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Water quality as related to the concentrations of nitrate-N, chloride, orthophosphate-P, and dissolved solids in runoff from agricultural watersheds

Jimmy C. Castellaw

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To the Graduate Council:

I am submitting herewith a thesis written by Jimmy C. Castellaw entitled "Water quality as related to the concentrations of nitrate-N, chloride, orthophosphate-P, and dissolved solids in runoff from agricultural watersheds." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Plant, Soil and Environmental Sciences.

Gary M. Lessman, Major Professor

We have read this thesis and recommend its acceptance:

Russell Lewis, Vernon Reich

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

To the Graduate Council:

I am submitting herewith a thesis written by Jimmy C. Castellaw entitled "Water Quality as Related to the Concentrations of Nitrate-N, Chloride, Orthophosphate-P, and Dissolved Solids in Runoff from 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.

Gary M. Lessman

Gary M. Lessman, Major Professor

We have read this thesis and recommend its acceptance:

Vernon H Reich

Russell J. Lewis

Accepted for the Council:

L Evans Roth

Vice Chancellor
Graduate Studies and Research

WATER QUALITY AS RELATED TO THE CONCENTRATIONS OF NITRATE-N, CHLORIDE, ORTHOPHOSPHATE-P, AND DISSOLVED SOLIDS IN RUNOFF FROM AGRICULTURAL WATERSHEDS

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Jimmy C. Castellaw
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ABSTRACT

Experiments were conducted from the Fall of 1974 until the Spring of 1977 on the Middle Tennessee Experiment Station at Spring Hill and on the Milan Field Station in West Tennessee to determine the quality of runoff and nutrient losses from agricultural watersheds. A total of 713 water samples were analyzed for NO_3-N, chloride, ortho-P and dissolved solids. The two watersheds at Spring Hill were treated annually with applications of liquid dairy manure. One watershed at Milan received single application of municipal sewage sludge and was planted to corn. The other watershed at Milan underwent extensive land grading to reduce runoff losses.

Only the ortho-P levels at MTES 1 and MFS 2 were significantly different from each other for the four constituents analyzed. This was probably due to the phosphatic parent material of the soils at Spring Hill and the relatively low P fertility of the soils on MFS 2.

In most cases, the nutrient levels in the runoff were not significantly higher after the various treatments were implemented. This indicates future applications of the same and possibly higher rates of waste loading might be used on certain soils. The inorganic fertilizers applied at MFS 2 apparently did not affect the water quality.

An attempt was made to formulate an equation to predict nutrient concentrations in runoff from runoff rate and volume. Though significant positive correlations appeared for runoff rate with nutrient concentrations for a given watershed, similar patterns are not found for other watersheds.

Individual and combined regression equations proved of little benefit as predicted concentrations often fell below 0.0 ppm.

TABLE OF CONTENTS

CHAPTER PAGE

LIST OF TABLES

TABLE PAGE

CHAPTER I

REVIEW OF LITERATURE

The necessity of augmenting food production brought on by an ever expanding population has increased the amount of inputs needed to keep pace with this demand. The United States Department of Agriculture estimated that increased fertilizer use has accounted for over 50 percent of the increase in crop production per hectare since 1940 (24).

This paper is a report of an investigation of the effects of increasing fertilizer use and organic waste utilization on cropland, with emphasis being placed on prevention of nutrient loss from farmland.

Nitrogen (N) usage has increased from one third million metric tons in 1940 to 9.27 million metric tons in 1971 (35). Over the past ten years, N usage has increased at an average rate of almost 500,000 metric tons per year (9).

From 1968 to 1976, phosphorus (P) production increased from 1.8 to 2.07 million metric tons (35). Not all of the P manufactured was used in the production of fertilizer material. In 1965, nonfarm utilization resulted in 23 percent of the P being consumed in detergent production.

Confined animal production caused large concentrations of wastes to accumulate in small areas. Land application has been considered to be the least expensive method of disposal if enough area adjacent to the production site was available (20).

There are several benefits that can be obtained by the use of organic wastes on farmland (32). By growing crops, most nutrients contained by organic wastes can be utilized. Otherwise these nutrients would be lost from beneficial production if allowed to escape to surface waters. The organic matter from these wastes tends to increase the soil's water holding capacity, cation exchange capacity, and improves the tilth. Also the soil acts as a nutrient sink preventing or reducing the pollution load on surface waters (29).

The agricultural trend to use these technologies has increased the potential for water pollution both in the surface and in the ground water (22). Total P emissions from nonpoint sources has been estimated to be 0.73 million metric tons per year or about 25 percent of the P made available in the form of fertilizer and livestock wastes. Perhaps one million metric tons, of a total of five to six million metric tons of N lost to surface and ground water, have been attributable to the use of fertilizers. Sediment has been considered to be one of the largest pollutants in our waters not only because of the solid matter effects and the filling of lakes and reservoirs but because for every metric ton of sediment that has reached surface water one kg of N and 0.8 kg of P were carried along (36).

Nutrient losses have also occurred as a result of runoff, infiltration, percolation, and wind (22). Enhanced plant nutrient levels resulted in oxygen depletion in the deeper parts of our lakes and increased vegetation in the more shallow areas. Although N in our surface waters increased over the past years, the percentage of P increase has been much greater. Natural waters contained an estimated P level of seven parts per billion as did western Lake Erie in 1942. The N/P ratio at that time was 35:1 which kept P as a limiting factor in the growth of aquatic organisms. However, in 1966 P increased 480 percent while the N increased only 30 percent decreasing the ratio to 9:1. In 1970 Verduin (34) reported that all major streams of the United States have at one time exhibited P levels five to thirty times higher than the natural level of seven parts per billion.

I. SLUDGES

Application of sewage sludge to farmland has been practiced in Europe for many years. Berlin and Paris sewage farms experienced a reduction in yields due to an accumulation of Cu and Zn. The concentration of heavy metals appeared to be the main drawback to utilization of sewage sludges on farmlands (26).

The buildup of these heavy metals, Cu, Zn, Ni, and Cd, can reduce crop yields. Chaney (4) suggested sludge application rates be adjusted along lines of heavy metal concentrations in the sludge and concentrations already present in the soil. When Cu and Ni are present in sludges, they should be considered two and four times as toxic to plants as Zn respectively. Copper and Ni values can then be expressed in terms of "Zn equivalent." In general, he found heavy metal additions should not exceed "Zn equivalent" levels equal to 5 percent of the cation exchange capacity of the soil at $pH \geq 6.5$. Chaney also recommended that sludges containing a Cd concentration greater than 1 percent of the Zn concentration should not be applied to land (4).

Researchers have found that an analysis of sludges should be made before application to prevent the overloading of soils with these heavy metals. A study of thirty-five Wisconsin municipality sludges reported heavy metal concentrations and ranges of Zn, 490-12,200 mg/kg; Cu, 140-10,000 mg/kg; and Ni, 14-1,700 mg/kg. Soils amended with sludges should be maintained at a $pH \geq 6.5$ for retention or slow release of the heavy metals. At $pH < 6.5$ the heavy metals could become more available to plants and possibly enter the edible portions of them (13).

Sludges usually contain anywhere from 45 to 60 percent organic matter. With the amount of heavy metals present in sludges, the organic matter could possibly be important, acting as a chelating agent to prevent the release of metals to the soil solution. Chaney found that as organic matter levels decreased, the protective effects also disappeared (4). Therefore, additional applications of organic matter on sludge amended soils may be necessary to maintain the chelating effect.

King and Morris found that applications of sludge may cause deficiencies of Ca, K, and Mg. Leaching of Ca and Mg with the NO_3-ion resulted in a lowering of the pH on sludge amended soils. Sludges supply little K and also decrease the availability of exchangeable K in the soil. Therefore, they recommended applications of dolomitic limestone and supplemental K fertilizers to maintain the productivity of areas receiving regular sludge applications (15).

Pathogenic organisms are also present in sewage sludge and caution should be used if wastes containing pathogens are used. Law (19) recommended that raw, untreated sludge should not be applied to any cropland.

However, after lime treatments, sewage sludge was recommended as a soil conditioner and fertilizer on crops to be consumed only by livestock. With the treatments of lime and of chlorine gas, sewage sludge could be used on crops grown for human consumption.

II. MANURES

Generally, animal manures do not contain the concentration of metals that industrial and municipal sewage contain. Animal manures were usually found to contain from 1.5 to 3.9 percent total N and 0.4 to 1.6 percent total P (37). Soil loading rates for manures are usually based on the N requirement of the crop to be grown; the N in the manure applied being equal to total N uptake by the crop (13). The N recommendation could be as much as 150 percent of the N requirement of the crop due to N loss through volatization and denitrification and other biochemical processes (3). Supplemental additions of P fertilizers may be needed due to the low percentages of P found in the manure (33).

From the standpoint of decreased nutrient movement, Klausner, et al., (17) found the optimum time to apply manure is in the late spring after the stream flow has decreased and evapotranspiration begins to increase. This usually coincides with the beginning of the growing season and at that time the vegetation would be utilizing the nutrients rather than N and P being lost to runoff or leaching through the soil. Because of time, labor, storage, and land limitations, many producers found it difficult to apply manure prior to and during the growing season. Therefore, fall and winter applications were practiced.

Fall applications of manure were used in Minnesota as a mulch on plowed ground. Reduced runoff and conservation of badly needed soil moisture were obtained and this was done without necessarily adding to the pollution of surface waters (39).

In New York, manure was applied in the winters of 1972-74 (17). Four of the plots received 35 metric tons/ha, two received 100 metric tons/ha, and two received 200 metric tons/ha. Although very few differences in nutrient loss were recorded between the treatments, several kg more nutrients were lost in 1972 than the other two years. The applications made in 1972 were during a snow melt and runoff was very high at that time. Nitrogen losses for 1972-74 were 16.0, 1.0, and 0.2 kg/ha and the P losses were 3.5, 0.7, and 0.01 kg/ha respectively.

Manure was applied fall, winter, and spring to six alfalfa plots in Wisconsin (5). Duplicate plots received manure at a rate of 2.25 kg per square meter (wet basis). Four other plots received no manure and served as a check. The investigators found at this rate of application manure could have been applied during any season on the alfalfa.

Another Wisconsin study concerned with time of application used 33.6 metric tons/ha of manure (wet basis). The winter treated plots lost 15.25 kg/ha of N and 3.39 kg/ha of P. Losses from the spring treated plots and the check plots were similar but were only a fourth of what was lost from the winter treated plots (10).

Watersheds around Fennimore, Wisconsin, received 24.75 kg/ha of N and 5.40 kg/ha of P in the form of manure and commercial fertilizers.

Of the 4.45 cm of runoff from the watershed, 75 percent was accounted for by rain that fell on frozen ground. Losses of N from January to September amounted to 4.05 kg/ha. Phosphorus losses were 1.28 kg/ha for that same time period. The winter rains played an important role in total nutrient loss from this watershed (38).

In Alabama, a three year study was conducted on spring application of manure. Rye and pearl millet were grown on land that received 45 metric tons of manure/ha/year (dry weight). The manure was incorporated to a depth of fifteen centimeters. Nitrate-N levels in the runoff were not affected by the manure applications and the concentration was less than five ppm for the entire three years of the study (21).

III. INORGANIC FERTILIZERS

As was stated previously, the use of inorganic fertilizers has played a major role in agricultural production through the years. The proportion of the fertilizer elements utilized by the crops versus the quantity lost to surface and ground water has concerned many. Attempts to analyze this problem were made to determine the exact role agriculture has played in the degradation of our lakes and streams.

In New York, a rural watershed of 330 square kilometers was studied to determine P sources in the stream flow. Point sources accounted for 35 percent and natural geochemical processes accounted for 45 percent of the P concentration in the stream draining the watershed. Nonpoint sources associated with farming yielded only 20 percent of the P lost from the watershed, which was less than 1 percent of the P applied as chemical fertilizers and manures (12).

In Kentucky, Thomas and Crutchfield found that of the eight watersheds they studied, the highest NO_3-N discharge occurred from a bluegrass pasture that received little N fertilizer (31). They also corroborated other findings that P content of the streams draining the watersheds was related to the geological formations through which the streams ran.

In North Carolina researchers fertilized grassed watersheds to determine nutrient losses. One watershed containing 1.89 ha received 112 kg/ha of N and 48 kg/ha of P while the other watersheds received four times as much N and P on 1.48 ha. The 1.89 ha watersheds lost 3.28 kg/ha of N and 0.15 kg/ha of P. The other watershed that received the larger application of nutrients lost 12.08 kg/ha of N and 0.27 kg/ha of P. The researchers concluded that these grassed watersheds were not an important source of nutrients to surface waters (14).

In Louisiana, researchers incorporated two different fertilizer blends into a Loring silt loam. Nitrogen rates of 112 kg/ha and P rates of 49 kg/ha were achieved using a fertilizer with an NH_4-NO_3 base and one with an NH_4-N base. Less N was lost from the fertilizer with the NH_4-N base due to the absorption of the NH_4^+ion by soil particles. The NO_3^-ion was more mobile and therefore more N was lost from the blend containing the NH_4-NO_3. In either case, the amount of all elemental fertilizer lost was less than 1 percent of the total applied (6).

Duplicate four hectare watersheds were used in a five year study to determine NO_3-N loss from Blackland Prairie soils of Texas (16). Nitrogen was applied at a rate of 67 kg/ha on each plot. The average concentration of NO_3-N in the runoff was 2.9 and 2.3 ppm. This amounted to an average total loss of 3.2 kg of N/ha/year.

In Georgia, a Cowarts loamy sand was fertilized with 896 kg/ha of 4-12-12 and cropped to continuous corn. Thirty days after planting, the corn was sidedressed with 168 kg of N/ha. In the three years this experiment was conducted, NO_3-N concentrations in the runoff averaged less than one ppm (11).

IV. NATURAL SOURCES

Five southern pine watersheds in Mississippi were studied to determine the importance of rain as a nutrient source. In 1973, the watersheds received 189 cm which was 40 percent above the average annual precipitation. The rain contributed 3.12 kg/ha of NO_3-N but only 0.32 kg/ha was reported in the runoff from the watershed. The same pattern held true for the ortho-P which had a runoff rate of 0.04 kg/ha after receiving 0.07 kg/ha from the rain (27).

A Minnesota study concluded that more NO_3-N remained on the area of rainfall reception than was present in the runoff. In this experiment, more ortho-P ran off the watershed than was received in the rainfall. The extra ortho-P lost was associated with losses of sediment and plant material in the water flow (2).

V. SUMMARY

High rates of runoff have increased the loss of nutrients from the soil surface (23). Therefore, the most practical first step in eliminating

N and P as pollutants in surface runoff has been to control erosion. When P is applied to the soil, it reacts chemically with Fe, Al, and Ca and is immobilized as insoluble forms (30). A large part of the total N and P lost has been associated with losses of sediment (28). Nitrogen losses are usually highest at the beginning of the cropping season and decrease progressively throughout the year, reflecting a seasonal effect believed to be associated with nutrient removal by the crop, leaching, and N tie-up in organic matter. Except for limited areas of irrigation, precipitation has been the main source of water for croplands. This in itself is a source of nutrients and pollutants.

It is apparent that nutrient losses into streams and lakes has been going on for ages. It is up to the farmer and those associated with farming to do their part in preventing agriculture from lowering the quality of our environment. Judiciously used, sludges, manures, and inorganic fertilizers can provide a means of producing food without jeopardizing the productivity of our soil and purity of our waters.

CHAPTER II

PROCEDURES

This thesis is a report of a project initiated in 1973 by the Plant and Soil Science and the Agricultural Engineering Departments. Our departmental responsibility was the determination of NO_3-N, ortho-P, chlorides, and dissolved solids. The data were collected from 4.9 hectare and 80.7 hectare watersheds at the Middle Tennessee Experiment Station near Spring Hill (Table 1) and 3.7 hectare and 14.5 hectare watersheds at the Milan Field Station in West Tennessee (Table 2).

The smaller watershed at Spring Hill (MTES 1) is a subwatershed of the other (MTES 2). The soils on these two watersheds are either of residuum or alluvium from phosphatic limestone parent material (Table 3).

At Milan, the soils were derived from windblown loess. The smaller watershed (MFS 1) received semiweekly applications of municipal sewage sludge with primary sedimentation treatment between January 2 and April 15, 1976. These applications resulted in an average of 20.8 t/ha (dry wt.) of sludge being deposited on this area. The sludge was spread in strips which extended across the width of the watershed. Those strips were disk harrowed and plowed immediately after each application.

The larger watershed (MFS 2) was reported in the tables as 14.5 ha. From July to August, 1975, 90 percent of the watershed was land graded. The average depth of cut was 15 cm and maximum depth of cut was approximately 91 cm. A vegetated waterway was constructed to divert water from

TABLE 1

FIELD TREATMENT SCHEDULE AT MIDDLE TENNESSEE EXPERIMENT STATION

	MTES 1	
1974	100% orchard grass pasture (1.7 beef cattle/ha)	112 kg/ha K
1975	100% orchard grass pasture (1.7 beef cattle/ha)	112 kg/ha K 40 kg/ha N (applied as urea)
1976	100% orchard grass pasture (1.7 beef cattle/ha)	40,200 l/ha liquid dairy manure (applied in March)
	MTES 2	
1974	60% pasture (1.4 beef cattle/ha) 20% wheat 10% hay 10% corn	55 kg/ha N on 8% of area (applied as NH_4-NO_3) 112 kg/ha K on 30% of area
1975	60% pasture (1.4 beef cattle/ha) 30% wheat 5% hay 5% corn	40 kg/ha N on 65% of area (applied as urea) 112 kg/ha K on 30% of area
1976	60% pasture (1.4 beef cattle/ha) 30% wheat 5% hay 5% corn	76 kg/ha N on 5% of area (applied as urea) 112 kg/ha K on 8% of area 40,200 l/ha liquid manure on 6% of area

TABLE 2

FIELD TREATMENT SCHEDULE AT MILAN FIELD STATION

		MFS 1
1974	soybeans followed by wheat	20 kg/ha P 34 kg/ha K
1975	soybeans followed by wheat	67 kg/ha N in February applied as urea
1976	corn	20.8 t/ha (dry wt.) municipal sewage sludge 4.5 t/ha lime in February 16.8 kg/ha P in March 67.2 kg/ha K in March
		MFS 2
1974	90% cotton followed by wheat 10% corn	336 kg/ha 10-9-17 NPK in March 4.5 t/ha lime in April 55 kg/ha N in May
1975	90% wheat	67 kg/ha N in February 336 kg/ha 9-17-17 NPK in September
1976	wheat	63 kg/ha N in February

TABLE 3

SERIES, FAMILY AND PARENT MATERIAL OF SOILS ON RESEARCH WATERSHEDS

Series	Soil Family	Parent Material
	MIDDLE TENNESSEE EXPERIMENT STATION	
ARMOUR	Fine-silty, Mixed, Thermic Typic Hapludalfs	Residuum from phosphatic limestone
MAURY	Fine, Mixed, Mesic Typic Paleudults	Residuum from phosphatic limestone
HUNTINGTON	Fine-silty, Mixed, Mesic Fluventic Hapludolls	Alluvium from phosphatic limestone
LINDSIDE	Fine-silty, Mixed, Mesic Fluvaquentic Eutrochrepts	Alluvium from phosphatic limestone
	MILAN FIELD STATION	
MEMPHIS	Fine-silty, Mixed, Thermic Typic Hapludalfs	Loess
LORING	Fine-silty, Mixed, Thermic Typic Fragiudalf	Loess
CALLOWAY	Fine-silty, Mixed, Thermic Glossaquic Fragiudalfs	Loess
HENRY	Coarse-silty, Mixed, Thermic Typic Fragiaqualfs	Loess
COLLINS	Coarse-silty, Mixed, Acid, Thermic Aquic Udifluvents	Recent alluvium from loess

the upper 20 percent of the area away from the watershed resulting in MFS 2 being reduced to 11.3 ha.

At each of the sites, a Stevens A-35 continuous water level recorder was used to measure flow rates. Also at each site was a Product Manufacturing Company Model PS-69 pumping sampler. The PS-69 samplers were activated when the depth of flow reached 6.1 centimeters in the channel. At that time, a sample would be taken and marked on the Stevens A-35 record chart to determine rate of flow during the sample period. This procedure was repeated every thirty minutes as long as the minimum flow rate was exceeded. The samples were removed after each rainfall event and placed in frozen storage for later transportation to Knoxville. Klingaman and Nelson (18) found the best overall technique for preservation of unfiltered water samples appears to be storage at subzero temperature F°.

I. LABORATORY ANALYSES

Orthophosphate-P concentrations were determined by the automated stannous chloride procedure (7). Ammonium molybdate reacts with the ortho-P in an acid medium to form a heteropoly acid. This acid is reduced by the stannous chloride to form the molybdenum blue color complex, which is directly proportional to the amount of phosphorus present.

Nitrate-N concentrations were determined by the automated cadmium reduction method (8). In this procedure, nitrates are reduced to nitrites by the use of a copper-cadmium catalyst. The nitrites then react with sulfanilamide to form a diazo compound which in turn is coupled with N-1 naphthyl-ethylenediamine hydrochloride to form the azo dye. The azo dye intensity is proportional to the nitrite concentration.

The automated chloride procedure was used for the determination of the Cl ion (8). The thiocynate ion is liberated from mercuric thiocyanate through sequestration of mercury by the chloride ion to form anionized mercuric chloride. In the presence of ferric ion, the liberated thiocyanate ions form highly colored ferric thiocyanate in proportion to the original chloride concentration.

Dissolved solids were determined by the total filterable residue procedure (8). In this method, a Gelman type A filter is used to remove suspended matter from the sample. Aliquots were dried in a forced-air oven and the residue was weighed.

Samples from MFS 1, sludge, soil, and corn ear leaf were analyzed for N using the total Kjeldahl-N procedure while Al, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, and Zn were determined by an emission spectrograph. Soil pH was measured by a pH meter using a glass electrode with a 1:1 soil: water ratio. The sludge was also analyzed for P, K, Ca, Cl, Mg, and Na using an emission spectrograph.

II. STATISTICAL ANALYSES

All statistical analyses were performed on the IBM 360/65. Statistical Analysis System (SAS) developed by Barr, et al. (1) was used for the analyses of variance, Pearson's correlation, mean separation, coefficients of determination for the regression models, and the regression equations. Statistical Package for the Social Sciences (SPSS) developed by Nie, et al. (25) was used for frequency distribution.

The analyses of variance were for unbalanced nested designs with samples nested within days within years within watersheds. Analyses were performed for NO_3-N, Cl, ortho-P, dissolved solids, runoff and volume.

Using the expected mean squares, "F" tests were calculated to determine any significance of the classification variables. Pearson's correlation coefficients were obtained for all variables. The best model for the regression equations was derived by the coefficients of determination. The best model was then used in the General Linear Model to determine significance of the slope of the line and the intercept. Because of unequal subcell frequencies, mean separations were accomplished by Kramer's modification of Duncan's New Multiple Range test.

Frequency tables and cumulative polygons were produced by SPSS. Also obtained in this program were the median and mode for each variable. The frequency tables produced absolute frequencies, adjusted frequencies, and cumulative frequencies.

CHAPTER III

RESULTS AND DISCUSSION

Water samples were collected from the Fall of 1974 until the Spring of 1977. The number of samples, maximum, minimum, mean, median, and mode for each constituent appear on Tables 4-7. Only the samples from MTES 1 and MTES 2 were recorded in 1977. No samples were recorded at MTES 1 and Milan in 1975. The data obtained in 1974 came from MFS 2. The other data shown include whole years. There may be no differences in average yearly concentration among years for a particular watershed but differences will appear in the quantity of a nutrient lost. This is probably due to the unequal number of sampling months as previously stated or due to differences in the quantity of runoff observed among years.

The highest mean and maximum concentration of NO_3-N occurred at MTES 2 (Table 4). This could have been caused by the application of N in various forms (Table 1, p. 12). However, MTES 1, which is a subwatershed of MTES 2, had the lowest mean NO_3-N concentration. Part of the area at MTES 2 was under cultivation while MTES 1 was in continuous pasture. Several samples (24 percent at MTES 1, 3 percent at MFS 1, and 28 percent at MFS 2) had concentrations below 0.01 ppm NO_3-N, the smallest detectable level possible with this analytical method (Figure 1). All of the samples at MTES 1, and more than 90 percent of the samples collected at the rest of the watersheds fell below the 1.0 ppm level.

TABLE 4

MAXIMUM, MINIMUM, MEAN, MEDIAN, AND MODE VALUES FOR NITRATE-N IN RUNOFF

Watershed	Number of Samples	Maximum	Minimum	Mean	Median	Mode
		ppm				
MTES 1	21	0.11	0.00	0.08 a[+]	0.04	0.00
MTES 2	188	8.60	0.08	0.78 a	0.52	0.68
MFS 1	142	1.40	0.00	0.41 a	0.28	0.20
MFS 2	362	5.80	0.00	0.34 a	0.09	0.00
Combined	713	8.60	0.00	0.46	0.20	0.00

[+] Means followed by a common letter are not significantly different at the .05 level of probability.

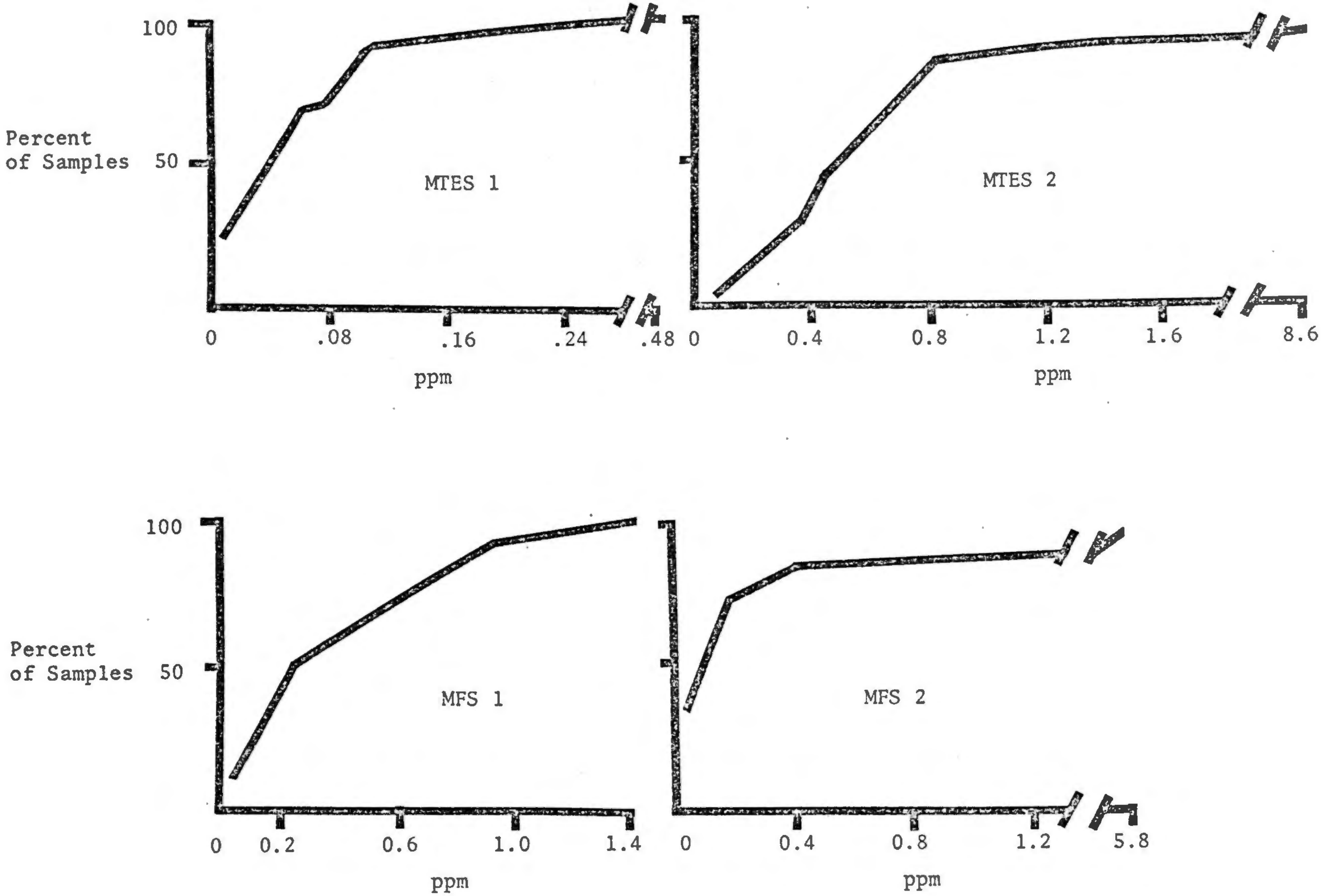

Figure 1. Cumulative frequency polygons of nitrate-N levels at four locations.

The maximum and the highest mean concentration for Cl occurred at MFS 1 (Table 5). This area received a 20.8 t/ha sludge application and 110 kg/ha of KCl for corn production which could have added to the concentration of Cl samples. The modal concentration for all watersheds except MTES 1 was 1.0 ppm. The overall average of Cl for the watersheds was 3.3 ppm. The Cl levels were higher at MTES 2 than at MTES 1 and only 45 percent of the samples at MTES 2 fell below the overall average as compared with 76 percent that fell below at MTES 1 (Figure 2). The highest Cl levels were recorded at MFS 1, but 73 percent of the samples were below the overall average. Eighty-seven percent of the MFS 2 samples were below 3.3 ppm.

The watershed MTES 1 had a mean, median, and mode ortho-P concentration of 2.2 ppm (Table 6). This mean was significantly higher than the mean of 0.12 ppm on MFS 2. Probably the phosphatic nature of the soils at Spring Hill contributed to the P levels in the runoff as the watersheds there had not received any P fertilization in recent history, yet the mean concentrations of ortho-P are higher than at Milan watersheds which received P amendments. Only 42 percent of the samples at MTES 1 were below 1.0 ppm while over 90 percent of the samples at Milan were below this level (Figure 3).

Dissolved solids are a measure of the salts in solution and should reflect changes according to variations in nutrient content of the sample. Since MFS 2 had the lowest Cl and ortho-P levels and many of the NO_3-N sample concentrations were below the lowest standard, it should follow that the dissolved solid levels would be the lowest of the four watersheds.

TABLE 5

MAXIMUM, MINIMUM, MEAN, MEDIAN, AND MODE VALUES FOR CHLORIDE IN RUNOFF

Watershed	Number of Samples	Maximum	Minimum	Mean	Median	Mode
		ppm				
MTES 1	21	11.0	0.5	3.6 a[+]	2.85	3.0
MTES 2	188	30.0	1.0	4.8 a	3.54	1.0
MFS 1	142	32.0	0.5	5.2 a	1.05	1.0
MFS 2	362	18.0	0.1	1.8 a	0.96	1.0
Combined	713	32.0	0.1	3.3	1.05	1.0

[+] Means followed by a common letter are not significantly different at the .05 level of probability.

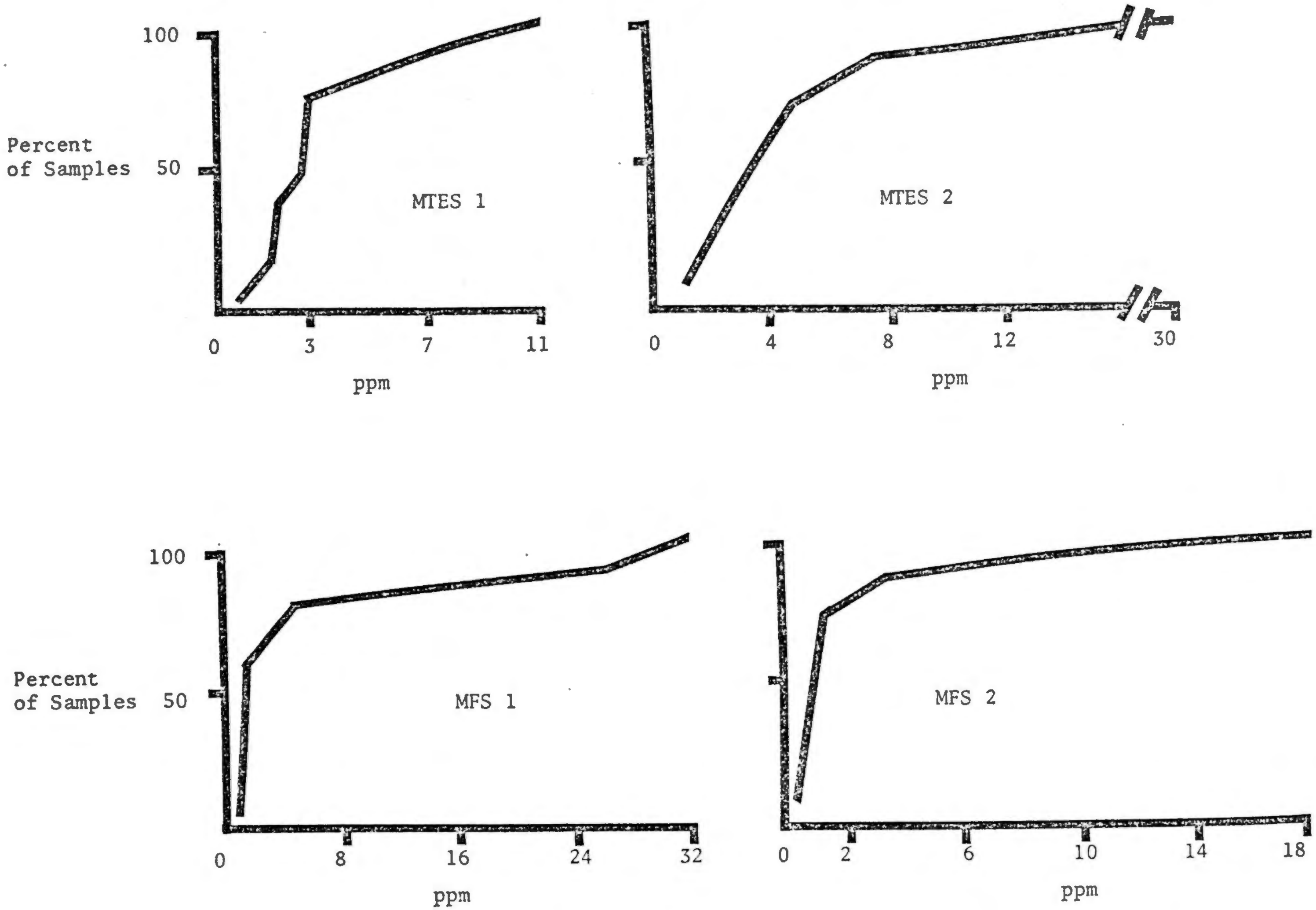

Figure 2. Cumulative frequency polygons of chloride levels at four locations.

TABLE 6

MAXIMUM, MINIMUM, MEAN, MEDIAN, AND MODE VALUES FOR ORTHOPHOSPHATE-P IN RUNOFF

Watershed	Number of Samples	Maximum	Minimum	Mean	Median	Mode
		ppm				
MTES 1	21	4.60	0.20	2.20 a[+]	2.20	2.20
MTES 2	188	4.40	0.01	0.46 ab	0.28	0.05
MFS 1	142	1.80	0.01	0.28 ab	0.08	0.03
MFS 2	362	3.00	0.00	0.12 b	0.30	0.10
Combined	713	4.60	0.00	0.30	0.06	0.01

[+] Means followed by a common letter are not significantly different at the .05 level of probability.

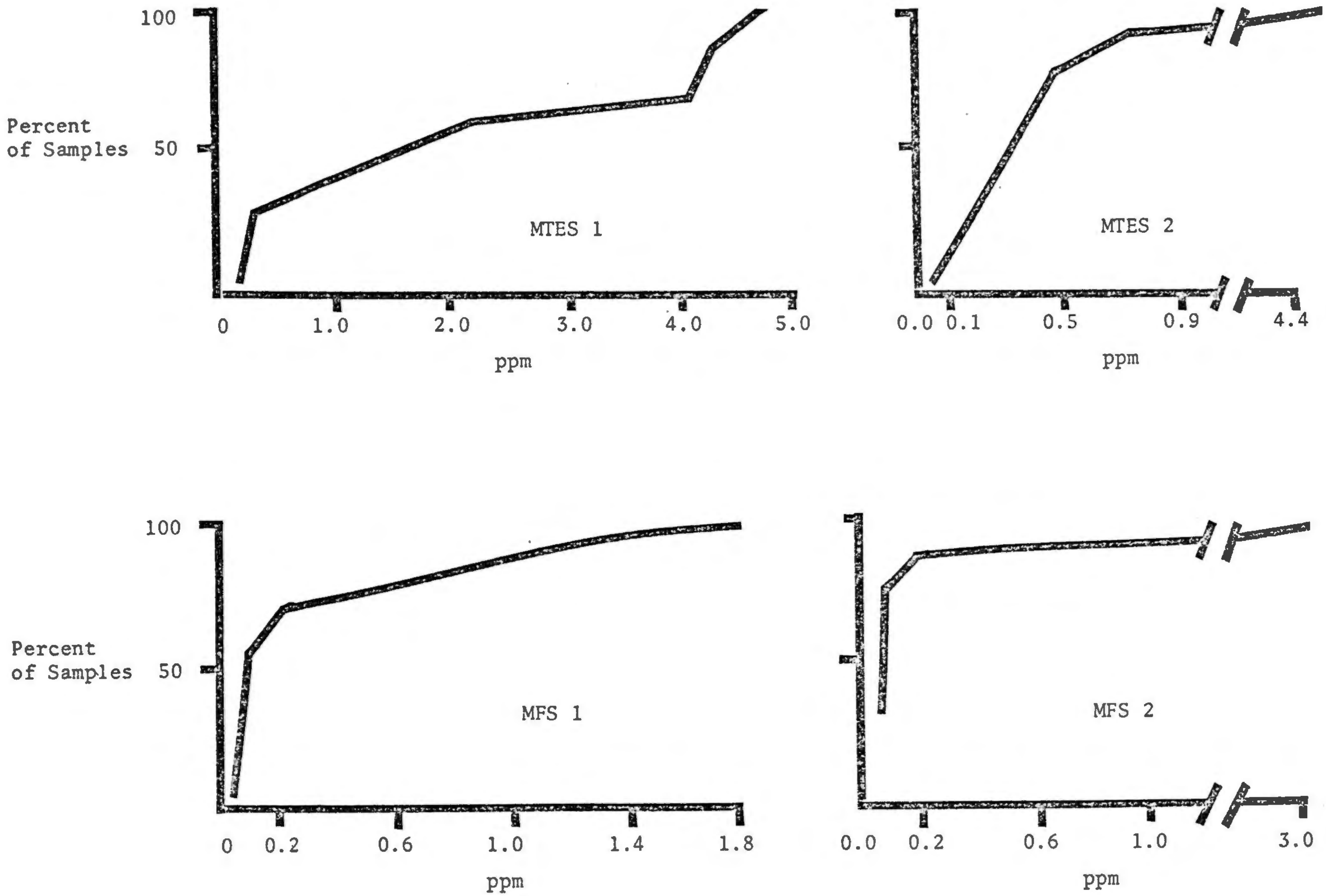

Figure 3. Cumulative frequency polygons of ortho-P levels at four locations.

This can be seen in Table 7. The overall average for dissolved solids was 73.6 ppm. Only 19 percent of the samples at MTES 1 fell below this level (Figure 4). The means were very similar to those at MTES 2. Also, MFS 1 had only 35 percent of its samples below 73.6 ppm. One explanation for this low average value was that MFS 2 had the largest number of samples of the four watersheds and many of the values were rather small resulting in a low combined average.

Yearly averages may give a better view of the impact that various cultural practices have on concentrations of nutrients in the runoff. Nitrate-N levels at MTES 1 remained virtually the same each year even though the area received 40,200 l/ha of liquid dairy manure in 1976 (Table 8).

Twice as much NO_3-N was lost in 1976 as in 1977 (Table 9) even though the average concentration was approximately the same. Approximately the same rate of manure was applied on MTES 2 in 1976 as on MTES 1. The yearly averages indicated a rise in NO_3-N levels for that year (Table 8). Samples collected in 1977 exhibit the same levels found in samples collected in 1975 indicating the influence of the manure application was diminishing. The quantity of NO_3-N/ha lost was no greater in 1976 (99.3 g/ha) than in 1975 (111.7 g/ha).

During the first three months of 1976 at MFS 1, 1975 kg/ha of N was applied in the form of municipal sewage sludge. The mean NO_3-N concentration for 1976 (0.37 ppm) was about the same as the previous year (0.60 ppm) before the sludge applications (Table 8). The area was planted to corn, a large consumer of N, in 1976. Since no real

TABLE 7

MAXIMUM, MINIMUM, MEAN, MEDIAN, AND MODE VALUES FOR DISSOLVED SOLIDS IN RUNOFF

Watershed	Number of Samples	Maximum	Minimum	Mean	Median	Mode
		ppm				
MTES 1	21	144.0	64.0	95.0 a[+]	88.0	64.0
MTES 2	188	232.0	28.0	93.7 a	93.0	104.0
MFS 1	142	193.0	32.0	94.2 a	92.5	60.0
MFS 2	362	168.0	8.0	53.9 a	49.5	36.0
Combined	713	232.0	8.0	73.6	67.4	44.0

[+] Means followed by the same letter are not significantly different at the .05 level of probability.

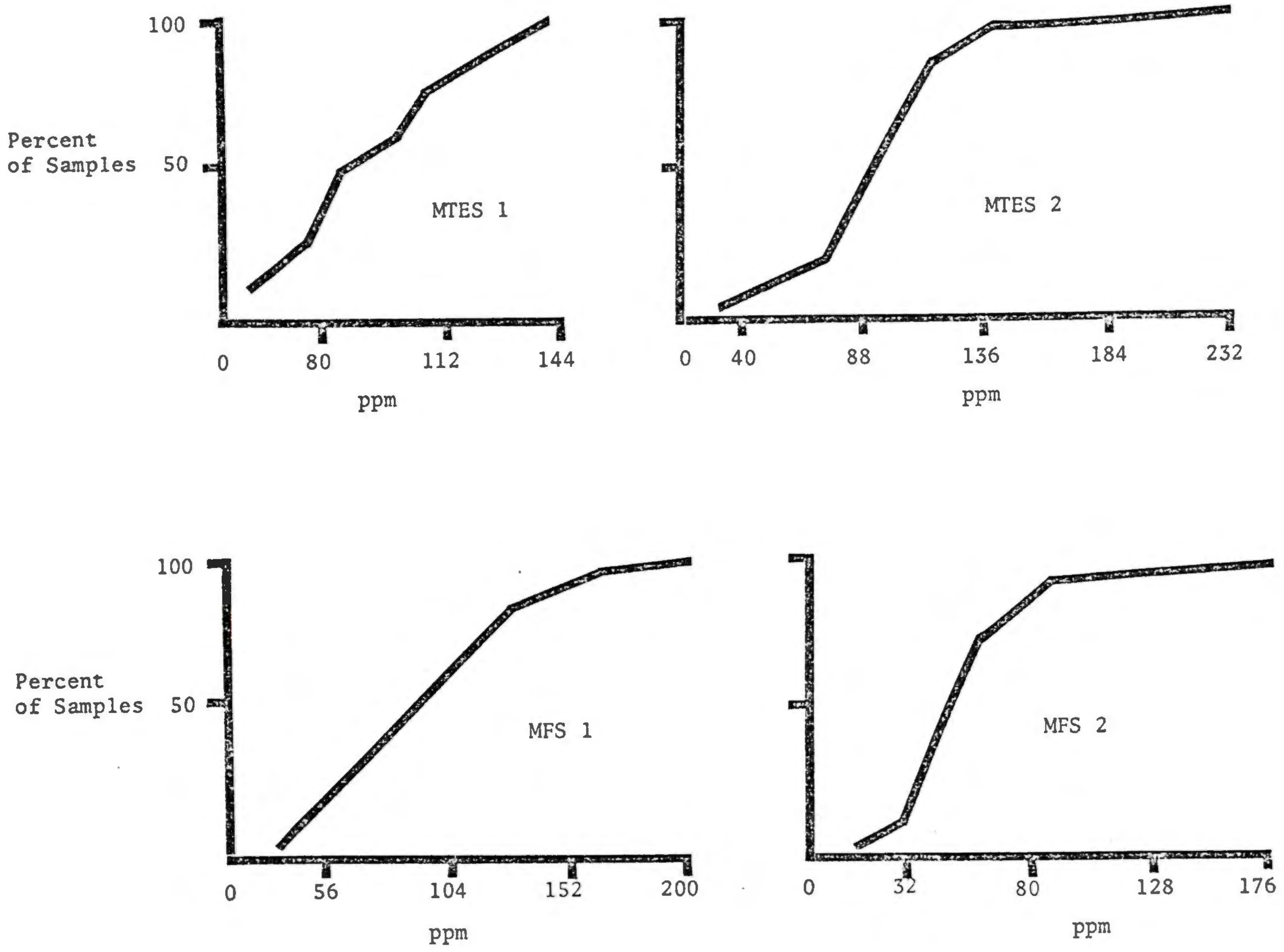

Figure 4. Cumulative frequency polygons of dissolved solids levels at four locations.

TABLE 8

YEARLY MEAN CONCENTRATIONS OF NITRATE-N ON EACH WATERSHED

	MTES 1	MTES 2	MFS 1	MFS 2
	------------------ppm------------------			
1974	------*	------	------	0.20 a
1975	------	0.51 a	0.60 a	0.50 a
1976	0.08 a[+]	1.22 a	0.37 a	0.11 a
1977	0.07 a	0.51 a	------	------

*Blanks indicate no samples were taken that year at that watershed.

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

TABLE 9

NITRATE-N LOSSES FOR EACH WATERSHED

	MTES 1	MTES 2	MFS 1	MFS 2
	------------------g /ha------------------			
1974	------*	------	------	16
1975	------	112	294	2,856
1976	7	99	374	285
1977	4	16	------	------

*Blanks indicate no samples were taken at that watershed that year.

differences occurred between the years, the corn probably utilized much of the NO_3-N that was released from the organic matter.

The mean concentration for NO_3-N was the highest at MFS 2 in 1975 (Table 8). The area had received regular applications of N fertilizers including 1975. That year an extensive land grading operation performed in the summer effectively decreased the size of the watershed by 20 percent. The quantity of NO_3-N/ha lost was also highest in 1975. The amount listed for 1974 is a partial year and the latter part of 1976 was extremely droughty (Table 9).

The mean Cl concentration (Table 10) was highest in 1976 for each watershed except for MFS 2 which was influenced by the partial year in 1974. The Cl concentrations at Spring Hill were probably influenced by the liquid dairy manure applications and the droppings from the beef cattle grazing in the area. The concentrations at MFS 1 may have reflected the sludge applications in 1976. Analysis revealed that the sludge contained 40.2 kg/ha of Cl. The highest mean concentration for Cl at MFS 2 occurred in 1974 and was significantly higher than the concentrations in the other two years. The land grading that took place in 1975 may have lowered the Cl concentrations for that year. The area was fertilized with NPK in the fall of 1975 which may be the reason for the increased Cl levels of 1976 over 1975 since Cl is associated with K in the fertilizer.

The quantity of Cl/ha lost in 1976 was from 13 to 17 times greater at Milan than at Spring Hill (Table 11).

TABLE 10

YEARLY MEAN CONCENTRATION OF CHLORIDE FOR EACH WATERSHED

	MTES 1	MTES 2	MFS 1	MFS 2
	ppm			
1974	------*	------	------	6.4 a
1975	------	4.8 a	3.0 a	0.8 b
1976	4.3 a[+]	5.3 a	5.7 a	2.2 b
1977	1.8 a	2.7 a	------	------

*Blanks indicate no samples were taken at that watershed that year.

[+] Means within a column followed by a common letter are not significantly different at the .05 levels of probability.

TABLE 11

CHLORIDE LOSSES FOR EACH WATERSHED

	MTES 1	MTES 2	MFS 1	MFS 2
	g/ha			
1974	------*	------	------	995
1975	------	1,123	967	3,966
1976	320	419	5,554	5,502
1977	89	81	------	------

*Blanks indicate no samples were taken at that watershed that year.

The mean concentration of ortho-P at MTES 1 was higher in 1976 than in 1977 (Table 12). Limited sampling time in 1977 may have clouded the true picture in this case. However, the concentrations in 1977 are similar to those exhibited at MTES 2.

Although the concentration of ortho-P in 1974 at MFS 2 was significantly higher than the other two years, not much else can be said about the losses. None of the watersheds lost ortho-P in great quantities (Table 13). The relatively high ortho-P levels at Spring Hill were probably due to the decomposition of the phosphatic parent material.

Very few differences were noticeable in mean dissolved solid concentrations among years for any watershed except at MFS 2 (Table 14). The mean concentration for 1975 was significantly lower than the mean concentration for 1974 or 1976, again perhaps reflecting the impact of land grading. Even though the mean concentration was lower in 1975, that year the highest amount of dissolved solids/ha lost for this or any other watershed studied (Table 15). One of the reasons for the land grading was to curtail the volume of runoff occurring at MFS 2.

Fertilization practices can cause differences in nutrient levels in the runoff. Soon after fertilization, nutrient levels may increase as a major portion of the fertilizer components are water soluble. After time the concentrations may decrease as ortho-P is fixed by the soil and NO_3-N is absorbed by plants and Cl is leached through the profile. Also, the release of nutrients from the degradation of organic matter vary from season to season.

TABLE 12

YEARLY MEAN CONCENTRATION OF ORTHO-P FOR EACH WATERSHED

	MTES 1	MTES 2	MFS 1	MFS 2
	----------	----------	ppm ----------	----------
1974	------*	------	------	0.62 a
1975	------	0.30 a	0.39 a	0.05 b
1976	2.99 a	0.80 a	0.26 a	0.07 b
1977	0.25 a	0.06 a	------	------

*Blanks indicate no samples were taken at that watershed that year.

+Means within a column followed by a common letter are not significantly different at the .05 level of probability.

TABLE 13

ORTHOPHOSPHATE-P LOSSES FOR EACH WATERSHED

	MTES 1	MTES 2	MFS 1	MFS 2
	----------	----------	g/ha ----------	----------
1974	------*	------	------	57
1975	------	62	132	202
1976	271	79	210	109
1977	15	2	------	------

*Blanks indicate no samples were taken at that watershed that year.

TABLE 14

YEARLY MEAN CONCENTRATION OF DISSOLVED SOLIDS FOR EACH WATERSHED

	MTES 1	MTES 2	MFS 1	MFS 2
	ppm			
1974	------*	------	------	77 a
1975	------	88 a	87 a	45 b
1976	87 a+	99 a	96 a	61 a
1977	115 a	104 a	------	------

*Blanks indicate no samples were taken at that watershed that year.

+Means within a column followed by a common letter are not significantly different at the .05 level of probability.

TABLE 15

DISSOLVED SOLID LOSSES FOR EACH WATERSHED

	MTES 1	MTES 2	MFS 1	MFS 2
	g/ha			
1974	------*	------	------	11,307
1975	------	19,301	37,616	216,350
1976	7,843	8,118	96,841	173,200
1977	5,953	3,435	------	------

*Blanks indicate no samples were taken at that watershed that year.

From the analysis of variance, "F" values for the concentrations were obtained using the unbalanced nested design described previously. Days were significant for all watersheds (Table 16). This is to be expected for the same reasons variation occurred among the means for days as discussed previously.

In this design, years were preferred not to be significant. If years did not vary significantly, the variation of days among years might form patterns of highs and lows through the seasons. But the combined analysis of all watersheds revealed significant variation among years for ortho-P. The wide differences between mean concentration of ortho-P at MTES 1 in 1976 and 1977 (Table 10) may have been responsible for much of the variation exhibited here.

Taking a closer look, MFS 2 had a significant variation among years for Cl, ortho-P, and dissolved solids. Referring to Tables 9 and 10, the mean concentrations of Cl and ortho-P for 1974 were significantly higher than the concentrations for the years 1975 and 1976. The mean dissolved solid concentration in 1975 was significantly lower than the mean for 1974 and 1976.

MFS 2 also had the lowest mean dissolved solid concentration for all of the watersheds. This might explain the significant variation that occurred among watersheds for dissolved solids.

Also, an attempt was made by the use of statistical inferences to eliminate part of the required laboratory work involved in this project or similar projects in the future. The first step involved obtaining correlation coefficients between the concentrations of NO_3-N, ortho-P, Cl, dissolved solids, and runoff rate (Table 17). Significant negative correlations were found between rate of flow with NO_3-N, Cl and dissolved solids.

TABLE 16

F VALUES FOR WATERSHEDS, YEARS, AND DAYS FOR NO_3-N, Cl, ORTHOPHOSPHATE-P, AND DISSOLVED SOLIDS

Watershed	Source of Variation	NO_3-N	Cl	PO_4-P	Dissolved Solids
MTES 1	Year	0.01	1.06	4.21	2.23
	Day	18.58*	31.04*	474.19*	11.24*
MTES 2	Year	0.42	0.18	1.32	0.78
	Day	61.02*	25.63*	6.17*	4.13*
MFS 1	Year	1.50	0.30	0.31	0.20
	Day	20.50*	48.05*	20.80*	22.22*
MFS 2	Year	1.09	11.69*	14.92*	7.55*
	Day	24.80*	13.75*	8.47*	6.73*
Combined	Watershed	1.28	2.31	2.73	9.44*
	Year	0.84	0.95	5.04*	1.73
	Day	31.78*	32.48*	8.54*	8.52*

*Significant at the .05 level of probability.

TABLE 17

CORRELATION COEFFICIENTS FOR NITRATE-N, ORTHO-P, CHLORIDES, DISSOLVED SOLIDS, AND RUNOFF RATE

		Chloride	Ortho-P	Dissolved Solids	Runoff Rate
NO_3-N	MTES 1	0.17	-0.38	-0.01	-0.24
	MTES 2	0.82*	-0.08	0.56*	-0.18*
	MFS 1	-0.21*	-0.07	0.21*	-0.18
	MFS 2	-0.10	-0.03	-0.02	-0.10
	Combined	0.24*	-0.04	0.26*	-0.11*
CHLORIDE	MTES 1		0.05	0.30	-0.17
	MTES 2		-0.19*	0.61*	-0.29*
	MFS 1		0.73*	0.62*	-0.08
	MFS 2		0.77*	0.49*	-0.10
	Combined		0.24*	0.60*	-0.14*
ORTHO-P	MTES 1			-0.57*	0.28
	MTES 2			-0.08	0.00
	MFS 1			0.50*	-0.03
	MFS 2			0.40*	0.01
	Combined			0.23*	-0.06
DISSOLVED SOLIDS	MTES 1				-0.37
	MTES 2				-0.49*
	MFS 1				-0.25*
	MFS 2				-0.02
	Combined				-0.16*

*Significant at the .05 level of probability.

With negative correlations, the hypothesis is that as runoff rate increased nutrient concentrations would decrease due to a dilution effect. Significant positive correlations were found between dissolved solids with NO_3-N, Cl, and ortho-P. The hypothesis being that as dissolved solid concentrations increased, NO_3-N, Cl, and ortho-P concentrations would increase accordingly.

Following this procedure, coefficients of determination were obtained for all possible regression equations to determine the best linear model. Runoff rate explained 7 percent of the variation in NO_3-N, 13 percent of the variation in Cl, 4 percent of the variation in ortho-P, and 9 percent of the variation in dissolved solids. The variation in dissolved solids by itself explained 7 percent of the variation in NO_3-N, 36 percent of the variation in Cl, and 5 percent of the variation in ortho-P. The best model was found to be dissolved solids predicting concentrations in NO_3-N, Cl, and ortho-P. The slopes and intercepts associated with this model are reported in Table 18.

Special attention has been given to MFS 1 since this area received an application of sewage sludge. From January until April of 1976, municipal sewage sludge with primary sedimentation treatment was applied in semiweekly intervals. After each application, the area was disk harrowed then turned with a plow. As mentioned previously, sewage sludge can pose a health hazard because of heavy metals that may be present. Samples of the sludge received were analyzed for several elements including the heavy metals. Monthly mean concentrations and loading rates of these elements are found in Table 19. The loading rate was determined by using guidelines suggested by Chaney (4) for heavy metal loadings.

TABLE 18

INTERCEPTS AND SLOPES FOR INDIVIDUAL WATERSHEDS USING DISSOLVED SOLIDS AS THE PREDICTOR

Watershed		NO_3-N	Cl	PO_4-P
MTES 1	Intercept	0.081	0.252	6.382*
	Slope	0.000	0.035	-0.044*
MTES 2	Intercept	-1.253*	-3.553*	0.685*
	Slope	0.022*	0.089*	-0.002
MFS 1	Intercept	0.230*	-7.184*	-0.218*
	Slope	0.002*	0.138*	0.005*
MFS 2	Intercept	0.375*	-1.249*	-0.147*
	Slope	-0.001	0.057*	0.005*
TOTAL	Intercept	-0.011	-3.083*	-0.029
	Slope	0.006*	0.087*	0.005*

*Significant at the .05 level of probability.

TABLE 19

MONTHLY MEAN CONCENTRATIONS AND LOADING RATES OF SELECTED CONSTITUENTS IN APPLIED SEWAGE SLUDGE

		Tot. N	P	K	Ca	Cl	Mg	Na	Al	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
January	ppm	8300	1000	190	4100	1700	300	210	1	1	800	40	3600	0.24	40	90	370	440
	kg/ha	27.3	3.3	0.6	13.5	5.6	1.0	0.7	.003	.003	2.3	0.1	11.8	.001	0.1	0.3	1.2	1.4
February	ppm	9800	1000	200	1800	2200	300	160	1	1	800	50	1600	0.16	30	180	280	320
	kg/ha	71.1	7.3	1.5	13.1	16.0	2.2	1.2	.007	.007	5.8	0.4	11.6	.001	0.2	1.3	2.0	2.3
March	ppm	7000	900	170	3100	1800	300	140	1	2	800	70	3300	0.14	40	80	300	350
	kg/ha	36.9	4.7	0.9	16.3	9.5	1.6	0.7	.005	.011	4.2	0.4	17.4	.001	0.2	0.4	1.6	1.8
April	ppm	7500	700	120	2700	1700	200	120	2	2	800	60	2500	0.11	30	100	240	300
	kg/ha	40.1	3.7	0.6	14.4	9.1	1.1	0.6	.011	.011	4.3	0.3	13.4	.011	0.2	0.5	1.3	1.6
Average	ppm	8150	900	170	2925	1850	275	158	1.2	1.5	800	55	2750	0.16	35	112	298	353
Total	kg/ha	175.4	19.0	3.6	57.3	40.2	5.9	3.2	.026	.032	16.6	1.2	54.2	.004	0.7	2.5	6.1	7.1

After the sludge application, runoff samples were collected and analyzed for the same elements (Table 20). Of the elements considered to be the most harmful in the food chain, Cd was found to be present in the concentration of 0.009 ppm, Cu less than 0.1 ppm, Ni less than 0.2 ppm, and Zn 0.30 ppm. Mercury (Hg) and lead (Pb) were at 0.5 and 1.0 ug/l levels respectively. In August of 1976, soil and corn ear leaf samples were collected and analyzed for selected elements. The results can be found in Table 21.

Despite the additions of heavy metals in the sludge treatment the concentrations in corn tissue, with the exception of Hg, were found to be normal. This illustrates the property of plant selectivity in preventing accumulations of nonessential elements. Crop growth appeared to the normal throughout the growing season and yielded 7087 kg/ha.

TABLE 20

CONCENTRATIONS OF SELECTED CONSTITUENTS IN RUNOFF FROM MFS 1 AFTER APPLICATION OF SEWAGE SLUDGE

		N	P	K	Ca	Cl	Mg	Na	Al	Cd	Cr	Cu	Fe	Hg*	Mn	Ni	Pb*	Zn
February	17	3.5	0.39	7.7	21.0	1.9	5.0	1.4	12.6	.005	<.2	<.1	11.6	<.5	0.3	<.2	<1	.16
February	21	5.9	0.35	7.1	23.0	5.2	4.9	2.1	8.5	.008	<.2	<.1	7.1	<.5	<.1	<.2	36	.18
March	5	5.3	0.19	8.4	21.8	1.9	2.9	1.2	6.5	.031	<.2	0.2	4.3	<.5	<.1	<.2	<1	.46
March	8	3.2	0.31	4.6	10.9	0.5	2.8	0.9	6.7	.003	<.2	<.1	5.1	<.5	<.1	<.2	<1	.14
March	9	3.2	0.19	4.3	19.6	0.9	3.6	1.2	5.0	.005	<.2	<.1	3.2	<.5	<.1	<.2	<1	.62
March	26	3.4	0.37	14.0	16.0	21.8	3.4	2.3	8.0	.005	<.2	<.1	5.8	<.5	<.1	<.2	<1	.24
March	29	2.9	1.00	13.3	15.9	18.9	5.1	2.5	26.0	.015	<.2	<.1	22.0	<.5	0.4	<.2	<1	.78
April	24	5.9	1.20	5.5	6.1	1.2	3.8	1.2	90.0	.003	<.2	<.1	30.5	3.5	1.7	<.2	3	.40
May	14	2.5	0.49	3.1	5.7	1.4	2.1	1.4	14.5	.030	<.2	<.1	8.5	<.5	<.1	<.2	<1	.19
May	15	3.1	0.56	4.0	9.3	4.3	2.7	1.6	15.0	.002	<.2	<.1	13.4	<.5	0.4	<.2	<1	.19
May	18	2.5	0.39	3.5	9.3	1.2	2.6	1.5	15.0	.002	<.2	<.1	10.2	<.5	0.3	<.2	<1	.17
May	28	5.6	0.67	4.6	15.0	3.8	2.8	1.1	15.2	.008	<.2	<.1	11.2	<.5	0.3	<.2	<1	.14
June	2	2.9	0.59	6.7	7.5	0.7	3.6	0.9	41.5	.002	<.2	<.1	23.0	<.5	0.5	<.2	<1	.19
Mean		3.8	0.52	6.7	13.9	4.9	3.5	1.5	20.3	.009	<.2	<.1	12.0	<.5	0.3	<.2	<1	.30

*Mercury and Pb are reported as parts per billion. All others are reported as parts per million.

TABLE 21

CONCENTRATIONS OF SELECTED CONSTITUENTS IN SOIL AND CORN LEAVES AT THREE SITES ON MFS

	Al	Cd	Cr	Cu	Hg	Na	Ni	Pb	Zn
	ppm								
Site 1 (Henry Silt Loam)									
Soil (0-15 cm)	47,100	1	46	18	16	1430	21	4	--
Soil (15-30 cm)	42,700	1	22	22	20	370	3	14	--
Corn Ear Leaves	120	1	2	12	17	350	1	5	87
Site 2 (Calloway Silt Loam)									
Soil (0-15 cm)	43,000	1	26	17	16	240	2	26	--
Soil (15-30 cm)	45,200	1	49	14	11	220	3	34	--
Corn Ear Leaves	100	1	1.5	17	7	790	2	16	76
Site 3 (Loring Silt Loam)									
Soil (0-15 cm)	48,600	1	50	19	5	320	14	4	--
Soil (15-30 cm)	48,200	1	16	11	11	320	4	10	--
Corn Ear Leaves	90	1	2	15	8	890	3	5	59
Mean (Soil)	45,800	1	35	17	13	483	8	15	--
Mean (Leaves)	103	1	2	15	11	677	2	9	74

CHAPTER IV

SUMMARY

Runoff water samples were collected from four watersheds, two at Spring Hill on the Middle Tennessee Experiment Station and two from the Milan Field Station, from the Fall of 1974 until the Spring of 1977 to evaluate the quality of runoff water.

Nitrate-N levels were lowest at MTES 1 which remained in continuous pasture. The larger watershed at Spring Hill (MTES 2), which was treated approximately the same as MTES 1, had the highest NO_3-N levels. Various treatments appeared to have little effect on NO_3-N concentrations at any of the watersheds. In 1975, MTES 2 lost 112 g/ha of NO_3-N while MFS 2 lost 2,855 g/ha. Problems were encountered at MFS 2 due to the large volume of runoff recorded at the station. Part of the runoff at MFS 2 may have been backwater which was undetectable on the automatic water level recorders. Hence, the large amount of NO_3-N/ha reported.

The Cl concentrations were highest at MFS 1 and appeared to be influenced by an application of municipal sewage sludge. The lowest Cl levels were recorded at MFS 2. The soils at Milan on these two watersheds are basically the same. The major difference in treatments was the sludge applications. In 1976, both of the watersheds at Milan lost approximately 5,500 g/ha of Cl again indicating the large volume of runoff at MFS 2.

Even though the watersheds at Spring Hill had not received any P fertilizations in recent years, the ortho-P concentrations in the runoff were higher than at Milan which received regular applications of P fertilizers. The high P levels of the soils at Spring Hill could have influenced the amount of ortho-P found in the runoff water.

The land grading that took place at MFS 2 in 1975 appeared to have a marked influence on nutrient levels in the runoff. The land grading apparently reduced the velocity of the water leaving the watershed, thus reducing the nutrient loads in the runoff. Also, the possibility existed that fertility levels were affected by the land grading. However, the large volume of water that left MFS 2 almost always resulted in this watershed losing the greatest quantity of nutrients, including total dissolved solids.

Application of liquid dairy manure on the Spring Hill pastures had little affect on nutrient concentrations in the runoff. The pasture grasses offered more resistance to water flow possibly allowing nutrients more time to enter the soil.

Even though a reliable method of predicting nutrient concentrations in runoff was not found with this experiment, the data indicate present waste loading and commercial fertilization practices can be maintained without jeopardizing the quality of water evolving from agricultural systems.

During the period of time this study was conducted, the weather was quite inconsistent from year to year. In order for a reliable method of predicting nutrient losses is to be obtained, several more years of data need to be collected to possibly eliminate some of the variation that occurs among years. There was some indication of seasonal patterns in nutrient levels in the runoff, but this can be altered by cultural and fertilization practices that accompany the changing seasons.

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VITA

Jimmy Clark Castellaw was born in Alamo, Tennessee, on January 12, 1954. He received his primary and secondary education in Crockett Mills, Tennessee and was graduated from Hamlett-Robertson High School in June 1971.

In the fall of 1971 he entered the University of Tennessee at Martin and in June 1975, he received the degree of Bachelor of Science in Agriculture. He accepted a graduate research assistantship at the University of Tennessee at Knoxville in the summer of 1975. He received the Master of Science degree with a major in Plant and Soil Science in August 1978.

He is married to the former Pamela Tenry of Morris Chapel, Tennessee.