To the Graduate Council:

I am submitting herewith a thesis written by Ronald Hugh Rogers entitled "Selected Quality Parameters of Runoff Water from Small Agricultural Watersheds." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Plant and Soil Science.

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SELECTED QUALITY PARAMETERS OF RUNOFF WATER FROM SMALL AGRICULTURAL WATERSHEDS

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee

Ronald Hugh Rogers

December 1975

1266537

ACKNOWLEDGMENTS

The author wishes to express sincere appreciation to the following:

The Plant and Soil Science Department (Dr. Lloyd F. Seatz, Head) for providing materials and equipment;

Dr. G. M. Lessman for serving as committee chairman and for directing the preparation of this manuscript;

Dr. V. H. Reich and Mr. C. H. Shelton for their advice and constructive criticism of this manuscript;

The work reported herein was jointly supported by the University of Tennessee Water Resources Research Center Project A-031-Tn, "Effects of Agricultural Practices and Land Disposal of Solid Waste on Quality of Water from Small Watersheds" and by the University of Tennessee Agricultural Experiment Station Project H-204, "Factors Affecting Water Yield from Small Watersheds in Tennessee";

Fellow graduate students for their encouragement and assistance;

Mr. C. D. Wade for invaluable technical assistance with laboratory analysis;

His father and his wife's parents for their aid and inspiration throughout college study;

His wife, Linda, for her many sacrifices and encouragement during the course of this study.

ABSTRACT

Experiments were conducted in 1974 on the Middle Tennessee Experiment Station at Spring Hill and on the Milan Field Station at Milan to determine the effect of different cultural factors on some quality parameters of runoff from small agricultural watersheds. There were a total of 5 watersheds utilized in this study, 2 at Middle Tennessee and 3 at Milan. Water samples were collected by automated water sampling equipment at 30 minute intervals, and were analyzed for dissolved solids, nitrate-nitrogen, chlorides, and orthophosphate-phosphorus.

The experimental design was a nested design. Simple regression and correlation were performed using runoff rate as the independent variable. As there were not equal numbers of observations from each watershed, a special modification of Duncan's New Multiple Range, developed by Kramer, was used to separate means.

There were a total of 615 samples analyzed. There was no significant difference in mean dissolved solids among watersheds with Milan Field Station (MFS) watershed 1, a 40 acre tract in cotton, being slightly lower than the other 4 watersheds. Nitrate-N values were higher on all of the Milan watersheds although not significantly so. Middle Tennessee Experiment Station (MTES) watershed 1, 198 acres in corn, soybeans, and pasture, MTES 2, a 12 acre pasture, and MFS 2, 67 acres in cotton, soybeans, and woodland, were significantly higher in mean Cl concentration than MFS 1 or MFS 3, a 9 acre field in soybeans,

which were significantly the same. The P concentrations were much higher at the MTES watersheds (over 4 times higher) with MTES 2 significantly higher in P than any other watershed. This was to be expected since most of the soils at Middle Tennessee are very high in P with several of the soils classified as phosphatic. Only at MFS 1 did the maximum NO_3-N concentration exceed the level of 10 parts per million (ppm) established as the maximum level permissible for public drinking water and this occurred in only 3 samples. The highest mean concentration was 2.2 ppm on MFS 2 which is well within acceptable limits.

The mean runoff rate during rainfall events producing runoff ranged from 0.85 cubic feet per second (cfs) on MFS 2 to 5.08 cfs on MFS 1. The highest nutrient and dissolved solids losses came from MFS 1 which had the 5.08 mean cfs runoff. Watershed MFS 1 had 20 times more dissolved solids, 25 times more NO_3-N, 8 times more Cl, and triple the P losses of the next highest watershed for these nutrients and dissolved solids.

Month and rainfall event definitely affected the nutrient concentration of the runoff. Rainfall was significant at nearly every watershed. The exact significance of the rainfall event was impossible to determine since it often rained at one location and not the other, and watersheds at the same location received differing rainfalls. Equipment malfunction also prevented the same number of samples from being taken on each watershed during runoff events. The statistical analysis used determined that significant differences existed among rainfalls. Significant differences among months were found for dissolved

solids at MTES 2, MFS 1, and MFS 2. Differences among months were also significant at MFS 2 and MFS 3 for NO_3-N, only at MFS 2 for Cl, and for P at MTES 2, MFS 1, and MFS 2. Regression values were negative, suggesting that an inverse relationship existed between nutrients and dissolved solids and runoff rate.

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CHAPTER I

INTRODUCTION

Each year the world demand for food increases in response to the ever increasing population. To help meet this demand, usage of various fertilizer amendments has increased in both rate of application and scope of use. With this increased fertilizer use, the probability of fertilizer induced pollution seems to increase.

Agriculture has been under increasing pressure recently to reduce or even restrict the use of certain chemicals. Environmentalists contend that pesticides, herbicides, and fertilizers are polluting our lakes and streams. Nitrogen and phosphorus are felt by many to be the major contributors to excessive algae growth. This excessive growth, which is called eutrophication, has caused a marked deterioration in water quality of some of our surface water.

Insufficient data have been presented on nutrient loss by runoff and claims of pollution from fertilizers are not a proven certainity. The objective of this experiment was to determine the effects of selected cultural practices on certain quality parameters, (NO_3-N, P, Cl, and dissolved solids) of surface runoff from agricultural lands.

CHAPTER II

LITERATURE REVIEW

During the past few years, the topic of environmental pollution has become increasingly popular. Much of this increased awareness has been centered on the agricultural use of chemicals and the pollution of our surface water. Water pollution can be defined as the degradation of water quality to the degree that it interferes with another legitimate use (6). Eutrophication is one such pollution. Eutrophication has existed for millions of years, however only in the last few years has accelerated, man-made eutrophication been damaging our water quality. Viets (21) defined eutrophication as the production of organic matter through photosynthetic activity of algae and phytoplankton in excess of organic matter destruction, so that lakes "die" and the water becomes unsuited for domestic and industrial supply and water sports. Many environmentalists contend that agriculture pollution from chemical fertilizers, especially phosphates (PO_4) and nitrates (NO_3), are primary contributors to eutrophication.

Sources of water pollution can be broken down into 4 categories; (1) natural sources, (2) municipal sewage, (3) industrial effluents, and (4) agricultural operations. A major question is of what importance is nutrient loss from agricultural lands in this pollution problem? Only very small amounts of nutrients are necessary for high levels of eutrophication. Viets (21) gives a value of 15 parts per billion (ppb)

soluble P and 0.3 parts per million (ppm) soluble inorganic N in spring as sufficient to produce noxious algal blooms in summer.

Garman (7) feels that organic carbon, not P, is the key to eutrophication. Each ton of algal tissue contains 800 to 1000 pounds of C and only 5 to 15 pounds of P. Water normally contains only 0.4 to 1 ppm CO_2 or the equivalent of 0.1 to 0.21 ppm C. Therefore a source of organic matter, such as sewage, must be present for algal growth.

I. NUTRIENT LOSS OF N AND P

Romkens and Nelson (15) studied the effect of P fertilization on the P composition of runoff. They concluded that the relation of P addition rate to the soluble orthophosphate in runoff was approximately linear. Thomas and Crutchfield (20), in research conducted on streams draining agricultural watersheds in Kentucky, found that the P concentrations in the stream water were closely related to local geology and not to land use. They also concluded that no good relationship existed between land use and the NO_3-N content of stream water.

Klausner et al. (12), on research relating losses of N and P to management systems, reported that except for heavy fall N fertilization on poorly managed soils, the total yearly discharge in surface runoff did not exceed the amount delivered in rainfall. The inorganic P losses were directly related to fertilizer rate and soil management practices. The concentration of soluble N and P appeared to be a function of the

time of year and timing of fertilizer inputs, and not related to the volume of surface runoff.

Kilmer (10) studied nutrient loss from fertilized, grassed watersheds in western North Carolina over a 4 year period. There was a higher loss on the more heavily fertilized watersheds, but the measured NO_3-N concentration exceeded 10 ppm, the level set as the highest concentration permissible in drinking water, at only one sampling time. The annual P losses were neglible and P fertilization had no apparent effect on the P losses in the drainage. Based upon results of their study, steep, sloping pastures, when fertilized using good present management systems, are not important sources of nutrients entering ground or surface water.

Hill and McCague (8) studied the effects of NO_3 concentrations as influenced by N fertilization of adjacent fields in Ontario, Canada. The maximum NO_3 levels ranged from 3 ppm near a sod field to 10 ppm downstream from tobacco and potato fields. The relationship between well defined peaks in NO_3 concentrations and the date of fertilizer application suggest that N fertilization was the source of the increased NO_3 stream level. The soils of this area are coarse textured and favor loss of NO_3 from heavily fertilized fields.

Holt et al. (9) concluded that eroded soil contributes substantial amounts of P to surface water but soil materials have a tremendous sorption capacity and little P is released to the water. Leaching of vegetation can supply large amounts of P to lakes and streams and may be the most important contributor. Deep fertilizer incorporation reduces the P loss over shallow fertilizer incorporation.

In research conducted on agricultural watersheds on Missouri Valley loess, Schuman et al. (17) showed P is lost primarily by adsorption to eroded soil transported by runoff. Control of erosion will control most of the P entering water supplies. Ryder et al. (16) pointed out the tremendous variability of watersheds and the difficulty in studying a typical watershed for P losses. This tends to create problems in research data interpretation.

Research conducted for 3 years at Coshocton, Ohio, by Taylor et al. (19), measured NO_3 and P concentrations in streams draining woodland and farmland. No relationship existed between any nutrient concentration and streamflow, and no seasonal changes in concentrations were found. Nutrient losses were greater from farmland than from woodland. The NO_3-N concentrations in the farm runoff was below 2 ppm, and P was 22 ppb from farm runoff and 15 ppb from woodland runoff. The inputs of N from rainfall was greater than the loss in runoff from both watersheds.

II. CHLORIDES

Kolenbrander (13) reported that an application of 100 kg. of Cl/Ha/Yr increased groundwater content by a maximum of 9 ppm on a sandy soil over a 37 year period in the Netherlands. Fertilizer application of Cl did not constitute a deterioration of drinking water sources. Research by Kissel et al. (11) on leaching losses from a swelling clay soil showed that Cl moves easily in leachate through large pores in the soil and increased by 7 ppm in the first 25 millimeters.

Smith (18), in leaching experiments that involved 15 widely varying surface soils and 0.01 N $CaCl_2$, found Cl moved through soils 1.04 to 1.67 times faster than it would if it had been associated uniformly with all the soil water. Increases in Cl movement was highly correlated with soil cation exchange capacity and surface area.

Barker (4), working on irrigation with dairy manure slurries, analyzed runoff from conventional pasture and resting areas on which no slurry was applied and found Cl levels with a range of 5 to 12.5 ppm with a median of 10 ppm on Watershed A, and a 7.5 to 17.5 ppm range with a median of 10 ppm on Watershed B. He also reported dissolved solids of 169 to 360 ppm with a median of 264 ppm on Watershed A, and 227 to 351 ppm with a median of 313 ppm on Watershed B.

III. FUTURE TRENDS AND THE POSSIBLE REGULATION OF FERTILIZER

Viets (22) believes that fertilizer restriction imposed on a state or national level would not result in enough water quality improvement to risk a less abundant and more costly food supply. Nitrogen and P water pollution would, in fact increase, since marginal land would have to be used to meet the demand for food production and would result in increased erosion. However, restriction of fertilizer may become necessary on small areas to improve local situation.

The Illinois Pollution Control Board, in a landmark decision (3), rejected attempts to regulate the use of fertilizer in that state. No alternative to commercial fertilizer that would provide adequate food

without an equal potential for water pollution by NO_3 now exists. None of the experts could state whether the substitution of livestock and human wastes or N-fixing legumes for fertilizer N would reduce the amount of NO_3 that would leach or run off the soil. The board also stated that the nutrient effect of flowing midwestern streams has been negligible and there is no concrete evidence supporting the view that P in streams is a major water quality destroyer.

Aldrich (1) summarized the situation by indicating that if no fertilizer were used, we would have to farm 3 times our present acreage of corn just to maintain our present production level. These increased crop acres mean more erosion and increased sediment loads in streams and lakes and thus an increased amount of nutrients leading to a higher level of pollution.

CHAPTER III

MATERIALS AND METHODS

Experiments were conducted in 1974 at the Middle Tennessee Experiment Station at Spring Hill and at the Milan Field Station at Milan to evaluate the effect of certain cropping and cultural practices on the quality of surface runoff from small watersheds. Water samples were analyzed for dissolved solids, nitrate-nitrogen, orthophosphate-phosphorus, and chlorides. This study is part of an overall project done in cooperation with the Department of Agricultural Engineering. Their phase of the investigation examined the parameters of sediment, turbidity, and total suspended matter from the same samples which were analyzed in this study.

There were a total of 5 different watersheds used in the study, 2 at Middle Tennessee and 3 at Milan. Size of each watershed, crops grown on them, and predominant soil types for each watershed is given in Table I. The series name, subgroup, and family classification for all major soils groups found on the watersheds of both locations is given in Table II. Hereafter the watersheds will be referred to as MTES 1 and MTES 2 for Middle Tennessee watersheds and MFS 1, MFS 2, and MFS 3 for the Milan watersheds.

Samples were taken by automatic water samplers every 30 minutes when the flow depth over a constructed stream gage spillway exceeded 0.2 foot. Samples on MTES 2 and MFS 3 were taken by a modified Instrumentation Specialties Model 1390 sample collector, and MTES 1,

TABLE I

SIZE, CROP, AND PREDOMINANT SOIL TYPE
OF EACH RESEARCH WATERSHED

Location	Acreage	Crop	Soil Type
MTES 1	198	Corn, Soybeans, Pasture	Linside-Phosphatic Armour Maury
MTES 2	12	Pasture	Linside-Phosphatic Armour Maury
MFS 1	40	Cotton	Collins Loring Falaya
MFS 2	67	Cotton, Soybeans, Woodland	Grenada Henry Loring
MFS 3	9	Soybeans	Calloway Henry

TABLE II

SERIES, SUBGROUP, AND FAMILY OF SOILS
ON THE RESEARCH WATERSHEDS

Series	Subgroup	Family
	MTES	
Armour	Ultic Hapludalfs	Fine Silty Mixed Thermic
Linside-Phosphatic	Fluvaquentic Eutrochrepts	Fine Silty Mixed Mesic
Maury	Typic Paleudults	Clayey Mixed Mesic
	MFS	
Calloway	Glossaquic Fragiudults	Fine Silty Mixed Thermic
Collins	Aquic Udifluvents	Coarse Silty Mixed Acid Thermic
Falaya	Aeric Ochraqualfs	Coarse Silty Mixed Thermic
Grenada	Glossic Fragiudalfs	Fine Silty Mixed Thermic
Henry	Typic Fragiaqualfs	Coarse Silty Mixed Thermic
Loring	Typic Fragiudalfs	Fine Silty Mixed Thermic

MFS 1, and MFS 2 samples were taken by a Product Manufacturing Company Model PS-69 automatic pumping sampler. The samples were dated, numbered, and frozen after being removed from the sampler before transport to Knoxville for laboratory analysis. Freezing was necessary since NO_3-N is unstable and is rather quickly converted to gaseous forms of N by bacteria present and is thus lost from the sample.

The experimental design was a nested design with samples nested within rainfalls, rainfalls nested within months, months nested within watersheds, and watersheds nested within locations. Analysis of variance, regression and correlation, and a modified Duncan's New Multiple Range Test (DMR) was performed. All statistical analyses, except for DMR, were performed on the IBM 360/65 computer at the University of Tennessee Computing Center, and followed standard statistical methods. The DMR analysis was a modification developed by Kramer (14) to group means with unequal numbers of observations.

Runoff flow rates were obtained by a water-level recorder at each watershed. Because of equipment malfunction, runoff data were not available for every sample taken. The regression analysis was based on these runoff data and therefore regression was performed only on those samples with runoff data available.

I. LABORATORY ANALYSIS OF SAMPLES

Dissolved solids were determined by using a modification of the method outlined in Methods for Chemical Analysis of Water and Wastes (5).

Nitrate-N, Cl, and P were determined by the methods as outlined in the above handbook.

Modification of the dissolved solids analysis involved filtering the sample through a Gelman Type A filter or equivalent to remove all non-filterable solids. A known volume was then oven dried at 105 degrees Celsius, and the residue weighed to determine the weight of the dissolved solids.

Nitrate-N, Cl, and P were determined by colorimetric reactions on the Technicon Autoanalyzer. Nitrate-N was determined by the automated cadmium reduction method and measured NO_2 as well as the NO_3 form of N. Chlorides were determined by the automated ferricyanide method, and P was determined by the automated single reagent method.

CHAPTER IV

RESULTS AND DISCUSSION

There were a total of 615 samples analyzed. The number of samples, as well as maximum, minimum, and mean concentrations of dissolved solids, NO_3-N, Cl, and P for each watershed is given in Tables III through VI. Wide variations in dissolved solids and nutrient concentrations are to be expected in surface runoff samples, making the mean concentrations much more meaningful in the interpretation of results. There was no significant difference for the mean dissolved solids concentration, although MFS 1 was the lowest of the 5 watersheds. Mean NO_3-N concentrations were higher on all Milan watersheds although the differences were not significant. The Cl concentrations were higher at Middle Tennessee probably because some of the runoff came from pastures and cattle resting areas. Various salts are important constituents of cattle feeds, and increased Cl levels can be expected in runoff from areas where cattle are located. Watersheds MTES 1, MTES 2, and MFS 2 were all higher in mean Cl concentration than MFS 1, with MFS 3 intermediate. The mean P concentrations were much higher (at least 4 times higher) on the Middle Tennessee watersheds with MTES 2 significantly higher than any other watershed. The higher P concentrations were expected on the Middle Tennessee watersheds and will be discussed in greater detail later. At only MFS 1 did the maximum NO_3-N concentration exceed the level of 10 ppm set for public drinking water, and this

TABLE III

MAXIMUM, MINIMUM, AND MEAN VALUES FOR DISSOLVED SOLIDS FOR EACH WATERSHED

Watershed	Number of Samples	Maximum	Minimum	Mean
		- - - - - - - - - ppm - - - - - - - - - -		
MTES 1	120	256.0	8.0	89.5 a[+]
MTES 2	33	182.0	6.0	97.0 a
MFS 1	210	454.0	4.0	58.9 a
MFS 2	195	226.0	14.0	96.2 a
MFS 3	57	224.0	8.0	77.0 a

[+]Values within a column followed by the same letter are not significantly different at the .05 level of probability.

TABLE IV

MAXIMUM, MINIMUM, AND MEAN VALUES FOR NO_3-N FOR EACH WATERSHED

Watershed	Number of Samples	Maximum	Minimum	Mean
		ppm		
MTES 1	120	1.55	0.01	0.31 a[+]
MTES 2	33	0.92	0.01	0.15 a
MFS 1	210	13.00	0.01	0.99 a
MFS 2	195	9.10	0.02	2.20 a
MFS 3	57	3.52	0.01	0.53 a

[+]Values within a column followed by the same letter are not significantly different at the .05 level of probability.

TABLE V

MAXIMUM, MINIMUM, AND MEAN VALUES
FOR Cl FOR EACH WATERSHED

Watershed	Number of Samples	Maximum	Minimum	Mean
		ppm		
MTES 1	120	14.8	1.8	5.5 a[+]
MTES 2	33	16.5	2.0	8.6 a
MFS 1	210	15.0	0.1	1.5 b
MFS 2	195	21.0	1.0	5.7 a
MFS 3	57	30.2	0.5	4.1 ab

[+]Values within a column followed by the same letter are not significantly different at the .05 level of probability.

TABLE VI

MAXIMUM, MINIMUM, AND MEAN VALUES
FOR P FOR EACH WATERSHED

Watershed	Number of Samples	Maximum	Minimum	Mean
		ppm		
MTES 1	120	1.16	0.01	0.338 b[+]
MTES 2	33	1.80	0.11	0.818 a
MFS 1	210	0.23	0.01	0.035 c
MFS 2	195	0.56	0.01	0.063 c
MFS 3	57	0.62	0.01	0.091 bc

[+]Values within a column followed by the same letter are not significantly different at the .05 level of probability.

occurred during only 3 samples. The highest mean NO_3-N concentration was only 2.2 ppm and occurred on MFS 2.

The P values are affected tremendously by the soils on a watershed. Almost all P reaching surface water is in association with sediment (9, 17, 19). Most of the soils of the Middle Tennessee Experiment Station are extremely high in P, and many of them are classified phosphatic. The soils at Milan are basically loessal derived, and are much lower in P concentrations than those at Middle Tennessee. In water quality investigation, the soils of the area play important roles in the nutrient and dissolved solids concentration in runoff. Proper understanding of the chemical and physical characteristics of the soils greatly aids in data interpretation. A normal P level in runoff water from Middle Tennessee would be abnormally high if observed at Milan.

Mean runoff ranged from 0.85 cubic feet per second (cfs) on MFS 2 to 5.08 cfs on MFS 1 for the entire sampling period (Table VII). No runoff data were available for MTES 2 due to failure of event marker to function properly on the water-level recorder making collation of sample and runoff data impossible. Milan Field Station 1 is a 40 acre field in cotton, and had a much higher runoff rate (over 3 times higher) than did the next highest, which was MTES 1, a 198 acre tract in corn, soybeans, and pasture.

Mean amounts of dissolved solids, NO_3-N, Cl, and P for each sample time are also given in Table VII. The highest losses came from MFS 1 which had over 20 times more dissolved solids, 25 times more NO_3-N, 8 times more Cl, and triple the P losses than did the next highest

watershed for each of these variables. A more detailed and concentrated study should be made to discover the exact reasons for this high nutrient concentration. Except for MFS 1, runoff and nutrient loss was not excessive on any other watershed.

TABLE VII

MEAN RUNOFF RATE AND POUNDS DISSOLVED SOLIDS, NO_3-N, Cl, AND P LOST FOR EACH SAMPLE PERIOD ON SELECTED WATERSHEDS

Watershed	Mean Runoff Rate	Dissolved Solids	NO_3-N	Cl	P
	(CFS)	- - - - - - - - - - Lbs - - - - - - - - - -			
MTES 1	1.61	16.2	0.055	0.98	0.060
MFS 1	5.08	335.9	5.640	8.49	0.190
MFS 2	0.85	8.2	0.184	0.48	0.005
MFS 3	1.21	10.5	0.072	0.55	0.010

Table VIII lists the total pounds of nutrients lost for the sampling period during the year 1974. Watershed MFS 1 had the largest loss of nutrients. The nutrient concentration in the runoff water from MFS 1 varied little from any other watershed, but the very high total runoff raised the total to the high levels observed.

TABLE VIII

TOTAL POUNDS DISSOLVED SOLIDS, NO_3-N, Cl, AND P
LOST FROM SELECTED WATERSHEDS

Watershed	Dissolved Solids	NO_3-N	Cl	P
	- - - - - - - - - - - - - -	Lbs	- - - - - - - - - - - - - -	
MTES 1	1,942	6.7	118	7.3
MFS 1	70,558	1185.2	1,784	40.9
MFS 2	1,607	35.9	95	1.1
MFS 3	597	4.1	32	0.7

I. STATISTICAL ANALYSIS

The statistical significance of each month and each rainfall event for which runoff data were collected was determined by an "F" test (Table IX). Kramer's modification of DMR (14) was then performed on variables upon which the month had a significant effect. The DMR was not performed on rainfall means even when significant differences were found among rainfalls since it often rained at one location and not the other, and often watersheds at the same location received different rainfall rates and volumes. As can be seen from the data in Table IX, the month of the year had a significant effect on the dissolved solids concentration at MTES 2, MFS 1, and MFS 2. Month was significant only at MFS 2 and MFS 3 for NO_3-N, while rainfall events were significant at all watersheds. Month was significant for P at MTES 2, MFS 1, and

TABLE IX

F VALUE AND SIGNIFICANCE FOR MONTH AND RAINFALL EVENT FOR EACH WATERSHED FOR ALL VARIABLES

Watershed	Source of Variation	Dissolved Solids	NO_3-N	Cl	P
MTES 1	Month	1.21	2.69	0.03	2.70
	Rain	3.21 *	35.46 **	30.79 **	15.89 **
MTES 2	Month	9.57 *	0.30	3.04	20.55 **
	Rain	0.84	17.17 **	3.32 *	2.16
MFS 1	Month	14.57 **	1.44	0.46	5.32 **
	Rain	1.58	14.27 **	52.55 **	5.05 **
MFS 2	Month	18.10 **	16.04 **	22.46 **	9.07 **
	Rain	3.78 **	15.64 **	9.07 **	19.93 **
MFS 3	Month	0.38	4.40 *	0.20	0.54
	Rain	1.91	4.82 **	5.15 **	2.61 *

*Significant at the .05 level of probability.

**Significant at the .01 level of probability.

MFS 2, while rainfall was significant at all watersheds except for MTES 2. Based on this study the month of the year might be a better factor to consider than rainfall. The month allows a better study of fertilization and cultural practices. Rainfall events are too scattered and unpredictable and on large watersheds rainfall distribution could be uneven.

All possible correlations were performed, but no significance was found and no data on these correlations were included. Linear regression for watersheds MTES 1, MFS 1, and MFS 2 was performed (Table X). The regression model used was to set dissolved solids, NO_3-N, Cl, and P as dependent variables and consider runoff rate as the independent variable. Watershed MTES 2 was omitted since event marker failure made interpertation of runoff data impossible. Watershed MFS 3 was omitted because insufficient samples were collected. All variables had significant regression at MTES 1, while there was no significant regression for any variable at MFS 2. Dissolved solids and P had significant regressions at MFS 1, while NO_3-N and Cl were not. All variables gave a negative regression except for P concentrations at MTES 1 and MFS 1. When MTES 1, MFS 1, MFS 2, and MFS 3 were combined to give the total regression, all slope values were negative and all were significant. This suggests that the total amount of dissolved solids, NO_3-N, Cl, and P lost in runoff from a watershed tends to be a fixed amount. For each unit increase in runoff, there was a slight decrease in the concentration of the variables. The rate of runoff may be of little importance as

TABLE X

SIMPLE REGRESSION VALUES FOR WATERSHEDS MTES 1, MFS 1, AND MFS 2[@]

Watershed	Parameter Estimate	Dissolved Solids	NO_3-N	Cl	P
MTES 1	Intercept	102.10	.41	6.04	0.273
	Slope	-7.35 **	-0.03 *	-0.33 *	0.033 **
MFS 1	Intercept	74.36	1.83	2.03	0.026
	Slope	-0.01	-0.05 **	-0.03	0.001 **
MFS 2	Intercept	101.87	2.41	6.29	0.065
	Slope	-4.75	-0.13	-0.39	-0.012
Combined[@]	Intercept	88.75	1.39	4.82	0.135
	Slope	-0.79 *	-0.03 *	-0.16 **	-0.003 *

[@]Watersheds MTES 2 and MFS 3 are not included because of lack of runoff data and too few samples respectively.

[@]Combined regression includes MTES 1, MFS 1, MFS 2, and MFS 3.

*Significant at the .05 level of probability.

**Significant at the .01 level of probability.

long as sediment loads are not considered. This may suggest the possibility of predicting the amount of nutrients lost from a watershed provided that soil type, fertility, crop, and cropping systems are known, with a given rainfall pattern. This observation could be very important if it could be conclusively proven.

The mean dissolved solids concentration was found to be significantly lower in April than May, June, or July which were significantly the same at MTES 2 (Table XI). At both MFS 1 and MFS 2 the month of May was found to have a significantly higher concentration than the other months. Not all months are represented since data were not taken for every month at every watershed because of sampler malfunction or lack of rainfall.

Only MFS 2 and MFS 3 were found to be significantly different by month for NO_3-N (Table XII). May was significantly higher than June at MFS 2 as these were the only months samples were obtained, while July was significantly higher than April, May, June, or August which were all the same at MFS 3.

Orthophosphate-P, on MTES 2, was found to be the same in June and July, and was significantly higher than May with April being significantly lower in concentration than any other month. At MFS 1, September was significantly higher than any other month except for April and May, but there was no difference between April, May, June, July, August, or October. May was significantly higher than June at MFS 2 as these were the only 2 months samples were obtained (Table XIII).

TABLE XI

MEAN DISSOLVED SOLIDS CONCENTRATION BY MONTH FOR SELECTED WATERSHEDS

Month	MTES 2	MFS 1	MFS 2
	- - - - - - - - - - - - ppm - - - - - - - - - - - -		
April[+]	43.6 b[++]	87.4 ab	
May	105.6 a	97.2 a	124.4 a
June	114.8 a	59.5 bc	81.8 b
July	142.0 a	58.0 bc	
August		39.6 c	
September		26.4 c	
October		18.4 c	

[+]Months with blank data indicate no samples taken during that month.

[++]Values within a column followed by the same letter are not significantly different at the .05 level of probability.

TABLE XII

MEAN NITRATE-N CONCENTRATION BY MONTH
FOR SELECTED WATERSHEDS

Month	MFS 2	MFS 3
	- - - - - - ppm	- - - - - - -
April[+]		.313 b
May	4.14 a[++]	.379 b
June	1.06 b	.708 b
July		2.120 a
August		.082 b

[+]Months with blank data indicate no samples taken during that month.

[++]Values within a column followed by the same letter are not significantly different at the .05 level of probability.

TABLE XIII

MEAN ORTHOPHOSPHATE-P CONCENTRATION BY MONTH
FOR SELECTED WATERSHEDS

Month	MTES 2	MFS 1	MFS 2
	- - - - - - - - - -	ppm	- - - - - - - - - -
April[+]	.17 c[++]	.066 ab	
May	.62 b	.048 ab	.143 a
June	1.28 a	.014 b	.018 b
July	1.20 a	.016 b	
August		.024 b	
September		.091 a	
October		.016 b	

[+]Months with blank data indicate no samples taken during that month.

[++]Values within a column followed by the same letter are not significantly different at the .05 level of probability.

CHAPTER V

SUMMARY AND CONCLUSIONS

I. SUMMARY

During the past few years, the use of agricultural fertilizers and chemicals has increased. Also during this time, concern over environmental pollution has arisen. Many environmentalists contend that agricultural chemicals have contributed heavily to this pollution and is one of the primary causes of the degradation of much of our surface water. Unless reliable data are presented to counter their claims, legislation might be passed that could severely restrict the use of chemical fertilizers. This would prove a hardship to both the farmer and the consumer as yields would decrease and prices would most certainly increase.

This study represents only one year of data on limited acreage and cropping systems. More related research needs to be conducted before any definite conclusions can be reached. However, based upon data collected and analyzed in this study, there appears to be little reason to be concerned over the pollution of surface water by agricultural practices and chemical fertilizers. The concentration of nutrients in the surface runoff from the small watersheds studied was certainly within acceptable limits and should cause none or very little surface water pollution.

II. CONCLUSIONS

The following conclusions were drawn from the results of this study:

1. The concentration of nutrients in runoff from the watersheds at the Middle Tennessee Experiment Station and at the Milan Field Station were not high enough to warrant any concern about pollution of surface water from the runoff.
2. Due to the inherent difficulties of an unbalanced nested design, statistical analyses of the data were difficult. The experimental design should have been given more consideration prior to the initiation of the experiment in order to determine if more precise information could have been obtained with a different design.
3. Month and rainfall event definitely affect the concentration of nutrients in runoff.
4. The background or normal concentration of nutrients in water must be known in order to make data interpretation significant.
5. The soils of a specific watershed vary in their properties and these properties must be known in order to interpret data.
6. An inverse relationship exists between dissolved solids and nutrients and the runoff rate as is shown by the negative regression values.

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