nutrient contributions to stream channels from both surface and subsurface sources. No channel routing procedures are included. Thus, the Model is applicable to watersheds that are small enough that channel processes and transformations can be assumed negligible. Although the limiting area will vary with climatic and topographic characteristics, watersheds greater than one to two square miles are approaching the upper limit of applicability of the ARM Model. Channel processes will significantly affect the water quality resulting from larger watersheds.

Figure 1 demonstrates the general structure and operation of the ARM Model The major components of the Model individually simulate the hydrologic response (LANDS) of the watershed, sediment production (SEDT), pesticide adsorption/desorption (ADSRB), pesticide degradation (DEGRAD), and nutrient transformations (NUTRNT). The executive routine, MAIN, controls the overall execution of the program; calling subroutines at proper intervals, transferring information between routines, and performing the necessary input and output functions. Table 1 describes the functions of each of the ARM Model components.

In order to simulate vertical movement and transformations of pesticides and nutrients in the soil profile, specific soil zones (and depths) are established so that the total soil mass in each zone can be specified. Total soil mass is a necessary ingredient in the pesticide adsorption/desorption reactions and nutrient transformations. Figure 2 depicts the zones and depths, assumed in the ARM Model. The depths of the surface and upper soil zones are specified by the model input parameters, SZDPTH and UZDPTH, respectively. The upper zone depth corresponds to the depth of incorporation of soil-incorporated chemicals. It also indicates the depth used to calculate the mass of soil in the upper zone whether agricultural chemicals are soil-incorporated or surface applied. The depths of the surface and lower zones are important because the active surface zone is crucial to the washoff and degradation of agricultural chemicals, while the extent of the lower zone determines to what degree soluble pollutants will contaminate the groundwater. The zonal depths will vary with the geology and topography of the watershed. Although the relative specification of the soil depths indicated in Figure 2 is reasonable, further evaluation of these zones is presently in progress.

The transport and vertical movement of pesticides and nutrients, as conceived in the ARM Model, is indicated in Figure 3. Pollutant

ARM Model structure and operation

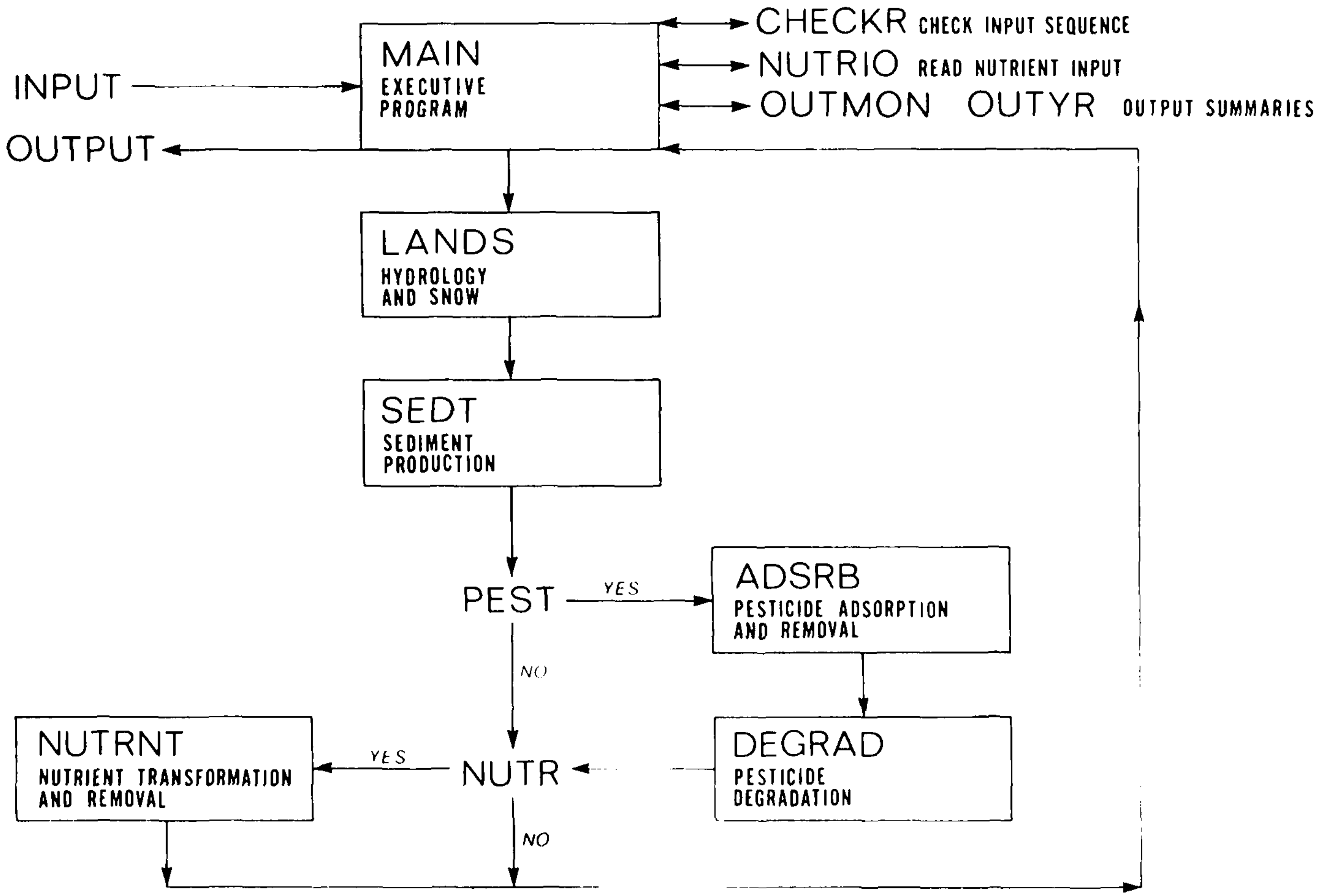


Figure 1

Table 1. ARM MODEL COMPONENTS

Major Program	Component Subroutine	Function
MAIN		Master program and executive control routine
	CHECKR	Checks input parameter errors
	BLOCK DATA	Data initialization for common variables
	NUTRIO	Reads and checks nutrient input data
	OUTMON	Prints monthly output summaries
	OUTYR	Prints yearly output summaries
LANDS		Performs hydrologic simulation and snowmelt calculations
SEDT		Performs sheet erosion simulation
ADSRB		Performs pesticide soil adsorption/ desorption simulation
	DSPTN	Performs desorption calculations
DEGRAD		Performs pesticide degradation simulation
NUTRNT		Performs nutrient simulation
	TRANS	Performs nutrient transformations

Assumed soil depths for pesticide and nutrient storage

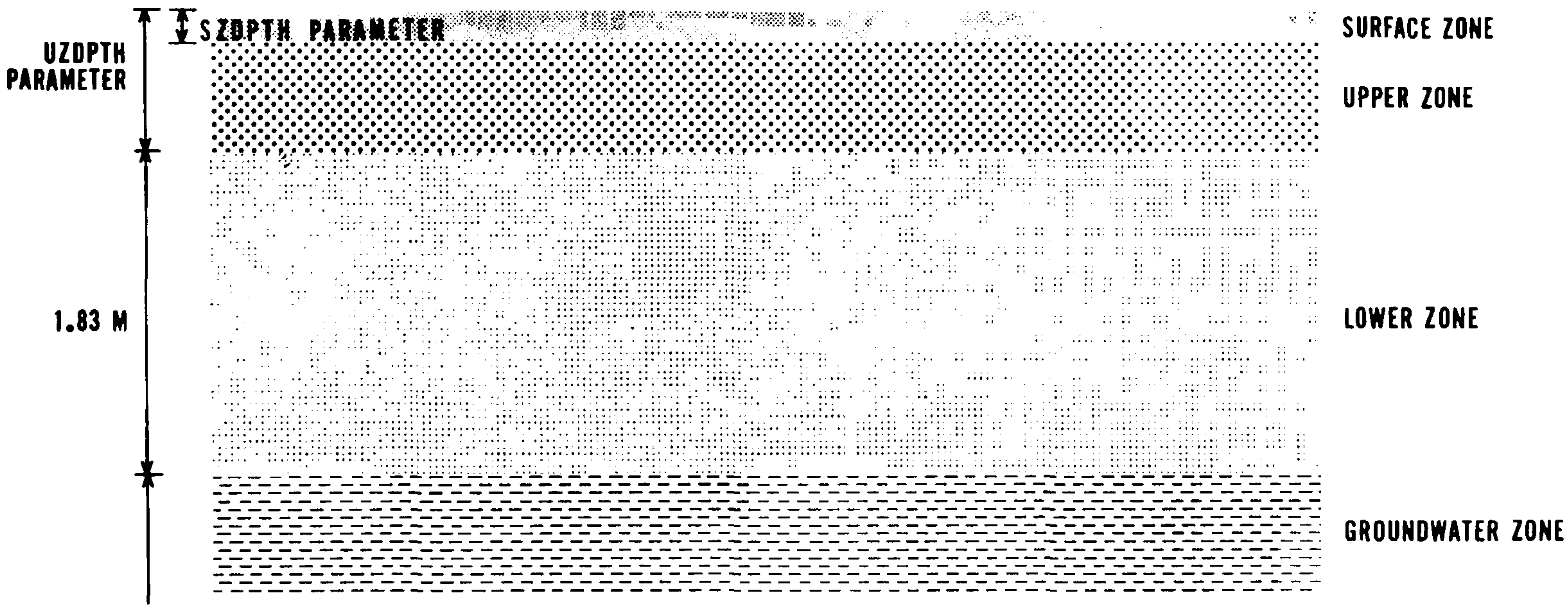


Figure 2

Pesticide and Nutrient movement in the ARM model

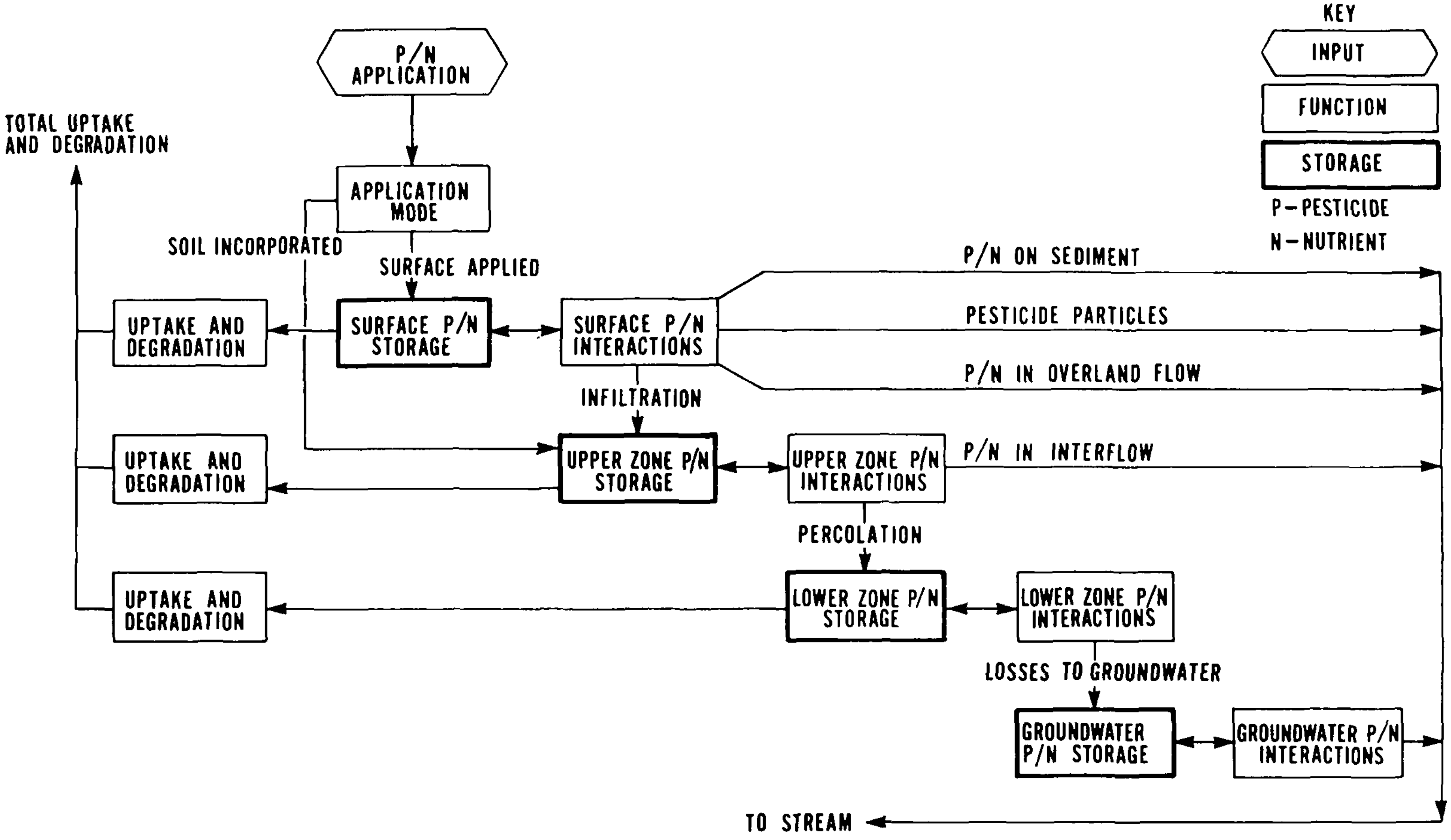


Figure 3

contributions to the stream can occur from the surface zone, the upper zone, and the groundwater zone. Surface runoff is the major transport mechanism carrying dissolved chemicals, pesticide particles, or sediment and adsorbed chemicals. The interflow component of runoff can transport dissolved pesticides or nutrients occurring in the upper zone. Vertical chemical movement between the soil zones is the result of infiltrating and percolating water. From the surface, upper, and lower zones, uptake and transformation of nutrients and degradation of pesticides is allowed. On the watersheds tested, the groundwater zone has been considered a sink for deep percolating chemicals since the groundwater flow contribution has been negligible. However, on larger watersheds this contribution could be significant.

HYDROLOGY

To truly comprehend the movement of pesticides and nutrients in the ARM Model, one must have a basic understanding of the hydrology subprogram, LANDS. A flowchart of LANDS is shown in Figure 4 (the snowmelt subroutine will be described in Section V). The mathematical foundation of LANDS was originally derived from the Stanford Watershed Model[2], and has been presented, with minor variations, in numerous subsequent publications.[1,3] For this reason, the algorithms will not be fully described here. The major parameters of the LANDS subprogram are defined in Table 2, and in the User Manual (Appendix A). These parameters are identical to those in the PTR Model and also in the Hydrocomp Simulation Program, HSP[3]. In brief, the LANDS subprogram simulates the hydrologic response of the watershed to inputs of precipitation and evaporation. LANDS simulates runoff continuously through a set of mathematical functions derived from theoretical and empirical evidence. It is basically a moisture accounting procedure on the land surface for water in each major component of the hydrologic cycle. The parameters (Table 2) within the mathematical functions are used to characterize the land surface and soil profile characteristics of the watershed. These parameters must be selected, tested, and modified when LANDS is applied to a new watershed. Calibration is the process whereby the parameters are modified as a result of a comparison of simulated and recorded runoff data for the watershed. The calibration procedure is described in the User Manual (Appendix A).

Modifications to the Stanford and HSP versions of the LANDS algorithms have been discussed in the PTR Model Report.[1] The present version of the LANDS subprogram of the ARM Model includes these modifications to simulate the areal variation in agricultural chemical concentrations on the land surface. For completeness and clarity, the following section entitled, "Areal Zone Concept", describing the LANDS modification is abstracted from the PTR Model Report.

LANDS Simulation

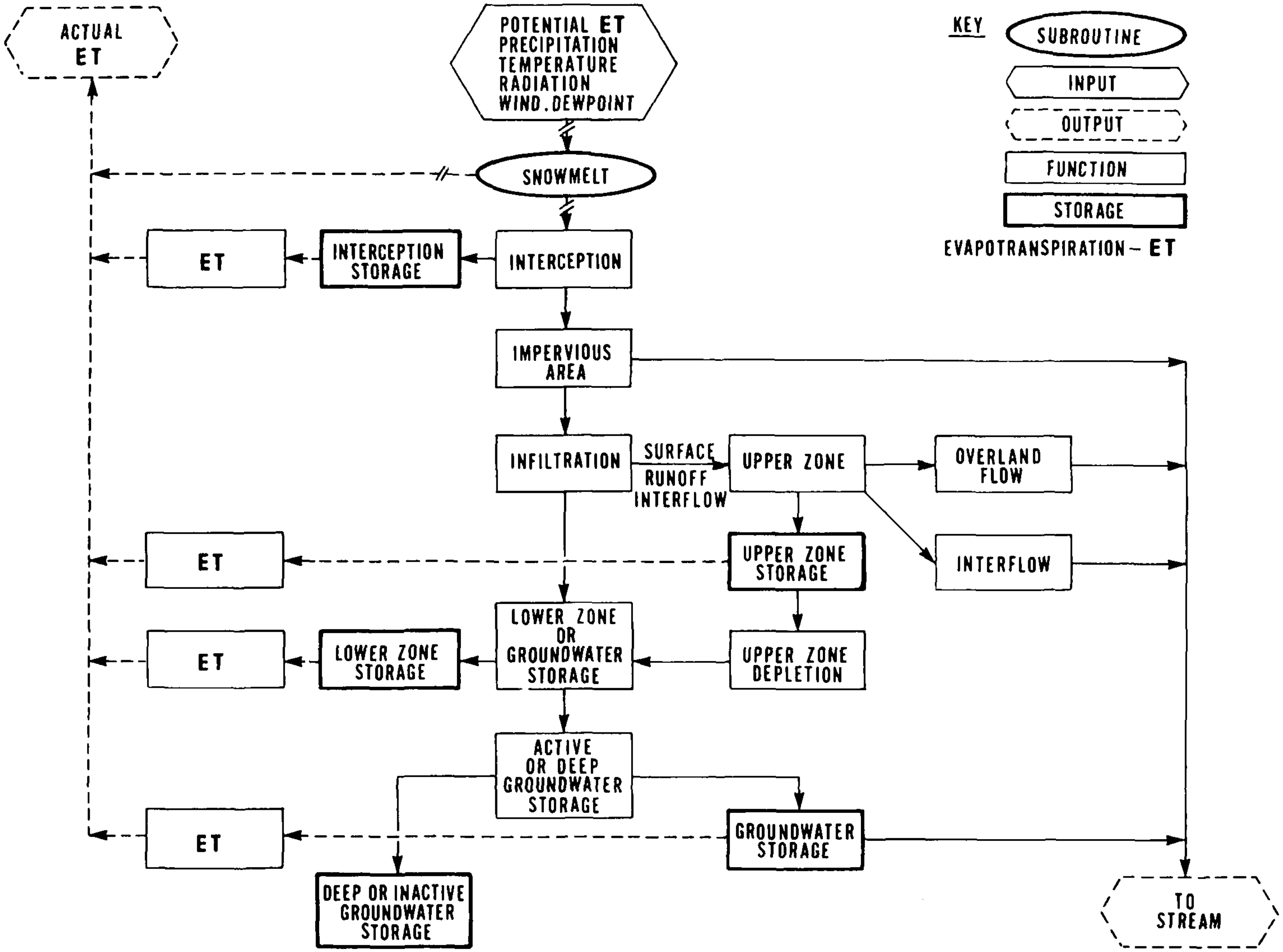


Figure 4

Table 2. HYDROLOGIC MODEL (LANDS) PARAMETERS

A	A fraction representing the impervious area in a watershed.
EPXM	The interception storage parameter, related to vegetal cover density.
UZSN	The nominal upper zone soil moisture storage parameter.
LZSN	The nominal lower zone soil moisture storage parameter.
K3	Index to actual evaporation (a function of vegetal cover).
K24L, K24EL	Parameters controlling the loss of water from groundwater storage. K24L is the fraction of groundwater recharge that percolates to deep groundwater tables. K24EL is the fraction of the segment area where shallow water tables put groundwater within reach of vegetation.
INFIL	This parameter is a function of soil characteristics defining the infiltration characteristics of the watershed.
INTER	This parameter defines the interflow characteristics of the watershed.
L	Length of overland flow plane.
SS	Average overland flow slope.
NN	Manning's "n" for overland flow.
IRC, KK24	The interflow and groundwater recession parameters.
KV	The parameter KV is used to allow a variable recession rate for groundwater discharge.

Areal Zone Concept

The major concern in modifying the HSP LANDS module for pesticide transport was the desire to accommodate the expected areal variation in pesticide concentration over the land surface. It is generally accepted in hydrology that infiltration is time and area dependent. Infiltration capacity will vary even within small watersheds with reasonably homogeneous soil characteristics. This areal variation in infiltration results in source areas, or zones, with low infiltration capacity within the watershed, contributing a large component of overland flow. Since overland flow and sediment loss are the major mechanisms of pesticide transport to the watercourse, the low infiltration source areas will also experience a greater loss of pesticide than the remainder of the watershed. Consequently, the pesticide concentration on the land surface will vary, in spite of an initially uniform application. The pesticide concentration within the soil profile will also vary as a function of the volume of infiltration. Obviously, the extent of pesticide areal variation depends upon the solubility and transport characteristics of the specific pesticide applied and upon topographic and watershed characteristics. Natural hydrologic conditions and watershed characteristics are sufficiently non-uniform to justify the above described mechanisms leading to areal variations in infiltration and pesticide concentrations.

HSP LANDS employs a cumulative frequency distribution of infiltration capacity to account for the areal variation. Figure 5a graphically presents the infiltration function of HSP LANDS. A mean infiltration capacity, f, is calculated and a linear approximation to the actual cumulative distribution is assumed. Interflow is determined as a function of infiltration and lower zone moisture storage. It is evaluated in Figure 5a as a second linear cumulative distribution denoted by f(c-1). Since the X-axis is unity (i.e. 100 percent of watershed area), the area of each wedge in Figure 5a represents the portion of the moisture supply allocated to each component. During any time interval, the available moisture supply is distributed to surface detention, interflow detention, and infiltration. Overland flow and interflow are determined as losses from surface detention and interflow detention respectively. Lower zone moisture storage and groundwater components are derived from the infiltration component.

The LANDS subprogram of the ARM Model employs the same infiltration function as HSP LANDS, with one modification; the watershed is divided into five zones, each representing 20 percent of the total area. The zonal division is based on infiltration capacity. Schematically, Figure 5b shows that zone 1 will infiltrate much less water than zone 5. Conversely, zone 5 will provide less overland flow than zone 1. Thus, the areal variation in infiltration capacity is approximated. Zones with lower infiltration capacity will serve as the major source areas for

Figure 5a. Cumulative frequency distribution of infiltration capacity showing infiltrated volumes, interflow and surface detention

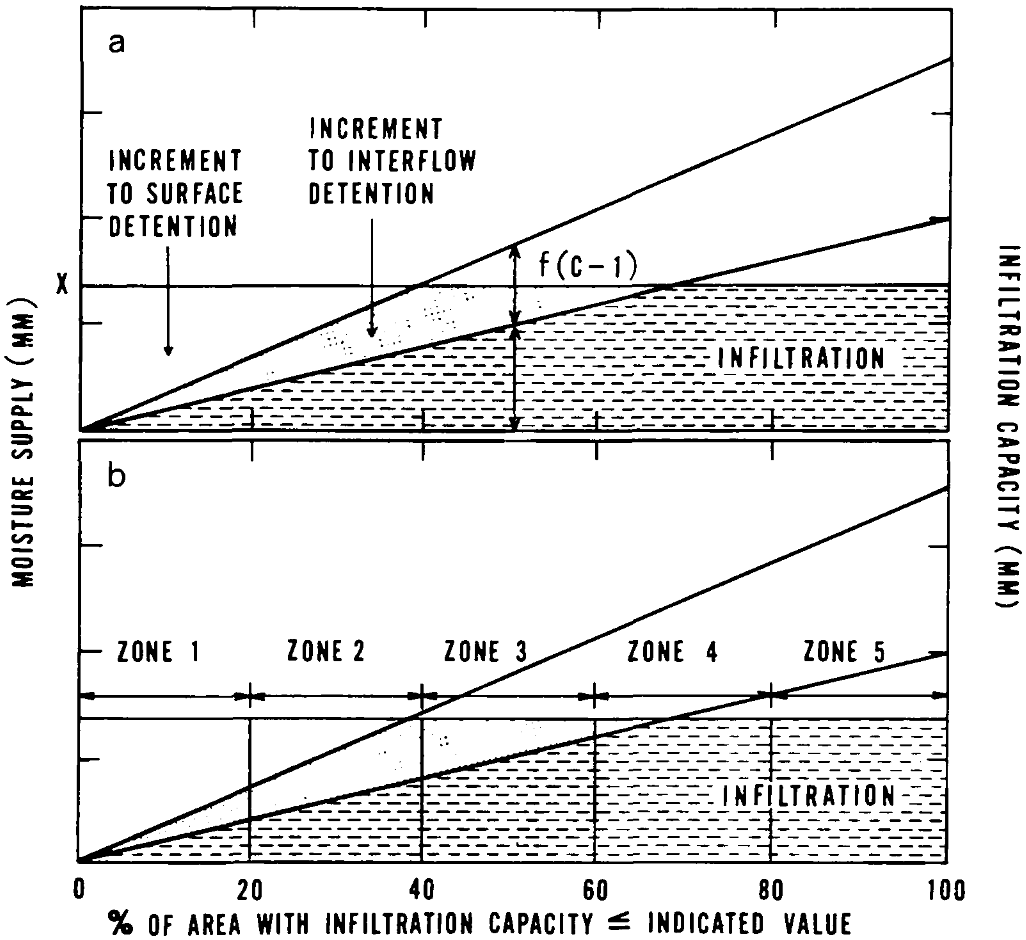


Figure 5b. Source-zones superimposed on the infiltration capacity function

Infiltration capacity and areal source-zone functions

Figure 5

overland flow, sediment, and pesticide loss. Generally, zones with high infiltration will contain more pesticide in the soil profile because of the greater amount of infiltrated water.

Conceptually, the zones are not necessarily concentric, continuous, or contiguous. Each is connected directly to the stream channel by the overland flow plane. As with any simulation model, this source zone concept is an approximation. It is an attempt to portray mechanisms which are known to occur, but are impossible to simulate in detail.

A full description of the operation and calibration procedures for the LANDS subprogram is included in the User Manual (Appendix A).

SEDIMENT LOSS SIMULATION

The basis for sediment loss simulation in the PTR Model was derived from work by Moshe Negev at Stanford University.[4] Although Negev simulated the entire spectrum of the erosion process, only sheet and rill erosion were included in the the PTR Model since gully erosion was not significant on the small test watersheds. The two component processes of sheet and rill erosion pertain to (1) detachment of soil fines (silt and clay fraction) by raindrop impact, and (2) pick-up and transport of soil fines by overland flow. These mechanisms were represented in the PTR Model by the following algorithms:

Soil fines detachment:

$$RER(t) = (1 - COVER(T))*KRER*PR(t)^{JRER} \tag{1}$$

Soil fines transport:

$$SER(t) = KSER*SRER(t)*OVQ(t)^{JSER} \tag{2}$$

$$ERSN(t) = SER(t)*F \tag{3}$$

where RER(t) soil fines detached during time interval t, tonnes/ha
COVER(T) = fraction of vegetal cover as a function of time, T, within the growing season
KRER = detachment coefficient for soil properties
PR(t) = precipitation during the time interval, mm
JRER = exponent for soil detachment
SER(t) = transport of fines by overland flow, tonnes/ha
JSER exponent for fines transport by overland flow

KSER	=	coefficient of transport
SRER(t)	=	reservoir of soil fines at the beginning of the time interval, t, tonnes/ha
OVQ(t)	=	overland flow occurring during the time interval, t, mm
F	=	fraction of overland flow reaching the stream during the time interval, t
ERSN(t)	=	sediment loss to the stream during the time interval, t, tonnes/ha

Since the original equations by Negev were designed for simulation on an hourly basis, the coefficients KSER and KRER were modified to allow 5 and 15 minute simulation. In the operation of the algorithms, the soil fines detachment (RER) during each interval is calculated by Equation 1 and added to the total fines storage or reservoir (SRER). Next, the total fines transport (SER) is determined by Equation 2 and the sediment loss to the stream (ERSN) is calculated in Equation 3 by the fraction of overland flow which reaches the stream. A land surface flow routing technique[3] determines the overland flow contribution to the stream in each time interval. After the fines storage (SRER) is reduced by the sediment loss to the stream (ERSN), the algorithms are prepared for simulation of the next time interval.

Although the general operation of the algorithms described above is identical in the ARM Model, certain modifications have been necessary. A more comprehensive vegetal cover function and an attempt to simulate the effects of tillage operations have been included. Also, Equation 2 has been modified to more closely represent the physical process of sediment transport by overland flow. Table 3 defines the sediment parameters included in the ARM Model.

The goal of simulating sediment washoff by overland flow is to approximate the capacity of the flow to transport detached soil fines. Equation 2, derived from Negev's formulation, actually calculates transport as a continuous function of the detached fines. If Equation 2 is rearranged as follows,

$$SER(t)/SRER(t) = KSER*OVQ(t)^{JSER} \qquad (4)$$

it becomes obvious that this formulation is calculating the fraction of detached fines which can be transported in any time interval, regardless of the physical transport capacity of the overland flow. This is conceptually incorrect; transport capacity is a function of overland flow, soil and surface characteristics.[5,6] As long as the transport capacity is less than available detached fines, it should be independent of the fines storage, SRER. Thus, the formulation of Equation 2 in the ARM Model is

Table 3. SEDIMENT PRODUCTION PARAMETERS

COVPMO	Fraction of land cover on a monthly basis (12 values).
TIMTIL	Time when soil is tilled (Julian day, i.e., day of the year, e.g., January 1 is 1, December 31 is 365 or 366, etc.), (5 dates).
YRTIL	Corresponding year (last two digits only) for TIMTIL (5 values).
SRERTL	Fine deposits produced by tillage corresponding to TIMTIL and YRTIL (5 values).
JRER	Exponent of rainfall intensity in soil splash equation.
KRER	Coefficient in soil splash equation.
JSER	Exponent of overland flow in sediment washoff equation.
KSER	Coefficient in sediment washoff equation.
SRERI	Initial detached soil fines deposit.

$$SER(t) = KSER*OVQ(t)^{JSER} \tag{5}$$

subject to

$$SER(t) \leq SRER(t) \tag{6}$$

Although this remains a simple representation of the complex erosion process, the formulation is conceptually sound and provides an opportunity for future improvements. The effects of slope, surface roughness, rainfall intensity, etc. on transport capacity can be included in this formulation as required by future testing and research.

The vegetal cover or crop canopy function in the PTR Model required the input of the maximum vegetal cover attained in the growing season and dates of application (assumed to coincide with planting), crop maturity, and harvesting. As shown in Figure 6a, the vegetal cover was assumed to increase linearly from zero at the time of application (TIMAP) to the maximum cover fraction (COVMAX) at the time of crop maturity (TIMAT). The cover remained at the maximum value until harvesting when it returned to zero. Land cover was assumed to be zero before and after the growing season. This assumption proves to be invalid to varying degrees on most agricultural watersheds. Consequently, the land cover algorithm shown in Figure 6b is used in the ARM Model. Monthly cover values assumed to occur on the first of the month, are specified by the user. Cover on any day is determined by linear interpolation between the monthly values. This algorithm allows greater flexibility than the original PTR Model algorithm, but additional investigation into plant growth and crop canopy functions is needed. Various research efforts[7,8,9] have related the concept of leaf area index (LAI) to light interception by a crop canopy. An analogy between light interception and rainfall interception could lead to a more precise crop canopy function, if an algorithm for the changes in LAI (for different crops and cropping patterns) with time could be developed. Research on this topic by Watson[10] and McCollum[11] appears promising. At the present state-of-the-art, the cover function in the ARM Model is adequate until a more physically representative function can be developed.

Tillage operations and conservation practices have a major effect on the sediment loss from an agricultural watershed. Although this is obvious, the magnitude and mechanism of tillage operations could not be evaluated with the seven months of data (July 1972-February 1973) available for the PTR Model development. Minimum tillage practices were followed and numerous non-runoff-producing events helped to compact the land surface prior to the first major runoff-producing event. However, during the 1973 growing season several severe storms immediately following tillage and planting operations (see Section VIII) served to dramatize the need to

Figure 6a. Land cover algorithm in the PTR model

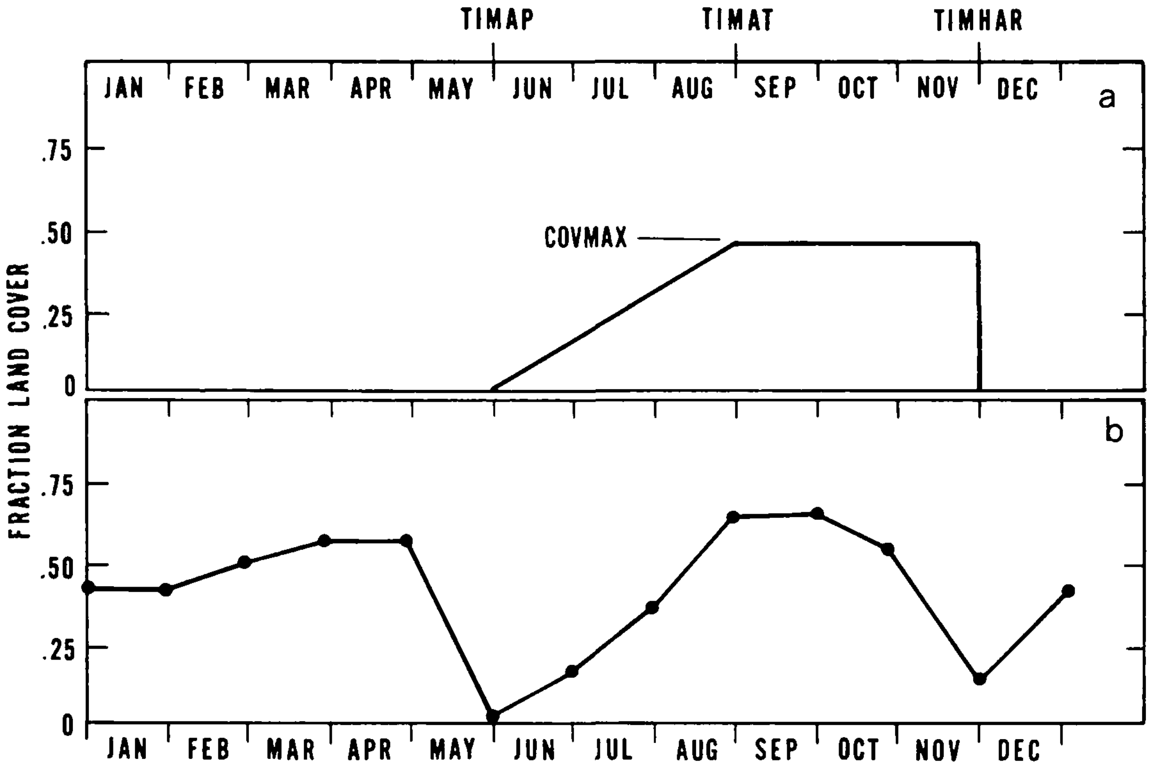


Figure 6b. Land cover algorithm in the ARM model

Comparison of land cover algorithms in the PTR and ARM models

Figure 6

accommodate tillage operations within the Model structure. With regard to sediment production, the effect of tillage operations is to increase the mass of soil fines available for transport and produce a reasonably uniform distribution of fines across the watershed. Consequently, the ARM Model allows the user to specify the dates of tillage, planting, or other land-surface disturbing operations. For each of these dates the user must specify a new detached soil fines storage (SRERTL) resulting from the operation. At the beginning of each tillage day the ARM Model resets the fines storage in each of the areal zones to the new value, resulting in a uniform fines distribution across the watershed. The amount of fines storage produced by different tillage operations is related to the depth and extent of the operation, and edaphic characteristics. Further study is needed to develop guidelines for the specification of fines storage as affected by tillage and other agricultural management operations.

In conclusion, the present version of the sediment loss algorithms of the ARM Model is a stepping stone on the continuing path of model development. As additional testing, refinements, and retesting is performed, a greater understanding of the erosion process and methods for its simulation will evolve.

PESTICIDE ADSORPTION/DESORPTION SIMULATION

Once the hydrology and sediment production of a watershed have been simulated, the process of pesticide adsorption/desorption onto sediment particles is a major determinant of the amount of pesticide loss which will occur. This process establishes the division of available pesticide between the water and sediment phases, and thus specifies the amounts of pesticide transported in solution and on sediment. The algorithm employed to simulate this process in the PTR Model was described as follows:

$$X/M \quad KC^{(1/N)} + F/M \qquad (7)$$

where X/M = pesticide adsorbed per unit soil, μg/gm

F/M = pesticide adsorbed in permanent fixed state per unit soil. F/M is less than or equal to FP/M, where FP/M is the permanent fixed capacity of soil in mg/gm for pesticide. This can be approximated by the cation or anion exchange capacity for that particular soil type.

C = equilibruim pesticide concentration in solution, mg/l

N = exponent

K = coefficient

Basically this algorithm is comprised of an empirical term, F/M, plus the standard Freundlich single-valued (SV) adsorption/desorption isotherm (Figure 7a). The empirical term, F/M, accounts for pesticides which are permanently adsorbed to soil particles and will not desorb under repeated washing. As indicated in Figure 7a, the available pesticide must exceed the capacity of the soil to permanently adsorb pesticides before the adsorption/desorption equilibrium is operative. Thus the pesticide concentration on soil particles must exceed FP/M before the equilibrium soil and solution pesticide concentrations are evaluated by the Freundlich curve. An in-depth description and discussion of the underlying assumptions is presented in the PTR Model report.[1]

A major conclusion of the PTR Model development work was that the above algorithm did not adequately represent the division of pesticides between the sediment and solution phases. This was especially true for pesticides which are transported by both sediment and surface runoff, i.e. soluble pesticides which also adsorb onto soil particles. Research has indicated that the assumption of single-valued adsorption/desorption (Figure 7a) is not valid for many pesticides.[12,13,14] In these cases, the adsorption and desorption processes would follow different curves as indicated in Figure 7b. Although a controlled laboratory experiment cannot hope to duplicate the vagaries of nature present in a field situation, the basic mechanisms should be similar in both circumstances. Since field data has been inconclusive, the present version of the ARM Model allows the user to specify the use of either single-valued (SV) as in Figure 7a or non-single-valued adsorption/desorption (Figure 7b). Table 4 defines the pesticide simulation parameters in the ARM Model. The DESORP parameter indicates the adsorption/desorption function to be used. The NSV algorithm (Figure 7b) utilizes the above SV algorithm (path No. 1) as a base from which different desorption curves are calculated. The form of the desorption curve is identical to Equation 7 except that K and N values are replaced by K' and N' respectively. The prime denotes the desorption process. The user specifies the N' value as an input parameter (NP), and the ARM Model calculates K' from the following expression based on work by Davidson et al.[14]

$$K' = K^{(N/N')} S_{max}^{(1-N/N')} \qquad (8)$$

where K' = desorption coefficient
K = adsorption coefficient
N' = desorption exponent
N = adsorption exponent
S_{max} = solution pesticide concentration prior to initiating desorption

When the desorption process is initiated, the maximum attained solution concentration S_{max}, is utilized with K, N, and N' to calculate a value of K'.

Figure 7a. Single-valued adsorption/desorption algorithm

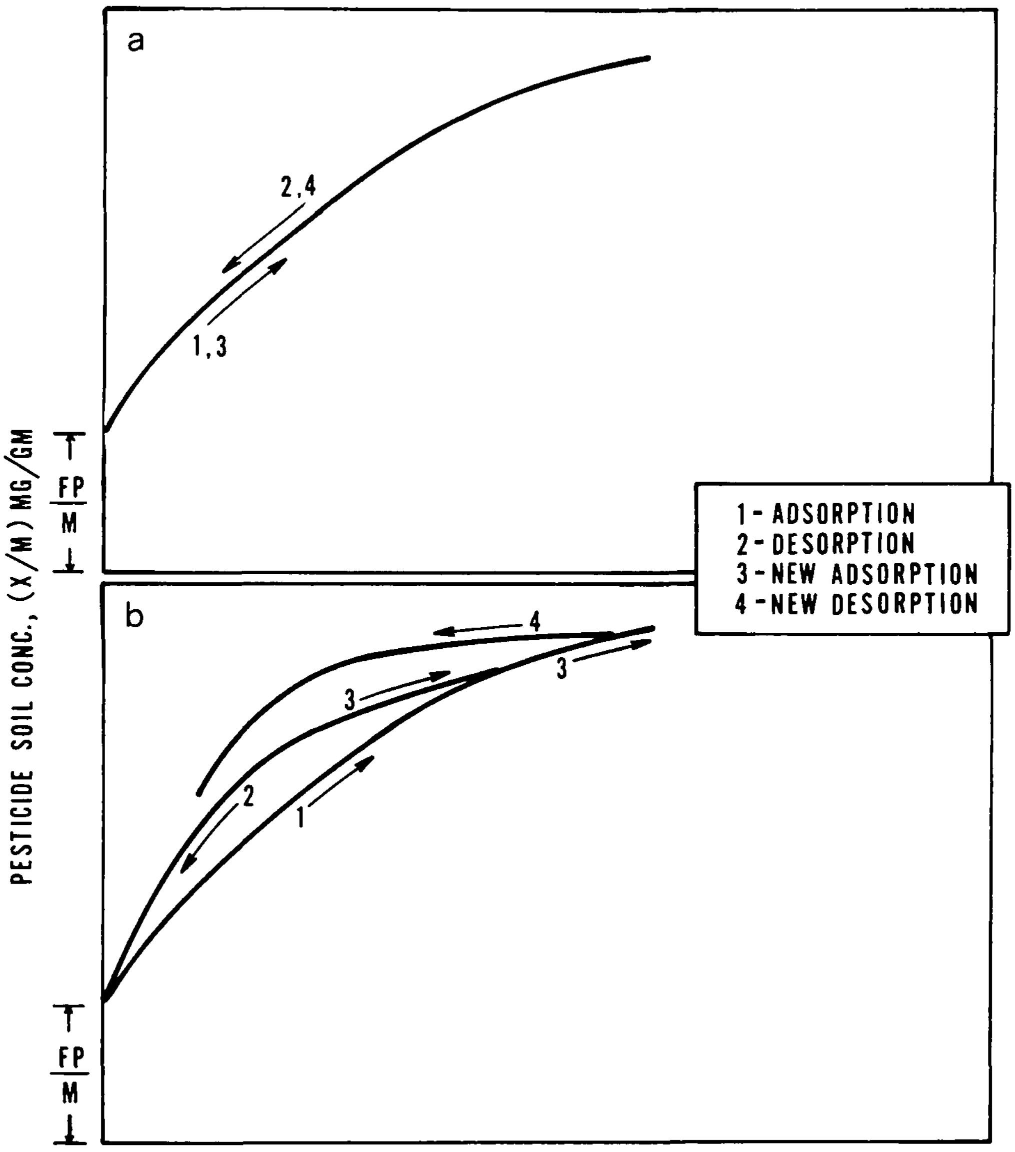


Figure 7b. Non-single-valued adsorption/desorption algorithm

Adsorption/desorption algorithms in the ARM Model

Figure 7

Table 4. PESTICIDE SIMULATION PARAMETERS

APMODE	Application mode, SURF-surface applied, SOIL-soil incorporated.
DESORP	NO-single-valued adsorption/desorption algorithm used, YES-non-single-valued adsorption/desorption algorithm used.
SSTR	Pesticide application for each block (5 values).
TIMAP	Time of pesticide application (Julian day).
YEARAP	Year of pesticide application (last two digits only).
CMAX	Maximum solubility of pesticide in water.
DD	Permanent fixed pesticide adsorption capacity of the soil.
K	Coefficient in Freundlich adsorption equation.
N	Exponent in Freundlich adsorption equation.
NP	Exponent in Freundlich desorption equation.
SZDPTH	Depth of the surface zone.
UZDPTH	Upper zone depth or depth of soil incorporation.
BULKD	Bulk density of soil.
DEGCON	First-order pesticide degradation rate.

As desorption continues (path No. 2), the Model continues to use the K' and N' values to calculate the soil and solution concentrations. When re-adsorption is initiated (path No. 3), the Model follows the desorption curve back to the junction with the SV adsorption curve, and continues on this curve until desorption again occurs. At the new occurrence of desorption, a new K' is calculated resulting in a new desorption curve (path No. 4). The process is continued indefinitely producing a series of desorption curves emanating from the base SV adsorption curve.

The results of testing both algorithms is presented in Section VIII, ARM Model Testing and Simulation Results. Further testing on different pesticides on different soil types is presently in progress. Brown[15] has indicated that the equilibrium type algorithms presented above may not be valid under field conditions. Consequently, a kinetic non-equilibrium approach is another possibility for future investigations.

PESTICIDE ATTENUATION

The attenuation processes of degradation and volatilization of pesticides are critical to the simulation of pesticide loss since these mechanisms control the mass of chemical available for transport at any time following application. Highly volatile or degradable pesticides can be reduced to insignificant levels after only one month of exposure in the field (see Section VIII). On the other hand, non-volatile or non-degradable pesticides can continue to contribute to stream pollution months, or possibly years, after the initial application. In addition, volatilization and degradation, by microbial, chemical, or photochemical means, often accounts for the great majority of the applied pesticide removed from the soil environment; surface runoff and erosion removal of pesticides is generally a small fraction of the total application amount.

The PTR Model included surface and soil-incorporated volatilization models and a general pesticide degradation model. However, the volatilization models, derived from work by Farmer and Letey[16] were not utilized in the pesticide simulation due to lack of field data for testing purposes. The degradation model assumed a simple first-order decay. It was needed to estimate the amount of pesticide available for transport at any time during the growing season. In this way the runoff and erosion transport processes occurring during storm events could be evaluated. Neither model allowed for the effects of environmental conditions on the attenuation processes.

Due to the lack of data for testing, the volatilization models are not included in the present version of the ARM Model. The simple first-order degradation model remains so that the surface transport mechanism can be simulated and evaluated. Further research on these attenuation processes and on the effects of soil moisture, soil temperature, pH, etc. is needed before reliable models can be developed and utilized in the ARM Model. Steen[17] has suggested a subsurface pesticide attenuation model which attempts to account for soil temperature and moisture conditions. This model is presently under evaluation for addition to the ARM Model.

SECTION V

SNOW ACCUMULATION AND MELT SIMULATION

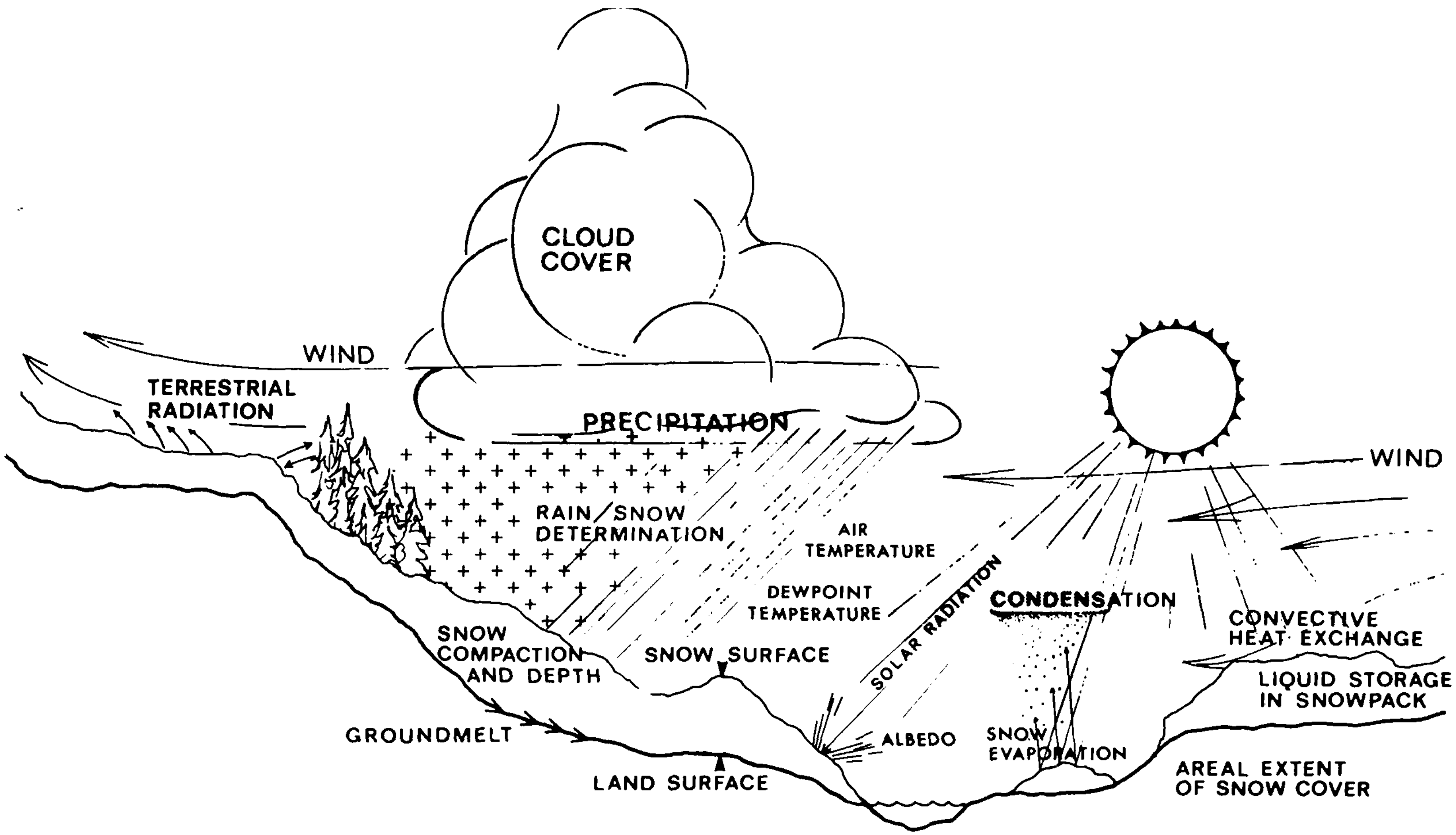
In the simulation of water quality processes, the mechanisms of snow accumulation and melt are often neglected. The stated reasons for this omission generally pertain to an assumed minor influence on water quality, the extensive data requirements, and the extreme complexity of the component processes. Obviously, in the southern latitudes of the United States and at many coastal locations, snow accumulation during winter months is often negligible. However, considering its location in a temperate climatic zone, over 50 percent of the continental United States experiences significant snow accumulation. In many areas streamflow contributions from melting snow continue throughout the spring and well into the summer. For many urban areas, the supply of water during the critical summer period is entirely a function of the extent of snow accumulation during the previous winter. Section III stressed the importance of continuous simulation in the modeling of agricultural nonpoint source pollutants. Snow accumulation and melt is a major factor in continuous hydrologic simulation. Thus, the consideration of these processes is an important part of any hydrologic model which is to provide a basis for the simulation of water quality processes.

PHYSICAL PROCESS DESCRIPTION

Snow accumulation and melt are separate but often concurrent mechanisms. The initial snow accumulation is largely a function of air (and atmospheric) temperature at the time of precipitation; whereas, snowmelt is an energy transfer process in the form of heat between the snowpack and its environment. Basically, 80 cal/cm^2 of heat must be supplied to obtain one centimeter of water from a snowpack at 0 °C (203 cal/cm^2 or 750 Btu/ft^2 for one inch of melt at 32 °F). This heat or energy requirement is derived from the following sources:

(1) Solar (shortwave) radiation
(2) Terrestrial (longwave) radiation
(3) Convective and advective transfer of sensible heat from overlying air
(4) Condensation of water vapor from the air
(5) Heat conduction from soil and surroundings
(6) Heat content of precipitation

The complexity of the snowmelt process is due to the many factors that influence the contributions from each of the above energy sources. Figure 8 conceptually indicates the factors and processes involved in snow accumulation and melt on a watershed. The combination of precipitation and near or below freezing temperatures results in the initial



Snow accumulation and melt processes **Figure 8** accumulation of the snowpack. Although relative humidity and air pressure influence the form of precipitation, temperature is the major determining factor in the rain/snow division. The rain/snow division is important to the hydrologic response of the watershed. Precipitation in the form of rain can become surface runoff immediately, and will contain sufficient heat energy to melt a portion of the snowpack. On the other hand, precipitation in the form of snow will augment the snowpack, and is more likely to contribute to soil moisture, groundwater, and subsurface flow as the snowpack melts.

Just as the snow begins to accumulate, the major melt processes are initiated. Both solar (shortwave) radiation and terrestrial (longwave) radiation are contributors to the snowmelt process, although solar radiation provides the major radiation melt component. The effective energy transfer to the snowpack from solar radiation is modified by the albedo, or reflectivity, of the snow surface and the forest canopy in watersheds with forested land. Terrestrial radiation exchange occurs between the atmosphere, clouds, trees, buildings and even the snowpack itself. Generally, solar radiation dominates the net radiation exchange during daylight hours resulting in a heat gain to the snowpack. Terrestrial radiation continues during the night causing a net heat loss from the snowpack during the dark hours. The radiation balance, in addition to the other heat exchange processes, allows melting of the pack during the day and a refreezing during the night.

When air temperatures are above freezing, convective and advective heat transfer to the snowpack producess another melt component. Condensation of water vapor on the snowpack from the surrounding air, and the opposing mechanism of snow evaporation from the pack, respectively add and subtract a component in the snowpack heat balance. Wind movement is a significant factor in all of these processes; its effect on heat transfer is readily acknowledged by anyone who has experienced a chilling northeaster. Depending on climatic conditions condensation and convection can contribute to a significant portion of the snowmelt.

The remaining melt mechanisms include the ground melt component resulting from heat from the land surface and surroundings, and rainmelt due to the heat input of rain impinging on the snowpack. Ground melt is due to the temperature difference between the snowpack and the land surface and subsurface. Areas that experience relatively light snowfall and low temperatures will have a small ground melt component due to the insulating effects of frost and frozen ground conditions. On the other hand, ground melt can be significant in areas with rapid accumulation and deep snowpacks. Also, urban areas with heat input from roads, buildings, and underground utilities, and special geologic areas (hot springs, volcanic activity, etc.) can experience an unusually high ground melt contribution.

Snowmelt caused by rain on a pack is usually quite small. Twenty-five millimeters (1 inch) of rainfall at 10 °C (50 °F) will produce only 3.2

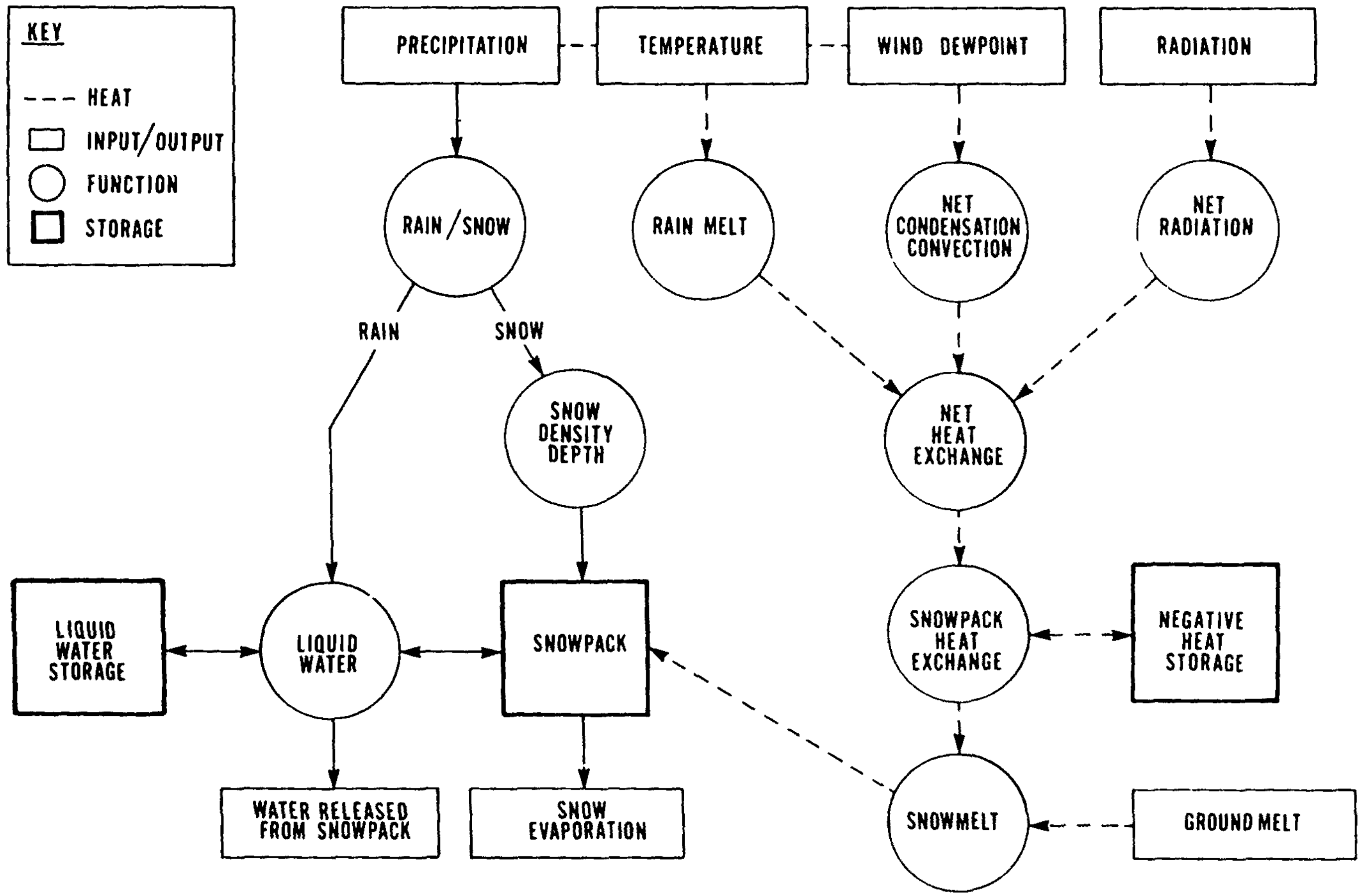
millimeters (0.125 inch) of melt. However, rain often occurs at high atmospheric humidity when condensation of water vapor can take place; condensation of 25 millimeters (1 inch) of water vapor (water equivalent) can produce 190 millimeters (7.5 inches) of melt. Thus, water vapor condensation can cause rapid snowmelt, and seems to be responsible for the myth that rainfall causes rapid snowmelt.

The release of melt from the snowpack is a function of the liquid moisture holding capacity of the snowpack and does not necessarily occur at the time of melt. The snowpack contains moisture in both frozen and liquid form; spaces between snow crystals contain water molecules. As melt occurs, more water molecules are added to the spaces in the snowpack until the moisture holding capacity is reached. Additional melt will reach the land surface and possibly result in runoff. As the snowpack increases in depth over the season, compaction of the pack results in a lower depth and a higher snow density. As density increases the moisture holding capacity of the snowpack decreases due to less pore space between snow crystals and a change in crystal structure.

Thus, the snowmelt reaching the land surface results from complex interactions between the melt components, climatic conditions, and snowpack characteristics. For the most part, the snowpack behaves like a moisture reservoir gradually releasing its storage. However, the combination of extreme climatic conditions and snowpack characteristics can lead to abnormally high liquid moisture holding capacity and sudden release of melt in relatively short time periods.[18] The damage which can occur during such events emphasizes the need to further study and understand the snowmelt process.

ALGORITHM DESCRIPTION

The objective of snow accumulation and melt simulation is to approximate the physical processes (described above) and their interactions in order to evaluate the timing and volume of melt water released from the snowpack. The algorithms used in simulating the processes shown in Figure 8 are based on extensive work by the Corps of Engineers,[19] Anderson and Crawford,[20] and Anderson.[21] Empirical relationships are employed when quantitative descriptions of the process are not available. The algorithms presented below are identical to those employed in HSP and have demonstrated reasonably successful results on numerous watersheds.[22,23,24,25] A flowchart of the snowmelt routine is shown in Figure 9. The major simulated processes can be divided into the two general categories of melt components and snowpack characteristics. The algorithms for the individual processes within each of these categories are briefly presented below in computer format and English units to promote recognition of the equations in the Model source code. The interested reader is referred to the original source materials for a more in-depth explanation.



Snowmelt simulation

Figure 9

Melt Components

Radiation Melt-

The total melt component in each hour due to incident radiation energy is

$$RM = (RA + LW)/203.2 \tag{9}$$

where RM = radiation melt, in/hr
RA = net solar radiation, langleys/hr
LW = net terrestrial radiation, langleys/hr
203.2 = langleys required to produce 1 inch of melt from snow at 32 °F

The effects of solar and terrestrial radiation are evaluated separately. An input parameter, RADCON, allows the user to adjust the solar radiation melt component to the conditions of the particular watershed. Daily solar radiation is required input data for the present version of the snowmelt routine. Hourly values are derived from a fixed 24-hour distribution and are modified by the effective albedo (calculations described under 'snowpack characteristics') and the watershed forest cover. An input parameter, F, indicates the fraction of the watershed covered by forests. On small agricultural watersheds F will usually be zero. However, forest cover affects many snowmelt processes and must be included whenever the snowmelt routine of the ARM Model is applied to forested watersheds or forested portions of agricultural watersheds.

Terrestial radiation is not generally measured; hence, an estimate must be obtained from theoretical considerations and modified by environmental factors (e.g. cloud cover, forest canopy, etc.). The following relationship for terrestrial radiation based on Stefan's Law of Black Body Radiation is found in "Snow Hydrology".[19]

$$R = \sigma TA^4\{F + (1-F)0.757\} - \sigma TS^4 \tag{10}$$

where R = net terrestrial radiation, langleys/min
F = fraction forest cover
TA = air temperature, °K
TS = snow temperature, °K
σ = Stefan's constant, 0.826×10^{-10}, langleys/min/°K

The snowmelt routine employs a linear approximation to the above relationship and modifies the resulting hourly terrestrial radiation for cloud cover effects. Back radiation from clouds can partially offset terrestrial radiation losses from the snowpack. Since cloud cover data information is not generally available and transposition of data from the osest observation point can be highly inaccurate, a daily cloud cover rrection factor is estimated to reduce this radiation loss from the ck. For days when precipitation occurs, terrestrial radiation loss from e pack is reduced by 85 percent to account for the effects of complete oud cover; this reduction factor decreases to zero in the days following e storm event.

ndensation-Convection Melt-
e melt resulting from heat exchange due to condensation and convection often combined in a single equation. A constant ratio between the efficients of convection and condensation (Bowen's ratio) is generally sumed. Since the two mechanisms are operative under different climatic tuations, the algorithms are presented here separately. Condensation curs only when the vapor pressure of the air is greater than saturation, ereas convection melt occurs when the air temperature is greater than eezing. The algorithms are as follows:

$$CONV = CCFAC*.00026*WIN*(TX-32)*(1.0-0.3*(MELEV/10000)) \qquad (11)$$

$$CONDS = CCFAC*.00026*WIN*8.59*(VAPP-6.108) \qquad (12)$$

ere CONV = convection melt, in/h
CONDS = condensation melt, in/hr
CCFAC = input correction factor to adjust melt values to field conditions
WIN = wind movement, mi/hr
TX = air temperature, °F
MELEV = mean elevation of the watershed, 1000's ft (Note: the expression 1.0-0.3*(MELEV/10000) is a linear approximation of the relative change in air pressure with elevation, and corresponds to P/Po in "Snow Hydrology".)
VAPP = vapor pressure of the air, millibars
6.108 = saturation vapor pressure over ice at 32 °F, millibars
0.00026,
8.59 = constants in the analogous expression in "Snow Hydrology" (Note: 0.00026 corresponds to the daily coefficient, 0.00629, adjusted to an hourly basis.)

in melt-
enever rain occurs on a snowpack, heat is transmitted to the snowpack, d melt is likely to occur. The quantity of snowmelt from this component calculated as follows, assuming the temperature of the rain equals air mperature:

$$RAINM = ((TX-32)*PX)/144 \quad (13)$$

where RAINM = rain melt, in/hr
PX = rain, in/hr
TX = air temperature, °F
144 = units conversion factor, °F

Ground melt-
As mentioned previously, melt due to heat supplied from the land surface and subsurface can be significant in the overall water balance. Since ground melt is relatively constant, an input parameter specifies the daily contribution. Heat loss from the snowpack can result in snowpack temperatures less than 32 °F. When this occurs, the ground melt component is reduced 3 percent for each degree below 32 °F.

Snowpack Characteristics

Rain/Snow Determination-
The form of precipitation is critical to the reliable simulation of runoff and snowmelt. The following empirical expression based on work by Anderson[21] is used to calculate the effective air temperature below which snow occurs:

$$SNTEMP = TSNOW + (TX-DEWX)*(0.12 + 0.008*TX) \quad (14)$$

where SNTEMP = temperature below which snow occurs
TSNOW = input parameter
TX = air temperature
DEWX = dewpoint temperature

Variable meteorologic conditions and the relatively imprecise estimates of hourly temperature derived from maximum and minimum daily values can cause some discrepancies in this determination. For this reason, the use of TSNOW as an input parameter allows the user flexibility in specifying the form of precipitation recorded in meteorologic observation. The above expression allows snow to occur at air temperatures above TSNOW if the dewpoint temperature is sufficiently depressed. However, a maximum variation of one Fahrenheit degree is specified resulting in a maximum value for SNTEMP = TSNOW + 1.

Snow Density and Compaction-
The variation of the density of new snow with air temperature is obtained from "Snow Hydrology"[19] in the following form:

$$DNS = IDNS + (TX/100)^2 \quad (15)$$

where DNS = density of new snow
IDNS = density of new snow at an air temperature of 0 °F
TX = air temperature, °F

Snow density is expressed in inches of water equivalent for each inch of snow. With snow fall and melt processes occurring continuously, the snow density is evaluated each hour. If the snow density is less than 0.55, compaction of the pack is assumed to occur. The new value for snow depth is calculated by the empirical expression:

DEPTH2 = DEPTH1*(1.0-0.00002*(DEPTH1*(.55-SDEN))) (16)

where DEPTH2 new snow depth, in
DEPTH1 = old snow depth, in
SDEN = snow density

Areal Snow Coverage-
The areal snow coverage of a watershed is highly variable. Watershed response differs depending on whether the precipitation, especially in the form of rain, is falling on bare ground or snow covered land. The areal snow coverage is modeled by specifying that the water equivalent of the existing snowpack, PACK, must exceed the variable IPACK for complete coverage. IPACK is initially set to a low value to insure complete coverage for the initial events of the season and is reset to the maximum value of PACK attained to date in each snowmelt season. Since the ratio PACK/IPACK indicates the fraction of the watershed with snow coverage, less than complete coverage results as the melt process reduces the value of PACK. An input parameter, MPACK, allows the user to specify the water equivalent required for complete snow coverage. Thus MPACK is the maximum value of IPACK, resulting in complete coverage when PACK is greater than MPACK, and less than complete coverage (PACK/MPACK) when PACK decreases to values less than MPACK.

Albedo-
The albedo or reflectivity of the snowpack is a function of the condition of the snow surface and the time since the last snow event. During the snow season, the maximum and minimum values for albedo are specified as 0.85 and 0.60, respectively. It is reset to approximately the maximum value with each major snow event and decreases gradually as the snowpack ages.

Snow evaporation-
Evaporation from the snow surface is usually quite small, but its inclusion in snowmelt calculations is necessary to complete the overall water balance of the snowpack. The physical process is the opposite of condensation occurring only when the vapor pressure of the air is less than the saturation vapor pressure over snow. The following empirical

relationship is used to calculate hourly snow evaporation:

$$SEVAP = EVAPSN*0.0002*WIN*(VAPP-SATVAP)*PACKRA \quad (17)$$

where SEVAP = snow evaporation, in/hr
EVAPSN = correction factor to adjust to field conditions
WIN = wind movement, mi/hr
VAPP = vapor pressure of the air, millibars
SATVAP = saturation vapor pressure over snow, millibars
PACKRA = fraction of watershed covered with snow

Snowpack Heat Loss-
Heat loss from the snowpack can occur if terrestrial back radiation from the pack is large, or if air temperatures are very low. Since this heat is emitted by the pack, it is simulated as a negative heat storage, NEGMLT, which must be satisfied before melt can occur. Any heat available to the snowpack first offsets NEGMLT before melting can occur. The hourly increment to NEGMLT is calculated from the following empirical relation whenever the air temperature is less than the temperature of the pack:

$$GM = 0.0007*(TP-TX) \quad (18)$$

where GM = hourly increment to negative heat storage, in
TP = temperature of the pack, $^{\circ}F$
TX = air temperature, $^{\circ}F$

NEGMLT and GM are calculated in terms of inches of melt corresponding to the heat loss from the pack. The current value of NEGMLT is used to calculate the temperature of the pack simulating the drop in temperature as heat loss from the pack continues. A maximum value of NEGMLT is calculated as a function of air temperature and the water equivalent of the pack by assuming that the temperature in the pack varies linearly from ambient air temperature at the snow surface to 32 $^{\circ}F$ at the soil surface. This maximum negative heat storage is calculated as follows:

$$NEGMM = 0.00695*(PACK/2.0)*(32.0-TX) \quad (19)$$

where NEGMM = maximum negative heat storage, in
PACK = water equivalent of the snowpack, in
TX = air temperature, $^{\circ}F$ ($<32\,^{\circ}F$)
0.00695 = conversion factor, $^{\circ}F^{-1}$

Snowpack Liquid Water Storage-
Liquid water storage within the snowpack is limited by a user input parameter, WC, which specifies the maximum allowable water content per inch of snowpack water equivalent. Thus, the maximum liquid water storage is calculated as WC x PACK. However, this value is reduced if high snow density values are attained.

MODEL OPERATION AND DATA REQUIREMENTS

The snowmelt routine operates on an hourly interval calculating the various components of the snow accumulation and melt process and providing hourly values of the water released from the snowpack (Figure 9). Since the LANDS simulation is performed on 5 or 15 minute intervals, the hourly melt values are divided into the shorter time intervals to continue the simulation. Because the snowmelt process is much slower than the runoff process, the hourly time interval appears to be adequate.

In addition to precipitation and evaporation, the present version of the snowmelt routine in the ARM Model requires continuous data series for daily max-min air temperature, daily wind movement, daily dewpoint temperature, and daily solar radiation. Since the routine operates on an hourly basis, hourly values for each of these meteorologic values would be preferable. However, with the exception of experimental watersheds, few locations would have such detailed data on a regular basis. Consequently, the routine provides an empirical hourly distribution for wind movement and solar radiation, and assumes that dewpoint temperature is relatively constant throughout the day. The daily max-min air temperature values are fitted to a sinusoidal distribution assuming minimum and maximum temperatures occur during the hour beginning at 6:00 AM and 3:00 PM. Thus, daily values are required for the meteorologic data series.

Table 5 defines the input parameters required for model operation, many of which have been discussed above. Parameter evaluation and model calibration are discussed in Appendix A. An understanding of the physical processes and the algorithm approximations is critical to the intelligent use of the snowmelt routine. Consequently, the potential user is advised to re-read and study the algorithm descriptions and parameter definitions prior to attempting application of the snowmelt routine.

Table 5. SNOWMELT PARAMETERS

RADCON:	Parameter to adjust theoretical solar radiation melt equations to field conditions
CCFAC:	Parameter to adjust theoretical condensation and convection melt equation to field conditions
EVAPSN:	Parameter to adjust theoretical snow evaporation to field conditions
MELEV:	Mean elevation of the watershed
ELDIF:	Elevation difference between the temperature station and the midpoint of the watershed
TSNOW:	Wet-bulb air temperature below which snowfall occurs
MPACK:	Water equivalent of the snowpack required for complete coverage of the watershed
DGM:	Daily groundmelt
WC:	Maximum water content of the snow
IDNS:	Index density of new snow at $0^{\circ}F$
SCF:	Snow correction factor to compensate for deficiencies in the gage during snowfall
PETMAX:	Temperature below which input potential evapotranspiration is reduced by 50 percent
PETMIN:	Temperature below which input potential evapotranspiration is reduced to zero
PETMUL:	Potential evapotranspiration multiplier to adjust observed daily input values
WMUL:	Wind multiplier to adjust observed daily wind values
RMUL:	Solar radiation multiplier to adjust observed daily solar radiation values
F:	Fraction of watershed with forest cover
KUGI:	Index to the extent of undergrowth in forested areas

SECTION VI

NUTRIENT MODELING

Water pollution from agricultural land has been increasing due to greater use of machinery and chemicals to improve crop yields. Chemicals are applied to prevent unwanted plants (herbicides) and animals (pesticides), and to increase available plant nutrients (fertilizers). After application, herbicides persist in the soil until they are degraded to less harmful compounds or are removed from the soil by washoff or leaching. Fertilizers on the other hand are applied as a supplement to nutrients present in the soil profile. Plants do not absorb all the applied fertilizer. Typically, only 5 to 10 percent of the applied phosphorus and about 50 percent of the applied nitrogen is recovered in the crop. The remaining nutrients can be retained in the soil in unavailable forms or lost by volatilization, leaching, and surface washoff. Although greater fertilizer application will improve crop yields, it will increase nutrients in the soil available for contamination of streams and groundwaters.

Excess nutrient applications are undesirable from three viewpoints: health, aesthetics, and economics. Drinking water containing high nitrate concentrations may cause methomoglobinemia in small children. High nitrates can result from natural soil conditions or excess fertilization from agriculture or silviculture. The U.S. Public Health Service Drinking Water Standards for nitrate were set to prevent the occurrence of this disease. Aesthetically, addition of nitrogen and phosphorus in surface waters can greatly accelerate the eutrophication process causing unsightly algal blooms and preventing recreational and other uses of the water body. The final point of concern is the efficient utilization of energy resources. Ammonia, the most common nitrogen fertilizer, requires natural gas for its production. Thus, unnecessary loss of fertilizer is a waste of scarce energy supplies. Recent increases will tend to reduce fertilizer use; this alone may not be sufficient to ameliorate the impact of nutrients from agriculture on the aquatic environment.

Methods for nutrient control can be investigated and developed through costly field experiments or through the use of a mathematical model of the important processes occurring on and in the soil profile.

Nutrient simulation in the ARM Model attempts to predict nutrient losses from erosion, surface washoff, leaching, and biological conversion. With testing and calibration the Model could be used to develop fertilizer management plans to maximize fertilizer efficiency and minimize the water quality impact of fertilizer use.

NUTRIENT CYCLES

Nitrogen

Many nitrogen compounds are indigenous to the soil and undergo chemical and biological transformations of importance to crop production and pollution control. A general nitrogen cycle for agricultural lands is depicted in Figure 10. Most soil nitrogen is in the organic form as decaying plant residues and rather resistant soil humus.[26] Organic nitrogen can be broken down to ammonia through the process of mineralization, also called ammonification. Ammonia is usually strongly adsorbed to soil surfaces and can undergo nitrification to nitrite and nitrate. Nitrite is rapidly converted to nitrate which is the most common form of the mobile nitrogen compounds. Dissolved nitrates can be removed by overland flow and interflow, and leached to groundwater. Biologically, nitrate can be absorbed by plants, reduced anaerobically to various nitrogen gases and immobilized by microorganisms in the presence of nitrogen-deficient organic material. Nitrogen absorbed by plants is often lost from the soil through harvesting. Nitrogen input to the soil occurs by a number of pathways including rainfall, plant residues, dry fall of dust and dirt, biological fixation of atmospheric nitrogen, and direct application of fertilizer nitrogen. Although the soil nitrogen cycle is quite complex, the major pathways can be sufficiently quantified to allow mathematical simulation.

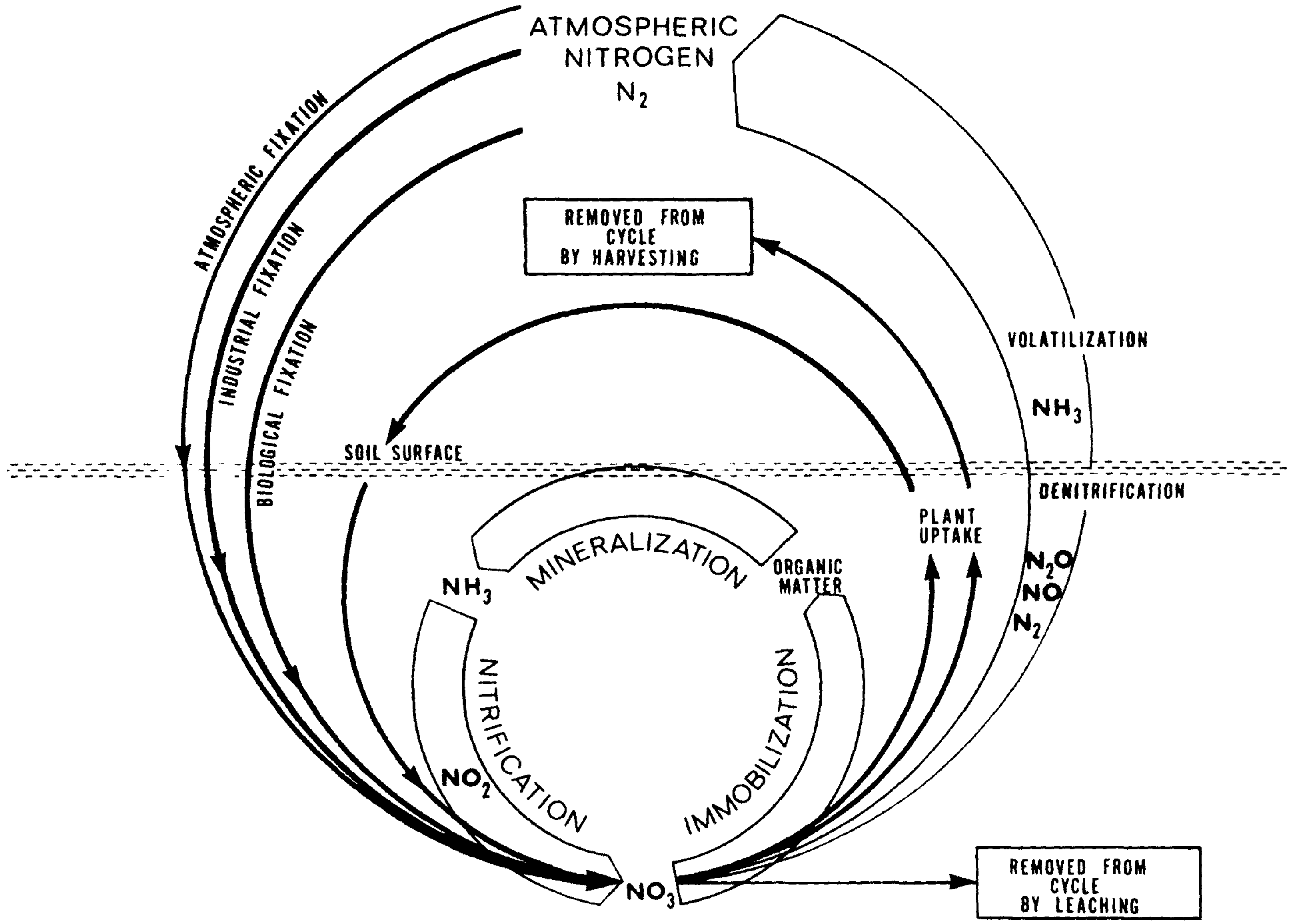
Phosphorus

While phosphorus does not exist in as many forms as nitrogen, phosphorus compounds undergo transformations important to agriculture as shown in Figure 11. Organic phosphorus can be mineralized to inorganic phosphates and under special circumstances, the reaction can be reversed to immobilization of inorganic phosphates to organic phosphorus. Inorganic phosphates are either strongly adsorbed to clay particles, or present as insoluble calcium, magnesium, iron or aluminum phosphates. Soluble phosphate concentration rarely exceeds 0.2 mg/l. Thus, the major mechanism for the loss of phosphorus compounds is soil erosion.[27]

PAST WORK

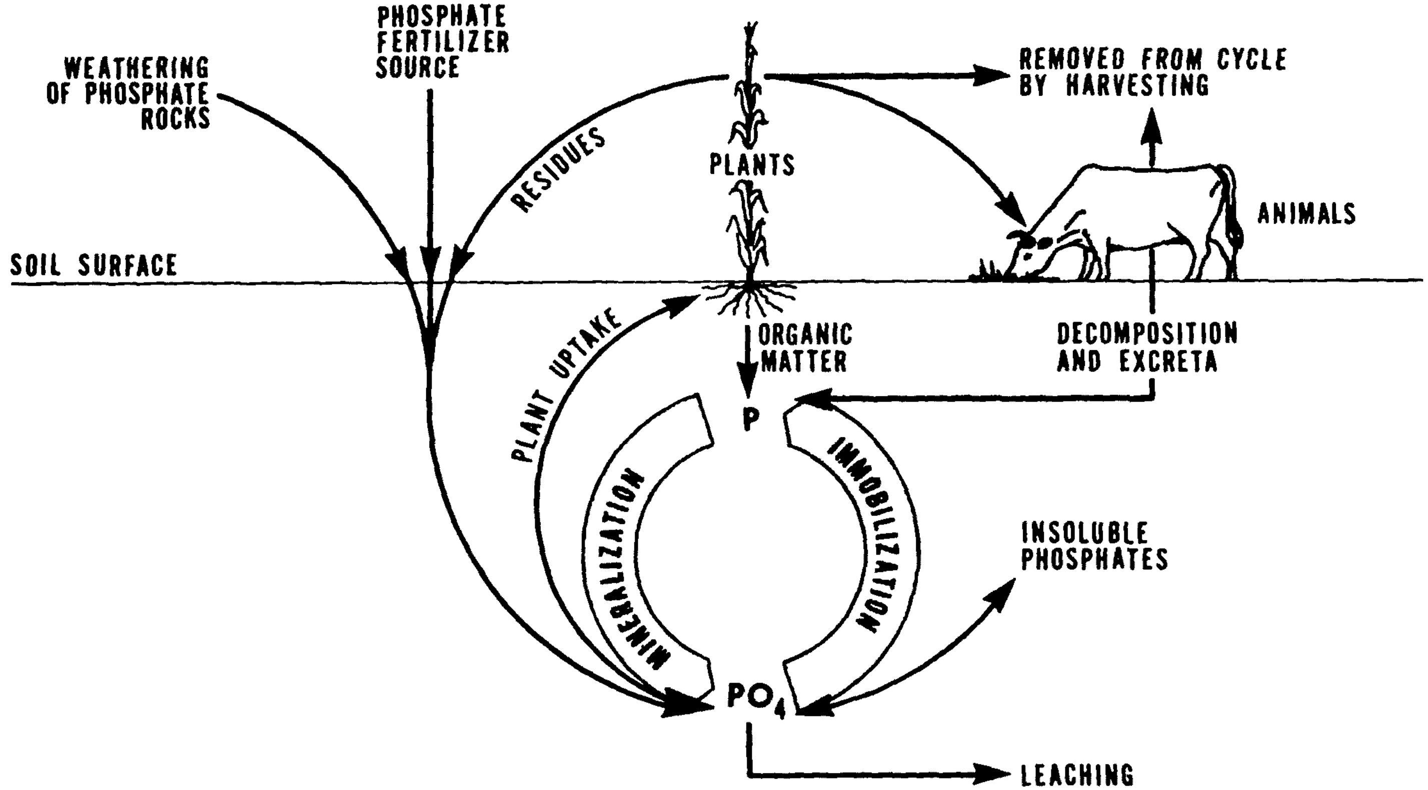
A number of models have been developed recently to predict nutrient washoff from agricultural lands. Models in which actual soil processes were considered are discussed below.

A complex watershed model for irrigated land was developed by Dutt and others[28] at the University of Arizona. The model includes procedures



Nitrogen Cycle

Figure 10



Phosphorus Cycle

Figure 11

for calculating moisture flow and chemical and biological nutrient reactions. The nitrogen transformation rates were developed by regression analysis on data from arid regions. The following assumptions were made:

(1) no denitrification or volatilization occurs
(2) soil pH is in the range of 7.0 to 8.5
(3) symbiotic and non-symbiotic nitrogen fixation is small compared to other nitrogen transformations
(4) nitrite is only present in trace amounts
(5) fertilizers and other nitrogen additions are applied uniformly and thoroughly mixed with the soil
(6) the microbial populations of different soils are approximately equivalent in their responses to parameters associated with nitrogen transformations.

The model would be difficult to use in non-arid regions because the reaction rates are permanently fixed by the regression equations.

Hagin and Amberger[29] have developed a computer model for predicting nitrogen and phosphorus movement and transformations on agricultural land. They used the IBM Continuous System Modeling Program (CSMP) for simulating ecological processes and transport phenomena in the soil. The model includes mineralization and immobilization of nitrogen, nitrification, denitrification, sediment washoff of phosphate and transport of oxygen and heat. The report is particularly useful because it contains considerable information on the effect of various environmental factors on the reaction rates. Graphs are included for correcting reaction rates for temperature, pH, moisture and oxygen level. Unfortunately, the model was not tested on observed data. Thus, the model assumptions have not been verified.

The Agricultural Research Service has developed the Agricultural Chemical Transport Model (ACTMO)[30] which includes hydrologic, sediment, and chemical transport simulation. The nitrogen simulation considers mineralization of organic nitrogen to nitrate, plant uptake of nitrate, and nitrate removal by overland flow and leaching. The mineralization rate is a first-order reaction modified for temperature and moisture levels. The rate of nitrate uptake by plants is a function of the evapotranspiration rate. The model does not include the loss of nitrogen by sediment transport or denitrification. ACTMO was tested with available hydrologic, sediment and pesticide data on a small watershed, but no testing of the nitrogen model was reported.

A preliminary model of nitrogen transformations in agricultural soils was reported by Mehran and Tanji.[31] They developed a complex nitrogen transformation model for batch reactors assuming all reactions proceed by first-order kinetics. The model will be added to a water movement model in the future to allow for advective movement of nitrogen compounds in the soil column. The model did not adjust reaction rates for environmental factors such as temperature, pH, water content, aeration and organic matter. Through adjustment of reaction rates, the model was able to reproduce data collected in four different laboratory experiments.

ALGORITHM DESCRIPTIONS

In the ARM Model, as a first approximation, all chemical and biological reactions are represented by first-order kinetics. The rate of a first order reaction is proportional to the amount of the reactant; the proportionality factor is the rate constant. Below is a general discussion of first-order kinetics as they relate to biological and chemical reactions. The method of temperature correction for the reaction rates is also discussed, followed by a presentation of the algorithms which represent the nitrogen and phosphorus transformations in the ARM Model.

First-Order Kinetics

The biological conversion of compound A to compound B with reaction rate constant k can be expressed as

$$A \xrightarrow{k} B \tag{20}$$

The rate of this reaction is expressed in terms of the rate of change in A and B with time or

$$-\frac{d}{dt}\{A\} = \frac{d}{dt}\{B\} = k\{A\} \tag{21}$$

Solution of the differential equation for A and B yields

$$A = A_o e^{-kt} \tag{22}$$

$$B = A_o (1 - e^{-kt}) \tag{23}$$

where A_o = initial amount of compound A at time t = 0.

In chemical reactions there is also a backward reaction of B going to A, expressed as

$$A \underset{k_b}{\overset{k_f}{\rightleftharpoons}} B \qquad (24)$$

and

$$-\frac{d}{dt}\{A\} \quad \frac{d}{dt}\{B\} - k_f\{A\} - k_b\{B\} \qquad (25)$$

where k_f = forward rate constant
k_b = backward rate constant

At equilibrium when the rate of change in concentration is zero, Equation 25 becomes

$$0 = k_f\{A\} - k_b\{B\} \qquad (26)$$

On solving for A, a linear relationship is obtained between A and B at equilibrium

$$\{A\} = \frac{k_b}{k_f}\{B\} \qquad (27)$$

Chemical reactions that proceed rapidly can be viewed as instantaneously obtaining equilibrium or quickly approaching equilibrium with rapid forward and backward reaction rates. Modeling of adsorption-desorption chemical reactions with first-order kinetics produces a linear relationship between adsorbed and dissolved compounds at equilibrium. This is a simplification of the equilibrium relationship defined by more complex methods.

Two equations are commonly used to describe the equilibrium distribution of a compound between adsorbed and dissolved states. The Freundlich equation is

$$\frac{x}{m} - KC^{1/n} \qquad (28)$$

where $\frac{x}{m}$ = amount adsorbed per unit weight adsorbent

C = equilibrium concentration of adsorbate in solution after adsorption
K,n = empirical constants

Usually n is greater than 1.0. However, if n is set to 1.0, the equation reduces to a linear relationship between the amount adsorbed and dissolved. The Langmuir equation is another relationship relating adsorbed concentration to the dissolved concentration at equilibrium:

$$\frac{x}{m} = a\{C/(\frac{1}{b} + C)\} \tag{29}$$

where $\frac{x}{m}$ = amount adsorbed per unit weight adsorbent
C = equilibrium concentration of adsorbate in solution after adsorption
a,b = empirical constants

When the solution concentration is small such that $1/b \gg C$, the Langmuir equation reduces to a linear isotherm

$$\frac{x}{m} = abC \tag{30}$$

Thus, a first-order kinetic approach to adsorption-desorption reactions results in a linear isotherm which is also obtainable from the Freundlich and Langmuir equations. A general discussion of adsorption-desorption reaction kinetics is given by Oddson et al.[32]

Temperature Correction of Reaction Rates

In chemical and biological reactions, an increase in temperature will cause an increase in the reaction rate for a certain temperature range. Reaction rates can be adjusted for different temperatures by a simplification of the Arrhenius Equation:[33]

$$k_T = k_{35}\theta^{(T-35)} \tag{31}$$

where k_T = reaction rate at temperature T
k_{35} = reaction rate at 35°C
θ = temperature correction coefficient
T = temperature in degrees Celsius

Typically biological reaction rates will double with each ten Celsius degree rise in temperature. This corresponds to $\theta = 1.07$. For nutrient transformations in the ARM Model, the reaction rates are modified for temperatures less than 35 °C. At temperatures of 35 °C or greater, the reaction rates are assumed to remain constant. In this temperature range the assumption of a constant temperature correction coefficient, θ, is doubtful, and different bacterial species demonstrate widely varying behavior. Each nutrient reaction rate requires its own temperature correction coefficient.

Nitrogen Transformations

Seven different forms of nitrogen and ten reaction rates are used to represent nitrogen transformations in the soil. Figure 12a is a diagram of the nitrogen forms, and their interaction. Table 6 presents the resulting system of coupled differential equations. The reaction rate equations for the specific transformations are developed below.

Mineralization and Immobilization-

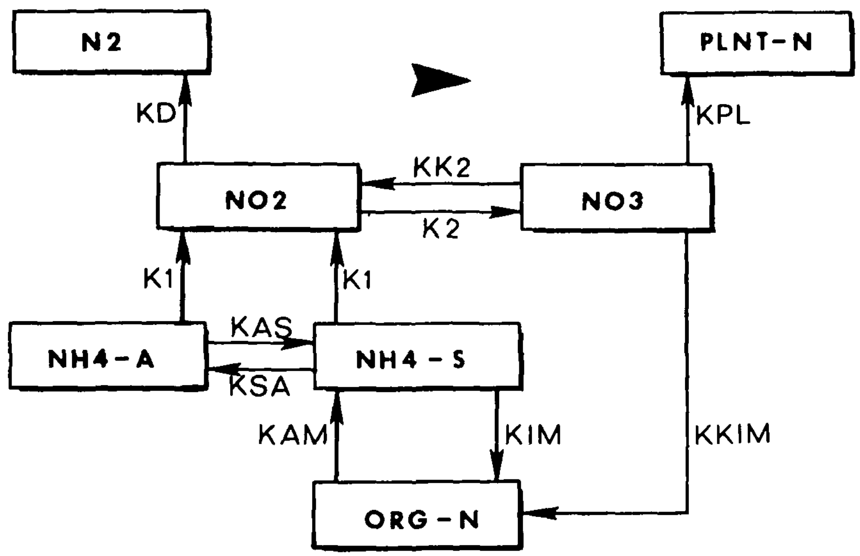
These processes are difficult to measure independently so researchers usually report only the net amount of mineralization or immobilization. The basic mechanisms occurring in the soil can be visualized as

$$\text{Organic -N} \xrightarrow{\text{mineralization}} \text{NH4, NO3} \xrightarrow[\text{(uptake)}]{\text{microbial immobilization}} \text{protein complexes} \quad (32)$$

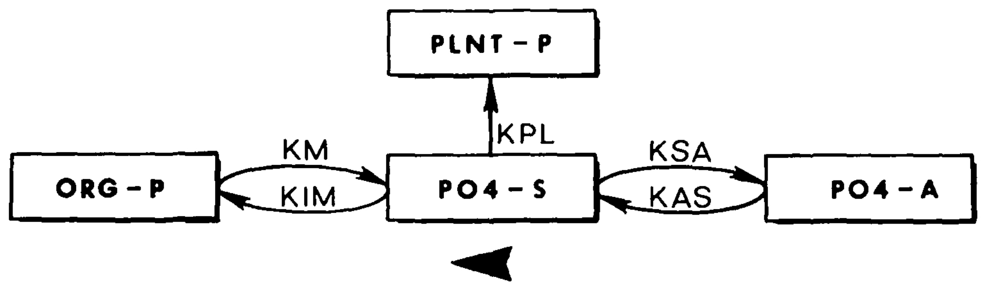
There is net mineralization when mineralization exceeds microbial uptake, and net immobilization when uptake exceeds mineralization. The amount of organic nitrogen in the soil far exceeds other nitrogen forms. Mineralization, even at the slow rate, can have considerable impact on the amount of inorganic nitrogen available for plant uptake and leaching. The most significant studies to date on quantifying the rate of organic nitrogen mineralization have been done by George Stanford and his co-workers at the Agriculture Research Service, Beltsville, Maryland.[34,35,36] Stanford incubated 39 different soils to determine the soil nitrogen mineralization potentials and mineralization rates. The soil nitrogen mineralization potential is the amount of organic nitrogen in the soil which is susceptible to mineralization. The incubation studies found that 5 to 41 percent of the organic nitrogen was mineralizable, and that the first-order decay rate was relatively uniform for the different soils. Mineralization rates were also measured at different temperatures for selected soils. The reaction rate approximately doubled for each ten Celsius degree increase in the temperature range investigated.

The mineralization rate was also found to be dependent on soil moisture. The rate increased up to a maximum, at about 80 to 90 percent filled pore space, and then declined with higher soil moisture. At higher moisture levels the rate of oxygen diffusion into the soil was retarded, resulting in lower mineralization due to the lack of oxygen.

Nutrient transformations in the ARM model



A. Nitrogen transformations in ARM model



B. Phosphorus transformations in ARM model

Figure 12

Table 6. COUPLED SYSTEM OF DIFFERENTIAL EQUATIONS FOR NITROGEN TRANSFORMATIONS

Organic Nitrogen:

$$\frac{d}{dt}\{\text{ORG-N}\} = \text{KIM}\{\text{NH4-S}\} + \text{KKIM}\{\text{NO3}\} - \text{KAM}\{\text{ORG}\}$$

Solution Ammonia:

$$\frac{d}{dt}\{\text{NH4-S}\} = \text{KAM}\{\text{ORG-N}\} - (\text{KSA} + \text{K1} + \text{KIM})\{\text{NH4-S}\} + \text{KAS}\{\text{NH4-A}\}$$

Adsorbed Ammonia:

$$\frac{d}{dt}\{\text{NH4-A}\} = \text{KSA}\{\text{NH4-S}\} - (\text{KAS} + \text{K1})\{\text{NH4-A}\}$$

Nitrite:

$$\frac{d}{dt}\{\text{NO2}\} = \text{K1}\{\text{NH4-S}\} + \text{K1}\{\text{NH4-A}\} - (\text{KD} + \text{K2})\{\text{NO2}\} + \text{KK2}\{\text{NO3}\}$$

Nitrate:

$$\frac{d}{dt}\{\text{NO3}\} = \text{K2}\{\text{NO2}\} - (\text{KK2} + \text{KKIM} + \text{KPL})\{\text{NO3}\}$$

Nitrogen Gas:

$$\frac{d}{dt}\{\text{N2}\} \quad \text{KD}\{\text{NO2}\}$$

Plant Nitrogen:

$$\frac{d}{dt}\{\text{PLNT-N}\} = \text{KPL}\{\text{NO3}\}$$

The mineralization rate equation used in the ARM Model is

$$\frac{d}{dt}\{ORG\text{-}N\} = KAM\{ORG\text{-}N\}\theta_{KAM}^{(T-35)} \qquad (33)$$

where ORG-N = organic nitrogen mass, kg/ha
KAM = mineralization rate constant at 35°C, per day
θ_{KAM} = temperature correction coefficient for mineralization
T = soil temperature, °C

The decrease in organic nitrogen will result in an increase of ammonia as shown in Figure 12a. At this time corrections for oxygen and moisture levels are not included. Work is presently underway to incorporate the effects of these environmental factors.

Immobilization of inorganic nitrogen in the soil has been reviewed by Bartholomew.[37] When plant residues low in nitrogen are added to the soil, ammonia or nitrate will be removed from the soil solution to make more protein needed for larger microorganism populations. The immobilization process has not been studied extensively and immobilization rates are not readily available. Bartholomew indicated immobilization was a first order reaction with temperature and moisture dependence. More reaction rate and temperature dependence data are needed to adequately model this process.

The ARM Model represents immobilization as potentially removing ammonia and nitrate according to the following equations:

$$-\frac{d}{dt}\{NH4\text{-}S\} = KIM\{NH4\text{-}S\}\theta_{KIM}^{(T-35)} \qquad (34)$$

$$-\frac{d}{dt}\{NO3\} = KKIM\{NO3\}\theta_{KKIM}^{(T-35)} \qquad (35)$$

where KIM, KKIM = immobilization rate constants at 35 °C, per day
NH4-S, NO3 = ammonia in solution and nitrate concentration, kg/ha
θ_{KIM}, θ_{KKIM} = temperature correction coefficients
T = temperature, °C

Nitrification-

Nitrification is a two-step process in which ammonia is oxidized first to nitrite and then to nitrate. This is an important soil reaction because a largely immobile form of nitrogen, ammonia, is converted to a highly mobile form, nitrate, which may be absorbed by plants, lost by leaching and denitrification, or removed by surface runoff. Alexander[38] provided a good description of the nitrification process and an overview of current research. Quantification of the nitrification process can be approached from a simplification of the works of A. D. McLaren,[39] of U.C. Berkeley, who has published many articles relating nitrogen transformations to enzyme kinetics and bacterial growth dynamics. The basic equation is

$$- \frac{d}{dt}\{s\} = A \frac{dm}{dt} + \alpha m + \frac{k''\beta\{s\}}{k_m+\{s\}} \qquad (36)$$

where
- $\{s\}$ = nitrogen substrate concentration
- m = biomass
- A = nitrogen oxidized per unit weight of biomass synthesized
- α = nitrogen oxidized per unit weight of biomass per unit time for maintenance
- β = amount of enzyme per unit biomass involved in waste metabolism
- k'' = proportionality constant
- k_m = half saturation constant

The first term on the right side of Equation 36 represents consumption for microbial growth, the second is for maintenance, and the third term accounts for substrate oxidized by the enzyme system but not needed for growth or maintenance. The basic equation can be simplified by assuming a fully enriched soil where dm/dt = 0, and small substrate concentrations ($s \ll K_m$). Following these assumptions, Equation 36 becomes

$$- \frac{d}{dt}\{s\} = \alpha m_{max} + K\{s\} \qquad (37)$$

This equation can be simplified further when the first term is much smaller than the second, resulting in the first-order rate equation.

$$- \frac{d}{dt}\{s\} = k\{s\} \qquad (38)$$

Although McLaren was able to evaluate the parameters appearing in Equation 36, parameter estimates are not available for other soil types under field conditions. Alexander[38] presented some discussion on the effects of temperature, pH, aeration, and moisture on the nitrification process. More quantitative information on environmental factors was published in a report by Hagin and Amberger.[29]

In the ARM Model nitrification is represented as a two-step process, each step with its own rate constant and temperature correction factor. The oxidation of solution and adsorbed ammonia to nitrite is followed by the rapid oxidation of nitrite to nitrate. These reactions are

$$-\frac{d}{dt}\{NH4\text{-}S + NH4\text{-}A\} = K1\ \{NH4\text{-}S + NH4\text{-}A\}\theta_{K1}^{(T-35)} \qquad (39)$$

$$-\frac{d}{dt}\{NO2\} = K2\ \{NO2\}\theta_{K2}^{(T-35)} \qquad (40)$$

where NH4-S + NH4-A = mass of ammonia in solution and adsorbed, kg/ha
NO2 = mass of nitrite, kg/ha
K1, K2 = first and second step rate constants at 35 °C, per day
θ_{K1}, θ_{K2} = first and second step temperature correction coefficients
T = temperature, °C

Denitrification-

Until recently prediction of denitrification rates has not been possible although the mechanisms have been known for some time. Denitrification is favored in wet, poorly aerated soils that have sufficient decomposable organic matter. The tremendous increase in the use of nitrogen fertilizers and the possibility of losing over 30 percent of the applied nitrogen through denitrification has sparked recent interest in quantifying and predicting these losses.[40]

The most quantitative description of the denitrification process has been published recently by Stanford et al.[41,42] Similar to the incubation studies used for measuring mineralization rates and potentials, 30 soil types were mixed with water and incubated at 35 °C following the addition of nitrate. The rate of nitrate disappearance was used to measure the denitrification rate. The authors found denitrification fit a first-order process better than a zero-order process. Unlike the results from the mineralization studies where the mineralization rate was relatively constant among the soils, the denitrification rate constant varied by a factor of 30 from the slowest rate to the fastest rate. Seventy-eight percent of this variation could be predicted by a regression equation based on a soluble carbon index. The soluble carbon index was better than a total carbon index because much of the total carbon of soils is highly resistant to decomposition.

Stanford et al.[41,42] also evaluated the denitrification rate constant at temperatures other than 35 °C. They found the reaction rate increased about twofold for each ten Celsius degree increase in temperature over the range 15 to 35 °C. There was little change in the rate constant when the temperature increased from 35 °C to 45 °C.

Denitrification is represented in the ARM Model as a two-step process, first reduction of nitrate to nitrite, and then reduction of nitrite to nitrogen gas. The rate equations are

$$-\frac{d}{dt}\{NO3\} = KK2\ \{NO3\}\theta_{KK2}^{(T-35)} \qquad (41)$$

and

$$\frac{d}{dt}\{NO2\} = KD\ \{NO2\}\theta_{KD}^{(T-35)} \qquad (42)$$

where

NO3, NO2	=	nitrate and nitrite mass, kg/ha
KK2, KD	=	first and second step rate constants at 35 °C, per day
θ_{KK2}, θ_{KD}	=	temperature correction coefficients
T	=	temperature, °C

In spite of the importance of oxygen level on the denitrification rate, it was not possible to include a correction for oxygen level because it is not simulated in the present model. Thus, at this time, the denitrification reactions are either turned on or turned off all the time depending on the values of KK2 and KD. Future work will attempt to include oxygen uptake and diffusion in the soil and allow for internal adjustment of denitrification rate as a function of oxygen level.

Plant Uptake-

The primary mechanism for removal of nitrogen from agricultural land is through plant uptake. Viets[43] provided a general review of nitrogen uptake by plants. Van der Honert and Hooymons[44] showed that the rate of nitrate uptake was a first-order reaction at nitrate concentrations less than 5 mg/l and a zero-order reaction at higher concentrations. The effect of temperature and pH on the rate of uptake was also discussed.

The ARM Model represents plant uptake of nitrates according to the following equation:

$$\frac{d}{dt}\{PLNT\text{-}N\} \quad KPL\ \{NO3\}\theta_{KPL}^{(T-35)} \qquad (43)$$

where PLNT-N = mass of nitrogen taken up by plants, kg/ha
NO3 = mass of nitrate, kg/ha
KPL = plant uptake rate constant, per day
θ_{KPL} = temperature correction coefficient
T = temperature, °C

All plant nitrogen is assumed to be removed during harvesting. Future work will need to evaluate the extent to which plant nitrogen contributes to soil nitrogen in the form of plant residues remaining on the watershed.

Ammonia Adsorption-Desorption-
Ammonia can exist in three different forms in the soil: dissolved in soil water, adsorbed to surfaces of soil particles and fixed inside crystal lattices. Mortland and Wolcott[45] discussed the various ammonia complexes with clays but did not present a general theory to allow prediction of the different forms. Instead of developing a complex model for specific soil types and conditions, a much simpler approach was used that might represent a much broader range of soils. The ARM Model assumes two forms of ammonia exist in the soil: the adsorbed ammonia attached to the soil particles, and dissolved ammonia which moves with the soil water. Rate of transfer from one type to the other is governed by first-order reactions. These reactions can be represented by

$$\{NH4\text{-}S\} \underset{KAS}{\overset{KSA}{\rightleftharpoons}} \{NH4\text{-}A\} \qquad (44)$$

and the rate equations are

$$-\frac{d}{dt}\{NH4\text{-}S\} = \frac{d}{dt}\{NH4\text{-}A\} \quad KSA\{NH4\text{-}S\}\theta_{KSA}^{(T-35)}$$
$$- KAS\{NH4\text{-}A\}\theta_{KAS}^{(T-35)} \qquad (45)$$

where NH4-S mass of ammonia in solution, kg/ha
NH4-A = mass of ammonia adsorbed to soil, kg/ha
KSA = first-order rate constant for adsorption reaction at 35 °C, per day
KAS = first-order rate constant for desorption reaction at 35 °C, per day
θ_{KSA}, θ_{KAS} = temperature correction coefficients
T = temperature, °C

Usually very little ammonia is in solution; most is adsorbed to soil particle surfaces. This would correspond to an adsorption reaction rate much greater than the desorption rate or KSA>>KAS.

Phosphorus Transformations

Phosphorus was assumed to exist in only four forms: organic phosphorus, solid phosphate compounds, dissolved phosphates, and phosphorus absorbed by plants. The reactions of mineralization-immobilization, adsorption-desorption, and plant uptake are modeled as first-order rates. A diagram of the phosphorus cycle as represented by the ARM Model is given in Figure 12b, and Table 7 contains the system of coupled differential equations developed below.

Mineralization-Immobilization-

Organic phosphorus is not as important in the phosphorus cycle as organic nitrogen is in the nitrogen cycle. Larsen[46] reviewed the literature on soil phosphorus and did not present any general findings on mineralization and immobilization rates. In the ARM Model, phosphorus mineralization and immobilization mechanisms were assumed to be similar to the corresponding nitrogen processes. Thus, they are represented as

$$-\frac{d}{dt}\{ORG\text{-}P\} = KM\ \{ORG\text{-}P\}\theta_{KM}^{(T-35)} \qquad (46)$$

$$\frac{d}{dt}\{PO4\text{-}S\} = KIM\ \{PO4\text{-}S\}\theta_{KIM}^{(T-35)} \qquad (47)$$

where ORG-P - mass of organic phosphorus, kg/ha
PO4-S = mass of phosphate in solution, kg/ha
KM = first-order mineralization rate at 35 °C, per day
KIM = first-order immobilization rate at 35 °C, per day
θ_{KM}, θ_{KIM} = temperature correction coefficients
T = temperature, °C

Soil organic phosphorus is assumed to be insoluble and only leaves the watershed with the eroded sediment.

Adsorption-Desorption-

Organic phosphorus mineralization results in the release of inorganic phosphates which can remain in the soil solution, precipitate as sparingly soluble salts of calcium, magnesium, aluminum, or iron phosphates, or adsorb onto the surface of clay or calcium carbonate soil particles.[46] The Model represents these three forms of phosphate in two categories; that is, phosphates in solution, and phosphates in solid form including both adsorbed and precipitated forms. Solid phosphates will be referred to as adsorbed phosphates, and the transfer between solution and adsorbed phosphates is modeled by adsorption and desorption reactions:

Table 7. COUPLED SYSTEM OF DIFFERENTIAL EQUATIONS FOR PHOSPHORUS TRANSFORMATIONS

Organic Phosphorus:

$$\frac{d}{dt}\{ORG\text{-}P\} = -KM\{ORG\text{-}P\} + KIM\{PO4\text{-}S\}$$

Solution Phosphate:

$$\frac{d}{dt}\{PO4\text{-}S\} = KM\{ORG\text{-}P\} - (KIM + KSA + KPL)\{PO4\text{-}S\} + KAS\{PO4\text{-}A\}$$

Adsorbed and Combined Phosphate:

$$\frac{d}{dt}\{PO4\text{-}A\} = KSA\{PO4\text{-}S\} - KAS\{PO4\text{-}A\}$$

Plant Phosphorus:

$$\frac{d}{dt}\{PLNT\text{-}P\} = KPL\{PO4\text{-}S\}$$

$$\{P04\text{-}S\} \underset{KAS}{\overset{KSA}{\rightleftharpoons}} \{P04\text{-}A\} \qquad (48)$$

The resulting rate expressions are

$$-\frac{d}{dt}\{P04\text{-}S\} = \frac{d}{dt}\{P04\text{-}A\} \quad KSA\{P04\text{-}S\}\theta_{KSA}^{(T-35)} - KAS\{P04\text{-}A\}\theta_{KAS}^{(T-35)} \qquad (49)$$

where P04-S = mass of phosphate in solution, kg/ha
P04-A = mass of phosphate adsorbed, kg/ha
KSA = first-order rate constant for adsorption at 35 °C, per day
KAS = first-order rate constant for desorption at 35 °C, per day
θ_{KSA} θ_{KAS} = temperature correction coefficients
T - temperature, °C

Fried et al.[47] studied the desorption reaction and found that the data fit a first-order rate equation. The reaction rate increased by 80 percent for a temperature increase of 12 Celsius degrees. Enfield and Shew[48] studied both reactions and found that the magnitude of the adsorption rate was much greater than the desorption rate, or KSA >> KAS. At equilibrium, in most soils the dissolved phosphates rarely exceed 0.2 mg/l and the majority of the phosphates are in solid form.

Plant Uptake-

Fried et al.[47] also studied the rate of phosphate uptake by plant roots under laboratory conditions and found that the absorption rate was approximately proportional to the solution concentration, thus a first order mechanism. Van der Honert et al.[44] showed that phosphate uptake was a first-order reaction up to 1.0 mg PO_4/l. Since soil solutions rarely exceed this concentration, a first-order uptake mechanism is a reasonable assumption.

The rate expression used in the ARM Model is

$$\frac{d}{dt}\{PLNT\text{-}P\} = KPL\ \{P04\text{-}S\}\theta_{KPL}^{(T-35)} \qquad (50)$$

where PLNT-P = mass of plant phosphorus, kg/ha
P04-S = mass of phosphates in solution, kg/ha
KPL = first-order absorption rate, kg/ha
θ_{KPL} = temperature correction coefficient
T = temperature, °C

The nutrient model assumes that plant phosphorus can be removed from the watershed only by harvesting. This assumption is valid for plants, such as grain crops, that contain phosphorus largely in the portion harvested. Moreover, the conversion of phosphorus is plant residues to soil organic phosphorus is a slow process especially in dry, cold regions. However, in warm, humid areas and where substantial plant residues remain on the watershed, the conversion of plant phosphorus to soil organic phosphorus may be significant. Further development of the nutrient model will need to evaluate the importance of this process and possibly allow for its simulation.

Review of Assumptions

The nutrient model required many assumptions in its development. A review of these assumptions is essential to a full understanding of the model. The assumption of first-order kinetics is generally valid for chemical and biological reactions when the reactants are not in high concentrations. From the literature cited, it appears conditions existing in the soil are such that first-order kinetics is a reasonable assumption. Temperature correction of reaction rates using a simplified form of the Arrhenius equation is flexible and can closely approximate changes in rates reported in the literature. The reaction rates were assumed to be constant for temperatures greater than 35 °C because the behavior of chemical and biological reactions is not well defined at high temperatures. Until the ARM Model is able to simulate soil temperatures, the average daily air temperature will be used to approximate soil temperatures.

The environmental factors of pH, moisture, oxygen, and organic matter are not directly taken into account for reaction rate modification. Soil pH is relatively constant due to the high buffering capacity of the soil itself. Any pH correction could be done when the reaction rates are input to the Model. Reaction rates should be corrected for moisture levels because biological activity is dependent on soil moisture. Oxygen levels in the soil are needed to determine if oxidative processes like mineralization and nitrification, or reductive processes, like denitrification, will occur. Organic matter in the soil can deplete the oxygen in the soil and accelerate the rate of denitrification.

Some of the limitations in the nutrient model due to neglecting pH, moisture, oxygen, and organic matter can be circumvented by having separate reaction rates for each of the four soil layers. For example, the denitrification rate could be set to zero in the surface and upper zone because they are usually well aerated. Likewise the denitrification rate would be close to zero in the groundwater zone because of low organic content. Thus, the input of four values, one for each soil layer, is a temporary correction for soil properties and environmental factors at different depths.

Numerical Solution Techniques

Tables 6 and 7 display the nitrogen and phosphorus rate equations which result from the assumption of first-order kinetics. Analytic solutions of coupled systems of equations for constituent concentrations are quite difficult when advective processes, like leaching and sediment loss, are simulated in addition to reaction rate adjustments for temperature. Because of the problems with analytic solutions, the nutrient model numerically solves the coupled system of differential equations for the nitrogen and phosphorus masses in each soil layer.

There are numerous solution techniques available. The choice depends upon the equations to be solved, the accuracy desired and the amount of computer time available.[49] The technique used in the nutrient model is a simple Euler integration scheme illustrated by the following example. Given the differential equation for a first-order reaction rate

$$\frac{d}{dt} y(t) = -ky(t) \tag{51}$$

where $y(t)$ = mass at time t
k = rate constant

the time derivative can be approximated by

$$\frac{d}{dt} y(t) \approx \frac{y(t + \Delta t) - y(t)}{\Delta t} \tag{52}$$

when Δt, the time step, is small. Substitution of the derivative approximation into the differential Equation 51, yields

$$\frac{y(t + \Delta t) - y(t)}{\Delta t} \approx - ky(t) \tag{53}$$

Rearranging and solving for $y(t + \Delta t)$ gives

$$y(t + \Delta t) \approx y(t) - \Delta tky(t) \tag{54}$$

Thus, the mass at the next time step can be approximated with the mass at the present time; the differential equation is integrated step by step to obtain the mass for future time steps. The coupled system of differential equations of nitrogen and phosphorus transformations are solved by a similar procedure in the ARM Model. The accuracy of the solution depends on the size of the term Δtk which should be much less than one in order to change the mass by only a small amount in each time step.

CONCLUSIONS

A preliminary model of nitrogen and phosphorus compounds has been developed for agricultural lands. The model includes advective losses to the stream through sediment, overland flow and interflow, and leaching to groundwater. An attempt was made to represent with actual first-order kinetics chemical and biological transformations occurring in the soil. Numerous assumptions were necessary for model development; verification of the nutrient model must await the comparison of simulated results with recorded field data. Further development of model algorithms and testing with field data will be undertaken in a continuing research grant.

SECTION VII

DATA COLLECTION AND ANALYSIS PROGRAMS

The ARM Model development effort is supported by an extensive data collection and analysis program sponsored by the U.S. Environmental Protection Agency's Environmental Research Laboratory in Athens, Georgia (ERL-Athens). Test sites located in Georgia and Michigan have been instrumented for the continuous monitoring and sampling of runoff and sediment. Collected samples are refrigerated on site and later analyzed for pesticide and nutrient content. In addition, meteorologic conditions are continuously monitored and soil core samples are taken and analyzed immediately following application and periodically throughout the growing season. Table 8 presents pertinent details on the test watersheds. The individual programs in Georgia and Michigan are described below.

GEORGIA TEST SITE

This program is a joint effort between the ERL-Athens and the U.S. Department of Agriculture's Southern Piedmont Conservation Research Center (SPCRC) in Watkinsville, Georgia (see Location Map, Figure 13). Two test watersheds (P1, P3) since 1972 and two additional test watersheds (P2, P4) since 1973 have been instrumented, in addition to two small runoff plots (SP1, SP3). A series of twelve 6 x 9 meter attenuation plots were instrumented to study the degradation and vertical movement of pesticides in the soil profile. Recording rain gages have been established at each test watershed, and a weather station was set up at the attenuation plots to record air temperature, pan evaporation, and wind data. The attenuation plots were also instrumented to record soil moisture and temperature at various soil depths, wind velocity and direction, solar radiation, air temperature, and relative humidity at different heights above the soil surface. This data is automatically recorded on magnetic tape by a PDP-8 computer.

The SPCRC is responsible for the general care (pesticide applications, planting, harvesting, etc.) of the test watersheds, the collection, operation, and analysis of rainfall, runoff, and sediment data, and the nutrient analyses of runoff samples. Automated stage recording and sampling instrumention provides continuous monitoring of the watersheds. Minimum-tillage procedures are followed whereby tillage operations are performed only as preparation for planting. Runoff and sediment samples are transferred to the ERL-Athens where pesticide analyses are performed. The pesticide analyses are accomplished by an integrated method involving gas chromatographic and calorimetric analysis techniques.[50] At the end of the 1975 growing season the joint ERL-Athens/ USDA program in Georgia will have completed four seasons of continuous data collection and analysis of agricultural runoff.

Table 8. TEST WATERSHEDS FOR ARM MODEL TESTING

Watershed Designation	Location	Owner/ Operator	Area (ha)	Mean Elevation (m above msl)	Soils	Conservation	1973 Growing Season Crop	Pesticide Applied	Application (kg/ha)
P1	Watkinsville, Georgia	USDA/EPA	2.70	238	Cecil sandy loam	non-terraced	soybeans	paraquat diphenamid trifluralin	1.12 3.36 1.12
P2	Watkinsville, Georgia	USDA/EPA	1.30	231	Cecil sandy loam	non-terraced	corn	paraquat atrazine	1.12 3.36
P3	Watkinsville, Georgia	USDA/EPA	1.26	239	Cecil sandy loam	terraced	soybeans	paraquat diphenamid trifluralin	1.12 3.36 1.12
P4	Watkinsville, Georgia	USDA/EPA	1.38	239	Cecil sandy loam	terraced	corn	paraquat atrazine	1.12 3.36
006(East)	East Lansing, Michigan	Michigan State Univ	0.80	272	Spinks sandy loam, Also Traverse Hillsdale, Tuscola loam	non-terraced	soybeans	paraquat diphenamid trifluralin	1.12 3.36 1.12
007(West)	East Lansing, Michigan	Michigan State Univ	0.55	271	Spinks sandy loam, Also Traverse Hillsdale, Tuscola loam	non-terraced	soybeans	paraquat diphenamid trifluralin	1.12 3.36 1.12

Experimental watersheds in Georgia

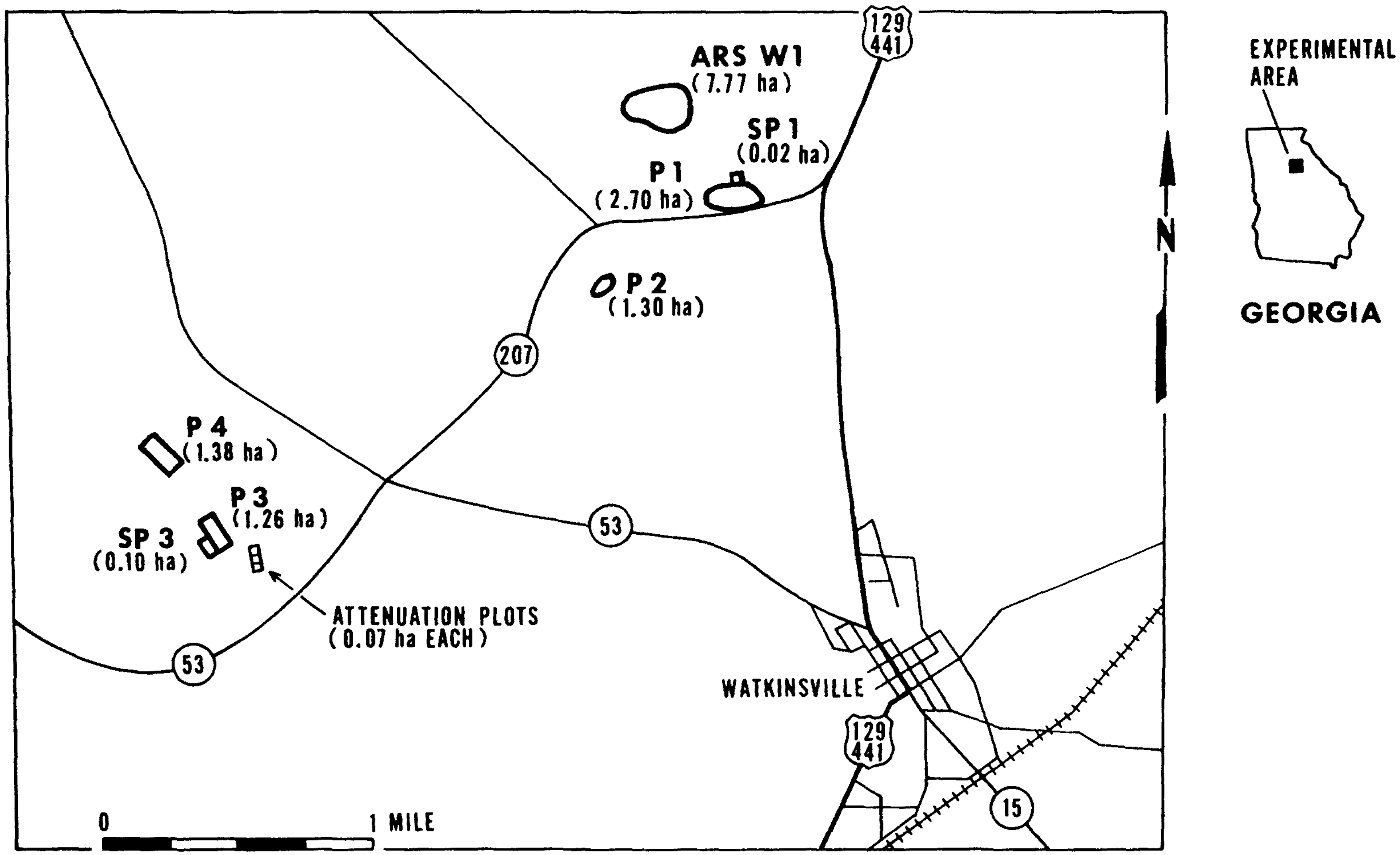


Figure 13

MICHIGAN TEST SITE

The Michigan test site is operated by the Michigan State University's Department of Crop and Soil Science and Department of Entomology in a cooperative agreement with the ERL-Athens. The two test watersheds (listed in Table 8) are located approximately two miles south of East Lansing, Michigan on the MSU Campus (Figure 14). Initially instrumented in 1941, the watersheds have been operated since that time under various research projects. A permanent weather station (East Lansing 3 SE, Index No. 2395) adjacent to the watersheds provides continuous information on rainfall, evaporation, solar radiation, air temperature, and wind movement.

Similar to the program at the ERL-Athens, the Michigan test watersheds are instrumented for continuous monitoring and sampling of runoff and sediment; a Coshocton wheel for sample splitting is included in the automated instrumentation. Pesticides are applied and analyzed in soil core and runoff samples by a gas chromatograph feeding directly to a computer for data logging. In addition, snow depth and water equivalent is recorded, and snowmelt runoff samples are analyzed for pesticide and nutrient content. Pesticides have also been applied in the fall to facilitate detection in the snowmelt. Initiated in 1973, the MSU project is expected to continue in operation for both pesticide and nutrient monitoring until Spring 1976.

Experimental watersheds in Michigan

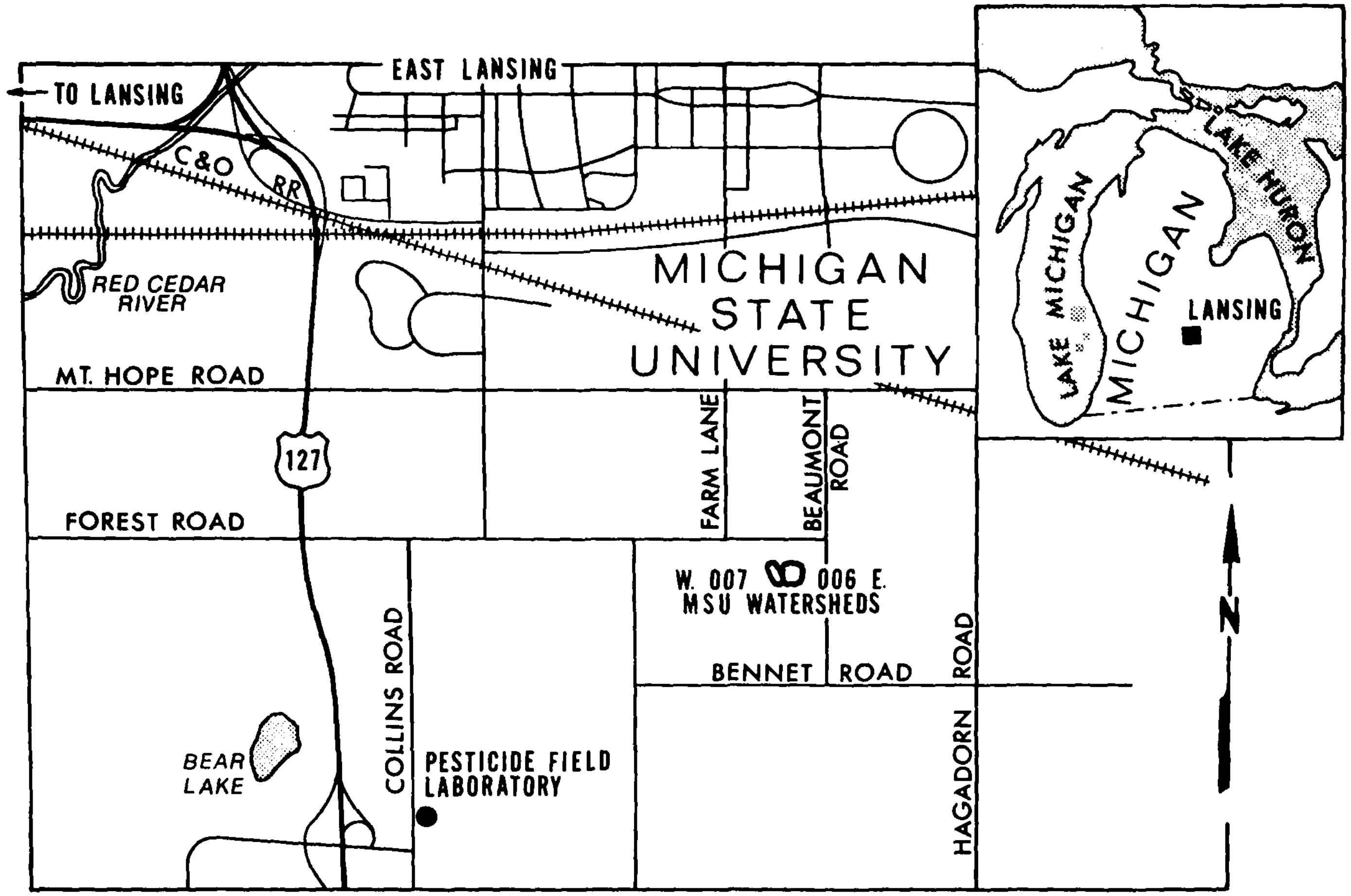


Figure 14

SECTION VIII

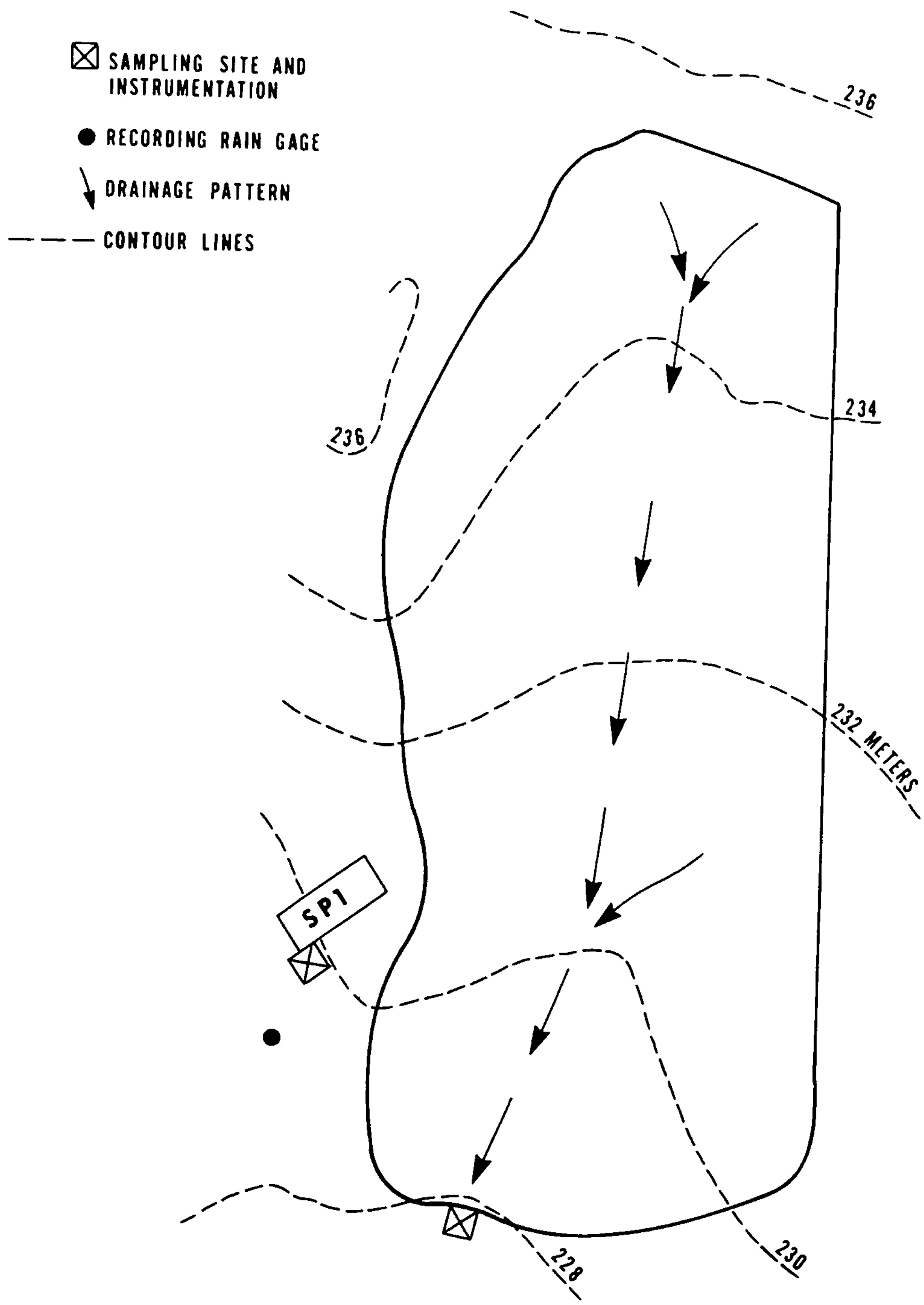
ARM MODEL TESTING AND SIMULATION RESULTS

Model testing for runoff, sediment loss, and pesticide loss was completed on one additional year of data (January 1973-December 1973) from the P1 and P3 watersheds in Watkinsville, Georgia. Data for 1974 and for the four remaining watersheds (Section VII) in Georgia and Michigan is presently being analyzed and prepared for testing purposes. In addition, nutrient runoff data for 1974 from both the Georgia and Michigan sites will become available for future testing of the nutrient portions of the ARM Model.

Figures 15 and 16 present detailed maps of the P1 and P3 test watersheds in Georgia. As indicated in Table 8, P1 is a natural watershed while P3 is a terraced watershed with a grass waterway. This difference is especially important in the relative sediment loss from the two watersheds. P1 and P3 received identical management practices during 1973: minimum tillage was employed, soybeans were planted, and the herbicides paraquat (1,1'-dimethyl-4,4-bipyridinium ion), diphenamid (N, N-dimethyl-2, 2-diphenylacetamide), and trifluralin (α,α,α-trifluoro-2, 6-dinitro-N, N-dipropyl-p-toluidine) were applied at 1.1, 3.4 and 1.1 kg/ha, respectively. Pesticide simulations were performed for paraquat and diphenamid; trifluralin was not simulated due to the lack of reliable laboratory isotherm data. The following portions of this section discuss the hydrology, sediment production, and pesticide simulation results for the P1 and P3 watersheds. Results are presented and analyzed, and data and simulation problems are enumerated. This section concludes with a discussion on indicated future topics of research and major conclusions from the ARM Model testing.

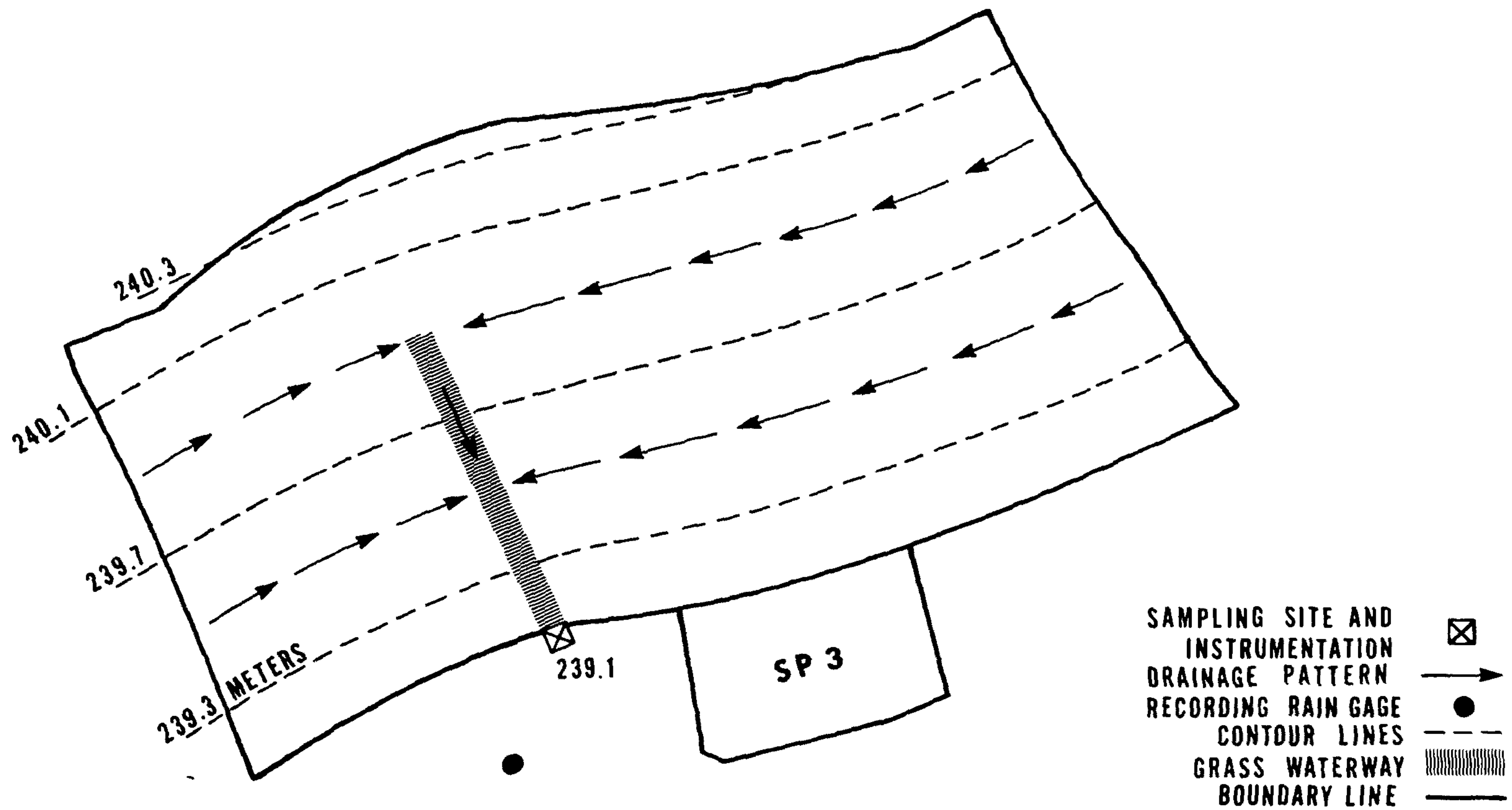
HYDROLOGY AND SEDIMENT PRODUCTION SIMULATION

The hydrologic subroutine, LANDS, is the most highly developed and tested portion of the ARM Model. The algorithms have been employed and tested in the Stanford Watershed Model and the Hydrocomp Simulation Program on numerous watersheds of differing size across the country. Although their use on extremely small watersheds has been limited, the simulation results on the P1 and P3 watersheds are highly promising. Figures 17 and 18 and Tables 9 and 10 present the recorded monthly rainfall and recorded and simulated monthly runoff and sediment loss for the P1 and P3 watersheds, respectively. In both cases, monthly runoff is reasonably well simulated for 1973, especially for the critical summer period, June through October. On the P1 watershed, the summer period appears to be more accurately simulated than the winter-spring period. This may indicate a possible seasonal variation in hydrologic parameters that warrants further



P1 Watershed, Watkinsville, Georgia (2.70 ha)

Figure 15



P3 Watershed, Watkinsville, Georgia (1.26 ha)

Figure 16

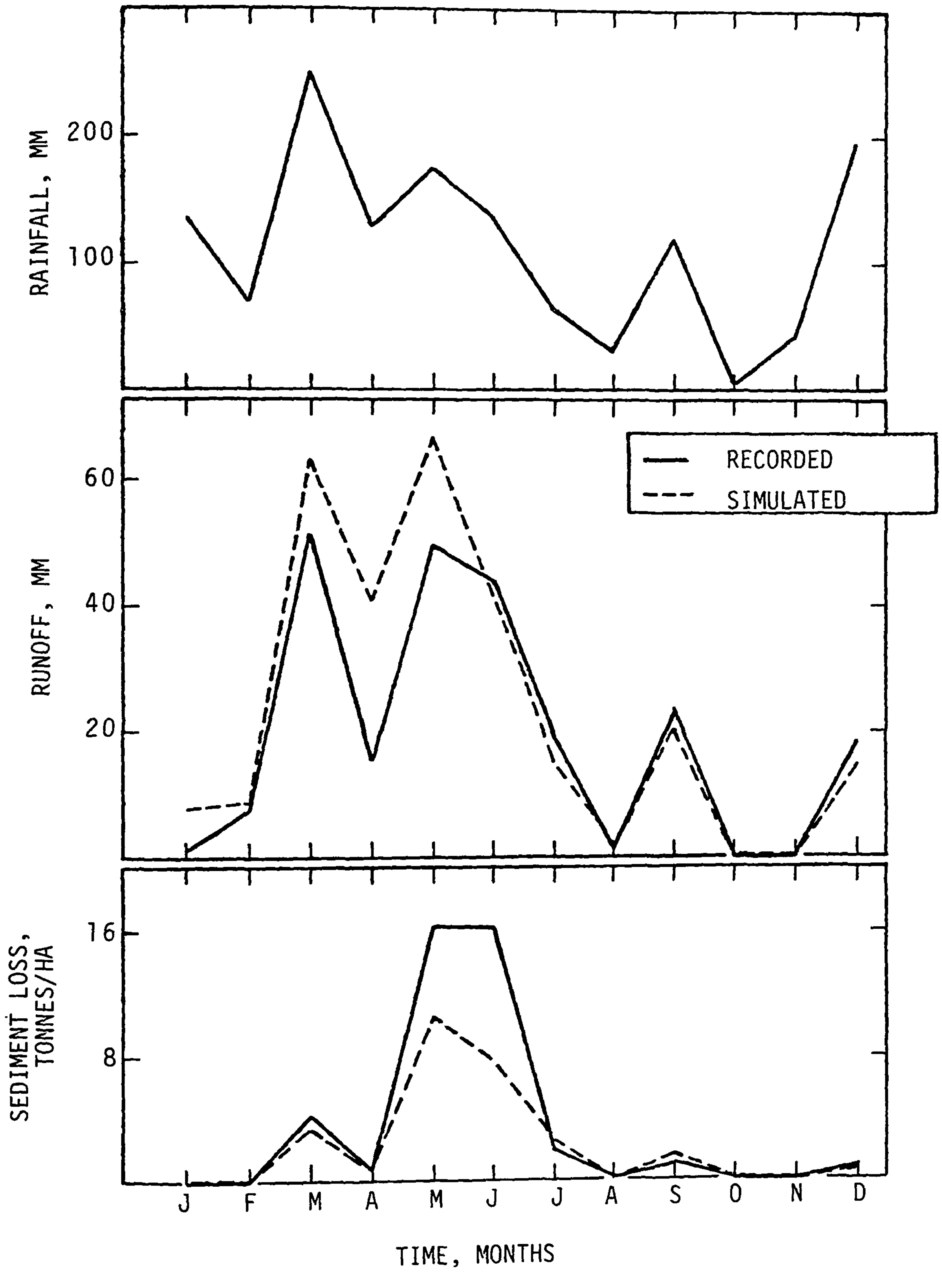


Figure 17. 1973 monthly rainfall, runoff, and sediment loss for the P1 watershed

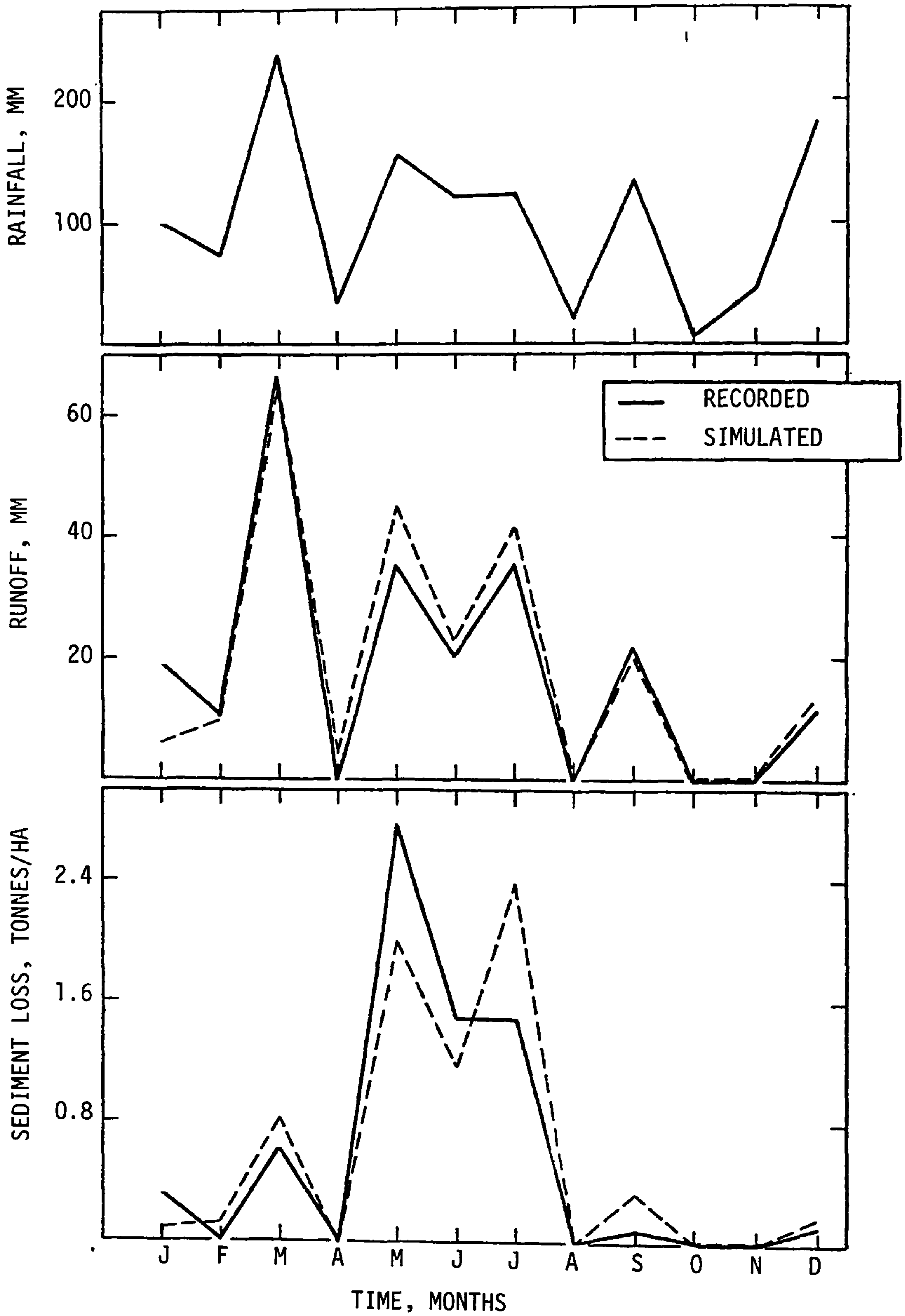


Figure 18. 1973 monthly rainfall, runoff, and sediment loss for the P3 watershed

Table 9. 1973 SUMMARY OF RAINFALL, RUNOFF, AND SEDIMENT LOSS FOR THE P1 WATERSHED (RECORDED AND SIMULATED)

Month	Rainfall		Total Runoff				Sediment Loss			
			Recorded		Simulated		Recorded		Simulated	
	mm	(in)	mm	(in)	mm	(in)	tonne/ha	ton/ac	tonne/ha	ton/ac
Jan	135.4	(5.33)	1.3	(.05)	7.9	(.31)	0	(0)	.09	(.04)
Feb	69.3	(2.73)	7.4	(.29)	8.6	(.34)	.002	(.001)	.13	(.06)
Mar	250.7	(9.87)	51.6	(2.03)	62.7	(2.47)	4.19	(1.87)	3.43	(1.53)
Apr	127.5	(5.02)	15.0	(.59)	40.1	(1.58)	.83	(.37)	.96	(.43)
May	174.0	(6.85)	49.8	(1.96)	66.3	(2.61)	16.9	(7.54)*	10.5	(4.70)
Jun	135.1	(5.32)	43.9	(1.73)	41.9	(1.65)	16.6	(7.42)*	7.7	(3.47)
Jul	65.3	(2.57)	19.1	(.75)	14.7	(.58)	2.0	(.89)	2.62	(1.17)
Aug	31.8	(1.25)	1.3	(.05)	2.3	(.09)	.09	(.04)	.11	(.05)
Sep	119.9	(4.72)	23.1	(.91)	20.3	(.80)	1.1	(.49)	1.64	(.73)
Oct	6.6	(.26)	0	(0)	0	(0)	0	(0)	0	(0)
Nov	44.5	(1.75)	0	(0)	.5	(.02)	0	(0)	.02	(.01)
Dec	196.1	(7.72)	18.5	(.73)	15.0	(.59)	.85	(.38)	.60	(.27)
Total	1356.2	(53.39)	231.0	(9.09)	280.3	(11.04)	42.56	(19.00)	27.97	(12.46)

* Estimated values due to equipment malfunction.

Table 10. 1973 SUMMARY OF RAINFALL, RUNOFF, AND SEDIMENT LOSS FOR THE P3 WATERSHED (RECORDED AND SIMULATED)

Month	Rainfall		Total Runoff				Sediment Loss			
			Recorded		Simulated		Recorded		Simulated	
	mm	(in)	mm	(in)	mm	(in)	tonne/ha	ton/ac	tonne/ha	ton/ac
Jan	100.8	(3.97)	18.8	(.74)	6.4	(.25)	.31	(.14)	.09	(.04)
Feb	73.9	(2.91)	10.4	(.41)	9.9	(.39)	.02	(.01)	.13	(.06)
Mar	239.5	(9.43)	66.3	(2.61)	65.3	(2.57)	.61	(.27)	.83	(.37)
Apr	34.8	(1.37)	0	(0)	4.3	(.17)	0	(0)	.02	(.01)
May	156.0	(6.14)	35.3	(1.39)	45.0	(1.77)	2.77	(1.24)	2.02	(.90)
Jun	120.4	(4.74)	20.0	(.79)	22.6	(.89)	1.48	(.66)	1.16	(.52)
Jul	123.2	(4.85)	35.3	(1.39)	41.7	(1.64)	1.48	(.66)	2.37	(1.06)
Aug	22.9	(.90)	0	(0)	0	(0)	0	(0)	0	(0)
Sep	135.1	(5.32)	21.8	(.86)	20.1	(.79)	.08	(.04)	.34	(.15)
Oct	5.1	(.20)	0	(0)	0	(0)	0	(0)	0	(0)
Nov	43.2	(1.70)	0	(0)	.8	(.03)	0	(0)	.01	(.01)
Dec	180.9	(7.12)	11.7	(.46)	14.0	(.55)	.11	(.05)	.18	(.08)
Total	1235.8	(48.65)	219.6	(8.65)	230.1	(9.05)	6.86	(3.07)	7.15	(3.20)

investigation. The terraces and grass waterway on P3 seemed to have little effect on monthly runoff volumes. In fact, the LANDS parameters initially calibrated on the P1 watershed performed somewhat better on the P3 watershed as indicated by the monthly runoff volumes. In any case, the runoff results presented in Figures 17 and 18 are a true verification of the LANDS subroutine and the calibration. Verification refers to the results of split-sample testing, i.e., a comparison of simulated and recorded values for a period of record other than that on which a model is calibrated. The results in Figures 17 and 18 were obtained with parameters calibrated in the PTR Model development work on data for July to December 1972. The agreement between the 1973 simulated and recorded values verifies the hydrologic simulation by the LANDS subroutine.

The simulation of sediment loss continues to require algorithm refinement and testing. Due to sediment algorithm changes (Section IV), the sediment parameters were re-calibrated to obtain the results presented in Figures 17 and 18. Even with the re-calibration efforts, certain discrepancies remain between recorded and simulated monthly sediment loss. The simulated sediment values on P1 agree reasonably well with recorded values except for the extremely large amounts in May and June. In these months, a major portion of the monthly sediment loss was estimated because an unusual sequence of events (described below) resulted in equipment malfunctions on the P1 watershed. Consequently, the recorded values contain a certain margin of error. The P3 monthly sediment loss (Figure 18) is substantially less than the P1 values due to the effects of terracing and the grass waterway. The simulated monthly sediment loss for P3 is somewhat closer to recorded values but further improvement is needed. A more detailed examination of the effects of the grass waterway, the terraces, and the existence of a winter cover crop on the P3 watershed sediment loss is indicated.

Simulated and recorded storm hydrographs and curves of sediment concentration (gm/l) and sediment mass flow (kg/min) for the P1 watershed are presented in Figures 19-23 for the 1973 storms of May 28 (AM), June 6, June 13, June 21, and September 9. Corresponding results for the P3 watershed are shown in Figures 24-28 for the 1973 storms of May 28 (AM), June 6, July 8, July 14, and September 9. Although these storms occurred during a five-month summer period, the simulation accuracy is representative of the results obtained throughout the 1973 calendar year. These storms were chosen because they (1) demonstrate the effects of tillage operations or (2) occur during the critical period for pesticide loss, i.e. one to three months following application.

In general the agreement between recorded and simulated runoff is quite good, while the agreement between recorded and simulated sediment loss is fair to good. Numerous factors could be responsible for the deviations in both runoff and sediment loss. However, before a full evaluation of the simulation results can be performed, the sequence of events which occurred on the watersheds during this period must be specified. Table 11 presents

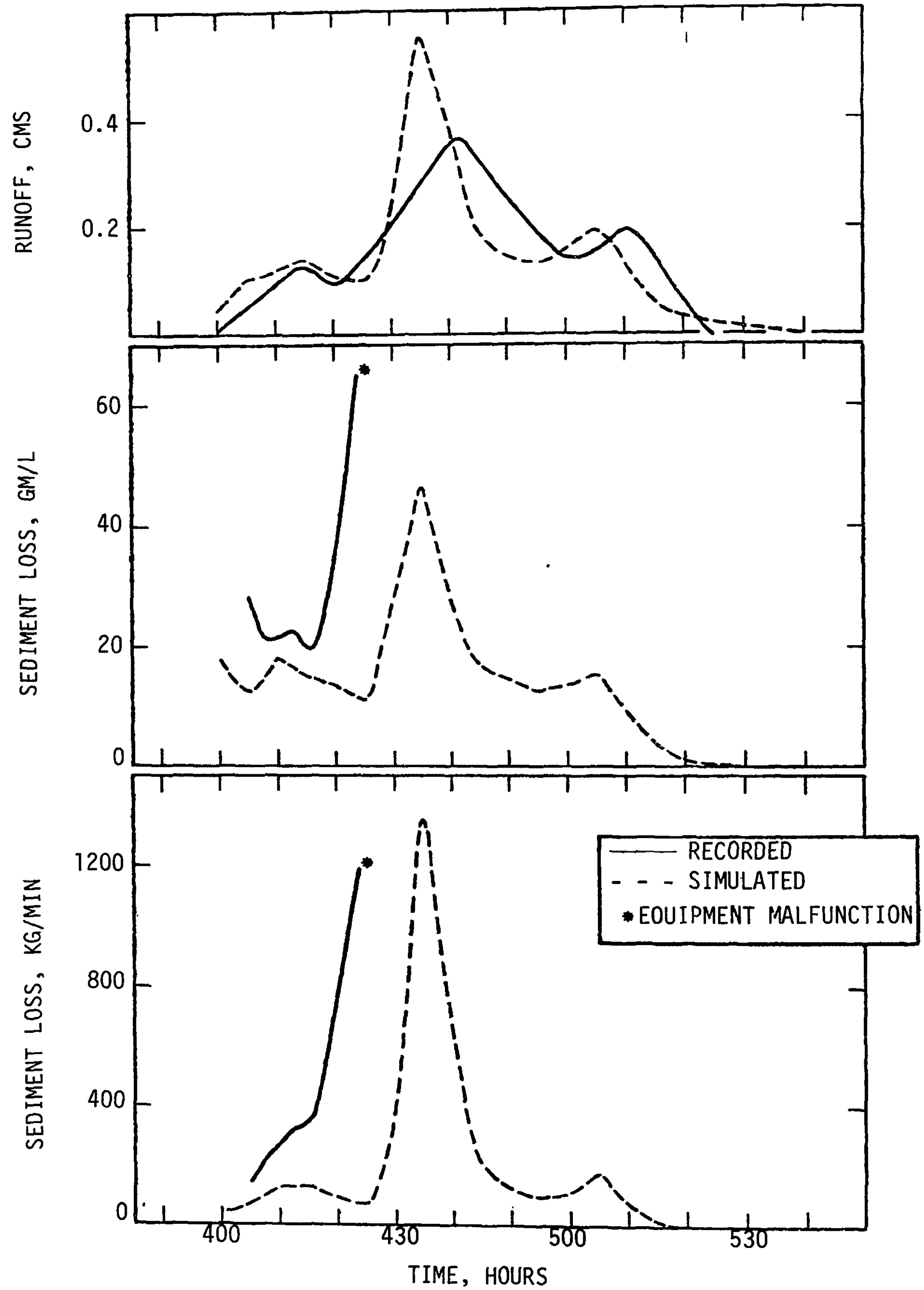


Figure 19. Runoff and sediment loss from the P1 watershed on May 28 (a.m.), 1973

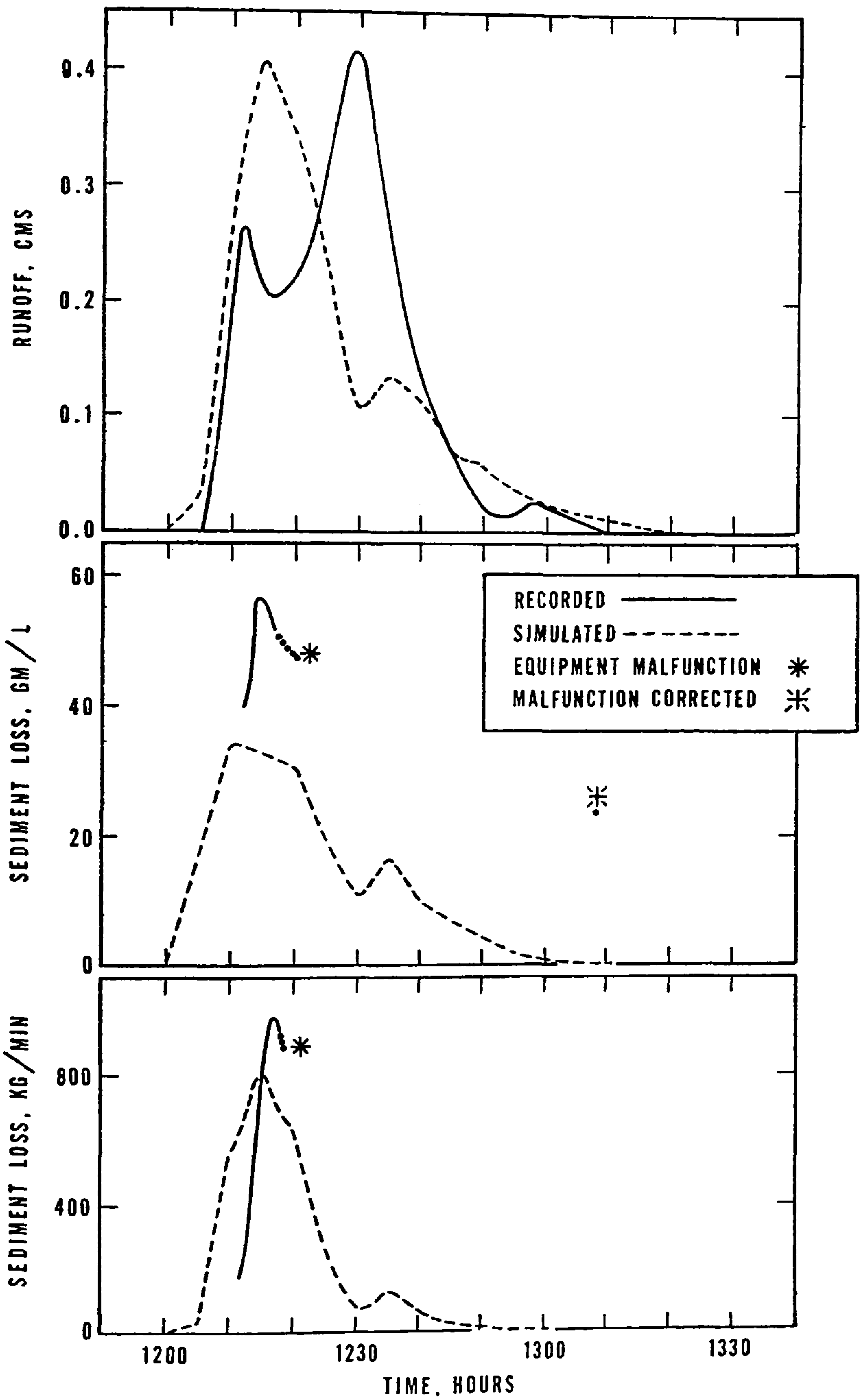


Figure 20. Runoff and sediment loss from the P1 watershed on June 6, 1973

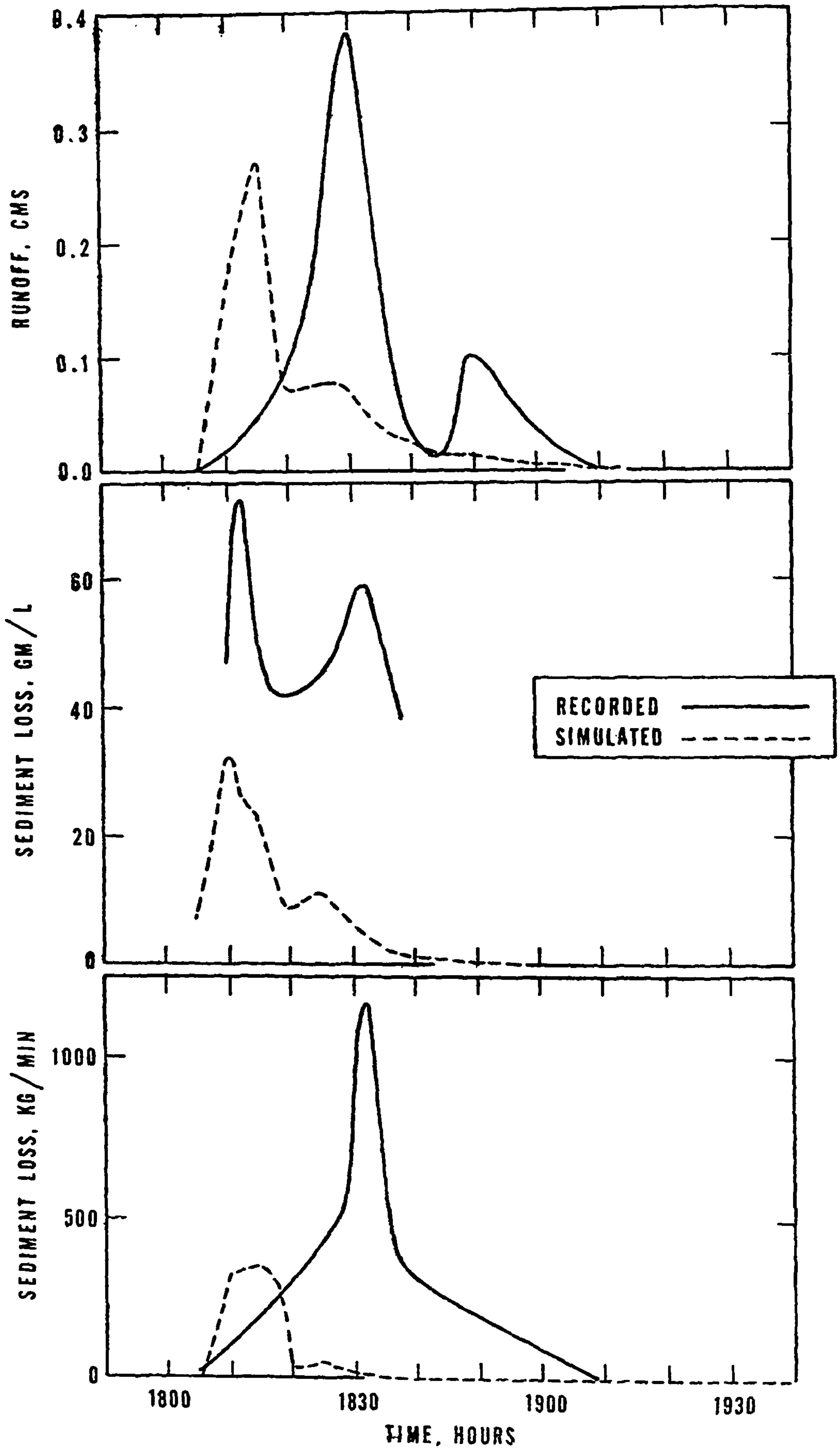


Figure 21. Runoff and sediment loss from the P1 watershed on June 13, 1973

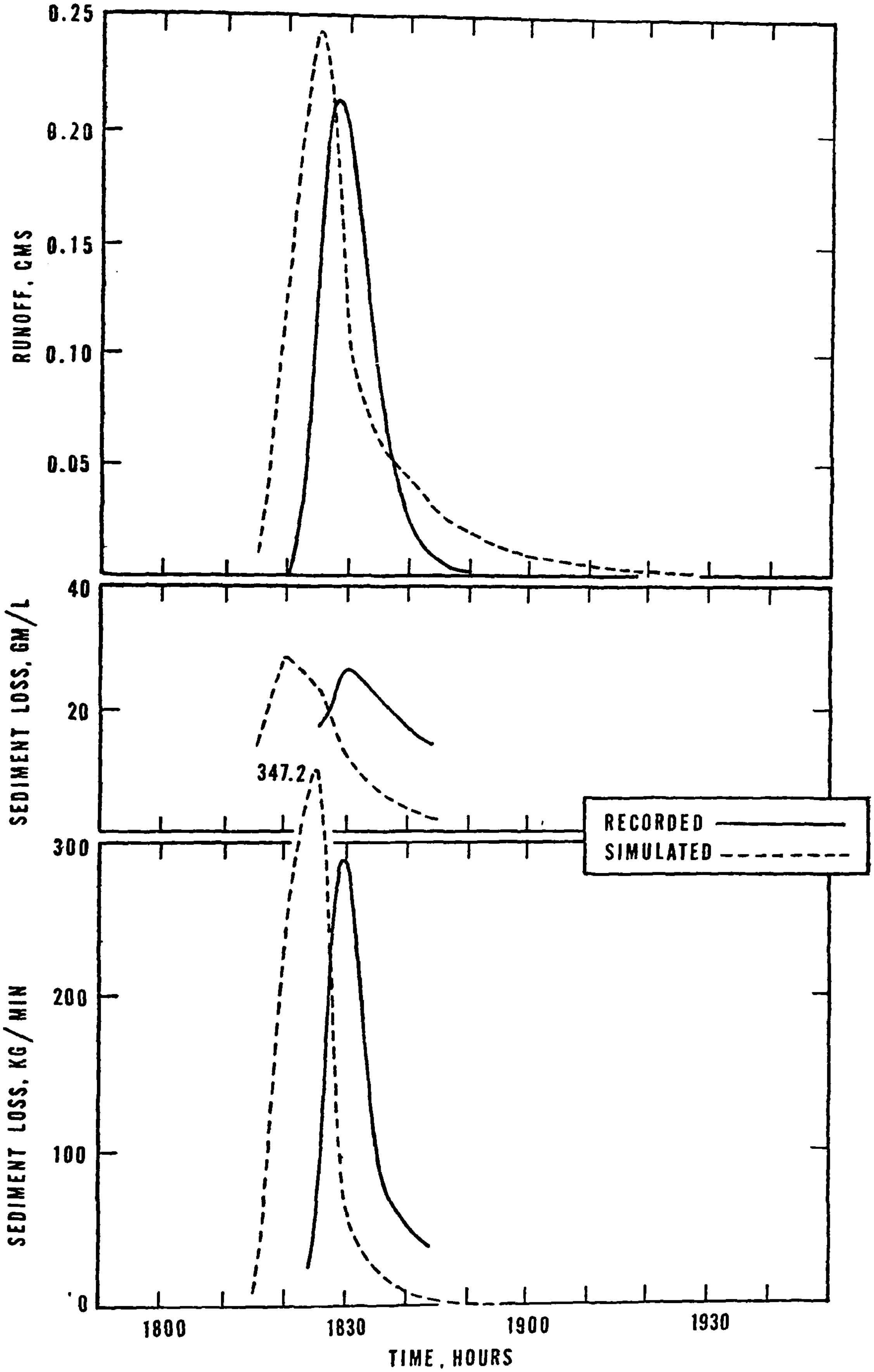


Figure 22. Runoff and sediment loss from the P1 watershed on June 21, 1973.

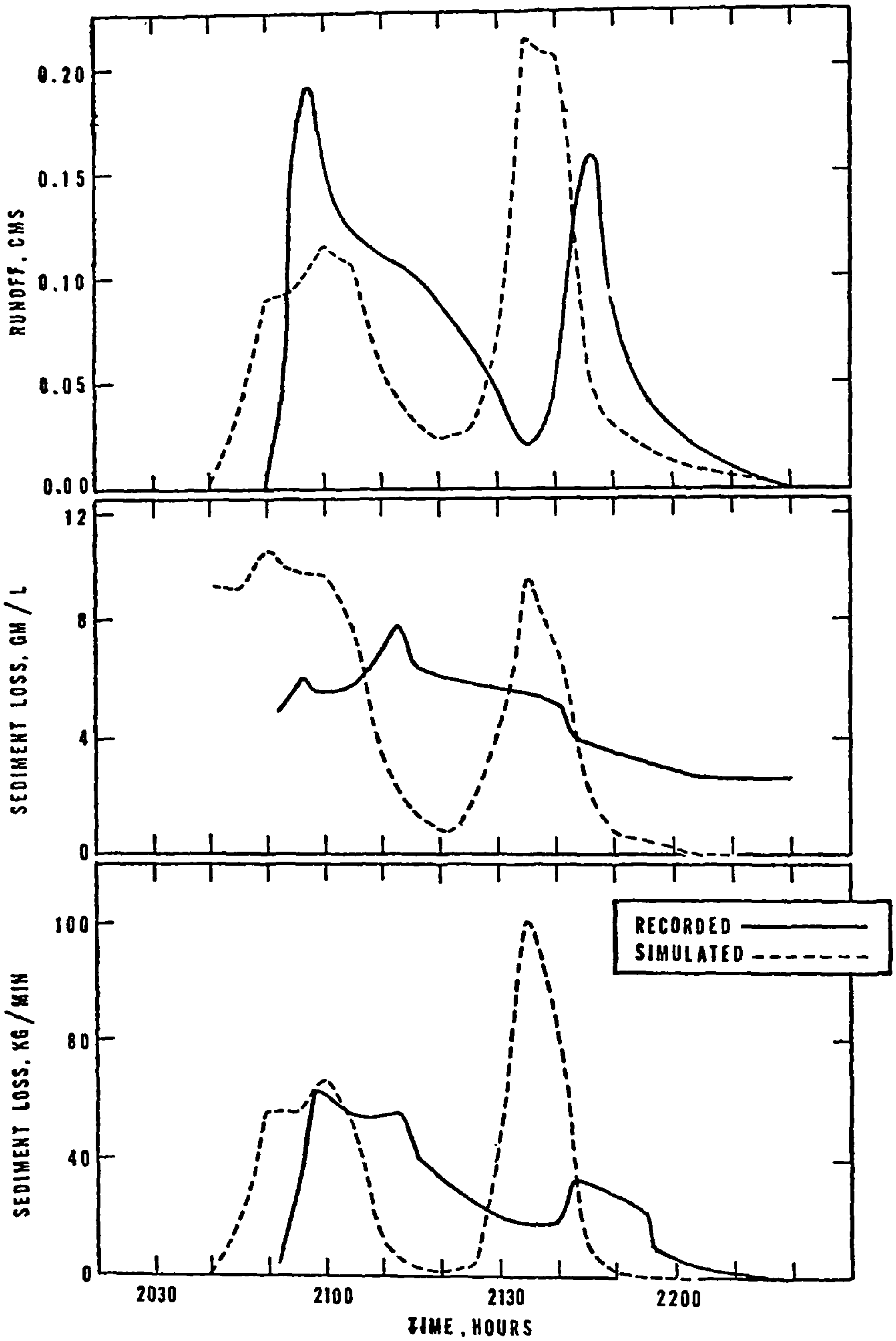


Figure 23. Runoff and sediment loss from the P1 watershed on September 9, 1973

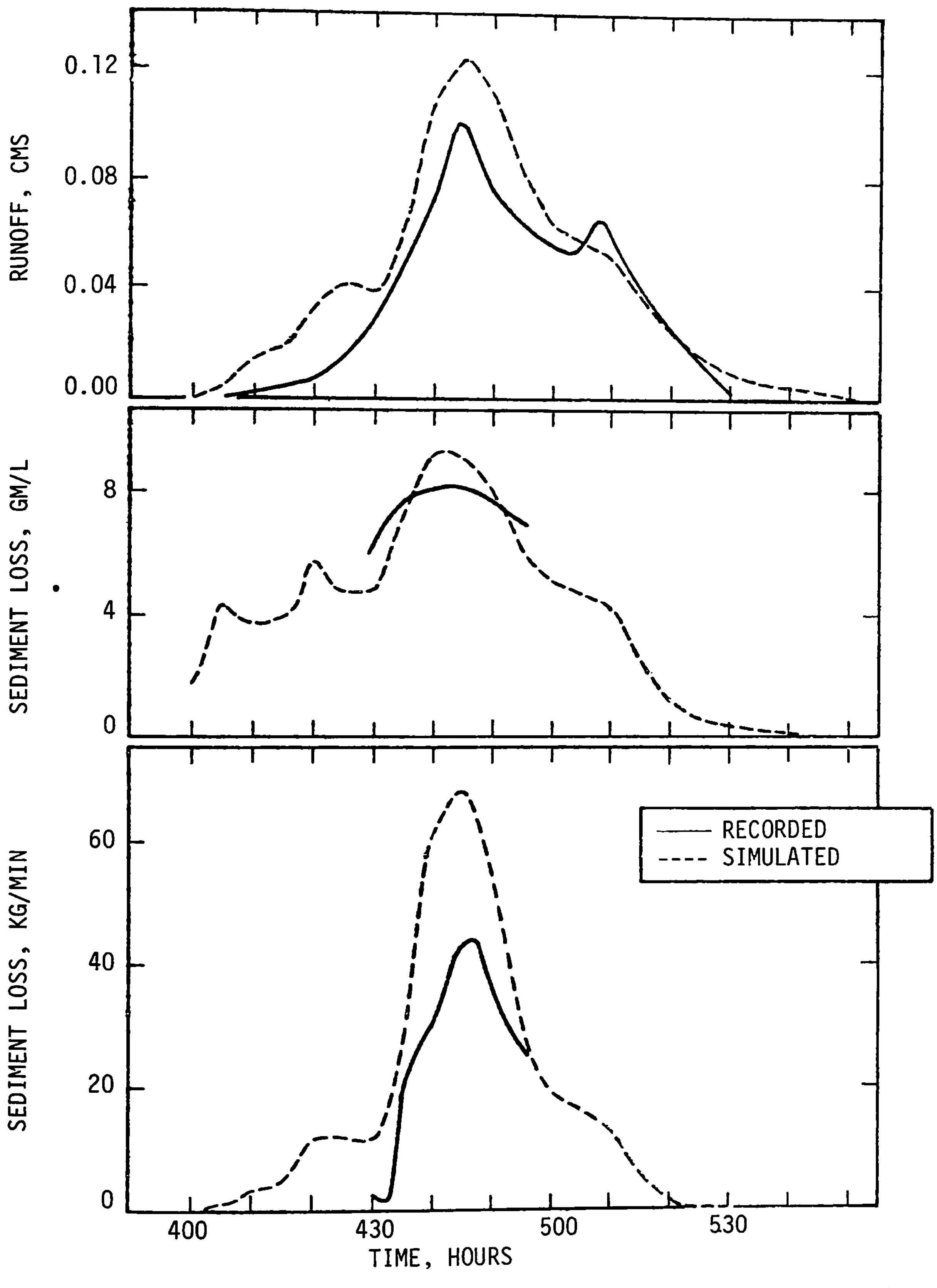


Figure 24. Runoff and sediment loss from the P3 watershed on May 28 (a.m.), 1973

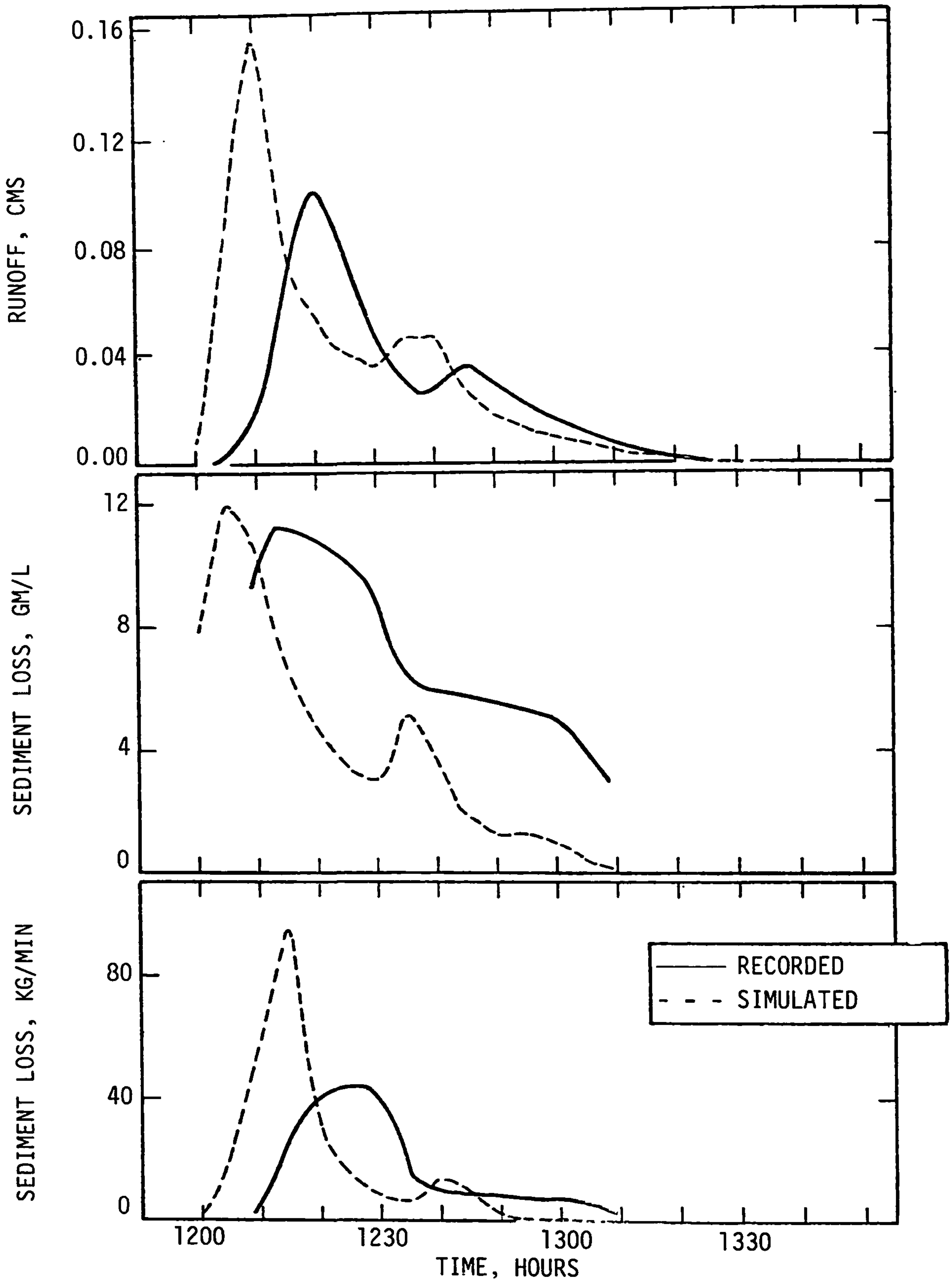


Figure 25. Runoff and sediment loss from the P3 watershed on June 6, 1973

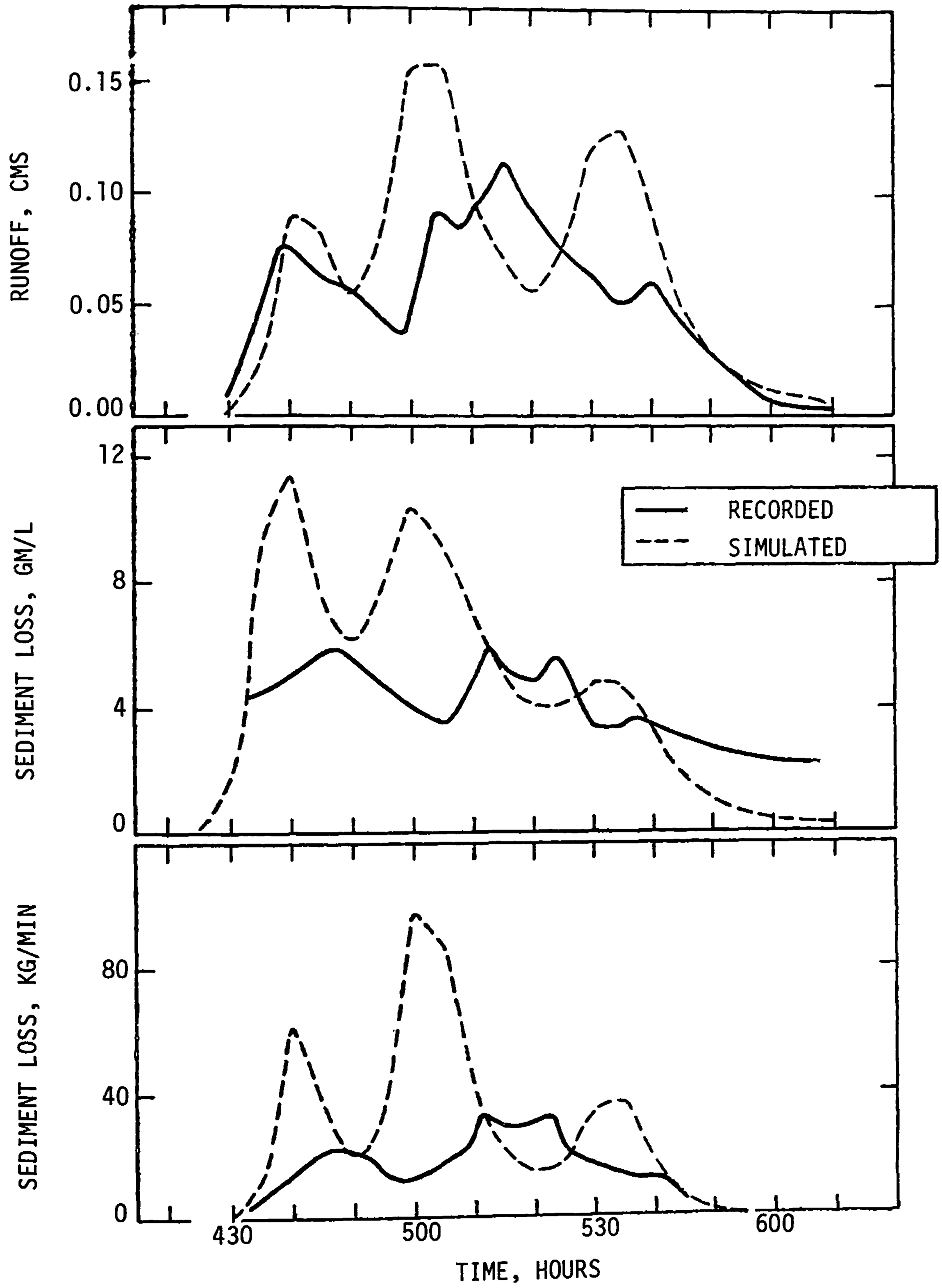


Figure 26. Runoff and sediment loss from the P3 watershed on July 8, 1973

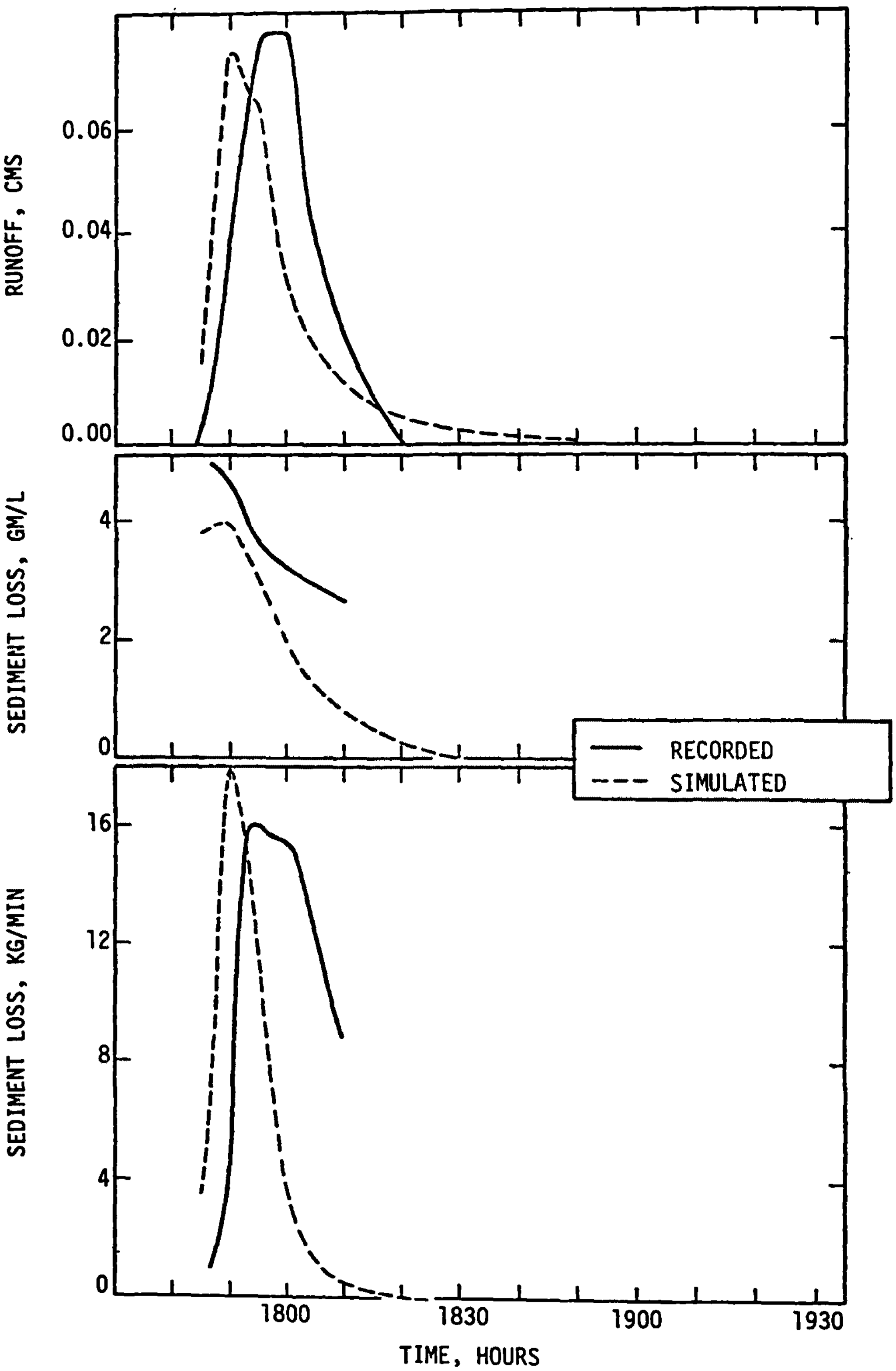


Figure 27. Runoff and sediment loss from the P3 watershed on July 14, 1973

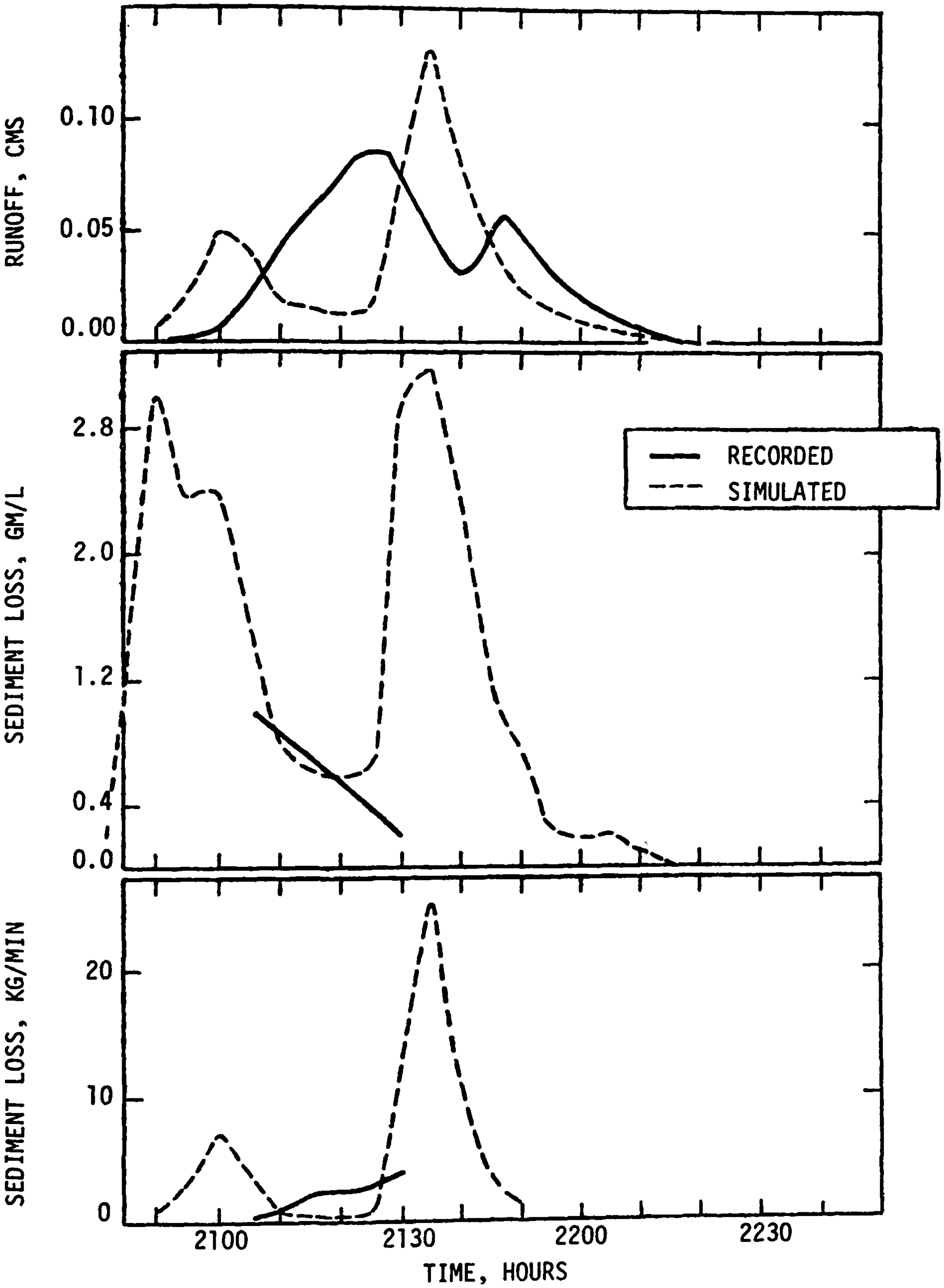


Figure 28. Runoff and sediment loss from the P3 watershed on September 9, 1973

Table 11. SEQUENCE OF CRITICAL EVENTS AND OPERATIONS ON THE P1 AND P3 WATERSHEDS DURING THE 1973 GROWING SEASON

Date	Watershed	Event/Operation
Prior to 5-22-73	P1	Watershed was covered with soybean stubble and residue.
	P3	Winter cover crop (barley) was harvested and removed.
5-22-73	P1, P3	Fertilizer was applied and incorporated with a disc harrow.
5-28-73	P1, P3	Severe storms occurred (AM and PM storms) resulting in high sediment loss from the freshly tilled land surface.
6-4-73	P1, P3	Watersheds were refertilized and tilled (fertilizer incorporation) with a disc harrow.
6-6-73	P1, P3	Severe storms occurred with high sediment loss from the P1 watershed.
6-7-73	P1	Watershed was refertilized and tilled (fertilizer incorporation) with a disc harrow.
6-13-73	P1	Watershed was planted in the morning. Planting operation includes a rolling cultivator which lightly tills the soil. A severe evening storm resulted in heavy sediment loss.
	P3	No storm occurred.
6-15-73	P3	Watershed was planted and a rolling cultivator was used.
6-21-73	P1	Medium intensity storm occurred.
	P3	No storm occurred.
11-7-73	P3	Soybeans were harvested.
11-14-73	P3	Winter cover crop, rye, was planted with a grain drill.
11-19-73	P1	Soybeans were harvested and residue remained on the watershed. No winter crop was planted.

the dates and corresponding events and operations which occurred on the P1 and P3 watersheds during the 1973 growing season. In light of these events and the simulation results for runoff and sediment loss, the following conclusions are indicated:

(1) Tillage operations have a major effect on runoff and sediment loss from small agricultural watersheds. The effect on sediment loss appears to be somewhat greater than the effect on runoff.

(2) Peak flow tends to increase, and the rising limb of the hydrograph becomes steeper as the time since tillage operations increases, i.e., freshly tilled soil tends to dampen the peak and retard the overland flow. This is especially noticeable when comparing early storms (Figures 19, 20, 21, 24, 25) with storms later in the season (Figures 22, 23, 26, 27, 28). Natural compaction of the land surface and the compacting effect of rainfall tend to increase the hydrologic responsiveness of the land surface as the growing season progresses. The present version of the ARM Model does not account for this phenomenon. Thus, the simulated hydrographs indicate what might be expected from a no-tillage cropping system.

(3) The storms of May 28 (Figures 19 and 24) and June 6 (Figures 20 and 25), especially on the P1 watershed, dramatize the enormous influence of tillage operations prior to a storm event. Although the recorded data is sketchy due to equipment malfunction, the general indication is that the simulated P1 sediment loss is considerable less than what would have been observed. However, the June 21st storm on P1, which occurred approximately one week after tillage operations and after the June 13th event, is well simulated for both runoff and sediment loss. Consequently, more testing is needed to fully evaluate the discrepancies in simulated and recorded sediment loss for the early season storm events.

(4) The combined influence of the terraces and the grass waterway on the P3 watershed results in much lower sediment loss than on the P1 watershed. In addition the winter cover crop on the P3 watershed tends to lower the winter sediment loss from what is observed on the P1 watershed. In general, the simulated monthly sediment loss and storm sediment curves are reasonably close but somewhat higher than recorded values. Further research is needed into the effects of terracing, contour planting, grass waterways and other management practices on the ARM Model parameters.

(5) The spatial variation in rainfall is a critical factor in simulation, especially in thunderstorm-prone areas such as Georgia. Although the P1 and P3 watersheds are only 2 miles apart, the monthly rainfall shown in Figures 17 and 18 can vary significantly. This is most noticeable in the months of April and July. Also, the storms of June 13 and June 21 on the P1 watershed did not even occur on the P3 watershed while the July 14 storm on P3 completely missed the P1 watershed. The spatial variation is especially critical if the rainfall measured at the gage is not representative of what actually fell on the watershed. The June 6th storm (Figure 20) on the P1 watershed is a possible example. Runoff volume and peak flows for all the other major summer storms are either well simulated or slightly higher than recorded; both are below recorded values on June 6. Since the ARM Model does not recognize the hydrologic effects of tillage operations, one would expect the June 6th simulated values to be higher than recorded. Thus the spatial variation in rainfall is a prime suspect. This aspect needs to be evaluated in all areas where thunderstorms occur.

In summary, although some discrepancies exist between simulated and recorded runoff and sediment loss, the results presented here indicate that the ARM Model can represent the general behavior of the P1 and P3 watersheds. This provides a workable foundation for the analysis and evaluation of the pesticide simulation results presented below.

PESTICIDE SIMULATION

The goal of the pesticide simulations was to evaluate the use of a non-single-valued (NSV) adsorption/desorption function (described in Section IV) to represent the pesticide-soil interactions. A conclusion of the PTR Model work was that the single-valued (SV) adsortion/desorption function did not appear to adequately simulate these interactions.[1] The major problems were associated with the simulation of pesticides contained in both the water and sediment components of surface runoff, and the division between the two transport phases. Since the goal of the pesticide modeling effort is to use pesticide characteristics determined from laboratory experiments, the pesticide parameters are not subject to calibration. The values used to obtain the simulation results were those derived from laboratory isotherm data. The parameter values are identical for both the SV and NSV functions in order to provide a meaningful evaluation of the performance of the different functions. The simulation results will be described separately for each pesticide since paraquat and diphenamid have quite different chemical and transport characteristics.

Paraquat

Simulated and recorded monthly paraquat loss is presented in Figure 29 and Table 12 for the P1 and P3 watersheds. Paraquat is a highly ionic herbicide that rapidly and essentially irreversibly adsorbs onto sediment particles. Consequently, the question of single-valued versus non-single-valued adsorption/desorption is irrelevant for paraquat simulation since paraquat is entirely and permanently bound to the sediment. Comparison of Figure 29 with Figures 17 and 18 will show that the monthly paraquat loss closely follows the monthly sediment loss. This is also true for the simulated curves. Deviations in the simulated sediment loss are reflected by the simulated paraquat loss. This is also evident in the storm graphs of paraquat concentration and mass removal shown in Figures 30, 31 and 32 for the June 13, June 21 and September 9 storms on P1, and Figures 33, 34, and 35 for the July 8, July 14, and September 9 storms on P3. For example, the June 21 storm on P1 is accurately simulated for both runoff and sediment loss (Figure 22). The simulated paraquat concentrations and mass removal for this storm (Figure 31) are also in agreement with recorded values. On the other hand, the June 13 storm on P1 is under-simulated for sediment loss (Figure 21); thus, the paraquat mass removal for this storm (Figure 30) is also under-simulated, even though simulated and recorded concentrations are in good agreement. This same relationship can be recognized in other storms on both watersheds. In general, although concentration (ppm) is a significant unit of measurement in terms of environmental effects, mass removal (kg/min) is a more indicative measurement unit for simulating pesticide transport. Pesticide concentrations can vary considerable during a storm event for no apparent reason. This could be a result of equipment problems leading to non-uniform application, or preferential pesticide adsorption on particles passing the gage at any time. Pesticide mass removal demonstrates the close association between pesticide loss and the transport mechanisms of runoff and sediment loss.

For paraquat, the measured pesticide concentrations are almost independent of the instantaneous flow and sediment concentrations. Comparison of the paraquat concentrations measured on sediment from the P1 and P3 watersheds, demonstrates that the P3 recorded paraquat concentrations are considerably higher than those on P1. For pesticides like paraquat that are permanently bound to the soil particles, the measured concentrations are a direct function of the following factors:

(a) the amount of pesticide applied
(b) the amount of pesticide in the surface zone prior to application
(c) the depth of the active surface zone
(d) the rate of pesticide attenuation and degradation

The present version of the ARM Model includes input parameters to accommodate factors a, c, and d (above). However, the Model assumes no

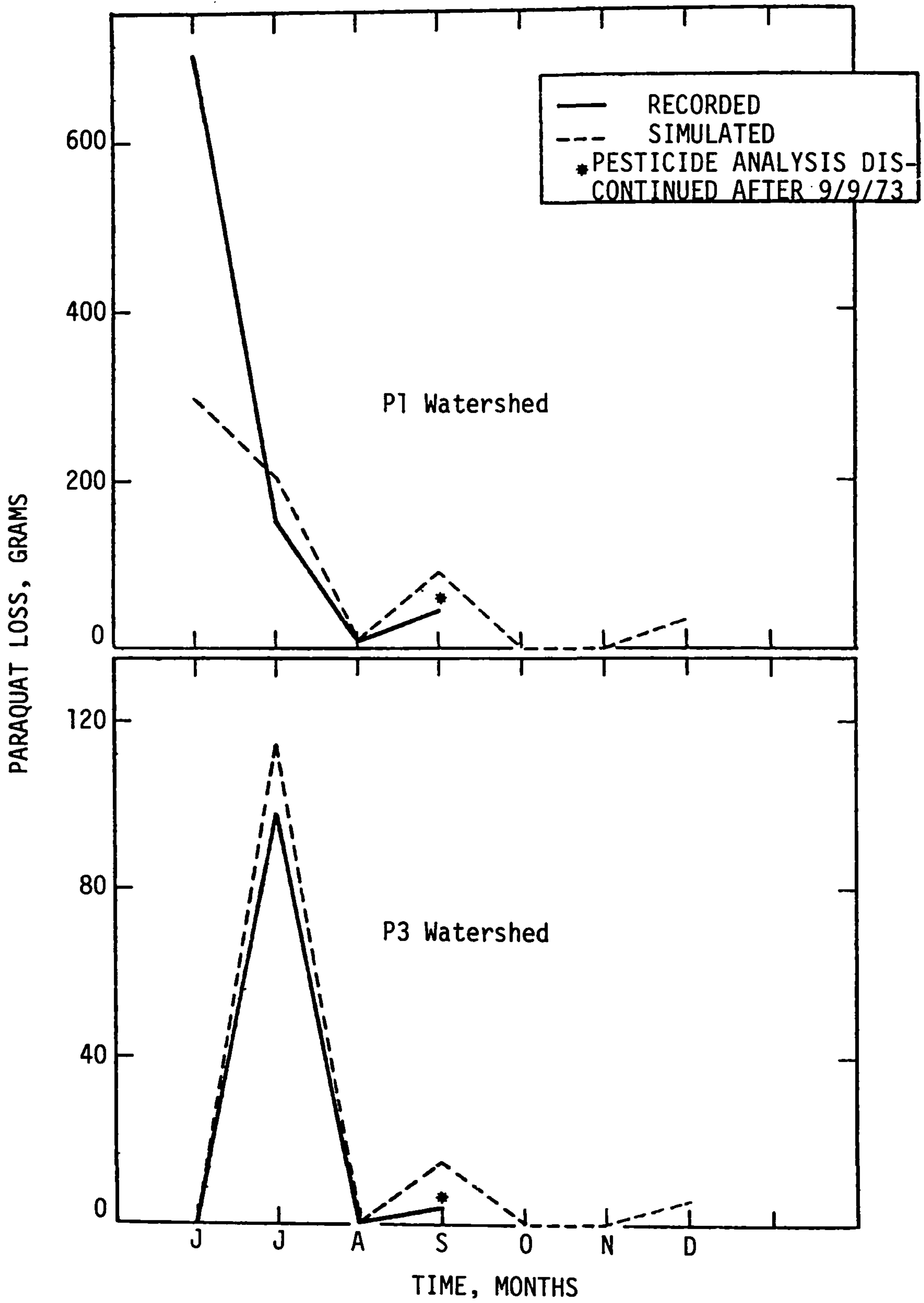


Figure 29. Monthly paraquat loss from the P1 and P3 watersheds for the 1973 growing season

Table 12. MONTHLY PARAQUAT LOSS
FROM THE P1 AND P3 WATERSHEDS DURING THE
1973 GROWING SEASON

Month	P1 Watershed				P3 Watershed			
	Recorded		Simulated		Recorded		Simulated	
	gm	(lbs)	gm	(lbs)	gm	(lbs)	gm	(lbs)
June	703.5	(1.551)	298.7	(.658)	0.0	(0.0)	.45	(.001)
July	153.9	(.339)	204.8	(.451)	98.2	(.217)	114.4	(.252)
August	9.1	(.020)	6.8	(.015)	0.0	(0.0)	0.0	(0)
September**	45.0	(.099)	87.6	(.193)	4.3	(.010)	14.5	(.032)
October	-	-	0.0	(0.0)	-	-	0.0	(0.0)
November	-	-	1.4	(.003)	-	-	.45	(.001)
December	-	-	34.1	(.075)	-	-	5.9	(.013)

* all paraquat loss was detected on sediment, paraquat was not found in solution for any events.

** pesticide analyses were discontinued after 9/9/73.

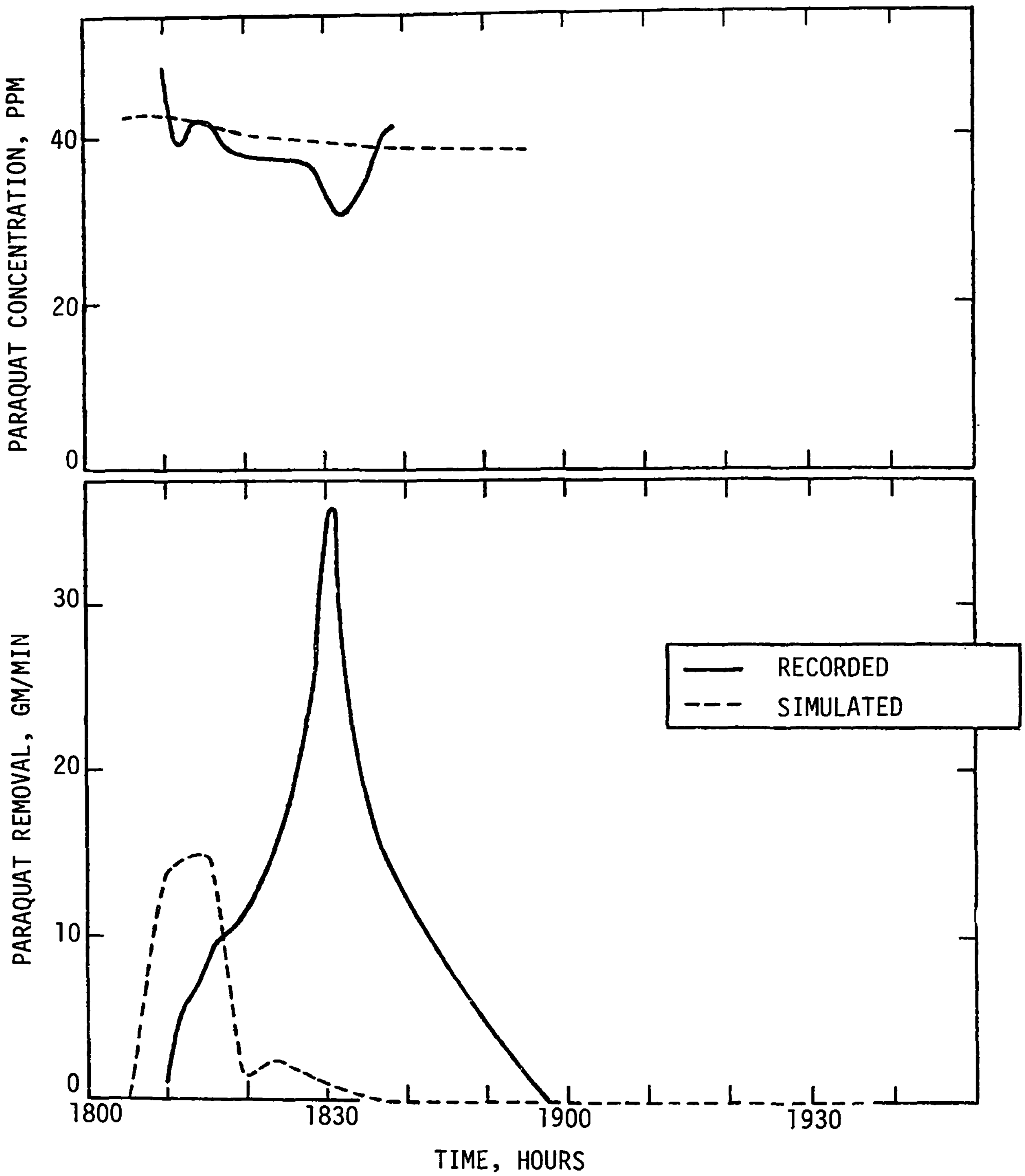


Figure 30. Paraquat loss from the P1 watershed on June 13, 1973

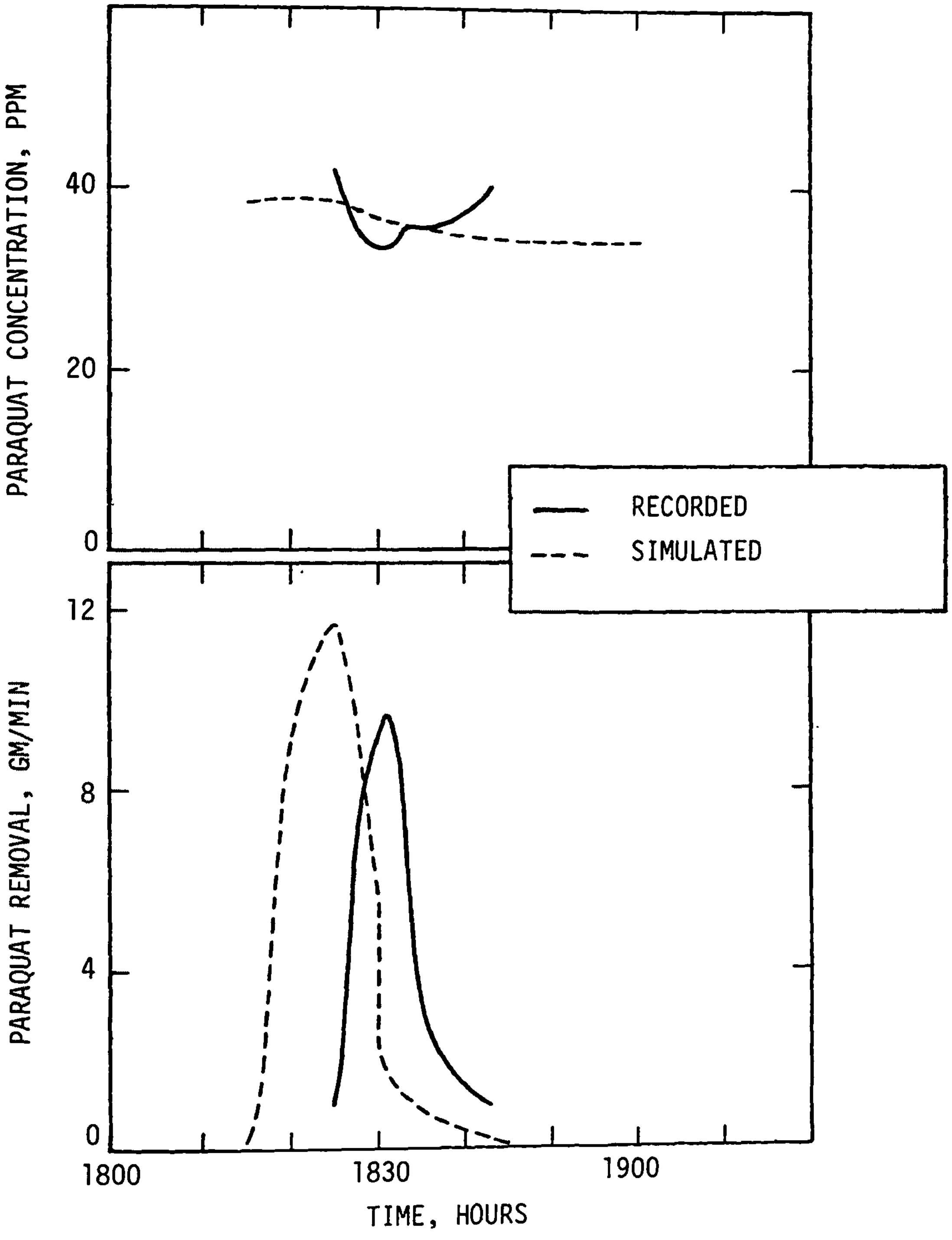


Figure 31. Paraquat loss from the P1 watershed on June 21, 1973

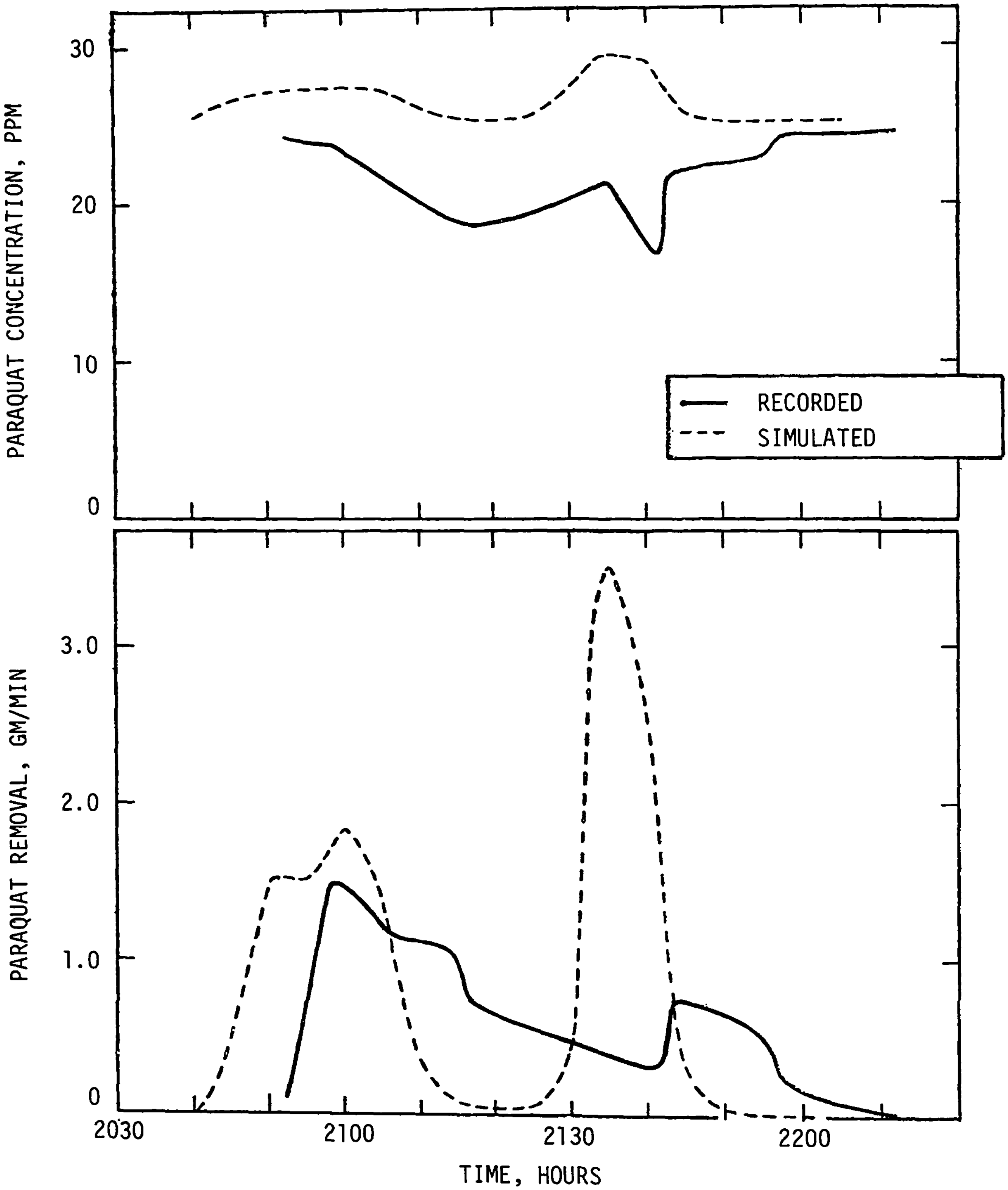


Figure 32. Paraquat loss from the P1 watershed on September 9, 1973

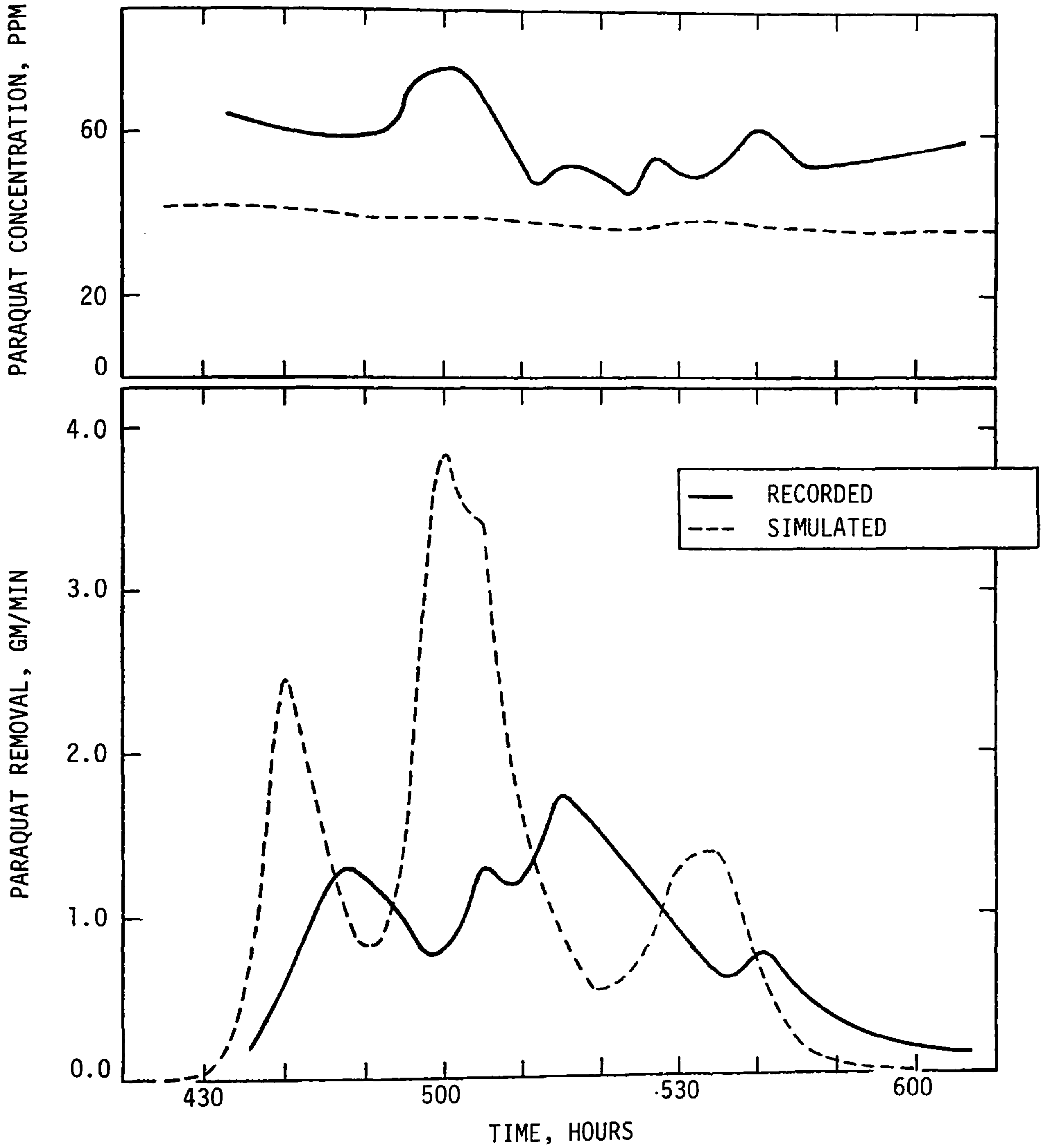


Figure 33. Paraquat loss from the P3 watershed on July 8, 1973

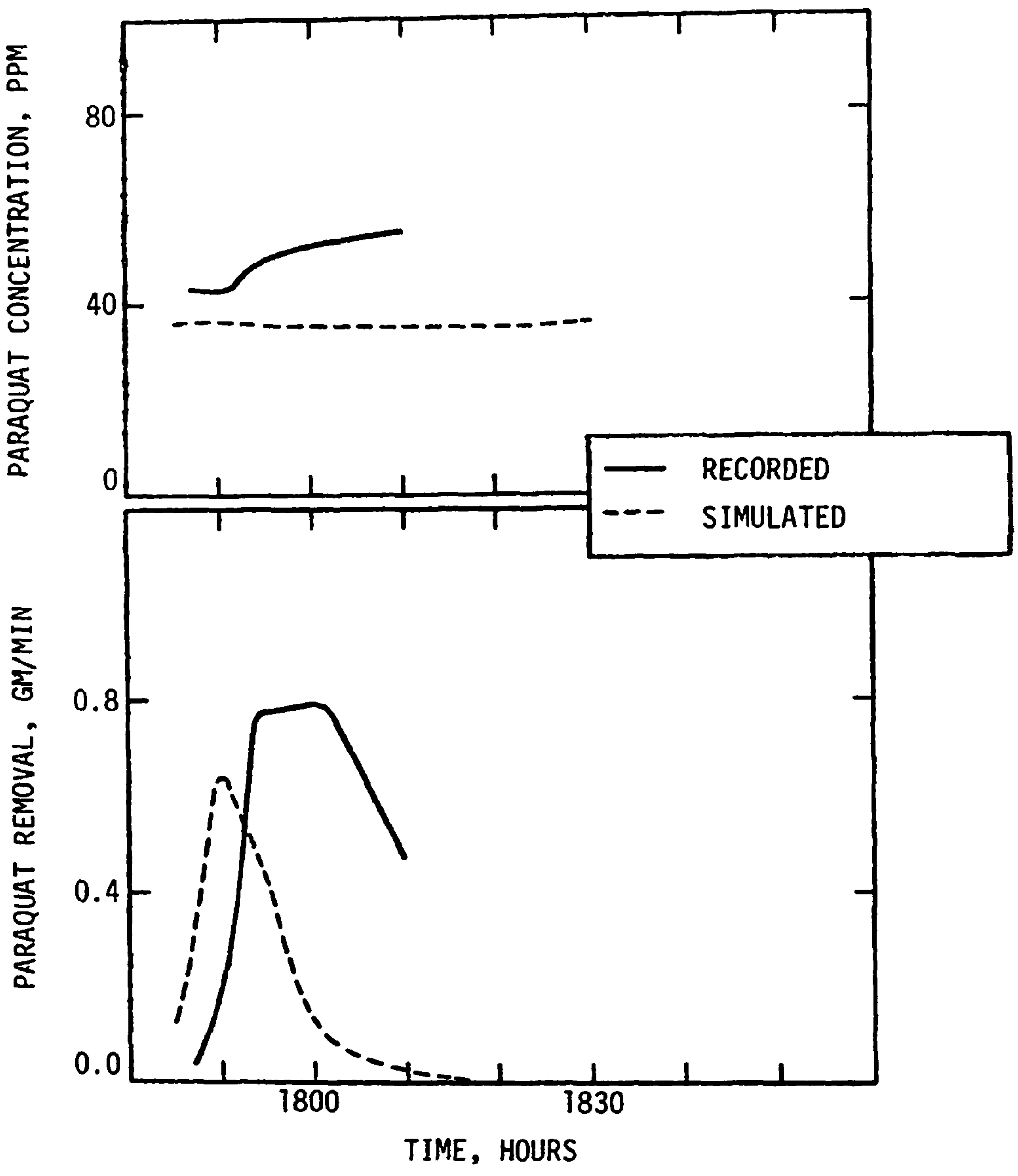


Figure 34. Paraquat loss from the P3 watershed on July 14, 1973

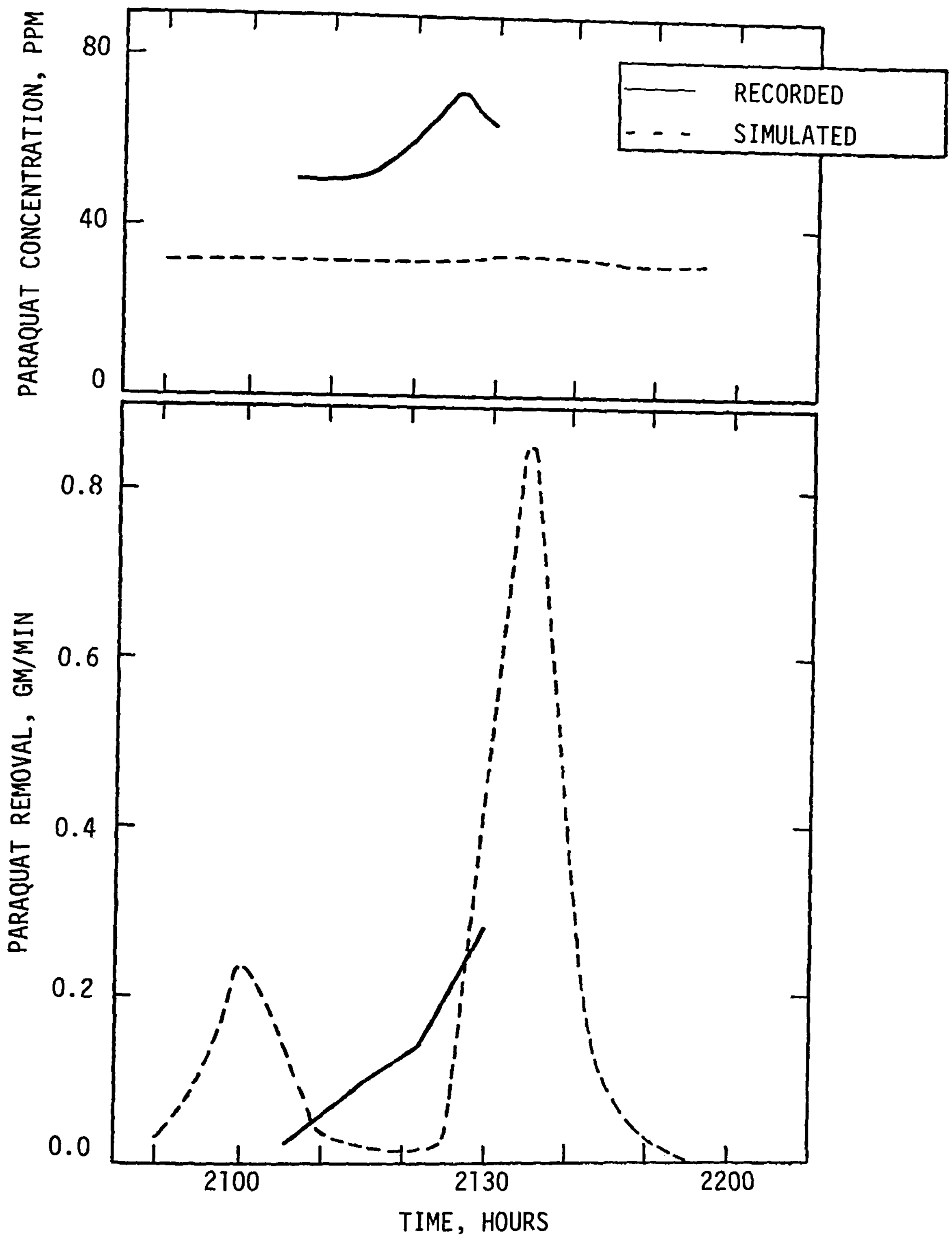


Figure 35. Paraquat loss from the P3 watershed on September 9, 1973

pesticide is present in the soil prior to application; future modifications will include this capability. Thus, with the present Model, some variation from measured concentrations was expected. The initial simulation runs on the P1 watershed produced paraquat concentrations much lower than recorded. The depth of the active surface zone (SZDPTH parameter) was then reduced from 3.2 mm to 1.6 mm and the daily degradation rate (DEGCON parameter) was increased from 0.0001 to 0.002 per day. These changes produced the results presented here. The parameter changes are within reasonable limits for these parameters since little information is available on the extent of an active surface zone, and mass balance calculations have not produced reliable information on degradation rates for paraquat. These are two areas which require further investigation.

Although the parameter changes gave reasonable results for the P1 watershed, the same changes on the P3 watershed yielded low simulated concentrations as shown in Figures 33, 34, and 35. These low concentrations resulted in monthly paraquat loss close to recorded values because simulated monthly sediment loss was much higher than recorded; thus compensating errors occurred. Further investigation indicated that prior to application, almost twice as much paraquat was present in the top centimeter of the soil profile on the P3 watershed as compared to the P1 watershed, i.e. approximately 6.8 kg/ha of paraquat was detected on the P1 watershed and 12.5 kg/ha on the P3 watershed in the top centimeter of the soil. The terraced P3 watershed experiences only much less sediment loss and corresponding paraquat loss, resulting in more paraquat remaining on the watershed from the previous season. This additional paraquat would, in effect, double the stated application rate on the P3 watershed when proportioned to the depth of the active surface zone. The result would be a doubling of the simulated paraquat concentrations in Figures 33, 34, and 35 and closer agreement between simulated and recorded values. This phenomenon did not occur in the PTR Model work because 1972 was the first year of paraquat application. Thus, inclusion of the paraquat present in the soil prior to application would further improve the agreement between simulated and recorded values.

Diphenamid

The simulation of diphenamid loss allowed an initial evaluation and comparison of the single-valued (SV) and non-single-valued (NSV) adsorption/desorption functions. Since the majority of pesticides are transported by both runoff and sediment, the behavior of these chemicals in the soil-water environment is an important factor in simulating their movement. The division between the water and sediment phase is critical to the evaluation of the impact of different pesticides. Highly soluble pesticides will infiltrate to greater depths in the soil profile than less soluble ones. Soil erosion prevention practices will have a greater effect on pesticides whose major transport mechanism is sediment loss while water-transported pesticides will be affected more by runoff reduction practices. In addition, attenuation and degradation processes are influenced differently by the solution and adsorbed states of the pesticide. These processes determine the length of time following application that a pesticide will be susceptible to transport by runoff and sediment, and thus are critical to the simulation of pesticide transport.

Figure 36 and Tables 13 and 14 (NSV function only) present the monthly diphenamid loss for both the P1 and P3 watersheds. The results of employing both the SV and NSV functions are included in Figure 36. The storm event simulations for diphenamid concentrations and mass removal are presented in Figures 37, 38, 39 and 40 for the June 13 and June 21 events on the P1 watershed. Each figure presents the concentration (top graph) and mass removal (bottom graph) for either the water or sediment phase. Thus, for June 13, Figure 37 displays the diphenamid loss by sediment and Figure 38 displays diphenamid loss by runoff. Figures 39 and 40 are the analogous graphs for the storm of June 21. The corresponding results for the P3 watershed for the July 8 and July 14 events are contained in Figures 41, 42, 43 and 44. Results of employing both the SV and NSV adsorption/desorption functions are displayed in all figures.

Since diphenamid is a highly degradable herbicide, recorded concentrations in the runoff are essentially negligible within two months following application. Consequently, the first runoff-producing storms after application are the critical events for diphenamid loss. Since the major storm events after application occurred in June on the P1 watershed, essentially all the diphenamid loss occurred in June. However, July was the major month for storms on the P3 watershed; thus, the recorded diphenamid loss for P3 occurs in July.

In general, the simulation of diphenamid transport often shows considerable deviation from the recorded values. The simulated monthly diphenamid loss (Figure 36) on the P1 watershed is reasonably close to the observed values, while on the P3 watershed the values are quite different. The monthly diphenamid loss on P3 emphasizes the need for accurate hydrology and sediment simulation on storms following pesticide application, especially for degradable pesticides like diphenamid. On June 20, 1973 a relatively minor, but intense, thunderstorm (9.65 mm, 0.38 inches, in 9 minutes) on the P3 watershed produced a simulated peak flow of 0.013 cms (0.46 cfs) although no actual runoff or sediment loss was observed. This minor storm produced the entire simulated monthly diphenamid loss for the month of June shown in Figure 36. Since the storm occurred within five days of application, the diphenamid on the land surface was exceptionally susceptible to movement even by the relatively small amount of runoff simulated. Thus the diphenamid loss is

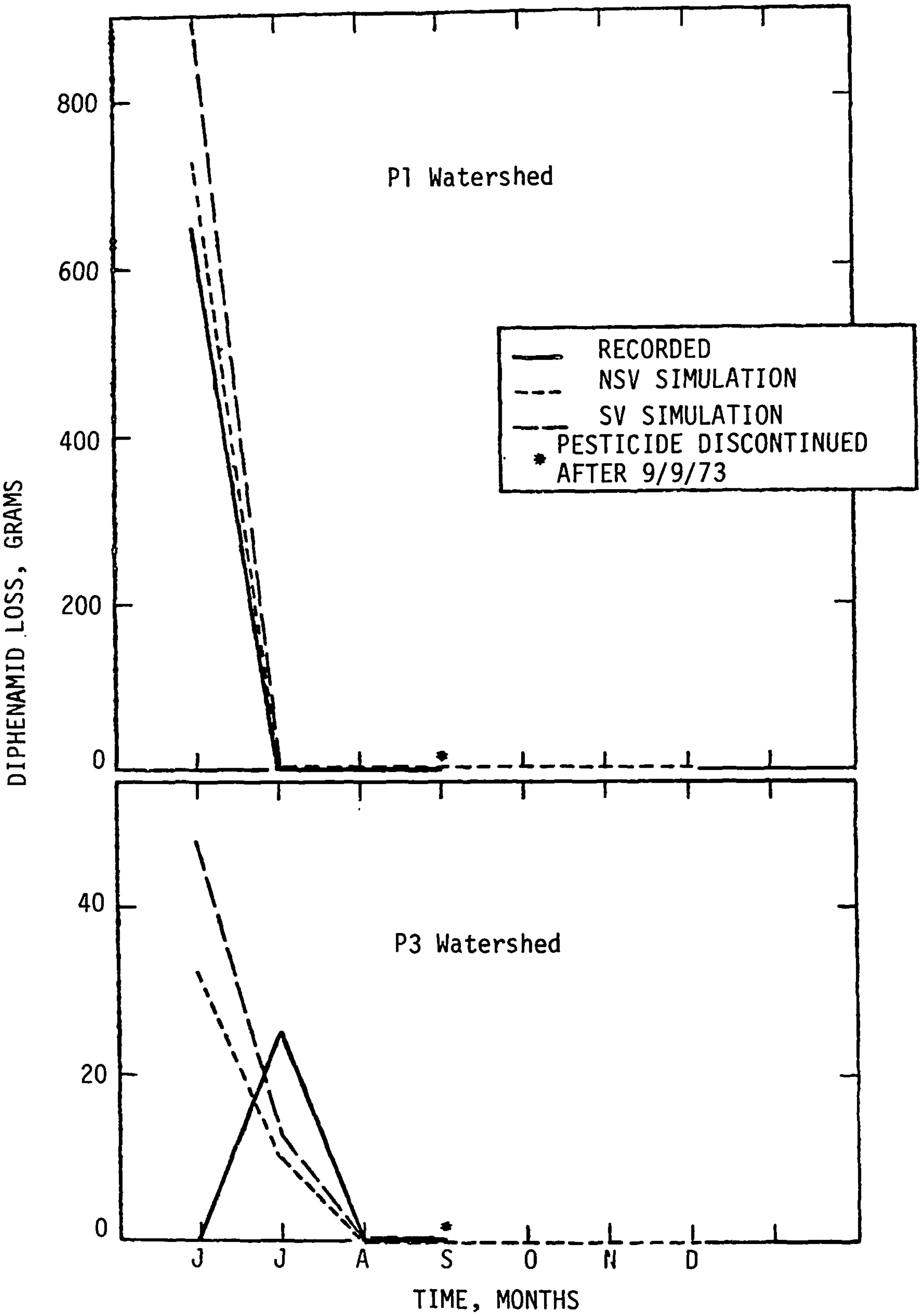


Figure 36. Monthly diphenamid loss from the P1 and P3 watersheds during the 1973 growing season

Table 13. DIPHENAMID LOSS FROM THE P1 WATERSHED DURING THE 1973 GROWING SEASON

Month	On Sediment				In Water				Total			
	Recorded		Simulated		Recorded		Simulated		Recorded		Simulated	
	gm	(lbs)	gm	(lbs)	gm	(lbs)	gm	(lbs)	gm	(lbs)	gm	(lbs)
June	12.2	(.027)	49.9	(.11)	636.5	(1.404)	667.4	(1.47)	648.7	(1.44)	721.9	(1.59)
July	.7	(.002)	0.0	(0.0)	2.7	(.006)	.9	(.002)	3.4	(.007)	.9	(.002)
August	.01	(0.0)	0.0	(0.0)	.03	(0.0)	0.0	(0.0)	.04	(0.0)	0.0	(0.0)
September*	.14	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	.14	(0.0)	0.0	(0.0)
October	-	-	0.0	(0.0)	-	-	0.0	(0.0)	-	-	0.0	(0.0)
November	-	-	0.0	(0.0)	-	-	0.0	(0.0)	-	-	0.0	(0.0)
December	-	-	0.0	(0.0)	-	-	0.0	(0.0)	-	-	0.0	(0.0)

* pesticide analyses were discontinued after 9/9/73

Table 14. DIPHENAMID LOSS FROM THE P3 WATERSHED DURING THE 1973 GROWING SEASON

Month	On Sediment				In Water				Total			
	Recorded		Simulated		Recorded		Simulated		Recorded		Simulated	
	gm	(lbs)	gm	(lbs)	gm	(lbs)	gm	(lbs)	gm	(lbs)	gm	(lbs)
June	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	32.2	(.071)	0.0	(0.0)	32.2	(.071)
July	1.1	(.002)	1.1	(.002)	24.0	(.053)	9.1	(.020)	25.1	(.055)	10.0	(.022)
August	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
September *	.001	(0.0)	0.0	(0.0)	.15	(0.0)	0.0	(0.0)	.15	(0.0)	0.0	(0.0)
October	-	-	0.0	(0.0)	-	-	0.0	(0.0)	-	-	0.0	(0.0)
November	-	-	0.0	(0.0)	-	-	0.0	(0.0)	-	-	0.0	(0.0)
December	-	-	0.0	(0.0)	-	-	0.0	(0.0)	-	-	0.0	(0.0)

* pesticide analyses were discontinued after 9/9/73

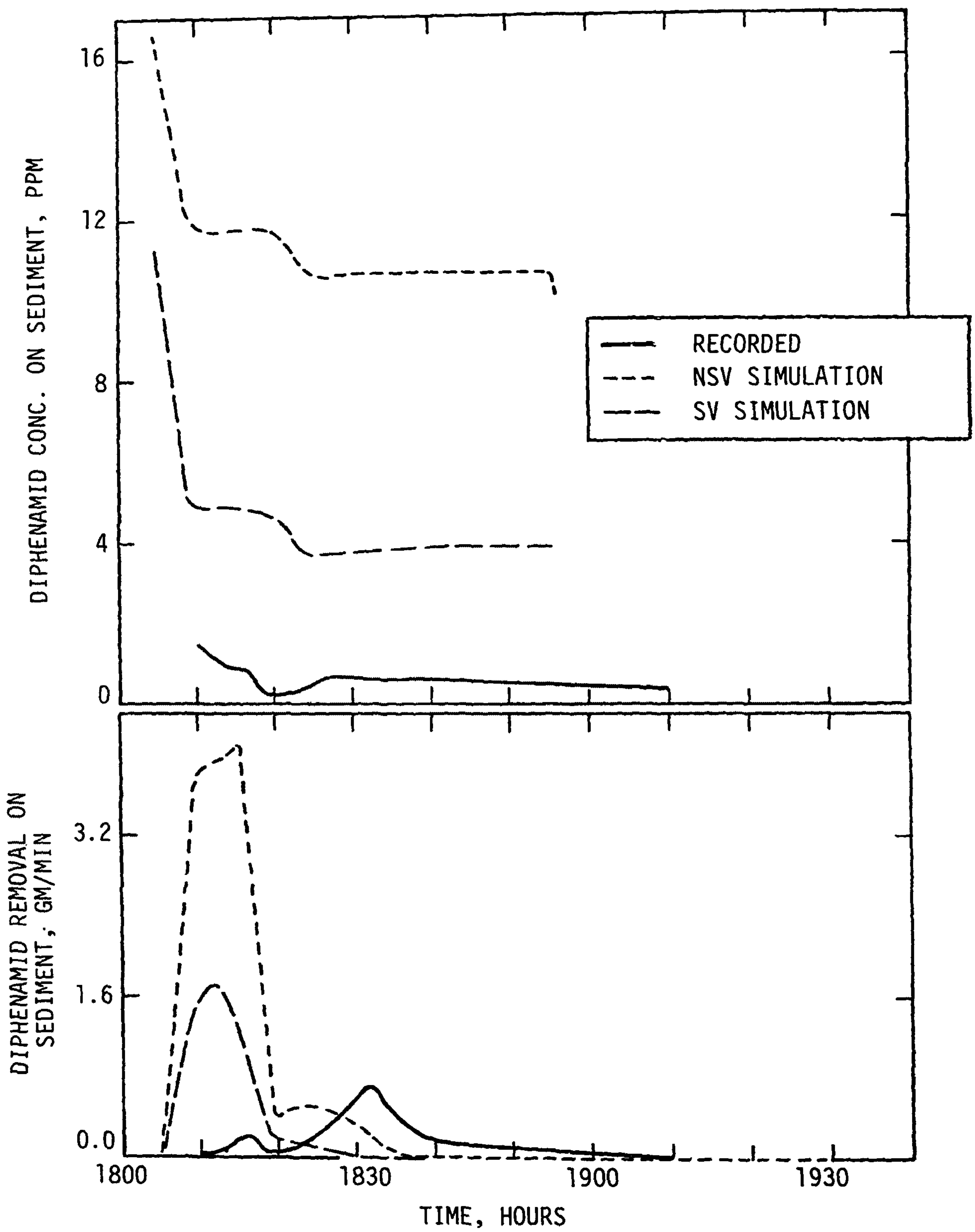


Figure 37. Diphenamid loss on sediment from the P1 watershed on June 13, 1973

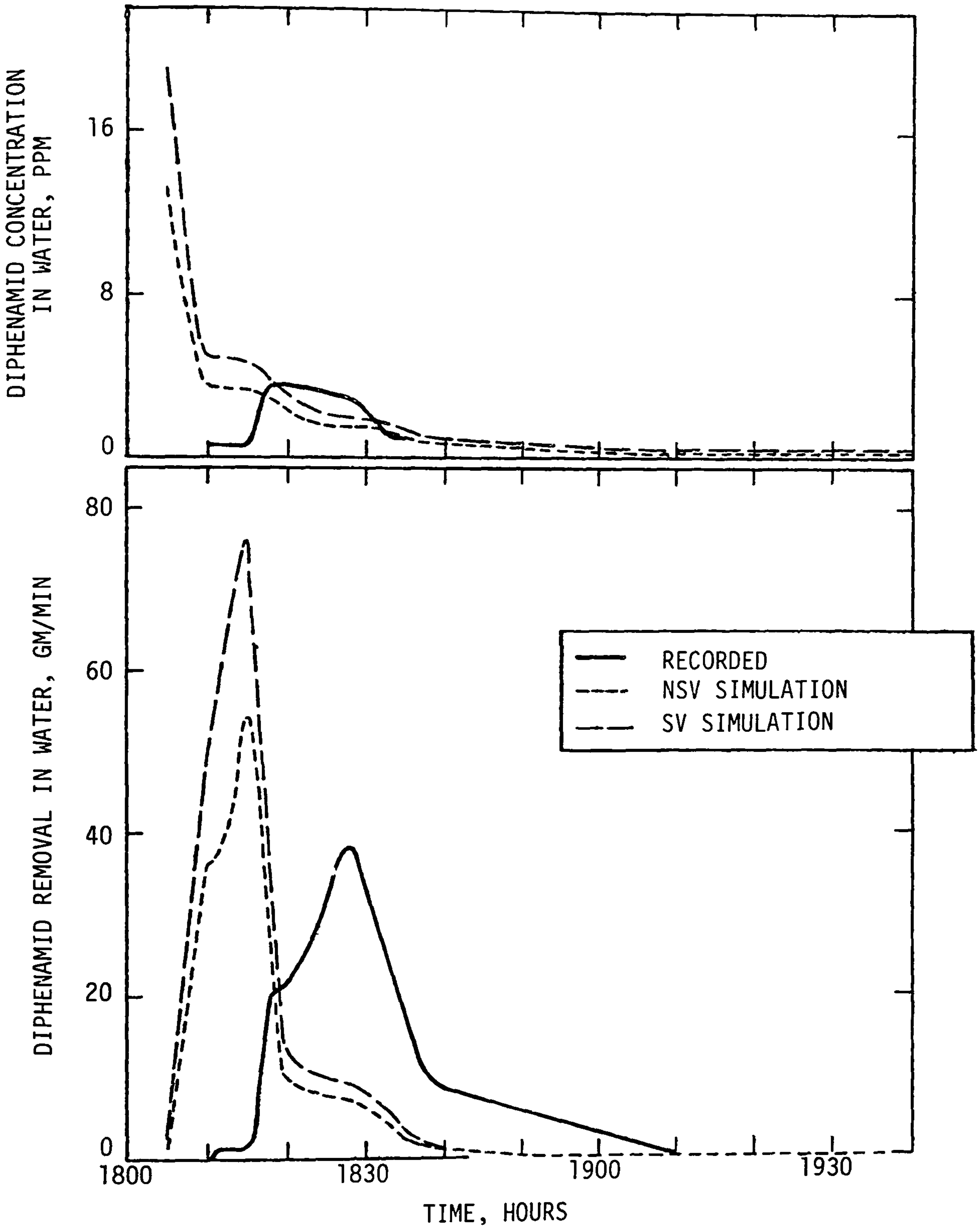


Figure 38. Diphenamid loss in water from the P1 watershed on June 13, 1973

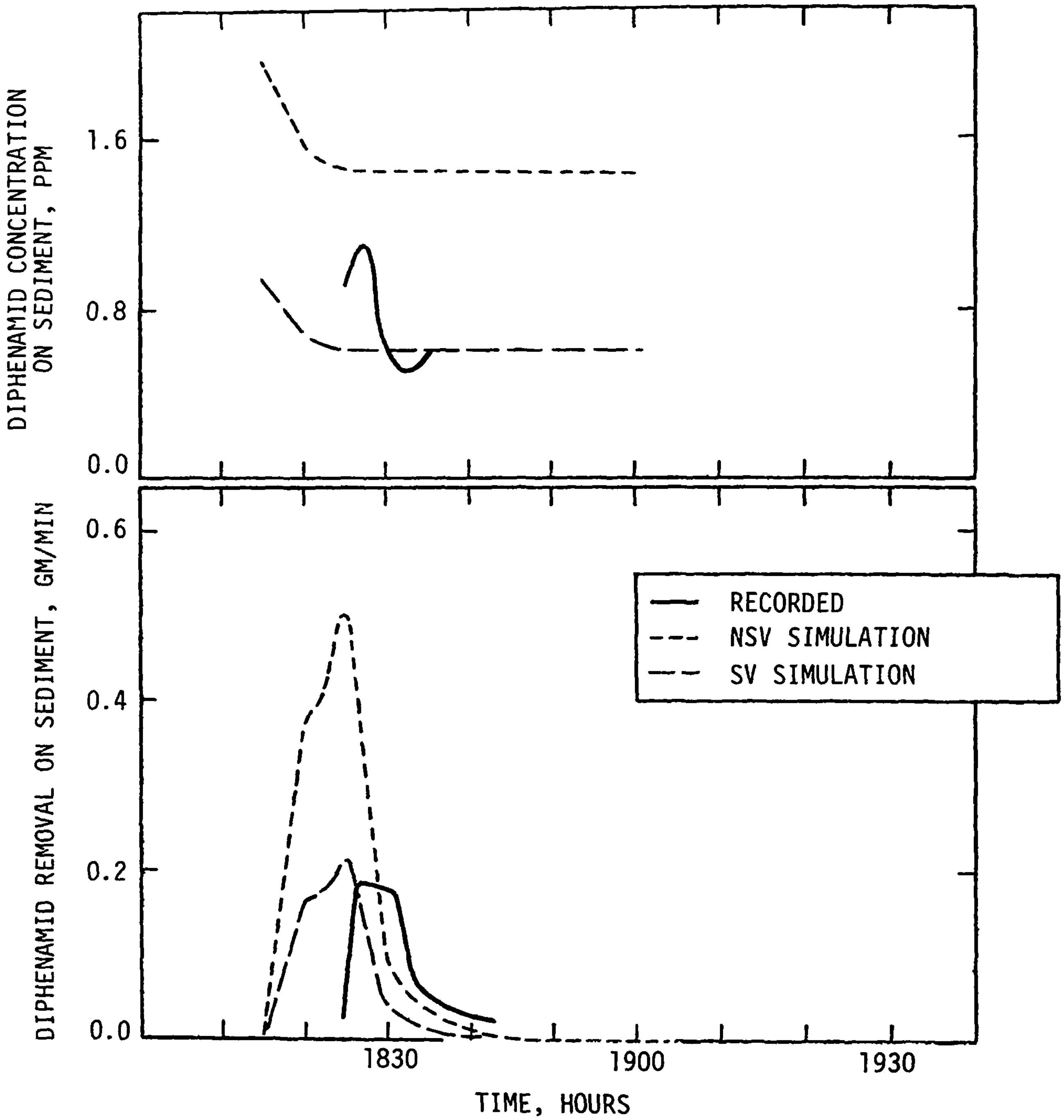


Figure 39. Diphenamid loss on sediment from the P1 watershed on June 21, 1973

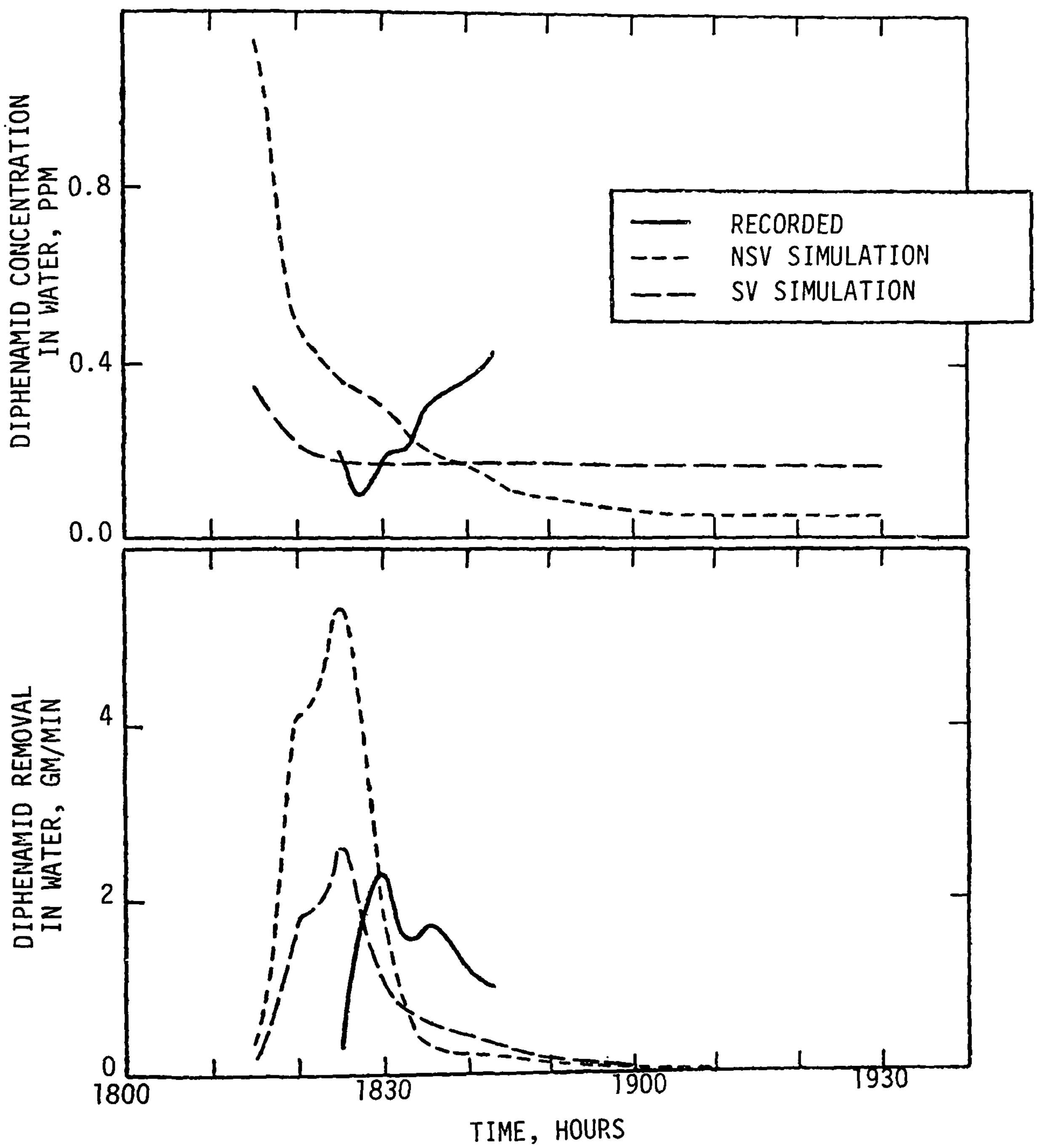


Figure 40. Diphenamid loss in water from the P1 watershed on June 21, 1973

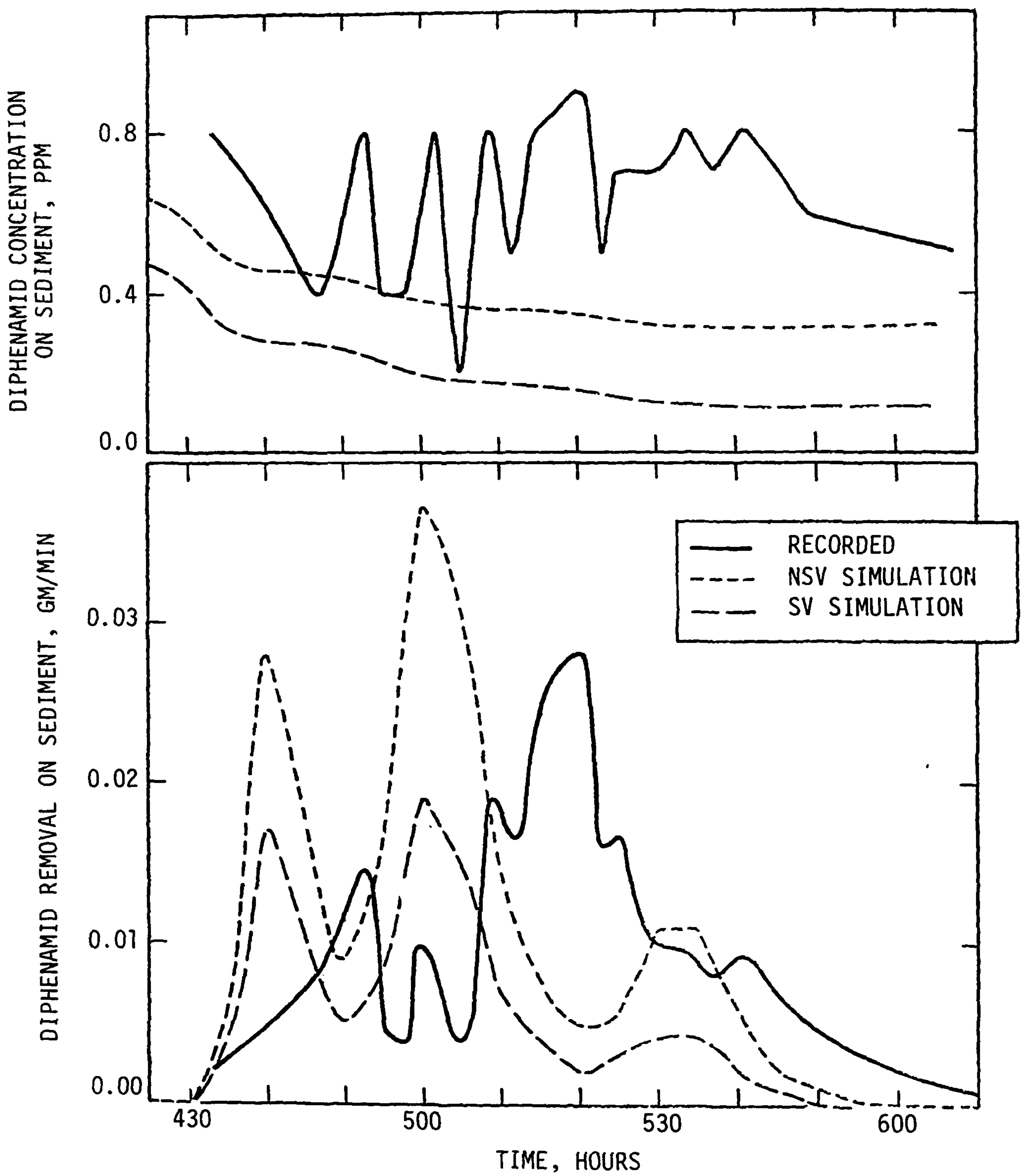


Figure 41. Diphenamid loss on sediment from the P3 watershed on July 8, 1973

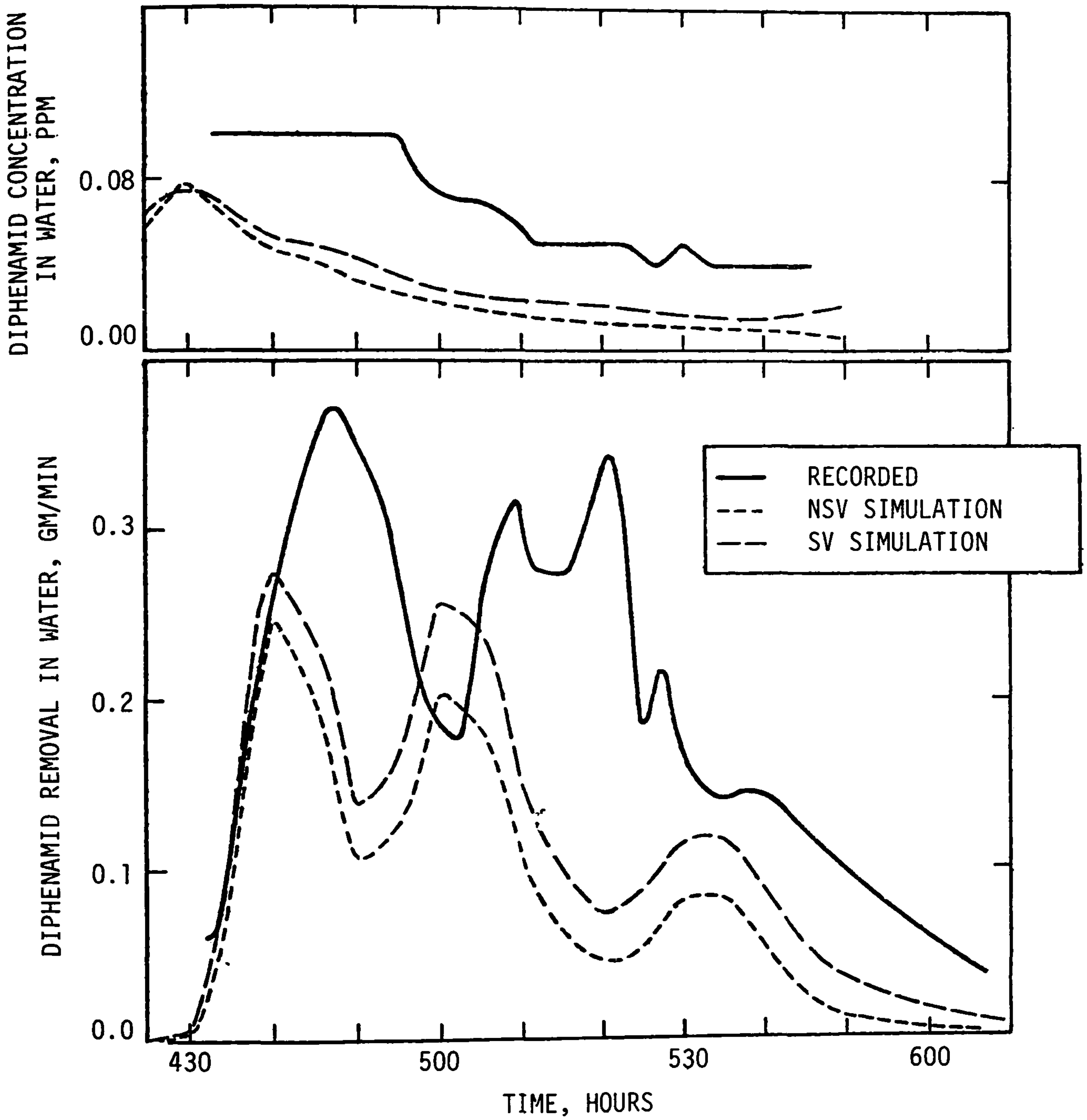


Figure 42. Diphenamid loss in water from the P3 watershed on July 8, 1973

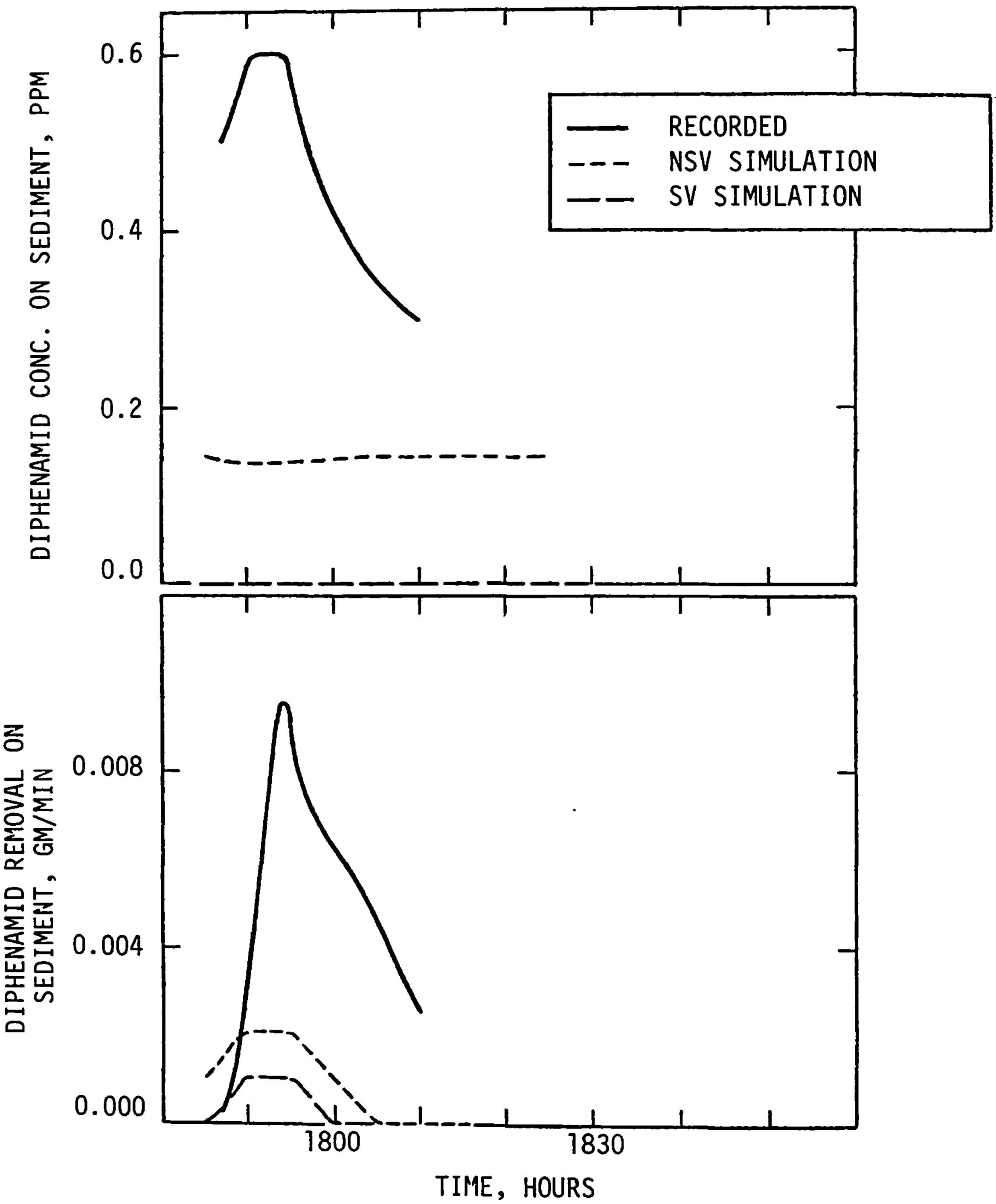


Figure 43. Diphenamid loss on sediment from the P3 watershed on July 14, 1973

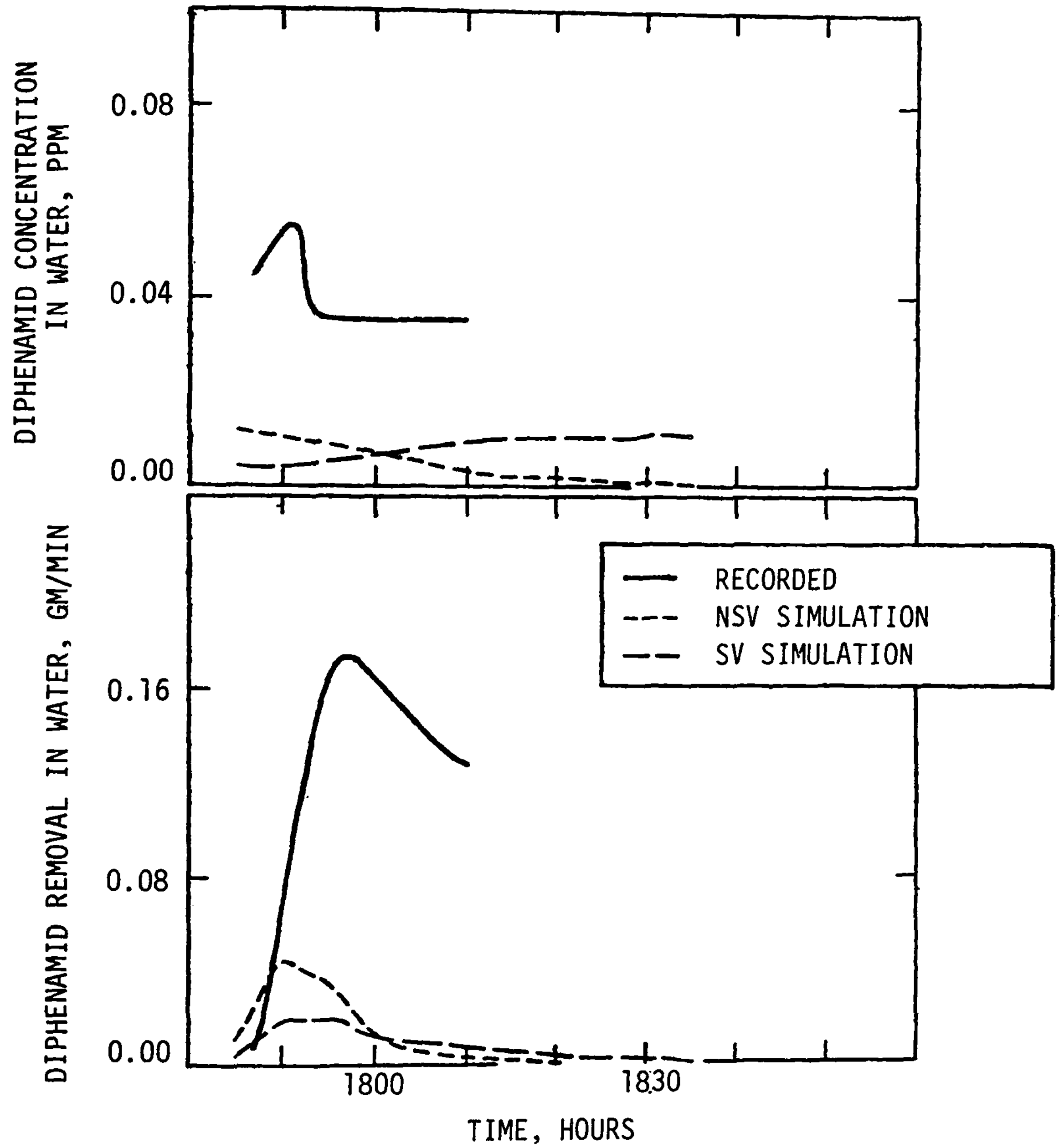


Figure 44. Diphenamid loss in water from the P3 watershed on July 14, 1973

directly dependent on the timing and magnitude of the individual storm events on the watershed.

From an analysis of the simulated and recorded results in Figures 37 to 44, the following points are indicated:

(1) The results of comparing the SV and NSV adsorption/desorption functions are inconclusive. The NSV function produces greater diphenamid concentrations on sediment and less in solution than the SV function. For the June 21 storm on the P1 watershed (Figures 39 to 40) the SV function represents reasonably well the mass diphenamid removal both on sediment and in solution. While on the P3 watershed, the NSV function is generally closer to the recorded values.

(2) Although the June 13 simulated flow and sediment loss (Figure 21) are less than recorded, the simulated diphenamid loss is much greater than recorded. Since the storm occurred approximately six hours after pesticide application, the discrepancy could be due to an inaccurate estimation of the actual amount of pesticide applied or the amount lost by degradation/volatilization in the intervening six hours. In addition to the adsorption/desorption function, the assumed depth of the surface zone has a critical impact on diphenamid concentrations, especially during the initial storm events. Since the initial storms following pesticide application are the important events for pesticide loss, the uncertainties and behavior of the attenuation and adsorption/desorption be further investigated during this time period.

(3) Comparison of diphenamid concentrations for all four storms indicates that simulated concentrations are greater than recorded for the June storms (Figures 37 to 40) and less than recorded for the July storms (Figures 41 to 49). Although the storms occurred on different watersheds, this trend demonstrates the possibility that the assumed first-order degradation rate underestimates degradation during the initial month of the growing season and overestimates degradation near the middle and end of the growing season. A similar conclusion resulted from the PTR Model work. The accurate representation of pesticide attenuation processes is crucial to the evaluation of the amount of pesticide available for movement by any storm event. Efforts are presently underway to develop such a representation.

(4) As noted in the discussion of the paraquat simulation, the unit of pesticide mass removal (grams/minute) is more indicative of pesticide loss than the instantaneous pesticide concentrations. This is especially noticeable in Figure 41. The instantaneous diphenamid concentrations vary erratically throughout the event

while the diphenamid mass removal is similar to the hydrograph and the sediment mass loss. Thus the connection between pesticide loss and its transporting mechanisms is clearly displayed by the pesticide mass removal graphs.

CONCLUSIONS

The testing of the ARM Model has indicated that the hydrology and sediment simulations reasonably represent the observed data while the pesticide simulations can show considerable deviation from recorded values. This is especially true for pesticides that move by both runoff and sediment loss. The effects of tillage operations and management practices need to be further evaluated for hydrology and sediment production. Parameter changes as a result of agricultural practices need to be quantified. Although the results of sediment simulation have been promising, certain deviations in the results indicate a lack of understanding of certain aspects of the physical process. Other processes in the soil erosion mechanism, such as natural compaction of the surface following tillage and the effect of rainfall intensity on the transport capacity, need to be evaluated for possible inclusion in the Model. Although the hydrology model has been applied to hundreds of watersheds in the United States, the accompanying sediment model has been applied to only a few. If the ARM Model is to be generally applicable, the most immediate need is to evaluate the sediment simulation capability in varying climatic and edaphic regions.

For pesticide simulation, the results demonstrate the need to further investigate the processes of pesticide degradation and pesticide-soil interactions. Both the SV and NSV adsorption/desorption functions require further research. A non-equilibrium approach should be investigated to determine its applicability. The interactions in the active surface zone appear to control the major portion of pesticide loss especially for highly sediment-adsorbed pesticides like paraquat. The depth of the active surface zone and the extent of pesticide degradation in that zone are critical to the simulation of pesticide loss for any storm event.

The need for testing the ARM Model in other regions also pertains to the pesticide functions. The mechanisms recommended for further research should be studied and evaluated in many regions of the country. Investigations of these mechanisms is presently continuing for the Georgia and Michigan watersheds. Other agricultural areas must be included in future studies in order to establish the general applicability of the ARM Model.

SECTION IX

SENSITIVITY ANALYSIS

To fully evaluate, quantify, and display the effects of parameter changes on simulation results, sensitivity analyses were performed for the hydrology, sediment, and pesticide parameters of the ARM Model. The sensitivity of the snowmelt and nutrient parameters will be investigated in future work. The analyses involved a series of Model runs on the P1 watershed in Georgia. Each run was performed while changing the value of a single parameter. The calibrated parameter set provided baseline simulation results. Two Model runs were performed for each parameter with parameter values greater than and less than the calibrated value. Thus, the change in simulation results obtained from a change in the parameter value indicates the sensitivity of the Model to the specific parameter. Tables 15, 16, and 17 present the ARM Model hydrology, sediment, and pesticide values respectively chosen for the sensitivity analyses. The hydrology parameters were analyzed on a six-month period, April 1973 to September 1973, while the sediment and pesticide parameters were analyzed on the critical summer period, June 1973 to September 1973. The results are presented in Figures 45 to 51 in terms of the effects of parameter changes on (1) total runoff, sediment, and pesticide loss during the simulation period, and (2) peak runoff, sediment mass, and pesticide mass removal (in water and on sediment) for the storm of June 21, 1973. The ARM Model parameters are defined in Section IV, Tables 2, 3, and 4. The sensitivity results are displayed in terms of percent parameter change versus the resulting percent change in runoff, sediment, or pesticide loss. Thus the slope (positive or negative) indicates the relative sensitivity of the parameters; i.e., steeper slopes correspond to the more sensitive parameters. The shaded areas in each figure indicate the region where the stated parameter change produces a greater percent change in the quantity of interest, e.g. a +44 percent change in JSER results in a +60 percent change in sediment loss in Figure 46. The hydrology, sediment, and pesticide parameter sensitivities are discussed separately below.

HYDROLOGY PARAMETERS

Figures 45 and 46 display the effects of changes in the hydrology parameters on the total runoff for the April to September 1973 period and the peak runoff for the June 21 storm, respectively, on the P1 watershed. Infiltration (INFIL) and lower zone soil moisture (LZSN) characteristics have the greatest impact on total runoff volumes. This is generally true in most areas of the country. For this reason, the INFIL and LZSN parameters are most directly involved in the hydrologic calibration of a specific watershed. Although the topographic (L, SS, NN) and vegetal canopy (EPXM) parameters do affect runoff volume, their relative impact is

Table 15. HYDROLOGY PARAMETER VALUES FOR SENSITIVITY ANALYSIS (English Units)

Parameter	Baseline Value	Trial #1	Trial #2
UZSN	0.05	0.01	0.25
LZSN	18.0	14.0	22.0
INFIL	0.5	0.2	0.8
INTER	0.7	0.4	1.0
SS	0.05	0.02	0.08
L	160.0	100.0	220.0
NN	0.20	0.10	0.30
K3	0.40	0.20	0.60
EPXM	0.12	0.06	0.18

Table 16. SEDIMENT PARAMETER VALUES FOR SENSITIVITY ANALYSIS (English Units)

Parameter	Baseline Value	Trial #1	Trial #2
JRER	2.2	1.4	3.0
KRER	0.17	0.10	0.24
JSER	1.8	1.0	2.6
KSER	1.2	0.8	1.6
COVPMO	J J A S O 0.0, 0.0, 0.25, 0.5, 0.7	increased 20%	decreased 20%
SRERTL	5.0, 2.0	increased 20%	decreased 20%

Table 17. PESTICIDE PARAMETER VALUES FOR SENSITIVITY ANALYSIS
(English Units)

Parameter	Baseline Value**	Trial #1	Trial #2
CMAX	0.00026	0.00013	0.00052
DD	0.0	0.00010	0.00020
BULKD	103.0	93.0	113.0
K	1.8	0.6	3.0
N	1.6	1.0	2.2
NP	3.7	2.3	5.1
SSTR	5*4.002	5*2.0	5*6.0
UZDPTH	6.125	4.125	8.125
SZDPTH	0.125	0.062	0.250
DEGCON	0.08	0.04	0.12
DESORP	YES	NO	

** Baseline pesticide values are for diphenamid characteristics

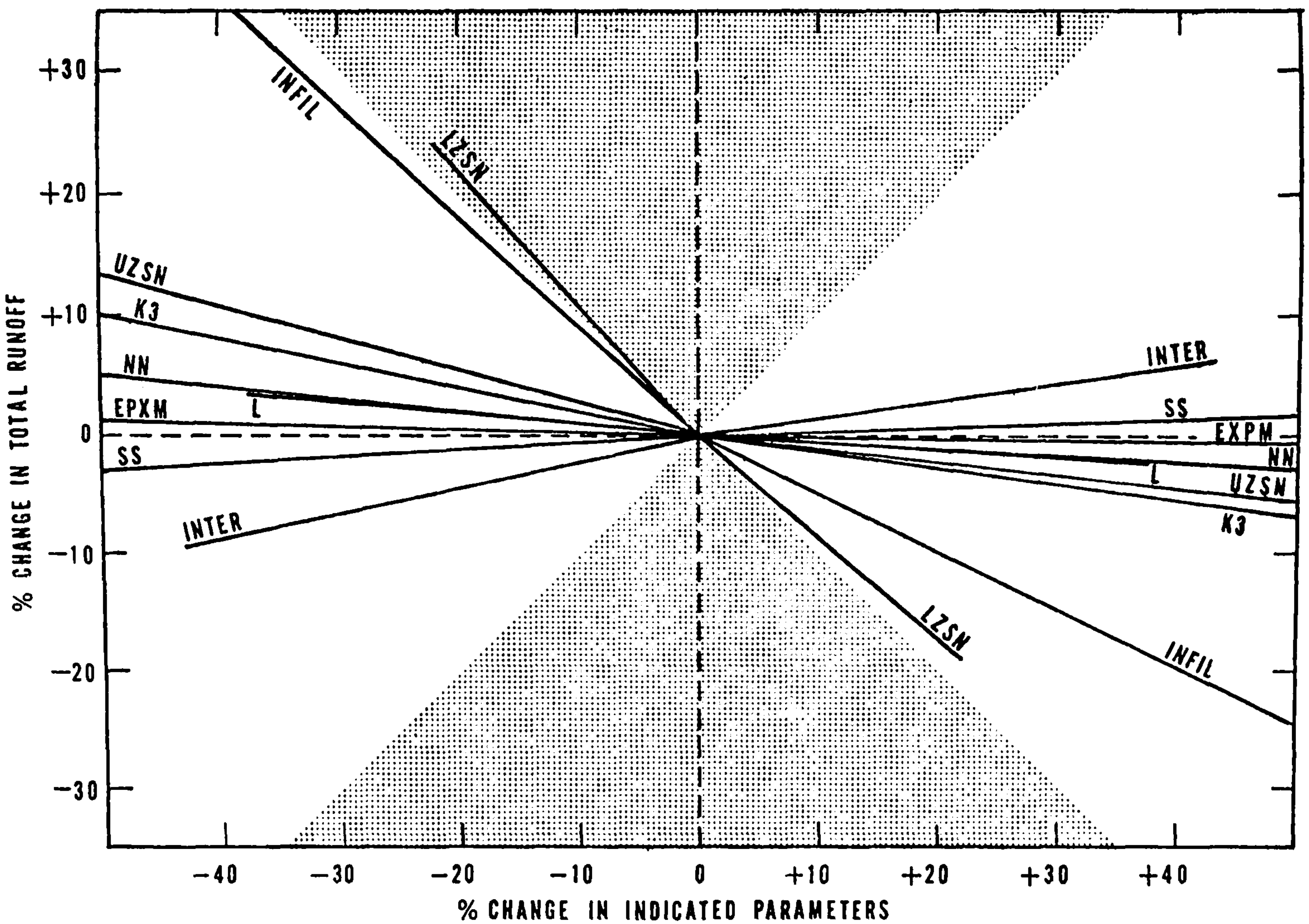


Figure 45. Hydrology parameter sensitivity - total runoff

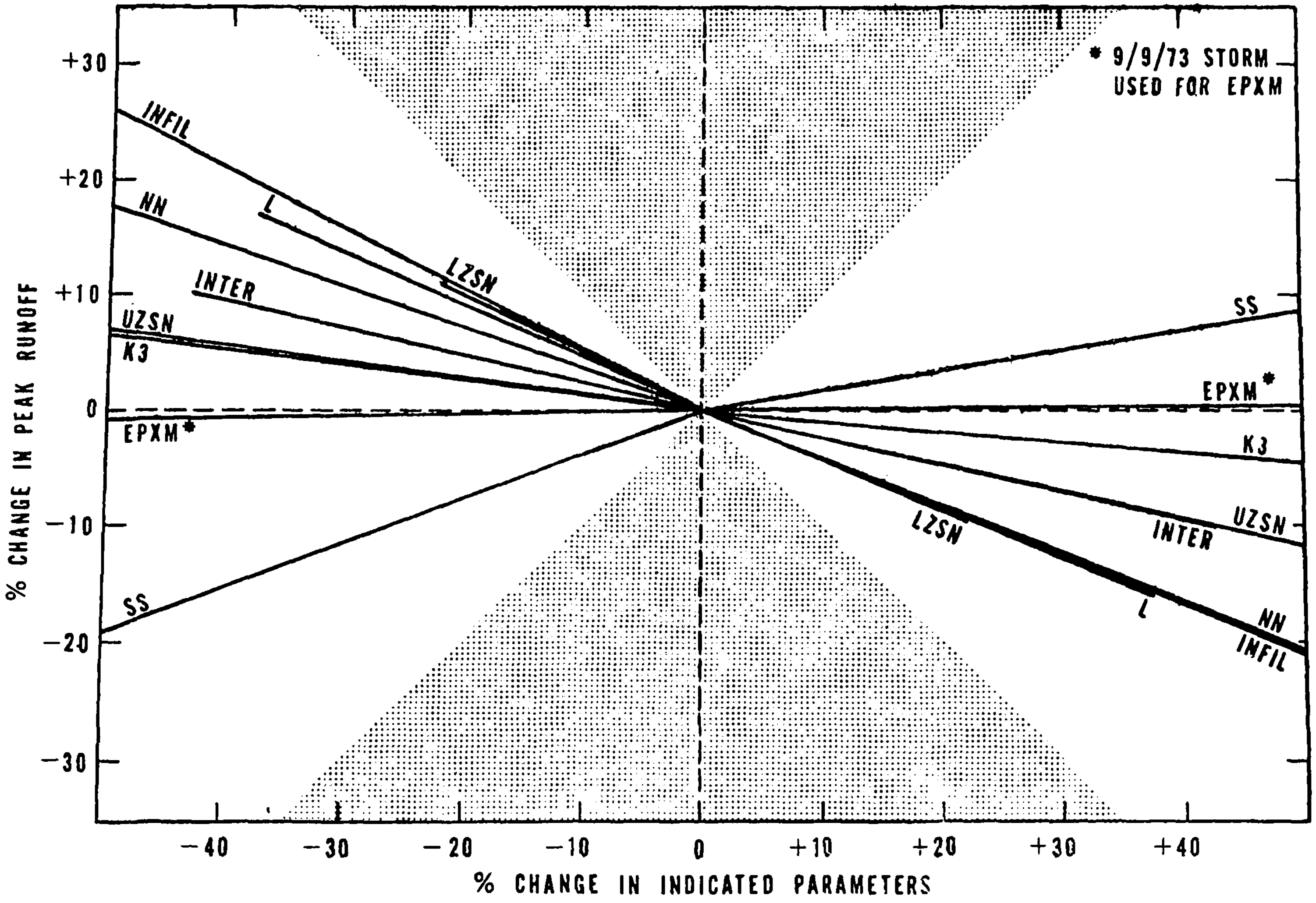


Figure 46. Hydrology parameter sensitivity - peak runoff
(P1 watershed, storm of June 21, 1973)

less than what might be expected. The interflow parameter (INTER) is generally thought to have no effect on runoff volume. This is generally true, especially in large watersheds. The runoff change shown in Figure 45 due to the interflow parameter is a result of the manner in which interflow is calculated in the ARM Model. The interflow component is subtracted from the moisture available for surface runoff, and reaches the stream channel through a delaying storage mechanism. The remaining surface runoff undergoes a kinematic overland flow routing technique which determines the amount of surface runoff reaching the stream channel during the time interval. The surface runoff which does not reach the stream is available to infiltrate during the next time interval. Thus as interflow increases a larger fraction of surface moisture is assured of reaching the stream through the interflow storage mechanism resulting in a minor increase in runoff volume.

The effects of parameter changes on peak runoff (Figure 46) are similar but not as dramatic. Infiltration and soil moisture characteristics remain important. However, topographic factors such as slope, length of flow, and surface roughness have a significantly greater impact on peak runoff rates as compared to runoff volumes. The relative ranking of the parameters is much the same in both Figures 45 and 46. However, overland flow length (L) and surface roughness (NN) increase in importance, and the impact of the interflow parameter (INTER) is reversed. An increase in interflow will reduce peak runoff while slightly increasing total runoff. In general, Figures 45 and 46 indicate that agricultural management practices which influence land slope, surface roughness, and overland flow length have a relatively greater impact on peak runoff than on total runoff volumes.

SEDIMENT PRODUCTION PARAMETERS

The effects of sediment parameter changes on total sediment production (June to September 1973) and peak sediment loss (storm of June 21, 1973) on the P1 watershed are shown in Figures 47 and 48, respectively. A review of the sediment algorithm and parameters described in Section IV would be helpful to the understanding of this discussion. In general, the washoff parameters (JSER, KSER) appear to have the greatest impact on both total and peak sediment loss. Since the simulation period for the sensitivity analysis was during the summer growing season, tillage operations produced a large volume of detached soil fines. Thus, sediment transport by flow was not restricted by the amount of soil fines available for transport. The singular importance of the washoff, or transport, parameters is because the washoff process was the controlling mechanism during the simulation period. In areas where tillage operations are not performed, or during seasons when the land surface is not disturbed, the soil splash parameters (JRER, KRER) would have a greater impact than is indicated in Figures 47 and 48. In such circumstances, the soil splash mechanism could control sediment loss by limiting the amount of detached

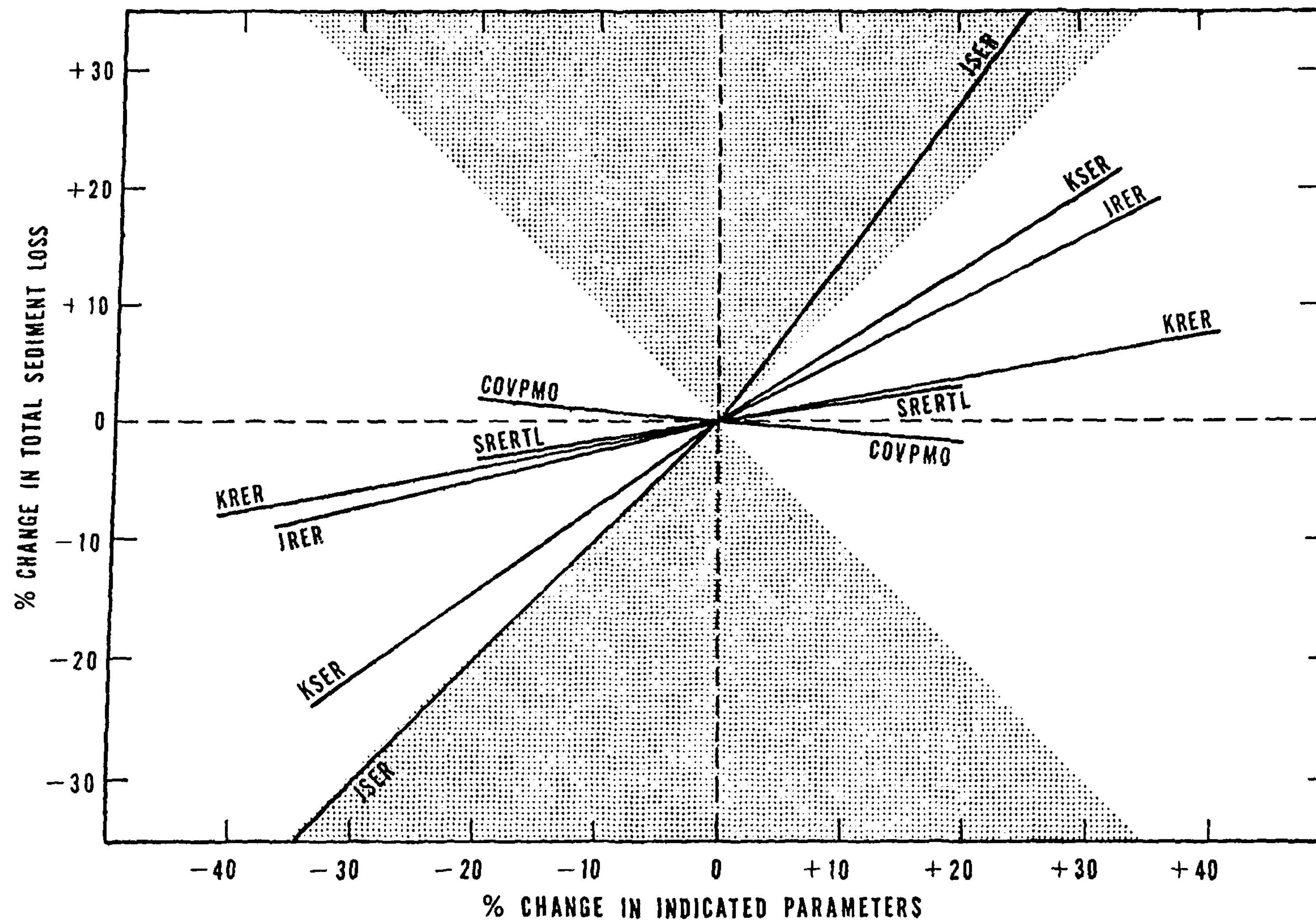


Figure 47. Sediment parameter sensitivity - total sediment loss

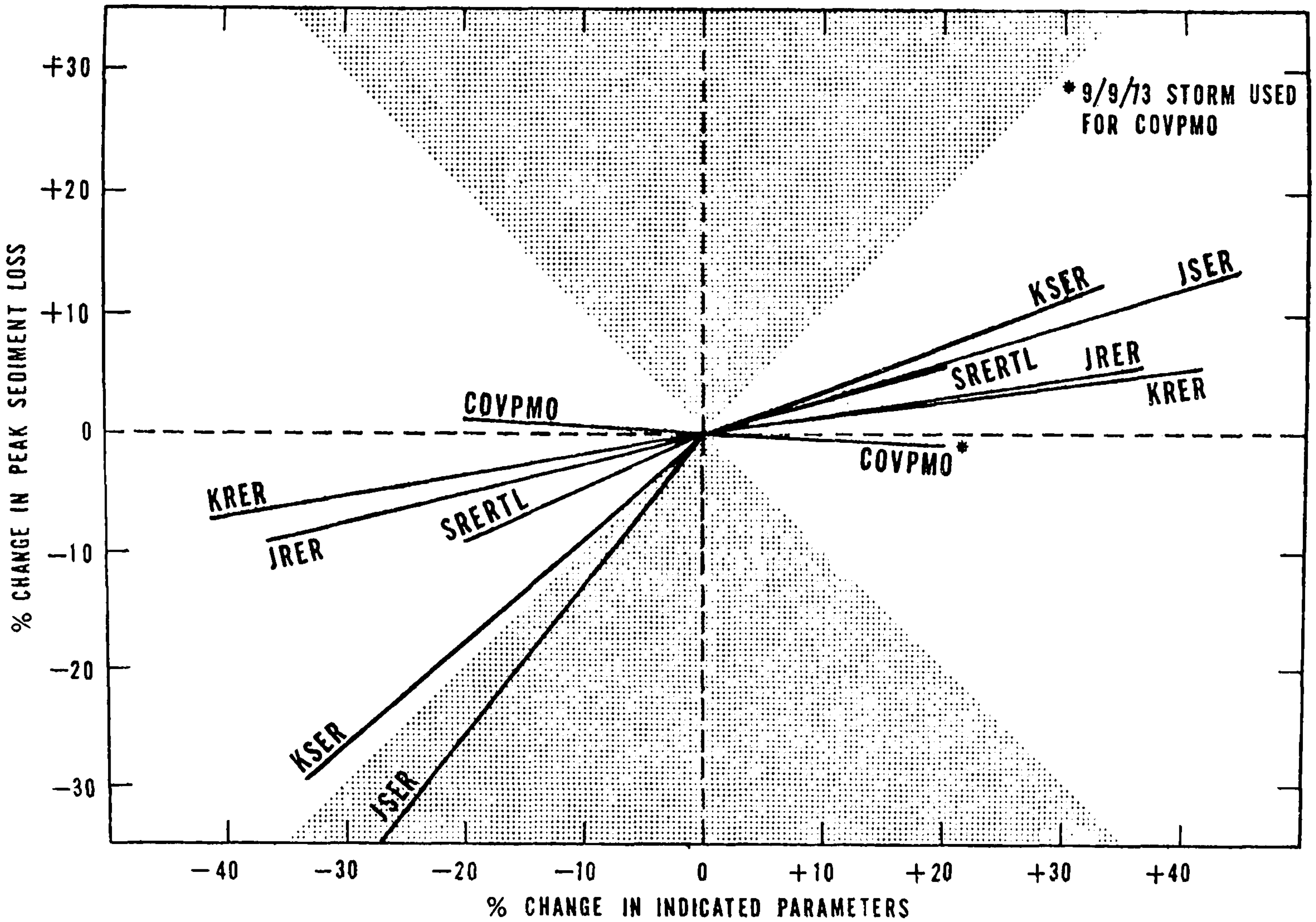


Figure 48. Sediment parameter sensitivity - peak sediment loss (P1 watershed, storm of June 21, 1973)

soil fines available for washoff by overland flow, i.e., detached soil fines would be less than the transport capacity of overland flow. Since the soil splash parameters determine the detachment of soil fines, their effect on sediment loss would be greater than the effect of the washoff parameters when the land surface is undisturbed.

The two remaining sediment parameters are the monthly vegetal cover fraction (COVPMO) and the detached fines produced by tillage operations (SRERTL). The sensitivity of each of these parameters indicated in Figures 47 and 48 is influenced by the fact that the analysis was performed on a summer period. The major events during this period occurred in June and July when vegetal cover was minimal; hence, the effect of COVPMO on the total sediment loss is rather small. Since no crop canopy had developed for the June 21 storm, the COVPMO sensitivity in Figure 48 was derived from the September 9 storm on P1. The impact of cover would be much greater during the late fall when a full canopy would exist. On the other hand, the impact of SRERTL as shown in Figures 47 and 48 is relatively greater during the summer period due to the possible occurrence of storms following tillage operations. This is indicated by the greater impact of SRERTL on peak sediment loss (Figure 48) than on total sediment (Figure 47) because the June 21 storm occurred within one week of planting and tillage operations. In reality little is known about the absolute value of detached fines resulting from different tillage operations. Logically, one would expect that the effects of tillage would not extend more than one to two months, i.e. the amount of detached fines from tillage operations would not limit transport of sediment by overland flow until one to two months following the operation. However, further investigation of this topic is needed.

Although the sensitivity of the sediment parameters is affected by the period on which the analysis was performed, the summer period is the critical time for simulation of pesticide loss. Consequently, the analysis also indicates the relative importance of sediment parameters for simulating pesticides transported by sediment particles.

PESTICIDE PARAMETERS

The results of sensitivity trials for the pesticide parameters are shown in Figures 49, 50 and 51. The effects of parameter changes on total pesticide loss (June to September 1973) is presented in Figure 49 while the corresponding effects on peak pesticide removal in water and on sediment (June 21 storm on P1) is shown in Figures 50 and 51, respectively. The relative positions of the parameter sensitivity lines remain reasonably fixed in all three figures. From analysis of these results, the following points are noteworthy:

(1) Pesticide solubility has negligible impact on pesticide loss within the range of values tested for the present version of the

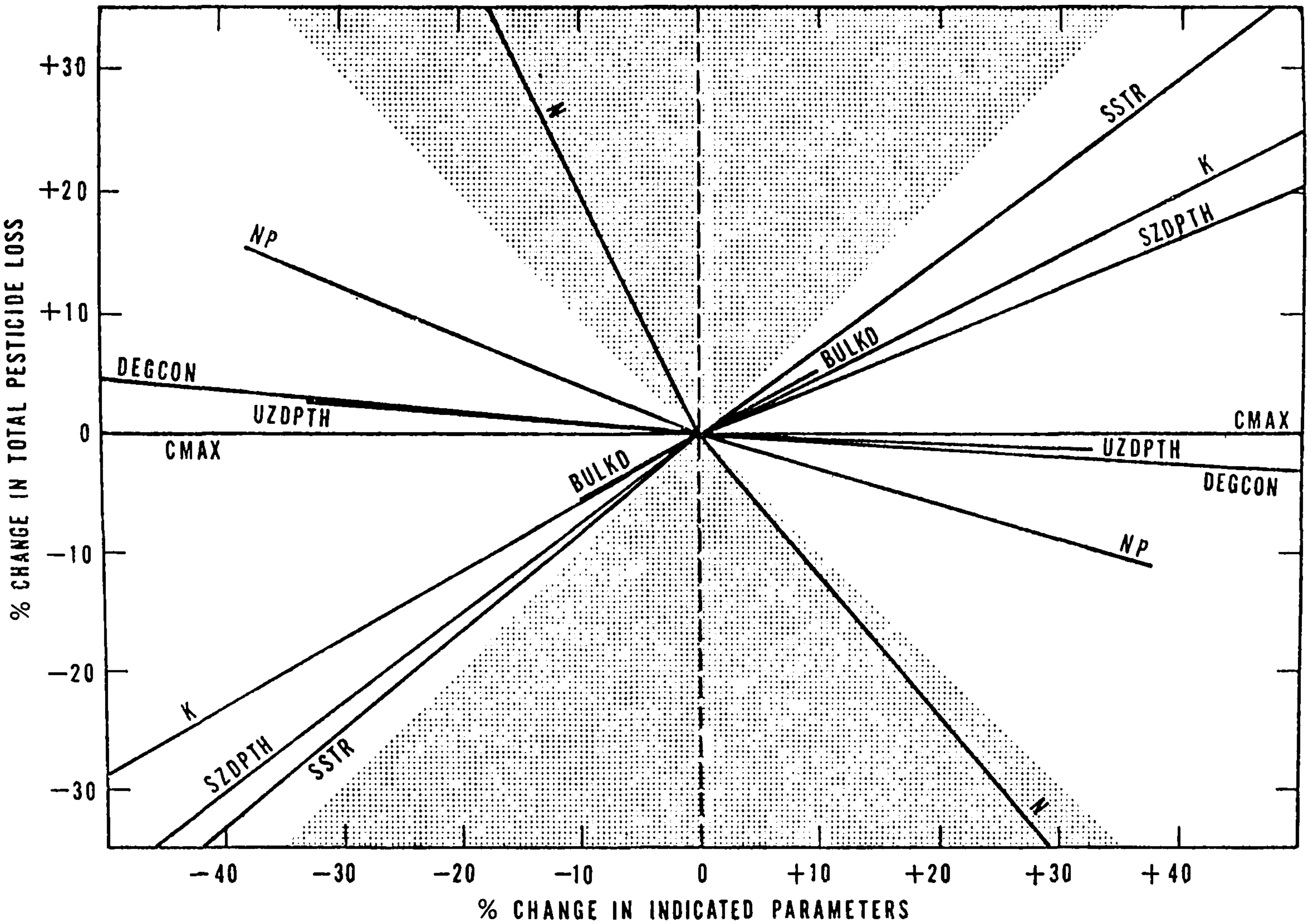


Figure 49. Pesticide parameter sensitivity - total pesticide loss

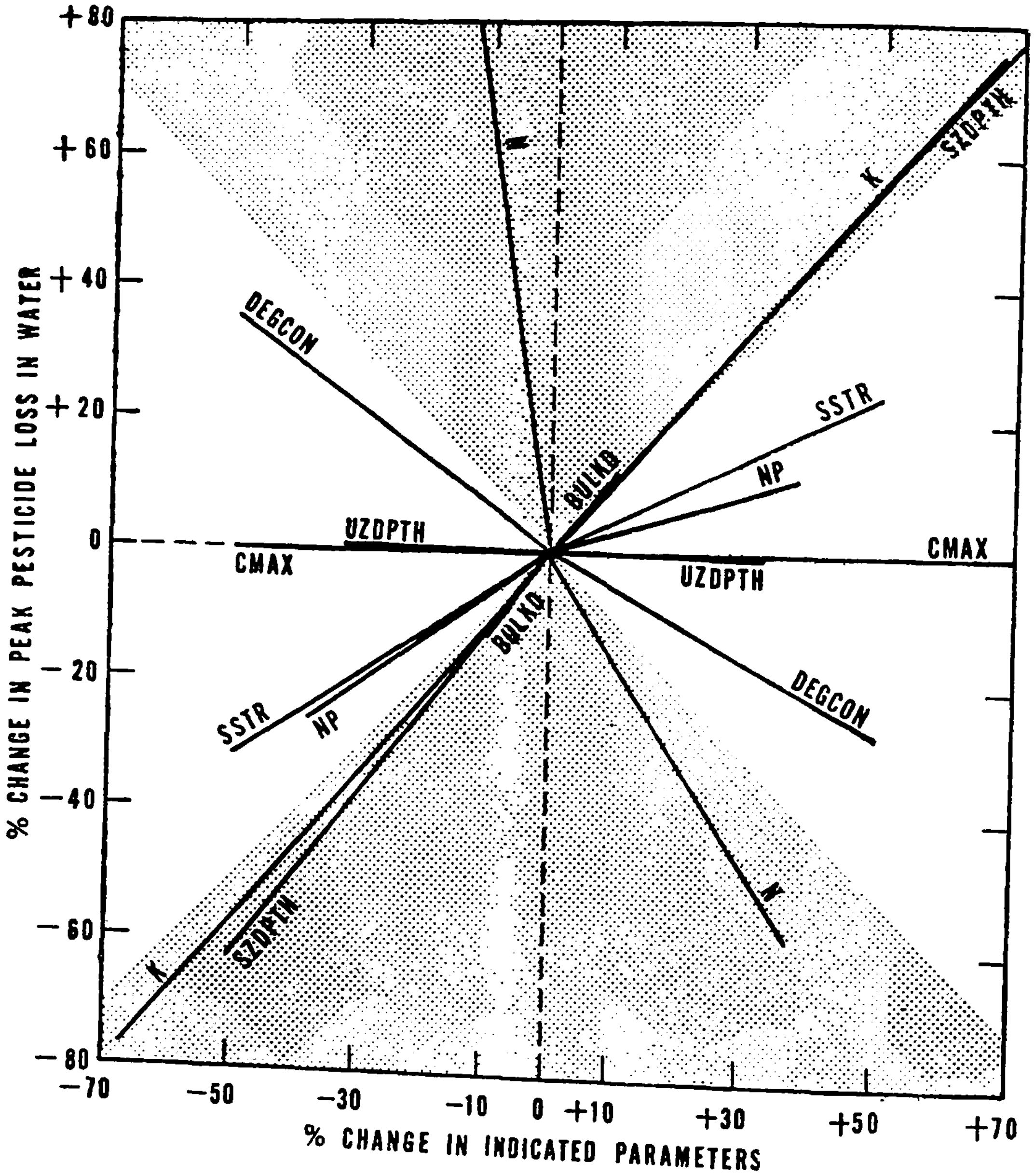


Figure 50. Pesticide parameter sensitivity peak pesticide loss in water (P1 watershed, storm of June 21, 1973)

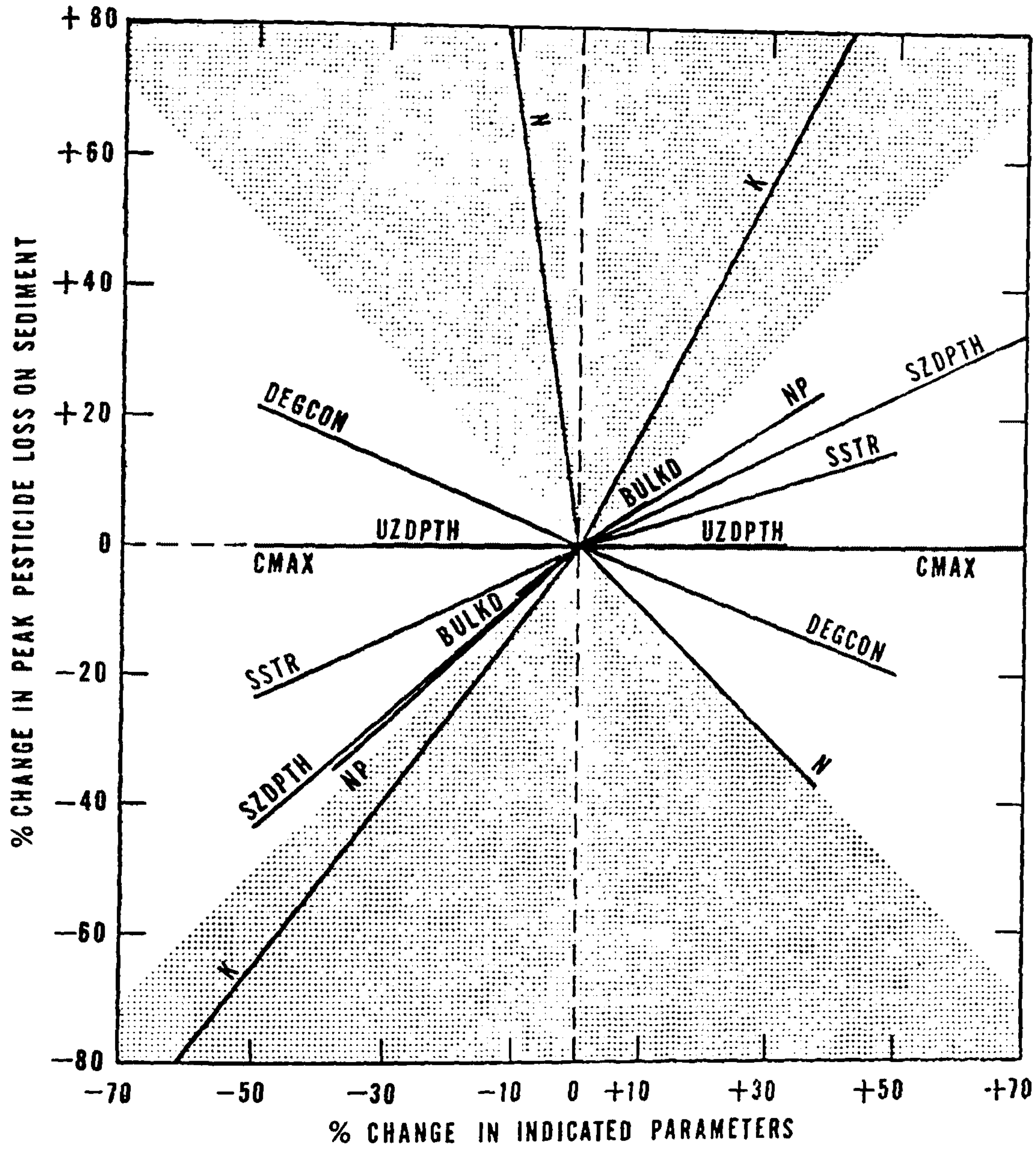


Figure 51. Pesticide parameter sensitivity peak pesticide loss on sediment (P1 watershed, storm of June 21, 1973)

pesticide algorithms. In effect, the equilibrium pesticide concentration in runoff never approaches the pesticide solubility.

(2) As a corollary to (1), the adsorption/desorption characteristics for the specific pesticide-soil combination are the major determinants of pesticide loss. Other than pesticide application (SSTR) which obviously has a critical effect on pesticide loss, the adsorption/desorption characteristics (K, N, NP) have the greatest impact (i.e. steepest slopes in Figures 49, 50, and 51) on both total and peak pesticide loss.

(3) The soil bulk density (BULKD) is an important parameter since it determines the mass of soil involved in the pesticide-soil-water equilibrium in each vertical soil zone. An increase in BULKD results in a greater mass of soil in each zone. For pesticides which move by both runoff and sediment loss, the larger surface soil mass would retain more pesticide in the surface zone. Thus, more pesticide would be available for transport from the active surface zone. The increase in pesticide loss with BULKD in Figures 49, 50 and 51 demonstrates this effect. On the other hand, pesticides like paraquat that are completely adsorbed onto sediment particles would behave differently. Since complete mixing is assumed in the surface zone, the greater surface soil mass resulting from a larger BULKD would produce lower pesticide concentrations in the surface zone for the same application rate. The lower concentrations would result in less total and peak pesticide loss. Consequently, the relative impact of changes in soil bulk density is dependent upon the adsorption/desorption characteristics of the specific pesticide-soil combination.

(4) The depth of the active surface zone (SZDPTH) has essentially identical effects on pesticide loss as described above for bulk density. Increasing SZDPTH results in a greater soil mass in the active surface zone. The effects on pesticide loss described above are due to the greater soil mass. Comparison of the SZDPTH and BULKD sensitivity lines in Figures 49, 50 and 51 demonstrates the parallel effects. The differences between these lines are due to the effect of BULKD on all the soil zones while SZDPTH pertains only to the surface zone. Thus, the impact of SZDPTH is also a function of the pesticide-soil combination.

(5) The depth of the upper soil zone (UZDPTH) has a relatively minor effect on pesticide loss within the range of parameter values analyzed. The only mechanism for pesticide loss from the upper zone is the interflow component of runoff. Since interflow is a small portion of total runoff during the summer months on the P1

watershed, Figures 49, 50 and 51 indicate the minimal effect of UZDPTH. However, for highly soluble pesticides in areas with significant interflow, the UZDPTH parameter would have greater impact.

(6) The pesticide degradation rate (DEGCON) has a greater influence on total pesticide loss than is indicated in Figure 49. Degradation determines the time during which significant pesticide loss can occur. During the pesticide sensitivity trials, the only significant events for the loss of degradable pesticides occurred on June 13 and June 21. Since pesticides were applied on June 13, the daily first-order degradation rate had no effect on pesticide loss for that storm. Figures 50 and 51 demonstrate the influence of degradation for the storm of June 21 on peak pesticide loss in water and on sediment respectively. Thus, the DEGCON sensitivity lines in Figures 50 and 51 are more indicative of the importance of degradation rates on pesticide loss than the corresponding lines in Figure 49.

CONCLUSIONS

The utility of the sensitivity analyses performed on the ARM Model parameters (excluding snow and nutrient parameters) is the information and understanding gleaned from an analysis of Model behavior resulting from parameter variations. Comparing the ARM Model results with the physical processes simulated can provide a sound base for further algorithm refinements. Highly sensitive parameters indicate topics for additional investigation. Moreover, an understanding of the ARM Model is critical to successful calibration and application to other areas. Although the results presented here should not be extrapolated beyond the individual parameter values in Tables 15, 16, and 17, the relative importance and impact of the various parameters is generally valid for agricultural watersheds in the southern Piedmont. Experience indicates that the relative ranking of the hydrology parameters is more widely applicable across the United States. However, testing in other climatic, topographic, and edaphic regions, and with a larger range of parameter values is needed before a similar claim can be made for the sediment and pesticide parameters. In general, the results indicate that the most sensitive parameters are related to soil moisture and infiltration, land surface, sediment transport, pesticide-soil interactions, and pesticide degradation. Study of these topics would provide the greatest benefit to further algorithm refinement.

SECTION X

CONCLUSIONS AND RECOMMENDATIONS

Unfortunately, as man acquires a greater understanding of his physical environment, the number and complexity of the questions which probe his mind tend to increase rather than decrease. In other words, research often tends to raise more questions than it answers. In many respects this is true for the research effort on the continued development and refinement of the ARM Model described in this report. Some questions have been answered while new problems have been uncovered. Perhaps the greatest benefit derived from this work is the insight and increased understanding of the processes controlling the quantity and quality of agricultural runoff. As these processes are further studied, better simulation methods will develop. This understanding is a significant addition to the existing body of knowledge on this topic. This report is an attempt to distribute this additional knowledge to the scientific community for general review and comment. Thus, the major findings of this research effort are as follows:

(1) The Agricultural Runoff Management (ARM) Model has been used successfully for simulating runoff, sediment, and pesticide loss from small agricultural watersheds. Model testing for sediment and pesticide loss has been performed on watersheds in the Southern Piedmont and is presently underway on watersheds in the Great Lakes region.

(2) The simulation of surface runoff with the ARM Model has been verified by split-sample testing for the Southern Piedmont watersheds. The hydrology parameters calibrated on six months of 1972 data allowed the Model to simulate 1973 data with reasonable accuracy. Past experience with the hydrologic simulation methodology indicates that similar accuracy can be expected in other geographical regions.

(3) The method of snowmelt simulation presented in this report has been employed successfully on watersheds across the United States. Although its use on small agricultural watersheds has been limited, the methodology of energy balance calculations is conceptually valid. Calibration and testing is presently underway on watersheds in the Great Lakes region.

(4) Tillage operations and practices have a significant impact on both surface runoff and sediment loss from watersheds in the Southern Piedmont. The effect is relatively greater on sediment loss than on surface runoff and tends to decrease with time since the last tillage operation. Both total sediment loss and

peak sediment concentrations are increased by frequent tillage operations while peak runoff is generally reduced and delayed in time.

(5) The ARM Model simulation of sediment production is relatively accurate except for storms immediately following tillage operations. In general, monthly sediment loss and storm concentrations are close to observed values when the hydrologic simulation is accurate. The sediment simulation methodology allows for the inclusion of tillage operations, but further testing and calibration are needed to more reliably quantify tillage effects.

(6) Simulation of pesticide loss from the Southern Piedmont watersheds with the ARM Model indicates the following:

a. Simulation results are good for pesticides like paraquat that are completely adsorbed onto sediment particles. In these cases, the accuracy of the pesticide simulation is directly dependent upon the accuracy of the sediment simulation.

b. Simulation of pesticides that move both in water and on sediment is dependent upon the partitioning between the two phases (water and sediment) as specified by the adsorption/desorption function. Simulation results for this type of pesticide (e.g. diphenamid) using laboratory isotherm data is fair to poor. Initial comparison of simulation results from single-valued (SV) and non-single-valued (NSV) adsorption/desorption functions is inconclusive. The SV function appears to simulate some storms better than the NSV function, but the reverse is true for other storms. Further comparisons and evaluations are warranted.

c. Pesticide attenuation processes are critical to the simulation of pesticide loss since they determine the amount of pesticide available for transport from the land surface. Storms, even minor ones, occurring immediately or soon after pesticide application are the major events for pesticide loss. The applied pesticide has not attenuated to a significant extent; thus, it is highly susceptible to transport. The first order degradation rate presently used in the ARM Model appears to underestimate attenuation at the beginning of the growing season and overestimate it at the middle and end of the growing season. Accurate simulation of pesticide attenuation would provide a more valid base for the evaluation of adsorption/desorption functions and improvement of the overall pesticide simulation.

(7) The ARM Model provides a structure for simulating the transport and soil transformations of plant nutrients. Testing and comparison of simulated and observed results will provide a basis for modification and refinement of the nutrient algorithms presented in this report. Data from the Southern Piedmont and Great Lakes watersheds is expected to be available for nutrient model testing in the near future.

(8) A sensitivity analysis of the ARM Model parameters for hydrology, sediment production, and pesticide loss indicates that the most sensitive parameters are related to soil moisture and infiltration, land surface sediment transport, pesticide-soil interactions, and pesticide degradation. These mechanisms are the critical ones for the accurate simulation of pesticide loss from agricultural watersheds.

The questions that have been raised or left unanswered by this research effort are presented below in terms of needs, or opportunities, for further study of the simulation of agricultural runoff. It is hoped that others in the research community will recognize the importance of these topics and provide impetus for further research efforts.

(1) Application and testing of the ARM Model on watersheds in different regions of the country is of primary concern at this time. The hydrologic methodology of the ARM Model has demonstrated its general applicability from the results of testing on hundreds of watersheds; similar testing is needed for the sediment production methodology. In this way, the simulation of the transport mechanisms (runoff and sediment loss) for agricultural pollutants can be tested, refined, and verified for general application. Moreover, the relationship of the ARM Model parameters to climatic and edaphic characteristics could be investigated.

(2) Testing of the nutrient model is crucial to the reliable simulation of plant nutrients. Although a nutrient model has been developed, only testing and comparison with observed data can indicate the validity of the model assumptions and the need for model refinements.

(3) The impacts of different agricultural management techniques on the transport mechanisms of runoff and sediment loss need to be further investigated. Since the ARM Model will be applied to managed agricultural lands, the relationships between land management techniques and the ARM Model parameters must be established. This is a necessity if the Model is to be used for evaluating the efficacy of land and agricultural management plans. Also, for widespread use, the Model must accommodate practices employed in different agricultural regions of the country.

(4) Pesticide-soil interactions and pesticide attenuation processes must be further investigated in order to improve the accuracy and reliability of the pesticide simulation. Both the single-valued and non-single-valued adsorption/desorption functions warrant further investigation, in addition to a kinetic, or non-equilibruim, approach to the pesticide-soil interaction processes. First-order pesticide degradation should be replaced with a more sophisticated degradation model. Various candidate approaches are presently under investigation. Environmental conditions (e.g. soil temperature, soil moisture, and oxygen content) need to be included where they are significant.

(5) To promote the general use of the ARM Model for investigation, evaluation, and management of agricultural runoff, the following recommendations are extended:

   a. The ARM Model structure should be modified to allow a more user-oriented method of application. The acceptance and use of the ARM Model by the user community is contingent upon the ease of Model application, calibration, parameter evaluation, data management, and output interpretation. To date, Model development has concentrated on the testing and evaluation of algorithms to simulate the physical processes. Efforts should now be directed to the goal of making the Model more amenable for use by potential users.

   b. The use of the ARM Model as a tool for the planning and evaluation of agricultural management techniques for the control of sediment, pesticides, and nutrients should be demonstrated. It is insufficient to develop and document a model like the ARM Model without a clear demonstration of its potential application in the planning and management process. In addition, recommendations, guidelines, and a proposed methodology should be developed to insure the effective use and to avoid misuse of the ARM Model.

SECTION XI

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SECTION XII

APPENDICES

APPENDIX A

ARM MODEL USER MANUAL

MODEL OPERATION AND PARAMETERS

The general structure and operation of the ARM Model was discussed in Section IV, and is depicted graphically in Figure 52. The Model consists of a series of subprograms whose execution is controlled by the executive program, MAIN. Table 18 lists all subprograms of the ARM Model, defines their functions, and includes the beginning line number of each subprogram in the Model source listing (Appendix C). The Model operates on a number of different time intervals. The major interval of model operation is specified by the user and corresponds to the time interval of available precipitation data; 5 or 15 minute intervals are allowed by the present version of the ARM Model. For days on which storms occur, the LANDS, SEDT, and ADSRB subprograms perform calculations on the 5 or 15 minute interval. For days on which storms do not occur, the LANDS subprogram continues to operate on the 5 or 15 minute interval while the remaining programs operate on a daily basis. In the present version of the Model, the DEGRAD subprogram always operates on a daily basis, and snowmelt calculations are performed hourly. The time interval for nutrient transformations is determined by a user-specified input parameter. The MAIN program monitors the passage of real time and keys the operation of the separate subprograms at the proper time intervals.

Table 19 includes a complete list and descriptions of the ARM Model parameters. The 'control' parameters (i.e. HYCAL, INPUT, OUTPUT, PRINT, SNOW, PEST, NUTR, ICHECK) and 'nutrient control' parameters (TSTEP, NAPPL, TIMHAR) specify the mode of operation, the units and type of input and output, and the simulation calculations to be performed in each Model run. The HYCAL and PRINT parameters determine the mode of Model operation and the frequency of printed output, respectively. The two modes of operation allowed by the present version of the ARM Model are referred to as calibration (HYCAL = CALB) and production (HYCAL = PROD) runs. The monthly and yearly summaries obtained from calibration and production runs are basically similar. The production summaries provide more detailed information for pesticide and nutrient concentrations in the soil profile. Tables 20 and 21 are sample monthly summaries for the calibration and production modes of operation, respectively. Note that the word 'BLOCK' is used to indicate the areal-source zones discussed in Section IV, in order to prevent confusion with the vertical soil zones (i.e. surface, upper, lower, groundwater). The basic difference between the calibration and production modes is the type and form of information obtained for simulation periods between the monthly summaries. A calibration run provides detailed information on runoff, sediment concentration and mass

ARM Model structure and operation

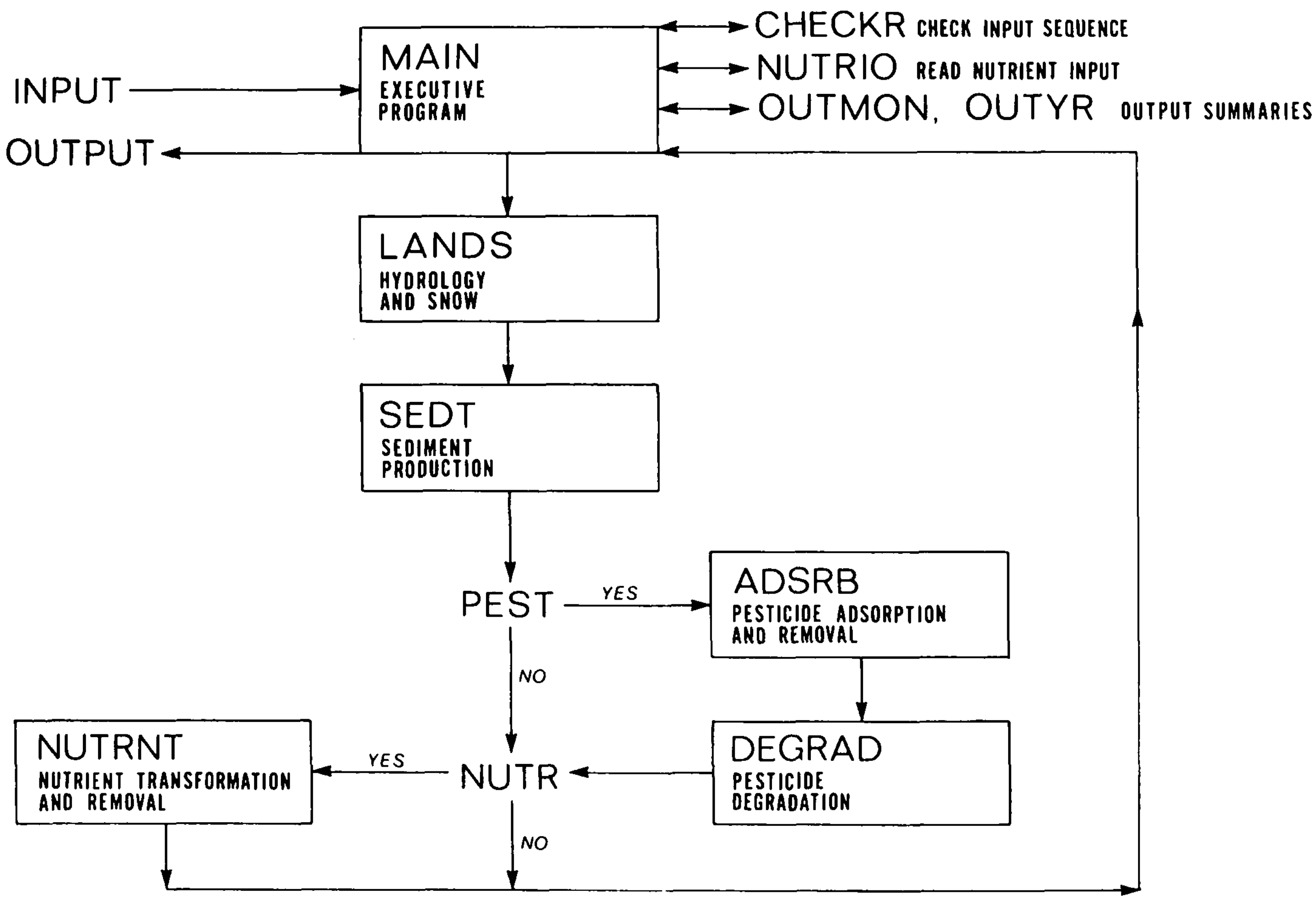

Figure 52

Table 18. ARM MODEL COMPONENTS

Major Program	Component Subroutine	Function	Beginning Line No.
MAIN		Master program and executive control routine	10.
	CHECKR	Checks input parameter errors	1200.
	BLOCK DATA	Data initialization for common variables	1600.
	NUTRIO	Reads and checks nutrient input data	6200.
	OUTMON	Prints monthly output summaries	8000.
	OUTYR	Prints yearly output summaries	9000.
LANDS		Performs hydrologic simulation and snowmelt calculations	2000.
SEDT		Performs sheet erosion simulation	4000.
ADSRB		Performs pesticide soil adsorption/ desorption simulation	5000.
	DSPTN	Performs desorption calculations	5800
DEGRAD		Performs pesticide degradation simulation	6000.
NUTRNT		Performs nutrient simulation	7000.
	TRANS	Performs nutrient transformations	7800.

Table 19. ARM MODEL INPUT PARAMETER DESCRIPTION

TYPE	NAME	DESCRIPTION
Control	HYCAL	Specifies type of information desired PROD-production run, prints full tables for each interval as specified by PRINT CALB-calibration run, prints removal values for each interval as specified by PRINT
	INPUT	Input units, ENGL-english, METR-metric
	OUTPUT	Output units, ENGL-english, METR-metric, BOTH-both
	PRINT	Denotes the interval of printed output, INTR-each interval, HOUR-each hour, DAYS-each day, MNTH-each month
	SNOW	NO-snowmelt not performed, YES,snowmelt calculations performed
	PEST	No-pesticides not performed, YES-pesticide calculations performed
	NUTR	NO-nutrients not performed, YES-nutrients calculations performed
	ICHECK	ON-checks most of the hydrology, snow (if used), sediment, and pesticide (if used) input parameter values and prints out error and warning statements for input parameter values that are outside of acceptable value limits, OFF-no check is made
	INTRVL	Time interval of operation (5 or 15 minutes)
	HYMIN	Minimum flow for printed output during a time interval
	AREA	Watershed area
	BGNDAY BGNMON BGNYR	Date simulation begins-day, month, year
	ENDDAY ENDMON ENDYR	Date simulation ends-day, month, year
Hydrology	UZSN	Nominal upper zone storage
	UZS	Initial upper zone storage
	LZSN	Nominal lower zone storage
	LZS	Initial lower zone storage
	L	Length of overland flow to channel
	SS	Average overland flow slope
	NN	Manning's for overland flow
	A	Fraction of area that is impervious
	K3	Fraction index to actual evaporation
	EPXM	Maximum interception storage
	INFIL	Mean infiltration rate
	INTER	Interflow parameter, alters runoff timing
	IRC	Interflow recession rate

Table 19. (Continued)

	K24L	Fraction of groundwater recharge percolating to deep groundwater
	KK24	Groundwater recession rate
	K24EL	Fraction of watershed area where groundwater is within reach of vegetation
	SGW	Initial groundwater storage
	GWS	Initial groundwater slope
	KV	Parameter to allow variable recession rate for groundwater discharge
	ICS	Initial interception storage
	OFS	Initial overland flow storage
	IFS	Initial interflow storage
Snow	RADCON	Correction factor for radiation melt
	CCFAC	Correction factor for condensation and convection melt
	SCF	Snow correction factor for raingage catch deficiency
	ELDIF	Elevation difference from temperature station to mean watershed elevation
	IDNS	Initial density of new snow
	F	Fraction of watershed with complete forest cover
	DGM	Daily groundmelt
	WC	Water content of snowpack by weight
	MPACK	Water equivalent of snowpack for complete watershed coverage
	EVAPSN	Correction factor for snow evaporation
	MELEV	Mean elevation of watershed
	TSNOW	Temperature below which precipitation becomes snow
	PACK	Initial water equivalent of snowpack
	DEPTH	Initial depth of snowpack
	PETMIN	Minimum temperature at which PET occurs
	PETMAX	Temperature at which PET is reduced by 50 percent
	PETMUL	Potential evapotranspiration data correction factor
	WMUL	Wind data correction factor
	RMUL	Radiation data correction factor
	KUGI	Index to forest density and undergrowth
Sediment	COVPMO	Fraction of crop cover on a monthly basis (12 values)
	TIMTIL	Time when soil is tilled (Julian day, i.e. day of the year, e.g. January 1 = 1, December 31 = 365/366) (5 dates)
	YRTIL	Corresponding year (last two digits only) for TIMTIL (5 values)
	SRERTL	Fine deposits produced by tillage corresponding to TIMTIL and YRTIL (5 values)
	SZDPTH	Depth of the surface zone
	UZDPTH	Upperzone depth or depth of soil incorporation
	BULKD	Bulk density of soil
	JRER	Exponent of rainfall intensity in soil splash equation
	KRER	Coefficient in soil splash equation

Table 19. (Continued)

	JSER	Exponent of overland flow in sediment washoff equation
	KSER	Coefficient in sediment washoff equation
	SRERI	Initial fines deposit
Pesticide	PESTICIDE	Title word to begin the reading of pesticide input parameters
	APMODE	Application mode, SURF-surface applied, SOIL-soil incorporated
	DESORP	NO-single-valued adsorption/desorption used, YES-non-single-valued adsorption/desorption algorithm used
	SSRT	Pesticide application for each block (5 values)
	TIMAP	Time of pesticide application (Julian day)
	YEARAP	Year of pesticide application (last two digits only)
	CMAX	Maximum solubility of pesticide in water
	DD	permanent fixed capacity
	K	Coefficient in Freundlich adsorption equation
	N	Exponent in Freundlich adsorption equation
	NP	Exponent in Freundlich desorption equation
	DEGCON	First order pesticide decay rate
Nutrient Control	TSTEP	Timestep of chemical and biological transformations, must be an integer number of time steps in a day, and an integer number of simulation intervals (INTRVL) in a TSTEP, range of TSTEP is 5 or 15 minutes to 1440 minutes
	NAPPL	Number of fertilizer applications, values may range from 0 to 5
	TIMHAR	Time of plant harvesting, Julian day of the year, value may range from 0 to 366
Nitrogen Reaction Rates		
	K1	Oxidation rate of ammonia (dissolved and absorbed) to nitrite
	K2	Oxidation rate of nitrite to nitrate
	KK2	Reduction rate of nitrate to nitrite
	KD	Reduction rate of nitrite to nitrogen gas
	KPL	Uptake rate of nitrate by plants
	KAM	Ammonification or mineralization rate of ORG-N to ammonia
	KIM	Immobilization rate of dissolved ammonia to ORG-N
	KKIM	Immobilization rate of nitrate to ORG-N
	KSA	Transfer rate of ammonia from solution to adsorbed (adsorption)
	KAS	Transfer rate of ammonia from adsorbed to solution (desorption)

Table 19. (Continued)

Phosphorus Reaction Rates

KM	Mineralization rate of ORG-P to PO4-P
KIM	Immobilization rate of PO4-P to ORG-P
KPL	Uptake rate of phosphate (adsorbed and in solution) by plants
KSA	Transfer rate of phosphate from solution to adsorbed form
KAS	Transfer rate of phosphate from adsorbed to solution form

Nitrogen Storages

ORG-N	Organic nitrogen assumed to be solid or attached to soil
NH3-S	Ammonia in solution
NH3-A	Ammonia adsorbed to soil
NO2	Nitrite
NO3	Nitrate
N2	Nitrogen gas from denitrification
PLNT-N	Plant nitrogen

Phosphorus Storages

ORG-P	Organic phosphorus attached to soil
PO4-S	Phosphate in solution
PO4-A	Phosphate adsorbed to soil
PLNT-P	Plant phosphorus

Chloride Storage

CL	Chloride

Table 20. CALIBRATION RUN OUTPUT - MONTHLY SUMMARY (Pesticide Simulation)

SUMMARY FOR MONTH OF JUNE 1973

	BLOCK 1	BLOCK 2	BLOCK 3	BLOCK 4	BLOCK 5	TOTAL
WATER, INCHES						
RUNOFF						
OVERLAND FLOW	0.362	0.250	0.141	0.047	0.087	0.163
INTERFLOW	0.034	0.061	0.083	0.084	0.064	0.065
IMPERVIOUS						0.0
TOTAL	0.396	0.311	0.220	0.132	0.071	0.228
BASE FLOW						0.0
GROWATER RECHARGE						0.191
PRECIPITATION	0.75	0.75	0.75	0.75	0.75	0.75
EVAPOTRANSPIRATION						
POTENTIAL	0.27	0.27	0.27	0.27	0.27	0.27
NET	0.27	0.27	0.21	0.27	0.27	0.27
CROP COVER						1.00
STORAGES						
UPPER ZONE	0.108	0.108	0.109	0.102	0.054	0.096
LOWER ZONE	20.333	20.333	20.333	20.333	20.333	20.333
GROUNDWATER	0.0	0.0	0.0	0.0	0.0	0.0
INTERCEPTION	0.118	0.118	0.118	0.118	0.118	0.118
OVERLAND FLOW	0.0	0.0	0.0	0.0	0.0	0.0
INTERFLOW	0.0	0.0	0.0	0.0	0.0	0.0
WATER BALANCE= 0.0						
SEDIMENT, TONS/ACRE						
ERODED SEDIMENT	0.901	0.566	0.275	0.065	0.089	0.363
FINES DEPOSIT	1.099	1.434	1.725	1.535	1.991	1.637
PESTICIDE, POUNDS						
SURFACE LAYER	1.278	1.257	1.313	1.325	1.328	6.541
ADSORBED	1.278	1.297	1.313	1.325	1.328	6.554
CRYSTALLINE	0.0	0.0	0.0	0.0	0.0	0.0
DISSOLVED	0.0	0.0	0.0	0.0	0.0	0.0
UPPER ZONE LAYER	0.0	0.0	0.0	0.0	0.0	0.0
ADSORBED	0.0	0.0	0.0	0.0	0.0	0.0
CRYSTALLINE	0.0	0.0	0.0	0.0	0.0	0.0
DISSOLVED	0.0	0.0	0.0	0.0	0.0	0.0
INTERFLOW STORAGE	0.0	0.0	0.0	0.0	0.0	0.0
LOWER ZONE LAYER						0.0
ADSORBED						0.0
CRYSTALLINE						0.0
DISSOLVED						0.0
GROUNDWATER LAYER						0.0
ADSORBED						0.0
CRYSTALLINE						0.0
DISSOLVED						0.0
PESTICIDE REMOVAL, LBS.	0.051	0.032	0.016	0.004	0.080	0.102
OVERLAND FLOW REMOVAL	0.0	0.0	0.0	0.0	0.0	0.0
SEDIMENT REMOVAL	0.051	0.032	0.016	0.004	0.000	0.102
INTERFLOW REMOVAL	0.0	0.0	0.0	0.0	0.0	0.0
PESTICIDE DEGRADATION LOSS, LBS.						
TOTAL						0.026
FROM SURFACE						0.026
FROM UPPER ZONE						0.0
FROM LOWER ZONE						0.0
PESTICIDE BALANCE= 0.0						

Table 21. PRODUCTION RUN OUTPUT MONTHLY SUMMARY (Pesticide and Nutrient Simulation)

SUMMARY FOR MONTH OF JUNE 1973

	BLOCK 1	BLOCK 2	BLOCK 3	BLOCK 4	BLOCK 5	TOTAL
WATER, INCHES						
RUNOFF						
OVERLAND FLOW	1.191	0.887	0.567	0.403	0.305	0.671
INTERFLOW	0.413	0.464	0.388	0.350	0.310	0.385
IMPERVIOUS						0.0
TOTAL	1.604	1.351	0.955	0.753	0.615	1.056
BASE FLOW						0.0
GRDWATER RECHARGE						1.668
PRECIPITATION	4.740	4.740	4.740	4.740	4.740	4.740
EVAPOTRANSPIRATION						
POTENTIAL	3.493	3.493	3.493	3.493	3.493	3.493
NET	2.623	2.623	2.623	2.623	2.623	2.623
CROP COVER						0.193
STORAGES						
UPPER ZONE	0.002	0.002	0.002	0.002	0.002	0.003
LOWER ZONE	18.750	18.750	18.750	18.750	18.750	18.750
GROUNDWATER	0.0	0.0	0.0	0.0	0.0	0.0
INTERCEPTION	0.0	0.0	0.0	0.0	0.0	0.0
OVERLAND FLOW	0.0	0.0	0.0	0.0	0.0	0.0
INTERFLOW	0.0	0.0	0.0	0.0	0.0	0.0
WATER BALANCE= 0.0004						
SEDIMENT, TONS/ACRE						
TOTAL SEDIMENT LOSS	0.899	0.934	0.540	0.376	0.285	0.607
FINES DEPOSIT	1.094	1.105	1.108	1.109	1.110	1.105
PESTICIDE, POUNDS						
SURFACE LAYER	0.596	0.596	0.597	0.597	0.597	2.982
ADSORBED	0.596	0.596	0.597	0.597	0.597	2.988
CRYSTALLINE	0.0	0.0	0.0	0.0	0.0	0.0
DISSOLVED	0.0	0.0	0.0	0.0	0.0	0.0
UPPER ZONE LAYER	0.0	0.0	0.0	0.0	0.0	0.0
ADSORBED	0.0	0.0	0.0	0.0	0.0	0.0
CRYSTALLINE	0.0	0.0	0.0	0.0	0.0	0.0
DISSOLVED	0.0	0.0	0.0	0.0	0.0	0.0
INTERFLOW STORAGE	0.0	0.0	0.0	0.0	0.0	0.0
LOWER ZONE LAYER						0.0
ADSORBED						0.0
CRYSTALLINE						0.0
DISSOLVED						0.0
GROUNDWATER LAYER						0.0
ADSORBED						0.0
CRYSTALLINE						0.0
DISSOLVED						0.0
PESTICIDE REMOVAL, LBS.	0.001	0.000	0.000	0.000	0.000	0.001
OVERLAND FLOW REMOVAL	0.0	0.0	0.0	0.0	0.0	0.0
SEDIMENT REMOVAL	0.001	0.000	0.000	0.000	0.000	0.001
INTERFLOW REMOVAL	0.0	0.0	0.0	0.0	0.0	0.0
PESTICIDE DEGRADATION LOSS, LBS.						
TOTAL						0.097
FROM SURFACE						0.097
FROM UPPER ZONE						0.0
FROM LOWER ZONE						0.0
PESTICIDE_BALANCE= 0.0						

Table 21. (Continued)

NUTRIENTS - LB/AC	ORG-N	NH3-S	NH3-A	NO2	NO3	N2	PLNT-N	ORG-P	PO4-S	PO4-A	PLNT-P	CL
STORAGE												
SURFACE LAYER	23.	0.092	0.181	0.110	0.060	0.0	0.069	5.	0.020	0.600	0.001	-0.000
BLOCK 1	23.	0.090	0.177	0.107	0.058	0.0	0.069	5.	0.019	0.586	0.001	-0.000
BLOCK 2	23.	0.091	0.179	0.109	0.059	0.0	0.069	5.	0.019	0.594	0.001	-0.000
BLOCK 3	23.	0.092	0.181	0.110	0.060	0.0	0.069	5.	0.020	0.602	0.001	-0.000
BLOCK 4	24.	0.093	0.183	0.111	0.061	0.0	0.069	5.	0.020	0.607	0.001	-0.000
BLOCK 5	24.	0.093	0.184	0.111	0.062	0.0	0.069	5.	0.020	0.609	0.001	0.0
UPPER ZONE	1127.	6.701	9.117	8.222	35.633	0.0	3.631	225.	1.103	29.726	0.043	15.188
BLOCK 1	1127.	9.480	9.275	11.779	73.788	0.0	3.988	225.	1.323	29.904	0.042	34.984
BLOCK 2	1127.	6.975	9.137	8.576	40.602	0.0	3.681	225.	1.114	29.746	0.040	13.555
BLOCK 3	1127.	6.033	9.086	7.371	28.439	0.0	3.570	225.	1.033	29.688	0.040	12.728
BLOCK 4	1127.	5.760	9.062	7.018	22.655	0.0	3.506	225.	1.029	29.664	0.040	9.813
BLOCK 5	1127.	5.256	9.025	6.368	12.639	0.0	3.409	225.	1.017	29.627	0.039	4.727
INTERFLOW	0.	0.0	0.0	0.0	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
BLOCK 1	0.	0.0	0.0	0.0	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
BLOCK 2	0.	0.0	0.0	0.0	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
BLOCK 3	0.	0.0	0.0	0.0	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
BLOCK 4	0.	0.0	0.0	0.0	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
BLOCK 5	0.	0.0	0.0	0.0	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0
LOWER ZONE	11078.	55.912	4.731	41.749	685.735	0.0	25.136	2240.	14.666	117.145	0.375	68.790
GROUNDWATER	0.	0.321	0.015	0.301	5.869	0.0	0.050	0.	0.080	0.052	0.030	0.443
REMOVAL												
ADVECTIVE												
SEDIMENT	0.	0.0	0.006	0.0	0.0	0.0	0.0	0.	0.0	0.010	0.0	0.0
BLOCK 1	1.	0.0	0.015	0.0	0.0	0.0	0.0	0.	0.0	0.024	0.0	0.0
BLOCK 2	1.	0.0	0.010	0.0	0.0	0.0	0.0	0.	0.0	0.015	0.0	0.0
BLOCK 3	0.	0.0	0.005	0.0	0.0	0.0	0.0	0.	0.0	0.007	0.0	0.0
BLOCK 4	0.	0.0	0.001	0.0	0.0	0.0	0.0	0.	0.0	0.002	0.0	0.0
BLOCK 5	0.	0.0	0.000	0.0	0.0	0.0	0.0	0.	0.0	0.000	0.0	0.0
OVERLAND FLOW	0.	0.000	0.0	0.000	0.001	0.0	0.0	0.	0.000	0.0	0.0	0.001
BLOCK 1	0.	0.001	0.0	0.001	0.003	0.0	0.0	0.	0.000	0.0	0.0	0.002
BLOCK 2	0.	0.000	0.0	0.000	0.002	0.0	0.0	0.	0.000	0.0	0.0	0.001
BLOCK 3	0.	0.000	0.0	0.000	0.001	0.0	0.0	0.	0.000	0.0	0.0	0.000
BLOCK 4	0.	0.000	0.0	0.000	0.000	0.0	0.0	0.	0.000	0.0	0.0	0.000
BLOCK 5	0.	0.000	0.0	0.000	0.000	0.0	0.0	0.	0.000	0.0	0.0	0.000
INTERFLOW	0.	3.959	0.0	5.484	25.696	0.0	0.0	0.	0.313	0.0	0.0	14.579
BLOCK 1	0.	4.056	0.0	5.617	26.322	0.0	0.0	0.	0.321	0.0	0.0	14.934
BLOCK 2	0.	5.156	0.0	7.141	33.462	0.0	0.0	0.	0.407	0.0	0.0	18.985
BLOCK 3	0.	4.897	0.0	6.783	31.783	0.0	0.0	0.	0.387	0.0	0.0	19.332
BLOCK 4	0.	3.597	0.0	4.983	23.348	0.0	0.0	0.	0.284	0.0	0.0	13.247
BLOCK 5	0.	2.090	0.0	2.895	13.565	0.0	0.0	0.	0.165	0.0	0.0	7.596
TOTAL TO STREAM	0.	3.959	0.006	5.484	25.697	0.0	0.0	0.	0.313	0.010	0.0	14.579
PERCOLATION TO GROUNDWATER	0.	0.557	0.0	0.456	5.543	0.0	0.0	0.	0.132	0.0	0.0	0.443
BIOLOGICAL - TOTAL	0.	0.0	0.0	0.0	0.0	0.0	28.886	0.	0.0	0.0	0.417	0.0
SURFACE	0.	0.0	0.0	0.0	0.0	0.0	0.069	0.	0.0	0.0	0.001	0.0
UPPER ZONE	0.	0.0	0.0	0.0	0.0	0.0	3.631	0.	0.0	0.0	0.043	0.0
LOWER ZONE	0.	0.0	0.0	0.0	0.0	0.0	25.136	0.	0.0	0.0	0.375	0.0
GROUNDWATER	0.	0.0	0.0	0.0	0.0	0.0	0.050	0.	0.0	0.0	0.030	0.0
HARVEST	0.	0.0	0.0	0.0	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0

MASS BALANCE
NITROGEN = -0.141
PHOSPHORUS = -0.007
CHLORIDE = -0.001

removal, and pesticide or nutrient concentrations and mass removal for each simulation interval (5 or 15 minutes). Tables 22, 23, and 24 present the type of output obtained from calibration runs with various simulation options. The goal of the calibration form of operation is to provide the information needed to compare simulated runoff, sediment loss, and pesticide or nutrient loss with recorded values for storm events. Since information is provided in each simulation interval the PRINT parameter must be specified for interval output (i.e. PRINT = INTR) for all calibration runs. Due to output printing limitations, pesticides and nutrients cannot be run simultaneously in the calibration mode.

The production mode of operation provides summaries of runoff, sediment, pesticide, and nutrient loss, in addition to the amount of pesticide and nutrients remaining in the various soil zones. Thus, the production mode provides a complete picture of the mass balance of pesticides and nutrients applied to the watershed. Pesticide and nutrient simulation can be performed simultaneously in the production mode. The production output is printed in tables similar to the monthly summaries. The frequency of printing is controlled by the PRINT parameter which allows printing to be done on each interval (PRINT = INTR), each hour (PRINT = HOUR), or at the end of each day (PRINT = DAYS) or each month (PRINT = MNTH). Table 25 presents a sample production output for daily printout. Generally, production runs will be employed for daily or monthly print intervals. Use of the interval (INTR) or hourly (HOUR) printout in the production mode should be restricted to short simulation periods due to the large amount of printed output provided, e.g. over 500 pages of output is provided each day of simulation for a production run which prints output for each 5 minute interval.

The SNOW, PEST, and NUTR control parameters specify whether or not snowmelt, pesticide, or nutrient calculations, respectively, will be performed in each model run. As indicated above, pesticide and nutrient calculations can be performed simultaneously in a production run but not in a calibration run. An error message will be printed, and execution will be prevented, if this rule is violated.

The remaining control parameters, INPUT, OUTPUT, and ICHECK will be discussed in the following section on Model input and output (I/O).

DATA REQUIREMENTS AND MODEL INPUT/OUTPUT (I/O)

Data requirements for use of the ARM Model include those related to operation, parameter evaluation, and calibration. This section will discuss the data requirements for Model operation and I/O while the following section will discuss parameter evaluation and calibration. Once initial parameter values have been chosen, the driving force of Model operation is the input meteorologic data series. Table 26 describes the input sequence and attributes of the meteorologic data series required for

Table 22. CALIBRATION RUN OUTPUT - STORM EVENTS (Hydrology and Sediment Simulation Only)

DATE		TIME	FLOW(CFS-CMS)		SEDIMENT (LBS-KG-KG/MIN-GM/L)					PESTICIDE (GM-GM/MIN-PPM) WATER	SEDIMENT
JULY	8	4:25	0.008	0.000	0.06	0.03	0.01	0.38			
JULY	8	4:30	0.029	0.001	3.01	1.37	0.27	5.62			
JULY	8	4:35	0.825	0.023	473.03	214.76	42.95	30.63			
JULY	8	4:40	2.999	0.085	2043.84	927.90	185.58	36.42	*		
JULY	8	4:45	2.770	0.078	1346.80	611.45	122.29	25.98			
JULY	8	4:50	1.923	0.054	742.54	337.11	67.42	20.64	*		
JULY	8	4:55	2.717	0.077	1051.41	481.88	96.38	20.88	**		
JULY	8	5: 0	5.440	0.154	2271.60	1031.40	206.28	22.32	***		
JULY	8	5: 5	5.440	0.154	2031.52	922.31	184.46	19.95	**		
JULY	8	5:10	3.500	0.099	976.45	444.22	88.84	14.94	**		
JULY	8	5:15	2.507	0.071	502.37	228.07	45.61	10.71	**		
JULY	8	5:20	1.977	0.056	310.91	141.15	28.23	8.40	**		
JULY	8	5:25	2.658	0.075	440.96	200.20	40.04	8.87	***		
JULY	8	5:30	4.163	0.118	771.99	350.48	70.10	9.91	***		
JULY	8	5:35	4.539	0.128	827.63	375.74	75.15	9.74	***		
JULY	8	5:40	3.297	0.093	438.85	199.24	39.85	7.11	***		
JULY	8	5:45	1.765	0.050	143.43	65.12	13.02	4.34	**		
JULY	8	5:50	1.000	0.028	41.92	19.03	3.81	2.24	**		
JULY	8	5:55	0.638	0.018	15.40	6.99	1.40	1.29	*		
JULY	8	6: 0	0.421	0.012	7.12	3.23	0.65	0.90	*		
JULY	8	6: 5	0.300	0.008	5.09	2.31	0.46	0.91	*		
JULY	8	6:10	0.200	0.006	2.04	0.93	0.19	0.55			
JULY	8	6:15	0.136	0.004	0.50	0.23	0.05	0.20			
JULY	8	6:20	0.095	0.003	0.03	0.02	0.00	0.02			
JULY	8	6:25	0.070	0.002	0.0	0.0	0.0	0.0			
JULY	8	6:30	0.046	0.001	0.0	0.0	0.0	0.0			
JULY	8	6:35	0.031	0.001	0.0	0.0	0.0	0.0			
JULY	8	6:40	0.021	0.001	0.0	0.0	0.0	0.0			
JULY	8	6:45	0.014	0.000	0.0	0.0	0.0	0.0			
JULY	8	6:50	0.009	0.000	0.0	0.0	0.0	0.0			
JULY	8	6:55	0.006	0.000	0.0	0.0	0.0	0.0			
JULY	8	7: 0	0.004	0.000	0.0	0.0	0.0	0.0			
JULY	8	7: 5	0.003	0.000	0.03	0.01	0.00	0.52			
JULY	8	7:10	0.019	0.001	0.02	0.01	0.00	0.07			
JULY	8	7:15	0.019	0.001	0.0	0.0	0.0	0.0			

Note: Asterisks (*) indicate that the detached fines storage is less than the overland flow sediment transport capacity in an areal zone (or block), e.g. three asterisks (***) indicate that this occurs in three such zones.

Table 23. CALIBRATION RUN OUTPUT - STORM EVENTS (Pesticide Simulation)

DATE		TIME	FLOW (CFS-CMS)		SEDIMENT (LBS-KG-KG/MIN-GM/L)				PESTICIDE (GM-GM/MIN-PPM)					
									WATER			SEDIMENT		
JULY	8	4:25	0.010	0.000	0.02	0.01	0.00	0.13	0.0	0.0	0.0	0.000	0.000	40.811
JULY	8	4:30	0.032	0.001	1.02	0.46	0.09	1.71	0.0	0.0	0.0	0.019	0.004	40.812
JULY	8	4:35	0.877	0.025	146.45	66.49	13.30	8.92	0.0	0.0	0.0	2.715	0.543	40.826
JULY	8	4:40	3.119	0.088	666.61	302.64	60.53	11.42	0.0	0.0	0.0	12.306	2.461	40.663
JULY	8	4:45	2.847	0.081	405.25	183.98	36.80	7.61	0.0	0.0	0.0	7.359	1.472	39.996
JULY	8	4:50	1.967	0.056	228.90	103.92	20.78	6.22	0.0	0.0	0.0	4.113	0.823	39.580
JULY	8	4:55	2.766	0.078	418.61	190.05	38.01	8.09	0.0	0.0	0.0	7.499	1.500	39.459
JULY	8	5: 0	5.504	0.156	1070.66	486.08	97.22	10.39	0.0	0.0	0.0	19.204	3.841	39.508
JULY	8	5: 5	5.583	0.158	946.60	429.76	85.95	9.06	0.0	0.0	0.0	16.678	3.336	38.808
JULY	8	5:10	3.662	0.104	475.57	215.91	43.18	6.94	0.0	0.0	0.0	8.230	1.646	38.120
JULY	8	5:15	2.587	0.073	243.96	110.76	22.15	5.04	0.0	0.0	0.0	4.159	0.834	37.639
JULY	8	5:20	2.025	0.057	157.09	71.32	14.26	4.15	0.0	0.0	0.0	2.655	0.533	37.388
JULY	8	5:25	2.705	0.077	209.54	95.13	19.03	4.14	0.0	0.0	0.0	3.585	0.717	37.680
JULY	8	5:30	4.213	0.119	377.55	171.41	34.28	4.79	0.0	0.0	0.0	6.512	1.302	37.991
JULY	8	5:35	4.581	0.130	399.64	181.43	36.29	4.66	0.0	0.0	0.0	6.881	1.376	37.928
JULY	8	5:40	3.328	0.094	203.65	92.46	18.49	3.27	0.0	0.0	0.0	3.462	0.692	37.449
JULY	8	5:45	1.752	0.050	59.21	26.88	5.38	1.81	0.0	0.0	0.0	0.934	0.197	36.608
JULY	8	5:50	1.006	0.028	18.65	8.47	1.69	0.99	0.0	0.0	0.0	0.305	0.061	36.178
JULY	8	5:55	0.644	0.018	6.99	3.17	0.63	0.58	0.0	0.0	0.0	0.115	0.023	36.089
JULY	8	6: 0	0.426	0.012	3.73	1.69	0.34	0.47	0.0	0.0	0.0	0.061	0.012	36.066
JULY	8	6: 5	0.306	0.009	1.77	0.80	0.16	0.31	0.0	0.0	0.0	0.029	0.006	36.056
JULY	8	6:10	0.205	0.006	0.62	0.28	0.06	0.16	0.0	0.0	0.0	0.010	0.002	36.052
JULY	8	6:15	0.139	0.004	0.16	0.07	0.01	0.06	0.0	0.0	0.0	0.003	0.001	35.050
JULY	8	6:20	0.097	0.003	0.01	0.01	0.00	0.01	0.0	0.0	0.0	0.000	0.000	35.050
JULY	8	6:25	0.071	0.002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
JULY	8	6:30	0.047	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
JULY	8	6:35	0.032	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
JULY	8	6:40	0.021	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
JULY	8	6:45	0.014	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
JULY	8	6:50	0.009	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
JULY	8	6:55	0.006	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
JULY	8	7: 0	0.004	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
JULY	8	7: 5	0.003	0.000	0.01	0.00	0.00	0.15	0.0	0.0	0.0	0.000	0.000	36.050
JULY	8	7:10	0.020	0.001	0.01	0.00	0.00	0.02	0.0	0.0	0.0	0.000	0.000	35.050
JULY	8	7:15	0.019	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
JULY	8	7:20	0.013	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
JULY	8	7:25	0.009	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
JULY	8	7:30	0.006	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
JULY	8	7:35	0.004	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
JULY	8	7:40	0.003	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
JULY	8	7:45	0.002	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 24. CALIBRATION RUN OUTPUT - STORM EVENTS (Nutrient Simulation)

DATE	TIME	FLOW (CFS)	SEDIMENT (LB)	DISSOLVED IN WATER NO3 (LB) (MG/L)	NO2 (LB) (MG/L)	NH3 (LB) (MG/L)	PO4 (LB) (MG/L)	CL (LB) (MG/L)	ADSORBED TO SEDIMENT NH3 (LB) (PPM)	ORG-N (LB) (PPM)	PO4 (LB) (PPM)	ORG-P (LB) (PPM)	TOT-N (LB)	TOT-P (LB)
TILLAGE OF THE SOIL OCCURS ON JUNE 13 (TIMTIL=164), RESULTING IN A NEW FINES DEPOSIT STORAGE OF 2.000 TONS/ACRE														
NUTRIENT APPLICATION NO. 1 OCCURS ON JUNE 13 (DAY = 164)														
JUNE 13	18:10	2.874	1460.83	0.002	0.000	0.000	0.000	0.001	0.013	0.740	0.019	0.148	0.755	0.167
				0.0	0.0	0.0	0.0	0.0	8.7	506.6	13.3	101.3		
JUNE 13	18:15	5.791	2202.84	11.172	2.384	1.721	0.136	6.338	0.019	1.107	0.029	0.221	16.404	0.386
				103.1	22.0	15.9	1.3	58.5	8.6	502.7	13.2	100.5		
JUNE 13	18:20	1.952	331.54	26.888	4.458	3.218	0.254	11.851	0.003	0.164	0.004	0.033	28.731	0.291
				572.0	122.1	88.1	7.0	324.5	8.5	495.3	13.0	99.1		
JUNE 13	18:25	2.217	492.35	22.179	4.733	3.417	0.270	12.583	0.004	0.243	0.006	0.049	30.576	0.325
				534.7	114.1	82.4	6.5	303.4	8.4	494.2	12.9	98.8		
JUNE 13	18:30	2.189	280.72	25.995	5.548	4.005	0.317	14.748	0.002	0.138	0.004	0.028	35.688	0.348
				634.5	135.4	97.8	7.7	360.0	8.4	491.6	12.9	98.3		
JUNE 13	18:35	1.162	56.18	23.079	4.925	3.556	0.281	13.094	0.000	0.027	0.001	0.005	31.588	0.287
				1061.0	226.4	163.5	12.9	602.0	8.4	488.7	12.8	97.7		
JUNE 13	18:40	0.729	15.34	18.773	4.006	2.892	0.229	10.651	0.000	0.007	0.000	0.001	25.680	0.230
				1375.7	293.6	212.0	16.8	780.5	8.3	487.5	12.8	97.5		
JUNE 13	18:45	0.476	4.39	13.564	2.895	2.090	0.165	7.696	0.000	0.002	0.000	0.000	18.551	0.166
				1523.4	325.1	234.7	18.5	864.3	8.3	487.4	12.8	97.5		
JUNE 13	18:50	0.317	0.81	10.032	2.141	1.546	0.122	5.692	0.000	0.000	0.000	0.000	13.720	0.122
				1689.3	361.5	260.3	20.6	958.4	8.3	487.4	12.8	97.5		
JUNE 13	18:55	0.216	0.0	7.637	1.630	1.177	0.093	4.333	0.0	0.0	0.0	0.0	10.443	0.093
				1887.0	402.7	290.7	23.0	1070.6	0.0	0.0	0.0	0.0		
JUNE 13	19: 0	0.161	0.0	6.026	1.286	0.928	0.073	3.419	0.0	0.0	0.0	0.0	8.240	0.073
				2003.2	427.5	308.6	24.4	1136.5	0.0	0.0	0.0	0.0		
JUNE 13	19: 5	0.107	0.0	4.017	0.857	0.619	0.049	2.279	0.0	0.0	0.0	0.0	5.493	0.049
				2003.2	427.5	308.6	24.4	1136.5	0.0	0.0	0.0	0.0		

Table 25. PRODUCTION RUN OUTPUT - DAILY PRINTOUT (Pesticide Simulation)

241.0 ON 31 DECEMBER 1974

	BLOCK 1	BLOCK 2	BLOCK 3	BLOCK 4	BLOCK 5	TOTAL
WATER, INCHES						
RUNOFF						
OVERLAND FLOW	0.853	0.386	0.230	0.135	0.072	0.335
INTERFLOW	0.317	0.190	0.159	0.157	0.156	0.196
IMPERVIOUS						0.0
TOTAL	1.170	0.576	0.389	0.292	0.227	0.531
BASE FLOW						0.0
GROWATER RECHARGE						0.903
PRECIPITATION	2.10	2.10	2.10	2.10	2.10	2.10
EVAPOTRANSPIRATION						
POTENTIAL	0.07	0.07	0.07	0.07	0.07	0.07
NET	0.07	0.07	0.07	0.07	0.07	0.07
CROP COVER						0.59
STORAGES						
UPPER ZONE	0.132	0.110	0.105	0.105	0.106	0.112
LOWER ZONE	20.568	20.568	20.558	20.568	20.568	20.568
GROUNDWATER	0.0	0.0	0.0	0.0	0.0	0.0
INTERCEPTION	0.083	0.083	0.083	0.083	0.083	0.083
OVERLAND FLOW	0.0	0.0	0.0	0.0	0.0	0.0
INTERFLOW	0.003	0.000	0.000	0.000	0.000	0.001
WATER BALANCE= 0.0						
SEDIMENT, TONS/ACRE						
ERODED SEDIMENT	0.063	0.060	0.059	0.059	0.033	0.054
FINES DEPOSIT	0.001	0.013	0.028	0.054	0.088	0.037
SURFACE LAYER PESTICIDE						
PESTICIDE, LBS	0.606	0.609	0.610	0.611	0.613	3.052
ABSORBED	0.606	0.609	0.610	0.611	0.613	3.052
CRYSTALLINE	0.0	0.0	0.0	0.0	0.0	0.0
DISSOLVED	0.0	0.0	0.0	0.0	0.0	0.0
PESTICIDE, PPM	42.270	42.314	42.370	42.462	42.586	42.400
ABSORBED	42.270	42.314	42.370	42.462	42.586	42.400
CRYSTALLINE	0.0	0.0	0.0	0.0	0.0	0.0
DISSOLVED	0.0	0.0	0.0	0.0	0.0	0.0
REMOVAL, LBS	0.003	0.003	0.003	0.003	0.002	0.014
SEDIMENT	0.003	0.003	0.003	0.003	0.002	0.014
OVERLAND FLOW	0.0	0.0	0.0	0.0	0.0	0.0
PERCOLATION	0.0	0.0	0.0	0.0	0.0	0.0
UPPER ZONE LAYER PESTICIDE						
PESTICIDE, LBS	0.0	0.0	0.0	0.0	0.0	0.0
ABSORBED	0.0	0.0	0.0	0.0	0.0	0.0
CRYSTALLINE	0.0	0.0	0.0	0.0	0.0	0.0
DISSOLVED	0.0	0.0	0.0	0.0	0.0	0.0
INTERFLOW STORAGE	0.0	0.0	0.0	0.0	0.0	0.0

Table 25. (Continued)

PESTICIDE, PPM	0.0	0.0	0.0	0.0	0.0	0.0
ADSORBED	0.0	0.0	0.0	0.0	0.0	0.0
CRYSTALLINE	0.0	0.0	0.0	0.0	0.0	0.0
DISSOLVED	0.0	0.0	0.0	0.0	0.0	0.0
REMOVAL, LBS	0.0	0.0	0.0	0.0	0.0	0.0
INTERFLOW	0.0	0.0	0.0	0.0	0.0	0.0
PERCOLATION	0.0	0.0	0.0	0.0	0.0	0.0
LOWER ZONE LAYER PESTICIDE						
PESTICIDE, LBS						0.0
ADSORBED						0.0
CRYSTALLINE						0.0
DISSOLVED						0.0
PESTICIDE, PPM						
ADSORBED						0.0
CRYSTALLINE						0.0
DISSOLVED						0.0
REMOVAL, LBS						0.0
PERCOLATION						0.0
GROUNDWATER LAYER PESTICIDE						
PESTICIDE, LBS						0.0
ADSORBED						0.0
CRYSTALLINE						0.0
DISSOLVED						0.0
PESTICIDE DEGRADATION LOSS, LBS.						
TOTAL						0.006
FROM SURFACE						0.006
FROM UPPER ZONE						0.0
FROM LOWER ZONE						0.0

Table 26. METEOROLOGIC DATA INPUT SEQUENCE AND ATTRIBUTES*

Data	Interval	Units: English	Units: Metric	Comments
Potential Evapotranspiration	Daily	in x 100	mm x 1000	Assumed equal to lake evaporation and lake evaporation = pan evaporation x pan coefficient
Max-Min Air Temperature	Daily	degrees F	degrees C	1. Caution: Time of observation determines whether the recorded values refer to the day of observation or the previous day. 2. Required only for nutrient and snow simulation.
Wind	Daily	miles/day	km/day	Required only for snow simulation.
Solar Radiation	Daily	langleys/ day	langleys/ day	1. Total incident solar radiation. 2. Required only for snow simulation. 3. 1 langley = 1 calorie/cm^2
Dewpoint	Daily	degrees F	degrees C	1. Required only for snow simulation. 2. Average daily value since variations during the day are assumed minor.
Precipitation	5 minutes 15 minutes	in x 100	mm x 1000	

* All meteorologic data is input in integer form. Format specifications are described in Table 30.

Model operation. Except for precipitation which is input on 5 or 15 minute intervals, daily meteorologic observations are needed. The extent of data requirements is dependent upon the simulation options. Thus for hydrology, sediment, and pesticide simulation, without snowmelt calculations, only precipitation and evaporation are required in the present version of the ARM Model. For nutrient simulation, max-min air temperature is an additional requirement, and for snow simulation, the required data series include max-min air temperature, daily wind movement, daily solar radiation, and daily dewpoint temperature (in addition to precipitation and evaporation).

The ARM Model accepts parameter and data input on a 'sequential' basis in either English or Metric units, as specified by the INPUT parameter, i.e. INPUT = ENGL or INPUT - METR. Table 27 presents the overall input sequence for the ARM Model. Model parameters are input in two different formats depending on the simulation options chosen. The majority of the ARM Model parameters (except the control parameters) are input in the FORTRAN 'namelist' format. The input sequence and attributes for these parameters are described in Table 28. The nutrient parameters (except for the 'nutrient control' parameters) are input under format control due to the number of transformations, reaction rates, and storages which must be defined. Table 29 describes the input sequence and attributes for the nutrient parameters. Study of Tables 28 and 29 and comparison with the sample input listing in Appendix B should clarify the ordering of the parameter input sequence.

As described in Table 28, the first two lines of the input sequence provide space for specifying the watershed name, pesticide or chemical name, and other information describing the Model run. Next, eight control parameters and three control namelists (CNTL, STRT, ENDD) are input. The ICHECK control parameter allows the user to direct the ARM Model to check for errors and reasonableness of the parameter values; the CHECKR subroutine performs this function. With ICHECK = ON, the Model checks the input sequence, indicates errors, and then stops if any errors are found. After errors have been corrected the Model can be run again with ICHECK = ON in order to check corrections and to perform the simulations.

The control namelist statements specify the simulation interval (INTRVL), the minimum flow for hydrograph output (HYMIN), the area of the watershed (AREA), and the beginning and ending dates of simulation (namelists STRT and ENDD respectively).

Next in sequence are the four hydrologic parameter namelist statements (LND1, LND2, LND3, and LND4). If snowmelt simulation is specified by the SNOW control parameter (SNOW = YES), the corresponding snowmelt namelists (SNO1, SNO2, SNO3, SNO4) are next in line. Otherwise, the sediment namelist statements (CROP, MUD1, DIRT, SMDL) would follow. If

Table 27. INPUT SEQUENCE FOR THE ARM MODEL

ARM Model Parameters Potential Evapotranspiration Max-Min Air Temperature Wind Movement Solar Radiation Dewpoint Temperature Precipitation	1st Year
Potential Evapotranspiration Max-Min Air Temperature Wind Movement Solar Radiation Dewpoint Temperature Precipitation	2nd Year

etc.

Table 28. ARM MODEL PARAMETER INPUT SEQUENCE AND ATTRIBUTES (excluding nutrient input and parameters)

Namelist Name	Parameter Name	Type	English Units	Metric Units
	Watershed name (up to 80 characters)			
	Chemical name and/or run information (up to 80 characters)			
	HYCAL	character		
	INPUT	character		
	OUTPUT	character		
	PRINT	character		
	SNOW	character		
	PEST	character		
	NUTR	character		
	ICHECK	character		
CNTL	INTRVL	integer	minutes	minutes
	HYMIN	real	cubic feet/sec	cubic meters/sec
	AREA	real	acres	hectares
STRT	BGNDAY	integer		
	BGNMON	integer		
	BGNYR	integer		
ENDD	ENDDAY	integer		
	ENDMON	integer		
	ENDYR	integer		
LND1	UZSN	real	inches	millimeters
	UZS	real	inches	millimeters
	LZSN	real	inches	millimeters
	LZS	real	inches	millimeters
LND2	L	real	feet	meters
	SS	real		
	NN	real		
	A	real		
	K3	real		
	EPXM	real	inches	millimeters
LND3	INFIL	real	inches/hour	millimeters/hour
	INTER	real		
	IRC	real		
	K24L	real		
	KK24	real		
	K24EL	real		

Table 28. (Continued)

LND4	SGW	real	inches	millimeters
	GWS	real		
	KV	real		
	ICS	real	inches	millimeters
	OFS	real	inches	millimeters
	IFS	real	inches	millimeters
SNO1	RADCON	real		
	CCFAC	real		
	SCF	real		
	ELDIF	real	1000 feet	kilometers
	IDNS	real		
	F	real		
SNO2	DGM	real	inches/day	millimeters/day
	WC	real		
	MPACK	real	inches	millimeters
	EVAPSN	real		
	MELEV	real	feet	meters
	TSNOW	real	degrees F	degrees C
SNO3	PACK	real	inches	millimeters
	DEPTH	real	inches	millimeters
SNO4	PETMIN	real	degrees F	degrees C
	PETMAX	real	degrees F	degrees C
	PETMUL	real		
	WMUL	real		
	RMUL	real		
	KUGI	integer		
CROP	COVPMO	real		
MUD1	TIMTIL	integer	days	days
	YRTIL	integer	year	year
	SRERTL	real	tons/acre	tonnes/hectare
DIRT	SZDPTH	real	inches	millimeters
	UZDPTH	real	inches	millimeters
	BULKD	real	pounds/cubic foot	grams/cubic cm
SMDL	JRER	real		
	KRER	real		
	JSER	real		
	KSER	real		
	SRERI	real	tons/acre	tonnes/hectare
	PESTICIDE	character		
	APMODE	character		
	DESORP	character		

Table 28. (Continued)

AMDL	SSTR	real	pounds/block	kilograms/block
	TIMAP	integer	days	days
	YEARAP	integer	year	year
	CMAX	real	pounds/pound	kilograms/kg
	DD	real	lbs. pesticide/ lbs. soil	kgs. pesticide/ kgs. soil
	K	real		
	N	real		
	NP	real		
DEG1	DEGCON	real	per day	per day

pesticide simulation is to be performed, the sediment namelists are followed by the title word 'PESTICIDE' (starting in column 1), the pesticide parameters APMODE and DESORP and the pesticide namelist statements (AMDL, DEG1). This completes the parameter input sequence for hydrology, sediment, and pesticides.

If nutrient simulation is to be performed, as indicated by the control parameter NUTR (i.e. NUTR = YES) then the nutrient parameters must follow in sequence. Reference to Table 29 and Appendix B is important to understanding the nutrient input sequence. The sequence begins with the title word 'NUTRIENTS' (in column 1) and is followed by the namelist statement, NUTRIN. This is the only namelist statement in the nutrient parameter input sequence. The remaining input of nutrient information is done under format control. Also, character strings are input and checked by the program to verify the accuracy of the input sequence. The section begins with the character string 'REACTION RATES' and then the words 'NITROGEN' or 'PHOSPHORUS' to indicate which rates are being input. First order reaction rates may be input for both nitrogen and phosphorus chemical and biological transformations. Separate rates are allowed for the four soil zones: SURFACE, UPPER, LOWER, and GROUNDWATER. Following the character string, 'NITROGEN', the word 'SURFACE' appears on the next line; then 10 reaction rates are listed in F8.0 format on the following line. These reaction rates refer to the various nitrogen forms described in Table 29. Following the surface rates, the word 'UPPER' appears in column 1, and the reaction rates for the upper zone are input on the next line. Lower zone and groundwater rates follow in a similar manner. The word 'TEMPERATURE COEFFICIENTS' appears after the groundwater rates and the following line contains the ten constants used for correcting the corresponding reaction rates for non-optimal temperatures. Phosphorus reaction rates and temperature coefficients are input in a similar manner except that there are only five reaction rates appearing in an F8.0 format (see Appendix B). The word END terminates input of reaction rates. Specifying nitrogen or phosphorus rates is optional, and if values are not given, the program will default the rates to 0.0.

The next section of nutrient input specifies the initial nitrogen, phosphorus, and chloride concentration present in the four soil layers. The word 'INITIAL' begins this section; title words are used in the manner described above. The seven different nitrogen forms, four various constituents are described in Table 29. The sequence is demonstrated in Appendix B. Nutrient concentration is input by soil layer. If initial values are not given for the nitrogen, phosphorus, or chloride forms, the program defaults them to 0.0. The character string 'END' terminates the initialization section.

The final section of the nutrient input sequence indicates the date and amount of application of nutrients during the simulation period. Each

Table 29. ARM MODEL NUTRIENT PARAMETER INPUT SEQUENCE AND ATTRIBUTES

Block	Section & Subsection	Name	Type	Column Position	Units English	Units Metric	Comments
NUTRIENT			Character	1-8			Name to indicate start of nutrient input sequence.
	&NUTRIN		Character	2-7			Namelist name of nutrient control information.
		TSTEP	Integer	Any	minutes	minutes	Length of timestep for chemical and biological transformations. There must be an even number of time steps in a day, and an even number of simulation intervals in a TSTEP. Range= 5 or 15 to 1440.
		NAPPL	Integer	Any			Number of nutrient applications over a year of simulation. Values may range from 0 to 5.
		TIMHAR	Integer	Any	day	day	Time of plant harvesting, Julian day of the year. Value may range from 0 to 366.
		&END	Character	Any			Indicate end of namelist input of nutrient control information.
REACTION RATES			Character	1-14			Name to indicate start of nutrient input sequence.
	NITROGEN		Character	1-8			Indicates nitrogen reaction rate will follow.
	SURFACE		Character	1-7			Surface layer reaction rates follow.
		K1	Real	1-8	per day	per day	Oxidation rate of ammonia (dissolved and adsorbed) to nitrite.
		K2	Real	9-16	per day	per day	Oxidation rate of Nitrite to nitrate.
		KK2	Real	17-24	per day	per day	Reduction rate of nitrate to nitrite.
		KD	Real	25-32	per day	per day	Reduction rate of nitrite to nitrogen gas.
		KPL	Real	33-40	per day	per day	Uptake of nitrate by plants.
		KAM	Real	41-48	per day	per day	Ammonification or mineralization rate of organic-N to ammonia.
		KIM	Real	49-56	per day	per day	Immobilization rate of dissolved ammonia to organic-N.
		KKIM	Real	57-64	per day	per day	Immobilization rate of nitrate to organic-N.

Table 29. (Continued)

Block	Section & Subsection	Name	Type	Column Position	Units English	Units Metric	Comments
		KSA	Real	65-72	per day	per day	Transfer rate of ammonia from solution to adsorbed (adsorption).
		KAS	Real	73-80	per day	per day	Transfer rate of ammonia from adsorbed to solution (desorption).
	UPPER ZONE		Character	1-10			Upper zone reaction rates follow.
		K1	Real	1-8	per day	per day	Oxidation rate of ammonia (dissolved and adsorbed) to nitrite.
		K2	Real	9-16	per day	per day	Oxidation rate of Nitrite to nitrate.
		KK2	Real	17-24	per day	per day	Reduction rate of nitrate to nitrite.
		KD	Real	25-32	per day	per day	Reduction rate of nitrite to nitrogen gas.
		KPL	Real	33-40	per day	per day	Uptake of nitrate by plants.
		KAM	Real	41-48	per day	per day	Ammonification or mineralization rate of organic-N to ammonia.
		KIM	Real	49-56	per day	per day	Immobilization rate of dissolved ammonia to organic-N.
		KKIM	Real	57-64	per day	per day	Immobilization rate of nitrate to organic-N.
		KSA	Real	65-72	per day	per day	Transfer rate of ammonia from solution to adsorbed (adsorption).
		KAS	Real	73-80	per day	per day	Transfer rate of ammonia from adsorbed to solution (desorption).
	LOWER ZONE		Character	1-10			Lower zone reaction rates folow.
		K1	Real	1-8	per day	per day	Oxidation rate of ammonia (dissolved and adsorbed) to nitrite.
		K2	Real	9-16	per day	per day	Oxidation rate of Nitrite to nitrate.
		KK2	Real	17-24	per day	per day	Reduction rate of nitrate to nitrite.
		KD	Real	25-32	per day	per day	Reduction rate of nitrite to nitrogen gas.
		KPL	Real	33-40	per day	per day	Uptake of nitrate by plants.
		KAM	Real	41-48	per day	per day	Ammonification or mineralization rate of organic-N to ammonia.
		KIM	Real	49-56	per day	per day	Immobilization rate of dissolved ammonia to organic-N.
		KKIM	Real	57-64	per day	per day	Immobilization rate of nitrate to organic-N.
		KSA	Real	65-72	per day	per day	Transfer rate of ammonia from solution to adsorbed (adsorption).
		KAS	Real	73-80	per day	per day	Transfer rate of ammonia from adsorbed to solution (desorption).

Table 29. (Continued)

Block	Section & Subsection	Name	Type	Column Position	Units English	Units Metric	Comments
	GROUNDWATER		Character	1-11			Groundwater reaction rates follow.
		K1	Real	1-8	per day	per day	Oxidation rate of ammonia (dissolved and adsorbed) to nitrite.
		K2	Real	9-16	per day	per day	Oxidation rate of nitrite to nitrate.
		KK2	Real	17-24	per day	per day	Reduction rate of nitrate to nitrite.
		KD	Real	25-32	per day	per day	Reduction rate of nitrite to nitrogen gas.
		KPL	Real	33-40	per day	per day	Uptake of nitrate by plants.
		KAM	Real	41-48	per day	per day	Ammonification or mineralization rate of organic-N to ammonia.
		KIM	Real	49-56	per day	per day	Immobilization rate of dissolved ammonia to organic-N.
		KKIM	Real	57-64	per day	per day	Immobilization rate of nitrate to organic-N.
		KSA	Real	65-72	per day	per day	Transfer rate of ammonia from solution to adsorbed (adsorption).
		KAS	Real	73-80	per day	per day	Transfer rate of ammonia from adsorbed to solution (desorption).
	TEMPERATURE COEFFICIENTS		Character	1-23			Temperature coefficients for reaction rates.
		THK1	Real	1-8	per day	per day	
		THK2	Real	9-16	per day	per day	
		THKK2	Real	17-24	per day	per day	
		THKD	Real	25-32	per day	per day	Temperature coefficients for corresponding nitrogen reactions, should be greater than or equal to 1.0.
		THKPL	Real	33-40	per day	per day	
		THKAM	Real	41-48	per day	per day	
		THKIM	Real	49-56	per day	per day	
		THKKIM	Real	57-64	per day	per day	
		THKSA	Real	65-72	per day	per day	
		THKAS	Real	73-80	per day	per day	

Table 29. (Continued)

Block	Section & Subsection	Name	Type	Column Position	Units English	Units Metric	Comments
	PHOSPHORUS		Character	1-10			Indicates phosphorus reaction rates will follow.
	SURFACE		Character	1-7			Surface layer reaction rates.
		KM	Real	1-8	per day	per day	Mineralization rate of Organic-P to P04-5
		KIM	Real	9-16	per day	per day	Immobilization rate of dissolved P04-P to Organic-P.
		KPL	Real	17-24	per day	per day	Uptake of phosphate (dissolved and adsorbed) by plants.
		KSA	Real	25-32	per day	per day	Transfer rate of phosphate from solution to adsorbed.
		KAS	Real	33-40	per day	per day	Transfer rate of phosphate from adsorbed to solution.
	UPPER ZONE		Character	1-10			Upper zone reaction rates follow.
		KM	Real	1-8	per day	per day	Mineralization rate of Organic-P to P04-P dissolved.
		KIM	Real	9-16	per day	per day	Immobilization rate of dissolved P04-P to Organic-P.
		KPL	Real	17-24	per day	per day	Uptake of phosphate (dissolved and adsorbed) by plants.
		KSA	Real	25-32	per day	per day	Transfer rate of phosphate from solution to adsorbed.
		KAS	Real	33-40	per day	per day	Transfer rate of phosphate from adsorbed to solution.
	LOWER ZONE		Character	1-10			Lower zone reaction rates follow.
		KM	Real	1-8	per day	per day	Mineralization rate of Organic-P to P04-P dissolved.
		KIM	Real	9-16	per day	per day	Immobilization rate of dissolved P04-P to Organic-P.
		KPL	Real	17-24	per day	per day	Uptake of phosphate (dissolved and adsorbed) by plants.
		KSA	Real	25-32	per day	per day	Transfer rate of phosphate from solution to adsorbed.
		KAS	Real	33-40	per day	per day	Transfer rate of phosphate from adsorbed to solution.
	GROUNDWATER		Character	1-11			Lower zone reaction rates follow.
		KM	Real	1-8	per day	per day	Mineralization rate of Organic-P to P04-P dissolved.

Table 29. (Continued)

Block	Section & Subsection	Name	Type	Column Position	Units English	Units Metric	Comments
		KIM	Real	9-16	per day	per day	Immobilization rate of dissolved PO4-P to Organic-P.
		KPL	Real	17-24	per day	per day	Uptake of phosphate (dissolved and adsorbed) by plants.
		KSA	Real	25-32	per day	per day	Transfer rate of phosphate from solution to adsorbed.
		KAS	Real	33-40	per day	per day	Transfer rate of phosphate from adsorbed to solution.
	TEMPERATURE COEFFICIENTS		Character	1-23			Temperature coefficients for reaction rates.
		THKM	Real	1-8	per day	per day	
		THKIM	Real	9-16	per day	per day	Temperature coefficients for phosphorus reactions, should be greater than or equal to 1.0.
		THKPL	Real	17-24	per day	per day	
		THKSA	Real	25-32	per day	per day	
		THKAS	Real	33-40	per day	per day	
END			Character	1-3			'END' terminates input of rates. Nitrogen and phosphorus rates are optional, program defaults them to 0.0 if not specified.
INITIAL			Character	1-7			Initialization of soil constituents follows.
	NITROGEN		Character	1-8			Initial nitrogen forms follow.
	SURFACE		Character	1-7			Surface layer initialization follows.
		NBLK	Integer	16			Number of blocks which will be input. 0 or 1 indicate the average concentration over the surface layer in input on one line, and NBLK=5 means five lines of input follow, one line per block. Only 0,1,5 allowed. A blank in co. 16 is read as 0.
		ORG-N	Real	1-8	lb/ac	kg/ha	Potentially mineralizable nitrogen.
		NH3-S	Real	9-16	lb/ac	kg/ha	Ammonia in solution

Table 29. (Continued)

Block	Section & Subsection	Name	Type	Column Position	Units English	Units Metric	Comments
		NH3-A	Real	17-24	lb/ac	kg/ha	Ammonia adsorbed to soil.
		NO2	Real	25-32	lb/ac	kg/ha	Nitrite
		NO3	Real	33-40	lb/ac	kg/ha	Nitrate
		N2	Real	41-48	lb/ac	kg/ha	Nitrogen gas from demitrification.
		PLNT-N	Real	49-56	lb/ac	kg/ha	Plant nitrogen
	UPPER ZONE		Character	1-10			Upper zone initialization follows.
		NBLK	Integer	16			Number of blocks which will be input. 0 or 1 indicate the average concentration over the surface layer is input on one line, and NBLK=5 means five lines of input follow, one line per block. Only 0,1,5 allowed. A blank in co. 16 is read as 0.
		ORG-N	Real	1-8	lb/ac	kg/ha	Potentially mineralizable nitrogen.
		NH3-S	Real	9-16	lb/ac	kg/ha	Ammonia in solution
		NH3-A	Real	17-24	lb/ac	kg/ha	Ammonia adsorbed to soil.
		NO2	Real	25-32	lb/ac	kg/ha	Nitrite
		NO3	Real	33-40	lb/ac	kg/ha	Nitrate
		N2	Real	41-48	lb/ac	kg/ha	Nitrogen gas from demitrification.
		PLNT-N	Real	49-56	lb/ac	kg/ha	Plant nitrogen
	LOWER ZONE		Character	1-10			Lower zone initialization.
		ORG-N	Real	1-8	lb/ac	kg/ha	Potentially mineralizable nitrogen.
		NH3-S	Real	9-16	lb/ac	kg/ha	Ammonia in solution
		NH3-A	Real	17-24	lb/ac	kg/ha	Ammonia adsorbed to soil.
		NO2	Real	25-32	lb/ac	kg/ha	Nitrite
		NO3	Real	33-40	lb/ac	kg/ha	Nitrate
		N2	Real	41-48	lb/ac	kg/ha	Nitrogen gas from demitrification.
		PLNT-N	Real	49-56	lb/ac	kg/ha	Plant nitrogen

Table 29. (Continued)

Block	Section & Subsection	Name	Type	Column Position	Units English	Metric	Comments
	GROUNDWATER		Character	1-11			Groundwater zone initialization.
		ORG-N	Real	1-8	lb/ac	kg/ha	Potentially mineralizable nitrogen.
		NH3-S	Real	9-16	lb/ac	kg/ha	Ammonia in solution
		NH3-A	Real	17-24	lb/ac	kg/ha	Ammonia adsorbed to soil.
		NO2	Real	25-32	lb/ac	kg/ha	Nitrite
		NO3	Real	33-40	lb/ac	kg/ha	Nitrate
		N2	Real	41-48	lb/ac	kg/ha	Nitrogen gas from demitrification.
		PLNT-N	Real	49-56	lb/ac	kg/ha	Plant nitrogen
	PHOSPHORUS		Character	1-10			Initial phosphorus forms follow.
	SURFACE		Character	1-7			Surface layer.
		NBLK	Integer	16			Number of blocks which will be input.
		ORG-P	Real	1-8	lb/ac	kg/ha	Organic phosphorus.
		PO4-S	Real	9-16	lb/ac	kg/ha	Phosphate in solution.
		PO4-A	Real	17-24	lb/ac	kg/ha	Phosphate adsorbed to soil.
		PLNT-P	Real	25-32	lb/ac	kg/ha	Plant phosphorus.
	UPPER ZONE		Character	1-10			Upper zone phosphorus initialization.
		NBLK	Integer	16			Number of blocks which will be input.
		ORG-P	Real	1-8	lb/ac	kg/ha	Organic phosphorus.
		PO4-S	Real	9-16	lb/ac	kg/ha	Phosphate in solution.
		PO4-A	Real	17-24	lb/ac	kg/ha	Phosphate adsorbed to soil.
		PLNT-P	Real	25-32	lb/ac	kg/ha	Plant phosphorus.
	LOWER ZONE		Character	1-10			Lower zone initialization.
		ORG-P	Real	1-8	lb/ac	kg/ha	Organic phosphorus.

Table 29. (Continued)

Block	Section & Subsection	Name	Type	Column Position	Units English	Units Metric	Comments
		P04-S	Real	9-16	lb/ac	kg/ha	Phosphate in solution.
		P04-A	Real	17-24	lb/ac	kg/ha	Phosphate adsorbed to soil.
		PLNT-P	Real	25-32	lb/ac	kg/ha	Plant phosphorus.
	GROUNDWATER		Character	1-11			Groundwater initialization.
		ORG-P	Real	1-8	lb/ac	kg/ha	Organic phosphorus.
		P04-S	Real	9-16	lb/ac	kg/ha	Phosphate in solution.
		P04-A	Real	17-24	lb/ac	kg/ha	Phosphate adsorbed to soil.
		PLNT-P	Real	25-32	lb/ac	kg/ha	Plant phosphorus.
	CHLORIDE		Character	1-8			Initial chloride levels follow.
	SURFACE		Character	1-7			Surface layer chloride.
		NBLK	Integer	16			Number of blocks which will be input.
		CL	Real	1-8	lb/ac	kg/ha	Chloride storage.
	UPPER ZONE		Character	1-10			Upper zone initialization.
		NBLK	Integer	16			Number of blocks which will be input.
		CL	Real	1-8	lb/ac	kg/ha	Chloride storage.
	LOWER ZONE		Character	1-10			Lower zone.
		CL	Real	1-8	lb/ac	kg/ha	Chloride storage.
	GROUNDWATER		Character	1-11			Groundwater.
		CL	Real	1-8	lb/ac	kg/ha	Chloride storage.
END			Character	1-3			"END" terminates input of initial nutrient storages. Nitrogen, phosphorus, and chloride storages default to 0.0 if not input in this SECTION.
APPLICATION			Character	1&11			Name to indicate start of nutrient application section, expected the number of applications is greater than 0.
		APDAY	Integer	14-16			Application day of the year (Julian Day).

Table 29. (Continued)

Block	Section & Subsection	Name	Type	Column Position	Units English	Units Metric	Comments
	NITROGEN		Character	1-8			Nitrogen applications follow.
	SURFACE		Character	1-7			Surface applications follow.
		NBLK	Integer	16			Number of blocks which will be input, 0 or 1 indicate one line follows containing the average application over the watershed. A 5 indicates five lines follow, one line for each block.
		ORG-N	Real	1-8	lb/ac	kg/ha	Potentially mineralizable nitrogen applied.
		NH3-S	Real	9-16	lb/ac	kg/ha	Ammonia in solution.
		NH3-A	Real	17-24	lb/ac	kg/ha	Ammonia adsorbed to soil.
		NO2	Real	25-32	lb/ac	kg/ha	Nitrite
		NO3	Real	33-40	lb/ac	kg/ha	Nitrate
		N2	Real	41-43	lb/ac	kg/ha	Nitrogen gas.
		PLNT-N	Real	49-56	lb/ac	kg/ha	Plant nitrogen.
	UPPER ZONE		Character	1-10			Upper zone applications follow
		NBLK	Integer	16			Number of blocks which will be input.
		ORG-N	Real	1-8	lb/ac	kg/ha	Potentially mineralizable nitrogen applied.
		NH3-S	Real	9-16	lb/ac	kg/ha	Ammonia in solution.
		NH3-A	Real	17-24	lb/ac	kg/ha	Ammonia adsorbed to soil.
		NO2	Real	25-32	lb/ac	kg/ha	Nitrite
		NO3	Real	33-40	lb/ac	kg/ha	Nitrate
		N2	Real	41-48	lb/ac	kg/ha	Nitrogen gas.
		PLNT-N	Real	49-56	lb/ac	kg/ha	Plant nitrogen.
							Note: nutrients can only be applied to surface and upper zone.

Table 29. (Continued)

Block	Section & Subsection	Name	Type	Column Position	Units English	Units Metric	Comments
	PHOSPHORUS		Character	1-10			Phosphorus applications follow
	SURFACE		Character	1-7			Surface layer application.
		NBLK	Integer	16			Number of blocks which will be input.
		ORG-P	Real	1-8	lb/ac	kg/ha	Organic phosphorus.
		PO4-S	Real	9-16	lb/ac	kg/ha	Soluble phosphate.
		PO4-A	Real	17-24	lb/ac	kg/ha	Adsorbed phosphate.
		PLNT-P	Real	25-32	lb/ac	kg/ha	Plant phosphorus.
	UPPER ZONE		Character	1-10			Upper zone application.
		NBLK	Integer	16			Number of blocks which will be input.
		ORG-P	Real	1&8	lb/ac	kg/ha	Organic phosphorus.
		PO4-S	Real	9-16	lb/ac	kg/ha	Soluble phosphate.
		PO4-A	Real	17-24	lb/ac	kg/ha	Adsorbed phosphate.
		PLNT-P	Real	25-32	lb/ac	kg/ha	Plant phosphorus.
	CHLORIDE		Character	1-8			Chloride applications follow
	SURFACE		Character	1-7			Surface layer application.
		NBLK	Integer	16			Number of blocks which will be input.
		CL	Real	1-8	lb/ac	kg/ha	Chloride applied.
	UPPER ZONE		Character	1-10			Upper zone applications.
		NBLK	Integer	16			Number of blocks which will be input.
		CL	Real	1-8	lb/ac	kg/ha	Chloride applied.
END			Character	1-3			"END" terminates input of applications for that day. Note: Nitrogen, phosphorus and chloride do not need to be specified on input sequence if none are applied that day. Program defaults all applications to 0.0.

nutrient application begins with the word APPLICATION followed by the Julian day of application (e.g. 164 in Appendix B). The words following indicate which constituents are to be applied: NITROGEN, PHOSPHORUS, or CHLORIDE. Below the constituent type, the application amounts are entered for the surface and upper zone only. The character string END terminates the input of the nutrient application at one time. For multiple applications, the sequence is repeated with the character string APPLICATION and the Julian day of application. Applications have to be sequential with the first one applied in the year appearing first in the input sequence. This completes the nutrient input sequence and the entire ARM Model parameter input sequence.

As indicated in Table 27, the ARM Model parameters are followed by the meteorologic data in the input sequence. The daily meteorologic data is input as a block of 31 lines (or cards) with 12 values in each line. Thus, the 31 x 12 matrix corresponds to the 12 months of the year with a maximum of 31 days each. Table 30 demonstrates the format for the daily meteorologic data. The only modification to this is for daily max-min air temperature since two values are input for each day. In this case, the six spaces allowed for each daily value are divided in half. The first three spaces contain the maximum, and the second three spaces contain the minimum air temperature for the day. Table 31 indicates the format for precipitation data input on 5 or 15 minute intervals. For further clarification of these formats, see the sample input listing in Appendix B.

The Model operates continuously from the beginning to the end of the simulation period. To simplify input procedures and reduce computer storage requirements, the meteorologic data is input on a calendar year basis. Each block of meteorologic data indicated in Table 27 must contain all daily values for the portion of the calendar year to be simulated. Thus if the simulation period is July to February, the Model reads and stores all the daily meteorologic data for the July to December period. The Model then reads the precipitation data, on the 5 or 15 minute intervals, and performs the simulation day-by-day from July to December. When the month of December is completed, the Model reads the daily meteorologic data for January and February, and then continues stepping through the simulation period by reading the precipitation and performing the simulation day-by-day for the months of January and February. Thus the input data must be ordered on a calendar year basis to conform with the desired simulation period.

The major forms of Model output have been presented in Tables 20 through 25 with the discussion of the calibration and production modes of operation. Daily snowmelt output for calibration runs is presented in Table 32; the values are defined in Table 33. Prior to simulation, the ARM Model prints a heading which contains run information, input parameters, and initial storage values. Table 34 presents the heading for the hydrology, sediment, and pesticide parameters, while Table 35

Table 30. SAMPLE INPUT AND FORMAT FOR DAILY METEOROLOGIC DATA

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Day
EVAP73	18	74	60	29	13	266	131	103	19	41	90	68	1
EVAP73	18	90	170	29	13	70	163	96	63	69	72	68	2
EVAP73	18	60	43	30	14	65	140	53	189	97	48	47	3
EVAP73	0	61	43	60	4	70	156	162	124	104	48	52	4
EVAP73	35	61	43	112	202	171	145	34	115	117	114	47	5
EVAP73	28	82	71	15	99	8	185	122	24	138	54	42	6
EVAP73	28	121	4	15	100	72	87	65	161	124	12	31	7
EVAP73	28	69	41	15	34	70	145	105	92	90	0	57	8
EVAP73	28	7	35	15	135	37	62	130	145	117	78	36	9
EVAP73	28	20	20	15	210	108	185	36	218	159	72	10	10
EVAP73	28	21	20	16	202	68	175	139	185	76	60	57	11
EVAP73	28	21	21	16	219	142	133	162	145	34	48	36	12
EVAP73	28	16	123	113	145	132	185	4	99	110	48	57	13
EVAP73	28	54	123	113	176	90	154	72	211	117	54	36	14
EVAP73	27	46	132	113	192	156	246	208	125	76	24	36	15
EVAP73	33	47	103	113	222	121	140	115	158	83	24	104	16
EVAP73	19	45	61	1	171	160	89	123	191	90	60	73	17
EVAP73	41	45	61	88	173	70	58	92	139	110	120	47	18
EVAP73	41	46	61	88	159	72	80	72	112	117	66	57	19
EVAP73	54	46	61	88	72	161	46	130	119	104	24	73	20
EVAP73	54	81	112	88	103	84	168	205	73	83	48	104	21
EVAP73	55	83	44	88	198	149	129	178	79	83	36	109	22
EVAP73	118	101	104	88	154	183	136	143	132	83	66	99	23
EVAP73	32	45	87	13	232	62	141	122	152	77	36	83	24
EVAP73	24	46	87	13	153	262	71	112	112	71	30	10	25
EVAP73	24	46	87	19	114	109	65	136	92	65	48	42	26
EVAP73	24	28	72	332	90	126	27	52	33	59	24	68	27
EVAP73	25	60	86	58	152	59	43	170	66	53	78	36	28
EVAP73	25		50	58	3	137	148	37	79	48	54	16	29
EVAP73	91		31	58	153	213	155	249	165	69	204	47	30
EVAP73	17		31		198		103	38		14		68	31
7	14	20	26	32	38	44	50	56	62	68	74	80	

Month (column headings); Column Number (bottom row)

Notes:
1. Columns 1-7 are ignored. They can be used to identify the data.
2. All data is input in integer form.
3. Identical format for evaporation, wind, solar radiation, and dewpoint temperature.
4. For Max-Min air temperature data, the six spaces allowed for each daily value (above) are divided in half; the first three spaces contain the maximum temperature, and the second three spaces contain the minimum temperature. See listing in Appendix B.

Table 31. ARM MODEL PRECIPITATION INPUT DATA FORMAT

Column No.	Description and Format
1	Blank
2-7	Year, Month, Day (e.g. January 1, 1940 is 400101).
8	Card Number: each card represents a 3-hour period Card #1 Midnight to 3:00 AM #2 3:00 AM to 6:00 AM #3 6:00 AM to 9:00 AM . . . . . . #8 9:00 PM to Midnight All eight cards are required if rain occurred any time during the day. A card number of 9 signifies that no rain occurred during the entire day, and no other rainfall cards are required for that day.
9-80	Precipitation data (000's of millimeters (00's of inches)). 15-minute intervals: 6 column per each 15-minutes in the 3-hour period of each card. Number must be right justified, i.e. number must end in the 6th column for the 15-minute period. 5-minute intervals: 2 columns per each 5-minute interval, i.e. the 15-minute period still occupies 6 columns, but it is broken down into three 5-minute intervals.

Notes:

1. Appendix B contains a sample of input data.
2. At least one precipitation card is required for each day of simulation.
3. Blanks are interpreted as zeros by the Model: consequently, zeros do no need to be input.

Table 32. DAILY SNOWMELT OUTPUT
(Calibration Run, English Units)

DATE TIME FLOW(CFS-CMS) SEDIMENT (LBS-KG-KG/MIN-GM/L) PESTICIDE (GM-GM/MIN-PPM)
WATER SEDIMENT

SNOWMELT OUTPUT FOR DECEMBER 1

HOUR	PACK	DEPTH	SDEN	ALPFDO	CLDF	NEGMELT	LIQW	TX	RA	LW	PX	MELT	CONV	RAINM	CONDS	ICE
1	0.6	3.0	0.204	0.735	1.000	0.015	0.018	23.77	0.	-8.	0.0	0.0	0.0	0.0	0.0	0.4
2	0.6	3.0	0.204	0.734	1.000	0.017	0.018	22.61	0.	-8.	0.0	0.0	0.0	0.0	0.0	0.4
3	0.6	3.0	0.204	0.733	1.000	0.021	0.018	21.74	0.	-8.	0.0	0.0	0.0	0.0	0.0	0.4
4	0.6	3.0	0.205	0.732	1.000	0.023	0.018	21.16	0.	-8.	0.0	0.0	0.0	0.0	0.0	0.4
5	0.6	3.0	0.205	0.731	1.000	0.024	0.018	20.58	0.	-9.	0.0	0.0	0.0	0.0	0.0	0.4
6	0.6	3.0	0.205	0.730	1.000	0.025	0.018	20.00	0.	-9.	0.0	0.0	0.0	0.0	0.0	0.4
7	0.6	3.0	0.204	0.730	1.000	0.024	0.018	20.38	1.	-9.	0.0	0.0	0.0	0.0	0.0	0.4
8	0.6	3.0	0.204	0.729	1.000	0.022	0.018	21.52	2.	-8.	0.0	0.0	0.0	0.0	0.0	0.4
9	0.6	3.0	0.204	0.728	1.000	0.016	0.018	24.18	3.	-8.	0.0	0.0	0.0	0.0	0.0	0.4
10	0.6	3.0	0.204	0.727	1.000	0.009	0.018	27.60	4.	-7.	0.0	0.0	0.0	0.0	0.0	0.4
11	0.6	3.0	0.203	0.726	1.000	0.001	0.018	31.40	5.	-7.	0.0	0.0	0.0	0.0	0.0	0.4
12	0.6	3.0	0.202	0.725	1.000	0.001	0.018	34.63	5.	-6.	0.0	0.0	0.002	0.0	0.0	0.4
13	0.6	2.9	0.203	0.725	1.000	0.0	0.018	37.10	5.	-6.	0.0	0.003	0.005	0.0	0.0	0.4
14	0.6	2.9	0.204	0.724	1.000	0.0	0.018	38.24	5.	-5.	0.0	0.006	0.006	0.0	0.0	0.4
15	0.6	2.9	0.205	0.723	1.000	0.0	0.017	38.81	5.	-5.	0.0	0.007	0.007	0.0	0.0	0.4
16	0.6	2.9	0.206	0.722	1.000	0.0	0.017	39.00	5.	-5.	0.0	0.005	0.007	0.0	0.0	0.4
17	0.6	2.8	0.205	0.721	1.000	0.0	0.017	38.05	4.	-5.	0.0	0.002	0.006	0.0	0.0	0.4
18	0.6	2.8	0.204	0.721	1.000	0.0	0.017	36.72	3.	-6.	0.0	0.0	0.004	0.0	0.0	0.4
19	0.6	2.8	0.204	0.720	1.000	0.0	0.017	34.82	1.	-6.	0.0	0.0	0.002	0.0	0.0	0.4
20	0.6	2.8	0.203	0.719	1.000	0.0	0.017	32.35	0.	-7.	0.0	0.0	0.000	0.0	0.0	0.4
21	0.6	2.8	0.203	0.718	1.000	0.002	0.017	29.50	0.	-7.	0.0	0.0	0.0	0.0	0.0	0.4
22	0.6	2.8	0.202	0.717	1.000	0.005	0.017	27.03	0.	-7.	0.0	0.0	0.0	0.0	0.0	0.4
23	0.6	2.8	0.202	0.717	1.000	0.009	0.017	24.75	0.	-8.	0.0	0.0	0.0	0.0	0.0	0.4
24	0.6	2.8	0.202	0.716	1.000	0.014	0.017	23.23	0.	-8.	0.0	0.0	0.0	0.0	0.0	0.4

Table 33. DAILY SNOWMELT OUTPUT DEFINITIONS
(calibration run, English units)

HOUR:	Hour of the day, numbered 1 to 24
PACK:	Water equivalent of the snowpack, inches
DEPTH:	Snow depth, inches
SDEN:	Snow density in inches of water per inch of snow
ALBEDO:	Albedo, or snow reflectivity, percent
CLDF:	Fraction of sky that is cloudless
NEGMELT:	Heat loss from the snowpack, equivalent inches of melt
LIQW:	Liquid water content of the snowpack, inches
TX:	Hourly air temperature, degrees Fahrenheit
RA:	Incident solar radiation, langleys
LW:	Net terrestrial radiation, langleys (negative value indicates outgoing radiation from the pack)
PX:	Total snowmelt reaching the land surface, inches
MELT:	Total melt, inches
CONV:	Convection melt, inches
RAINM:	Rain melt, inches
CONDS:	Condensation melt, inches
ICE:	Ice formation at the land surface, inches

Table 34. ARM MODEL OUTPUT HEADING (Excluding Nutrients)

THIS IS A PRODUCTION RUN FOR PESTICIDES

WATERSHED: P-3 WATERSHED NEAR WATKINSVILLE, GEORGIA

CHEMICAL: PARAQUAT (1 LB/AC APPLIED ON DECEMBER 30)

INPUT UNITS: ENGLISH

OUTPUT UNITS: BOTH ENGLISH AND METRIC

PRINT INTERVAL: EACH DAY

SNOWMELT NOT PERFORMED

ADSORPTION AND DESORPTION ALGORITHMS USED

PESTICIDE APPLICATION: SURFACE-APPLIED

INTRVL= 5	HYMIN= 0.0010	AREA= 3.0800			
BGNDAY= 30	BGNMON= 12	BGNYR= 1973			
ENDDAY= 31	ENDMON= 12	ENDYR= 1973			

UZSN= 0.0500	UZS= 0.0020	LZSN= 18.0000	LZS= 19.3600		
L= 220.0000	SS= 0.0300	NN= 0.2000	A= 0.0	K3= 0.4000	EPXM= 0.1200
INFIL= 0.5000	INTER= 0.7000	IRC= 0.0	K24L= 1.0000	KK24= 0.6000	K24EL= 0.0
SGW= 0.0	GWS= 0.0	KV= 0.0	ICS= 0.0	OFS= 0.0	IFS= 0.0

Table 34. (Continued)

```
COVPMC= 0.60  0.70  0.70  0.70  0.0   0.0   0.20  0.60  0.85  0.80  0.70  0.30
TIMTIL=   0    0  142  155  165      YRTIL= 73   73   73   73   73      SRERTL=  2.000   2.000   2.000   2.000   1.000
SZDPTH=   0.0625       UZDPTH=   6.0625       BULKD= 103.0000
JRER=   2.2000         KRER=   0.0700         JSER=   1.8000         KSER=   0.3500         SRERI=   0.0

TIMAP=      364        YEARAP=       73       SSTR=   0.616    0.616    0.616    0.616    0.616
CMAX= 0.000010         CD= 0.000300           K= 120.0000            N=   2.0000            NP=    4.6000
DEGCON= 0.002000

HYCAL=PRED  INPUT=ENGL  OUTPUT=BOTH  PRINT=DAYS  SNOW=NO    PEST=YES   NUTR=NO    ICHECK=ON
APMODE=SURF  DESORP=YES
```

Table 35. NUTRIENT SIMULATION OUTPUT HEADING

```
THIS IS A PRODUCTION RUN FOR NUTRIENTS

          WATERSHED:        TEST INPUT SEQUENCE
          CHEMICAL:         NITROGEN, PHOSPHORUS, AND CHLORIDE
          INPUT UNITS:      ENGLISH
          OUTPUT UNITS:     ENGLISH
          PRINT INTERVAL: EACH DAY
          SNOWMELT NOT PERFORMED

INTRVL=  5          HYMIN=   0.0010       AREA=     6.6700
BGNDAY= 12          BGNMON=  6            BGNYR= 1973
ENDDAY= 13          ENDMON=  6            ENDYR= 1973

UZSN=   0.0500      UZS=    0.1000        LZSN=  18.0000     LZS=  20.3900
L= 160.0000         SS=    0.0500         NN=   0.2000       A=    0.0          K3=    0.4000      EPXM=    0.1200
INFIL=   0.5000     INTER=   0.7000       IRC=    0.0        K24L=   1.0000     KK24=   0.6000     K24EL=   0.0
SGW=   0.0          GWS=   0.0            KV=   0.0          ICS=   0.0         OFS=   0.0         IFS=   0.0

COVPMO= 1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00
TIMTIL=   0    0    0  155  164      YRTIL= 73  73  73  73  73      SRERTL=  5.000   5.000   5.000   5.000   2.000
SZDPTH=   0.1250    UZDPTH=   6.1250      BULKD= 103.0000
JRER=   2.2000      KRER=   0.1700        JSER=   1.8000     KSER=   1.2000      SRERI=   2.6300
```

Table 35. (Continued)

HYCAL=PROD INPUT=ENGL OUTPUT=ENGL PRINT=DAYS SNOW=NO PEST=NO NUTR=YES ICHECK=OFF

NUTRIENT SIMULATION INFORMATION

```
***************************************
*                                     *
*    WARNING: NUTRIENT ALGORITHMS     *
*    HAVE NOT BEEN VERIFIED WITH      *
*    OBSERVED DATA                    *
*                                     *
***************************************
```

TIME STEP FOR TRANSFORMATIONS = 60 MIN
NUMBER OF NUTRIENT APPLICATIONS = 1
DATE OF PLANT HARVESTING = 360

NITROGEN REACTION RATES	K1	K2	KK2	KD	KPL	KAM	KIM	KKIM	KSA	KAS
SURFACE	2.0000	4.0000	0.0	0.0	0.0360	0.0077	0.0	0.0	0.2000	1.0000
UPPER ZONE	2.0000	4.0000	0.0	0.0	0.0360	0.0077	0.0	0.0	0.2000	1.0000
LOWER ZONE	2.0000	4.0000	0.0	0.0	0.0360	0.0077	0.0	0.0	0.2000	1.0000
GROUNDWATER	2.0000	4.0000	0.0	0.0	0.0360	0.0077	0.0	0.0	0.2000	1.0000
TEMPERATURE COEF.	1.050	1.050	1.050	1.050	1.050	1.050	1.050	1.050	1.050	1.050

PHOSPHORUS REACTION RATES	KM	KIM	KPL	KSA	KAS
SURFACE	0.0077	0.0	0.0180	2.0000	0.1000
UPPER ZONE	0.0077	0.0	0.0180	2.0000	0.1000
LOWER ZONE	0.0077	0.0	0.0180	2.0000	0.1000
GROUNDWATER	0.0077	0.0	0.0180	2.0000	0.1000
TEMPERATURE COEF.	1.050	1.050	1.050	1.050	1.050

NUTRIENTS - LB/AC INITIAL STORAGES	ORG-N	NH3-S	NH3-A	NO2	NO3	N2	PLNT-N	ORG-P	PO4-S	PO4-A	PLNT-P	CL
SURFACE LAYER												
AVERAGE	24.	0.0	1.000	0.0	0.0	0.0	0.0	5.	0.0	0.200	0.0	0.0
BLOCK 1	24.	0.0	1.000	0.0	0.0	0.0	0.0	5.	0.0	0.200	0.0	0.0
BLOCK 2	24.	0.0	1.000	0.0	0.0	0.0	0.0	5.	0.0	0.200	0.0	0.0
BLOCK 3	24.	0.0	1.000	0.0	0.0	0.0	0.0	5.	0.0	0.200	0.0	0.0
BLOCK 4	24.	0.0	1.000	0.0	0.0	0.0	0.0	5.	0.0	0.200	0.0	0.0
BLOCK 5	24.	0.0	1.000	0.0	0.0	0.0	0.0	5.	0.0	0.200	0.0	0.0

Table 35. (Continued)

UPPER ZONE												
AVERAGE	1144.	0.0	48.000	0.0	0.0	0.0	0.0	228.	0.0	9.600	0.0	0.0
BLOCK 1	1144.	0.0	48.000	0.0	0.0	0.0	0.0	228.	0.0	9.600	0.0	0.0
BLOCK 2	1144.	0.0	48.000	0.0	0.0	0.0	0.0	228.	0.0	9.600	0.0	0.0
BLOCK 3	1144.	0.0	48.000	0.0	0.0	0.0	0.0	228.	0.0	9.600	0.0	0.0
BLOCK 4	1144.	0.0	48.000	0.0	0.0	0.0	0.0	228.	0.0	9.600	0.0	0.0
BLOCK 5	1144.	0.0	48.000	0.0	0.0	0.0	0.0	228.	0.0	9.600	0.0	0.0
LOWER ZONE												
STORAGE	11250.	0.0	480.000	0.0	0.0	0.0	0.0	2275.	0.0	96.000	0.0	0.0
GROUNDWATER												
STORAGE	0.	0.0	0.0	0.0	0.0	0.0	0.0	0.	0.0	0.0	0.0	0.0

TOTAL NITROGEN IN SYSTEM = 12947.000 LB/AC
TOTAL PHOSPHORUS IN SYSTEM = 2613.600 LB/AC
TOTAL CHLORIDE IN SYSTEM = 0.0 LB/AC

NUTRIENTS - LB/AC	ORG-N	NH3-S	NH3-A	NO2	NO3	N2	PLNT-N	ORG-P	PO4-S	PO4-A	PLNT-P	CL
APPLICATION FOR DAY 164												
SURFACE LAYER												
AVERAGE	0.	0.0	4.000	0.0	0.0	0.0	0.0	0.	0.0	0.400	0.0	2.000
BLOCK 1	0.	0.0	4.000	0.0	0.0	0.0	0.0	0.	0.0	0.400	0.0	2.000
BLOCK 2	0.	0.0	4.000	0.0	0.0	0.0	0.0	0.	0.0	0.400	0.0	2.000
BLOCK 3	0.	0.0	4.000	0.0	0.0	0.0	0.0	0.	0.0	0.400	0.0	2.000
BLOCK 4	0.	0.0	4.000	0.0	0.0	0.0	0.0	0.	0.0	0.400	0.0	2.000
BLOCK 5	0.	0.0	4.000	0.0	0.0	0.0	0.0	0.	0.0	0.400	0.0	2.000
UPPER ZONE												
AVERAGE	0.	0.0	196.000	0.0	0.0	0.0	0.0	0.	0.0	19.600	0.0	98.000
BLOCK 1	0.	0.0	196.000	0.0	0.0	0.0	0.0	0.	0.0	19.600	0.0	98.000
BLOCK 2	0.	0.0	196.000	0.0	0.0	0.0	0.0	0.	0.0	19.600	0.0	98.000
BLOCK 3	0.	0.0	196.000	0.0	0.0	0.0	0.0	0.	0.0	19.600	0.0	98.000
BLOCK 4	0.	0.0	196.000	0.0	0.0	0.0	0.0	0.	0.0	19.600	0.0	98.000
BLOCK 5	0.	0.0	196.000	0.0	0.0	0.0	0.0	0.	0.0	19.600	0.0	98.000

presents the heading for the nutrient parameters. The control parameter OUTPUT allows the user to specify Model output for the production mode in English (OUTPUT = ENGL) or Metric (OUTPUT = METR) units, or both (OUTPUT = BOTH). The option for output in both sets of units should be used sparingly due to the vast amount of computer printout which results. The calibration mode output for storm events is provided in a mixed set of units (see Tables 22, 23, and 24) to simplify comparison of simulated and recorded values in the calibration process.

PARAMETER EVALUATION AND CALIBRATION

The process of applying the ARM Model to a watershed requires a fitting or calibration of the Model parameters to the specific watershed. The large majority of the parameters are easily determined from topographic maps, watershed and soil characteristics, or pesticide chemical properties. Hydrology and sediment parameters which cannot be deterministically evaluated must then be evaluated through the calibration process as a result of comparison of simulated and recorded results. The following discussion provides guidelines for estimating the ARM Model parameters relating to hydrology, snowmelt, sediment, and pesticide simulation. Nutrient parameters are excluded due to lack of testing and experience with the nutrient model. In addition, the parameters included below are limited to those which are not self-explanatory by their definitions in Table 19. A complete list of the P1 and P3 watershed parameters is provided in Table 36.

Table 36. P1 and P3 WATERSHED PARAMETERS

Parameter	P1 Watershed	P3 Watershed
Hydrology		
UZSN	0.05	0.05
LZSN	18.0	18.0
L	160.0	220.0
SS	0.05	0.03
NN	0.20	0.20
A	0.0	0.0
K3	0.40	0.40
EPXM	0.12	0.12
INFIL	0.50	0.50
INTER	0.70	0.70
IRC	0.0	0.0
K24L	1.0	1.0
KK24	0.6	0.6
K24EL	0.0	0.0
KV	0.0	0.0
Sediment		
COVPMO		
January	0.30	0.60
February	0.30	0.70
March	0.30	0.70
April	0.30	0.70
May	0.0	0.0
June	0.0	0.0
July	0.0	0.20
August	0.25	0.60
September	0.50	0.85
October	0.70	0.70
November	0.70	0.70
December	0.60	0.30
TIMTIL, YRTIL, SRERTL		
	0, 73, 0.0	0, 73, 0.0
	0, 73, 0.0	0, 73, 0.0
	142, 73, 5.0	142, 73, 2.0
	155, 73, 5.0	155, 73, 2.0
	164, 73, 2.0	166, 73, 1.0
BULKD	103.0	103.0
JRER	2.20	2.20
KRER	0.17	0.07
JSER	1.80	1.80
KSER	1.20	0.35

Table 36.(continued)

<u>Pesticide</u>		
TIMAP	164	166
YEARAP	73	73
AREA	6.67	3.08
<u>Pesticide-Diphenamid</u>		
SSTR	5*4.002	1.848
CMAX	0.00026	0.00026
DD	0.0	0.0
K	1.8	1.8
N	1.6	1.6
NP	3.7	3.7
DEGCON	0.08	0.08
APMODE	SURF	SURF
SZDPTH	0.125	0.125
UZDPTH	6.125	6.125
<u>Pesticide Paraquat</u>		
SSTR	5*1.340	5*0.616
CMAX	0.00001	0.00001
DD	0.0003	0.0003
K	120.0	120.0
N	2.0	2.0
NP	4.6	4.6
DEGCON	0.002	0.002
APMODE	SURF	SURF
SZDPTH	0.0625	0.0625
UZDPTH	6.0625	6.0625
<u>Initial Conditions</u> (January 1, 1973)		
UZS	0.02	0.2
LZS	19.51	18.0
SGW	0.0	0.0
GWS	0.0	0.0
ICS	0.0	0.0
OFS	0.0	0.0
IFS	0.0	0.0
SRERI	1.8	0.3

HYDROLOGY PARAMETERS

A: A is the fraction representing the impervious area in the watershed. Usually A will be negligible for agricultural watersheds, except in cases of extensive outcrops along channel reaches.

EPXM: This interception storage parameter is a function of cover density.

Grassland	0.10 in.
Forest cover (light)	0.15 in.
Forest cover (heavy)	0.20 in.

UZSN: The nominal storage in the upper zone is generally related to LZSN and watershed topography. However, agriculturally managed watersheds may deviate significantly from the following guidelines:

Low depression storage, steep slopes, limited vegetation	0.06xLZSN
Moderate depression storage slopes and vegetation	0.08xLZSN
High depression storage, soil fissures, flat slopes, heavy vegetation	0.14xLZSN

LZSN: The nominal lower zone soil moisture storage parameter is related to the annual cycle of rainfall and evapotranspiration. Approximate values range from 5.0 to 20.0 inches for most of the continental United States depending on soil properties. The proper value will need to be checked by computer trials.

K3: Index to actual evaporation. Values range from 0.25 for open land and grassland to 0.7-0.9 for heavy forest. The area covered by forest or deep rooted vegetation as a fraction of total watershed area is an estimate of K3.

K24L, K24EL: These parameters control the loss of water from near surface or active groundwater storage to deep percolation and transpiration respectively. K24L is the fraction of the groundwater recharge that percolates to deep groundwater table. Thus a value of 1.0 for K24L would preclude any groundwater contribution to surface runoff. K24EL is the fraction of watershed area where shallow water tables put groundwater within reach of vegetation.

INFIL: This parameter is an index to the mean infiltration rate on the watershed and is generally a function of soil characteristics. As for LZSN, approximate or initial values will need to be checked by computer trials. INFIL can range from 0.01 to 1.0 in/hr depending on the cohesiveness and permeability of the soil.

INTER: This parameter refers to the interflow component of runoff and generally alters runoff timing. It is closely related to INFIL and LZSN and values generally range from 0.5 to 5.0. Examples of its effect are discussed below and in Section IX, Sensitivity Analysis.

L: Length of overland flow is obtained from topographic maps and approximates the length of travel to a stream channel. Its value can be approximated by dividing the watershed area by twice the length of the drainage path or channel.

SS: Average overland flow slope is also obtained from topographic maps. The average slope can be estimated by superimposing a grid pattern on the watershed, estimating the land slope at each point of the grid, and obtaining the average of all values measured.

NN: Manning's n for overland flow. Approximate values are:

Asphalt	0.014
Packed Clay	0.03
Turf	0.25
Heavy Turf and Forest Litter	0.35

IRC,
KK24: These parameters are the interflow and groundwater recession rates. They can be estimated graphically (51) or found by trial from simulation runs. Since these parameters are defined below on a daily basis, they are generally close to 0.0 for small watersheds that only experience runoff during or immediately following storm events.

$$\text{IRC} = \frac{\text{Interflow discharge on any day}}{\text{Interflow discharge 24 hours earlier}}$$

$$\text{KK24} = \frac{\text{Groundwater discharge on any day}}{\text{Groundwater discharge 24 hours earlier}}$$

KV: The parameter KV is used to allow a variable recession rate for groundwater discharge. If KV = 1.0 the effective recession rate for different levels of KK24 and the variable groundwater slope parameter GWS is as follows:

		GWS		
KK24	0.0	0.5	1.0	2.0
0.99	0.99	0.985	0.98	0.97
0.98	0.98	0.97	0.96	0.94
0.97	0.97	0.955	0.94	0.91
0.96	0.96	0.94	0.92	0.88

For small watersheds without a groundwater flow component, a value of 0.0 is generally used.

SNOWMELT PARAMETERS

RADCON, CCFAC: These parameters adjust the 'theoretical melt' equations for solar radiation and condensation/convection melt to actual field conditions. Values near 1.0 are to be expected. RADCON is sensitive to watershed slopes and exposure.

SCF: The snow correction factor is used to compensate for catch deficiency in rain gages when precipitation occurs as snow. Px(SCF-1.0) is the added catch. Values are generally greater than 1.0.

ELDIF: This parameter is the elevation difference from the temperature station to mean elevation in the watershed in thousands of feet (or kilometers). It is used to correct the observed air temperatures for the watershed using a lapse rate of 3 degrees F per 1,000 feet elevation gain.

IDNS: This parameter is the density of new snow at 0 degrees F. The expected values are from 0.10 to 0.20. Equation 15 gives a variation in snow density with temperature.

F: This parameter is the fraction of the watershed that has complete forest cover. Areal photographs are the best basis for estimates.

DGM: DGM is the daily groundmelt. Values of 0.01 in/day or less are usual.

WC: This parameter is the maximum water content of the snowpack by weight. Experimental values range from 0.01 to 0.05.

MPACK: The estimated water equivalent of the snowpack for complete areal coverage in a watershed.

EVAPSN: Adjusts the amounts of snow evaporation given by an analytic equation. Values near 0.1 are expected.

MELEV: The mean elevation of each watershed segment in feet (meters).

TSNOW: Temperature below which snow is assumed to occur. Values of 31 degrees to 33 degrees F are often used.

PETMIN, PETMAX: These parameters allow a reduction in potential evapotranspiration for air temperatures near or below 32 degrees F. PETMIN specifies the air temperature below which potential evapotranspiration is zero. For air temperature between PETMIN and PETMAX, potential evapotranspiration is reduced by 50 percent while no reduction is performed for temperatures above PETMAX. Values of 35 degrees F and 40 degrees F have been used for PETMIN and PETMAX, respectively.

PETMUL, WMUL, RMUL: These three parameters are used to adjust input potential evapotranspiration, wind movement, and solar radiation, respectively, for expected conditions on the watershed. Values of 1.0 are used if the input meteorologic data is observed on or near the watershed to be simulated.

KUGI: KUGI is an integer index to forest density and undergrowth for the reduction of wind in forested areas. Values range from 0 to 10; for KUGI = 0, wind in the forested area is 35 percent of the input wind value, and for KUGI = 10 the corresponding value is 5 percent. For medium undergrowth and forest density a value of 5 is generally used.

SEDIMENT PARAMETERS

JRER: JRER is the exponent in the soil splash equation (Equation 1) and thus approximates the relationship between rainfall intensity and incident energy to the land surface for the production of soil fines. Values in the range of 2.0 to 3.0 have demonstrated reasonable results on the limited number of watersheds tested. (A value of 2.2 was chosen for the Georgia watersheds.)

KRER: This parameter is the coefficient of the soil splash equation and is related to the erodibility or detachability of the specific soil type. KRER is directly related to the 'K' factor in the Universal Soil Loss Equation (52). Initial estimation of KRER can be performed in the same manner as the evaluation of the K factor (52, 53). However, this initial value will need to be checked through calibration trials.

JSER: JSER is the exponent in the sediment washoff, or transport, equation (Equation 5), and thus approximates the relationship between overland flow intensity and sediment transport capacity. Values in the range of 1.0 to 2.5 have been used on the limited number of watersheds tested to date. (A value of 1.8 was chosen for the Georgia watersheds).

KSER: This parameter is the coefficient in the sediment washoff, or transport, equation. It is an attempt to combine the effects of (1) slope, (2) overland flow length, (3) sediment particle size, and (4) surface roughness on sediment transport capacity of overland flow into a single calibration parameter. Consequently, at the present time calibration is the major method of evaluating KSER. Terracing, tillage practices, and other agricultural management techniques will have a significant effect on KSER. Limited experience to date has indicated a possible range of values of 0.01 to 5.0. However, significant variations from this can be expected. (The values determined on the P1 and P3 Georgia watersheds were 1.2 and 0.35, respectively.)

SRERI, SRERTL: These parameters indicate the amount of detached soil fines on the land surface at the beginning of the simulation period (SRERI) and the amount produced by tillage operations (SRERTL). Very little research or experience relates to the estimation of these parameters. Thus, calibration is the method of evaluation. For SRERI, one would expect that spring and summer periods on agricultural watersheds would require higher values than fall and winter periods due to the growing season disturbances and activities on the watershed. Values of SRERTL are related to the severity or depth of the tillage operation, and must be input to correspond with the dates of tillage operations (TIMTIL, YRTIL). Values of these parameters on the Georgia watersheds have ranged from 0.5 to 5.0 tons/ac.

COVPMO: This parameter is the percent land cover on the watershed, and is used to decrease the fraction of the land surface that is susceptible to soil fines detachment by raindrop impact. Twelve monthly values for the first day of each month are input to the Model, and the cover on any day is determined by linear interpolation. COVPMO values can be evaluated as one minus the C factor in the Universal Soil Loss Equation, i.e. COVPMO = 1 - C, when C is a monthly value. Evaluation methods for the C factor have been published in the literature (52, 54).

PESTICIDE PARAMETERS

DD, K, N, NP: These parameters define the adsorption/desorption functions used in the present version of the ARM Model. Their values must be determined for each pesticide-soil combination from laboratory experiments or from published research results.

CMAX: CMAX is the water solubility of the specific pesticide being simulated. Literature values are generally used, and no temperature correction is performed. As indicated in Section IX, simulation results are relatively insensitive to CMAX.

DEGCON: This parameter defines the daily first-order general attenuation, or degradation, rate for the pesticide. Values can be derived from observed field measurements or from the literature.

SZDPTH, UZDPTH: Although these parameters specify the depth of the vertical soil layers, their major impact is on pesticide simulation. Very little experience exists for evaluation of these depths. UZDPTH is generally evaluated as the depth of tillage or pesticide soil incorporation while SZDPTH is the depth of the active surface zone. UZDPTH must be greater than SZDPTH. Expected ranges for these parameters would be 2.0 to 6.0 inches for UZDPTH and 1/16 to 1/4 inches for SZDPTH.

BULKD: This soil parameter also has a major impact on pesticide simulation. BULKD, the soil bulk density, can be evaluated in the laboratory or from the literature.

CALIBRATION

Calibration is an iterative procedure of parameter evaluation and refinement as a result of comparing simulated and observed values of interest. It is required for parameters that cannot be deterministically evaluated from topographic, climatic, edaphic, or physical/chemical characteristics. Fortunately, the large majority of the ARM Model parameters do not fall in this category. At the present time, calibration of the ARM Model generally involves only hydrolgy and sediment parameters. As indicated in Section VIII, the goal of pesticide transport modeling is to develop a model which can be used in various regions of the country with pesticide parameters evaluated from laboratory experiements or from the literature. If calibration is required for determining pesticide parameters, then recorded pesticide data would be required for each watershed simulated. This would limit application to few watersheds across the country. Although future developments may require calibration of pesticide parameters, the goal of the ARM Model development at present is to limit calibration to hydrology and sediment parameters for which data is more generally available.

Hydrology calibration must preceed sediment calibration since surface runoff is the transport mechanism by which sediment loss occurs. The procedure is to compare simulated and recorded monthly runoff volumes (as indicated in Section VIII for the P1 and P3 watersheds) obtained from initial parameter values. Calibration trials should not be performed for periods of less than 9 months to avoid the effects of initial soil moisture conditions. The hydrology parameters LZSN, INFIL, and INTER are the ones most directly evaluated by calibration; for managed, or disturbed watersheds UZSN is often included in this list. LZSN and INFIL have the greatest effect on runoff volumes and thus are most often modified to increase agreement between simulated and recorded monthly runoff volumes. When monthly values are in reasonable agreement, the INTER parameter is often used to modify hydrograph shape to improve simulation of storm hydrographs. Minor adjustments to INFIL and UZSN (in the case of small agricultural watersheds) can also be employed to improve storm hydrograph simulation. Thus, hydrologic calibration involves comparison and parameter modification for the simulation of both monthly runoff volumes and storm hydrographs. The sensitivity analysis in Section IX indicates the relative effects of parameter changes as an aid to calibration. A detailed discussion of the hydrologic calibration process is available to the interested user in other publications.[1, 2, 3]

Sediment parameter calibration is more uncertain than hydrologic calibration due to less experience with sediment simulation in different regions of the country. The process is analogous; the major sediment parameters are modified to increase agreement between simulated and recorded monthly sediment loss and storm event sediment removal. A balance between the generation of detached soil fines and the transport, or removal, of soil particles must be developed so that the storage of detached fines is not continually increasing or decreasing throughout the calibration period. The KRER and KSER parameters are most directly involved in sediment calibration and the development of this sediment balance since they are relatively less well defined by theoretical and physical considerations. Thus a balance must be established between the KRER and KSER parameters in the agreement of simulated and recorded monthly sediment loss. The SRERTL parameter has a major effect on sediment simulation on agricultural watersheds since it specifies the amount of detached soil fines produced by tillage operations. The soil fines are then available for transport by overland flow from the watershed. The value of SRERTL is also instrumental in the balance between soil fines generation and transport. Storms occurring soon after tillage operations would likely transport sediment at or near the transport capacity of the overland flow, while storms occurring later in the growing season would have sediment loss limited by the amount of fines available for transport. SRERTL should be large enough to have a major impact on sediment loss by storms soon after tillage, but small enough to have a minor effect on sediment loss late in the growing season. As an aid to calibration, an asterisk is printed in the ARM Model sediment calibration output (see Table 22) whenever sediment removal is limited in each areal zone (or block) by the availability of soil fines. Thus when asterisks are printed, sediment removal is being controlled by the generation and availability of soil fines. Whereas, when no asterisks are printed, the washoff or transport mechanism is the major controlling factor. When the washoff mechanism is controlling, the JSER parameter can be modified to improve the shape of the simulated sediment removal graph. In a similar manner, the JRER parameter will affect the sediment removal graph when the generation and availability of detached soil fines is controlling sediment removal.

In summary, the calibration process requires an understanding of the physical process being simulated and of the impact of the critical ARM Model calibration parameters. Study of the parameter definitions, algorithm formulation, and sensitivity analyses results presented in this report should allow the user to become reasonably effective in calibrating and applying the ARM Model.

APPENDIX B

ARM Model Sample Input Listing

```
//CCB7508 JCB (C510,510,1,30),'J7508BEYERLEIN'
//JOBLIB DD CSNAME=C510.CCB.J75C8.ARM,DISP=(OLD,KEEP),
//         UNIT=2314,VOL=SER=FILEC
//STEP1 EXEC PGM=ARM
//SYSPRINT CC SYSOUT=A
//FT06FC01 CC SYSCUT=A
//FT05FCC1 CD *
SAMPLE INPUT FCR HYPCTHETICAL WATERSHED
CATA SET UP FCR SNCW, PESTICICE, AND NUTRIENTS
HYCAL=PRCD
INPUT=ENGL
CUTPUT=ENGL
PRINT=CAYS
SNCW=YES
PEST=YES
NUTR=YES
ICHECK=CN
 &CNTL  INTRVL=5, HYMIN=0.0C1, AREA=3.08  &END
 &STRT  BGNCAY=20, BGNMCN=12,  BGNYR=1973  &END
 &ENDD  ENDCAY=24, ENDMCN=2, ENCYR=1974   &END
 &LND1  UZSN=0.C5, UZS=0.002, LZSN=18.0, LZS=19.36  &END
 &LND2  L=220., SS=0.03, NN=0.20, A=0.00, K3=0.40, EPXM=0.12  &END
 &LND3  INFIL=C.50, INTER=0.7, IFC=0.0, K24L=1.0, KK24=0.6, K24EL=0.0  &END
 &LND4  SGW=0.0, GWS=0.C, KV=C.C, ICS=0.0, OFS=0.0, IFS=0.0  &END
 &SNO1  RADCCN=1.0,CCFAC=1.0,SCF=1.0,ELDIF=0.0,IDNS=0.14,F=0.0  &END
 &SNO2  DGM=0.C,WC=0.03,MPACK=1.0,EVAPSN=1.0,MELEV=0.0,TSNOW=32.0  &END
 &SNO3  PACK=C.C, DEPTH=0.0  &ENC
 &SNO4  PETMIN=4C.0,PETMAX=5C.0,PETMUL=1.0,WMUL=1.0,RMUL=1.0,KUGI=0.0  &END
 &CROP  CCVFMO=C.6,0.7,C.7,C.7,C.C,C.0,0.2,0.6,0.85,0.8,0.7,0.3 &END
 &MUD1  TIMTIL=C,0,142,155,166,
        YRTIL=5*73,        SPERTL=2.0,2.0,2.0,2.0,1.0  &END
 &CIRT  SZDPTH=C.0625, LZCPTH=6.C625, BULKD=103.0  &END
 &SMDL  JRER=2.2, KRER=C.07, JSER=1.8, KSER=0.35, SRERI=0.0  &END
PESTICICE
APMODE=SURF
DESORP=YES
 &APDL  SSTR=5*C.616, TIMAP=364, YEARAP=73, CMAX=0.00001,
        DC=C.CC03, K=120., N=2.C, NP=4.6  &END
 &CEG1  DEGCCN=C.0020  &ENC
NUTRIENT
 &NUTRIN   TSTEP=60,  NAPPL=1, TIMHAR=34,    &END

REACTICN RATES
NITROGEN
SURFACE
     2.0    4.C    0.0    C.C   .0360   .0077   0.0    0.0    0.2    1.0
UPPER ZCNE
     2.0    4.0    0.0    C.C   .0360   .0077   0.0    0.0    0.2    1.0
LCWER ZCNE
     2.0    4.0    0.0    C.C   .0360   .0077   0.0    0.0    0.2    1.0
GRCUNCWATER
     2.0    4.C    0.0    C.C   .0360   .0077   0.0    0.0    0.2    1.0
TEMPERATURE CCEFFICIENTS
    1.C5   1.C5   1.C5   1.C5   1.05   1.05   1.05   1.05   1.05   1.05

 PHCSPHCRUS
 SURFACE
   .0077    0.C    .018    2.C    0.1
 UPPER ZCNE
```

```
   .0077      0.0      .018      2.0      0.1
LOWER ZONE
   .0077      0.0      .018      2.0      0.1
GROUNDWATER
   .0077      0.0      .018      2.0      0.1
TEMPERATURE COEFFICIENTS
    1.05     1.05      1.05     1.05     1.05
END

INITIAL
NITROGEN
SURFACE
     24.      0.0      1.0       0.0      0.0      0.0      0.0
UPPER ZONE
   1144.      0.0      48.       0.0      0.0      0.0      0.0
LOWER ZONE
  11250.      0.0     480.       0.0      0.0      0.0      0.0
GROUNDWATER
     0.0      0.0      0.0       0.0      0.0      0.0      0.0

PHOSPHORUS
SURFACE
     4.8      0.0      0.2       0.0
UPPER ZONE
    228.      0.0      9.6       0.0
LOWER ZONE
   2275.      0.0      96.       0.0
GROUNDWATER
     0.0      0.0      0.0       0.0

CHLORIDE
SURFACE
     0.0
UPPER ZONE
     0.0
LOWER ZONE
     0.0
GROUNDWATER
     0.0
END


APPLICATION   364
NITROGEN
SURFACE
     0.0      0.0      4.0       0.0      0.0      0.0      0.0
UPPER ZONE
     0.0      0.0    196.0       0.0      0.0      0.0      0.0

PHOSPHORUS
SURFACE
     0.0      0.0      0.4       0.0
UPPER ZONE
     0.0      0.0     19.6       0.0

CHLORIDE
SURFACE
     2.0
UPPER ZONE
    98.0
```

Appendix B (continued)

ENC

EVAP73	18	74	60	29	13	266	131	103	19	41	90	68
EVAP73	18	90	170	29	13	70	163	96	63	69	72	68
EVAP73	18	60	43	30	14	65	140	53	189	97	48	47
EVAP73	0	61	43	60	4	70	156	162	124	104	48	52
EVAP73	35	61	43	112	202	171	145	34	115	117	114	47
EVAP73	28	82	71	15	99	8	185	122	24	138	54	42
EVAP73	28	121	4	15	100	72	87	65	161	124	12	31
EVAP73	28	69	41	15	34	70	145	105	92	90	0	57
EVAP73	28	7	35	15	135	37	62	130	145	117	78	36
EVAP73	28	20	20	15	210	108	185	36	218	159	72	10
EVAP73	28	21	20	16	202	68	175	139	185	76	60	57
EVAP73	28	21	21	16	219	142	133	162	145	34	48	36
EVAP73	28	16	123	113	145	132	185	4	99	110	48	57
EVAP73	28	54	123	113	176	90	154	72	211	117	54	36
EVAP73	27	46	132	113	192	156	246	208	125	76	24	36
EVAP73	33	47	103	113	222	121	140	115	158	83	24	104
EVAP73	19	45	61	1	171	160	89	123	191	90	60	73
EVAP73	41	45	61	88	173	70	58	92	139	110	120	47
EVAP73	41	46	61	88	159	72	80	72	112	117	66	57
EVAP73	54	46	61	88	72	161	46	130	119	104	24	73
EVAP73	54	81	112	88	103	84	168	205	73	83	48	104
EVAP73	55	83	44	88	198	149	129	178	79	83	36	109
EVAP73	118	101	104	88	154	183	136	143	132	83	66	99
EVAP73	32	45	87	13	232	62	141	122	152	77	36	83
EVAP73	24	46	87	13	153	262	71	112	112	71	30	10
EVAP73	24	46	87	19	114	109	65	136	92	65	48	42
EVAP73	24	28	72	232	90	126	27	52	33	59	24	68
EVAP73	25	60	86	58	152	59	43	170	66	53	78	36
EVAP73	25		50	58	3	137	148	37	79	48	54	16
EVAP73	91		31	58	153	213	155	249	165	69	204	47
EVAP73	17		31		198		103	38		14		68

TEMP73	72	53	78	57	84	58	78	65	90	70	71	45	50	31	39	20
TEMP73	72	49	82	55	87	64	78	57	92	63	71	53	48	29	46	20
TEMP73	63	36	61	58	83	65	60	57	93	64	70	57	46	22	57	38
TEMP73	55	34	80	65	79	60	82	56	90	69	70	51	42	20	55	40
TEMP73	62	31	80	62	79	60	85	60	88	64	67	43	41	17	55	33
TEMP73	66	37	79	63	84	55	85	65	82	56	67	36	37	14	33	24
TEMP73	70	53	77	57	88	65	65	64	77	52	67	58	39	14	31	26
TEMP73	69	53	83	63	88	69	90	69	75	44	77	53	42	22	37	20
TEMP73	74	50	83	68	89	67	89	69	74	55	78	51	34	15	37	20
TEMP73	73	52	89	56	89	65	82	67	76	46	78	51	40	18	34	23
TEMP73	67	46	90	75	83	53	64	62	76	61	79	51	39	16	31	21
TEMP73	61	42	90	68	80	52	84	58	73	44	77	57	54	25	34	15
TEMP73	52	39	83	55	92	71	82	56	74	45	77	56	60	35	34	24
TEMP73	55	34	82	51	92	62	61	59	75	52	68	45	63	34	33	9
TEMP73	59	35	85	59	76	55	79	56	74	48	67	53	55	30	22	13
TEMP73	49	46	84	69	78	51	82	52	69	46	62	39	33	19	20	10
TEMP73	55	32	72	59	81	51	82	58	60	42	60	37	44	19	17	3
TEMP73	65	28	74	60	85	55	83	55	65	39	53	41	47	24	26	6
TEMP73	66	47	83	64	86	64	83	60	65	42	64	32	47	29	20	15
TEMP73	67	40	81	60	86	69	82	65	63	45	78	42	51	25	25	18
TEMP73	72	41	80	60	74	63	72	52	63	36	64	34	57	34	23	5
TEMP73	72	49	79	57	82	59	72	48	75	46	69	36	58	22	22	8
TEMP73	62	55	75	54	83	59	71	54	74	63	73	34	53	24	28	19
TEMP73	73	44	76	55	83	62	78	58	72	70	73	43	60	23	29	15
TEMP73	71	51	81	54	88	67	84	55	83	47	72	42	59	27	43	27
TEMP73	67	49	81	65	88	71	91	67	83	55	63	43	44	27	45	32
TEMP73	65	50	81	62	82	64	95	74	83	55	59	37	50	32	35	34
TEMP73	75	55	81	60	82	63	94	73	77	43	55	35	47	27	34	27

Appendix B (continued)

TEMP73	59	52	68	57	79	55	92	69	65	47	55	22	39	19	36	22
TEMP73	57	45	72	55	81	60	89	68	65	47	51	36	49	24	24	16
TEMP73	74	42			81	65	89	65			51	36			69	12
WIND73		112		135		54		34		47		95		80		120
WIND73		126		65		55		69		50		30		80		110
WIND73		209		100		44		52		35		10		120		25
WIND73		195		63		81		33		57		100		40		195
WIND73		97		67		39		57		52		100		90		110
WIND73		103		33		46		49		116		49		220		250
WIND73		90		70		60		59		90		26		50		50
WIND73		134		81		75		65		40		40		190		50
WIND73		126		113		65		62		23		55		160		0
WIND73		103		95		60		65		57		60		120		200
WIND73		147		100		90		60		126		70		50		50
WIND73		134		70		42		67		94		100		120		160
WIND73		80		85		118		21		30		80		80		190
WIND73		40		35		100		41		63		150		120		100
WIND73		65		60		60		46		64		90		110		100
WIND73		125		50		40		34		88		78		130		100
WIND73		110		109		30		32		73		12		20		100
WIND73		39		49		30		16		102		110		50		50
WIND73		49		89		52		38		74		70		30		200
WIND73		49		61		41		100		124		80		60		100
WIND73		45		72		77		109		48		10		210		140
WIND73		27		80		80		48		147		35		140		110
WIND73		71		70		80		13		101		35		10		100
WIND73		29		60		60		17		60		50		100		150
WIND73		53		58		35		40		140		100		140		250
WIND73		40		75		55		40		60		100		150		100
WIND73		80		67		98		79		62		50		110		150
WIND73		80		91		137		74		78		110		80		200
WIND73		23		91		71		50		5		92		220		200
WIND73		45		48		62		34		110		178		190		230
WIND73		72				42		49		95		80				30
RADI73														193		175
RADI73														186		165
RADI73														247		175
RADI73														149		75
RADI73														160		75
RADI73														274		125
RADI73														107		72
RADI73														178		80
RADI73														155		67
RADI73														195		85
RADI73														67		117
RADI73														112		161
RADI73														79		29
RADI73														169		166
RADI73														24		152
RADI73														115		193
RADI73														198		215
RADI73														67		118
RADI73														44		75
RADI73														125		88
RADI73														35		183
RADI73														178		104
RADI73														164		100
RADI73														25		133
RADI73														35		32
RADI73														21		56

Appendix B (continued)

RACI73											47	48
RACI73											47	81
RADI73											1C2	68
RACI73											161	102
RADI73												175
CEWPT73	C	0	C	0	61	61	63	66	75	61	34	22
CEWPT73	0	0	0	0	52	62	68	63	68	59	39	36
CEWPT73	0	0	0	C	33	68	67	56	71	57	31	47
CEWPT73	C	0	0	C	39	67	60	61	66	63	30	49
CEWPT73	0	0	0	0	38	63	59	70	63	43	30	31
CEWPT73	C	0	0	C	44	61	62	65	49	42	29	25
CEWPT73	0	0	0	0	53	60	68	67	51	51	30	19
DEWPT73	0	0	0	0	55	62	71	72	51	61	32	24
CEWPT73	0	0	0	C	57	56	67	72	51	63	31	29
CEWPT73	0	0	0	0	48	69	69	63	57	63	31	19
DEWPT73	C	0	0	C	44	69	38	68	48	58	24	25
CEWPT73	0	0	0	C	49	66	60	60	46	63	43	22
CEWPT73	0	0	0	C	39	51	65	58	49	58	50	9
CEWPT73	0	0	0	C	30	55	61	64	51	46	41	-10
CEWPT73	0	0	0	C	35	63	54	57	51	41	40	-5
CEWPT73	0	0	0	C	36	67	50	59	44	35	32	-5
CEWPT73	0	0	0	C	33	63	56	67	47	23	30	-1
DEWPT73	0	0	0	C	34	67	58	62	45	36	41	-143
CEWPT73	0	0	0	C	46	66	67	66	49	49	39	10
CEWPT73	0	0	0	C	40	57	68	61	41	38	40	12
CEWPT73	C	0	0	C	54	56	64	54	48	44	42	6
CEWPT73	0	0	0	C	56	59	56	54	59	45	46	-3
CEWPT73	C	0	0	0	56	61	66	54	49	46	40	24
CEWPT73	0	0	C	C	54	58	71	61	52	47	57	23
CEWPT73	0	0	0	C	59	58	70	69	66	52	38	37
DEWPT73	C	0	0	C	51	65	72	75	67	43	41	29
DEWPT73	0	0	0	C	56	62	60	73	69	48	46	26
CEWPT73	C	0	0	0	57	60	59	72	57	45	31	29
CEWPT73	C	0	0	C	52	58	59	70	58	46	29	14
CEWPT73	0	0	0	C	47	62	66	68	52	46	28	6
DEWPT73	0	0	0	C	56	0	71	70	0	45	0	5
7312201						4						
7312202												
7312203												
7312204												
7312205												
7312206												
7312207												
7312208												
7312211												
7312212												
7312213												
7312214												
7312215												
7312216				1	412							
7312217	182510	5										
7312218												
7312229												
7312239												
7312249												
7312251												
7312252												
7312253												
7312254												
7312255												

Appendix B (continued)

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 7312256                       5
 7312257
 7312258
 7312261
 7312262           1 410
 7312263
 7312264
 7312265
 7312266
 7312267
 7312268
 7312279
 7312281
 7312282               16
 7312283
 7312284
 7312285
 7312286                                     10 1 3 1
 7312287
 7312288
 7312299
 7312301           1   1 1 2 1 1
 7312302
 7312303
 7312304
 7312305
 7312306   1 2 2 2 2 1   1 1   1 1 1 1   1   1 1   1 3 9 3 3 4 82816 110 2 2 1 3
 7312307 3 4   1   1     1   1   1 1 2 1 2 1 2 1 1 2 1 1 1 2 1 1 1 1 1 1 1 1 2 2
 7312308 2 1 2 2 1 2 1 2 1 1 2 3 3 2 2 1 2 2 1 2 1 1 2 1 2 1 1 1 1   1   1
 7312311           1   1 1 2 1 1
 7312312
 7312313
 7312314
 7312315
 7312316   1 2 2 2 2 1   1 1   1 1 1 1   1   1 1   1 3 9 3 3 4 82816 110 2 2 1 3
 7312317 3 4   1   1     1   1   1 1 2 1 2 1 2 1 1 2 1 1 1 2 1 1 1 1 1 1 1 1 2 2
 7312318 2 1 2 2 1 2 1 2 1 1 2 3 3 2 2 1 2 2 1 2 1 1 2 1 2 1 1 1 1   1   1
EVAP74        92    76   126    98   140    77   206    80   177
EVAP74        86    69   141    84   158    34   120   181   155
EVAP74        86    88   126   252   176    38   217   103    57
EVAP74        16    69   111   175   201   237   174    70   172
EVAP74         5   158   148   217    95   120   109   113   131
EVAP74        92   132     7   175    22   157    28   175     7
EVAP74       108    94     0   252   169   192    84   185    20
EVAP74        43    82   155   189   119     0   120     0    32
EVAP74        11    69   111   196   123   140   102    49    34
EVAP74         5    94   126   133   164   203   210   136    63
EVAP74        43   132   118   140   144    45   217   213    84
EVAP74        86    50   148   140   171   325   150    76   125
EVAP74        81    50   133   161   199   202   151    61   100
EVAP74        86    94   170   147   190   156    77   116    92
EVAP74        59    69   170   175   205    72    85   209    26
EVAP74        22    69   141     7   119   260    94   195    98
EVAP74        43    19   104    14   187   195   197    71    66
EVAP74        27    50    89   140    93   207    92   144    46
EVAP74        38   126   141    98   271    92   510   224   117
EVAP74        22    69    81   140   145   110   133   206   101
EVAP74        49   107    89    49    57   211   158   301    11
EVAP74        98    69   111   105    68   271   163   132    95
EVAP74        54   101   104   210   210   276    82   215    95
```

Appendix B (continued)

EVAP74	22	69	37	175	103	211	13	126	110
EVAP74	5	82	118	147	168	171	236	147	11
EVAP74	22	113	30	147	239	122	44	146	37
EVAP74	32	158	59	203	4	365	20	130	31
EVAP74	43	82	59	168	171	530	16	123	30
EVAP74	65		133	156	195	134	136	156	104
EVAP74	38		15	156	147	181	140	207	137
EVAP74	43		185		156		300	76	
TEMP74	32	30	42	38					
TEMP74	32	30	44	39					
TEMP74	33	33	47	32					
TEMP74	32	30	40	28					
TEMP74	32	30	36	35					
TEMP74	32	30	30	30					
TEMP74	34	34	31	30					
TEMP74	22	22	36	35					
TEMP74	32	30	38	36					
TEMP74	32	30	42	38					
TEMP74	35	35	45	39					
TEMP74	34	34	47	40					
TEMP74	34	34	50	38					
TEMP74	34	34	52	38					
TEMP74	39	39	48	39					
TEMP74	39	39	46	40					
TEMP74	41	41	42	40					
TEMP74	35	35	47	39					
TEMP74	39	39	52	40					
TEMP74	32	30	45	42					
TEMP74	39	39	48	41					
TEMP74	39	39	49	41					
TEMP74	33	33	53	45					
TEMP74	32	30	47	46					
TEMP74	32	30	49	44					
TEMP74	32	30	49	44					
TEMP74	35	35	39	32					
TEMP74	39	39	44	37					
TEMP74	34	34							
TEMP74	32	30							
TEMP74	29	27							
WIND74	80	120							
WIND74	80	110							
WIND74	120	25							
WIND74	40	195							
WIND74	90	110							
WIND74	220	250							
WIND74	50	50							
WIND74	190	50							
WIND74	160	0							
WIND74	120	200							
WIND74	50	50							
WIND74	120	160							
WIND74	80	190							
WIND74	120	100							
WIND74	110	100							
WIND74	130	100							
WIND74	20	100							
WIND74	50	50							
WIND74	30	200							
WIND74	60	100							
WIND74	210	140							

Appendix B (continued)

WIND74	140	110
WIND74	10	100
WIND74	100	150
WIND74	140	250
WIND74	150	100
WIND74	110	150
WIND74	80	200
WIND74	220	
WIND74	150	
WIND74	30	
RADI74	193	175
RADI74	166	165
RADI74	247	175
RADI74	149	75
RADI74	160	75
RADI74	274	125
RADI74	107	72
RADI74	178	80
RADI74	155	67
RADI74	155	85
RADI74	67	117
RADI74	112	161
RADI74	79	29
RADI74	169	166
RADI74	24	152
RADI74	115	193
RADI74	198	215
RADI74	67	118
RADI74	44	75
RADI74	125	88
RADI74	35	183
RADI74	178	104
RADI74	164	100
RADI74	25	133
RADI74	39	32
RADI74	21	56
RADI74	47	48
RADI74	47	81
RADI74	102	
RADI74	161	
RADI74	175	
CEWPT74	14	22
CEWPT74	19	36
CEWPT74	11	47
CEWPT74	10	49
CEWPT74	10	31
CEWPT74	29	25
CEWPT74	10	19
CEWPT74	12	24
CEWPT74	11	29
CEWPT74	11	19
CEWPT74	24	25
CEWPT74	23	22
CEWPT74	20	9
CEWPT74	21	10
CEWPT74	20	5
CEWPT74	12	5
CEWPT74	10	1
CEWPT74	21	13
CEWPT74	19	10

CEWPT74	20	12		
CEWPT74	22	6		
CEWPT74	26	3		
CEWPT74	20	24		
CEWPT74	27	23		
CEWPT74	18	37		
CEWPT74	21	29		
CEWPT74	26	26		
CEWPT74	11	29		
CEWPT74	14			
CEWPT74	6			
CEWPT74	5			
7401019				
7401029				
7401039				
7401049				
7401059				
7401069				
7401079				
7401081				
7401082				
7401083				
7401084				
7401085				
7401086			2 5 8 6 5 2 6 9 9 3	3 3
7401087	3 3 3			
7401088				
7401099				
7401109				
7401119				
7401129				
7401139				
7401149				
7401159				
7401161				
7401162				
7401163				
7401164				
7401165				
7401166				
7401167				1 4 614 1
7401168	2 5 2			
7401171				
7401172				
7401173				
7401174			20 4 1 4 1	
7401175				
7401176				
7401177				
7401178				
7401189				
7401199				
7401209				
7401219				
7401229				
7401239				
7401249				
7401251				
7401252				
7401253				

Appendix B (continued)

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7401254
7401255
7401256
7401257                                                                2       3
7401258       2   3           1 4
7401269
7401279
7401289
7401299
7401301
7401302
7401303
7401304
7401305
7401306
7401307                            13383911 5 4
7401308
7401319
7402011
7402012
7402013
7402014
7402015
7402016                                                                        2
7402017 6 5 2                   2 6 2
7402018
7402029
7402039
7402049
7402059
7402069
7402079
7402089
7402099
7402109
7402119
7402129
7402139
7402149
7402159
7402169
7402171
7402172
7402173
7402174
7402175                                                             22 3     5
740217610 5
7402177
7402178
7402181
7402182
7402183
7402184             101010          5
7402185
7402186
7402187
7402188
7402199
7402209
7402219
```

Appendix B (continued)

```
7402229
7402239
7402249
/*
```

APPENDIX C

ARM Model Source Listing

```
//CC87508 JOB (C51C,51C,6,25),'J7508BEYERLEIN'
/* SERVICE CLASS=LARGE
//STEP1 EXEC FORTHCL,LEVEL=BIG,PARM.FORT='OPT=1,MAP,XREF'
//FORT.SYSIN DD *
C
C
C
C        *****************************************************************
C        *                                                               *
C        *          AGRICULTURAL RUNOFF MANAGEMENT (ARM) MODEL           *
C        *                                                               *
C        *****************************************************************
C
C                                      DEVELOPED BY:  HYDROCOMP, INCORPORATED
C                                                     1502 PAGE MILL ROAD
C                                                     PALO ALTO, CA.  94304
C                                                       415-493-5522
C
C                                               FOR:  U.S. ENVIRONMENTAL
C                                                      PROTECTION AGENCY
C                                                     OFFICE OF RESEARCH
C                                                      AND DEVELOPMENT
C                                                     SOUTHEAST ENVIRONMENTAL
C                                                      RESEARCH LABORATORY
C                                                     ATHENS, GA.  30601
C                                                       404-546-3147
C
C
C
C                                      MAIN PROGRAM
C
      IMPLICIT  REAL(L)
C
       DIMENSION RESE(5),RESB1(5),RESB(5),SRGX(5),INTF(5),RGX(5),INFL(5),
     1 LZSB(5),APERCB(5),RIB(5),ERSN(5)
       DIMENSION SRER(5),ROBTOM(5),ROBTOT(5),INFTOM(5),INFTOT(5),
     1 ROITOM(5),ROITOT(5),RXB(5),ERSTOM(5),ERSTOT(5),MNAM(12),RAD(24),
     2 TEMPX(24),WINDX(24),RAIN(288),SRERMT(5),ERSNMT(5)
       DIMENSION PESTOM(5),PRSTOT(5),PROTOM(5),PROTOT(5),UPITOM(5),
     1 UPITOT(5),STS(5),UTS(5),SAS(5),SCS(5),SDS(5),SSTR(5),
     2 UAS(5),UCS(5),LCS(5),USTR(5),UPRIS(5)
       DIMENSION IRAIN(288),IRAD(12,31),
     1 IWIND(12,31),ITEMP(12,31,2),GRAD(24),RADDIS(24),WINDIS(24),
     2 IEVAP(12,31),IDEW(12,31)
       DIMENSION WSNAME(20),CHNAME(20),CUVPMO(12),DPM(12)
       DIMENSION TIMTIL(5),YRTIL(5),SRERTL(5)
C
       COMMON /ALL/ RU,HYMIN,PRNTKE,HYCAL,DPST,OUTPUT,TIMFAC,LZS,AREA,
     1 RESB1,ROSE,SRGX,INTF,RGX,INFL,UZSB,APERCB,RIB,ERSN,M,P3,A,
     2 CALB,PROC,PEST,NUTR,ENGL,METR,BOTH,RESB,YES,NO,IMIN,IHR,TF,
     3 JCOUNT,PRINT,INTR,DAYS,HOUR,MNTH
C
       COMMON /LAND/ MNAM,PRTOT,ERSNTT,PRTOM,ERSNTM,DAY,
     1 RUTOM,NEPTOM,ROSTOM,RITOM,RINTOM,BASTOM,RCHTOM,RUTOT,
     2 NEPTOT,ROSTOT,RITOT,RINTOT,BASTOT,RCHTOT,TWBAL,EPTOM,EPTOT,
     3 UZS,UZSN,LZSN,INFIL,INTER,IRC,NN,L,SS,SGW1,PR,SGW,GWS,KV,
     4 K24L,KK24,K24EL,EP,IFS,K3,EPXM,RESS1,RESS,SCEP,SCEP1,SRGXT,
     5 SRGXT1,JRER,KRER,JSER,KSER,SRERT,MMPIN,METOPT,SNOW,CCFAC,
     6 SCF,IDNS,F,DGM,WC,MPACK,EVAPSN,MELEV,TSNOW,PETMIN,PETMAX,ELDIF,
```

Appendix C (continued)

```
              7 DEWX,PACK,DEPTH,MONTH,SDEN,IPACK,TMIN,SUMSNM,PXSNM,XK3,
              8 MELRAM,RADMEM,CDRMEM,CRAINM,CONMEM,SGMM,SNEGMM,SEVAPM,SUMSNY,
              9 PXSNY,MELRAY,RADMEY,CDRMEY,SGMY,CONMEY,CRAINY,SNEGMY,SEVAPY,
              * TSNBAL,CCVER,CCVFMX,ROBTOM,ROBTOT,RXB,ROITOM,ROITOT,INFTOM,
              1 INFTOT,ERSTOM,ERSTOT,SRER,TEMPX,RAD,WINDX,RAIN,INPUT
      C
               COMMON /PESTC/ SIST,SPROTM,SPRSTM,SAST,SCST,SDST,UTST,UAST,UCST,K,
              1 UDST,FP,CMAX,NI,SPROTT,SPRSTT,MUZ,FMUZ,UPRITM,
              2 UPRITT,KGPLB,FFLZ,MLZ,LSTR,LAS,LCS,LDS,GSTR,GAS,GCS,GDS,
              3 APMODE,TPEAL,
              4 DEGSCM,DEGSCT,DEGUOM,
              5 DEGUOT,DEGL,DEGS,NIP,DEGCON,DEGLOM,DEGLOT,NCCM,
              6 PRSTCM,PRSTCT,PROTOM,PROTOT,UPITOM,UPITOT,STS,UTS,SAS,
              7 SCS,SDS,SSTR,UAS,UCS,UDS,USTR,UPRIS,UIST,TOTPAP,TIMAP,YEARAP,
              8 DESORP,SURF,SOIL,SULG
      C
               CCMMCN /NUT/  DELT,STEMP,SN,SNT,SNRSM,SNROM,UN,UNT,UNI,UNIT,
              1             UNRIM,NRSM,LN,LNRPM,GN,SNRBM,UNRBM,LNRBM,GNRBM,TNRBM,
              2             SNRSY,SNROY,UNRIY,NRSY,LNRPY,SNRBY,UNRBY,LNRBY,GNRBY,
              3             TNRBY,TNRHV,TNRHVM,TNRHVY,TNA,TPA,TCLA,
              4             KN,THKN,KP,THKP,NBAL,PHBAL,CLBAL,
              5             ISTEP,NSTEP,SFLG,UFLG,LFLG,GFLG
      C
      C
               INTEGER  BGNDAY, EGNMON, BGNYR, ENDDAY, ENDMON, ENDYR
               INTEGER  DYSTRT, DYEND, YEAR, MONTH, DAY, H, HYCAL, TIME
               INTEGER  YR, MO, DY, DN, TF, PRNTKE, PRINT, DA, APMODE, OUTPUT
               INTEGER  INFLT, SNOW, DESORP, SURF, SOIL, TIMFAC, ON, OFF
               INTEGER  CALB,PFOD,NUTR,PEST,ENGL,METR,BOTH,INTR,HOUR,DAYS,NO,YES
               INTEGER  WSNAME,CHNAME,DPM
               INTEGER  JDCUNT,TIMAP,TIMTIL,YRTIL,YEARAP,MNTH
      C
               REAL*8   MNAM
               REAL*8  PESTIC/'PESTICID'/
               REAL*8  CHAR
      C
               REAL  IRC, NN, KV, K24L, KK24, INFIL, INTER, INFL
               REAL  IFS, ICS, K24EL, K3, NEPTOM, NEPTOT
               REAL  JRER, KRER, JSER, KSER
               REAL  M, N, NI, R, MUZ, MU, ML, MLZ
               REAL  INFTOM, INFTOT
               REAL  MMPIN, METOPT, KGPLB
               REAL  SPRTMT, ERSNTT, ERSNMT
               REAL NF, NIF, NCCM
               REAL IONS, MPACK, MELEV, KUGI, MELRAM, MELRAY, IPACK
      C
      C        NUTRIENT VARIABLES -- DECLARED,DIMENSIONED,INITIALIZED
      C
      C
               INTEGER*4  ISTEP,NSTEP,SFLG,UFLG,LFLG,GFLG
      C
               REAL*4  DELT,STEMP(4,24),
              1        SN(20,5),SNT(20),SNRSM(20,5),SNROM(20,5),
              2        UN(20,5),UNT(20),UNI(20,5),UNIT(20),UNRIM(20,5),
              3        NRSM(20,5),      LN(20),LNRPM(20),          GN(20),
              4        SNRBM(20,5),UNRBM(20,5),LNRBM(20),GNRBM(20),TNRBM(20),
              5        SNRSY(20,5),SNROY(20,5),UNRIY(20,5),NRSY(20,5),
              6        LNRPY(20),SNRBY(20,5),UNRBY(20,5),LNRBY(20),GNRBY(20),
              7        TNRBY(20),TNRHV(20),TNRHVM(20),TNRHVY(20),TNA,TPA,TCLA,
              8        KN(10,4),THKN(10),KP(5,4),THKP(5),NBAL,PHBAL,CLBAL
```

```
C
C
      REAL*4  SNAPL(20,5,5),UNAPL(20,5,5),KNI(10,4),KPI(5,4)
C
      INTEGER*4  APDAY(5),APLCNT/1/,JHOUR,NAPPL,J,IBLK,TIMHAR,
     1           SELHV(20)/0,0,0,0,0,0,1,0,0,0,0,0,0,1,0,0,0,0,0,0/
      INTEGER*4 DPMM1(12)/0,31,28,31,30,31,30,31,31,30,31,30/
C
      DATA  TIMTIL/5*0/,YRTIL/5*0/,SRERTL/5*0.0/
      DATA  COVPMO/12*0.0/
      DATA  ICS, CFS/2*0.0/
C
      DATA ON/'ON'/,OFF/'OFF'/
C
      DATA GRAD/0.04,0.04,0.03,0.02,
     *0.02,0.02,0.02,0.06,0.14,0.18,0.20,0.17,0.13,0.06,0.03,0.01,0.05,
     *0.07,0.10,0.13,0.15,0.13,0.12,0.08/
      DATA RADDIS/6*0.0,0.019,
     *0.041,0.067,0.088,0.102,0.110,0.110,0.110,0.105,0.095,0.081,0.055,
     *0.017,5*0.0/
      DATA WINDIS/7*0.034,0.035,
     *0.037,0.041,0.046,0.050,0.053,0.054,0.058,0.057,0.056,0.050,0.043,
     *0.040,0.038,0.036,0.036,0.035/
      DATA DPM/31,28,31,30,31,30,31,31,30,31,30,31/
      DATA PETMUL,WMUL,RMUL/3*1.0/
C
C                    DATA INPUT -- NAMELIST VARIABLES
C
      NAMELIST /CNTL/  INTRVL,HYMIN,AREA
      NAMELIST /STRT/  BGNDAY,BGNMON,BGNYR
      NAMELIST /ENDD/  ENDDAY,ENDMON,ENDYR
      NAMELIST /LND1/  UZSN,UZS,LZSN,LZS
      NAMELIST /LND2/  L,SS,NN,A,K3,EPXM
      NAMELIST /LND3/  INFIL,INTER,IRC,K24L,KK24,K24EL
      NAMELIST /LND4/  SGW,GWS,KV,ICS,CFS,IFS
      NAMELIST /SNO1/  RADCON,CCFAC,SCF,ELDIF,IDNS,F
      NAMELIST /SNO2/  DGM,WC,MPACK,EVAPSN,MELEV,TSNOW
      NAMELIST /SNO3/  PACK,DEPTH
      NAMELIST /SNO4/  PETMIN,PETMAX,PETMUL,WMUL,RMUL,KUGI
      NAMELIST /CROP/  COVPMO
      NAMELIST /MLC1/  TIMTIL,YRTIL,SRERTL
      NAMELIST /DIRT/  SZDPTH,UZDPTH,BULKD
      NAMELIST /SPCL/  JRER,KRER,JSER,KSER,SRERI
      NAMELIST /APCL/  SSTR,TIMAP,YEARAP,CMAX,DD,K,N,NP
      NAMELIST /DEG1/  DEGCON
C
C         INPUT PARAMETER DESCRIPTION
C  WSNAME: WATERSHED NAME (80 CHARACTERS)
C  CHNAME: CHEMICAL NAME (80 CHARACTERS)
C  HYCAL : INDICATES WHAT FACTORS ARE TO BE SIMULATED
C        - PROD  PRODUCTION RUN
C        = CALB  CALIBRATION RUN
C  INPUT : INPUT UNITS: ENGLISH(ENGL), METRIC(METR)
C  OUTPUT: OUTPUT UNITS: ENGLISH(ENGL), METRIC(METR), BOTH(BOTH)
C  PRINT : DENOTES FREQUENCY OF OUTPUT; EACH INTERVAL(INTR),
C          EACH HOUR(HOUR), OR EACH DAY(DAYS),OR EACH MONTH(MNTH)
C  SNOW  : (NO) SNOWMELT NOT PERFORMED, (YES) SNOWMELT CALC'S PERFORMED
C  PEST  : (NO) PESTICIDES NOT PERFORMED, (YES) PESTICIDE CALC'S PERFORMED
C  NUTR  : (NO) NUTRIENTS NOT PERFORMED, (YES) NUTRIENT CALC'S PERFORMED
C  ICHECK: CHECKS MOST OF THE INPUT IF SET EQUAL TO ON, OTHERWISE SET
```

Appendix C (continued)

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      C            TO OFF
      C   INTRVL: TIME INTERVAL ( 5 OR 15 MINUTES)
      C   HYMIN : MINIMUM FLOW FOR OUTPUT DURING A TIME INTERVAL (CFS, CMS)
      C   AREA  : WATERSHED AREA (AC, HA)
      C   BGNDAY, BGNMON, BGNYR : DATE SIMULATION BEGINS
      C   ENDDAY, ENDMON, ENDYR : DATE SIMULATION ENDS
      C   UZSN  : NOMINAL UPPER ZONE STORAGE (IN, MM)
      C   UZS   : INITIAL UPPER ZONE STORAGE (IN, MM)
      C   LZSN  : NOMINAL LOWER ZONE STORAGE (IN, MM)
      C   LZS   : INITIAL LOWER ZONE STORAGE (IN, MM)
      C   L     : LENGTH OF OVERLAND FLOW TO CHANNEL (FT, M)
      C   SS    : AVERAGE OVERLAND FLOW SLOPE
      C   NN    : MANNING'S N FOR OVERLAND FLOW
      C   A     : FRACTION OF AREA THAT IS IMPERVIOUS
      C   K3    : INDEX TO ACTUAL EVAPORATION
      C   EPXM  : MAXIMUM INTERCEPTION STORAGE (IN, MM)
      C   INFIL : INFILTRATION RATE (IN/HR, MM/HR)
      C   INTER : INTERFLOW PARAMETER, ALTERS RUNOFF TIMING
      C   IRC   : INTERFLOW RECESSION RATE
      C   K24L  : FRACTION OF GROUNDWATER RECHARGE PERCOLATING TO DEEP
      C            GROUNDWATER
      C   KK24  : GROUNDWATER RECESSION RATE
      C   K24EL : FRACTION OF WATERSHED AREA WHERE GROUNDWATER IS WITHIN
      C            REACH OF VEGETATION
      C   SGW   : INITIAL GROUNDWATER STORAGE (IN, MM)
      C   GWS   : GROUNDWATER SLOPE
      C   KV    : PARAMETER TO ALLOW VARIABLE RECESSION RATE FOR GROUNDWATER
      C            DISCHARGE
      C   ICS   : INITIAL INTERCEPTION STORAGE (IN, MM)
      C   OFS   : INITIAL OVERLAND FLOW STORAGE (IN, MM)
      C   IFS   : INITIAL INTERFLOW STORAGE (IN, MM)
      C
      C   ONLY IF SNOW=YES SHOULD PARAMETERS RADCON THROUGH KUGI BE INPUTTED
      C
      C   RADCON: CORRECTION FACTOR FOR RADIATION
      C   CCFAC : CORRECTION FACTOR FOR CONDENSATION AND CONVECTION
      C   SCF   : SNOW CORRECTION FACTOR FOR RAINGAGE CATCH DEFICIENCY
      C   ELDIF : ELEVATION DIFFERENCE FROM TEMP. STATION TO MEAN SEGMENT ELEVATION
      C            (1000 FT, KM)
      C   IDNS  : DENSITY OF NEW SNOW AT 0 DEGREES F.
      C   F     : FRACTION OF SEGMENT WITH COMPLETE FOREST COVER
      C   DGM   : DAILY GROUNDMELT (IN/DAY, MM/DAY)
      C   WC    : MAXIMUM WATER CONTENT OF SNOWPACK BY WEIGHT
      C   MPACK : ESTIMATED WATER EQUIVALENT OF SNOWPACK FOR COMPLETE COVERAGE
      C   EVAPSN: CORRECTION FACTOR FOR SNOW EVAPORATION
      C   MELEV : MEAN ELEVATION OF WATERSHED (FT, M)
      C   TSNOW : TEMPERATURE BELOW WHICH SNOW FALLS (F, C)
      C   PACK  : INITIAL WATER EQUIVALENT OF SNOWPACK (IN, MM)
      C   DEPTH : INITIAL DEPTH OF SNOWPACK (IN, MM)
      C   PETMIN: TEMPERATURE AT WHICH ZERO PET OCCURS (F, C)
      C   PETMAX: TEMPERATURE AT WHICH PET IS REDUCED BY 50% (F, C)
      C   PETMUL: POTENTIAL EVAPOTRANSPIRATION MULTIPLICATION FACTOR
      C   WMUL  : WIND MULTIPLICATION FACTOR
      C   RMUL  : RADIATION MULTIPLICATION FACTOR
      C   KUGI  : INDEX TO FOREST DENSITY AND UNDERGROWTH (0.0-10.0)
      C   COVPMO: PERCENTAGE CROP COVER ON MONTHLY BASIS
      C   TIMTIL: TIME (IN JULIAN DAYS) WHEN SOIL IS TILLED
      C   YRTIL:  THE CORRESPONDING YEAR IN WHICH TIMTIL APPLIES
      C   SFERTL: FINE DEPOSITS PRODUCED BY TILLAGE (TONS/ACRE, TONNES/HECTARE)
      C   SZDPTH: SURFACE LAYER SOIL DEPTH (IN THE RANGE OF 1/8 INCH) (IN, MM)
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      C   UZDPTH: DEPTH OF SOIL INCORPORATION AND UPPER ZONE (IN, MM)
      C   BULKD : BULK DENSITY OF SOIL (LB/FT(3)), (G/CM(3))
      C   JRER  : EXPONENT OF RAINFALL INTENSITY  IN SOIL SPLASH EQUATION
      C   KRER  : COEFFICIENT IN SOIL SPLASH EQUATION
      C   JSER  : EXPONENT OF OVERLAND FLOW IN SURFACE SCOUR EQUATION
      C   KSER  : COEFFICIENT IN SURFACE SCOUR EQUATION
      C   SRERI : INITIAL FINES DEPOSIT (TONS/ACRE, TONNES/HECTARE)
      C
      C   ONLY IF PEST=YES SHOULD TITLE PESTICIDE AND PARAMETERS APMODE
      C   THROUGH DEGCON BE INPUTTED
      C
      C   TITLE WORD PESTICIDE MUST BE INCLUDED IN THE INPUT SEQUENCE
      C   PRIOR TO ANY PESTICIDE INPUT PARAMETERS
      C
      C   APMODE: APPLICATION MODE; SURFACE APPLIED (SURF),
      C                               SOIL INCORPORATED (SOIL)
      C   DESORP: (NO) ONLY ADSORPTION ALGORITHM USED, (YES) BOTH ADSORPTION
      C           AND DESORPTION USED
      C   SSTR  : PESTICIDE APPLICATION FOR EACH BLOCK (LB, KG)
      C   TIMAP : TIME OF PESTICIDE APPLICATION (JULIAN DAY)
      C   YEARAP: THE CORRESPONDING YEAR IN WHICH TIMAP APPLIES
      C   CMAX  : MAXIMUM SOLUBILITY OF PESTICIDE IN WATER (LB/LB)
      C   DD    : PERMANENTLY FIXED CAPACITY (LB PESTICIDE/LB SOIL)
      C   K     : COEFICIENT IN FREUNDLICH ADSORPTION CURVE
      C   N     : EXPONENT IN FREUNDLICH ADSORPTION CURVE
      C   NP    : DESORPTION EXPONENT IN FREUNDLICH CURVE
      C   DEGCON: FIRST ORDER PESTICIDE DECAY RATE (PER DAY)
      C
              READ (5,1096) (WSNAME(I),I=1,20)
              READ (5,1096) (CHNAME(I),I=1,20)
              READ (5,1097)  HYCAL
              READ (5,1097)  INPUT
              READ (5,1098)  OUTPLT
              READ (5,1097)  PRINT
              READ (5,1099)  SNOW
              READ (5,1099)  PEST
              READ (5,1099)  NUTR
              READ (5,1098)  ICHECK
      C
              READ (5,CNTL)
              READ (5,STR1)
              READ (5,ENDD)
              READ (5,LND1)
              READ (5,LND2)
              READ (5,LND3)
              READ (5,LND4)
      C
              IF (SNOW .EQ. NO)  GO TO 400
              READ (5,SNO1)
              READ (5,SNO2)
              READ (5,SNO3)
              READ (5,SNO4)
      C
          400 READ (5,CROP)
              READ (5,MUD1)
              READ (5,DIRT)
              READ (5,SPOL)
      C
              IF (PEST .EQ. NO)  GO TO 402
              READ (5,1100)  CHAR
```

```
      IF (CHAR.EQ.PESTIC)  GO TO 401
          WRITE (6,1122)
          GO TO 1080
C
  401 READ (5,1098)  APMODE
      READ (5,1098)  DESORP
      READ (5,AMCL)
      READ (5,DEG1)
C
C
C                         PRINTING OF INPUT PARAMETERS
C
  402 IF (HYCAL.EQ.CALB)  GO TO 1002
          WRITE (6,1091)
          IF (PEST.EQ.YES.AND.NUTR.EQ.NO)  WRITE (6,1123)
          IF (PEST.EQ.NO .AND.NUTR.EQ.YES) WRITE (6,1124)
          IF (PEST.EQ.NO .AND.NUTR.EQ.NO)  WRITE (6,1125)
          IF (PEST.EQ.YES.AND.NUTR.EQ.YES) WRITE (6,1126)
          WRITE (6,1092)
          GO TO 1003
C
 1002 WRITE (6,1093)
          IF (PEST.EQ.YES.AND.NUTR.EQ.NO)  WRITE (6,1123)
          IF (PEST.EQ.NO .AND.NUTR.EQ.YES) WRITE (6,1124)
          IF (PEST.EQ.NO .AND.NUTR.EQ.NO)  WRITE (6,1125)
          WRITE (6,1092)
          IF (PEST.EQ.NO .OR. NUTR.EQ.NO)  GO TO 1003
          WRITE (6,1121)
          GO TO 1080
C
 1003 WRITE (6,1107) (WSNAME(I),I=1,20)
      WRITE (6,1106) (CHNAME(I),I=1,20)
      IF (INPUT .EQ. ENGL)  WRITE (6,1108)
      IF (INPUT .EQ. METR)  WRITE (6,1109)
      IF (OUTPUT .EQ. ENGL) WRITE (6,1110)
      IF (OUTPUT .EQ. METR) WRITE (6,1111)
      IF (OUTPUT .EQ. BOTH) WRITE (6,1112)
      IF (PRINT .EQ. INTR)  WRITE (6,1113)
      IF (PRINT .EQ. HOUR)  WRITE (6,1114)
      IF (PRINT .EQ. DAYS)  WRITE (6,1115)
      IF (PRINT .EQ. MNTH)  WRITE (6,1128)
      IF (SNOW .EQ. YES)    WRITE (6,1116)
      IF (SNOW .EQ. NO)     WRITE (6,1117)
      IF (PEST .EQ. NO)  GO TO 1010
      IF (DESORP .EQ. YES)  WRITE (6,1118)
      IF (DESORP .EQ. NO)   WRITE (6,1119)
      IF (APMODE .EQ. SOIL)  WRITE (6,1105)
      IF (APMODE .EQ. SURF)  WRITE (6,1104)
 1010 WRITE (6,1092)
C
      WRITE (6,1164) INTRVL,HYMIN,AREA
      WRITE (6,1165) BGNDAY,BGNMON,BGNYR
      WRITE (6,1166) ENDDAY,ENDMON,ENDYR
      WRITE (6,1167) UZSN,UZS,LZSN,LZS
      WRITE (6,1168) L,SS,NN,A,K3,EPXM
      WRITE (6,1169) INFIL,INTER,IRC,K24L,KK24,K24EL
      WRITE (6,1170) SGW,GWS,KV,ICS,OFS,IFS
      IF (SNOW .EQ. NO) GO TO 1011
      WRITE (6,1171) RADCON,CCFAC,SCF,ELDIF,IDNS,F
      WRITE (6,1172) DGM,WC,MPACK,EVAPSN,MELEV,TSNOW
```

```
          WRITE (6,1173) PACK,DEPTH
          WRITE (6,1174) PETMIN,PETMAX,PETMUL,WMUL,RMUL,KUGI
     1011 WRITE (6,1175) (CCVFMO(I),I=1,12)
          WRITE (6,1183)(TIMTIL(I),I=1,5),(YRTIL(I),I=1,5),(SRERTL(I),I=1,5)
          WRITE (6,1176) SZDPTH,UZDPTH,BULKD
          WRITE (6,1177) JFER,KRER,JSER,KSER,SRERI
          IF (PEST .EQ. NO) GO TO 1012
          WRITE (6,1178) TIMAP, YEARAP, (SSTR(I),I=1,5)
          WRITE (6,1179) CMAX,DD,K,N,NP
          WRITE (6,1182) DEGCON
     1012 WRITE (6,1120) HYCAL,INPUT,OUTPUT,PRINT,SNOW,PEST,NUTR,ICHECK
          IF (PEST.EQ.YES)  WRITE (6,1127) APMODE,DESORP
          WRITE (6,1092)
          IF (INPUT .EQ. METR) GO TO 559
          GO TO 449
C
C  CONVERSION OF METRIC INPUT DATA TO ENGLISH UNITS
C
  559 HYMIN= HYMIN*35.3
      UZSN = UZSN/MMPIN
      LZSN = LZSN/MMPIN
      INFIL= INFIL/MMPIN
      L    = L*3.281
      UZS  = UZS/MMPIN
      LZS  = LZS/MMPIN
      SGW  = SGW/MMPIN
      ICS  = ICS/MMPIN
      OFS  = OFS/MMPIN
      IFS  = IFS/MMPIN
      EPXM = EPXM/MMPIN
      UZDPTH= UZDPTH/MMPIN
      SZDPTH= SZDPTH/MMPIN
C       28328. = UNIT CONVERSION, CM(3)/FT(3)
      BULKD = BULKD*28328./454.
      SRERI= SRERI/(METOPT*2.471)
      AREA   AREA*2.471
      DO 451 I=1,5
  451    SRERTL(I) = SRERTL(I)/(METOPT*2.471)
C
      IF (SNOW .EQ. NO)  GO TO 403
      ELDIF = ELDIF*3.281
      DGM   = DGM/MMPIN
      MELEV   MELEV*3.281
      TSNOW - 1.8*TSNOW + 32.0
      PACK  = PACK/MMPIN
      DEPTH = DEPTH/MMPIN
      PETMAX= 1.8*PETMAX + 32.0
      PETMIN= 1.8*PETMIN + 32.0
C
  403 IF (PEST .EQ. NO)  GO TO 449
      DO 501 I=1,5
  501    SSTR(I) = SSTR(I)*2.205
C
  449 IERROR = 0
      IF (ICHECK .EQ. OFF) GO TO 452
C
      CALL CHECKR (HYMIN,INTRVL,UZSN,LZSN,IRC,NN,L,SS,A,UZS,LZS,
     1             K24L,KK24,K24EL,K3,SSTR,UZDPTH,
     2             CMAX,BULKD,AREA,HYCAL,INPUT,OUTPUT,PRINT,PEST,
     3             SNOW,APMODE,DESORP,ICHECK,ENDYR,ENDMON,ENDDAY,
```

```
     4                BGNYR,BGNMON,BGNDAY,IERROR,CALB,PROD,
     5                ENGL,METR,BOTH,INTR,HOUR,DAYS,MNTH,YES,NO,SURF,
     6                SOIL,CN,OFF,SZOPTH,COVPMO,TIMTIL,RADCON,CCFAC,
     7                SCI,ELCIF,IUNS,F,OGM,WC,EVAPSN,MELEV,TSNOW,
     8                PETMIN,PETMAX,PETMUL,WMUL,RMUL,KUGI,TIMAP,
     9                YEARAP,DEGCON,NUTR)
C
      IF (IERROR .GT. 0) GO TO 1080
C
  452 IF (NUTR .EQ. NO)  GO TO 450
         CALL NUTRIC  (IOERR,INTRVL,NAPPL,SNAPL,UNAPL,TIMHAR,
     1                INFLT,OUTPUT,APDAY,KNI,KPI)
         IF (IOERR .EQ. 1)  GO TO 1080
C
C                     ADJUSTMENT OF CONSTANTS
C
  450 H = 60/INTRVL
      TIMFAC = INTRVL
      INTRVL = 24*H
C
      KRER = KRER*H**(JRER-1.)
      KSER - KSER*H**(JSER-1.)
C
      M = BULKD*(SZDPTH/12.0)*43560.*AREA*0.2
C                                            INITIALIZE TEMP DIST VARIABLES
      TEMPI = 35.
      CHANGE = -12.
      GRAD(1) = 0.04
      GRAD(2) = 0.04
C
      IPACK=0.01
C
      JCOUNT = BGNDAY
      DO 601 I=1,BGNMON
         JCOUNT = JCOUNT + DPMM1(I)
  601 CONTINUE
      IF (MOD(BGNYR,4).EQ.0 .AND. BGNMON.GT.2)  JCOUNT=JCOUNT+1
C
      DO 1005  I=1,5
         SRER(I) = SRERI
         UZSE(I) = UZS
         RESE(I) = OFS
         SRGX(I) = IFS
 1005 CONTINUE
C
      RESS1 = OFS
      RESS = OFS
      SCEP = ICS
      SCEP1 = ICS
      SRGXT = IFS
      SRGXT1 = IFS
      SGW1 = SGW
      XK3 = K3
      COVRMX = 0.0
      DO 1006 I=1,12
 1006    IF (COVRMX.LT.COVPMO(I))  COVRMX=COVPMO(I)
C
      IF (PEST .EQ. NO) GO TO 1007
C
      IIFLAG = 0
```

```
            IJFLAG = 0
            NI = 1.0/N
            NIP = 1.0/NF
            NCCM = NIP/NI
      C
            MU = BLLKD*((LZDPTH-SZDPTH)/12.0)
            ML = BLLKD*6.0
            MUZ = MU*43560.*AREA*0.2
            MLZ = ML*43560.*AREA
      C
            DO 1000 I=1,5
       1000    TOTPAP = TOTPAP + SSTR(I)
      C
            FP = DC*M
            FPUZ = DC*MLZ
            FPLZ = DC*MLZ
      C
            IF (AFMCDE.EQ.SLPF) GO TO 1007
            DO 999 I=1,5
               LSTR(I) = SSTR(I)
               SSTR(I) = SSTR(I)*(SZDPTH/UZDPTH)
               LSTR(I) = LSTR(I) - SSTR(I)
        999 CONTINUE
      C
      C                               PROGRAM EXECUTION
      C                                                     BEGIN YEARLY LOOP
       1007 DO 1070  YEAR=BGNYR,ENDYR
               IF (YEAR .EQ. BGNYR) JCOUNT = JCOUNT - 1
               MNSTRT = 1
               MNEND = 12
               IF (YEAR .EQ. BGNYR)  MNSTRT = BGNMON
               IF (YEAR .EQ. ENDYR)  MNEND = ENDMON
      C
      C
      C  EVAP, TEMP(MAX-MIN), RAD, AND WIND  DATA INPUT
      C
             DO  1008  DA = 1,31
       1008   READ (5,1264) (IEVAP(MN,DA), MN =1,12)
      C
      C
             IF (SNOW.EQ.NO .AND. NUTR.EQ.NO)  GO TO 610
              DO   1013 DA = 1,31
       1013   READ(5,1265) ((ITEMP(MN,DA,IT), IT=1,2),MN=1,12)
      C
            IF (SNOW .EQ. NO)  GO TO 610
              DO   1014 DA = 1,31
       1014   READ(5,1264) (IWIND(MN,DA), MN=1,12)
      C
              DO 600 DA =1,31
        600   READ (5,1264) (IRAD(MN,DA), MN=1,12)
      C
              DO 605 DA=1,31
        605   READ (5,1264) (IDEW(MN,DA), MN=1,12)
      C
        610   IF (INPUT .EQ. ENGL) GO TO 625
              DO 700 DA=1,31
                 DO 650 MN=1,12
                    IEVAP(MN,DA) = IEVAP(MN,DA)*3.937
                    IF (SNOW.EQ.YES) IWIND(MN,DA) = IWIND(MN,DA)*0.6214
                    IF (SNOW.EQ.YES) IDEW(MN,DA) = 1.8*IDEW(MN,DA) + 32.5
```

```
                       DO 640 IT=1,2
      640              IF (SNOW.EQ.YES .OR. NUTR.EQ.YES)
        1                 ITEMP(MN,DA,IT) = 1.8*ITEMP(MN,DA,IT) + 32.5
      650           CONTINUE
      700        CONTINUE
C                                          SAV TMIN OF JAN 1 ON 11/31
      625 IF (SNOW.EQ.YES .OR. NUTR.EQ.YES) ITEMP(11,31,2) = ITEMP(1,1,2)
C
C
C
C                                                               BEGIN MONTHLY LOOP
            DO 1060  MONTH=MNSTRT,MNEND
C
              COVER1 = COVPMO(MONTH)
              IF (MONTH.LT.12)  COVER2 = COVPMO(MONTH+1)
              IF (MONTH.EQ.12)  COVER2 - COVPMO(1)
C
              IF (HYCAL .EQ. PROD)  GO TO 1009
              IF (NUTR.EQ.YES)  GO TO 800
C
              WRITE (6,1263)
              WRITE (6,382)
              WRITE (6,1092)
              GO TO 1009
C
C                               NUTRIENT CALIBRATION OUTPUT FORMAT
C
800           WRITE (6,4001)
              IF (OUTPUT.EQ.ENGL .OR. OUTPUT.EQ.BOTH)  WRITE (6,4002)
              IF (OUTPUT .EQ. METR)  WRITE (6,4003)
              WRITE (6,4004)
C
      1009    DYSTRT - 1
C
              DYEND = DPM(MONTH)
              IF (MOD(YEAR,4).EQ.0.AND.MONTH.EQ.2)  DYEND=29
C
              IMDEND=DYEND
              IF (YEAR.EQ.BGNYR .AND. MONTH.EQ.BGNMON)  DYSTRT = BGNDAY
              IF (YEAR.EQ.ENDYR .AND. MONTH.EQ.ENDMON)  DYEND  = ENDDAY
C
C                                                               BEGIN DAILY LOOP
              DO 1090  DAY=DYSTRT,DYEND
                 IF ((MONTH .EQ. 1) .AND. (DAY .EQ. 1)) JCOUNT = 0
                 TIME = 0
                 RAINT = 0.0
                 EP = PETMUL*IEVAP(MONTH,DAY)/1000.
C
              IF (SNOW.EQ.NO .AND. NUTR.EQ.NO)  GO TO 1018
C
                 TEMP = (ITEMP(MONTH,DAY,1)+ITEMP(MONTH,DAY,2))*.5
                 IF (SNOW .EQ. NO)  GO TO 1018
                 WIND = IWIND(MONTH,DAY)
                 DEWX = IDEW(MONTH,DAY)
      1018       DO 1019  I=1,INTRVL
                    IRAIN(I) = 0
                    RAIN(I) = 0.0
      1019          CONTINUE
C
C
```

```
C              CHECK TO SEE IF SNOWMELT CALC'S WILL BE DONE - IF YES THEN
C              CALCULATE CONTINUOUS TEMP, WIND, RAD AND APPLY CORRES MULT
C              FACTORS
C
      IF (SNOW .EQ. NO)  GO TO 949
      WINF=(1.0-F) + F*(.35-.03*KUGI)
C                                      WINF REDUCES WIND FOR FORESTED AREAS
C
C            /* KUGI IS INDEX TO UNDERGROWTH AND FOREST DENSITY,*/
C            /* WITH VALUES 0 TO 10 - WIND IN FOREST IS 35% OF  */
C            /* WIND IN OPEN WHEN KUGI=0, AND 5% WHEN KUGI=10 - */
C            /* WIND IS ASSUMED MEASURED AT 1-5 FT ABOVE GROUND */
C            /* OR SNOW SURFACE  */
C
      TMIN = ITEMP(MONTH,DAY,2)
      DEWX = DEWX - 1.0*ELDIF
C                        DEWPT USES A LAPSE RATE OF 1 DEGREE/1000 FT
C
      IF ((PACK .LE. 0.0).AND.(TMIN .GT. PETMAX))  GO TO 949
C
C     CALCULATE CONTINUOUS TEMP, WIND, AND RAD
C
      TGRAD = 0.0
      R = IRAD(MONTH,DAY)
      DO 948 I=1,24
        IF (I-7)  940, 900, 910
  900   CHANGE = ITEMP(MONTH,DAY,1) - TEMPI
  910   IF (I.NE.17) GO TO 940
C                           IMDEND IS LAST DAY OF PRESENT MONTH
        IF (DAY .NE. IMDEND)  CHANGE =ITEMP(MONTH,DAY+1,2) - TEMPI
        IF (MONTH.NE.12) GO TO 925
        IF (DAY .EQ. IMDEND)  CHANGE = ITEMP(11,31,2) - TEMPI
        GO TO 940
  925   IF (DAY .EQ. IMDEND)  CHANGE = ITEMP(MONTH+1,1,2) - TEMPI
C
  940   IF (ABS(CHANGE).GT.0.001)  GO TO 945
        TGRAD = 0.0
        GO TO 947
  945   TGRAD = GRAD(I)*CHANGE
  947   TEMPX(I) = TEMPI + TGRAD
        WINDX(I)  = WMUL*WIND*WINF*WINDIS(I)
        RAD(I)   = RMUL*R*RADCON*RADDIS(I)
        TEMPI = TEMPI + TGRAD
  948 CONTINUE
C
C       CHECK OF TILLAGE TIME
  949          JCOUNT = JCOUNT + 1
               DO 951 I=1,5
                  IF (JCOUNT.NE.TIMTIL(I) .OR. YEAR.NE.(YRTIL(I)+1900))
     1               GO TO 951
                  WRITE (6,1082)  MNAM(MONTH), DAY, TIMTIL(I), SRERTL(I)
                  DO 950 J=1,5
                    SRER(J) = SRERTL(I)
  950             CONTINUE
  951          CONTINUE
C
C  CROP CANOPY EFFECTS - ASSUMES LINEAR CHANGE BETWEEN MONTHLY VALUES
C
      COVER = COVER1 + (1.0 - (FLOAT(DYEND+1-DAY)/FLOAT(DYEND)))*
     1          (COVER2-COVER1)
```

```
C
      IF (NUTR .EQ. NO)  GO TO 1020
C
C                               NUTRIENT DAILY CALCULATIONS.
C
C                               FILL IN SOIL TEMP ARRAY WITH AVG. AIR TEMP
C
      DO 810  JHOUR=1,24
         DO 805  IZONE=1,4
            STEMP(IZONE,JHOUR) = TEMP
  805    CONTINUE
  810 CONTINUE
C
C                               TEST FOR APPLICATION OF FERTILIZERS
C
  815 IF (APLCNT .GT. NAPPL)  GO TO 860
      IF (APDAY(APLCNT) .GE. JCOUNT)  GO TO 820
         APLCNT = APLCNT + 1
         GO TO 815
  820 IF (JCOUNT .NE. APDAY(APLCNT))  GO TO 860
C
C                               ADD NUTRIENT APPLICATIONS TO STORAGES
C                               AND INCREMENT MASS TOTALS IN SYSTEM
C
      DO 830  IBLK=1,5
         DO 825  J=1,20
            SN(J,IBLK) = SN(J,IBLK) + SNAPL(J,IBLK,APLCNT)
            UN(J,IBLK) = UN(J,IBLK) + UNAPL(J,IBLK,APLCNT)
  825    CONTINUE
  830 CONTINUE
C
      DO 840  J=1,7
         SUM = 0.0
         DO 835  IBLK=1,5
            SUM = SUM + SNAPL(J,IBLK,APLCNT) + UNAPL(J,IBLK,APLCNT)
  835    CONTINUE
         TNA = TNA + SUM/5.
  840 CONTINUE
      DO 850  J=11,14
         SUM = 0.0
         DO 845  IBLK=1,5
            SUM = SUM + SNAPL(J,IBLK,APLCNT) + UNAPL(J,IBLK,APLCNT)
  845    CONTINUE
         TPA = TPA + SUM/5.
  850 CONTINUE
      SUM = 0.0
      DO 855  IBLK=1,5
         SUM = SUM + SNAPL(20,IBLK,APLCNT) + UNAPL(20,IBLK,APLCNT)
  855 CONTINUE
      TCLA = TCLA + SUM/5.
C
      WRITE (6,4005)  APLCNT, MNAM(MONTH), DAY, JCOUNT
      APLCNT = APLCNT + 1
C
  860 IF (JCOUNT .NE. TIMHAR)  GO TO 881
C
C                               COMPUTE AMOUNT HARVESTED AND DECREASE STORAGES
C
      DO 870  J=1,20
         TNRHV(J) = 0.0
```

```
                 IF (SELHV(J) .EQ. 0)  GO TO 870
                 SUM = 0.C
                 DO 865  IBLK=1,5
                    SUM = SUM + SN(J,IBLK) + UN(J,IBLK)
                    SN(J,IBLK) = 0.0
                    UN(J,IBLK) = 0.0
       865       CCNTINLE
                 TNRHV(J) = SUM/5. + LN(J) + GN(J)
                 LN(J) = C.C
                 GN(J) = C.0
                 TNRHVM(J) = TNRHVM(J) + TNRHV(J)
       870    CCNTINLE
              WRITE (6,40C6)  MNAM(MONTH), DAY
       C
       C                               TRANSFER INPUT REACTION RATES (KNI,KPI) INTO
       C                               REACTION RATES IN COMMON /NUT/  (KN,KP)
       C                               PLANT UPTAKE RATES ARE INPUT FOR 100% COVER,
       C                               RATES DECREASED LINEARLY FOR COVER < 100%.
       C
       881    CC 884  IZCNE=1,4
                 CC 882  J=1,1C
                    KN(J,IZCNE) = KNI(J,IZONE)
       882       CCNTINLE
                 DC 883  J=1,5
                    KP(J,IZCNE) = KPI(J,IZONE)
       883       CCNTINUE
       884    CCNTINLE
       C
              DO 885  IZCNE=1,4
                 KN(5,IZCNE) = KN(5,IZONE)*COVER
                 KP(3,IZCNE) = KP(3,IZONE)*COVER
       885    CONTINLE
       C
       C
       C                                    PRECIP READ LOOP
       C
        1C2C DO 1021 J=1,8
                 JK = J*18C/TIMFAC
                 JJ = JK - 18C/TIMFAC + 1
                 IF (TIMFAC.EC.5)  READ (5,1095) YR,MO,DY,CN,(IRAIN(I),I=JJ,JK)
                 IF (TIMFAC.EC.15) READ (5,1094) YR,MO,DY,CN,(IRAIN(I),I=JJ,JK)
                 IF ((YR+19C0).LE.BGNYR .AND. MO.LE.BGNMON .AND. DY.LT.BGNDAY)
           1              GC TC 1020
                 IF (INFLT.EC.ENGL) GO TO 708
                 DC 7C6 I=JJ,JK
                    IRAIN(I) = IRAIN(I)*3.937 + 0.5
         7C6     CCNTINLE
         7C8     JJJ = J
                 YR = YR + 19CC
                 IF (CN.EC.9) JJJ = 9
                 IT = (YEAR-YR) + (MONTH-MO) + (DAY-DY) + (JJJ-CN)
                 IF (IT.NE.C) GC TO 1022
                 IF (CN.EC.9) GC TO 1025
        1C21 CCNTINLE
              GO TC 1023
        1022 WRITE (6,1C90) JJJ,MCNTH,DAY,YEAR,CN,MO,DY,YR
              GO TO 1080
       C
       C
        1023           CC 1024  I=1,INTRVL
```

```
                            RAIN(I) = IRAIN(I)/100.
                            RAINT = RAINT + RAIN(I)
       1024                 CONTINUE
      C
                       IF (RAINT.GT.0.0) GO TO 1026
      C
      C
      C  USE RAIN LOOP IF MOISTURE STORAGES ARE NOT EMPTY
      C
       1025  IF ((RESS.LT.0.001).AND.(SRGXT.LT.0.001)) GO TO 1040
      C
      C
      C                      RAIN LOOP
      C
       1026            DO 1036  I=1,INTRVL
                            TIME = TIME + 1
                            TF = 1
                            PR = RAIN(I)
      C
                            IMIN = MOD(TIME,H)
                            IHR = (TIME - IMIN)/H
                            IMIN = TIMFAC*IMIN
                            PRNTKE = 0
                            IF (PRINT.EQ.HOUR) GO TO 1028
                            IF (PRINT.EQ.DAYS) GO TO 1029
                            IF (PRINT.EQ.MNTH) PRNTKE = 2
                            IF (PRINT.EQ.INTR) PRNTKE = 1
                               GO TO 1030
       1028                    IF (IMIN .LT. 1)  PRNTKE = 1
                               GO TO 1030
       1029                    IF (IHR .EQ. 24)  PRNTKE = 1
      C
       1030                 IF (PRNTKE .NE. 1)  GO TO 1031
      C
                            IF (HYCAL .EQ. CALB)  GO TO 1031
      C
                            WRITE (6,1101)  IHR, IMIN, DAY,MNAM(MONTH),YEAR
                            WRITE (6,1102)
                            WRITE (6,1103)
      C
       1031                 CALL LANDS
                            IF ((RESS .GE. 0.001).OR.(PR .GT. 0.001))  GO TO 1034
                            DO 1033  J=1,5
                               EPSN(J) = 0.0
       1033                    CONTINUE
                            IF (PRNTKE .EQ. 0)  GO TO 1035
       1034                 CALL SEDT
      C
       1035                IF (SLLG .GE. 0.001)  GO TO 1037
                           IF (REST .EQ. NO)  GO TO 971
                           IF (YEAR .LT. (YEARAP+1900))  GO TO 971
                           IF (JCOUNT.LT.TIMAP .AND. YEAR.EQ.(YEARAP+1900))
            1                GO TO 971
                           IF (IIFLAG .EQ. 0)  GO TO 1037
                           IF (SLLG .LT. 0.001)  GO TO 971
       1037                CALL ADSRB
                           IIFLAG = 1
                            IF (IHR .EQ. 24)  GO TO 1038
                             DEGS = 0.0
                             DEGL = 0.0
```

```
                           GO TO 971
       1038                CALL DEGRAD
        971             IF (NUTR .EQ. NO)  GO TO 1036
      C
      C
                           CALL NUTRNT
      C
       1036                CONTINUE
      C
                        GO TO 1050
      C
      C                      NO RAIN LOOP
      C
      C
       1040             IF    INTRVL
                        PR - 0.0
                        R3    0.0
                        DO  1042  I=1,5
       1042                RESE1(I) = 0.0
                        PRNTKE = 1
                        IF (PRINT.EQ.MNTH)  PRNTKE = 2
                        IMIN = 00
                        IHR = 24
                        IF (HYCAL.EQ.CALB .OR. PRNTKE.EQ.2)  GO TO 1043
                        WRITE (6,1101)  IHR, IMIN, DAY, MNAM(MONTH), YEAR
                        WRITE (6,1102)
                        WRITE (6,1103)
      C
       1043             CALL LANDS
                        SRERT = 0.0
                        ERSNT = 0.0
                        DO 1041  J=1,5
                           SRERT = SRERT + SRER(J)*0.2
                           ERSN(J) = 0.0
       1041                CONTINUE
                        IF (HYCAL.EQ.CALB .OR. PRNTKE.EQ.2)  GO TO 1044
                     IF (OUTPUT.EQ. METR) GO TO 1081
                        WRITE (6,1209)
                        WRITE (6,1210) ERSN, ERSNT
                        WRITE (6,1211)  SRER, SRERT
       1081             IF (OUTPUT.EQ. ENGL) GO TO 1044
      C  METRIC CONVERSIONS FOR OUTPUT
                        ERSNTT=ERSNT*METOPT*2.471
                        SRRTMT=SRERT*METOPT*2.471
                        DO 1163 I=1,5
                          ERSNMT(I)=ERSN(I)*METOPT*2.471
                          SRERMT(I)=SRER(I)*METOPT*2.471
       1163             CONTINUE
                        WRITE (6,1208)
                        WRITE (6,1210) ERSNMT, ERSNTT
                        WRITE (6,1211) SRERMT, SRRTMT
      C
       1044            IF (SLLG .GE. 0.001)  GO TO 1047
                       IF (REST .EQ. NO)  GO TO 972
                       IF (YEAR .LT. (YEARAP+1900))  GO TO 972
                       IF (JCOUNT.LT.TIMAP .AND. YEAR.EQ.(YEARAP+1900)) GO TO 972
                       IF (IJFLAG .EQ. 0)  GO TO 1047
                       IF (SLLG .LT. 0.001)  GO TO 972
       1047            CALL ACSFE
                       IJFLAG = 1
```

```
                        CALL DEGFAC
       972        IF (NLTF .EQ. NC)  GO TO 1050
                        CALL NLTFNT
      C                                                    END DAILY LOOP
       1050             CONTINUE
      C
      C                       MONTHLY SUMMARY
      C
                        CALL OUTMON (YEAR)
      C
      C
      C                                                    END MONTHLY LOOP
       1060           CONTINUE
      C
      C                       YEARLY SUMMARY
                      CALL OUTYR (YEAR)
      C
                      APLCNT = 1
      C                                                    END YEARLY LOOP
       1070     CONTINUE
      C
       1080 WRITE (6,1260)
      C
      C                       FORMAT STATEMENTS
      C
       1090 FORMAT ('1','*****ERROR*****  INCORRECT INPUT DATA    DESIRED '
          *    'CARD ',I1,' FOR ',I2,'/',I2,'/',I4,'; READ CARD ',I1,' FOR ',
          *    I2,'/',I2,'/',I4)
       1082 FORMAT ('0','TILLAGE OF THE SOIL OCCURS ON',1X,A8,1X,I2,2X,
          1          '(TIMTIL=',I3,'), RESULTING IN A NEW FINES DEPOSIT ',
          1          'STORAGE OF',F6.3,' TONS/ACRE')
       1091 FORMAT ('1',25X,'THIS IS A PRODUCTION RUN')
       1092 FORMAT ('0')
       1093 FORMAT ('1',24X,'THIS IS A CALIBRATION RUN')
       1094 FORMAT (1X,3I2,I1,12I6)
       1095 FORMAT (1X,3I2,I1,36I2)
       1096 FORMAT (20A4)
       1097 FORMAT (6X,A4)
       1098 FORMAT (7X,A4)
       1099 FORMAT (5X,A4)
       1100 FORMAT (A8)
       1101 FORMAT ('1',25X,I2,':',I2,'  ON  ',I2,1X,A8,1X,I4)
       1102 FORMAT ('+',25X,'_____________________________' )
       1103 FORMAT ('0',34X,'BLOCK 1   BLOCK 2   BLOCK 3   BLOCK 4   BLOCK 5',
          C  5X,'TOTAL')
       1104 FORMAT ('0',32X,'PESTICIDE APPLICATION:  SURFACE-APPLIED')
       1105 FORMAT ('0',32X,'PESTICIDE APPLICATION:  SOIL-INCORPORATED')
       1106 FORMAT ('0',32X,'CHEMICAL:           ',20A4)
       1107 FORMAT ('0',32X,'WATERSHED:          ',20A4)
       1108 FORMAT ('0',32X,'INPUT UNITS:    ENGLISH')
       1109 FORMAT ('0',32X,'INPUT UNITS:    METRIC')
       1110 FORMAT ('0',32X,'OUTPUT UNITS:   ENGLISH')
       1111 FORMAT ('0',32X,'OUTPUT UNITS:   METRIC')
       1112 FORMAT ('0',32X,'OUTPUT UNITS:   BOTH ENGLISH AND METRIC')
       1113 FORMAT ('0',32X,'PRINT INTERVAL: EACH INTERVAL')
       1114 FORMAT ('0',32X,'PRINT INTERVAL: EACH HOUR')
       1115 FORMAT ('0',32X,'PRINT INTERVAL: EACH DAY')
       1128 FORMAT ('0',32X,'PRINT INTERVAL: EACH MONTH')
       1116 FORMAT ('0',32X,'SNOWMELT CALCULATIONS PERFORMED')
       1117 FORMAT ('0',32X,'SNOWMELT NOT PERFORMED')
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      1118 FORMAT ('0',32X,'ADSCRPTION AND DESORPTION ALGORITHMS USED')
      1119 FORMAT ('0',32X,'ADSORPTION CALCULATED ONLY, NO DESORPTION')
      1120 FORMAT ('0',/'0','HYCAL=',A4,2X,'INPUT=',A4,2X,'OUTPUT=',A4,2X,
          1'PRINT=',A4,2X,'SNOW=',A4,2X,'PEST=',A4,2X,'NUTR=',A4,2X,
          2'ICHECK=',A4)
      1121 FORMAT ('0','INPUT ERROR: IT IS NOT POSSIBLE TO MAKE CALIBRATION R
          1UN WITH BOTH PESTICIDES AND NUTRIENTS TOGETHER',/,' ','CHANGE HYCA
          2L TO PROD, OR EITHER PEST OR NUTR FROM YES TO NO')
      1122 FORMAT ('0','INPUT ERROR: THE FIRST LINE OF THE PESTICIDE INPUT SE
          1QUENCE MUST BE THE WORD PESTICIDE, CORRECT AND RUN AGAIN')
      1123 FORMAT ('+',50X,'FOR PESTICIDES')
      1124 FORMAT ('+',50X,'FOR NUTRIENTS')
      1125 FORMAT ('+',50X,'FOR HYDROLOGY AND SEDIMENT ONLY')
      1126 FORMAT ('+',50X,'FOR PESTICIDES AND NUTRIENTS')
      1127 FORMAT ('0','ABDCCE=',A4,2X,'DESORP=',A4)
     1164  FORMAT ('0','INTRVL= ',I2,13X,'HYMIN= ',F8.4,8X,'AREA= ',F10.4)
     1165  FORMAT ('0','BGNDAY= ',I2,13X,'BGNMON= ',I2,13X,'BGNYR= ',I4)
     1166  FORMAT ('0','ENDDAY= ',I2,13X,'ENDMON= ',I2,13X,'ENDYR= ',I4)
     1167  FORMAT ('0',/'0','UZSN= ',F8.4,9X,'UZS= ',F8.4,10X,'LZSN= ',F8.4,
          19X,'LZS= ',F8.4)
     1168  FORMAT ('0','L= ',F8.4,12X,'SS= ',F8.4,11X,'NN= ',F8.4,11X,'A= ',
          1F8.4,12X,'K3= ',F8.4,11X,'EPXM= ',F8.4)
     1169  FORMAT ('0','INFIL= ',F8.4,8X,'INTER= ',F8.4,8X,'IRC= ',F8.4,10X,
          1'K24L= ',F8.4,9X,'KK24= ',F8.4,9X,'K24EL= ',F8.4)
     1170  FORMAT ('0','SGW= ',F8.4,10X,'GWS= ',F8.4,10X,'KV= ',F8.4,11X,
          1'ICS= ',F8.4,10X,'CFS= ',F8.4,10X,'IFS= ',F8.4)
     1171  FORMAT ('0',/'0','RADCON= ',F8.4,7X,'CCFAC= ',F8.4,8X,'SCF= ',
          1F8.4,10X,'ELDIF= ',F8.4,8X,'IDNS= ',F8.4,9X,'F= ',F8.4)
     1172  FORMAT ('0','DGM= ',F8.4,10X,'WC= ',F8.4,11X,'MPACK= ',F8.4,8X,
          1'EVAPSN= ',F8.4,7X,'MELEV= ',F8.0,8X,'TSNOW= ',F8.4)
     1173  FORMAT ('0','PACK= ',F8.4,9X,'DEPTH= ',F8.4)
     1174  FORMAT ('0','PETMIN= ',F8.4,7X,'PETMAX= ',F8.4,7X,'PETMUL= ',F8.4,
          17X,'WMUL= ',F8.4,9X,'RMUL= ',F8.4,9X,'KUGI= ',F8.4)
     1175  FORMAT ('0',/'0','COVPMO= ', 12(F4.2,2X) )
     1176  FORMAT ('0','SZDPTH= ',F8.4,7X,'UZDPTH= ',F8.4,7X,'BULKD= ',F8.4)
     1177  FORMAT ('0','JRER= ',F8.4,9X,'KRER= ',F8.4,9X,'JSER= ',F8.4,9X,
          1'KSER= ',F8.4,9X,'SRERI= ',F8.4)
     1178  FORMAT ('0',/'0','TIMAP= ',I8,8X,'YEARAP= ',I8,7X,
          1            'SSTF=     ',5(F6.3,3X))
     1179  FORMAT ('0','CMAX= ',F8.6,9X,'DD= ',F8.6,11X,
          1'K= ',F8.4,12X,'N= ',F8.4,12X,'NP= ',F8.4)
     1182  FORMAT ('0','DECCON= ',F8.6)
     1183  FORMAT ('0','TIMTIL= ',5(I3,2X),4X,'YRTIL= ',5(I2,2X),4X,
          1            'SREFTL= ',5(F6.3,2X))
       382 FORMAT (' ',67X,'WATER',24X,'SEDIMENT')
      1208 FORMAT ('0',6X,'SEDIMENT,TONNES/HECTARE')
      1209 FORMAT ('0', 6X,'SEDIMENT, TONS/ACRE')
      1210 FORMAT (' ',11X,'ERODED SEDIMENT    ',5(3X,F7.3),4X,F7.3)
      1211 FORMAT (' ',11X,'FINES DEPOSIT',6X,5(3X,F7.3),4X,F7.3)
      1260 FORMAT ('1','END OF SIMULATION')
      1263 FORMAT ('1',5X,'DATE',4X,'TIME',4X,'FLOW(CFS-CMS)',6X,
          X            'SEDIMENT (LBS-KG-KG/MIN-GM/L)',23X,
          X            'PESTICIDE (GM-GM/MIN-PPM)')
      1265 FORMAT (8X,24I3)
      1264 FORMAT (8X,12I6)
     4001  FORMAT     ('1',40X,'|',10X,'DISSOLVED IN WATER',11X,'|',
          1            6X,'ADSORBED TO SEDIMENT',5X,'|',/,
          2            ' ',4X,'DATE',6X,'TIME',7X,'FLOW    SEDIMENT',
          3            5X,'NO3',5X,'NO2',5X,'NH3',5X,'PO4',6X,'CL',
          4            5X,'NH3',3X,'ORG-N',5X,'PO4',3X,'ORG-P',6X,
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         5           'TOT-N',3X,'TOT-P')
   4002  FORMAT      (' ',24X,'(CFS)',5X,'(LB)',2X,9(4X,'(LB)'),7X,'(LB)',
         1           4X,'(LB)')
   4003  FORMAT      (' ',24X,'(CFS)',5X,'(KG)',2X,9(4X,'(KG)'),7X,'(KG)',
         1           4X,'(KG)')
   4004  FORMAT      (' ',40X,5(2X,'(MG/L)'),4(3X,'(PPM)'))
   4005  FORMAT      ('0','NUTRIENT APPLICATION NO. ',I2,' OCCURS ON ',
         1            A8,2X,I2,'   (DAY = ',I3,')' )
   4006  FORMAT      ('0','PLANT HARVESTING OCCURS ON ',A8,1X,I2)
C
         STOP
         END
C
C
C
C
         SUBROUTINE CHECKP (HYMIN,INTRVL,UZSN,LZSN,IRC,NN,L,SS,A,UZS,LZS,
       1                   K24L,KK24,K24EL,K3,SSTR,UZDPTH,
       2                   CMAX,BULKD,AREA,HYCAL,INPUT,OUTPUT,PRINT,PEST,
       3                   SNOW,APMODE,DESORP,ICHECK,ENDYR,ENDMON,ENDDAY,
       4                   BGNYR,BGNMON,BGNDAY,IERROR,CALB,PROD,
       5                   ENGL,METR,BOTH,INTR,HOUR,DAYS,MNTH,YES,NO,SURF,
       6                   SOIL,ON,OFF,SZDPTH,COVPMO,TIMTIL,RADCON,CCFAC,
       7                   SCF,ELDIF,IONS,F,DGM,WC,EVAPSN,MELEV,TSNOW,
       8                   PETMIN,PETMAX,PETMUL,WMUL,RMUL,KUGI,TIMAP,
       9                   YEARAP,DEGCON,NUTR)
C
         DIMENSION  SSTR(5),COVPMO(12),TIMTIL(5)
C
         REAL LZSN,IRC,NN,L,LZS,K24L,KK24,K24EL,K3
         REAL  IONS,MELEV,KUGI
         INTEGER  HYCAL,INPUT,OUTPUT,PRINT,SNOW,APMODE,DESORP,ICHECK
         INTEGER  ENDYR,ENDMON,ENDDAY,BGNYR,BGNMON,BGNDAY,PEST
         INTEGER  CALB,PROD,ENGL,METR,BOTH,INTR,HOUR,DAYS,YES,NO
         INTEGER  SURF,SOIL,ON,OFF
         INTEGER  TIMTIL,TIMAP,YEARAP,NUTR
C
         IF (HYMIN .GT. 0.0) GO TO 1501
               WRITE (6,1600)  HYMIN
               IERROR = IERROR + 1
    1501 IF (INTRVL .EQ. 5 .OR. INTRVL .EQ. 15) GO TO 1502
               WRITE (6,1601)  INTRVL
               IERROR = IERROR + 1
    1502 IF (UZSN .LT. LZSN) GO TO 1503
               WRITE (6,1602)
               IERROR = IERROR + 1
    1503 IF (IRC .LE. 1.0) GO TO 1504
               WRITE (6,1603)  IRC
               IERROR = IERROR + 1
    1504 IF (NN .LE. 1.0) GO TO 1505
               WRITE (6,1604)  NN
               IERROR = IERROR + 1
    1505 IF (L .GT. 1.0) GO TO 1506
               WRITE (6,1605)  L
               IERROR = IERROR + 1
    1506 IF (SS .LT. 1.0) GO TO 1507
               WRITE (6,1606)  SS
               IERROR = IERROR + 1
    1507 IF (A .LE. 0.0) GO TO 1508
               WRITE (6,1607)  A
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                IERROR = IERROR + 1
      1508 IF (UZS .LT. LZS) GO TO 1509
                WRITE (6,1608)
                IERROR = IERROR + 1
      1509 IF (K24L .LE. 1.0) GO TO 1510
                WRITE (6,1609)  K24L
                IERROR = IERROR + 1
      1510 IF (KK24 .LE. 1.0) GO TO 1511
                WRITE (6,1610)  KK24
                IERROR = IERROR + 1
      1511 IF (K24EL .LE. 1.0) GO TO 1512
                WRITE (6,1611)  K24EL
                IERROR = IERROR + 1
      1512 IF (K3 .LE. 1.0) GO TO 1513
                WRITE (6,1612)  K3
                IERROR = IERROR + 1
      1513 IF (LZDPTH .GT. SZDPTH) GO TO 1514
                WRITE (6,1613)
                IERROR = IERROR + 1
      1514 IF (SZDPTH .LT. 1.0) GO TO 1515
                WRITE (6,1614) SZDPTH
                IERROR= IERROR + 1
      1515 DO 1516 I=1,12
           IF (CCVPMO(I) .LE. 1.0) GO TO 1516
                WRITE (6,1615) CCVPMO(I)
                IERROR= IERROR + 1
      1516 CONTINUE
           DO 1526 I=1,5
           IF (TIMTIL(I) .GE. 0 .AND. TIMTIL(I) .LT. 367) GO TO 1526
                WRITE (6,1617) TIMTIL(I)
                IERROR= IERROR + 1
      1526 CONTINUE
      1518 IF (BULKD .GT. 62.4) GO TO 1519
                WRITE (6,1618)  BULKD
                IERROR = IERROR + 1
      1519 IF (AREA .GT. 0.01) GO TO 1520
                WRITE (6,1619)  AREA
                IERROR = IERROR + 1
      1520 IF (HYCAL .EQ. CALB .OR. HYCAL .EQ. PROD)  GO TO 1521
                WRITE (6,1620)  HYCAL
                IERROR = IERROR + 1
      1521 IF (INPUT .EQ. ENGL .OR. INPUT .EQ. METR) GO TO 1522
                WRITE (6,1621)  INPUT
                IERROR = IERROR + 1
      1522 IF (OUTPUT .EQ. ENGL .OR. OUTPUT .EQ. METR .OR. OUTPUT .EQ. BOTH)
          1     GO TO 1523
                WRITE (6,1622)  OUTPUT
                IERROR = IERROR + 1
      1523 IF (PRINT .EQ. INTR .OR. PRINT .EQ. HOUR .OR. PRINT .EQ. DAYS
          1     .OR. PRINT .EQ. MNTH) GO TO 1524
                WRITE (6,1623)  PRINT
                IERROR = IERROR + 1
      1524 IF (SNOW .EQ. YES .OR. SNOW .EQ. NO) GO TO 1525
                WRITE (6,1624)  SNOW
                IERROR   IERROR + 1
      1525 IF (SNOW .EQ. NO) GO TO 1550
           IF (RADCON .GT. 0.0) GO TO 1529
                WRITE (6,1628) RADCON
                IERROR= IERROR + 1
      1529 IF (CCFAC .GT. 0.0) GO TO 1530
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                WRITE (6,1629) CCFAC
                IERROR= IERROR + 1
      1530 IF (SCF .GT. 0.0) GO TO 1531
                WRITE (6,1630) SCF
                IERROR= IERROR + 1
      1531 IF (ELDIF .LT. 30.0) GO TO 1532
                WRITE (6,1631) ELDIF
                IERROR= IERROR + 1
      1532 IF (IDNS .LT. 1.0) GO TO 1533
                WRITE (6,1632) IDNS
                IERROR= IERROR + 1
      1533 IF (F .LE.  1.0) GO TO 1534
                WRITE (6,1633) F
                IERROR= IERROR + 1
      1534 IF (DGM .LT. 1.0) GO TO 1535
                WRITE (6,1634) DGM
                IERROR= IERROR + 1
      1535 IF (WC .LT. 1.0) GO TO 1536
                WRITE (6,1635) WC
                IERROR= IERROR + 1
      1536 IF (EVAPSN .GT. 0.0) GO TO 1537
                WRITE (6,1636) EVAPSN
                IERROR= IERROR + 1
      1537 IF (MELEV .LT. 30000.0) GO TO 1538
                WRITE (6,1637) MELEV
                IERROR= IERROR + 1
      1538 IF (TSNOW .GT. 20.0 .AND. TSNOW .LT. 40.0) GO TO 1539
                WRITE (6,1638) TSNOW
                IERROR= IERROR + 1
      1539 IF (PETMIN .GT. 30.0) GO TO 1540
                WRITE (6,1639) PETMIN
                IERROR= IERROR + 1
      1540 IF (PETMAX .LT. 60.0) GO TO 1541
                WRITE (6,1640) PETMAX
                IERROR= IERROR + 1
      1541 IF (PETMUL .GT. 0.0) GO TO 1542
                WRITE (6,1641) PETMUL
                IERROR= IERROR + 1
      1542 IF (WMUL .GT. 0.0) GO TO 1543
                WRITE (6,1642) WMUL
                IERROR= IERROR + 1
      1543 IF (RMUL .GT. 0.0) GO TO 1544
                WRITE (6,1643) RMUL
                IERROR= IERROR + 1
      1544 IF (KUGI .GE. 0.0 .AND. KUGI .LE. 10.0) GO TO 1550
                WRITE (6,1644) KUGI
                IERROR= IERROR + 1
      1550 IF (PEST .EQ. YES .OR. PEST .EQ. NO) GO TO 1551
                WRITE (6,1650) PEST
                IERROR= IERROR + 1
      1551 IF (PEST .EQ. NO)  GO TO 1565
           IF (APMODE .EQ. SURF .OR. APMODE .EQ. SOIL) GO TO 1553
                WRITE (6,1652)  APMODE
                IERROR = IERROR + 1
      1553 IF (DESORP .EQ. YES .OR. DESORP .EQ. NO) GO TO 1554
                WRITE (6,1653)  DESORP
                IERROR = IERROR + 1
      1554 DO 1555 I=1,5
           IF (SSTR(I) .GT. 0.0) GO TO 1555
                WRITE (6,1654)
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                IERROR = IERROR + 1
      1555 CONTINUE
           IF (CMAX .LE. 1.0) GO TO 1557
                WRITE (6,1656)  CMAX
                IERROR = IERROR + 1
      1557 IF (TIMAP .GT. 0 .AND. TIMAP .LT. 367) GO TO 1558
                WRITE (6,1657) TIMAP
                IERROR= IERROR + 1
      1558 IF (YEARAP + 1900 .GE. BGNYR .AND. YEARAP + 1900 .LE. ENDYR)
          1    GO TO 1559
                WRITE (6,1658)
                IERROR= IERROR + 1
      1559 IF (DEGCON .LT. 1.0) GO TO 1565
                WRITE (6,1659) DEGCON
                IERROR= IERROR + 1
      1565 IF (NUTR .EQ. YES .OR. NUTR .EQ. NO) GO TO 1580
                WRITE (6,1665) NUTR
                IERROR= IERROR + 1
      1580 IF (ICHECK .EQ. ON) GO TO 1581
                WRITE (6,1680)  ICHECK
                IERROR = IERROR + 1
      1581 IF (ENDYR .GT. BGNYR) GO TO 1582
           IF (ENDYR .EQ. BGNYR .AND. ENDMON .GT. BGNMON) GO TO 1582
           IF (ENDYR .EQ. BGNYR .AND. ENDMON .EQ. BGNMON .AND. ENDDAY
          1          .GE. BGNDAY) GO TO 1582
                WRITE (6,1681)
                IERROR = IERROR + 1
      1582 IF (IERROR .GT. 0) WRITE (6,1682) IERROR
     C
     C CHECKR ERROR STATEMENTS
     C
      1600 FORMAT ('0','ERROR: HYMIN HAS BEEN INPUTTED AS ',F8.4,'; IT MUST B
          1E SET GREATER THAN 0.0')
      1601 FORMAT ('0','ERROR: INTRVL HAS BEEN INPUTTED AS ',I4,'; IT MUST BE
          1 SET EQUAL TO EITHER 5 OR 15 MINUTES')
      1602 FORMAT ('0','ERROR: UZSN HAS BEEN INPUTTED GREATER THAN OR EQUAL T
          1O LZSN, THIS IS NOT REALISTIC')
      1603 FORMAT ('0','ERROR: IRC HAS BEEN INPUTTED AS ',F8.4,'; IT MUST BE
          1SET LESS THAN OR EQUAL TO 1.0')
      1604 FORMAT ('0','ERROR: NN HAS BEEN INPUTTED AS ',F8.4,'; IT MUST BE S
          1ET LESS THAN 1.0')
      1605 FORMAT ('0','ERROR: L HAS BEEN INPUTTED AS ',F8.4,'; THIS LOOKS RA
          1THER STRANGE - REMEMBER THE UNITS ARE IN FEET OR METERS')
      1606 FORMAT ('0','WARNING: SS HAS BEEN INPUTTED AS ',F8.4,'; A LAND SLO
          1PE OF 45 DEGREES OR GREATER IS QUESTIONABLE, HOWEVER IF THIS ACTUA
          2LLY IS TRUE',/,' ','SET ICHECK=OFF AND RUN AGAIN')
      1607 FORMAT ('0','WARNING: A HAS BEEN INPUTTED AS ',F8.4,'; IMPERVIOUS
          1AREA IS NOT CONSIDERED IN SEDIMENT REMOVAL AS THE MODEL IS BASICAL
          2LY FOR ',/,' ','AGRICULTURAL AREAS, HOWEVER IF IMPERVIOUS AREA IS
          3DESIRED SET ICHECK=OFF AND RUN AGAIN')
      1608 FORMAT ('0','ERROR: UZS HAS BEEN INPUTTED GREATER THAN OR EQUAL TO
          1 LZS, THIS IS NOT REALISTIC')
      1609 FORMAT ('0','ERROR: K24L HAS BEEN INPUTTED AS ',F8.4,'; IT MUST BE
          1 SET LESS THAN OR EQUAL TO 1.0')
      1610 FORMAT ('0','ERROR: KK24 HAS BEEN INPUTTED AS ',F8.4,'; IT MUST BE
          1 SET LESS THAN OR EQUAL TO 1.0')
      1611 FORMAT ('0','ERROR: K24EL HAS BEEN INPUTTED AS ',F8.4,'; IT MUST B
          1E SET LESS THAN OR EQUAL TO 1.0')
      1612 FORMAT ('0','ERROR: K3 HAS BEEN INPUTTED AS ',F8.4,'; IT MUST BE S
          1ET LESS THAN OR EQUAL TO 1.0')
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      1613 FORMAT ('0','ERROR: UZDPTH HAS BEEN INPUTTED LESS THAN OR EQUAL TO
          1 SZDPTH; THIS IS NOT REALISTIC')
      1614 FORMAT ('0','ERROR: SZDPTH HAS BEEN INPUTTED AS ',F8.4,'; IT MUST
          1BE LESS THAN 1.0 INCHES')
      1615 FORMAT ('0','ERROR: ONE OF THE VALUES FOR COVPMO HAS BEEN INPUTTED
          1 AS ',F8.4,'; COVPMO MUST BE LESS THAN 1.0')
      1617 FORMAT ('0','ERROR: ONE OF THE VALUES FOR TIMTIL HAS BEEN INPUTTED
          1 AS ',I8,'; TIMTIL MUST BE A POSITIVE INTEGER LESS THAN 367')
      1618 FORMAT ('0','ERROR: BULKD HAS BEEN INPUTTED AS ',F8.4,'; IT MUST B
          1E GREATER THAN 62.4 LB/FT(3)')
      1619 FORMAT ('0','ERROR: AREA HAS BEEN INPUTTED AS ',F8.6,'; IT SHOULD
          1BE INPUTTED IN ACRES, HOWEVER IF THIS IS ACTUALLY THE CASE THEN SE
          2T ICHECK=OFF',/,' ','AND RUN AGAIN')
      1620 FORMAT ('0','ERROR: HYCAL HAS BEEN INPUTTED AS ',A4,'; IT MUST BE
          1SET EQUAL TO CALB OR PROD')
      1621 FORMAT ('0','ERROR: INPUT HAS BEEN INPUTTED AS ',A4,'; IT MUST BE
          1SET EQUAL TO ENGL OR METR')
      1622 FORMAT ('0','ERROR: OUTPUT HAS BEEN INPUTTED AS ',A4,'; IT MUST BE
          1 SET EQUAL TO EITHER ENGL, METR, OR BOTH')
      1623 FORMAT ('0','ERROR: PRINT HAS BEEN INPUTTED AS ',A4,'; IT MUST BE
          1SET EQUAL TO EITHER INTR, HOUR, DAYS, OR MNTH')
      1624 FORMAT ('0','ERROR: SNOW HAS BEEN INPUTTED AS ',A4,'; IT MUST BE S
          1ET EQUAL TO YES OR NO')
      1628 FORMAT ('0','ERROR: RADCON HAS BEEN INPUTTED AS ',F8.4,'; RADCON M
          1UST BE GREATER THAN 1.0')
      1629 FORMAT ('0','ERROR: CCFAC HAS BEEN INPUTTED AS ',F8.4,'; CCFAC MUS
          1T BE GREATER THAN 0.0')
      1630 FORMAT ('0','ERROR: SCF HAS BEEN INPUTTED AS ',F8.4,'; SCF MUST BE
          1 GREATER THAN 0.0')
      1631 FORMAT ('0','ERROR: ELDIF HAS BEEN INPUTTED AS ',F8.4,'; ELDIF SHO
          1ULD BE INPUT IN THOUSANDS OF FEET AND CANNOT EXCEED 30.0')
      1632 FORMAT ('0','ERROR: IDNS HAS BEEN INPUTTED AS ',F8.4,'; IDNS MUST
          1BE LESS THAN 1.0')
      1633 FORMAT ('0','ERROR: F HAS BEEN INPUTTED AS ',F8.4,'; F MUST BE LES
          1S THAN OR EQUAL TO 1.0')
      1634 FORMAT ('0','WARNING: DGM HAS BEEN INPUTTED AS ',F8.4,'; VALUES GR
          1EATER THAN 1.0 INCHES FOR DGM ARE QUESTIONABLE')
      1635 FORMAT ('0','ERROR: WC HAS BEEN INPUTTED AS ',F8.4,'; WC MUST BE L
          1ESS THAN 1.0')
      1636 FORMAT ('0','ERROR: EVAPSN HAS BEEN INPUTTED AS ',F8.4,'; EVAPSN C
          1ANNOT BE A NEGATIVE NUMBER')
      1637 FORMAT ('0','ERROR: MELEV HAS BEEN INPUTTED AS ',F9.1,'; MELEV CAN
          1NOT HAVE A VALUE GREATER THAN 30000.0')
      1638 FORMAT ('0', 'ERROR: TSNOW HAS BEEN INPUTTED AS ',F8.4,'; TSNOW MU
          1ST HAVE A VALUE GREATER THAN 20.0 AND LESS THAN 40.0')
      1639 FORMAT ('0','ERROR: PETMIN HAS BEEN INPUTTED AS ',F8.4,'; PETMIN M
          1UST BE GREATER THAN 30.0')
      1640 FORMAT ('0','ERROR: PETMAX HAS BEEN INPUTTED AS ',F8.4,'; PETMAX M
          1UST BE LESS THAN 60.0')
      1641 FORMAT ('0','ERROR: PETMUL HAS BEEN INPUTTED AS ',F8.4,'; PETMUL M
          1UST BE GREATER THAN 0.0')
      1642 FORMAT ('0','ERROR: WMUL HAS BEEN INPUTTED AS ',F8.4,'; WMUL MUST
          1BE GREATER THAN 0.0')
      1643 FORMAT ('0','ERROR: RMUL HAS BEEN INPUTTED AS ',F8.4,'; RMUL MUST
          1BE GREATER THAN 0.0')
      1644 FORMAT ('0','ERROR: KUGI HAS BEEN INPUTTED AS ',F8.4,'; KUGI MUST
          1BE A POSITIVE NUMBER LESS THAN 10.0')
      1650 FORMAT ('0','ERROR: PEST HAS BEEN INPUTTED AS ',A4,'; IT MUST BE S
          1ET EQUAL TO YES OR NO')
      1652 FORMAT ('0','ERROR: APMODE HAS BEEN INPUTTED AS ',A4,'; IT MUST BE
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     1 SET EQUAL TO SURF OR SOIL')
 1653 FORMAT ('0','ERROR: DESORP HAS BEEN INPUTTED AS ',A4,'; IT MUST BE
     1 SET EQUAL TO YES OR NO')
 1654 FORMAT ('0','WARNING: SOME OF THE FIVE SSTR VALUES INPUTTED ARE EQ
     1UAL TO 0.0; IF THIS IS ACTUALLY DESIRED SET ICHECK=OFF AND RUN AGA
     2IN')
 1656 FORMAT ('0','ERROR: CMAX HAS BEEN INPUTTED AS ',F8.4,'; IT SHOULD
     1BE SET LESS THAN OR EQUAL TO 1.0')
 1657 FORMAT ('0','ERROR: TIMAP HAS BEEN INPUTTED AS ',I4,'; TIMAP MUST
     1BE A POSITIVE INTEGER LESS THAN 367')
 1658 FORMAT ('0','ERROR: THE INPUTTED YEAR OF APPLICATION DOES NOT OCCU
     1R WITHIN THE PERIOD OF SIMULATION')
 1659 FORMAT ('0','ERROR: DEGCON HAS BEEN INPUTTED AS ',F8.4,'; DEGCON M
     1UST BE LESS THAN 1.0')
 1665 FORMAT ('0','ERROR: NUTR HAS BEEN INPUTTED AS ',A4,'; IT MUST BE S
     1ET EQUAL TO YES OR NO')
 1680 FORMAT ('0','ERROR: ICHECK HAS BEEN INPUTTED AS ',A4,'; IT MUST BE
     1 SET EQUAL TO ON OR OFF')
 1681 FORMAT ('0','ERROR: THE INPUTTED END DATE (ENDDAY,ENDMON,ENDYR) OC
     1CURS BEFORE THE BEGIN DATE (BGNDAY,BGNMON,BGNYR)')
 1682 FORMAT ('0','THE TOTAL NUMBER OF DETECTED ERRORS IN THE INPUT SEQU
     1ENCE EQUALS',I3,', PLEASE CORRECT AND TRY AGAIN OR CONTACT HYDROCO
     2MP, INC.')
C
      RETURN
      END
C
C
C
C
      BLOCK DATA
C
C
C                    BLOCK DATA TO INITIALIZE VARIABLES
C
C
      IMPLICIT  REAL(L)
C
      DIMENSION RESE(5),RESE1(5),ROSB(5),SRGX(5),INTF(5),RGX(5),INFL(5),
     1 UZSB(5),APERCB(5),RIB(5),ERSN(5)
      DIMENSION SRER(5),ROBTOM(5),ROBTOT(5),INFTOM(5),INFTOT(5),
     1 ROITOM(5),ROITOT(5),RXB(5),ERSTOM(5),ERSTOT(5),MNAM(12),RAD(24),
     2 TEMPX(24),WINDX(24),RAIN(288)
      DIMENSION PRSTOM(5),PRSTOT(5),PROTOM(5),PROTOT(5),UPITOM(5),
     1 UPITOT(5),STS(5),UTS(5),SAS(5),SCS(5),SDS(5),SSTR(5),
     2 UAS(5),UCS(5),LCS(5),USTR(5),UPRIS(5)
C
      COMMON /ALL/ RL,HYMIN,PRNTKE,HYCAL,DPST,OUTPUT,TIMFAC,LZS,AREA,
     1 RESB1,ROSB,SRGX,INTF,RGX,INFL,UZSB,APERCB,RIB,ERSN,M,P3,A,
     2 CALB,PROD,PEST,NUTR,ENGL,METR,BOTH,RESB,YES,NO,IMIN,IHR,TF,
     3 JCOUNT,PRINT,INTF,DAYS,HOUR,MNTH
C
      COMMON /LAND/ MNAM,PRTOT,ERSNTT,PRTOM,ERSNTM,DAY,
     1 RUTOM,NEPTOM,ROSTOM,RITOM,RINTOM,BASTOM,RCHTOM,RUTOT,
     2 NEPTOT,ROSTOT,RITOT,RINTOT,BASTOT,RCHTOT,TWBAL,EPTOM,EPTOT,
     3 UZS,UZSN,LZSN,INFIL,INTER,IRC,NN,L,SS,SGW1,PR,SGW,GWS,KV,
     4 K24L,KK24,K24EL,EP,IFS,K3,EPXM,RESB1,RESS,SCEP,SCEP1,SRGXT,
     5 SRGXT1,JRER,KRER,JSER,KSER,SRERT,MMPIN,METOPT,SNOW,CCFAC,
     6 SCF,IDNS,F,DGM,WC,MPACK,EVAPSN,MELEV,TSNOW,PETMIN,PETMAX,ELDIF,
     7 DEWX,PACK,DEPTH,MONTH,SDEN,IPACK,TMIN,SUMSNM,PXSNM,XK3,
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     8 MELRAM,RADMEM,CCFMEM,CRAINM,CONMEM,SGMM,SNEGMM,SEVAPM,SUMSNY,
     9 PXSNY,MELRAY,RADMEY,CORMEY,SGMY,CONMEY,CRAINY,SNEGMY,SEVAPY,
     * TSNBAL,CCVER,CCVRMX,ROBTOM,ROBTOT,RXB,ROITOM,ROITOT,INFTOM,
     1 INFTCT,ERSTCM,ERSTCT,SRER,TEMPX,RAD,WINDX,RAIN,INPUT
C
      COMMON /PESTC/ STST,SPRGTM,SPRSTM,SAST,SCST,SDST,UTST,UAST,UCST,K,
     1 UDST,FP,CMAX,NI,SPRCTT,SPRSTT,MUZ,FPUZ,UPRITM,
     2 UPRITT,KGPLB,FFLZ,MLZ,LSTR,LAS,LCS,LDS,GSTR,GAS,GCS,GDS,
     3 APMCDE,TFEAL,
     4 DEGSCM,DEGSCT,DEGUCM,
     5 DEGUCT,DEGL,DEGS,NIP,DEGCON,DEGLOM,DEGLOT,NCOM,
     6 PRSTCM,PRSTCT,FFCTCM,PROTOT,UPITOM,UPITOT,STS,UTS,SAS,
     7 SCS,SDS,SSTR,LAS,UCS,UDS,USTR,UPRIS,UIST,TOTPAP,TIMAP,YEARAP,
     8 DESORF,SURF,SOIL,SULG
C
      COMMON /NUT/  CELT,STEMP,SN,SNT,SNRSM,SNROM,UN,UNT,UNI,UNIT,
     1              LNRIM,NRSM,LN,LNRPM,GN,SNRBM,UNRBM,LNRBM,GNREM,TNRBM,
     2              SNRSY,SNROY,UNRIY,NRSY,LNRPY,SNRBY,UNRBY,LNRBY,GNRBY,
     3              TNREY,TNRHV,TNRHVM,TNRHVY,TNA,TPA,TCLA,
     4              KN,THKN,KP,THKP,NBAL,PHBAL,CLBAL,
     5              ISTEP,NSTEP,SFLG,UFLG,LFLG,GFLG
C
C
      INTEGER  PRNTKE,CUTPUT,HYCAL,CALB,PROD,NUTR,PEST,ENGL,METR,BOTH
      INTEGER  SURF,SOIL,TIMFAC,YES,NO,JCOUNT,TIMAP
      INTEGER  PRINT,INTR,HOUR,DAYS,MNTH
       REAL*8  MNAM
C
      REAL  M, K, NI, MUZ, MLZ
      REAL  LZSN, IRC, NN, L, LZS, KV, K24L, KK24, INFIL, INTER
      REAL  IFS, K24EL, K3, NEPTOM, NEPTOT
      REAL  INFTCM, INFTCT, INTF, INFL
      REAL  MMPIN, METCFT, KGPLB
      REAL  NF, NIF, MCCM
      REAL  MELRAM, MELRAY
C
      REAL*4  DELT,STEMP(4,24),
     1        SN(20,5),SNT(20),SNRSM(20,5),SNROM(20,5),
     2        UN(20,5),UNT(20),UNI(20,5),UNIT(20),UNRIM(20,5),
     3        NRSM(20,5),      LN(20),LNRPM(20),          GN(20),
     4        SNREM(20,5),UNRBM(20,5),LNRBM(20),GNRBM(20),TNRBM(20),
     5        SNRSY(20,5),SNROY(20,5),UNRIY(20,5),NRSY(20,5),
     6        LNRPY(20),SNRBY(20,5),UNRBY(20,5),LNRBY(20),GNRBY(20),
     7        TNREY(20),TNRHV(20),TNRHVM(20),TNRHVY(20),TNA,TPA,TCLA,
     8        KN(10,4),THKN(10),KP(5,4),THKP(5),NBAL,PHBAL,CLBAL
C
      DATA  PRTCT, ERSNTT/2*0.0/
      DATA  PRTCM, ERSNTM/2*0.0/
      DATA  RUTCM, RCSTCM, RITOM, RINTCM, NEPTOM/5*0.0/
      DATA  RUTCT, RCSTCT, RITOT, RINTCT, NEPTOT/5*0.0/
      DATA  RCBTCM, RCBTOT, INFTOM, INFTCT, ROITOM, ROITOT/30*0.0/
      DATA  FFCTCM, FFCTCT, PRSTOM, PRSTOT, UPITOM, UPITOT/30*0.0/
      DATA  THBAL, RESE, SRGX, INTF, ERSTOM, ERSTOT, SDST/27*0.0/
      DATA  RESE1, EASTCM, RCHTOM, BASTOT, RCHTOT/9*0.0/
      DATA  SPRCTM, SPRSTM, EPTOM, EPTOT/4*0.0/, PRNTKE/0/
      DATA  STS, STST, SAST, SCST, UTS, UTST, UAST, UCST,UDST/17*0.0/
      DATA  PR, R3, RXE, RGX, INFL, UZSB, APERCB, DPST/28*0.0/
      DATA  TIMFAC/0/, LZSN, LZSN, INFIL, INTER, IRC, NN, L, SS/8*0.0/
      DATA  A, UZS, LZS, SGW, GWS, KV, K24L, KK24/8*0.0/
      DATA  IFS, K24EL, K3, EPXM, COVER, COVRMX/6*0.0/
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      DATA  ERSN/5*0.0/, SRER/5*0.0/, SRERT/0.0/
      DATA  SAS/5*0.0/, SCS/5*0.0/, SDS/5*0.0/, AREA, M, K/3*0.0/
      DATA  NI, FP, CMAX, SSTR/8*0.0/
      DATA  SFRCTT, SFFSTT/2*0.0/
      DATA  UAS/5*0.0/, UCS/5*0.0/, UDS/5*0.0/, USTR, MUZ, FPUZ/7*0.0/
      DATA  UPRITT, UFRITM/2*0.0/, UPRIS/5*0.0/, UIST/0.0/
      DATA  LSTR, LAS, LCS, LDS, MLZ/5*0.0/
      DATA  GSTR, GAS, GCS, GDS, FPLZ/5*0.0/
      DATA  MNAM/' JANUARY','FEBRUARY','  MARCH ',' APRIL ',
     *          '  MAY   ','  JUNE  ','  JULY  ',' AUGUST ',
     *          'SEPTMBER',' OCTOBER','NOVEMBER','DECEMBER'/
      DATA  MMPIN/25.4/, METOPT/0.9072/, KGPLB/0.4536/
      DATA  DEGSCM, DEGSOT, DEGUOM, DEGUOT, DEGU, DEGS/6*0.0/
      DATA  DEGLCM, DEGLCT/2*0.0/,TOTPAP/0.0/
      DATA  NIP, NCCM/2*0.0/, TPBAL/0.0/, SULG/0.0/
      DATA SUMSNM, PXSNM, MELRAM, RADMEM, CORMEM, CRAINM,
     *     CONMEM, SGMM, SNEGMM, SEVAPM, SUMSNY, PXSNY, MELRAY,
     *     RADMEY, CORMEY, CONMEY, CRAINY, SGMY. SNEGMY, SEVAPY,
     *     TSNEAL/21*0.0/,PACK/0.0/,SDEN/0.0/
      DATA CALB/'CALB'/,PROD/'PROD'/
      DATA ENGL/'ENGL'/,METR/'METR'/,BOTH/'BOTH'/
      DATA NO/'NO'/,YES/'YES'/,SURF/'SURF'/,SOIL/'SOIL'/
      DATA  JCOUNT/0/,TIMAP/999/
      DATA  HOUR/'HOUR'/,DAYS/'DAYS'/,MNTH/'MNTH'/,INTR/'INTR'/
C
      DATA  SNRSM/100*0.0/,SNROM/100*0.0/,LNRIM/100*0.0/,NRSM/100*0.0/,
     1      LNRPM/20*0.0/,SNRBM/100*0.0/,UNRBM/100*0.0/,LNRBM/20*0.0/,
     2      GNRBM/20*0.0/,TNRBM/20*0.0/,SNRSY/100*0.0/,SNROY/100*0.0/,
     3      LNRIY/100*0.0/,NRSY/100*0.0/,LNRPY/20*0.0/,SNRBY/100*0.0/,
     4      LNRBY/100*0.0/,LNRBY/20*0.0/,GNRBY/20*0.0/,TNRBY/20*0.0/,
     5      TNRHV/20*0.0/,TNRHVM/20*0.0/,TNRHVY/20*0.0/,
     6      TNA/0.0/,TPA/0.0/,TCLA/0.0/
C
      END
C
C
C
C
      SUBROUTINE LANDS
C
C
C                               HSP LANDS
C
C
      IMPLICIT  REAL(L,K)
C
      DIMENSION RESB(5),RESB1(5),ROSB(5),SRGX(5),INTF(5),RGX(5),RUZB(5),
     1 LZSB(5),APERCB(5),RIB(5),ERSN(5)
      DIMENSION SREF(5),ROBTOM(5),ROBTOT(5),INFTOM(5),INFTOT(5),
     1 ROITOM(5),ROITOT(5),RAB(5),ERSTOM(5),ERSTOT(5),MNAM(12),RAD(24),
     2 TEMPX(24),WINDX(24),RAIN(288),UZSBMT(5),RESBMT(5),SRGXMT(5),
     3 SRERMT(5)
      DIMENSION SPRD(5),RXX(5),DEEPL(5),UZRA(5),PRE(5),INFL(5),UZI(5),
     1 EVDIST(24),ROSINT(5),PERCB(5),
     2 ARCSB(5),AINTF(5),AROSIT(5),LAPSE(24),SVP(40),SNCUT(24,16)
C
      COMMON /ALL/ RU,HYMIN,PRNTKE,HYCAL,OPST,OUTPUT,TIMFAC,LZS,AREA,
     1 RESB1,ROSB,SRGX,INTF,RGX,INFL,UZSB,APERCB,RIB,ERSN,M,P3,A,
     2 CALB,PROD,PEST,NLTR,ENGL,METR,BOTH,RESB,YES,NO,IMIN,IHR,TF.
     3 JCOUNT,PRINT,INTF,DAYS,HOUR,MNTH
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C
      COMMON /LAND/ MNAM,PRTOT,ERSNTT,PRTOM,ERSNTM,DAY,
     1 RUTOM,NEPTOM,RCSTOM,RITOM,RINTOM,BASTOM,RCHTOM,RUTOT,
     2 NEPTOT,RCSTOT,RITOT,RINTOT,BASTOT,RCHTOT,TWBAL,EPTOM,EPTOT,
     3 UZS,UZSN,LZSN,INFIL,INTER,IRC,NN,L,SS,SGW1,PR,SGW,GWS,KV,
     4 K24L,KK24,K24EL,EP,IFS,K3,EPXM,RESS1,RESS,SCEP,SCEP1,SRGXT,
     5 SRGXT1,JREF,KREF,JSER,KSER,SRERT,MMPIN,METOPT,SNOW,CCFAC,
     6 SCF,ICNS,F,CGM,WC,MPACK,EVAPSN,MELEV,TSNOW,PETMIN,PETMAX,ELDIF,
     7 DEWX,PACK,DEPTH,MONTH,SDEN,IPACK,TMIN,SUMSNM,PXSNM,XK3,
     8 MELRAM,RADMEM,CDRMEM,CRAINM,CONMEM,SGMM,SNEGMM,SEVAPM,SUMSNY,
     9 PXSNY,MELRAY,RADMEY,CDRMEY,SGMY,CONMEY,CRAINY,SNEGMY,SEVAPY,
     * TSNBAL,CCVEF,CCVFMX,ROBTOM,ROBTOT,KXB,RUITOM,ROITOT,INFTOM,
     1 INFTOT,ERSTOM,ERSTOT,SRER,TEMPX,RAD,WINDX,RAIN,INPUT
C
       INTEGER   TF,FRNTKE,HYCAL,DAY,OUTPUT,SNOW,HRFLAG,H,SFLAG,INPUT
       INTEGER   CALE,PRCC,NLTR,PEST,ENGL,METR,BOTH,NC,YES,DESCRP,TIMFAC
       INTEGER   PRINT,INTR,HOUR,DAYS,MNTH
C
        REAL*8  MNAM
C
       REAL   INFIL, INTER, NN, INFLT, IRC, INTF, INFL
       REAL   IRC4, ICS, IFS, NEPTOM, NEPTOT
       REAL   INFTOM, INFTOT, QMETRC
       REAL   MMPIN, METCFT, KGPLB
       REAL   LZSMET, LZSMET, SGWMET, SCEPMT, RESSMT
       REAL   TWBLMT, SRGXTM, RESBMT, SRGXMT
       REAL ICNS, MPACK, MELEV, KUGI, NEGMLT, NEGMM
       REAL MELT, INCT, KCLD, IPACK, MELRAM, MELRAY, MELRAD
C
       DATA   IHRR,SFLAG,HRFLAG/3*0/
       DATA   PERC, INFLT/0.0,0.0/
       DATA   SEAS/0.0/
       DATA   SNET1, SNET, SRCH/3*0.0/, NUMI/0/
       DATA   RCSIN1/5*0.0/, REPIN, EPIN1, AETR, KF/4*0.0/
       DATA   EVDIST/6*0.0,0.019,0.041,0.067,0.088,0.102,3*0.11,0.105,
      C       0.095,0.081,0.055,0.017,5*0.0/
       DATA SVP/10*1.005,1.01,1.01,1.015,1.02,
      *1.03,1.04,1.06,1.08,1.1,1.29,1.66,2.13,2.74,3.49,4.40,5.55,6.87,
      *8.36,10.09,12.19,14.63,17.51,20.86,24.79,29.32,34.61,40.67,47.68,
      *55.71,64.88/
       DATA LAPSE/6*3.5,3.7,4.0,4.1,
      *4.3,4.6,4.7,4.8,4.9,5.0,5.0,4.8,4.6,4.4,4.2,4.0,3.8,3.7,3.6/
       DATA   AFR, AEFIN/2*0.0/
       DATA   ARCSB, AINTF, AROSIT/15*0.0/
       DATA   ARU, ARLI, ARCS, ARGXT, ASNET, ASBAS, ASRCH/7*0.0/
       DATA   SUMSN, INCT, KCLD, PXONSN, SEVAPT, RADME, CDRME, LIQW1,
      *       CONME, CRAIN, NEGMLT, SNEGM, NEGMM, LIQS,  LIQW, XICE,
      *       XLNMLT,SGM, SPX, WBAL, SEVAP/21*0.0/
       DATA   SNCLT/384*0.0/,CLDF/-1.0/,ALBEDO/0.6/
       DATA   SUMSND,PXSND,MELRAD,RADMED,CDRMED,CONMED,CRAIND,SGMD,
      1       SNEGMD,SEVAPD/10*0.0/
C
C                       ZEROING OF VARIABLES
C
       LZS1 = LZS
       LZS1 = LZS
       NUMI = 0
       DPST = 0.0
       PACK1 = PACK
       LIQW1 = LIQW
```

```
            PRR = PR
      C
            DO 184 I=1,5
        184    APERCB(I) = 0.0
      C
              PA=1.0-A
              IRC4=IRC**(1.0/96.0)
              LIRC4=1.0-IRC4
             KK4=KK24**(1.0/96.0)
              LKK4= 1.0 - KK4
      C
            IF ((1440./TIMFAC).LE.100.) GO TO 187
            LIRC4 = LIRC4/3.0
            LKK4 = LKK4/3.0
      C
       187  DEC= 0.00982*((NN*L/SQRT(SS))**0.6)
            SRC= 1020.*SQRT(SS)/(NN*L)
      C
            RESS = 0.0
            LNRAT=LZS/LZSN
            D3FV=(2.0*INFIL)/(LNRAT*LNRAT)
            D4F= (TIMFAC/60.)*D3FV
      C                                      REDUCE INFILTRATION IF ICE EXISTS
      C                                      AT THE BOTTOM OF THE PACK -
      C                                     ATTEMPT TO CORRECT FOR FROZEN LAND
            IF (SNOW .EQ. NO)  GO TO 188
            D4FX = (1.0 -XICE)
            IF (D4FX .LT. 0.1)  D4FX = 0.1
            D4F = D4F*D4FX
      C
        188 RATIO= INTER*EXP(0.693147*LNRAT)
            IF ((RATIO).LT.(1.0)) RATIO=1.0
            D4RA= D4F*RATIO
            H = TF/24
      C
      C                                 TF IS 1 FOR RAIN DAYS, AND 96
      C                                 OR 288 FOR NON-RAIN DAYS
      C
            IF (TF .GT. 2)  IHRR=0
      C
            DO 155  III=1,TF
      C
            LNRAT = LZS/LZSN
            IF (TF .LT. 2)  GO TO 4
            NUMI =NUMI + 1
            IF (NUMI .NE. H)  GO TO 4
            NUMI = 0
      C
        4   SBAS = 0.0
            SRCH   0.0
            RCS = 0.0
            RU = 0.0
            GWF = 0.0
            RGXT = 0.0
            PERC = 0.0
            INFLT = 0.0
      C
      C   TIMFAC - TIME INTERVAL IN MINUTES
      C   L      - LENGTH OF OVERLAND SLOPE
      C   NN     - MANNING'S N FOR OVERLAND SLOPE
```

```
C    A       - IMPEFVIOLS AREA
C    FA    - FERVICLS AREA
C
C
C
C
C PR IS INCCMING FAINFALL
C P3 IS RAIN REACHING SLRFACE(.00'S INCHES)
C P4 IS TOTAL MOISTLRE AVAILABLE( IN.)
C RESS  IS CVERLANC FLCW STCRAGE( IN.)
C C4F IS 'B' IN CF. MANLAL
C RATIC IS 'C' IN CF. MANUAL
C EP -  CAILY EVAF ( IN.)
C EPHR - HOURLY EVAF
C EPIN - INTERVAL EVAF
C EPXX - FACTCR FCR REDLCING EVAP FOR SNOW AND TEMP
C
C
C
C
C      DETERMINE IF SNOWMELT IS TO BE DONE
C
       HRFLAG=0
       ITEST = IMIN/TIMFAC
       IF (NLMI .EC. 1)  HRFLAG = 1
       IF (ITEST.EC.1)  HRFLAG = 1
C
C      HRFLAG=1 INDICATES BEGINNING OF THE HOUR
C
       IF (HRFLAG.EC.0) GO TC 999
       IEND   C
       IF (IHR.EC.24) GC TO 202
       IHRR = IHR + 1
       GO TO 5C1
   202 IHRR   IHRR + 1
   5C1  EPHR = EVDIST(IHRR)*EP
        IF (EPHR.LE.(C.CC01))  EPHR=0.0
        EPIN= EPHR
        EPIN1=EPIN
       IF (SNCW .EC. NC) GC TO 999
       IF ((PACK .LE. C.0).AND.(TMIN .GT. PETMAX))  GO TO 999
C                                                    ************************************
C                                                                BEGIN SNOWMELT
C                                                    ************************************
       ISNOW1 = ISNCW + 1.
       SNTEMP = 32.
       SEVAP - 0.0
       SFLAG - 0
       PRHR=0.C
       EPXX = 1.0
       IKENC = 60./(TIMFAC)
       IPT = (IHRR-1)*IKEND
C                                     SUM PRECIP FOR THE HOUR
       PX=0.0
       DO 502 II = 1,IKEND
   5C2 PRHR = PRHR + RAIN(IPT+II)
C                                            CORRECT TEMP FOR ELEVATION DIFF
C                                            USING LAPSE RATE OF 3.5 DURING RAIN
C                                            PERIODS, AND AN HOURLY VARIATION IN
C                                            LAPSE RATE (LAPSE(I)) FCR CRY PERIOC
```

```
C
      LAPS = LAPSE(IHFR)
      IF (PRHR .GT. 0.05)  LAPS = 3.5
      TX = TEMPX(IHFR) - LAPS*ELDIF
C
C
C                                               REDUCE REG EVAP FOR SNOWMELT
C                                               CONDITIONS BASED ON PETMIN AND
C                                               PETMAX VALUES
C
      IF (PACK.LE.IPACK) GO TO 504
      E1E=0.0
      PACKRA = 1.0
      GO TO 505
  504 PACKRA = PACK/IPACK
      E1E=1.0 - PACKRA
  505 EPXX = (1.0-F)*E1E + F
      IF (TX.GE.PETMAX) GO TO 512
      IF (EPXX .GT. 0.5)  EPXX=0.5
C
C                                              REDUCE EVAP BY 50% IF TX IS BETWEEN
C                                              PETMIN AND PETMAX
      IF (TX.LT.PETMIN) EPXX = 0.0
C
C
  512 EPHR = EPHR*EPXX
      EPIN = EPIN*EPXX
      IEND=0
      SNEAL = 0.0
      IF ((TX .GT. TSNOW) .AND. (PRHR .GT. .02)) DEWX = TX
C
C     SET DEWPT TEMP EQUAL TO AIR TEMP WHEN RAINING
C     ON SNOW TO INCREASE SNOWMELT
C
      IF (DEWX .GT. TX) DEWX = TX
      SNTEMP = TSNOW + (TX-DEWX)*(0.12 + 0.008*TX)
C
C     RAIN/SNOW TEMP. DIVISION - SEE ANDERSON, WRR, VOL. 4, NO. 1,
C     FEB. 1968, P. 27, EQ. 28
C
      IF (SNTEMP .GT. TSNOW1) SNTEMP = TSNOW1
      IF (TX.LT.SNTEMP) GO TO 521
      IF  (PACK) 997, 997, 525
  521 SFLAG = 1
C
      IF ((PACK.LE.0.0) .AND. (PRHR.LE.0.0))  GO TO 997
C  SKIP SNOWMELT IF BOTH PACK AND PRECIP ARE ZERO
C    FOR THE HOUR
C
  525 IEND = 1
C
C     SNOWMELT CALCULATIONS ARE DONE IF IT IS SNOWING, OR,
C     IF A SNOWPACK EXISTS
C
      PX = PRHR
      IF (PX.LE.0.0) GO TO 550
C                                               KCLD IS INDEX TO CLOUD COVER
      KCLD = 35.
      IF (SFLAG.LE.0) GO TO 555
C                                              SNOW IS FALLING
```

```
          PX = PX*SCF
          APR = APR + (SCF-1.0)*PRHR
          PRHR = PRHR*SCF
          SUMSN = SUMSN + PX
          DNS = IDNS
          IF (TX .GT. 0.0)  DNS = DNS + ((TX/100.)**2)
C
C         SNOW DENSITY WITH TEMP. - APPROX TO FIG. 4, PLATE B-1
C         SNOW HYDROLOGY  SEE ALSO ANDERSON, TR 36, P. 21
C
          PACK = PACK + PX
C
          IF (PACK.LE.IPACK) GO TO 548
          IPACK = PACK
          IF (IPACK .GT. MPACK)  IPACK   MPACK
C
      548 DEPTH = DEPTH + (PX/DNS)
          IF (DEPTH .GT. 0.0) SDEN = PACK/DEPTH
          INDT = INDT - 1000*PX
          IF (INDT .LT. 0.0) INDT - 0.0
          PX = 0.0
          GO TO 555
      550 KCLD = KCLD - 1.
      555 IF (KCLD .LT. 0.0) KCLD = 0.0
          PACKRA = PACK/IPACK
          IF (PACK .GT. IPACK)  PACKRA = 1.0
C
          IF (PACK.GE.0.005) GO TO 580
C
C         IPACK IS AN INDEX TO AREAL COVERAGE OF THE SNOWPACK
C         FOR INITIAL STORMS IPACK = .1*MPACK SO THAT COMPLETE
C         AREAL COVERAGE RESULTS.  IF EXISTING PACK > .1 *MPACK THEN
C         IPACK IS SET EQUAL TO MPACK WHICH IS THE WATER EQUI. FOR
C         COMPLETE AREAL COVERAGE PACKRA IS THE FRACTION AREAL COVERAGE
C         AT ANY TIME.
C
          IPACK = 0.1*MPACK
          XICE = 0.0
          XLNMLT - 0.0
          NEGMLT = 0.0
          PX = PX + PACK + LIQW
          PACK   0.0
          LIQW = 0.0
C       ZERO SNOWMELT OUTPUT ARRAY
          DO 570 I=1,24
             DO 570 MM=1,16
      570 SNOUT(I,MM) = 0.0
          GO TO 557
C
C
      580 PXCNSN   PXCNSN + PX
          IF (DEPTH .GT. 0.0) SDEN = PACK/DEPTH
          IF (INDT .LT. 800.) INDT = INDT + 1.
C                                        INDT IS INDEX TO ALBEDO
          MELT = 0.0
          IF (SDEN .LT. 0.55) DEPTH=DEPTH*(1.0 - 0.00002*(DEPTH*(.55-SDEN)))
C
C         EMPIRICAL RELATIONSHIP FOR SNOW COMPACTION
C
          IF (DEPTH .GT. 0.0) SDEN = PACK/DEPTH
```

```
          WIN = WINDX(IHRF)
C
C         HOURLY WIND VALUE
C
          LREF = (TX + 100.)/5
          LREF = IFIX(LREF)
          SVPP = SVP (LREF)
          ITX = IFIX(TX)
          SATVAP = SVPP +(MOD(ITX,5)/5)*(SVP(LREF + 1) - SVPP)
          LREF = (DEWX + 100.)/5
          LREF = IFIX(LREF)
          SVPP = SVP (LREF)
          IDEWX = IFIX(DEWX)
          VAPP   SVPP + (MOD(IDEWX,5)/5)*(SVP(LREF + 1) - SVPP)
C                           CALCULATION OF VAPOR PRESSURE AT AIRTEMP
C                           AND DEWPOINT
          SEVAP = 0.0
          IF (VAPP.LE.6.108) GO TO 610
          CNM = 8.59*(VAPP - 6.108)
          GO TO 620
      610 CNM = 0.0
          DUMMY=(VAPP-SATVAP)*PACKRA
          IF (VAPP .LT. SATVAP) SEVAP   EVAPSN*0.0002*WIN*DUMMY
          PACK = PACK + SEVAP
          SEVAPT   SEVAPT - SEVAP
C
C         CONDENSATION - CONVECTION MELT, EQ. T-29B, P.176, SNOW HYDROLOGY
C         CCNV - CONVECTION, CCNDS - CONDENSATION
C         SEVAP - EVAP FROM SNOW (NEGATIVE VALUE)
C
      620 CNV = 0.0
          IF (TX .GT. 32.) CNV = (TX-32.)*(1.0 - 0.3*(MELEV/10000.))
          CCXC = CCFAC*.00026*WIN
C
C         .00026 = .00625/24, I.E. .00026 IS THE DAILY COEFFICIENT
C         (FROM SNOW HYDROLOGY) REDUCED TO HOURLY VALUES.
C
          CCNV = CNV*CCXC
          CCNDS = CNM*CCXC
C                               CLOUD COVER
C                               CLDF IS FRACTION OPEN SKY - MINIMUM VALUE 0.15
          IF (IHRF.EQ.1 .OR. CLDF.LT.0.0) CLDF   (1.0 - 0.085*(KCLD/3.5))
C                               ALBEDO
          IF (MONTH.GT.9) GO TO 640
          IF (MONTH.LT.4) GO TO 640
          ALBEDO = 0.8 - 0.1*(SQRT(INDT/24.))
          IF (ALBEDO .LT. 0.45)  ALBEDO = 0.45
          GO TO 650
      640 ALBEDO = 0.85 - 0.07*(SQRT(INDT/24.0))
          IF (ALBEDO .LT. 0.6)  ALBEDO = 0.6
C                               SHORT WAVE RADIATION-RA - POSITIVE INCOMING
      650 RA   RAD(IHRF)*(1.0 -ALBEDO)*(1.0-F)
C                               LONG WAVE RADIATION - LW - POSITIVE INCOMING
          DEGHR = TX - 32.0
          IF (DEGHR.LE.0.0) GO TO 660
          LW = F* 0.26*DEGHR + (1.0 - F)*(0.2*DEGHR - 6.6)
          GO TO 665
      660 LW = F*0.2*DEGHR + (1.0 - F)*(0.17*DEGHR - 6.6)
C
C                                  LW IS A LINEAR APPROX. TO CURVES IN
```

```
      C                              FIG. 6, PL 5-3, IN SNOW HYDROLOGY.  6.6
      C                              IS AVE BACK RADIATION LOST FROM THE SNOWPACK
      C                              IN OPEN AREAS, IN LANGLEYS/HR.
      C
      C                              CLOUD COVER CORRECTION
        665 IF (LW .LT. 0.0)  LW = LW*CLDF
      C
      C                              RAIN MELT
            RAINM    0.0
      C
      C                                           RAINMELT IS OPERATIVE IF IT IS
      C                                           RAINING AND TEMP IS ABOVE 32 F
      C
            IF ((SFLAG .LT. 1).AND.(TX .GT. 32.))  RAINM   DEGHR*PX/144.
      C                              TOTAL MELT
            RM    (LW + RA)/203.2
      C                              203.2 LANGLEYS REQUIRED TO PRODUCE I INCH
      C                              RUNOFF FROM SNOW AT 32 DEGREES F
            IF (PACK.GE.IPACK) GO TO 680
            RM = RM*PACKRA
            CONV = CONV*PACKRA
            CONDS   CONDS*PACKRA
            RAINM = RAINM*PACKRA
            IF (IMRR.NE.6) GO TO 680
            XLNEM = 0.01*(32.0 - TX)
            IF (XLNEM .GT. XLNMLT) XLNMLT = XLNEM
        680 RADME   RADME + RM
            CORME   CORME + CONDS
            CONME = CONME + CONV
            CRAIN = CRAIN + RAINM
            MELT = RM + CONV + CONDS + RAINM
            IF (MELT.GE.0.0) GO TO 700
            NEGMM = 0.0
            IF (TX .LT. 32.) NEGMM = 0.00695*(PACK/2.0)*(32.0 - TX)
      C
      C                                           HALF OF PACK IS USED TO CALCULATE
      C                                           MAXIMUM NEGATIVE MELT
      C
            TP = 32.0 - (NEGMLT/(0.00695*PACK))
      C
      C     TP IS TEMP OF THE SNOWPACK
      C     0.00695 IS IN. MELT/IN. SNOW/DEGREE F
      C
            IF (TP.LE.TX) GO TO 695
            GM = 0.0007*(TP - TX)
            NEGMLT = NEGMLT + GM
            SNEGM = SNEGM + GM
        695 IF (NEGMLT .GT. NEGMM)  NEGMLT = NEGMM
            MELT = 0.0
      C
      C                              MELTING PROCESS BALANCE
      C
        700 PXBY = (1.0 - PACKRA)*PX
            PX   PACKRA*PX
      C
      C     PXBY IS FRACTION OF PRECIP FALLING ON BARE GROUND
      C
            IF ((MELT + PX).LE.0.0) GO TO 795
      C
      C     SATISFY NEGMLT FROM PRECIP(RAIN) AND SNOWMELT
```

```
C
      IF (MELT.GE.NEGMLT) GO TO 720
      NEGMLT = NEGMLT   MELT
      MELT - 0.0
      GO TO 725
  720 MELT = MELT - NEGMLT
      NEGMLT = 0.0
C
  725 IF (PX.GE.NEGMLT) GO TO 735
      NEGMLT - NEGMLT - PX
      PACK = PACK + PX
      PX = 0.0
      GO TO 740
  735 PX = PX - NEGMLT
      PACK = PACK + NEGMLT
      NEGMLT = 0.0
C
  740 IF ((PX + MELT) .EQ. 0.0) GO TO  800
C
C     COMPARE SNOWMELT TO EXISTING SNOWPACK AND WATER CONTENT OF
C     THE PACK
C
      IF (MELT.LE.PACK) GO TO 750
      MELT = PACK + LIQW
      DEPTH   0.0
      PACK - 0.0
      LIQW = 0.0
      INDT = 0.0
      GO TO 765
  750 PACK = PACK - MELT
      IF (SDEN .GT. 0.0)  DEPTH = DEPTH - (MELT/SDEN)
      IF (PACK .GE. (0.9*DEPTH))  DEPTH - 1.11*PACK
      IF (PACK.GE.0.001) GO TO 760
      LIQW - LIQW + PACK
      PACK - 0.0
  760 LIQS = WC*PACK
      IF (SDEN .GT. 0.6) LIQS = WC*(3.0 - (3.33)*SDEN)*PACK
      IF (LIQS .LT. 0.0) LIQS = 0.0
C
C     COMPARE AVAILABLE MOISTURE WITH AVAILABLE STORAGE IN SNOWPACK
C     -LIQS
C
  765 IF ((LIQW + MELT + PX).LE.LIQS) GO TO 775
      PX = MELT + PX + LIQW - LIQS
      LIQW   LIQS
      GO TO 780
  775 LIQW = LIQW + MELT + PX
      PX = 0.0
  780 IF (PX.LE.XLNMLT) GO TO 790
      PX = PX - XLNMLT
      PACK   PACK + XLNMLT
      XICE = XICE + XLNMLT
      XLNMLT = 0.0
      GO TO 795
  790 PACK = PACK + PX
      XICE = XICE + PX
      XLNMLT = XLNMLT - PX
      PX = 0.0
  795 IF (XICE .GT. PACK) XICE - PACK
C
```

```
C
C                                        END MELTING PROCESS BALANCE
C
  800 IF (DEPTH .GT. 0.0) SDEN = PACK/DEPTH
      IF (SDEN .LT. 0.1) SDEN = 0.1
C                                              GROUNDMELT
      IF (IHRR.NE.12) GO TO 830
      DGMM = DGM
      IF (TP .LT. 5.0)  TP = 5.0
      IF (TP .LT. 32.)  DGMM = DGMM - DGM*.03*(32.0 - TP)
      IF (PACK.LE.DGMM) GO TO 825
      PX = PX + DGMM
      PACK = PACK - DGMM
      DEPTH = DEPTH - (DGMM/SDEN)
      SGM = SGM + DGMM
      GO TO 830
  825 PX = PACK + PX + LIQW
      SGM = SGM + PACK
      PACK = 0.0
      DEPTH = 0.0
      LIQW = 0.0
      NEGMLT = 0.0
  830 CONTINUE
      PX = PX + PXBY
      SPX = SPX + PX
C
C                                        HOUR VALUE ASSIGNMENT
  997 SUMSNH = SUMSN
      PXSNH = PXCNSN
      SPXH = SPX
      RADMEH = RADME
      CDRMEH = CDRME
      CCNMEH = CCNME
      CRAINH = CRAIN
      SGMH = SGM
      SNEGMH = SNEGM
      SEVAPH = SEVAPT
C
C                                        DAILY SUMS
      IF (PRINT.NE.DAYS)  GO TO 996
      SUMSND = SUMSND + SUMSN
      PXSND  = PXSND  + PXCNSN
      MELRAD = MELRAD + SPX
      RADMED = RADMED + RADME
      CDRMED = CDRMED + CDRME
      CCNMED = CCNMED + CCNME
      CRAIND = CRAIND + CRAIN
      SGMD   = SGMD   + SGM
      SNEGMD = SNEGMD + SNEGM
      SEVAPD = SEVAPD + SEVAPT
C
C                                        MONTHLY SUMS
  996 SUMSNM = SUMSNM + SUMSN
      PXSNM  = PXSNM  + PXCNSN
      MELRAM = MELRAM + SPX
      RADMEM = RADMEM + RADME
      CDRMEM = CDRMEM + CDRME
      CCNMEM = CCNMEM + CCNME
      CRAINM = CRAINM + CRAIN
      SGMM   = SGMM   + SGM
```

```
            SNEGMM = SNEGMM + SNEGM
            SEVAPM = SEVAPM + SEVAPT
      C
      C                                 YEARLY SUMS
            SUMSNY = SUMSNY + SUMSN
            PXSNY  = PXSNY  + PXCNSN
            MELRAY = MELRAY + SPX
            RADMEY = RADMEY + RADME
            CCRMEY = CCRMEY + CCRME
            CONMEY - CCNMEY + CCNME
            CRAINY = CRAINY + CRAIN
            SGMY   = SGMY   + SGM
            SNEGMY = SNEGMY + SNEGM
            SEVAPY = SEVAPY + SEVAPT
      C
      C                                 ZERO HOURLY VALUES
            SUMSN = 0.0
            PXCNSN = 0.0
            SPX = 0.0
            RADME = 0.0
            CCRME = 0.0
            CCNME = 0.0
            CRAIN = 0.0
            SGM = 0.0
            SNEGM = 0.0
            SEVAPT = 0.0
      C
      C                            SNOWMELT OUTPUT
      C
      C
      C
            SNOUT(IHRR,1) = PACK
            SNOUT(IHRR,2) = DEPTH
            SNOUT(IHRR,3) = SDEN
            SNOUT(IHRR,4) = ALBEDO
            SNOUT(IHRR,5) = CLDF
            SNOUT(IHRR,6) = NEGMLT
            SNOUT(IHRR,7) = LIQW
            SNOUT(IHRR,8) = TX
            SNOUT(IHRR,9) = RA
            SNOUT(IHRR,10) = LW
            SNOUT(IHRR,11) = FX
            SNOUT(IHRR,12) = MELT
            SNOUT(IHRR,13) = CONV
            SNOUT(IHRR,14) = RAINM
            SNOUT(IHRR,15) = CONDS
            SNOUT(IHRR,16) = XICE
      C
            IF (OUTPUT .EQ. ENGL)  GO TO 845
            IF (OUTPUT .EQ. ECTH .AND. INPUT .EQ. ENGL)  GO TO 845
      C
      C  CONVERSION TO METRIC SNOW OUTPUT
      C
              SNOUT(IHRR,1) = PACK*MMPIN
              SNOUT(IHRR,2) = DEPTH*MMPIN
              SNOUT(IHRR,6) = NEGMLT*MMPIN
              SNOUT(IHRR,7) = LIQW*MMPIN
              SNOUT(IHRR,8) = 0.556*(TX-32.0)
              DO 842 ISNOUT=11,16
                 SNOUT(IHRR,ISNOUT) = SNOUT(IHRR,ISNOUT)*MMPIN
```

```
      842  CONTINUE
C
  845 IF (HYCAL.EQ.PROD)  GO TO 998
C
      IF (IHRR .NE. 24)  GO TO 998
      IF (PACK.LE.0.0)  GO TO 998
      WRITE (6,992) MNAM(MONTH),DAY
      WRITE(6,990)
C
      DO 880 I=1,24
      WRITE (6,991) I,(SNOUT(I,MM),MM=1,16)
      DO 881 MMM=1,16
  881 SNOUT(I,MMM) = 0.0
  880 CONTINUE
      WRITE (6,994)
      WRITE (6,995)
C
C
  990 FORMAT ('0','HOUR     PACK      DEPTH    SDEN  ALBEDO  CLDF   NEGMELT
     1   LIQW      TX      RA    LW     PX      MELT     CONV     RAINM
     2CONDS     ICE')
  991 FORMAT (' ',I2,2X,2(F8.1,2X),3(F6.3,1X),2(F8.3,1X),
     1         F7.2,1X,2(F4.0,1X),5(F8.3,1X),F6.1)
  992 FORMAT ('0',25X,'SNOWMELT OUTPUT FOR',4X,A8,2X,I2)
  994 FORMAT ('0',5X,'DATE',4X,'TIME',4X,'FLOW(CFS-CMS)',6X,
     X         'SEDIMENT (LBS-KG-KG/MIN-GM/L)',23X,
     X         'PESTICIDE (GM-GM/MIN-PPM)')
  995 FORMAT (' ',67X,'WATER',24X,'SEDIMENT')
C
C                              CORRECT WATER BALANCE FOR SNOWMELT
C                              PACK AND SNOW EVAP
C
C                              PRR IS INCOMING PRECIP
C                              PX  IS MOISTURE TO THE LAND SURFACE
C                              SEVAP IS SNOW EVAP - NEGATIVE
  996 IF (IEND.EQ.1)  SNBAL   PRHR+SEVAP-PX-PACK+PACK1-LIQW+LIQW1
      IF ((SNBAL.LT.0.0001).AND.(SNBAL.GT.-0.0001))  SNBAL=0.0
      TSNBAL   TSNBAL + SNBAL
C
C
      PACK1 = PACK
      LIQW1 = LIQW
C                ************************************
C                              END SNOWMELT
C                ***********************************
C                                             PX IS TOTAL MOISTURE INPUT TO
C                                             THE LAND SURFACE FROM PRECIP
C                                             AND SNOWMELT DURING THE HOUR
C
  999 IF (IEND .GT. 0) PR=PX*TIMFAC/60.
C                                           IEND>0 INDICATES SNOWMELT
C                                           OCCURRED DURING THE HOUR
C
C
C
C
C   * * *    INTERCEPTION  FUNC.     * * *
C
C
C EPXM - MAX. INTERCEPTION STORAGE
```

```
      C SCEP - EXISTING INTER. STORAGE
      C EPX  - AVAILABLE INTER. STORAGE
      C RLI  - IMPERVIOUS RUNOFF DURING INTERVAL
      C
      C
      C
              IF (COVER.GT.0.0001) GO TO 204
              SNET = SNET + SCEP
              SCEP = 0.0
              EPX = 0.0
              GO TO 203
      C
      C
       204     EPX=EPXM*(COVER/COVRMX)-SCEP
               IF(EPX.LT.(0.0001))  EPX=0.0
               IF (PR.LT.EPX) GO TO 205
         203   P3= PR-EPX
               RL= P3*A
                RLI=RU
               SCEP = SCEP+EPX
               GO TO 206
         205   SCEP = SCEP+PR
               P3=0.0
               RU=0.0
               RLI=0.0
      C
      C
      C
      C   * * *       INTERCEPTION EVAP       * * *
      C
      C
        206   IF ((NUMI.NE.0).OR.(IMIN.NE.0)) GO TO 221
              IF (SCEP.LE.0.0) GO TO 221
              IF (SCEP.GE.EPIN) GO TO 210
              EPIN = EPIN - SCEP
              SNET = SNET + SCEP
              SCEP = 0.0
              GO TO 221
        210   SCEP=SCEP-EPIN
              SNET=SNET+EPIN
              EPIN = 0.0
      C
      C
      C     ***  INFILTRATION FUNC.  ***
      C  P4 IS TOTAL MOISTURE IN STORAGE BLOCK
      C SHRD(I) = SURFACE DETENTION AND INTERFLOW FROM BLOCK I
      C RXX(I) = SURFACE DETENTION FROM BLOCK I
      C RGXX(I) - INTERFLOW  COMPONENT FROM BLOCK I
      C  RGX(I) = VOLUME TO INTER. DETEN STOR. FROM BLOCK I
      C
      C
      C      BEGINNING OF BLOCK LOOP
      C
      C
        221 DO 100 I=1,5
            P4 = P3 + RESB(I)
            RESB1(I) = RESB(I)
            IF ((10.*P4).LE.(((2*I)-1)*D4F)) GO TO 10
            SHRD(I) = (P4-(((2*I)-1)*D4F/10.))
            IF ((10.*P4).LE.(((2*I)-1)*D4RA)) GO TO 25
```

```
          RXX(I) = (F4-(((2*I)-1)*D4RA/10.))
          GO TO 31
       10 SHRC(I) = 0.0
       25 RXX(I) = 0.0
       31 RGXX   = SHRC(I)-RXX(I)
C
C
C    ***  UPPER ZONE FUNCTION ***
C
C PRE(I)  - % SURFACE DETENTION TO OVERLAND FLOW
C UZSB(I) -  UPPER ZONE STORAGE IN EACH BLOCK
C UZS   - TOTAL UPPER ZONE STORAGE
C RUZB(I) - ADDITION TO U.Z. STORAGE DURING INTERVAL
C
          IF (UZSB(I).LT.0.0)  UZSB(I)=0.0
          UZRA(I)= UZSB(I)/UZSN
          IF (UZRA(I).GT.4.0) GO TO 7
          IF (UZRA(I).GT.2.0) GO TO 8
          UZI(I)= 2.0*ABS((UZRA(I)/2.0)-1.0) +1.0
          PRE(I)= (UZRA(I)/2.0)*((1.0/(1.0+UZI(I)))**UZI(I))
          GO TO 9
        7 PRE(I) = 1.0
          GO TO 9
        8 UZI(I)= (2.0*ABS(UZRA(I)-2.0))+1.0
          PRE(I)= 1.0-((1.0/(1.0+UZI(I)))**UZI(I))
        9 RXB(I)= RXX(I)* PRE(I)
            RGX(I)=RGXX*PRE(I)
            RGXX=0.0
            RUZB(I)=SHRC(I)-RGX(I)-RXB(I)
            UZSB(I)=UZSB(I)+RUZB(I)
C
            RIB(I) = F4 - RXB(I)
C
C
C
C     * * *       UPPER ZONE EVAP     * * *
C
C
C REPIN - ACCUM DAILY EVAP POT. FOR L.Z. AND GROWATER, I.E
C          PORTION NOT SATISFIED FROM U.Z.
C
C
             IF ((NUMI.NE.0).OR.(IMIN.NE.0)) GO TO 290
             IF (EPIN.LE.(0.0))  GO TO 290
               EFFECT=1.0
               IF(UZRA(I).LE.2.0) GO TO 230
               IF (UZSB(I).LE.EPIN) GO TO 270
               UZSB(I)=UZSB(I)-EPIN
               RUZB(I)= RUZB(I)-EPIN
               SNET=SNET+PA*EPIN*0.20
               GO TO 290
      230      EFFECT= 0.5*UZRA(I)
               IF (EFFECT.LT.(0.02))  EFFECT=0.02
               IF (UZSB(I).LE.EPIN*EFFECT)  GO TO 270
               UZSB(I)=UZSB(I) - (EPIN*EFFECT)
               RUZB(I)= RUZB(I)-(EPIN*EFFECT)
               EDIFF= (1.0-EFFECT)*EPIN
               REPIN=REPIN + EDIFF*0.20
               EDIFF=0.0
               SNET= SNET + (PA*EPIN*EFFECT)*0.20
```

```
            GO TO 290
  270       EDIFF= EFIN - UZSB(I)
            REFIN= REFIN + EDIFF*0.20
            EDIFF=0.0
            SNET= SNET + FA*UZSB(I)*0.20
            UZSB(I)=0.0
            RUZB(I)=0.0
C
C
C     * * * *     INTERFLOW FUNCTION * * *
C
C       SRGX(I) - INTERFLOW DETENTION STORAGE FROM BLOCK I
C       INTF(I) - INTERFLOW LEAVING STORAGE FROM BLOCK I
C       SRGXT - TOTAL INTERFLOW STORAGE
C       RGXT  - TOTAL INTERFLOW LEAVING STORAGE DURING INTERVAL
C
  290     INTF(I) = LIRC4*SRGX(I)
          SRGX(I)=SRGX(I)+(RGX(I)*PA)-INTF(I)
           RU=RU + INTF(I)*0.20
          SRGXT= SRGXT + (RGX(I)*PA-INTF(I))*0.20
          RGXT=RGXT + INTF(I)*0.20
C
C ***     OVERLAND FLOW ROUTING ***
C
C
C RXB(I) = VOLUME TO OVERLAND SURFACE DETENTION FROM BLOCK I
C  ROSB(I) = VOLUME OF OVERLAND FLOW TO STREAM FROM BLOCK I
C  RESB(I) = VOLUME OF OVERLAND Q REMAINING ON SURFACE
C                FROM BLOCK I
C
        F1= RXB(I)-(RESB(I))
        F3= (RESB(I))+ RXB(I)
        IF (RXB(I).LE.(RESB(I))) GO TO 34
        DE= DEC*((F1)**0.6)
        GO TO 35
   34 DE= (F3)/2.0
   35 IF (F3.GT.(2.0*DE)) DE = F3/2.0
        IF (F3.LE.0.005) GO TO 40
        DUMV=(1.0+0.6*(F3/(2.0*DE))**3.)**1.67
        ROSB(I)=(TIMFAC/60.)*SRC*((F3/2.)**1.67)*DUMV
        IF (ROSB(I) .GT. 0.95*RXB(I))  ROSB(I) = .95*RXB(I)
         GO TO 43
   40  ROSB(I) = 0.0
   43 RESB(I)= RXB(I)-ROSB(I)
           ROSB(I)   ROSB(I)*PA
          ROSINT(I) = ROSB(I) + INTF(I)
C
C
C
C           * * *  UPPER ZONE DEPLETION * * *
C
C  DEEPL(I) - DIFFERENCE IN UPPER AND LOWER ZONE RATIOS
C  PERCB(I) - UPPER ZONE DEPLETION FROM EACH BLOCK
C  PERC  - TOTAL L.Z. DEPLETION
C  INFLT  - TOTAL INFILTRATION
C  ROS  - TOTAL OVERLAND FLOW TO THE STREAM FROM ALL BLOCKS
C
           IF ((NUMI .EQ. 0).AND.(IMIN .EQ. 0))  GO TO 44
           PERCB(I) = 0.0
           GO TO 47
```

```
      C
        44      DEEPL(I)= ((LZSB(I)/UZSN)-(LZS/LZSN))
                IF (DEEPL(I).LE.0.01) GO TO 47
                 PERCB(I)=0.1*INFIL*UZSN*(DEEPL(I)**3)
      C
            IF (SNOW .EQ. YES) PERCB(I) = PERCB(I)*D4FX
      C
                 IF (UZSB(I).GT.PERCB(I)) GO TO 48
                 PERCB(I) = UZSB(I)*PERCB(I)/(PERCB(I)+UZSB(I))
                 GO TO 47
      C
         48      LZSB(I)=LZSB(I)-PERCB(I)
                 PERC=PERC+PERCB(I)*0.2
                 RLZB(I) = RLZB(I) - PERCB(I)
        47       INFL(I)= F4-SHRD(I)
                  INFLT=INFLT + INFL(I)*0.20
            RESS = RESS + RESB(I)*0.2
             LZS= LZS + RLZB(I)*0.20
            ROS = ROS + ROSB(I)*0.2
        100 CONTINUE
            IF (UZS .LE. 0.0001) UZS=0.0
      C
      C END OF BLOCK LOOP
      C
                 RU=RU + ROS
               IF ((RESS).GE.(0.0001))  GO TO 302
               LZS = LZS + RESS
               RESS = 0.0
               DO 306  IK= 1,5
        306    RESB(IK)= 0.0
        302    IF (SRGXT.GE.(0.0001))  GO TO 305
               LZS = LZS + SRGXT/PA
               SRGXT = 0.0
                 DO 304  IK= 1,5
        304      SRGX(IK)= 0.0
      C
      C
      C     * * * LOWER ZONE AND GROUNDWATER  * * *
      C
      C  SBAS  - BASE STREAMFLOW
      C  SRCH  - SUM OF GRDWATER RECHARGE
      C PREL - % OF INFILTRATION AND U.Z. DEPLETION ENTERING L.Z
      C  F1A  - GROUNDWATER RECHARGE - IE. PORTION OF INFIL.
      C         AND U.Z. DEPLETION ENTERING GRDWATER
      C  K24L  - FRACTION OF F1A LOST TO DEEP GRDWATER
      C
        305       LZI=1.5*ABS((LZS/LZSN)-1.0)+1.0
                  PREL=(1.0/(1.0+LZI))**LZI
                  IF (LZS.LT.LZSN)  PREL=1.0-PREL*LNRAT
                  F3= PREL*(INFLT)
                  F1A = (1.0-PREL)*INFLT
                  IF ((NLMI.NE.0).OR.(IMIN.NE.0)) GO TO 309
                  F3 = F3 + PREL*PERC
                  F1A = F1A + (1.0-PREL)*PERC
        309       LZS= LZS+F3
               F1= F1A*(1.0 - K24L)*PA
               GWF=SGW*LKK4*(1.0 + KV*GWS)
               RL = RU + GWF
               SBAS= GWF
               SRCH= F1A*K24L*PA
```

```
                 SGW=SGW - GWF + F1
                 GWS=GWS + F1
      C
      C   * * *       GROUNDWATER EVAP   * * *
      C
      C
      C LOS  - EVAP LOST FROM GROUNDWATER
      C
      C      NOTE: EVAP FROM GRDWATER AND LZ IS CALCULATED ONLY DAILY
      C
              IF ((HRFLAG.EQ.0).OR.(IHRR.NE.21)) GO TO 101
              IF (GWS .GT. (.0001)  GWS = 0.97*GWS
              LOS= SGW*K24EL*REFIN*PA
              SGW=SGW - LOS
              GWS=GWS - LOS
              SNET= SNET + LOS
              REPIN= REFIN - LOS
              IF (GWS.LT.(0.0))  GWS=0.0
      C
      C  * * *       LOWER ZONE EVAP  * * *
      C
      C AETR - EVAP LOST FROM L.Z.
      C
      C
             IF (REFIN.LT.(0.0001))  GO TO 351
             LNRAT = LZS/LZSN
             K3 = XK3
             IF (COVER.GE.XK3)  K3 = COVER
              IF (K3.LT.1.0) GO TO 300
              KF=50.0
              GO TO 320
        300   KF=0.25/(1.0-K3)
        320   IF (REPIN.GE.(KF*LNRAT))  GO TO 340
              AETR= REPIN*(1.0-(REPIN/(2.0*KF*LNRAT)))
              GO TO 350
        340   AETR= 0.5*(KF*LNRAT)
        350   IF (K3.LT.(0.50))  AETR=AETR*(2.0*K3)
              LZS=LZS - AETR
              SNET= SNET + PA*AETR
              ASNET   ASNET + LCS + PA*AETR
        351   REFIN   0.0
        101   SNETI = SNET - SNET1
      C
      C
      C
      C WBAL   WATER BALANCE IN THE INTERVAL
      C TWBAL - ACCUMULATED WATER BALANCE
      C
      C
              WBAL = (LZS-LZS1+UZS-UZS1+RESS-RESS1)*PA+(SNET-SNET1+SGW-SGW1+
          X             SCEP-SCEP1+SRCH+SRGXT-SRGXT1+RU-PR)
              IF ((WBAL .LE. 0.0001).AND.(WBAL .GE. -0.0001))  WBAL = 0.0
             TWBAL=TWBAL+WBAL
      C
            DPS = F1A*PA
            DPST = DPST + DPS
      C
      C
      C                    RESETTING VARIABLES
      C
```

```
            LZS1=LZS
            UZS1=UZS
            RESS1=RESS
            SCEP1=SCEP
            SRGXT1=SRGXT
            SGW1=SGW
            SNET1=SNET
      C
             ASBAS = ASBAS + SBAS
             ASRCH = ASRCH + SRCH
            APR = APR + PRR
               ARU = ARU + RU
               ARUI = ARUI + RUI
               AROS = AROS + ROS
               ARGXT = ARGXT + RGXT
               IF ((NUMI.NE.0).OR.(IMIN.NE.0))  GO TO 148
               AEPIN = AEPIN + EPIN1
               ASNET = ASNET + SNET1
        148 DO 150  I=1,5
               APERCB(I) = APERCB(I) + PERCB(I)
               AROSB(I) = AROSB(I) + ROSB(I)
               AINTF(I) = AINTF(I) + INTF(I)
               AROSIT(I) = AROSIT(I) + ROSINT(I)
        150    CONTINUE
      C
        155 CONTINUE
      C
            IF (PRNTKE .EQ. 0)  GO TO 180
      C
      C                          CUMULATIVE RECORDS
      C
            PRTCM = PRTCM + APR
            EPTCM = EPTCM + AEPIN
            RLTCM = RLTCM + ARU
            RCSTCM = RCSTCM + AROS
            RITCM = RITCM + ARUI
            RINTCM = RINTCM + ARGXT
            NEPTCM = NEPTCM + ASNET
            BASTCM = BASTCM + ASBAS
            RCHTCM = RCHTCM + ASRCH
      C
              DO 157  I=1,5
                 ROBTCM(I) = ROBTCM(I) + AROSB(I)
                 ROBTCT(I) = ROBTCT(I) + AROSB(I)
                 INFTCM(I) = INFTCM(I) + AINTF(I)
                 INFTCT(I) = INFTCT(I) + AINTF(I)
                 ROITCM(I) = ROITCM(I) + AROSIT(I)
        157      ROITCT(I) = ROITCT(I) + AROSIT(I)
      C
            PRTCT = PRTCT + APR
            EPTCT = EPTCT + AEPIN
            RLTOT = RLTCT + ARU
            RCSTCT = RCSTCT + AROS
            RITCT = RITCT + ARUI
            RINTCT =RINTCT + ARGXT
            NEPTOT = NEPTCT + ASNET
            BASTCT = BASTCT + ASBAS
            RCHTCT = RCHTCT + ASRCH
      C
            IF (PRNTKE .EQ. 2)  GO TO 171
```

```
      IF (HYCAL.EQ.PROD) GO TO 160
C
C                  OUTPUT FOR HSP LANDS CALIBRATION RUN
C
C
      IF (TF .GT. 2)  GO TO 170
      RU = (RU*AREA*43560.)/(TIMFAC*720.)
      IF (RU .LT. HYMIN)  GO TO 170
      QMETRC=RU*.0283
      IF (NUTR .EQ. YES)  GO TO 982
      WRITE (6,379) MNAM(MONTH),DAY,IHR,IMIN
      WRITE (6,378) RU,QMETRC
      GO TO 170
C
  982 IF (OUTPUT.EQ.ENGL .OR. OUTPUT.EQ.BOTH)
     1     WRITE (6,4901)  MNAM(MONTH), DAY, IHR, IMIN, RU
      IF (OUTPUT .EQ. METR)
     1     WRITE (6,4901)  MNAM(MONTH), DAY, IHR, IMIN, QMETRC
      GO TO 170
C
  160 IF (SNOW.EQ.NO .OR. PRINT.NE.DAYS)  GO TO 169
         SUMSNH = SUMSND
         PXSNH - PXSND
         SPXH = MELRAD
         RADMEH = RADMED
         CDRMEH = CDRMED
         CONMEH = CONMED
         CRAINH = CRAIND
         SGMH = SGMD
         SNEGMH  = SNEGMD
         SEVAPH = SEVAPD
C
C                  OUTPUT FOR HSP LANDS PRODUCTION RUN  AND SUMMARIES
C
  169 IF (OUTPUT.EQ. METR) GO TO 161
      WRITE (6,360)
      WRITE (6,362)
      WRITE (6,363) ARCSB,AROS
      WRITE (6,364) AINTF,ARGXT
      WRITE (6,365) ARLI
      WRITE (6,366) ARCSIT,ARU
      WRITE (6,380) ASEAS
      WRITE (6,381) ASRCH
      WRITE (6,361) APR,APR,APR,APR,APR,APR
      IF ((SNOW.EQ.NO).OR.(PACK.LE.0.0))  GO TO 181
C                          SNOWMELT OUTPUT
      WRITE (6,478) SUMSNH
      WRITE (6,479) PXSNH
      WRITE (6,480) SPXH
      WRITE (6,481)
      WRITE (6,482) RADMEH
      WRITE (6,483) CONMEH
      WRITE (6,484) CDRMEH
      WRITE (6,485) CRAINH
      WRITE (6,486) SGMH
      WRITE (6,487) SNEGMH
      WRITE (6,490) PACK
         COVR = 100.
         IF (PACK .LT. IPACK) COVR   (PACK/IPACK)*100.
         IF (PACK.GT.0.01) GO TO 1078
```

```
            CCVR=0.0
            SDEN=0.0
     1076 WRITE (6,491) SDEN
          WRITE (6,492) CCVR
          WRITE (6,486) SEVAPH
      181 WRITE (6,367)
          WRITE (6,368) AEPIN,AEPIN,AEPIN,AEPIN,AEPIN,AEPIN
          WRITE (6,369) ASNET,ASNET,ASNET,ASNET,ASNET,ASNET
          WRITE (6,383) CCVER
          WRITE (6,370)
          WRITE (6,371) UZSB,LZS
          WRITE (6,372) LZS,LZS,LZS,LZS,LZS,LZS
          WRITE (6,373) SGW,SGW,SGW,SGW,SGW,SGW
          WRITE (6,374) SCEP,SCEP,SCEP,SCEP,SCEP,SCEP
          WRITE (6,375) RESB,RESS
          WRITE (6,376) SRGX,SRGXT
          WRITE (6,377) TWBAL
          IF ((SNOW.EQ.YES).AND.(PACK.GT.0.0)) WRITE (6,489) TSNBAL
      161 IF (OUTPUT.EQ. ENGL) GO TO 171
C
C  METRIC CONVERSIONS FOR OUTPUT
          APR    =APR*MMPIN
          AROS   =AROS*MMPIN
          ARGXT  =ARGXT*MMPIN
          ARUI   =ARUI*MMPIN
          ARU    =ARU*MMPIN
          ASBAS  =ASBAS*MMPIN
          ASRCH  =ASRCH*MMPIN
          AEPIN  =AEPIN*MMPIN
          ASNET  =ASNET*MMPIN
          LZSMET=LZS*MMPIN
          LZSMET=LZS*MMPIN
          SGWMET=SGW*MMPIN
          SCEPMT=SCEP*MMPIN
          RESSMT=RESS*MMPIN
          TWBLMT=TWBAL*MMPIN
          SRGXTM=SRGXT*MMPIN
C  SNOW
          IF (SNOW .EQ. NO)  GO TO 163
          SUMSNH = SUMSNH*MMPIN
          PXSNH = PXSNH*MMPIN
          SPXH = SPXH*MMPIN
          RADMEH = RADMEH*MMPIN
          CCNMEH = CCNMEH*MMPIN
          CDRMEH = CDRMEH*MMPIN
          CRAINH = CRAINH*MMPIN
          SGMH = SGMH*MMPIN
          SNEGMH = SNEGMH*MMPIN
          PACKML = PACK*MMPIN
          SEVAPH = SEVAPH*MMPIN
          TSNBML = TSNBAL*MMPIN
      163 DO 162 I=1,5
            ARCSB(I) =ARCSB(I)*MMPIN
            AINTF(I) =AINTF(I)*MMPIN
            ARCSIT(I)=ARCSIT(I)*MMPIN
            UZSBMT(I)=UZSB(I)*MMPIN
            RESBMT(I)=RESB(I)*MMPIN
            SRGXMT(I)=SRGX(I)*MMPIN
      162 CONTINUE
          WRITE (6,460)
```

```
      WRITE (6,362)
      WRITE (6,363) AFCSB,AROS
      WRITE (6,364) AINTF,ARGXT
      WRITE (6,365) AFLI
      WRITE (6,366) ARCSIT,ARU
      WRITE (6,380) ASEAS
      WRITE (6,381) ASRCH
      WRITE (6,361) APP,APR,APR,APR,APR,APR
      IF (SNOW.EQ.NO .OR. PACK.LE.0.0)  GO TO 182
      WRITE (6,478)  SUMSNH
      WRITE (6,479)  PXSNH
      WRITE (6,480)  SFXH
      WRITE (6,481)
      WRITE (6,482)  RADMEH
      WRITE (6,483)  CONMEH
      WRITE (6,484)  CORMEH
      WRITE (6,485)  CRAINH
      WRITE (6,486)  SGMH
      WRITE (6,487)  SNEGMH
      WRITE (6,490)  PACKML
         COVR = 100.0
         IF (PACK.LT.IPACK)  COVR = (PACK/IPACK)*100.
         IF (PACK.GT.0.01)  GO TO 1079
         COVR = 0.0
         SCEN = 0.0
 1079 WRITE (6,491)  SCEN
      WRITE (6,492)  COVR
      WRITE (6,488)  SEVAPH
  182 WRITE (6,367)
      WRITE (6,368) AEPIN,AEPIN,AEPIN,AEPIN,AEPIN,AEPIN
      WRITE (6,369) ASNET,ASNET,ASNET,ASNET,ASNET,ASNET
      WRITE (6,383) COVER
      WRITE (6,370)
      WRITE (6,371) UZSEMT, UZSMET
      WRITE (6,372) LZSMET, LZSMET, LZSMET, LZSMET, LZSMET, LZSMET
      WRITE (6,373) SGWMET, SGWMET, SGWMET, SGWMET, SGWMET, SGWMET
      WRITE (6,374) SCEPMT, SCEPMT, SCEPMT, SCEPMT, SCEPMT, SCEPMT
      WRITE (6,375) RESSMT, RESSMT
      WRITE (6,376) SRGXMT, SRGXT
      WRITE (6,377) TWBLMT
      IF (SNOW.EQ.YES .AND. PACK.GT.0.0)  WRITE (6,489)  TSNBML
C
  171 IF (PRINT.NE.DAYS)  GO TO 170
         SUMSND = 0.0
         PXSND  = 0.0
         MELRAD = 0.0
         RADMED = 0.0
         CORMED = 0.0
         CONMED = 0.0
         CRAIND = 0.0
         SGMD   = 0.0
         SNEGMD = 0.0
         SEVAPD = 0.0
C
C                    FORMAT STATEMENTS
C
  378 FORMAT ('+',21X,F6.3,2X,F6.3)
  379 FORMAT (' ',A8,1X,I2,2X,I2,':',I2)
  360 FORMAT ('0',8X,'WATER, INCHES')
  362 FORMAT ('0',11X,'RUNOFF')
```

```
      363 FORMAT (' ',14X,'OVERLAND FLOW',5X,5(F8.3,2X),1X,F8.3)
      364 FORMAT (' ',14X,'INTERFLOW',9X,5(F8.3,2X),1X,F8.3)
      365 FORMAT (' ',14X,'IMPERVIOUS',59X,F8.3)
      366 FORMAT (' ',14X,'TOTAL',13X,5(F8.3,2X),1X,F8.3)
      380 FORMAT ('0',11X,'BASE FLOW',63X,F8.3)
      381 FORMAT (' ',11X,'GRDWATER RECHARGE',55X,F8.3)
      361 FORMAT ('0',11X,'PRECIPITATION',8X,5(F7.2,3X),1X,F7.2)
      478 FORMAT (' ',14X,'SNOW',65X,F7.2)
      479 FORMAT (' ',14X,'RAIN ON SNOW',57X,F7.2)
      480 FORMAT (' ',14X,'MELT & RAIN',58X,F7.2)
      481 FORMAT ('0',11X,'MELT')
      482 FORMAT (' ',14X,'RADIATION',60X,F7.2)
      483 FORMAT (' ',14X,'CONVECTION',59X,F7.2)
      484 FORMAT (' ',14X,'CONDENSATION',57X,F7.2)
      485 FORMAT (' ',14X,'RAIN MELT',60X,F7.2)
      486 FORMAT (' ',14X,'GROUND MELT',58X,F7.2)
      487 FORMAT (' ',14X,'CUM NEG HEAT',57X,F7.2)
      490 FORMAT ('0',11X,'SNOW PACK',63X,F7.2)
      491 FORMAT (' ',11X,'SNOW DENSITY',60X,F7.2)
      492 FORMAT (' ',11X,'% SNOW COVER',60X,F7.2)
      488 FORMAT ('0',11X,'SNOW EVAP',63X,F7.2)
      367 FORMAT ('0',11X,'EVAPOTRANSPIRATION')
      368 FORMAT (' ',14X,'POTENTIAL',9X,5(F7.2,3X),1X,F7.2)
      369 FORMAT (' ',14X,'NET',15X,5(F7.2,3X),1X,F7.2)
      383 FORMAT (' ',14X,'CROP COVER',59X,F7.2)
      370 FORMAT ('0',11X,'STORAGES')
      371 FORMAT (' ',14X,'UPPER ZONE',8X,5(F8.3,2X),1X,F8.3)
      372 FORMAT (' ',14X,'LOWER ZONE',8X,5(F8.3,2X),1X,F8.3)
      373 FORMAT (' ',14X,'GROUNDWATER',7X,5(F8.3,2X),1X,F8.3)
      374 FORMAT (' ',14X,'INTERCEPTION',6X,5(F8.3,2X),1X,F8.3)
      375 FORMAT (' ',14X,'OVERLAND FLOW',5X,5(F8.3,2X),1X,F8.3)
      376 FORMAT (' ',14X,'INTERFLOW',9X,5(F8.3,2X),1X,F8.3)
      377 FORMAT ('0',11X,'WATER BALANCE=',F8.4)
      489 FORMAT (' ',11X,'SNOW BALANCE= ',F8.4)
      460 FORMAT ('0',8X,'WATER, MILLIMETERS')
     4901 FORMAT ('0',A8,1X,I2,2X,I2,':',I2,3X,F8.3)
C
  170 APR = 0.0
      AEPIN = 0.0
      ARU = 0.0
      ARUI = 0.0
      AROS = 0.0
      ARGXT = 0.0
      ASNET = 0.0
      ASBAS = 0.0
      ASRCH = 0.0
      DO 172  I=1,5
         AROSB(I) = 0.0
         AINTF(I) = 0.0
         AROSIT(I) = 0.0
  172    CONTINUE
C
  180 IF (SNOW.EQ.NO)  GO TO 190
C
C                                        ZERO HOURLY VALUES
      SUMSNH = 0.0
      PXSNH = 0.0
      RADMEH = 0.0
      CORMEH = 0.0
      CONMEH = 0.0
```

```
      CRAINH = 0.0
      SGMH = 0.0
      SNEGMH = 0.0
      SEVAPH = 0.0
      SPXH = 0.0
  190 RETURN
      END
C
C
C
C
      SUBROUTINE SECT
C
C
C                              SEDIMENT EROSION MODEL
C
C
      DIMENSION RESE(5),RESB1(5),ROSB(5),SRGX(5),INTF(5),RGX(5),INFL(5),
     1 UZSB(5),APERCB(5),RIB(5),ERSN(5)
      DIMENSION SRER(5),ROBTOM(5),ROBTOT(5),INFTOM(5),INFTOT(5),
     1 ROITOM(5),ROITOT(5),RXB(5),ERSTOM(5),ERSTOT(5),MNAM(12),RAD(24),
     2 TEMPX(24),WINDX(24),RAIN(288),UZSBMT(5),RESBMT(5),SRGXMT(5),
     3 SRERMT(5)
      DIMENSION AERSN(5),AERSNM(5)
      DIMENSION ISTAR(5)
C
      COMMON /ALL/ RU,HYMIN,PRNTKE,HYCAL,DPST,OUTPUT,TIMFAC,LZS,AREA,
     1 RESB1,ROSB,SRGX,INTF,RGX,INFL,UZSB,APERCB,RIB,ERSN,M,P3,A,
     2 CALB,PROD,PEST,NUTR,ENGL,METR,BOTH,RESB,YES,NO,IMIN,IHR,TF,
     3 JCOUNT,PRINT,INTR,DAYS,HOUR,MNTH
C
      COMMON /LAND/ MNAM,PRTOT,ERSNTT,PRTOM,ERSNTM,DAY,
     1 RUTOM,NEPTOM,RESTOM,RITOM,RINTOM,BASTOM,RCHTOM,RUTOT,
     2 NEPTOT,RESTOT,RITOT,RINTOT,BASTOT,RCHTOT,TWBAL,EPTOM,EPTOT,
     3 LZS,UZSN,LZSN,INFIL,INTER,IRC,NN,L,SS,SGW1,PR,SGW,GWS,KV,
     4 K24L,KK24,K24EL,EP,IFS,K3,EPXM,RESS1,RESS,SCEP,SCEP1,SRGXT,
     5 SRGXT1,JRER,KRER,JSER,KSER,SRERT,MMPIN,METOPT,SNOW,CCFAC,
     6 SCF,IDNS,F,DGM,WC,MPACK,EVAPSN,MELEV,TSNOW,PETMIN,PETMAX,ELDIF,
     7 DEWX,PACK,DEPTH,MONTH,SDEN,IPACK,TMIN,SUMSNM,PXSNM,XK3,
     8 MELRAM,RADMEM,CDRMEM,CRAINM,CONMEM,SGMM,SNEGMM,SEVAPM,SUMSNY,
     9 PXSNY,MELRAY,RADMEY,CDRMEY,SGMY,CONMEY,CRAINY,SNEGMY,SEVAPY,
     * TSNEAL,COVER,COVRMX,ROBTOM,ROBTOT,RXB,ROITOM,ROITOT,INFTOM,
     1 INFTOT,ERSTOM,ERSTOT,SRER,TEMPX,RAD,WINDX,RAIN,INPUT
C
      INTEGER  PRNTKE,HYCAL,OUTPUT,CALB,PROD,ENGL,METR,BOTH,TIMFAC
      INTEGER  PEST,NUTR,YES,NO
      REAL*8  MNAM
C
      REAL JRER, KRER, JSER, KSER
      REAL  ERSNTT, SRERMT
      REAL  MMPIN, METOPT, KGPUB
C
      DATA  ERSNT/0.0/, AERSN/5*0.0/
      DATA  IASTRK/'*'/, IBLANK/' '/
C
C  SER = TRANSPORT CAPACITY OF OVERLAND FLOW IN TONS/ACRE
C  ERSN = EROSION REACHING STREAM
C  SRER = FINES DEPOSIT IN TONS/ACRE
C
C                        ZEROING OF VARIABLES
```

```
C
            SRERT = 0.0
            DO 4599 I=1,5
      4599  ISTAR(I) = IBLANK
            ERSNT = 0.0
C
C                          SOIL EROSION LOOP
C
              RER = (1.0 - COVER)*KRER*PR**JRER
            DO 4452 I=1,5
                SRER(I) = SRER(I) + RER
              IF ((ROSB(I)+RESB(I)).GT.0.0) GO TO 4444
C
                ERSN(I) = 0.0
                SER = 0.
                GO TO 4446
C
       4444     SER = KSER*(ROSB(I)+RESB(I))**JSER
                IF (SER .LE. SRER(I)) GO TO 4501
                SER = SRER(I)
                ISTAR(I) = IASTRK
C
       4501     ERSN(I) = SER*ROSB(I)/(ROSB(I)+RESB(I))
                SRER(I) = SRER(I) - ERSN(I)
                IF (SRER(I) .LT. 0.) SRER(I) = 0.
C
       4446   AERSN(I) = AERSN(I) + ERSN(I)
       4452   CONTINUE
C
             IF (PRNTKE .EQ. 0)  GO TO 4490
C
              DO 4456  I=1,5
                ERSNT = ERSNT + AERSN(I)*0.2
                SRERT = SRERT + SRER(I)*0.2
                ERSTOM(I) = ERSTOM(I) + AERSN(I)
                ERSTOT(I) = ERSTOT(I) + AERSN(I)
       4456     CONTINUE
C
C                          CUMULATIVE RECORDS
C
             ERSNTM = ERSNTM + ERSNT
             ERSNTT = ERSNTT + ERSNT
C
             IF (PRNTKE .EQ. 2)  GO TO 4487
C
               ERSNTP = 0.0
               ERSNTK = 0.0
               ERSNKM = 0.0
               ERSNCM = 0.0
C
              IF (HYCAL .EQ. PROD)  GO TO 4460
              IF (RU .LT. HYMIN)  GO TO 4487
C
C   CONVERSION OF SEDIMENT LOSS TO LBS., KGS., KGS/MINUTE, AND
C                                          GM/L FOR OUTPUT
C
              ERSNTP = ERSNT*2000.*AREA
              ERSNTK = ERSNTP*.454
              ERSNKM = ERSNTK/TIMFAC
              ERSNCM = ERSNTP*454./(RU*TIMFAC*60.*28.32)
```

```
          IF (NUTR .EQ. YES)  GO TO 892
C
           WRITE (6,4484) ERSNTP, ERSNTK, ERSNKM, ERSNCM
          GO TO 893
C
     892  IF (OUTPUT.EQ.ENGL .OR. OUTPUT.EQ.BOTH)  WRITE (6,4902)  ERSNTP
          IF (OUTPUT .EQ. METR)  WRITE (6,4902)  ERSNTK
C
     893  IF (HYCAL.EQ.CALB .AND. PEST.EQ.NO .AND. NUTR.EQ.NO)
         1                   WRITE (6,4999) (ISTAR(I),I=1,5)
      4999            FORMAT ('+',74X,5A1)
           GO TO 4487
C
C
C                            PRINTING OF OUTPUT
C
      4460 IF (OUTPUT.EQ. METR) GO TO 4462
          WRITE (6,4480)
          WRITE (6,4481)  (AERSN(I), I=1,5), ERSNT
          WRITE (6,4482)  (SRER(I), I=1,5), SRERT
      4462 IF (OUTPUT.EQ. ENGL) GO TO 4487
          ERSNTI=ERSNT*METOPT*2.471
          SRRTMT=SRERT*METOPT*2.471
          DO 4461 I=1,5
            AERSNM(I)=AERSN(I)*METOPT*2.471
            SRERMT(I)=SRER(I)*METOPT*2.471
      4461 CONTINUE
          WRITE (6,4485)
          WRITE (6,4481) AERSNM, ERSNTI
          WRITE (6,4482) SRERMT, SRRTMT
C
C                            FORMAT STATEMENTS
C
      4480 FORMAT ('0',8X,'SEDIMENT, TONS/ACRE')
      4481 FORMAT (' ',11X,'ERODED SEDIMENT',4X,5(3X,F7.3),4X,F7.3)
      4482 FORMAT (' ',11X,'FINES DEPOSIT',6X,5(3X,F7.3),4X,F7.3)
      4484 FORMAT ('+',36X,4(2X,F7.2))
      4485 FORMAT ('0',8X,'SEDIMENT, TONNES/HECTARE')
      4902 FORMAT ('+',30X,F8.2)
C
      4487 DO 4489  I=1,5
             AERSN(I) = 0.0
      4489    CONTINUE
C
      4490 CONTINUE
C
          RETURN
          END
C
C
C
C
          SUBROUTINE ACSRE
C
C
C
          IMPLICIT  REAL(L)
C
          DIMENSION RESB(5),RESB1(5),ROSB(5),SRGX(5),INTF(5),RGX(5),INFL(5),
         1 UZSB(5),AFERCB(5),RIB(5),ERSN(5)
```

```
      DIMENSION PRSTOM(5),PRSTOT(5),PROTOM(5),PROTOT(5),UPITOM(5),
     1 UPITOT(5),STS(5),UTS(5),SAS(5),SCS(5),SDS(5),SSTR(5),SPRP(5),
     2 UAS(5),UCS(5),LCS(5),USTR(5),UPRP(5),CT(5),ST(5),JFLAG(5),KD(5),
     3 CAD(5),CTU(5),STU(5),KFLAG(5),KDU(5),CADU(5),STSMET(5),SASMET(5),
     4 SCSMET(5),SDSMET(5),UTSMET(5),UASMET(5),UCSMET(5),UDSMET(5)
      DIMENSION SAPS(5),SCPS(5),SPRS(5),SPRO(5),SPR(5),SPS(5),SCSC(5),
     1 SASC(5),SDSC(5),SFCFS(5),ASPR(5),ASPRS(5),ASPRO(5),ASPRP(5)
      DIMENSION UPRI(5),JNFW(5),UDSC(5),UPRIS(5),UPR(5),UPS(5),UCSC(5),
     1 UASC(5),AUPR(5),AUPRI(5),AUPRP(5),UPRISM(5)
      DIMENSION CTL(5),MFLAG(5),CADL(5),STL(5),KDL(5)
C
      COMMON /ALL/ RL,HYMIN,PRNTKE,HYCAL,DPST,OUTPUT,TIMFAC,LZS,AREA,
     1 RESBL,RCSB,SRGX,INTF,RGX,INFL,UZSB,APERCB,RIB,ERSN,M,P3,A,
     2 CALB,PROD,PEST,NUTR,ENGL,METR,BOTH,RESB,YES,NO,IMIN,IHR,TF,
     3 JCOUNT,PRINT,IMIF,DAYS,HOUR,MNTH
C
      COMMON /PESTC/ SIST,SPROTM,SPRSTM,SAST,SCST,SDST,UTST,UAST,UCST,K,
     1 UDST,FF,CMAX,NI,SPRCTT,SPRSTT,MUZ,FPUZ,UPRITM,
     2 UPRITT,KGPLB,FFLZ,MLZ,LSTR,LAS,LCS,LDS,GSTR,GAS,GCS,GDS,
     3 APMODE,TPBAL,
     4 DEGSCM,DEGSCT,DEGUCM,
     5 DEGLCT,DEGL,DEGS,NIP,DEGCON,DEGLCM,DEGLUT,NCCM,
     6 PRSTCM,PRSTCT,PRCTCM,PROTOT,UPITOM,UPITOT,STS,UTS,SAS,
     7 SCS,SDS,SSTR,LAS,LCS,UDS,USTR,UPRIS,UIST,TOTPAP,TIMAP,YEARAP,
     8 DESORP,SURF,SOIL,SULG
C
      INTEGER  PRNTKE,HYCAL,OUTPUT,CALB,PROD,NUTR,PEST,ENGL,METR,BOTH
      INTEGER  DESORP,YES,NO,TIMFAC
C
      REAL  M, NI, K, KK, INFW, INFL
      REAL  STSTMT, SASTMT, SCSTMT, SDSTMT
      REAL  STSMET, SASMET, SCSMET, SDSMET
      REAL  MMPIN, METCFT, KGPLB
      REAL  NP, NIF, NCCM, KD, CT, ST, CAD
C
      REAL  UTSTMT, UASTMT, UCSTMT, UDSTMT
      REAL  UTSMET, UASMET, UCSMET, UDSMET
      REAL  MUZ, JNFW, INTF
      REAL  KDU, CTU, STU, CADU
C
      REAL  KNFW, MLZ
      REAL  LSTRMT, LASMET, LCSMET, LDSMET
      REAL  GSTRMT, GASMET, GCSMET, GDSMET
      REAL  KDL, CTL, STL
C
      REAL  C,Z,X,FF,FTCT,FPUZ,CADL,FPLZ
      INTEGER  MFLAG, JFLAG, KFLAG
C
C
      DATA  SPST, SASCT, SCSCT, SPRT, SPRST, SPRTT, SPRPTT/7*0.0/
      DATA  SPRCT, SPFFT/2*0.0/, INFW/0.0/
      DATA  ASPR, ASPRS, ASPRO, ASPRP/20*0.0/
      DATA  SDSC, SFCFS, SDSCT/11*0.0/
C
      DATA  UPST, UASCT, UCSCT, UPRT/4*0.0/
      DATA  UDSCT, UPFFT/2*0.0/, JNFW/5*0.0/, UPRIT/0.0/
      DATA  AUPR, AUPRI, AUPRP/15*0.0/
      DATA  AUPRF/0.0/
C
      DATA  CT/5*0.0/,JFLAG/5*0/,CAD/5*0.0/,ST/5*0.0/
```

```
                DATA  CTU/5*0.0/,KFLAG/5*0/,CADU/5*0.0/,STU/5*0.0/
                DATA  CTL/5*0.0/,MFLAG/5*0/,CADL/5*0.0/,STL/5*0.0/,KDL/5*0.0/
      C
      C
      C                          SURFACE SOLUTION ADSORPTION-DESORPTION MODEL
      C
      C                       ZEROING VARIABLES
      C
                STST = 0.0
                SAST = 0.0
                SCST = 0.0
                SDST = 0.0
                ERSNT = 0.0
                ASPTOT = 0.0
      C
      C                       ADSORPTION-DESORPTION SOLUTION LOOP
      C                          WITH REVERSIBLE DESORPTION
      C
                PA = 1.0 - A
                Z = 1000000.**(NI-1)
                KK = M*K*Z
                DO 5320  I=1,5
                   INFW = 0.2*AREA*(P3+RESB1(I))*226512.
                   PTOT = SAS(I) + SCS(I) + SDS(I) + SSTR(I)
                   ASPTOT = ASPTOT + PTOT
                   IF (PTOT.GT.FP) GO TO 5315
                      SAS(I) = PTOT
                      SCS(I) = 0.0
                      SDS(I) = 0.0
                      JFLAG(I) = 0
                      CT(I) = 0
                      GO TO 5320
        5315       X = KK*CMAX**NI + FP
                   PSLD = PTOT - X - INFW*CMAX
                   IF (PSLD .LT. 0.0)  GO TO 5316
                      SAS(I) = X
                      SCS(I) = PSLD
                      SDS(I) = CMAX*INFW
                      JFLAG(I) = 0
                      CT(I) = 0
                      GO TO 5320
      C
        5316          SCS(I) = 0.0
                      IF (INFW.GE.0.001) GO TO 5321
                      SAS(I) = PTOT
                      SDS(I) = 0.0
                      JFLAG(I) = 0
                      CT(I) = 0
                      GO TO 5320
      C
      C            COMPUTE C AND X BY THE ADSORPTION EQUATION
      C
        5321          C = CMAX*PTOT/(X + INFW*CMAX)
        5317          X = KK*C**NI + FP
                      Q = (PTOT/(X+INFW*C)) - 1.
                      IF (ABS(Q).LE.0.01) GO TO 5319
                         C = C*PTOT/(X + INFW*C)
                         GO TO 5317
      C
        5319             IF (DESORP .EQ. NO)  GO TO 5324
```

```
      C
            CALL DSFTN (I,CT,C,JFLAG,CAD,KD,K,Z,NCOM,
           1             ST,X,P,NIP,FP,PTOT,INFW)
      C
       5324          SCS(I) = (C*INFW)*(PTOT/(X+C*INFW))
                     SAS(I) = X*(PTOT/(X+C*INFW))
      C
       5320    CONTINUE
      C
      C                      PESTICIDE REMOVAL LOOP
      C
            DO 5330  I=1,5
      C
               QS = 400.*AREA*ERSN(I)/M
               IF (QS .GT. 1.0)  QS = 1.0
               SAPS(I) = SAS(I)*QS
               SCPS(I) = SCS(I)*QS
               SPRS(I) = SAPS(I) + SCPS(I)
               SAS(I) = SAS(I) - SAPS(I)
               SCS(I) - SCS(I) - SCPS(I)
      C
                  SPRC(I) = 0.0
                  SPCFS(I) = 0.0
                  SPRP(I) = 0.0
                  SPR(I) = 0.0
               IF (P3 +RESB1(I).LE.0.0) GO TO 5329
                  SPRC(I) = SCS(I)*ROSB(I)/((RESB1(I)+P3)*PA)
      C
               SPCFS(I) = SCS(I)*(RESB(I)/(RESB1(I)+P3))
               SPRP(I)    SCS(I) - SPRO(I) - SPCFS(I)
               SPR(I)    SPRC(I) + SPRS(I) + SPRP(I)
       5329    SDS(I) = SPCFS(I)
      C
               ASPR(I) = ASPR(I) + SPR(I)
               ASPRS(I)    ASPRS(I) + SPRS(I)
               ASPRC(I) = ASPRC(I) + SPRO(I)
               ASPRP(I) = ASPRP(I) + SPRP(I)
      C
      C
               RESB1(I) = 0.0
      C
       5330    CONTINUE
      C
            IF (PRNTKE .EQ. 0)  GO TO 5390
      C
      C                      PREPARATION OF OUTPUT
      C
               DO 5335  I=1,5
                  SPRT = SPRT +ASPR(I)
                  SPRCT    SPRCT +ASPRO(I)
                  SPRST = SPRST +ASPRS(I)
                  SPRPT = SPRPT +ASPRP(I)
      C
                  SAST - SAST + SAS(I)
                  SCST = SCST + SCS(I)
                  SDST = SDST + SDS(I)
      C
                  SASC(I) = (SAS(I)/M)*1000000.
                  SASCT = SASCT + SASC(I)*0.2
                  SCSC(I) - (SCS(I)/M)*1000000.
```

```
                  SCSCT = SCSCT + SCSC(I)*0.2
                  SDSC(I) = (SDS(I)/M)*1000000.
                  SDSCT = SDSCT + SDSC(I)*0.2
      C
                  STS(I) = SAS(I) + SCS(I) + SDS(I)
                  SPS(I) = SASC(I) + SCSC(I) + SDSC(I)
                  STST = STST + STS(I)
                  SPST = SPST + SPS(I)*0.2
      C
                  ERSNT = ERSNT + ERSN(I)*0.2*AREA
      C
       5335       CONTINUE
      C
      C                     CUMULATIVE RESULTS
               DO 5337  I= 1,5
                  PRSTCM(I) = PRSTOM(I) + ASPRS(I)
                  PROTCM(I) = PROTCM(I) + ASPRO(I)
                  PROTOT(I) = PROTOT(I) + ASPRO(I)
       5337       PRSTOT(I) = PRSTOT(I) + ASPRS(I)
      C
               SPROTM = SPROTM + SPROT
               SPRSTM = SPRSTM + SPRST
      C
               SPRTT = SPRTT + SPRT
               SPROTT = SPROTT + SPROT
               SPRPTT = SPRPTT + SPRPT
               SPRSTT = SPRSTT + SPRST
      C
            IF (PRNTKE .EQ. 2)  GO TO 5370
               IF (MYCAL .EQ. PROD)  GO TO 5340
               IF (RU .LT. MYMIN)  GO TO 5370
                  SPRTGM = SPROT*454.
                  SPRTCM = (SPROT/(RU*TIMFAC*60.*62.43))*1000000.
                  SPRTGS = SPRST*454.
                  SPRTCS = 0.0
                  IF (ERSNT.GT.0.0)  SPRTCS = (SPRST/(ERSNT*2000.))*1000000.
                  GO TO 5370
      C                     PRINTING OF OUTPUT
      C
       5340 IF (OUTPUT.EQ. METR) GO TO 5341
            WRITE (6,5350)
            WRITE (6,5351)  STS, STST
            WRITE (6,5352)  SAS, SAST
            WRITE (6,5353)  SCS, SCST
            WRITE (6,5361) SDS, SDST
            WRITE (6,5354)  SPS, SPST
            WRITE (6,5352)  SASC, SASCT
            WRITE (6,5353)  SCSC, SCSCT
            WRITE (6,5361)  SDSC, SDSCT
            WRITE (6,5355)  ASPR, SPRT
            WRITE (6,5356)  ASPRS, SPRST
            WRITE (6,5357)  ASPRO, SPROT
            WRITE (6,5359)  ASPRP, SPRPT
       5341 IF (OUTPUT.EQ. ENGL) GO TO 5370
      C
      C  METRIC CONVERSIONS FOR OUTPUT
            STSTMT=STST*KGPLB
            SASTMT=SAST*KGPLB
            SCSTMT=SCST*KGPLB
            SDSTMT=SDST*KGPLB
```

```
          SPRT  =SPRT*KGPLB
          SPRST =SPRST*KGPLB
          SPROT =SPROT*KGPLB
          SPRPT =SPRPT*KGPLB
          DO 5343 I=1,5
            STSMET(I)=STS(I)*KGPLB
            SASMET(I)=SAS(I)*KGPLB
            SCSMET(I)=SCS(I)*KGPLB
            SDSMET(I)=SDS(I)*KGPLB
            ASPR(I)   =ASPR(I)*KGPLB
            ASPRS(I)  =ASPRS(I)*KGPLB
            ASPRC(I)  =ASPRC(I)*KGPLB
            ASPRP(I)  =ASPRP(I)*KGPLB
     5343 CONTINUE
          WRITE (6,5350)
          WRITE (6,5363) STSMET, STSTMT
          WRITE (6,5352) SASMET, SASTMT
          WRITE (6,5353) SCSMET, SCSTMT
          WRITE (6,5361) SDSMET, SDSTMT
          IF (OUTPUT.EQ. EOTH) GO TO 5345
          WRITE (6,5354)  SPS, SPST
          WRITE (6,5352)  SASC, SASCT
          WRITE (6,5353)  SCSC, SCSCT
          WRITE (6,5361)  SDSC, SDSCT
     5345 WRITE (6,5374) ASPR,SPRT
          WRITE (6,5356)  ASPRS, SPRST
          WRITE (6,5357)  ASPRC, SPROT
          WRITE (6,5359)  ASPRP, SPRPT
    C
    C
    C                           ZEROING VARIABLES
    C
     5370 DO 5380  I=1,5
             ASPR(I) = 0.0
             ASPRC(I) = 0.0
             ASPRS(I) = 0.0
             ASPRP(I) = 0.0
     5380    CONTINUE
    C
     5390 SPST = 0.0
          SASCT = 0.0
          SCSCT = 0.0
          SDSCT = 0.0
          SPRT = 0.0
          SPRST = 0.0
          SPROT = 0.0
          SPRPT = 0.0
    C
          DO 5391  I= 1,5
     5391 SSTR(I) = 0.0
    C
    C
    C
    C                              UPPER ZONE SOLUTION ADSORPTION-DESORPTION MODEL
    C
    C
    C                           ZEROING VARIABLES
    C
          UTST = 0.0
          UAST = 0.0
```

Appendix C (continued)

```
            UCST = 0.0
            UDST = 0.0
            UIST = 0.0
            AUPTOT = 0.0
C
C                        SOLUTION ADSORPTION-DESORPTION LOOP
C
C  45302.4 - 0.2 * 43560 FT(2)/ACRE * 1 FT/12 INCHES * 62.4 LB/FT(3)
C
            KK = MLZ*K*Z
C
            DO 6320  I=1,5
               JNFW(I) = AREA*PA*(UZSB(I)+APERCB(I)+INFL(I)+RGX(I))*45302.4
               PTOT = UAS(I) + UCS(I) + UDS(I) + SPRP(I) + USTR(I)
               AUPTOT = AUPTOT + PTOT
               C5 = 0.0
               IF (JNFW(I) .GT. 0.0)  C5 = UDS(I)/JNFW(I)
C
               IF (PTOT.GT.FFLZ) GO TO 6315
                  UAS(I) = PTOT
                  UCS(I) = 0.0
                  UDS(I) = 0.0
                  KFLAG(I) = 0
                  CTU(I) = 0
                  GO TO 6320
C
 6315          X = KK*CMAX**NI + FPUZ
               PSLD = PTOT - X - JNFW(I)*CMAX
               IF (PSLD .LT. 0.0)  GO TO 6316
                  UAS(I) = X
                  UCS(I) = PSLD
                  UDS(I) = CMAX*JNFW(I)
                  KFLAG(I) = 0
                  CTU(I) = 0
                  GO TO 6320
C
 6316             UCS(I) = 0.0
C
                  C = C5
                  IF (C  .LE. 0.0)  C = 0.001
 6317             X = KK*C**NI + FPUZ
                  C = (PTOT/(X+JNFW(I)*C)) - 1.
                  IF (ABS(C).LE.0.01) GO TO 6319
                     C = C*PTOT/(X+JNFW(I)*C)
                     GO TO 6317
C
 6319                IF (JNFW(I) .LE. 0.001)  X = PTOT
                     IF (DESORP .EQ. NO)  GO TO 6324
                         RJNFW = JNFW(I)
C
            CALL DSPTN (I,CTL,C,KFLAG,CADU,KDU,K,Z,NCOM,
         1              STL,X,MLZ,NIP,FPUZ,PTOT,RJNFW)
C
 6324                UDS(I) = (C*JNFW(I))*(PTOT/(X+C*JNFW(I)))
                     UAS(I) = X*(PTOT/(X+C*JNFW(I)))
C
 6320       CONTINUE
C
C                        PESTICIDE REMOVAL LOOP
C
```

```
          DO 6330  I=1,5
C
             IF (JNFW(I) .LE. 0.0001)  GO TO 6327
             CSP = AREA*FA*(INFL(I)+APERCB(I))*45302.4/JNFW(I)
             UPRP(I) = UCS(I)*CSP
             IF (SRGX(I)+INTF(I) .LT. 0.0001)  GO TO 6329
             CSI = AREA*FA*45302.4*RGX(I)/JNFW(I)
             UPRII = UCS(I)*CSI
             UPRIS(I) = UPRIS(I) + UPRII
             UPRI(I)  = UPRIS(I)*INTF(I)/(SRGX(I)+INTF(I))
             UPRIS(I) = UPRIS(I) - UPRI(I)
             GO TO 6328
  6327       UPRP(I) = 0.0
  6329       UPRII = 0.0
             UPRI(I) = 0.0
  6328       UDS(I) = UDS(I) - UPRP(I) - UPRII
             UPR(I) = UPRP(I) + UPRI(I)
C
             AUPR(I) = AUPR(I) + UPR(I)
             AUPRI(I) = AUPRI(I) + UPRI(I)
             AUPRP(I) = AUPRP(I) + UPRP(I)
             UIST = UIST + UPRIS(I)
C
  6330       CONTINUE
C
          IF (PRNTKE .EQ. 0)  GO TO 6380
C
C                          PREPARATION OF OUTPUT
C
             DO 6335  I=1,5
                UPRT = UPRT + AUPR(I)
                UPRIT = UPRIT + AUPRI(I)
                UPRPT = UPRPT + AUPRP(I)
C
                UAST = UAST + UAS(I)
                UCST = UCST + UCS(I)
                UDST = UDST + UDS(I)
C
                UASC(I) = (UAS(I)/MUZ)*1000000.
                UCSC(I) = (UCS(I)/MUZ)*1000000.
                IF (UZSB(I) .LE. 0.0001)  GO TO 6333
                UDSC(I) = (UDS(I)/(UZSB(I)*AREA*45302.4))*1000000.
                GO TO 6334
  6333          UDSC(I) = 0.0
  6334          UPS(I) = UASC(I) + UCSC(I) + UDSC(I)
C
                UASCT = UASCT + UASC(I)*0.2
                UCSCT = UCSCT + UCSC(I)*0.2
                UDSCT = UDSCT + UDSC(I)*0.2
                UPST = UPST + UPS(I)*0.2
C
                UTS(I) = UAS(I) + UCS(I) + UDS(I) + UPRIS(I)
                UTST = UTST + UTS(I)
C
  6335          CONTINLE
C
C                          CUMULATIVE RESULTS
C
             DO 6340  I= 1,5
                UPITOM(I) = UPITOM(I) + AUPRI(I)
```

```
 6340       UPITOT(I) = UPITOT(I) + AUPRI(I)
      UPRITM = UPRITM + UPRIT
      UPRITT = UPRITT + UPRIT
C
      IF (PRNTKE .EQ. 2)  GO TO 6365
C
      IF (HYCAL .EQ. FEED) GO TO 6341
      IF (RU.LT.HYMIN) GO TO 6365
         UPRTGW = UPRIT*454.
         UPRTCW = 1000000.*UPRIT/(RU*TIMFAC*60.*62.43)
         TPRTGW = UPRTGW + SPRTGW
         TPRTCW = UPRTCW + SPRTCW
         TPRTGM = TPRTGW/TIMFAC
         SPRTGM = SPRTGS/TIMFAC
      WRITE (6,6460) TPRTGW,TPRTGM,TPRTCW,SPRTGS,SPRTGM,SPRTCS
      GO TO 6365
C
C                     PRINTING OF OUTPUT
C
 6341 IF (OUTPUT.EQ. METR) GO TO 6342
      WRITE (6,6350)
      WRITE (6,5351)  UTS, UTST
      WRITE (6,5352)  UAS, UAST
      WRITE (6,5353)  UCS, UCST
      WRITE (6,5361)  UDS, UDST
      WRITE (6,6362)  UPRIS, UIST
      WRITE (6,5354)  UPS, UPST
      WRITE (6,5352)  UASC, UASCT
      WRITE (6,5353)  UCSC, UCSCT
      WRITE (6,5361)  UDSC, UDSCT
      WRITE (6,5355)  AUPR, UPRT
      WRITE (6,6358)  AUPRI, UPRIT
      WRITE (6,5359)  AUPRP, UPRPT
 6342 IF (OUTPUT.EQ. ENGL) GO TO 6365
C
C  METRIC CONVERSIONS FOR OUTPUT
      UTSTMT=UTST*KGPLB
      UASTMT=UAST*KGPLB
      UCSTMT=UCST*KGPLB
      UDSTMT=UDST*KGPLB
      UPRT  =UPRT*KGPLB
      UPRIT =UPRIT*KGPLB
      UPRPT =UPRPT*KGPLB
      UIST = UIST*KGPLB
      DO 6344 I=1,5
        UTSMET(I)=UTS(I)*KGPLB
        UASMET(I)=UAS(I)*KGPLB
        UCSMET(I)=UCS(I)*KGPLB
        UDSMET(I)=UDS(I)*KGPLB
        AUPR(I)  =AUPR(I)*KGPLB
        AUPRI(I) =AUPRI(I)*KGPLB
        AUPRP(I) =AUPRP(I)*KGPLB
        UPRISM(I)=UPRIS(I)*KGPLB
 6344 CONTINUE
      WRITE (6,6350)
      WRITE (6,5363) UTSMET, UTSTMT
      WRITE (6,5352) UASMET, UASTMT
      WRITE (6,5353) UCSMET, UCSTMT
      WRITE (6,5361) UDSMET, UDSTMT
      WRITE (6,6362) UPRISM, UIST
```

```
            IF (OUTPUT.EQ. BOTH) GO TO 6345
            WRITE (6,5354)  UPS, UPST
            WRITE (6,5352)  UASC, UASCT
            WRITE (6,5353)  UCSC, UCSCT
            WRITE (6,5361)  UDSC, UDSCT
       6345 WRITE (6,5374) ALPR, UPRT
            WRITE (6,5358)  ALPRI, UPRIT
            WRITE (6,5359)  ALPRP, UPRPT
      C
      C
      C                        ZEROING VARIABLES
      C
       6365 DO 6370  I=1,5
               ALPR(I) = 0.0
               AUPRI(I) = 0.0
               AUPRP(I) = 0.0
       6370    CONTINUE
      C
       6380 UPST = 0.0
            UASCT = 0.0
            UCSCT = 0.0
            UDSCT = 0.0
            UPRT = 0.0
            UPRPT = 0.0
            UPRIT = 0.0
      C
            DO  6381  I= 1,5
       6381 USTR(I) = 0.0
      C
      C
      C
      C                                  LOWER ZONE AND GROUNDWATER
      C                                  SOLUTION ADSORPTION-DESORPTION MODEL
      C
      C
      C
      C
      C                        SOLUTION ADSORPTION-DESORPTION LOOP
      C
            LCS = 0.0
            LAS = 0.0
            LDS = 0.0
            LPRP = 0.0
            ALPTCT = 0.0
      C
            KNFW = AREA*(LZS+CPST)*226512.
            KK = MLZ*K*2
      C
            DO 7305  I=1,5
               LSTR = LSTR + LPRP(I)
               ALPTCT = ALPTCT + LSTR
       7305    CONTINUE
      C
               IF (LSTR .LE. 0.0001)  GO TO 7330
      C
            I=1
            PTCT = LSTR
            C5 = 0.0
            IF (KNFW .GT. 0.0)  C5 = LAS/KNFW
            IF (PTCT.GT.PFLZ) GO TO 7315
```

```
                LAS = PTOT
                LCS = 0
                LDS = 0
                MFLAG(I) = 0
                CTL(I) = C
                GO TO 7320
      C
       7315 X = KK*CMAX**NI + FPLZ
            PSLD = PTOT - X - KNFW*CMAX
            IF (PSLD .LT. 0.0)  GO TO 7316
                LAS = X
                LCS = PSLD
                LDS   CMAX*KNFW
                MFLAG(I) = 0
                CTL(I) = C
                GO TO 7320
      C
       7316     LCS = 0.0
      C
                C = C5
                IF (C .LE. 0.0)  C   0.001
       7317     X = KK*C**NI + FPLZ
                C = (PTOT/(X+KNFW*C)) - 1.
                IF (ABS(C).LE.0.01) GO TO 7319
                   C = C*PTOT/(X+KNFW*C)
                   GO TO 7317
      C
       7319 IF (KNFW .LE. 0.001)  X = PTOT
            IF (DESORP .EQ. NO) GO TO 7324
      C
            CALL DSPTN (I,CTL,C,MFLAG,CADL,KDL,K,Z,NCOM,
           1               STL,X,MLZ,NIP,FPLZ,PTOT,KNFW)
      C
       7324   LDS = (C*KNFW)*(PTOT/(X+C*KNFW))
                   LAS   X*(PTOT/(X+C*KNFW))
      C
       7320     CONTINUE
      C
      C                       PESTICIDE REMOVAL LOOP
      C
            LPRP   LDS*CPST/(CPST+LZS)
            LDS = LDS - LPRP
      C
            LSTR = LAS + LCS + LDS
      C
            ALPRP = ALPRP + LPRP
      C
       7330 IF (PRNTKE .EQ. 2)  GO TO 7379
            IF (PRNTKE.NE.1 .OR. HYCAL.EQ.CALB)  GO TO 7380
      C
      C                       PREPARATION OF OUTPUT
      C
      C
            LASC = (LAS/MLZ)*1000000.
            LCSC = (LCS/MLZ)*1000000.
            LDSC   (LDS/(LZS*AREA*226512.))*1000000.
      C
      C                        PRINTING OF OUTPUT
      C
            IF (OUTPUT.EQ. METR) GO TO 7340
```

```
         WRITE (6,7350)
         WRITE (6,7351)  LSTR
         WRITE (6,7352)  LAS
         WRITE (6,7353)  LCS
         WRITE (6,7354)  LDS
         WRITE (6,7355)
         WRITE (6,7352)  LASC
         WRITE (6,7353)  LCSC
         WRITE (6,7354)  LDSC
         WRITE (6,7357)  ALPRP
         WRITE (6,7359)  ALPRP
    7340 IF (OUTPUT.EQ. ENGL) GO TO 7379
C
C  METRIC CONVERSIONS FOR OUTPUT
         LSTRMT=LSTR*KGPLB
         LASMET=LAS*KGPLB
         LCSMET=LCS*KGPLB
         LDSMET=LDS*KGPLB
         ALPRP =ALPRP*KGPLB
         WRITE (6,7350)
         WRITE (6,7360) LSTRMT
         WRITE (6,7352) LASMET
         WRITE (6,7353) LCSMET
         WRITE (6,7354) LDSMET
         IF (OUTPUT.EQ. BOTH) GO TO 7345
         WRITE (6,7355)
         WRITE (6,7352)  LASC
         WRITE (6,7353)  LCSC
         WRITE (6,7354)  LDSC
    7345 WRITE (6,7361) ALPRP
         WRITE (6,7359) ALPRP
C
C
C                       ZEROING OF VARIABLES
C
    7379 ALPRP = 0.0
C
    7380 CONTINUE
C
C  SULG IS THE SUMMATION OF PESTICIDE IN STORAGE IN THE SURFACE,
C   UPPER, AND LOWER ZONES (IT DOES NOT INCLUDE PESTICIDE IN
C   GROUNDWATER STORAGE) AND IS USED AS A CHECK IN MAIN TO DECIDE
C   WHETHER OR NOT TO CONTINUE PESTICIDE CALCULATIONS
C
         SULG   ASPTOT + ALPTCT + ALPTOT
C
C
C                                  GROUNDWATER ADSORPTION-DESORPTION MODEL
C
C
         GSTR = GSTR + LPRP
         IF (FPLZ .GT. 0.0)  GO TO 7520
            GAS = 0.0
            GCS = GSTR
            GDS = 0.0
C
    7520    GAS = GSTR
            GCS = 0.0
            GDS = 0.0
C
```

```
            IF ((PRNTKE .NE. 1).OR.(HYCAL.EQ.CALB))  GO TO 7580
      C
      C                        PRINTING OF OUTPUT
      C
            IF (OUTPUT.EQ. METR) GO TO 7530
            WRITE (6,7550)
            WRITE (6,7351)  GSTR
            WRITE (6,7352)  GAS
            WRITE (6,7353)  GCS
            WRITE (6,7354)  GDS
       7530 IF (OUTPUT.EQ. ENGL) GO TO 7580
      C
      C  METRIC CONVERSIONS FOR OUTPUT
            GSTRMT=GSTR*KGPLB
            GASMET=GAS*KGPLB
            GCSMET=GCS*KGPLB
            GDSMET=GDS*KGPLB
            WRITE (6,7550)
            WRITE (6,7360) GSTRMT
            WRITE (6,7352) GASMET
            WRITE (6,7353) GCSMET
            WRITE (6,7354) GDSMET
      C
       7580 CONTINUE
      C
      C                        FORMAT STATEMENTS
      C
       5350 FORMAT  ('0', 5X,'SURFACE LAYER PESTICIDE')
       5351 FORMAT  ('0',8X,'PESTICIDE, LBS',8X,5(3X,F7.3),3X,F8.3)
       5352 FORMAT  (' ',11X,'ADSORBED',11X,5(3X,F7.3),3X,F8.3)
       5353 FORMAT  (' ',11X,'CRYSTALLINE',8X,5(3X,F7.3),3X,F8.3)
       5354 FORMAT  ('0',8X,'PESTICIDE, PPM',8X,5(3X,F7.3),3X,F8.3)
       5355 FORMAT  ('0',8X,'REMOVAL, LBS',10X,5(3X,F7.3),3X,F8.3)
       5356 FORMAT  (' ',11X,'SEDIMENT',11X,5(3X,F7.3),3X,F8.3)
       5357 FORMAT  (' ',11X,'OVERLAND FLOW',6X,5(3X,F7.3),3X,F8.3)
       5359 FORMAT  (' ',11X,'PERCOLATION',8X,5(3X,F7.3),3X,F8.3)
       5361 FORMAT (' ',11X,'DISSOLVED',10X,5(3X,F7.3),3X,F8.3)
       5363 FORMAT ('0',8X,'PESTICIDE, KGS',8X,5(3X,F7.3),3X,F8.3)
       5374 FORMAT ('0',8X,'REMOVAL, KGS',10X,5(3X,F7.3),3X,F8.3)
      C
       6350 FORMAT  ('0', 5X,'UPPER ZONE LAYER PESTICIDE')
       6358 FORMAT  (' ',11X,'INTERFLOW',10X,5(3X,F7.3),3X,F8.3)
       6362 FORMAT  (' ',11X,'INTERFLOW STORAGE',2X,5(2X,F8.3),3X,F8.3)
       6460 FORMAT  ('+',72X,2(3X,F8.3,2X,F8.3,2X,F7.3))
      C
       7350 FORMAT  ('0', 5X,'LOWER ZONE LAYER PESTICIDE')
       7351 FORMAT  ('0',8X,'PESTICIDE, LBS',61X,F8.3)
       7352 FORMAT  (' ',11X,'ADSORBED',64X,F8.3)
       7353 FORMAT  (' ',11X,'CRYSTALLINE',61X,F8.3)
       7354 FORMAT  (' ',11X,'DISSOLVED',63X,F8.3)
       7355 FORMAT  ('0',8X,'PESTICIDE, PPM',61X,F8.3)
       7357 FORMAT  ('0',8X,'REMOVAL, LBS',63X,F8.3)
       7359 FORMAT  (' ',11X,'PERCOLATION',61X,F8.3)
       7360 FORMAT  ('0',8X,'PESTICIDE, KGS',61X,F8.3)
       7361 FORMAT  ('0',8X,'REMOVAL, KGS',63X,F8.3)
      C
       7550 FORMAT  ('0',5X,'GROUNDWATER LAYER PESTICIDE')
            RETURN
            END
      C
```

```
C
C
C
      SUBROUTINE DSRTN (I,CT,C,JFLAG,CAD,KD,K,Z,NCOM,
     1                  ST,X,M,NIP,FP,PTOT,INFW)
C
C
C
      DIMENSION CT(5),JFLAG(5),CAD(5),KD(5),ST(5)
C
      INTEGER I,JFLAG
      REAL CT,C,CAD,KD,K,Z,NCOM,ST,X,M,NIP,FP,PTOT,INFW
C
C  THE DESORPTION ALGORITHM IS BASED ON THE FREUNDLICH EQUATION; THE
C  DIFFERENCE BEING THAT THE CONSTANT (K) AND EXPONENT (N) OF THE
C  DESORPTION EQUATION DIFFER FROM THE ADSORPTION VALUES.  DESORPTION
C  OCCURS WHEN THE CONCENTRATION OF PESTICIDE IN WATER (C) IS LESS THAN
C  THE CONCENTRATION (CT) AT THE LAST TIME STEP.  THE DESORPTION
C  EXPONENT (NP -- INPUTTED BY THE USER) AND THE DESORPTION CONSTANT
C  (KD -- CALCULATED BY SETTING THE DESORPTION EQUATION EQUAL TO THE
C  ADSORPTION EQUATION AND SOLVING FOR KD) THEN DEFINE THE NEW DESORP-
C  TION CURVE.  THE ASSUMPTION OF REVERSIBLE DESORPTION IS MADE.  ONCE
C  DESORPTION STOPS ADSORPTION BEGINS BY MOVING BACK UP THE DESORPTION
C  CURVE UNTIL IT INTERSECTS THE ADSORPTION CURVE (I.E., WHEN C EQUALS
C  CAD -- THE CONCENTRATION OF PESTICIDE IN WATER AT WHICH THE ADSORP-
C  TION AND DESORPTION CURVES INTERSECT).  THEN ADSORPTION CONTINUES UP
C  THE ADSORPTION CURVE UNTIL DESORPTION OCCURS AGAIN.  DEFINTIONS OF
C  THE DESORPTION VARIABLES FOLLOW BELOW.
C
C          CT  :  CONCENTRATION OF PESTICIDE IN WATER (LB/LB)
C                   AT THE LAST TIME INTERVAL
C          CAD  :  CONCENTRATION C AT WHICH THE ADSORPTION AND
C                    DESORPTION EQUATIONS MEET, CAD IS SET
C                    EQUAL TO CT WHEN DESORPTION BEGINS AS A
C                    MARKER TO LATER DETERMINE WHEN THE ADSORP-
C                    TION PROCESS LEAVES THE REVERSIBLE DESORP-
C                    TION CURVE AND RETURNS TO THE NON-REVERSIBLE
C                    ADSORPTION CURVE
C          ST  :  CONCENTRATION OF ADSORBED PESTICIDE IN THE SOIL
C                   (LB/LB) AT THE LAST TIME INTERVAL
C          JFLAG  :  FLAG WHICH NOTES WHETHER C WAS CALCULATED ON THE
C                     ADSORPTION CURVE DURING LAST TIME STEP (JFLAG=0)
C                     OR ON THE DESORPTION CURVE (JFLAG=1)
C          NP  :  DESORPTION EXPONENT, APPROXIMATELY 2.3 TIMES N
C                   (INPUTTED BY USER)
C          NIP  :  INVERSE OF NP
C          KD  :  DESORPTION CONSTANT FOR FREUNDLICH CURVE
C          NCOM  :  RATIO OF NIP TO NI
C
C
      IF (CT(I).LE.C) GO TO 5396
      IF (JFLAG(I).EQ.1) GO TO 5393
C
      CAD(I) = CT(I)
      KD(I) = ((K*Z)**NCOM)*(ST(I)**(1.-NCOM))
 5393 X = M*KD(I)*(C**NIP) + FP
      Q = (PTOT/(X+INFW*C)) - 1.0
      IF (ABS(Q).LE.0.01) GO TO 5395
      C = C*PTOT/(X+INFW*C)
      GO TO 5393
```

```
      C
       5395 JFLAG(I) = 1
            CT(I) = C
            GO TO 5398
      C
       5396 IF (JFLAG(I).EQ.0) GO TO 5397
            IF (C.LT.CAD(I)) GO TO 5393
      C
       5397 JFLAG(I) = 0
            CT(I) = C
            ST(I) = X/M
            CAD(I) = 0
      C
       5398 RETURN
            END
      C
      C
      C
      C
                          SUBROUTINE DEGRAD
      C
      C
      C                                DEGRADATION MODEL
      C
      C
      C
      C
            DIMENSION RESB(5),RESB1(5),ROSB(5),SRGX(5),INTF(5),RGX(5),INFL(5),
           1 UZSB(5),APERCB(5),RIB(5),ERSN(5)
            DIMENSION PRSTCM(5),PRSTOT(5),PROTCM(5),PROTOT(5),UPITOM(5),
           1 UPITOT(5),STS(5),UTS(5),SAS(5),SCS(5),SDS(5),SSTR(5),
           2 UAS(5),UCS(5),UDS(5),USTR(5),UPRIS(5),UPRISM(5),
           3 STSMET(5),SASMET(5),
           4 SCSMET(5),SDSMET(5),UTSMET(5),UASMET(5),UCSMET(5),UDSMET(5)
      C
            COMMON /ALL/ RU,MNMIN,PRNTKE,HYCAL,DPST,OUTPUT,TIMFAC,LZS,AREA,
           1 RESB1,ROSB,SRGX,INTF,RGX,INFL,UZSB,APERCB,RIB,ERSN,M,P3,A,
           2 CALB,PROC,PEST,NUTR,ENGL,METR,BOTH,RESB,YES,NO,IMIN,IHR,TF,
           3 JCOUNT,PRINT,INTF,DAYS,HOUR,MNTH
      C
            COMMON /PESTC/ STST,SPROTM,SPRSTM,SAST,SCST,SDST,UTST,UAST,UCST,K,
           1 UDST,FF,CMAX,NI,SPRCTT,SPRSTT,MUZ,FPUZ,UPRITM,
           2 UPRITT,KGPLB,FFLZ,MLZ,LSTR,LAS,LCS,LDS,GSTR,GAS,GCS,GDS,
           3 APMODE,TPBAL,
           4 DEGSCM,DEGSCT,DEGUCM,
           5 DEGUCT,DEGL,DEGS,NIP,DEGCON,DEGLCM,DEGLOT,NCCM,
           6 PRSTCM,PRSTOT,PROTCM,PROTOT,UPITOM,UPITOT,STS,UTS,SAS,
           7 SCS,SDS,SSTR,UAS,UCS,UDS,USTR,UPRIS,UIST,TOTPAP,TIMAP,YEARAP,
           8 DESORP,SURF,SOIL,SULG
      C
      C
             REAL LSTR,LAS,LCS,LDS
             REAL  MNMIN, METCPT, KGPLB
             INTEGER APMODE,PRNTKE,HYCAL,OUTPUT,CALB,PROC,ENGL,METR,BOTH
             INTEGER SURF,SOIL,TIMFAC
      C
      C
      C                                 DEGRADATION OF PESTICIDE FROM ADSORBED (A),
      C                                 CRYSTALLINE (C), AND DISSOLVED (D) FORMS
      C                                 DEGCON = FIRST ORDER DECAY RATE (PER DAY)
```

```
      C
      C                           UPPER ZONE
      C
            DEGU = 0.0
            IF (UTST .LE. 0.0)  GO TO 8021
            UTST = 0.0
            DO 8020  I=1,5
               DEGUA = DEGCON*UAS(I)
               UAS(I) = UAS(I) - DEGUA
               UAST = UAST - DEGUA
               DEGUC = DEGCON*UCS(I)
               UCS(I) = UCS(I) - DEGUC
               UCST = UCST - DEGUC
               DEGUD = DEGCON*UDS(I)
               UDS(I) = UDS(I) - DEGUD
               UDST = UDST - DEGUD
               DEGU = DEGU + DEGUA + DEGUC + DEGUD
               UTS(I) = UAS(I) + UCS(I) + UDS(I) + UPRIS(I)
               UTST = UTST + UTS(I)
       8020 CONTINUE
      C
      C                           SURFACE ZONE
      C
       8021 DEGS = 0.0
            IF (STST .LE. 0.0)  GO TO 8023
            STST = 0.0
            DO 8022  I=1,5
               DEGSA = DEGCON*SAS(I)
               SAS(I) = SAS(I) - DEGSA
               SAST = SAST - DEGSA
               DEGSC - DEGCON*SCS(I)
               SCS(I) = SCS(I) - DEGSC
               SCST = SCST - DEGSC
               DEGSD = DEGCON*SDS(I)
               SDS(I) = SDS(I) - DEGSD
               SDST = SDST - DEGSD
               DEGS = DEGS + DEGSA + DEGSC + DEGSD
               STS(I) = SAS(I) + SCS(I) + SDS(I)
               STST = STST + STS(I)
       8022 CONTINUE
      C
      C                           LOWER ZONE
      C
       8023 DEGL = 0.0
            IF (LSTR .LE. 0.0)  GO TO 8090
            DEGLA = DEGCON*LAS
            LAS = LAS - DEGLA
            DEGLC = DEGCON*LCS
            LCS = LCS - DEGLC
            DEGLD = DEGCON*LDS
            LDS = LDS - DEGLD
            DEGL = DEGLA + DEGLC + DEGLD
            LSTR = LAS + LCS + LDS
      C
       8090       CONTINUE
      C
      C
      C
      C             CUMULATIVE RESULTS
      C
```

```
            DEGSCM = DEGSCM + DEGS
            DEGSOT   DEGSOT + DEGS
            DEGUCM - DEGUCM + DEGU
            DEGUOT   DEGUOT + DEGU
            DEGLCM = DEGLCM + DEGL
            DEGLOT = DEGLOT + DEGL
      C
            TDEG = DEGS + DEGU + DEGL
      C
              IF ((FRNTKE .NE. 1).OR.(HYCAL.EQ.CALB))  GO TO 8600
      C
            IF (OUTPUT.EQ. METR) GO TO 8200
               WRITE (6,8505)
               WRITE (6,8501) TDEG
               WRITE (6,8502) DEGS
               WRITE (6,8503) DEGU
               WRITE (6,8507) DEGL
       8200 IF (OUTPUT.EQ. ENGL) GO TO 8600
      C
      C  METRIC CONVERSIONS FOR OUTPUT
            TDEGMT=TDEG*KGPLB
            DEGSMT=DEGS*KGPLB
            DEGUMT=DEGU*KGPLB
            DEGLMT=DEGL*KGPLB
            WRITE (6,8506)
            WRITE (6,8501) TDEGMT
            WRITE (6,8502) DEGSMT
            WRITE (6,8503) DEGUMT
            WRITE (6,8507) DEGLMT
      C
      C
       8501 FORMAT (' ',8X,'TOTAL',71X,F7.3)
       8502 FORMAT (' ',8X,'FROM SURFACE',64X,F7.3)
       8503 FORMAT (' ',8X,'FROM UPPER ZONE',61X,F7.3)
       8505 FORMAT ('0',5X,'PESTICIDE DEGRADATION LOSS, LBS.')
       8506 FORMAT ('0',5X,'PESTICIDE DEGRADATION LOSS, KGS.')
       8507 FORMAT (' ',8X,'FROM LOWER ZONE',61X,F7.3)
      C
       8600 RETURN
            END
      C
      C
      C
      C
            SUBROUTINE NUTRIC (ICERR,INTRVL,NAPP,SNAPL,UNAPL,TIMHR,
           1                   INPUT,OUTPUT,APDAY,KNI,KPI)
      C
      C                THIS SUBROUTINE READS NUTRIENT INPUT SEQ.
      C                FOR REACTION RATES, INITIAL STORAGES, AND
      C                APPLICATIONS.  INPUT INFORMATION IS SCANNED
      C                FOR ERRORS WHICH ARE FLAGGED BY ICERR=1.
      C                ON RETURN TO MAIN IOERR=1 WILL STOP THE RUN
      C
      C                SUBROUTINE ALSO OUTPUTS REACTION RATES,
      C                INITIAL STORAGES, AND APPLICATIONS
      C
      C                DECLARATIONS
      C
      C                COMMON VARIABLES
      C
```

```
            INTEGER*4  ISTEP,NSTEP,SFLG,UFLG,LFLG,GFLG
      C
            REAL*4  DELT,STEPP(4,24),
           1        SN(20,5),SNT(20), SNRSM(20,5),SNROM(20,5),
           2        UN(20,5),UNT(20),UNI(20,5),UNIT(20),UNRIM(20,5),
           3        NRSM(20,5),        LN(20),LNRPM(20),          GN(20),
           4        SNREM(20,5),UNRBM(20,5),LNRBM(20),GNRBM(20),TNRBM(20),
           5        SNRSY(20,5),SNROY(20,5),UNRIY(20,5),NRSY(20,5),
           6        LNRPY(20),SNRBY(20,5),UNRBY(20,5),LNRBY(20),GNRBY(20),
           7        TNRBY(20),TNRHV(20),TNRHVM(20),TNRHVY(20),TNA,TPA,TCLA,
           8        KN(10,4),THKN(10),KP(5,4),THKP(5),NBAL,PHBAL,CLBAL
      C
            COMMON /NUT/  DELT,STEMP,SN,SNT,SNRSM,SNROM,UN,UNT,UNI,UNIT,
           1             UNRIM,NRSM,LN,LNRPM,GN,SNRBM,UNRBM,LNRBM,GNRBM,TNRBM,
           2             SNRSY,SNROY,UNRIY,NRSY,LNRPY,SNRBY,UNRBY,LNRBY,GNRBY,
           3             TNRBY,TNRHV,TNRHVM,TNRHVY,TNA,TPA,TCLA,
           4             KN,THKN,KP,THKP,NBAL,PHBAL,CLBAL,
           5             ISTEP,NSTEP,SFLG,UFLG,LFLG,GFLG
      C
      C
            INTEGER*4  NAPPL,NAPP,TIMHAR,TIMHR
            NAMELIST /NUTRIN/ TSTEP,NAPPL,TIMHAR
      C
            INTEGER*4  NSTRT,NEND,APDAY(5),IOERR,ICHK,IZONE,IBLK,J,
           1             IAPPL,INPUT,OUTPUT
      C
            REAL*4  SNAPL(20,5,5),SNAPLT(20),UNAPL(20,5,5),UNAPLT(20),
           1        TNMET,TPMET,TCLMET,KNI(10,4),KPI(5,4)
      C
            REAL*8  CONC, LBPAC/'LB/AC'/, KGPHA/'KG/HA'/, NTRT/'NUTRIENT'/,
           1        CHARE, BLANK8/'        '/
      C
      C                         CHARACTER STRINGS USED TO COMPARE AND
      C                         INTERPRET INPUT SEQUENCE, NAMES OF
      C                         REACTION RATES, AND INPUT UNITS OPTION.
      C
            INTEGER*4  CHAR,TYPE,BLANK/'    '/, REAC/'REAC'/, NITR/'NITR'/,
           1        PHOS/'PHOS'/, CHLO/'CHLO'/, END/'END '/, SURF/'SURF'/,
           2        UPPE/'UPPE'/, LOWE/'LOWE'/, GROU/'GROU'/, TEMP/'TEMP'/,
           3        INIT/'INIT'/, APPL/'APPL'/, METR/'METR'/, ENGL/'ENGL'/,
           4        KNNAME(10)/'  K1', '  K2', ' KK2', '  KD', ' KPL',
           5                   ' KAM', ' KIM', 'KKIM', ' KSA', ' KAS'/,
           6        KPNAME(5)/'  KM', ' KIM', ' KPL', ' KSA', ' KAS'/
      C
      C                         INITIALIZATION OF STORAGES AND FLAGS
      C
            IOERR = 0
            SFLG = 1
            UFLG = 1
            LFLG = 1
            GFLG = 1
            DO 130  J=1,20
               DO 120  IBLK=1,5
                  SN(J,IBLK) = 0.0
                  UN(J,IBLK) = 0.0
                  UNI(J,IBLK) = 0.0
        120    CONTINUE
               LN(J) = 0.0
               GN(J) = 0.0
        130 CONTINUE
```

```
            DO 135  IZONE=1,4
               DO 132  J=1,10
                  KNI(J,IZONE) = 0.0
      132      CONTINUE
               DO 134  J=1,5
                  KPI(J,IZONE) = 0.0
      134      CONTINUE
      135   CONTINUE
      C
      C
      136   READ (5,3001)  CHAR8
            IF (CHAR8 .EQ. BLANK8)  GO TO 136
            IF (CHAR8 .EQ. NTFT)  GO TO 142
               IOERR = 1
               WRITE (6,4599)  CHAR8
               RETURN
      142   READ (5,NLTFIN)
            WRITE (6,4600)
            WRITE (6,4005)
            WRITE (6,4007)
            WRITE (6,4005)
            WRITE (6,4610)  TSTEP,NAPPL,TIMHAR
            NAPP=NAPPL
            TIMHR = TIMHAR
      C
      C                           CHECK TSTEP TO SEE IF AN INTEGER NUMBER ARE
      C                           IN A DAY (1440 MIN) AND CHECK THAT TSTEP IS
      C                           AN INTEGER MULTIPLE OF THE SIMULATION
      C                           INTERVAL (5 OR 15 MIN).
      C                           DELT IS THE TIME STEP IN HOURS BECAUSE
      C                           REACTION RATES ARE PER HOUR (INTERNALLY).
      C
            ICHK = 0
            IF ( MOD(1440,TSTEP) .NE. 0)  ICHK=1
            IF ( MOD(TSTEP,INTRVL) .NE. 0)  ICHK=1
            IF (ICHK .EQ. 0)  GO TO 145
               WRITE (6,4770) TSTEP
               TSTEP = 60
      145   DELT = TSTEP/60.
            NSTEP = 1440/TSTEP
      C
      C
      C                           INPUT REACTION RATES
      C
      C
      150   READ (5,3000)  CHAR
            IF (CHAR .EQ. BLANK)  GO TO 150
            IF (CHAR .EQ. REAC)  GO TO 160
               IOERR = 1
               WRITE (6,4619)
               WRITE (6,4630)  REAC, CHAR
               RETURN
      160   READ (5,3000)  TYPE
            IF (TYPE .EQ. BLANK)  GO TO 160
            IF (TYPE .EQ. NITR)  GO TO 170
            IF (TYPE .EQ. PHOS)  GO TO 220
            IF (TYPE .EQ. END)  GO TO 300
               IOERR = 1
               WRITE (6,4619)
               WRITE (6,4640)  TYPE
```

```
            RETURN
      C
      C                              NITROGEN RATES
      C
      170   READ (5,3000)  CHAR
            IF (CHAR .EQ. SURF)  GO TO 180
               ICERR = 1
               WRITE (6,4620)  TYPE
               WRITE (6,4630)  SURF, CHAR
               RETURN
      180   READ (5,3010)  (KNI(J,1),J=1,10)
      C
            READ (5,3000)  CHAR
            IF (CHAR .EQ. UPPE)  GO TO 190
               IOERR   1
               WRITE (6,4620)  TYPE
               WRITE (6,4630)  UPPE, CHAR
               RETURN
      190   READ (5,3010)  (KNI(J,2),J=1,10)
      C
            READ (5,3000)  CHAR
            IF (CHAR .EQ. LOWE)  GO TO 200
               ICERR = 1
               WRITE (6,4620)  TYPE
               WRITE (6,4630)  LOWE, CHAR
               RETURN
      200   READ (5,3010)  (KNI(J,3),J=1,10)
      C
            READ (5,3000)  CHAR
            IF (CHAR .EQ. GROU)  GO TO 205
               IOERR = 1
               WRITE (6,4620)  TYPE
               WRITE (6,4630)  GROU, CHAR
               RETURN
      205   READ (5,3010)  (KNI(J,4),J=1,10)
      C
            READ (5,3000)  CHAR
            IF (CHAR .EQ. TEMP)  GO TO 210
               ICERR = 1
               WRITE (6,4620)  TYPE
               WRITE (6,4630)  TEMP, CHAR
               RETURN
      210   READ (5,3010)  (THKN(J),J=1,10)
            GO TO 160
      C
      C                              PHOSPHORUS RATES
      C
      220   READ (5,3000)  CHAR
            IF (CHAR .EQ. SURF)  GO TO 230
               IOERR = 1
               WRITE (6,4620)  TYPE
               WRITE (6,4630)  SURF, CHAR
               RETURN
      230   READ (5,3010)  (KPI(J,1),J=1,5)
      C
            READ (5,3000)  CHAR
            IF (CHAR .EQ. UPPE)  GO TO 240
               IOERR = 1
               WRITE (6,4620)  TYPE
               WRITE (6,4630)  UPPE, CHAR
```

```
                 RETURN
      240     READ (5,3010)   (KPI(J,2),J=1,5)
      C
              READ (5,3000)  CHAR
              IF (CHAR .EQ. LCWE)  GO TO 250
                 IOERR = 1
                 WRITE (6,4620)  TYPE
                 WRITE (6,4630)  LCWE, CHAR
                 RETURN
      250     READ (5,3010)   (KPI(J,3),J=1,5)
      C
              READ (5,3000)  CHAR
              IF (CHAR .EQ. GRCU)  GO TO 260
                 IOERR = 1
                 WRITE (6,4620)  TYPE
                 WRITE (6,4630)  GRCU, CHAR
                 RETURN
      260     READ (5,3010)   (KPI(J,4),J=1,5)
      C
              READ (5,3000)  CHAR
              IF (CHAR .EQ. TEMP)  GO TO 270
                 IOERR = 1
                 WRITE (6,4620)  TYPE
                 WRITE (6,4630)  TEMP, CHAR
                 RETURN
      270     READ (5,3010)   (THKP(J),J=1,5)
              GO TO 160
      C
      C                              OUTPUT OF REACTION RATES AND TEMPERATURE
      C                              CORRECTION FACTORS.
      C
      300     WRITE (6,4650)   (KNNAME(J),J=1,10),
             1                 ((KNI(J,IZONE),J=1,10),IZONE=1,4),(THKN(J),J=1,10)
              WRITE (6,4660)   (KPNAME(J),J=1,5),
             1                 ((KPI(J,IZONE),J=1,5),IZONE=1,4),(THKP(J),J=1,5)
      C
      C                              CONVERT RATES FROM PER DAY TO PER HOUR, AND
      C                              CHECK REACTION RATES BY ZONE FOR
      C                              1) REASONABLENESS, I.E. >= 0.0
      C                              2) VALIDITY OF NUMERICAL SOLUTION TECHNIQUE
      C                                 THE EXPRESSION KNI(J,IZONE)*DELT IS THE
      C                                 FRACTION OF THE CONSTITUTENT REMOVED
      C                                 DURING THE TIMESTEP.  THIS NUMBER SHOULD
      C                                 BE MUCH LESS THAN 1. FOR ACCURATE SOLUTION
      C                                 CHECK SET AT 0.5.
      C                              3) ON OR OFF, IF KNI AND KPI ARE ALL ZERO FOR
      C                                 A ZONE, THEN NO TRANSFORMATIONS ARE DONE.
      C                                 S,U,L, AND UFLG ARE FLAGS TO INDICATE
      C                                 IF TRANSFORMATIONS ARE DONE (1) OR NOT(0).
      C
              DO 311  IZONE=1,4
                 SUM = 0.0
                 DO 303  J=1,10
                    KNI(J,IZONE) = KNI(J,IZONE)/24.
                    IF (KNI(J,IZONE) .GE. 0.0)  GO TO 301
                       IOERR = 1
                       WRITE (6,4780)  KNNAME(J), IZONE, KNI(J,IZONE)
                       RETURN
      301           IF (DELT*KNI(J,IZONE) .LT. 0.5)  GO TO 302
                       WRITE (6,4790)  KNNAME(J), IZONE
```

```
302          SUM = SUM + KNI(J,IZONE)
303       CONTINUE
          DO 306  J=1,5
             KPI(J,IZONE) = KPI(J,IZONE)/24.
             IF (KPI(J,IZONE) .GE. 0.0)  GO TO 304
                IOERR = 1
                WRITE (6,4800)  KPNAME(J), IZONE, KPI(J,IZONE)
                RETURN
304          IF (DELT*KPI(J,IZONE) .LT. 0.5)  GO TO 305
                WRITE (6,4810)  KPNAME(J), IZONE
305          SUM = SUM + KPI(J,IZONE)
306       CONTINUE
          IF (SUM .LT. 0.00001)  GO TO (307,308,309,310), IZONE
             GO TO 311
307       SFLG = 0
             GO TO 311
308       UFLG = 0
             GO TO 311
309       LFLG = 0
             GO TO 311
310       GFLG = 0
311    CONTINUE
       DO 313  J=1,10
          IF (THKN(J) .GE. 1.0)  GO TO 313
             WRITE (6,4812)  KNNAME(J)
313    CONTINUE
       DO 314  J=1,5
          IF (THKP(J) .GE. 1.0)  GO TO 314
             WRITE (6,4814)  KPNAME(J)
314    CONTINUE
C
C
C                               INPUT OF INITIAL NUTRIENT STORAGES
C
C
319    READ (5,3000)  CHAR
       IF (CHAR .EQ. BLANK)  GO TO 319
       IF (CHAR .EQ. INIT)  GO TO 320
          IOERR = 1
          WRITE (6,4665)  CHAR
          RETURN
320    READ (5,3000)  TYPE
       IF (TYPE .EQ. BLANK)  GO TO 320
       IF (TYPE .EQ. NITR)  GO TO 330
       IF (TYPE .EQ. PHOS)  GO TO 340
       IF (TYPE .EQ. CHLO)  GO TO 350
       IF (TYPE .EQ. END)  GO TO 560
          IOERR = 1
          WRITE (6,4725)
          WRITE (6,4740)  TYPE
          RETURN
330    NSTRT = 1
       NEND = 7
          GO TO 360
340    NSTRT = 11
       NEND = 14
          GO TO 360
350    NSTRT = 20
       NEND = 20
C
```

```
      C                                SURFACE
      C
  360 READ (5,3020)  CHAR, NBLK
      IF (CHAR .EQ. SURF)  GO TO 365
         IOERR = 1
         WRITE (6,4670)  TYPE
         WRITE (6,4630)  SURF, CHAR
         RETURN
  365 IF (NBLK.EQ.0 .OR. NBLK.EQ.1 .OR. NBLK.EQ.5)  GO TO 370
         IOERR = 1
         WRITE (6,4670)  TYPE
         WRITE (6,4650)  SURF, NBLK
         RETURN
  370 IF (NBLK .EQ. 5)  GO TO 400
      READ (5,3010)  (SNT(J),J=NSTRT,NEND)
      DO 390  J=NSTRT,NEND
         DO 380  IBLK=1,5
            SN(J,IBLK) = SNT(J)
  380    CONTINUE
  390 CONTINUE
      GO TO 440
      C
  400 DO 410  IBLK=1,5
         READ (5,3010)  (SN(J,IBLK),J=NSTRT,NEND)
  410 CONTINUE
      DO 430  J=NSTRT,NEND
         SUM = 0.0
         DO 420  IBLK=1,5
            SUM = SUM + SN(J,IBLK)
  420    CONTINUE
         SNT(J) = SUM/5.
  430 CONTINUE
      C
      C                                UPPER ZONE
      C
  440 READ (5,3020)  CHAR, NBLK
      IF (CHAR .EQ. UPPE)  GO TO 450
         IOERR = 1
         WRITE (6,4670) TYPE
         WRITE (6,4630)  UPPE, CHAR
         RETURN
  450 IF (NBLK.EQ.0 .OR. NBLK.EQ.1 .OR. NBLK.EQ.5)  GO TO 460
         IOERR = 1
         WRITE (6,4670)  TYPE
         WRITE (6,4650)  UPPE, NBLK
         RETURN
  460 IF (NBLK .EQ. 5)  GO TO 490
      READ (5,3010)  (UNT(J),J=NSTRT,NEND)
      DO 480  J=NSTRT,NEND
         DO 470  IBLK=1,5
            UN(J,IBLK) = UNT(J)
  470    CONTINUE
  480 CONTINUE
      GO TO 530
      C
  490 DO 500  IBLK=1,5
         READ (5,3010)  (UN(J,IBLK),J=NSTRT,NEND)
  500 CONTINUE
      DO 520  J=NSTRT,NEND
         SUM = 0.0
```

```
            DO 510  IBLK=1,5
               SUM = SUM + UN(J,IBLK)
      510   CONTINUE
            UNT(J) = SUM/5.
  520    CONTINUE
C
C                                LOWER ZONE
C
  530    READ (5,3000)  CHAR
         IF (CHAR .EQ. LOWE)  GO TO 540
            IDERR = 1
            WRITE (6,4670)  TYPE
            WRITE (6,4630)  LOWE, CHAR
            RETURN
  540    READ (5,3010)  (LN(J),J=NSTRT,NEND)
C
C                                GROUNDWATER
C
         READ (5,3000)  CHAR
         IF (CHAR .EQ. GROU)  GO TO 550
            IDERR = 1
            WRITE (6,4670)  TYPE
            WRITE (6,4630)  GROU, CHAR
            RETURN
  550    READ (5,3010)  (GN(J),J=NSTRT,NEND)
C
         GO TO 320
C
C                                OUTPUT OF INITIAL NUTRIENT STORAGES
C
  560    WRITE (6,4005)
         WRITE (6,4005)
C
         CONC = LBPAC
         IF (INPUT .EQ. METR)  CONC=KGPHA
         WRITE (6,4000)  CONC
         WRITE (6,4700)
         WRITE (6,4010)
         WRITE (6,4025)  (SNT(J),J=1,7),(SNT(J),J=11,14),SNT(20)
         WRITE (6,4030)  (IBLK,(SN(J,IBLK),J=1,7),(SN(J,IBLK),J=11,14),
        1                SN(20,IBLK),  IBLK=1,5)
         WRITE (6,4090)
         WRITE (6,4025)  (UNT(J),J=1,7),(UNT(J),J=11,14),UNT(20)
         WRITE (6,4030)  (IBLK,(UN(J,IBLK),J=1,7),(UN(J,IBLK),J=11,14),
        1                UN(20,IBLK),  IBLK=1,5)
         WRITE (6,4110)
         WRITE (6,4020)  (LN(J),J=1,7),(LN(J),J=11,14),LN(20)
         WRITE (6,4120)
         WRITE (6,4020)  (GN(J),J=1,7),(GN(J),J=11,14),GN(20)
C
C                                CONVERSION OF METRIC INPUT TO ENGLISH (LB/AC)
C
         IF (INPUT .EQ. ENGL)  GO TO 573
         DO 570  J=1,20
            DO 565  IBLK=1,5
               SN(J,IBLK) = SN(J,IBLK)*.8924
               UN(J,IBLK) = UN(J,IBLK)*.8924
  565       CONTINUE
            LN(J) = LN(J)*.8924
            GN(J) = GN(J)*.8924
```

```
      570 CONTINUE
      C
      C                               COMPUTE TOTAL NITROGEN (TNA), TOTAL PHOSPHORUS
      C                               (TPA), AND TOTAL CHLORIDE (TCLA) IN THE SYSTEM
      C                                UNITS = LB/AC.
      C
      573 TNA = 0.0
          DO 575  J=1,7
             SUM = 0.0
             DO 574  IBLK=1,5
                SUM = SUM + SN(J,IBLK) + UN(J,IBLK)
      574    CONTINUE
             TNA = TNA + LN(J) + GN(J) + SUM/5.
      575 CONTINUE
      C
          TPA = 0.0
          DO 585  J=11,14
             SUM = 0.0
             DO 580  IBLK = 1,5
                SUM = SUM + SN(J,IBLK) + UN(J,IBLK)
      580    CONTINUE
             TPA = TPA + LN(J) + GN(J) + SUM/5.
      585 CONTINUE
      C
          TCLA = 0.0
          DO 590  IBLK=1,5
             TCLA = TCLA + SN(20,IBLK) + UN(20,IBLK)
      590 CONTINUE
          TCLA = LN(20) + GN(20) + TCLA/5.
      C
          IF (INFLT .EQ. METR)  GO TO 595
             CONC = LBPAC
             WRITE (6,4820)  TNA,CONC, TPA,CONC, TCLA,CONC
          GO TO 600
      595    CONC = KGPHA
             TNMET = TNA*1.121
             TPMET = TPA*1.121
             TCLMET = TCLA*1.121
             WRITE (6,4820)  TNMET,CONC, TPMET,CONC, TCLMET,CONC
      C
      C
      C                                 NUTRIENT APPLICATIONS
      C
      C
      600 IF (NAPPL.GE.0 .AND. NAPPL.LE.5)  GO TO 610
             ICERR = 1
             WRITE (6,4710)  NAPPL
             RETURN
      610 IF (NAPPL .EQ. 0)  GO TO 910
      C
          CONC = LBPAC
          IF (INFLT .EQ. METR)  CONC=KGPHA
          WRITE (6,4000)  CONC
      C
          DO 900  IAPPL=1,NAPPL
             DO 614  J=1,20
                SNAPLT(J) = 0.0
                LNAPLT(J) = 0.0
                DO 612  IBLK=1,5
                   SNAPL(J,IBLK,IAPPL) = 0.0
```

```
                 UNAPL(J,IBLK,IAPPL) = 0.0
       612     CONTINUE
       614   CONTINUE
       C
       620   READ (5,3020)  CHAR, APDAY(IAPPL)
             IF (CHAR .EQ. BLANK)  GO TO 620
             IF (CHAR .EQ. APPL)  GO TO 630
               ICERR = 1
               WRITE (6,4720)
               WRITE (6,4630)  APPL, CHAR
               RETURN
       630   IF (APDAY(IAPPL).GE.0 .AND. APDAY(IAPPL).LE.366)  GO TO 635
               ICERR = 1
               WRITE (6,4720)
               WRITE (6,4730)  IAPPL, APDAY(IAPPL)
               RETURN
       635   IF (IAPPL .EQ. 1)  GO TO 640
             IF (APDAY(IAPPL) .GT. APDAY(IAPPL-1))  GO TO 640
               ICERR = 1
               WRITE (6,4720)
               WRITE (6,4725)  IAPPL
               RETURN
       640   READ (5,3000)  TYPE
             IF (TYPE .EQ. BLANK)  GO TO 640
             IF (TYPE .EQ. NITR)  GO TO 650
             IF (TYPE .EQ. PHOS)  GO TO 660
             IF (TYPE .EQ. CHLO)  GO TO 670
             IF (TYPE .EQ. END)  GO TO 870
               ICERR = 1
               WRITE (6,4720)
               WRITE (6,4745)  TYPE, IAPPL
               RETURN
       650   NSTRT = 1
             NEND = 7
               GO TO 680
       660   NSTRT = 11
             NEND = 14
               GO TO 680
       670   NSTRT = 20
             NEND = 20
       C
       C                         SURFACE
       C
       680   READ (5,3020)  CHAR, NBLK
             IF (CHAR .EQ. SURF)  GO TO 690
               ICERR = 1
               WRITE (6,4720)
               WRITE (6,4750)  IAPPL, TYPE, SURF, CHAR
               RETURN
       690   IF (NBLK.EQ.0 .OR. NBLK.EQ.1 .OR. NBLK.EQ.5)  GO TO 700
               ICERR = 1
               WRITE (6,4720)
               WRITE (6,4650)  SURF, NBLK
               RETURN
       700   IF (NBLK .EQ. 5)  GO TO 730
             READ (5,3010)  (SNAPLT(J),J=NSTRT,NEND)
             DO 720  J=NSTRT,NEND
               DO 710  IBLK=1,5
                 SNAPL(J,IBLK,IAPPL) = SNAPLT(J)
       710     CONTINUE
```

```
      720       CONTINUE
                GO TO 770
      C
      730       DO 740  IBLK=1,5
                   READ (5,3010)  (SNAPL(J,IBLK,IAPPL),J=NSTRT,NEND)
      740       CONTINUE
                DO 760  J=NSTRT,NEND
                   SUM = 0.0
                   DO 750  IBLK=1,5
                      SUM = SUM + SNAPL(J,IBLK,IAPPL)
      750          CONTINUE
                   SNAPLT(J) = SUM/5.
      760       CONTINUE
      C
      C                                  UPPER ZONE
      C
      770       READ (5,3020)  CHAR, NBLK
                IF (CHAR .EQ. UPPE)  GO TO 780
                   ICERR = 1
                   WRITE (6,4720)
                   WRITE (6,4750)  IAPPL, TYPE, SURF, CHAR
                   RETURN
      780       IF (NBLK.EQ.0 .OR. NBLK.EQ.1 .OR. NBLK.EQ.5)  GO TO 790
                   ICERR = 1
                   WRITE (6,4720)
                   WRITE (6,4650)  UPPE, NBLK
                   RETURN
      790       IF (NBLK .EQ. 5)  GO TO 820
                READ (5,3010)  (UNAPLT(J),J=NSTRT,NEND)
                DO 810  J=NSTRT,NEND
                   DO 800  IBLK=1,5
                      UNAPL(J,IBLK,IAPPL) = UNAPLT(J)
      800          CONTINUE
      810       CONTINUE
                GO TO 860
      C
      820       DO 830  IBLK=1,5
                   READ (5,3010)  (UNAPL(J,IBLK,IAPPL),J=NSTRT,NEND)
      830       CONTINUE
                DO 850  J=NSTRT,NEND
                   SUM = 0.0
                   DO 840  IBLK=1,5
                      SUM = SUM + UNAPL(J,IBLK,IAPPL)
      840          CONTINUE
                   UNAPLT(J) = SUM/5.
      850       CONTINUE
      860       GO TO 640
      C
      C                                  OUTPUT OF NUTRIENT APPLICATIONS
      C
      870       WRITE (6,4760)  APDAY(IAPPL)
                WRITE (6,4010)
                WRITE (6,4025) (SNAPLT(J),J=1,7),(SNAPLT(J),J=11,14),SNAPLT(20)
                WRITE (6,4030)  (IBLK,(SNAPL(J,IBLK,IAPPL),J=1,7),
           1                    (SNAPL(J,IBLK,IAPPL),J=11,14),
           2                    SNAPL(20,IBLK,IAPPL),  IBLK=1,5)
      C
                WRITE (6,4090)
                WRITE (6,4025) (UNAPLT(J),J=1,7),(UNAPLT(J),J=11,14),UNAPLT(20)
                WRITE (6,4030)  (IBLK,(UNAPL(J,IBLK,IAPPL),J=1,7),
```

```
     1                        (UNAPL(J,IBLK,IAPPL),J=11,14),
     2                        UNAPL(20,IBLK,IAPPL),  IBLK=1,5)
C
C                              CONVERT APPLICATIONS FROM METRIC TO ENGLISH
C
           IF (INPUT .EQ. ENGL)  GO TO 900
           DO 890  J=1,20
              DO 880  IBLK=1,5
                 SNAPL(J,IBLK,IAPPL) = SNAPL(J,IBLK,IAPPL)*.8924
                 UNAPL(J,IBLK,IAPPL) = UNAPL(J,IBLK,IAPPL)*.8924
880           CONTINUE
890        CONTINUE
C
900   CONTINUE
C
C
910   RETURN
C
C
C
3000  FORMAT  (A4)
3001  FORMAT  (A8)
3010  FORMAT  (10F8.0)
3020  FORMAT  (A4,5X,I3)
4000  FORMAT ('0',/,'0','NUTRIENTS - ',A5,11X,'ORG-N',3X,'NH3-S',3X,
     1         'NH3-A',5X,'NO2',5X,'NO3',6X,'N2',2X,'PLNT-N',3X,'ORG-P',
     2         3X,'PO4-S',3X,'PO4-A',2X,'PLNT-P',6X,'CL')
4005  FORMAT  ('0')
4007  FORMAT ('0',40('*')/' ','*',38X,'*',
     1         /,' ','*     WARNING: NUTRIENT ALGORITHMS',6X,'*',
     2         /,' ','*     HAVE NOT BEEN VERIFIED WITH',7X,'*',
     3         /,' ','*     OBSERVED DATA',21X,'*',
     4         /,' ','*',38X,'*',/' ',40('*') )
4010  FORMAT ('0',3X,'SURFACE LAYER')
4020  FORMAT ('0',6X,'STORAGE',12X,F8.0,6F8.3,F8.0,3F8.3,F8.3)
4025  FORMAT ('0',6X,'AVERAGE',12X,F8.0,6F8.3,F8.0,3F8.3,F8.3)
4030  FORMAT (' ',12X,'BLOCK',I2,6X,F8.0,6F8.3,F8.0,3F8.3,F8.3)
4090  FORMAT ('0',3X,'UPPER ZONE')
4110  FORMAT ('0',3X,'LOWER ZONE')
4120  FORMAT ('0',3X,'GROUNDWATER')
4599  FORMAT  ('0','---ERROR---  EXPECTING THE WORD  NUTRIENT  BUT ',
     1          'READ IN ',A8)
4600  FORMAT  ('1',40X,'NUTRIENT SIMULATION INFORMATION')
4610  FORMAT  ('0',3X,'TIME STEP FOR TRANSFORMATIONS = ',I5,' MIN',
     1          /,' ',3X,'NUMBER OF NUTRIENT APPLICATIONS = ',I2,
     2          /,' ',3X,'DATE OF PLANT HARVESTING = ',I4)
4619  FORMAT  ('0','---ERROR---  IN REACTION RATES SECTION OF INPUT')
4620  FORMAT  ('0','---ERROR--- IN ',A4,' REACTION RATES SECTION OF ',
     1          'INPUT')
4630  FORMAT  (' ',12X,'EXPECTING ',A5,' BUT READ IN  ',A4)
4640  FORMAT  (' ',12X,'EXPECTING NITR, PHOS, OR END, BUT READ ',
     1          'IN  ',A4)
4650  FORMAT  ('0','NITROGEN REACTION RATES',10(4X,A4)/,
     1          ' ',6X,'SURFACE',12X,10(2X,F6.4)/
     2          ' ',6X,'UPPER ZONE',9X,10(2X,F6.4)/
     3          ' ',6X,'LOWER ZONE',9X,10(2X,F6.4)/
     4          ' ',6X,'GROUNDWATER',8X,10(2X,F6.4)/
     5          ' ',3X,'TEMPERATURE COEF.',5X,10F8.3)
4660  FORMAT  ('0','PHOSPHORUS REACTION RATES',  5(4X,A4)/
     1          ' ',6X,'SURFACE',12X,5(2X,F6.4)  /
```

```
          2         ' ',6X,'UPPER ZONE',9X,5(2X,F6.4)  /
          3         ' ',6X,'LOWER ZONE',9X,5(2X,F6.4)  /
          4         ' ',6X,'GROUNDWATER',8X,5(2X,F6.4)  /
          5         ' ',3X,'TEMPERATURE COEF.',5X,5F8.3)
     4665  FORMAT  ('0','---ERROR---  EXPECTING  INIT  BUT READ IN ',A4)
     4670  FORMAT  ('0','---ERROR--- IN INITIAL ',A5,' STORAGE SECTION OF ',
          1         'INPUT')
     4690  FORMAT  (' ',11X,'FOR ',A5,' EXPECTING BLOCKS=0, 1, OR 5',
          1         ' INPUT VALUE = ',I3)
     4700  FORMAT  (' ',3X,'INITIAL STORAGES')
     4710  FORMAT  ('0','---ERROR--- NUMBER OF NUTRIENT APPLICATIONS CAN ',
          1         'RANGE FROM 0 TO 5 ONLY, INPUT VALUE = ',I3)
     4720  FORMAT  ('0','---ERROR--- IN NUTRIENT APPLICATION SECTION')
     4725  FORMAT  ('0','---ERROR--- IN INITIAL STORAGE SECTION')
     4730  FORMAT  (' ',11X,'IN APPLICATION NO. ',I2,' THE DAY OF ',
          1         'APPLICATION IS NOT IN THE RANGE 1 TO 366, INPUT ',
          2         'VALUE = ',I3)
     4735  FORMAT  (' ',12X,'THE DAY OF APPLICATION NO. ',I2,
          1         ' DOES NOT EXCEED THE PREVIOUS APPLICATION DAY')
     4740  FORMAT  ('0',11X,'EXPECTING NITR, PHOS, CHLO, OR END, BUT ',
          1         'READ IN ',A5)
     4745  FORMAT  ('0',11X,'EXPECTING NITR, PHOS, CHLO, OR END, BUT '
          1         'READ IN ',A5,' FOR APPL. NO. ',I2)
     4750  FORMAT  ('0',11X,'IN APPLICATION NO. ',I2,' FOR ',A4,
          1         'EXPECTING ',A5, ' BUT READ IN ',A5)
     4760  FORMAT  ('0','APPLICATION FOR DAY ',I3)
     4770  FORMAT  ('0','INVALID TSTEP SPECIFIED, INPUT WAS ',I4,
          1         ' EXECUTION CONTINUING WITH TSTEP = 60 MIN.')
     4780  FORMAT  ('0','---ERROR---  INVALID NITROGEN REACTION RATE FOR ',
          1         A4,' IN ZONE ',I2,' INPUT VALUE = ',F8.6)
     4790  FORMAT  ('0','---WARNING---  NITROGEN REACTION RATE ',A4,
          1         ' IN ZONE ',I2,/14X,
          2         ' IS TOO LARGE FOR TIME STEP SELECTED, CONSIDER ',
          3         'REDUCING TSTEP FOR MORE ACCURATE SOLUTION')
     4800  FORMAT  ('0','---ERROR---  INVALID PHOSPHORUS REACTION RATE FOR ',
          1         A4,' IN ZONE ',I2,' INPUT VALUE = ',F8.6)
     4810  FORMAT  ('0','---WARNING---  PHOSHORUS REACTION RATE ',A4,
          1         ' IN ZONE ',I2/14X,
          2         ' IS TOO LARGE FOR TIME STEP SELECTED, CONSIDER ',
          3         'REDUCING TSTEP FOR MORE ACCUATE SOLUTION')
     4812  FORMAT  ('0','---WARNING---  TEMPERATURE COEFFICIENT FOR NITROGEN'
          1         ,' REACTION RATE ',A4,' SHOULD BE >= 1.0')
     4814  FORMAT  ('0','---WARNING---  TEMPERATURE COEFFICIENT FOR ',
          1         'PHOSPHORUS REACTION RATE ',A4,' SHOULD BE >= 1.0')
     4820  FORMAT  ('0',3X,'TOTAL NITROGEN IN SYSTEM = ',2X,F10.3,2X,A5/
          1         ' ',3X,'TOTAL PHOSPHORUS IN SYSTEM = ',F10.3,2X,A5/
          2         ' ',3X,'TOTAL CHLORIDE IN SYSTEM = ',2X,F10.3,2X,A5)
C
C
           END
C
C
C
C
           SUBROUTINE NUTRNT
C
C                                   THIS SUBROUTINE IS CALLED EVERY INTERVAL ON
C                                   A RAIN DAY OR ONLY ONCE A DAY ON A NO RAIN
C                                   DAY TO COMPUTE NUTRIENT LOSSES AND TRANS-
C                                   FORMATIONS.  ADVECTIVE LOSS IS COMPUTED
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C                            EVERYTIME SUBROUTINE IS CALLED, WHILE
C                            CHEMICAL AND BIOLOGICAL TRANSFORMATIONS
C                            ARE DONE AT SELECTED INTERVALS AS
C                            SPECIFIED BY INPUT PARAMETER TSTEP.
C
C                            DECLARATIONS
C                            COMMON VARIABLES
C
      INTEGER*4  TSTEP,NSTEP,SFLG,UFLG,LFLG,GFLG
C
      REAL*4  DELT,STEMP(4,24),
     1        SN(20,5),SNT(20),SNRSM(20,5),SNROM(20,5),
     2        UN(20,5),UNT(20),UNI(20,5),UNIT(20),UNRIM(20,5),
     3        NRSM(20,5),     LN(20),LNRPM(20),          GN(20),
     4        SNRBM(20,5),UNRBM(20,5),LNRBM(20),GNRBM(20),TNRBM(20),
     5        SNRSY(20,5),SNROY(20,5),UNRIY(20,5),NRSY(20,5),
     6        LNRPY(20),SNRBY(20,5),UNRBY(20,5),LNRBY(20),GNRBY(20),
     7        TNRBY(20),TNRHV(20),TNRHVM(20),TNRHVY(20),TNA,TPA,TCLA,
     8        KN(10,4),THKN(10),KP(5,4),THKP(5),NBAL,PHBAL,CLBAL
C
      COMMON /NUT/  DELT,STEMP,SN,SNT,SNRSM,SNROM,UN,UNT,UNI,UNIT,
     1              UNRIM,NRSM,LN,LNRPM,GN,SNRBM,UNRBM,LNRBM,GNRBM,TNRBM,
     2              SNRSY,SNROY,UNRIY,NRSY,LNRPY,SNRBY,UNRBY,LNRBY,GNRBY,
     3              TNRBY,TNRHV,TNRHVM,TNRHVY,TNA,TPA,TCLA,
     4              KN,THKN,KP,THKP,NBAL,PHBAL,CLBAL,
     5              TSTEP,NSTEP,SFLG,UFLG,LFLG,GFLG
C
C
      INTEGER*4  PRNTKE,HYCAL,OUTPUT,TIMFAC,IMIN,IHR,TF,JCOUNT,
     1              CALB,PROD,ENGL,METR,BOTH,YES,NO,PEST,NUTR
C
      REAL*4  RU,HYMIN,DPST,LZS,AREA,RESB1(5),ROSB(5),SRGX(5),INTF(5),
     1        RGX(5),INFL(5),UZSB(5),APERCB(5),RIB(5),ERSN(5),RESB(5),
     2        M,F3,A
C
      COMMON /ALL/  RU,HYMIN,PRNTKE,HYCAL,DPST,OUTPUT,TIMFAC,LZS,AREA,
     1             RESB1,ROSB,SRGX,INTF,RGX,INFL,UZSB,APERCB,RIB,ERSN,
     2             M,F3,A,CALB,PROD,PEST,NUTR,ENGL,METR,BOTH,RESB,YES,NO,
     3             IMIN,IHR,TF,JCOUNT,PRINT,INTR,DAYS,HOUR,MNTH
C
C                            DECLARATIONS FOR INTERNAL STORAGE ALLOCATION
C
      REAL*4  SNRS(20,5),SNRO(20,5),SNRP(20,5),ASNRS(20,5)/100*0.0/,
     1        ASNRST(20),ASNRO(20,5)/100*0.0/,  ASNROT(20),
     2        ASNRP(20,5)/100*0.0/,ASNRPT(20),UNTI(20,5),UNRI(20,5),
     3        UNRP(20,5),NRS(20,5),AUNRI(20,5)/100*0.0/,AUNRIT(20),
     4        AUNRP(20,5)/100*0.0/,AUNRPT(20),ANRS(20,5)/100*0.0/,
     6        ANRST(20),LNRP(20),ALNRP(20)/20*0.0/,
     7        ASNRB(20,5)/100*0.0/,ASNRBT(20),
     8        AUNRB(20,5)/100*0.0/,AUNRBT(20),
     9        ALNRB(20)/20*0.0/,  AGNRB(20)/20*0.0/,ATNRB(20)/20*0.0/
C
C                            DECLARATIONS FOR OTHER INTERNAL VARIABLES
C
      INTEGER*4  ITIME,NCYCLE,IHOUR,IBIO,IZONE,IBLK
C
      REAL*8  CONC,LBPAC/'LB/AC'/,KGPHA/'KG/HA'/
C
      REAL*4  FS,FC,FF,TW,TWI,FII,FLI,T(4),
     1        DELPE(20,5),DELN(20),
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     2           SUM,SUMC,SUMA,NDSM(20),NDSC(20),NASM(20),
     3           NASC(20),ERSNT,CONFC,CONFS,TOTN,TOTP,
     4           CONVF/1.121/,SNMET(20,5),UNMET(20,5),LNMET(20),GNMET(20),
     5           SNTMET(20),UNTMET(20),UNITMT(20),UNIMET(20,5),
     6           PA,CLMV(20),DUMA(20,5)
C
C                           INITIALIZATION AND DECLARATION OF SELECTORS
C                           USED FOR ADVECTING AND REMOVING NUTRIENTS
C                           BY MEANS OF SEDIMENT (SD), OVERLAND FLOW
C                           (OF), INTERFLOW (IF), PERCOLATION (PC),
C                           BIOLOGICAL (BL).
C
      INTEGER*4  SELSC(20)/1,0,1,0,0,0,0,0,0,0,1,0,1,0,0,0,0,0,0,0/,
     1           SELOF(20)/0,1,0,1,1,0,0,0,0,0,0,1,0,0,0,0,0,0,0,1/,
     2           SELIF(20)/0,1,0,1,1,0,0,0,0,0,0,1,0,0,0,0,0,0,0,1/,
     3           SELPC(20)/0,1,0,1,1,0,0,0,0,0,0,1,0,0,0,0,0,0,0,1/,
     4           SELBL(20)/0,0,0,0,0,1,1,0,0,0,0,0,0,1,0,0,0,0,0,0/
C
C
C                     BRIEF DESCRIPTION OF VARIABLE NAMING CONVENTION:
C                     1) FIRST TWO LETTERS SN,UN,LN,GN STAND FOR SURFACE,
C                        UPPER ZONE, LOWER ZONE, AND GROUNDWATER NUTRIENTS
C                        UNI   INTERFLOW STORAGE OF DISSOLVED NUTRIENTS
C                     2) FIRST LETTER A STANDS FOR AN ACCUMULATION OF A
C                        NUTRIENT LOSS OVER THE INTERVALS BETWEEN PRINTING
C                     3) THE THIRD OR FOURTH LETTER 'R' STANDS FOR REMOVAL
C                     4) FOLLOWING THE 'R' A LETTER INDICATES THE CAUSE OF
C                        REMOVAL;  'S'=SEDIMENT, 'O'=OVERLAND FLOW,
C                        'P'=PERCOLATION, 'I'=INTERFLOW, 'B'=BIOLOGICAL
C                     5) LETTERS 'M' AND 'Y' INDICATE MONTHLY AND YEARLY
C                        SUMS OF REMOVALS, MONTHLY SUM IS ACCUMULATED IN
C                        NUTRNT AND PASSED TO MAIN FOR OUTPUT, AND YEARLY
C                        AMOUNTS ARE CALCULATED AND PRINTED IN MAIN
C                     6) THE LETTER 'T' APPEARING AT THE VERY END INDICATES
C                        THE TOTAL OR AVERAGE MASS OF THE 5 BLOCKS IN THE
C                        SURFACE AND UPPER ZONES
C
C                        NUTRIENTS ARE STORED IN VECTORS AND ARRAYS IN THE
C                        FOLLOWING SEQUENCE OF ELEMENTS:
C                        1 = ORG-N,  ORGANIC NITROGEN
C                        2 = NH3-S,  AMMONIA IN SOLUTION
C                        3 = NH3-A,  AMMONIA ADSORBED TO SOIL
C                        4 = NO2,    NITRITE
C                        5 = NO3,    NITRATE
C                        6 = N2-GAS, NITROGEN GAS FROM DENITRIFICATION
C                        7 = PLNT-N, PLANT NITROGEN
C                        8 = OPEN
C                        9 = OPEN
C                        10 = OPEN
C                        11 = ORG-P,  ORGANIC PHOSPHORUS
C                        12 = PO4-S,  PHOSPHATE IN SOLUTION
C                        13 = PO4-A,  PHOSPHATE ADSORBED TO SOIL
C                        14 = PLNT-P, PLANT PHOSPHORUS
C                        15 = OPEN
C                        16 = OPEN
C                        17 = OPEN
C                        18   OPEN
C                        19 = OPEN
C                        20 = CL,     CHLORIDE
C
```

```
            PA = 1.0 - A
      C
      C                             ADVECTIVE LOSSES
      C
      C                             SURFACE ZONE
      C
            DO 120  IBLK=1,5
      C
      C                             SEDIMENT REMOVAL
      C
               IF (ERSN(IBLK) .LE. 0.0)  GO TO 40
               FS = 2000.*AREA*0.2*ERSN(IBLK)/M
               IF (FS .GT. 1.0)  FS=1.0
               DO 20  J=1,20
                  SNRS(J,IBLK) = SELSD(J)*FS*SN(J,IBLK)
   20          CONTINUE
               GO TO 60
   40          DO 50  J=1,20
                  SNRS(J,IBLK) = 0.0
   50          CONTINUE
      C
      C                             OVERLAND FLOW AND PERCOLATION
      C
   60          IF ((P3+RESB1(IBLK)) .LE. 0.0)  GO TO 80
               FO = ROSB(IBLK)/(PA*(P3+RESB1(IBLK)))
               FP = RIB(IBLK)/(P3+RESB1(IBLK))
               DO 70  J=1,20
                  SNRO(J,IBLK) = SELOF(J)*FO*SN(J,IBLK)
                  SNRP(J,IBLK) = SELPC(J)*FP*SN(J,IBLK)
   70          CONTINUE
               GO TO 100
   80          DO 90  J=1,20
                  SNRO(J,IBLK) = 0.0
                  SNRP(J,IBLK) = 0.0
   90          CONTINUE
      C
      C                             CHANGE SURFACE STORAGES AND ACCUMULATE
      C                             REMOVALS
      C
  100          DO 110  J=1,20
                  SN(J,IBLK) = SN(J,IBLK) - SNRS(J,IBLK) - SNRO(J,IBLK) -
     1                         SNRP(J,IBLK)
                  UN(J,IBLK) = UN(J,IBLK) + SNRP(J,IBLK)
                  ASNRS(J,IBLK) = ASNRS(J,IBLK) + SNRS(J,IBLK)
                  ASNRO(J,IBLK) = ASNRO(J,IBLK) + SNRO(J,IBLK)
                  ASNRP(J,IBLK) = ASNRP(J,IBLK) + SNRP(J,IBLK)
  110          CONTINUE
  120       CONTINUE
      C
      C                             UPPER ZONE
      C
            DO 220  IBLK=1,5
      C
      C                             PERCOLATION AND INTERFLOW
      C                             UNIT - TRANSFER FROM UZ TO INTERFLOW
      C
               TW = UZSB(IBLK) + RGX(IBLK) + APERCB(IBLK) + INFL(IBLK)
               TWI = SRGX(IBLK) + INTF(IBLK)
               IF (TW .LE. 0.0)  GO TO 140
               FII = RGX(IBLK)/TW
```

```
                FP = (INFL(IBLK) + APERCB(IBLK))/TW
                DO 130  J=1,20
                   UNTI(J,IBLK) = SELIF(J)*FII*UN(J,IBLK)
                   UNI(J,IBLK) = UNI(J,IBLK) + UNTI(J,IBLK)
                   UNRP(J,IBLK) = SELPC(J)*FP*UN(J,IBLK)
      130       CONTINUE
                GO TO 160
      140       DO 150  J=1,20
                   UNTI(J,IBLK) = 0.0
                   UNRP(J,IBLK) = 0.0
      150       CONTINUE
      C
      C                             LOSS FROM INTERFLOW STORAGE
      C
      160       IF (TWI .LE. 0.0)  GO TO 180
                FLI = INTF(IBLK)/TWI
                DO 170  J=1,20
                   UNRI(J,IBLK) = FLI*UNI(J,IBLK)
      170       CONTINUE
                GO TO 200
      180       DO 190  J=1,20
                   UNRI(J,IBLK) = 0.0
      190       CONTINUE
      C
      C                             REMOVE AND ADD STORAGES AND ACCUMULATE
      C
      200       DO 210  J=1,20
                   UN(J,IBLK) = UN(J,IBLK) - UNTI(J,IBLK) - UNRP(J,IBLK)
                   UNI(J,IBLK) = UNI(J,IBLK) - UNRI(J,IBLK)
                   AUNRI(J,IBLK) = AUNRI(J,IBLK) + UNRI(J,IBLK)
                   AUNRP(J,IBLK) = AUNRP(J,IBLK) + UNRP(J,IBLK)
                   LN(J) = LN(J) + UNRP(J,IBLK)*0.2
      210       CONTINUE
      220    CONTINUE
      C
      C                             COMPUTE NUTRIENT REMOVAL TO STREAM (NRS)
      C                             AND ACCUMULATIONS
      C
             DO 240  IBLK=1,5
                DO 230  J=1,20
                   NRS(J,IBLK) = SNRS(J,IBLK) + SNRO(J,IBLK) + UNRI(J,IBLK)
                   ANRS(J,IBLK) = ANRS(J,IBLK) + NRS(J,IBLK)
      230       CONTINUE
      240    CONTINUE
      C
      C                             LOWER ZONE
      C
             TW = LZS + DPST
             IF (TW .LE. 0.0)  GO TO 260
             FP = DPST/TW
             DO 250  J=1,20
                LNRP(J) = SELPC(J)*FP*LN(J)
      250    CONTINUE
             GO TO 280
      260    DO 270  J=1,20
                LNRP(J) = 0.0
      270    CONTINUE
      C
      280    DO 290  J=1,20
                LN(J) = LN(J) - LNRP(J)
```

```
                 GN(J) = GN(J) + LNRP(J)
                 ALNRP(J) = ALNRP(J) + LNRP(J)
      250    CONTINUE
      C
      C                             GROUNDWATER
      C                             NO ADVECTIVE LOSS FROM GROUNDWATER
      C
      C
      C                             CHECK TO SEE IF PHYSICAL AND BIOLOGICAL
      C                             TRANSFORMATIONS ARE TO BE DONE THIS
      C                             INTERVAL ON A RAIN DAY, OR SETUP THE
      C                             NUMBER OF TIMES TO LOOP FOR A NO RAIN
      C                             DAY
      C
             IF (TF .GT. 1)  GO TO 300
             ITIME = IMIN + 60*IHR
             IF ( MOD(ITIME,TSTEP) .NE. 0)  GO TO 810
             NCYCLE = 1
             GO TO 310
      300    NCYCLE = NSTEP
      C
      310    DO 800  IBIO=1,NCYCLE
      C
      C                             COMPUTE HOUR OF THE DAY TO ACCESS HOURLY
      C                             SOIL TEMP DATA FOR THE 4 SOIL ZONES:
      C                             SURFACE, UPPER, LOWER, GROUNDWATER
      C
                IF (TF .GT. 1)  GO TO 320
                IHOUR = IHR + 1
                GO TO 330
      320       IHOUR = 1 + (IBIO*TSTEP)/60
      330       IF (IHOUR .EQ. 25)  IHOUR=24
                DO 340  IZONE=1,4
                   T(IZONE) = STEMP(IZONE,IHOUR)
      340       CONTINUE
      C
      C                             SURFACE ZONE TRANSFORMATIONS
      C
                IF (SFLG .EQ. 0)  GO TO 450
                IZONE = 1
      C
                CALL TRANS (DELT,IZONE,DUMV,SN,KN,THKN,KP,THKP,T,DUMV,DELNB)
      C
      C                             COMPUTE AND ACCUMULATE AMOUNT REMOVED
      C                             BIOLOGICALLY
      C
                DO 440  IBLK=1,5
                   DO 430  J=1,20
                      ASNRB(J,IBLK) = ASNRB(J,IBLK) + SELBL(J)*DELNB(J,IBLK)
      430          CONTINUE
      440       CONTINUE
      C
      C                             UPPER ZONE TRANSFORMATIONS
      C
      450       IF (UFLG .EQ. 0)  GO TO 560
                IZONE = 2
      C
                CALL TRANS (DELT,IZONE,DUMV,UN,KN,THKN,KP,THKP,T,DUMV,DELNB)
      C
                DO 550  IBLK=1,5
```

```
                  DO 540  J=1,20
                     AUNRB(J,IBLK) = AUNRB(J,IBLK) + SELBL(J)*DELNB(J,IBLK)
      540         CONTINUE
      550      CONTINUE
      C
      C                                LOWER ZONE TRANSFORMATIONS
      C
      560      IF (LFLG .EQ. 0)  GO TO 660
               IZONE = 3
      C
               CALL TRANS (CELT,IZONE,LN,DUMA,KN,THKN,KP,THKP,T,DELN,DUMA)
      C
               DO 650  J=1,20
                  ALNRB(J) = ALNRB(J) + SELBL(J)*DELN(J)
      650      CONTINUE
      C
      C                                GROUNDWATER ZONE
      C
      660      IF (GFLG .EQ. 0)  GO TO 800
               IZONE = 4
      C
               CALL TRANS (CELT,IZONE,GN,DUMA,KN,THKN,KP,THKP,T,DELN,DUMA)
      C
               DO 750  J=1,20
                  AGNRB(J) = AGNRB(J) + SELBL(J)*DELN(J)
      750      CONTINUE
      C
      800   CONTINUE
      C
      C                                END OF NO RAIN INTERVAL LOOP
      C
        810 IF (PRNTKE .EQ. 0)  GO TO 1300
      C
      C                                COMPUTE BIOLOGICAL REMOVALS
      C                                ACCUMULATE MONTHLY VALUES OF ADVECTIVE
      C                                AND BIOLOGICAL REMOVALS
      C                                ATNRB = ACCUM. TOTAL NUTR REMOVAL BIOL.
      C
            DO 920  J=1,20
               SUM = 0.0
               DO 910  IBLK=1,5
                  SUM = SUM + ASNRB(J,IBLK) + AUNRB(J,IBLK)
      910      CONTINUE
               ATNRB(J) = SUM/5. + ALNRB(J) + AGNRB(J)
      920   CONTINUE
      C
            DO 940  J=1,20
               DO 930  IBLK=1,5
                  SNRSM(J,IBLK) = SNRSM(J,IBLK) + ASNRS(J,IBLK)
                  SNROM(J,IBLK) = SNROM(J,IBLK) + ASNRO(J,IBLK)
                  UNRIM(J,IBLK) = UNRIM(J,IBLK) + AUNRI(J,IBLK)
                  NRSM(J,IBLK) = NRSM(J,IBLK) + ANRS(J,IBLK)
                  SNRBM(J,IBLK) = SNRBM(J,IBLK) + ASNRB(J,IBLK)
                  UNRBM(J,IBLK) = UNRBM(J,IBLK) + AUNRB(J,IBLK)
      930      CONTINUE
               LNRPM(J) = LNRPM(J) + ALNRP(J)
               LNRBM(J) = LNRBM(J) + ALNRB(J)
               GNRBM(J) = GNRBM(J) + AGNRB(J)
               TNRBM(J) = TNRBM(J) + ATNRB(J)
      940   CONTINUE
```

```
      C
            IF (PRNTKE .EQ. 2)  GO TO 1200
      C                             OUTPUT OPTIONS
      C
            IF (HYCAL .EQ. PROD)  GO TO 1100
            IF (TF.GT.1 .OR. FU.LT.HYMIN)  GO TO 1200
      C
      C                             COMPUTE CONCENTRATIONS AND MASSES IN STREAM
      C                             FOR CALIBRATION OUTPUT
      C                             NDSM=NUTRIENTS DISSOLVED IN STREAM,MASS
      C                             NDSC=NUTRIENTS DISSOLVED IN STREAM, CONC.
      C                             NASM=NUTRIENTS ADSORBED IN STREAM, MASS
      C                             NASC=NUTRIENTS ADSORBED IN STREAM, CONC.
      C                             CONFC = CONVERSION FACTOR TO GET MG/L UNITS
      C                             CONFS = CONV. FACTOR TO GET ADSORBED NUTR.
      C                                     CONC. IN PPM OF SEDIMENT
      C
            ERSNT = 0.0
            DO 945  IBLK=1,5
               ERSNT = ERSNT + ERSN(IBLK)
      945   CONTINUE
            ERSNT = ERSNT/5.
            CONFC = 454000./(FU*TIMFAC*60.*28.32)
            IF (ERSNT .GT. 0.0)  CONFS = 1.0E6/(ERSNT*2000.*AREA)
            DO 970  J=1,20
               SUMD = 0.0
               SUMA = 0.0
               DO 950  IBLK=1,5
                  SUMD = SUMD + ASNRO(J,IBLK) + AUNRI(J,IBLK)
                  SUMA = SUMA + ASNRS(J,IBLK)
      950      CONTINUE
               NDSM(J) = SUMD*AREA/5.
               NDSC(J) - NDSM(J)*CONFC
               NASM(J) = SUMA*AREA/5.
               IF (ERSNT .LE. 0.0)  GO TO 960
                  NASC(J) = NASM(J)*CONFS
               GO TO 970
      960      NASC(J) = 0.0
      970   CONTINUE
      C
      C                             COMPUTE TOTAL MASS OF N (TOTN) AND P (TOTP)
      C                             IN STREAM
      C
            TOTN   0.0
            TOTP   0.0
            DO 971  J=1,7
               TOTN = TOTN +NDSM(J) + NASM(J)
      971   CONTINUE
            DO 972  J=11,14
               TOTP = TOTP + NDSM(J) + NASM(J)
      972   CONTINUE
      C
      C                             MODIFICATIONS FOR METRIC OUTPUT
      C                             CONVERT MASS FROM LB. TO KG. CONC. IN MG/L
      C
            IF (OUTPUT.EQ.ENGL .OR. OUTPUT.EQ.BOTH)  GO TO 1000
            DO 980  J=1,20
               NDSM(J) = NDSM(J)/2.205
               NASM(J)   NASM(J)/2.205
      980   CONTINUE
```

```
            TOTN = TOTN/2.2C5
            TOTP = TOTP/2.2C5
      C
      1C00  WRITE (6,413C)  NDSM(5),NDSM(4),NDSM(2),NDSM(12),NDSM(20),
           1                NASM(3),NASM(1),NASM(13),NASM(11), TOTN, TOTP
            WRITE (6,4140)  NDSC(5),NDSC(4),NDSC(2),NDSC(12),NDSC(20),
           1                NASC(3),NASC(1),NASC(13),NASC(11)
            GO TO 1200
      C
      C                          PRODUCTION OUTPUT
      C                          COMPUTE WATERSHED AVG. FROM BLOCK STORAGES
      C
      11CC  DO 1120  J=1,20
               SNT(J) = C.0
               UNT(J) = 0.0
               UNIT(J) = C.C
               ASNRST(J) = C.C
               ASNRCT(J) = C.0
               ASNRPT(J) = C.C
               AUNRIT(J) = C.0
               AUNRPT(J) = C.0
               ANRST(J) = 0.C
               ASNRBT(J) = C.0
               AUNRBT(J) = C.C
               DO 111C  IBLK=1,5
                  SNT(J) = SNT(J) + SN(J,IBLK)*0.2
                  UNT(J) = UNT(J) + UN(J,IBLK)*0.2
                  UNIT(J)   UNIT(J) + UNI(J,IBLK)*0.2
                  ASNRST(J) = ASNRST(J) + ASNRS(J,IBLK)*0.2
                  ASNRCT(J) = ASNROT(J) + ASNRO(J,IBLK)*0.2
                  ASNRPT(J) = ASNRPT(J) + ASNRP(J,IBLK)*0.2
                  AUNRIT(J) = AUNRIT(J) + AUNRI(J,IBLK)*0.2
                  AUNRPT(J) = AUNRPT(J) + AUNRP(J,IBLK)*0.2
                  ANRST(J) = ANRST(J) + ANRS(J,IBLK)*0.2
                  ASNRBT(J) = ASNRBT(J) + ASNRB(J,IBLK)*0.2
                  AUNRBT(J) = AUNRBT(J) + AUNRB(J,IBLK)*0.2
      1110     CONTINUE
      1120  CONTINUE
      C
            IF (OUTPUT .EQ. METR)  GO TO 1130
            CONC = LBPAC
            WRITE (6,4C05)
            WRITE (6,4CCC)  CONC
      C
      C                          SURFACE
      C
            WRITE (6,401C)
            WRITE (6,4020)  (SNT(J),J=1,7),(SNT(J),J=11,14),SNT(20)
            WRITE (6,403C)  (IBLK,(SN(J,IBLK),J=1,7),(SN(J,IBLK),J=11,14),
           1                SN(20,IBLK),  IBLK=1,5)
            WRITE (6,404C)
            WRITE (6,405C)  (ASNRST(J),J=1,7),(ASNRST(J),J=11,14),ASNRST(20)
            WRITE (6,4030) (IBLK,(ASNRS(J,IBLK),J=1,7),(ASNRS(J,IBLK),J=11,14)
           1               ,ASNRS(20,IBLK),  IBLK=1,5)
            WRITE (6,406C)  (ASNRCT(J),J=1,7),(ASNROT(J),J=11,14),ASNRCT(20)
            WRITE (6,403C) (IBLK,(ASNRO(J,IBLK),J=1,7),(ASNRO(J,IBLK),J=11,14)
           1               ,ASNRO(20,IBLK),  IBLK=1,5)
            WRITE (6,407C)  (ASNRPT(J),J=1,7),(ASNRPT(J),J=11,14),ASNRPT(20)
            WRITE (6,4C3C) (IBLK,(ASNRP(J,IBLK),J=1,7),(ASNRP(J,IBLK),J=11,14)
           1               ,ASNRP(20,IBLK),  IBLK=1,5)
```

```
      WRITE (6,4080)  (ASNRBT(J),J=1,7),(ASNRBT(J),J=11,14),ASNRBT(20)
      WRITE (6,4030) (IBLK,(ASNRB(J,IBLK),J=1,7),(ASNRB(J,IBLK),J=11,14)
     1               ,ASNRB(20,IBLK),  IBLK=1,5)
C
C                           UPPER ZONE
C
      WRITE (6,4090)
      WRITE (6,4020)  (UNT(J),J=1,7),(UNT(J),J=11,14),UNT(20)
      WRITE (6,4030) (IBLK,(UN(J,IBLK),J=1,7),(UN(J,IBLK),J=11,14)
     1               ,UN(20,IBLK),  IBLK=1,5)
      WRITE (6,4100)  (UNIT(J),J=1,7),(UNIT(J),J=11,14),UNIT(20)
      WRITE (6,4030) (IBLK,(UNI(J,IBLK),J=1,7),(UNI(J,IBLK),J=11,14)
     1               ,UNI(20,IBLK),  IBLK=1,5)
      WRITE (6,4040)
      WRITE (6,4100)  (AUNRIT(J),J=1,7),(AUNRIT(J),J=11,14),AUNRIT(20)
      WRITE (6,4030) (IBLK,(AUNRI(J,IBLK),J=1,7),(AUNRI(J,IBLK),J=11,14)
     1               ,AUNRI(20,IBLK),  IBLK=1,5)
      WRITE (6,4070)  (AUNRPT(J),J=1,7),(AUNRPT(J),J=11,14),AUNRPT(20)
      WRITE (6,4030) (IBLK,(AUNRP(J,IBLK),J=1,7),(AUNRP(J,IBLK),J=11,14)
     1               ,AUNRP(20,IBLK),  IBLK=1,5)
      WRITE (6,4080)  (AUNRBT(J),J=1,7),(AUNRBT(J),J=11,14),AUNRBT(20)
      WRITE (6,4030) (IBLK,(AUNRB(J,IBLK),J=1,7),(AUNRB(J,IBLK),J=11,14)
     1               ,AUNRB(20,IBLK), IBLK=1,5)
C
C                           LOWER ZONE AND GROUNDWATER
C
      WRITE (6,4110)
      WRITE (6,4020)  (LN(J),J=1,7),(LN(J),J=11,14),LN(20)
      WRITE (6,4040)
      WRITE (6,4070)  (ALNRP(J),J=1,7),(ALNRP(J),J=11,14),ALNRP(20)
      WRITE (6,4080)  (ALNRB(J),J=1,7),(ALNRB(J),J=11,14),ALNRB(20)
      WRITE (6,4120)
      WRITE (6,4020)  (GN(J),J=1,7),(GN(J),J=11,14),GN(20)
      WRITE (6,4040)
      WRITE (6,4080)  (AGNRB(J),J=1,7),(AGNRB(J),J=11,14),AGNRB(20)
C
1130  IF (OUTPUT .EQ. ENGL)  GO TO 1200
C
C                           METRIC CONVERSIONS FOR OUTPUT
C
      CONC = KGPHA
      DO 1150  J=1,20
         SNTMET(J) = SNT(J)*CONVF
         ASNRST(J) = ASNRST(J)*CONVF
         ASNRCT(J) = ASNRCT(J)*CONVF
         ASNRPT(J) = ASNRPT(J)*CONVF
         ASNRBT(J) = ASNRBT(J)*CONVF
C
         UNTMET(J) = UNT(J)*CONVF
         UNITMT(J) = UNIT(J)*CONVF
         AUNRIT(J) = AUNRIT(J)*CONVF
         AUNRPT(J) = AUNRPT(J)*CONVF
         AUNRBT(J) = AUNRBT(J)*CONVF
C
         LNMET(J) = LN(J)*CONVF
         ALNRP(J)   ALNRP(J)*CONVF
         ALNRB(J) = ALNRB(J)*CONVF
         GNMET(J) = GN(J)*CONVF
         AGNRB(J) = AGNRB(J)*CONVF
         DO 1140  IBLK=1,5
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                  SNMET(J,IBLK) = SN(J,IBLK)*CONVF
                  ASNRS(J,IBLK) = ASNRS(J,IBLK)*CONVF
                  ASNRO(J,IBLK) = ASNRO(J,IBLK)*CONVF
                  ASNRP(J,IBLK) = ASNRP(J,IBLK)*CONVF
                  ASNRB(J,IBLK) = ASNRB(J,IBLK)*CONVF
                  UNMET(J,IBLK) = UN(J,IBLK)*CONVF
                  UNIMET(J,IBLK) = UNI(J,IBLK)*CONVF
                  AUNRI(J,IBLK) = AUNRI(J,IBLK)*CONVF
                  AUNRP(J,IBLK) = AUNRP(J,IBLK)*CONVF
                  AUNRB(J,IBLK) = AUNRB(J,IBLK)*CONVF
 1140         CONTINUE
 1150     CONTINUE
          WRITE (6,4005)
          WRITE (6,4000)  CONC
C
C                               SURFACE
C
          WRITE (6,4010)
          WRITE (6,4020)  (SNTMET(J),J=1,7),(SNTMET(J),J=11,14),SNTMET(20)
          WRITE (6,4030)  (IBLK,(SNMET(J,IBLK),J=1,7),
         1                 (SNMET(J,IBLK),J=11,14),
         2                 SNMET(20,IBLK),   IBLK=1,5)
          WRITE (6,4040)
          WRITE (6,4050)  (ASNRST(J),J=1,7),(ASNRST(J),J=11,14),ASNRST(20)
          WRITE (6,4030) (IBLK,(ASNRS(J,IBLK),J=1,7),(ASNRS(J,IBLK),J=11,14)
         1               ,ASNRS(20,IBLK),   IBLK=1,5)
          WRITE (6,4060)  (ASNROT(J),J=1,7),(ASNROT(J),J=11,14),ASNROT(20)
          WRITE (6,4030) (IBLK,(ASNRO(J,IBLK),J=1,7),(ASNRO(J,IBLK),J=11,14)
         1               ,ASNRO(20,IBLK),   IBLK=1,5)
          WRITE (6,4070)  (ASNRPT(J),J=1,7),(ASNRPT(J),J=11,14),ASNRPT(20)
          WRITE (6,4030) (IBLK,(ASNRP(J,IBLK),J=1,7),(ASNRP(J,IBLK),J=11,14)
         1               ,ASNRP(20,IBLK),   IBLK=1,5)
          WRITE (6,4080)  (ASNRBT(J),J=1,7),(ASNRBT(J),J=11,14),ASNRBT(20)
          WRITE (6,4030) (IBLK,(ASNRB(J,IBLK),J=1,7),(ASNRB(J,IBLK),J=11,14)
         1               ,ASNRB(20,IBLK),   IBLK=1,5)
C
C                               UPPER ZONE
C
          WRITE (6,4090)
          WRITE (6,4020)  (UNTMET(J),J=1,7),(UNTMET(J),J=11,14),UNTMET(20)
          WRITE (6,4030) (IBLK,(UNMET(J,IBLK),J=1,7),
         1               (UNMET(J,IBLK),J=11,14),
         2               UNMET(20,IBLK),   IBLK=1,5)
          WRITE (6,4100)  (UNITMT(J),J=1,7),(UNITMT(J),J=11,14),UNITMT(20)
          WRITE (6,4030)  (IBLK,(UNIMET(J,IBLK),J=1,7),
         1               (UNIMET(J,IBLK),J=11,14),
         2               UNIMET(20,IBLK),   IBLK=1,5)
          WRITE (6,4040)
          WRITE (6,4100)  (AUNRIT(J),J=1,7),(AUNRIT(J),J=11,14),AUNRIT(20)
          WRITE (6,4030) (IBLK,(AUNRI(J,IBLK),J=1,7),(AUNRI(J,IBLK),J=11,14)
         1               ,AUNRI(20,IBLK),   IBLK=1,5)
          WRITE (6,4070)  (AUNRPT(J),J=1,7),(AUNRPT(J),J=11,14),AUNRPT(20)
          WRITE (6,4030) (IBLK,(AUNRP(J,IBLK),J=1,7),(AUNRP(J,IBLK),J=11,14)
         1               ,AUNRP(20,IBLK),   IBLK=1,5)
          WRITE (6,4080)  (AUNRBT(J),J=1,7),(AUNRBT(J),J=11,14),AUNRBT(20)
          WRITE (6,4030) (IBLK,(AUNRB(J,IBLK),J=1,7),(AUNRB(J,IBLK),J=11,14)
         1               ,AUNRB(20,IBLK),  IBLK=1,5)
C
C                               LOWER ZONE AND GROUNDWATER
C
```

```
            WRITE (6,4110)
            WRITE (6,4020)  (LNMET(J),J=1,7),(LNMET(J),J=11,14),LNMET(20)
            WRITE (6,4040)
            WRITE (6,4070)  (ALNRP(J),J=1,7),(ALNRP(J),J=11,14),ALNRP(20)
            WRITE (6,4080)  (ALNRB(J),J=1,7),(ALNRB(J),J=11,14),ALNRB(20)
            WRITE (6,4120)
            WRITE (6,4020)  (GNMET(J),J=1,7),(GNMET(J),J=11,14),GNMET(20)
            WRITE (6,4040)
            WRITE (6,4080)  (AGNRB(J),J=1,7),(AGNRB(J),J=11,14),AGNRB(20)
      C
      C                            ZERO OUT ACCUMULATIONS AFTER PRINTING
      C
      1200  DO 1220  J=1,20
               DO 1210  IELK=1,5
                  ASNRS(J,IELK) = 0.0
                  ASNRC(J,IELK) = 0.0
                  ASNRP(J,IELK) = 0.0
                  ASNRB(J,IELK) = 0.0
                  ALNRI(J,IELK) = 0.0
                  ALNRP(J,IELK) = 0.0
                  ALNRB(J,IELK) = 0.0
                  ANRS(J,IELK) = 0.0
      1210     CONTINUE
               ALNRP(J) = 0.0
               ALNRB(J) = 0.0
               AGNRB(J) = 0.0
      1220  CONTINUE
      C
      C
      1300  RETURN
      C
      C
      C
      4000  FORMAT ('0','NUTRIENTS - ',A5,11X,'ORG-N',3X,'NH3-S',3X,'NH3-A',
           1          5X,'NO2',5X,'NO3',6X,'N2',2X,'PLNT-N',3X,'ORG-P',3X,
           2          'PO4-S',3X,'PO4-A',2X,'PLNT-P',6X,'CL')
      4005  FORMAT ('0')
      4010  FORMAT ('0',3X,'SURFACE LAYER')
      4020  FORMAT ('0',6X,'STORAGE',12X,F8.0,6F8.3,F8.0,3F8.3,F8.3)
      4030  FORMAT (' ',12X,'BLOCK',I2,6X,F8.0,6F8.3,F8.0,3F8.3,F8.3)
      4040  FORMAT ('0',6X,'REMOVAL')
      4050  FORMAT ('0',9X,'SEDIMENT',8X,F8.0,6F8.3,F8.0,3F8.3,F8.3)
      4060  FORMAT ('0',9X,'OVERLAND FLOW',3X,F8.0,6F8.3,F8.0,3F8.3,F8.3)
      4070  FORMAT ('0',9X,'PERCOLATION',5X,F8.0,6F8.3,F8.0,3F8.3,F8.3)
      4080  FORMAT ('0',9X,'BIOLOGICAL',6X,F8.0,6F8.3,F8.0,3F8.3,F8.3)
      4090  FORMAT ('0',3X,'UPPER ZONE')
      4100  FORMAT ('0',9X,'INTERFLOW',7X,F8.0,6F8.3,F8.0,3F8.3,F8.3)
      4110  FORMAT ('0',3X,'LOWER ZONE')
      4120  FORMAT ('0',3X,'GROUNDWATER')
      4130  FORMAT ('+',40X,9F8.3,4X,2F8.3)
      4140  FORMAT (' ',40X,9F8.1)
      C
            END
      C
      C
      C
      C
            SUBROUTINE TRANS (DELT,IZONE,N,NB,KN,THKN,KP,THKP,T,DELN,DELNB)
      C
      C                       THIS SUBROUTINE
```

```
C                          1) CORRECTS REACTION RATES FOR SOIL TEMP
C                             LESS THAN 35 DEG C.
C                             KNC - VECTOR OF NITROGEN REACTION RATES
C                                CORRECTED FOR EFFECTS OF ENVIR. FACTORS
C                             KPC = VECTOR OF PHOSPHORUS RATES, CORRECTED
C                          2) DEVELOPS COEFFICIENT ARRAY OF CORRECTED RATES
C
C                          3) THEN SOLVES A SYSTEM OF FIRST
C                             ORDER DIFFERENTIAL EQUATIONS FOR THE
C                             CONSTITUTENT CONCENTRATIONS AT THE NEXT
C                             TIME STEP.
C
C                             CALLING VARIABLES ARE:
C                             N(20) = VECTOR OF CONCENTRATIONS   (LB/AC)
C                             DELT = TIME STEP (DELTA T)   (HR)
C                             IZONE = SOIL LAYERS 1 TO 4
C                             KN(10,4) = NITROGEN REACTION RATES AT 35 C
C                             THKN(10 = TEMP. CORRECTION COEF FOR KN
C                             KP(5,4) = PHOSPHORUS RATES AT 35 C
C                             THKP(5) = TEMP. COEF. FOR KP
C                             T(4) = SOIL TEMP AT 4 SOIL LAYERS, DEG C
C                             DELN(20) = CHANGE IN CONCENTRATION THIS
C                                        TIME STEP (LB/AC)
C
C                             NB(20,5)    ARRAY OF CONCENTRATIONS,BY
C                                         BLOCK (LB/AC)
C                             DELNB(20,5) = CHANGE IN NB, BY BLOCK
C                                            (LB/AC)
C
C                             SOLUTION TECHNIQUE CONSIDERED HERE IS A
C                             SIMPLE EULER INTEGRATION SCHEME:
C                               Y(T+1)    Y(T) + DELT*DY(T)/DT
C                             WITH
C                               DY(T)/DT = C*Y(T)
C                             SUBROUTINE COMPUTES AND RETURNS
C                                DELN = DELT * C * Y
C                             AND Y(T+1)
C
      REAL*4  N(20),DELT,DELN(20),C(20,20)/400*0.0/,
     1        KN(10,4),THKN(10),KP(5,4),THKP(5),T(4),
     2        NB(20,5),DELNB(20,5),SUM,RELT,FTN(10),FTP(5),
     3        KNC(10),KPC(5)
C
      INTEGER*4  IROW,ICOL,IBLK,IZONE
      IF (IZONE.EQ.1 .OR. IZONE.EQ.2)  GO TO 310
C
C                             TEMPERATURE CORRECTION OF REACTION RATES
C
      IF (T(IZONE) .GE. 35)  GO TO 37
      RELT = T(IZONE) - 35.
      DO 35  J=1,10
         FTN(J) = THKN(J)**RELT
   35 CONTINUE
      DO 36  J=1,5
         FTP(J) = THKP(J)**RELT
   36 CONTINUE
      GO TO 40
   37 DO 38  J=1,10
         FTN(J) = 1.0
   38 CONTINUE
```

```
      DO 39  J=1,5
         FTP(J) = 1.0
39    CONTINUE
C
40    DO 41  J=1,10
         KNC(J) = KN(J,IZONE)*FTN(J)
41    CONTINUE
      DO 42  J=1,5
         KPC(J) = KP(J,IZONE)*FTP(J)
42    CONTINUE
C
C                          DEVELOP COEFFICIENT ARRAY
C
      C(1,1) = -KNC(6)
      C(1,2) = KNC(7)
      C(1,5) = KNC(8)
      C(2,1) = KNC(6)
      C(2,2) = -(KNC(9) + KNC(1) + KNC(7))
      C(2,3) = KNC(10)
      C(3,2) = KNC(9)
      C(3,3) = -(KNC(10) + KNC(1))
      C(4,2) = KNC(1)
      C(4,3) = KNC(1)
      C(4,4) = -(KNC(4) + KNC(2))
      C(4,5) = KNC(3)
      C(5,4) = KNC(2)
      C(5,5) = -(KNC(3) + KNC(5) + KNC(8))
      C(6,4) = KNC(4)
      C(7,5) = KNC(5)
C
      C(11,11) = -KPC(1)
      C(11,12) = KPC(2)
      C(12,11) = KPC(1)
      C(12,12) = -(KPC(2) + KPC(4) + KPC(3))
      C(12,13) = KPC(5)
      C(13,12) = KPC(4)
      C(13,13) = -KPC(5)
      C(14,12) = KPC(3)
C
C                              SOLUTION
C
      DO 200  IROW=1,20
         SUM = 0.0
         DO 100  ICOL=1,20
            SUM = SUM + C(IROW,ICOL)*N(ICOL)
100      CONTINUE
         DELN(IROW) = DELT*SUM
200   CONTINUE
      DO 300  J=1,20
         N(J) = N(J) + DELN(J)
300   CONTINUE
      RETURN
C
C                              FOLLOWING SECTION IS FOR THE BLOCKS
C                              USED IN THE SURFACE AND UPPER ZONE
C
C
C                              TEMPERATURE CORRECTION OF REACTION RATES
C
310   IF (T(IZONE) .GE. 35)  GO TO 370
```

```
              RELT = T(IZONE) - 35.
              DO 350  J=1,10
                 FTN(J) = THKN(J)**RELT
       350    CONTINUE
              DO 360  J=1,5
                 FTP(J) = THKP(J)**RELT
       360    CONTINUE
              GO TO 400
       370    DO 380  J=1,10
                 FTN(J) = 1.0
       380    CONTINUE
              DO 390  J=1,5
                 FTP(J) = 1.0
       390    CONTINUE
       C
       400    DO 410  J=1,10
                 KNC(J) = KN(J,IZONE)*FTN(J)
       410    CONTINUE
              DO 420  J=1,5
                 KPC(J) = KP(J,IZONE)*FTP(J)
       420    CONTINUE
       C
       C                                DEVELOP COEFFICIENT ARRAY
       C
              C(1,1) = -KNC(6)
              C(1,2) = KNC(7)
              C(1,5)   KNC(8)
              C(2,1) = KNC(6)
              C(2,2) = -(KNC(9) + KNC(1) + KNC(7))
              C(2,3) = KNC(10)
              C(3,2) - KNC(9)
              C(3,3) = -(KNC(10) + KNC(1))
              C(4,2) = KNC(1)
              C(4,3) = KNC(1)
              C(4,4) = -(KNC(4) + KNC(2))
              C(4,5) = KNC(3)
              C(5,4) = KNC(2)
              C(5,5) = -(KNC(3) + KNC(5) + KNC(8))
              C(6,4) = KNC(4)
              C(7,5) - KNC(5)
       C
              C(11,11) = -KPC(1)
              C(11,12) = KPC(2)
              C(12,11)   KPC(1)
              C(12,12) = -(KPC(2) + KPC(4) + KPC(3))
              C(12,13)   KPC(5)
              C(13,12) = KPC(4)
              C(13,13) = -KPC(5)
              C(14,12) - KPC(3)
       C
       C                                   SOLUTION
       C
              DO 700  IBLK=1,5
                 DO 500  IROW=1,20
                    SUM = 0.0
                    DO 450  ICOL=1,20
                       SUM = SUM + C(IROW,ICOL)*NB(ICOL,IBLK)
       450          CONTINUE
                    DELNB(IROW,IBLK) = DELT*SUM
       500       CONTINUE
```

```
              DO 600 J=1,20
                 NB(J,IBLK) = NB(J,IBLK) + DELNB(J,IBLK)
      600     CONTINUE
      700  CONTINUE
      C
           RETURN
           END
      C
      C
      C
      C
           SUBROUTINE OUTMON (YEAR)
      C
      C                        THIS SUBROUTINE OUTPUTS MONTHLY
      C                        TABLES, AND ZEROS ACCUMULATIONS
      C
           INTEGER*4  YEAR
      C
      C
           COMMON /ALL/  RU,HYMIN,PRNTKE,HYCAL,DPST,OUTPUT,TIMFAC,LZS,AREA,
          1             RESB1,ROSB,SRGX,INTF,RGX,INFL,UZSB,APERCB,RIB,ERSN,
          2             M,P3,A,CALB,PRCD,PEST,NUTR,ENGL,METR,BOTH,RESB,YES,NO,
          3             IMIN,IHR,TF,JCOUNT,PRINT,INTR,DAYS,HOUR,MNTH
      C
           INTEGER*4   PRNTKE,HYCAL,OUTPUT,TIMFAC,IMIN,IHR,TF,JCOUNT,
          1             CALB,PRCD,ENGL,METR,BOTH,YES,NO,PEST,NUTR
      C
           REAL*4   RU,HYMIN,DPST,LZS,AREA,RESB1(5),ROSB(5),SRGX(5),INTF(5),
          1         RGX(5),INFL(5),UZSB(5),APERCB(5),RIB(5),ERSN(5),RESB(5),
          2         M,P3,A
      C
           COMMON /LAND/ MNAM,PRTOT,ERSNTT,PRTOM,ERSNTM,DAY,
          1 RUTOM,NEPTOM,ROSTOM,RITOM,RINTOM,BASTOM,RCHTOM,RUTOT,
          2 NEPTOT,ROSTOT,RITOT,RINTOT,BASTOT,RCHTOT,TWBAL,EPTOM,EPTOT,
          3 UZS,LZSN,LZSN,INFIL,INTER,IRC,NN,L,SS,SGW1,PR,SGW,GWS,KV,
          4 K24L,KK24,K24EL,EP,IFS,K3,EPXM,RESS1,RESS,SCEP,SCEP1,SRGXT,
          5 SRGXT1,JRER,KRER,JSER,KSER,SRERT,MMPIN,METOPT,SNOW,CCFAC,
          6 SCF,IDNS,F,DGM,WC,MPACK,EVAPSN,MELEV,TSNOW,PETMIN,PETMAX,ELDIF,
          7 DEWX,PACK,DEPTH,MONTH,SDEN,IPACK,TMIN,SUMSNM,PXSNM,XK3,
          8 MELRAM,RADMEM,CDRMEM,CRAINM,CONMEM,SGMM,SNEGMM,SEVAPM,SUMSNY,
          9 PXSNY,MELRAY,RADMEY,CDRMEY,SGMY,CONMEY,CRAINY,SNEGMY,SEVAPY,
          * TSNBAL,COVER,COVRMX,ROBTOM,ROBTOT,RXB,ROITOM,ROITOT,INFTOM,
          1 INFTOT,ERSTOM,ERSTOT,SRER,TEMPX,RAD,WINDX,RAIN,INPUT
      C
           REAL*8   MNAM(12)
      C
           REAL*4   PRTOT,ERSNTT,PRTOM,ERSNTM,RUTOM,RITOM,RINTOM,BASTOM,
          1         RCHTOM,RUTOT,NEPTOT,ROSTOT,RITOT,RINTOT,BASTOT,RCHTOT,
          2         TWBAL,EPTOM,EPTOT,UZS,UZSN,LZSN,INFIL,INTER,IRC,
          3         NN,L,SS,SGW1,PR,SGW,GWS,KV,K24L,KK24,K24EL,EP,IFS,
          4         K3,EPXM,RESS1,RESS,SCEP,SCEP1,SRGXT,SRGXT1,JRER,KRER,
          5         JSER,KSER,SRERT,MMPIN,METOPT,  NEPTOM,ROSTOM,
          6         CCFAC,SCF,IDNS,F,DGM,WC,MPACK,EVAPSN,MELEV,TSNOW,PETMIN,
          7         PETMAX,ELDIF,DEWX,PACK,DEPTH,SDEN,IPACK,TMIN,SUMSNM,
          9         PXSNM,XK3,MELRAM,RADMEM,CDRMEM,CRAINM,SGMM,SNEGMM,SEVAPM,
          A         SUMSNY,PXSNY,MELRAY,RADMEY,CDRMEY,SGMY,CONMEY,
          B         CRAINY,SNEGMY,SEVAPY,TSNBAL,CONMEM,
          C         COVER,COVRMX,ROBTOM(5),ROBTOT(5),RXB(5),ROITOM(5),
          D         ROITOT(5),INFTOM(5),INFTOT(5),ERSTOM(5),ERSTOT(5),
          E         SRER(5),TEMPX(24),RAD(24),WINDX(24),RAIN(288)
```

```
C
       INTEGER*4  DAY,SNOW,MONTH
C
C
       COMMON /PESTC/ STST,SPROTM,SPRSTM,SAST,SCST,SDST,UTST,UAST,UCST,K,
      1 UDST,FP,CMAX,NI,SPROTT,SPRSTT,MUZ,FPUZ,UPRITM,
      2 UPRITT,KGPLB,FPLZ,MLZ,LSTR,LAS,LCS,LDS,GSTR,GAS,GCS,GDS,
      3 APMODE,TPBAL,
      4 DEGSOM,DEGSOT,DEGUOM,
      5 DEGLOT,DEGL,DEGS,NIP,DEGCON,DEGLOM,DEGLOT,NCOM,
      6 PRSTOM,PRSTOT,PROTOM,PROTOT,UPITOM,UPITOT,STS,UTS,SAS,
      7 SCS,SDS,SSTR,UAS,UCS,UDS,USTR,UPRIS,UIST,TOTPAP,TIMAP,YEARAP,
      8 DESORP,SURF,SOIL,SLLG
C
C
       REAL*4  STST,SPROTM,SPRSTM,SAST,SCST,SDST,UTST,UAST,UCST,
      1        K,UDST,FP,CMAX,NI,SPROTT,SPRSTT,MUZ,FPUZ,UPRITM,
      2        UPRITT,KGPLB,FPLG,MLZ,LSTR,LAS,LCS,LDS,GSTR,GAS,
      3        GCS,GDS,TPBAL,DEGSOM,DEGSOT,DEGUOM,DEGUOT,DEGU,DEGS,
      4        NIP,DEGCON,DEGLOM,DEGLOT,NCOM,
      5        PRSTOM(5),PRSTOT(5),PROTOM(5),PROTOT(5),UPITOM(5),
      6        UPITOT(5),STS(5),UTS(5),SAS(5),SCS(5),SDS(5),SSTR(5),
      7        LAS(5),LCS(5),UDS(5),USTR(5),UPRIS(5),UIST
C
       INTEGER*4  APMODE,DESORP,SURF,SOIL,TIMAP,YEARAP
C
       COMMON /NUT/  DELT,STEMP,SN,SNT,SNRSM,SNROM,UN,UNT,UNI,UNIT,
      1        UNRIM,NRSM,LN,LNRPM,GN,SNRBM,UNRBM,LNRBM,GNRBM,TNRBM,
      2        SNRSY,SNROY,UNRIY,NRSY,LNRPY,SNRBY,UNRBY,LNRBY,GNRBY,
      3        TNRBY,TNRHV,TNRHVM,TNRHVY,TNA,TPA,TCLA,
      4        KN,THKN,KP,THKP,NBAL,PHBAL,CLBAL,
      5        TSTEP,NSTEP,SFLG,UFLG,LFLG,GFLG
C
       REAL*4  DELT,STEMP(4,24),
      1        SN(20,5),SNT(20),SNRSM(20,5),SNROM(20,5),
      2        UN(20,5),UNT(20),UNI(20,5),UNIT(20),UNRIM(20,5),
      3        NRSM(20,5),        LN(20),LNRPM(20),         GN(20),
      4        SNRBM(20,5),UNRBM(20,5),LNRBM(20),GNRBM(20),TNRBM(20),
      5        SNRSY(20,5),SNROY(20,5),UNRIY(20,5),NRSY(20,5),
      6        LNRPY(20),SNRBY(20,5),UNRBY(20,5),LNRBY(20),GNRBY(20),
      7        TNRBY(20),TNRHV(20),TNRHVM(20),TNRHVY(20),TNA,TPA,TCLA,
      8        KN(10,4),THKN(10),KP(5,4),THKP(5),NBAL,PHBAL,CLBAL
C
C
       INTEGER*4  TSTEP,NSTEP,SFLG,UFLG,LFLG,GFLG
C
C
C                     HYDROLOGY AND PESTICIDE VARIABLES USED
C                     INTERNALLY
C
       REAL*4  PRT/0.0/,PRTT,PRTTOM(5),PRTTOT(5),DEGTOM,DEGTOT,
      1        DEGT/0.0/,PBAL,COVR,PACKMM,TSNBMM,
      2        UZSMET,LZSMET,SGWMET,SCEPMT,RESSMT,TWBLMT,SRGXTM,
      3        SRRTMT,STSTMT,SASTMT,SCSTMT,SDSTMT,UTSTMT,
      4        UASTMT,UCSTMT,UDSTMT,LSTRMT,LASMET,LCSMET,LDSMET,
      5        GSTRMT,GASMET,GCSMET,GDSMET,DEGTMT,DEGSMT,DEGUMT,
      6        DEGLMT,TPBALM,UZSBMT(5),RESBMT(5),SRGXMT(5),
      7        SRERMT(5),STSMET(5),SASMET(5),SCSMET(5),SDSMET(5),
      8        UTSMET(5),UASMET(5),UCSMET(5),UDSMET(5),UPRISM(5)
C
```

```
C                                 NUTRIENT INTERNAL VARIABLES
C
          REAL*8  CONC, LBPAC/'LB/AC'/, KGPHA/'KG/HA'/
C
          REAL*4  NBALMT,PBALMT,CLBLMT,
         1        SNMET(20,5),SNTMET(20),UNMET(20,5),UNTMET(20),
         2        LNMET(20),GNMET(20),SNRSMT(20),SNROMT(20),
         3        UNRIMT(20),SNRBMT(20),UNRBMT(20),NRSMT(20),
         4        NRSYT(20),SNRSYT(20),SNROYT(20),SNRBYT(20),
         5        UNRIYT(20),UNRBYT(20),UNITMT(20),UNIMET(20,5),
         6        TR(20)/20*0.0/,TNR,TPR,TCLR,TNS,TPS,TCLS,
         7        SLM,SLMS,SUMO,SUMI,SUMB,SUMRS,  CONVF/1.121/
C
C
C
C                         MONTHLY SUMMARY
C
               IF (PEST .EQ. NO)  GO TO 973
C
               DO 1051  I= 1,5
 1051          PRTTCM(I) = PRSTCM(I) + PROTCM(I) + UPITOM(I)
C
C
               DEGTCM = DEGSCM + DEGUOM + DEGLOM
               DEGT = DEGT + DEGTOM
C
                 PRTM = SPRCTM + SPRSTM + UPRITM
               PRT   PRT + PRTM
C
               PBAL = SIST + LTST + LSTR + GSTR + PRT + DEGT - TOTPAP
               IF ((PBAL .LE. 0.0).AND.(PBAL .GE. -0.0009))  PBAL = 0.0
               IF (JCCUNT.LT.TIMAP .AND. YEAR.LE.(YEARAP+1900))  PBAL = 0.0
               TPBAL = TPBAL + PBAL
C
  973          IF (NUTR .EQ. NO)  GO TO 990
C
C                                 COMPUTE MONTHLY NUTRIENT TOTALS BY ZONE,
C                                 ACCUMULATE YEARLY REMOVALS,
C                                 COMPUTE TOTAL N, P, CL MASS BALANCES
C
C                                 SURFACE
          DO 991  J=1,20
             SLMS = 0.0
             SLMO = 0.0
             SLMB = 0.0
             SNT(J) = 0.0
             DO 989  IBLK=1,5
                SLMS = SLMS + SNRSM(J,IBLK)
                SLMO = SLMO + SNROM(J,IBLK)
                SLMB = SLMB + SNRBM(J,IBLK)
                SNT(J) = SNT(J) + SN(J,IBLK)
  989        CONTINUE
             SNRSMT(J) = SLMS/5.
             SNROMT(J) = SLMO/5.
             SNRBMT(J) = SLMB/5.
             SNT(J) = SNT(J)/5.
  991     CONTINUE
C
C                                 UPPER ZONE
C
```

```
      DO 993  J=1,20
         SUMI = 0.0
         SUMB = 0.0
         UNT(J) = 0.0
         UNIT(J) = 0.0
         DO 992  IBLK=1,5
            SUMI = SUMI + UNRIM(J,IBLK)
            SUMB = SUMB + UNRBM(J,IBLK)
            UNT(J) = UNT(J) + UN(J,IBLK)
            UNIT(J) = UNIT(J) + UNI(J,IBLK)
992      CONTINUE
         UNRIMT(J) = SUMI/5.
         UNRBMT(J) = SUMB/5.
         UNT(J) = UNT(J)/5.
         UNIT(J) = UNIT(J)/5.
993   CONTINUE
C
C                           TOTAL REMOVAL TO STREAM
C
      DO 995 J=1,20
         SUMRS = 0.0
         DO 994  IBLK=1,5
            SUMRS = SUMRS + NRSM(J,IBLK)
994      CONTINUE
         NRSMT(J) = SUMRS/5.
995   CONTINUE
C
C                           YEARLY ACCUMULATIONS
C
      DO 997  J=1,20
         DO 996  IBLK=1,5
            SNRSY(J,IBLK) = SNRSY(J,IBLK) + SNRSM(J,IBLK)
            SNRDY(J,IBLK) = SNRDY(J,IBLK) + SNRDM(J,IBLK)
            SNRBY(J,IBLK) = SNRBY(J,IBLK) + SNRBM(J,IBLK)
C
            UNRIY(J,IBLK) = UNRIY(J,IBLK) + UNRIM(J,IBLK)
            UNRBY(J,IBLK) = UNRBY(J,IBLK) + UNRBM(J,IBLK)
C
            NRSY(J,IBLK) = NRSY(J,IBLK) + NRSM(J,IBLK)
996      CONTINUE
         LNRPY(J) = LNRPY(J) + LNRPM(J)
         LNRBY(J) = LNRBY(J) + LNRBM(J)
         GNRBY(J) = GNRBY(J) + GNRBM(J)
         TNRHVY(J) = TNRHVY(J) + TNRHVM(J)
997   CONTINUE
C
C                           MASS BALANCES AND TOTAL REMOVALS
C                           TR(20) = TOTAL REMOVAL OVER SIMULATION PERIOD
C                           TNR = TOTAL NITROGEN REMOVAL
C                           TPR = TOTAL PHOSPHORUS REMOVAL
C                           TCLR = TOTAL CHLORIDE REMOVAL
C                           TNS = TOTAL NITROGEN IN STORAGE
C                           TPS = TOTAL PHOSPHORUS IN STORAGE
C                           TCLS = TOTAL CHLORIDE IN STORAGE
C                           TNA = TOTAL NITROGEN ADDED, AND INITIAL STRG.
C                           TPA = TOTAL PHOSPHORUS ADDED
C                           TCLA = TOTAL CHLORIDE ADDED
C
      DO 503  J=1,20
         SUMB = 0.0
```

```
                  DO 502  IBLK=1,5
                     SUMB = SUMB + NRSM(J,IBLK)
      502         CONTINUE
                  TR(J) = TR(J) + SUMB/5. + TNRHVM(J)
      503      CONTINUE
               TNR = 0.0
               DO 504  J=1,7
                  TNR = TNR + TR(J)
      504      CONTINUE
               TPR = 0.0
               DO 505  J=11,14
                  TPR = TPR + TR(J)
      505      CONTINUE
               TCLR = TR(20)
      C
               TNS = 0.0
               DO 511  J=1,7
                  SUMB = 0.0
                  DO 510  IBLK = 1,5
                     SUMB = SUMB + SN(J,IBLK) + UN(J,IBLK) + UNI(J,IBLK)
      510         CONTINUE
                  TNS = TNS + SUMB/5. + LN(J) + GN(J)
      511      CONTINUE
               NBAL = TNS + TNR - TNA
      C
               TPS = 0.0
               DO 513  J=11,14
                  SUMB = 0.0
                  DO 512  IBLK=1,5
                     SUMB   SUMB + SN(J,IBLK) + UN(J,IBLK) + UNI(J,IBLK)
      512         CONTINUE
                  TPS = TPS + SUMB/5. + LN(J) + GN(J)
      513      CONTINUE
               PBAL - TPS + TPR - TPA
      C
               SUMB = 0.0
               DO 514  IBLK=1,5
                  SUMB = SUMB + SN(20,IBLK) + UN(20,IBLK) + UNI(20,IBLK)
      514      CONTINUE
               TCLS = SUMB/5. + LN(20) + GN(20)
               CLBAL = TCLS + TCLR - TCLA
      C
      C
        999          WRITE (6,1200)  MNAM(MONTH), YEAR
                     WRITE (6,1201)
                     WRITE (6,1103)
      C
               IF (OUTPLT.EQ. METR) GO TO 1053
               WRITE (6,360)
               WRITE (6,362)
               WRITE (6,363) RCETOM, ROSTOM
               WRITE (6,364) INFTOM, RINTOM
               WRITE (6,365) RITOM
               WRITE (6,366) ROITOM, RUTOM
               WRITE (6,380) EASTOM
               WRITE (6,381) ROHTOM
               WRITE (6,361) PRTOM,PRTOM,PRTOM,PRTOM,PRTOM,PRTOM
               IF (SNOW .EQ. NO)  GO TO 1071
               WRITE (6,478) SUMSNM
               WRITE (6,479) FXSNM
```

```
      WRITE (6,480) MELFAM
      WRITE (6,481)
      WRITE (6,482) RACMEM
      WRITE (6,483) CCMMEM
      WRITE (6,484) CCRMEM
      WRITE (6,485) CFAINM
      WRITE (6,486) SGMM
      WRITE (6,487) SMEGMM
      WRITE (6,490) PACK
         COVR = 100.
         IF (PACK .LT. IPACK) COVR = (PACK/IPACK)*100.
         IF (PACK.GT.0.01) GO TO 1078
         COVF=0.0
         SDEN=0.0
 1078 WRITE (6,491) SDEN
      WRITE (6,492) COVF
      WRITE (6,488) SEVAPM
 1071 WRITE (6,367)
      WRITE (6,368) EPTOM,EPTOM,EPTOM,EPTOM,EPTOM,EPTOM
      WRITE (6,369) NEPTOM,NEPTOM,NEPTOM,NEPTOM,NEPTOM,NEPTOM
      WRITE (6,383) COVER
      WRITE (6,370)
      WRITE (6,371) LZSB,UZS
      WRITE (6,372) LZS,LZS,LZS,LZS,LZS,LZS
      WRITE (6,373) SGW,SGW,SGW,SGW,SGW,SGW
      WRITE (6,374) SCEP,SCEP,SCEP,SCEP,SCEP,SCEP
      WRITE (6,375) RESB,RESS
      WRITE (6,376) SRGX,SRGXT
      WRITE (6,377) TWBAL
      IF (SNOW.EQ.YES)  WRITE (6,489) TSNBAL
            WRITE (6,1209)
            WRITE (6,1210) ERSTOM,  ERSNTM
            WRITE (6,1211)  SRER, SRERT
C
            IF (PEST .EQ. NO)  GO TO 974
C
            WRITE (6,1220)
            WRITE (6,1221)  STS, STST
            WRITE (6,1222)  SAS, SAST
            WRITE (6,1223)  SCS, SCST
            WRITE (6,1227) SDS, SDST
            WRITE (6,1224)  UTS, UTST
            WRITE (6,1222)  UAS, UAST
            WRITE (6,1223)  UCS, UCST
            WRITE (6,1227)  UDS, UDST
            WRITE (6,1226)  UPRIS, UIST
            WRITE (6,1228)  LSTR
            WRITE (6,1229)  LAS
            WRITE (6,1230)  LCS
            WRITE (6,1231)  LDS
            WRITE (6,1232)  GSTR
            WRITE (6,1229)  GAS
            WRITE (6,1230)  GCS
            WRITE (6,1231)  GDS
            WRITE (6,1240)  PRTTOM, PRTM
            WRITE (6,1241)  PROTCM, SPROTM
            WRITE (6,1242)  PRSTOM, SPRSTM
            WRITE (6,1243)  UPITOM, UPRITM
            WRITE (6,1248)
            WRITE (6,1245) DEGTOM
```

```
                  WRITE (6,1246) DEGSOM
                  WRITE (6,1247) DEGUOM
                  WRITE (6,1252) DEGLOM
                  WRITE (6,1266) TPBAL
C
  974     IF (NLTR .EQ. NO)  GO TO 1053
C
C                                MONTHLY NUTRIENT OUTPUT
C
       CCNC    LBPAC
       WRITE (6,1092)
       WRITE (6,4000)  CCNC
       WRITE (6,4005)
       WRITE (6,4006)  (SNT(J),J=1,7),(SNT(J),J=11,14),SNT(20)
       WRITE (6,4030) (IBLK,(SN(J,IBLK),J=1,7),(SN(J,IBLK),J=11,14)
      1                ,SN(20,IBLK),   IBLK=1,5)
       WRITE (6,4007)  (UNT(J),J=1,7),(UNT(J),J=11,14),UNT(20)
       WRITE (6,4030) (IBLK,(UN(J,IBLK),J=1,7),(UN(J,IBLK),J=11,14)
      1                ,UN(20,IBLK),   IBLK=1,5)
       WRITE (6,4015)  (UNIT(J),J=1,7),(UNIT(J),J=11,14),UNIT(20)
       WRITE (6,4030) (IBLK,(UNI(J,IBLK),J=1,7),(UNI(J,IBLK),J=11,14),
      1               UNI(20,IBLK),   IBLK=1,5)
       WRITE (6,4008)  (LN(J),J=1,7),(LN(J),J=11,14),LN(20)
       WRITE (6,4009)  (GN(J),J=1,7),(GN(J),J=11,14),GN(20)
C
       WRITE (6,4011)
       WRITE (6,4012)
       WRITE (6,4013)  (SNRSMT(J),J=1,7),(SNRSMT(J),J=11,14),SNRSMT(20)
       WRITE (6,4030) (IBLK,(SNRSM(J,IBLK),J=1,7),
      1               (SNRSM(J,IBLK),J=11,14),
      2               SNRSM(20,IBLK),   IBLK=1,5)
       WRITE (6,4014)  (SNROMT(J),J=1,7),(SNROMT(J),J=11,14),SNROMT(20)
       WRITE (6,4030) (IBLK,(SNROM(J,IBLK),J=1,7),
      1               (SNROM(J,IBLK),J=11,14),
      2               SNROM(20,IBLK),   IBLK=1,5)
       WRITE (6,4015)  (UNRIMT(J),J=1,7),(UNRIMT(J),J=11,14),UNRIMT(20)
       WRITE (6,4030) (IBLK,(UNRIM(J,IBLK),J=1,7),
      1               (UNRIM(J,IBLK),J=11,14),
      2               UNRIM(20,IBLK),   IBLK=1,5)
       WRITE (6,4016)  (NRSMT(J),J=1,7),(NRSMT(J),J=11,14),NRSMT(20)
       WRITE (6,4017)  (LNRPM(J),J=1,7),(LNRPM(J),J=11,14),LNRPM(20)
       WRITE (6,4018)  (TNRBM(J),J=1,7),(TNRBM(J),J=11,14),TNRBM(20),
      1                (SNRBMT(J),J=1,7),(SNRBMT(J),J=11,14),SNRBMT(20),
      2                (UNRBMT(J),J=1,7),(UNRBMT(J),J=11,14),UNRBMT(20),
      3                (LNRBM(J),J=1,7),(LNRBM(J),J=11,14),LNRBM(20),
      4                (GNRBM(J),J=1,7),(GNRBM(J),J=11,14),GNRBM(20)
       WRITE (6,4019)  (TNRHVM(J),J=1,7),(TNRHVM(J),J=11,14),TNRHVM(20)
       WRITE (6,4021)  NBAL, PHBAL, CLBAL
C
C
 1053 IF (CLTFLT.EQ. ENCL) GO TO 1055
C  CONVERSIONS TO METRIC
C  NEW PARAMETERS DEFINED FOR VARIABLES NOT RESET TO ZERO.
C
        PRTCM =PRTCM*MMFIN
        POSTCM=POSTCM*MMFIN
        RINTCM=RINTCM*MMFIN
        RITCM =RITCM*MMFIN
        FLTCM =FLTCM*MMFIN
        BASTCM =BASTCM*MMFIN
```

```
          RCHTCM=RCHTCM*MMPIN
          EPTCM =EPTCM*MMPIN
          NEPTCM =NEPTCM*MMPIN
          LZSMET=LZS*MMPIN
          LZSMET=LZS*MMPIN
          SGWMET=SGW*MMPIN
          SCEPMT=SCEP*MMPIN
          RESSMT=RESS*MMPIN
          TWBLMT=TWBAL*MMPIN
          SRGXTM=SRGXT*MMPIN
C   SEDIMENT
          ERSNTM=ERSNTM*METCPT*2.471
          SRRTMT=SRERT*METCPT*2.471
C   SNOW
          IF (SNOW .EQ. NO)  GO TO 970
          SUMSNM = SUMSNM*MMPIN
          PXSNM    PXSNM*MMPIN
          MELRAM = MELRAM*MMPIN
          RADMEM = RADMEM*MMPIN
          CONMEM = CONMEM*MMPIN
          CDRMEM = CDRMEM*MMPIN
          CRAINM = CRAINM*MMPIN
          SGMM = SGMM*MMPIN
          SNEGMM = SNEGMM*MMPIN
          PACKMM = PACK*MMPIN
          SEVAPM = SEVAPM*MMPIN
          TSNBMM    TSNBAL*MMPIN
C   PESTICIDE
      970 IF (PEST .EQ. NO)  GO TO 975
          STSTMT=STST*KGPLB
          SASTMT=SAST*KGPLB
          SCSTMT=SCST*KGPLB
          SDSTMT=SDST*KGPLB
          LTSTMT=LTST*KGPLB
          LASTMT=LAST*KGPLB
          LCSTMT=LCST*KGPLB
          LDSTMT=LDST*KGPLB
          LIST=LIST*KGPLB
          LSTRMT=LSTR*KGPLB
          LASMET=LAS*KGPLB
          LCSMET=LCS*KGPLB
          LDSMET=LDS*KGPLB
          GSTRMT=GSTR*KGPLB
          GASMET=GAS*KGPLB
          GCSMET=GCS*KGPLB
          GDSMET=GDS*KGPLB
          PRTM  =PRTM*KGPLB
          SPRGTM=SPRGTM*KGPLB
          SPRSTM=SPRSTM*KGPLB
          LPRITM=LPRITM*KGPLB
          DEGTMT=DEGTCM*KGPLB
          DEGSMT=DEGSCM*KGPLB
          DEGUMT=DEGUCM*KGPLB
          DEGLMT=DEGLCM*KGPLB
          TPBALM=TPBAL*KGPLB
C
C ARRAY METRIC MODIFICATIONS
      975 DO 1048 I=1,5
            RCBTCM(I)=RCBTCM(I)*MMPIN
            INFTCM(I)=INFTCM(I)*MMPIN
```

```
                 RCITCM(I)=RCITCM(I)*MMPIN
                 UZSBMT(I)=UZSB(I)*MMPIN
                 RESBMT(I)=RESB(I)*MMPIN
                 SRGXMT(I)=SRGX(I)*MMPIN
                 ERSTCM(I)=ERSTCM(I)*METOPT*2.471
                 SRERMT(I)=SRER(I)*METOPT*2.471
                IF (PEST .EQ. NO)  GO TO 1048
                 STSMET(I)=STS(I)*KGPLB
                 SASMET(I)=SAS(I)*KGPLB
                 SCSMET(I)=SCS(I)*KGPLB
                 SDSMET(I)=SDS(I)*KGPLB
                 LTSMET(I)=LTS(I)*KGPLB
                 UASMET(I)=UAS(I)*KGPLB
                 UCSMET(I)=UCS(I)*KGPLB
                 UDSMET(I)=UDS(I)*KGPLB
                 UPRISM(I)=UPRIS(I)*KGPLB
                 PRTTCM(I)=PRTTCM(I)*KGPLB
                 PROTCM(I)=PROTCM(I)*KGPLB
                 PRSTCM(I)=PRSTCM(I)*KGPLB
                 LPITCM(I)=LPITCM(I)*KGPLB
      1048 CONTINUE
           WRITE (6,460)
           WRITE (6,362)
           WRITE (6,363) RCETCM,ROSTOM
           WRITE (6,364) INFTCM,RINTOM
           WRITE (6,365) RITCM
           WRITE (6,366) RCITCM,RUTOM
           WRITE (6,380) BASTCM
           WRITE (6,381) RCHTCM
           WRITE (6,361) PRTCM,PRTOM,PRTOM,PRTOM,PRTOM,PRTOM
           IF (SNOW .EQ. NO)  GO TO 1089
           WRITE (6,478)  SLPSNM
           WRITE (6,479)  FXSNM
           WRITE (6,480)  MELRAM
           WRITE (6,481)
           WRITE (6,482)  RACMEM
           WRITE (6,483)  CONMEM
           WRITE (6,484)  CCFMEM
           WRITE (6,485)  CRAINM
           WRITE (6,486)  SGMM
           WRITE (6,487)  SNEGMM
           WRITE (6,490)  PACKMM
              COVR = 100.0
              IF (PACK .LT. IPACK)  COVR = (PACK/IPACK)*100.
              IF (PACK .GT. 0.01)  GO TO 1088
              COVR = 0.0
              SCEN = 0.0
      1088 WRITE (6,491)  SCEN
           WRITE (6,492)  COVR
           WRITE (6,488)  SEVAPM
      1089 WRITE (6,367)
           WRITE (6,368) EPTCM,EPTOM,EPTOM,EPTOM,EPTOM,EPTOM
           WRITE (6,369) NEPTCM,NEPTOM,NEPTOM,NEPTOM,NEPTOM,NEPTOM
           WRITE (6,383) COVER
           WRITE (6,370)
           WRITE (6,371) UZSBMT,UZSMET
           WRITE (6,372) LZSMET,LZSMET,LZSMET,LZSMET,LZSMET,LZSMET
           WRITE (6,373) SGWMET,SGWMET,SGWMET,SGWMET,SGWMET,SGWMET
           WRITE (6,374) SCEPMT,SCEPMT,SCEPMT,SCEPMT,SCEPMT,SCEPMT
           WRITE (6,375) RESBMT,RESSMT
```

```
            WRITE (6,376) SRGXMT,SRGXTM
            WRITE (6,377) TNBLMT
            IF (SNCH .EQ. YES)  WRITE (6,489)  TSNBMM
            WRITE (6,1208)
            WRITE (6,1210) ERSTCM,ERSNTM
            WRITE (6,1211) SREPMT,SRRTMT
      C
              IF (PEST .EQ. NO)  GO TO 976
      C
            WRITE (6,1207)
            WRITE (6,1221) STSMET,STSTMT
            WRITE (6,1222) SASMET,SASTMT
            WRITE (6,1223) SCSMET,SCSTMT
            WRITE (6,1227) SDSMET,SDSTMT
            WRITE (6,1224) UTSMET,UTSTMT
            WRITE (6,1222) UASMET,UASTMT
            WRITE (6,1223) UCSMET,UCSTMT
            WRITE (6,1227) UDSMET,UDSTMT
            WRITE (6,1226) UPRISM,UIST
            WRITE (6,1228) LSTRMT
            WRITE (6,1229) LASMET
            WRITE (6,1230) LCSMET
            WRITE (6,1231) LDSMET
            WRITE (6,1232) GSTRMT
            WRITE (6,1229) GASMET
            WRITE (6,1230) GCSMET
            WRITE (6,1231) GDSMET
            WRITE (6,1239) PRTTCM,PRTM
            WRITE (6,1241) PROTCM,SPROTM
            WRITE (6,1242) PRSTCM,SPRSTM
            WRITE (6,1243) UPITCM,UPRITM
            WRITE (6,1249)
            WRITE (6,1245) DEGTMT
            WRITE (6,1246) DEGSMT
            WRITE (6,1247) DEGUMT
            WRITE (6,1252) DEGLMT
            WRITE (6,1266) TPBALM
      C
        976 IF (NUTR .EQ. NO)  GO TO 1055
      C
      C                            CONVF CONVERTS LB/AC TO KG/HA
      C
           DO 520  J=1,20
              SNRSMT(J) = SNFSMT(J)*CONVF
              SNRCMT(J) = SNFCMT(J)*CONVF
              UNRIMT(J) = UNFIMT(J)*CONVF
              NRSMT(J) = NFSMT(J)*CONVF
              LNRFM(J) = LNFFM(J)*CONVF
              TNRBM(J) = TNFBM(J)*CONVF
              SNRBMT(J) = SNFBMT(J)*CONVF
              UNRBMT(J) = UNFBMT(J)*CONVF
              LNRBM(J) = LNFBM(J)*CONVF
              GNRBM(J) = GNFBM(J)*CONVF
              TNRHVM(J) = TNRHVM(J)*CONVF
      C
               SNTMET(J) = SNT(J)*CONVF
               UNTMET(J) = UNT(J)*CONVF
               UNITMT(J) = UNIT(J)*CONVF
               LNMET(J) = LN(J)*CONVF
               GNMET(J) = GN(J)*CONVF
```

```
                DO 519  IBLK=1,5
                    SNRSM(J,IBLK) = SNRSM(J,IBLK)*CONVF
                    SNROM(J,IBLK) = SNROM(J,IBLK)*CONVF
                    UNRIM(J,IBLK) = UNRIM(J,IBLK)*CONVF
      C
                    IF (MYCAL .EQ. CALB)  GO TO 519
                     SNMET(J,IBLK) = SN(J,IBLK)*CONVF
                     UNMET(J,IBLK)   UN(J,IBLK)*CONVF
                     UNIMET(J,IBLK) = UNI(J,IBLK)*CONVF
      519       CONTINUE
      520     CONTINUE
              NBALMT = NBAL*CONVF
              PHBLMT = PHBAL*CONVF
              CLBLMT = CLBAL*CONVF
      C
      C
              CONC = KGPHA
              WRITE (6,1052)
              WRITE (6,4000)  CONC
              WRITE (6,4005)
              WRITE (6,4006)  (SNTMET(J),J=1,7),(SNTMET(J),J=11,14),SNTMET(20)
              WRITE (6,4030) (IBLK,(SNMET(J,IBLK),J=1,7),(SNMET(J,IBLK),J=11,14)
             1               ,SNMET(20,IBLK),  IBLK=1,5)
              WRITE (6,4007)  (UNTMET(J),J=1,7),(UNTMET(J),J=11,14),UNTMET(20)
              WRITE (6,4030) (IBLK,(UNMET(J,IBLK),J=1,7),(UNMET(J,IBLK),J=11,14)
             1               ,UNMET(20,IBLK),  IBLK=1,5)
              WRITE (6,4015)  (UNITMT(J),J=1,7),(UNITMT(J),J=11,14),UNITMT(20)
              WRITE (6,4030)  (IBLK,(UNIMET(J,IBLK),J=1,7),
             1                (UNIMET(J,IBLK),J=11,14),
             2                UNIMET(20,IBLK),  IBLK=1,5)
              WRITE (6,4008)  (LNMET(J),J=1,7),(LNMET(J),J=11,14),LNMET(20)
              WRITE (6,4009)  (GNMET(J),J=1,7),(GNMET(J),J=11,14),GNMET(20)
      C
              WRITE (6,4011)
              WRITE (6,4012)
              WRITE (6,4013)  (SNRSMT(J),J=1,7),(SNRSMT(J),J=11,14),SNRSMT(20)
              WRITE (6,4030) (IBLK,(SNRSM(J,IBLK),J=1,7),
             1               (SNRSM(J,IBLK),J=11,14),
             2               SNRSM(20,IBLK),  IBLK=1,5)
              WRITE (6,4014)  (SNROMT(J),J=1,7),(SNROMT(J),J=11,14),SNROMT(20)
              WRITE (6,4030) (IBLK,(SNROM(J,IBLK),J=1,7),
             1               (SNROM(J,IBLK),J=11,14),
             2               SNROM(20,IBLK),  IBLK=1,5)
              WRITE (6,4015)  (UNRIMT(J),J=1,7),(UNRIMT(J),J=11,14),UNRIMT(20)
              WRITE (6,4030) (IBLK,(UNRIM(J,IBLK),J=1,7),
             1               (UNRIM(J,IBLK),J=11,14),
             2               UNRIM(20,IBLK),  IBLK=1,5)
              WRITE (6,4016)  (NRSMT(J),J=1,7),(NRSMT(J),J=11,14),NRSMT(20)
              WRITE (6,4017)  (LNRPM(J),J=1,7),(LNRPM(J),J=11,14),LNRPM(20)
              WRITE (6,4018)  (TNRBM(J),J=1,7),(TNRBM(J),J=11,14),TNRBM(20),
             1                (SNRBMT(J),J=1,7),(SNRBMT(J),J=11,14),SNRBMT(20),
             2                (UNRBMT(J),J=1,7),(UNRBMT(J),J=11,14),UNRBMT(20),
             3                (LNRBM(J),J=1,7),(LNRBM(J),J=11,14),LNRBM(20),
             4                (GNRBM(J),J=1,7),(GNRBM(J),J=11,14),GNRBM(20)
              WRITE (6,4019)  (TNRHVM(J),J=1,7),(TNRHVM(J),J=11,14),TNRHVM(20)
              WRITE (6,4021)  NBALMT, PHBLMT, CLBLMT
      C
      C                       ZEROING OF VARIABLES
      C
       1055         PRTCM = 0.0
```

```
            RUTCM = 0.0
            NEPTCM = 0.0
            RGSTCM = 0.0
            RITCM = 0.0
            RINTCM = 0.0
            RASTCM = 0.0
            RCHTCM = 0.0
                  EPTCM = 0.0
                  EPSNTM = 0.0
                  PRTM = 0.0
                  SPRCTM = 0.0
                  SPRSTM = 0.0
                  LPRITM = 0.0
                  DEGSCM = 0.0
                  DEGUCM = 0.0
                  DEGLCM = 0.0
            SUMSNM = 0.0
            PXSNM = 0.0
            MELRAM = 0.0
            RADMEM = 0.0
            CDRMEM = 0.0
            CONMEM = 0.0
            CRAINM = 0.0
            SGMM = 0.0
            SNEGMM = 0.0
            SEVAPM = 0.0
      C
                  DO 1058  I=1,5
                     ERSTCM(I) = 0.0
                     RCETCM(I) = 0.0
                     INFTCM(I) - 0.0
                     PRTTCM(I) = 0.0
                     FRCTCM(I) = 0.0
                     PRSTCM(I) = 0.0
                     LPITCM(I) = 0.0
       1058          RCITCM(I)= 0.0
      C
            IF (NUTR .EQ. NO)  GO TO 1060
      C
      C                          ZERO MONTHLY ACCUMULATIONS
      C
            DO 522  J=1,20
               LNRFM(J) = 0.0
               LNREM(J) = 0.0
               GNREM(J) = 0.0
               TNREM(J) = 0.0
               TNRHVM(J) = 0.0
               DO 521  IELK=1,5
                  SNRSM(J,IELK) = 0.0
                  SNRCM(J,IELK) = 0.0
                  LNRIM(J,IELK) = 0.0
                  NRSM(J,IELK) = 0.0
                  SNREM(J,IELK) = 0.0
                  LNREM(J,IELK) = 0.0
      521      CONTINUE
      522   CONTINUE
      C
      1060  RETURN
      C
      C                          FORMATS
```

```
      C
       1092 FORMAT ('0')
       1200 FORMAT ('1',25X,'SUMMARY FOR MONTH OF ',A8,1X,I4)
       1201 FORMAT ('+',25X,'___________________________________')
       1103 FORMAT ('0',34X,'BLOCK 1   BLOCK 2   BLOCK 3   BLOCK 4   BLOCK 5',
           C  5X,'TOTAL')
       1206 FORMAT ('0',8X,'SEDIMENT,TONNES/HECTARE')
       1207 FORMAT ('0',5X,'PESTICIDE, KILOGRAMS')
       1209 FORMAT ('0', 8X,'SEDIMENT, TONS/ACRE')
       1210 FORMAT (' ',11X,'ERODED SEDIMENT     ',5(3X,F7.3),4X,F7.3)
       1211 FORMAT (' ',11X,'FINES DEPOSIT',6X,5(3X,F7.3),4X,F7.3)
       1220 FORMAT ('0',5X,'PESTICIDE, POUNDS')
       1221 FORMAT ('0', 8X,'SURFACE LAYER',9X,5(3X,F7.3),3X,F8.3)
       1222 FORMAT (' ',11X,'ADSORBED',11X,5(3X,F7.3),3X,F8.3)
       1223 FORMAT (' ',11X,'CRYSTALLINE',8X,5(3X,F7.3),3X,F8.3)
       1224 FORMAT ('0', 8X,'UPPER ZONE LAYER',6X,5(3X,F7.3),3X,F8.3)
       1226 FORMAT (' ',11X,'INTERFLOW STORAGE',2X,5(2X,F8.3),3X,F8.3)
       1227 FORMAT (' ',11X,'DISSOLVED',10X,5(3X,F7.3),3X,F8.3)
       1228 FORMAT ('0', 8X,'LOWER ZONE LAYER',59X,F8.3)
       1229 FORMAT (' ',11X,'ADSORBED',64X,F8.3)
       1230 FORMAT (' ',11X,'CRYSTALLINE',61X,F8.3)
       1231 FORMAT (' ',11X,'DISSOLVED',63X,F8.3)
       1232 FORMAT ('0', 8X,'GROUNDWATER LAYER',58X,F8.3)
       1239 FORMAT ('0',8X,'PESTICIDE REMOVAL, KGS.',2X,5(F7.3,3X),F8.3)
       1240 FORMAT ('0', 8X,'PESTICIDE REMOVAL, LBS.',2X,5(F7.3,3X),F8.3)
       1241 FORMAT (' ',11X,'OVERLAND FLOW REMOVAL',1X,5(F7.3,3X),F8.3)
       1242 FORMAT (' ',11X,'SEDIMENT REMOVAL',6X,5(F7.3,3X),F8.3)
       1243 FORMAT (' ',11X,'INTERFLOW REMOVAL',5X,5(F7.3,3X),F8.3)
       1245 FORMAT (' ',11X,'TOTAL',68X,F7.3)
       1246 FORMAT (' ',11X,'FROM SURFACE',61X,F7.3)
       1247 FORMAT (' ',11X,'FROM UPPER ZONE',56X,F7.3)
       1248 FORMAT ('0',8X,'PESTICIDE DEGRADATION LOSS, LBS.')
       1249 FORMAT ('0',8X,'PESTICIDE DEGRADATION LOSS, KGS.')
       1250 FORMAT ('1',25X,'SUMMARY FOR ',I4)
       1252 FORMAT (' ',11X,'FROM LOWER ZONE',56X,F7.3)
       1266 FORMAT ('0',11X,'PESTICIDE BALANCE=',F8.4)
        360 FORMAT ('0',8X,'WATER, INCHES')
        362 FORMAT ('0',11X,'RUNOFF')
        363 FORMAT (' ',14X,'OVERLAND FLOW',5X,5(F8.3,2X),1X,F8.3)
        364 FORMAT (' ',14X,'INTERFLOW',9X,5(F8.3,2X),1X,F8.3)
        365 FORMAT (' ',14X,'IMPERVIOUS',59X,F8.3)
        366 FORMAT (' ',14X,'TOTAL',13X,5(F8.3,2X),1X,F8.3)
        380 FORMAT ('0',11X,'BASE FLOW',63X,F8.3)
        381 FORMAT (' ',11X,'GRDWATER RECHARGE',55X,F8.3)
        361 FORMAT ('0',11X,'PRECIPITATION',6X,5(F7.2,3X),1X,F7.2)
        478 FORMAT (' ',14X,'SNOW',65X,F7.2)
        479 FORMAT (' ',14X,'RAIN ON SNOW',57X,F7.2)
        480 FORMAT (' ',14X,'MELT & RAIN',58X,F7.2)
        481 FORMAT ('0',11X,'MELT')
        482 FORMAT (' ',14X,'RADIATION',60X,F7.2)
        483 FORMAT (' ',14X,'CONVECTION',59X,F7.2)
        484 FORMAT (' ',14X,'CONDENSATION',57X,F7.2)
        485 FORMAT (' ',14X,'RAIN MELT',60X,F7.2)
        486 FORMAT (' ',14X,'GROUND MELT',58X,F7.2)
        487 FORMAT (' ',14X,'CUM NEG HEAT',57X,F7.2)
        490 FORMAT ('0',11X,'SNOW PACK',63X,F7.2)
        491 FORMAT (' ',11X,'SNOW DENSITY',60X,F7.2)
        492 FORMAT (' ',11X,'% SNOW COVER',60X,F7.2)
        488 FORMAT ('0',11X,'SNOW EVAP',63X,F7.2)
        367 FORMAT ('0',11X,'EVAPOTRANSPIRATION')
```

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      368 FORMAT (' ',14X,'POTENTIAL',9X,5(F7.2,3X),1X,F7.2)
      369 FORMAT (' ',14X,'NET',15X,5(F7.2,3X),1X,F7.2)
      363 FORMAT (' ',14X,'CROP COVER',59X,F7.2)
      370 FORMAT ('0',11X,'STORAGES')
      371 FORMAT (' ',14X,'UPPER ZONE',8X,5(F8.3,2X),1X,F8.3)
      372 FORMAT (' ',14X,'LOWER ZONE',8X,5(F8.3,2X),1X,F8.3)
      373 FORMAT (' ',14X,'GROUNDWATER',7X,5(F8.3,2X),1X,F8.3)
      374 FORMAT (' ',14X,'INTERCEPTION',6X,5(F8.3,2X),1X,F8.3)
      375 FORMAT (' ',14X,'OVERLAND FLOW',5X,5(F8.3,2X),1X,F8.3)
      376 FORMAT (' ',14X,'INTERFLOW',9X,5(F8.3,2X),1X,F8.3)
      377 FORMAT ('0',11X,'WATER BALANCE=',F8.4)
      489 FORMAT (' ',11X,'SNOW BALANCE= ',F8.4)
      460 FORMAT ('0',6X,'WATER, MILLIMETERS')
C
C                                   NUTRIENT FORMATS
C
 4000  FORMAT ('0','NUTRIENTS - ',A5,11X,'ORG-N',3X,'NH3-S',3X,'NH3-A',
     1          5X,'NO2',5X,'NO3',6X,'N2',2X,'PLNT-N',3X,'ORG-P',3X,
     2          'PO4-S',3X,'PO4-A',2X,'PLNT-P',6X,'CL')
 4005  FORMAT  ('0',2X,'STORAGE')
 4006  FORMAT  ('0',9X,'SURFACE LAYER',3X,F8.0,6F8.3,F8.0,3F8.3,F8.3)
 4007  FORMAT  ('0',9X,'UPPER ZONE',6X,F8.0,6F8.3,F8.0,3F8.3,F8.3)
 4008  FORMAT  ('0',9X,'LOWER ZONE',6X,F8.0,6F8.3,F8.0,3F8.3,F8.3)
 4009  FORMAT  ('0',9X,'GROUNDWATER',5X,F8.0,6F8.3,F8.0,3F8.3,F8.3)
 4011  FORMAT  ('0',2X,'REMOVAL')
 4012  FORMAT  ('0',6X,'ADVECTIVE')
 4013  FORMAT  ('0',9X,'SEDIMENT',8X,F8.0,6F8.3,F8.0,3F8.3,F8.3)
 4014  FORMAT  ('0',9X,'OVERLAND FLOW',3X,F8.0,6F8.3,F8.0,3F8.3,F8.3)
 4015  FORMAT  ('0',9X,'INTERFLOW',7X,F8.0,6F8.3,F8.0,3F8.3,F8.3)
 4016  FORMAT  ('0',9X,'TOTAL TO STREAM ',F8.0,6F8.3,F8.0,3F8.3,F8.3)
 4017  FORMAT  ('0',9X,'PERCOLATION TO '/,' ',12X, 'GROUNDWATER',2X,
     1           F8.0,6F8.3,F8.0,3F8.3,F8.3)
 4018  FORMAT  ('0',6X,'BIOLOGICAL - TOTAL ',F8.0,6F8.3,F8.0,3F8.3,F8.3,
     1          /,' ',9X,'SURFACE',9X,F8.0,6F8.3,F8.0,3F8.3,F8.3,
     2          /,' ',9X,'UPPER ZONE',6X,F8.0,6F8.3,F8.0,3F8.3,F8.3,
     3          /,' ',9X,'LOWER ZONE',6X,F8.0,6F8.3,F8.0,3F8.3,F8.3,
     4          /,' ',9X,'GROUNDWATER',5X,F8.0,6F8.3,F8.0,3F8.3,F8.3)
 4019  FORMAT  ('0',6X,'HARVEST',12X,F8.0,6F8.3,F8.0,3F8.3,F8.3)
 4021  FORMAT  ('0',3X,'MASS BALANCE',
     1          /,' ',6X,'NITROGEN    = ',F8.3,
     2          /,' ',6X,'PHOSPHORUS = ',F8.3,
     3          /,' ',6X,'CHLORIDE    = ',F8.3)
 4030  FORMAT (' ',12X,'BLOCK',I2,6X,F8.0,6F8.3,F8.0,3F8.3,F8.3)
       END
C
C
C
C
       SUBROUTINE OUTYR (YEAR)
C
C                             THIS SUBROUTINE OUTPUTS YEARLY
C                             TABLES, AND ZEROS ACCUMULATIONS
C
       INTEGER*4  YEAR
C
C
       COMMON /ALL/  RU,MNMIN,PRNTKE,HYCAL,DPST,OUTPUT,TIMFAC,LZS,AREA,
     1            RESB1,ROSB,SRGX,INTF,RGX,INFL,UZSB,APEPCB,RIB,ERSN,
     2            M,P3,A,CALB,PROD,PEST,NUTR,ENGL,METR,BOTH,RESB,YES,NO,
     3            IMIN,IHR,IF,JCOUNT,PRINT,INTR,DAYS,HOUR,MNTH
```

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C
      INTEGER*4  FRNTME,FYCAL,OUTPUT,TIMFAC,IMIN,IHR,TF,JCOUNT,
     1           CALE,FRCC,ENGL,METR,BOTH,YES,NO,PEST,NUTR
C
      REAL*4  RL,FYMIN,CPST,LZS,AREA,RESB1(5),ROSB(5),SRGX(5),INTF(5),
     1        RGX(5),INFL(5),UZSB(5),APERCB(5),RIB(5),ERSN(5),RESB(5),
     2        M,P3,A
C
      COMMON /LAND/ MNAM,PRTOT,ERSNTT,PRTOM,ERSNTM,DAY,
     1 RUTOM,NEPTOM,ROSTOM,RITOM,RINTOM,BASTOM,RCHTOM,RUTOT,
     2 NEPTOT,ROSTOT,RITOT,RINTOT,BASTOT,RCHTOT,TWBAL,EPTOM,EPTOT,
     3 LZS,UZSN,LZSN,INFIL,INTER,IRC,NN,L,SS,SGW1,PR,SGW,GWS,KV,
     4 K24L,KK24,K24EL,EP,IFS,K3,EPXM,RESB1,RESS,SCEP,SCEP1,SRGXT,
     5 SRGXT1,JRER,KRER,JSER,KSER,SRERT,MMPIN,METOPT,SNOW,CCFAC,
     6 SCF,IDNS,F,DGM,WC,MPACK,EVAPSN,MELEV,TSNOW,PETMIN,PETMAX,ELDIF,
     7 DEWX,PACK,DEPTH,MONTH,SDEN,IPACK,TMIN,SUMSNM,PXSNM,XK3,
     8 MELRAM,RADMEM,CDRMEM,CRAINM,CONMEM,SGMM,SNEGMM,SEVAPM,SUMSNY,
     9 PXSNY,MELRAY,RADMEY,CDRMEY,SGMY,CONMEY,CRAINY,SNEGMY,SEVAPY,
     * TSNBAL,COVER,COVRMX,ROBTOM,ROBTOT,RXB,ROITOM,ROITOT,INFTOM,
     1 INFTOT,ERSTOM,ERSTOT,SRER,TEMPX,RAD,WINDX,RAIN,INPUT
C
      REAL*8  MNAM(12)
C
      REAL*4  PRTOT,ERSNTT,PRTOM,ERSNTM,RUTOM,RITOM,RINTOM,BASTOM,
     1        RCHTOM,RUTOT,NEPTOT,ROSTOT,RITOT,RINTOT,BASTOT,RCHTOT,
     2        TWBAL,EPTOM,EPTOT,UZS,UZSN,LZSN,INFIL,INTER,IRC,
     3        NN,L,SS,SGW1,PR,SGW,GWS,KV,K24L,KK24,K24EL,EP,IFS,
     4        K3,EPXM,RESB1,RESS,SCEP,SCEP1,SRGXT,SRGXT1,JRER,KRER,
     5        JSER,KSER,SRERT,MMPIN,METOPT,  NEPTOM,ROSTOM,
     6        CCFAC,SCF,IDNS,F,DGM,WC,MPACK,EVAPSN,MELEV,TSNOW,PETMIN,
     7        PETMAX,ELDIF,DEWX,PACK,DEPTH,SDEN,IPACK,TMIN,SUMSNM,
     9        PXSNM,XK3,MELRAM,RADMEM,CDRMEM,CRAINM,SGMM,SNEGMM,SEVAPM,
     A        SUMSNY,PXSNY,MELRAY,RADMEY,CDRMEY,SGMY,CONMEY,
     B        CRAINY,SNEGMY,SEVAPY,TSNBAL,
     C        COVER,COVRMX,ROBTOM(5),ROBTOT(5),RXB(5),ROITOM(5),
     D        ROITOT(5),INFTOM(5),INFTOT(5),ERSTOM(5),ERSTOT(5),
     E        SRER(5),TEMPX(24),RAD(24),WINDX(24),RAIN(288)
C
      INTEGER*4  DAY,SNOW,MONTH
C
C
      COMMON /PESTC/ STST,SPROTM,SPRSTM,SAST,SCST,SDST,UTST,UAST,UCST,K,
     1 UDST,FP,CMAX,NI,SPROTT,SPRSTT,MUZ,FPUZ,UPRITM,
     2 UPRITT,KGPLB,FPLG,MLZ,LSTR,LAS,LCS,LDS,GSTR,GAS,GCS,GDS,
     3 APMODE,TPBAL,
     4 DEGSOM,DEGSOT,DEGUOM,
     5 DEGUOT,DEGU,DEGS,NIP,DEGCON,DEGLOM,DEGLOT,NCOM,
     6 PRSTOM,PRSTOT,PROTOM,PROTOT,UPITOM,UPITOT,STS,UTS,SAS,
     7 SCS,SDS,SSTR,LAS,UCS,UDS,USTR,UPRIS,UIST,TOTPAP,TIMAP,YEARAP,
     8 DESCRP,SURF,SOIL,SUBS
C
C
      REAL*4  STST,SPROTM,SPRSTM,SAST,SCST,SDST,UTST,UAST,UCST,
     1        K,UDST,FP,CMAX,NI,SPROTT,SPRSTT,MUZ,FPUZ,UPRITM,
     2        UPRITT,KGPLB,FPLG,MLZ,LSTR,LAS,LCS,LDS,GSTR,GAS,
     3        GCS,GDS,TPBAL,DEGSOM,DEGSOT,DEGUOM,DEGUOT,DEGU,DEGS,
     4        NIP,DEGCON,DEGLOM,DEGLOT,NCOM,
     5        PRSTOM(5),PRSTOT(5),PROTOM(5),PROTOT(5),UPITOM(5),
     6        UPITOT(5),STS(5),UTS(5),SAS(5),SCS(5),SDS(5),SSTR(5),
     7        LAS(5),LCS(5),UDS(5),USTR(5),UPRIS(5),UIST
```

```
C
      INTEGER*4  APPCDE,DESORP,SURF,SOIL,TIMAP,YEARAP
C
      COMMON /NUT/  CELT,STEMP,SN,SNT,SNRSM,SNROM,UN,UNT,UNI,UNIT,
     1          UNRIM,NRSM,LN,LNRPM,GN,SNRBM,UNRBM,LNRBM,GNRBM,TNRBM,
     2          SNRSY,SNROY,UNRIY,NRSY,LNRPY,SNRBY,UNRBY,LNRBY,GNRBY,
     3          TNRBY,TNRHV,TNRHVM,TNRHVY,TNA,TPA,TCLA,
     4          KN,THKN,KP,THKP,NBAL,PHBAL,CLBAL,
     5          ISTEP,NSTEP,SFLG,UFLG,LFLG,GFLG
C
      REAL*4  CELT,STEMP(4,24),
     1       SN(20,5),SNT(20),SNRSM(20,5),SNROM(20,5),
     2       UN(20,5),UNT(20),UNI(20,5),UNIT(20),UNRIM(20,5),
     3       NRSM(20,5),        LN(20),LNRPM(20),          GN(20),
     4       SNRBM(20,5),UNRBM(20,5),LNRBM(20),GNRBM(20),TNRBM(20),
     5       SNRSY(20,5),SNROY(20,5),UNRIY(20,5),NRSY(20,5),
     6       LNRPY(20),SNRBY(20,5),UNRBY(20,5),LNRBY(20),GNRBY(20),
     7       TNRBY(20),TNRHV(20),TNRHVM(20),TNRHVY(20),TNA,TPA,TCLA,
     8       KN(10,4),THKN(10),KP(5,4),THKP(5),NBAL,PHBAL,CLBAL
C
C
      INTEGER*4  ISTEP,NSTEP,SFLG,UFLG,LFLG,GFLG
C
C
C                     HYDROLOGY AND PESTICIDE VARIABLES USED
C                     INTERNALLY
C
      REAL*4  PRTT,PRTTOM(5),PRTTOT(5),DEGTOM,DEGTOT,
     1       PBAL,COVF,PACKMY,TSNBMY,
     2       UZSMET,LZSMET,SGWMET,SCEPMT,RESSMT,TWBLMT,SRGXTM,
     3       SRRTMT,STSTMT,SASTMT,SCSTMT,SDSTMT,UTSTMT,
     4       UASTMT,UCSTMT,UDSTMT,LSTRMT,LASMET,LCSMET,LDSMET,
     5       GSTPMT,GASMET,GCSMET,GDSMET,DEGTMT,DEGSMT,DEGUMT,
     6       DEGLMT,TPBALM,UZSBMT(5),RESBMT(5),SRGXMT(5),
     7       SRERMT(5),STSMET(5),SASMET(5),SCSMET(5),SDSMET(5),
     8       UTSMET(5),UASMET(5),UCSMET(5),UDSMET(5),UPRISM(5)
C
C                     NUTRIENT INTERNAL VARIABLES
C
      REAL*8  CONC, LBPAC/'LB/AC'/, KGPHA/'KG/HA'/
C
      REAL*4  NBALMT,PHBLMT,CLBLMT,
     1       SNMET(20,5),SNTMET(20),UNMET(20,5),UNTMET(20),
     2       LNMET(20),GNMET(20),SNRSMT(20),SNROMT(20),
     3       UNRIMT(20),SNRBMT(20),UNRBMT(20),NRSMT(20),
     4       NRSYT(20),SNRSYT(20),SNROYT(20),SNRBYT(20),
     5       UNRIYT(20),UNRBYT(20),UNITMT(20),UNIMET(20,5),
     6       TNR,TPR,TCLR,TNS,TPS,TCLS,
     7       SUM,SUMS,SUMD,SUMI,SUMB,SUMRS,  CONVF/1.121/
C
C                     YEARLY OUTPUT
C
      IF (PEST .EQ. NO)  GO TO 981
         DO 1061  I= 1,5
 1061    PRTTOT(I) = PRSTOT(I) + PROTOT(I) + UPITOT(I)
C
         DEGTOT = DEGSOT + DEGUOT + DEGLOT
C
         PRTT = SPRCTT + SPRSTT + UPRITT
C
```

```
      981    IF (NLTR .EQ. NO)  GO TO 977
             DO 526  J=1,20
                SUMS = 0.0
                SUMO = 0.0
                SUMB = 0.0
                DO 523  IBLK=1,5
                   SUMS = SUMS + SNRSY(J,IBLK)
                   SUMO = SUMO + SNROY(J,IBLK)
                   SUMB = SUMB + SNRBY(J,IBLK)
      523       CONTINUE
                SNRSYT(J) = SUMS/5.
                SNROYT(J) = SUMO/5.
                SNRBYT(J) = SUMB/5.
      C
                SUMI = 0.0
                SUMB = 0.0
                DO 524  IBLK=1,5
                   SUMI = SUMI + UNRIY(J,IBLK)
                   SUMB = SUMB + UNRBY(J,IBLK)
      524       CONTINUE
                UNRIYT(J) = SUMI/5.
                UNRBYT(J) = SUMB/5.
      C
                SUMRS = 0.0
                DO 525  IBLK=1,5
                   SUMRS = SUMRS + NRSY(J,IBLK)
      525       CONTINUE
                NRSYT(J) - SUMRS/5.
      526    CONTINUE
      C
      C
        977     WRITE (6,1250)  YEAR
                WRITE (6,1251)
                WRITE (6,1103)
      C
             IF (OUTPUT.EQ. METR) GO TO 1066
             WRITE (6,360)
             WRITE (6,362)
             WRITE (6,363) RCETOT, ROSTOT
             WRITE (6,364) INFTOT, RINTOT
             WRITE (6,365) RITOT
             WRITE (6,366) RCITOT, RUTOT
             WRITE (6,380) EASTOT
             WRITE (6,381) RCHTOT
             WRITE (6,361) PRTOT,PRTOT,PRTOT,PRTOT,PRTOT,PRTOT
      C
             IF (SNOW .EQ. NO)  GO TO 1072
             WRITE (6,478) SUMSNY
             WRITE (6,479) PXSNY
             WRITE (6,480) MELRAY
             WRITE (6,481)
             WRITE (6,482) RADMEY
             WRITE (6,483) CONMEY
             WRITE (6,484) CORMEY
             WRITE (6,485) CRAINY
             WRITE (6,486) SCMY
             WRITE (6,487) SNEGMY
             WRITE (6,490) PACK
                COVR = 100.
                IF (PACK .LT. IPACK) COVR = (PACK/IPACK)*100.
```

Appendix C (continued)

```
              IF (PACK.GT.0.0) GO TO 1074
              CCVF=0.0
              SDEN=0.0
      1074 WRITE (6,491) SDEN
           WRITE (6,492) CCVF
           WRITE (6,488) SEVAPY
      1072 WRITE (6,367)
           WRITE (6,368) EPTOT,EPTOT,EPTOT,EPTOT,EPTOT,EPTOT
           WRITE (6,369) NEPTOT,NEPTOT,NEPTOT,NEPTOT,NEPTOT,NEPTOT
           WRITE (6,383) COVER
           WRITE (6,370)
           WRITE (6,371) UZSE,UZS
           WRITE (6,372) LZS,LZS,LZS,LZS,LZS,LZS
           WRITE (6,373) SGW,SGW,SGW,SGW,SGW,SGW
           WRITE (6,374) SCEP,SCEP,SCEP,SCEP,SCEP,SCEP
           WRITE (6,375) RESB,RESS
           WRITE (6,376) SRGX,SRGXT
           WRITE (6,377) TWBAL
           IF (SNOW.EQ.YES)  WRITE (6,489) TSNBAL
              WRITE (6,1209)
              WRITE (6,1210) ERSTOT,  ERSNTT
              WRITE (6,1211)  SRER, SRERT
C
                 IF (PEST .EQ. NO)  GO TO 978
C
              WRITE (6,1220)
              WRITE (6,1221)  STS, STST
              WRITE (6,1222)  SAS, SAST
              WRITE (6,1223)  SCS, SCST
              WRITE (6,1227) SDS, SDST
              WRITE (6,1224)  UTS, UTST
              WRITE (6,1222)  UAS, UAST
              WRITE (6,1223)  UCS, UCST
              WRITE (6,1227)  UDS, UDST
              WRITE (6,1226)  UPRIS, UIST
              WRITE (6,1228)  LSTR
              WRITE (6,1229)  LAS
              WRITE (6,1230)  LCS
              WRITE (6,1231)  LDS
              WRITE (6,1232)  GSTR
              WRITE (6,1229)  GAS
              WRITE (6,1230)  GCS
              WRITE (6,1231)  GDS
              WRITE (6,1240)  PRTTOT, PRTT
              WRITE (6,1241)  PRCTOT, SPROTT
              WRITE (6,1242)  PRSTOT, SPRSTT
              WRITE (6,1243)  UPITOT, UPRITT
              WRITE (6,1248)
              WRITE (6,1245) DEGTOT
              WRITE (6,1246) DEGSOT
              WRITE (6,1247) DEGUOT
              WRITE (6,1252) DEGLOT
              WRITE (6,1266) TPBAL
C
       978 IF (NUTR .EQ. NO)  GO TO 1066
C
C                               YEARLY NUTRIENT OUTPUT
C
C
           CCNC = LBPAC
```

```
      WRITE (6,1092)
      WRITE (6,4000)  CONC
C
      WRITE (6,4005)
      WRITE (6,4006)  (SNT(J),J=1,7),(SNT(J),J=11,14),SNT(20)
      WRITE (6,4030) (IBLK,(SN(J,IBLK),J=1,7),(SN(J,IBLK),J=11,14)
     1               ,SN(20,IBLK),   IBLK=1,5)
      WRITE (6,4007)  (UNT(J),J=1,7),(UNT(J),J=11,14),UNT(20)
      WRITE (6,4030) (IBLK,(UN(J,IBLK),J=1,7),(UN(J,IBLK),J=11,14)
     1               ,UN(20,IBLK),   IBLK=1,5)
      WRITE (6,4015)  (UNIT(J),J=1,7),(UNIT(J),J=11,14),UNIT(20)
      WRITE (6,4030) (IBLK,(UNI(J,IBLK),J=1,7),(UNI(J,IBLK),J=11,14),
     1               UNI(20,IBLK),   IBLK=1,5)
      WRITE (6,4008)  (LN(J),J=1,7),(LN(J),J=11,14),LN(20)
      WRITE (6,4009)  (GN(J),J=1,7),(GN(J),J=11,14),GN(20)
C
      WRITE (6,4011)
      WRITE (6,4012)
      WRITE (6,4013)  (SNRSYT(J),J=1,7),(SNRSYT(J),J=11,14),SNRSYT(20)
      WRITE (6,4030) (IBLK,(SNRSY(J,IBLK),J=1,7),
     1               (SNRSY(J,IBLK),J=11,14),
     2               SNRSY(20,IBLK),   IBLK=1,5)
      WRITE (6,4014)  (SNROYT(J),J=1,7),(SNROYT(J),J=11,14),SNROYT(20)
      WRITE (6,4030) (IBLK,(SNROY(J,IBLK),J=1,7),
     1               (SNROY(J,IBLK),J=11,14),
     2               SNROY(20,IBLK),   IBLK=1,5)
      WRITE (6,4015)  (UNRIYT(J),J=1,7),(UNRIYT(J),J=11,14),UNRIYT(20)
      WRITE (6,4030) (IBLK,(UNRIY(J,IBLK),J=1,7),
     1               (UNRIY(J,IBLK),J=11,14),
     2               UNRIY(20,IBLK),   IBLK=1,5)
      WRITE (6,4016)  (NRSYT(J),J=1,7),(NRSYT(J),J=11,14),NRSYT(20)
      WRITE (6,4017)  (LNRPY(J),J=1,7),(LNRPY(J),J=11,14),LNRPY(20)
      WRITE (6,4018)  (TNRBY(J),J=1,7),(TNRBY(J),J=11,14),TNRBY(20),
     1                (SNRBYT(J),J=1,7),(SNRBYT(J),J=11,14),SNRBYT(20),
     2                (UNRBYT(J),J=1,7),(UNRBYT(J),J=11,14),UNRBYT(20),
     3                (LNRBY(J),J=1,7),(LNRBY(J),J=11,14),LNRBY(20),
     4                (GNRBY(J),J=1,7),(GNRBY(J),J=11,14),GNRBY(20)
      WRITE (6,4019)  (TNRHVY(J),J=1,7),(TNRHVY(J),J=11,14),TNRHVY(20)
      WRITE (6,4021)  NBAL, PHBAL, CLBAL
C
C
 1066 IF (CLTPLT .EQ. ENGL) GO TO 1065
C  CONVERSIONS
      PRTOT =PRTOT*MMFIN
      ROSTOT=ROSTOT*MMFIN
      RINTOT=RINTOT*MMFIN
      RITOT =RITOT*MMFIN
      RLTOT =RLTOT*MMFIN
      BASTOT=BASTOT*MMFIN
      RCHTOT=RCHTOT*MMFIN
      EPTOT =EPTOT*MMFIN
      NEPTOT=NEPTOT*MMFIN
      UZSMET=UZS*MMFIN
      LZSMET=LZS*MMFIN
      SGWMET=SGW*MMFIN
      SCEPMT=SCEP*MMFIN
      RESSMT=RESS*MMFIN
      TWBLMT=TWBAL*MMFIN
      SRGXTM=SRGXT*MMFIN
      ERSNTT=ERSNTT*METCPT*2.471
```

```
      SRRTMT=SRERT*METOPT*2.471
C  SNOW
      IF (SNOW .EQ. NO)  GO TO 982
      SLMSNY = SLMSNY*MMPIN
      PXSNY = PXSNY*MMPIN
      MELRAY = MELRAY*MMPIN
      RADMEY = RADMEY*MMPIN
      CONMEY = CONMEY*MMPIN
      CDRMEY = CDRMEY*MMPIN
      CRAINY = CRAINY*MMPIN
      SGMY = SGMY*MMPIN
      SNEGMY = SNEGMY*MMPIN
      PACKMY = PACK*MMPIN
      SEVAPY = SEVAPY*MMPIN
      TSNBMY = TSNBAL*MMPIN
C  PESTICIDE
  982 IF (PEST .EQ. NO)  GO TO 979
      STSTMT=STST*KGPLB
      SASTMT=SAST*KGPLB
      SCSTMT=SCST*KGPLB
      SDSTMT=SDST*KGPLB
      LTSTMT=LTST*KGPLB
      LASTMT=LAST*KGPLB
      LCSTMT=LCST*KGPLB
      LDSTMT=LDST*KGPLB
      LIST=LIST*KGPLB
      LSTRMT=LSTR*KGPLB
      LASMET=LAS*KGPLB
      LCSMET=LCS*KGPLB
      LDSMET=LDS*KGPLB
      GSTRMT=GSTR*KGPLB
      GASMET=GAS*KGPLB
      GCSMET=GCS*KGPLB
      GDSMET=GDS*KGPLB
      PRTT  =PRTT*KGPLB
      SPRCTT=SPRCTT*KGPLB
      SPRSTT=SPRSTT*KGPLB
      UPRITT=UPRITT*KGPLB
      DEGTMT=DEGTCT*KGPLB
      DEGSMT=DEGSCT*KGPLB
      DEGUMT=DEGUCT*KGPLB
      DEGLMT=DEGLCT*KGPLB
      TPBALM=TPBAL*KGPLB
C  METRIC MODIFICATION OF ARRAYS
  979 DO 1062 I=1,5
         RCBTCT(I)=RCBTCT(I)*MMPIN
         INFTCT(I)=INFTCT(I)*MMPIN
         RDITCT(I)=RDITCT(I)*MMPIN
         UZSBMT(I)=UZSB(I)*MMPIN
         RESBMT(I)=RESB(I)*MMPIN
         SRGXMT(I)=SRGX(I)*MMPIN
         ERSTCT(I)=ERSTCT(I)*METOPT*2.471
         SRERMT(I)=SRER(I)*METOPT*2.471
           IF (PEST .EQ. NO)  GO TO 1062
         STSMET(I)=STS(I)*KGPLB
         SASMET(I)=SAS(I)*KGPLB
         SCSMET(I)=SCS(I)*KGPLB
         SDSMET(I)=SDS(I)*KGPLB
         UTSMET(I)=UTS(I)*KGPLB
         UASMET(I)=UAS(I)*KGPLB
```

```
            UCSMET(I)=LCS(I)*KGPLB
            UDSMET(I)=LCS(I)*KGPLB
            UPRISM(I)=LPRIS(I)*KGPLB
            PRTTCT(I)=FFTTCT(I)*KGPLB
            PRCTCT(I)=FRGTCT(I)*KGPLB
            FRSTCT(I)=FRSTCT(I)*KGPLB
            LPITCT(I)=LPITCT(I)*KGPLB
   1062 CONTINUE
C
          WRITE (6,460)
          WRITE (6,362)
          WRITE (6,363) RCBTCT,ROSTOT
          WRITE (6,364) INFTOT,RINTOT
          WRITE (6,365) RITCT
          WRITE (6,366) RCITOT,RUTOT
          WRITE (6,380) BASTOT
          WRITE (6,381) RCHTOT
          WRITE (6,361) FFTCT,PRTOT,PRTOT,PRTOT,PRTOT,PRTOT
          IF (SNOW .EQ. NO)  GO TO 1089
          WRITE (6,478)  SLPSNY
          WRITE (6,479)  FXSNY
          WRITE (6,480)  MELRAY
          WRITE (6,481)
          WRITE (6,482)  FACMEY
          WRITE (6,483)  CCNMEY
          WRITE (6,484)  CCFMEY
          WRITE (6,485)  CRAINY
          WRITE (6,486)  SGMY
          WRITE (6,487)  SNEGMY
          WRITE (6,490)  PACKMY
            COVR = 100.0
            IF (PACK .LT. IPACK)  COVR = (PACK/IPACK)*100.
            IF (PACK .GT. 0.01)  GO TO 1088
            COVR = 0.0
            SDEN - 0.0
   1088 WRITE (6,491)  SDEN
          WRITE (6,492)  COVR
          WRITE (6,488)  SEVAPY
   1089 WRITE (6,367)
          WRITE (6,368) EPTCT,EPTOT,EPTOT,EPTOT,EPTOT,EPTOT
          WRITE (6,369) NEPTOT,NEPTOT,NEPTOT,NEPTOT,NEPTOT,NEPTOT
          WRITE (6,383) COVER
          WRITE (6,370)
          WRITE (6,371) UZSEMT,UZSMET
          WRITE (6,372) LZSMET,LZSMET,LZSMET,LZSMET,LZSMET,LZSMET
          WRITE (6,373) SGWMET,SGWMET,SGWMET,SGWMET,SGWMET,SGWMET
          WRITE (6,374) SCEPMT,SCEPMT,SCEPMT,SCEPMT,SCEPMT,SCEPMT
          WRITE (6,375) RESBMT,RESSMT
          WRITE (6,376) SRGXMT,SRGXTM
          WRITE (6,377) TWBLMT
          IF (SNOW .EQ. YES)  WRITE (6,489)  TSNBMY
          WRITE (6,1208)
          WRITE (6,1210) ERSTCT,ERSNTT
          WRITE (6,1211) SRERMT,SRRTMT
C
           IF (PEST .EQ. NO)  GO TO 980
C
          WRITE (6,1207)
          WRITE (6,1221) STSMET,STSTMT
          WRITE (6,1222) SASMET,SASTMT
```

```
            WRITE (6,1223) SCSMET,SCSTMT
            WRITE (6,1227) SDSMET,SDSTMT
            WRITE (6,1224) UTSMET,UTSTMT
            WRITE (6,1222) UASMET,UASTMT
            WRITE (6,1223) UCSMET,UCSTMT
            WRITE (6,1227) UDSMET,UDSTMT
            WRITE (6,1226) UFRISM,UIST
            WRITE (6,1228) USTRMT
            WRITE (6,1229) UASMET
            WRITE (6,1230) UCSMET
            WRITE (6,1231) UDSMET
            WRITE (6,1232) GSTRMT
            WRITE (6,1229) GASMET
            WRITE (6,1230) GCSMET
            WRITE (6,1231) GDSMET
            WRITE (6,1239) FRITCT,PRTT
            WRITE (6,1241) FFCTCT,SPROTT
            WRITE (6,1242) FFSTCT,SPRSTT
            WRITE (6,1243) UFITCT,UPRITT
            WRITE (6,1245)
            WRITE (6,1245) DEGTMT
            WRITE (6,1246) DEGSMT
            WRITE (6,1247) DEGUMT
            WRITE (6,1252) DEGLMT
            WRITE (6,1266) TFEALM
C
C
  580 IF (NLTF .EQ. NC)  GO TO 1065
C
C                              CONVF CONVERTS LB/AC TO KG/HA
C
      DO 530  J=1,20
         SNRSYT(J) = SNRSYT(J)*CONVF
         SNRDYT(J) = SNRDYT(J)*CONVF
         UNRIYT(J) = UNRIYT(J)*CONVF
         NRSYT(J)  = NRSYT(J)*CONVF
         UNRFY(J) = UNRFY(J)*CONVF
         TNRBY(J) = TNRBY(J)*CONVF
         SNRBYT(J) = SNRBYT(J)*CONVF
         UNRBYT(J) = UNRBYT(J)*CONVF
         UNRBY(J) = UNRBY(J)*CONVF
         GNRBY(J) = GNRBY(J)*CONVF
         TNRHVY(J) = TNRHVY(J)*CONVF
C
          SNTMET(J) = SNT(J)*CONVF
          UNTMET(J) = UNT(J)*CONVF
          UNITMT(J) = UNIT(J)*CONVF
          UNMET(J) = UN(J)*CONVF
          GNMET(J) = GN(J)*CONVF
         DO 529  IBLK=1,5
            SNRSY(J,IBLK) = SNRSY(J,IBLK)*CONVF
            SNROY(J,IBLK) = SNROY(J,IBLK)*CONVF
            UNRIY(J,IBLK) = UNRIY(J,IBLK)*CONVF
C
            IF (HYCAL .EQ. CAL6)  GO TO 529
             SNMET(J,IBLK) = SN(J,IBLK)*CONVF
             UNMET(J,IBLK) = UN(J,IBLK)*CONVF
             UNIMET(J,IBLK) = UNI(J,IBLK)*CONVF
  529    CONTINUE
  530 CONTINUE
```

```
          NEALMT = NEAL*CCNVF
          PHBLMT = PHBAL*CCNVF
          CLBLMT   CLBAL*CCNVF
C
C
          CCNC = KGPHA
          WRITE (6,1C92)
          WRITE (6,40C0)  CCNC
C
          WRITE (6,4CC5)
          WRITE (6,40C6)  (SNTMET(J),J=1,7),(SNTMET(J),J=11,14),SNTMET(20)
          WRITE (6,403C) (IBLK,(SNMET(J,IBLK),J=1,7),(SNMET(J,IBLK),J=11,14)
         1               ,SNMET(20,IBLK),   IBLK=1,5)
          WRITE (6,4CC7)  (UNTMET(J),J=1,7),(UNTMET(J),J=11,14),UNTMET(20)
          WRITE (6,4030) (IBLK,(UNMET(J,IBLK),J=1,7),(UNMET(J,IBLK),J=11,14)
         1               ,UNMET(20,IBLK),   IBLK=1,5)
          WRITE (6,4015)  (UNITMT(J),J=1,7),(UNITMT(J),J=11,14),UNITMT(20)
          WRITE (6,4030)  (IBLK,(UNIMET(J,IBLK),J=1,7),
         1                (UNIMET(J,IBLK),J=11,14),
         2                UNIMET(20,IBLK),   IBLK=1,5)
          WRITE (6,4CC8)  (LNMET(J),J=1,7),(LNMET(J),J=11,14),LNMET(20)
          WRITE (6,40C9)  (GNMET(J),J=1,7),(GNMET(J),J=11,14),GNMET(20)
C
          WRITE (6,4011)
          WRITE (6,4012)
          WRITE (6,4C13)  (SNRSYT(J),J=1,7),(SNRSYT(J),J=11,14),SNRSYT(20)
          WRITE (6,403C) (IBLK,(SNRSY(J,IBLK),J=1,7),
         1               (SNRSY(J,IBLK),J=11,14),
         2               SNRSY(20,IBLK),   IBLK=1,5)
          WRITE (6,4014)  (SNROYT(J),J=1,7),(SNROYT(J),J=11,14),SNROYT(20)
          WRITE (6,4C3C) (IBLK,(SNROY(J,IBLK),J=1,7),
         1               (SNROY(J,IBLK),J=11,14),
         2               SNROY(20,IBLK),   IBLK=1,5)
          WRITE (6,4015)  (UNRIYT(J),J=1,7),(UNRIYT(J),J=11,14),UNRIYT(20)
          WRITE (6,4C3C) (IBLK,(UNRIY(J,IBLK),J=1,7),
         1               (UNRIY(J,IBLK),J=11,14),
         2               UNRIY(20,IBLK),   IBLK=1,5)
          WRITE (6,4C16)  (NRSYT(J),J=1,7),(NRSYT(J),J=11,14),NRSYT(20)
          WRITE (6,4017)  (LNRPY(J),J=1,7),(LNRPY(J),J=11,14),LNRPY(20)
          WRITE (6,4018)  (TNRBY(J),J=1,7),(TNRBY(J),J=11,14),TNRBY(20),
         1                (SNRBYT(J),J=1,7),(SNRBYT(J),J=11,14),SNRBYT(20),
         2                (UNRBYT(J),J=1,7),(UNRBYT(J),J=11,14),UNRBYT(20),
         3                (LNRBY(J),J=1,7),(LNRBY(J),J=11,14),LNRBY(20),
         4                (GNRBY(J),J=1,7),(GNRBY(J),J=11,14),GNRBY(20)
          WRITE (6,4C19)  (TNRHVY(J),J=1,7),(TNRHVY(J),J=11,14),TNRHVY(20)
          WRITE (6,4021)  NEALMT, PHBLMT, CLBLMT
C
C                       ZEROING OF VARIABLES
C
 1065     PRTCT = 0.0
          RUTCT = 0.0
          NEPTCT = 0.0
          ROSTCT = 0.0
          RITOT = 0.0
          RINTCT = 0.0
          EASTCT = 0.0
          RCHTCT = 0.0
             EPTCT = 0.0
             ERSNTT = 0.0
             PRTT = 0.0
```

```
                SPROTT = 0.0
                SPRSTT = 0.0
                UPRITT = 0.0
                DEGSCT = 0.0
                DEGLCT = 0.0
                DEGLCT = 0.0
             SUMSNY = 0.0
             PXSNY = 0.0
             MELRAY = 0.0
             RADMEY = 0.0
             CORMEY = 0.0
             CCNMEY = 0.0
             DRAINY = 0.0
             SGMY = 0.0
             SNEGMY = 0.0
             SEVAPY = 0.0
      C
                DO 1068  I=1,5
                   ERSTCT(I) = 0.0
                   FCBTCT(I) = 0.0
                   INFTCT(I) = 0.0
                   PRTTCT(I) = 0.0
                   FRSTCT(I) = 0.0
                   FRCTCT(I) = 0.0
                   LFITCT(I) = 0.0
       1068        FCITCT(I) = 0.0
      C
             IF (NUTR .EQ. NO)  GO TO 1070
      C
      C                                ZERO YEARLY NUTRIENT ACCUMULATIONS
      C
             DO 534  J=1,20
                LNRFY(J) = 0.0
                LNREY(J) = 0.0
                GNREY(J) = 0.0
                TNREY(J) = 0.0
                TNRFWY(J) = 0.0
                DO 533  IBLK=1,5
                   SNRSY(J,IBLK) = 0.0
                   SNRCY(J,IBLK) = 0.0
                   LNRIY(J,IBLK) = 0.0
                   NRSY(J,IBLK)  = 0.0
                   SNRBY(J,IBLK) = 0.0
                   LNRBY(J,IBLK) = 0.0
      533       CONTINUE
      534    CONTINUE
      C
      1070   RETURN
      C
      C
      C                                FORMATS
      C
       1052 FORMAT ('0')
       1103 FORMAT ('0',34X,'BLOCK 1   BLOCK 2   BLOCK 3   BLOCK 4   BLOCK 5',
           C  5X,'TOTAL')
       1208 FORMAT ('0',8X,'SEDIMENT,TONNES/HECTARE')
       1207 FORMAT ('0',5X,'PESTICIDE, KILOGRAMS')
       1209 FORMAT ('0', 8X,'SEDIMENT, TONS/ACRE')
       1210 FORMAT (' ',11X,'ERODED SEDIMENT    ',5(3X,F7.3),4X,F7.3)
       1211 FORMAT (' ',11X,'FINES DEPOSIT',6X,5(3X,F7.3),4X,F7.3)
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```
      1220 FORMAT ('0',5X,'PESTICIDE, POUNDS')
      1221 FORMAT ('0', 8X,'SURFACE LAYER',9X,5(3X,F7.3),3X,F8.3)
      1222 FORMAT (' ',11X,'ADSORBED',11X,5(3X,F7.3),3X,F8.3)
      1223 FORMAT (' ',11X,'CRYSTALLINE',8X,5(3X,F7.3),3X,F8.3)
      1224 FORMAT ('0', 8X,'UPPER ZONE LAYER',6X,5(3X,F7.3),3X,F8.3)
      1226 FORMAT (' ',11X,'INTERFLOW STORAGE',2X,5(2X,F8.3),3X,F8.3)
      1227 FORMAT (' ',11X,'DISSOLVED',10X,5(3X,F7.3),3X,F8.3)
      1228 FORMAT ('0', 8X,'LOWER ZONE LAYER',59X,F8.3)
      1229 FORMAT (' ',11X,'ADSORBED',64X,F8.3)
      1230 FORMAT (' ',11X,'CRYSTALLINE',61X,F8.3)
      1231 FORMAT (' ',11X,'DISSOLVED',63X,F8.3)
      1232 FORMAT ('0', 8X,'GROUNDWATER LAYER',58X,F8.3)
      1239 FORMAT ('0',8X,'PESTICIDE REMOVAL, KGS.',2X,5(F7.3,3X),F8.3)
      1240 FORMAT ('0', 8X,'PESTICIDE REMOVAL, LBS.',2X,5(F7.3,3X),F8.3)
      1241 FORMAT (' ',11X,'OVERLAND FLOW REMOVAL',1X,5(F7.3,3X),F8.3)
      1242 FORMAT (' ',11X,'SEDIMENT REMOVAL',6X,5(F7.3,3X),F8.3)
      1243 FORMAT (' ',11X,'INTERFLOW REMOVAL',5X,5(F7.3,3X),F8.3)
      1245 FORMAT (' ',11X,'TOTAL',68X,F7.3)
      1246 FORMAT (' ',11X,'FROM SURFACE',61X,F7.3)
      1247 FORMAT (' ',11X,'FROM UPPER ZONE',58X,F7.3)
      1248 FORMAT ('0',8X,'PESTICIDE DEGRADATION LOSS, LBS.')
      1249 FORMAT ('0',8X,'PESTICIDE DEGRADATION LOSS, KGS.')
      1250 FORMAT ('1',25X,'SUMMARY FOR ',I4)
      1251 FORMAT ('+',25X,'_______________')
      1252 FORMAT (' ',11X,'FROM LOWER ZONE',58X,F7.3)
      1266 FORMAT ('0',11X,'PESTICIDE BALANCE=',F8.4)
       360 FORMAT ('0',8X,'WATER, INCHES')
       362 FORMAT ('0',11X,'RUNOFF')
       363 FORMAT (' ',14X,'OVERLAND FLOW',5X,5(F8.3,2X),1X,F8.3)
       364 FORMAT (' ',14X,'INTERFLOW',9X,5(F8.3,2X),1X,F8.3)
       365 FORMAT (' ',14X,'IMPERVIOUS',59X,F8.3)
       366 FORMAT (' ',14X,'TOTAL',13X,5(F8.3,2X),1X,F8.3)
       380 FORMAT ('0',11X,'BASE FLOW',63X,F8.3)
       381 FORMAT (' ',11X,'GRDWATER RECHARGE',55X,F8.3)
       361 FORMAT ('0',11X,'PRECIPITATION',6X,5(F7.2,3X),1X,F7.2)
       478 FORMAT (' ',14X,'SNOW',65X,F7.2)
       479 FORMAT (' ',14X,'RAIN ON SNOW',57X,F7.2)
       480 FORMAT (' ',14X,'MELT & RAIN',58X,F7.2)
       481 FORMAT ('0',11X,'MELT')
       482 FORMAT (' ',14X,'RADIATION',60X,F7.2)
       483 FORMAT (' ',14X,'CONVECTION',59X,F7.2)
       484 FORMAT (' ',14X,'CONDENSATION',57X,F7.2)
       485 FORMAT (' ',14X,'RAIN MELT',60X,F7.2)
       486 FORMAT (' ',14X,'GROUND MELT',58X,F7.2)
       487 FORMAT (' ',14X,'CUM NEG HEAT',57X,F7.2)
       490 FORMAT ('0',11X,'SNOW PACK',63X,F7.2)
       491 FORMAT (' ',11X,'SNOW DENSITY',60X,F7.2)
       492 FORMAT (' ',11X,'% SNOW COVER',60X,F7.2)
       488 FORMAT ('0',11X,'SNOW EVAP',63X,F7.2)
       367 FORMAT ('0',11X,'EVAPOTRANSPIRATION')
       368 FORMAT (' ',14X,'POTENTIAL',9X,5(F7.2,3X),1X,F7.2)
       369 FORMAT (' ',14X,'NET',15X,5(F7.2,3X),1X,F7.2)
       383 FORMAT (' ',14X,'CROP COVER',59X,F7.2)
       370 FORMAT ('0',11X,'STORAGES')
       371 FORMAT (' ',14X,'UPPER ZONE',8X,5(F8.3,2X),1X,F8.3)
       372 FORMAT (' ',14X,'LOWER ZONE',8X,5(F8.3,2X),1X,F8.3)
       373 FORMAT (' ',14X,'GROUNDWATER',7X,5(F8.3,2X),1X,F8.3)
       374 FORMAT (' ',14X,'INTERCEPTION',6X,5(F8.3,2X),1X,F8.3)
       375 FORMAT (' ',14X,'OVERLAND FLOW',5X,5(F8.3,2X),1X,F8.3)
       376 FORMAT (' ',14X,'INTERFLOW',9X,5(F8.3,2X),1X,F8.3)
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      377 FORMAT ('0',11X,'WATER BALANCE=',F8.4)
      489 FORMAT (' ',11X,'SNOW BALANCE= ',F8.4)
      460 FORMAT ('0',8X,'WATER, MILLIMETERS')
C
C                               NUTRIENT FORMATS
C
 4000  FORMAT ('0','NUTRIENTS - ',A5,11X,'ORG-N',3X,'NH3-S',3X,'NH3-A',
     1          5X,'NO2',5X,'NO3',6X,'N2',2X,'PLNT-N',3X,'ORG-P',3X,
     2          'PO4-S',2X,'PO4-A',2X,'PLNT-P',6X,'CL')
 4005  FORMAT  ('0',3X,'STORAGE')
 4006  FORMAT  ('0',5X,'SURFACE LAYER',3X,F8.0,6F8.3,F8.0,3F8.3,F8.3)
 4007  FORMAT  ('0',5X,'UPPER ZONE',6X,F8.0,6F8.3,F8.0,3F8.3,F8.3)
 4008  FORMAT  ('0',5X,'LOWER ZONE',6X,F8.0,6F8.3,F8.0,3F8.3,F8.3)
 4009  FORMAT  ('0',5X,'GROUNDWATER',5X,F8.0,6F8.3,F8.0,3F8.3,F8.3)
 4011  FORMAT  ('0',3X,'REMOVAL')
 4012  FORMAT  ('0',6X,'ADVECTIVE')
 4013  FORMAT  ('0',9X,'SEDIMENT',8X,F8.0,6F8.3,F8.0,3F8.3,F8.3)
 4014  FORMAT  ('0',9X,'OVERLAND FLOW',3X,F8.0,6F8.3,F8.0,3F8.3,F8.3)
 4015  FORMAT  ('0',9X,'INTERFLOW',7X,F8.0,6F8.3,F8.0,3F8.3,F8.3)
 4016  FORMAT  ('0',9X,'TOTAL TO STREAM ',F8.0,6F8.3,F8.0,3F8.3,F8.3)
 4017  FORMAT  ('0',9X,'PERCOLATION TO '/,' ',12X, 'GROUNDWATER',2X,
     1          F8.0,6F8.3,F8.0,3F8.3,F8.3)
 4018  FORMAT  ('0',6X,'BIOLOGICAL - TOTAL ',F8.0,6F8.3,F8.0,3F8.3,F8.3,
     1          /,' ',9X,'SURFACE',9X,F8.0,6F8.3,F8.0,3F8.3,F8.3,
     2          /,' ',9X,'UPPER ZONE',6X,F8.0,6F8.3,F8.0,3F8.3,F8.3,
     3          /,' ',9X,'LOWER ZONE',6X,F8.0,6F8.3,F8.0,3F8.3,F8.3,
     4          /,' ',9X,'GROUNDWATER',5X,F8.0,6F8.3,F8.0,3F8.3,F8.3)
 4019  FORMAT  ('0',6X,'HARVEST',12X,F8.0,6F8.3,F8.0,3F8.3,F8.3)
 4021  FORMAT  ('0',3X,'MASS BALANCE',
     1          /,' ',6X,'NITROGEN    = ',F8.3,
     2          /,' ',6X,'PHOSPHORUS  = ',F8.3,
     3          /,' ',6X,'CHLORIDE    = ',F8.3)
 4030  FORMAT (' ',12X,'BLOCK',I2,6X,F8.0,6F8.3,F8.0,3F8.3,F8.3)
C
       END
/*
//LKED.SYSLMOD DD DSNAME=C510.DCB.J7508.ARM6A,DISP=(NEW,KEEP),
//                SPACE=(TRK,(50,2,1),RLSE),UNIT=2314,VOL=SER=FILED
//LKED.SYSIN DD *
    NAME  ARM
/*
```

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

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2.

3. RECIPIENT'S ACCESSION NO.

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7. AUTHOR(S)
Anthony S. Donigian, Jr., and Norman H. Crawford

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13. TYPE OF REPORT AND PERIOD COVERED Final

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15. SUPPLEMENTARY NOTES

16. ABSTRACT

Modifications, testing, and further development of the Pesticide Transport and Runoff (PTR) Model have produced the Agricultural Runoff Management (ARM) Model. The ARM Model simulates runoff, snow accumulation and melt, sediment loss, pesticide-soil interactions, and soil nutrient transformations on small agricultural watersheds. The report discusses the major modifications to and differences between the PTR and ARM Models. An energy-balance method of snow simulation, and a first-order transformation approach to nutrient modeling are included. Due to lack of data, the nutrient model was not tested with observed data; testing and refinement are expected to begin in the near future.

Instrumented watersheds in Georgia provided data for testing and refinement of the runoff, sediment and pesticide portions of the ARM Model. Comparison of simulated and recorded values indicated good agreement for runoff and sediment loss, and fair to good agreement for pesticide loss. Pesticides transported only by sediment particles were simulated considerably better than pesticides that move both in solution and on sediment. A sensitivity analysis of the ARM Model parameters demonstrated that soil moisture and infiltration, land surface sediment transport, pesticide-soil interactions, and pesticide degradation are the critical mechanisms in simulating pesticide loss from agricultural watersheds.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Simulation, Runoff, Hydrology, Soil erosion, Nitrogen, Phosphorus, Snowmelt, Watersheds, Pesticides	Agricultural runoff, Hydrologic modeling, Pollutant pathways, Nitrogen compounds, Phosphorus compounds, Snowpacks, Small watersheds	12A 2A 6F 8H

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