CBP/TRS 49/90
September 1990

Estimation of Nonpoint Source Loading Factors in the Chesapeake Bay Watershed Model

Chesapeake
Bay
Program

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Grant Number 87-EXCA-3-0829

NATIONAL WATER QUALITY EVALUATION PROJECT

Biological and Agricultural Engineering Department
North Carolina State University
Raleigh, North Carolina

In Cooperation With:

U.S. Department of Agriculture
U.S. Environmental Protection Agency

June 1990

Printed by the U.S. Environmental Protection Agency for the Chesapeake Bay Program

Final Report

Estimation of Nonpoint Source Loading
Factors in the Chesapeake Bay Model

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Introduction

Attention focused on water quality problems in the Chesapeake Bay has revealed that agricultural activities are in large part responsible for the degradation of water quality and associated animal and plant life. The objective of the project entered into by the US Environmental Protection Agency (US EPA) and North Carolina State University (NCSU) was to assist the Chesapeake Bay Program in developing appropriate parameters to calibrate the model US EPA has selected to simulate physical processes in the bay watershed, namely Hydrological Simulation Program--Fortran (HSPF). HSPF will be used to evaluate nonpoint source pollution control methods for improving water quality in the Chesapeake Bay. There are, however, two significant drawbacks to the use of HSPF. One is that many of the parameters are empirical in nature and require calibration to determine their value and second is the need of a long period of hydrological data to calibrate these parameters which is either hard to obtain or nonexistent.

The model we selected to develop these parameters is CREAMS (A Field Scale Model for Chemicals, Runoff, and Erosion from Agricultural Management Systems). CREAMS (Knisel et al, 1980) is a physically based, daily simulation model used to estimate runoff, erosion, plant nutrient and pesticide yield from field-sized areas. We used a hypothetical, prototype watershed with soils and characteristics similar to those that would be encountered in the Chesapeake Bay watershed. Sediment yield and nutrient loading rates obtained from CREAMS simulation runs will be the basis for calibrating HSPF.

CREAMS MODEL

Hydrology Submodel

The hydrology submodel accounts for infiltration, soil water movement, and soil/plant evapotranspiration between storms and maintains a continuous water balance. The SCS curve number equation is used to predict surface runoff:

$$Q = \frac{(P - 0.2s)2}{P + 0.8s}$$

where Q = daily runoff, inches
P = daily rainfall, inches
s = retention parameter, inches

A depth-weighted retention parameter is used to compute the effect of antecedent moisture, soil conditions, land use, and conservation practices on runoff and is related to soil water content by:

$$s = s,max \left[1 - \sum_{i=1}^{N} Wi\left(\frac{SM_i}{UL_i}\right)\right]$$

where s,max = maximum retention parameter in inches
Wi = weighting factor (function of depth of each of seven layers and effective rooting depth of crop)
SM = soil water content in the root zone in inches
UL = upper limit of soil water storage in the root zone in inches

s,max is estimated using the CNI moisture condition and the following SCS equation:

$$s,max = \frac{1000}{CNI} - 10$$

CNI is for low runoff potential with soil having low antecedent moisture suitable for cultivation and is related to CNII by the following polynomial:

$$CNI = -16.91 + 1.348CNII - .01279CNII2 + .0001171CNII3$$

CNII selection is outlined in Appendix 1. However, the same results are obtained as appear in Table A-4 in the CREAMS PC manual (Rawls, et al, 1980) saving one the trouble of calculating each curve number.

Potential evapotranspiration (ET) is computed using daily temperature and daily solar radiation. Soil evaporation and plant transpiration are computed separately; both use potential ET and the leaf area index. The leaf area index is defined as the area of all leaves and stem within one square meter. The submodel uses a soil storage routing technique to predict flow through the root zone when accounting for percolation. The root zone is divided into seven layers or storages for routing purposes. An appropriate rooting depth for the crop on the field is selected by the user and the total soil water storage for each of the seven layers is determined based on soil properties.

Erosion Submodel

CREAMS is capable of representing sediment yield from a field with overland flow, channel flow, and/or impoundments. The user selects the most descriptive combination. In the erosion submodel, detachment on interrill and rill areas and transport and deposition by rill flow are the erosion-transport processes in the overland flow option. Detachment is described using slope, slope length, and K, C, and P factors from the Universal Soil Loss Equation (USLE), K being the soil erodibility factor, C the soil loss ratio, and P the contouring factor. Runoff volume, peak runoff rate, and storm erosivity (EI) are also needed in the detachment equations and are computed in the hydrology submodel and passed to the erosion submodel. The Yalin equation is used to calculate sediment transport capacity. The submodel computes an initial potential sediment load (up-slope segment sediment load + lateral inflow sediment load). If this potential load is less than the transport capacity, detachment occurs; if the potential load is greater than transport capacity, then deposition occurs. Separate equations are used for determining soil detachment and sediment transport.

An enrichment ratio (ER) is computed in the erosion submodel using specific surface areas for sand, silt, clay, and organic matter. This value represents the total specific surface area for the sediment yield to that of the original soil. An runoff velocity decreases, larger soil particles drop out of suspension and are deposited on the field. Finer particles settle out more slowly by remaining in suspension longer and are transported to the edge of the field. Clay particles with their high surface area-to-volume ratio are noted for this type of behavior and enrichment. Therefore, high enrichment ratios indicate that primarily clays are in the runoff and that the implementation of good land conservation management practices have reduced the amount of sediment leaving the field by limiting the size of the soil particles leaving the field to small fines. Conversely, low enrichment ratios indicate that sediment yield is being controlled by detachment and that larger soil particles are leaving the field.

Nutrient Submodel

The nutrient submodel in CREAMS simulates nitrogen and phosphorus processes in and losses from the field. Nitrogen processes include nitrogen in runoff and sediment, mineralization, plant uptake, leaching, denitrification, fertilizer application, and rainfall nitrogen. Phosphorus processes are field applications and losses in sediment and runoff. The loading rate of nitrogen and phosphorus transported by sediment (SED_) is predicted by the following equations:

$$SED\_ = SOIL\_ * SED * ER\_ \text{ , and}$$

$$ER\_ = A- * SEDB\_$$

where SOIL_ = N or P content (kg/kg soil) in the field
SED = sediment predicted by the erosion model, kg/ha
ER_ = enrichment ration of N or P
A_ = coefficient for N or P
B_ = exponent for N or P

Conservation practices (best management practices) are commonly used to reduce runoff and soil erosion from fields in the hopes of maintaining the field's maximum production capability in a cost-effective manner. In so doing, a fringe benefit is realized in that fertilizer nutrients are retained on the field available for plants to take up and subsequently, the amount which leaves the field and enters rivers, streams and other water bodies is reduced. [Whether these practices are effective in improving water quality is still a question for discussion.] Therefore, we decided to compare the effects of conventional and conservational tillage practices on runoff and sediment, nitrogen and phosphorus yields from the field. Loading rates for sediment, nitrogen, and phosphorus generated by CREAMS can be used to more accurately estimate the potency factor parameter [ratio of constituent yield to sediment (washoff or scour) outflow] used in the HSPF watershed model.

HSPF POTENCY FACTORS

The HSPF subroutine QUALSD simulates the removal of a quality constituent from a pervious land surface by association with the sediment removal determined in module section SEDMNT. This approach assumes that the particular quality constituent removed from the land surface is proportional to the sediment removal. The relation is specified with user-input potency factors. Potency factors, then, indicate the constituent strength relative to the sediment removed from the surface. For each quality constituent associated with sediment, the user supplies separate potency factors for association with washed off and scoured sediment. The basic equation for removal of sediment-associated constituents by sediment detached in washoff is simulated by:

$$WASHQS = WSSD*POTFW$$

where:

WASHQS = flux of quality constituent associated with detached sediment washoff in quantity/acre per interval
WSSD = washoff of detached sediment in tons/acre per interval
POTFW = washoff potency factor in quantity/ton

And the removal of constituents by scouring of the soil matrix is simulated by:

$$SCRQS = SCRSD*POTFS$$

where:

SCRQS = flux of quality constituent associated with scouring of the matrix soil in quantity/acre per interval
SCRSD = scour of matrix soil in tons/acre per interval
POTFS = scour potency factor in quantity/ton

SOILS AND FARMING PRACTICES

We simulated runoff, sediment, nitrogen and phosphorus yields from a 35-acre watershed planted in continuous corn. We selected five (5) soil types to represent soils characteristic of the major regions in the bay watershed--Galestown (Psammentic Hapludult, Sandy), Norfolk (Typic Paleudult, Fine-Loamy), two types of Cecil (Typic Hapludult, Clayey), and Penn Loam (Table 1). For our hypothetical field, we represented sediment yield from the field using the overland flow option. The slope of our field ranged from 2 to 10 percent depending on soil type. In all cases, slope length was 120 feet and a simple, uniform slope profile was used. We chose a length-to-width ration of 3.8 based on a hydrologic map obtained from the Chesapeake Bay Liaison Office (CBLO). We broadcast a 10-5-5 fertilizer in April 14 at the rate of 150 lb N/acre. We selected the daily rainfall option using 1974-78 rainfall data also obtained from the CBLO. Total annual precipitation for the 5-year period ranged from 39 to 53 inches (Appendix 2). We also used actual bay area average monthly temperatures and solar radiation values for the five (5) years, also obtained from the CBLO. The farming activities we selected for our hypothetical field include chisel plowing on April 15, disking on April 16, planting on April 20, and harvesting on October 1.

Table 1. SOILS USED IN SIMULATION

Soil 1	Galestown, loamy sand (not typically found on 8% or 10% slopes)
Soil 2	Norfolk, loamy sand, loamy fine sand, sandy loam
Soil 3	Cecil, sandy loam, sandy clay loam, clay loam, clay
Soil 4	Cecil, sandy clay loam, clay loam, clay
Soil 5	Cecil, sandy clay loam, clay loam, clay -- eroded phase (not typically found on 2% slope)
Soil 6	Penn Loam, loam, silt loam

See Appendix 1 for soil profile descriptions.

We designed two scenarios to compare the difference that selected management practices made in runoff and sediment, nitrogen, and phosphorus yields. The base, or reference, scenario we defined as a field under conventional tillage with up-and-down slope plowing with less than 30 percent crop residue at time of planting. The alternate scenario was defined as a field under conservation tillage with contour chisel plowing with more than 30 percent crop residue at time of planting. We defined conventional tillage as a tillage operation which would leave less than 30 percent crop residue at time of planting. We obtained soil profiles and characteristics from appropriate Soils 5 sheets and the CREAMS manual (Appendix 3).

RESULTS OF CREAMS SIMULATONS

As expected, runoff was reduced from the field when the alternative management practices were employed (Table 2). Reduction ranged from 21-44 percent, depending on soil type. What we did not expect was the small amount of runoff. Several inches per year were expected but instead, runoff averaged from less and one (1) inch to about 1.5 inches over the 5-year period. A sensitivity analysis of the hydrology submodel parameters revealed that the most influential parameter in generating runoff is the SCS curve number which influences the retention parameter; i.e., the maximum potential difference between rainfall and runoff at the start of the storm. The larger the curve number, the smaller the retention parameter and the more runoff you get and vice versa. We used curve numbers from Table A-4 in the CREAMS PC manual (USDA SCS TR 71) for appropriate soil-cover situations and these curve number just did not generate the runoff experience told us we should expect (Refer to Hydrology Submodel section above for description of how runoff is predicted.). Because we knew that the driving parameter in the runoff equation was the curve number, we decided to increase the curve number on the Soil 5 scenario just to see what would happen (Table 2). An increase in runoff did occur (from 1.5 to 2.7 inches), but because there was no justification for using the larger values; i.e., no actual data, we continued to use the recommended values from Table A-4.

Table 2. RUNOFF AS A FUNCTION OF SOIL TYPE (1974-78)
Annual Average Precipitation = 44.4 inches)

	BASE SCENARIO[1]	ALTERNATE SCENARIO[2]	% REDUCTION
	--------inches--------		
SOIL 1[3]	.072 (67)[4]	.040 (65)	44.0
SOIL 2	.806 (78)	.592 (76)	26.5
SOIL 3	1.130 (78)	.858 (76)	24.0
SOIL 4	1.530 (78)	1.206 (76)	21.0
SOIL 5	2.688 (83)	2.154 (81)	19.9
SOIL 6	3.068 (85)	2.171 (82)	29.2

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[1] Conventional tillage with up-and-down slope plowing, residue less than 30 percent.

[2] Conservation tillage with residue greater than 30 percent.

[3] Soil 1: Galestown, loamy sand (Hydrologic Group A, not typically found on 8% or 10% slopes)
Soil 2: Norfolk, loamy sand, loamy fine sand, sandy loam (Hydrologic Group B)
Soil 3: Cecil, sandy loam, sandy clay loam, clay loam, clay (Hydrologic Group B)
Soil 4: Cecil, sandy clay loam, clay loam, clay (Hydrologic Group B)
Soil 5: Cecil, sandy clay loam, clay loam, clay -- eroded phase (not typically found on 2% slope)
Soil 6: Penn Loam, loam, silt loam (Hydrologic Group C)

[4] Curve number for antecedent rainfall condition II in parentheses ().

Because runoff was low, sediment yields from the field were also low and less than expected. Values ranged from 0 to 2.6 tons/acre (Table 3, Soil 5 with higher curve number not included in range given here). The results, however, do reflect a reduction in sediment yield when conservation tillage with contour plowing is implemented, with values ranging from about 47 to almost 67 percent, depending on the soil type and the slope of the field.

Table 3. SEDIMENT YIELD AS A FUNCTION OF SOIL TYPE, SLOPE, AND TILLAGE PRACTICE (1974-78 averages, Annual Average Precipatation = 44.4 inches)

	SOIL 1[1] (67/65)[2]	SOIL 2 (78/76)	SOIL 3 (78/76)	SOIL 4 (78/76)	SOIL 5 (83/81)	SOIL 6 (85/82)
	---tons/acre---					
2% slope						
Base[3]	0	.028	.066	.090		.208
Alt.[4]	0	.012	.030	.042		.086
% red.	0	57.0	54.5	53.3		58.7
4% slope						
Base	.006	.108	.240	.314	.554	.714
Alt.	.002	.042	.106	.144	.260	.312
% red.	66.7	61.1	55.8	54.1	53.1	56.3
6% slope						
Base	.018	.200	.484	.632	1.214	1.542
Alt.	.006	.078	.232	.336	.542	.674
% red.	66.7	61.0	52.1	46.8	55.4	56.3
8% slope						
Base		.336	.798	1.130	2.05	2.644
Alt.		.142	.404	.558	.89	1.122
% red.		57.7	49.4	50.6	56.6	57.6
10% slope						
Base		.528	1.208	1.736	3.05	
Alt.		.234	.596	.800	1.326	
% red.		55.7	50.7	53.9	56.5	

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[1] Soil 1: Galestown, loamy sand (not typically found on 8% or 10% slope); Soil 2: Norfolk, loamy sand, looam fine sand, sandy loam; Soil 3: Cecil, sandy loam, sandy clay loam, clay loa m, clay; Soil 4: Cecil, sandy clay loam, clay loam, clay; Soil 5: Cecil, sandy clay loam, clay loam, clay -- eroded phase (not typically found on 10% slope); Soil 6: Penn Loam, loam, silt loam

[2] Curve numbers for antecedent rainfall condition II base and alternate scenarios.

[3] Conventional tillage with up-and-down slope plowing, residue less than 30%.

[4] Conservation tillage with residue greater than 30%.

Enrichment ratios (ER) for the six soils are shown in Table 4. As expected, ERs decreased as sediment yield increased, indicating detachment and transport of large soil particles along with fines and organic matter. The extremely high ER values for Soils 1 and 2 at low slopes indicate that runoff was low and, consequently, the sediment yield was zero or very near zero. A couple of observations can be made from these data. First, because sediment yield was either zero or very near zero, nutrient losses computed in the nutrient submodel, if any, will be known to exist in runoff and not in erosion. Therefore, to aid in reducing nutrient losses, it is important to control runoff first. In so doing, not only are runoff and accompanying nutrients reduced, but because erosion is driven by runoff, erosion is controlled as well. Second, note that when conservation practices are employed, ER values are generally higher. The exceptions in these runs, we think, are due to the questionable results obtained by using the recommended curve numbers from Table A-4 in the CREAMS PC manual (USDA SCS TR 72).

Table 4. AVERAGE ANNUAL ENRICHMENT RATIOS (1974-78)
Annual Average Precipitation = 44.4 inches

	2%	4%	6%	8%	10%
Soil 1					
Base[1]	11.339	8.516	6.809		
Alt.[2]	11.373	9.183	7.322		
Soil 2					
Base	6.256	4.374	4.025	3.441	2.884
Alt.	6.268	4.351	4.168	3.446	2.863
Soil 3					
Base	3.515	2.567	2.174	1.922	1.759
Alt.	3.494	2.618	2.102	1.865	1.751
Soil 4					
Base	2.783	2.153	1.888	1.663	1.549
Alt.	2.743	2.188	1.781	1.654	1.562
Soil 5					
Base		1.956	1.653	1.464	1.345
Alt.		1.947	1.674	1.476	1.343
Soil 6					
Base	2.278	1.751	1.493	1.360	
Alt.	2.263	1.754	1.512	1.369	

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[1] Soil 1: Galestown, loamy sand (not typically found on 8% or 10% slopes)
Soil 2: Norfolk, loamy sand, loamy fine sand, sandy loam
Soil 3: Cecil, sandy loam, sandy clay loam, clay loam, clay
Soil 4: Cecil, sandy clay loam, clay loam, clay
Soil 5: Cecil, sandy clay loam, clay loam, clay -- eroded phase (not typically found on 2% slope)
Soil 6: Penn loam, loam, silt loam

[2] Conventional tillage with up-and-down slope plowing, residue less than 30%.

[3] Conservation tillage with residue greater than 30%.

Soil type, field slope, and management practice also affected the amount of total nitrogen and total phosphorus leaving the field (Tables 5 and 6). Total nitrogen and total phosphorus include runoff- and sediment-associated constituents. Average annual losses ranged from 0.04 - 5.6 kg/ha for nitrogen and 0.006 - 1.6 kg/ha for phosphorus. The use of conservation tillage and contour plowing reduced the loading rate by 28 - 59 percent for nitrogen and 33 - 70 percent for phosphorus. Notice that there are some nutrient losses on Soil 1 at 2, 4, and 6 percent slopes. Recalling that there was little to no sediment yield on this soil at these slopes, it is our conclusion that nitrogen and phosphorus losses occurred primarily in runoff rather than erosion. Hence, it is important to implement first those conservation practices that will reduce runoff from the field.

A complete set of output results appears in Appendix 4.

HSPF washoff potency factors were calculated by dividing the sediment loss from the field for associated nitrogen and phosphorus by the total sediment yield (Table 7). Most of the alternate scenario values are larger than the base scenario values because the fines associated with reduced runoff are usually smaller than soil particles associated with runoff without conservation practices and therefore have a higher adsorption capacity. We did not calculate potency factors for soil matrix scouring.

NITROGEN LEACHING STUDY

We also used CREAMS to examine nitrogen leaching by simulating fertilizer application at different nitrogen rates. We used the same commercial 10-5-5 fertilizer broadcast at rates ranging from 50-350 lb N/acres. The base scenario (conventional tillage with up-and-down slope plowing) was used on Soil 4 (eroded Cecil) with the 35-acre field in continuous corn at 10 percent slope for the 5-year (1974-78) simulation period. Potential nitrogen uptake was related to the potential yield in bushels.

Results of the study on nitrogen leaching reduction as a function of fertilizer application rate and potential corn yield indicate that there is a maximum uptake rate of nitrogen after which the uptake rate levels out (Table 7). Reductions ranged from 26 to 64 percent (Fig. 1; negative values indicate a nitrogen deficit). However, it is important to bear in mind that although reduction of leached nitrogen was greater than 50 percent in most simulations, these data must be understood in light of all the data--rates of uptake, leaching, and excess nitrogen. The model assumes that all nitrogen in excess of plant requirement is available to leach. Hence, these data indicate that the plant can take up a given amount of nitrogen after which the excess, no longer available to plants, is leached below the root zone. In these simulations, the amount of leached nitrogen ranged from 5 to 227 kg/ha. So the fact that part of the data suggest significant reductions, the remainder of the data indicate that the plants were unable to take up the excess and that the excess was then available to migrate down to the groundwater, eventually entering streams and tributaries which empty into the Chesapeake Bay. We caution the interpreter of similar simulations to make decisions based on all of the data and not just selected portions.

Table 5. NITROGEN (N) LOSS AS A FUNCTION OF SOIL TYPE, SLOPE, AND TILLAGE PRACTICE (1974-78 averages, Annual Average Precipitaton = 44.4 inches)

	SOIL 1[1]	SOIL 2	SOIL 3	SOIL 4	SOIL 5	SOIL 6
	kg/ha					
2% slope						
Base[2]	.073	.950	1.534	2.129		5.040
Alt.[3]	.040	.645	1.065	1.537		3.077
% red.	45.1	32.2	30.6	27.8		38.9
4% slope						
Base	.097	1.206	2.015	2.745	5.576	6.319
Alt.	.040	.766	1.312	1.884	3.856	3.756
% red.	58.9	36.5	34.9	31.4	30.8	40.6
6% slope						
Base	.138	1.456	2.600	3.501	6.981	8.076
Alt.	.064	.911	1.663	2.408	4.553	4.638
% red.	53.5	37.5	36.0	31.2	34.8	42.6
8% slope						
Base		1.834	3.277	4.512	8.501	10.080
Alt.		1.089	2.094	2.918	5.356	5.640
% red.		40.6	36.1	35.3	37.0	44.0
10% slope						
Base		2.240	4.061	5.608	0.261	
Alt.		1.315	2.510	3.458	6.253	
% red.		41.3	38.1	38.3	39.1	

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[1] Soil 1: Galestown, loamy sand (not typically found on 8% or 10% slopes)
Soil 2: Norfolk, loamy sand, loamy fine sand, sandy loam
Soil 3: Cecil, sandy loam, sandy clay loam, clay loam, clay
Soil 4: Cecil, sandy clay loam, clay loam, clay
Soil 5: Cecil, sandy clay loam, clay loam, clay -- eroded phase (not typically found on 2% slope)
Soil 6: Penn Loam, loam, silt loam

[2] Conventional tillage with up-and-down slope plowing, residue less than 30 percent.

[3] Conservation tillage with residue greater than 30 percent.

SUMMARY AND CONCLUSIONS

The use of conservation tillage and contour plowing reduced the amount of runoff, sediment yield, nitrogen, and phosphorus leaving the field. Low runoff values were due to the curve numbers selected. Subsequent low sediment and nutrient yields reflect insufficient runoff to generate higher losses. Use of a higher curve number generated more runoff and subsequent higher sediment and nutrient yields. Additional simulations using actual soils from the Chesapeake Bay watershed and further investigation of the curve number are recommended.

Table 6. PHOSPHORUS (P) LOSS AS A FUNCTION OF SOIL TYPE, SLOPE, AND TILLAGE PRACTICE (1974-78 averages, Annual Average Precipitaton = 44.4 inches)

	SOIL 1[1]	SOIL 2	SOIL 3	SOIL 4	SOIL 5	SOIL 6
	kg/h					
2% slope						
Base[2]	.010	.143	.235	.320		.770
Alt.[3]	.006	.088	.152	.214		.448
% red.	44.6	38.1	35.5	33.1		41.8
4% slope						
Base	.019	.235	.409	.541	1.070	1.230
Alt.	.006	.132	.241	.339	.685	.692
% red.	69.9	43.8	41.1	37.4	36.0	43.7
6% slope						
Base	.034	.410	.619	.814	1.576	1.863
Alt.	.015	.162	.367	.528	.935	1.010
% red.	57.3	60.4	40.7	35.1	40.7	45.8
8% slope						
Base		.461	.863	1.178	2.123	2.584
Alt.		.248	.522	.711	1.225	1.371
% red.		46.1	39.5	39.6	42.3	46.9
10% slope						
Base		.607	1.145	1.582	2.756	
Alt.		.330	.672	.906	1.548	
% red.		45.7	41.3	42.8	43.8	

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[1] Soil 1: Galestown, loamy sand (not typically found on 8% or 10% slopes)
Soil 2: Norfolk, loamy sand, loamy fine sand, sandy loam
Soil 3: Cecil, sandy loam, sandy clay loam, clay loam, clay
Soil 4: Cecil, sandy clay loam, clay loam, clay
Soil 5: Cecil, sandy clay loam, clay loam, clay -- eroded phase (not typically found on 2% slope)
Soil 6: Penn Loam, loam, silt loam

[2] Conventional tillage with up-and-down slope plowing, residue less than 30 percent.

[3] Conservation tillage with residue greater than 30 percent.

Table 7: POTENCY FACTORS FOR DETACHED SEDIMENT WASHOFF FOR NITROGEN (N) AND PHOSPORUS (P)

	SOIL 1[1]		SOIL 2		SOIL 3		SOIL 4		SOIL 5		SOIL 6	
	N	P	N	P	N	P	N	P	N	P	N	P
2% slope												
Base[2]			0.015	0.002	0.01	0.002	0.01	0.002			0.011	0.002
Alt.[3]			0.024	0.003	0.016	0.002	0.008	0.002			0.016	0.002
4% slope												
Base	0.007	0.001	0.005	0.001	0.004	0.001	0.004	0.001	0.004	0.001	0.004	0.001
Alt.	0.009	0.001	0.008	0.001	0.005	0.001	0.006	0.001	0.007	0.001	0.005	0.001
6% slope												
Base	0.003	0.001	0.003	0.001	0.002	0.001	0.002	0.001	0.003	0.001	0.002	0.001
Alt.	0.005	0.001	0.005	0.001	0.003	0.001	0.003	0.001	0.004	0.001	0.003	0.001
8% slope												
Base			0.002	0.001	0.002	0.0005	0.002	0.0005	0.002	0.0005	0.002	0.0004
Alt.			0.003	0.001	0.002	0.001	0.002	0.0006	0.003	0.0006	0.002	0.0005
10% slope												
Base			0.002	0.001	0.001	0.0004	0.001	0.0004	0.002	0.0004		
Alt.			0.002	0.001	0.002	0.0005	0.002	0.0005	0.002	0.0005		

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[1] Soil 1: Galestown, loamy sand (not typically found on 8% or 10% slopes)
Soil 2: Norfolk, loamy sand, loamy fine sand, sandy loam
Soil 3: Cecil, sandy loam, sandy clay loam, clay loam, clay
Soil 4: Cecil, sandy clay loam, clay loam, clay
Soil 5: Cecil, sandy clay loam, clay loam, clay -- eroded phase (not typically found on 2% slope)
Soil 6: Penn Loam, loam, silt loam

[2] Conventional tillage with up-and-down slope plowing, residue less than 30 percent.

[3] Conservation tillage with residue greater than 30 percent..pa

Table 8. REDUCTION OF NITROGEN LEACHING AS A FUNCTION OF FERTILIZER APPLICATION RATE (1974-78 averages, Ann. Ave. Precipitation = 44.4 inches)[1]

lb N/ac applied	N uptake	N leached	N excess	Efficiency of Fertilizer Reduction[2]
Potential Nitrogen Uptake = 150 kg/ha (134 lb/ac) Potential Corn Yield = 85 bushels				
	kg/ha			%
50	123	57	-73	
150	123	120	27	63
200	123	152	77	64
250	123	215	127	62
300	123	215	177	64
350	123	247	227	64
Potential Nitrogen Uptake = 225 kg/ha (200 lb/ac) Potential Corn Yield = 128 bushels				
50	148	41	-98	
150	184	86	-34	45
200	184	118	16	64
250	184	149	66	62
300	184	181	116	64
350	184	213	166	64
Potential Nitrogen Uptake = 300 kg/ha (268 lb/ac) Potential Corn Yield = 170 bushels				
50	154	37	-104	
150	220	63	- 70	26
200	238	86	- 38	46
250	245	116	5	60
300	246	147	54	62
350	248	179	102	64

---

[1] Simulations done on Soil 4 (Cecil, sandy clay loam, clay loam, clay) planted in continuous corn at 10 percent slope.

[2] Percentage of application increment that is leached.

REFERENCES

Knisel, W. G. (Ed.). CREAMS: A field-scale model for Chemicals, Runoff, and Erosion from Agricultural Management Systems. U.S. Department of Agriculture, Conservation Research Report No. 26, 643 pp.

Rawls, W. J., C. A. Onstad, and H. H. Richardson. 1980. Residue and tillage effects on SCS runoff curve numbers. In: Knisel, W. G. (Ed.). CREAMS: A field-scale model for Chemicals, Runoff, and Erosion from Agricultural Management Systems. U.S. Department of Agriculture, Conservation Research Report No. 26, Vol. III, pp. 405-425.

APPENDIX 1

CONSERVATION TILLAGE EFFECTS ON CURVE NUMBER

Watershed in good hydrologic condition with soils in hydrologic group A and B and is farmed in straight row, continuous corn. Planned tillage operations are chisel plowing and heavy disking before planting corn.

Hydrologic Group A

Step 1. Determine curve number without conservation tillage.

CN = 67 (Table 1)

Step 2. Determine residue amount left on surface.

Corn residue = 4500 lb/ac (Jim Hannawald, CBLO)

Reduction as a result of tillage operations (Table 2)

(4500 lb/ac)(0.65 chisel plow)(0.30 heavy disk) = 877.5 lb/ac

Corn residue remaining = 880 lb/ac

Step 3. Reduce curve number (Table 3).

Corn is a large residue crop; interpolation give a
CN reduction = 3%

Step 4. Adjust curve number for conservation tillage.

CN = (CN from Step 1)(1 - CN reduction %/100)

CN = (67)(1 - 3/100) = 64.99

CN = 65

Hydrologic Group B

Step 1. Determine curve number without conservation tillage.

CN = 78 (Table 1)

Step 2-3. Same as above.

Step 4. Adjust curve number for conservation tillage.

CN = (78)(1-3/100) = 75.66

CN = 76

Source: "Procedure To Estimate Effects of Conservation Tillage on Reducing Direct Runoff Using SCS Curve Number," CREAMS, CRR 26, pp. 420-425.

Table 1. Runoff Curve Numbers for Hydrologic Soil-Cover Complexes for Antecedent Rainfall Condition II, and $I_a = 0.2S$

Land Use or Cover	*Treatment or Practice*	*Hydrologic Condition*	**Hydrologic Soil Group*			
			A	*B*	*C*	*D*
Fallow	Straight row	—	77	86	91	94
Row crops	Straight row	Poor	72	81	88	91
	Straight row	Good	67	78	85	89
	Contoured	Poor	70	79	84	88
	Contoured	Good	65	75	82	86
	Terraced	Poor	66	74	80	82
	Terraced	Good	62	71	78	81
Small grain	Straight row	Poor	65	76	84	88
	Straight row	Good	63	75	83	87
	Contoured	Poor	63	74	82	85
	Contoured	Good	61	73	81	84
	Terraced	Poor	61	72	79	82
	Terraced	Good	59	70	78	81
Close-seeded legumes or rotation meadow	Straight row	Poor	66	77	85	89
	Straight row	Good	58	72	81	85
	Contoured	Poor	64	75	83	85
	Contoured	Good	55	69	78	83
	Terraced	Poor	63	73	80	83
	Terraced	Good	51	67	76	80
Pasture or range		Poor	68	79	86	89
		Fair	49	69	79	84
		Good	39	61	74	80
	Contoured	Poor	47	67	81	88
	Contoured	Fair	25	59	75	83
	Contoured	Good	6	35	70	79
Meadow (permanent)		Good	30	58	71	78
Woods (farm woodlots)		Poor	45	66	77	83
		Fair	36	60	73	79
		Good	25	55	70	77
Farmsteads		—	59	74	82	86
Roads and right-of-way (hard surface)		—	74	84	90	92

Source: U. S. Soil Conservation Service, *National Engineering Handbook, Hydrology*, Section 4 (1972) and U. S. Dept. Agr. ARS 41-172 (1970).

Table 2. Residue remaining from tillage operations (1)

Tillage operations	Residue remaining
	(%)
Chisel plow	65
Rod weeder	90
Light disk	70
Heavy disk	30
Moldboard plow	10
Till plant	80
Fluted coulter	90
V Sweep	90

(1) Crop residue remaining = (crop residue from table 1) x (tillage factor (s)).

Table 3. Reduction in runoff curve numbers caused by conservation tillage and management

Large residue crop(1) (lb/acre)	Medium residue crop(2) (lb/acre)	Surface covered by residue (%)	Reduction in curve number(3) (%)
0	0	0	0
400	150	10	0
700	300	19	2
1,100	450	28	4
1,500	700	37	6
2,000	950	46	8
2,500	1,200	55	10
6,200	3,500	90	10

(1) Large-residue crop (corn)

(2) Medium residue crop (wheat, oats, barley, rye, sorghum, soybeans).

(3) Percent reduction in curve number can be interpolated linearly. Only apply 1 to 1/2 of these percent reductions to CN's for contouring and terracing practices when they are used in conjunction with conservation tillage.

PROCEDURE TO ESTIMATE EFFECTS OF CONSERVATION TILLAGE ON REDUCING DIRECT RUNOFF USING THE SCS CURVE NUMBER

Conservation tillage is a form of noninversion tillage that retains protective amounts of residue mulch on the surface throughout the year. Conservation tillage practices include fill planting, chisel planting, strip tillage, sweep tillage, chop planting, and no-till. Of these, only no-till has not reduced direct runoff consistently when applied year after year on experimental plots and watersheds. Direct runoff and associated peak discharges are reduced by crop residue cover, which increases infiltration potential through 1) lessening rainfall impact and surface crusting, 2) decreasing runoff velocity by lengthening flow paths and increasing surface roughness, 3) creating additional surface storage, and 4) providing organic matter to improve soil structure.

Direct runoff is computed using thee SCS runoff curve number technique, as described in chapters 9 and 10 of the National Engineering Handbook, Section 4, Hydrology. The selected runoff curve number can be reduced by a percentage to account for the effects of conservation tillage and residue management practices. To take advantage of this reduction, conservation tillage and residue management must be continued for the expected life of the engineering practice. The adaptability of the tillage practices to the local soil and crop growth conditions should be checked. This includes drainage limitations of the soils, pest control problems, equipment on hand, and the attitude and abilities of the farmers. No reductions should be used with continuous no-till or similar practices that do not increase infiltration significantly.

Estimating the amount and type of residue cover remaining after harvest is necessary for this procedure. Assumptions incorporated into the procedure are, 1) normal decomposition of residue over the dormant season and 2) no carryover of residue from year to year.

The approximate amount of residue can be determined by:

1. <u>Estimating residue for local conditions by experienced personnel.</u>

The SCS State resource conservationist or agronomist can estimate the percentage of the surface presently covered by residue or the amount of residue resulting from specific crops and tillage practices.

2) <u>Estimating residue cover by sampling along a transect.</u>

One technique is to use a cord, 50 ft. or longer. that has 100 equally spaced knots or other readily visible markings. This cord is stretched diagonally across several rows, and the knots that contact a piece of mulch are counted. Each knot represents 1% of the sample. This procedure is repeated at randomly selected locations on the field, and the data are averaged to obtain a representative percentage of surface area covered by residue for the field.

3) <u>Estimating residue from empirical data developed from crop and tillage operation records.</u>

a. Estimate the residue produced by the crop in pounds per acre from the estimated crop yield using the equation and data given in Table 4.

b. Compute the amount of residue that will remain on the surface by using the types of tillage practice and remaining residue from Table 5.

The type of residue is classified according to the maximum amount of residue the crop will produce. Medium residue crop will produce residue amounts up to about 4,000 lb per acre and include wheat, oats, barley, rye, sorghum, and soybeans. A large-residue crop, such as corn, can produce from about 4,000 to 8,000 lb per acre of residue.

The computations of direct runoff from areas using conservation tillage and residue management practices involves five steps:

1. Determine the curve number (CN) for the hydrologic soil group, land use, and treatment given in the National Engineering Handbook, Section 4, (Table 1, this section).

2. Estimate the percentage of the surface covered by crop residue or the amount (lb per acre) of crop residues to be left on the surface. An of the three preceding methods can be used.

3. Determine the percentage reduction in runoff curve number caused by conservation tillage practices from Table 6.

4. Determine the adjusted CN by reducing the CN obtained in step 1 by the percentage obtained in step 3.

5. Obtain the direct runoff from the given rainfall using the curve number obtained in step 4, according to the procedure in the National Engineering Handbook, Section 4, (figure 10.1). The adjusted CN also can be used to determine the associated peak discharge.

Table 4--Method for converting crop yields to residue(1)

Crop	Straw/grain ratio	Bushel weight
		(lbs)
Barley	1.5	48
Corn	1.0	56
Oats	2.0	32
Rice	1.5	45
Rye	1.5	56
Sorghum	1.0	56
Soybeans	1.5	60
Winter wheat	1.7	60
Spring wheat	1.3	60

(1) Crop residue = (straw/grain ratio) x (bushel weight in lb/bu) x (crop yield in bu/acre).

Table 5--Residue remaining from tillage operations(1)

Tillage operation	Residue remaining
	(%)
Chisel plow	65
Rod weeder	90
Light disk	70
Heavy disk	30
Moldboard plow	10
Till plant	80
Fluted coulter	90
V Sweep	90

(1) Crop residue remaining = (crop residue from table 1) x (tillage factor (s)).

Table 6--Reduction in runoff curve numbers cause by conservation tillage and residue management.

Large residue crop(1)	Medium residue crop(2)	Surface Covered by residue	Reduction in number(3)
(lb/acre)	(lb/acre)	(%)	(%)
0	0	0	0
400	150	10	0
700	300	19	2
1,100	450	28	4
1,500	700	37	6
2,000	950	46	8
2,500	1,200	55	10
6,200	3,500	90	10

(1) Large-residue crop (corn).
(2) Medium residue crop (wheat, oats, barley, rye, sorghum, and soybeans).
(3) Percent reduction in curve numbers can be interpolated linearly. Only apply 0 to 1/2 of these percent reductions to CN's for contouring and terracing practices when they are used in conjunction with conservation tillage.

When conservation tillage and residue management are used in conjunction with contouring or with contouring and terracing, 0 to one-half of the table 3 reduction is needed, based on the type of soil and the increased potential for infiltration. The smaller reduction is applied to the CN for contouring or contouring and terracing. Research data are unavailable to determine the combined effects of residue and these conservation practices to reduce runoff.

Example 1:

A cultivated area in poor hydrologic condition with soils in hydrologic soil group C is farmed in straight-row continuous corn. Corn yields are 90 bu per acre. Conservation tillage operations are estimated to provide a 50% surface coverage with corn residue. Determine the direct runoff from a 3.0" rainfall in 24-hr.

Step 1. Determine curve number without conservation tillage.
For straight-row, continuous corn, in poor hydrologic condition, in a "C" soil; C = 88 (Table 1).

Step 2. Determine residue amounts left on surface.
The estimate of surface covered by corn residue was given directly as 50%.

Step 3. Reduce curve number.
Entering Table 6 with 50% surface cover; CN reduction = 9%.

Step 4. Adjust curve number for conservation tillage.
CN = (CN from step 1) x (1-(CN reduction %/100)).

CN = 88 (1-(9/100))

CN = 80.1, use 80.

Step 5. Determine direct runoff, in inches, with conservation tillage.
With 3.0" rainfall and CN = 80; runoff = 1.3"(NEH, Sec.4, Table 10.1).

Example 2:

The watershed above a proposed engineering practice is a good hydrologic condition with soils in hydrologic group B and is farmed in a straight-row corn-soybean rotation. Corn yields are expected to average 100 bu per acre and soybean yields 40 bu per acre. The only tillage operations planned are chisel plowing and heavy disking before planting soybeans and heavy disking only before corn planting. The farmer is committed to these conservation tillage practices, which are suitable for the local conditions. Assume 50% of the cultivated area is in corn and 50% in soybeans in any one year. Determine the direct runoff from a 3.0" rainfall in 24-hr as follows:

Step 1 Determine curve number without conservation tillage.
For corn: CN = 78 (table 1).
For soybeans: CN = 78 (table 1).

Step 2 Residue amounts left on surface,

(a) After harvest (from Table 4):

Crop residue = (straw/grain ratio x bushel weight x crop yield).
Corn residue = (1.0 x 56 lb/bu x 100 bu/ac) = 5,600 lb/acre.
Soybean residue = (1.5 x 60 lb/bu x 40 bu/ac) = 3,600 lb/acre).

(b) Reduction in crop residue as a result of tillage operations, (from Table 5).

Corn residue remaining = (5,600 lb/ac x 0.65 chisel plow x heavy disk) = 1090 lb/acre.

Soybean residue remaining = (3,600 lb/ac x 0.30 heavy disk)
= 1,080 lb/acre.

Step 3 Reduce curve number (from Table 6).

(a) Soybeans following corn, with corn residue = 1,090 lb/acre since corn is a large-residue crop; CN reduction = 4%.

(b) Corn following soybeans, with soybean residue = 1,080 lb/acre since soybean is a medium-residue crop; CN reduction = 9%.

Step 4 Adjust curve numbers for conservation tillage.

CN = (CN from step 1) x (1-(CN reduction %/100)).

(a) Soybeans following corn (corn residue).

CN = 78 x (1-(4/100)) = 74.9; use CN = 75.

(b) Corn following soybeans (soybean residue).

CN = 78 x (1-(9/100)) = 71

(c) Average CN for cultivated area, 50% of each crop.

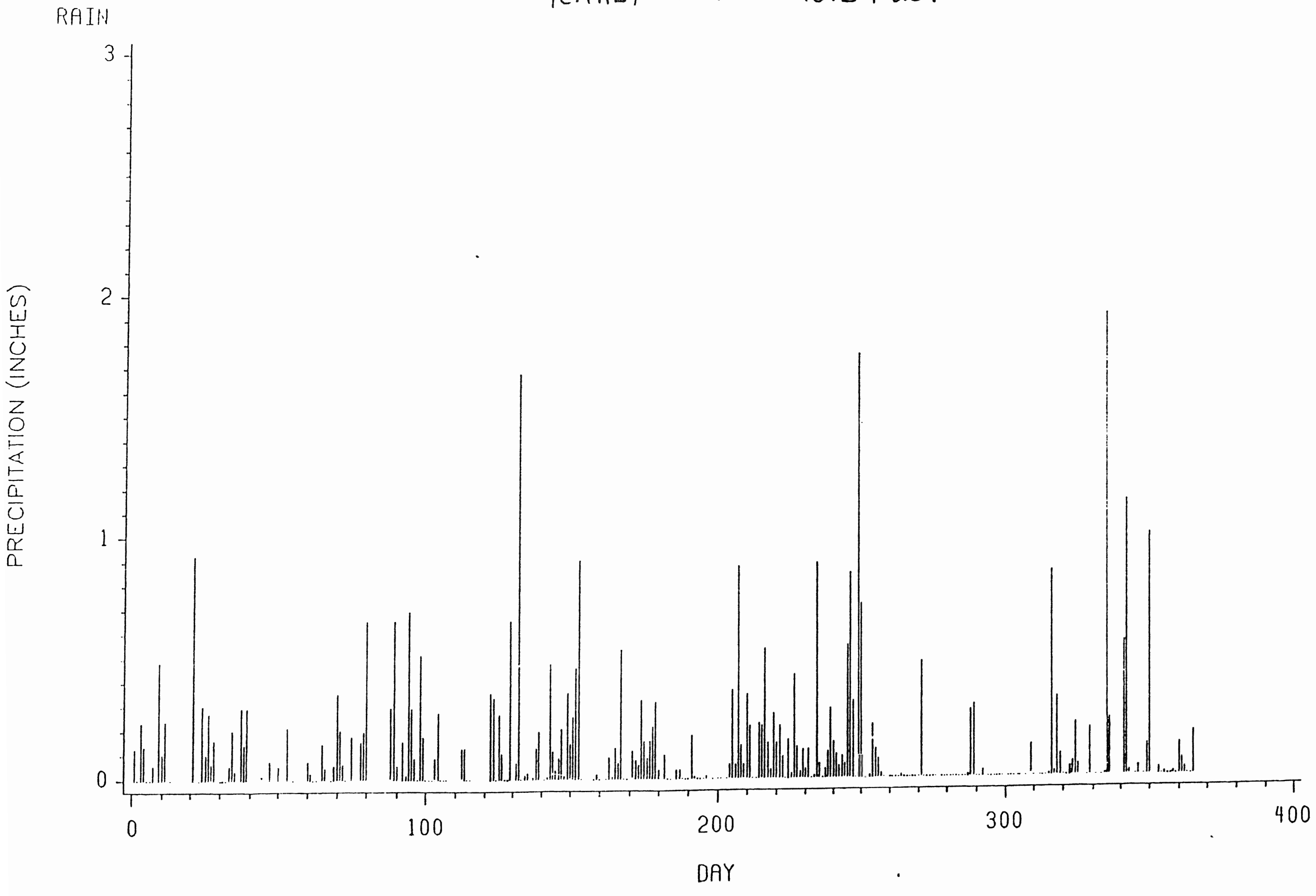
CN = (75 CN soybeans + 71 CN corn)/2
CN = 73.

Step 5 Direct runoff in inches with conservation tillage with 3.0" rainfall and CN = 73: runoff = 0.9" (NEH, Sect. 4, figure 10.1). Without conservation tillage, CN = 78; runoff would be 1.1". This amounts to an 18% reduction in runoff.

APPENDIX 2

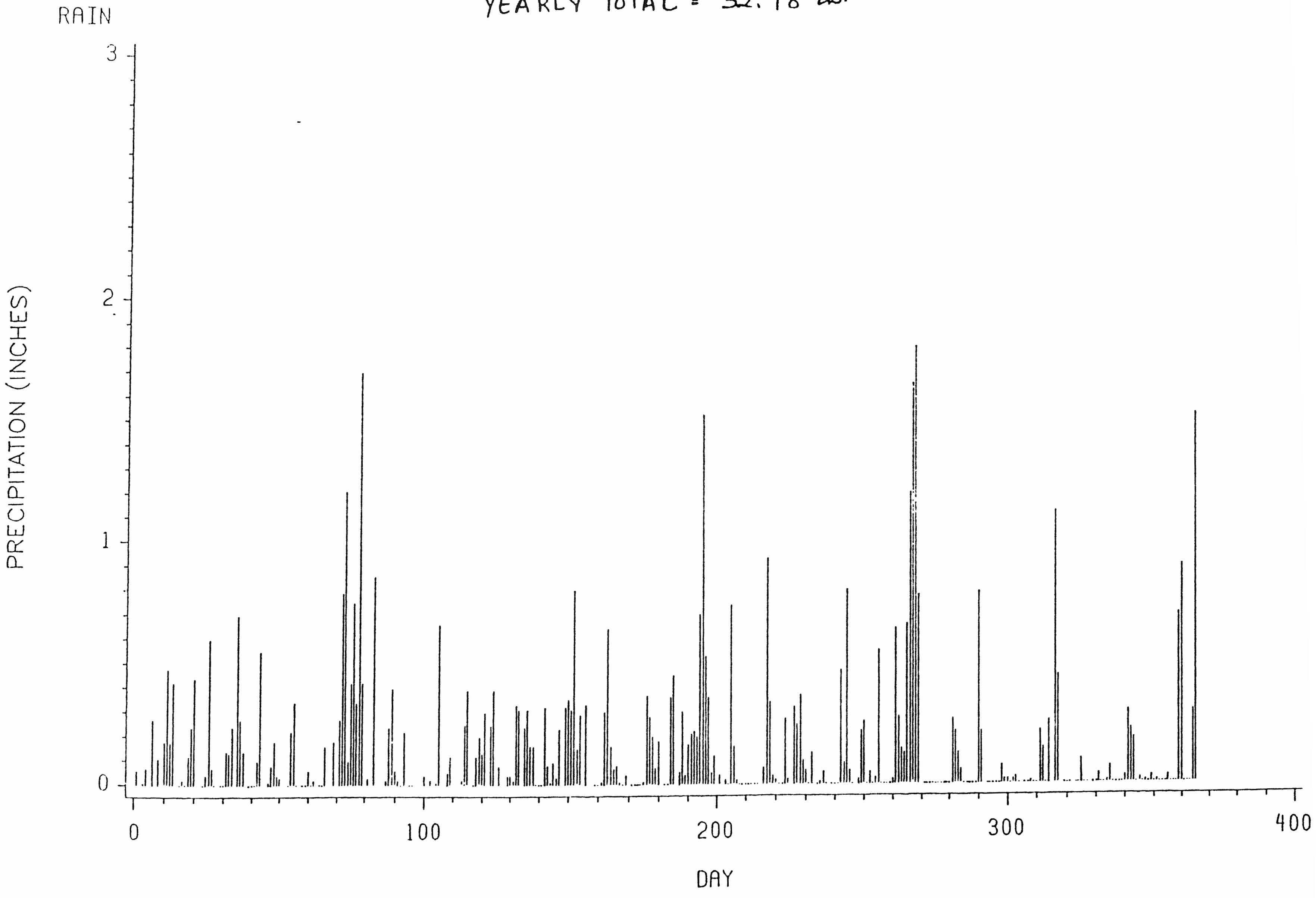
CHESAPEAKE BAY DAILY PRECIPITATION
YEAR=74

YEARLY TOTAL = 40.59 in.



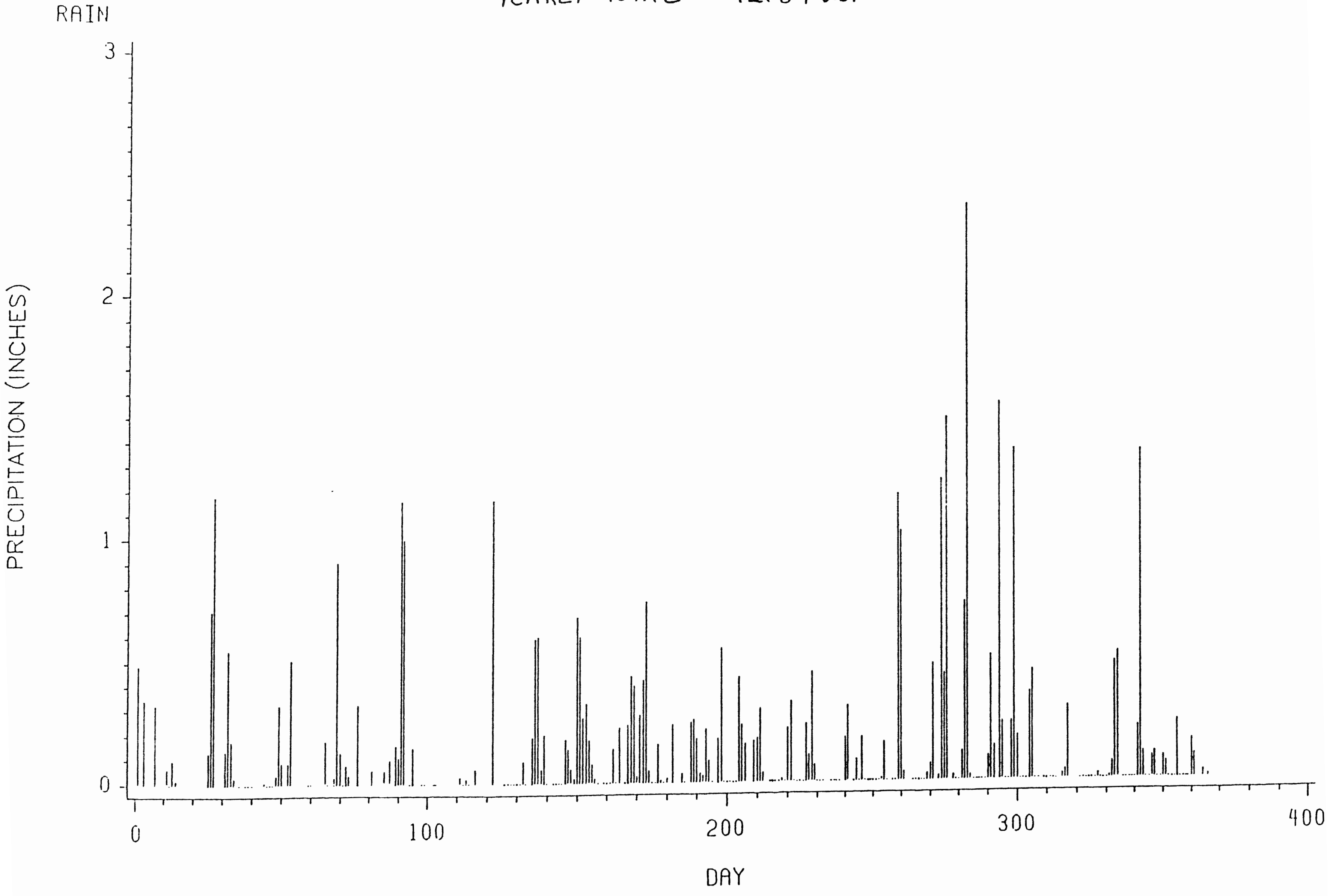
CHESAPEAKE BAY DAILY PRECIPITATION
YEAR=75

YEARLY TOTAL = 52.78 in.



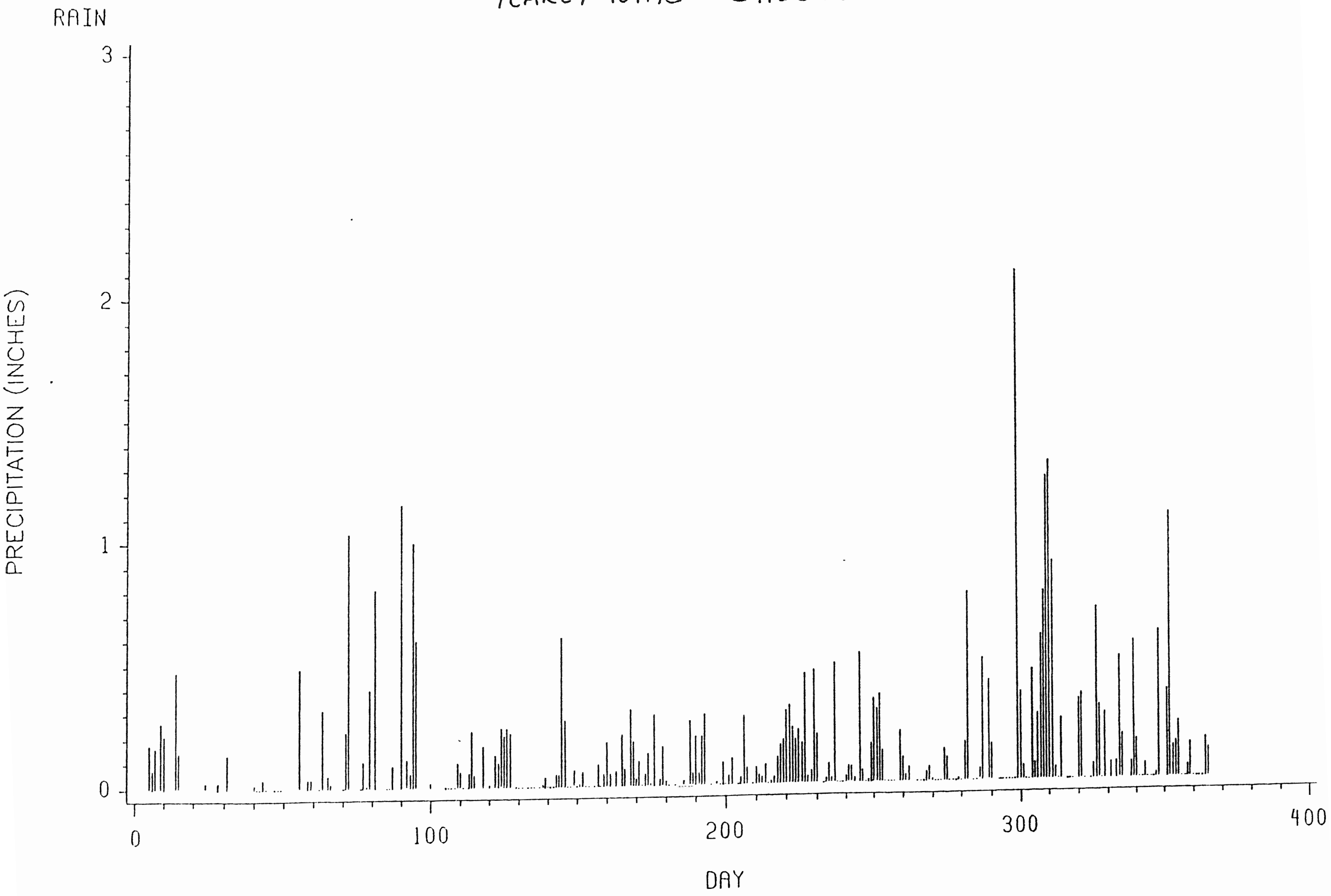
CHESAPEAKE BAY DAILY PRECIPITATION
YEAR=76

YEARLY TOTAL: 42.89 in.



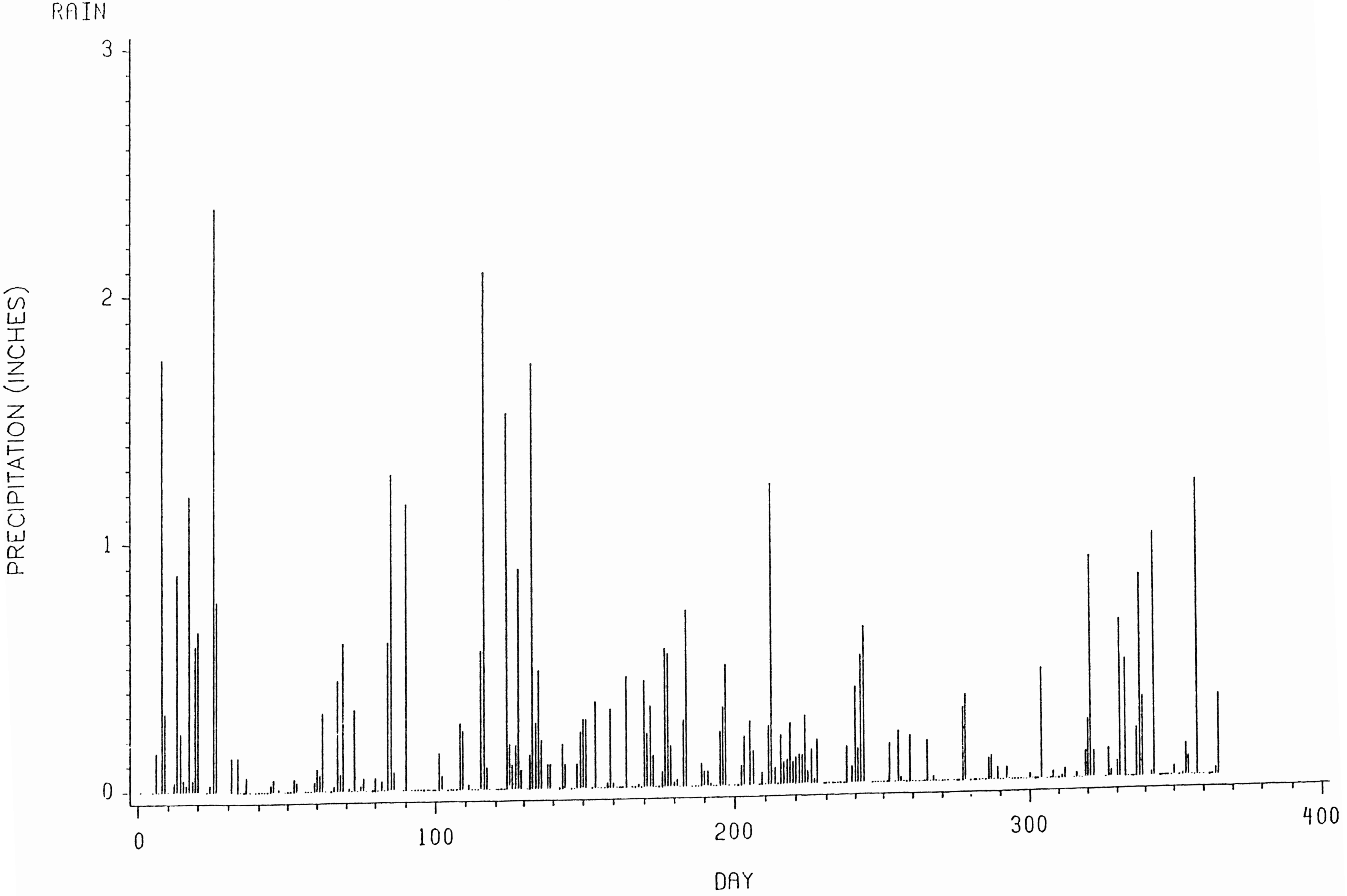
CHESAPEAKE BAY DAILY PRECIPITATION
YEAR=77

YEARLY TOTAL = 39.03 in.



CHESAPEAKE BAY DAILY PRECIPITATION
YEAR=78

YEARLY TOTAL = 46.5 in.



APPENDIX 3

SOIL 1. GALESTOWN

DEPTH	TEXTURE	POROS.	BR15	FUL	CONA
0-24"	LS	0.40	0.05	0.4	3.3

Source: Soils 5 sheet and CREAMS manual.

```
---|-----------------------|---
   |        UL(1)          | 1"
   |- - - - - - - - - - - -|---
   |        UL(2)          | 3"
   |- - - - - - - - - - - -|---
   |        UL(3)          |
   |- - - - - - - - - - - -|
24"|        UL(4)          |
   |- - - - - - - - - - - -|
   |        UL(5)          | 20"
   |- - - - - - - - - - - -|
   |        UL(6)          |
   |- - - - - - - - - - - -|
   |        UL(7)          |
 --|-----------------------|---
```

Rooting Depth, RD = 24"
(Soil Layer Depth)(RD)
1/36(24") = 0.67"
5/36(24") = 3.33"
1/6(24") = 4.0"

Saturated Hydraulic Conductivity, RC, for good, straight row crops, Hydrologic Group A = 0.45
(CRR, p 184)

UL = (POROS - BR15)(RD)(Soil Layer Depth)
UL(1) = (0.4 - 0.05)(0.67) = 0.23
UL(2) = (0.4 - 0.05)(3.33) = 1.17
UL(3) = (0.4 - 0.05)(4.0) = 1.40
UL(4) = 1.40
UL(5) = 1.40
UL(6) = 1.40
UL(7) = 1.40

7 - Layer Averages
FUL = 0.40
CONA = 3.30
BR15 = 0.05
POROS = 0.40

K - factor = 0.17
(Soils 5 sheet)

SOIL 2. NORFOLK

DEPTH	TEXTURE	POROS.	BR15	FUL	CONA
0-16"	LS,LFS	0.40	0.05	0.49	3.3
16-24"	SL	0.40	0.08	0.44	3.5

Source: Soils 5 sheet and CREAMS manual.

```
---|-----------------------|------
   |        UL(1)          | 1"
   |- - - - - - - - - - - -|---
   |        UL(2)          | 3"
   |- - - - - - - - - - - -|---
   |        UL(3)          |
   |- - - - - - - - - - - -|    16"
24"|        UL(4)          |
   |- - - - - - - - - - - -|
   |        UL(5)          |
   |- - - - - - - - - - - -|------
   |        UL(6)          |
   |- - - - - - - - - - - -|     8"
   |        UL(7)          |
 --|-----------------------|------
```

Rooting Depth, RD = 24"
(Soil Layer Depth)(RD)
1/36(24") = 0.67"
5/36(24") = 3.33"
1/6(24") = 4.0"

Saturated Hydraulic Conductivity, RC, for good, straight row crops, Hydrologic Group B = 0.21 (CRR, p 184)

UL = (POROS - BR15)(RD)(Soil Layer Depth)
UL(1) = (0.4 - 0.05)(0.67) = 0.23
UL(2) = (0.4 - 0.05)(3.33) = 1.17
UL(3) = (0.4 - 0.05)(4.0) = 1.40
UL(4) = 1.40
UL(5) = 1.40
UL(6) = (0.4 - 0.08)(4.0) = 1.28
UL(7) = 1.28

7 - Layer Averages
FUL = 0.4433
CONA = 3.40
BR15 = 0.06
POROS = 0.40

K - factor = 0.17
(Soils 5 sheet)

SOIL 3. CECIL

DEPTH	TEXTURE	POROS.	BR15	FUL	CONA
0-8"	SL	0.40	0.08	0.44	3.5
8-12"	SCL,CL	.4,.4	.18,.22	.54,.72	4.0,4.0
12-24	C	0.47	0.28	0.58	3.5

Source: Soils 5 sheet and CREAMS manual.

```
---|-----------------------|------
   |        UL(1)          | 1"
   |- - - - - - - - - - - -|--- 8"
   |        UL(2)          | 3"
   |- - - - - - - - - - - -|------
   |        UL(3)          |    4"
   |- - - - - - - - - - - -|------
24"|        UL(4)          |
   |- - - - - - - - - - - -|
   |        UL(5)          | 20"
   |- - - - - - - - - - - -|   12"
   |        UL(6)          |
   |- - - - - - - - - - - -|
   |        UL(7)          |
 --|-----------------------|------
```

Rooting Depth, RD = 24"
(Soil Layer Depth)(RD)
1/36(24") = 0.67"
5/36(24") = 3.33"
1/6(24") = 4.0"

<u>Saturated Hydraulic Conductivity, RC</u>, for good, straight row crops, Hydrologic Group B = 0.21 (CRR, p 184)

UL = (POROS - BR15)(RD)(Soil Layer Depth)
UL(1) = (0.4 - 0.08)(0.67) = 0.2144
UL(2) = (0.4 - 0.08)(3.33) = 1.0656
UL(3) = (0.4 - 0.18)(4.0) = 0.88
UL(4) = (0.4 - 0.22)(4.0) = 0.72
UL(5) = (0.47- 0.28)(4.0) = 0.76
UL(6) = 0.76
UL(7) = 0.76

<u>7 - Layer Averages</u>
FUL = 0.527
CONA = 3.57
BR15 = 0.20
POROS = 0.43

<u>K - factor = 0.28</u>
(Soils 5 sheet)

SOIL 4. AND 5. CECIL

DEPTH	TEXTURE	POROS.	BR15	FUL	CONA
0-8"	SCL	0.40	0.18	0.54	4.0
8-12"	CL	0.40	0.22	0.72	4.0
12-24	C	0.47	0.28	0.58	3.5

Source: Soils 5 sheet and CREAMS manual.

```
---|------------------------|------
   |        UL(1)           | 1"
   |- - - - - - - - - - - - |--- 8"
   |        UL(2)           | 3"
   |- - - - - - - - - - - - |------
   |        UL(3)           |    4"
   |- - - - - - - - - - - - |------
24"|        UL(4)           |
   |- - - - - - - - - - - - |
   |        UL(5)           | 20"
   |- - - - - - - - - - - - |   12"
   |        UL(6)           |
   |- - - - - - - - - - - - |
   |        UL(7)           |
 --|------------------------|------
```

Rooting Depth, RD = 24"
(Soil Layer Depth)(RD)
1/36(24") = 0.67"
5/36(24") = 3.33"
1/6(24") = 4.0"

<u>Saturated Hydraulic Conductivity, RC</u>, for good, straight row crops, Hydrologic Group B = 0.21
(CRR, p 184)

UL = (POROS - BR15)(RD)(Soil Layer Depth)
UL(1) = (0.4 - 0.18)(0.67) = 0.1474
UL(2) = (0.4 - 0.20)(3.33) = 0.666
UL(3) = (0.4 - 0.20)(4.0) = 0.80
UL(4) = (0.4 - 0.22)(4.0) = 0.72
UL(5) = (0.47- 0.28)(4.0) = 0.76
UL(6) = 0.76
UL(7) = 0.76

<u>7 - Layer Averages</u>
FUL = 0.61
CONA = 3.786
BR15 = 0.2343
POROS = 0.43

<u>K - factor = 0.28</u>
(Soils 5 sheet)

SOIL 6. PENN LOAM
(0 - 8% slope)

DEPTH	TEXTURE	POROS.	BR15	FUL	CONA
0-8"	L	0.40	0.11	0.52	4.5
8-24"	SIL	0.43	0.12	0.64	4.5

Source: Soils 5 sheet and CREAMS manual.

```
---|-----------------------|---
   |        UL(1)          |
   |- - - - - - - - - - - -|
   |        UL(2)          | 8"
   |- - - - - - - - - - - -|
   |         UL(3)          |
   |- - - - - - - - - - - -|---
24"|        UL(4)          |
   |- - - - - - - - - - - -|
   |        UL(5)          |
   |- - - - - - - - - - - -|16"
   |        UL(6)          |
   |- - - - - - - - - - - -|
   |        UL(7)          |
 --|-----------------------|---
```

Rooting Depth, RD = 24"
(Soil Layer Depth)(RD)
1/36(24") = 0.67"
5/36(24") = 3.33"
1/6(24") = 4.0"

Saturated Hydraulic Conductivity, RC, for good, straight row crops, Hydrologic Group C = 0.10
(average between 0.5 - 0.15)
(CREAMS Manual)

UL = (POROS - BR15)(RD)(Soil Layer Depth)
UL(1) = (0.4 - 0.11)(0.67) = 0.19
UL(2) = (0.4 - 0.11)(3.33) = 0.97
UL(3) = (0.4 - 0.11)(4.0) = 1.16
UL(4) = (0.43- 0.12)(4.0) = 1.24
UL(5) = 1.24
UL(6) = 1.24
UL(7) = 1.24

7 - Layer Averages
FUL = 0.58
CONA = 4.5
BR15 = 0.115
POROS = 0.415

K - factor = 0.32

CNII: 85/82

C - factor

base	.22	.25	.25	.22	.19	.16	.22
alt.	.19	.14	.14	.13	.11	.09	.19

APPENDIX 4

Summary
5-yr. Simulation (1974-78)
Continuous Corn w/One Fertilizer Application (Broadcast)
Field size - 35 acres 2% Slope

	PRECIP	RUNOFF	SOIL LOSS	TOT N	TOT P	N LEACHED	N UPTAKE	ENRICHMENT
	(in)	(in)	(t/ac)	-----------(kg/ha)-------------				RATIO
Soil 1 (Loamy Sand)								
Base Scenario (CNII=67)								
1974	40.590	0.020	0.000	0.016	0.002	95.552	190.472	11.206
1975	52.780	0.050	0.000	0.035	0.004	89.031	184.873	11.493
1976	42.890	0.130	0.000	0.090	0.012	74.406	182.529	11.173
1977	39.030	0.000	0.000	0.000	0.000	103.393	163.723	
1978	46.500	0.160	0.000	0.223	0.034	135.180	134.206	11.407
Mean	44.358	0.072	0.000	0.073	0.010	99.512	171.160	
Std Dev	4.904	0.062	0.000	0.081	0.013	20.214	20.548	
Alternate Scenario (CNII=65)								
1974	40.590	0.000	0.000	0.000	0.000	95.583	190.472	
1975	52.780	0.010	0.000	0.007	0.001	89.050	184.872	11.206
1976	42.890	0.090	0.000	0.062	0.008	74.441	182.529	11.238
1977	39.030	0.000	0.000	0.000	0.000	103.389	163.723	
1978	46.500	0.100	0.000	0.131	0.020	135.397	134.112	11.472
Mean	44.358	0.040	0.000	0.040	0.006	99.572	171.142	
Std Dev	4.904	0.045	0.000	0.051	0.008	20.279	20.582	
Percent Reduction		44.444	ERR	45.150	44.636	-0.060	0.011	
il 2 (Loamy Sand, Fine Loamy Sand, Sandy Loam)								
Base Scenario (CII=78)								
1974	40.590	0.510	0.020	0.762	0.115	83.573	199.281	7.186
1975	52.780	0.900	0.030	0.803	0.124	81.587	190.197	6.540
1976	42.890	1.010	0.020	0.791	0.106	69.873	191.317	7.868
1977	39.030	0.300	0.000	0.302	0.027	97.452	168.240	11.203
1978	46.500	1.310	0.070	2.094	0.342	124.174	144.225	5.164
Mean	44.358	0.806	0.028	0.950	0.143	91.332	178.652	
Std Dev	4.904	0.360	0.023	0.602	0.106	18.610	20.065	
Alternate Scenario (CII=76)								
1974	40.590	0.370	0.010	0.472	0.058	84.747	198.738	7.689
1975	52.780	0.650	0.010	0.487	0.058	81.866	190.111	7.469
1976	42.890	0.740	0.010	0.581	0.082	70.216	191.317	7.422
1977	39.030	0.210	0.000	0.208	0.019	97.905	168.240	11.257
1978	46.500	0.990	0.030	1.474	0.226	125.747	143.194	4.842
Mean	44.358	0.592	0.012	0.645	0.088	92.096	178.320	
Std Dev	4.904	0.275	0.010	0.433	0.072	18.992	20.300	
Percent Reduction		26.551	57.143	32.172	38.059	-0.837	0.186	

Soil 1	Galestown, loamy sand
Soil 2	Norfolk, loamy sand, loamy fine sand, sandy loam
Soil 3	Cecil, sandy loam, sandy clay loam, clay loam, clay
Soil 4	Cecil, sandy clay loam, clay loam, clay
Soil 5	Cecil, sandy clay loam, clay loam, clay
Soil 6	Penn Loam, loam, silt loam

Summary, con't.
5-yr. Simulation (1974-78)
Continuous Corn w/One Fertilizer Application (Broadcast)
Field size - 35 acres   2% Slope

	PRECIP	RUNOFF	SOIL LOSS	TOT N	TOT P	N LEACHED	N UPTAKE	ENRICHMENT
	(in)	(in)	(t/ac)	-----------(kg/ha)-------------				RATIO
Soil 3 (Sandy Loam, Sandy Clay Loam, Clay Loam, Clay)								
Base Scenario (CNII=78)								
1974	40.590	0.670	0.040	1.266	0.189	75.351	188.988	3.620
1975	52.780	1.290	0.100	1.306	0.210	83.762	212.038	3.177
1976	42.890	1.420	0.040	1.215	0.145	75.327	180.246	4.356
1977	39.030	0.530	0.010	0.566	0.060	111.780	152.406	5.525
1978	46.500	1.740	0.140	3.316	0.572	110.135	179.419	3.283
Mean	24.643	0.628	0.037	0.852	0.131	57.044	114.137	
Std Dev	22.343	0.658	0.048	1.031	0.176	46.043	89.698	
Alternate Scenario (CNII=76)								
1974	40.590	0.500	0.020	0.891	0.129	76.585	188.988	3.424
1975	52.780	1.000	0.040	0.868	0.115	83.908	212.038	3.279
1976	42.890	1.100	0.020	0.939	0.119	75.937	180.246	3.959
1977	39.030	0.340	0.010	0.329	0.028	112.605	152.406	5.589
1978	46.500	1.350	0.060	2.299	0.368	111.958	178.135	3.257
Mean	44.358	0.858	0.030	1.065	0.152	92.199	182.363	
Std Dev	4.904	0.379	0.018	0.655	0.114	16.636	19.206	
Percent Reduction		-36.673	18.182	-25.003	-16.106	-61.626	-59.775	
Soil 4 (Sandy Clay Loam, Clay Loam, Clay)								
Base Scenario (CII=78)								
1974	40.590	0.860	0.060	1.610	0.228	67.678	187.934	2.686
1975	52.780	1.920	0.130	2.149	0.318	82.455	212.506	2.639
1976	42.890	1.970	0.070	1.906	0.266	70.084	180.628	3.047
1977	39.030	0.730	0.020	0.765	0.076	106.556	153.271	3.573
1978	46.500	2.170	0.170	4.216	0.711	104.166	185.847	2.712
Mean	44.358	1.530	0.090	2.129	0.320	86.188	184.037	
Std Dev	4.904	0.607	0.053	1.143	0.211	16.456	18.905	
Alternate Scenario (CII=76)								
1974	40.590	0.640	0.040	1.153	0.162	69.341	187.934	2.542
1975	52.780	1.550	0.050	1.509	0.191	82.841	212.506	2.711
1976	42.890	1.600	0.040	1.395	0.171	70.877	180.628	2.816
1977	39.030	0.520	0.010	0.499	0.043	107.447	153.271	3.598
1978	46.500	1.720	0.070	3.127	0.502	106.063	184.564	2.699
Mean	44.358	1.206	0.042	1.537	0.214	87.314	183.780	
Std Dev	4.904	0.516	0.019	0.869	0.153	16.554	18.888	
Percent Reduction		21.176	53.333	27.830	33.102	-1.306	0.139	

Summary

5-yr. Simulation (1974-78)
Continuous Corn w/One Fertilizer Application (Broadcast)
Field size - 35 acres 4% Slope

	PRECIP	RUNOFF	SOIL LOSS	TOT N	TOT P	N LEACHED	N UPTAKE	ENRICHMENT
	(in)	(in)	(t/ac)	-----------(kg/ha)			--------------	RATIO
Soil 1 (Loamy Sand)								
Base Scenario (CII=67)								
1974	40.590	0.020	0.000	0.016	0.002	95.552	190.472	11.183
1975	52.780	0.050	0.000	0.035	0.004	89.031	184.873	11.003
1976	42.890	0.130	0.010	0.134	0.028	74.406	182.529	9.752
1977	39.030	0.000	0.000	0.000	0.000	103.393	163.723	
1978	46.500	0.160	0.020	0.300	0.062	135.180	134.206	7.716
Mean	44.358	0.072	0.006	0.097	0.019	99.512	171.160	
Std Dev	4.904	0.062	0.008	0.112	0.024	20.214	20.548	
Alternate Scenario (CNII=65)								
1974	40.590	0.000	0.000	0.000	0.000	95.583	190.472	
1975	52.780	0.010	0.000	0.007	0.001	89.050	184.872	11.860
1976	42.890	0.090	0.000	0.062	0.008	74.441	182.529	10.710
1977	39.030	0.000	0.000	0.000	0.000	103.389	163.723	
1978	46.500	0.100	0.010	0.131	0.020	135.397	134.112	8.351
Mean	44.358	0.040	0.002	0.040	0.006	99.572	171.142	
Std Dev	4.904	0.045	0.004	0.051	0.008	20.279	20.582	
Percent Reduction		44.444	66.667	58.922	69.927	-0.060	0.011	
l 2 (Loamy Sand, Fine Loamy Sand, Sandy Loam)								
ase Scenario (CII=78)								
1974	40.590	0.510	0.100	1.047	0.217	83.573	199.281	3.815
1975	52.780	0.900	0.120	1.117	0.237	81.587	190.197	4.442
1976	42.890	1.010	0.090	1.002	0.182	69.873	191.317	4.680
1977	39.030	0.300	0.010	0.346	0.043	97.452	168.240	9.564
1978	46.500	1.310	0.220	2.517	0.494	124.174	144.225	4.209
Mean	44.358	0.806	0.108	1.206	0.235	91.332	178.652	
Std Dev	4.904	0.360	0.067	0.712	0.147	18.610	20.065	
Alternate Scenario (CII=76)								
1974	40.590	0.370	0.040	0.639	0.118	84.747	198.738	4.164
1975	52.780	0.650	0.040	0.621	0.106	81.866	190.111	4.446
1976	42.890	0.740	0.050	0.672	0.114	70.216	191.317	3.999
1977	39.030	0.210	0.000	0.208	0.019	97.905	168.240	10.639
1978	46.500	0.990	0.080	1.688	0.303	125.747	143.194	4.251
Mean	44.358	0.592	0.042	0.766	0.132	92.096	178.320	
Std Dev	4.904	0.275	0.026	0.491	0.093	18.992	20.300	
Percent Reduction		26.551	61.111	36.496	43.778	-0.837	0.186	

Soil 1	Galestown, loamy sand
Soil 2	Norfolk, loamy sand, loamy fine sand, sandy loam
Soil 3	Cecil, sandy loam, sandy clay loam, clay loam, clay
Soil 4	Cecil, sandy clay loam, clay loam, clay
Soil 5	Cecil, sandy clay loam, clay loam, clay
Soil 6	Penn Loam, loam, silt loam

Summary, con't.
5-yr. Simulation (1974-78)
Continuous Corn w/One Fertilizer Application (Broadcast)
Field size - 35 acres 4% Slope

	PRECIP (in)	RUNOFF (in)	SOIL LOSS (t/ac)	TOT N <-------------(kg/ha)-------------->	TOT P	N LEACHED	N UPTAKE	ENRICHMENT RATIO
Soil 3 (Sandy Loam, Sandy Clay Loam, Clay Loam, Clay)								
Base Scenario (CII=78)								
1974	40.590	0.670	0.190	1.646	0.326	75.351	188.988	2.731
1975	52.780	1.290	0.310	1.943	0.439	83.762	212.038	2.144
1976	42.890	1.420	0.170	1.641	0.299	75.327	180.246	3.232
1977	39.030	0.530	0.030	0.688	0.104	111.780	152.406	5.241
1978	46.500	1.740	0.500	4.159	0.875	110.135	179.419	2.363
Mean	44.358	1.130	0.240	2.015	0.409	91.271	182.620	
Std Dev	4.904	0.459	0.157	1.152	0.257	16.374	19.156	
Alternate Scenario (CNII=76)								
1974	40.590	0.500	0.070	1.059	0.189	76.585	188.988	2.732
1975	52.780	1.000	0.120	1.171	0.224	83.908	212.038	2.256
1976	42.890	1.100	0.110	1.186	0.208	75.937	180.246	2.976
1977	39.030	0.340	0.010	0.373	0.044	112.605	152.406	5.416
1978	46.500	1.350	0.220	2.772	0.538	111.958	178.135	2.409
Mean	44.358	0.858	0.106	1.312	0.241	92.199	182.363	
Std Dev	4.904	0.379	0.069	0.789	0.162	16.636	19.206	
Percent Reduction		24.071	55.833	34.880	41.105	-1.017	0.141	
S 4 (Sandy Clay Loam, Clay Loam, Clay)								
Base Scenario (CNII=78)								
1974	40.590	0.860	0.210	2.046	0.385	67.678	187.934	2.422
1975	52.780	1.920	0.430	3.001	0.625	82.455	212.506	1.849
1976	42.890	1.970	0.260	2.396	0.442	70.084	180.628	2.536
1977	39.030	0.730	0.060	0.931	0.137	106.556	153.271	3.333
1978	46.500	2.170	0.610	5.349	1.118	104.166	185.847	2.002
Mean	44.358	1.530	0.314	2.745	0.541	86.188	184.037	
Std Dev	4.904	0.607	0.189	1.466	0.328	16.456	18.905	
Alternate Scenario (CNII=76)								
1974	40.590	0.640	0.080	1.260	0.200	69.341	187.934	2.532
1975	52.780	1.550	0.190	2.044	0.384	82.841	212.506	1.908
1976	42.890	1.600	0.140	1.767	0.305	70.877	180.628	2.447
1977	39.030	0.520	0.030	0.633	0.091	107.447	153.271	3.329
1978	46.500	1.720	0.280	3.715	0.714	106.063	184.564	2.043
Mean	44.358	1.206	0.144	1.884	0.339	87.314	183.780	
Std Dev	4.904	0.516	0.087	1.034	0.212	16.554	18.888	
Percent Reduction		21.176	54.140	31.371	37.397	-1.306	0.139	

Summary
5-yr. Simulation (1974-78)
Continuous Corn w/One Fertilizer Application (Broadcast)
Field size - 35 acres 6% Slope

	PRECIP	RUNOFF	SOIL LOSS	TOT N	TOT P	N LEACHED	N UPTAKE	ENRICHMENT RATIO
	(in)	(in)	(t/ac)	(kg/ha)				
Soil 1 (Loamy Sand)								
Base Scenario (CNII=67)								
1974	40.590	0.020	0.000	0.016	0.002	95.552	190.472	11.411
1975	52.780	0.050	0.010	0.080	0.020	89.031	184.873	8.086
1976	42.890	0.130	0.020	0.167	0.040	74.406	182.529	7.080
1977	39.030	0.000	0.000	0.000	0.000	103.393	163.723	
1978	46.500	0.160	0.060	0.429	0.108	135.180	134.206	6.467
Mean	44.358	0.072	0.018	0.138	0.034	99.512	171.160	
Std Dev	4.904	0.062	0.022	0.157	0.040	20.214	20.548	
Alternate Scenario (CNII=65)								
1974	40.590	0.000	0.000	0.000	0.000	95.583	190.472	
1975	52.780	0.010	0.000	0.007	0.001	89.050	184.872	11.818
1976	42.890	0.090	0.010	0.106	0.024	74.441	182.529	7.366
1977	39.030	0.000	0.000	0.000	0.000	103.389	163.723	
1978	46.500	0.100	0.020	0.208	0.048	135.397	134.112	7.088
Mean	44.358	0.040	0.006	0.064	0.015	99.572	171.142	
Std Dev	4.904	0.045	0.008	0.082	0.019	20.279	20.582	
Percent Reduction		44.444	66.667	53.513	57.286	-0.060	0.011	
il 2 (Loamy Sand, Fine Loamy Sand, Sandy Loam)								
3ase Scenario (CNII=78)								
1974	40.590	0.510	0.170	1.180	0.690	83.573	199.281	3.897
1975	52.780	0.900	0.200	1.348	0.320	81.587	190.197	4.331
1976	42.890	1.010	0.170	1.316	0.295	69.873	191.317	4.423
1977	39.030	0.300	0.030	0.379	0.055	97.452	168.240	7.431
1978	46.500	1.310	0.430	3.057	0.689	124.174	144.225	3.518
Mean	44.358	0.806	0.200	1.456	0.410	91.332	178.652	
Std Dev	4.904	0.360	0.129	0.875	0.246	18.610	20.065	
Alternate Scenario (CNII=76)								
1974	40.590	0.370	0.060	0.705	0.142	84.747	198.738	4.124
1975	52.780	0.650	0.070	0.809	0.064	81.866	190.111	4.770
1976	42.890	0.740	0.080	0.813	0.165	70.216	191.317	4.267
1977	39.030	0.210	0.010	0.253	0.035	97.905	168.240	7.599
1978	46.500	0.990	0.170	1.974	0.406	125.747	143.194	3.577
Mean	44.358	0.592	0.078	0.911	0.162	92.096	178.320	
Std Dev	4.904	0.275	0.052	0.570	0.131	18.992	20.300	
Percent Reduction		26.551	61.000	37.468	60.431	-0.837	0.186	

Soil 1	Galestown, loamy sand
Soil 2	Norfolk, loamy sand, loamy fine sand, sandy loam
Soil 3	Cecil, sandy loam, sandy clay loam, clay loam, clay
Soil 4	Cecil, sandy clay loam, clay loam, clay
Soil 5	Cecil, sandy clay loam, clay loam, clay
Soil 6	Penn Loam, loam, silt loam

Summary, con't.
5-yr. Simulation (1974-78)
Continuous Corn w/One Fertilizer Application (Broadcast)
Field size - 35 acres   6% Slope

	PRECIP (in)	RUNOFF (in)	SOIL LOSS (t/ac)	TOT N	TOT P	N LEACHED	N UPTAKE	ENRICHMENT RATIO
				(kg/ha)				
Soil 3 (Sandy Loam, Sandy Clay Loam, Clay Loam, Clay)								
Base Scenario (CNII=78)								
1974	40.590	0.670	0.440	2.281	0.555	75.351	188.988	1.932
1975	52.780	1.290	0.530	2.468	0.628	83.762	212.038	2.038
1976	42.890	1.420	0.400	2.246	0.516	75.327	180.246	2.535
1977	39.030	0.530	0.070	0.795	0.143	111.780	152.406	4.166
1978	46.500	1.740	0.980	5.210	1.253	110.135	179.419	2.060
Mean	44.358	1.130	0.484	2.600	0.619	91.271	182.620	
Std Dev	4.904	0.459	0.293	1.436	0.359	16.374	19.156	
Alternate Scenario (CNII=76)								
1974	40.590	0.500	0.170	1.331	0.287	76.585	188.988	2.014
1975	52.780	1.000	0.230	1.465	0.330	83.908	212.038	2.177
1976	42.890	1.100	0.260	1.575	0.348	75.937	180.246	2.127
1977	39.030	0.340	0.040	0.495	0.088	112.605	152.406	4.081
1978	46.500	1.350	0.460	3.448	0.782	111.958	178.135	1.930
Mean	44.358	0.858	0.232	1.663	0.367	92.199	182.363	
Std Dev	4.904	0.379	0.137	0.970	0.227	16.636	19.206	
Percent Reduction		24.071	52.066	36.035	40.735	-1.017	0.141	
Soil 4 (Sandy Clay Loam, Clay Loam, Clay)								
Base Scenario (CNII=78)								
1974	40.590	0.860	0.440	2.609	0.587	67.678	187.934	1.879
1975	52.780	1.920	0.880	4.037	0.998	82.455	212.506	1.693
1976	42.890	1.970	0.540	3.146	0.712	70.084	180.628	2.174
1977	39.030	0.730	0.120	1.087	0.192	106.556	153.271	2.852
1978	46.500	2.170	1.180	6.627	1.579	104.166	185.847	1.809
Mean	44.358	1.530	0.632	3.501	0.814	86.188	184.037	
Std Dev	4.904	0.607	0.366	1.834	0.462	16.456	18.905	
Alternate Scenario (CNII=76)								
1974	40.590	0.640	0.200	1.673	0.349	69.341	187.934	1.710
1975	52.780	1.550	0.420	2.614	0.589	82.841	212.506	1.674
1976	42.890	1.600	0.370	2.339	0.511	70.877	180.628	1.966
1977	39.030	0.520	0.070	0.806	0.154	107.447	153.271	2.728
1978	46.500	1.720	0.620	4.609	1.036	106.063	184.564	1.663
Mean	44.358	1.206	0.336	2.408	0.528	87.314	183.780	
Std Dev	4.904	0.516	0.189	1.265	0.295	16.554	18.888	
Percent Reduction		21.176	46.835	31.216	35.145	-1.306	0.139	

Summary
5-yr. Simulation (1974-78)
Continuous Corn w/One Fertilizer Application (Broadcast)
Field size - 35 acres 8% Slope

	PRECIP	RUNOFF	SOIL LOSS	TOT N	TOT P	N LEACHED	N UPTAKE	ENRICHMENT
	(in)	(in)	(t/ac)	-----------(kg/ha)			--------------	RATIO
Soil 2 (Loamy Sand, Fine Loamy Sand, Sandy Loam)								
Base Scenario (CNII=78)								
1974	40.590	0.510	0.240	1.377	0.336	83.573	199.281	3.512
1975	52.780	0.900	0.380	1.837	0.496	81.587	190.197	3.219
1976	42.890	1.010	0.270	1.622	0.405	69.873	191.317	4.545
1977	39.030	0.300	0.070	0.552	0.117	97.452	168.240	6.450
1978	46.500	1.310	0.720	3.781	0.949	124.174	144.225	2.828
Mean	44.358	0.806	0.336	1.834	0.461	91.332	178.652	
Std Dev	4.904	0.360	0.216	1.067	0.275	18.610	20.065	
Alternate Scenario (CNII=76)								
1974	40.590	0.370	0.100	0.819	0.182	84.747	198.738	3.476
1975	52.780	0.650	0.140	0.990	0.239	81.866	190.111	3.447
1976	42.890	0.740	0.130	1.016	0.238	70.216	191.317	4.465
1977	39.030	0.210	0.030	0.286	0.047	97.905	168.240	6.858
1978	46.500	0.990	0.310	2.335	0.536	125.747	143.194	2.655
Mean	44.358	0.592	0.142	1.089	0.248	92.096	178.320	
Std Dev	4.904	0.275	0.092	0.676	0.160	18.992	20.300	
Percent Reduction		26.551	57.738	40.611	46.086	-0.837	0.186	
il 3 (Sandy Loam, Sandy Clay Loam, Clay Loam, Clay)								
Base Scenario (CNII=78)								
1974	40.590	0.670	0.600	2.572	0.659	75.351	188.988	1.903
1975	52.780	1.290	0.910	3.337	0.941	83.762	212.038	1.786
1976	42.890	1.420	0.710	2.958	0.773	75.327	180.246	2.139
1977	39.030	0.530	0.130	0.937	0.194	111.780	152.406	3.562
1978	46.500	1.740	1.640	6.582	1.747	110.135	179.419	1.776
Mean	44.358	1.130	0.798	3.277	0.863	91.271	182.620	
Std Dev	4.904	0.459	0.493	1.844	0.507	16.374	19.156	
Alternate Scenario (CNII=76)								
1974	40.590	0.500	0.230	1.500	0.348	76.585	188.988	2.020
1975	52.780	1.000	0.450	2.085	0.553	83.908	212.038	1.792
1976	42.890	1.100	0.390	1.950	0.483	75.937	180.246	2.131
1977	39.030	0.340	0.070	0.586	0.121	112.605	152.406	3.308
1978	46.500	1.350	0.880	4.350	1.106	111.958	178.135	1.625
Mean	44.358	0.858	0.404	2.094	0.522	92.199	182.363	
Std Dev	4.904	0.379	0.272	1.244	0.327	16.636	19.206	
Percent Reduction		24.071	49.373	36.095	39.486	-1.017	0.141	

Soil 1	Galestown, loamy sand
Soil 2	Norfolk, loamy sand, loamy fine sand, sandy loam
Soil 3	Cecil, sandy loam, sandy clay loam, clay loam, clay
Soil 4	Cecil, sandy clay loam, clay loam, clay
Soil 5	Cecil, sandy clay loam, clay loam, clay
Soil 6	Penn Loam, loam, silt loam

Summary, con't.
5-yr. Simulation (1974-78)
Continuous Corn w/One Fertilizer Application (Broadcast)
Field size - 35 acres   8% Slope

	PRECIP	RUNOFF	SOIL LOSS	TOT N	TOT P	N LEACHED	N UPTAKE	ENRICHMENT
	(in)	(in)	(t/ac)	(kg/ha)				RATIO
Soil 4 (Sandy Clay Loam, Clay Loam, Clay)								
Base Scenario (CNII=78)								
1974	40.590	0.860	0.760	3.293	0.833	67.678	187.934	1.617
1975	52.780	1.920	1.670	5.589	1.557	82.455	212.506	1.460
1976	42.890	1.970	0.960	4.039	1.033	70.084	180.628	1.977
1977	39.030	0.730	0.220	1.421	0.313	106.556	153.271	2.624
1978	46.500	2.170	2.040	8.220	2.152	104.166	185.847	1.596
Mean	44.358	1.530	1.130	4.512	1.178	86.188	184.037	
Std Dev	4.904	0.607	0.650	2.288	0.629	16.456	18.905	
Alternate Scenario (CNII=76)								
1974	40.590	0.640	0.320	1.956	0.451	69.341	187.934	1.660
1975	52.780	1.550	0.680	3.173	0.790	82.841	212.506	1.518
1976	42.890	1.600	0.600	2.957	0.733	70.877	180.628	1.830
1977	39.030	0.520	0.140	0.947	0.204	107.447	153.271	2.507
1978	46.500	1.720	1.050	5.555	1.377	106.063	184.564	1.526
Mean	44.358	1.206	0.558	2.918	0.711	87.314	183.780	
Std Dev	4.904	0.516	0.313	1.538	0.394	16.554	18.888	
Percent Reduction		21.176	50.619	35.340	39.620	-1.306	0.139	

Summary
5-yr. Simulation (1974-78)
Continuous Corn w/One Fertilizer Application (Broadcast)
Field size - 35 acres 10% Slope

	PRECIP	RUNOFF	SOIL LOSS	TOT N	TOT P	N LEACHED	N UPTAKE	ENRICHMENT
	(in)	(in)	(t/ac)	(kg/ha)				RATIO
Soil 2 (Loamy Sand, Fine Loamy Sand, Sandy Loam)								
Base Scenario (CNII=78)								
1974	40.590	0.510	0.350	1.647	0.433	83.573	199.281	3.027
1975	52.780	0.900	0.620	2.379	0.691	81.587	190.197	2.512
1976	42.890	1.010	0.410	1.915	0.510	69.873	191.317	4.103
1977	39.030	0.300	0.120	0.659	0.155	97.452	168.240	5.819
1978	46.500	1.310	1.140	4.599	1.244	124.174	144.225	2.289
Mean	44.358	0.806	0.528	2.240	0.607	91.332	178.652	
Std Dev	4.904	0.360	0.345	1.307	0.362	18.610	20.065	
Alternate Scenario (CNII=76)								
1974	40.590	0.370	0.140	0.926	0.221	84.747	198.738	3.195
1975	52.780	0.650	0.250	1.247	0.331	81.866	190.111	2.478
1976	42.890	0.740	0.190	1.158	0.289	70.216	191.317	4.139
1977	39.030	0.210	0.060	0.432	0.099	97.905	168.240	5.990
1978	46.500	0.990	0.530	2.813	0.708	125.747	143.194	2.165
Mean	44.358	0.592	0.234	1.315	0.330	92.096	178.320	
Std Dev	4.904	0.275	0.161	0.800	0.205	18.992	20.300	
Percent Reduction		26.551	55.682	41.287	45.665	-0.837	0.186	
Soil 3 (Sandy Loam, Sandy Clay Loam, Clay Loam, Clay)								
Base Scenario (CNII=78)								
1974	40.590	0.670	0.810	3.041	0.828	75.351	188.988	1.801
1975	52.780	1.290	1.530	4.466	1.347	83.762	212.038	1.590
1976	42.890	1.420	0.980	3.507	0.970	75.327	180.246	2.090
1977	39.030	0.530	0.210	1.153	0.272	111.780	152.406	3.201
1978	46.500	1.740	2.510	8.136	2.307	110.135	179.419	1.598
Mean	44.358	1.130	1.208	4.061	1.145	91.271	182.620	
Std Dev	4.904	0.459	0.775	2.305	0.676	16.374	19.156	
Alternate Scenario (CNII=76)								
1974	40.590	0.500	0.340	1.731	0.431	76.585	188.988	1.897
1975	52.780	1.000	0.730	2.709	0.778	83.908	212.038	1.570
1976	42.890	1.100	0.570	2.358	0.629	75.937	180.246	2.065
1977	39.030	0.340	0.120	0.745	0.178	112.605	152.406	2.923
1978	46.500	1.350	1.220	5.009	1.343	111.958	178.135	1.556
Mean	44.358	0.858	0.596	2.510	0.672	92.199	182.363	
Std Dev	4.904	0.379	0.374	1.416	0.391	16.636	19.206	
Percent Reduction		24.071	50.662	38.180	41.314	-1.017	0.141	

Soil 1	Galestown, loamy sand
Soil 2	Norfolk, loamy sand, loamy fine sand, sandy loam
Soil 3	Cecil, sandy loam, sandy clay loam, clay loam, clay
Soil 4	Cecil, sandy clay loam, clay loam, clay
Soil 5	Cecil, sandy clay loam, clay loam, clay
Soil 6	Penn Loam, loam, silt loam

Summary, con't.
5-yr. Simulation (1974-78)
Continuous Corn w/One Fertilizer Application (Broadcast)
Field size - 35 acres   10% Slope

	PRECIP (in)	RUNOFF (in)	SOIL LOSS (t/ac)	TOT N	TOT P	N LEACHED	N UPTAKE	ENRICHMENT RATIO
				-----------(kg/ha)-------------				
Soil 4 (Sandy Clay Loam, Clay Loam, Clay)								
Base Scenario (CNII=78)								
1974	40.590	0.860	1.080	3.944	1.078	67.678	187.934	1.507
1975	52.780	1.920	2.580	7.113	2.106	82.455	212.506	1.364
1976	42.890	1.970	1.460	5.061	1.402	70.084	180.628	1.819
1977	39.030	0.730	0.340	1.741	0.428	106.556	153.271	2.511
1978	46.500	2.170	3.220	10.181	2.897	104.166	185.847	1.486
Mean	44.358	1.530	1.736	5.608	1.582	86.188	184.037	1.507
Std Dev	4.904	0.607	1.036	2.870	0.851	16.456	18.905	
Alternate Scenario (CNII=76)								
1974	40.590	0.640	0.480	2.372	0.600	69.341	187.934	1.526
1975	52.780	1.550	0.990	3.952	1.071	82.841	212.506	1.428
1976	42.890	1.600	0.820	3.385	0.887	70.877	180.628	1.714
1977	39.030	0.520	0.210	1.154	0.279	107.447	153.271	2.421
1978	46.500	1.720	1.500	6.428	1.691	106.063	184.564	1.459
Mean	44.358	1.206	0.800	3.458	0.906	87.314	183.780	
Std Dev	4.904	0.516	0.442	1.764	0.476	16.554	18.888	
Percent Reduction		21.176	53.917	38.337	42.759	-1.306	0.139	