WRC Research Report No. 211

HYDROLOGY AND SEDIMENTOLOGY MODELING ON ILLINOIS AGRICULTURAL WATERSHEDS

by

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Project No. G-1420-04

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January 1989

The work on which this report is based was supported in part by funds provided by the United States Department of the Interior as authorized under the Water Resources Research Act of 1984. The contents of this report do not necessarily reflect the views and policies of the U.S. Department of the Interior, nor does mention of trade names or commercial products constitute their endorsement by the United States Government.

ABSTRACT

The CREAMS (Chemicals, Runoff and Erosion from Agricultural Management Systems) model was evaluated for predicting runoff and sediment delivery from central Illinois fields without calibration. CREAMS was found to be fairly accurate in predicting annual runoff and sediment delivery, if parameter values were based on the best available information. The violation of the assumption of applying CREAMS to fields having uniform characteristics, was not critical if weighted averages for parameter values were used in expressing the variability of a field. The effect of variations in parameter values on runoff and sediment delivery predicted by CREAMS was determined. This analysis identified the parameters whose values must be accurately chosen so that CREAMS can produce accurate results. The parameters related to infiltration, sheet and rill erosion, soil detachment capacity by concentrated flow, and sediment transport by overland and concentrated flow were found to produce the most variation in the prediction of runoff and sediment delivery by CREAMS.

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HYDROLOGY AND SEDIMENTOLOGY MODELING ON ILLINOIS AGRICULTURAL WATERSHEDS
Final Project Report, Water Resources Center, University of Illinois, January, 1989, Urbana, Illinois, 22p.

KEYWORDS -- simulation analysis/ model testing/ computer models/ land management/ watershed management/ sediment yield/ water pollution sources/ agricultural runoff

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INTRODUCTION

Soil erosion resulting from agricultural practices in the United States has been a serious problem since the formation of this nation (Pimental et al., 1976). The problem exists not only from the detrimental effects of erosion on soils, resulting in poor crop growth and poor economic returns, but also from the harmful effects on bodies of water receiving sediment from erosion. Sediment has been recognized as being a major pollutant of surface waters because of its large volume and because it is widespread (Novotny and Chesters, 1981). In addition to the harm caused by sediment, it also carries nutrients and toxicants that pollute the surface waters (Mulkey and Falco, 1977).

The problems caused by soil erosion can be minimized by adopting agricultural management practices, often called best management practices (BMPs), which reduce the susceptibility of land to the erosive forces of wind and water, and which reduce the removal of sediment from land to water bodies. Many BMPs have been proposed and are currently being used, but their effects and usefulness have not been adequately determined.

There is a high priority need on soil productivity/water quality--methods to analyze the impact of agricultural management systems for the humid regions of the United States, according to the Soil and Water Resources: Research Priorities for the Nation - Executive Summary (Van Doren et al., 1981). It is stated: "New knowledge and improved models of soil erosion; crop growth; and movement of water, sediment and chemicals over and through the soil are needed to evaluate alternative management strategies for their potential impact on both short- and long-term soil productivity and off-site water quality."

The proposed objective for this project was to evaluate and verify the hydrology and sedimentology components of two models, MODANSW and CREAMS, for the distributed modeling of those processes and their interactions on small agricultural watersheds in central Illinois. Evaluation and verification of these modeled processes for central Illinois conditions will further the effort of developing a comprehensive management-strategies analysis model.

CREAMS and MODANSW were developed from criteria that are important for analyses of erosion/sediment delivery on agricultural lands in central Illinois. CREAMS, as a field-scale model, can best be used to evaluate the long-term effects of BMPs at the location where they are applied. MODANSW, as a distributed watershed-scale model, can best be used to evaluate the effects of BMPs on the production of sediment from a watershed by individual storm events. While neither of these models considers all factors that are important to management decisions, future models will use components based on the criteria from both models.

The accomplished objectives are different than the proposed objective in that the MODANSW model was not evaluated. MODANSW is a modified version of the ANSWERS model (Beasley et al., 1980). It was developed by replacing the erosion/sediment delivery component, a rill and interrill representation, of the ANSWERS model with a splash and flow erosion representation. Since the development and initial limited evaluation of MODANSW, extensive advances have been made in the development of the parent ANSWERS model, so many advances that it seemed futile to perform a detailed analysis of the entire MODANSW model since it is unlikely that this model will receive much attention in the future while being in the shadow of ANSWERS. Therefore, efforts were directed solely to the analysis of the CREAMS model.

The accomplished objectives of this project were: (1) to evaluate the use of the CREAMS model as an uncalibrated model for determining the effects of agricultural management practices on runoff and sediment delivery from agricultural fields in central Illinois; and (2) to perform a sensitivity analysis of selected parameters of the model to identify critical parameters that have the greatest effect on the model results, and thereby identify parameters whose values must be carefully selected to obtain accurate predictions.

PROCEDURE

CREAMS Model

CREAMS (Chemicals, Runoff and Erosion from Agricultural Management Systems) was developed by the Science and Education Administration-Agricultural Research, an agency of the U.S. Department of Agriculture, as a comprehensive model of runoff, percolation, erosion, and plant nutrient and pesticide losses (Knisel, 1980). The model was developed with four objectives in mind: (1) to be physically based, thereby not requiring calibration for specific applications; (2) to be simple and easy to use while remaining a fairly accurate representation of the physical system; (3) to be capable of estimating annual values of runoff, percolation, erosion, and dissolved and adsorbed plant nutrients and pesticide losses; and (4) to be able to distinguish between different agricultural management practices.

CREAMS has three components: hydrology, erosion/sedimentation, and chemical transport. Evaluation and sensitivity analysis were conducted on the hydrology and erosion/sedimentation components. However, the third component, chemical transport, was not evaluated because there were no observed data to compare with the predictions of this component.

The hydrology component has two options: one to be used with daily rainfall data and another to be used with hourly or breakpoint rainfall data. The daily rainfall option uses the SCS curve number model for partitioning runoff and infiltration, while the second option uses a two-staged Green and Ampt infiltration model. Peak runoff rates are estimated using kinematic flow equations solved by the method of characteristics. Also modeled are percolation from the plant root zone, soil and plant evaporation, and plant transpiration.

The erosion/sedimentation component utilizes the results of the hydrology component to compute erosion and sedimentation for overland flow, channel flow, and impoundments. Erosion for the overland flow elements is computed using a modified Universal Soil Loss Equation (USLE). A detachment relationship based on flow shear stress is used to compute channel erosion. The Yalin sediment transport equation is used to compute the sediment transport capacity of runoff. Sedimentation is computed according to the fall velocity of sediment size classes. An accounting procedure is used in determining the sources of sediment that fill the transport capacity of the flow within the various flow elements. Sediment movement is routed through each successive flow element using a continuity of mass equation.

Allerton Watersheds

CREAMS was used to model the hydrology and sedimentology of two watersheds with nested subwatersheds located southwest of Monticello, Illinois, on the University of Illinois' Allerton Farms. The two watersheds, IA and IB (Fig. 1), are mildly sloping and have been row cropped. Watershed IA has an area of 80.3 acres with three nested watersheds: IA1 (30.5 acres), IA2 (18.4 acres), and IA3 (4.0 acres). Watershed IB has an area of 44.8 acres with two nested subwatersheds: IB1 (33.0 acres) and IB2 (25.2 acres). Specific characteristics of the watersheds are presented in the section on Input Data Requirements. Observed data obtained from the watersheds are described in Appendix D.

Input Data Requirements

Hydrology component. Input data required for the hydrology component of CREAMS include rainfall data in either daily amounts for option 1 or in hourly or breakpoint amounts for option 2. Also required are values for various parameters that represent watershed geometry, soil characteristics, weather, and crop characteristics, and values for simulation control.

The rainfall data used by CREAMS can be either measured data or synthetic data. Measured data can come from either NOAA weather stations, which are located close to the watershed, or from raingages installed on or near the watersheds. Rainfall data measured near the watersheds by the University of Illinois Department of Agricultural Engineering were used in this study. Option 2 of the hydrology component was used in all simulations. A summary of the breakpoint data measured at the Allerton watersheds is given in Table 1. The full breakpoint data set is given in Appendix A.

Table 1. Rainfall data summary

Year	No. of storms	Volume (inches)			Duration (hours)	
		Total	Mean	Range	Mean	Range
1980	67	29.62	0.442	0.02-1.79	8.48	0.07-32.04
1981	69	52.01	0.754	0.03-4.43	11.56	0.05-41.43
1982	93	47.57	0.512	0.02-5.26	9.98	0.01-33.52
1983	64	38.46	0.601	0.02-4.91	8.95	0.11-31.26

The parameters that CREAMS uses to describe the watershed geometry are drainage area, effective hydrologic slope, and effective hydrologic slope length. The values of these parameters were determined from a topographic map (scale: 1 inch = 150 feet) drawn with a 2-feet contour interval. These

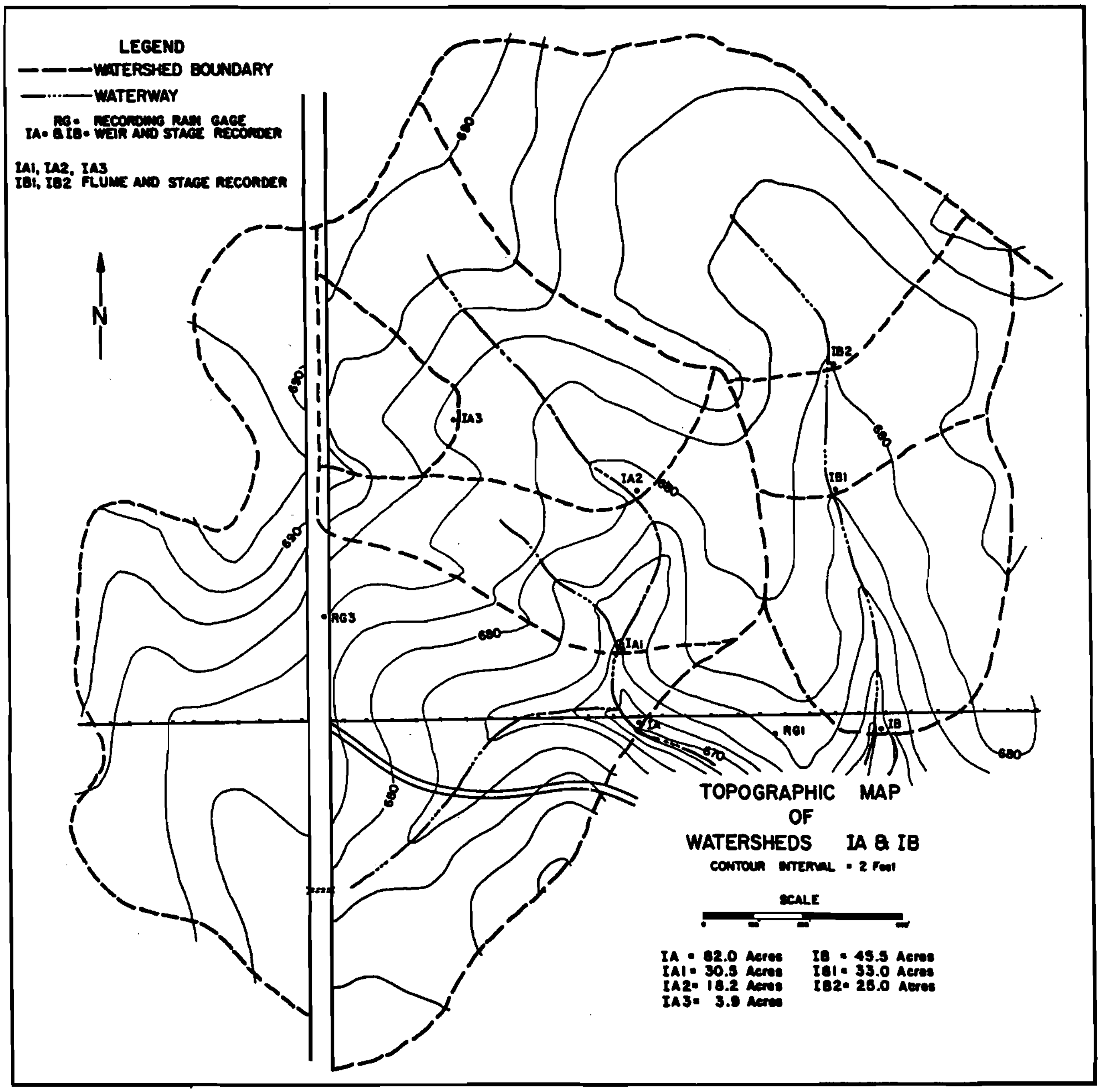

Figure 1. Topographic map of Allerton watersheds IA and IB.

parameter values for each of the seven watersheds and a brief description of how they were obtained are given in Appendix B.

Soil types of the watersheds are Drummer silty clay loam, Flanagan silt loam, Thorp silt loam and Sunbury silt loam (Fig. 2). The composition of each watershed is given in Table 2. CREAMS describes a soil by parameters for saturated hydraulic conductivity, fraction of pore space filled at field capacity, soil evaporation parameter, soil porosity, wilting point soil water content, depth of surface soil layer, and effective capillary tension of soil. Parameter values were obtained from the Soils-5 informational database developed by the U.S. Department of Agriculture, Wascher et al (1950), and from Holtan et al (1968). The first two sources provided information about the general soil types, while the Holtan publication provided information about the specific soils found on the watersheds. The parameter values for the seven watersheds and a brief description of how they were determined are given in Appendix B.

Table 2. Soil types and component areas of the Allerton watersheds

	Watershed						
	IA3	IA2	IA1	IA	IB2	IB1	IB
Soil type	Area (acres)						
Drummer silty clay loam	0.37	3.15	5.46	13.23	10.50	13.79	16.34
Flanagan silt loam	3.58	15.11	25.15	58.13	14.71	19.17	22.94
Thorp silt loam	0	0	0	0	0	0	1.67
Sunbury silt loam	0	0	0	9.18	0	0	3.89

Weather in the hydrology component of CREAMS is represented by temperature and solar radiation. Average daily air temperatures for the watersheds were obtained from two sources: weather stations, operated by the National Oceanic and Atmospheric Administration (1980, 1981, 1982, 1983), that are located near the watersheds; and from a recording weather station, operated by the University of Illinois Department of Agricultural Engineering, that is located on the watersheds. Average monthly solar radiation was obtained from Changnon (1959) and from the U.S. Department of Commerce (1968). The data that were used in the simulations are given in Appendix B.

Conditions resulting from the crops grown on the watersheds are characterized in CREAMS by the following parameters: depth of maximum root growth layer, Manning's "n" for overland flow, winter cover factor, and leaf area index for crop growth. The values of these parameters were determined from cropping records and tables of parameter values found in the CREAMS users guide (Soil Conservation Service, 1984). The fields situated in the watersheds and the crops grown in these fields are shown in Figure 3 and cropping areas for the watersheds are given in Table 3. Parameter values for the seven watersheds and how they were obtained are given in Appendix B.

Several parameters are required by the hydrology component of CREAMS to control the simulation for specific conditions. These parameters allow the user to identify the simulation, specify the type of output to receive, select

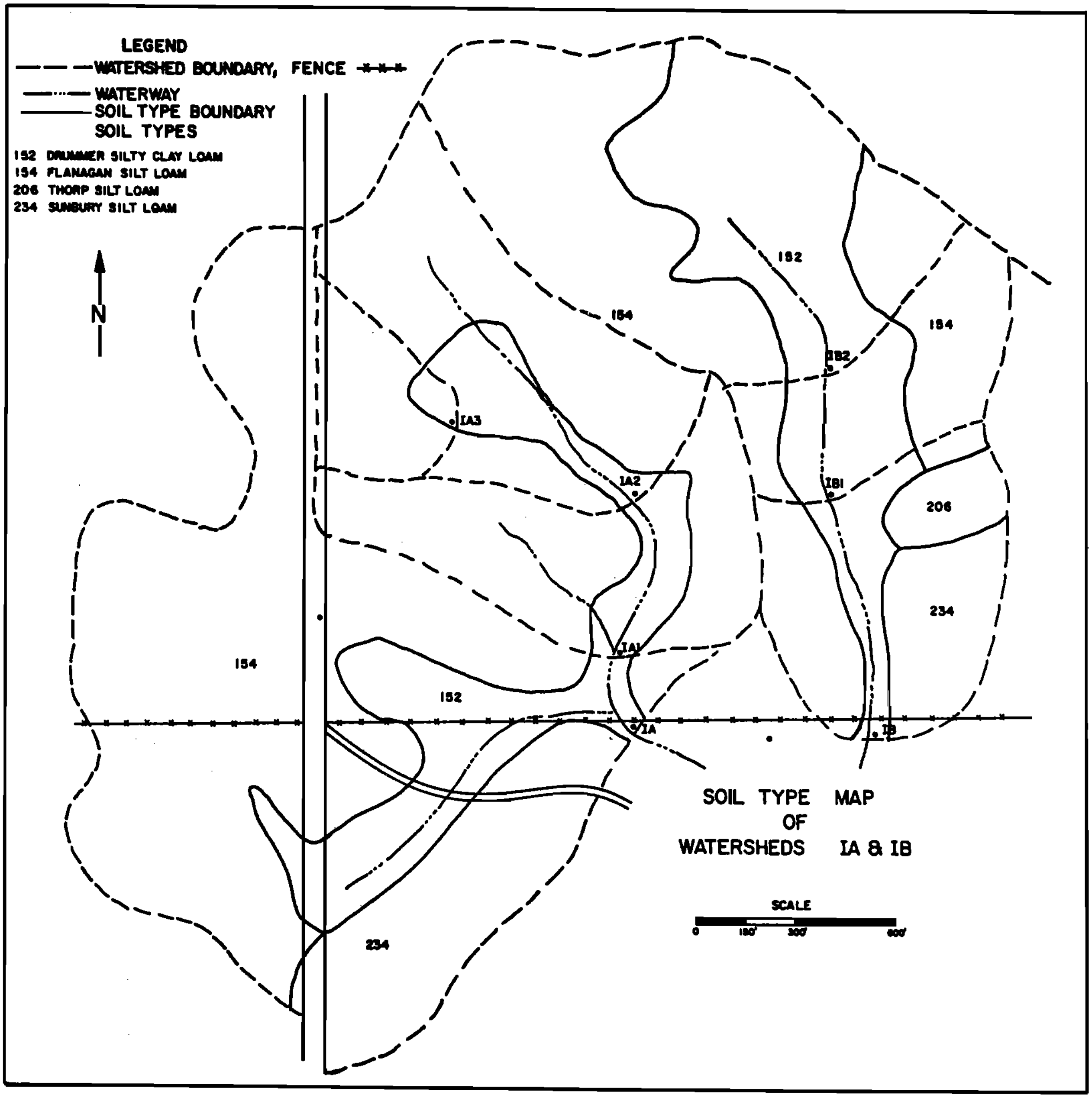

Figure 2. Soil type map of Allerton watersheds IA and IB.

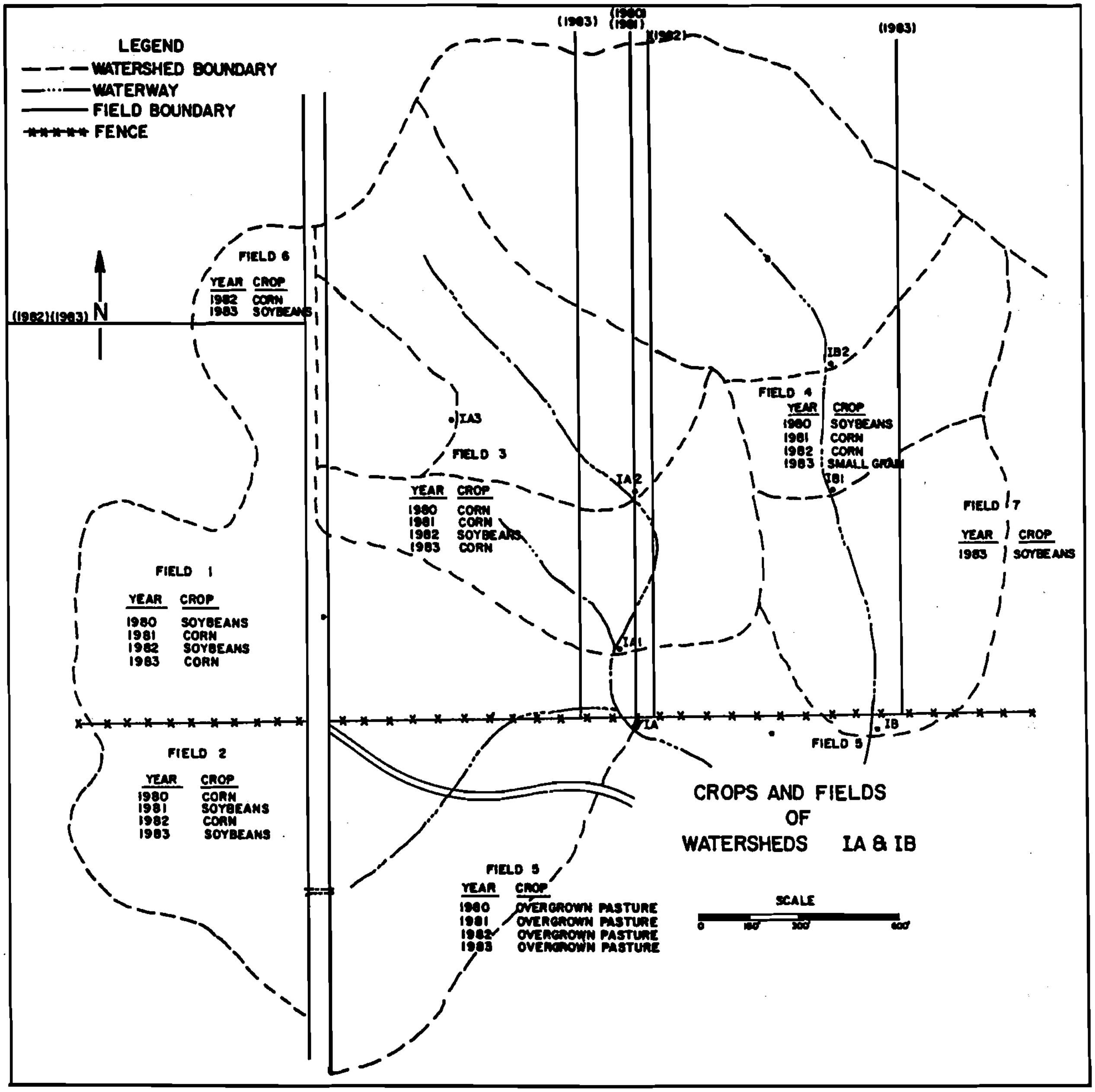

Figure 3. Crops and fields map of Allerton watersheds IA and IB.

the rainfall data option, and direct the reading of input data. The parameter values used for the simulations of the seven watersheds are given in Appendix B.

Table 3. Cropping areas of the Allerton watersheds

		Crop			
		Corn	Soybeans	Overgrown pasture	Small grain
Watershed	Year			Area (acres)	
IA3	1980	4.0			
	1981	4.0			
	1982		4.0		
	1983	4.0			
IA2	1980	16.7	1.6		
	1981	18.3			
	1982	1.0	17.3		
	1983	14.6			3.7
IA1	1980	23.7	6.8		
	1981	30.5			
	1982	5.7	24.8		
	1983	20.1			10.4
IA	1980	42.4	23.2	14.7	
	1981	55.1	10.5	14.7	
	1982	18.8	46.8	14.7	
	1983	41.0	12.7	14.7	11.9
IB2	1980	8.5	16.6		
	1981	25.1			
	1982	15.6	9.5		
	1983	5.4	1.1		18.6
IB1	1980	8.5	24.5		
	1981	33.0			
	1982	9.5	23.5		
	1983	5.4	4.9		22.7
IB	1980	8.5	36.0	0.4	
	1981	44.5		0.4	
	1982	34.9	9.6	0.4	
	1983	5.4	10.5	0.4	28.6

Erosion/sedimentation component. Input data required for the erosion/sedimentation component of CREAMS are hydrology characteristics generated by the hydrology components and values of parameters that represent watershed configuration, soil and sediment characteristics, erosion and sediment transport, and parameters for simulation control. The hydrology input data can be either measured data or data generated by the hydrology component.

The hydrology component was used in all simulations to generate the hydrology input data.

The erosion/sedimentation component considers erosion/deposition and sediment transport on sequences of various combinations of an overland flow element with channel flow elements and an impoundment element. The physical characteristics of these elements are described to CREAMS using parameters for Manning's "n" for each element, drainage areas, slope length, slope profile, channel shape and geometry, and flow characteristics. Values for these parameters were determined based on the topographic map (Fig. 1) of the watersheds and from tables of parameter values provided in the CREAMS users manual (Soil Conservation Service, 1984). Parameter values used for the simulations of the seven watersheds and a brief description of how they were determined are given in Appendix C.

The soil and sediment characteristics are described by parameters for soil density, soil erodibility, soil and sediment particle size distributions and specific surface areas, and depth to the nonerodible layer along a channel. The values of these parameters were determined from the soil type descriptions and tables of parameter values provided in the CREAMS user manual (Soil Conservation Service, 1984). Parameter values used for the simulations of the seven watersheds and a brief description of how they were determined are given in Appendix C.

Erosion/deposition and sediment transport characteristics of the watershed soils are represented by parameters for sediment transport equation coefficient, soil loss ratios, contouring factors, and critical shear stress. The values of these parameters were determined by using cropping and tillage data for surface conditions, soil types, and tables provided with the CREAMS users manual (Soil Conservation Service, 1984). The parameter values used for the simulations of the seven watersheds and a brief description of how they were determined are given in Appendix C.

Simulation control for the erosion/sedimentation component is obtained through three parameters: beginning and ending dates of the simulation; input data reading; and output generated. The parameter values used for the simulations of the seven watersheds are given in Appendix C.

CREAMS Evaluation

This study determined the accuracy of CREAMS in predicting runoff volumes and soil erosion rates from fields in central Illinois. Parameter values were chosen based on available data concerning the characteristics of the watersheds and not by calibrating the model to measured data. Predicted results were compared with measured data to determine the accuracy of those predictions.

Two types of data were available for some of the parameters. One type was general data that were representative of the general weather, soils, crops, etc. that are found in central Illinois. The other data type was specific, in other words, data derived from measurements made of the weather and soils found specifically on the watersheds. Therefore, two simulation runs were made for each watershed, one which used parameter values derived from general data and the other which used parameter values derived from specific data. The variability in the accuracy of CREAMS, which depends on the source of data used to determine parameter values, was thereby determined.

The measured data used to determine the accuracy of the hydrology and erosion/sedimentation components of CREAMS were total runoff amounts and total sediment delivery of each storm that occurred on the watersheds. These data were summarized in monthly, yearly, and average annual amounts for comparison with amounts predicted by the model. The observed data are given in Appendix D.

Predicted results from each simulation were compared with observed results by using a statistical paired comparison using Student's "t" distribution. The null hypothesis of the paired comparison was that the population mean of the distribution equaled zero and the alternative hypothesis was that the population mean was not equal to zero. Using this statistical analysis, monthly results, monthly results averaged over the four years, average monthly results for summer months (April, May, June, July, August, and September), average monthly results for winter months (January, February, March, October, November, and December), annual results, and average annual results were compared.

Sensitivity Analysis of CREAMS

An analysis was performed to determine the sensitivity of the model results to changes in selected parameters. Simulations were made using parameter values which were +/- 50 percent and +/- 20 percent from the base value of that parameter. The set of parameter values used as the base values was the determined parameter value set for the IB2 watershed. The value of each selected parameter was varied while setting all other parameters to their base values. The sensitivity analysis input values of each parameter are given in Appendix E.

The parameters of the hydrology component and erosion/sedimentation component considered to have the most subjective estimate of their values or the ones that could contain the greatest error were selected for the sensitivity analysis. For the hydrology component, these parameters were selected: saturated hydraulic conductivity (RC); fraction of pore space filled at field capacity (FUL); fraction of available water content that is filled when simulation begins (BST); soil evaporation parameter (CONA), soil porosity (POROS); immobile soil water content (BR15); depth of surface soil layer (DS); depth of maximum root growth layer (DP); effective capillary tension of soil (GA); Manning's "n" for overland flow; effective hydrologic slope (SLOPE); and effective hydrologic slope length (XLP).

For the erosion/sedimentation component, these parameters were selected: weight density of soil (WTDSOI); Manning's "n" for overland flow over bare soil (NBAROV); soil erodibility of overland slopes (KSOIL); soil erodibility for erosion by concentrated flow in a channel (KCH); kinematic viscosity of water (KINVIS); Manning's "n" for channel flow over bare soil (NBARCH); area represented by the overland flow profile (DAOVR); slope length of the representative overland flow profile (SLNGTH); slope shape represented by parameters SB, SM, SE, XIN(3), YIN(3), XIN(4) and YIN(4); average slope of the representative overland flow profile (AVGSLP); channel shape (FLAGC); flow control at the outlet (CTLO); side slope of the outlet control channel cross-section (CTLZ); Manning's "n" for the outlet control channel (CTLN); slope of the outlet control channel (CTLSL); channel length (LNGTH); drainage area above upper end of the channel segment (DACHU); slope of channel segments (SSLP); soil loss ratio for overland flow profile segments (CFACT); contouring factors for overland flow profile segments (PFACT); Manning's "n" for overland flow profile segments (NFACT); Manning's "n" for channel profile segments (NCHAN); critical shear stress for channel profile segments (CCHAN); depth to the nonerodible layer along the channel side for channel profile segments (SCHAN); depth to the nonerodible layer in the channel middle for channel profile segments (DCHAN); and top width of the channel for channel profile segments (WCHAN).

The sensitivity of CREAMS to the values of its parameters was determined by computing:

$$DV = [n \ {}_i (Y_i - X_i)^2]^{1/2} / \ {}_i Y_i \qquad (1)$$

where DV = deviation, n = number of values, Y_i = observed value, and X_i = predicted value. The deviation parameter has a value greater than or equal to zero. Sensitivity is determined as the change in the deviation for relative changes in a parameter value.

RESULTS

Evaluation of CREAMS

The statistical results of the comparison of the predicted runoff and sediment delivery to the measured runoff and sediment delivery are summarized in Table 4; the actual predictions are given in Appendix F. The results presented are the overall average prediction accuracy, the average prediction accuracy based on the parameter set derived from specific or general watershed data, and the average prediction accuracy based on the time representation of the results. The effect of watershed size on prediction accuracy is shown in Figure 4. Prediction accuracy is represented by the level of significance of the statistical comparison; a smaller value represents a greater significant difference between predicted and measured values.

The overall prediction accuracy (first line of Table 4) is the average of the levels of significance over all watersheds, both parameter sets, and all time representations of the results, except for the seasonal results. Its interpretation is that CREAMS did better at predicting sediment delivery than at predicting runoff. If a significance level of 0.05 was set to draw conclusions from the statistical tests, the conclusion would be that there is not a significant difference between predicted and measured runoff and sediment delivery values; therefore, CREAMS was adequate in predicting runoff and sediment delivery from these watersheds.

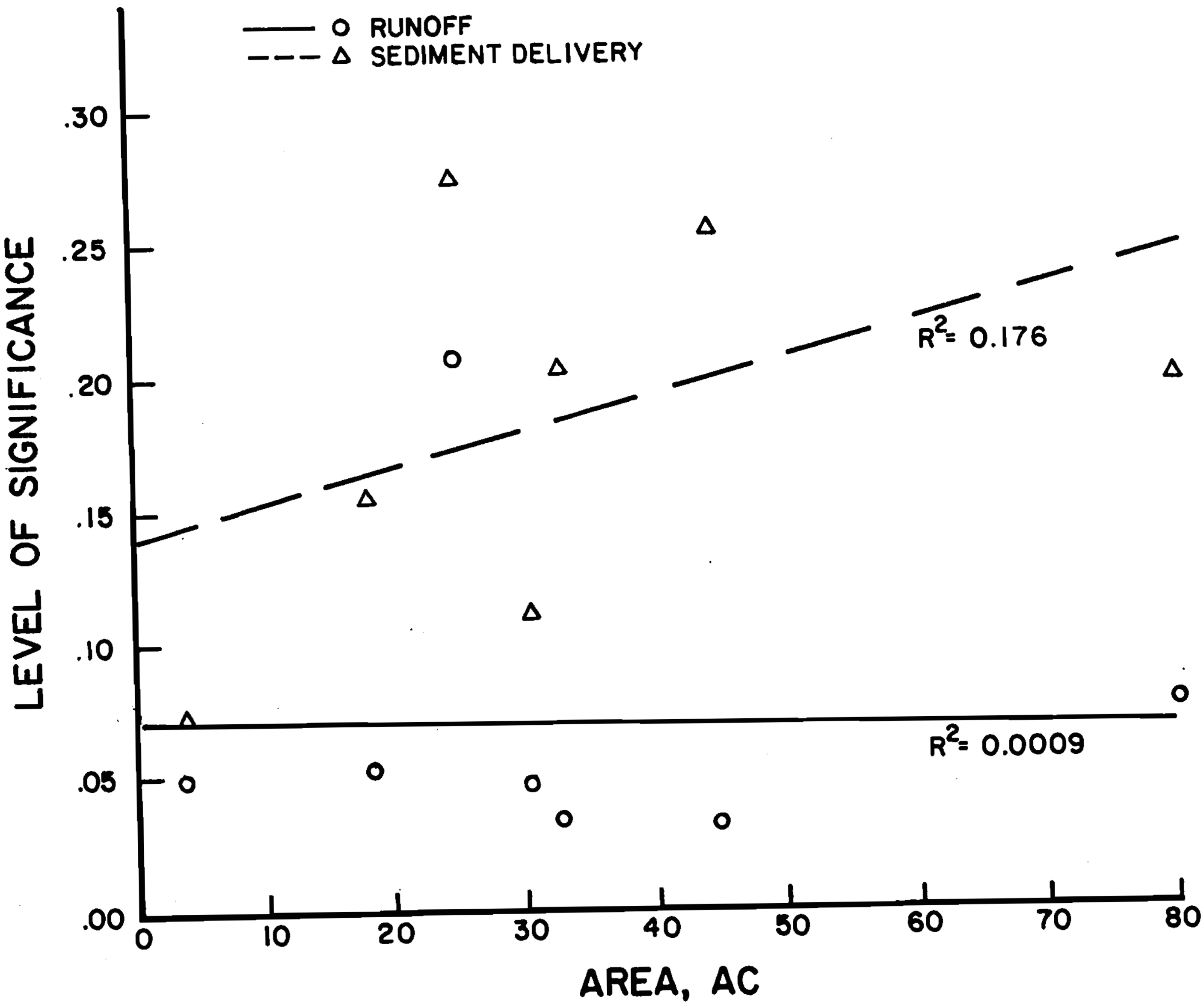

Figure 4. Effect of watershed area on prediction of runoff and sediment delivery by CREAMS.

Table 4. Prediction accuracy of CREAMS

Prediction base	Runoff		Sediment delivery	
	Mean[1/]	Coef. of variation	Mean	Coef. of variation
Overall	0.0686	1.53	0.183	0.62
Parameter value representativeness				
Specific parameter values	0.109	1.19	0.139	0.78
General parameter values	0.0278	1.66	0.228	0.46
Time representation				
Monthly results	0.0411	2.53	0.156	0.76
Average monthly results	0.0714	1.60	0.170	0.64
Annual results	0.102	0.97	0.230	0.47
Average annual results	0.0061	1.37	0.147	1.13
Seasons				
Summer	0.0851	1.43	0.183	0.67
Winter	0.308	0.43	0.349	0.10

1/ Mean values for runoff and sediment delivery represent the average level of significance of paired testing of predicted and measured runoff and sediment delivery values.

The effect of representativeness of the data that were used to determine CREAMS parameter values on the accuracy of prediction was determined (Table 4). The source of data used in determining parameter values determined representativeness. Less representative data were assumed to come from national database summaries of soil types, weather, and so on, while data obtained from or very near to the watersheds were assumed to be more representative. Parameter values derived from these data sets were designated general and specific, respectively. Representativeness is an important consideration since CREAMS was developed to be applied without calibration of the values of its parameters. Parameter values of CREAMS were not calibrated for this evaluation.

Representativeness primarily affected runoff prediction. Runoff that was predicted using specific parameter values was less significantly different from measured runoff than was runoff that was predicted using general parameter values. However, sediment delivery was equally well predicted. It was anticipated that specific parameters would give more accurate results than general parameters. The primary reason for little difference in the sediment delivery prediction accuracy is that only a few of the runoff events produced measurable soil loss and CREAMS seems capable of determining whether or not soil loss will occur.

CREAMS attempts to predict total runoff and sediment delivery for each month simulated and the average runoff and sediment delivery for each month, determined by averaging over the years of simulation. Also, total annual and average annual runoff and sediment delivery are determined. The prediction accuracy of CREAMS for each of these time periods is given in Table 4. A direct comparison of prediction accuracy between time periods is inappropriate because of the large variation in number of values for each time period. CREAMS predictions of average monthly and annual runoff is not significantly different from measured values if a level of significance of 0.05 is chosen for significant difference. All sediment delivery predictions were not significantly different from measured values at a level of significance of 0.05. The average annual comparison may be misleading because only four years of data were available to determine an average.

CREAMS was found to be more accurate at predicting average monthly runoff and sediment delivery during winter months than during summer months (Table 4). However, predictions for summer months were not significantly different from measured values. The greater accuracy of prediction for winter months was primarily due to the small number and magnitude of runoff events during the winter months.

No relationship was found between watershed size and the accuracy of CREAMS in predicting runoff (Fig. 4). However, a slight increase was found in the accuracy of CREAMS in predicting sediment delivery (Fig. 4). CREAMS was developed for predicting hydrology and erosion/sedimentation from field size areas, which are described as having uniform characteristics. Variability found in Allerton watershed characteristics for areas from 4 to 80 acres did not affect the predictive accuracy of CREAMS. Variability of the watershed characteristics was considered by determining input parameter values as weighted averages.

Sensitivity Analysis of CREAMS

Hydrology component. The sensitivities of the prediction of mean monthly runoff by CREAMS to changes in five hydrologic component parameters are shown in Figure 5. Predicted monthly runoff is most sensitive to saturated hydraulic conductivity (RC) and less sensitive to soil porosity (POROS) and effective capillary tension (GA). Manning's roughness (RMN) and effective hydrologic slope length produced only a slight sensitivity. Predicted monthly runoff was not sensitive to any of the other parameters tested.

The parameters to which the hydrologic component of CREAMS was found to be sensitive affect the computed infiltration capacity of the soil. Saturated hydraulic conductivity is the most sensitive because it is directly related to the infiltration rate, which is the most significant abstraction from rainfall in determining runoff. Sensitivity to larger values of RC is constant because the infiltration rate for those values exceeds the rainfall rate for most storms. Porosity and capillary tension affect infiltration and therefore CREAMS is sensitive to their values.

This sensitivity analysis produced results similar to those obtained by CREAMS developers (Knisel, 1980). The only exception was that in this analysis CREAMS was not determined to be sensitive to CONA, whereas, in the analysis reported by Knisel (1980), it was determined to be moderately sensitive.

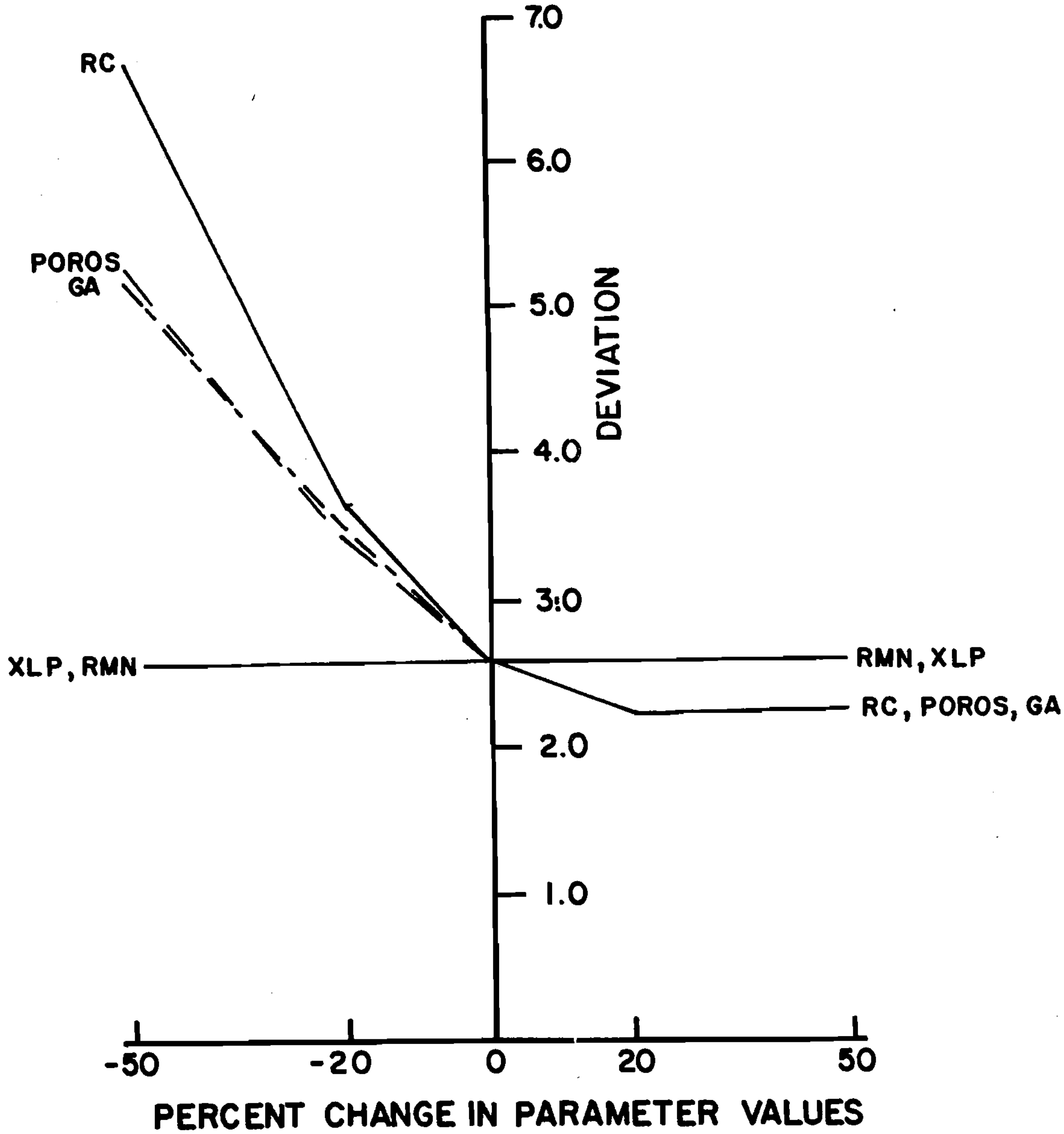

Figure 5. Variability of runoff prediction by CREAMS for variations in the values of hydrologic component parameters.

The sensitivity curves could be used to direct the selection of values that would provide better predicted results. Larger values for RC, POROS, and GA would give better results for the watershed conditions of this sensitivity analysis because only a small amount of runoff from this watershed was measured.

Erosion/sedimentation component. Sensitivities of CREAMS prediction of averaged monthly sediment yield to selected input parameters are shown in Figure 6 and Table 5. The parameters for which CREAMS is highly sensitive are NBAROV, WTDSOI, NBARCH, FLAGC, LNGTH, SSLP, NFACT, CCHAN and DCHAN. The parameters for which CREAMS is moderately sensitive are KCH, AVGSLP, slope shape, KSOIL, DACHU, CFACT and SCHAN. CREAMS was not sensitive to KINVIS, SLNGTH, PFACT or NCHAN.

The sensitivity of the erosion/sedimentation component to its parameter values can be understood by grouping the parameters according to the processes of sheet and rill erosion, channel erosion, and the sediment transport by overland and channel flow. Sheet and rill erosion predicted by the model is affected by the parameters AVGSLP, KSOIL, CFACT and those that describe slope shape. These parameters are directly related to the parameters of the modified Universal Soil Loss Equation (USLE), which is used to predict sheet and rill erosion. The parameters NBAROV and NFACT are directly related to shear stress, which is used in computing sediment transport by overland flow.

The erosion/sedimentation component is sensitive to KCH, WTDSOI and CCHAN because these parameters are used directly in computing the detachment capacity of channel flow. The parameters SSLP, LNGTH, FLAGC and NBARCH are directly related to the friction slope of a channel, which is used in determining soil detachment and sediment transport capacity of channel flow. The sensitivity of the model to the parameters SCHAN and DCHAN results directly from their quantification of the depth of soil in a channel that can be eroded.

Table 5. CREAMS sensitivity to NBAROV, slope shape and FLAGC

Parameter	Value	Deviation
NBAROV	0.005	236
	0.010	248
	0.020	495
	0.050	818
	0.100	824
slope shape	simple concave	248
	simple uniform	266
	simple convex	288
	convex-concave	248
	concave-convex	287
FLAGC	1= triangular	57
	2= rectangular	57
	3= naturally eroded	248

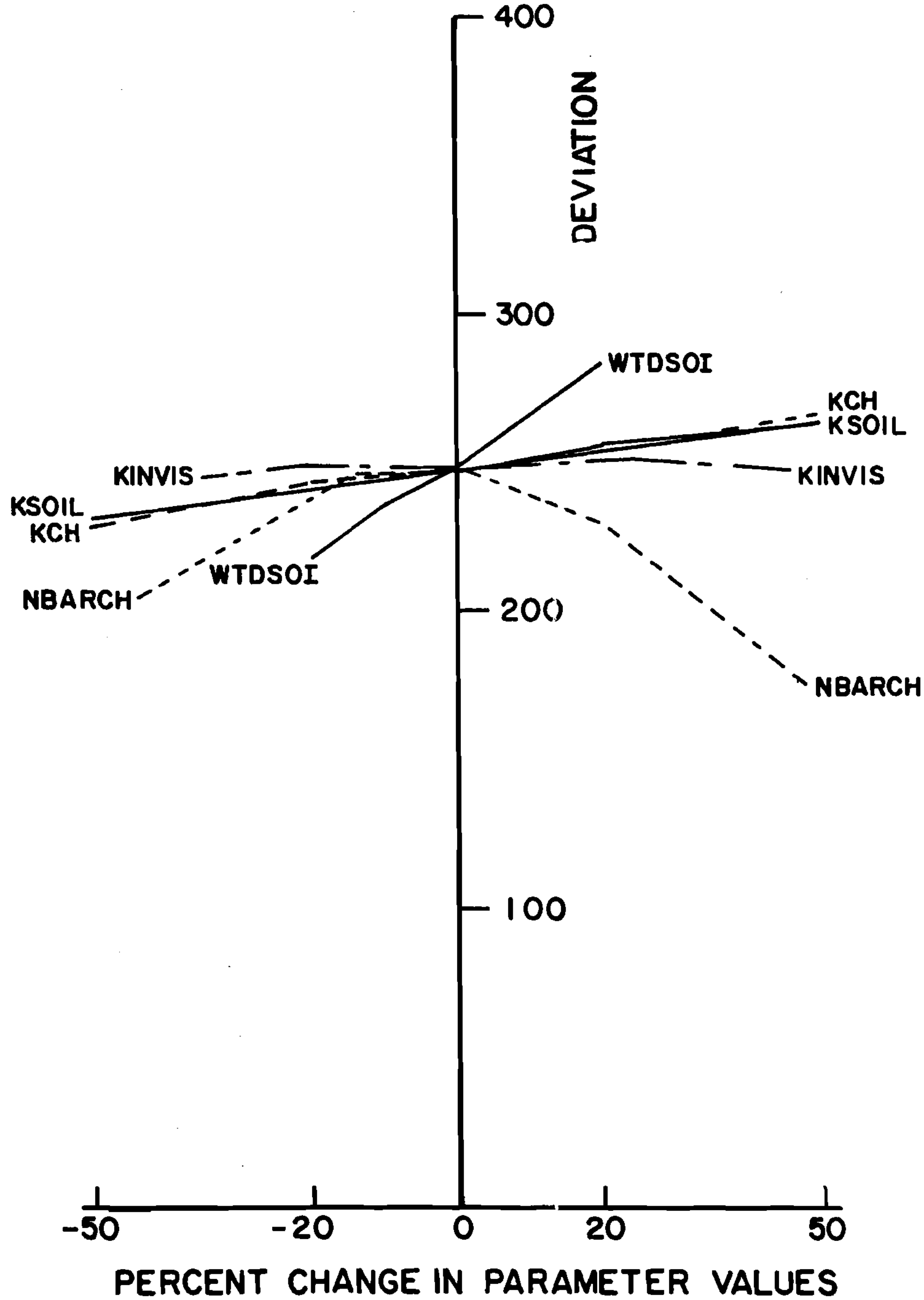

Figure 6. Variability of sediment delivery prediction by CREAMS for variations in the values of erosion/sedimentation component parameters.

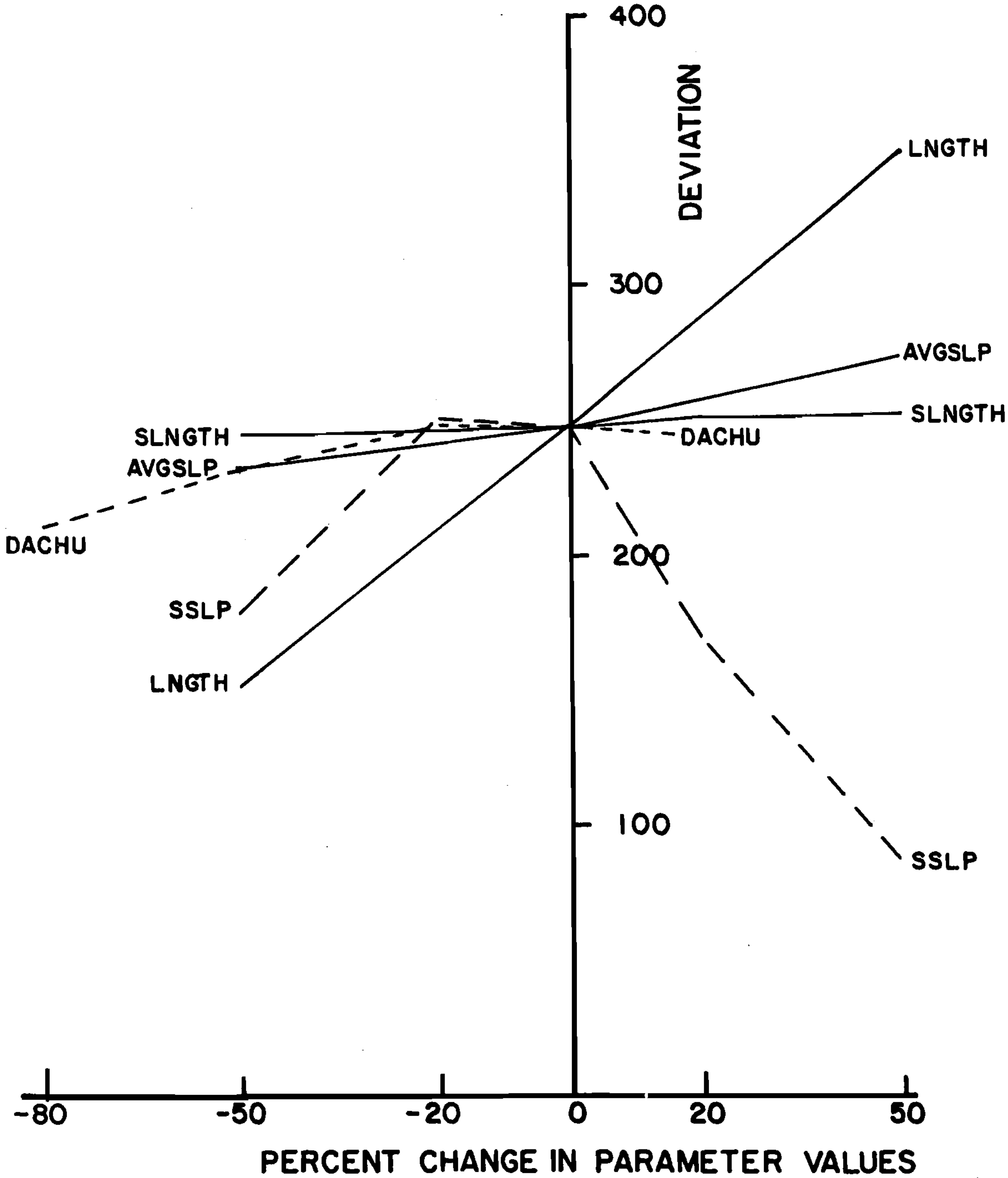

Figure 6. Variability of sediment delivery prediction by CREAMS for variations in the values of erosion/sedimentation component parameters (continued).

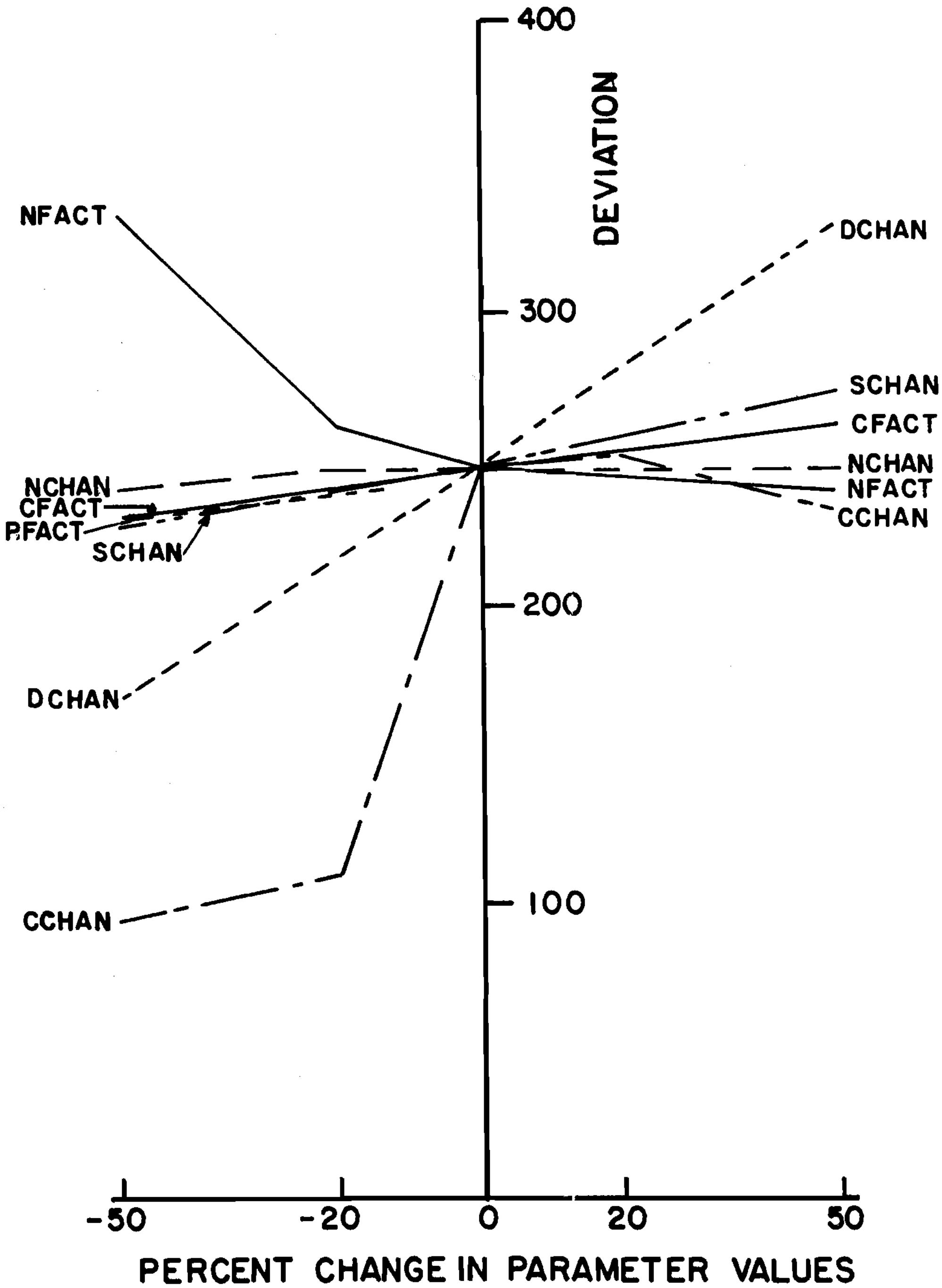

Figure 6. Variability of sediment delivery prediction by CREAMS for variations in the values of erosion/sedimentation component parameters (continued).

The results of this sensitivity analysis are comparable to the results of the sensitivity analysis reported by Knisel (1980). Significant differences in sensitivities were found for CCHAN, NCHAN and NBARCH. This analysis determined CREAMS to be very sensitive to CCHAN instead of moderately sensitive. The sensitivities of NCHAN and NBARCH were reversed in this analysis; sediment delivery being slightly sensitive to NCHAN but very sensitive to NBARCH. This may be because the channel of watershed IB2 was eroding with little sedimentation.

Better predictions of sediment delivery could be obtained by reselecting values for the parameters to which the erosion/sedimentation component is the most sensitive. Figure 6 and Table 5 show the trends for obtaining better predictions. Parameter values resulting in smaller deviations would give better predictions. However, the suggestions derived from Figure 6 and Table 5 are very specific to the event and the site and therefore can not be used in making any general recommendations about parameter values for these watersheds.

CONCLUSIONS

The following conclusions were made from this evaluation and sensitivity analysis of the hydrology and erosion/sedimentation components of CREAMS:

1) CREAMS may be used to compute runoff and sediment delivery from ungaged fields in central Illinois with reasonable accuracy; however, care should be exercised in selecting parameter values by using the best information available.

2) CREAMS predicts annual runoff and sediment delivery best in comparison to predictions for other time periods. Average annual results from this evaluation may be misleading since only four years of data were available for comparison.

3) The assumed application of CREAMS to field-sized areas, considered as having homogeneous and uniform properties, was not violated by using weighted averages for parameter values to characterize the variability of watershed properties. The variability of watershed properties increased as the areas of the nested watersheds increased.

4) The predictive accuracy of the hydrology component of CREAMS is sensitive to the parameters that are used in determining the infiltration rate into the soil. These parameters are saturated hydraulic conductivity (RC), soil porosity (POROS), and effective capillary tension (GA).

5) The predictive accuracy of the erosion/sedimentation component of CREAMS is sensitive to the parameters that are used in determining sheet and rill erosion, sediment transport by overland flow, detachment capacity of channel flow, sediment transport capacity of channel flow, and the soil available in a channel for erosion. The parameters for sheet and rill erosion are average slope of the overland flow profile (AVGSLP), soil erodibility factor (KSOIL),

soil loss ratio for the overland flow profile (CFACT), and slope shape parameters (SB, SM, SE, XIN(3), YIN(3), XIN(4), and YIN(4)). The parameters for sediment transport by overland flow are Manning's "n" for overland flow over bare soil (NBAROV) and Manning's "n" for the overland flow profile (NFACT). The parameters for channel detachment capacity are soil erodibility by concentrated flow in a channel (KCH), weight density of soil (WTDSOI), and critical shear stress for channel profile (CCHAN). The parameters for channel detachment capacity and sediment transport by channel flow are slope of channel profile (SSLP), channel length (LNGTH), channel cross-section shape (FLAGC), and Manning's "n" for channel flow over bare soil (NBARCH). The parameters for erodible soil are depth to the nonerodible layer in the channel middle (DCHAN) and depth to the nonerodible layer along the channel sides (SCHAN).

6) The sensitivity analysis can be used to direct the selection of values for parameters which will result in better predictions of runoff and sediment delivery for specific events.

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APPENDIX

Because of the large volume of data contained in Appendices A - F, they will not be included herein. Copies of these appendices may be obtained from:

University of Illinois
Agricultural Engineering Department
Soil and Water Division
1304 W. Pennsylvania Ave.
Urbana, IL 61801

Please refer to appendices for:

HYDROLOGY AND SEDIMENTOLOGY MODELING ON ILLINOIS AGRICULTURAL WATERSHEDS
Final Project Report, Water Resources Center, University of Illinois, August, 1988, Urbana, Illinois, 22p.