Evaluation of vegetative filter strips as a best management practice for feed lots


ABSTRACT: Vegetative filter strips (VFS) as an effective best management practice for the control of some nonpoint source pollutants were studied. Field experiments, designed to investigate the transport of sediment, nitrogen, and phosphate from areas of confined livestock activity, as influenced by flow characteristics and filter strip length, were conducted. Results indicated that VFS are effective for the removal of sediment and other suspended solids contained in surface runoff from feedlots if runoff is shallow and uniform; effectiveness of VFS for sediment removal decreases with time as sediment accumulates within the filter; total nitrogen and phosphorus are not removed as effectively as sediment; and soluble nitrogen and phosphorus are not removed effectively. J. Water Pollut. Control Fed., 60, 1231 (1988).

KEYWORDS: (vegetative filter strips), sediment, nutrients, nitrogen, phosphorus, nonpoint pollution.

The Environmental Protection Agency (EPA) Chesapeake Bay Program identified agriculture as a major source of sediment and nitrogen (N) and a significant source of phosphorus (P) in the Chesapeake Bay drainage basin. To help reduce agricultural nonpoint source (NPS) pollutant inputs to the Bay system, the Commonwealth of Virginia implemented cost-sharing programs to encourage adoption of best management practices (BMPs) by farmers. Use of vegetative filter strips (VFS) is one promoted practice. Vegetative filter strips are bands of planted or indigenous vegetation situated downslope of cropland or animal production facilities. They provide localized erosion protection and filter nutrients, sediment, organics, pathogens, and pesticides from agricultural runoff before they reach receiving waters. Because of low installation and maintenance costs, and perceived effectiveness in removing pollutants, VFS use has been encouraged by conservation and regulatory agencies.

Vegetative filter strips are 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 (\(\text{NO}_3^-\)) or orthophosphorus (\(\text{PO}_4^{3-}\), however, is much less certain, and has not been sufficiently addressed.

This study evaluates circumstances under which VFS are effective in reducing sediment and nutrient losses from areas of confined livestock activity. Field experiments, designed to investigate the transport of sediment, N, and P as influenced by flow rate and filter strip length, were conducted. The effect of concentrated flow on VFS performance, as opposed to shallow uniform flow, was of special interest.

Literature Review

Sediment, N, and P are three primary pollutants associated with surface runoff from areas of confined livestock activity. VFS are one technique for removing these pollutants. The major pollutant removal mechanisms associated with VFS involve changes in flow hydraulics that enhance the opportunity for runoff and pollutants to infiltrate into the soil profile, deposition of total suspended solids (TSS), filtration of suspended sediment by vegetation, adsorption on soil and plant surfaces, and absorption of soluble pollutants by plants. Surface runoff must pass slowly and uniformly through the filter to provide sufficient contact time for removal mechanisms to function.

Infiltration is a significant removal mechanism that affects VFS performance, because many pollutants associated with surface runoff enter the soil profile in the vegetated areas as infiltration takes place. Once in the soil profile, the pollutants, particularly N and P, are trapped by a combination of physical, chemical, and biological processes. Infiltration is also important because it decreases surface runoff, which in turn reduces the ability of runoff to transport pollutants. Because infiltration is one of the more easily quantifiable mechanisms affecting VFS performance, many VFS have been designed to allow all runoff from a design storm to infiltrate. This approach results in large land requirements because it ignores other removal mechanisms.

The VFS also purify runoff through deposition. Because VFS are usually composed of grasses and other dense vegetation, which offer high resistance to shallow overland flow, they decrease overland flow velocity immediately upslope and in the filter. This decreases sediment transport capacity significantly. If the transport capacity is less than the incoming load of suspended solids (SS), excess is deposited and trapped in the VFS. Presumably, sediment-bound pollutants will also be removed during this process.
Solid particle filtration by vegetation during overland flow and the absorption process are not understood as well as the infiltration and deposition processes. Filtration is probably most significant for larger soil particles, aggregates, and manure particles while absorption is a significant factor with respect to soluble pollutant removal.

**Sediment transport.** Historically, VFS design has been based almost entirely on local custom. Neibling and Alberts used experimental field plots with 7% slope and a rainfall simulator to show that grass filters 0.6, 1.2, 2.4, and 4.9 m long all reduced total sediment discharge from bare soil areas. Filters 6.1 m long reduced discharge by more than 90%. 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 solids deposition was observed to have occurred just upslope of the filter strips leading edges, and 91% of the incoming sediment load was deposited in the first 0.6 m of the filter.

The most comprehensive research to date on sediment transport in VFS was conducted by researchers at the University of Kentucky, Lexington, who worked on erosion control in surface mining areas. Some presented design equations that related the fraction of sediment trapped in simulated vegetal media to the mean flow velocity, flow depth, particle fall velocity, filter length, and spacing hydraulic radius of the simulated media. Others developed a steady-state model for determining grass media sediment filtration capacity as a function of flow, sediment load, particle size, flow duration, slope, and media density. Effluent concentrations were primarily a function of slope and media spacing for a given flow condition. The model was extended for unsteady flow and non-homogeneous sediment.

Using three different types of grasses, model predictions were in close agreement with laboratory data. Field data was used to evaluate the model for multiple storm events, with eroded material from fallow cropland used as a sediment source. Kentucky 31 tall fescue, trimmed to 10 cm, was used and the model predictions agreed with the measured sediment discharge values. The majority of sediment deposition occurred just upslope and in the first meter of the filter, until upper portions of the filter were buried in sediment. Subsequent sediment flow into the filter resulted in the advance of a wedge-shaped sediment deposit down through the filter. High trapping efficiencies were reported as long as the vegetal media was not submerged, but decreased dramatically at higher runoff rates that inundated the media.

**Nutrient transport.** Nutrient movement through filter strips has been investigated by several researchers. Others studied nutrient transport from dairy wastes through grass filters and found significant reductions (62% for soluble P) after passage through 4 m of grass filter. Researchers investigated runoff from open dairy lots and found that 12% of the applied P appeared in runoff. They also observed that high intensity storms were responsible for most pollutant transport even though these storms were responsible for only 17% of the total precipitation.

A rainfall simulator was used to study VFS ability 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 orchardgrass, or a sorghum-sudangrass mixture. Water was applied to the plots to simulate a 25-year recurrence interval, 24-hour duration storm. Total runoff, total suspended solids (TSS), total P (P), and total N (N) were reduced by 81, 66, 88, and 87%, respectively, by the orchardgrass and by 61, 82, 81, and 84%, by the sorghum-sudangrass mixture. It was concluded that VFS are a promising treatment alternative.

Storm runoff was measured and sampled for 3 years as it left a paved feedlot, after it passed through a shallow concrete settling basin, and after it passed through two consecutive 30.5 m long fence filter strips. Runoff, TSS, P, and N, were reduced by −2, 50, 49, and 48%, respectively, after passing through the first filter and by an additional −6, 45, 52, and 49% after passing through the second filter. Total runoff from the filters was greater than the incoming runoff because rainfall rates during runoff events exceeded filter infiltration capacity. The rainfall excess coupled with the added filter area caused increased runoff.

**Experimental Procedures**

**Study scope.** A series of nine experimental field plots was constructed. Each contained a simulated feedlot source area and VFS of known length. A rainfall simulator was then used to apply artificial rainfall to each plot three times at each of two different manure loading rates. Runoff was collected at each VFS base and channeled through a flume equipped with a stage recorder for flow measurement. Runoff samples were collected manually at 3-minute intervals during a rainfall-runoff event, then frozen, and later analyzed. Analyses were conducted for the determination of TSS, P, PO₄, NO₃, total Kjeldahl nitrogen (TKN), filtered P (P₉), filtered TKN (TKN₉), and total ammonia (NH₄⁺). An in-depth description of experimental procedures used in this study was given elsewhere.

**Plot design and location.** Experimental plot studies on VFS were conducted during fall 1984 on an eroded Groscelot silt loam (clayey, mixed, mesic Typic Hapludult) soil. The plots were located at the Prices Fork Agricultural Research Farm, 10 km west of Blacksburg, Va. Figure 1 is a sketch of one set of experimental plots. Each plot’s lower edge was bounded by a gutter designed to collect and transport runoff and sediment to a 150 mm H-flume equipped with a FW-1 stage recorder for flow measurement. Each plot had a simulated feedlot area 5.5 m wide and 18.3 m long. Each set had a plot with no VFS, a 4.5-m VFS, and a 9.1 m long VFS. For experimental purposes, 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 is a potential source of error in the present study because soil erodibility is spatially variable even in the same contiguous soil unit. The present study assumes that this potential error is not significant.

Table I summarizes the physical characteristics of each field plot. The first two sets of plots, QF1-QF3 and QF4-QF6, had negligible cross slope. The cross slope of 4% in the third set of plots (QF7-QF9) was used to cause runoff to accumulate and flow along the border on one side of these plots. The resulting accumulated flow was used to
evaluate flow concentration effects on VFS performance. Concentrated flow was a major concern here because experimental field plots generally are designed and constructed so that flow will be shallow and uniform. Realistic VFS, however, tend to have more fully developed drainage that encourage concentrated flow, filter inundation, and poor performance.

**Plot construction.** The experimental field plots were initially constructed during summer 1984. Plots were installed so that feedlot (pollutant source area) portions of the plots were located in an area previously planted in no-till corn while the VFS portions of the plots were located in previously established orchard grass strips that had been part of a normal contour strip-farming rotation.

After the borders and gutters were installed, crop residue and weeds were removed from the feedlot portions of the plots. Bare areas were then tilled to a depth of 15 to 20 cm. After tillage, the bare areas were compacted with smooth and sheepsfoot rollers to simulate feedlot soil densities. The plot preparation procedure described above approximates actual feedlot soil conditions, and sediment losses from real feedlots will undoubtedly vary significantly from those simulated in these experiments. This variation should not be of major concern in this study, however, because this investigation is concerned with the fate of nutrients in the VFS rather than in the pollutant source area.

Fresh dairy manure scraped from a paved feedlot at the Virginia Tech Dairy Center was applied to bare portions of each plot 24 to 48 hours before each set of simulated runoff events. Manure was applied to the plots at a rate of 7500 kg/ha (moist weight) during the first set of simulations and at 15 000 kg/ha during the second set. These manure applications were estimated accumulations in a feedlot after 7 and 14 days, respectively.

The manure nutrient content was 0.65% N, 0.15%, NH₄⁺, and 0.1% P, with a solids content of 17.1%. These values compare favorably with those reported by the Mid- west Plan Service of 0.5% N and 0.1% P, for fresh dairy manure. With these nutrient contents, approximately 80 g of P and 490 g of N were applied to each plot in the first set of simulations (Test 1) and twice these amounts in the second set of simulations (Test 2).

Manure was distributed uniformly over the plots by manual spreading with rakes. The plots were then compacted again with the sheepsfoot roller to simulate animal

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**Table 1—Plot characteristics and operating conditions.**

<table>
<thead>
<tr>
<th>Plot</th>
<th>QF1</th>
<th>QF2</th>
<th>QF3</th>
<th>QF4</th>
<th>QF5</th>
<th>QF6</th>
<th>QF7</th>
<th>QF8</th>
<th>QF9</th>
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<td>4.6</td>
<td>0.0</td>
<td>9.1</td>
<td>4.6</td>
<td>0.0</td>
<td>0.0</td>
<td>9.1</td>
<td>4.6</td>
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<td>11</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>5</td>
<td>5</td>
<td>5</td>
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<tr>
<td>Cross Slope, percent</td>
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<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>4*</td>
<td>4*</td>
<td>4*</td>
</tr>
</tbody>
</table>

**Filter strip vegetation**
- Orchard grass, trimmed to 10 cm
- Grosecole silt loam

**Feedlot simulation**
- Test 1 7 500 kg/ha dairy manure, moist
- Test 2 15 000 kg/ha dairy manure

**Simulated rainfall intensity**
- Run 1 60 minutes
- Run 2 30 minutes
- Run 3 30 minutes

* Plots with cross slope simulate effects of concentrated flow.

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Table 2—Sediment, nutrient, and water yields.

<table>
<thead>
<tr>
<th>Plot</th>
<th>Filter length, m</th>
<th>TSS</th>
<th>NH₄</th>
<th>NO₃</th>
<th>TKN</th>
<th>Nᵢ</th>
<th>Pᵢ</th>
<th>PO₄</th>
<th>TKNₑ</th>
<th>Pₑ</th>
<th>Runoff, mm</th>
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<td>500</td>
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<td>2.5</td>
<td>13.3</td>
<td>15.7</td>
<td>4.9</td>
<td>1.7</td>
<td>4.0</td>
<td>1.8</td>
<td>121.7</td>
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<td>1400</td>
<td>4.5</td>
<td>3.5</td>
<td>23.4</td>
<td>26.9</td>
<td>9.1</td>
<td>2.9</td>
<td>5.9</td>
<td>1.9</td>
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<td>1.9</td>
<td>25.6</td>
<td>26.7</td>
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<td>1.9</td>
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<td>0.5</td>
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<td>92.2</td>
<td>25.7</td>
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<td>0.7</td>
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<td>1.4</td>
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<td>38.9</td>
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<td>38.9</td>
<td>18.1</td>
<td>3.1</td>
<td>141.2</td>
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hoove action, which compacts and grinds manure into feedlot soil.

Rainfall simulator. The Department of Agricultural Engineering’s rainfall simulator was used to apply artificial rainfall to each set of plots. The rainfall simulator consisted of six rows of seven sprinklers each spaced 6.1 m apart.

Approximately 100 mm of rainfall was applied to each plot over 2 days during each test. Each test consisted of a 1-hour “dry” run (R1) followed 24 hours later by a 0.5-hour “wet” run (R2) and an additional 0.5-hour “very wet” run (R3) after a 0.5-hour rest interval. A rainfall intensity of approximately 50 mm/hour was used during all simulations. The first simulated rainfall event (R1) closely approximates a 2- to 5-year recurrence interval, 1-hour duration storm in Virginia. The three run sequence of “dry,” “wet,” and “very wet” was used to simulate various initial soil moisture conditions, which have direct influence on plot runoff rates. The 50 mm/hour rate of application is a standard research rate that allows for direct comparison of results from one location to another.

Sampling procedure and analytical techniques. Water quality samples were frozen immediately after collection and stored 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. All chemical analyses were conducted in accordance with procedures outlined elsewhere.

Results and Discussion

The rainfall simulator performed very well with respect to rainfall amounts and uniformity coefficients. The mean application rate was 50.1 mm/h and ranged from a low of 44.2 mm/h to a high of 56.8 mm/h. Uniformity coefficients, a measure of the uniformity of simulated rainfall applications, were excellent, averaging 93.4%.

Table 3—Percent reduction in sediment, nutrient, and water yields.

<table>
<thead>
<tr>
<th>Plot/Test</th>
<th>Filter length, m</th>
<th>TSS</th>
<th>NH₄</th>
<th>NO₃</th>
<th>TKN</th>
<th>Nᵢ</th>
<th>Pᵢ</th>
<th>PO₄</th>
<th>TKNₑ</th>
<th>Pₑ</th>
<th>Runoff</th>
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<td>38</td>
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<tr>
<td>QF1 Test2</td>
<td>90</td>
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<td>1</td>
<td>66</td>
<td>62</td>
<td>64</td>
<td>11</td>
<td>16</td>
<td>19</td>
<td>10</td>
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<tr>
<td>QF1 Overall</td>
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<td>80</td>
<td>77</td>
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<td>30</td>
<td>67</td>
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<td>80</td>
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<td>81</td>
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<td>27</td>
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<td>50</td>
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<tr>
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<td>63</td>
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<td>51</td>
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Sediment yield. As shown in Tables 2 and 3, the VFS were effective in removing TSS. Total sediment losses from the plots without filters were 10 500, 23 400, and 7 700 kg/ha for plots QF3, QF6, and QF7, respectively. The longer 9.1-m filters on the uniform flow plots (QF1 and QF4) reduced sediment loss by an average of 91% while the shorter 4.6-m filters (QF2 and QF5) reduced sediment loss by 81%. Just upslope and in the first few meters of the VFS was the most effective region for sediment removal, supporting the conclusions of previous investigations.

This assertion is supported by field observations of sediment accumulations 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.

Sediment first deposited at the front edge of the filters where overland flow depths increased due to flow resistance caused by vegetation. Flow resistance decreased flow velocity, resulting in ponding in and upslope of the VFS. Decreased sediment transport capacity resulted in deposition of the heavier soil particles and aggregates. As runoff and sediment delivery to the VFS continued, the ponded area upslope of the filter gradually filled with sediment until a steady-state situation was reached. After the ponded area upslope of the filter was filled, sediment began to gradually move down through the filter. Typically, sediment would fill a 0.5 m wide strip of the filter until a substantial portion of the vegetation was buried. As more vegetation was buried, vegetative flow resistance decreased, transport capacity increased, and sediment began to flow into the adjacent virgin area of the filter.

These observations are supported by data from plot QF5, which had a short filter length (4.6 m) and the greatest slope (16%). Intuitively, QF5 would be expected to be the first plot to fill with sediment and would consequently have the poorest performance. Plot observation during simulations showed a steady advance of the sediment front through the filter until it reached the lower end of the plot during the last two simulations. As shown in Table 3 and Figures 2 and 3, the sediment reduction for plot QF5 decreased from 90% in the first simulation to 77, 66, 74, 41, and 53% in the second to sixth simulations, respectively.

Plots QF7-QF9, which had cross slopes of 4%, were included in this study to assess potential impact of concentrated flow (as opposed to the desired shallow overland flow) on VFS performance. Observation during simulations confirmed that the cross slopes caused runoff from both bare and filtered portions of the plots to flow to one side of the plots where the flow concentrated and moved 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 entered other filter portions and most rainfall falling on the vegetated portions of the plots seemed to infiltrate rather than run off.

For the area in which concentrated flow occurred, considerable sediment accumulated along the entire length after the first two simulations but not as much as in the upper areas of the shallow uniform flow plots. Presumably, accumulation was caused by the concentrated flow which submerged and bent the grass over, thus minimizing flow resistance and increasing sediment transport capacity. As shown in Table 3, sediment yield reductions were 58 and 31% for the long and short VFS, respectively. These plots were 0.5 and 0.33 (Table 1) as steep as the first two sets of uniform flow plots, and their VFS would have been expected to be more effective because sediment transport capacity is directly proportional to slope. The decreased effectiveness, therefore, is most likely caused by concentrated flow effects.

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). Nevertheless, sediment concentrations that left uniform flow filters were considerably less than those from concentrated flow plots. The concentrated flow plots had sediment losses of 5400 (QF9)
and 3200 (QF8) kg/ha for the short and long filters, respectively, while sediment losses from the uniform flow plots were 5600 (QF5) and 2900 (QF4) kg/ha for the short and long VFS, respectively (Table 2). The concentrated flow plots had higher sediment losses even though sediment loading to uniform flow plots was 3.05 times greater.

Phosphorus yield. Total P loss from the plots during the first 3 simulations (Test 1) followed the same general trends as sediment loss except that percent reductions in P were generally smaller. This was expected because P in the runoff was present in both soluble and sediment-bound forms. Sediment-bound P was presumed removed by sediment deposition and filtration. Soluble P, however, is much more difficult to remove because it moves in solution independently of suspended sediment and its primary removal mechanisms probably involve infiltration, absorption, and soil sorption. If true, then soluble P removal should decrease with time as infiltration decreases, absorption capacity of the vegetation is satisfied, and surface soil P sorption sites become occupied.

As shown in Table 3, reductions in P, for all simulations were 80 and 63% for plots QF1 and QF2, and 57 and 52% for plots QF4 and QF5, respectively. The cross slope plots had considerably lower reductions, 19 and 2% for plots QF8 and QF9, respectively.

Reductions in soluble P as measured by PO₄ and Pr were not consistent. The VFS with shallow uniform flow were only moderately successful in removing PO₄ during the first set of simulations (Test 1) with reductions in the long VFS of 53% for QF1 and 47% for QF4 (Table 3). During Test 2, the percent reduction in QF1 decreased to 11%, and the effluent from QF4 had more soluble P than the influent. Overall, the long VFS with shallow uniform flow reduced PO₄ loss by 30% (QF1) and −51% (QF4). Concentrated flow plots also were not very successful in removing PO₄ as there was not a large reduction in PO₄ after passage through the filters (Figure 6).

Inspection of Table 3 shows many instances where effluent from the filters contained more PO₄ and Pr than the inflow. These observations are probably attributable to the release of P that was previously trapped in the filters. Presumably, this sediment-bound P was converted to soluble forms that were leached from the filters during subsequent events.

One common assumption concerning P transport in runoff is that P is predominantly sediment-bound and that conservation practices such as VFS, which remove
sediment, should be nearly as effective for P removal as for sediment. This assumption did not hold in the present study because heavy rainfall occurred shortly after manure application. As shown in Table 3, substantial sediment reductions were achieved, but P reductions were considerably less, perhaps because of the release of previously trapped P or because of the size of sediment and manure particles that transport sediment-bound P. Also, P present in manure is primarily organic as opposed to inorganic P, which is normally associated with soil particles. Manure P also becomes more mobile as degradation occurs and soluble P forms are released.

If deposition and filtration of SS are the predominant mechanisms controlling VFS performance, then VFS will be more effective in removing larger particles such as soil aggregates, sand, and larger manure particles. The filter effluent will then be enriched with smaller, more easily transported particles such as primary clay, silt, and small manure particles. Because these small particles may have a much higher capacity for P sorption than the original soil mass, passage of significant amounts of these particles through the filter may cause significant P transport in spite of a large decrease in gross sediment transport.

**Nitrogen yield.** Nitrogen loss from the plots followed the same general trends as soluble and sediment-bound P losses previously discussed. The 4.6 and 9.1 m long filters of the uniform flow plots reduced N, by an average of 67 and 74%, respectively (Table 3). Total Kjeldahl nitrogen accounted for approximately 97% of the N leaving the plots with no filters, and about 90% of the TKN was in a filterable or sediment-bound form (TKN - TKN, from Table 2). These results imply that approximately 87% of the N entering the filters was associated with sediment or manure particles. After passage through the 4.6- and 9.1-m filters, sediment-bound TKN accounted for 77 and 80% of the N leaving the filters, respectively, indicating that filters were not as effective in removing soluble N as they were in removing sediment-bound N. This observation is further supported by Tables 2 and 3, which show that soluble N losses (NH₄⁺, NO₃⁻, and soluble TKN) were reduced much less than sediment-bound N.

As with P, filter effectiveness in removing N decreased with time as sediment and nutrients built up in the filters. Plots QF4 and QF5 were more effective for N removal during the first three runs (Test 1) than during the second set of runs (Test 2) (Figure 7). Effectiveness was also influenced by higher runoff rates during Test 2 because of lower infiltration in the plots caused by higher soil moisture contents and possible surface healing.

The filter strips were ineffective in removing NO₃⁻. As shown in Table 3, the highest percent reduction in NO₃⁻ achieved by any uniform flow plot was 17% by plot QF4. During Test 2, NO₃⁻ 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 NO₃⁻. The other plots had much higher NO₃⁻ losses.

As shown in Table 3, the concentrated flow plots were totally ineffective for N removal. Overall, the 9.1-m concentrated flow plot (QF8) reduced influent N loss by only 9%, and the 4.6-m filter achieved no net reduction in N.

Effluent NO₃⁻ exceeded influent loadings, indicating that the filters trapped very little influent NO₃⁻ and released previously trapped N as NO₃⁻.

**Summary and Conclusions**

Simulated rainfall was applied to a series of 5.5 by 18.3 m bare soil plots with vegetative filters strips 4.6 and 9.1 m long located at the lower end of the plots. The plots were used to evaluate VFS effectiveness for controlling sediment and nutrient losses from feedlots. Fresh dairy manure was applied to bare portions of the plots at rates of 7 500 and 15 000 kg/ha and compacted with rollers to simulated feedlot conditions. Runoff samples were collected at the base of each plot to evaluate VFS effectiveness in removing sediment, N, and P from the simulated feedlot runoff. One set of plots was constructed with a cross slope so that flow through the filters would be concentrated rather than shallow and uniform. Analysis of the results of the plot studies led to the following conclusions.

The VFS are effective for the removal of sediment and other SS from the surface runoff of feedlots if flow is shallow and uniform and if the VFS have not been 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, respectively.

VFS effectiveness for sediment removal seems to decrease with time as sediment accumulates in the filter. On the average, VFS effectiveness decreased by approximately 9% with respect to sediment removal between the first and second set of simulations.

Total N and P were not removed by VFS as effectively as sediment. Much of the N and P in the runoff was soluble or associated with very fine sediment, which the 4.6- and 9.1-m VFS could not remove efficiently. The long and short filters of the uniform flow plots removed only 69 and 58% of the applied P and 74 and 64% of the applied N, respectively.
The VFS lengths used in this research were not effective in removing soluble N and P from the simulated feedlot runoff. Soluble P and N in the outflow from the filters was often higher than in the inflow, presumably because of the release of P and N that previously had been trapped in the filters. Soluble N and P as percent of N and P, entering the VFS were 15 and 8%, respectively. After passage through the filters, soluble N and P increased to 26 and 19%, respectively, of the influent N and P loading.

VFS that are characterized by concentrated or deeper channel type flow were much less effective for sediment, N, and P removal than filters with shallow uniform flow. Filters with concentrated flow were 40 to 60%, 70 to 95%, and 61 to 70% less effective with respect to sediment, P, and N removal, respectively, than were uniform flow plots. Unless VFS can be installed so that concentrated flow is minimized, it is unlikely that they will be very effective.

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