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Evaluating Nutrient and Sediment Losses from Agricultural Lands: Vegetative Filter Strips

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EVALUATING NUTRIENT AND SEDIMENT LOSSES FROM AGRICULTURAL LANDS: VEGETATIVE FILTER STRIPS

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PREFACE

This report is part of a bi-state research effort funded by the EPA Chesapeake Bay program between the states of Maryland and Virginia. This report describes the Virginia project. The Maryland project is described in another publication.

The Virginia project (EPA grant # X-00315-01-0) evaluates soils and slopes characteristic of the ridge and valley province. The Maryland project (EPA grant # X-00314-01-0) evaluates soils and slopes characteristic of the mid-Atlantic coastal plain. Together these projects provide an assessment of the effectiveness of vegetated filter strips in removing pollutants from surface water under different environmental conditions.

Each project used their own results to develop a empirical model that will assist in determining optimum applications and design requirements for vegetated filter strips.

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Hapludult) soil. A series of nine experimental field plots were established for VFS research. The plots were located at the Prices Fork Agricultural Research Farm, 10 km west of Blacksburg, Virginia. Figure 1 is a sketch of one set of experimental plots. The lower edge of each plot was bounded by a gutter which was designed to collect surface runoff and transport it to a 150 mm H-flume equipped with a FW-1 stage recorder for flow measurement. Each plot had a simulated feedlot or cropland area which was 5.5 m wide and 18.3 m long. One plot in each set had no VFS, another a 4.5 m VFS and the third a 9.1 m VFS. For experimental purposes, the discharge from the plot with no VFS was assumed to be the input to the VFS of the adjacent two plots in the same set. This assumption is a potential source of error in the present study as soil erodibility is spatially variable even within the same contiguous soil units. The present study assumes that this error is not significant. In future studies, flow from the bare areas should be concentrated, sampled and then redistributed with a flow spreader to the upper end of the VFS to minimize this potential error.

Table 1 is a summary of the physical characteristics of each field plot. As shown in Table 1, the first two sets of plots, QF1-QF3 and QF4-QF6 had negligible cross slope and longitudinal slopes of 11 and 16%, respectively. The third set of plots (QF7-QF9) had a longitudinal slope of 5% and a cross slope of 4%. The cross slope in these plots was used to cause runoff to accumulate and flow along the border on one side of each plot. This resulted in concentrated flow which could be used to evaluate the effects of flow concentration on VFS performance. This was a major concern in the present study because experimental field plots generally are designed and constructed so that flow will be shallow and uniform. "Real world" VFS, however, tend to have more fully developed drainageways which encourage concentrated flow, filter inundation, and poor performance. Also summarized in Table 1 are manure and commercial fertilizer loading rates, simulated rainfall intensities and durations, and the coding scheme used to differentiate between plots, manure and commercial fertilizer loading rates, and simulated runoff events.

ACKNOWLEDGEMENTS

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INTRODUCTION

The Environmental Protection Agency's Chesapeake Bay Program identified agriculture as the major source of sediment and nitrogen (N) and a significant source of phosphorus (P) in the Chesapeake Bay drainage basin (USEPA, 1983). To help reduce agricultural nonpoint source (NPS) pollutant inputs to the Bay system, the Commonwealth of Virginia implemented cost sharing programs to encourage the adoption of Best Management Practices (BMPs) by farmers. Vegetated filter strips (VFS) are one practice which is being promoted. Vegetative filter strips are bands of planted or indigeneous vegetation situated downslope of cropland or animal production facilities. Their purpose is to provide localized erosion protection and to filter nutrients, sediment, organics, pathogens, and pesticides from agricultural runoff before it can reach receiving waters. Due to their low installation and maintenance costs and perceived effectiveness in removing pollutants, conservation and regulatory agencies have encouraged their use.

Vegetated filter strips have been shown to be an effective BMP for the control of some NPS pollutants, especially sediment and sediment-bound contaminants. Their effectiveness for controlling pathogens, fine sediment, and soluble nutrients such as nitrate (NO_3) or ortho-phosphorus (O-P), however, is much less certain, and has not been addressed sufficiently. Although considerable research on VFS has been conducted over the past 10 years, efforts have focused almost exclusively on either sediment removal from strip mine runoff or nutrient and solids removal from feedlot runoff. Design procedures for the removal of sediment from runoff have been developed from the strip mine work but these procedures have not received widespread verification for cropland situations and do not consider nutrient transport. Research involving VFS and feedlot runoff has not produced any widely accepted design procedures other than those based on the premise that the VFS should be large enough to infiltrate all the runoff from a design storm.

Considerable research has also been conducted concerning the design of overland flow systems for the treatment of municipal wastewaters but their design is still based more on past experience than design formulas relating filter

The results of the experimental plot studies and field surveys of existing VFS are presented in the main body of this report and covers investigations performed in Virginia. A simplified procedure for VFS design based upon research conducted at Virginia Tech is presented in Appendix B. A separate report by the University of Maryland will present the results of a parallel and cooperative study conducted in Maryland. A comprehensive model derived from both the Virginia and Maryland plot studies will be presented in a latter report.

The filtration of solid particles by vegetation during overland flow and the absorption process are not as well understood as the infiltration and deposition processes. Filtration is probably most significant for the larger soil particles, aggregates, and manure particles while absorption is thought to be a significant factor with respect to the removal of soluble pollutants.

The use of VFS for removing pollutants from cropland runoff is a relatively new practice. Historically, pollution control efforts on cropland were designed to minimize offsite pollution by reducing erosion and surface runoff within the field. Vegetative filter strips on the other hand are designed to remove pollutants from runoff once it has left the field and reaches filter strips on the downslope boundaries of the field.

RUNOFF CONTROL FOR FEEDLOTS

Runoff control systems for feedlots are, or soon will be, mandatory in most states. Runoff control systems generally consist of a clean water diversion system, a runoff collection system, settling basins, holding basins, and a land application system. The clean water diversion system is used to minimize the amount of water which must be handled by the runoff collection system by excluding unpolluted outside surface water from the feedlot area. This is accomplished by diverting surface runoff from adjacent areas and feedlot building roofs away from the feedlot. These diversions are usually accomplished with diversion ditches and roof gutters. Runoff from the feedlot is transported to the settling basins and holding ponds by the runoff collection system.

Settling basins are used to remove settleable solids from feedlot runoff before it enters holding ponds or VFS. Settling basins typically remove 50-85% of the manure solids from runoff (Vanderholm et al., 1978). This prevents solids from reducing holding pond storage capacity or from being deposited in VFS. Settling basins are generally less than 1 m deep and usually have a detention time of 30 minutes. Designs are normally based upon a desired storage volume for solids plus temporary storage for the design storm runoff. Solids removed from the settling basins are generally applied directly to the land. Settling basin capacities commonly range from 1.5-3.0 m^3 per 100 m^2 of feedlot area.

SEDIMENT TRANSPORT THROUGH VFS

Historically, the design of VFS has been based almost entirely upon local custom. Wilson (1967) presented the results of a sediment trapping study which gave optimum distances required to trap sand, silt, and clay in flood waters on flat slopes. He concluded that filter length, sediment load, flow rate, slope, grass height and density, and degree of submergence all affect sediment removal. A method for estimating the relationship between the parameters and filter performance was not presented. Neibling and Alberts (1979) used experimental field plots with a slope of 7% and a rainfall simulator to show that 0.6, 1.2, 2.4, and 4.9 m long grass filters all reduced total sediment discharge by more than 90% from a 6.1 m long bare soil area. Discharge rates for the clay size fraction were reduced by 37, 78, 82, and 83%, for the 0.6, 1.2, 2.4, and 4.9 m filters, respectively. Significant deposition of solids was observed to occur just upslope of the leading edge of the VFS and 91% of the incoming sediment load was removed within the first 0.6 m of the filter. Sediment discharge of clay sized particles (<0.002 mm) was reduced 37% by the 0.6 m strip. No equations were presented to estimate the influence of parameters on sediment yield.

The most comprehensive research to date on sediment transport in VFS has been conducted by a group of researchers at the University of Kentucky working on erosion control in surface mining areas (Barfield et al., 1977; 1979; Kao and Barfield, 1978; Tollner et al., 1976; 1978; 1982; Hayes et al., 1979; 1983). Tollner et al. (1976) presented design equations relating the fraction of sediment trapped in simulated vegetal media to the mean flow velocity, flow depth, particle fall velocity, filter length, and the spacing hydraulic radius (a parameter similar to the hydraulic radius in open channel flow which is used to account for the effect of media spacing on flow hydraulics) of the simulated media. Barfield et al. (1979) developed a steady state model, the Kentucky filter strip model, for determining the sediment filtration capacity of grass media as a function of flow, sediment load, particle size, flow duration, slope, and media density. Outflow concentrations were primarily a function of slope

NUTRIENT TRANSPORT THROUGH VFS

Nutrient movement through VFS has been investigated by several researchers but no comprehensive design methods have been presented. Doyle et al. (1977) applied dairy manure to 7 x 5 m fescue plots on a Chester silt loam (fine-loamy, mixed, thermic, Typic Hapludult) soil with a slope of 10%. Soluble nutrient concentrations were measured after passing through 0.5, 1.5, and 4.0 m of fescue filter strips. Soluble P (filtered runoff samples) was reduced by 9, 8, and 62% after passage through the 0.5, 1.5, and 4.0 m filters, respectively. Soluble NO_3 losses decreased by 0, 57, and 68%, respectively, but NH_4 concentrations increased with increasing filter length presumably due to the release of NH_4 from decomposing organic N, which was trapped in the filter previously. Westerman and Overcash (1980) investigated runoff from an earthen open dairy lot or loafing area and reported that 4.8 and 12.0% of the applied N and P, respectively, appeared in runoff. They also observed that the largest storms were responsible for most of the pollutant transport even though these storms were responsible for only 17% of the total precipitation. Soil compaction in the dairy lot also was investigated and runoff, as a percent of rainfall, was 21% for the open dairy lot and 10% for neighboring pastures over a 30 month period.

Young et al. (1980) used a rainfall simulator to study the ability of VFS to control pollution from feedlot runoff. Field plots were constructed on a 4% slope with the upper 13.7 m in an active feedlot and the lower 27.4 m planted in either corn _(Zea mays)_ , oats _(Auena sativa)_ , orchardgrass, _(Dactylis glomerata)_ or a sorghum- _(Sorghum vulgare)_ sudangrass _(Sorghum sudanensis)_ mixture. Water was applied to the plots to simulate a 25-year, 24-hour duration storm. Total runoff, sediment, T-P, and total nitrogen (T-N) were reduced by 81, 66, 88, and 87%, respectively, by the orchardgrass and by 61, 82, 81, and 84%, respectively, with the sorghum-sudangrass mixture. The authors concluded that VFS were a promising treatment alternative.

Thompson et al. (1978) studied the effectiveness of orchardgrass filter strips on a sandy loam soil in reducing nutrient loss from the application of sumably due to mineralization of TKN and nitrification of NH_4 which had been trapped in the filter previously. Paterson et al. (1977) also noted problems with maintaining a good grass cover on the filter area. They recommended that several filter areas should be utilized and rotated on a weekly basis to maintain good grass cover.

Procedures for the design of VFS with respect to organics removal have been presented by Norman et al. (1978) and Young et al. (1982). However, these procedures were based primarily on infiltration or limited organics removal data. Regression type design equations for P reduction were presented by Young et al. (1982), but details of their development were not presented and they have not been verified.

SUMMARY

In summary, insufficient research data currently are available concerning VFS processes and performance to develop a reliable design procedure for VFS in Virginia if nutrient removal is a design constraint. The Kentucky filter strip model is presently the only available comprehensive design model but it only considers sediment transport. The model is structured, however, such that incorporation of sediment-bound nutrient transport sub-models are possible. Development of soluble nutrient transport models will be more difficult as previous research into VFS pollutant removal mechanisms has not been conducted.

To develop a VFS design model, which considers nutrient transport, it is essential that additional research be conducted concerning both the short and long-term dynamics of sediment, organics, and nutrient buildup in VFS. Significant issues which must be addressed include the ability of filter strip vegetation to recover after inundation with sediment, the effects of the buildup of degradable organics in the filters, and the ultimate fate of nutrients trapped within filters. Since N, P, and sediment loss from cropland and feedlots are the NPS pollutants of concern in Virginia with respect to water quality, the research presented herein will deal exclusively with these pollutants and their transport in VFS.

TABLE 1. PLOT CHARACTERISTICS AND OPERATING CONDITIONS

	Plot								
	QF1	QF2	QF3	QF4	QF5	QF6	QF7	QF8	QF9
Filter length, m	9.1	4.6	0.0	9.1	4.6	0.0	0.0	9.1	4.6
Slope, %	11	11	11	16	16	16	5	5	5
Cross Slope, %	<1	<1	<1	<1	<1	<1	4*	4*	4*

Filter strip vegetation	- Orchard grass (trimmed to 10 cm)
Soil type	- Groseclose silt loam
Feedlot simulation	- Test 1 (T1) 7500 kg/ha dairy manure (moist weight) - Test 2 (T2) 15,000 kg/ha dairy manure
Cropland simulation	- Test 3 (T3) 222 kg/ha N, 112 kg/ha K_2O 112 kg/ha P_2O_5 - Test 4 (T4) no additional fertilizer
Simulated rainfall intensity	- 50 mm/hr
Simulated rainfall duration	- Run 1 (R1) 60 min - Run 2 (R2) 30 min - Run 3 (R3) 30 min

*cross slope allowed to simulate effects of concentrated flow in "real world" filters kg/ha (moist weight), during the first set of simulations and at 15,000 kg/ha during the second set. These manure applications were the estimated manure accumulations within a feedlot after 7 and 14 days, respectively, and were obtained by assuming that: a) the cows spent 8 per day in the feedlot, b) half of the manure production in the feedlot occured near the feeders where it was not subject to runoff, c) manure production for the dairy cattle was 52 kg/day (moist weight), and d) 80 m^2 of space is required per cow in a good feedlot. (E. R. Collins, Extension Agricultural Engineer, VPI & SU, personal communication)

The nutrient content of the manure was 0.65% for T-N, 0.15% for NH_4, and 0.1% for T-P with a solids content of 17.1%. These values compare favorably with those estimated by the Midwest Plan Service (1985) of 0.5% for T-N and 0.1% for T-P for fresh dairy manure. With these nutrient contents, approximately 80 of P and 490 of N were applied to each plot during the first set of simulations (Test 1) and double these amounts during the second set (Test 2).

Manure was distributed uniformly over the plots by subdividing the bare portions of each plot into either 4 or 8 equal sized areas and applying either 1/4 or 1/8, respectively, of the total manure required for each plot to each sub area. Manure was then spread manually with rakes within each sub area as uniformly as possible. The plots were then compacted again with the sheepsfoot roller to simulate the action of animal hoofs which compact and grind manure into the soil of earthen feedlots.

PLOT PREPARATION FOR CROPLAND SIMULATIONS

After the feedlot simulations were completed in November, 1984, the plots were covered with clear plastic to protect them from further erosion during the winter. In early April, 1985, the plots were uncovered and prepared for the cropland simulations. The bare portions of the plots were tilled to a depth of 20 to 30 cm with a PTO driven tiller. Granular P_2O_5 and K_2O fertilizer were applied to the plots uniformly by hand at rates of 112 kg/ha. The plots were then tilled again to incorporate the granular fertilizer into the upper 20 to 30 cm of the soil profile.

The plots were protected from natural precipitation during the study period by covering them with plastic when rain appeared imminent. The plots were left uncovered at all other times so that the soils could dry normally.

Rainfall simulator application rates and uniformity were measured for each simulation by placing 9 to 15 rain gages within each plot. The rain gages were read after each simulation to determine the total amount of rainfall and the coefficient of uniformity for each run.

SAMPLING PROCEDURE

Water quality samples were collected manually from the plot discharges at 3-min intervals throughout the runoff process and a tick made on the stage recorder charts to precisely record the time and flow rate at which each sample was collected. This procedure greatly simplified mass flow calculations and minimized timing errors. Water quality samples were frozen immediately after collection and stored for up to 3 months before analysis.

Soil samples were collected from both the bare and VFS portions of each plot before each simulation for soil moisture analysis and before and after each set of runs for nutrient analyses. Before application of fertilizer and after the completion of the cropland simulations, the plots were sampled with a Giddings soil sampler to a depth of 100 cm to measure nutrient movement through the soil profile during the test and to determine bulk density for N balance techniques.

Grass samples were collected from the VFS after the runs were completed to estimate the hydraulic parameters required by the Kentucky filter strip model. Overland flow velocities were determined in the bare portion of each plot and within the VFS by timing the advance of a dye front. Sediment movement and accumulation within and upslope of the VFS were estimated using a network of sediment pins.

Total Phosphorus

Total P for both filtered and non-filtered samples was determined by following the procedures outlined in Method 365.4 described in Methods for Chemical Analysis of Water and Wastes (1979). Samples were digested for 2.5 h 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.

Ortho-Phosphorus

Ortho-phosphorus 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.

Chemical Oxygen Demand

Chemical Oxygen Demand (COD) was determined spectrophotometrically at 600 nm after sealed samples were placed in an oven in the presence of dichromate at 150 C for 2 h. Method 410.4 listed in Methods for Chemical Analysis for Water and Wastes was followed and a spectrophotometer was used in place of an autoanalyzer.

Extractable Soil Nitrogen

Extractable soil N was determined from 5 g soil samples (oven dried basis, but soil used was field moist) shaken with 50 mL of 2 M KCl for 1 h. Extractable NH_4 was determined colorimetrically with the indophenol blue procedure (Keeney and Nelson, 1982) and NO_3 + NO_2 was determined by the sulfanilamide method following reduction to NO_2 with a Cd-Cu column (Keeney and Nelson, 1982).

Table 2. Rainfall simulator performance.

			Plot							
			QF1		QF2		QF3		Mean QF1-3	
TEST	RUN	DATE OF RUN	RAINFALL (MM)	U.C. (%)	RAINFALL (MM)	U.C. (%)	RAINFALL (MM)	U.C. (%)	RAINFALL (MM)	U.C. (%)
1	1	10/17/84	47.7	94.5	47.4	94.5	47.5	95.4	47.5	94.8
	2	10/18/84	24.2	95.3	24.8	92.7	24.8	94.2	24.7	94.1
	3	10/18/84	24.5	94.0	24.5	93.6	24.4	96.4	24.5	95.0
2	1	11/06/84	47.5	94.9	48.7	94.9	45.9	95.8	47.4	95.2
	2	11/07/84	23.8	95.1	24.4	95.1	23.8	96.1	24.0	95.4
	3	11/07/84	22.1	94.2	23.4	95.5	22.7	95.8	22.7	95.2
			QF4		QF5		QF6		MEAN QF4-6	
1	1	10/19/84	54.8	94.2	52.5	95.8	48.2	94.7	51.8	94.9
	2	10/20/84	28.1	93.0	27.3	94.8	25.5	91.8	27.0	93.2
	3	10/20/84	28.6	93.0	25.8	92.2	25.2	90.0	26.5	92.0
2	1	11/01/84	55.4	87.8	50.3	95.1	52.3	95.3	52.7	92.7
	2	11/02/84	25.9	89.4	26.9	93.3	24.8	94.9	25.9	92.5
	3	11/02/84	24.8	90.5	28.4	80.6	23.3	95.5	25.5	88.9
			QF7		QF8		QF9		MEAN QF7-9	
1	1	10/23/84	50.0	92.6	48.1	94.1	52.2	95.3	50.1	94.0
	2	10/24/84	23.9	93.9	25.2	94.6	25.4	93.9	24.8	94.1
	3	10/24/84	25.1	91.7	24.9	93.6	25.7	93.2	25.2	92.8
2	1	10/30/84	51.3	94.6	50.7	92.6	52.1	94.1	51.4	93.8
	2	10/31/84	25.5	94.1	26.3	90.4	26.6	91.3	26.1	91.9
	3	10/31/84	24.8	94.3	26.2	89.2	26.7	89.6	25.9	91.0

WHERE: U.C. = UNIFORMITY COEFFICIENT

cumulations in the VFS and by the fact that doubling VFS length from 4.6 to 9.1 m resulted in only an additional 10% reduction in sediment yield.

Observation of the filter strips during and after simulated runoff events supported the conclusion of Neibling and Alberts (1979) and the Kentucky researchers, that sediment removal is most effective just upslope and within the

Table 4. Sediment, nutrient, and water yields from cropland simulations by plot and test.

PLOT/ TEST	FILTER LENGTH	TSS	NH4	NO3	TKN	T-N	T-P	O-P	TKN-F	TP-F	RUNOFF
	(M)	(KG)	(GM)	(GM)	(GM)	(GM)	(GM)	(GM)	(GM)	(GM)	(MM)
QF1T1	9.1	2.2	7.6	10.5	61.4	71.9	19.4	5.1	20.8	5.8	52.8
QF2T1	4.6	9.9	14.3	15.6	88.5	104.0	31.8	9.8	29.2	8.7	76.7
QF3T1	0.0	75.8	34.7	11.5	443.5	455.8	166.2	10.8	62.2	13.1	84.8
QF4T1	9.1	13.9	5.1	13.4	46.6	60.0	18.0	3.1	10.0	4.6	53.1
QF5T1	4.6	27.9	8.8	12.5	93.1	105.7	31.7	3.8	16.5	10.9	50.5
QF6T1	0.0	153.4	20.5	16.4	463.1	472.2	150.6	5.8	41.1	7.3	69.6
QF8T1	9.1	20.0	12.9	9.9	137.9	147.9	56.2	7.6	.	.	64.0
QF9T1	4.6	32.1	15.7	8.6	115.3	124.0	46.3	8.8	.	.	60.5
QF7T1	0.0	50.3	14.2	7.3	164.6	172.0	68.8	6.3	.	.	63.6
QF1T2	9.1	2.9	13.9	14.3	71.1	85.4	29.6	12.1	19.6	12.3	68.8
QF2T2	4.6	3.7	30.9	19.6	145.2	164.8	59.3	19.5	29.9	9.8	94.5
QF3T2	0.0	28.7	34.1	14.4	211.8	226.2	81.5	13.6	59.5	14.6	76.2
QF4T2	9.1	15.4	40.9	5.2	209.5	207.4	93.8	16.1	.	.	94.0
QF5T2	4.6	28.5	32.3	9.2	187.3	196.5	90.9	22.6	.	.	74.2
QF6T2	0.0	81.3	13.5	6.0	443.7	449.7	106.7	6.9	.	.	78.5
QF8T2	9.1	12.1	106.2	10.5	208.5	215.5	90.0	14.1	.	.	78.5
QF9T2	4.6	21.4	91.1	5.8	259.9	264.7	131.1	23.5	.	.	69.6
QF7T2	0.0	26.7	93.3	0.6	214.9	216.7	111.7	25.1	.	.	77.5

would be expected that this would be the first plot to fill with sediment and would consequently have the poorest performance.

Observation of the plot during the simulations showed a steady advance of the sediment front through the filter until it reached the trough during the last two simulations. As shown in Table 5 and Figures 2 and 3, the sediment yield reduction

for plot QF5 decreased from 90% during the first simulation (QF5T1R1) to 77, 66, 74, 41, and 53% during the second (QF5T1R2) to sixth simulations (QF5T2R3), respectively. Sediment reductions would have been poorer if sediment delivery

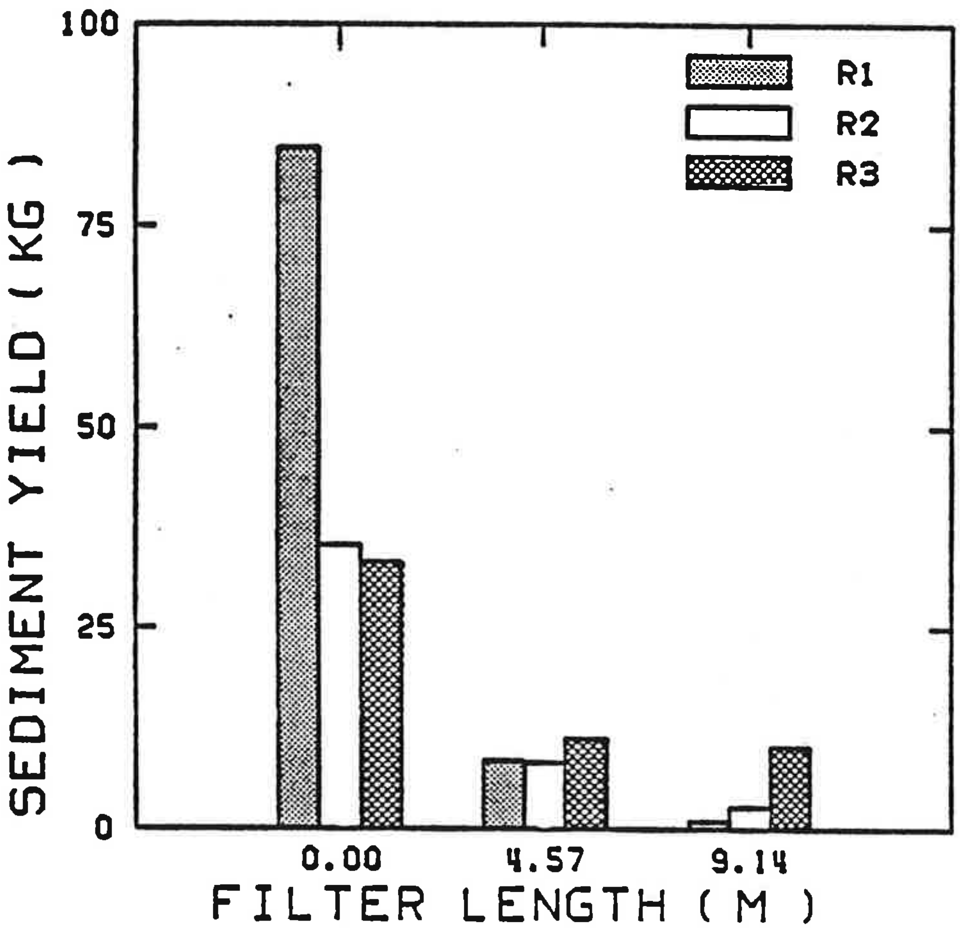

Figure 2. Sediment yields for plots QF4-6, Test 1 (feedlot simulation)

Plots QF7-9, which had cross slopes of 4%, were included in this study to assess the potential impact of concentrated flow (as opposed to the desired shallow overland flow) on VFS performance. Observations during the simulations confirmed that the cross slopes caused runoff from both the bare and filtered portions of the plots to flow to one side of the plots where it concentrated and then flowed down the side of the plot as deeper channel flow. Flow in the VFS was generally through a 0.5 to 1 m wide strip along one side (down slope with respect to cross slope) of each filter. Little flow was observed to enter the other portions of the filters and most rainfall falling on the non channel portions of the plots appeared to infiltrate into the VFS rather than running off.

Observations during the simulations showed that the area through which concentrated flow was occuring accumulated considerable sediment along its entire length after the first two simulations but not as much as the upper areas of the shallow uniform flow plots. Presumably, this resulted from the concentrated flow which submerged and bent the grass over, thus minimizing flow resistance and increasing sediment transport capacity. As shown in Table 6, sediment yield reductions were 58 and 31% for the long and short VFS, respectively. These plots were 1/2 and 1/3 as steep as the first two sets of plots and would have been expected to be more efficient since sediment transport capacity is directly proportional to slope. The decreased effectiveness of the concentrated flow plots therefore is most likely the result of concentrated flow.

Figures 4 and 5 also demonstrate this effect. The incoming sediment concentration (8 mg/L) of the concentrated flow plot (QF7) was less than that of the uniform flow plot QF6 (20 mg/L). In spite of this, the sediment concentrations leaving the uniform flow filters were considerably less than those from the concentrated flow plots. As shown in Table 5, the concentrated flow plots had gross sediment losses of 16.1 (QF9T1R1) and 7.4 kg (QF8T1R1) for the short and long filters, respectively, while sediment losses from the uniform flow plots (QF4T1R1 and QF5T1R1) were only 8.5 and 1.0 kg, respectively. This occurred even though the sediment loading to the uniform flow plots was 3.7 times as great.

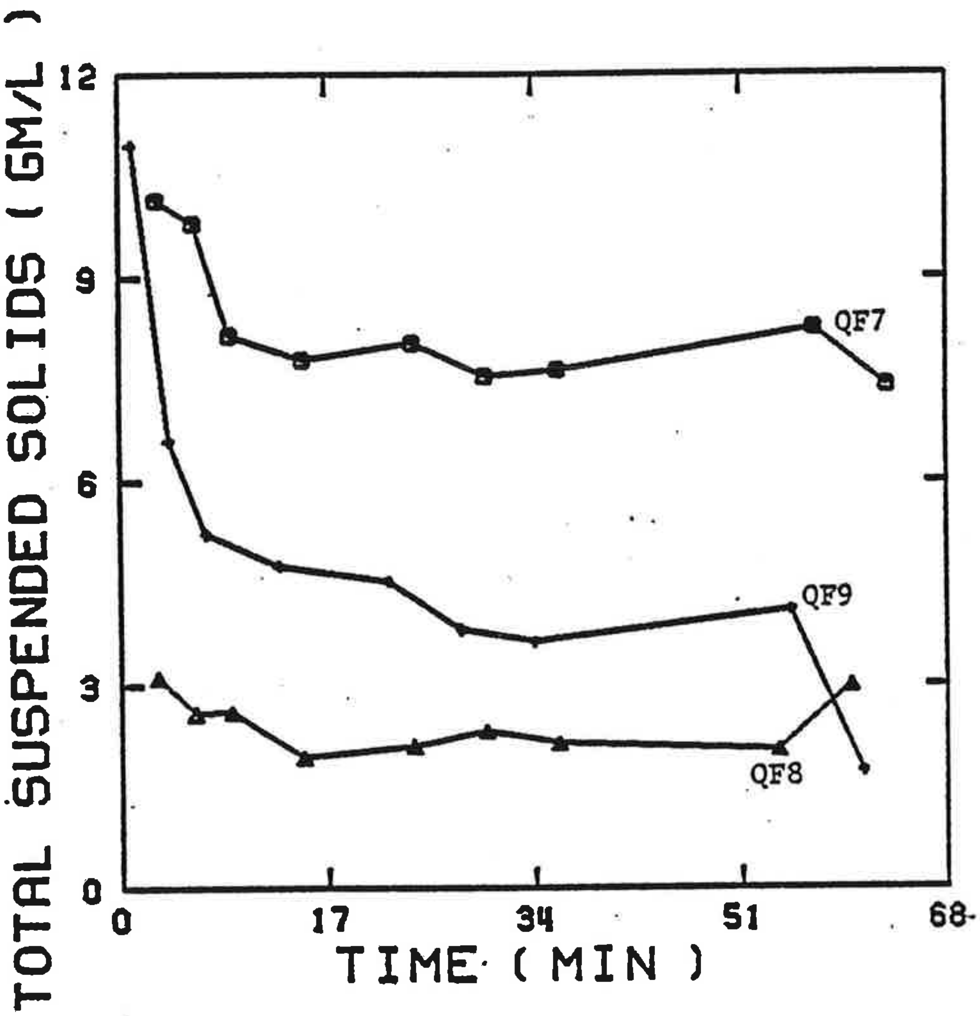

Figure 4. Sediment concentrations for plots QF7-9 Test 1 (concentrated flow plots) Run 1 (feedlot simulation)

Table 7. Percent reduction in simulated feedlot sediment, nutrient, and water yield by plot and test.

PLOT/ TEST/	FILTER LENGTH (M)	TSS	NH4	NO3	TKN	T-N	T-P	O-P	TKN-F	TP-F	RUNOFF
QF1T1	9.1	97.	78.	9.	86.	84.	88.	53.	67.	56.	38.
QF2T1	4.6	87.	59.	-36.	80.	77.	81.	9.	53.	34.	10.
QF3T1	0.0	-	-	-	-	-	-	-	-	-	-
QF4T1	9.1	91.	75.	18.	90.	87.	88.	47.	76.	37.	24.
QF5T1	4.6	82.	57.	24.	80.	78.	79.	34.	60.	-49.	27.
QF6T1	0.0	-	-	-	-	-	-	-	-	-	-
QF8T1	9.1	60.	9.	-36.	16.	14.	18.	-21.	-	-	0.
QF9T1	4.6	36.	-11.	-18.	30.	28.	33.	-40.	-	-	5.
QF7T1	0.0	-	-	-	-	-	-	-	-	-	-
QF1T2	9.1	90.	59.	1.	66.	62.	64.	11.	67.	16.	10.
QF2T2	4.6	87.	9.	-36.	31.	27.	27.	-43.	50.	33.	-24.
QF3T2	0.0	-	-	-	-	-	-	- -	-	-	
QF4T2	9.1	81.	-203.	13.	53.	54.	12.	-133.	-	-	-20.
QF5T2	4.6	65.	-139.	-53.	58.	56.	15.	-228.	-	-	5.
QF6T2	0.0	-	-	-	-	-	-	-	-	-	-
QF8T2	9.1	55.	-14.	-1650.	3.	1.	19.	44.	-	-	-1.
QF9T2	4.6	20.	2.	-867.	-21.	-22.	-17.	6.	-	-	-10.
QF7T2	0.0	-	-	-	-	-	-	-	-	-	-

sediment from the flow. Soluble P, however, is much more difficult to remove as it moves in solution independently of suspended sediment and its primary removal mechanisms probably involve infiltration, absorption, and soil 'sorption'. If this is the case, then soluble P removal should decrease with time as infiltration decreases, the absorption capacity of the vegetation is satisfied, and the surface soil P 'sorption' sites become occupied.

As shown in Table 6, reductions in T-P for all simulations were 80 and 63% for plots QF1 and 2, and 57 and 52% for plots QF4 and 5, respectively. The cross

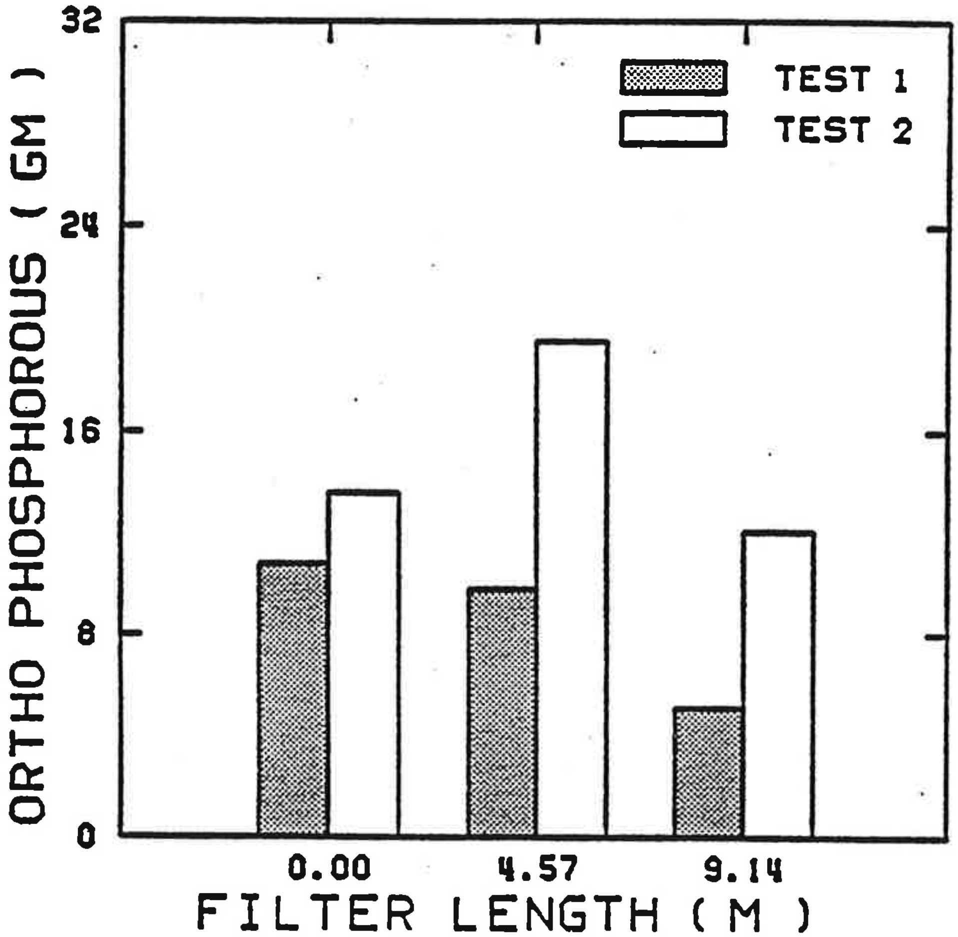

Figure 6. Ortho-phosphorus loss from plots QF1-3 (feedlot simulation)

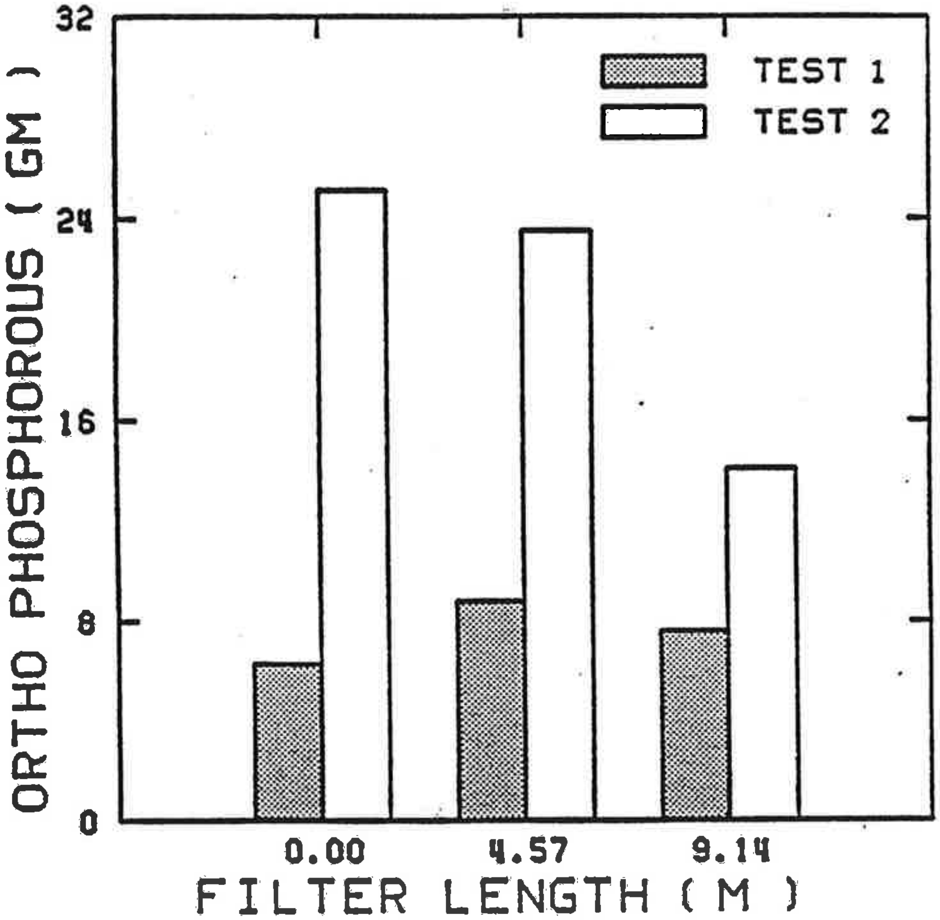

Figure 8. Ortho-phosphorus loss from plots QF7-9 (feedlot simulation)

particles. The filter effluent will then be enriched with smaller, more easily transported particles such as primary clay, silt, and small manure particles. Since these small particles may have a much higher capacity for the P sorption than the original soil mass, the passage of significant amounts of these particles through the filter may result in significant P transport in spite of a large decrease in gross sediment transport. The effects of effluent particle size distribution on VFS performance are currently being investigated.

Nitrogen Yield

Nitrogen loss from the simulated feedlot plots followed the same general trends as the soluble and sediment-bound P losses discussed previously. As shown in Tables 3 and 4, the 4.6 and 9.1 m filters on the uniform flow plots reduced T-N by 67 and 74%, respectively. Total Kjeldahl nitrogen accounted for approximately 97% of the N leaving the plots with no filters and about 85% of this TKN was in a filterable or sediment-bound form. This means that 82% of the N entering the filters was associated with sediment or manure particles. After passage through the 4.6 and 9.1 m filters, filterable TKN accounted for 67 and 59% of the N leaving the filters, respectively, indicating that the filters were not as effective in removing soluble N as they were sediment-bound N. This observation is further supported by Table 7 which shows that soluble N loss (NH_4, NO_3 and soluble TKN, (TKN-F)) was reduced much less than sediment-bound N.

As with P, the effectiveness of the filters decreased with time as sediment and nutrients built up in the filters. As shown in Figure 10, plots QF4 and 5 were more effective for N removal during the first three runs (Test 1) than the second set of runs (Test 2). This was also influenced by higher runoff rates during Test 2 due to lower infiltration in the plots caused by higher soil moisture contents and possibly surface sealing.

The filter strips were ineffective for removing soluble forms of N such as NO_3. As shown in Table 7, the highest percent reduction in NO_3 achieved by any uniform flow plot was 24% by plot QF5 during Test 1. During Test 2, NO_3 loss from this plot exceeded its influent loading by 53% indicating that N trapped in the filter during earlier runs was probably being mineralized and transported through the VFS as NO_3. The other plots had much higher NO_3 losses.

As shown in Tables 6 and 7, the concentrated flow plots were totally ineffective for N removal. Overall, the 9.1 m concentrated flow plot (QF8) reduced influent T-N by only 9% and the 4.6 m filter achieved no net reduction in T-N. Effluent NO_3 generally exceeded influent loadings indicating that the filters trapped very little influent NO_3 and released previously trapped N as NO_3.

CROPLAND SIMULATIONS

Sediment and nutrient concentrations of the 352 water quality samples collected during the cropland simulation portion of this project are presented in Table A-2 in conjunction with the plot discharges at the times each sample was collected. Tables 9 to 13, which summarize the results of the cropland simulations were derived from the data presented in Table A-2.

Rainfall Simulator Performance

Table 8 summarizes the performance of the rainfall simulator during the cropland simulations. As shown in Table 8, the mean application rate was 47.9 mm/h and ranged from a low of 41.2 mm/h (QF9T3R2) to a high of 52.4 mm/h (QF1T3R2). Uniformity coefficients averaged 93.3% with only 4 of 54 coefficients having values less than 90%. As with the feedlot simulations, the rainfall simulator performed quite well. The only major difference between the cropland and feedlot simulations was that the simulated rainfall intensity averaged 2.2 mm/h less during the cropland tests than the feedlot tests. This would be expected to reduce runoff by about 4% and erosion approximately 5%, relative to the 50.1 mm/h rainfall intensity produced during the feedlot tests.

Sediment Yield

As shown in Tables 9 to 13 and Figure 11, the VFS were very effective for sediment removal during the cropland simulations for both the shallow flow (QF1-6) and concentrated flow (QF7-9) plots. Sediment losses from the plots without filters were 39.3, 84.4, and 21.0 kg or 3.9, 8.9,

Table 9. Sediment, nutrient, and water yields from cropland simulations by plot.

PLOT/	FILTER LENGTH	TSS	NH4	NO3	TKN	T-N	T-P	O-P	TKN-F	TP-F	RUNOFF
	(M)	(KG)	(GM)	(GM)	(GM)	(GM)	(GM)	(GM)	(GM)	(GM)	(M3)
QF1	9.1	1.0	1.7	3.6	9.5	13.2	3.3	0.5	4.7	0.8	2.7
QF2	4.6	5.6	6.6	16.1	35.6	51.8	11.8	1.6	9.6	2.7	8.2
QF3	0.0	39.3	15.3	16.5	132.6	149.1	43.4	0.9	21.4	1.8	7.1
QF4	9.1	27.1	24.9	15.5	125.9	141.4	29.6	1.4	27.9	2.5	8.0
QF5	4.6	42.2	38.8	18.5	163.2	181.7	43.1	1.0	35.6	1.8	7.0
QF6	0.0	89.4	42.9	19.8	308.5	319.8	84.2	1.1	47.5	1.7	5.6
QF8	9.1	1.4	1.2	3.4	14.5	17.9	3.0	0.3	2.7	0.4	2.5
QF9	4.6	3.6	1.9	3.4	12.3	15.7	3.5	0.2	2.7	0.4	2.0
QF7	0.0	21.0	7.5	12.2	76.8	89.0	22.7	0.5	11.3	1.0	5.9

plots were tilled prior to storm events compared to the compacted feedlot plots. The higher infiltration rates and initial soil moisture differences resulted in average runoff reductions of 59, 68, and 74% for the cropland plots relative to the feedlot plots for the 0, 4.6, and 9.1 m filter plots, respectively.

As shown in Table 12, the 4.6 m VFS of plots QF2, 5, and 9 reduced sediment losses by 86, 53, and 83%, respectively, and the 9.1 m plots, QF1, 4, and 8, reduced sediment loss by 98, 70, and 93%, respectively. Doubling the filter lengths from 4.6 to 9.1 m reduced sediment loss by only an additional 12, 23, and 10% for the 11 and 16% slope uniform flow plots and the 5% slope concentrated flow plot, respectively. These results are similar to those from the feedlot simulations and indicate that the first few meters of the VFS are responsible for most sediment removal until the filters become inundated with sediment. After inundation, the lower portions of the VFS start trapping sediment which is not trapped by the upper buried portions.

It is interesting to note, as shown in Tables 12 and 13 and Figure 12, that the concentrated flow plots were more effective with respect to sediment and nutrient removal than the 16% slope uniform flow plots (QF4 and 5) and only

Table 11. Sediment, nutrient, and water yields from cropland simulations by plot, test, and run.

PLOT/ TEST/ RUN	FILTER LENGTH (M)	TSS (KG)	NH4 (GM)	NO3 (GM)	TKN (GM)	T-N (GM)	T-P (GM)	O-P (GM)	TKN-F (GM)	TP-F (GM)	RUNOFF (M3)
QF1T3R1	9.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
QF2T3R1	4.6	0.02	0.17	0.30	0.64	0.93	0.15	0.06	0.38	0.10	0.16
QF3T3R1	0.0	2.01	2.52	1.69	19.60	21.29	4.64	0.05	4.17	0.20	0.48
QF1T3R2	9.1	0.05	0.26	0.27	1.67	1.94	0.33	0.02	0.51	0.07	0.14
QF2T3R2	4.6	0.53	1.24	1.37	5.12	6.49	1.38	0.19	2.30	0.41	0.87
QF3T3R2	0.0	5.79	3.75	1.78	19.76	21.55	6.65	0.15	4.20	0.25	0.85
QF1T3R3	9.1	0.11	0.51	0.75	3.19	3.94	0.88	0.06	1.35	0.19	0.50
QF2T3R3	4.6	1.26	1.52	1.99	8.34	10.33	2.92	0.22	0.84	0.66	1.43
QF3T3R3	0.0	10.90	2.73	1.93	29.72	31.66	11.06	0.16	4.55	0.43	1.17
QF1T4R1	9.1	0.11	0.22	0.67	1.05	1.72	0.35	0.13	0.57	0.13	0.53
QF2T4R1	4.6	1.15	1.85	4.07	10.35	14.43	2.86	0.62	2.97	0.83	2.46
QF3T4R1	0.0	9.49	3.94	4.30	34.27	38.57	11.29	0.23	4.50	0.46	2.08
QF1T4R2	9.1	0.15	0.34	0.65	0.99	1.64	0.48	0.09	0.29	0.13	0.50
QF2T4R2	4.6	0.96	0.86	2.14	4.31	6.45	1.62	0.26	1.47	0.33	1.49
QF3T4R2	0.0	4.13	1.23	1.75	11.57	13.33	3.83	0.14	2.00	0.24	1.10
QF1T4R3	9.1	0.54	0.36	1.30	2.61	3.91	1.21	0.17	2.01	0.30	1.04
QF2T4R3	4.6	1.63	0.91	6.28	6.87	13.15	2.90	0.28	1.59	0.37	1.80
QF3T4R3	0.0	6.93	1.12	5.04	17.66	22.71	5.97	0.16	1.96	0.26	1.44
QF4T3R1	9.1	0.89	1.00	0.50	4.95	5.44	1.03	0.06	1.75	0.11	0.28
QF5T3R1	4.6	1.43	2.73	0.59	7.96	8.55	1.82	0.09	2.77	0.12	0.34
QF6T3R1	0.0	14.41	8.64	1.64	52.93	54.57	13.54	0.36	10.53	0.44	0.71
QF4T3R2	9.1	2.27	3.40	0.86	13.18	14.04	3.20	0.15	4.05	0.22	0.68
QF5T3R2	4.6	3.50	5.31	1.31	16.11	17.42	3.62	0.15	4.53	0.20	0.62
QF6T3R2	0.0	11.40	7.19	2.33	41.70	44.02	10.11	0.21	7.07	0.29	0.67
QF4T3R3	9.1	4.10	6.34	2.25	23.92	26.17	6.22	0.25	6.60	0.36	1.36
QF5T3R3	4.6	6.44	8.23	1.59	26.25	27.84	6.74	0.22	7.04	0.33	1.14
QF6T3R3	0.0	16.66	7.38	3.55	51.07	54.62	13.16	0.23	8.99	0.38	0.94
QF4T4R1	9.1	6.66	5.02	5.37	31.18	36.55	5.05	0.38	6.55	0.51	2.22
QF5T4R1	4.6	10.46	9.94	6.46	41.01	47.47	10.78	0.24	8.33	0.58	1.91
QF6T4R1	0.0	23.89	9.05	5.86	86.56	92.43	24.99	0.11	10.82	0.25	1.40

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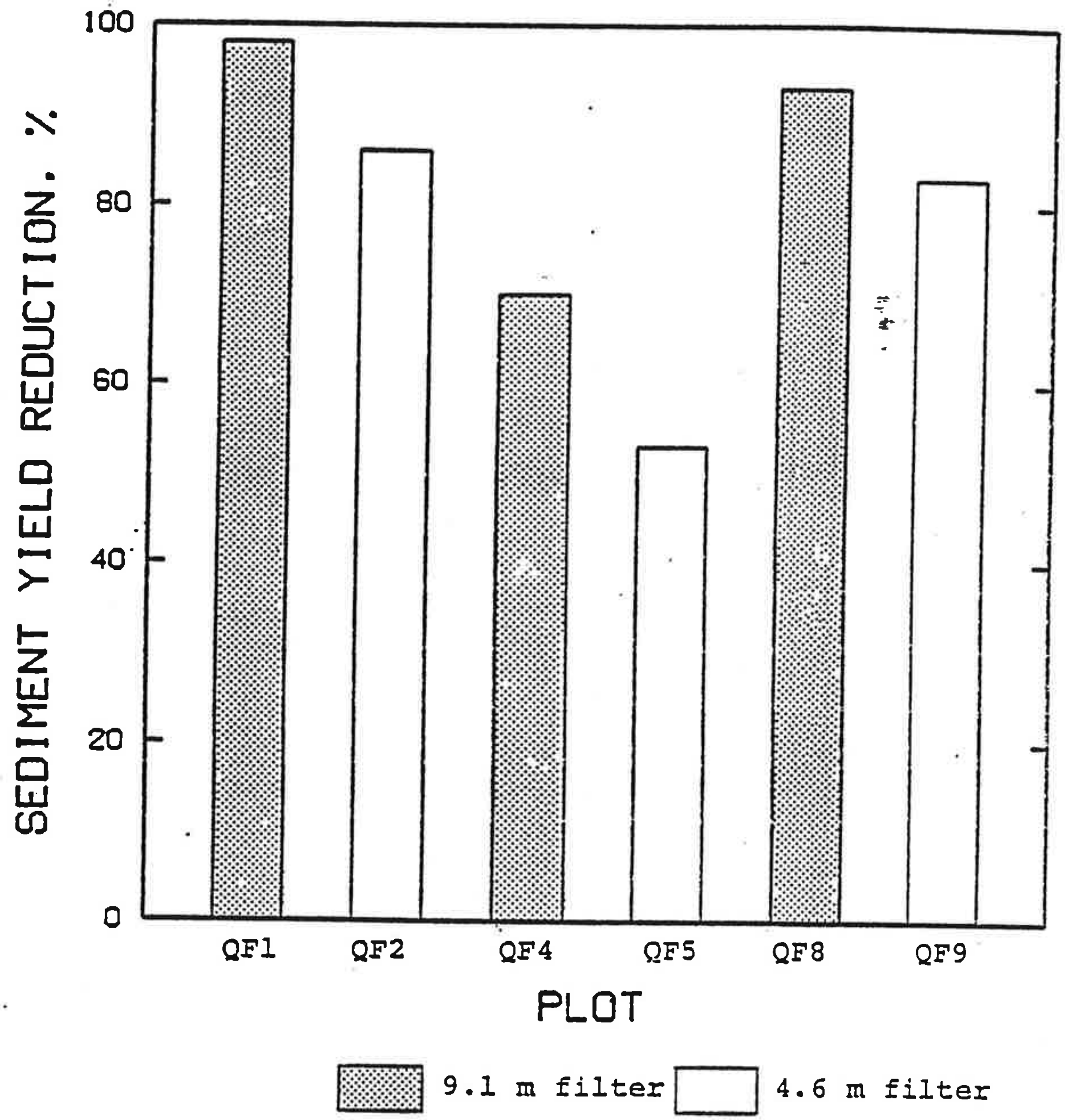

Figure 11. Percent reduction in sediment yield for plots QF1-9 (cropland simulation)

Table 13. Percent reduction in simulated cropland sediment, nutrient and water yield by plot and test.

PLOT/ TEST/	FILTER LENGTH	TSS	NH4	NO3	TKN	T-N	T-P	O-P	TKN-F	TP-F	RUNOFF
	(M)	(KG)	(GM)	(GM)	(GM)	(GM)	(GM)	(GM)	(GM)	(GM)	(M3)
QF1T3	9.1	99.	91.	81.	93.	92.	95.	78.	86.	70.	74.
QF2T3	4.6	90.	67.	32.	80.	76.	80.	-31.	73.	-33.	2.
QF3T3	0.0	-	-	-	-	-	-	-	-	-	-
QF4T3	9.1	83.	54.	52.	71.	70.	72.	43.	53.	38.	0.
QF5T3	4.6	73.	30.	54.	65.	65.	67.	43.	46.	41.	9.
QF6T3	0.0	-	-	-	-	-	-	-	-	-	-
QF8T3	9.1	93.	88.	81.	90.	89.	89.	71.	80.	82.	65.
QF9T3	4.6	86.	84.	84.	88.	88.	86.	79.	83.	79.	72.
QF7T3	0.0	-	-	-	-	-	-	-	-	-	-
QF1T4	9.1	96.	85.	76.	93.	90.	90.	26.	66.	42.	55.
QF2T4	4.6	82.	42.	-13.	66.	54.	65.	-119.	29.	-59.	-24.
QF3T4	0.0	-	-	-	-	-	-	-	-	-	-
QF4T4	9.1	58.	28.	3.	48.	42.	60.	-258.	26.	-192.	-72.
QF5T4	4.6	34.	-15.	-22.	31.	23.	35.	-100.	-2.	-87.	-48.
QF6T4	0.0	-	-	-	-	-	-	-	-	-	-
QF8T4	9.1	93.	83.	67.	77.	76.	86.	30.	74.	47.	55.
QF9T4	4.6	81.	69.	66.	82.	80.	84.	60.	71.	55.	63.
QF7T4	0.0	-	-	-	-	-	-	-	-	-	-

in Table 9). Since the filters were effective for sediment removal, they were also effective for P removal. The cropland VFS were much more effective than the feedlot plots for P removal for the same reasons that they were more effective for sediment removal, namely, reduced runoff and sediment transport capacity.

As shown in Table 13, the effectiveness of the filters in removing T-P decreased with time from 2 to 32% from Test 3 to Test 4. Like the feedlot simulations, there was a tendency for previously trapped P to be re-released during latter runs as O-P. Consequently, yields of soluble P (O-P) from the

VFS were often higher than the inflows, especially during the last set of runs (Test 4) as shown in Table 13.

As with sediment loss, Plots QF4 and 5, were least effective for P removal because they were quickly inundated with sediment reducing their sediment and therefore sediment-bound P trapping efficiency.

Nitrogen Yield

Percent reductions in T-N from the cropland simulations were similar to those observed for T-P but generally 2 to 9% less. Nitrogen yield like P yield appeared to be highly correlated with sediment yield indicating that N entering the plots was predominantly sediment-bound. Nitrogen from the simulated cropland plots was predominantly sediment-bound (Table 9) as 77, 65, and 66% of the T-N leaving the plots with no filters, the 4.6 m filters and the 9.1 m filters, respectively, was sediment-bound (total N - nitrate - soluble TKN).

As with P and sediment yield, the steepest plots (QF4-5) were least effective, the concentrated flow plots (QF8-9) were moderately effective, and the 11% slope plots (QF1-2) were the most effective for N removal.

As shown in Table 9, 93% of the T-N leaving the bare portions of the plots and entering the filters was in the form of TKN (organic-N plus NH_4). This was expected because most of the N in the plots was residual organic N which had built up in the soils previously and because 75% of the N fertilizer applied to the plots was either urea or NH_4. Both NH_4 and urea have a tendency to bind to and be transported along with clay particles and organic matter in the soil. Also, most of the urea N is rapidly hydrolyzed to NH_4. By the end of the tests, most of the NH_4 and urea were probably mineralized to NO_3 so residual organic N in the soil was presumably the primary source of N leaving the plots.

Soil Inorganic Nitrogen

Concentration of Inorganic N: The concentrations of both NO_3 (Fig. 13) and NH_4 (Fig. 14)
increased, as expected, after the cropland simulation and N application to the bare portions of the plots. The maximum NO_3 concentration was present in the surface horizon and ranged from 20 kg N/ha prior to the application of N and

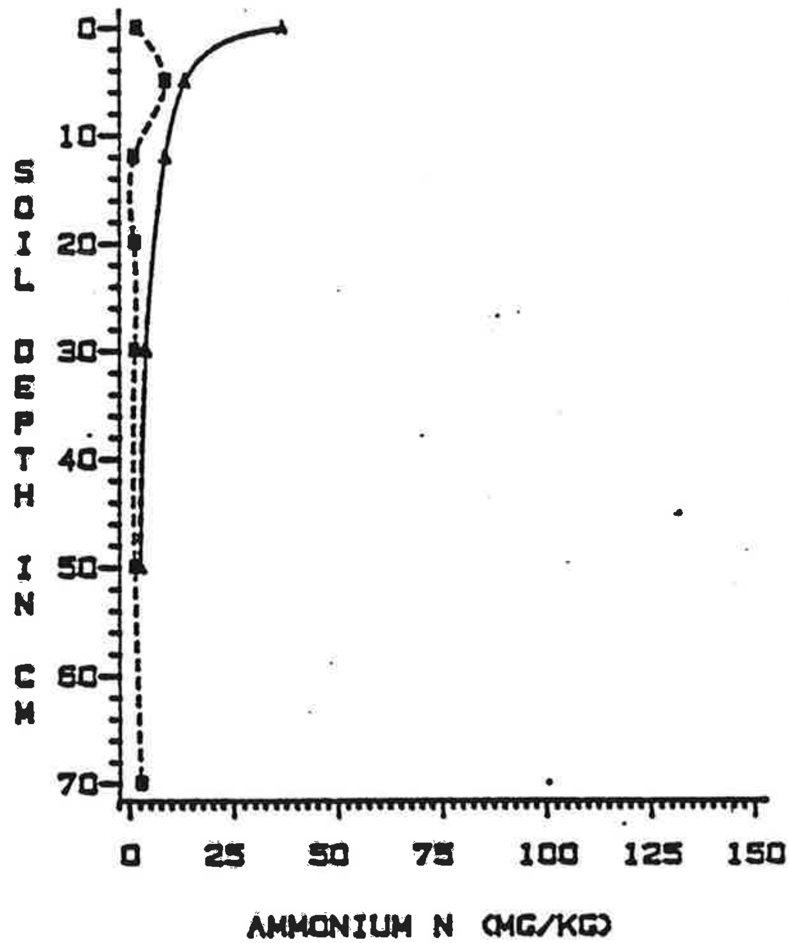

Figure 14. Ammonium nitrogen in the bare soil profile before (B - - B) and after (A —— A) cropland simulation.

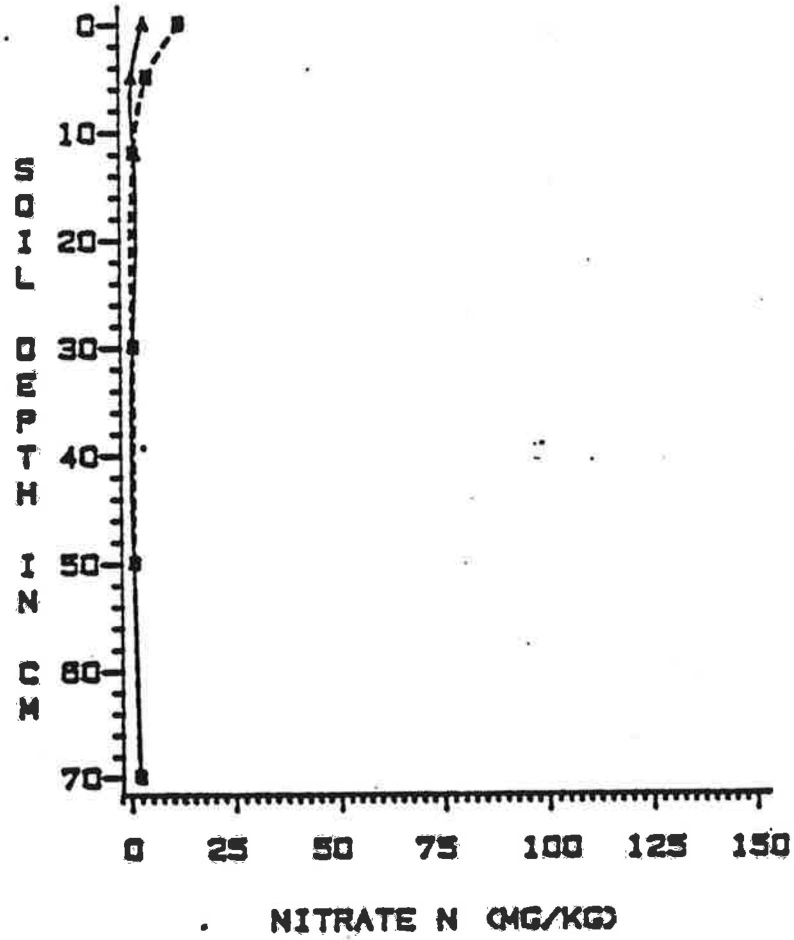

Figure 15. Nitrate nitrogen in the filter strip soil profile before (B - - B) and after (A —— A) cropland simulation.

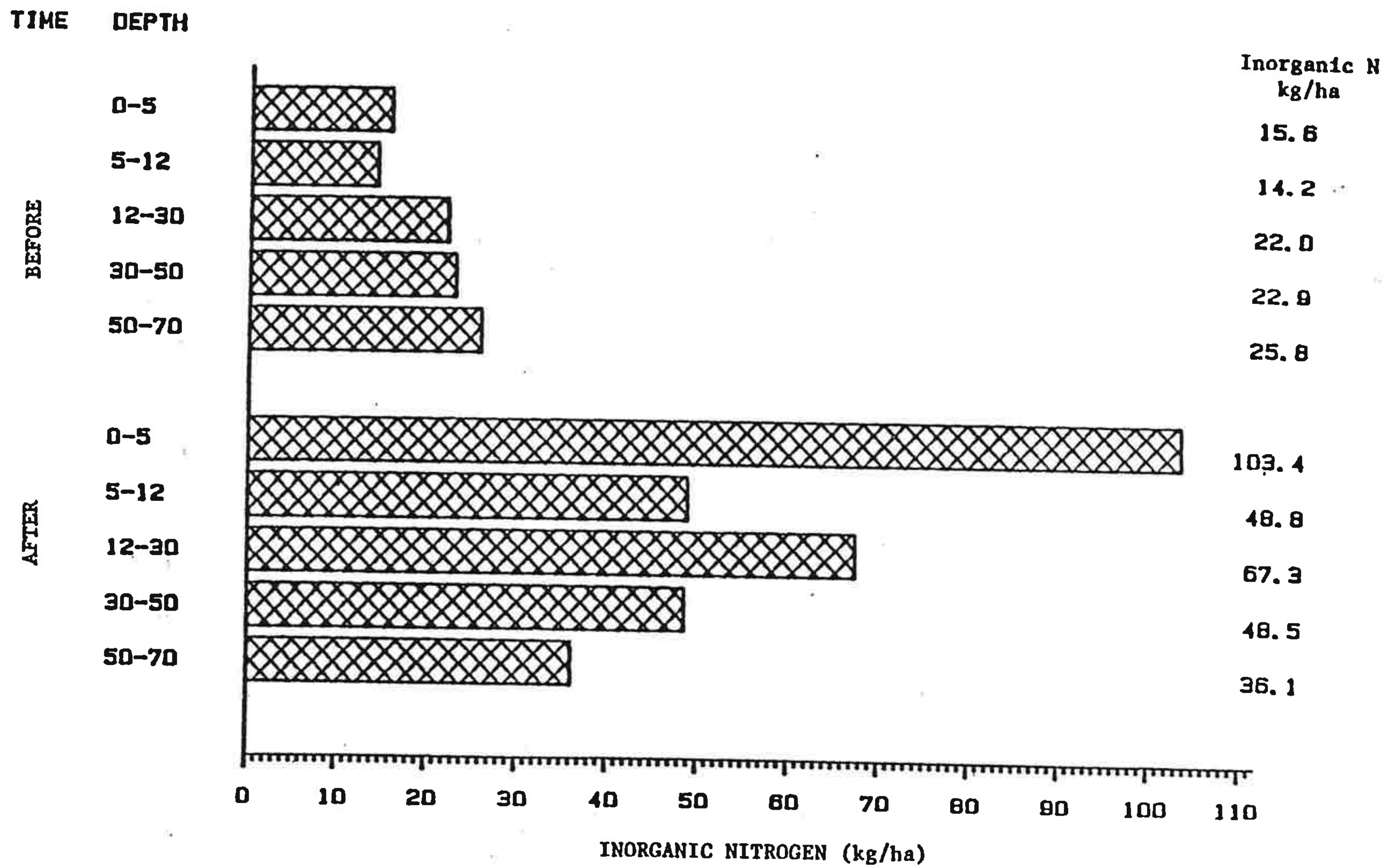

Figure 17. Inorganic nitrogen (kg/ha) present in selected soil layers in the bare soil profile before and after cropland simulation.

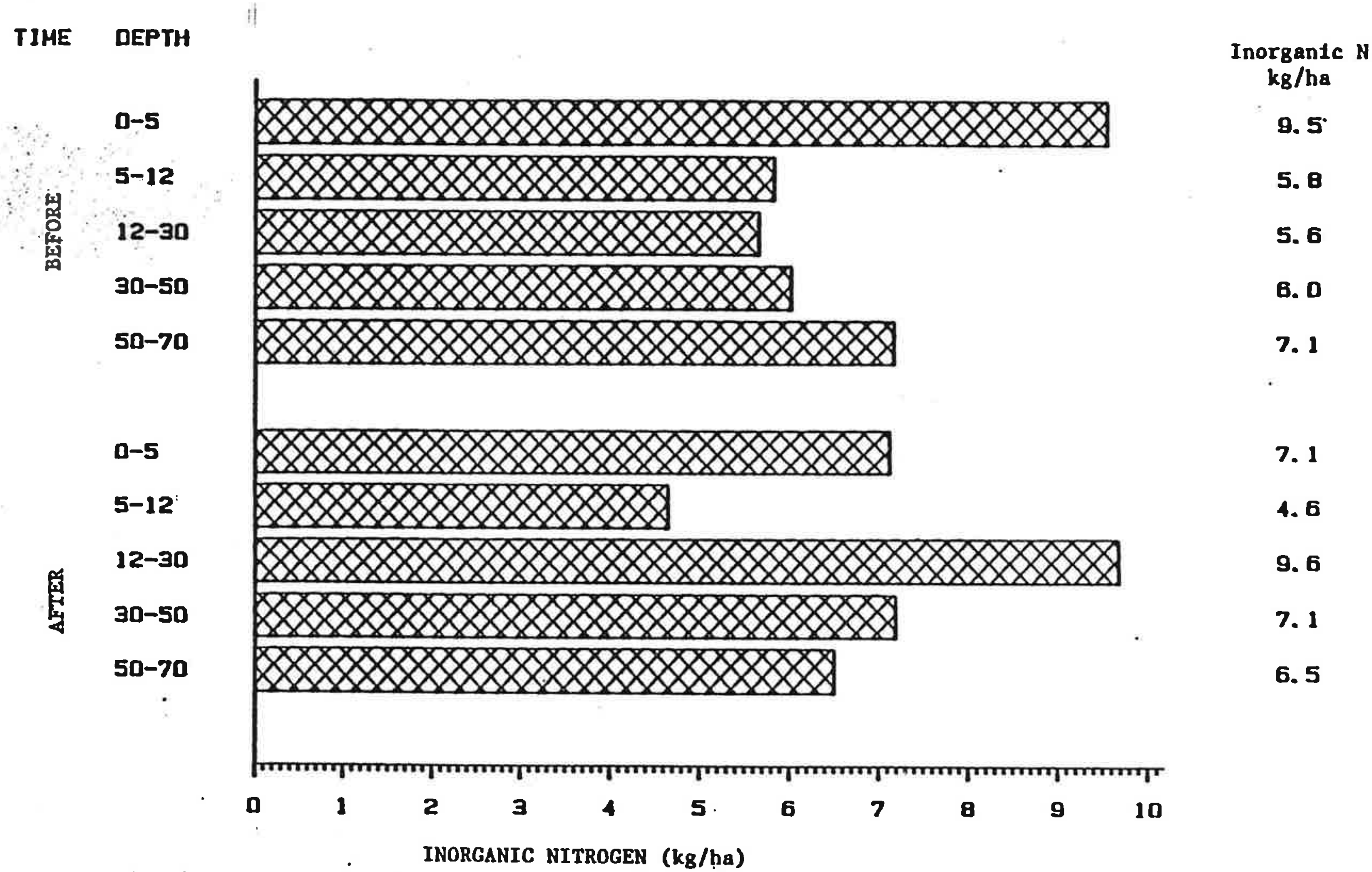

Figure 18. Inorganic nitrogen (kg/ha) present in selected soil layers in the filter strip soil profile before and after cropland simulation.

Table 15. Percent reduction in sediment, nutrient, and water yields for all simulations.

PLOT/ TEST/ RUN	FILTER LENGTH (M)	TSS (KG)	NH4 (GM)	NO3 (GM)	TKN (GM)	T-N (GM)	T-P (GM)	O-P (GM)	TKN-F (GM)	TP-F (GM)	RUNOFF (M3)
QF1	9.1	96.	71.	33.	82.	79.	82.	28.	69.	37.	10.
QF2	4.6	86.	38.	-19.	66.	61.	65.	-24.	52.	30.	-27.
QF3	0.0	-	-	-	-	-	-	-	-	-	-
QF4	9.1	83.	8.	19.	69.	67.	58.	-43.	57.	11.	-47.
QF5	4.6	70.	-4.	2.	64.	62.	51.	-93.	40.	-44.	10.
QF6	0.0	-	-	-	-	-	-	-	-	-	-
QF8	9.1	66.	-4.	-15.	22.	20.	27.	29.	-	-	-19.
QF9	4.6	41.	5.	15.	15.	15.	12.	-3.	-	-	9.
QF7	0.0	-	-	-	-	-	-	-	-	-	-

judged to be beneficial because they provide effective cover in areas immediately adjacent to streams which are often susceptible to severe localized channel and gully erosion. They also provide a narrow buffer between cropland and streams which may reduce the aerial drift of fertilizers and pesticides to streams during application.

In flatter areas, such as the coastal plain, VFS appeared to be more effective. Slopes were more uniform, and significant portions of stormwater runoff entered the VFS as shallow uniform flow. This observation was supported by the presence of significant sediment accumulations in many of the coastal plain filters surveyed. Several one to three year old filters were observed that had trapped so much sediment that they were higher than the fields they were protecting. In these cases, runoff tended to flow parallel to the VFS until a low point was reached where it flowed across as concentrated flow. In this situation, the VFS acted more like a terrace than a filter strip.

Flow parallel to the VFS also was observed on several farms where moldboard plowing was practiced. When soil was turn plowed away from the filter, a shallow ditch was formed parallel to the field. If this ditch was not removed

SUMMARY AND CONCLUSIONS

Simulated rainfall was applied to a series of 5.5 by 18.3 m bare soil plots with 4.6 and 9.1 m VFS located at the lower end of the plots as shown in Figure 1. The plots were used to evaluate the effectiveness of VFS for controlling sediment and nutrient losses from both feedlots and cropland. For the feedlot simulations, fresh dairy manure was applied to the bare portions of the plots at rates of 7500 and 15,000 kg/ha and compacted with rollers to simulate feedlot conditions. For the cropland simulations, commercial fertilizer, 112 kg/ha of granular P_2O_5 and K_2O and 222 kg-N/ha of non-pressurized N solution were applied to bare tilled plots. Water samples were collected from H-flumes at the base of each plot to evaluate the effectiveness of the VFS in removing sediment, N, and P from the simulated feedlot or cropland runoff. One set of plots was constructed with a cross slope so that flow through the filters would be deeper or concentrated rather than shallow and uniform. Observation of existing VFS in the Commonwealth of Virginia and analysis of the results of the plot studies led to the following conclusions:

1. Vegetative filter strips are effective for the removal of sediment and other suspended solids from the surface runoff of feedlots if flow is shallow and uniform and if the VFS have not previously filled with sediment. The 9.1 and 4.6 m VFS on the uniform flow plots removed 91 and 81% of the incoming sediment during the feedlot simulations, respectively, and 78 and 63% during the cropland simulations, respectively.

2. The effectiveness of VFS for sediment removal appears to decrease with time as sediment accumulates within the filter. On the average, VFS effectiveness decreased by approximately 9% with respect to sediment removal between the first and second set of the feedlot simulations. One set of the filters (QF4-5) during the cropland simulations was almost totally inundated with sediment and filter effectiveness dropped 30 to 60% between the first and second set of runs. This may or may not be a problem in "real world" VFS because filter strip vegetation should normally be able to grow through most sediment accumulations.

6. Nitrogen balances for the cropland simulation indicated that 91% of the applied fertilizer N remained in the soil profile. Assuming that the fertilizer N applied to the cropland simulation was present in the inorganic form, then only 1 to 3% of the applied N was lost from the source area via runoff. After passing through the VFS, runoff losses where on the order of 0.2 to 2.5%. Soil samples collected from the VFS before and after the cropland simulation indicated that NO_3 did not accumulate in the VFS soil profile as a result of the infiltration of soluble N.

7. Most on-farm VFS (cropland only) which were visited during this study were judged to be ineffective for sediment and nutrient removal. The majority of flow entering the filters was judged to be concentrated because runoff tended to accumulate in natural drainageways long before reaching the VFS. This was more of a problem in hilly areas and less of a problem in flatter areas such as the coastal plain. The effectiveness of the experimental filter strips used in this study should not be used as a direct indicator of real world VFS effectiveness because of the concentrated flow problems previously discussed. Concentrated flow effects under real agricultural conditions will be orders of magnitude greater than those measured during the experimental field studies.

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APPENDIX A

VEGETATIVE FILTER STRIP EVALUATION FORM

VFS code:________ Date:__________ Evaluated by:________________________

District:________________________ County:______________________________

Participant's name:____

Field number(s):_________________ Adjacent stream:_____________________

Length certified for payment (ft):_____________________________________

Average width (ft):_________ Mininum:_________ Maximum width:__________

Estimated age (Yrs):____________ Distance to stream:___________________

Cover condition: Excellent Good Fair Poor No visible VFS

(circle appropriate response and describe below)

____

Type of Vegetation:____

Is VFS damaged or in need of maintenance?_________________ (describe)

____

Land use, crops, etc. above VFS:____

____

Slope of field above VFS, % __________ Slope across VFS, % __________

Estimated percent of field drainage entering VFS as concentrated flow,

% :____________ Describe field drainage system:_____________________

____

Elevation of VFS with respect to field:_________________________________

____

Owner's attitude concerning VFS (good, bad?):___________________________

____

Owner's opinion of effectiveness of VFS for water quality improvement:

____

Would owner install VFS without cost sharing? :_________________________

Figure A-1. Sample filter strip evaluation form

QF2T1R1	10	0.389	1.90	1.72	17.70	19.40	4.40	1.60		4.90	1.55	6	1.3620
QF2T1R1	12	0.529	1.47	1.54	14.20	15.70	5.60	1.30		3.90	1.30	6	1.4272
QF2T1R1	16	0.357	1.33	1.49	12.40	13.90	3.30	1.10		2.75	1.10	18	1.4923
QF2T1R1	20	1.445	1.10	1.57	8.30	9.90	2.30	1.10		2.60	1.05	6	0.1388
QF2T1R2	1	0.430	1.69	2.23	3.40	5.60	0.80	0.70		3.90	0.75	2	0.9911
QF2T1R2	2	0.580	1.59	1.21	5.70	6.90	2.40	0.60		3.10	0.65	3	1.5404
QF2T1R2	4	2.153	1.17	1.73	11.20	12.90	4.80	0.60	136.	2.05	0.55	6	1.6056
QF2T1R2	6	0.570	1.18	1.58	3.20	4.80	1.80	0.60		2.25	0.65	6	1.6565
QF2T1R2	8	0.625	0.97	1.39	4.20	5.60	2.20	0.60		1.70	0.55	9	1.7925
QF2T1R2	10	0.379	0.82	1.51	4.80	6.30	2.30	0.60		1.70	0.55	6	0.7447
QF2T1R3	1	1.463	1.16	1.31	7.80	9.20	3.20	0.80		2.00	0.50	3	1.7415
QF2T1R3	2	0.883	1.12	1.19	5.00	6.20	2.80	0.50		2.05	0.50	3	1.7556
QF2T1R3	4	0.935	0.87	1.33	3.90	5.20	2.40	0.50		1.50	0.45	6	1.7556
QF2T1R3	6	4.857	0.68	0.58	5.50	6.00		0.60		1.85	0.60	6	1.7925
QF2T1R3	8	0.751	0.83	1.42	7.00	8.40	3.40	0.40		1.80	0.60	9	1.7755
QF2T1R3	10	2.355	0.83	1.34	9.80	11.10	4.00	0.50	106.	0.70	0.45	6	0.8580
QF2T2R1	1	0.121	4.66	6.99	22.50	29.50	5.10	2.10		15.00	2.40	1	0.0510
QF2T2R1	2	0.138	4.55	5.23	22.40	27.60	7.00	2.20		10.50	2.35	3	1.3450
QF2T2R1	3	0.135	4.25	4.07	21.20	25.30	8.10	2.00		9.00	2.35	3	1.5234
QF2T2R1	5	0.166	3.80	2.67	10.50	13.30	5.10	2.30	345.	7.65	2.35	6	1.7075
QF2T2R1	8	0.181	3.74	1.80	11.60	13.40	4.70	2.20		6.45	2.25	9	1.8859
QF2T2R1	10	0.174	2.99	1.36	17.60	19.00	6.40	1.60		5.30	1.55	6	2.0501
QF2T2R1	12	0.293	2.98	1.25	17.50	18.80	5.80	1.90		5.00	1.60	6	1.9878
QF2T2R1	16	0.180	2.34	1.00	9.90	10.90	3.60	1.80		4.80	1.70	21	2.0105
QF2T2R1	20	0.103	2.53	1.07	6.80	7.90	2.90	1.50				6	0.9458
QF2T2R2	1	0.211	2.63	4.45	10.90	15.40	2.70	1.40				1	0.0793
QF2T2R2	2	0.176	2.81	4.59	11.10	15.70	3.20	1.30				3	1.4583
QF2T2R2	4	0.133	2.52	2.71	7.00	9.70	4.00	1.20				6	1.6056
QF2T2R2	6	0.190	1.89	1.59	9.20	10.80	4.20	1.10				6	1.6877
QF2T2R2	8	0.408	1.94	1.43	18.90	20.30	6.60	1.30	139.			9	1.7755
QF2T2R2	10	0.126	1.79	1.33	5.80	7.10	3.10	1.30				6	0.9005
QF2T2R3	1	0.593	2.66	1.46	9.00	10.50	3.80	1.50				3	1.6877
QF2T2R3	2	0.396	2.38	1.28	9.70	11.00	5.10	1.40				3	1.6707
QF2T2R3	4	0.309	1.75	1.05	11.00	12.10	5.60	1.20				6	1.7245
QF2T2R3	8	0.745	1.50	0.93	9.20	10.10	4.80	1.10				15	1.8378
QF2T2R3	10	0.375	1.48	0.94	7.60	8.50	3.90	1.20				6	0.8127
QF3T1R1	1	12.580	13.70	12.45	91.70	104.20	45.50	2.40		34.80	3.20	5	0.9656
QF3T1R1	2	4.670	14.50	1.69	136.30	138.00	52.00	6.50		29.50	6.45	3	1.2516
QF3T1R1	3	4.543	11.40	0.13	118.60	118.70	38.00	5.50		23.00	5.35	3	1.2233
QF3T1R1	5	6.787	6.90	0.93	76.80	77.70	24.00	2.80		14.40	3.05	6	1.2516
QF3T1R1	8	9.855	5.25	0.68	64.30	66.00	23.10	1.70		8.65	1.85	9	1.3082
QF3T1R1	10	9.824	4.48	0.76	49.40	50.20	18.70	1.50		7.65	2.85	6	1.3366
QF3T1R1	12	9.673	4.32	0.72	25.30	26.00	13.90	1.30		5.65	1.50	6	1.3366
QF3T1R1	16	9.653	3.26	0.90	53.80	54.70	20.40	1.00		4.75	1.30	21	1.3082
QF3T1R1	20	8.897	4.33	1.06	49.10	50.20	16.40	1.40		7.40	1.45	6	0.5154
QF3T1R2	1	6.069	3.15	2.05	38.90	41.00	14.30	0.40		5.20	0.60	3	1.1298
QF3T1R2	2	6.770	2.73	1.56	36.10	37.70	11.50	0.40		3.80	0.55	3	1.1723
QF3T1R2	4	8.476	1.70	0.97	44.40	45.40	14.80	0.40		2.95	0.55	6	1.1978
QF3T1R2	6	7.288	1.59	0.73	44.30	45.00	15.40	0.40		3.05	0.50	6	1.1440
QF3T1R2	8	6.216	1.95	0.65	38.50	39.20	16.10	0.30	1452.	3.00	0.50	6	1.1723
QF3T1R2	10	7.575	1.72	0.93	46.80	47.70	18.30	0.30		2.75	0.45	6	1.1978
QF3T1R3	1	4.995	2.37	0.86	48.30	49.20	15.50	0.40		2.95	0.55	2	1.3649
QF3T1R3	2	7.344	1.97	1.18	19.10	20.30	6.30	0.50		2.90	0.65	3	1.3366
QF3T1R3	4	9.041	1.56	1.02	28.10	29.10	9.00	0.40		2.25	0.50	6	1.2516

QF4T2R1	15	1.930	4.05	0.20	8.70	12.00	5.10	1.75	572.			3	1.9850
QF4T2R1	16	1.014	2.35	0.20	5.40	12.00	5.10	1.98	587.			3	1.9340
QF4T2R1	17	1.286	1.82	0.20	14.10	12.00	7.90	1.86	498.			3	1.9850
QF4T2R1	18	0.992	0.45	0.20	15.50	12.00	4.70	1.68	252.			3	1.9850
QF4T2R1	19	0.788	4.15	0.34	10.00	10.30	4.90	1.10	171.			3	1.8661
QF4T2R1	20	0.586	4.55	0.46	6.70	7.20	3.50	1.20	99.			3	0.4955
QF4T2R1	21	1.678	4.05	0.40	9.30	9.70	4.40	1.25	127.			3	0.0878
QF4T2R2	1	0.886	6.10	0.57	16.40	17.00	4.10	1.75	524.			3	0.3171
QF4T2R2	2	1.086	4.15	0.86	13.20	14.10	4.90	0.85	172.			2	1.7358
QF4T2R2	3	1.002	3.25	0.79	13.10	13.90	5.30	0.70	474.			3	1.8151
QF4T2R2	4	1.094	2.09	0.89	12.70	13.60	5.40	0.85	445.			3	1.9510
QF4T2R2	5	0.846	2.00	0.69	6.10	6.80	4.30	0.83	454.			3	1.9510
QF4T2R2	6	0.956	1.75	0.73	8.30	9.00	4.30	0.73	228.			3	1.9850
QF4T2R2	7	0.786	1.63	0.62	9.40	10.00	3.30	0.65	156.			3	2.0020
QF4T2R2	8	0.734	2.21	0.63	7.00	7.60	3.50	0.68	227.			3	2.0388
QF4T2R2	9	0.762	2.19	0.62	7.50	8.10	4.40	0.53	187.			3	2.0020
QF4T2R2	10	0.568	2.16	0.74	3.80	4.50	3.50	0.60	108.			3	1.2431
QF4T2R3	1	0.454	2.23	0.44	16.10	16.50	6.00	1.01	221.			2	2.0020
QF4T2R3	2	1.104	2.13	0.49	9.40	9.90	5.20	0.94	193.			3	1.9850
QF4T2R3	3	1.640	1.62	0.44	4.40	4.80	3.10	0.74	217.			3	1.8661
QF4T2R3	4	0.952	3.30	0.49	6.30	6.80	1.40	0.75	222.			3	2.0558
QF4T2R3	5	1.458	2.11	0.47	9.40	9.90	2.50	0.62	210.			3	1.9340
QF4T2R3	6	1.578	1.31	0.83	4.00	4.80	3.10	1.03	210.			3	1.9680
QF4T2R3	7	0.926	1.36	0.46	8.60	9.10	1.80	0.63	196.			3	1.9850
QF4T2R3	8	1.350	1.12	0.72	3.60	4.30	1.40	0.96	194.			3	1.8831
QF4T2R3	9	1.080	1.36	0.68	5.00	5.70	1.30	0.91	154.			3	1.9171
QF4T2R3	10	1.164	1.38	0.65	3.40	4.00	0.90	0.77	143.			3	0.8891
QF4T2R3	11	0.762	1.35	0.58	1.60	2.20	2.50	0.71	131.			3	0.2775
QF5T1R1	1	4.530	4.62	5.52	23.20	28.70	9.20	1.02	327.	7.00	1.00	5	0.0113
QF5T1R1	2	2.936	3.78	3.97	19.20	23.20	5.70	0.92		5.10	1.20	3	0.0368
QF5T1R1	3	3.830	3.23	3.68	23.70	27.40	7.60	0.98		6.00	1.15	3	0.1472
QF5T1R1	5	2.336	2.95	2.86	20.70	23.60	6.40	0.83		4.45	0.95	6	0.3794
QF5T1R1	8	3.174	2.15	2.31	21.60	23.90	6.30	0.68		3.35	0.85	9	0.7476
QF5T1R1	10	4.294	2.03	2.19	18.50	20.70	6.00	0.67		4.05	0.80	6	0.8523
QF5T1R1	12	4.016	1.82	2.08	22.60	24.70	6.70	0.69		4.00	0.95	6	0.9146
QF5T1R1	16	4.302	1.63	1.92	11.90	13.80	4.80	0.66		3.55	0.80	15	1.0590
QF5T1R2	1	4.420	1.94	4.89	16.10	21.00	5.00	0.64		6.35	0.90	2	0.1756
QF5T1R2	2	4.008	1.67	3.53	13.00	16.50	4.70	0.62		4.20	0.80	3	1.0052
QF5T1R2	4	3.512	1.25	2.28	10.70	13.00	3.40	0.56		2.65	0.65	6	1.2120
QF5T1R2	6	5.056	1.18	1.92	12.80	14.70	4.50	0.46	19.	2.70	0.65	6	1.3450
QF5T1R2	8	4.332	1.06	1.74	10.50	12.20	3.80	0.49		1.95	0.65	9	1.3167
QF5T1R2	10	0.974	1.04	1.80	4.70	6.50	2.00	0.51		2.30	0.90	6	0.8665
QF5T1R3	1	6.660	1.16	2.53	26.10	28.60	7.80	0.72		3.85	0.95	1	0.0142
QF5T1R3	2	4.174	1.20	2.22	11.90	14.10	5.00	0.62		1.40	0.90	3	1.2120
QF5T1R3	4	3.726	0.89	1.52	12.10	13.60	4.00	0.53		1.20	3.70	6	1.3309
QF5T1R3	6	3.358	0.87	1.36	14.90	16.30	5.50	0.47	273.	1.10	8.70	6	1.5348
QF5T1R3	8	5.290	0.84	1.36	13.70	15.10	4.50	0.48		1.45	0.65	6	1.4866
QF5T1R3	10	6.952	0.88	1.25	17.70	18.90	5.40	0.53		1.15	0.70	6	1.5178
QF5T2R1	1	5.442	14.40	0.09	144.30	144.40	43.40	3.63				1	0.4361
QF5T2R1	2	4.742	14.40	1.08	62.00	63.10	26.30	6.52				3	1.0987
QF5T2R1	3	4.564	15.80	0.09	84.20	84.30	30.80	6.36				3	1.1553
QF5T2R1	5	3.616	8.00	0.70	37.60	38.30	15.60	4.96				6	1.3309
QF5T2R1	8	3.518	5.15	0.94	25.40	26.30	11.90	3.66				9	1.3620
QF5T2R1	10	3.356	4.42	1.01	24.90	25.90	11.30	2.72				6	1.3762

QF6T2R1	19	10.303	0.65	0.43	58.30	58.70	12.50	0.30	947.	3	1.2403
QF6T2R1	20	9.992	1.94	0.52	31.50	32.00	11.00	0.97	1395.	3	1.2233
QF6T2R1	21	9.946	3.38	0.24	43.30	43.50	11.50	1.39	1307.	3	0.2322
QF6T2R1	22	1.608	2.09	0.88	17.00	17.90	3.00	0.95	381.	3	0.0566
QF6T2R2	1	7.061	1.81	2.33	33.50	35.80	8.50	0.57	1313.	1	0.0113
QF6T2R2	2	6.488	1.46	0.77	36.50	37.30	7.50	0.52	1196.	3	1.1836
QF6T2R2	3	6.228	1.42	0.93	44.30	45.20	7.50	0.66	1284.	3	1.2516
QF6T2R2	4	7.619	0.75	0.55	45.00	45.50	10.50	0.30	758.	3	1.2516
QF6T2R2	5	6.657	0.90	0.94	41.80	42.70	14.00	0.50	802.	3	1.2120
QF6T2R2	6	7.305	0.60	0.54	31.50	32.00	9.50	0.20	642.	3	1.1695
QF6T2R2	7	5.710	0.98	0.34	26.80	27.10	7.00	0.47	1043.	3	1.2233
QF6T2R2	8	4.174	0.81	0.47	24.80	25.30	6.50	0.44	954.	3	1.1836
QF6T2R2	9	6.197	0.59	0.24	29.00	29.20	6.00	0.22	954.	3	1.1440
QF6T2R2	10	6.815	0.55	0.34	41.80	42.10	12.50	0.20	846.	3	1.1157
QF6T2R2	11	2.562	1.29	1.30	12.50	13.80	3.50	0.67	337.	3	0.4644
QF6T2R3	1	8.641	0.90	1.01	52.50	53.50	15.00	0.35	1167.	2	0.5522
QF6T2R3	2	8.542	0.90	0.34	21.80	22.10	8.50	0.47	1080.	3	1.3394
QF6T2R3	3	7.634	0.68	0.20	25.30	25.50	5.50	0.32	1123.	3	1.1978
QF6T2R3	4	6.984	0.91	0.36	33.80	34.20	5.00	0.56	895.	3	1.0902
QF6T2R3	5	7.154	0.50	0.39	37.80	38.20	11.50	0.15	802.	3	1.2233
QF6T2R3	6	5.724	0.61	0.29	32.80	33.10	4.50	0.30	1072.	3	1.1044
QF6T2R3	7	7.499	0.55	0.47	45.30	45.80	9.50	0.20	817.	3	1.1298
QF6T2R3	8	7.787	0.45	0.34	44.80	45.10	11.00	0.10	875.	3	1.1553
QF6T2R3	9	8.430	0.38	0.16	30.00	30.20	4.00	0.16	984.	3	1.1440
QF6T2R3	10	7.992	0.41	0.26	22.00	22.30	7.00	0.24	1072.	3	1.1836
QF6T2R3	11	4.225	0.35	0.60	7.50	8.10	1.50	0.21	43.	3	0.4134
QF7T1R1	1	10.140	8.65	5.91	39.50	45.40	11.60	2.67		3	0.4248
QF7T1R1	2	9.794	7.95	2.29	33.40	35.70	16.40	3.09		3	0.4332
QF7T1R1	3	8.152	7.90	1.60	46.90	48.50	17.00	3.39	1981.	3	0.4417
QF7T1R1	5	7.788	5.40	1.03	23.60	24.60	13.30	2.56		6	0.5239
QF7T1R1	8	8.034	4.35	0.78	32.90	33.70	15.90	2.00		9	0.6031
QF7T1R1	10	7.548	3.45	0.84	30.90	31.70	12.40	1.70		6	0.6683
QF7T1R1	12	7.636	2.85	0.86	30.60	31.50	12.80	1.52		6	0.8212
QF7T1R1	16	8.250	2.20	0.81	28.90	29.70	11.90	1.05		21	1.1723
QF7T1R1	20	7.406	4.50	0.72	39.30	40.00	16.20	2.68		6	0.0821
QF7T1R2	1	8.822	2.90	2.94	23.90	26.80	7.30	0.45		1	0.0028
QF7T1R2	2	6.714	1.99	1.38	29.80	31.20	11.80	0.59	1320.	3	1.1723
QF7T1R2	4	6.642	1.37	1.30	32.30	33.60	10.40	0.58		6	1.1978
QF7T1R2	6	6.678	1.25	1.30	19.90	21.20	8.70	0.51		6	1.2120
QF7T1R2	8	6.896	1.22	1.17	19.40	20.60	8.30	0.54		6	1.2771
QF7T1R2	10	7.110	1.25	1.06	16.80	17.90	7.50	0.50		6	1.2120
QF7T1R3	1	7.592	1.63	1.28	35.40	36.70	12.90	0.52	1589.	2	0.2492
QF7T1R3	2	8.120	1.27	1.11	15.10	16.20	6.70	0.55		3	1.2374
QF7T1R3	4	6.408	1.07	1.16	14.10	15.30	6.80	0.49		6	1.2374
QF7T1R3	6	8.044	0.98	1.00	13.80	14.80	6.70	0.42		6	1.2233
QF7T1R3	8	8.076	0.97	0.86	18.10	19.00	8.20	0.40		6	1.1865
QF7T1R3	10	4.964	0.99	0.93	23.10	24.00	8.20	0.41		6	1.1723
QF7T2R1	2	7.874	86.30	0.12	168.30	168.10	53.80	34.00	1301.	3	1.2120
QF7T2R1	3	6.682	77.50	0.11	113.00	113.10	49.40	23.30	1338.	3	1.2120
QF7T2R1	5	4.358	31.50	0.08	82.20	82.30	35.80	10.70	1221.	6	1.2120
QF7T2R1	8	5.512	11.50	0.06	26.80	26.90	21.60	2.65	1192.	9	1.2120
QF7T2R1	10	2.736	10.10	0.05	27.50	27.50	15.50	1.60	1526.	6	1.2120
QF7T2R1	12	3.214	7.00	0.06	20.00	20.10	14.10	2.40	1328.	6	1.2120
QF7T2R1	16	1.200	11.50	0.06	19.70	19.80	12.00	1.65	1144.	12	1.2120

QF8T2R3	8	0.436	3.05	2.01	4.40	6.40	2.50	0.77	232.	9	1.6764
QF8T2R3	10	0.206	3.80	2.79	4.70	7.50	2.20	0.80	83.	3	1.1383
QF9T1R1	1	10.950	6.95	6.99	30.90	37.90	10.10	1.83		1	0.0000
QF9T1R1	2	6.600	6.65	5.13	39.10	44.20	13.10	2.33	1072.	3	0.5975
QF9T1R1	3	5.236	5.60	1.92	27.50	29.40	10.70	2.47		3	0.7872
QF9T1R1	5	4.760	5.10	1.17	35.40	36.60	14.80	2.39		6	1.0052
QF9T1R1	8	4.536	3.70	0.86	13.60	14.50	8.70	1.87		9	1.1383
QF9T1R1	10	3.824	3.20	0.79	23.10	23.90	9.40	1.69		6	1.1780
QF9T1R1	12	3.638	2.65	0.82	29.80	30.60	8.70	1.57		6	1.2063
QF9T1R1	16	4.108	1.90	0.92	19.40	20.30	6.90	1.49		21	1.2346
QF9T1R1	20	1.718	1.61	1.07	4.00	5.10	1.10	1.28		6	0.7872
QF9T1R2	1	2.468	1.35	1.71	13.00	14.70	3.10	0.53		2	0.6088
QF9T1R2	2	4.294	1.96	1.94	13.60	15.50	4.30	0.58		3	1.0052
QF9T1R2	4	3.678	1.31	1.41	15.40	16.80	5.30	0.56	229.	6	1.0845
QF9T1R2	6	4.346	1.11	1.16	8.70	9.90	3.60	0.54		6	1.2091
QF9T1R2	8	4.314	1.03	1.08	6.40	7.50	2.30	0.56		9	1.1383
QF9T1R2	10	3.940	0.96	1.08	12.60	13.70	4.90	0.53		3	0.6881
QF9T1R3	1	8.868	1.70	0.94	16.70	17.60	5.60	0.40	759.	1	0.0057
QF9T1R3	2	4.986	1.37	1.00	7.90	8.90	3.20	0.57		3	1.1921
QF9T1R3	4	3.552	0.91	1.01	8.00	9.00	3.00	0.58		6	1.3989
QF9T1R3	6	3.958	0.89	0.97	6.90	7.90	2.10	0.51		6	1.4130
QF9T1R3	8	3.982	0.85	0.88	3.50	4.40	3.90	0.44		6	1.3507
QF9T1R3	10	3.754	0.63	0.95	4.50	5.40	4.00	0.40		6	1.3224
QF9T2R1	1	6.150	64.00	0.10	166.30	166.40	63.10	21.80	2175.	2	0.5210
QF9T2R1	2	5.164	60.50	0.06	137.00	137.10	56.20	18.50	2002.	3	1.3507
QF9T2R1	3	3.996	46.75	0.02	98.50	98.50	50.40	11.50	1950.	3	1.3507
QF9T2R1	5	4.966	29.00	0.05	61.10	61.10	32.80	4.85	1837.	6	1.3989
QF9T2R1	8	2.024	16.57	0.05	33.20	33.20	21.10	3.55	1695.	9	1.4583
QF9T2R1	10	3.038	13.75	0.05	36.50	36.60	18.80	2.20	1424.	6	1.4272
QF9T2R1	12	3.498	9.30	0.06	22.70	22.80	15.60	2.00	1661.	6	1.4725
QF9T2R1	16	2.962	6.30	0.05	32.90	33.00	14.40	1.95	1310.	21	1.4130
QF9T2R1	20	2.532	9.45	0.06	15.80	15.90	9.60	1.70	700.	6	0.7108
QF9T2R2	1	3.752	7.20	6.80	18.40	25.20	6.20	1.08	1118.	1	0.0000
QF9T2R2	2	1.258	2.95	5.25	15.00	18.00	5.80	0.76	215.	3	1.0449
QF9T2R2	4	1.096	2.15	3.53	10.00	12.00	3.70	0.60	373.	6	1.1921
QF9T2R2	6	1.200	2.20	1.25	5.50	6.80	4.80	1.04	407.	6	1.3366
QF9T2R2	8	0.924	2.00	1.12	20.40	21.50	8.20	1.01	526.	6	1.3366
QF9T2R2	10	1.178	1.80	1.01	15.70	16.70	7.10	0.94	488.	6	1.3989
QF9T2R3	1	3.654	4.20	0.74	7.30	8.00	5.10	1.80	1291.	1	0.0623
QF9T2R3	2	2.444	2.75	0.65	6.90	7.50	4.30	0.96	575.	3	0.9316
QF9T2R3	4	0.818	1.60	0.66	12.90	13.60	6.50	0.76	363.	6	1.3819
QF9T2R3	6	0.879	1.45	1.04	3.10	4.10	3.50	1.15	387.	6	1.3507
QF9T2R3	8	3.038	1.15	0.37	3.00	3.40	3.20	0.85	233.	6	1.3366
QF9T2R3	10	0.498	1.40	0.54	7.00	7.50	4.30	0.27	406.	6	1.3989

QF2T3R2	8	0.466	1.27	1.48	4.50	5.98	1.20	0.18		2.23	0.45	22	3.1149
QF2T3R3	1	0.640	0.96	1.31	7.10	8.41	1.90	0.21	183.	2.42	0.55	1	3.9644
QF2T3R3	2	0.646	0.90	1.32	5.70	7.02	1.80	0.19		0.56	0.60	4	4.7289
QF2T3R3	3	0.810	0.90	1.39	5.20	6.59	1.80	0.14		0.50	0.45	7	4.8139
QF2T3R3	4	0.676	1.08	1.37	5.30	6.67	2.00	0.14		0.53	0.50	10	4.9271
QF2T3R3	6	1.080	1.11	1.40	6.30	7.70	2.20	0.18		0.48	0.45	16	4.9554
QF2T3R3	8	1.082	1.11	1.40	5.70	7.10	2.00	0.14		0.42	0.40	22	4.9838
QF2T3R3	9	0.944	1.09	1.46	6.20	7.66	2.40	0.13		0.46	0.40	25	5.1537
QF2T3R3	10	0.612	1.24	1.41	5.20	6.61	1.80	0.12		0.46	0.40	28	2.8317
QF2T4R1	1	0.256	1.07	3.26	9.40	12.66	2.70	1.09		5,40	1.33	2	0.7079
QF2T4R1	2	0.310	0.67	2.58	6.80	9.38	2.10	0.49	155.	2.10	0.55	5	3.1149
QF2T4R1	3	0.348	0.67	2.56	2.90	5.46	1.30	0.37		1.90	0.43	8	4.1059
QF2T4R1	5	0.380	0.62	2.17	4.50	6.67	1.70	0.28		1.50	0.35	14	4.6440
QF2T4R1	8	0.524	0.51	1.44	2.90	4.34	0.80	0.26		1.30	0.33	23	4.9271
QF2T4R1	10	0.572	0.81	1.47	3.80	5.27	0.80	0.22		0.90	0.30	29	5.0970
QF2T4R1	12	0.460	0.87	1.38	4.80	6.18	0.90	0.22		1.00	0.30	35	5.1253
QF2T4R1	16	0.570	0.93	1.40	5.80	7.20	1.70	0.22		1.00	0.33	47	5.1537
QF2T4R1	17	0.216	0.75	1.64	1.30	2.94	0.40	0.16		0.90	0.30	50	3.3980
QF2T4R2	1	0.366	0.99	1.71	5.00	6.71	1.10	0.30		1.80	0.45	1	2.2653
QF2T4R2	2	0.639	1.08	1.51	3.30	4.81	1.00	0.22	71.	1.40	0.38	4	4.5307
QF2T4R2	4	0.620	0.52	1.44	2.60	4.04	1.20	0.20		1.10	0.20	10	5.0970
QF2T4R2	6	0.784	0.48	1.38	3.30	4.68	1.20	0.16		0.70	0.18	16	5.3802
QF2T4R2	8	0.700	0.47	1.37	3.20	4.57	1.30	0.14		0.90	0.18	23	5.5218
QF2T4R2	9	0.344	0.48	1.55	1.20	2.75	0.40	0.16		1.00	0.20	25	3.6812
QF2T4R3	1	0.882	0.06	1.47	4.50	5.97	1.70	0.20		1.30	0.28	2	5.1537
QF2T4R3	2	0.936	0.42	1.42	4.40	5.82	1.80	0.19	143.	1.20	0.25	5	5.3519
QF2T4R3	4	0.900	0.57	1.31	3.80	5.11	1.60	0.15		0.80	0.20	9	5.3802
QF2T4R3	6	0.878	0.60	1.34	4.00	5.34	1.70	0.15		0.80	0.20	15	5.4368
QF2T4R3	8	1.130	0.53	8.54	3.70	12.24	1.70	0.15		0.70	0.18	24	5.4368
QF2T4R3	10	0.550	0.54	6.46	2.50	8.96	1.00	0.13	88.	0.90	0.18	27	3.6812
QF3T3R1	1	5.556	13.90	8.66	83.40	92.06	7.00	0.09	773.	25.20	0.30	14	1.1327
QF3T3R1	2	4.528	9.10	6.34	52.90	59.24	10.80	0.09		16.00	0.30	17	1.5574
QF3T3R1	3	3.268	6.80	4.70	47.40	52.10	10.20	0.10		11.90	0.45	20	1.9822
QF3T3R1	4	4.370	6.40	3.61	43.20	46.81	10.20	0.10		10.30	0.45	23	2.2653
QF3T3R1	5	4.150	5.60	3.76	42.30	46.06	10.40	0.11		7.92	0.40	26	2.5485
QF3T3R1	6	4.320	5.00	3.45	39.40	42.85	9.30	0.10		6.87	0.40	29	2.6901
QF3T3R1	8	4.340	4.40	3.01	35.80	38.81	9.00	0.13		6.37	0.45	35	3.0865
QF3T3R1	10	3.870	3.70	2.60	35.70	38.30	10.40	0.10		7.47	0.45	42	3.0865
QF3T3R2	1	4.370	9.40	4.50	30.90	35.40	6.50	0.38	721.	2.45	0.55	2	1.6990
QF3T3R2	2	5.140	6.10	3.15	24.00	27.15	6.80	0.26		7.37	0.40	5	2.8317
QF3T3R2	4	5.200	4.70	2.29	24.00	26.29	7.60	0.17		5.72	0.30	11	3.6812
QF3T3R2	6	7.840	4.30	1.94	21.10	23.04	7.10	0.20		4.87	0.30	17	4.0776
QF3T3R2	8	7.000	3.70	1.77	23.80	25.57	8.40	0.10		3.66	0.25	23	4.0210
QF3T3R2	9	7.910	3.75	1.73	23.60	25.33	8.90	0.15		4.67	0.25	26	3.9644
QF3T3R3	1	7.980	3.84	2.59	28.20	30.79	11.50	0.15	815.	6.57	0.45	2	2.8317
QF3T3R3	2	8.450	2.80	1.91	22.70	24.61	7.80	0.15		4.42	0.40	5	4.1059
QF3T3R3	4	9.220	2.76	1.63	23.30	24.93	8.30	0.14		3.41	0.35	11	4.3891
QF3T3R3	6	9.260	1.27	1.57	20.70	22.27	7.80	0.14		4.12	0.40	17	4.2475
QF3T3R3	8	8.950	2.32	1.53	29.90	31.43	10.70	0.12		3.37	0.30	23	4.2475
QF3T3R3	10	10.700	2.28	1.47	28.60	30.07	11.70	0.15		3.70	0.40	30	4.2475
QF3T4R1	1	2.980	2.94	4.63	24.90	29.53	4.80	0.21		6.50	0.33	2	1.1327
QF3T4R1	2	3.480	3.18	3.13	17.50	20.63	4.90	0.17		4.70	0.25	5	2.6901
QF3T4R1	3	3.480	3.03	2.15	18.30	20.45	4.90	0.16		3.90	0.23	8	3.2848
QF3T4R1	5	4.780	2.49	1.76	17.60	19.36	5.10	0.15	425.	2.90	0.20	14	3.9644

QF4T4R3	2	5.070	3.63	3.19	18.70	21.89	5.10	0.13	548.	3.20	0.33	4	5.3802
QF4T4R3	4	4.510	2.75	1.66	16.90	18.56	4.40	0.12		2.40	0.35	10	5.6634
QF4T4R3	6	4.010	2.86	1.27	14.70	15.97	4.30	0.16		2.60	0.40	16	5.9465
QF4T4R3	8	3.640	2.73	1.30	15.30	16.60	4.50	0.15		2.30	0.40	22	6.2297
QF4T4R3	10	3.250	2.65	1.20	16.00	17.20	4.70	0.15		2.20	0.43	28	5.9465
QF4T4R3	11	2.480	2.82	1.23	12.20	13.43	3.50	0.19		2.40	0.38	31	3.1149
QF5T3R1	1	1.430	4.89	1.67	13.00	14.67	2.70	0.39		6.63	0.40	1	0.2832
QF5T3R1	2	2.970	6.77	1.90	18.20	20.10	3.90	0.45		8.38	0.50	4	1.3592
QF5T3R1	3	2.930	7.69	1.96	21.30	23.26	4.70	0.29	372.	8.53	0.35	7	1.5857
QF5T3R1	5	4.300	8.85	2.27	25.40	27.67	5.60	0.30		10.08	0.40	13	2.4069
QF5T3R1	7	4.750	8.36	1.70	24.70	26.40	5.80	0.28		7.83	0.35	19	3.0865
QF5T3R1	9	4.270	7.56	1.39	22.80	24.19	5.30	0.21		7.18	0.35	26	3.1149
QF5T3R1	10	2.260	8.14	1.53	17.70	19.23	4.00	0.25		8.18	0.35	28	0.7079
QF5T3R2	1	3.270	7.75	3.21	25.10	28.31	5.70	0.30	496.	8.28	0.40	2	1.2743
QF5T3R2	2	3.810	9.57	3.09	26.20	29.29	5.70	0.25		8.73	0.40	5	2.9166
QF5T3R2	4	5.430	9.55	2.70	26.30	29.00	5.90	0.25		7.93	0.30	11	3.5396
QF5T3R2	6	6.560	8.55	1.55	24.10	25.65	5.70	0.24		6.93	0.30	17	3.8794
QF5T3R2	8	6.110	7.05	1.63	29.40	31.03	6.30	0.20		6.23	0.30	24	3.8794
QF5T3R2	9	4.040	8.81	1.85	19.30	21.15	4.50	0.24		8.03	0.35	26	1.1327
QF5T3R3	1	6.360	9.91	2.49	21.60	24.09	4.70	0.26	608.	9.87	0.35	1	3.5396
QF5T3R3	2	5.420	11.02	1.91	23.70	25.61	5.70	0.22		7.28	0.30	4	4.1626
QF5T3R3	4	5.920	7.21	1.46	24.40	25.86	6.30	0.18		6.13	0.25	10	4.1626
QF5T3R3	6	6.110	6.20	1.22	22.90	24.12	6.00	0.17		5.58	0.25	16	4.2475
QF5T3R3	8	5.940	5.94	1.03	24.10	25.13	6.30	0.18		4.98	0.30	22	4.3891
QF5T3R3	9	6.440	5.79	1.27	24.00	25.27	6.30	0.19		5.63	0.30	25	4.3891
QF5T3R3	10	2.900	6.45	1.00	14.80	15.80	3.80	0.22		6.63	0.35	28	4.5307
QF5T3R3	11	4.170	4.28	1.65	37.70	39.35	12.10	0.25		4.48	0.30	31	0.3398
QF5T4R1	1	2.340	4.60	7.13	20.30	27.43	4.30	0.34		5.70	0.63	3	1.9822
QF5T4R1	2	4.290	6.67	7.78	23.40	31.18	5.10	0.23		5.50	0.45	6	3.0582
QF5T4R1	3	5.800	6.87	6.37	24.20	30.57	5.40	0.17		6.30	0.40	9	3.5396
QF5T4R1	5	6.300	6.37	4.62	24.00	28.62	6.10	0.14	520.	5.30	0.38	15	4.1059
QF5T4R1	8	4.890	5.44	3.44	21.30	24.74	5.70	0.13		4.10	0.35	24	4.2758
QF5T4R1	10	5.720	5.18	2.30	20.30	22.60	5.80	0:09		3.90	0.28	30	4.5024
QF5T4R1	12	5.030	4.68	2.26	20.90	23.16	5.80	0.11		4.00	0.22	36	4.5307
QF5T4R1	16	6.770	4.17	2.73	22.20	24.93	5.80	0.11		3.80	0.25	49	4.6723
QF5T4R1	20	2.050	4.40	2.20	11.20	13.40	2.90	0.09		3.80	0.20	51	3.1149
QF5T4R2	1	4.820	6.29	10.87	26.40	37.27	5.70	0.24	531.	6.20	0.35	2	3.1149
QF5T4R2	2	5.780	6.33	7.00	23.70	30.70	5.40	0.15		5.90	0.28	5	4.1909
QF5T4R2	4	6.490	5.46	3.94	23.10	27.04	5.80	0.14		5.00	0.20	11	4.5307
QF5T4R2	6	6.830	4.30	3.07	22.20	25.27	5.90	0.12		4.70	0.23	17	4.7572
QF5T4R2	8	6.950	4.58	2.41	23.70	26.11	6.20	0.12		4.50	0.23	23	4.8705
QF5T4R2	9	7.890	4.58	2.27	23.30	25.57	6.80	0.08		4.00	0.15	27	4.8988
QF5T4R2	10	3.310	5.22	2.36	15.60	17.96	4.30	0.08		4.00	0.15	29	2.2653
QF5T4R3	1	11.300		5.73	36.80	42.53	10.00	0.12		5.40	0.25	1	3.8228
QF5T4R3	2	8.210	5.22	4.12	25.50	29.62	7.00	0.06	551.	5.20	0.25	4	4.8139
QF5T4R3	4	6.750	4.12	2.14	22.40	24.54	6.60	0.06		4.10	0.15	10	4.9554
QF5T4R3	6	6.770	3.66	1.68	26.00	27.68	8.00	0.07		3.50	0.15	16	5.0970
QF5T4R3	8	6.800	3.41	1.44	24.30	25.74	7.40	0.08		3.50	0.15	22	4.9554
QF5T4R3	10	6.800	3.41	1.34	26.00	27.34	7.90	0.06		4.10	0.13	29	4.8139
QF6T3R1	1	7.170	17.40	15.48	69.30	84.78	7.30	0.46		46.73	0.60	1	0.2832
QF6T3R1	2	12.700	16.80	4.36	64.30	68.66	10.30	0.58		27.68	0.70	4	1.5574
QF6T3R1	3	11.700	14.70	4.56	56.30	60.86	11.00	0.57		19.73	0.70	7	1.9822
QF6T3R1	5	14.900	13.20	2.82	57.10	59.92	12.50	0.50		17.03	0.60	13	2.9733
QF6T3R1	8	16.100	11.50	1.86	68.40	70.26	17.90	0.43	1266.	13.03	0.55	22	3.5396

QF7T4R1	1	1.230	7.89	16.02	33.90	49.92	3.70	0.25		24.40	0.48	1	0.2832
QF7T4R1	2	2.400	3.46	6.09	16.90	22.99	4.00	0.12		5.40	0.20	4	1.8406
QF7T4R1	3	3.080	2.67	3.65	14.60	18.25	4.20	0.09		3.50	0.18	7	2.6901
QF7T4R1	5	2.930	1.76	2.63	13.30	15.93	4.20	0.09	420.	2.50	0.20	13	3.3980
QF7T4R1	8	3.250	1.21	1.82	12.50	14.32	3.90	0.08		1.80	0.20	22	3.9644
QF7T4R1	10	3.170	0.98	2.10	12.70	14.80	4.10	0.07		1.60	0.15	28	4.0493
QF7T4R1	12	3.200	0.97	1.89	11.40	13.29	3.80	0.07		1.40	0.18	34	4.0493
QF7T4R1	16	3.060	0.78	1.78	12.80	14.58	3.80	0.10		1.40	0.20	46	4.2475
QF7T4R1	19	3.290	1.79	1.41	13.80	15.21	4.20	0.13		1.00	0.23	55	4.2475
QF7T4R2	1	3.960	2.38	2.78	3.85	6.63	4.78	0.09		2.70	0.15	3	3.1149
QF7T4R2	2	3.720	1.74	2.29	14.55	16.84	4.60	0.05	589.	2.00	0.10	6	3.6812
QF7T4R2	4	3.790	1.31	1.66	13.69	15.35	2.40	0.06		1.60	0.13	12	4.1059
QF7T4R2	6	2.820	0.86	1.82	14.60	16.42	4.60	0.07		1.40	0.15	18	4.3891
QF7T4R2	8	3.660	0.99	1.68	12.90	14.58	4.33	0.04		1.30	0.10	24	4.5307
QF7T4R2	9	3.850	0.97	1.73	12.90	14.63	3.93	0.03		1.30	0.08	29	4.5307
QF7T4R3	1	5.000	1.66	2.06	15.70	17.76	4.12	0.05		2.20	0.10	2	3.1149
QF7T4R3	2	3.800	1.29	1.75	14.90	16.65	4.74	0.08		1.60	0.15	5	3.8228
QF7T4R3	4	4.000	0.98	1.61	10.40	12.01	2.18	0.05		1.30	0.13	11	3.8228
QF7T4R3	6	3.840	0.80	1.65	10.30	11.95	2.69	0.05	404.	1.20	0.10	17	4.8705
QF7T4R3	8	3.590	0.79	1.67	9.33	11.00	2.27	0.07		1.20	0.13	23	4.6723
QF7T4R3	10	3.730	0.74	1.83	15.50	17.33	4.90	0.07		1.00	0.15	30	4.7289
QF7T3R1	11	1.120	0.70	2.03	9.07	11.10	2.48	0.09	262.	1.10	0.15	32	2.2653
QF8T3R2	1	0.684	0.85	1.55	5.00	6.55	2.10	0.16		2.70	0.25	2	0.2832
QF8T3R2	2	0.686	0.58	1.45	4.30	5.75	1.30	0.12		2.40	0.15	5	1.4158
QF8T3R2	3	0.676	0.74	1.26	6.60	7.86	1.40	0.13		2.80	0.20	9	1.9255
QF8T3R2	4	0.598	0.58	1.32	2.90	4.22	1.00	0.12	175.	1.80	0.20	11	1.2743
QF8T3R3	1	0.604	0.28	1.27	3.30	4.57	1.10	0.11	163.	1.40	0.20	2	2.6901
QF8T3R3	2	0.690	0.48	1.41	2.90	4.31	1.10	0.14		1.30	0.20	5	3.1149
QF8T3R3	3	0.902	0.56	1.20	3.20	4.40	1.30	0.13		1.60	0.20	8	3.4830
QF8T3R3	4	0.884	0.58	1.28	3.70	4.98	1.40	0.12		1.40	0.10	11	3.5396
QF8T3R3	6	0.904	0.58	1.47	4.70	6.17	1.30	0.09		1.80	0.05	21	3.5396
QF8T3R3	8	0.678	0.64	1.27	4.40	5.67	1.10	0.09		1.70	0.05	23	2.5485
QF8T4R1	1	0.842	1.36	1.58	7.61	9.19	1.35	0.24		4.00	0.45	2	0.5663
QF8T4R1	2	0.558	0.99	1.76	4.53	6.29	1.41	0.19	160.	1.80	0.28	5	1.5574
QF8T4R1	3	0.414	0.80	1.67	6.50	8.17	1.47	0.18		1.40	0.28	8	1.9822
QF8T4R1	5	0.570	0.57	1.50	2.39	3.89	1.08	0.16		1.10	0.25	14	2.5485
QF8T4R1	8	0.292	0.32	1.43	3.16	4.59	1.32	0.12	82.	0.90	0.20	23	2.8317
QF8T4R1	12	0.378	0.43	1.33	3.76	5.09	1.24	0.09		0.80	0.20	35	3.0582
QF8T4R1	14	0.474	0.38	1.15	4.53	5.68	1.23	0.08		0.70	0.18	42	3.3980
QF8T4R1	15	0.364	0.29	1.37	4.53	5.90	3.71	0.12		0.80	0.20	44	2.2653
QF8T4R2	1	0.482	0.52	1.56	4.88	6.44	1.47	0.11		1.30	0.20	3	1.4158
QF8T4R2	4	0.408	0.58	1.52	4.78	6.30	1.29	0.12	134.	0.90	0.20	12	3.3980
QF8T4R2	6	0.356	0.32	1.43	4.19	5.62	1.65	0.13		0.80	0.20	19	3.3980
QF8T4R2	7	0.404	0.31	1.42	12.92	14.34	1.13	0.11		0.70	0.15	21	2.6901
QF8T4R3	1	1.480	1.50	1.54	5.90	7.44	4.69	0.13		2.30	0.23	1	0.2832
QF8T4R3	2	0.728	0.57	1.48	4.70	6.18	1.63	0.11		1.00	0.20	4	3.1149
QF8T4R3	6	0.692	0.37	1.31	17.96	19.27	0.67	0.09	210.	0.80	0.13	16	4.1626
QF8T4R3	8	0.508	0.34	1.30	3.42	4.72	0.71	0.07		0.70	0.13	22	3.9644
QF8T4R3	9	0.600	0.40	1.32	2.48	3.80	1.10	0.08		0.90	0.13	26	4.1626
QF8T4R3	10	0.592	0.37	1.37	2.68	4.05	0.97	0.12		0.60	0.18	28	3.2564
QF8T4R3	11	0.258	0.34	1.31	2.01	3.32	0.51	0.09		2.60	0.30	31	0.8495
QF9T3R1	1	1.350	1.01	1.62	7.10	8.72	2.00	0.27		2.80	0.35	5	0.5097
QF9T3R1	2	1.630	0.92	1.78	7.30	9.08	1.90	0.26	266.	2.60	0.35	8	0.6230
QF9T3R1	3	1.480	0.88	1.69	6.60	8.29	1.80	0.24		2.70	0.30	11	0.7646

APPENDIX B - VEGETATIVE FILTER STRIP DESIGN AND EVALUATION PROCEDURE

REGRESSION EQUATIONS

The equations and procedures presented herein were developed to assist in the design of new VFS and in the evaluation of existing VFS. The empirically derived equations were developed from the experimental plot studies discussed in the main body of this report. Because of the limited database from which these equations were derived, they must be used with caution and sound engineering judgment as conditions at other sites may differ considerably from those for which these equations were developed.

The following equations, describing percent reductions in TSS (RTSS), T-N (RTN), and T-P (RTP), were developed using multiple regression techniques. Data used in the regressions included filter slope (s) and length (L), average plot discharge per unit width (Q), and percent reductions in TSS, T-N, and T-P. These equations were developed from data obtained from the first set of runs during the feedlot simulations (Test 1) and cropland simulations (Test 3) only. Data from Tests 2 and 4 were not used to avoid problems associated with excessive sediment accumulation in the VFS. Use of all the plot data was undesirable because simualted rainfall amounts over the period of application (100 mm/h for 2-1 h periods and 4-30 min periods in 2 weeks) had an extremely high recurrence interval which is inappropriate for design purposes. Also, in the real world, the temporal distribution of natural precipitation would allow regrowth of inundated vegetation and some recovery of sediment and nutrient removal capabilities.

Table B.1 is a summary of the data which was used in the development of the regression equations. As indicated in the table, the flow width used in defining Q was 5.5m for the uniform flow plots (QF1, 2, 4, and 5) and either 0.75 m (QF8 and 9, Test 1) or 1.0 m (QF8 and 9, Test 3) for the concentrated flow plots. The flow rate per unit width was obtained by dividing the total discharge of the bare plot in the set (Runs 1, 2, and 3) by the rainfall duration and the filter width through which flow was occurring.

The following 3 equations were developed to describe filter strip performance:

5. Determine flow rate per unit width through filter strip for each subwatershed.

6. Estimate percent reduction in desired pollutant for each subwatershed using regression equations.

7. Area weight percent reductions obtained to determine if VFS is an appropriate BMP for the field under investigation.

DESIGN EXAMPLE

A 9.1 m VFS is proposed as a BMP for the contoured corn field shown in Figure B1. As shown in Figure B1, the watershed has been divided into 6 subwatersheds, all of which except one, subwatershed F, drain through the VFS below the field.

The area of each subwatershed along with assumed soil groups, land use, curve numbers (N), and S and Q values as determined by the SCS total runoff volume method (SCS, 1972) for a 2-year 1-hour duration storm in central Virginia (I = 40.6 mm/h) are shown in Table B2 for the hypothetical watershed. In this example, antecedent rainfall condition II is assumed.

If the effects of drainageways in the subwatersheds are neglected and all flow from the field is assumed to flow across the VFS as shallow uniform flow, RTSS is found to be 78% as shown in the last row of Table B2. A value of this magnitude would normally indicate that a VFS was an excellent BMP for this particular field but this is a false conclusion because the effects of concentrated flow and filter inundation were not considered.

A better method for evaluating VFS which was outlined in the previous section also is presented in Table B1. As shown in Table B2, RTSS ranges from 0 to 94% for individual subwatersheds. If these subwatershed values are area weighted for the area draining through the VFS, an effective RTSS value of 17% is obtained indicating that the VFS is only partially successful in removing suspended solids from the field's runoff. In a similar manner, the percent reduction in T-N and T-P were both approximately 16%.

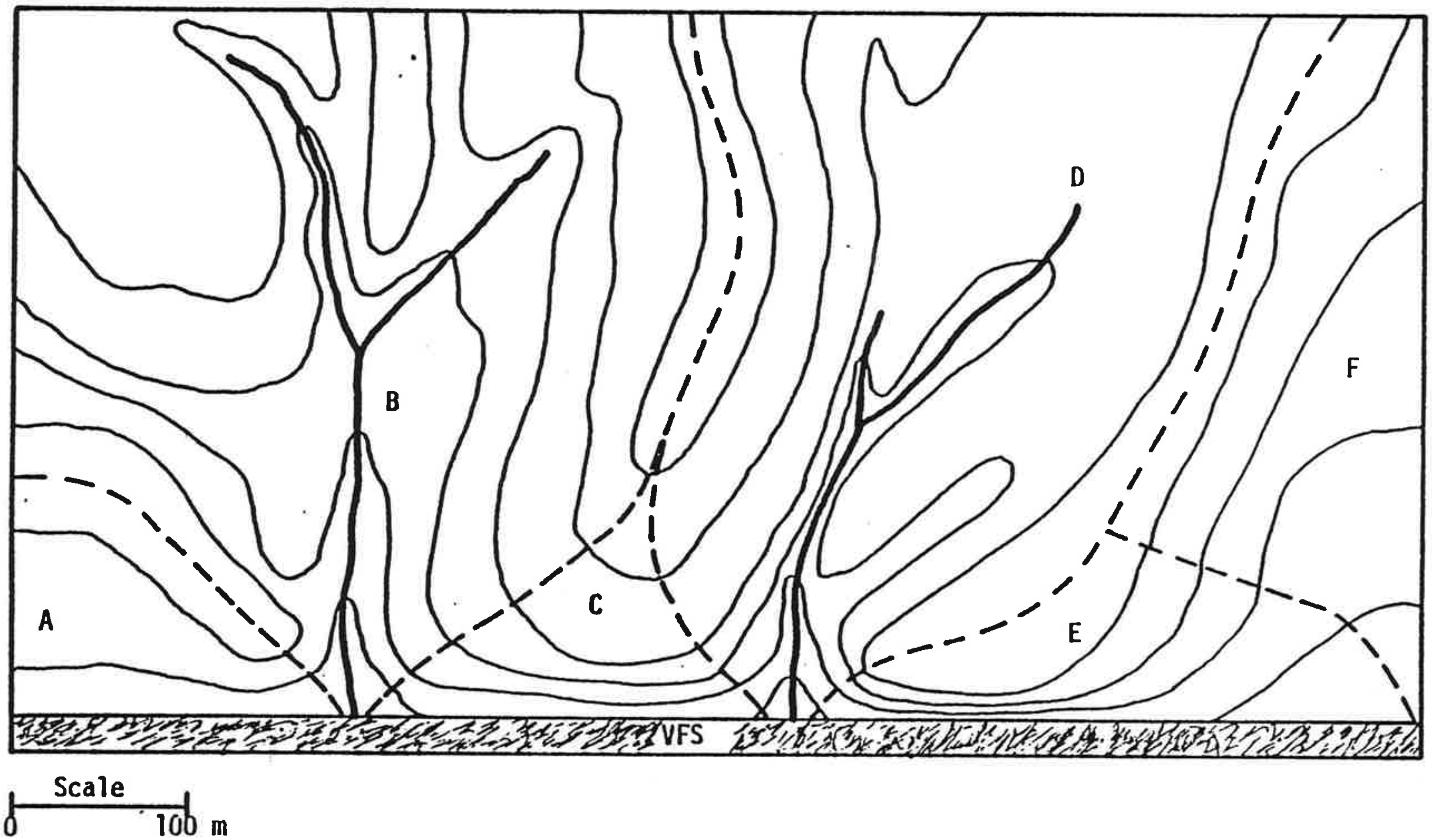

Figure B-1 Design Example

TABLE B-2. DESIGN EXAMPLE

Subarea	Area, (ha)	Soil Group	Land Use, Treatment, and Condition	Curve No, N	S^1 (mm)	Q^2 (mm)	Active Filter Width, (m)	Q, (L/s-m)	RTSS[3] (%)
A	1.7	C	row crop, contoured, good	82	55.8	10.2	190	0.25	92
B	12.6	C	row crop, contoured, good	82	55.8	10.2	3	119.0	0
C	1.3	C	row crop, contoured, good	82	55.8	10.2	230	0.14	94
D	10.4	B	row crop, contoured, good	75	84.7	5.2	3	50.1	0
E	2.1	B	row crop, contoured, good	75	84.7	5.2	345	0.09	94
F		Does not drain across VFS		--	--	--	--	--	--
Total Area	28.1			78.9	67.9	7.69	800	0.75	78

[1] $S = 25400/N-254$ [2] $Q = \frac{(I-0.2s)^2}{I+0.85}$

[3] From Equation B1