APPLICATION OF THE UNIVERSAL SOIL LOSS EQUATION TO THE BIG EAU PLEINE WATERSHED

by

Lois C. Hansen

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ABSTRACT

The Big Eau Pleine Reservoir in central Wisconsin is subject to rather extensive fish kills during the winter months. In 1974 this occurence sparked sportsmen and lakeshore property owners to request studies of the sources of pollution. Agricultural land use and management was one possible problem area. Soil, nutrients, and organic matter carried downstream and deposited in the reservoir decompose over time and contribute to oxygen depletion.

The Universal Soil Loss Equation was applied to 2.8 percent of the watershed area to estimate the extent of excessive soil erosion. Fifteen to twenty-five percent of the area in the basin exceeded the allowable soil loss tolerance limits. Most of this erosion occurred on cropland that was subjected to excessive row cropping, up and down slope farming, and removal of surface residues.

Reduction of cropland erosion could be accomplished by application of contour strips, grassed waterways, diversions, and terraces. Modifying tillage methods and crop rotations can also reduce erosion. A cost estimate for implementing such practices on the Big Eau Pleine watershed ranged from $2.3 to $8.6 million dollars. The lower figure would bring erosion below soil loss tolerance levels using Soil Conservation Service (SCS) parameters. The higher value would reduce erosion to levels that may comply with water quality standards.

The Universal Soil Loss Equation has been used mainly to compute

soil erosion on individual fields for SCS farm conservation plans. The present study is one of the first to utilize the equation in evaluating an entire watershed for its effect on downstream water quality. In the future such application may serve the dual purpose of planning farming techniques that reduce soil erosion to acceptable water quality limits and justifying enforcement of those limits.

APPROVED BY THE GRADUATE COMMITTEE OF:

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Professor of Soil Science and Water Science

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Professor or Soil Science

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Associate Professor of Soil Science

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Associate Professor of Soil Science

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River Basin--Watershed Planning Staff Leader, SCS

Date thesis is presented ____________________

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I also wish to express my appreciation to J.P. Cavanaugh and the River Basin--Watershed Planning Staff for the time they spent explaining the SCS Computer Program for Land Use, Land Treatment, Sedimentation, and Erosion to me. Tom Zeisler, a computer specialist at the UW--Stevens Point Computer Center, also provided assistance in making some essential modifications in that program.

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INTRODUCTION

The Big Eau Pleine Reservoir in central Wisconsin is often subject to extensive fish kills during the winter months because of inadequate oxygen supplies. Several variables determine the severity of oxygen depletion: snow and ice depths govern the amount of light available to oxygen producing winter algae, and the amount of decaying material from the previous growing season uses up a substantial amount of oxygen. Also, winter reservoir drawdown to provide a constant flow for hydroelectric power production on the Wisconsin River increases oxygen consumption by concentrating water near sediments and decreases oxygen availability by reducing the reservoir's water volume.

During the winter of 1974 an extensive fish kill energized lakeshore property owners and sportsmen into requesting studies on possible solutions to the problem. The Wisconsin Department of Natural Resources joined the Environmental Protection Agency and the Wisconsin Valley Improvement Company in funding a study of the Big Eau Pleine Reservoir. A research project proposal by Dr. Byron Shaw, University of Wisconsin--Stevens Point, was accepted and an in-depth investigation by graduate students began early in 1975. Computer modelling of the reservoir's variables required base line data on nutrient concentrations, algae, temperature, biochemical and sediment oxygen demand. The study of the Big Eau Pleine impoundment was not limited to the obvious problems occurring in the reservoir itself, however. If a solution was to be effected, the sources as well as the symptoms of eutrophication had to be identified and quantified. For this reason a comprehensive study of land use in the Big Eau Pleine watershed was undertaken. This thesis is a portion of that study. By applying the Universal Soil Loss Equation to a representative sample of the Big Eau Pleine watershed, an estimate of soil erosion exceeding SCS soil loss tolerance factors has been obtained.

The Big Eau Pleine watershed and its associated rivers and reservoir are located in central Wisconsin in portions of Marathon, Taylor, and Clark counties (Figure 1). The watershed area totals 365 square miles; the Big Eau Pleine Reservoir covers approximately 11 square miles when full. Long, cold winters and short, hot summers are characteristic of this region. Mean monthly temperatures range from 13 degrees Fahrenheit in January to 68 degrees Fahrenheit in July. The last killing frost in spring usually occurs about May 19 and the first killing frost in fall is around September 23, thus providing an average growing season of 126 days. Precipitation averages 33 inches per year. Snowfall accounts for about 15 percent of this yearly precipitation. The remainder falls as rain, primarily during the summer months of June, July, and August (Wischmeier and Smith, 1965).

Geologic history indicates that a lofty mountain range once occupied much of Wisconsin. It was worn down and uplifted several times before being submerged beneath the ocean. Layers of sandstones and limestones eventually covered the peneplain of these ancient mountains of Wisconsin.

Two hundred million years ago this section of North America was uplifted for the last time. Subsequent weathering and stream cutting has

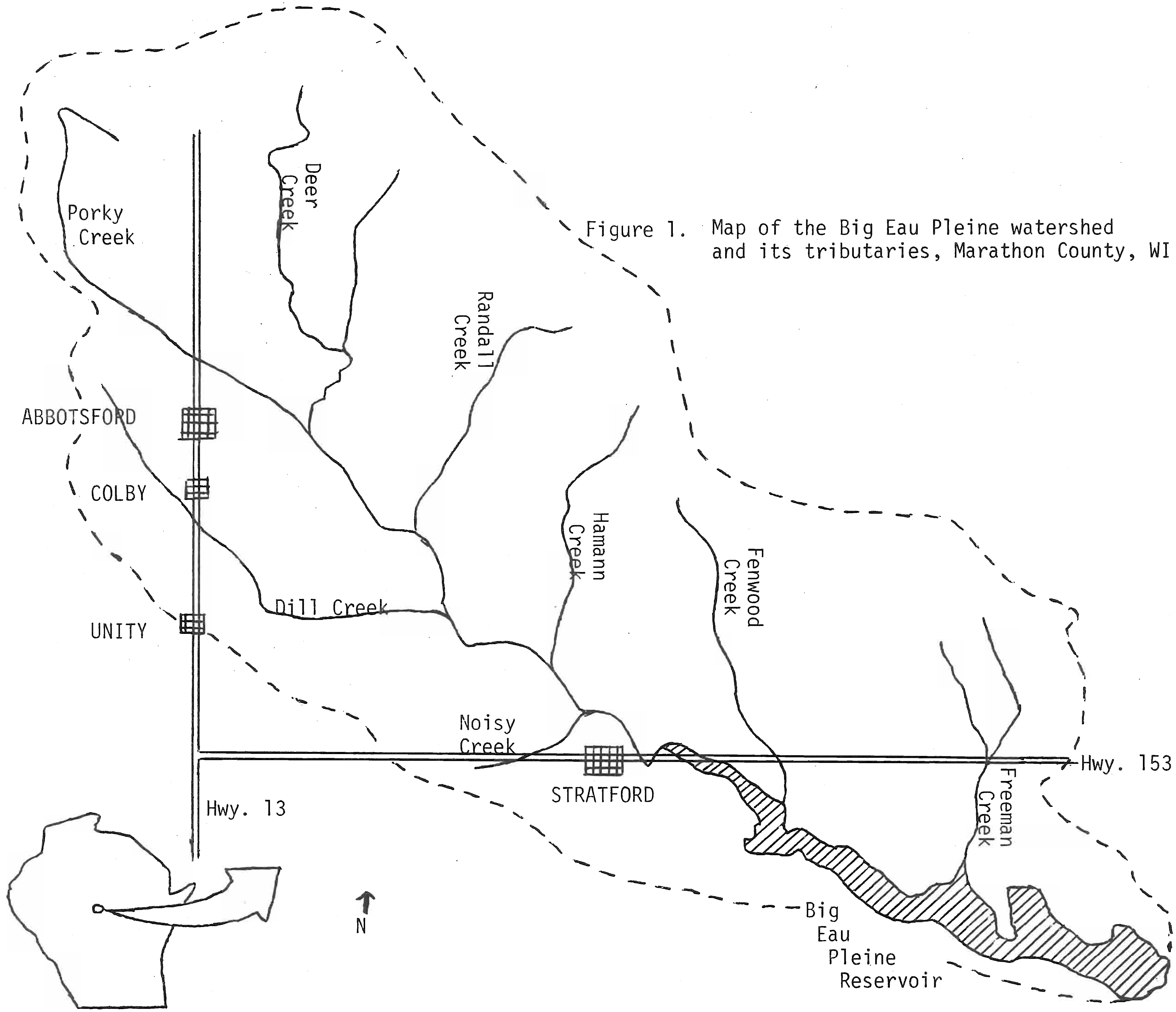


Figure 1. Map of the Big Eau Pleine watershed and its tributaries, Marathon County, WI

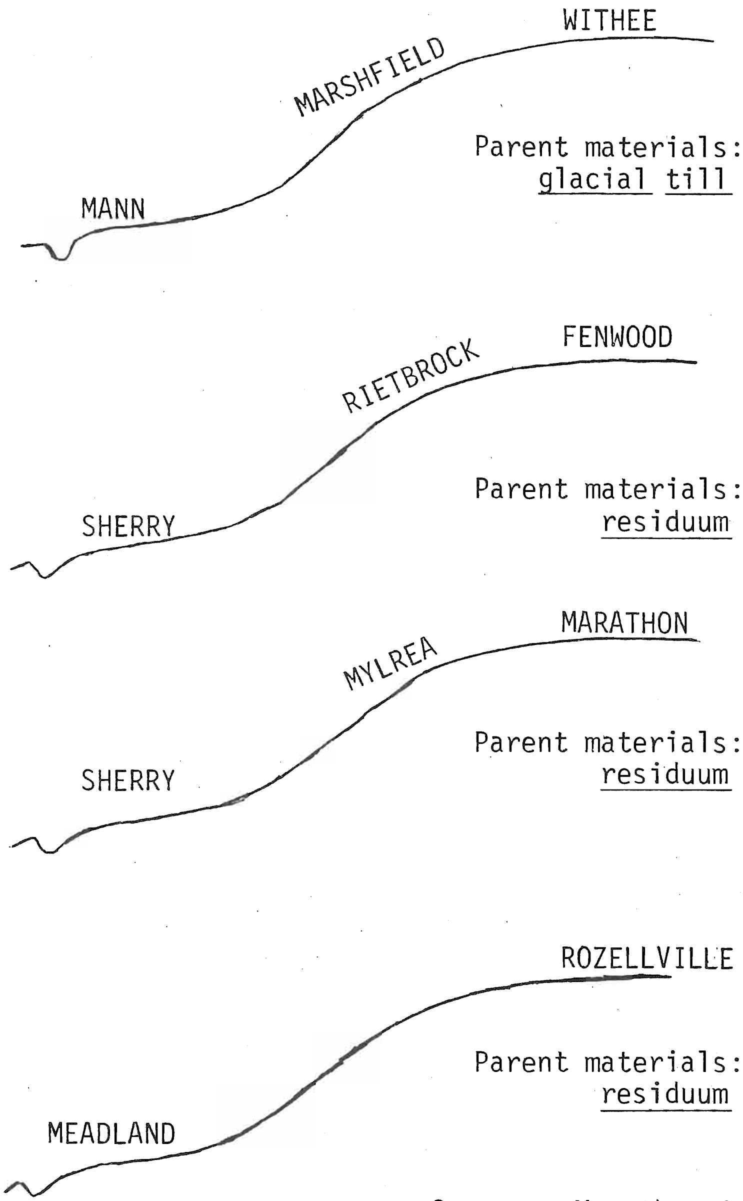
produced the present topography. The Big Eau Pleine watershed lies in the upland plain region of northern Wisconsin where local relief varies by only 200 feet. The gently rolling terrain allows most roads to follow section lines. Drainage patterns are dendritic and there are few lakes or swamps (Martin, 1932).

Glacial history in central Wisconsin indicates that the last glacial advance did not reach the Big Eau Pleine area. The western portion of the watershed is composed of older drift deposited by pre-Cary glaciers. The eastern section is believed to be in the driftless area (Martin, 1932). However, the possibility of glacial influence in this area has recently been suggested by Dr. Erling Gamble, Midwest Technical Service Center Soil Correlation Staff (Klingelhoets, 1978). Outwash deposits of gravel are found only in river bottoms.

Most soils in the western half of Marathon County are silt loams developed in a loess mantle over acid sandy-loam to clay-loam glacial till. The glacial deposits generally exceed five feet in depth; only Fenwood has bedrock within five feet of the soil surface (U.S. Department of Agriculture--Soil Conservation Service, 1972). Most of the bedrock underlying the watershed is composed of granite and undifferentiated igneous and metamorphic rocks (Hole, 1976).

Major soil types occur in four specific associations or catenas that are based mainly on drainage characteristics. The dominant catena is the Withee, Marshfield, Mann grouping that was formed in glacial till (Figure 2). The better drained soils (typic glossoboralfs) such as Withee, Fenwood, Marathon, and Rozellville occupy the higher portions of the land-

Figure 2. Dominant soil catenas found in the Big Eau Pleine watershed



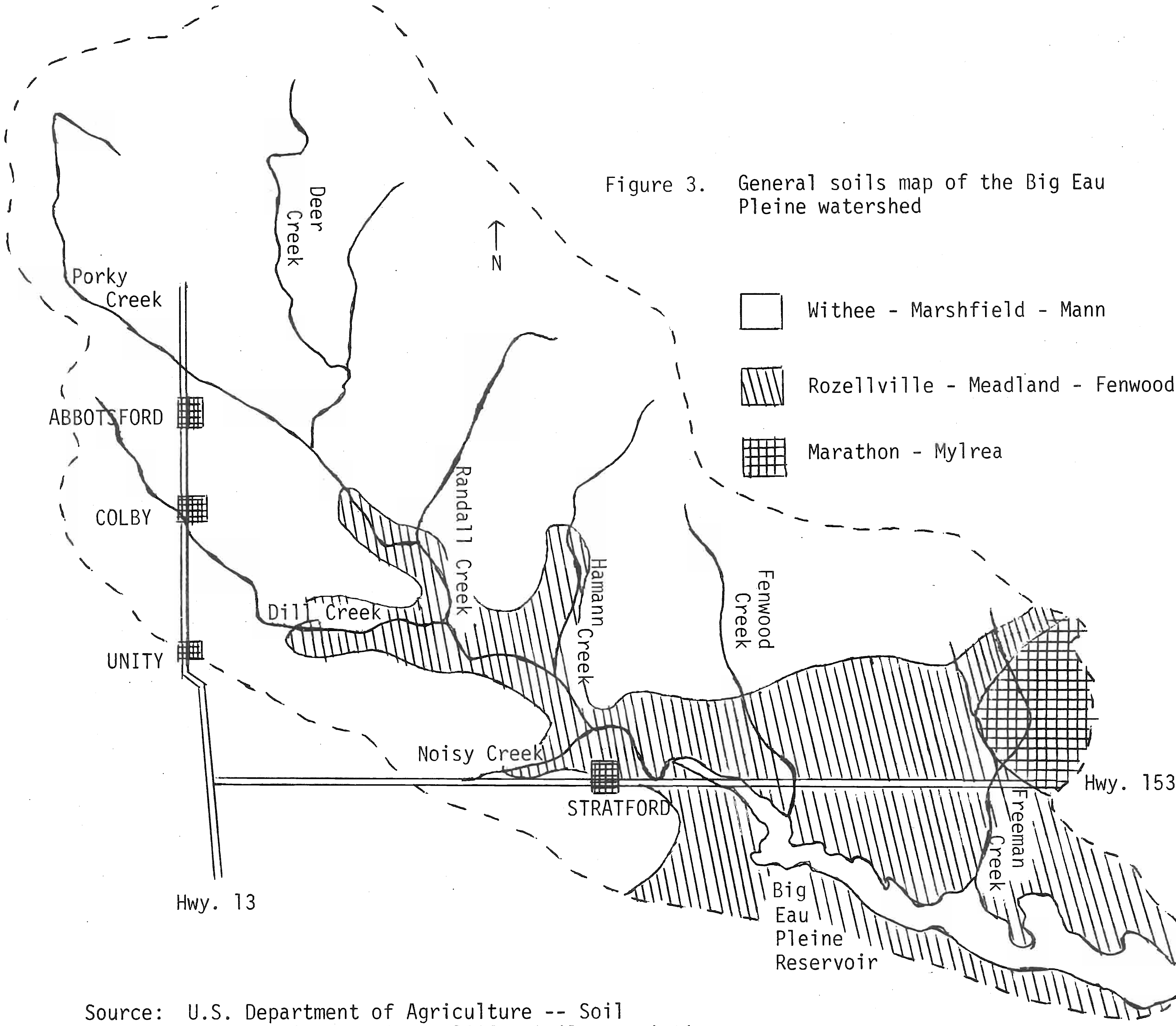
Source: Marathon County Soil Survey. 1973. Advance field sheets (incomplete) Soil Conservation Service scape. Wetter soil (aquic glossoboralfs and typic haplaquolls) such as Meadland, Mylrea, and Mann dominate drainageways (Figure 3).

Moderately slow permeabilities due to the predominance of silts and clays are typical of the major soil types in the Big Eau Pleine watershed (Table 1). Silty clay loam subsoils often impede drainage and soil depths generally exceed five feet. For these reasons, groundwater recharge is minimal (Hole, 1976). Surface runoff offers the greatest source of water for the reservoir.

The once forested Big Eau Pleine watershed gave way to the wheat farming era of the 1930s. Shortly after, however, the dairy industry developed and has since dominated this agricultural heartland of Wisconsin. Cheese factories and creameries are found in this region of red barns, blue silos, and small rural communities. Ditching to improve surface drainage, liming, and fertilizing are the most important farm management practices available to increase and maintain productivity levels. Corn yields fall into the 75-85 bushel per acre category while alfalfa-brome hay produces an average 3.5 tons per acre (U.S. Department of Agriculture--Soil Conservation Service, 1972). The Big Eau Pleine watershed is the highest producing dairy section of the state with approximately 60 percent of the land under a dairy oriented crop rotation.

However, when man interferes with Nature, a delicate balance is often upset. Land once covered by forests and grasses is now periodically torn up and planted with rows of corn. Snowmelt and rainwater no longer soak slowly into the forest littered ground. Small rivulets trickle down plowed fields, picking up soil particles and nutrients as they head

Figure 3. General soils map of the Big Eau Pleine watershed



Source: U.S. Department of Agriculture -- Soil Conservation Service. 1974. Soil association map of Marathon County, WI

Table 1. Soil properties of the primary soil types found in the Big Eau Pleine watershed

	Percent Area	USDA Texture	Permeability in./hr.	Hydrol. Group	Capab. Class	Soil Loss Tol.
WITHEE	47	sil	0.6-2.0	C	IIw4	3
MARSHFIELD	14	sil	0.6-2.0	C	IIIw3	3
FENWOOD	13	sil	0.6-2.0	B	IIs1	3
MARATHON	12	sil	0.6-2.0	B	IIe2	3
MEADLAND	3	l	0.6-2.0	C	IIw4	3
ROZELLVILLE	3	l	0.6-2.0	B	IIe1	3
MANN	2	sil	0.6-2.0	D	IVw3	3
MYLREA	2	sil	0.6-2.0	B	IIw3	3

Source: U.S. Department of Agriculture. 1972. Soil interpretation sheets for selected soils.

toward well-defined streams that feed into the Big Eau Pleine River. Then in 1937 the Wisconsin Valley Improvement Company dammed this river to create a reservoir to augment the Wisconsin River during low flow periods. Once the reservoir was created, eroded material was carried by streams into the impoundment and settled out in the still waters. Dissolved fertilizer and organic wastes also accumulated, supporting a growing amount of lake adapted algae. A eutrophic reservoir developed.

The purpose of this study is to evaluate the amount of sheet and rill erosion occurring in the Big Eau Pleine watershed and recommend remedial measures to slow the continuing eutrophication of the Big Eau Pleine Reservoir.

METHODS AND MATERIALS

Eutrophication of man-made lakes and reservoirs is caused primarily by sediment deposition and associated nutrient enrichment. The influx of sediments and/or nutrients into a body of water is called non-point pollution because it enters erratically along streambanks and shorelines. The current methods of estimating the amount of sediment washed into streams includes evaluating soil erosion. Erosion not only adds soil to reservoirs, it also adds nitrogen and phosphorus that are adsorbed to soil particles.

In 1961 two important articles on soil erosion were published. The first one described the estimation of soil loss by using a mathematical formula (U.S. Agricultural Research Service, 1961); the second article applied the results of this formula to conservation planning (Wischmeier and Smith, 1961). In 1965 these two papers were combined into a pamphlet titled *Predicting Rainfall-Erosion Losses from Cropland East of the Rocky Mountains: Guide to Selection of Practices for Soil and Water Conservation*. The mathematical formula was named the Universal Soil Loss Equation (USLE) and could be applied wherever numerical values for the following variables were available: $E = RKLSCP$

RAINFALL FACTOR (R)
SOIL ERODIBILITY FACTOR (K)
SLOPE LENGTH (L)
GRADIENT (S)
CROPPING MANAGEMENT FACTOR (C)
EROSION CONTROL FACTOR (P)

The result of this equation provides the average estimated soil loss from a particular field in tons per acre per year. By using the proper sediment delivery ratio for the area, an estimate of the amount of sediment entering the drainage ways from a particular area can be estimated. The sediment delivery ratio is simply the ratio between the amount of eroded soil particles that reach streams and the amount of eroded soil particles that are dislodged in the watershed, regardless of their ultimate deposition sites.

The actual mathematical relationships between the six factors involved in the USLE were the result of a combination of studies by several researchers. Work on a soil loss equation commenced in 1940 with Zingg's work on slope length and percent slope (Zingg, 1940). Browning added his studies on soil erodibility andd management factors (Browning, et al, 1947). The Musgrave equation was the end product of the above studies with the addition of a rainfall factor (Musgrave, 1947). Application of this equation nationwide was limited until adjustments for rainfall variations, length of growing seasons, and interrelationships between such variables as productivity level, crop sequence, and residue management were made. Since this paper deals primarily with the field application and results of the USLE, discussion of the theory and laboratory research used to develop the equation will be limited. A brief description of each factor to provide background for understanding field data follows.

The rainfall factor (R) shows soil loss is directly proportional to the product of the intensity and duration of spring and summer storm events, all other factors being constant. An isoerodent map joining points of equal rainfall energy can be produced; its values range from 50 in the Dakotas to 600 near the Gulf of Mexico (Figure 4).

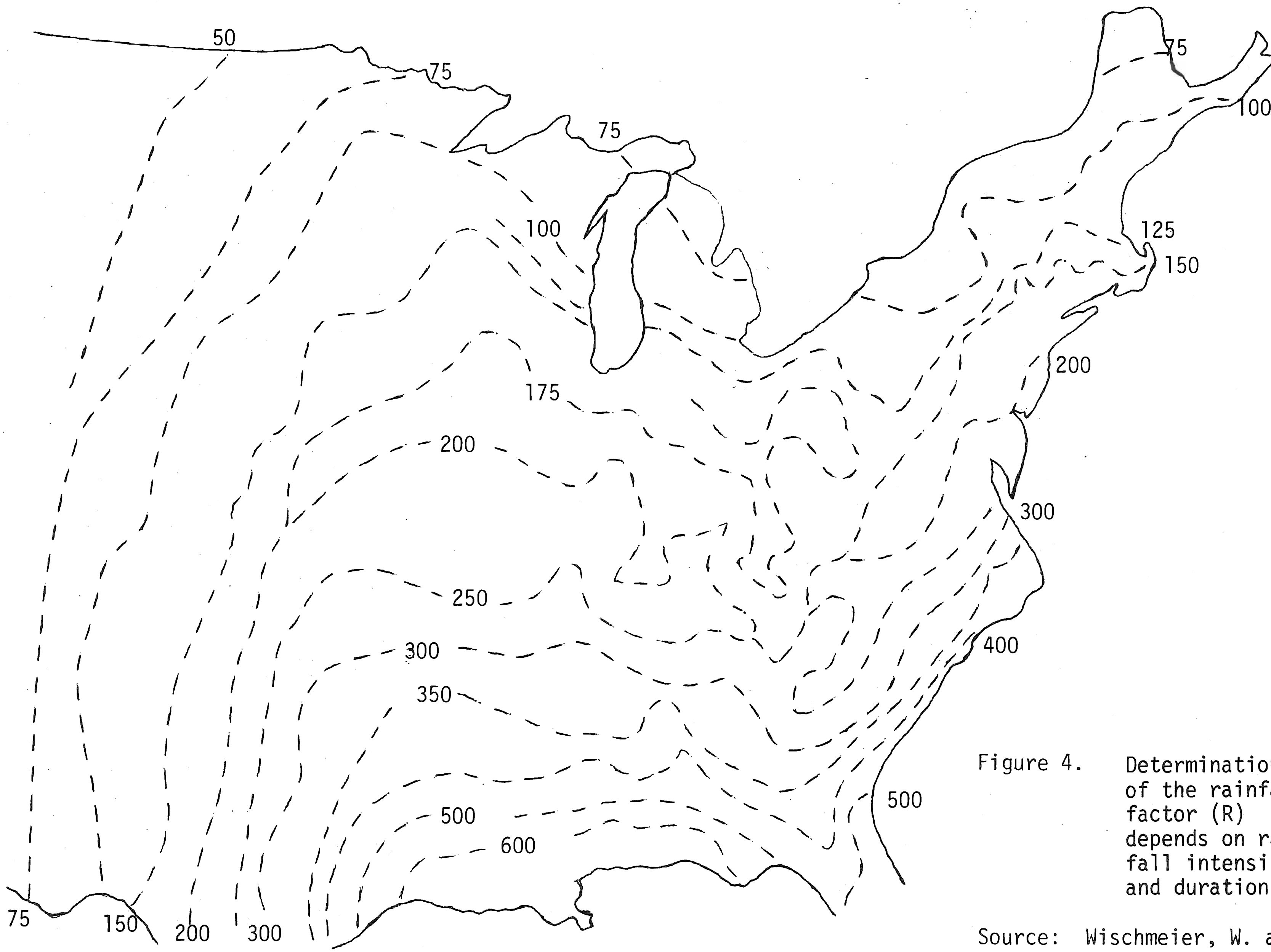


Figure 4. Determination of the rainfall factor (R) depends on rainfall intensity and duration.

Source: Wischmeier, W. and D. Smith. 1965.

The soil erodibility factor (K) shows that some soils are more susceptible to erosion than others. The nomogram specifies the four deciding soil characteristics: texture, permeability, structure, and organic matter content (Figure 5). Classification of erodibility was determined on plots having identical slopes and slope lengths. These plots were kept in a fallow condition for two years; each spring they were prepared as a corn seedbed and during the summer weeds and surface crusting were prevented by up and down slope tilling. Twenty-three major soils found in the United States studied in this way were given relative values from 0 to 1 (Olson and Wischmeier, 1963). All other soils were compared to these baseline soils and assigned interpolated values.

Slope length and gradient (LS) were combined and the resultant erosion compared to that occurring on a standard nine percent slope that was 72.6 feet long. When a slope involved several gradients of differing lengths, the most erosive segment determined the LS value. This decision was based on the fact that LS values are for uniform slopes but most slopes are either concave or convex; in either case the steeper section would erode faster that a uniform slope (Figure 6). Slope length is the distance from the origin of overland flow to the point of deposition or entrance of runoff into a well-defined channel (Figure 7).

Cropping patterns and management practices (C) were so closely interrelated that they were treated as one in the soil loss equation. The amount of erosion occurring depended upon the amount and intensity of rain during the period of least vegetative cover--this varied according to the rainfall region and cropping management. Cropping management

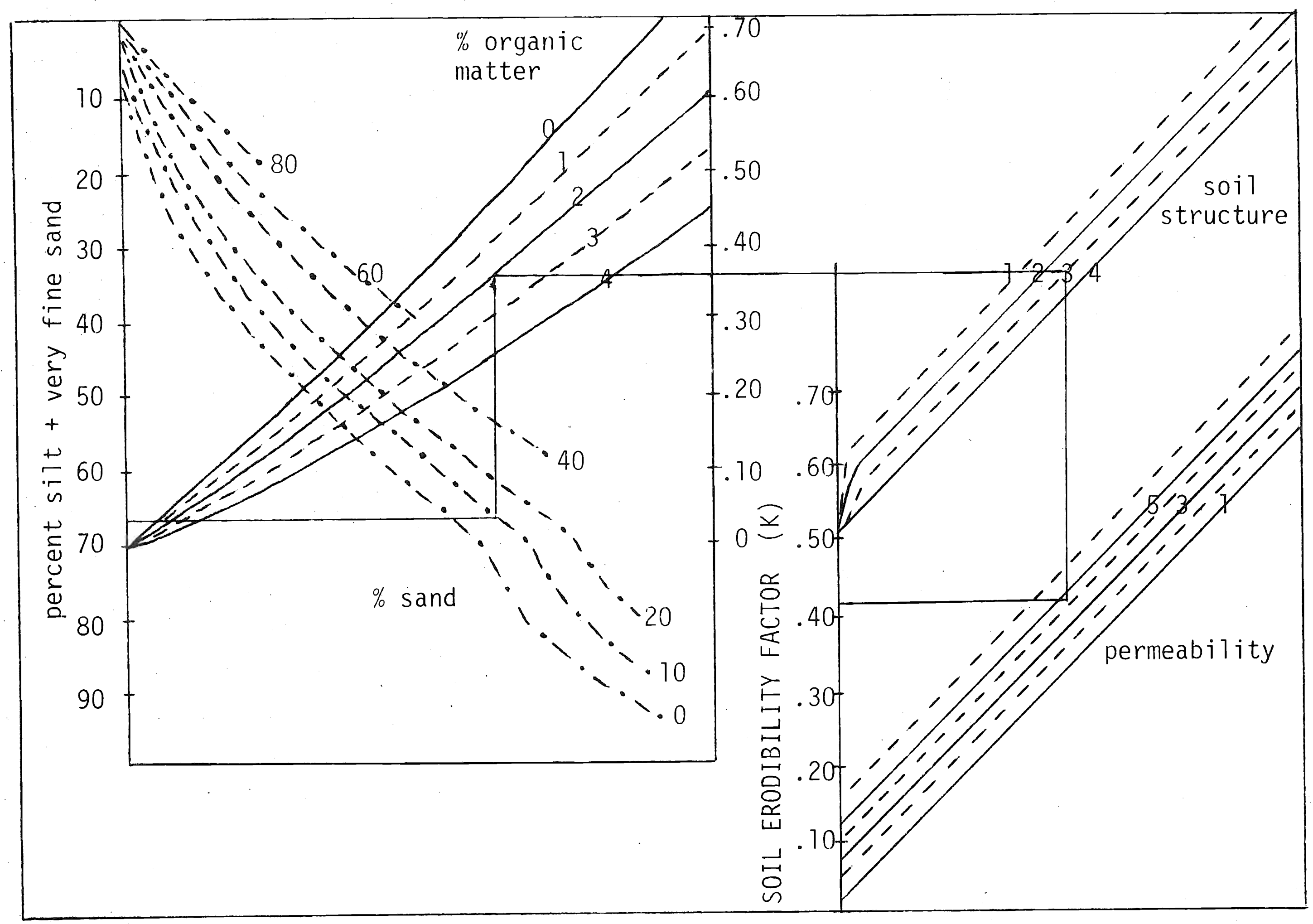


Figure 5. Soil erodibility (K) is determined by evaluation of soil texture, permeability, structure, and organic matter content.

soil structure

1 very fine granular
2 fine granular
3 medium or coarse granular
4 blocky, platy, or massive

permeability

6 very slow
5 slow
4 slow to moderate
3 moderate
2 moderate to rapid
1 rapid

Source: U.S. Agricultural Research Service and Environmental Protection Agency. 1975.

Figure 6. Gradient (S) determination depends on the amount of rise over a distance of 100 feet and is measured in percent

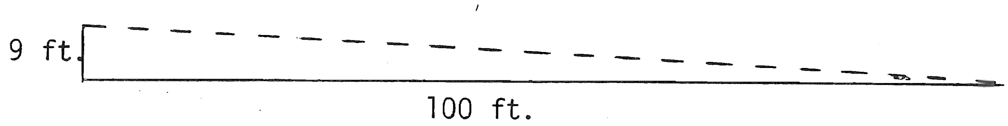
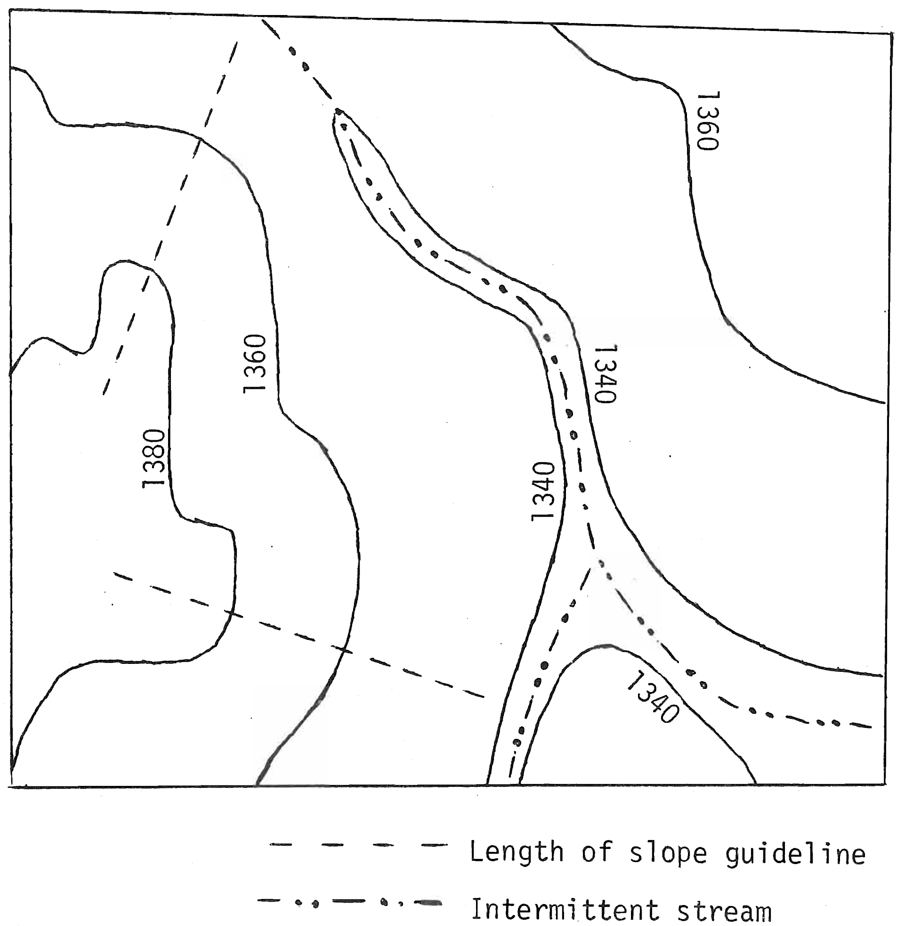


Figure 7. Slope length (L) is measured from the inception of overland flow to the point of deposition or entrance into a defined drainage way



variables would be length of meadow periods, planting winter cover seedlings, crop residue management, productivity level, fallowing, and crop rotations (Table 2). Plots were set up to compare soil loss on fallow fields to that on managed fields. Various tables have been developed to compute detailed C factors (Wischmeier and Smith, 1965).

The erosion control factor (P) is the ratio of soil loss with or without a conservation practice(s) applied. Comparing contour tillage, contour stripcropping, terrace systems, and stabilized waterways to fields farmed up and down slope emphasizes the importance that conservation practices play in reducing soil losses. On three to seven percent slopes, contouring can cut soil erosion in half. Stripcropping will reduce soil losses by 75 percent. Terracing is even more effective because it actually divides the slope length into shorter sections so the runoff won't gain enough momentum to cause much damage (Table 3).

Rather reliable soil losses can be estimated if the necessary weather and crop data is available at the close of a specific year. However, predicting soil losses for the succeeding year is next to impossible. The erosiveness of individual storms differ each year due to antecedent moisture, tillage, machinery compaction, soil crusting, and changes in plant cover. Therefore, prediction of soil loss using this equation can only provide averages over an extended period of time.

Another limitation to the USLE is that snowmelt, frost depth, and wind erosion are not taken into account in soil loss computations. Since snowmelt in the northern states contributes a major portion of the spring runoff when vegetation density is at its lowest, considerable unmeasured

Table 2. Determination of cover factor (C) depends on rotation and tillage practices

ROTATION	CONVENTIONAL TILLAGE Fall Plowed R*	L**	Spring Plowed R	L	CONSERVATION TILLAGE 1000 lb. corn residue Till/Chisel Plant	No Till
C3 O H	.30	.25	.25	.18	.20	.14
C3 O H2	.25	.20	.20	.16	.14	.12
C3 O H3	.20	.16	.16	.14	.12	.10
C3 O H4	.16	.14	.14	.12	.10	.09
C3 O H5	.14	.12	.12	.10	.08	.08
C2 O H	.18	.16	.16	.14	.12	.10
C2 O H2	.14	.12	.12	.10	.10	.08
C2 O H3	.12	.10	.10	.08	.08	.06
C2 O H4	.10	.08	.08	.07	.07	.05
C2 O H5	.08	.06	.06	.05	.06	.04
C O H	.10	.08	.08	.06	-	-
C O H2	.08	.06	.07	.05	-	-
C O H3	.07	.05	.06	.04	-	-
C O H4	.06	.04	.05	.03	-	-
C O H5	.05	.03	.04	.025	-	-

* residue removed (corn chopped)
** residue left (corn stalks left on field)

Source: U.S. Department of Agriculture--Soil Conservation Service. 1974. SCS technical guide--section III-A. Table 2A(1) Special: "C" factors for cropland--Wisconsin--longer rotations. Madison, WI

Table 3. Determination of conservation factor (P) depends on type of conservation practice installed or management factor used

Conservation Practice	% Erosion Compared to Up and Down Hill Tillage
TERRACES	10
STRIPCROPPING	25
GRASSED WATERWAYS	30
TILL OR CHISEL PLANTING	35
CONTOURING	50
RESIDUE LEFT	85
SPRING PLOW	90

Source: U.S. Agricultural Research Service and Environmental Protection Agency. 1975.

erosion is likely to occur. A fellow colleague calculated a modified (R) value of 184 by taking into account not only rainfall, but runoff factors as well (Kaminski, 1976). In fact, he found that during the spring one unit of runoff energy will yield 1.69 more units of sediment than in the summer.

In the spring freezing and semi-thawing loosens soil particles, and winter manure spreading provides additional organic matter. These sediments are picked up and transported downstream by runoff produced by spring thaw conditions. However, none of this erosion is accounted for in the (R) factor of the USLE because no rainfall energy is involved.

By increasing the (R) factor to 184, a more realistic appraisal of erosion on the Big Eau Pleine watershed can be made. Not only is more erosion occurring, but it is occurring during March, April, and May instead of during July and August. Anchoring vegetative cover is sparse during these spring months. This may mean utilizing different types of erosion control practices that are more effective during the spring runoff period.

Dynamic natural systems cannot easily be reduced to formulas. Studies of the variables involved will produce meaningful relationships. However, they indicate trends or estimates far more reliably than they measure actual amounts. Generally, for much of the environmental work, these estimates are sufficient. If acceptable and unacceptable ranges can be established, soil, wildlife, and plant life can be managed.

Field sampling of 42 quartersections

The primary object of this thesis was to apply the Universal Soil Loss Equation to a representative sample of the Big Eau Pleine watershed. By comparing the estimated soil loss in tons per acre per year to the soil loss tolerance factor for that particular soil type, the amount of excessive erosion could be obtained and extrapolated to the entire basin.

While a two percent sample size is generally considered adequate for planning or evaluating large areas, the Wisconsin River Basin--Watershed Planning Staff, SCS, suggested a slightly larger sample because of the size of the area and the number of items being sampled. Therefore, 27 quartersections that were soil surveyed for the 1958 Conservation Needs Inventory were used along with 15 other randomly selected soil surveyed sites (Figure 8). This amounted to 2.8% of the total watershed area.

As part of a nationwide program by the USDA, the Conservation Needs Inventory sites were analyzed in 1958 and again in 1967. Land use was recorded and soil conservation needs determined on these sample sites. Using the 27 sites in the Big Eau Pleine watershed will continue the ten year evaluation tradition so trends in land use and farmer involvement in conservation can be monitored over several decades.

Once the sample sites were selected, values for each factor in the USLE were determined for each field within each site. Rainfall factors are 125 for Marathon and Taylor counties and 150 for Clark county (Figure 9). Calculations using Kaminski's proposed (R) value of 184 were also computed. The other five factors in the USLE showed a

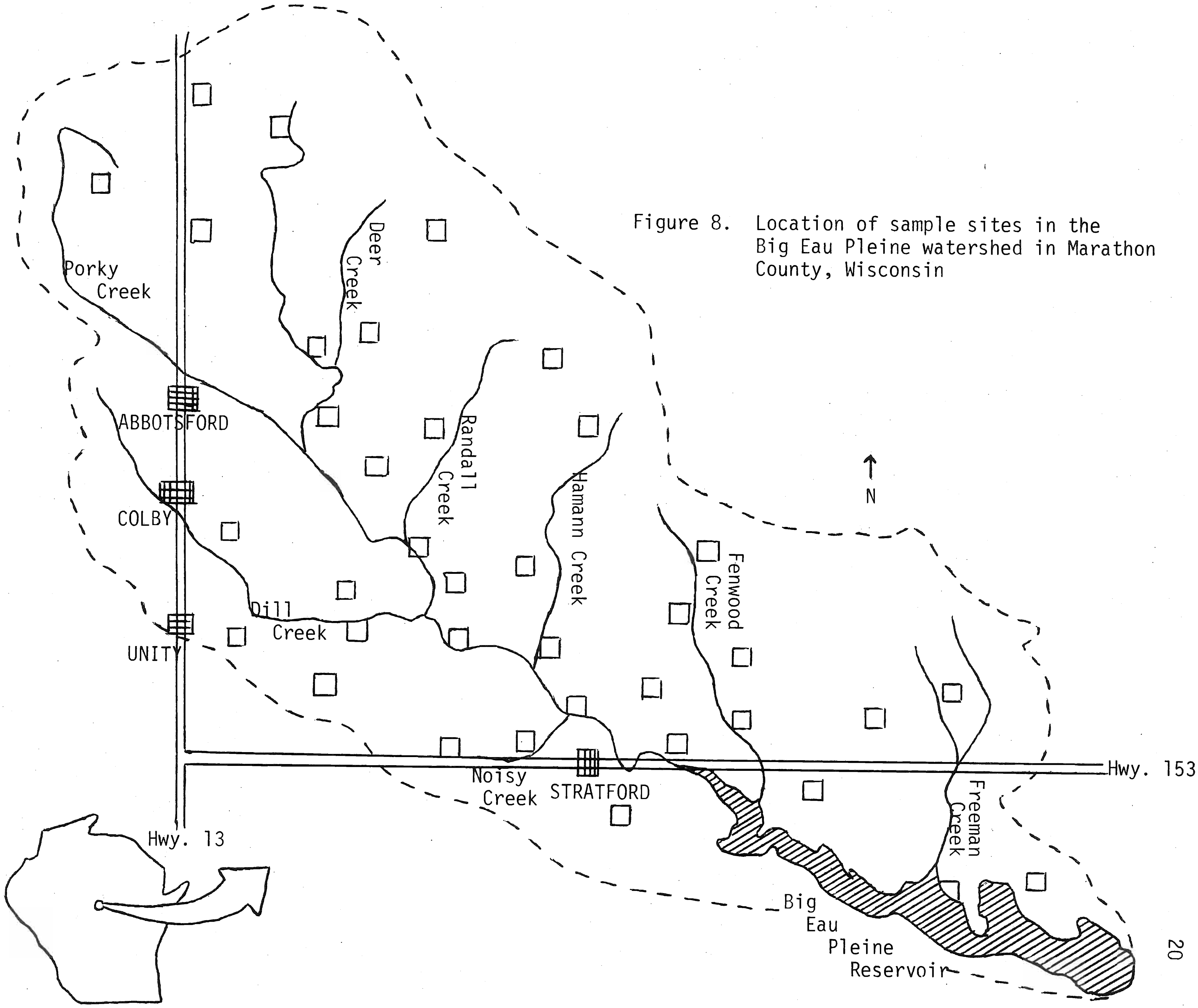
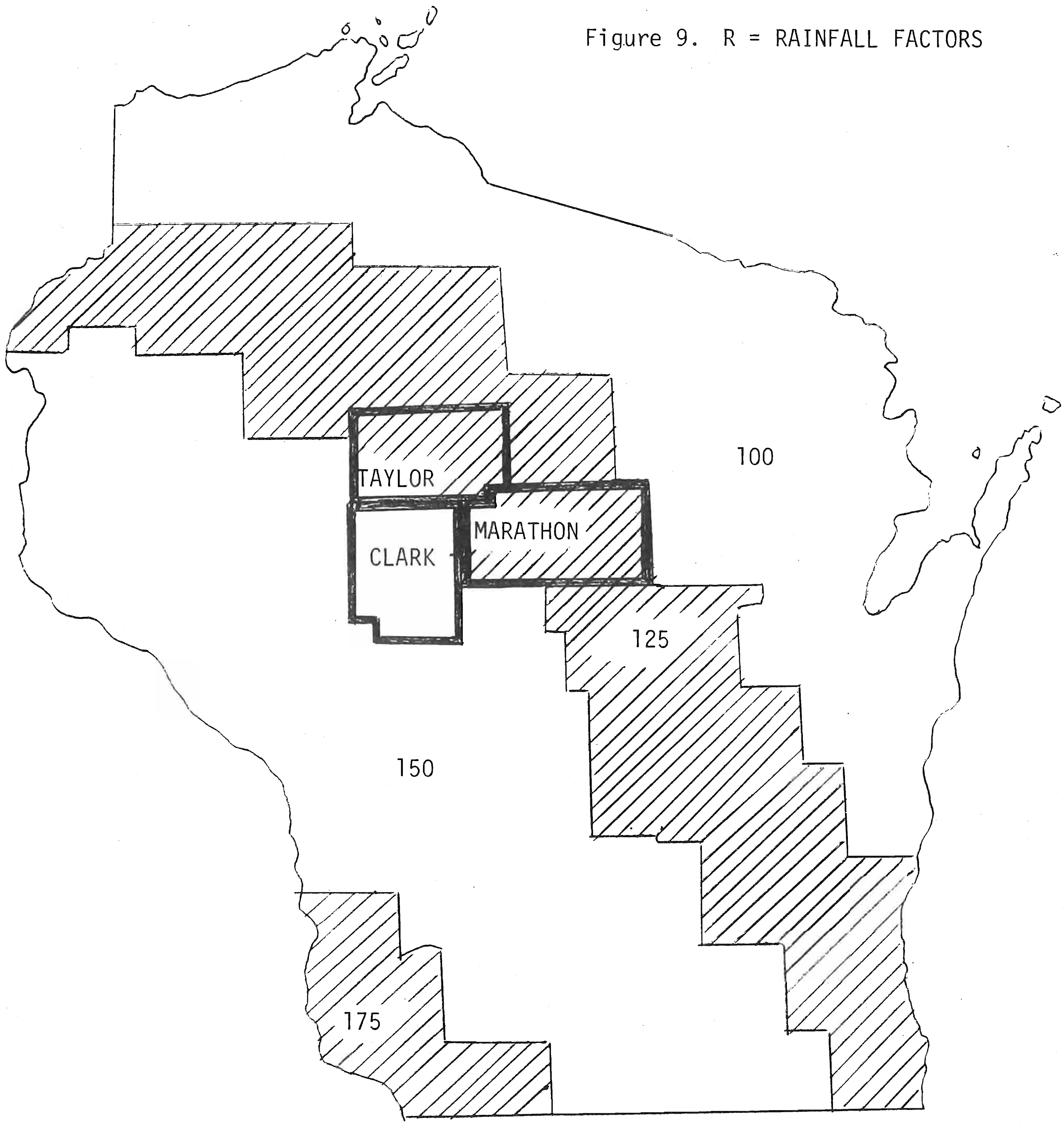


Figure 8. Location of sample sites in the Big Eau Pleine watershed in Marathon County, Wisconsin

Figure 9. R = RAINFALL FACTORS



Source: Wischmeier, W. and D. Smith. 1965. Predicting rainfall-erosion losses from cropland east of the Rocky Mountains.

great deal of variation within each quartersection. Therefore aerial photos from Marathon County Agricultural Stabilization and Conservation Service were used to divide the sample sites into plots where each factor was uniform (Figure 10). Soil type boundaries were transferred from Soil Conservation Service maps to provide the soil erodibility factor (K) and slope gradient (S).

Field visits and observations provided the remaining information. Slope lengths (L) for each parcel were paced and cover characteristics for grass and forest lands were evaluated. Farmers responded to questions on crop rotation, crop residue management, and plowing season (C). They pointed out conservation practices (P) that were installed or scheduled to be put in. Fertilization and manure management inquiries were also made. Conservation plans prepared by the Soil Conservation Service were examined.

Next the area of each parcel was determined using the dot grid method. That completed the initial portion of the project.

Computer Program for Land Use, Land Treatment, Sedimentation, and Erosion

The computations for the Universal Soil Loss Equation could have been performed manually by using charts and figures for every parcel within each quartersection. Farm planning done by the Soil Conservation Service usually goes this route because of the small number of fields involved. However, for a research project consisting of over 500 separate units, a computer program was much more efficient.

In July of 1975 the Soil Conservation Service published a progress report titled Computer Program for Land Use, Land Treatment, Sedimentation,

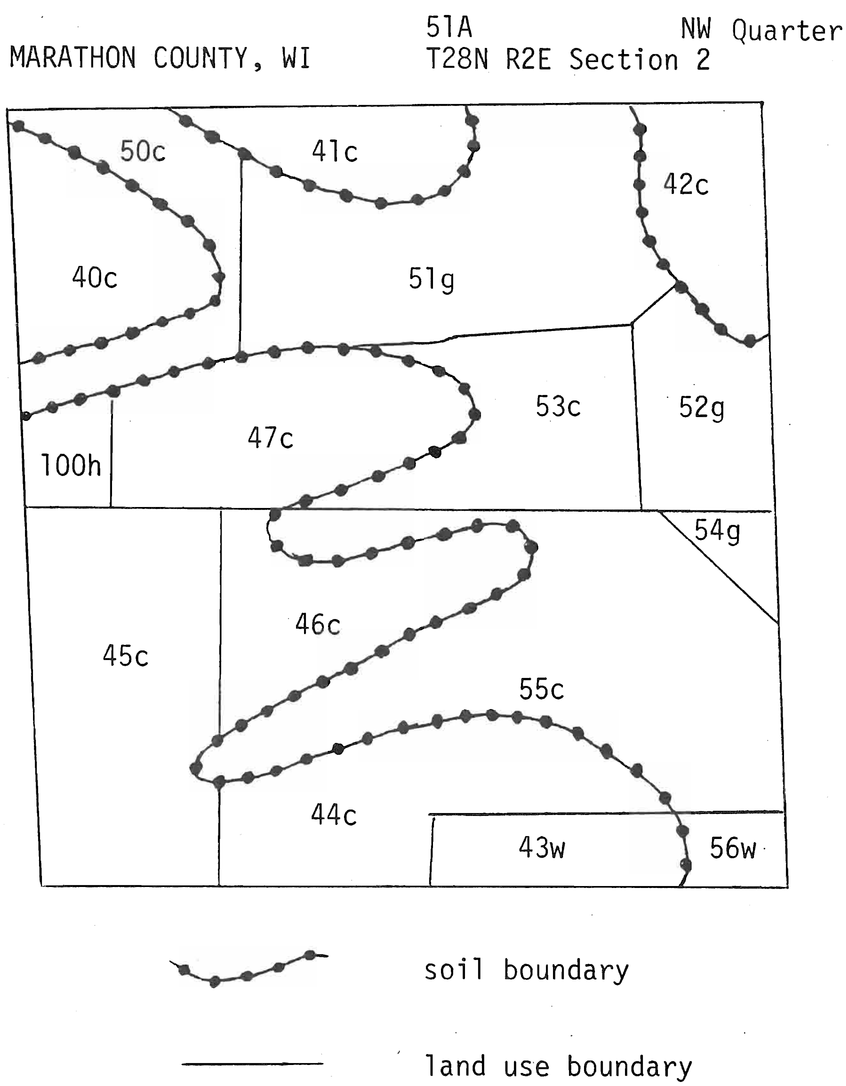


Figure 10. Field boundaries in randomly selected quartersections are determined by land use and soil type: 'c' represents cropland; 'w' is for woodland; 'g' indicates grassland; and 'h' stands for homestead. Numbers are coded to match soil type numbers.

and Erosion (U.S. Department of Agriculture--Soil Conservation Service, 1975). This program was developed under the supervision of J. P. Cavanaugh, Wisconsin River Basin--Watershed Planning Staff, USDA Soil Conservation Service. In recent years the demand for speed in processing multitudes of information has been increasing. Large federal and state water quality projects are involving entire watersheds in limited term programs. Development of appropriate computer programs for use in such projects is justified by the following:

1. Increase amount of data analyzed so a more detailed study can be made.

2. Reduction of time needed to analyze data.

3. Output data displayed in an easy to use format; computer library provides data summaries.

4. FORTRAN IV compiler language for an IBM 360/65 computer if used; this matches the ADP Unit in Fort Worth, Texas.

5. SCS conservationists and technicians can use the program.

The above mentioned program happened to include the Universal Soil Loss Equation. Some essential modifications in the program were made at the Computer Center at UW--Stevens Point by Tom Zeisler, a computer specialist. The five input formats for the five different land uses (cropland, woodland, grassland, urban, and other) worked fine. The problem lay in changing the alternative management recommendation for reducing excessive erosion. The original options included a few management practices to be entered by the local technician. The machine usually selected the first option to meet the soil tolerance (T) value. This generally was to increase the years of hay in the rotation. Marathon County already has a hay dominated rotation (corn, oats, hay, hay, hay), so this would not be readily accepted by most farmers (Table 4). Installing various conservation practices to cut erosion showed much more promise. Using data from a recently published ARS/USDA and EPA manual (U.S. Agricultural Research Service and Environmental Protection Agency, 1975), the format was changed to show the reduction in soil loss using each of the following alternatives: contouring, residue left, stripcropping, grassed waterways, no-till or chisel planting, terraces, and spring plowing. Any practice or combination of practices bringing soil loss below the soil loss tolerance level would solve the erosion problem. The term 'soil loss tolerance' means the maximum rate of soil erosion that will permit a high level of crop productivity to be sustained economically and indefinitely (Wischmeier and Smith, 1965). The maximum soil loss rates for soils in the Big Eau Pleine watershed fall into the three tons per acre per year range because of soil properties, soil depth, topography, and prior erosion (U.S. Department of Agriculture--Soil Conservation Service, 1972).

Output data was grouped first according to quartersection and then according to land use. Alternatives were listed in descending order of effectiveness (Table 5). Total acreages exceeding soil loss tolerance levels also appeared in each summary. The final table was an expanded summary of land use and erosion in the whole watershed (Tables 6, 7).

Aerial photos of study sites

In addition to the field data and computer modifications of the USLE, aerial color and color infrared slides of the 42 study sites were taken during three seasons. The winter slides showed patches of manure spreading

Table 4. Cropland acreage summary for the Big Eau Pleine watershed

CORN	29,000 acres
OATS	32,000 acres
HAY	75,600 acres
TOTAL	136,600 acres

Source: U.S. Department of Agriculture--Soil Conservation Service. 1975. Computer program for land use, land treatment, sedimentation, and erosion (applied to Big Eau Pleine watershed by author).

Table 5. Example of a computer print-out on the Universal Soil Loss Equation with possible alternatives listed

DATA CODE	TABLE NAME	SAMPLE NO.	COUNTY	DATA 2	SAMPLE DESCRIPTION
1	CROPLAND	51	1	0.00	A

FIELD NO.	SOIL TYPE	AREA (A.)	SLOPE (PCT.)	LENGTH (FT)	SOIL NAME	MANAGE-MENT	CROP ROTATION	COVER FACTOR	EROSION (T/A/Y)	TOL (T)	EROSION (TONS)
42	43	7.3	2.0	325.0	WITHEE	URF	C 0 H3	.0752	1.16	3	8.45
44	43	13.0	4.0	450.0	WITHEE	URS	C20 H2	.1384	5.43	3	70.57
THE ABOVE SYSTEM IS TOO EROSIVE, USE INSTEAD:							C 0 H3	.0700	2.75		35.69

ALTERNATE SYSTEMS:

	NEW EROSION RATE
TERRACES - - - - - - - - - - - -	0.54
CONTOUR STRIPCROPPING - - - - - - -	1.35
GRASSED WATERWAYS - - - - - - - - - -	1.63
NO-TILL OR CHISEL PLANTING - - - - - -	1.90
CONTOURING - - - - - - - - - - -	2.70
RESIDUE LEFT - - - - - - - - - -	4.61

Table 6. Land use and erosion analysis summary for the Big Eau Pleine watershed with rainfall factor (R) equal to 125, 150

	AREA (A.)	EROSION IN TONS			EROSION IN TONS PER ACRE PER YEAR		
		Present	Rotation Change*	Savings	Present	Rotation Change*	Percent Savings
CROPLAND	138,500	317,600	235,500	82,080	2.33	1.72	25
WOODLAND	40,500	2,200	2,100	180	0.06	0.05	8
PASTURE	34,500	14,400	14,000	430	0.42	0.41	3
OTHER	19,500	--	--	--	--	--	--
TOTAL	233,000	334,200	251,600	82,690	1.46	1.10	24

* Increase vegetative density or proportion of hay in rotation

Table 7. Land use and erosion analysis summary for the Big Eau Pleine watershed with rainfall factor (R) equal to 184

	AREA (A.)	EROSION IN TONS			EROSION IN TONS PER ACRE PER YEAR		
		Present	Rotation Change*	Savings	Present	Rotation Change*	Percent Savings
CROPLAND	138,500	463,100	263,300	200,000	3.39	1.93	43
WOODLAND	40,500	3,300	3,000	400	0.08	0.07	12
PASTURE	34,500	21,200	20,000	1,800	0.62	0.57	8
OTHER	19,500	--	--	--	--	--	--
TOTAL	233,000	487,600	286,300	202,200	2.12	1.24	41

* Increase vegetative density or proportion of hay in rotation

were passed, aerial photography would prove a quick and easily documented means of identifying offenders.

The April slides were taken as the last vestige of snow melted into the ground or ran off into streams. The color infrared slides of the Big Eau Pleine Reservoir revealed an expanse of muddy, turbid water extending downstream toward the dam. If the spring slides were taken just prior to snow melting, most manure speading would show up nicely whether it was done in late December of early March.

The summer slides indicated current land use patterns. Grain stubble showed yellow; pastures appeared as continuous green, corn occurred in neatly spaced rows. Such slides could be used to update older aerial photos, particularly when land clearing is under study. They also could provide base line data for future evaluation of land use changes and trends.

RESULTS AND DISCUSSION

The analysis of erosion on the Big Eau Pleine watershed was based primarily on the soil loss tolerance of each soil type. The term 'soil loss tolerance' means the highest rate of soil erosion that will still allow a high degree of productivity. Calculations indicate a range for most soils of one to five tons per acre is not excessive.

Soil erodibility, slope gradient, slope length, and cropping management factors were analyzed to determine the optimum conditions for excessive soil erosion. Withee silt loam showed a definite susceptibility to excessive soil erosion; this corresponds with its high soil erodibility (K) factor (Figure 11). Since Withee soils also account for almost half the acreage in the Big Eau Pleine watershed, management efforts should be intensified on them. Mulching will increase binding organic matter and reduce detachability during spring runoff (Ellison, 1947), but unless adequate drainage practices are applied, the soils will not dry out and warm up fast enough for spring planting.

Slope gradients have long been considered the main cause of erosion. Even on the deceptively gentle rolling slopes of central Wisconsin this rule applies. Four and five percent slopes contribute far more excessive erosion than their acreages warrant (Figure 12). In fact, Thoreson and Maddy (1963) maintain that doubling the steepness of the slope increases erosion by 250 percent. However, erosion caused by steep slope gradients can be reduced sharply by installing terraces or diversions on such slopes.

Slope length is perhaps one of the most neglected of the USLE factors.

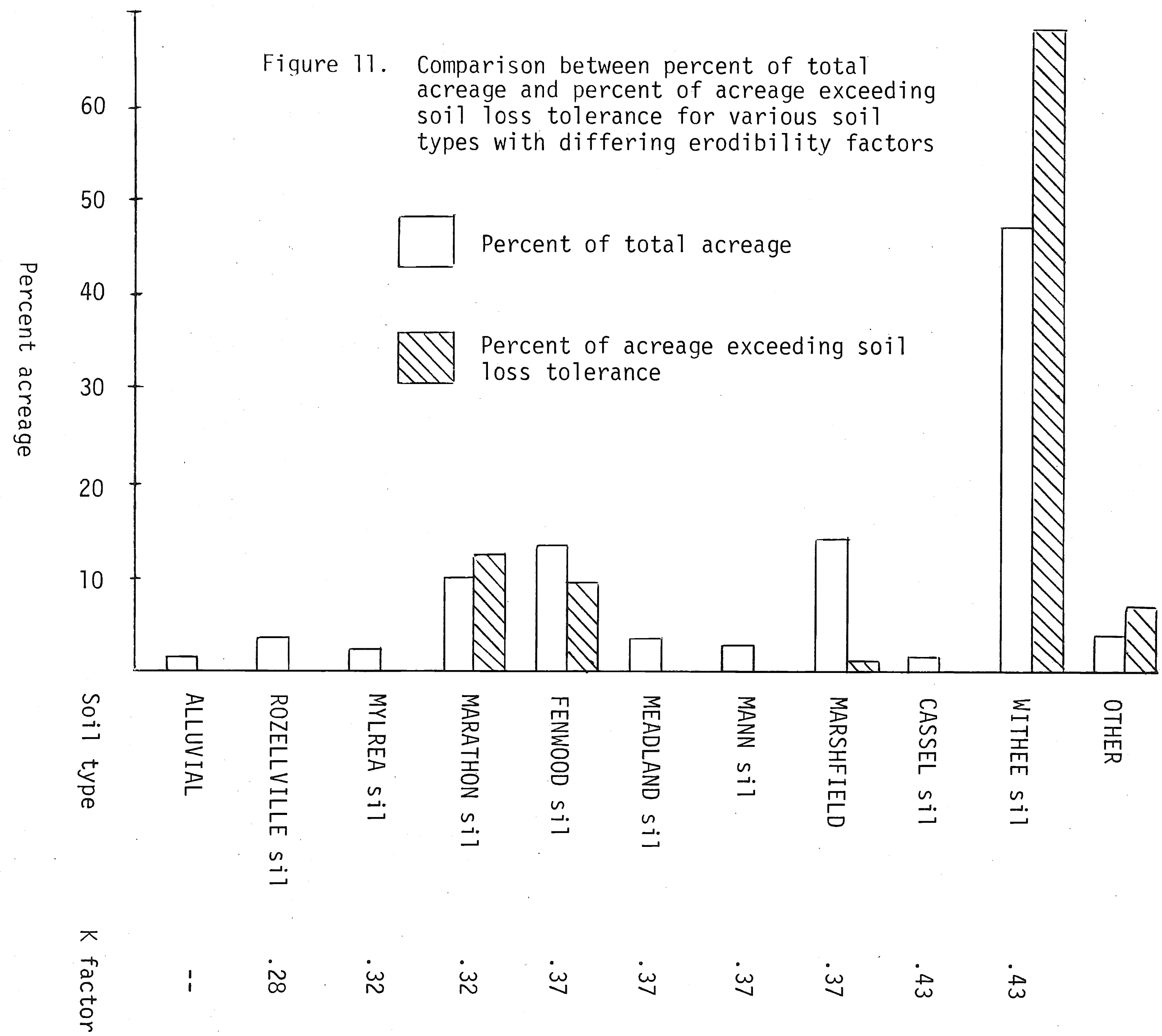


Figure 11. Comparison between percent of total acreage and percent of acreage exceeding soil loss tolerance for various soil types with differing erodibility factors

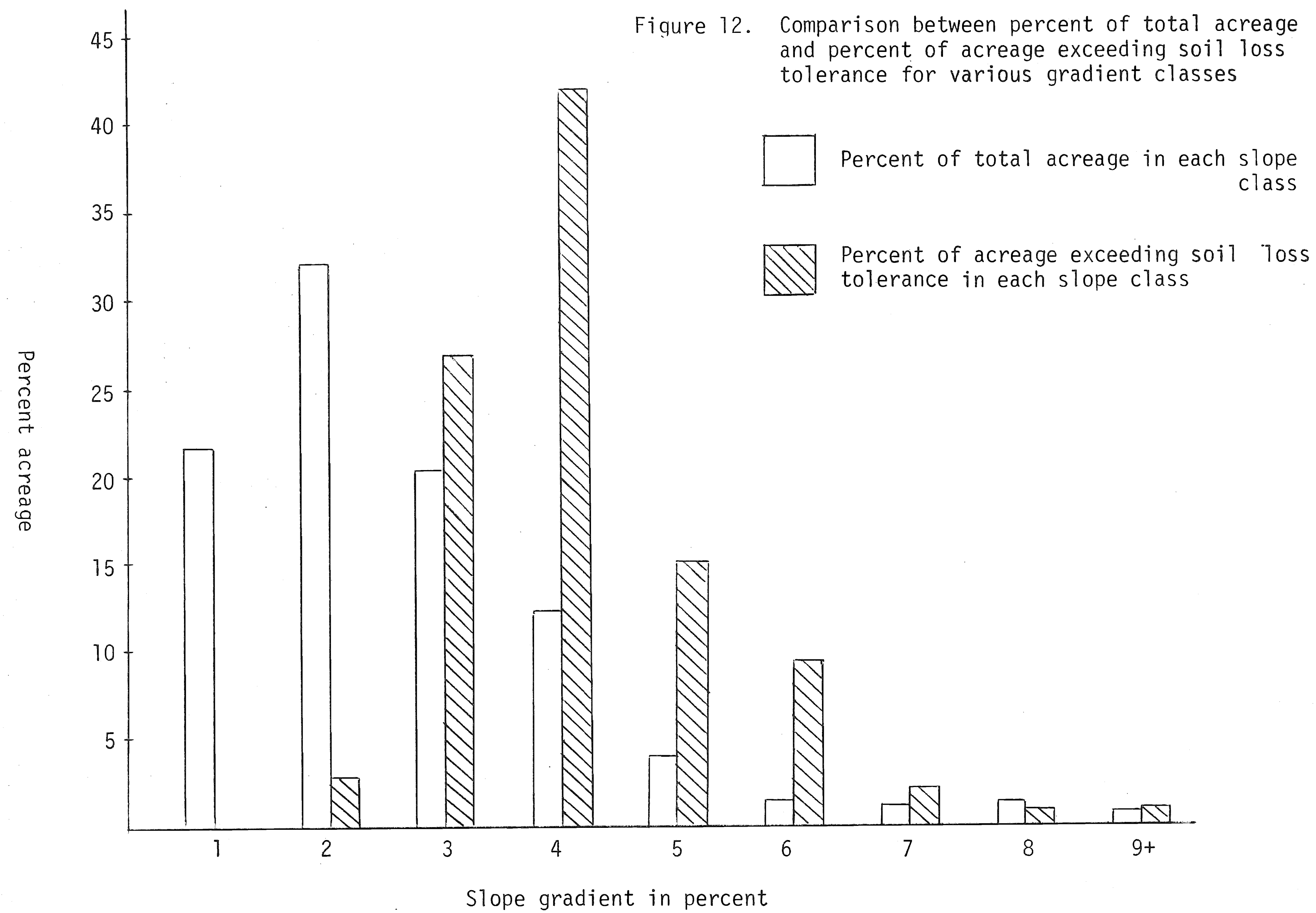


Figure 12. Comparison between percent of total acreage and percent of acreage exceeding soil loss tolerance for various gradient classes

According to Rogers, Barnett, and Cobb, Jr. (1964), very few, if any, tests have been performed on slope lengths exceeding 100 feet. The definition of slope length is at best rather vague. Finding the 'origin of overland flow' in a hayfield and pinpointing the point of deposition is difficult. Most slopes are not uniform in gradient, so they must be divided up so only the most erosive segment is considered. However ill-defined slope length is, field results show that it is a significant factor in computing excessive soil losses (Figure 13). Again, recommended management would be installation of terraces, diversions, or stripcropping.

Crop rotations definitely affect soil losses in excess of allowable rates (Figure 14). As a rule of thumb, if half or more of a rotation is devoted to row crops such as corn or oats, excessive erosion will be the result on most soils found in the Big Eau Pleine watershed. Since Marathon County has such a relatively short growing season, the majority of farmers plant only one year of corn in their four to five year rotations. The ones who are trying for several years of continuous corn are going to be faced with excessive soil losses and probably decreased productivities. No-till and conservation tillage are two of the most effective methods of keeping the soil in place if repeated row cropping is practiced.

Based on the above discussions and data, excessive soil loss on the Big Eau Pleine watershed is expected to be most prevalent on Withee soils found on four percent slopes whose lengths measure approximately 600 feet. The most popular rotation would likely be two to three years of row crops balanced with only three to four years of hay.

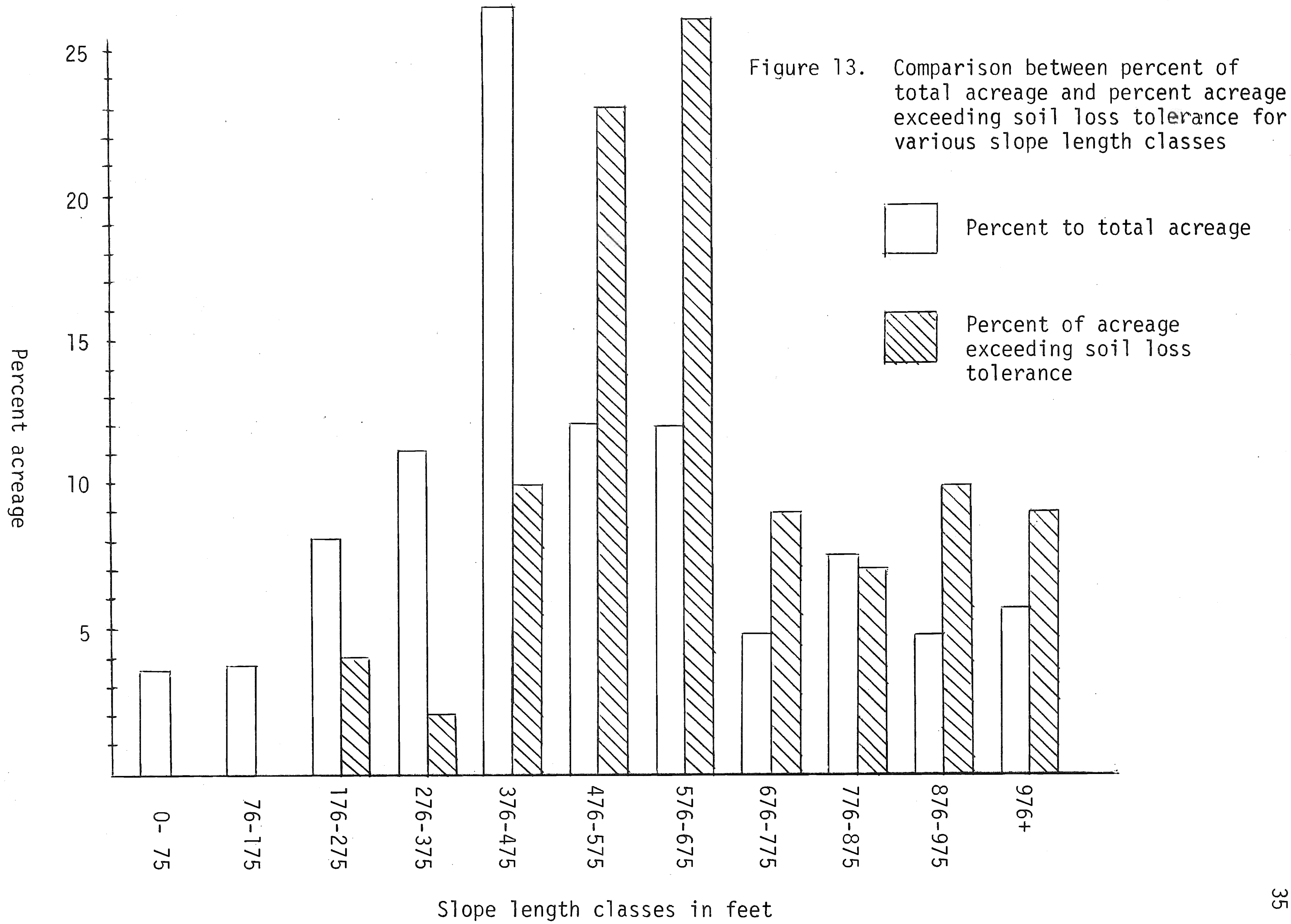
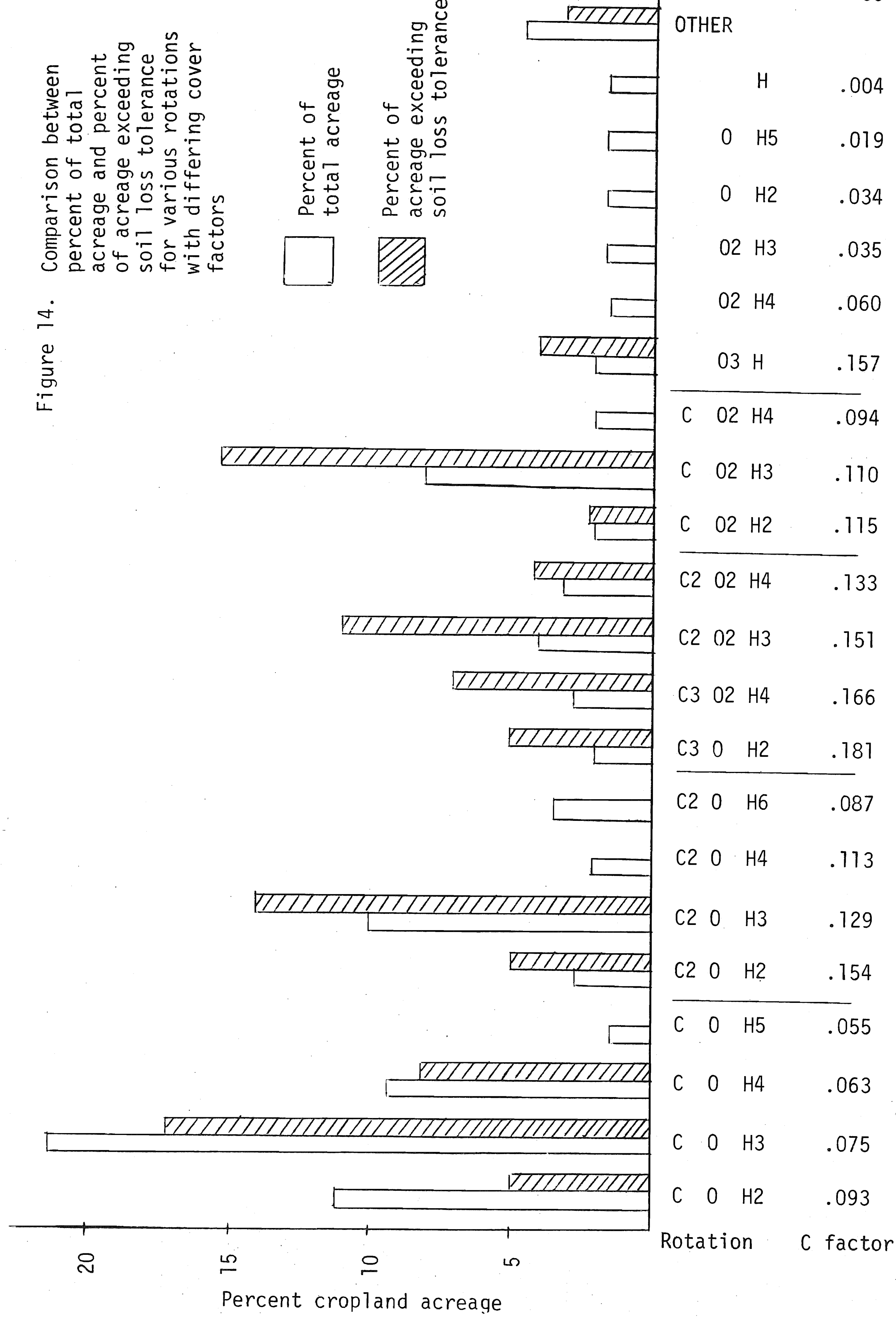


Figure 13. Comparison between percent of total acreage and percent acreage exceeding soil loss tolerance for various slope length classes

Figure 14. Comparison between percent of total acreage and percent of acreage exceeding soil loss tolerance for various rotations with differing cover factors



The total acreage in the watershed that exceeded soil loss tolerances was 36,000 acres or 15 percent of the entire watershed. The rainfall factors of 125 and 150 do not, however reflect the true year-round erosion caused by precipitation; snowmelt is not considered at all. In 1976 T. Kaminski researched the subject thoroughly and recommends using a value as high as 184 to represent the effects of yearly precipitation and runoff in the Big Eau Pleine watershed. The total acreage exceeding soil loss tolerances when using R=184 increased to 58,000 acres or 25 percent of the watershed area.

To date, erosion exceeding allowable soil loss tolerances has been the major concern. These tolerances were developed for maintaining cropland productivity. Water quality standards were not a primary concern. As laws are enacted and awareness of water pollution expands, soil loss tolerances may need to be redefined. Perhaps reservoirs cannot handle as much soil as farmers can afford to lose. Maybe soil loss tolerances should be reduced to one ton per acre per year from any soil, no matter how deep or renewable the soil may be. In the Big Eau Pleine watershed about half of the total erosion occurs at the rate of one to three tons per acre per year (Figures 15, 16). Losing this amount of soil is not particularly injurious to the farmer, but a certain amount of these 175,000 tons is very likely to end up in streams throughout the watershed. Even if this soil erosion is not considered excessive, the nutrients adsorbed to the soil particles very likely are. The Tennessee Department of Health (1971) found that sediment acts as a transporting agent for nitrogen and phosphorus. The primary source of these nutrients in a

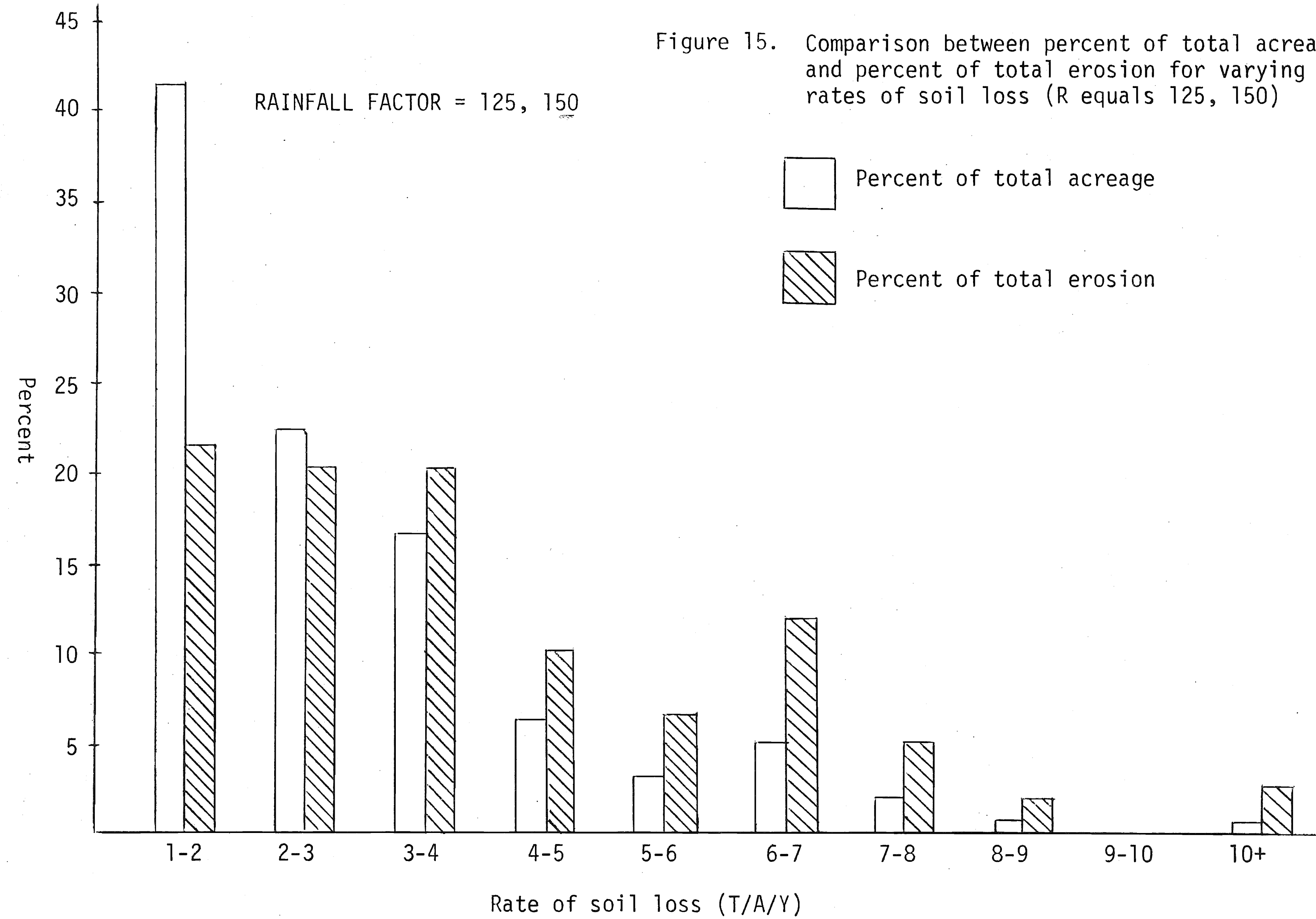
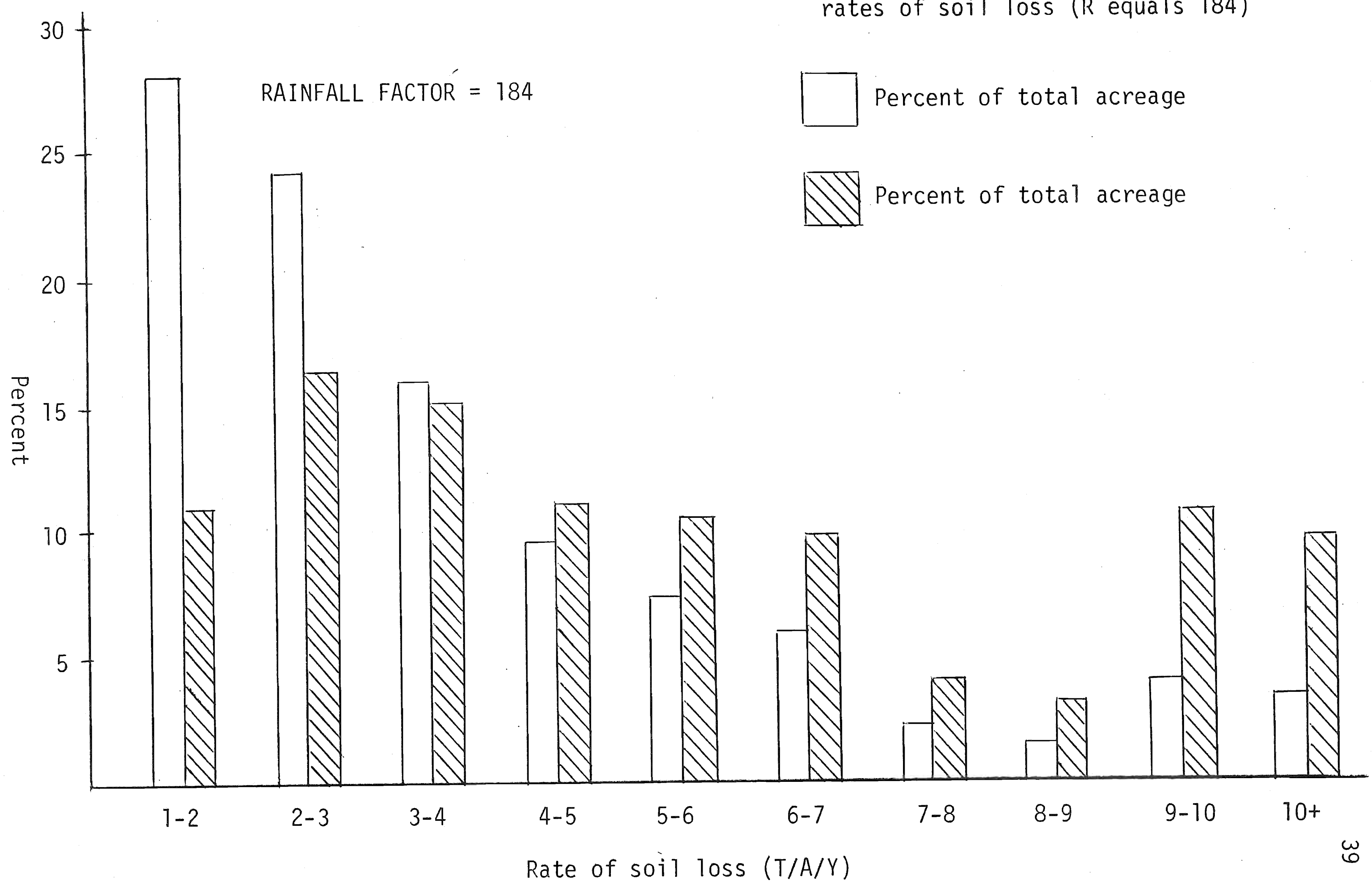


Figure 15. Comparison between percent of total acreage and percent of total erosion for varying rates of soil loss (R equals 125, 150)

Figure 16. Comparison between percent of total acreage and percent of total erosion for varying rates of soil loss (R equals 184)



heavily farmed area is the commercial fertilizer and the manure farmers use to maintain high productivity. These same nutrients encourage algal growth in reservoirs.

Sediment delivery ratios

The percentage of gross erosion that actually reaches the reservoir, lake, or watershed outlet is called the sediment delivery ratio. Sediment yield is the total amount of eroded soil particles from all sources (in tons per year) reaching the watershed streams. This yield is determined in part by climatic factors such as precipitation, temperature, and wind. Watershed factors such as drainage area size, topography, drainage pattern, degree of channellization, soils, and cover conditions also affect sediment yields. In general, the larger the watershed, the higher the sediment yield but the lower the sediment delivery ratio (Cavanaugh, 1978). More area is involved, but there is also a better chance for deposition to occur.

Sheet erosion is the least obvious type of erosion because only a thin, uniform layer of surface soil is removed by flowing water. Since runoff is distributed evenly over the landscape,carrying capacities are minimal and soil particles are only transported for very short distances before deposition occurs. Rill erosion, however, is the result of the channelling of runoff water. Channelled water flows rapidly and is able to detach and transport soil particles into perennial streams where they constitute a portion of the sediment yield.

Erosion from gullies, streambanks, and road ditches is not evaluated such as precipitation, temperature, and wind. Watershed factors such as drainage area size, topography, drainage pattern, degree of channellization, soils, and cover conditions also affect sediment yields. In general, the larger the watershed, the higher the sediment yield but the lower the sediment delivery ratio (Cavanaugh, 1978). More area is involved, but there is also a better chance for deposition to occur.

A rough estimate of the amount of sediment contributed to the Big Eau Pleine Reservoir by sheet and rill erosion can be determined by using the suggested sediment delivery ratio of 0.06 for a 365 square mile watershed (U.S. Agricultural Research Service and Environmental Protection Agency, 1975). With a gross erosion estimate of 334,000 tons per year for the watershed (R equals 125, 150), a total of at least 20,000 tons reaches the reservoir. Increasing the rainfall factor (R) to 184 means approximately 30,000 tons of sediment with its associated nutrients is deposited in the Big Eau Pleine Reservoir. No streambank erosion, organic matter runoff, gully or roadside erosion is included in the above estimations, nor was any subtraction made for deposition at the bottoms of slopes or in man-made devices.

A recent study involving the Big Eau Pleine watershed above the Stratford gauging station indicates that long term sediment yields average 18,900 tons annually from an area measuring 224 square miles (Kaminski, 1977). The entire Big Eau Pleine watershed is relatively homogeneous with respect to soil textures, drainage patterns, stream gradients, and particularly land use (Table 8). By extrapolation, long term sediment yields from the Big Eau Pleine watershed average

30,700 tons annually. This average compares favorably with the Soil Conservation Service estimate mentioned on the previous page. If Kaminski's recommended rainfall factor of 184 is used in conjunction with the sediment delivery ratio of 0.06, the comparison becomes even more favorable.

Common practices producing erosion

Farmers in Marathon County manage their land with productivity foremost is their minds. Over 80 percent of the cropland is plowed during the fall and left bare during the winter. In spring the soil dries out quicker and allows early corn planting. With a 126 day growing season, a couple extra weeks can be crucial. Manure spreading during the winter may be prevalent for the same reason; there is little spare time during the planting and harvesting season to load and haul manure. Once the ground is firm enough for machinery, farmers are eager to get their crops in. Most don't recognize the fact that spring runoff carries away much of their soil, manure, and associated nutrients. Optimum fertilizer utilization is often prevented by insufficient liming of acid soils (Peters, 1977). Therefore farmers may apply more commercial fertilizer than is required by their crops. This simply increases the nutrients adsorbed to eroded soil particles. The short growing season generally does not produce much mature corn, so farmers chop it and store it in silos; very little crop residue is returned to the soil to improve the organic matter content and to protect the soil from spring erosion and early summer rains.

Table 8. Comparison between 100 percent land use sampling in Hamnn/Noisy watershed (Kaminski, 1976), 2.8 percent random sampling in Hamann/Noisy watershed, and in the entire Big Eau Pleine watershed

	Hamann/Noisy watershed	Big Eau Pleine watershed	Two percent of Hamann watershed
	PERCENT AREA	PERCENT AREA	PERCENT AREA
Corn	13.8	12.5	14.0
Oats	14.1	14.0	14.0
Hay/pasture	53.9	47.7	50.5
Woodland	14.0	17.4	17.3
Other	4.2	8.4*	4.2
TOTALS	100.0	100.0	100.0

* contains some water areas

traditional up and down hill farming pattern that almost every farmer uses. Long and narrow fields probably have to be handled this way, but squarer fields could easily be plowed on the contour or at least across the slope.

Alternative practices to reduce erosion

Several practices are available that will reduce erosion and keep fertilizer and manure on fields, and out of the streams. Each farmer will need to use only one or two on any particular field, and he can choose those practices which best suit his style of farming. Soil Conservation Service employees have beem promoting some of the following practices for years; they do work, but the farmer must make the decision to put them in and then to maintain them. It's that simple and that difficult.

Contouring is simply plowing and planting along the slope instead of up and down it. SCS people stake out a line of equal elevation around the knoll or hill and the farmer uses it as a guide on his first pass through. On steeper slopes stripcropping is more effective because the entire hill is never planted in row crops in any one year, only crosswise alternating strips are. The buffer sod areas keep fertilizer and manure and soil up where they do the farmer the most good. Natural drainage ways where runoff tends to concentrate are kept in permanent sod. These grassed waterways are used in conjunction with stripcropping, diversions, and terraces. A diversion is a permanently grassed channel with a supporting ridge on the lower side constructed across the slope. Terraces are also channels that are constructed across slopes, but they can be farmed.

Some practices don't even require the expertise of a soil conservationist. Spring plowing on looser soils means less over-winter erosion from bare ground. Leaving crop residues wherever possible will also reduce erosion over winter. No-till or chisel planting will protect the soil even during the seedling and establishment crop stage periods. Since the corn stalks are chopped up but still left very near the surface, some resistance to erosion results. Chisel plowing also goes deeper than moldboard plowing; it may break up the plow pan and allow better drainage and drying for heavier soils. Thus spring plowing could become a viable practice for farmers in Marathon County.

A final management alternative in the Big Eau Pleine watershed is the installation of settling ponds in drainage ways. Such structures would not aid the farmer greatly in conserving his soil on his fields, but they could catch a major portion of spring runoff and summer stormwater. By confining this runoff temporarily, some debris and sediment would be deposited on the pond bottom. The remaining upper layer of water would eventually flow down sod waterways where additional filtering would occur.

Cost estimate analysis for controlling erosion

In an effort to provide a rough cost estimate for controlling erosion on the Big Eau Pleine watershed, conservation plans for 13 farms in the Hamann Creek watershed were analyzed. The total cropland acreage studied accounted for 10 percent of the watershed acreage. As previously mentioned, correlation between land use in Hamann Creek and the Big Eau Pleine watersheds were extremely close (Table 8). Average slopes also compared well. The Big Eau Pleine value was 3.1 percent; Hamann Creek data indicated an average of 2.9 percent (Kaminski, 1977).

Erosion control practices that were installed or planned were listed along with the recommended amounts. Price per unit figures were obtained from SCS employee John Kruger , who was stationed in the Stratford field office at the time. He referred to an amortization and cost estimate table prepared by SCS in Columbus, Ohio in July of 1975.

Except for one instance, all excessive erosion in the 42 quarter-sections was confined to cropland. Therefore a cost estimate of $62.83 per acre of cropland in Hamann Creek was used to figure the cost of treating cropland in the Big Eau Pleine watershed. Three methods of estimating the cost of controlling erosion on the Big Eau Pleine watershed were utilized (Table 9). Using the standard SCS method of comparing estimated soil losses to 'allowable' soil losses, a total of 36,000 acres needed treatment at a possible cost of $2.3 million. With the revised rainfall factor (R) of 184 substituted for the SCS values of 125 and 150,acreage needing treatment increased to 58,000 acres and estimated costs climbed to $3.7 million. The final cost estimate of $8.6 million was an attempt to treat all the cropland in the watershed according to SCS planning methods.

The effectiveness of the suggested practices has been proved time and time again under actual field conditions. In many cases, these practices bring erosion far below soil loss tolerance levels. Properly treated fields may even reach soil loss levels acceptable for maintaining water quality. Until water quality limitations and specifications are actually defined and written into law, the traditional methods of pre-

Table 9. Cost estimate analysis for controlling sheet and rill erosion on the Big Eau Pleine watershed using SCS planning methods

Practices Needed	Amount Needed	Price per Unit	Total Cost	Percent of Total Cost
CONTOUR STRIPS	479 A.	$4.00	$1,916.00	2.0
GRASSED WATERWAYS	81,350 ft.	0.45	36,608.00	38.0
DIVERSIONS	123,350 ft.	0.40	49,340.00	51.5
TERRACES	22,900 ft.	0.35	8,015.00	8.5
			$95,879.00	100.0

$$\frac{\text{Total cost of \$95,879.00}}{\text{Total cropland of 1526 A.}} = \text{\$62.83 per acre for erosion control practices}$$

RAINFALL FACTOR (R)	COST PER ACRE	CROPLAND EXCEEDING SOIL LOSS TOLERANCE (A.)	TOTAL COST ESTIMATE	LEVEL OF EROSION CONTROL
125, 150	$62.83	36,860	$2,300,000	below soil loss tolerance
184	$62.83	58,240	3,700,000	below soil loss tol.
--	$62.83	136,580	8,500,000	all cropland treated using SCS practices listed above

venting soil loss from drainage areas will probably be used.

The emphasis of this entire paper has been on evaluating erosion on the Big Eau Pleine watershed using the Universal Soil Loss Equation. However, non-point pollution includes far more than just sheet and rill erosion from cropped lands. Unmeasured runoff from barnyards and manured fields provide a concentrated supply of nutrients to streams. Non-functioning septic systems drain directly into road ditches that eventually lead into streams. Cattle graze contentedly along streambanks and leave their wastes to be carried downstream. Ideally, the result of this research paper should be combined with those addressing the barn-yard/septic system problems to provide an accurate overview of all the sources of non-point pollution contributing to the eutrophication of the Big Eau Pleine Reservoir.

MANAGEMENT RECOMMENDATIONS

Cropland erosion could be cut drastically by switching one simple tradition-bound practice in farming. If up and down slope plowing was permanently abolished from the entire watershed, a very significant step toward effective erosion control would be accomplished. Not only would cross-slope plowing and planting reduce erosion, but other conservation practices would become easier to install and maintain. Excess water could still be removed by diversions and sod waterways. Some gentle slopes need only minimum attention. However, long slopes of three to five percent gradients would be broken up by contour stripcropping as well. In addition, erosion control should be intensified on Withee soils since they have a high soil erodibility factor and comprise about half the area of the watershed.

The Big Eau Pleine watershed is characterized by long, deceptively gentle slopes. In general, the topography is ideal for contour stripping. The other most viable alternative is a series of diversions and waterways. True, both methods will take a little land out of crop production. Strip-cropping often means abandoning a few odd areas, and diversions require leaving strips in permanent sod.

Current practices result in topsoil being washed down hills and deposited at field boundaries or streams. This, in turn, requires application of more fertilizer and lime on the relatively unproductive subsoils left at the tops of slopes. Over 90 percent of the cropland in the watershed is presently farmed up and down slope. Farmers in some counties in southwestern Wisconsin have switched over to contour farming. Farmers in Marathon County may have to follow suit if they continue to increase the years of corn in their crop rotations. Southern Wisconsin farmers have traditionally leaned toward beef and corn raising because of the longer growing season. Successive years of corn is relatively new in Marathon County. If it continues, increased erosion control will also become a necessity in central Wisconsin. Already 30 percent of the watershed's cropland supports corn two to three years in succession (Figure 14).

Another very prevalent practice in Wisconsin is winter manure spreading. This tradition can cause problems all over the state if most of the snow melts before the ground thaws enough to absorb some of the moisture. Even nutrients from manure on gentle slopes will head streamward with the inevitable runoff. A two year study of water quality parameters in Hamann Creek watershed has confirmed this (Kaminski, 1977). The problem has a solution, but it is considerably more expensive than changing to contour plowing. Several types of manure storage facilities have been developed. The two most popular are the stacking system and the pit system. Both provide overwinter storage for the entire herd of cattle. In Marathon County the average is about 70 head per farm (Table 10). Once spring arrives farmers can spread the manure directly on their corn fields and plow it under immediately to utilize the nutrients most effectively. The most complete systems also include paved barnyards that are scraped into the pit or stacking platform. Runoff water from fields is diverted around the buildings and milking washwater is also funnelled into the pit. Obviously such systems are expensive. In

Table 10. Summary on livestock, manure, and fertilizer usage on the Big Eau Pleine watershed

LIVESTOCK AVERAGES (43 farms)

70 head of dairy livestock per farm
38 dairy cows per farm
32 heifers per farm

MANURE HANDLING OVER WINTER (56 farms)

13% STATED no manuring on frozen ground
48% spread until snow got too deep, then stacked
31% stacked during the winter
21% spread manure all winter

FERTILIZER USE FOR CORN, OATS, AND HAY

Crop	Average rate per acre	Range in pounds per acre	Number of farms
CORN	260	150--500	32
OATS	196	60--285	26
HAY	246	0--500	19

neighboring Taylor County seven to ten thousand dollars is the average cost per installation. Progressive farmers with financial assistance are installing some systems. They realize the convenience of such systems. Hauling manure out every single day of the winter, regardless of how high the snowdrifts or how low the temperature, is at best an unpleasant chore. Maintenance problems increase in cold weather as tractors refuse to start and manure spreaders freeze up. But the smaller farmer is not ready for such luxuries; quite simply, he can't afford them and still stay in business. His alternative could be much simpler. By stacking his manure on a slightly sloping cement platform with a small catch basin below it for liquids, he could conserve most of his manure. Diversions to carry clean water around his buildings and a small settling pond for barnyard runoff would complete his system. He would not need to invest money in pumps, pipes, and excavation work.

Only 13 percent of the farmers surveyed stated specifically that they did not spread manure during the winter; most farmers who stacked manure put it on the ground somewhere near the barn. Few had pits or concrete platforms. The remainder hauled all winter or whenever they could get into the fields (Table 10). Small wonder that spring runoff is so highly polluted! Even following the SCS guideline of no winter spreading on slopes exceeding five percent would not be particularly helpful--the average slope gradient in the watershed is a meager four percent. Runoff from such gentle slopes should not, however, be underestimated.

Excessive fertilizer applications can also create water quality problems. On the average, farmers in Marathon County spread 230 pounds of commercial and organic fertilizer per acre per year on their cropland (Table 10). If the fertilizer is worked into the ground immediately after application and no erosive rains occur during this period, probably little direct water pollution occurs.

However, winter applied manure cannot possibly be worked into the ground before spring runoff. Nor can sheet and rill erosion from recently fertilized and planted fields be eliminated. Applying proper amounts of fertilizer at the right time in the recommended manner can reduce the likelihood of nutrient pollution.

As previously mentioned, manure spreading on frozen ground should be avoided. Excessive fertilizer application should also be eliminated. A particularly rainy stretch one year may carry a great deal of soil and fertilizer off fields. Farmers may mistakenly conclude that they should apply <u>more</u> fertilizer the following year. Inadequate liming of acid soils may also decrease plant response to fertilizer (Hausenbuiller, 1972)--but increasing fertilizer applications is obviously not the answer. Not for water quality <u>or</u> production!

Farmers learn from the experiences of other farmers. Three or four farmers might put in some type of storage system for manure in a watershed. A couple years later friends or relatives may finally decide that maybe there is some virtue in digging a pit to store manure in. Manure storage systems reduce winter machinery use, conserve liquid wastes more effectively, promote spreading in fall and spring, and save time for farmers. The inefficient or troublesome systems get the publicity they deserve so when more conservative farmers start looking into manure handling systems, they are likely to choose a reliable, workable kind. In nearby Taylor County farmers talk among themselves and visit farmers who have installed systems. Information programs can help, but ultimately the farmer is going to put more trust in his neighbor's opinion than in some machinery dealer, conservation technician, or farm agent.

If an attempt to identify key farmers within each township were carried out, the installation of systems might be accelerated. By cost-sharing with these key farmers, other landowners in that locality would have easy access to on-site information. Most likely farmer candidates would be the natural leaders in the community because their opinions carry a certain amount of weight.

Publicizing manure handling systems in newspapers, county fairs, and farmer organizations may also get initial interest started. It is also helpful for farmers to be aware of the regulations governing manure systems before finalizing their plans. For example, many operators have only a hazy idea of how large the pit must be for one year's storage for 60 head of cattle. Others do not realize their pits must be 250 feet from the nearest well.

A little financial encouragement generally does not slow things down too much, either. The important thing to consider in distributing cost-share monies should be the potential pollution problem that presently exists. Farmers too close to streams should come first. As more funds become available from state and federal governments, less demanding sites can be treated.

Information workshops for construction firms should be set up so state guidelines are followed. Not all systems can be cost-shared but those that are put in independently should still meet specifications.

Even with all the erosion and pollution control practices, there will continue to be some nutrient enrichment of lakes and reservoirs. Runoff will occur whether the land is cropped, forested, or left in grass. Nutrients picked up from dead leaves and grass will still be carried downstream. The point to remember is simple: man did not create eutrophication--it has been going for years. But through his land use practices, man has greatly accelerated the process.

CONCLUSION

Unless farmers in the Big Eau Pleine watershed are willing to change some of their farming methods, nutrient enrichment of the Big Eau Pleine Reservoir will continue to increase. Additional land clearing and drainage of lowlands will bring more cropland into production. The inevitable soil erosion will provide more sediment to fill in the reservoir and more nutrients to trigger luxuriant algal blooms. Algal decomposition over winter will continue to lower the availability of oxygen for fish. Fishable and swimmable water will not be a reality by 1983 unless definite changes are made in the very near future.

Application of the Universal Soil Loss Equation to 2.8 percent of the Big Eau Pleine watershed clearly indicates that at least 15 to 25 percent of the area exceeds soil loss tolerances--and the vast majority of this erosion occurs on cropland. The most prevalent crop rotations include corn, oats, and hay. A good stand of hay provides excellent cover from erosion, so land planted to corn and (to a lesser extent) oats contribute the most soil to runoff. Slope length and gradient also affect erosion significantly.

Measurements of excessive erosion are presently based on the soil loss tolerance factor for each particular soil. This factor is, at best, deceptive. It is based entirely on maintaining the agricultural productivity of the soil. In the near future another set of soil loss tolerance factors should be established just for water quality. The average erosion rate for cropland in the Big Eau Pleine watershed is presently 2.3 tons per acre per year (Table 6). This value may have to be reduced considerably if water quality is to be maintained in the future.

Soil erosion is an important source of non-point pollution, but it is not the sole contributor. Manure and fertilizer both provide nutrients that piggyback on soil particles. Managing nutrient inputs is as important as controlling sediment inputs.

Two important steps are necessary to initiate the reduction of algal blooms in the Big Eau Pleine Reservoir. The first is an extensive educational program aimed at farmers, fertilizer dealers, and farm implement salesmen. Each group must be aware of the problem and how they can help reduce it. The second step involves incentives to change. The cooperation of respected key farmers in the community would motivate other farmers to at least consider alternative management methods. County agents and farm organizations should also play important roles in this persuasion process.

The basic management practices that should be changed are really relatively simple and beneficial to farmers. Elimination of winter manure spreading and reduction in excess fertilizer application can help farmers cut fuel and fertilizer costs. Cross-slope, contouring, or contour stripcropping may not provide such obvious short term benefits in terms of efficiency and production. The same may be said of fencing cattle out of streams. However, continued soil erosion is going to eventually affect farmers in the Big Eau Pleine watershed--even if it never reaches levels that limit agricultural production.

Up until the 1940s exploitation of natural resources was the accepted norm. The United States contains plenty of productive land in relation to its total population. A little waste here and a bit of erosion there hasn't hurt overall food production very much. The U.S. still exports vast quantities of foodstuffs. But the farmer no longer is the dominant figure in America. His numbers have dwindled to less than ten percent of the nation's population. The drive for water pollution control is coming from urban people and sportsmen. In 1972 Congress passed the Federal Water Pollution Control Act. It's stated goal was to achieve fishable and swimmable waters by 1983.

Time and experience have modified these goals into realistic objectives. Some streams must meet the original standards, but others may simply be maintained in their present state. Those bodies of water that must be improved to meet criteria used to define fishable and swimable waters are eligible for cost-sharing funds. This money comes from state and federal taxes. Since the public benefits from cleaner waters, the public should also foot part of the bill. As in most situations, a trade-off can be effected. Farmers and non-farmers alike should pay for better water quality in our lakes and streams. The farmer gains in efficient management of his soil and nutrients and the public benefits by enjoying swimming and fishing in clean, unpolluted waters.

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