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Effects of Tillage System, Crop Residue Level, and Fertilizer Application Technique on Losses of Phosphorus and Pesticides from Agricultural Lands

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S. Mostaghimi, V.O. Shanholtz, T.A. Dillaha,
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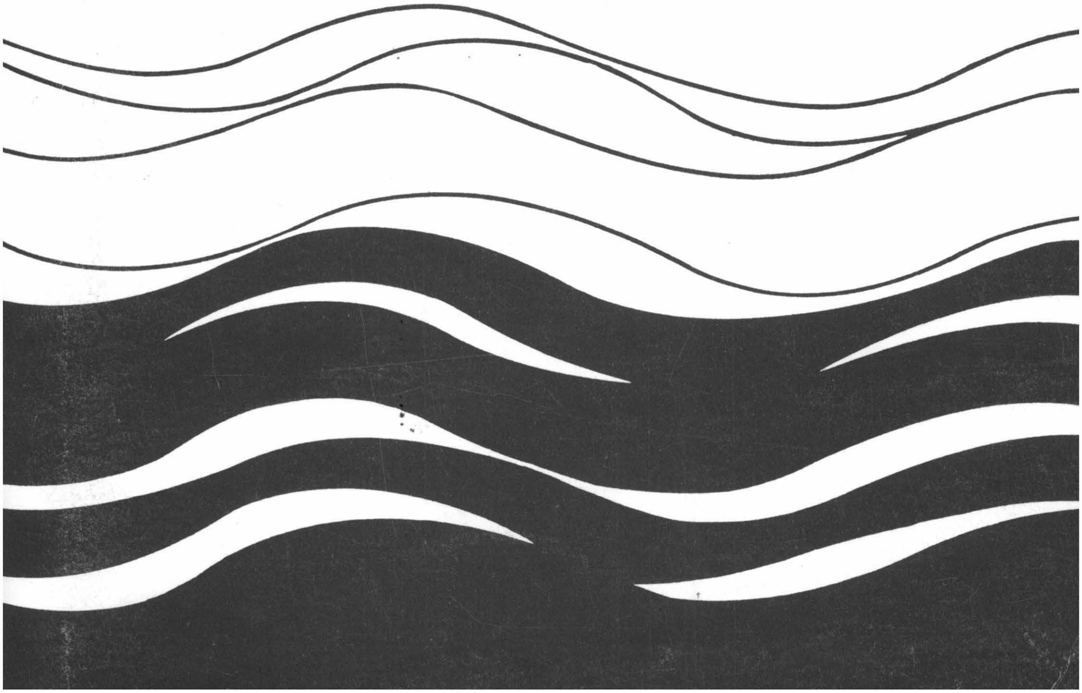

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S. Mostaghimi
V.O. Shanholtz
T.A. Dillaha
A.L. Kenimer
B.B. Ross
T.M. Younos
Department of Agricultural Engineering
Virginia Polytechnic Institute and State University

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ABSTRACT

A rainfall simulator was used to study the effectiveness of three best management practices — no-till, residue level and fertilizer application technique — for reducing sediment, phosphorus, and pesticide losses from agricultural lands. Simulated rainfall was applied to 12 experimental field plots, each 0.01 ha in size. The plots were divided into conventional and no-till systems. During phase I, the effectiveness of two fertilizer application methods — subsurface injection and surface application — were investigated for the two tillage systems. In phase II, three crop residue levels — 0, 750, and 1500 kg/ha — were studied within each tillage system. Granular fertilizer was applied at the rate 46 kg/ha. Atrazine and 2,4-D were applied at the rates of 2.24 and 0.56 kg/ha active ingredient, respectively. Fertilizer and herbicides were applied 24 to 48 hours before the start of rain simulation. Water samples were collected from the base of each plot and analyzed for sediment, nutrient, and pesticide content.

No-till was found to be very effective in reducing runoff and sediment losses. No-till with high residue level produced the greatest reductions in runoff and sediment losses, and the highest reduction for both runoff and sediment occurred with no-till and 1500 kg/ha crop residue level. No-till reduced sediment loss by 98% and total runoff volume by 92%. The injection fertilization method reduced O-P losses by 39% for no-till and 35% for conventional tillage. Reductions in T-P losses due to no-till practice were 89% and 91% for surface and injection fertilizer application methods, respectively, compared to the conventional system. Averaged across all fertilizer treatments, an equivalent of 0.9% and 8.9% of the total-P fertilizer applied to the plots was lost from no-till and conventional tillage plots, respectively. Concentrations of atrazine and 2,4-D in runoff and sediment were greater from the no-till plots than from the conventional plots, but total losses were less. Water was the major carrier for both herbicides, although the concentration of 2,4-D in sediment was higher than that of water. Averaged over all plots, the atrazine losses were 2.9% of the applied amount for conventional tillage and 0.3% for no-till. The corresponding values for 2,4-D were 0.3% and 0.02%.

Keywords: No-till, Conventional Tillage, Atrazine, 2,4-D, Phosphorus, Application Technique, Crop Residue Level, Rainfall Simulator

INTRODUCTION

Agriculture is increasingly criticized for contributing to the deterioration of the nation's water resources. Nonpoint sources of nutrients, primarily in runoff from agricultural lands, are thought to be a major factor promoting the eutrophic growth of algae and other aquatic plants in lakes and streams. These plants, in turn, may cause fish kills and limit the use of water for recreation, fish culture, irrigation, and other purposes. Recently, there has been renewed emphasis on the need for investigating methods of reducing the amount of sediment and chemicals leaving cropland during storm events. Effects of runoff and erosion are twofold: (1) sediment and chemicals leaving agricultural lands contribute to nonpoint source pollution problems, and (2) losses of soil and plant nutrients increase production costs and lower the long-term productivity of soil.

Conservation tillage practices, which leave all or part of the previous crop's residue on the soil surface, are known to be very effective in reducing soil erosion. Such tillage practices are becoming increasingly popular because of their erosion control capabilities, soil moisture conservation, lower production costs, and comparable or improved crop yields. Several researchers have projected that over 90% of the U.S. farmland will be under conservation tillage by the end of this century (Croson 1981).

Fine soil particles, particularly the colloidal fraction, are reported to be the principal carriers of nitrogen and phosphorus from agricultural lands. Therefore, management practices such as conservation tillage that reduce soil erosion should be effective in reducing the losses of sediment-bound nutrients. Some studies, however, have indicated that conservation tillage can increase soluble nutrient concentrations in runoff (Smith et al. 1974; Whitaker et al. 1978; Barisas et al. 1978). Soluble nutrient concentrations may increase, despite a significant reduction in soil loss, because fertilizers are usually surface-applied, rather than incorporated. Without incorporation, fertilizers are concentrated in the top few centimeters of the soil profile where they are most susceptible to erosion and runoff losses. An alternative method for applying fertilizers is subsurface injection. Because of the recent development in appropriate injection equipment, interest in this application method is increasing. This method should reduce nutrient losses in runoff significantly; however, because little research has been conducted in this area, the limited results are inconclusive.

Agricultural practices also have been blamed for the contamination of surface and ground water by pesticides. In 1982, agricultural pesticide usage exceeded 370,000 metric tons of active ingredient and accounted for 70% of the total pesticide used in the United States (Cohen et al. 1984). Conservation tillage systems, particularly no-till, are more dependent on pesticides to control weeds and pests than conventional tillage. The substitution of herbicides for cultivation in weed control may increase the amount of herbicides used per hectare. More pesticides may also be needed because surface residue intercepts the applied pesticides, preventing them from reaching the soil. In addition, surface residue increases soil moisture and decreases soil temperature. This alteration of soil environment may cause either slower or faster biological breakdown of the pesticides. Because the application rates of pesticides for conservation tillage are usually higher than for conventional tillage systems, the potential for increased pesticide losses from conservation tillage systems must be considered.

The importance of investigating the mechanics by which pesticides and nutrients are lost from croplands is evident because of the numerous cases of water quality degradation caused by their use and increased use of conservation tillage. The development of a better understanding of the effects of conservation tillage systems on the environment is needed to make sound recommendations on the implementation of these practices.

The overall goal of this study was to evaluate the effects of fertilizer application techniques, residue level and no-till systems on the losses of agricultural chemicals and sediment from cropland. To achieve this goal, the following specific objectives were undertaken:

1. To evaluate the effects of conventional tillage and no-till, with various crop residue levels, on runoff and the losses of sediment and phosphorus from cropland;

2. To evaluate the effects of fertilizer application techniques on phosphorus losses from conventional and no-till systems; and

3. To investigate the effects of tillage systems and crop residue levels on the losses of atrazine and 2,4-D from agricultural lands.

LITERATURE REVIEW

Agricultural activities contribute nearly three billion tons of sediment and over 9.5 million tons of nutrients every year to the surface waters of the United States (Baily and Wadell 1979). In 1982, over 370,000 metric tons of active pesticide ingredients were applied to agricultural lands. (Cohen et al. 1984). A high percentage of these pesticides will eventually move into the soil where they will be subjected to movement by hydrologic forces. Sediment, nitrogen, and phosphorus have been identified as the most significant agricultural nonpoint source pollutants. More recently, however, attention has been focused on the effects of pesticide losses on surface and ground water quality, and there is renewed interest in the techniques that reduce pesticide losses from agricultural lands. Methods of agricultural nonpoint source pollution control that are receiving increased interest include conservation tillage, crop residue management, and improved fertilizer application techniques.

I. Runoff, Sediment and Nutrient Losses

Conservation tillage systems, with proper management of crop residue, are thought to be the best available means to control erosion and maintain the quality of surface runoff from agricultural lands. Many researchers have reported lower runoff volumes with conservation tillage than with conventional tillage systems (Romkens et al. 1973; and Johnson et al. 1979). Others (Lindstrom and Onstad 1984; and Mueller et al. 1984) have concluded that conservation tillage practices, such as no-till, may in some cases increase the runoff volumes. Lindstrom and Onstad (1984) attributed the differences in runoff to varying effects of tillage on surface conditions and crop residue amounts left on the soil surface. No-till and other conservation tillage practices, however, have been shown to be very effective in reducing soil erosion (Angle et al. 1984; McGregor and Green 1982).

Romkens et al. (1973) studied the effect of five tillage planting systems on the losses of nitrogen (N) and phosphorus (P) in runoff water and sediment from corn plots. They used a rainfall simulator to produce runoff from 7.92-m by 10.67-m field plots. Coulter and chisel plow systems controlled soil loss, but runoff from surface-applied fertilizer plots contained high concentration of soluble N and P. Disking and conventional tillage systems were less effective for erosion control; however, they had lower concentrations of soluble N and P in the runoff water. Conventional tillage, in which fertilizers were incorporated by plowing under, had the highest soil loss and runoff volumes but smaller losses of soluble N and P. A large fraction of the nutrient loss from all plots was sediment-bound. The authors concluded that minimum tillage techniques did not necessarily reduce nutrient loss in runoff. They suggested, however, that nutrient losses might be reduced by modifying fertilizer application and tillage techniques.

Johnson et al. (1979) used six small (0.55-1.75 ha.) watersheds in Iowa to study the effects of tillage systems on nutrient losses in runoff produced by natural rain. Two conservation tillage systems were compared with a conventional tillage system. The Ridge-plant and till-plant tillage systems reduced runoff by 40% and soil loss by 90%. Total losses of N and P were highly correlated with soil loss and were reduced with the conservation tillage systems. However, they reported that soluble P losses and concentrations increased with residue level. The authors attributed this increase to a lack of fertilizer incorporation and nutrient leaching from the residue. Other investigators also have indicated that the concentrations of soluble nutrients may be high in the runoff from conservation tillage systems, where the sediment concentration is low (Holt et al. 1973; McDowell and Grissinger 1976; McDowell and McGregor 1980; and Laflen and Tabatabai 1984). However, because of substantial reductions in losses of soil and sediment-bound nutrients with reduced tillage systems, total nutrient losses were much lower for these systems.

Barisas et al. (1978), using simulated rainfall, studied the effect of conservation tillage practices on nutrient losses from experimental plots. As residue cover increased, P concentrations in the eroded soil increased, but residue cover had no significant effect on total N concentration. Losses of sediment-bound N were inversely related to the crop residue level. The authors reported that conservation tillage did not reduce the losses of soluble nutrients in runoff, probably due to leaching of nutrients from plant residues and reduced fertilizer incorporation. They suggested that improved fertilizer application techniques would make the no-till and chisel tillage practices effective in reducing P losses.

Smith et al. (1974) concluded that for the three tillage systems studied, which included both no-till and conventional tillage, P losses were higher where crop residues remained on the surface, probably due to nutrient leaching from the crop residue. Several other investigators (Tukey and Romberger 1959; Herber 1967; and Timmons et al. 1970) also have indicated that crop residues are sources of soluble nutrients.

Timmons et al. (1973), using simulated rainfall, found that nutrient losses were highest with no incorporation of applied fertilizer, intermediate with broadcast fertilizer on plowed and disked soil, and least from applications when the fertilizer was plowed under and then disked.

Baker and Laflen (1982) used small experimental plots (1.5m x 9.1m) to study the effects of corn residue and fertilizer management on soluble nutrient losses in runoff water. They concluded that increased nutrient concentrations in runoff under conservation tillage systems resulted, at least in part, from lack of fertilizer incorporation. Point-injected fertilizer did not increase concentrations in runoff relative to concentrations of unfertilized plots. The authors reported that although the test conditions did not truly represent conservation tillage systems, residue on the surface reduced the runoff amount and thus nutrient losses. However, they made no attempt to measure nutrient losses associated with sediment.

II. Pesticide Losses

Losses of pesticides from agricultural lands to the environment not only pose a threat to nontarget organisms, they also represent an economic loss to farmers. Pesticides in surface waters have been connected to fish kills and reproductive failure in birds (Rao et al. 1983).

Eleven watersheds in Ontario's Great Lake's Basin were monitored over a two-year period (Frank et al. 1982). The watersheds ranged in size from 1860 to 1913 ha, with an average crop coverage of 93.6%. A total of 81 different pesticides were applied to the eleven watersheds. Of these, 41 were tested for and 18 were identified in surface runoff.

Hall et al. (1972) studied the fate of atrazine for three years after a single application. The study was conducted on small plots (1.8 m by 22.3 m) to which atrazine was applied at six different rates ranging from 0.6 to 9.0 kg/ha. Average runoff losses of atrazine for all application rates were 2.4% of total pesticide applied. The concentration of atrazine increased in runoff and sediment in proportion to the rate of application. The concentrations of atrazine in sediment decreased with each consecutive runoff event.

Baker and Laflen (1982) investigated the effects of corn residue on herbicide losses and evaluated the benefits of applying herbicides below crop residue. The study was conducted on experimental plots to which propachlor, atrazine, and alachlor were broadcast. Residue levels on the plots ranged from 0 to 1500 kg/ha. Simulated rainfall was applied to the plots at 63.5 mm/hr for 2.0 hours. Results indicated that herbicide losses were not affected by their placement relative to crop residue. Herbicide losses were reduced in plots with crop residue because the residue delayed and reduced surface runoff. Concentrations of herbicide in runoff water and sediment decreased with time as runoff continued.

The effects of tillage practices on the movement of pesticide have been reported by few investigators. Ritter et al. (1974) reported that atrazine losses from a ridge-planted watershed were 76% less than losses from a conventional tillage watershed. However, in a study conducted by Baker and Johnson (1979), no significant differences were detected in pesticide losses in runoff water from six small watersheds in Iowa where the effects of ridge-plant, till-plant and conventional tillage systems were investigated. The authors reported that the time of application was a significant factor in determining the magnitude of pesticide losses from agricultural lands.

A laboratory study conducted by Martin et al. (1978) concluded that between 60% and 89% of the pesticides applied to corn residue was washed off by 3.5 cm of rainfall, and that as much was removed with the first 0.5 cm of rain as in the next 3.0 cm. Baker and Shiers (1985) concluded from laboratory experiments that total recoveries of applied pesticide after 6.8 cm of rainfall were 87% for cyanazine, 89% for alachlor, and 88% for propachlor.

III. Summary

Although other differences exist between conventional and conservation tillage systems, the amount of crop residue left on the soil is the most visible difference between the two systems. Several researchers have reported on the interaction of fertilizers and soil in relation to such factors as runoff, volatilization, and soil productivity, but little information is available pertaining to the interactions of crop residue and fertilizer. Fertilizer application by injection, without incorporation of surface residue, should reduce losses of fertilizers in surface runoff. The present study investigated the effects of conventional and no-till and crop residue levels as well as fertilizer application methods on the losses of P from agricultural lands.

Many factors affect washoff of pesticides by runoff as well as their movement through the soil profile. These factors include land use, soil type, rainfall characteristics, and pesticide characteristics such as persistence, solubility, volatility, and adsorbtivity. Many researchers have reported on the effects of these factors on the movement of pesticides into the environment. However, the effects of conservation practices such as no-till and crop residue on losses of pesticides from agricultural lands are poorly defined. In this study, the losses of atrazine and 2,4-D from conventional and no-till systems with various levels of crop residue were investigated. Atrazine and 2,4-D were chosen because they are commonly used in Virginia corn production.

EXPERIMENTAL PROCEDURES

Field experiments were conducted in the fall of 1985 and again in the spring of 1986 to assess the effects of two management practices, no-till and crop residue management, on the losses of runoff, sediment, P, and pesticides (atrazine and 2,4-D) from agricultural lands. Because of the unreliability of natural precipitation for such short-term field research, a rainfall simulator was used to produce runoff on these plots.

I. Plot Design and Location

Twelve experimental field plots located at Virginia Tech's Price's Fork Agricultural Research Farm, 10 km west of Blacksburg, were used for this study. Plots were located on a Groseclose silt loam soil (clayey, mixed, mesic Typic Hapludult). Groseclose soils occur on nearly level to very steep convex ridges and sideslopes in the Appalachian Valley and are formed from materials weathered from interbedded limestone, shale and sandstone. The soil is deep and well drained with slowly permeable subsoil. The Ap horizon is typically 0.25 m thick and has a loam texture with moderate fine granular structure. Some general characteristics of Groseclose silt loam soil are presented in Table 1.

Plots were prepared by installing metal borders to a depth of 15 cm along the boundaries and a concrete gutter with a pipe outlet at the base of each plot. Each plot had a surface area of 0.01 ha (5.5m by 18.3m). All border and gutter joints were sealed with caulking compounds to prevent leakage into or out of the plots. The gutters were installed so that their upper edge was level with the soil surface. The interface between the soil surface and the gutter was sealed with a cement grout and caulking to minimize leakage. The gutter was designed to collect and transport surface runoff to a 15-cm H-flume equipped with a FW-1 stage recorder for flow measurements.

II. Plot Preparation

A. Fall of 1985 Experiments

The objective of the 1985 field experiments was to study the effects of tillage systems and fertilizer application techniques on the losses of P from agricultural lands. The plots were divided into two tillage systems: (a) no-till and (b) conventional tillage. Within each tillage system, two fertilizer application methods were studied: (a) fertilizer surface-applied, and (b) fertilizer injected to a depth of 5-7.5 cm. There also were two control plots to which no fertilizer was applied. Two replications of each of these treatments required a total of twelve plots. All treatments within each tillage system were randomly assigned to the experimental plots.

The no-till plots were planted in winter rye in early 1985. The winter rye cover crop was killed with paraquat about a week prior to the start of simulation runs. The crop residue amounts on the plots were measured by randomly locating a 0.6 x 0.6-m square in each plot and removing all residue in the square for laboratory analysis. The conventional plots were tilled to a depth of 15-20 cm with a PTO-driven rototiller and then disked.

Granular P fertilizer was applied to the plots, 24-48 hours before rainfall simulation, at a rate of 46 kg/ha to all treatments except for control plots, which received no fertilization. These rates represent the values commonly used for corn production in Virginia. The surface fertilizer treatment was applied uniformly over the plots by subdividing each plot into 4 equal-sized subareas and manually applying 1/4 of the total fertilizer required for each plot to each subarea. The injection treatments were simulated by placing fertilizer in slots of 0.5-1 cm wide and 5 to 7.5 cm deep along the corn rows (90 cm apart), and perpendicular to the slope direction. All slots received the same amount of fertilizer. The injection treatment might not have closely simulated the actual field application methods since granular fertilizer was used in this study. However, considering the small plot areas, it was not practical to use commercial farm equipment and inject liquid fertilizers into the soil.

B. Spring of 1986 Experiments

The objective of this phase was to study the effects of tillage systems with varying levels of crop residue on the losses of P and pesticides from agricultural lands. The same 12 plots used in the fall were divided into two tillage systems: (a) no-till and (b) conventional tillage. Within each tillage system, three crop residue levels were studied: (a) no residue, (b) 750 kg/ha residue, and (c) 1500 kg/ha residue. Two replications of the six treatments required a total of 12 plots. All treatments were randomly assigned to the experimental plots.

All plots were planted in winter rye in the fall of 1985. In early summer, they were sprayed with paraquat and the crop residue was measured by harvesting and weighing all residue within a 0.6 m x 0.6 m square. The rye was then cut leaving sufficient stubble to give residues of 0, 750 and 1500 kg/ha. Six plots were randomly assigned to no-till and the remaining six were tilled to a depth of 15-20 cm with a PTO-driven rototiller and then disked to represent conventional tillage. Thus, the tillage operation incorporated the crop residue into the soil surface, whereas the residue was left standing on the no-till plots.

Nitrogen and phosphorus fertilizers were applied at the same rates as in the 1985 study. The only difference between Phase I and this study was that fertilizer was surface-applied to all plots. Atrazine and 2,4-D, two commonly used herbicides in Virginia corn production, were applied at rates of 2.24 and

0.56 kg/ha of active ingredient, respectively, to all treatments. The herbicides were applied, using a pressure-regulated hand-held sprayer, about 24 hours before rainfall simulations. Application rates were verified by determining the weight difference of six sets of 30-cm diameter filter paper on the plots before and after spraying.

III. Rainfall Simulator

The Department of Agricultural Engineering's rainfall simulator (Shanholtz et al. 1981; and Neff 1979) was used to apply approximately 100 mm of rainfall to each 3-plot set over a 2-day period. A 1-hr "dry" run (R1) was followed 24 hours later by a 30-minute "wet" run (R2) and followed 30 minutes later by a 30-minute "very wet run" (R3). A rainfall intensity of 50 mm/hr was used for all simulations. That intensity has about a 2-year return period in Southwest Virginia (Hershfield 1961), and should create critical conditions since pesticides and fertilizer had been applied during the previous 24 hours. The 3-run sequence of dry, wet, and very wet was used because it is a common artificial rainfall sequence used to simulate different initial soil moisture conditions for erosion research in the United States.

Plots were protected from natural precipitation during the study period by covering them with plastic sheets when rain appeared imminent. They were left uncovered at all other times so that the soil would dry normally.

Rainfall simulator application rates and uniformity were measured for each simulation by locating 12 volumetric rain gauges within each plot. The rain gauges were read after each simulation to determine the total amount of rain and the coefficient of uniformity for each run.

The total simulated rainfall amounts, along with the uniformity coefficients for simulation runs during 1985, are presented in Table 2. Because the results for the 1986 simulations were very similar, the data are not presented. The rainfall simulator performed remarkably well for all simulations. The mean application rate during all simulations was 50.9 mm/hr and ranged from 46.8 mm/hr to 54.4 mm/hr for the 1985 runs. The average application rate during 1986 simulations was 50.6 mm/hr and individual runs varied from 46.2 mm/hr to 55.6 mm/hr. Uniformity coefficients — a measure of the uniformity of rainfall application — were excellent, averaging 91.8% for 1985 and 92.3% for 1986.

IV. Sampling Procedure

Runoff water samples for nutrients were collected manually from the plot discharge at 3-minute intervals throughout the runoff process, using plastic bottles. A mark was made on the stage recorder charts whenever a sample was collected to record precisely the time and flow rate at which each sample was taken. This procedure greatly simplified mass flow calculations and minimized timing errors. All water quality samples were frozen immediately after collection and stored for subsequent analysis. Runoff rates were checked gravimetrically by making time-weight measurements frequently during the simulations. A wet sieving technique was used in 1985 to determine the particle size distribution of sediment in runoff water. This information is useful in characterizing the mechanics of soil erosion and P transport from the plots. Other data collected from the plots included overland flow velocity, soil moisture before and after each simulation, and soil bulk density.

Water samples collected from runoff events were analyzed at the Agricultural Engineering Water Quality Laboratory within 8-12 weeks of collection. Analyses were conducted for the determination of total suspended solids (TSS), total-P (T-P), orthophosphorus (O-P), and filtered total phosphorus (TP-F).

In the 1986 experiments, runoff was sampled for sediment, P, and also pesticides, using glass containers. During the first run (R1), runoff was sampled for pesticides from the outflow of each plot in 4L glass bottles at 3, 8, 13, 20, 45, and 60 minutes after the start of runoff. Likewise, runoff samples for runs two and three (R2 and R3) were collected at 2, 10, 20, and 30 minutes after the start of each runoff event. All pesticide samples were refrigerated immediately and analyzed for atrazine and 2,4-D within 6-8 weeks of collection.

V. Analytical Techniques

A. Suspended Solids

Suspended solids concentrations were determined in accordance with Method 160.2, contained in *Methods for Chemical Analysis of Water and Wastes* (U.S. EPA 1979). Sample volumes of 100 ml were filtered through pre-weighed 0.45-micron glass fiber filters. Filters and residue were then dried for approximately 24 hours at 105° C, transferred to a desiccator until cool, and then reweighed on an analytical balance. The change in dry weight divided by the sample volume was then determined and expressed in mg/l.

B. Total Phosphorus

Total P for both filtered and unfiltered samples was determined following the procedures outlined in Method 365.4 in *Methods for Chemical Analysis of Water and Wastes* (1979). Samples were digested for two and one-half hours in the presence of sulfuric acid, K_2SO_4 and $HgSO_4$. The resulting residue was cooled and diluted to 50 ml. Concentration of T-P was measured with an autoanalyzer.

C. Orthophosphorus

Orthophosphorus was determined in a similar manner with the procedure used to obtain T-P with the exception that acid digestion was not utilized and therefore organic P was not mineralized.

D. Atrazine and 2,4-D

A 900-ml subsample of water for pesticide analysis was decanted from each runoff sample after sediment settling was allowed for 48 hours. Sediment was separated from the remaining sample by filtering through medium flow filter under a vacuum. The atrazine in the water sample was extracted by shaking with 100 ml of methylene chloride amended with 5 to 10 g sodium sulfate. The extraction process was repeated to improve extraction efficiency. The methylene chloride was then drawn from the water subsample and prepared for gas liquid chromatography (GLC) analysis. 2,4-D was extracted by acidifying the remaining water sample and shaking with 100 ml ethyl ether. The ethyl ether was drawn from the water sample and methylated for GLC analysis (EPA 1980a). The atrazine was eluded from the sediment sample through a silica gel clean-up column with 250 ml of methylene chloride. The collected methylene chloride was then prepared for GLC analysis. Acidified acetone (250 ml) was added to the same column sample to extract 2,4-D (EPA 1980b). All extracts were analyzed with a GLC with a Ni^{63} electron capture detector. The GLC column contained 1.5% OV-17, 1.95% QF-1, 100/120 mesh, and Chromosorb-WHP, with a column temperature of 185° C, and inlet temperature of 215° C, a detector temperature of 350°C, and an N_2 carrier.

RESULTS AND DISCUSSION

Tables A-1 and A-2 of the Appendix contain the sediment and phosphorus concentrations of water quality samples analyzed during this study along with the plot discharge rate at the time each sample was taken. Tables 3 through 12 and Figures 1 through 4 were derived from those Appendix tables.

I. Runoff and Sediment Losses, 1985

As shown in Table 3, no-till was very effective in reducing runoff volume and sediment losses relative to the conventional tillage system. Total sediment and runoff losses from conventional tillage plots were 5034 kg/ha and 4.98 cm, respectively. Comparable sediment and runoff losses on the no-till plots were 92% and 67% less, respectively. Average sediment concentration in runoff from the conventional tillage plots varied from 1.4 (for R1) to 8.4 (for R3), the average sediment concentration of no-till.

The lower runoff volume from the no-till treatments can be attributed to increased surface retension and infiltration caused by the crop residue. The conventional system had no crop residue on the soil surface. The loose exposed soil of conventional tillage plots (in contrast to the firmer and more aggregated soil of the no-till plots), is easily detached and transported by raindrop impact and overland flow. This is evidenced by the higher sediment concentrations in runoff from the conventional plots (Table 3). Reduced runoff volumes from the no-till plots contributed to the low soil loss from these treatments. The 92% reduction in soil loss in no-till plots compares well with those presented by Angle et al. (1984) who reported an 88% reduction with no-till in Maryland.

The slopes of the experimental plots ranged from 8.3% to 15.1% with average values of 11.9% and 9.0% for no-till and conventional tillage plots, respectively. Neither runoff nor sediment showed any correlation with slope for either tillage system. These results are in agreement with those reported by Lembi et al. (1985) who suggested that other factors such as variability in soil texture, channel formation, and drainage pattern had more significant impacts on runoff than slope for a silty loam soil.

II. Phosphorus Yield, 1985

A. Phosphorus Concentration

The impacts of fertilizer application technique and tillage system on phosphorus concentration in runoff material are shown in Tables 4 and 5 and Figures 1 through 4. The form of P entering surface waters is very important in determining the quantity of P available to aquatic vegetation. Soluble P is readily available while sediment-bound P is not immediately available for uptake by algae. Soluble P is transported by runoff while sediment-bound P is adsorbed to soil particles and transported with eroded soil. However, there is a dynamic equilibrium between these two phases. Soluble P concentrations in runoff for all treatments exceeded the 0.1 ppm level believed to be necessary and sufficient for eutrophic algae growth.

The concentrations of O-P and sediment-bound P increased in the order of control < injection < surface-applied fertilizer for the conventional tillage plots (Table 4). The O-P and sediment-bound P concentrations for no-till plots were lowest for the control plots but the values for the injection method were higher than those from the surface application treatments. The concentrations of total P varied in the order of no fertilizer < injection < surface-applied fertilizer for both tillage systems. These results clearly show that injection of fertilizers reduces P concentrations in runoff. The increases in total P concentration due to lack of incorporation were 22.1% for no-till and 67.6% for conventional tillage plots. The effects of consecutive rain events on the P concentrations in runoff were inconsistent and no general trends were detected.

When averaged over all fertilizer application treatments, the concentrations of sediment-bound and total P were much higher with conventional tillage than with no-till (Table 5). Concentrations of sediment-bound P and total P for no-till averaged 84% and 74% less than conventional tillage, respectively. However, the concentration of O-P increased by 128% for no-till plots relative to conventional treatments. Since O-P is soluble and moves primarily with runoff water, the increase in O-P concentrations with no-till may be attributed to reduced dilution due to lower runoff volumes from these plots. The ratios of average sediment-bound P to O-P concentration were 1.2 and 17.6, for the no-till and conventional tillage, respectively. These results differ from those reported by Romkens et al. (1973) who concluded that the sediment-bound P fraction was greater from no-till than conventional tillage treatments. The much greater sediment-bound P concentration for conventional plots could be partially explained by the magnitude of the reductions obtained in runoff and sediment by no-till relative to the conventional tillage plots. While sediment losses from the no-till plots were reduced by 92%, runoff was reduced by only 67%; as a result, the concentrations of P in no-till were much lower than expected.

Ortho-P and T-P concentrations as a function of time after the start of runoff are shown in Figures 1 through 4 for R1. For the surface-applied fertilizer treatment, the concentrations of both O-P and T-P were initially high at the start of the rainfall, declined with time, and approached those of the control and injection treatments. The concentrations of O-P and T-P for the control and injection treatments were relatively stable. There were no significant differences in these concentrations between the injected and unfertilized treatments.

As shown in Figure 3, concentrations of O-P were generally higher for no-till than conventional tillage. The O-P concentration at the end of the first 6-minute period was 11.5 times the 57-minute concentration for no-till and 26.0 times the 57-minute concentration for conventional tillage plots. These ratios indicate a more rapid decline in the concentrations of O-P from the conventional tillage plots. The concentration of T-P, however, was much higher with conventional tillage than no-till as shown in Figure 4 because of high sediment-bound P losses. Total P concentrations also were much less variable over time.

B. Phosphorus Losses

Phosphorus loss in runoff as affected by tillage system and nutrient application method are shown in Table 6. The O-P losses for the no-till plots were 0.03, 0.24, and 0.15 kg/ha for the control, surface and injection application methods, respectively. The corresponding losses for the conventional plots were 0.12, 0.24, and 0.16 kg/ha. The O-P losses in runoff were greatest for surface application, intermediate for injection, and lowest for the control. The injection of fertilizer reduced O-P losses by 38.5% and 35.0% compared to surface application for no-till and conventional till, respectively. Tillage system did not affect O-P losses for either of the application methods. This suggests that tillage systems that control soil loss do not necessarily reduce losses of soluble nutrients such as O-P. Although the concentrations of O-P from the no-till plots were higher than those from the conventional plots (Figure 3), runoff reductions from the no-till plots compensated for the higher concentrations and total O-P losses were similar.

The subsurface injection of fertilizers reduced sediment-bound P losses relative to surface-applied fertilizer treatments by 37% for the no-till plots and 43% for the conventional tillage plots (Table 7). Tillage system had a much greater impact on sediment-bound P losses than the fertilizer application method. No-till reduced losses of sediment-bound P from injection and surface-applied fertilizer treatments by 92.6% and 93.3%, respectively, compared to the conventional tillage plots. The losses of sediment-bound P were higher for conventional tillage than no-till, regardless of fertilizer application method, mainly due to the greater losses of sediment from conventional plots. The sediment-bound P losses were larger than soluble P losses. Averaged across all fertilizer application treatments, the ratios of sediment-bound P to O-P were 1.4 for no-till and 17.0 for conventional tillage systems. These ratios indicate that for both tillage systems, sediment is the major source of P losses from agricultural lands. Therefore, conservation practices, such as no-till, should be nearly as effective for controlling P losses as for sediment.

Tillage system and fertilizer application method had a greater impact on T-P losses than O-P. As expected, the losses of T-P were least from the control plots.

The injection fertilizer application method (relative to the surface application treatments) reduced T-P losses by 54.8% for the no-till and 45.3% for conventional tillage systems. Differences in T-P losses among tillage systems were much greater for all fertilizer application methods. The no-till system reduced total P losses by 88.8% and 90.8% for surface-applied and injection fertilizer treatments, respectively, compared to the conventional system. Total P losses from the no-till plots during the three rainfall simulations were equivalent to 1.3% and 0.6% of the P applied to the surface and injected fertilizer treatment plots, respectively. The corresponding losses for the conventional tillage plots were 11.5% and 6.3%, respectively. Averaged across all fertilizer application treatments, an equivalent of 0.9% and 8.9% of the P applied to the plots were lost from no-till and conventional plots, respectively.

These results clearly demonstrate the effectiveness of no-till and the injection method of fertilizer application in reducing P losses from agricultural lands. The injection technique reduces the concentration of P in surface soil and, therefore, reduces P losses during runoff events.

III. Runoff and Sediment Losses, 1986

Average runoff and sediment losses for each tillage system and residue level are given in Table 8. Both runoff and sediment losses decreased as crop residue levels increased, regardless of the tillage system. Runoff volumes from the conventional tillage plots were about 12 times greater than from the no-till plots. For the conventional tillage plots, increasing the residue level from 0 to 1500 kg/ha resulted in a 49.2% reduction in runoff. The corresponding runoff reduction for the no-till plots at these residue levels was 95.6%. Comparing conventional plots with no residue to no-till with 1500 kg/ha residue resulted in a 99.4% reduction in runoff due to the synergistic effects of residue and no-till. The dramatic increase in runoff from the conventional plots reflects the lower infiltration rates due to poor structure and surface sealing.

Soil loss from the conventional tillage plots was much greater than that from no-till plots. The high soil loss from the conventional plots is the result of both higher runoff volumes and sediment concentrations. The high runoff rates increased the soil loss from these plots because of the increased sediment detachment and transport capacity of the overland flow. Averaged over the residue levels, the no-till plots reduced soil loss by 98.0% relative to the conventional tillage plots.

IV. Phosphorus Yield, 1986

A. Phosphorus Concentration

The average concentration data for O-P, sediment-bound P and T-P for the two tillage systems and three residue levels are summarized in Tables 9 and 10. The O-P concentrations for R1 were the highest and generally decreased with each consecutive run for both tillage systems. Increasing residue level from 0 to 750 kg/ha residue resulted in a decrease in average O-P concentration regardless of the tillage system. The decrease in concentrations can be attributed to the rapid decline of O-P in runoff with time (Baker and Laflen 1982). Another reason could be the delay in time for surface runoff to begin as residue level increased (Table 8).

As the crop residue level increased to 1500 kg/ha, the concentration of O-P increased compared to the lower residue levels. These results differ somewhat from those presented by Baker and Laflen (1982) who concluded that O-P concentration decreased as corn residue level increased. Several investigations (Tukey and Romberger 1959; Herber 1967; and Timmons et al. 1970) have reported that crop and crop residue are sources of soluble phosphorus. Barisas et al. (1978) also reported a positive correlation between average O-P concentration and percent residue cover for five of the six tillage systems they investigated. In this study the higher crop residue level of 1500 kg/ha treatment could have released more O-P compared to the 750 kg/ha treatment, thereby increasing the O-P concentrations in runoff from these plots. Lower runoff volumes at the 1500 kg/ha residue levels also can partially explain the higher O-P concentrations. Another possible explanation for the higher O-P concentration at 1500 kg/ha residue level is that the increased crop residue level may have increased P fertilizer interception and made it more susceptible to the washoff by rainfall and overland flow.

Sediment-bound P concentrations were much greater than O-P concentrations for all treatments except for no-till with 1500 kg/ha residue level. For no-till plots, there were no significant differences in sediment-bound P concentrations between the residue levels. However, for conventional tillage plots the concentrations decreased as residue levels increased. The average sediment-bound P concentrations for the 0 kg/ha residue level and conventional treatment were 3.03 times greater than those for 1500 kg/ha residue treatments. Total-P concentrations followed the same order as O-P. The T-P concentrations were highest for 0 kg/ha residue, least for 750 kg/ha residue, and intermediate for 1500 kg/ha residue treatment for both tillage systems. The ratios of the average T-P concentrations for 1500 kg/ha to those of 750 kg/ha were 9.1 for no-till and 2.0 for conventional tillage plots.

The average O-P concentrations in runoff from no-till plots were much higher than those from conventional plots. Ortho-P concentrations averaged about 5.5 times more for the no-till than for the conventional tillage plots. These results agree with those reported by Laflen and Tabatabai (1984) who reported average O-P concentrations of about five times more for no-till than for plow soil. Other researchers also found higher concentrations of soluble P in runoff from no-till than conventional tillage systems (McDowell and McGregor 1980; McDowell and Grissinger 1976; Holt el al. 1973; and Johnson et al. 1979). The increase in soluble P concentrations from no-till plots can be attributed, in part, to the insufficient suspended sediment in overland flow to sorb P from runoff water.

Sediment-bound P concentrations were greater with conventional tillage than with no-till. The reduction in sediment-bound P concentrations due to no-till was about 55% compared to conventional tillage treatments. Sediment-bound P concentrations for conventional tillage plots were higher than O-P concentrations, probably due to much higher sediment concentrations in runoff from these plots. The average sediment concentration in runoff was 1233 ppm for no-till and 5024 ppm for conventional till plots (Table 8). Total-P concentrations showed the same relative trend as those of O-P concentrations. Total-P concentrations from the no-till plots were 5.2 times higher than those from the conventional tillage plots. The differences in concentrations of total-P can be partially explained by the higher concentrations of soluble P from the no-till plots.

Romkens et al. (1973), in a study of surface runoff from five different tillage systems, concluded that all of the tillage systems yielded runoff water which exceeded the levels of O-P (0.1 ppm) necessary to support algal growth in lake water. Similarly, in this study runoff from both the conventional and no-till treatments contained O-P levels higher than 0.1 ppm. However, Romkens et al. (1973) also noted that O-P levels exceeding 0.1 ppm concentration are often encountered in runoff waters from unfertilized nonagricultural watersheds.

B. Phosphorus Losses

The losses of O-P, sediment-bound P, and T-P for different treatments are presented in Table 11. Residue level had the same effect on O-P losses as it did on O-P concentrations. O-P losses were greatest from no residue plots, intermediate from 1500 kg/ha, and least from 750 kg/ha residue treatments for both tillage systems. Factors that may have contributed to the greater O-P losses at 1500 versus 750 kg/ha of residue include: (a) more release of soluble P at the higher residue level; (b) insufficient suspended sediment to sorb P from solution; and (c) higher concentrations of O-P in runoff from these plots relative to other treatments.

Ortho-P losses as a percent of sediment-bound P losses ranged from 3.1% for the no-till with 750 kg/ha residue treatment to 32.8% for conventional tillage with no residue treatment. Residue level had no significant effect on the losses of sediment-bound P from the no-till plots. However, these losses decreased as residue level increased for the conventional tillage plots. These results are in agreement with the ones reported by Barisas et al. (1978), who concluded that losses of sediment-bound P decreased with increasing residue levels for five of the six tillage practices they studied.

Although the O-P concentrations from the no-till plots were much higher compared to the conventional plots the O-P losses were much greater for the conventional treatment. The greater loss of O-P from conventional plots can be explained by higher runoff losses from these plots relative to the no-till treatment. The no-till treatment reduced O-P losses from 8% (for no residue treatments) to 99% (for 750 kg/ha residue treatments) compared to the conventional tillage plots. Ortho-P losses were very low compared to the 46 kg/ha of P applied to the plots. The greatest losses recorded were 0.07 and 0.51 kg/ha for no-till and conventional tillage plots with no residue treatments, respectively. However, these losses represent only 0.15% and 1.1% of the fertilizer P applied.

The reduction in sediment-bound P losses due to no-till as compared to conventional tillage plots ranged from 91% for 1500 kg/ha residue level to 96% for no-residue treatments. The sediment-bound P losses were larger than O-P losses for both tillage systems. Averaged across all residue treatments, an equivalent of 0.15% and 2.20% of the T-P fertilizer applied was lost as sediment-bound P, for the no-till and conventional tillage systems, respectively.

Total-P losses were much lower from no-till than conventional tillage plots at all residue levels. The greatest losses recorded were 0.10 for no-till and 5.24 kg/ha for conventional tillage plots. Both of these losses occurred when no crop residue was present on the soil surface. These losses represent 0.22% and 11.40% of the total applied P fertilizer, respectively. The data indicate that with no crop residue, no-till reduced losses of T-P by 98% relative to the conventional tillage plots. In the presence of crop residue, the effectiveness of no-till in reducing T-P losses relative to conventional tillage systems was reduced.

The conditions simulated in our experimental setup typically occur in early fall or spring, when the fertilizer has just been applied to the soil and the potential for runoff is high. The P losses reported in this study may not constitute a serious economic loss to farmers, but they have significant potential for nutrient enrichment of runoff water from agricultural lands. This study clearly demonstrates that conservation tillage provides a means for reducing soil and P fertilizer losses, thereby reducing nonpoint source pollution problems originating from agricultural lands. A substantial reduction in runoff, sediment, and nutrient losses could be achieved through proper application of fertilizers and crop residue management with conservation tillage systems.

V. Pesticide Yield

A. Pesticide Concentrations in Runoff and Sediment

Concentrations of atrazine and 2,4-D in runoff for both tillage systems and all residue levels are presented in Table 13. Concentrations of atrazine ranged from

0.2 to 0.3 ppm, while those of 2,4-D varied from less than 0.01 to 0.02 ppm. These concentrations are well below the LC50 (lethal chronic dose for 50% mortality) for aquatic vertebrates such as rainbow trout (48 hours at 12.6 ppm atrazine and 24 hours at 250 ppm 2,4-D; Pimentel 1971).

Health Guidance Levels (HGL's), or acceptable daily intake values, adjusted to provide a safety factor for short-term exposure have been developed by the National Agricultural Chemicals Association (1985) for many pesticides. The HGL for 2,4-D is 1.25 ppm, which is well above the concentrations found in runoff from the plots. However, the HGL for atrazine is 0.38 ppm which is close to the maximum average atrazine concentration observed.

The concentration of atrazine in runoff as a function of residue level and rainfall event for no-till and conventional tillage systems are given in Figures 5 and 6, respectively. Atrazine concentrations generally decreased with time and increased with higher residue levels. Studies conducted by Baker et al. (1978) and Baker and Johnson (1979) reported similar trends with alachlor, cyanazine, and fonofos. The direct relationship between atrazine concentration and residue level is probably the result of pesticide washoff from the residue.

Concentrations of atrazine in runoff were generally higher for no-till than for the conventional tillage plots. Although not quantified in this experiment, the soil surface of the conventionally tilled plots was rougher than the no-till plots because tillage broke up the soil surface and mixed residue with the soil resulting in greater contact area between soil and the pesticides. The surface-applied atrazine was, therefore, better able to adsorb to soil particles on the conventionally tilled plots. Thus the losses of atrazine in surface runoff were reduced.

The concentrations of 2,4-D in runoff from the conventional tillage plots increased with residue level (Table 13). No general trend could be detected, however, for the concentrations of 2,4-D in runoff from the no-till treatments. When averaged over residue levels, the concentration of 2,4-D in runoff from the conventional plots was over twice as large as that from the no-till plots.

Atrazine and 2,4-D concentrations in sediment for each tillage system and residue levels also are given in Table 13. Concentrations of atrazine ranged from 0.08 ppm to 0.37 ppm, and 2,4-D concentrations varied from 0.05 ppm to 0.28 ppm. Although pesticides adsorbed to sediment are not as hazardous as pesticides in solution, the desorption process can release these chemicals into water where they may pose a health threat to humans and other organisms.

As shown in Table 13, atrazine concentrations in sediment were lowest at a residue level of 750 kg/ha, highest at 1500 kg/ha residue, and intermediate with no residue for both tillage systems. No general trends could be detected for the effect of residue level on the sediment losses of 2,4-D from the no-till plots; however, the 2,4-D concentration decreased with increased residue level on conventional tillage plots. These results differ from those of Baker and Laflen (1982) who reported that atrazine concentrations in sediment were similar for all residue levels in their study. Variation in conditions under which the two studies were conducted, such as soil type and rainfall amount and intensity, may explain these differences.

Atrazine and 2,4-D concentrations in sediment were generally higher during the first rainfall event than in subsequent events (data not shown). The lower concentrations during the later events may have been caused by washoff and infiltration during previous events. In addition, greater runoff volumes from runs R2 and R3 diluted the atrazine concentration.

The concentrations of both atrazine and 2,4-D in sediment from the no-till plots were greater than those from conventional tillage treatments (Table 13). The increases in concentrations in no-till plots relative to the conventional tillage plots were 131% for atrazine and 246% for 2,4-D. Baker and Johnson (1979) reported similar results for atrazine and alachlor with the concentrations from conservation tillage plots averaging twice those from conventional tillage plots. The average 2,4-D concentrations in runoff were 1% and 12% of those in sediment from no-till and conventional tillage plots, respectively. The corresponding values for atrazine were 117% and 215%.

B. Pesticide Losses in Runoff and Sediment

Despite the higher concentration of atrazine and 2,4-D in the sediment from no-till plots, total pesticide losses were greater from the conventionally tilled plots. The greater losses from those plots could be attributed to the increased sediment loss from these plots. A graphic representation of the data for each tillage system and residue level is given in Figure 7. Concentrations of atrazine in sediment from the no-till plots were 187% for 750 kg/ha residue to 251% for 1500 kg/ha residue — higher than those from the conventional plots. The corresponding values for 2,4-D ranged from 215% for 0 kg/ha residue to 578% for 750 kg/ha residue.

Atrazine and 2,4-D losses in runoff and sediment for each tillage system and residue level are presented in Table 14. Higher residue levels caused lower atrazine and 2,4-D losses in runoff and sediment for all cases except for 2,4-D in runoff water from the conventionally tilled plots. The 2,4-D losses in runoff water under conventional tillage followed an opposite trend. Although the concentration of 2,4-D in runoff water from conventionally tilled plots increased by 16 times (comparing no residue to 1500 kg/ha residue), runoff losses were reduced by only 2 times. Apparently, the reduction in 2,4-D losses due to decreased runoff volume from the no-till plots was negated by higher pesticide concentrations in the water.

The losses of atrazine and 2,4-D in sediment were usually greatest during either the second or the third rainfall event (Figure 9). These results are comparable to those presented by Baker et al. (1978). Greater losses of pesticides were expected during the later rainfall events because higher soil moisture contents resulted in increased runoff and larger sediment losses. The fact that the differences between losses during the first and third runoff events were greater on plots with residue cover may indicate that atrazine was first washed off the residue and was then transported downslope by subsequent surface runoff.

Both atrazine and 2,4-D losses were greater in runoff water than in sediment (Table 14). This result was anticipated since the volume of water lost was much greater than the volume of sediment. Our results follow those reported by Baker and Johnson (1979) who concluded that from 80% to 90% of the average atrazine losses were soluble rather than sediment-bound. Data presented in Table 14 indicate that the fractions of atrazine lost in sediment were 0.2% of the total loss for both no-till and conventional tillage plots. The corresponding values for 2,4-D were 8.3% and 7.2%.

Also presented in Table 13 are the overall losses of atrazine and 2,4-D for each tillage system as a percentage of the amount applied. The percent losses were greater with conventional tillage for both atrazine and 2,4-D. No-till reduced total pesticide losses as a result of both decreased runoff and decreased erosion, even though the pesticide concentrations were generally higher for these treatments. For 2,4-D, the average losses were 0.02% and 0.3% of that applied to the no-till and conventional tillage plots, respectively. The corresponding values for atrazine were 0.3% and 2.9 %. These values are similar in magnitude to those given by other researchers (Baker and Johnson 1979 and Hall et al. 1972).

Percent reductions in pesticide losses due to no-till relative to the conventional tillage plots are presented in Table 15. In all cases except one (2,4-D runoff losses for no residue), no-till resulted in significant reductions in pesticide losses. Averaged over the residue levels, no-till reduced losses of atrazine by 90% and 2,4-D by 92%. As indicated in Table 14, there is a positive relationship between the percent reduction and residue level for total losses of both pesticides. Maximum reductions in losses of atrazine (98%) and 2,4-D (99%) were achieved with no-till and a crop residue level of 1500 kg/ha. These reductions are comparable to results achieved with no-till by Hall et al. (1983).

Percent losses are larger for atrazine than for 2,4-D in both the dissolved and adsorbed phases. Atrazine is much less soluble in water than 2,4-D, leading one to anticipate larger percent losses of 2,4-D in runoff. 2,4-D loss may have been reduced as a result of volatilization. A good indicator of volatilization is vapor pressure. Pesticides having large vapor pressures are more susceptible to volatilization than those with lower vapor pressures. The surface application of these pesticides, coupled with the large amounts of residue cover, suggests that volatilization losses may have claimed a significant percentage of the non-adsorbed 2,4-D, which then would reduce the losses of 2,4-D in runoff.

SUMMARY AND CONCLUSIONS

A rainfall simulator was used to study the effects of tillage system, crop residue level and fertilizer application technique on the losses of P and pesticides from agricultural land. P was applied at the rate of 46 kg/ha. Atrazine and 2,4-D were applied at the rates of 2.24 and 0.56 kg/ha of active ingredients, respectively. A total of 10.16 cm of rainfall with an intensity of 5.0 cm/hr was applied to 12 field plots. Water samples were collected from H-flumes at the base of each plot and later analyzed for sediment, nutrient, and pesticide content. The following conclusions were drawn:

1. The no-till system reduced soil loss by up to 98% and runoff to 92% relative to the conventional tillage system.

2. Runoff and sediment losses increased as crop residue level decreased, regardless of the tillage system. Increased residue and no-till had a combined effect on reducing runoff and soil losses. The highest reduction for both runoff and erosion occurred with no-till and the highest residue level. Greater soil losses from conventional plots were attributed to the higher runoff volumes and sediment concentrations.

3. The concentration of T-P was highest with surface-applied fertilizer, intermediate with injected treatments, and least with the control plots for both conventional and no-till systems. The increase in T-P concentrations due to lack of incorporation were 22.1% for no-till and 67.6% for conventional tillage systems. Soluble P concentrations in runoff from all treatments exceeded the 0.1 ppm level believed to be sufficient for eutrophic algae growth.

4. Soluble P loss in runoff water followed the order of surface > injection > no fertilizer treatments for both tillage systems. The injection method reduced O-P losses by 38.5% for the no-till and 35.0% for conventional tillage plots.

5. The no-till system reduced T-P losses by 89% for surface-applied and 91% for injection fertilizer treatments, compared to the conventional system. Averaged across all fertilizer application treatments, an equivalent of 0.9% of the T-P applied to the plots was lost from the no-till and 8.9% from conventional tillage.

6. For both conventional tillage and no-till systems, increasing crop residue level from 0 to 750 kg/ha caused a decrease in average O-P concentration. However, as the crop residue level increased to 1500 kg/ha, the concentration of O-P increased compared to the lower residue levels.

7. Both O-P and T-P losses were highest from the no residue treatments, intermediate with 1500 kg/ha residue, and lowest with 750 kg/ha residue treatments. The higher P losses from the 1500 kg/ha, relative to 750 kg/ha residue treatments, were attributed to: (a) higher P leaching from the crop residue of 1500 kg/ha treatment; and (b) insufficient suspended sediment to sorb P from solution for the 1500 kg/ha residue level.

8. Atrazine concentrations in runoff water increased with increasing residue level, regardless of tillage treatment. Concentrations of atrazine in sediment were lowest at 750 kg/ha residue level and highest with 1500 kg/ha of residue for both tillage systems. Concentrations of 2,4-D in runoff water increased with increasing residue levels for conventional tillage. However, no relationship between concentrations of atrazine, in either runoff or sediment, and residue density was observed for no-till.

9. Concentrations of both atrazine and 2,4-D in sediment and atrazine in runoff water were higher for no-till than for conventional treatments.

10. The major carrier of both pesticides was water. Total atrazine losses, as percent of applied, were 2.9 for conventional tillage and 0.3 for no-till. The corresponding values for 2,4-D were 0.3 for conventional and 0.02 for no-till.

11. Total losses of both atrazine and 2,4-D were lower from no-till than from conventional tillage plots. Overall reductions in loading due to no-till were 90% for atrazine and 93% for 2,4-D.

The results of our study indicate that no-till provides a means for reducing runoff, phosphorus, soil, and pesticide losses, thereby reducing potential nonpoint source pollution from agricultural lands.

FIGURES

FIGURE 1
Concentration of Ortho-P in Runoff versus Time, R1, 1985

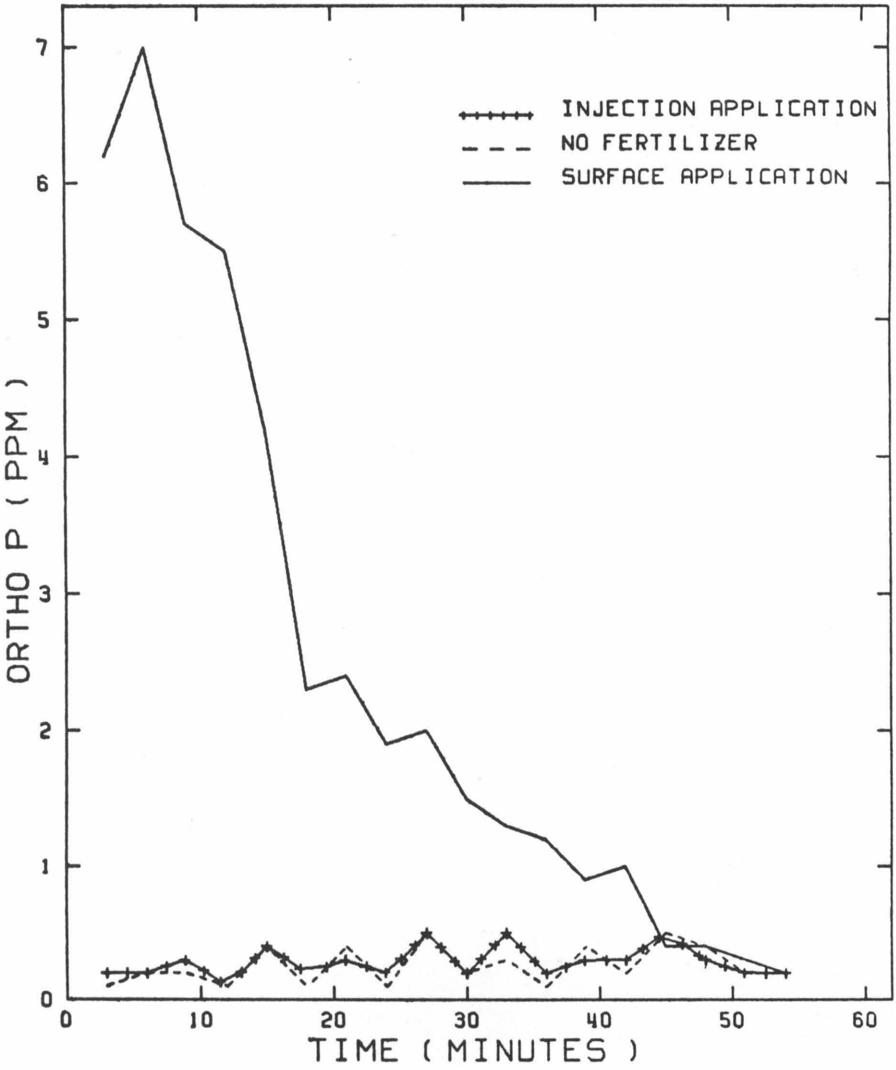


FIGURE 2
Concentration of Total-P versus Time, R1, 1985

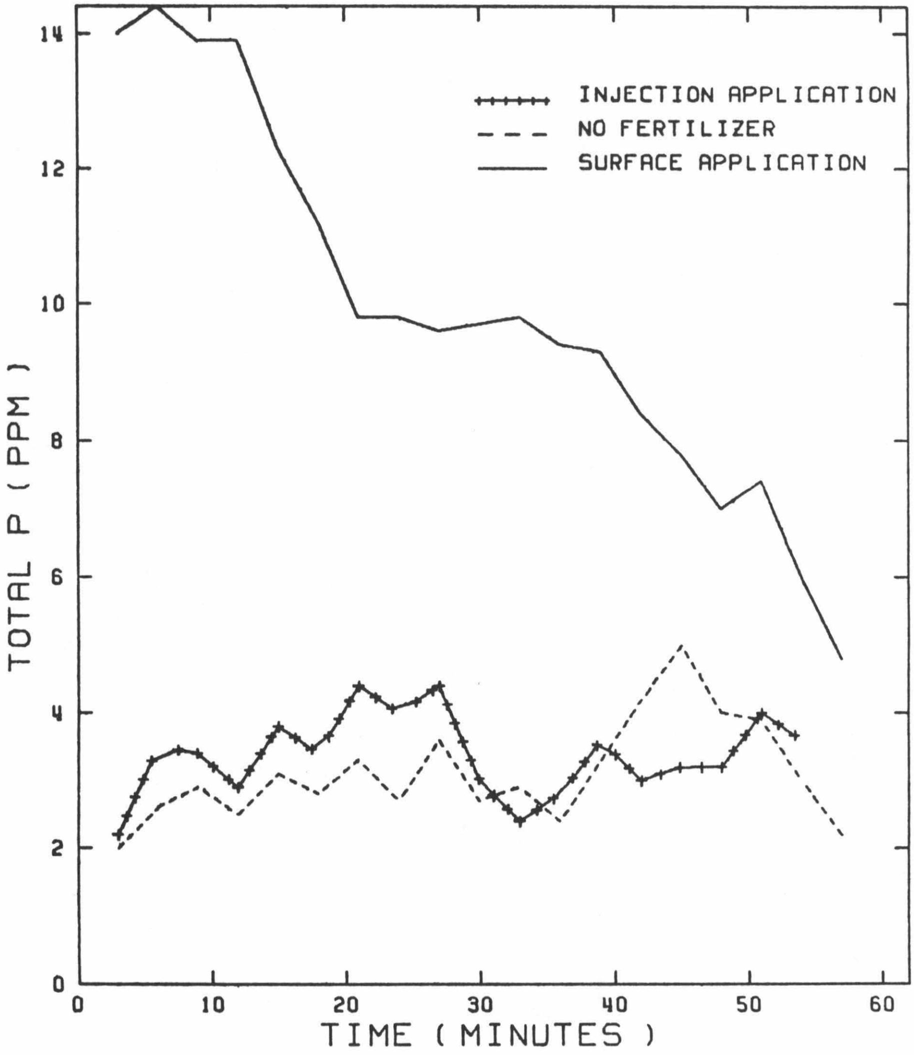


FIGURE 3
Effect of Tillage System on Ortho-P Concentration, R1, 1985

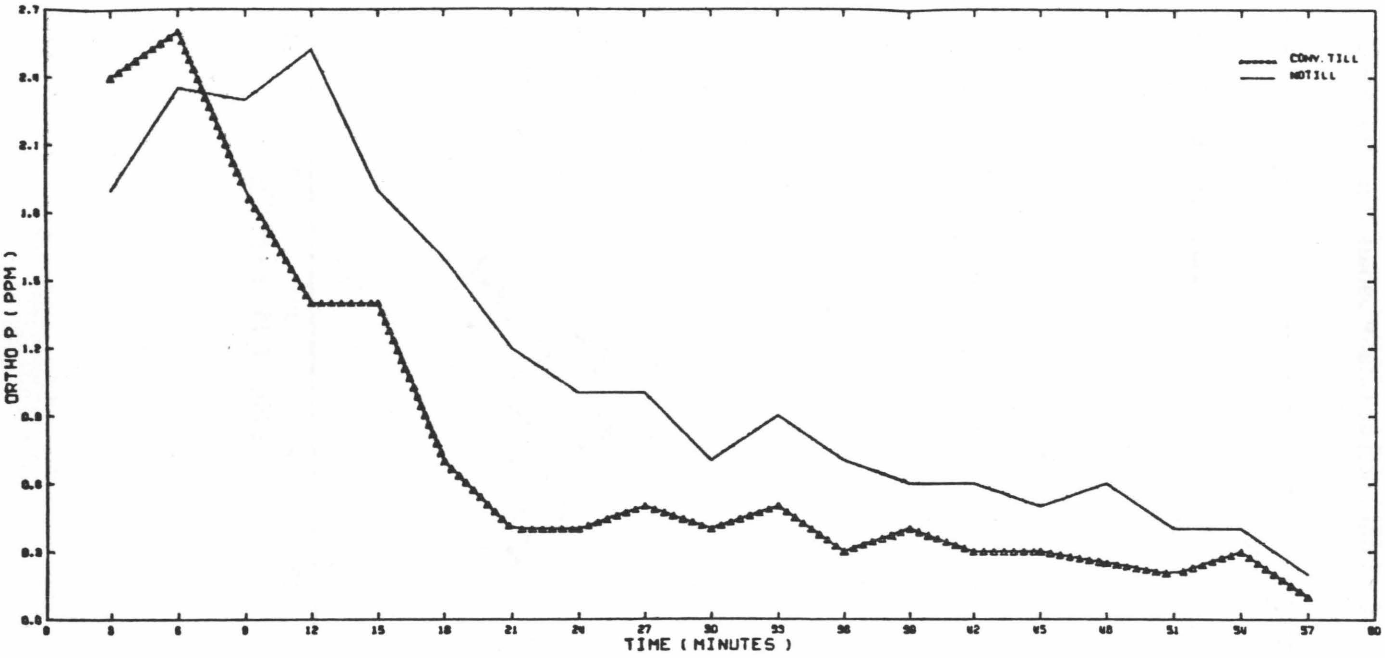


FIGURE 4
Effect of Tillage System on Total-P Concentration, R1, 1985

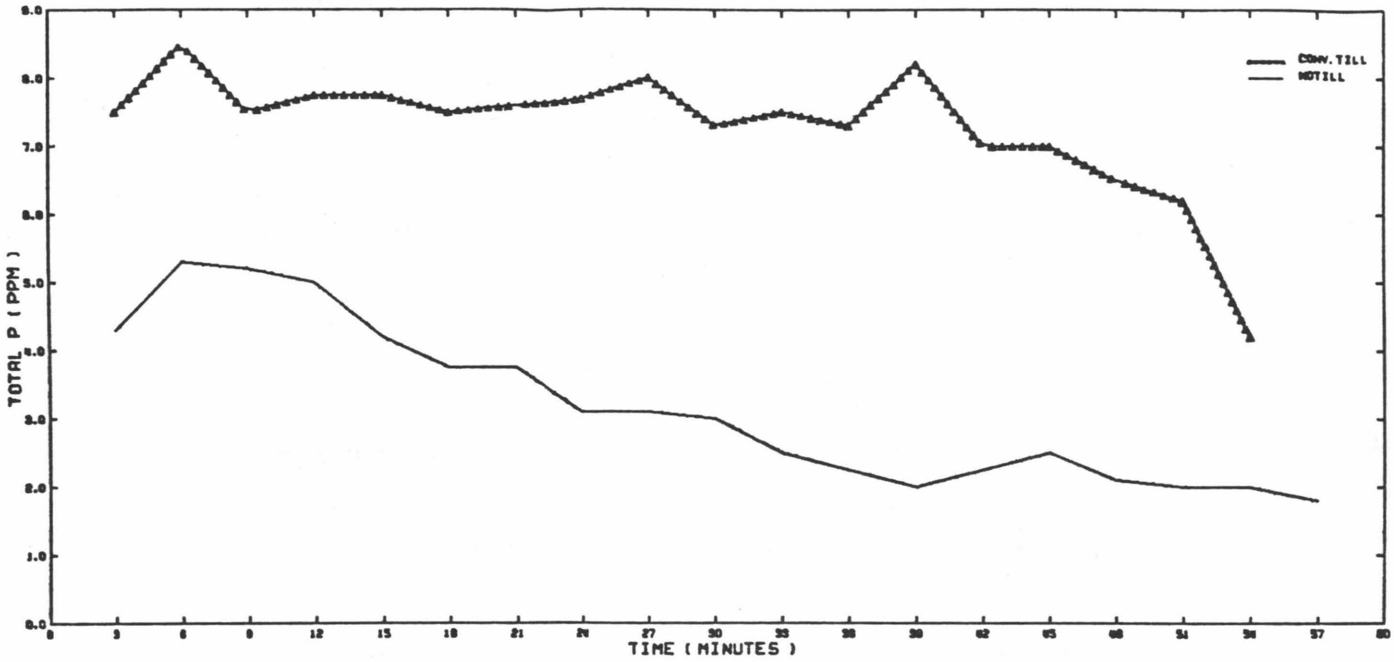


FIGURE 5
Atrazine Concentrations in Runoff from No-till Plots as Affected by Residue Level and Rainfall Event

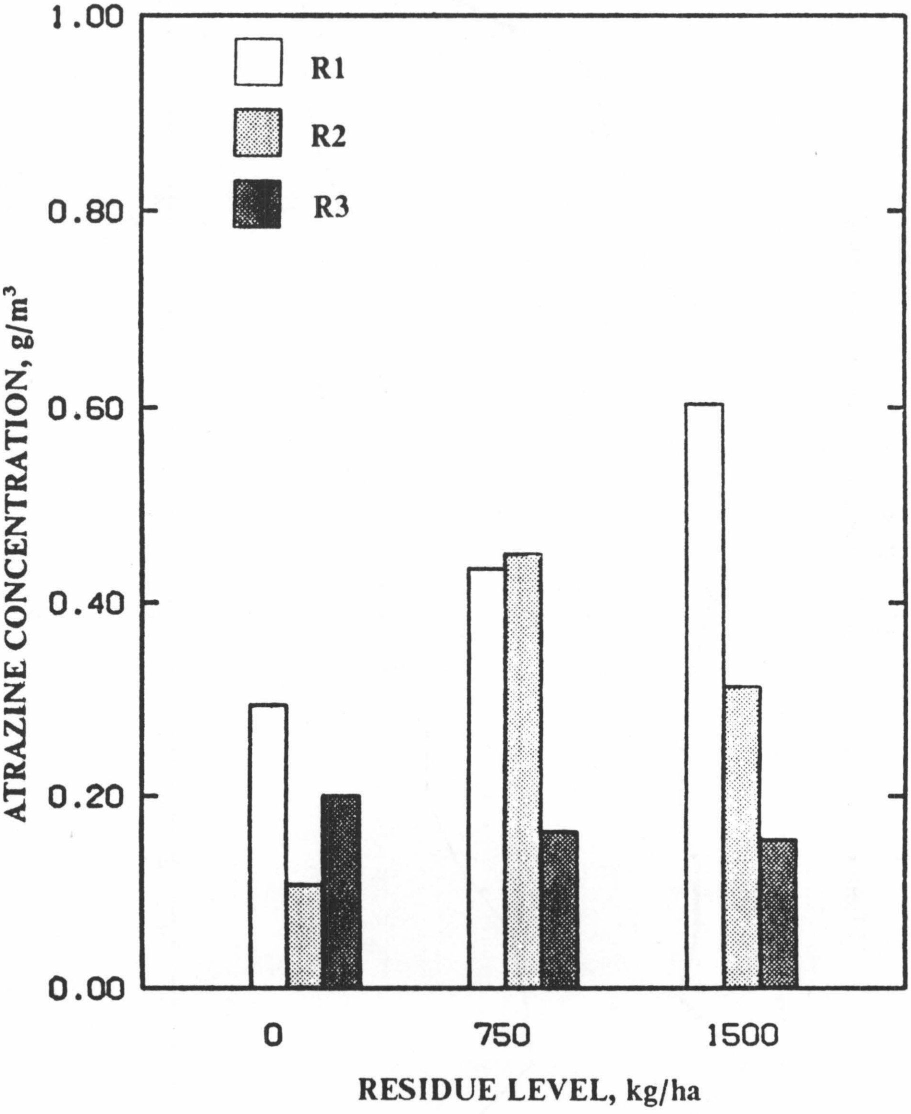


FIGURE 6
Atrazine Concentrations in Runoff from Conventional Tillage Plots as Affected by Residue Level and Rainfall Event

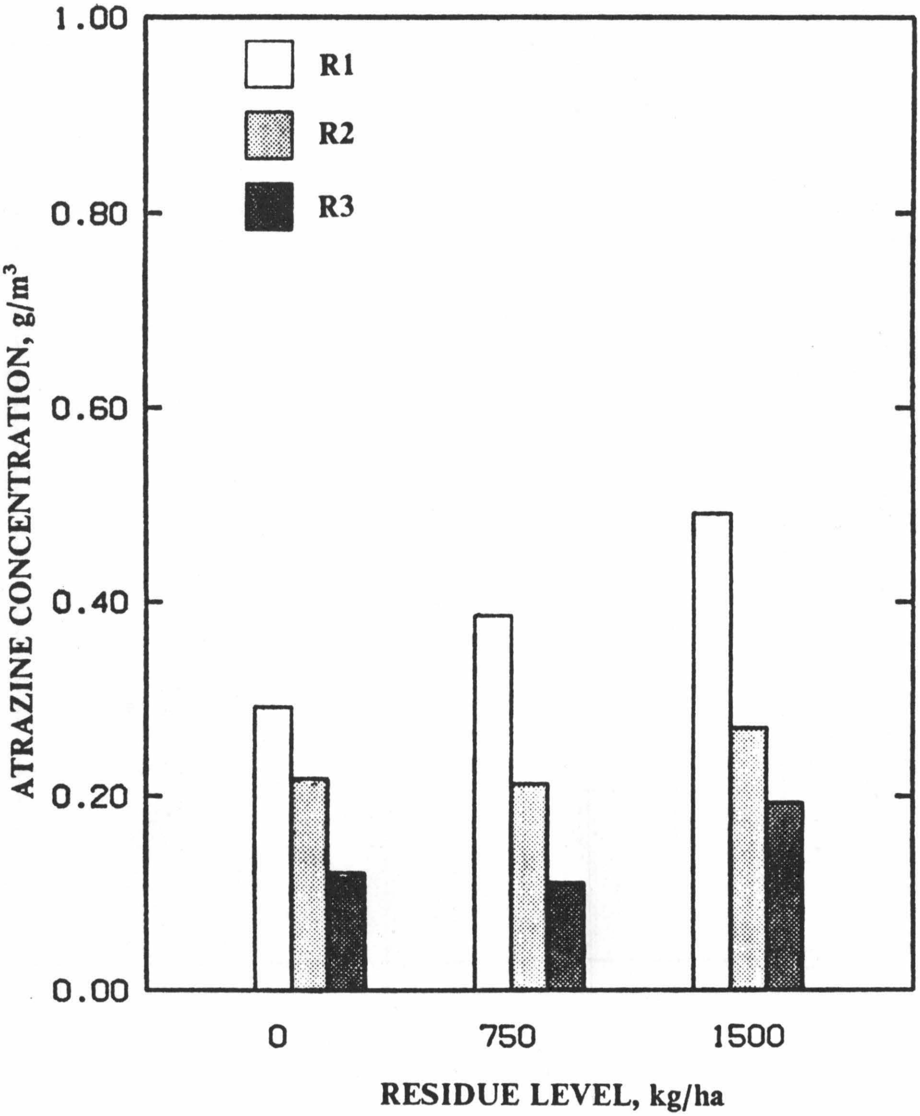
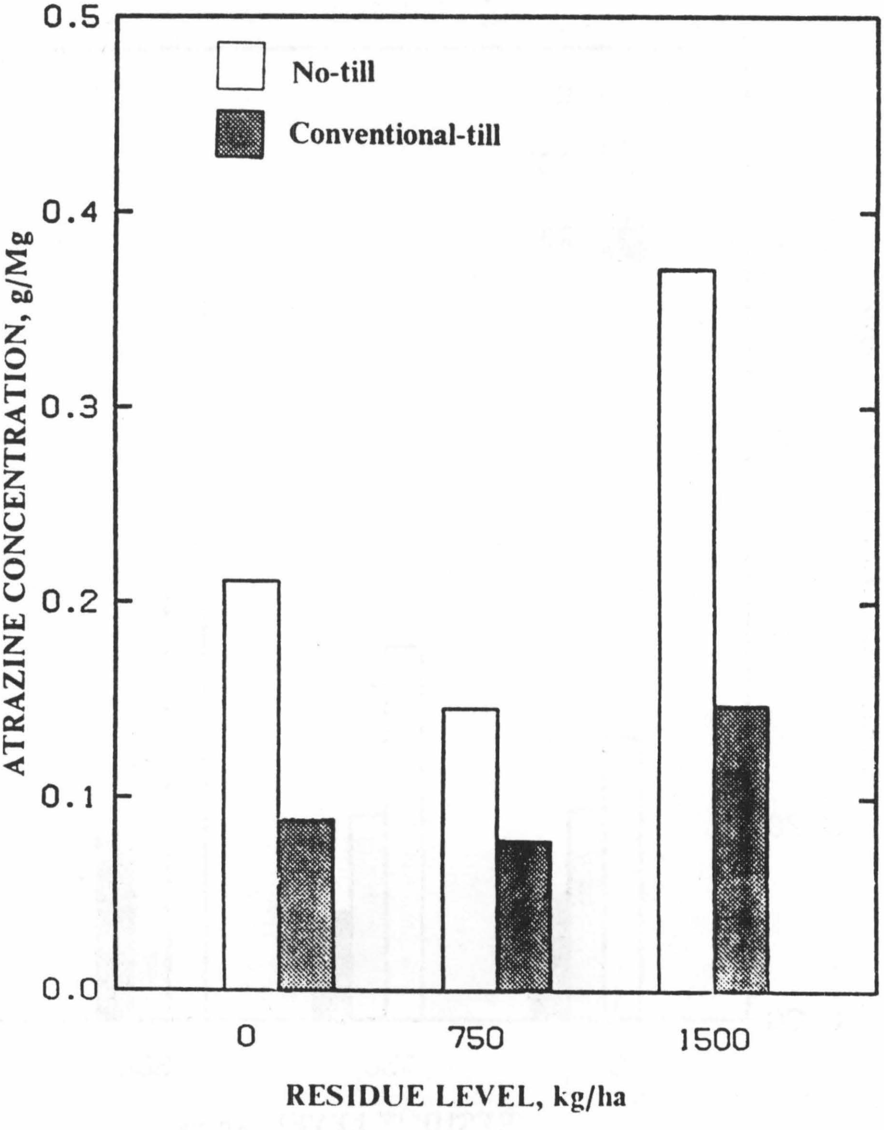
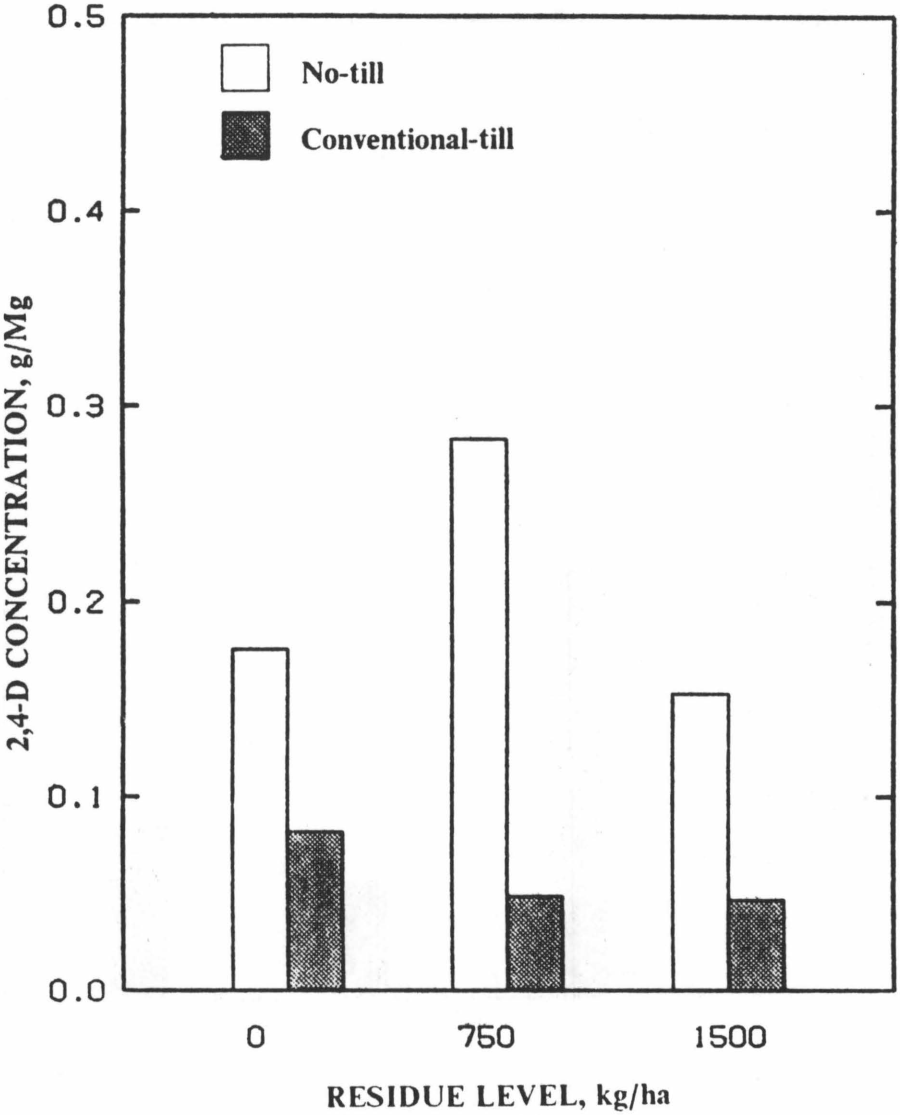


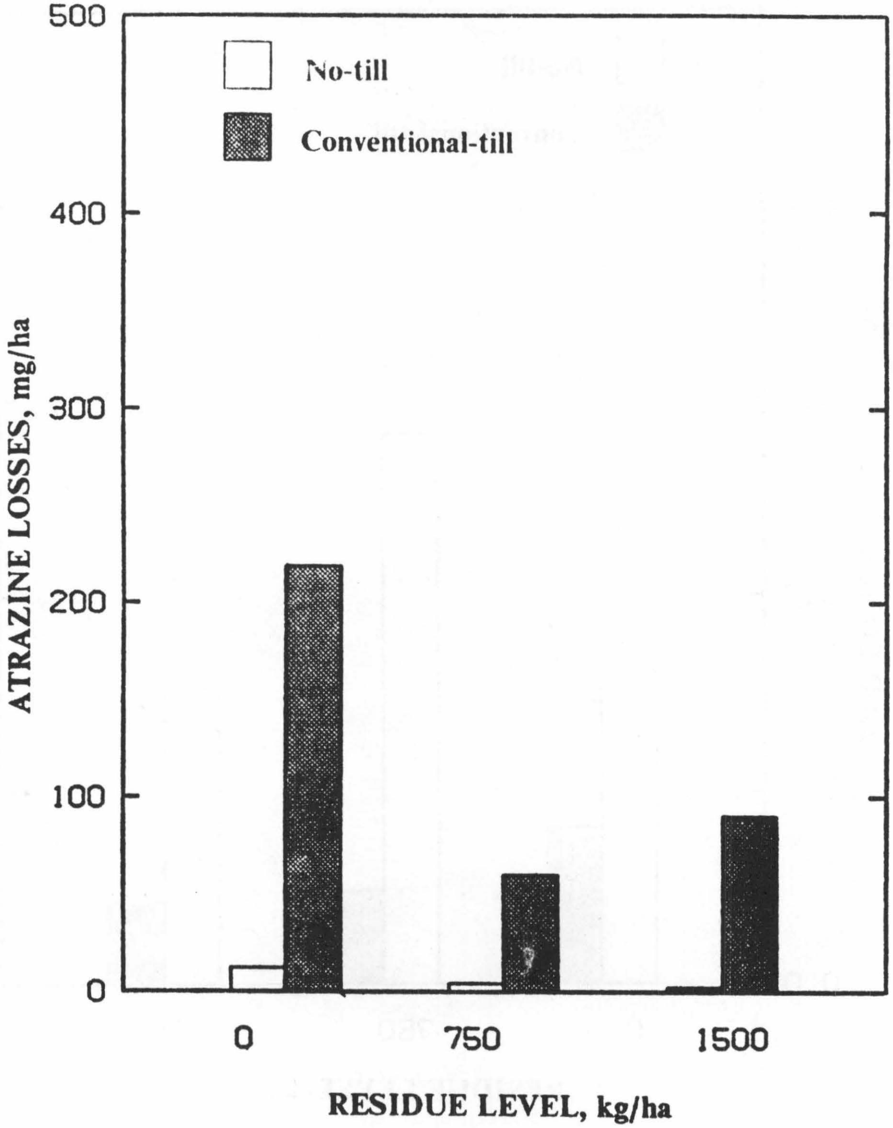
FIGURE 7
Concentrations of Atrazine and 2,4-D in Sediment for Different Tillage Systems and Crop Residue Levels





0.5
0.4
0.3
0.2
0.1
0.0
No-till
Conventional-till
2,4-D CONCENTRATION, g/Mg
0
750
1500
RESIDUE LEVEL, kg/ha

FIGURE 8
Sediment Losses of Atrazine and 2,4-D for Different
Tillage Systems and Crop Residue Levels



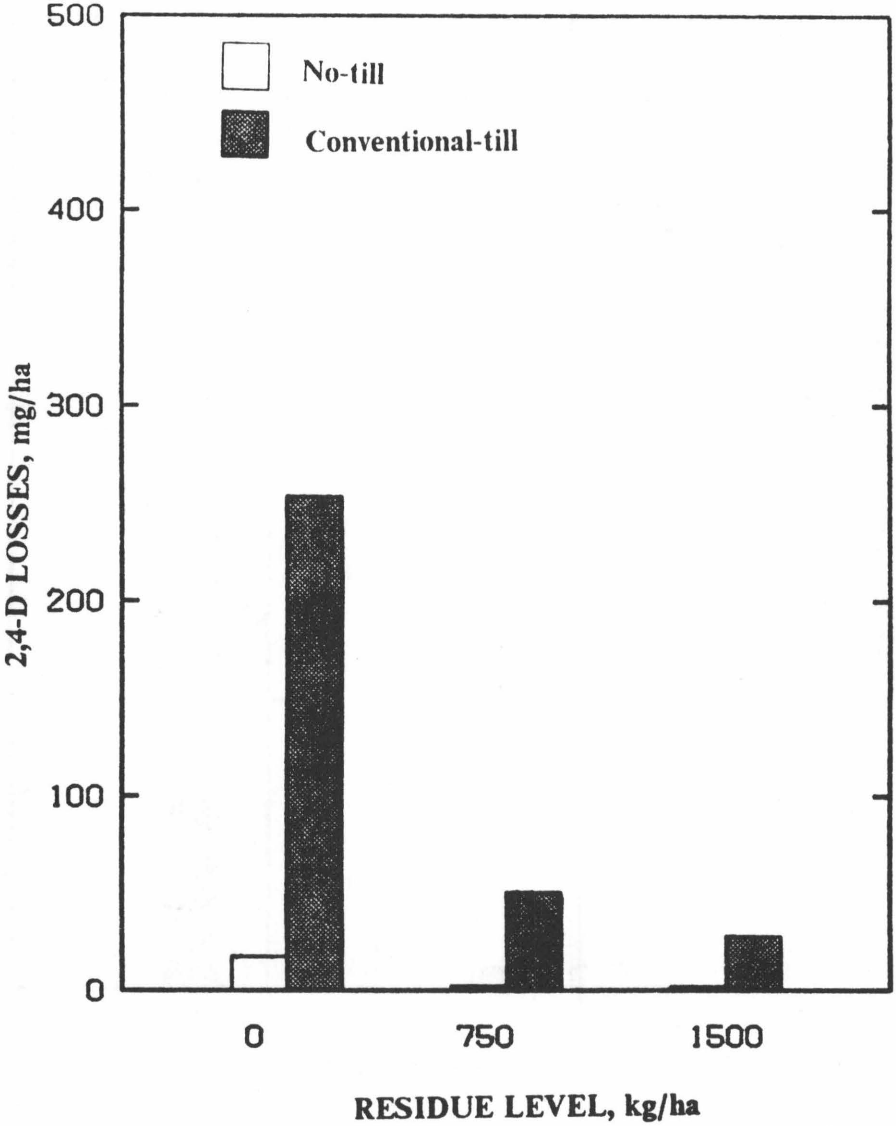
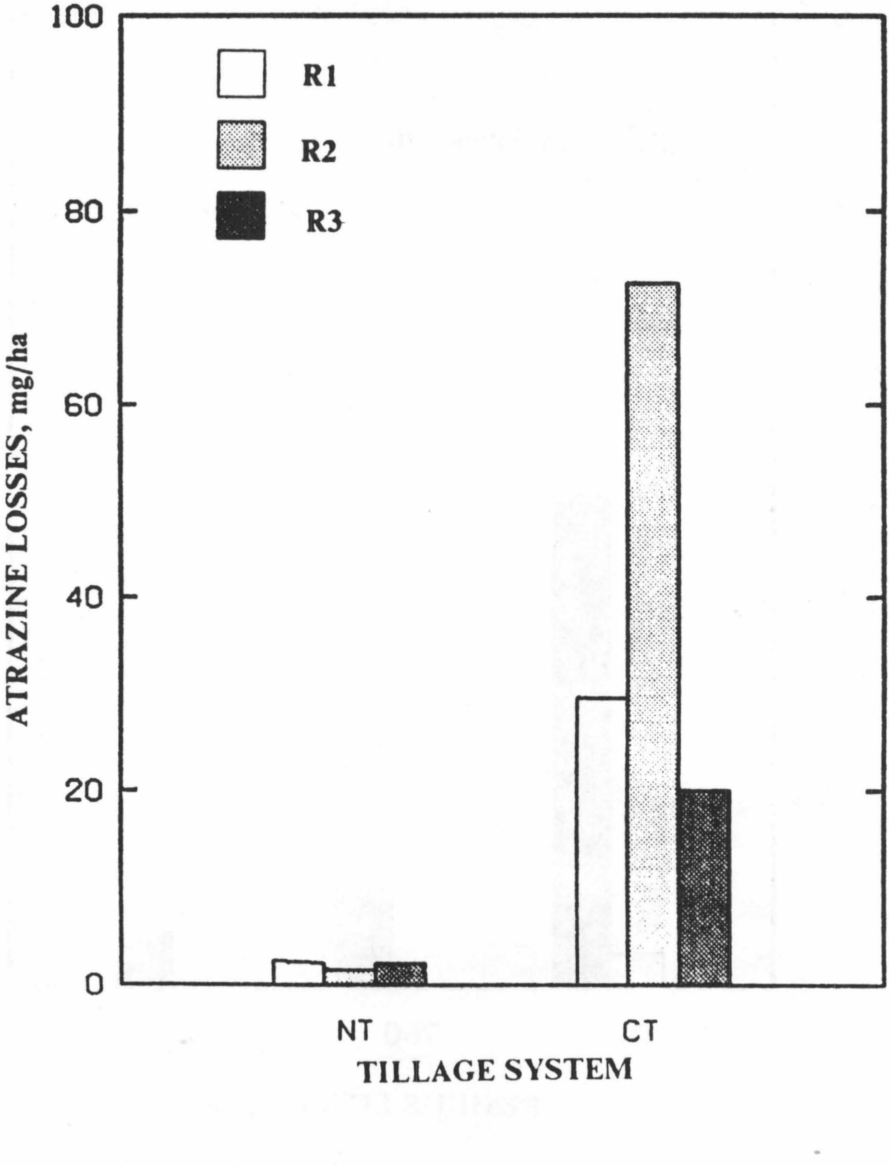
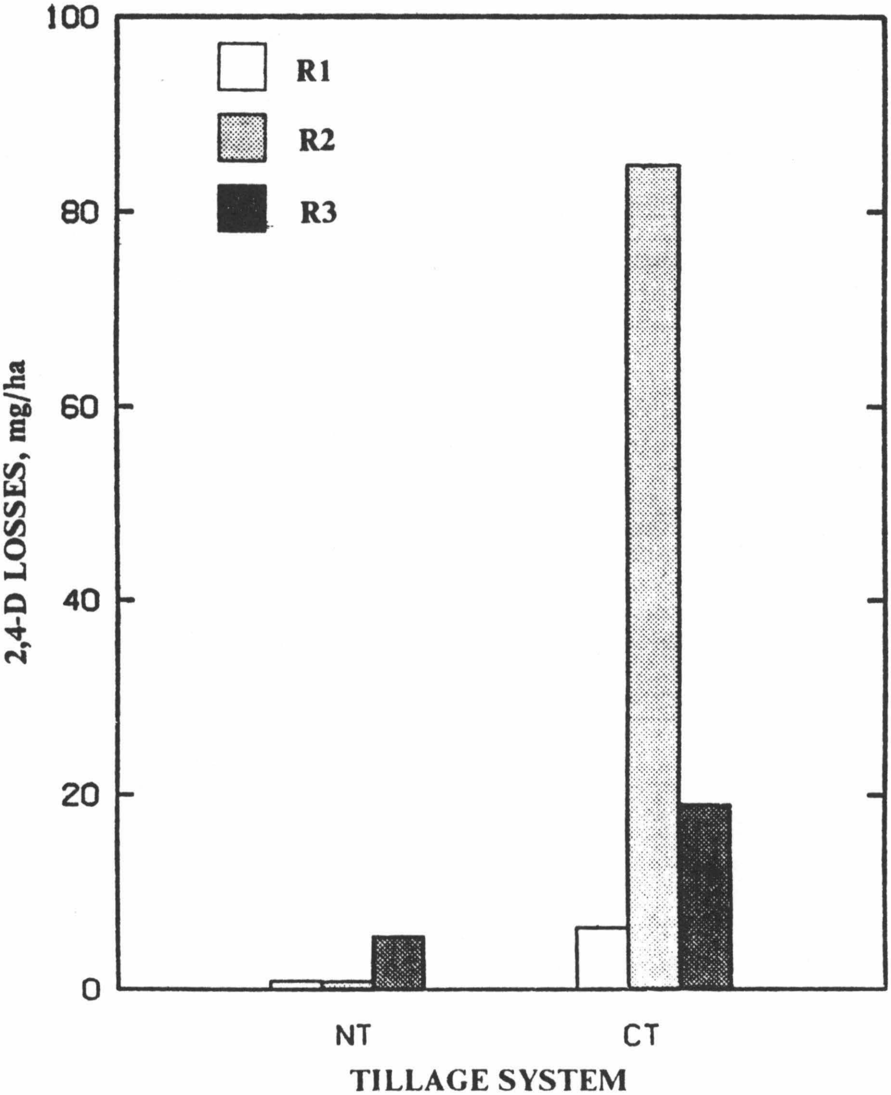

500
400
300
200
100
0
No-till
Conventional-till
2,4-D LOSSES, mg/ha
0
750
1500
RESIDUE LEVEL, kg/ha

FIGURE 9
Sediment Losses of Atrazine and 2,4-D for Different Tillage Systems and Rainfall Events




100
80
60
40
20
0
2,4-D LOSSES, mg/ha
R1
R2
R3
NT
CT
TILLAGE SYSTEM

TABLES

TABLE 1
Plot Characteristics and Treatments

	QF1	QF2	QF3	QF4	QF5	QF6
Tillage Treatments, 1985	NT	NT	NT	NT	NT	NT
Tillage Treatments, 1986	NT	CT	NT	CT	NT	CT
Residue Level, kg/ha, 1985	0	1500	1500	0	750	750
Slope, %	9.2	9.0	9.9	14.1	15.1	14.0
	QFA	QFB	QFC	QFD	QFE	QFF
Tillage Treatments, 1985	CT	CT	CT	CT	CT	CT
Tillage Treatments, 1986	NT	CT	CT	NT	CT	NT
Residue Level, kg/ha, 1985	1500	0	1500	750	750	0
Slope, %	9.7	8.9	9.1	9.4	8.6	8.3

Fertilizer application rate:	— nitrogen 147 kg/ha phosphorus 46 kg/ha
Pesticide application rate:	— atrazine 2.24 kg/ha 2,4-D 0.56kg/ha
Soil type:	— Groseclose silt loam
Bulk density:	— 1.39 g/cm^3
% sand:	— 17.9
% silt:	— 58.9
% clay:	— 23.2
% organic matter:	— 3.7
Simulated rainfall intensity:	— 50 mm/hr
Simulated rainfall duration:	— Run 1 (R1), 60 min — Run 2 (R2), 30 min — Run 3 (R3), 30 min

NT = No-till
CT = Conventional till

TABLE 2
Rainfall Simulator Performance

	QF 1		QF 2		QF 3		Mean QF1-QF3	
Run	Rainfall (mm)	U.C. %*	Rainfall (mm)	U.C. %	Rainfall (mm)	U.C. %	Rainfall (mm)	U.C. %
R1	51.7	91.9	50.3	94.0	49.2	94.4	50.4	93.8
R2	27.0	94.3	27.0	90.9	25.8	89.4	26.6	91.5
R3	25.5	96.2	26.3	86.5	24.9	96.6	25.6	93.0
	QF 4		QF 5		QF 6		Mean QF4-QF6	
	Rainfall (mm)	U.C. %	Rainfall (mm)	U.C. %	Rainfall (mm)	U.C. %	Rainfall (mm)	U.C. %
R1	48.7	94.3	49.2	94.6	50.7	96.1	49.5	95.0
R2	26.3	92.1	25.3	90.1	26.5	93.2	26.0	91.8
R3	26.7	88.0	24.7	85.2	27.2	89.7	26.2	87.0
	QF A		QF B		QF C		Mean QFA-QFC	
	Rainfall (mm)	U.C. %	Rainfall (mm)	U.C. %	Rainfall (mm)	U.C. %	Rainfall (mm)	U.C. %
R1	49.0	91.8	48.7	88.1	50.8	92.5	49.5	90.8
R2	24.6	92.6	25.7	95.2	23.4	95.1	24.6	94.3
R3	24.9	93.0	25.7	93.9	23.6	94.7	24.7	93.0
	QF D		QF E		QF F		Mean QFD-QFF	
	Rainfall (mm)	U.C. %	Rainfall (mm)	U.C. %	Rainfall (mm)	U.C. %	Rainfall (mm)	U.C. %
R1	47.1	93.5	50.3	87.9	51.2	92.3	49.5	91.0
R2	26.9	91.1	24.9	91.0	26.4	94.7	26.1	92.0
R3	28.8	85.5	24.0	91.5	26.8	83.8	26.5	86.0

PLOT

* U.C. = Uniformity Coefficient

TABLE 3
Effects of Tillage System on Soil Loss, Runoff, Sediment Concentration, and Peak Runoff Rate

						Percent Reduction Due to No-till		
Tillage Systems	Run	Soil Loss (kg/ha)	Runoff (cm)	Ave. Sed. Concent. (ppm)	Max. Peak Runoff Rate (cm/hr)	Soil Loss	Runoff Volume	Peak Flow Rate
CT	R1	1093	1.9	5781	4.1	—	—	—
	R2	1894	1.4	13629	4.0	—	—	—
	R3	2047	1.7	12273	4.2	—	—	—
	Total	5034	5.0	—	—	—	—	—
NT	R1	221	0.50	4248	1.9	80	73	53
	R2	58	0.30	1812	2.5	97	77	36
	R3	116	0.80	1462	2.4	94	54	43
	Total	394	1.60	—	—	92	67	—

TABLE 4
Effects of Fertilizer Application Method on the Average Concentration of Phosphorus in Runoff, 1985

Tillage System	Applic. Method	Run	Soluble P (O-P)	Sediment-bound P	Total P
				ppm	
NT	Control	R1	0.27	1.56	0.71
		R2	0.33	1.03	1.65
		R3	0.24	0.45	1.06
		Average	0.27	0.34	1.00
	Inject.	R1	2.18	1.10	1.63
		R2	0.27	1.07	1.53
		R3	0.50	1.79	2.35
		Average	1.11	1.37	1.90
	Surface	R1	1.82	1.95	4.05
		R2	0.47	0.30	1.42
		R3	0.37	0.67	1.41
		Average	0.89	1.10	2.32
CT	Control	R1	0.32	2.98	3.47
		R2	0.24	3.76	4.40
		R3	0.13	4.42	4.38
		Average	0.23	3.65	4.38
	Inject	R1	0.49	5.04	5.52
		R2	0.29	4.23	5.20
		R3	0.18	6.58	7.33
		Average	0.32	5.33	5.95
	Surface	R1	0.50	9.09	10.37
		R2	0.30	7.58	9.44
		R3	0.54	8.64	9.98
		Average	0.46	8.53	9.97

TABLE 5
Effects of Tillage System on the Average Concentration of Phosphorus in Runoff, 1985

Tillage System	Run	Soluble P (O-P)	Sediment-bound P	Total-P
		ppm	ppm	ppm
NT	R1	1.42	1.54	2.14
	R2	0.36	0.91	1.53
	R3	0.37	0.97	1.61
	Average	0.72	1.14	1.76
CT	R1	0.44	5.24	6.54
	R2	0.24	1.45	6.26
	R3	0.28	2.21	7.56
	Average	0.32	2.97	6.78

TABLE 6
Effects of Tillage System and Fertilizer Application Method on Phosphorus Losses in Runoff, 1985.

		SOLUBLE-P (O-P)			TOTAL-P		
Tillage System	Run	Control	Surf.	Inj.	Control	Surf.	Inj.
		kg/ha					
NT	R1	0.007	0.167	0.106	0.014	0.355	0.079
	R2	0.006	0.026	0.008	0.027	0.076	0.040
	R3	0.017	0.046	0.033	0.066	0.160	0.148
	Total	0.030	0.239	0.147	0.107	0.591	0.267
CT	R1	0.055	0.107	0.088	0.587	2.242	0.959
	R2	0.036	0.045	0.039	0.584	1.377	0.668
	R3	0.024	0.091	0.031	0.974	1.675	1.269
	Total	0.115	0.243	0.158	2.145	5.294	2.896

TABLE 7
Effects of Tillage System and Fertilizer Application Method on Losses of Sediment-bound Phosphorus, 1985

Tillage System	Run	SEDIMENT-P Control	SEDIMENT-P Surface	SEDIMENT-P Injected
		kg/ha		
NT	R1	0.003	0.189	0.054
	R2	0.016	0.034	0.028
	R3	0.025	0.081	0.111
	Total	0.044	0.304	0.193
CT	R1	0.486	1.966	0.877
	R2	0.508	1.124	0.578
	R3	0.808	1.465	1.157
	Total	1.802	4.555	2.612

TABLE 8

Effects of Residue Level and Tillage System on Runoff and Sediment Losses, 1986

Residue & Tillage Treatment	Runoff Volume (cm)	Runoff* Rate (cm/hr)	Time Runoff Began (min)	Sediment Losses (kg/ha)	Sediment Conc. (ppm)	Percent Reductions Due to No-till			
						Runoff Volume	Peak Runoff	Sediment Losses	Sediment Conc.
0 kg/ha									
NT	0.45	1.70	8	72	1593	87	67	97	80
CT	3.55	5.10	2	2812	7923	—	—	—	—
750 kg/ha									
NT	0.26	0.90	12	11	406	92	72	99	87
CT	3.27	3.40	5	1001	3069	—	—	—	—
1500 kg/ha									
NT	0.02	0.10	17	7	3250	99	98	99	16
CT	1.80	2.60	7	513	3848	—	—	—	—
overall**									
NT	0.24	1.70	16	30	1233	92	67	98	75
CT	2.87	5.10	5	1442	5024	—	—	—	—

* Maximum peak runoff rates observed during R1, R2, or R3

** Average over all residue levels

TABLE 9
Effects of Residue Level on the Average Concentration of Phosphorus, 1986

Tillage System	Residue Level	Run	Soluble—P (O-P)	Sediment-P	Total-P
	(kg/ha)				
			ppm		
NT	0	R1	2.03	6.66	21.28
	0	R2	1.70	0.69	11.53
	0	R3	1.65	0.16	1.77
	Average		1.79	2.50	11.53
NT	750	R1	2.15	0.08	10.24
	750	R2	1.02	0.03	10.06
	750	R3	0.79	4.41	5.27
	Average		1.32	1.51	8.52
NT	1500	R1	71.03	9.93	101.78
	1500	R2	22.33	5.46	84.53
	1500	R3	6.01	3.50	47.25
	Average		33.12	6.29	77.85
CT	0	R1	2.93	12.19	14.84
	0	R2	0.41	2.58	6.05
	0	R3	0.21	7.09	7.61
	Average		1.21	7.29	9.50
CT	750	R1	1.82	12.43	3.73
	750	R2	0.49	2.32	2.80
	750	R3	0.40	2.27	2.79
	Average		0.90	5.67	3.10
CT	1500	R1	9.19	16.64	11.01
	1500	R2	2.35	9.72	3.80
	1500	R3	2.01	2.70	4.01
	Average		4.51	9.69	6.27

TABLE 10
Effects of Tillage System on the Average Concentration of Phosphorus, 1986

Tillage System	Run	Soluble—P (O-P)	Sediment-P	Total-P
		ppm		
NT	R1	18.31	0.07	26.15
	R2	5.94	0.04	21.91
	R3	2.48	0.50	28.10
	Average	8.91	0.61	25.39
CT	R1	6.46	3.76	9.99
	R2	1.19	2.20	5.16
	R3	1.02	4.02	5.23
	Average	2.89	3.33	6.79

TABLE 11

Effects of Tillage System and Residue Level on Ortho-P and Total Phosphorus Losses in Runoff, 1986

		Soluble-P (O-P)			Total-P		
Tillage System	Run	0 kg/ha	750 kg/ha	1500 kg/ha	0 kg/ha	750 kg/ha	1500 kg/ha
		kg/ha					
NT	R1	0.048	0.001	0.017	0.030	0.002	0.028
	R2	0.003	0.000	0.003	0.036	0.000	0.011
	R3	0.022	0.001	0.007	0.035	0.055	0.058
	Total	0.073	0.002	0.027	0.101	0.057	0.097
CT	R1	0.284	0.157	0.108	3.476	0.317	0.690
	R2	0.065	0.043	0.130	0.664	0.248	0.302
R3	0.157	0.065	0.174	1.095	0.417	0.433	
	Total	0.506	0.265	0.412	5.235	0.982	1.425

TABLE 12

Effects of Tillage System and Residue Level on the Losses of Sediment-bound Phosphorus, 1986

Tillage System	Run	Sediment-P		
		0 kg/ha	750 kg/ha	1500 kg/ha
		ppm		
NT	R1	0.001	0.001	0.007
	R2	0.023	0.011	0.006
	R3	0.044	0.053	0.054
	Total	0.068	0.065	0.067
CT	R1	0.261	0.208	0.202
	R2	0.258	0.206	0.090
	R3	1.022	0.334	0.433
	Total	1.541	0.748	0.725

TABLE 13

Effects of Residue Level and Tillage System on the Concentrations of Atrazine and 2,4-D in Runoff and Sediment

Residue & Tillage	Water		Sediment		Water-to-Sediment Ratio	
Treatment	Atrazine	2,4-D	Atrazine	2,4-D	Atrazine	2,4-D
	ppm					
0 kg/ha						
NT	0.204	0.006	0.211	0.176	0.97	0.03
CT	0.204	0.001	0.089	0.082	2.29	0.01
750 kg/ha						
NT	0.340	0.002	0.146	0.283	2.33	0.01
CT	0.209	0.003	0.078	0.049	2.68	0.06
1500 kg/ha						
NT	0.308	0.002	0.371	0.153	0.83	0.01
CT	0.266	0.016	0.148	0.047	1.80	0.34
Overall*						
NT	0.284	0.003	0.243	0.204	1.17	0.01
CT	0.226	0.007	0.105	0.059	2.15	0.12

* Average over all residue levels and rain events

TABLE 14
Effects of Residue and Tillage System on Losses of Atrazine and 2,4-D in Runoff Water and Sediment

Residue & Tillage	Water		Sediment		Total		Water-to-Sed. Ratio	
Treatment	Atrazine	2,4-D	Atrazine	2,4-D	Atrazine	2,4-D	Atrazine	2,4-D
	g/ha							
0 kg/ha								
NT	9.21	0.29	0.01	0.02	9.22	0.31	921.00	14.50
CT	73.59	0.25	0.22	0.25	73.81	0.50	334.50	1.00
750 kg/ha								
NT	8.84	0.05	0.00	0.00	8.84	0.05	0.00	0.00
CT	70.36	1.10	0.06	0.05	70.42	1.15	1172.70	22.00
1500 kg/ha								
NT	0.71	0.00	0.00	0.00	0.71	0.01	0.00	0.00
CT	47.18	2.92	0.09	0.03	47.27	2.95	524.20	97.30
Overall*								
NT	6.25	0.11	0.01	0.01	6.26	0.12	625.00	11.00
CT	62.71	1.42	0.12	0.11	63.83	1.53	564.20	12.90
Overall Losses as Percent of Applied Amount								
NT	0.28	0.02	NS**	NS	0.28	0.02	—	—
CT	2.84	0.25	0.01	0.02	2.85	0.27	—	—

* Average over all residue levels and rain events

** Not significant

TABLE 15
Reductions in Pesticides Losses Due to No-till Practice (Negative Value Indicates Percent Increase)

Residue Level	Water		Sediment		Total	
Atrazine	2,4-D	Atrazine	2,4-D	Atrazine	2,4-D	Atrazine
	%					
(kg/ha)						
0	87	-17	94	93	88	38
750	87	95	93	95	87	96
1500	98	99	97	93	98	99
Overall*	90	92	95	93	90	93

* Average over all residue levels and rain events

APPENDIX

TABLE A-1
Water Quality Concentration Data and Plot Discharges, 1985

PLOT/ TEST/ RUN	SAMPLE NO.	TSS GM/L	O-P PPM	T-P PPM	FILTERED T-P PPM	DT MIN	FLOW CM/HR
QF1T5R1	1	1.666	0.082	0.875	0.337	3	0.00000
QF1T5R1	2	1.604	0.087	0.871	0.262	3	0.01130
QF1T5R1	3	1.406	0.188	0.737	0.243	3	0.05639
QF1T5R1	4	1.981	0.147	0.584	0.294	3	0.09164
QF1T5R1	8	1.250	0.056	0.892	0.710	12	0.09164
QF1T5R1	10	1.282	0.151	0.853	0.243	6	0.09870
QF1T5R1	12	1.480	0.137	0.930	0.299	6	0.11280
QF1T5R1	14	1.492	0.218	0.814	0.991	6	0.11280
QF1T5R1	16	1.466	0.171	0.892	0.346	6	0.12690
QF1T5R1	18	3.900	0.561	0.996	0.942	6	0.13678
QF1T5R1	19	2.364	0.217	1.950	1.214	3	0.21577
QF1T5R2	1	1.312	0.201	9.250	0.366	3	0.00000
QF1T5R2	2	1.186	0.139	9.100	0.362	3	0.03526
QF1T5R2	3	1.228	0.092	8.750	0.392	3	0.13678
QF1T5R2	5	1.338	0.192	8.060	0.431	6	0.14666
QF1T5R2	7	1.674	0.220	8.140	0.397	6	0.20589
QF1T5R2	9	1.538	0.413	7.420	0.522	6	0.28910
QF1T5R3	1	1.076	0.158	2.780	0.375	3	0.00000
QF1T5R3	2	1.824	0.279	3.290	0.478	3	0.17628
QF1T5R3	3	1.302	0.341	2.650	0.246	3	0.44564
QF1T5R3	5	1.456	0.522	2.040	0.608	6	1.44003
QF1T5R3	7	1.008	0.597	2.030	0.672	6	2.17203
QF1T5R3	9	0.964	0.442	1.970	0.642	6	2.27780
QF1T5R3	10	1.168	0.664	2.060	0.578	3	2.38356
QF1T5R3	11	0.136	0.752	1.850	0.500	3	1.02250
QF2T5R1	1	2.466	10.100	16.900	5.113	3	0.00000
QF2T5R1	2	2.502	9.120	14.200	6.869	3	0.41948
QF2T5R1	3	2.946	8.690	12.800	5.113	3	0.57628
QF2T5R1	4	2.680	7.260	12.600	3.039	3	0.63431
QF2T5R1	6	2.806	4.470	9.070	4.591	6	0.80772
QF2T5R1	8	2.568	2.920	6.630	2.050	6	1.02006
QF2T5R1	10	2.366	1.920	5.270	2.122	6	1.17754
QF2T5R1	12	2.090	1.650	4.070	2.001	6	1.22225
QF2T5R1	14	2.176	1.400	3.220	1.465	6	1.41732
QF2T5R1	16	2.143	1.300	3.450	1.135	6	1.54432
QF2T5R1	18	2.108	1.410	2.660	1.188	6	1.75364
QF2T5R2	1	1.466	0.249	8.210	0.638	3	0.00000
QF2T5R2	2	1.678	0.884	3.570	0.819	3	0.55014
QF2T5R2	3	1.632	0.573	3.920	0.916	3	0.89408
QF2T5R2	5	1.662	0.267	2.180	0.872	6	1.14605
QF2T5R2	7	0.432	0.772	1.870	0.853	6	1.46812
QF2T5R2	9	1.608	0.513	1.090	0.840	6	2.04219
QF2T5R3	1	1.120	0.333	0.797	0.539	3	0.00000
QF2T5R3	2	1.786	0.595	1.530	0.703	3	1.14605
QF2T5R3	3	1.762	0.297	1.810	0.701	3	1.59515
QF2T5R3	5	1.242	0.474	1.970	0.699	6	3.47779

QF2T5R3	7	1.302	0.278	1.900	0.721	6	3.95227
QF2T5R3	9	1.054	0.516	1.380	0.732	6	4.10467
QF2T5R3	10	1.032	0.668	1.460	0.737	3	4.15953
QF2T5R3	11	0.208	0.646	0.984	0.741	3	1.92027
QF3T5R1	1	3.626	0.173	2.490	0.539	3	0.00000
QF3T5R1	2	3.354	0.299	1.670	0.784	3	0.11669
QF3T5R1	3	3.084	0.203	1.490	0.438	3	0.18115
QF3T5R1	4	3.842	0.115	1.850	0.348	3	0.21956
QF3T5R1	6	2.628	0.111	1.420	0.426	6	0.24425
QF3T5R1	8	3.051	0.164	1.670	0.411	6	0.34300
QF3T5R1	10	3.298	0.178	1.700	0.805	6	0.41849
QF3T5R1	12	2.802	0.215	1.630	0.586	6	0.44869
QF3T5R1	14	2.721	0.280	1.460	0.542	6	0.67239
QF3T5R1	16	2.632	0.237	1.740	0.443	6	0.73414
QF3T5R1	18	2.590	0.144	1.920	0.326	6	0.83706
QF3T5R2	1	1.954	0.275	1.100	0.514	3	0.00000
QF3T5R2	2	2.270	0.281	1.420	0.414	3	0.20996
QF3T5R2	3	2.134	0.337	1.530	0.543	3	0.37320
QF3T5R2	5	2.086	0.317	1.130	0.453	6	0.56535
QF3T5R2	7	1.716	0.217	1.570	0.474	6	0.73414
QF3T5R2	9	1.722	0.292	0.870	0.409	6	0.94823
QF3T5R3	1	1.814	0.172	1.020	0.414	3	0.00000
QF3T5R3	2	1.242	0.167	1.380	0.410	3	0.40340
QF3T5R3	3	1.680	0.261	1.780	0.409	3	1.11150
QF3T5R3	5	1.722	0.185	0.142	0.409	6	1.75504
QF3T5R3	7	1.242	0.357	0.651	0.638	6	1.81816
QF3T5R3	9	1.170	0.346	0.870	0.652	6	2.04452
QF3T5R3	10	1.322	0.338	0.651	0.638	3	1.88125
QF3T5R3	11	0.300	0.338	0.839	0.711	3	0.41849
QF4T5R1	1	1.884	0.706	1.560	0.667	3	0.00000
QF4T5R1	2	2.406	3.870	10.400	7.028	3	0.02560
QF4T5R1	3	2.774	3.850	12.000	10.790	3	0.12121
QF4T5R1	5	3.096	4.910	8.850	7.294	6	0.18720
QF4T5R1	7	3.470	3.030	8.990	5.528	6	0.19665
QF4T5R1	9	3.426	2.280	5.900	4.113	6	0.33670
QF4T5R1	10	4.910	1.690	5.680	2.145	3	0.41082
QF4T5R1	11	3.858	1.800	4.300	2.614	3	0.58997
QF4T5R1	14	4.196	0.976	3.370	0.848	9	0.58997
QF4T5R1	15	2.302	0.910	1.850	1.709	3	0.60749
QF4T5R2	1	1.092	0.268	0.744	0.546	3	0.00000
QF4T5R2	2	1.660	0.147	1.030	0.714	3	0.15893
QF4T5R2	4	1.874	0.382	1.580	0.867	6	0.39601
QF4T5R2	6	2.462	0.378	1.320	0.795	6	0.50244
QF4T5R2	8	2.138	0.401	1.250	0.795	6	0.62499
QF4T5R2	10	2.312	0.352	1.360	0.679	6	0.78118
QF4T5R2	11	0.524	0.447	0.589	0.303	3	0.15893
QF4T5R3	1	3.154	0.189	1.540	0.722	3	0.00000
QF4T5R3	2	2.400	0.618	1.780	0.853	3	0.20607
QF4T5R3	4	2.210	0.354	1.460	0.881	6	0.72060
QF4T5R3	6	2.202	0.152	1.320	0.766	6	1.21895
QF4T5R3	8	1.914	0.074	1.630	0.795	6	1.24455
QF4T5R3	10	2.034	0.319	1.460	0.782	6	1.27015
QF4T5R3	11	0.838	0.380	0.730	0.682	3	1.34691

QF5T5R1	1	2.088	0.115	1.030	0.635	3	0.00000
QF5T5R1	2	2.018	0.244	1.100	0.603	3	0.02007
QF5T5R1	3	2.200	0.245	1.280	0.539	3	0.10018
QF5T5R1	5	1.862	0.210	1.060	0.794	6	0.13868
QF5T5R1	7	2.252	0.220	1.740	0.688	6	0.22499
QF5T5R1	9	1.692	0.363	1.170	0.709	6	0.40231
QF5T5R1	10	3.876	0.255	1.780	0.379	3	0.48704
QF5T5R1	11	1.578	0.448	1.030	0.656	3	0.61496
QF5T5R1	13	1.336	0.175	0.851	0.722	6	0.61496
QF5T5R1	14	2.858	0.196	0.892	0.917	3	0.65502
QF5T5R1	15	1.724	0.187	0.765	0.419	3	0.75519
QF5T5R1	17	1.292	0.251	0.741	0.419	6	0.80145
QF5T5R1	18	3.182	0.193	0.699	0.608	3	0.80145
QF5T5R1	19	1.684	0.296	0.671	0.462	3	0.82456
QF5T5R2	1	1.436	0.186	0.662	0.347	3	0.00000
QF5T5R2	2	1.416	0.197	1.180	0.390	3	0.12329
QF5T5R2	4	1.284	0.261	0.809	0.575	6	0.38537
QF5T5R2	6	1.370	0.166	0.662	0.439	6	0.53790
QF5T5R2	8	1.334	0.200	0.626	0.289	6	0.57488
QF5T5R2	10	1.150	0.498	0.773	0.676	6	0.73515
QF5T5R2	11	1.352	0.190	0.919	0.303	3	0.09248
QF5T5R3	1	2.150	0.168	1.460	0.977	3	0.00000
QF5T5R3	2	1.728	0.276	1.280	0.546	3	0.61496
QF5T5R3	4	1.342	0.162	1.460	0.503	6	1.01265
QF5T5R3	6	1.370	0.184	1.680	0.618	6	1.24846
QF5T5R3	8	1.290	0.209	2.390	0.575	6	1.45344
QF5T5R3	10	1.364	0.165	0.786	0.431	6	1.51201
QF5T5R3	11	1.165	0.274	0.285	0.259	3	0.52095
QF6T5R1	1	4.058	0.167	3.490	0.603	3	0.00000
QF6T5R1	2	4.898	0.377	4.040	0.754	3	0.03932
QF6T5R1	3	5.044	0.479	3.610	0.795	3	0.19507
QF6T5R1	5	4.916	0.431	3.270	0.853	6	0.20488
QF6T5R1	7	5.358	0.265	2.950	0.821	6	0.23716
QF6T5R1	9	4.976	0.436	2.100	0.751	6	0.32558
QF6T5R1	10	7.406	0.382	4.480	0.772	3	0.39715
QF6T5R1	11	4.382	0.469	2.130	0.761	3	0.41260
QF6T5R1	13	5.632	0.325	2.310	0.795	6	0.41260
QF6T5R1	14	6.554	0.366	3.840	0.260	3	0.45893
QF6T5R1	15	5.962	0.415	6.320	0.347	3	0.45893
QF6T5R1	17	5.940	0.287	4.110	0.448	6	0.48981
QF6T5R1	18	6.420	0.383	3.620	0.260	3	0.45893
QF6T5R1	19	5.246	0.163	2.510	0.708	3	0.45893
QF6T5R2	1	3.612	0.466	2.090	0.332	3	0.00000
QF6T5R2	4	3.880	0.218	2.060	0.867	9	0.30030
QF6T5R2	6	4.128	0.319	2.200	0.665	6	0.38171
QF6T5R2	8	4.216	0.330	2.280	0.737	6	0.45893
QF6T5R2	10	4.266	0.394	2.390	0.722	6	0.55999
QF6T5R3	1	4.922	0.420	2.870	0.374	3	0.00000
QF6T5R3	4	3.531	0.361	2.510	0.531	9	0.48981
QF6T5R3	3	3.012	0.341	2.920	0.488	6	1.27015
QF6T5R3	10	2.882	0.459	1.820	0.848	6	1.46246
QF6T5R3	11	5.000	0.321	3.100	0.647	3	0.55999
QFAT5R1	1	2.936	0.123	0.676	0.474	3	0.00000

QFAT5R1	2	5.558	0.390	1.450	0.575	3	0.00000
QFAT5R1	3	8.080	0.103	2.590	0.661	3	0.13411
QFAT5R1	5	10.342	0.445	3.180	0.742	6	0.16256
QFAT5R1	7	9.744	0.492	3.770	0.876	6	0.21133
QFAT5R1	9	13.124	0.570	5.530	0.503	6	0.74371
QFAT5R1	11	11.818	0.188	5.050	0.603	6	1.90503
Q1FAT5R1	13	11.854	0.645	24.200	0.917	6	2.86311
QFAT5R1	15	11.896	0.532	6.010	0.488	6	3.40566
QFAT5R1	17	14.124	0.196	5.420	0.417	6	3.44528
QFAT5R1	18	5.198	0.896	2.440	0.790	3	3.86895
QFAT5R2	1	4.808	0.095	3.840	0.546	3	0.00000
QFAT5R2	2	12.260	0.137	5.530	0.505	3	0.15545
QFAT5R2	4	13.842	0.323	5.490	0.328	6	2.82552
QFAT5R2	6	18.046	0.407	6.010	0.314	6	3.86895
QFAT5R2	8	12.582	0.040	5.310	0.109	6	3.95836
QFAT5R2	10	15.598	0.411	5.350	0.273	6	3.65559
QFAT5R2	11	11.206	0.289	3.070	0.546	3	3.65559
QFAT5R3	1	15.836	0.160	2.950	0.191	3	0.00000
QFAT5R3	2	14.320	0.156	3.820	0.164	3	3.91163
QFAT5R3	4	15.256	0.172	3.610	0.492	6	4.00510
QFAT5R3	6	13.798	0.143	5.220	0.328	6	4.09857
QFAT5R3	8	12.620	0.122	3.780	0.566	6	4.09857
QFAT5R3	10	13.140	0.508	10.900	0.512	6	4.14531
QFAT5R3	11	14.570	0.109	3.930	1.353	3	1.99342
QFBT5R1	1	5.524	0.364	2.110	0.488	3	0.00000
QFBT5R1	2	4.844	0.252	5.290	0.316	3	0.00000
QFBT5R1	3	9.662	0.526	4.980	0.488	3	0.02997
QFBT5R1	5	12.222	0.471	4.240	0.417	6	0.05080
QFBT5R1	7	12.168	0.302	5.130	0.488	6	0.46533
QFBT5R1	9	13.538	0.378	4.600	0.230	6	1.67538
QFBT5R1	11	15.926	0.483	1.710	0.445	6	2.20983
QFBT5R1	13	14.302	0.162	3.660	0.718	6	2.47094
QFBT5R1	15	16.470	0.264	3.360	0.402	6	2.67820
QFBT5R1	17	9.178	0.241	4.870	0.733	6	3.01348
QFBT5R1	18	4.736	0.294	2.410	0.919	3	3.24716
QFBT5R2	1	10.056	0.645	2.900	0.546	3	0.00000
QFBT5R2	4	19.536	0.083	11.200	0.546	9	2.67820
QFBT5R2	6	10.170	0.351	2.490	0.697	6	3.74094
QFBT5R2	8	14.114	0.592	6.610	0.656	6	3.82628
QFBT5R2	10	18.992	0.569	5.850	0.669	6	3.69827
QFBT5R2	11	11.668	0.093	0.601	0.150	3	4.00510
QFBT5R3	1	18.692	0.096	8.050	0.669	3	0.00000
QFBT5R3	2	19.852	0.093	9.330	0.669	3	3.61292
QFBT5R3	4	16.474	0.233	10.100	0.782	6	3.86895
QFBT5R3	6	8.332	0.266	5.720	0.644	6	3.95836
QFBT5R3	10	17.316	0.073	14.600	0.164	6	4.09857
QFBT5R3	11	10.818	0.091	9.470	0.137	3	1.84610
QFCT5R1	1	6.298	7.670	11.300	0.359	3	0.00000
QFCT5R1	2	12.252	9.680	22.200	10.120	3	0.01930
QFCT5R1	3	17.138	4.170	11.500	10.680	3	0.04572
QFCT5R1	5	31.560	3.400	15.700	4.399	6	0.10566
QFCT5R1	8	29.204	1.280	15.900	1.767	9	0.69190
QFCT5R1	9	29.404	1.630	16.400	1.365	3	2.33581

QFCT5R1	11	26.538	0.716	16.700	1.566	6	2.71275
QFCT5R1	13	24.984	0.328	14.900	3.994	6	2.90071
QFCT5R1	15	29.722	0.264	13.800	1.186	6	3.16791
QFCT5R1	17	4.782	0.152	13.000	0.683	6	3.48491
QFCT5R1	18	4.924	0.116	3.360	0.779	3	3.57025
QFCT5R2	1	6.174	0.835	2.490	2.746	3	0.00000
QFCT5R2	4	8.256	0.354	9.450	1.168	9	2.82552
QFCT5R2	6	29.496	0.980	12.400	1.806	6	3.69827
QFCT5R2	8	21.910	0.315	5.310	0.642	6	3.82628
QFCT5R2	10	30.534	0.180	9.600	0.560	6	3.65559
QFCT5R2	11	15.398	0.140	8.840	0.300	3	3.95836
QFCT5R3	1	15.998	0.315	16.300	0.287	3	0.00000
QFCT5R3	2	18.734	0.466	16.400	0.601	3	3.20754
QFCT5R3	4	18.888	0.704	16.900	0.410	6	4.19204
QFCT5R3	6	12.116	0.931	16.600	0.546	6	3.95836
QFCT5R3	8	22.346	1.710	10.500	0.557	6	3.44528
QFCT5R3	10	22.634	0.482	12.500	0.621	6	3.36603
QFCT5R3	11	13.622	0.126	5.540	0.545	3	3.40566
QFDT5R1	1	5.480	0.101	3.180	0.430	3	0.00000
QFDT5R1	2	7.920	0.131	4.340	0.215	3	0.00305
QFDT5R1	3	8.570	0.051	4.810	0.032	3	0.01930
QFDT5R1	4	6.916	0.073	4.190	0.285	3	0.04572
QFDT5R1	6	8.086	0.112	4.540	0.055	6	0.26619
QFDT5R1	8	6.438	0.090	3.020	0.110	6	0.54254
QFDT5R1	10	6.794	0.101	3.450	0.274	6	1.15418
QFDT5R1	12	6.664	0.133	3.180	0.214	6	1.26390
QFDT5R1	14	6.910	0.124	2.330	0.202	6	1.90503
QFDT5R1	16	6.418	0.160	4.190	0.193	6	2.20983
QFDT5R1	18	6.750	0.123	4.810	0.340	6	2.33581
QFDT5R2	1	4.514	0.150	3.800	0.869	3	0.00000
QFDT5R2	2	7.218	0.190	6.220	2.065	3	0.27737
QFDT5R2	3	6.758	0.120	4.050	1.152	3	1.31267
QFDT5R2	5	7.556	0.120	4.650	0.953	6	1.31267
QFDT5R2	7	7.184	0.110	5.440	1.888	6	2.75034
QFDT5R2	9	9.414	0.910	5.930	1.262	6	2.17833
QFDT5R2	10	6.558	0.100	4.720	0.309	3	2.54003
QFDT5R3	1	7.192	0.100	4.770	1.245	3	0.00000
QFDT5R3	3	7.510	0.130	4.800	1.009	6	3.32641
QFDT5R3	7	8.216	0.080	5.040	1.374	12	3.36603
QFDT5R3	10	11.286	0.110	5.700	1.682	9	3.65559
QFDT5R3	11	9.524	0.100	4.990	1.607	3	0.60757
QFET5R1	1	2.766	0.162	1.550	0.206	3	0.00000
QFET5R1	2	6.116	0.191	3.530	0.227	3	0.00305
QFET5R1	3	5.872	0.250	3.760	0.523	3	0.00356
QFET5R1	4	5.462	0.154	3.950	0.227	3	0.00508
QFET5R1	6	6.768	0.132	4.420	0.710	6	0.03353
QFET5R1	8	7.088	0.082	4.460	0.355	6	0.87681
QFET5R1	10	6.514	0.137	3.570	0.206	6	1.53822
QFET5R1	12	6.742	0.171	3.020	0.271	6	1.67538
QFET5R1	14	7.248	0.205	3.100	0.234	6	2.08384
QFET5R1	16	6.542	0.247	3.570	0.196	6	2.20983
QFET5R1	18	7.048	0.160	4.380	0.206	6	2.33581
QFET5R2	1	4.829	0.100	3.420	0.738	3	0.00000

QFET5R2	2	6.054	0.080	3.840	0.850	3	0.01219
QFET5R2	5	6.622	0.090	3.920	0.804	9	1.84610
QFET5R2	7	6.718	0.120	5.500	0.916	6	2.64366
QFET5R2	9	6.728	0.100	4.220	0.900	6	2.75034
QFET5R3	1	5.807	0.460	3.780	1.234	3	0.00000
QFET5R3	2	6.072	0.130	3.350	0.804	3	2.40185
QFET5R3	3	6.076	0.250	3.750	0.929	3	2.78793
QFET5R3	5	6.218	0.260	3.850	0.671	6	2.54003
QFET5R3	7	6.472	0.060	4.290	0.727	6	2.71275
QFET5R3	10	3.622	0.080	5.930	1.643	9	2.78793
QFET5R3	11	8.074	0.060	9.300	1.069	3	0.94082
QFFT5R1	1	12.028	6.170	20.600	7.793	3	0.00000
QFFT5R1	2	14.718	5.190	21.800	0.676	3	0.01219
QFFT5R1	3	13.338	6.120	17.200	5.326	3	0.04064
QFFT5R1	4	9.120	4.010	15.300	4.224	3	1.09017
QFFT5R1	6	5.400	0.183	13.100	2.822	6	1.59311
QFFT5R1	8	12.244	0.259	10.600	2.438	6	2.20983
QFFT5R1	10	12.004	0.959	9.340	0.981	6	2.27282
QFFT5R1	12	12.436	0.661	8.610	0.710	6	2.40185
QFFT5R1	14	10.884	0.543	8.330	0.691	6	2.57457
QFFT5R1	16	11.804	0.431	8.640	0.533	6	2.75034
QFFT5R1	18	10.200	0.352	8.610	0.514	6	2.78793
QFFT5R2	1	5.554	1.500	6.540	1.421	3	0.00000
QFFT5R2	2	11.132	0.270	7.560	1.978	3	1.70284
QFFT5R2	5	13.760	0.222	8.980	2.034	9	2.75034
QFFT5R2	7	12.710	0.280	14.800	3.012	6	3.05107
QFFT5R2	9	12.080	0.138	7.050	3.093	6	2.71275
QFFT5R2	10	10.890	0.179	8.070	2.625	3	2.82552
QFFT5R2	11	9.136	0.294	10.600	3.760	3	3.01348
QFFT5R3	1	10.520	0.450	8.000	1.849	3	0.00000
QFFT5R3	3	9.968	0.291	7.600	1.357	3	3.24716
QFFT5R3	5	10.650	0.210	7.450	1.635	6	3.08867
QFFT5R3	7	10.860	0.510	7.630	2.449	6	2.97589
QFFT5R3	9	11.200	0.240	8.140	2.192	6	3.16791
QFFT5R3	10	11.870	0.407	7.380	2.368	3	3.12829
QFFT5R3	11	7.492	0.234	6.690	2.414	3	3.08867

TABLE A-2
Water Quality Concentration Data and Plot Discharges, 1986

PLOT/ TEST/ RUN	SAMPLE NO.	TSS GM/L	T-P PPM	O-P PPM	FILTERED T-P PPM	DT MIN	FLOW CM/HR
QF1T6R1	1	0.110	0.465	0.272	0.458	3	0.05639
QF1T6R1	4	0.090	0.393	0.184	0.384	9	0.07048
QF1T6R1	8	0.170	0.978	0.587	0.818	12	0.07755
QF1T6R1	10	0.730	2.073	1.798	1.801	6	0.09870
QF1T6R2	1	0.220	0.771	0.284	0.523	3	0.00000
QF1T6R2	2	0.160	0.668	0.331	0.376	3	0.00564
QF1T6R2	3	0.180	0.737	0.279	0.376	3	0.00706
QF1T6R2	4	0.180	0.737	0.355	0.606	3	0.00988
QF1T6R3	1	0.270	1.046	0.667	0.691	3	0.00000
QF1T6R3	2	0.420	1.631	0.648	0.395	3	0.05639
QF1T6R3	3	0.500	1.562	0.751	0.480	3	0.11984
QF1T6R3	4	0.580	1.562	0.832	0.650	3	0.22565
QF1T6R3	6	0.490	2.043	0.643	0.553	6	0.54437
QF1T6R3	8	0.390	1.734	0.744	0.636	6	0.99852
QF1T6R3	10	0.240	2.249	0.892	0.198	6	1.16921
QF1T6R3	12	0.780	1.768	0.890	0.191	6	0.16640
QF2T6R1	1	1.340	8.506	5.266	5.076	3	0.57628
QF2T6R1	2	1.440	8.573	5.547	5.414	3	0.59078
QF2T6R1	3	1.590	8.696	5.208	5.109	3	0.63431
QF2T6R1	4	2.370	9.294	5.586	5.330	3	0.66332
QF2T6R1	5	2.020	10.330	9.478	7.049	3	0.73863
QF2T6R1	8	2.030	10.050	7.321	7.507	9	0.87681
QF2T6R1	10	1.350	8.951	7.058	6.705	6	1.11455
QF2T6R1	12	1.290	7.988	7.121	6.009	6	1.22225
QF2T6R1	13	0.540	8.745	7.992	7.008	3	1.64798
QF2T6R2	1	0.670	2.868	0.664	0.165	3	0.00000
QF2T6R2	2	0.830	2.421	0.903	0.955	3	0.39337
QF2T6R2	3	1.180	4.105	1.501	2.387	3	0.52403
QF2T6R2	4	0.830	4.105	2.305	2.490	3	0.63431
QF2T6R2	6	0.740	4.277	1.941	2.490	6	0.92558
QF2T6R2	8	0.800	3.899	1.921	1.978	6	2.13363
QF2T6R2	10	0.320	2.511	2.007	2.234	6	3.27967
QF2T6R3	1	0.770	1.916	0.855	1.006	3	0.00000
QF2T6R3	2	0.950	5.779	1.401	1.424	3	0.95707
QF2T6R3	3	0.830	2.808	1.425	1.450	3	2.45671
QF2T6R3	4	0.740	2.102	1.501	1.467	3	3.95227
QF2T6R3	6	0.710	2.028	1.453	1.322	6	4.59844
QF2T6R3	8	0.700	4.887	1.357	1.313	6	4.77119
QF2T6R3	10	0.680	2.028	1.474	1.202	6	4.94795
QF2T6R3	12	0.180	1.359	1.145	1.220	6	2.77269
QF2T6R3	14	0.200	2.139	1.209		6	0.73863
QF3T6R1	1	0.140	1.253	0.421	0.867	3	0.05486
QF3T6R1	3	0.110	1.424	0.310	0.466	6	0.07546
QF3T6R1	6	0.130	1.459	0.286	0.417	9	0.06861
QF3T6R1	9	0.150	1.619	0.245	0.401	9	0.08235
QF3T6R1	11	0.110	1.137	0.255	0.393	6	0.07546
QF3T6R2	1	0.100	0.765	0.375	0.529	3	0.00000
QF3T6R2	2	0.200	0.728	0.323	0.444	3	0.01372
QF3T6R2	3	0.090	0.728	0.292	0.452	3	0.01783
QF3T6R2	4	0.030	0.580	0.222	0.359	3	0.02195

QF3T6R2	8	0.100	0.654	0.204	0.333		
QF3T6R3	1	0.120	0.765	0.292	0.444	3	0.00000
QF3T6R3	2	0.100	0.654	0.254	0.427	3	0.01234
QF3T6R3	3	0.120	0.617	0.222	0.478	3	0.01783
QF3T6R3	4	0.090	0.877	0.230	0.478	3	0.03018
QF3T6R3	6	0.110	0.914	0.220	0.359	6	0.03429
QF3T6R3	8	0.130	0.765	0.222	0.411	6	0.03429
QF4T6R1	1	3.020	15.990	11.240	11.320	3	0.00000
QF4T6R1	4	6.060	16.400	8.901	5.395	9	0.00135
QF4T6R1	6	5.690	12.830	5.475	4.085	6	0.00406
QF4T6R1	8	5.670	10.420	4.186	2.996	6	0.13063
QF4T6R1	10	6.250	9.306	3.028	2.472	6	0.74079
QF4T6R1	12	6.340	8.195	2.676	2.856	6	1.11658
QF4T6R1	14	2.560	5.961	2.937	1.747	6	1.78468
QF4T6R2	1	5.110	10.980	2.728	3.606	3	0.00000
QF4T6R2	2	5.930	8.935	2.301	3.129	3	1.66075
QF4T6R2	3	5.840	7.598	1.091	1.901	3	2.34902
QF4T6R2	4	4.980	6.558	0.536	1.424	3	2.75717
QF4T6R2	6	6.650	6.855	0.514	1.083	6	2.87434
QF4T6R2	8	7.260	7.153	0.423	0.836	6	2.95245
QF4T6R2	10	5.270	5.407	0.443	0.717	6	2.83527
QF4T6R2	12	2.180	3.773	0.388	0.887	6	0.25187
QF4T6R3	1	8.350	9.009	0.441	1.006	3	0.00000
QF4T6R3	2	6.470	6.298	0.268	0.699	3	3.11407
QF4T6R3	3	7.330	6.336	0.315	0.742	3	3.32285
QF4T6R3	10	7.840	10.500	0.492	0.538	6	3.36461
QF4T6R3	12	12.530	21.600	0.871	0.955	6	0.95359
QF5T6R3	1	0.370	2.555	1.115	0.981	3	0.00000
QF5T6R3	2	0.490	1.793	0.537	0.721	3	0.01389
QF5T6R3	3	0.520	3.416	0.799	0.768	3	0.03856
QF5T6R3	4	0.420	1.429	0.621	0.691	3	0.06937
QF5T6R3	6	0.680	1.694	0.571	0.640	6	0.09248
QF5T6R3	8	0.620	1.826	0.609	0.674	6	0.16027
QF5T6R3	10	0.740	1.925	0.579	0.606	6	0.09248
QF6T6R1	1	2.700	13.490	10.660	1.218	3	0.00000
QF6T6R1	2	3.870	13.490	5.931	13.030	3	0.00701
QF6T6R1	3	5.310	19.190	14.340	11.530	3	0.01824
QF6T6R1	4	6.130	19.470	14.730	11.290	3	0.07722
QF6T6R1	6	6.080	14.830	10.780	1.474	6	0.28768
QF6T6R1	8	6.680	13.760	8.628	1.376	6	0.44348
QF6T6R1	10	5.680	10.980	4.336	1.109	6	0.65123
QF6T6R1	12	6.190	9.741	5.371	4.399	6	0.85616
QF6T6R1	16	3.270	7.714	3.406	4.035	12	0.99367
QF6T6R2	1	6.180	7.457	1.151	1.132	3	0.00000
QF6T6R2	2	5.060	5.701	1.069	1.134	3	0.26243
QF6T6R2	3	5.140	5.271	0.971	0.981	3	0.63299
QF6T6R2	4	4.690	5.138	0.902	0.904	3	0.87719
QF6T6R2	6	4.760	4.410	0.628	0.164	6	0.99367
QF6T6R2	8	4.780	4.774	1.066	0.682	6	1.21681
QF6T6R2	10	5.100	4.443	0.618	0.725	6	1.46246
QF6T6R2	12	2.280	3.383	0.605	0.836	6	0.02667
QF6T6R3	1	4.070	9.676	3.399	3.751	3	0.00000
QF6T6R3	2	3.330	7.622	2.770	2.822	3	0.99367
QF6T6R3	3	5.220	7.656	1.410	1.850	3	1.46246
QF6T6R3	4	6.180	7.324	1.477	2.592	3	1.55087
QF6T6R3	6	4.040	5.668	1.455	1.356	6	1.60983
QF6T6R3	10	5.700	5.801	0.979	1.145	12	1.60983
QF6T6R3	12	1.640	3.548	0.948	1.329	6	0.99367
QFAT6R1	1	0.410	6.099	4.513	4.759	3	0.00000

QFAT6R1	3	0.290	5.701	4.069	4.636	6	0.00203
QFAT6R1	4	4.730	4.708	0.680	1.118	3	0.00305
QFAT6R1	6	1.110	7.887	5.242	5.776	6	0.00356
QFAT6R1	8	0.500	7.291	5.382	5.934	6	0.00406
QFAT6R1	10	0.370	6.430	4.261	4.776	6	0.09144
QFAT6R1	11	0.380	6.099	4.526	4.864	3	0.20320
QFAT6R1	12	0.180	6.563	4.593	5.417	3	0.21133
QFAT6R2	1	0.390	3.083	1.530	1.978	3	0.00000
QFAT6R2	2	0.350	3.383	1.148	2.206	3	0.07620
QFAT6R2	3	0.300	4.075	1.636	1.820	3	0.11989
QFAT6R2	4	0.240	3.375	0.920	1.601	3	0.16256
QFAT6R2	6	0.300	3.825	0.734	1.886	6	0.17882
QFAT6R2	8	0.330	2.575	0.704	1.004	6	0.25502
QFAT6R2	10	0.180	2.725	0.667	1.132	6	0.03708
QFAT6R3	1	0.280	3.125	0.780	1.509	3	0.00000
QFAT6R3	2	0.370	2.625	0.469	0.379	3	0.27737
QFAT6R3	3	0.280	1.887	0.739	0.371	3	0.42875
QFAT6R3	4	0.310	2.075	0.328	0.218	3	0.79553
QFAT6R3	6	0.240	6.325	0.285	0.308	6	0.87681
QFAT6R3	8	0.200	2.175	0.616	0.272	6	0.89814
QFAT6R3	10	0.240	2.775	0.252	0.156	6	0.94082
QFAT6R3	12	0.120	4.925	0.285	0.236	6	0.02997
QFBT6R1	1	4.200	15.180	9.106	10.000	3	0.00000
QFBT6R1	2	5.270	18.780	10.660	11.600	3	0.00152
QFBT6R1	3	5.760	18.480	11.180	14.620	3	0.00203
QFBT6R1	4	6.100	14.810	8.817	11.780	3	0.00356
QFBT6R1	6	6.650	9.312	7.006	7.187	6	0.01575
QFBT6R1	8	5.050	4.717	4.160	4.657	6	0.40437
QFBT6R1	10	5.110	2.957	3.653	2.889	6	0.96215
QFBT6R1	12	5.020	2.875	2.540	2.755	6	1.56568
QFBT6R1	14	5.360	2.937	2.032	2.288	6	1.78717
QFBT6R1	16	4.450	2.076	1.375	1.812	6	1.87556
QFBT6R1	18	1.820	3.396	2.182	2.619	6	2.24132
QFBT6R2	1	4.860	3.942	2.806	2.376	3	0.00000
QFBT6R2	2	4.740	4.528	2.019	4.413	3	0.09855
QFBT6R2	3	4.370	4.528	1.446	1.733	3	1.41021
QFBT6R2	4	4.780	3.275	0.636	1.134	3	2.05235
QFBT6R2	6	7.190	5.660	0.428	0.799	6	2.14683
QFBT6R2	8	5.550	5.327	0.335	0.588	6	2.24132
QFBT6R2	10	5.150	5.714	0.252	0.509	6	2.40185
QFBT6R2	12	5.980	5.475	0.606	0.562	6	2.20983
QFBT6R3	1	5.180	7.375	0.554	0.588	3	0.00000
QFBT6R3	2	5.370	7.073	0.548	0.509	3	1.78717
QFBT6R3	3	6.150	4.149	0.499	0.421	3	2.24132
QFBT6R3	4	1.320	4.857	0.415	0.606	3	2.43639
QFBT6R3	6	6.370	5.498	0.295	0.483	6	2.54003
QFBT6R3	8	6.530	6.240	0.332	0.368	6	2.67820
QFBT6R3	10	6.110	4.149	0.285	0.333	6	2.60911
QFBT6R3	12	1.600	5.936	0.287	0.341	6	1.45898
QFCT6R1	1	2.510	3.779	1.199	3.622	3	0.00000
QFCT6R1	2	2.970	9.780	5.150	5.582	3	0.00000
QFCT6R1	3	3.900	13.790	8.082	10.950	3	0.00356
QFCT6R1	4	4.020	13.250	8.581	10.570	3	0.03353
QFCT6R1	6	3.100	11.870	7.767	7.980	6	0.18694
QFCT6R1	8	3.140	10.690	6.100	7.165	6	0.39218
QFCT6R1	10	3.160	9.173	4.954	6.033	6	0.74371
QFCT6R1	12	2.710	7.690	4.154	4.452	6	1.13284
QFCT6R1	14	2.870	7.049	3.496	3.916	6	1.41021
QFCT6R1	16	2.750	6.071	3.145	3.621	6	1.45898

QFCT6R1	18	0.930	5.599	4.004	4.282	6	1.70284
QFCT6R2	1	3.060	6.341	2.455	2.898	3	0.00000
QFCT6R2	2	1.710	5.228	2.025	2.389	3	0.49378
QFCT6R2	3	2.040	4.588	1.020	1.960	3	1.51079
QFCT6R2	4	1.960	4.116	0.836	1.630	3	1.96395
QFCT6R2	6	1.690	3.711	0.646	2.221	6	2.11534
QFCT6R2	8	2.170	3.438	0.774	3.396	6	2.11534
QFCT6R2	10	1.900	2.733	0.696	1.887	6	2.40185
QFCT6R2	12	0.520	2.261	0.779	1.453	6	0.39218
QFCT6R3	1	2.640	3.913	0.820	0.849	3	0.00000
QFCT6R3	2	2.050	3.205	0.663	0.755	3	1.45898
QFCT6R3	3	1.700	3.172	0.678	1.906	3	2.43639
QFCT6R3	4	1.680	2.700	0.510	1.321	3	2.64366
QFCT6R3	6	1.880	2.228	0.426	1.371	6	2.71275
QFCT6R3	10	1.440	2.025	0.363	1.261	6	2.82552
QFCT6R3	12	0.360	1.216	0.337	0.986	6	1.26390
QFDT6R1	1	0.810	8.398	5.709	6.290	3	0.00000
QFDT6R1	2	0.870	7.824	4.948	6.622	3	0.00102
QFDT6R1	3	0.910	6.509	4.395	4.714	3	0.00203
QFDT6R1	4	0.640	6.880	4.965	4.415	3	0.00254
QFDT6R1	6	0.560	5.667	4.791	2.224	6	0.00254
QFDT6R1	8	0.930	4.588	1.577	4.332	6	0.00356
QFDT6R1	10	0.750	3.610	2.799	2.705	6	0.00305
QFDT6R1	12	0.740	4.723	2.195	2.174	6	0.00864
QFDT6R1	14	0.750	2.834	1.652	2.042	6	0.00508
QFDT6R2	1	0.480	2.160	1.158	1.793	3	0.00000
QFDT6R2	2	0.390	1.857	0.857	1.079	3	0.00305
QFDT6R2	3	0.350	2.228	0.718	1.046	3	0.00508
QFDT6R2	6	0.490	1.418	0.515	0.847	9	0.00508
QFDT6R2	8	0.510	1.452	0.503	0.697	6	0.00457
QFDT6R3	1	0.290	1.452	0.552	0.780	3	0.00000
QFDT6R3	2	0.370	1.381	0.427	0.714	3	0.00457
QFDT6R3	3	0.340	1.282	0.350	0.730	3	0.00457
QFDT6R3	4	0.490	1.612	0.377	0.564	3	0.01575
QFDT6R3	6	0.620	1.314	0.265	0.481	6	0.02642
QFDT6R3	8	0.490	1.282	0.316	0.564	6	0.05080
QFDT6R3	10	0.420	1.447	0.225	0.564	6	0.03708
QFET6R1	1	1.340	3.461	1.635	1.975	3	0.00000
QFET6R1	2	1.510	3.461	1.499	1.925	3	0.00000
QFET6R1	3	1.450	3.461	2.332	2.174	3	0.00051
QFET6R1	4	2.880	5.838	3.166	3.104	3	0.00356
QFET6R1	6	3.150	11.080	4.611	5.577	6	0.06604
QFET6R1	8	4.300	10.860	6.294	6.025	6	0.16256
QFET6R1	10	4.260	10.490	3.584	3.386	6	0.40437
QFET6R1	12	4.360	8.645	4.449	3.586	6	0.52629
QFET6R1	14	3.990	10.530	3.675	3.010	6	0.55880
QFET6R1	16	3.890	6.961	3.372	2.631	6	0.74371
QFET6R1	18	1.680	6.697	3.901	3.040	6	0.00102
QFET6R2	1	3.490	5.508	1.102	1.417	3	0.00000
QFET6R2	2	3.710	5.640	1.474	1.539	3	0.19507
QFET6R2	3	3.500	5.211	1.019	1.129	3	0.70917
QFET6R2	4	3.250	4.320	1.297	1.129	3	1.43459
QFET6R2	6	3.370	3.626	0.691	0.765	6	1.93449
QFET6R2	8	3.520	3.692	0.570	0.963	6	2.33581
QFET6R2	10	3.720	4.055	0.520	0.661	6	2.33581
QFET6R2	12	1.030	2.239	0.603	0.717	6	0.24384
QFET6R3	1	3.290	5.178	0.354	0.476	3	0.00000
QFET6R3	2	3.830	3.718	0.448	0.494	3	1.81663
QFET6R3	3	3.680	3.299	0.371	0.494	3	2.24132

QFET6R3	4	3.240	3.195	0.571	0.327	3	2.43639
QFET6R3	6	3.430	3.892	0.372	0.420	6	2.54003
QFET6R3	8	2.950	2.671	0.280	0.383	6	2.47094
QFET6R3	10	3.070	4.973	0.300	0.680	6	2.54003
QFET6R3	12	0.930	1.555	0.061	0.940	6	0.40437
QFFT6R1	1	1.080	10.480	8.749	7.531	3	0.00000
QFFT6R1	3	1.250	10.620	10.090	8.367	6	0.00102
QFFT6R1	4	1.140	11.880	11.060	9.332	3	0.00406
QFFT6R1	6	1.280	12.510	9.872	8.794	6	0.00406
QFFT6R1	8	1.460	11.250	5.732	5.118	6	0.02286
QFFT6R1	10	1.730	9.368	4.753	4.189	6	0.03708
QFFT6R1	12	1.510	8.112	7.462	4.709	6	0.07620
QFFT6R1	14	1.610	7.031	5.656	4.572	6	0.12700
QFFT6R1	16	0.460	7.345	4.311	4.672	6	0.21946
QFFT6R2	1	0.800	3.508	2.331	1.627	3	0.00000
QFFT6R2	2	0.690	3.055	1.611	1.293	3	0.00051
QFFT6R2	3	0.700	3.613	1.336	0.996	3	0.01219
QFFT6R2	4	0.690	3.090	1.405	1.144	3	0.08128
QFFT6R2	6	0.980	2.462	1.163	1.032	6	0.14834
QFFT6R2	8	1.050	2.218	0.978	1.144	6	0.22758
QFFT6R2	10	0.950	2.183	0.875	1.518	6	0.10566
QFFT6R3	1	0.540	1.660	0.006	0.689	3	0.00000
QFFT6R3	2	0.940	2.148	0.905	0.749	3	0.29972
QFFT6R3	3	0.980	1.834	0.633	0.613	3	0.46533
QFFT6R3	4	1.050	1.625	0.583	0.461	3	0.69190
QFFT6R3	6	1.210	1.625	0.530	0.386	6	0.96215
QFFT6R3	8	1.040	1.520	0.605	0.371	6	1.13284
QFFT6R3	10	1.110	1.486	0.351	0.371	6	1.17551
QFFT6R3	12	0.360	1.137	0.401	0.320	6	0.01575

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Virginia Water Resources Research Center
Virginia Polytechnic Institute and State University
617 North Main Street
Blacksburg, Virginia 24060-3397
Phone (703) 961-5624