RURAL CONSERVATION CLUBS PROGRAM
ONTARIO CATTLEMEN'S ASSOCIATION

"Evaluation of Vegetative Filter Strips (VFS) to Treat Beef Feedlot and Dairy Yard Runoff in Ontario"

FINAL REPORT

EVALUATION OF VEGETATIVE FILTER STRIPS (VFS) TO TREAT BEEF FEEDLOT AND DAIRY YARD RUNOFF IN ONTARIO

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ABSTRACT

The vegetative filter strip (VFS) is a low-cost innovative approach for treating contaminated runoff from livestock yards. Five VFS have been constructed across the province on behalf of the Ontario Cattlemen's Association, through the Rural Conservation Clubs Program funded under the Canada-Ontario Agriculture Green Plan. The VFS system treats contaminated runoff through settling, filtration, infiltration, absorption and dilution of runoff. Monitoring included measurement, sampling and analysis of influent and effluent runoff for nitrates, ammonia, P, K, total dissolved solids, faecal coliform and BOD. Results revealed no accumulation of nutrients in the soil profile and no change in groundwater samples from preconstruction levels. Surface removal rates, soil profile results and groundwater monitoring results when taken together, establish that the VFS system is an environmentally sound treatment system for feedlot and barnyard runoff.

INTRODUCTION

Livestock and poultry production are essential to Ontario agriculture. Over half of all farms with $2,500 or more in sales in 1991 listed livestock or poultry as their main business. That same year 5.5 million head of livestock and 37.3 million chickens and turkeys were valued at $2.2 billion. Accompanying livestock production is waste production. The first goal of any waste management system is to maintain acceptable environmental standards. However, to be practical, the system must be affordable and suitable to the farm operation. In addition to the actual manure produced, many livestock farms produce large volumes of less-contaminated liquid waste. This waste can include milkhouse washwater and runoff from feedlots, pads, feed storages and solid manure storages.

Current recommendations generally suggest that these wastes be eliminated or stored and land-applied Due to the large volumes and relatively low fertility values the recommendations are generally not economically feasible nor practical. VF S in the United States (Dillaha *et. al.* 1989) have been demonstrated to be cost-effective, practical and environmentally safe solutions to handling agricultural wastewater and runoff.

The objectives of the study were to evaluate the performance of VFS for the treatment of feedlot and yard runoff under Ontario conditions, and to develop design criteria for VFS for Ontario.

MATERIALS AND METHODS

Vegetative Filter Strip Description

The VFS can be described as a system in which a vegetative area is used for treating runoff by infiltration, settling, dilution, filtration and absorption of pollutants. A VFS system consists of a settling, area, usually the yard, a filter box, a gravel spreader and the vegetative area. The filter box controls the flowrate of yard runoff and consisting of a picket fence, two removable mesh screens with 12.5 mm, and 6.25 mm square openings and a hickenbottom inlet.

The size of the VFS is dependent on the size of the contributing feedlot or yard, the slope of the land, and the soil type. The vegetative area can have a slope of 0.5 to 4 percent, and can be anywhere from 90 to 260 m long with typical widths starting at 9 m. Widths should also be adjusted to multiples of the width of the hay harvesting equipment to be used. A small ridge is constructed around the VFS to divert clean water away.

In the case of a small rainfall event, yard runoff will flow to a filter box at the low end of a yard. Large debris will be strained by the picket fence at the front of the filter box, smaller debris will be filtered out by the two successive filter screens. The runoff will then flow into the hickenbottom pipe at a controlled rate not exceeding the infiltration capacity of the soil. The runoff then flows into a gravel spreader 15 cm deep, 1.8 m wide, running across the width of the VFS. The gravel spreader will slow the runoff velocity down, filter out fine solids, and evenly distribute the flow across the vegetative strip. The depth of flow across the strip should not exceed 1.1 cm. The runoff will move slowly in a sheet flow, down the strip, infiltrating as it flows.

In the case of larger storms, the hickenbottom in the filter box will control the flow of runoff onto the strip by temporarily storing the runoff on the yard, usually no more than 12 hours, until it can be safely treated by the filter strip. The yard must be able to provide a temporary ponding or settling area to ensure the 1.3 cm depth of flow on the strip is not exceeded. The temporary ponding area also provides for settling of the larger particles in the runoff. The settling area should be as large as possible, and be easily accessible for maintenance. In some cases, instead of using the yard as a temporary settling area, it is economical to construct a temporary ponding area of earth or concrete off the existing yard.

Vegetative Filter Strip Design

The VFS design was developed after examining the literature and visiting several systems in other jurisdictions. The filter box and gravel spreader were adopted from Wisconsin (Bellam-Mather et al., 1992) based on their research data and actual trial and error field observations of systems installed over a 20 year period. The authors of the Wisconsin paper found it essential to keep solids off the vegetative area of the strip and a multiple mesh screen system evolved. The use of a gravel spreader to distribute the runoff evenly across the width of the strip also evolved over time. Concrete or wood structures are expensive and tended to shift allowing uneven flows over the vegetative strip. Gravel is inexpensive, flexible and if it shifts, it can be easily adjusted. The VFS area and calculations are similar to the Illinois vegetative filter design criteria (Steams et al., 1982) and to Vanderholm et. al. (1979), basing the infiltration area on the design storms. This approach (Dillaha, 1989) can lead to large land requirements as it ignores other removal mechanisms. However, as infiltration is the most easily quantifiable VFS treatment mechanism, it was felt that a conservative approach should be followed.

Barker et. al. (1985), Steams et. al. (1982) and Vanderholm, (1979) used a 1 year, 2 hour storm event. Schellinger et. al., (1992), used a 2 year, 24 hour storm event. The states of Minnesota, Iowa, Pennsylvania and North Carolina use a 25 year, 24 hour storm event in accordance with U.S. legislation for non-point source contaminants.

After reviewing the literature, examining historical precipitation data in Ontario and evaluating the consequences of undersizing the VFS system, a minimum of a 2 year 2 hour design storm was selected. The potential of the yard to provide increased ponding, in effect, increases the actual design storm used.

<u>Materials and Construction</u>

In order to keep costs low and to develop a readily adaptable system, an effort was made to select materials readily available from any hardware store. The mesh screens, pipes, and fasteners are common hardware material. Three of the five sites were constructed by contractors using bulldozers and laser levelling equipment. The remaining two sites were constructed by the farmers using farm equipment and levels.

<u>Plant Selection</u>

The vegetation was selected based on nutrient uptake, wet/dry tolerance and palatability. Vanderholm el. al., (1979), compared the use of orchard-grass, smooth bromegrass (Bromus inermus leyes) and reed canary grass (Phalaris *arundinacea L.)* for overload flow systems, concluding that reed canary grass; is the best grass for most situations. However, many Ontario farmers were hesitant to use a reed canary grass: because of its vigorous growth and poor palatability. For this project, a mixture of a new, more palatable variety of reed canary grass, along with a smooth bromegrass was used.

<u>Vegetative Filter Strip Management and Maintenance</u>

The VFS system requires ongoing management and maintenance to maintain its performance. The feedlot or yard should be regularly scraped, every ten days or before major storms. This reduces solids and nutrients loading on the system. The filter box screens and solids in the box should be cleaned after a storm event. The distribution pipe should be checked for clogging and to ensure even runoff distribution across the gravel spreader.

The VFS should be checked for solids build-up, rill formation and checked to ensure the side berms are intact. The vegetation should be harvested and treated as any hay field. Cattle should be kept off the VFS to prevent damage.

<u>Experimental Sites</u>

Sites were selected after a series of public announcements calling for volunteer sites. Over 50 farmers responded to the announcements. Sites were selected on their suitability, availability of staff/volunteers for sampling, and on their geographic distribution across Ontario. Sites with a low potential impact on the environment and minimal construction requirements were given a priority. Budgetary constraints limited site selections to five, of which groundwater was monitored at only three sites. The as-built parameters for the individual sites are listed in Table I. Cooperators at each site signed a contract detailing their obligations.

Site 1 - A 142 hectare farm with 130 head of cattle on a paved feedlot. The 13.7 in deep far-in well was located approximately 55 in from the VFS.

Site 2 - A 405 hectare farm with 135 head of cattle on a paved feedlot. This site had two 15.5 cm corrugated plastic drains running underneath the VFS parallel to the length of the strip. The drains, which started near the gravel spreader, were cut off and modified at the end of the strip such that they could be accessed and sampled. The 20.0 m deep farm well was located approximately 97.4 m from the VFS.

Site 3 - A 77 hectare dairy farm milking 30 head on a paved yard. This site was the most extensively monitored for groundwater. Two bundles of five piezometers, were located on opposite sides of the strip, 35 m downstream from the gravel spreader. The north piezometers were placed at depths of 3.95 in, 4.50 in, 5.03 m, 5.53 m and 6.05 m. The south piezometers were 3.72 m, 4.22 m, 4.72 m, 5.22 m. and 5.54 m, deep. The 3 8.7 m deep farm well was located approximately 80.4 m from the VFS. The VFS on this site was twice as wide as the design required to allow for the future possible addition of milkhouse washwater.

Site 4 - A 105 hectare farm with 250 head of cattle on a partially paved feedlot. There were two wells 7 m, deep -- one was located in the feedlot and the other was approximately 36.5 m from the VFS.

Site 5 - An 81 hectare dairy farm, milking 100 head with a constructed wetland to treat manure runoff and milkhouse washwater; the VFS was located to receive the effluent from the wetland. Five piezometers were installed for groundwater monitoring. The results for this site will be treated separately from Sites I to 4.

MONITORING

Monitoring included measurement, sampling and analysis of influent runoff, and effluent runoff, farm wells and groundwater, where applicable. The liquid sample parameters listed in Table 11 were analyzed by an accredited, professional laboratory. Soil sampling parameters included total nitrogen, phosphorus, potassium and pH to determine the effects of the runoff application on the location of soil nutrients on the soil profile. The percentage of sand, silt and clay in the soil profile was also determined. The following observations, monitoring and sampling data were collected from each site by the farmer and by field samplers:

<u>Observations</u>

• Type and changes in vegetation

• Harvest dates, amount baled
• Maintenance requirements - yard, screens, gravel strip, filter strip
• Damage to VFS., cattle access - rills, erosion

Monitoring and Sampling - During storm events

Precipitation - amount, duration, date

Feedlot/Yard - maximum height of pooled liquid in the yard
- time to peak - height of pooled liquid
- time to dissipate - time required for liquid to flow off the yard

VFS - maximum depth of liquid on strip (peaks) and average depth
- distribution of flow - pooling/channelling on strip
- maximum distance flow reached on strip

Influent - at picket wall (leaving yard) before screens

Effluent - at gravel spreader
- at maximum distance flow reached

Monitoring and Sampling - Regularly

Groundwater Sampling - Piezometers and &m wells seasonally (Oct/Jan/Apr/July)

Soil Sampling - two sets of samples per year, spring,, and fall

- sample depths at 0-5 cm, 5-10 cm, 10-20 cm, 20-30 cm, 10-46 cm, and 46-61 cm,

S sampled at 4 locations along the length of the strip a I m, 10 m, 30 m and 100 m from the gravel spreader (or the end of the filter strip if less than 100 m)

RESULTS AND DISCUSSION

The three year term for the research project (April 1994 to April 1997) is short for a natural or vegetative control system. In this time frame, sites must be selected, designed, constructed, and planted. The vegetation must be reasonably well established prior to loading the system with runoff. With the spring and fall planting windows available, some sites were only established well into the second year of the project. Each site was monitored from just prior to the construction completion date in Table I to fall 1996.

Under dry precedent conditions, 1 cm of precipitation was required before there was any flow onto the filter strips. IN general, vegetation was slow to establish, partially due to compaction caused during site construction. In the future, a starter fertilizer will be recommended. On Site 4, the screens clogged frequently. This was probably due to the storage of manure next to the filter box on an earthen feedlot, resulting in the yard rarely drying out between storm events. The clogged screens and pipes, however, did not hinder the treatment functions of the VFS on Sites 1 and 4. There was a buildup of solid material in the pipe distribution system. For this reason, the pipes were friction fitted together for easy dismantling and cleaning. The cleaning involved tilting the pipes vertically to allow the debris to run out. Site 1 experienced a buildup of solids in the gravel spreader and on the top of the vegetative area. On further investigation the stand pipe in the filter box had several holes at its base allowing for a small continuous trickle of runoff. These holes were patched and the solids buildup ceased. Soon after construction, Site 3 experienced some differential settling of the header pipe on the gravel spreader. The resultant flows were concentrated on one side of the VFS causing the small side berm to erode. However, despite these minor problems with the various sites, the VFS handled the runoff flows and physically functioned as expected. There were no observed events of runoff flowing, off the end of the VFS.

Table II contains a summary of the influent runoff parameters from Sites I through 4 which quantifies the range of waste parameters the VFS handled in this project.

The phosphorous soil test results showed the largest divergence at 1 m downstream from the gravel spreader. In comparing Sites 1 through 4, Site I showed consistently higher results in the fall 1996 tests until the results converged at a depth of 45 cm. For Site 2, the spring and fall 1996 results were lower than the fall 1995 results. For Site 3, the fall 1996 results were lower than earlier tests except in the top 10 cm- of the soil profile. The spring 1996 results, however, were consistently higher than the first test results. The largest divergence was at 10 cm where the sample was 300 ppm greater than the original tests. While the trend is most likely accurate, the actual value may be high.

For Site 4, the fall 1996 tests showed higher values at the 5 and 15 cm, depths. However, the spring and fall 1996 results were significantly lower than the fall 1995 results at the remaining depths. The phosphorous soil tests showed increasingly less divergence at the soil profiles 10 m, 30 m and at end of the last sample. There was some accumulation of phosphorous in the top of soil profile, however, usually only in the top 10 cm.

For Sites 1, 2 and 3 the nitrate soil tests showed the fall 1996 results to be consistently lower than the earlier soil test results. Site 4, however, showed higher nitrates in the fall 1996 than fall 1995 results in the top 10 cm, of the soil profile at I m and 10 m downstream from the gravel spreader. Except for Site 4, there was no accumulation of nitrates *in* the soil profile during the course of the project.

Table III contains the average, maximum, median, minimum and standard deviation for the percentage removal rates for surface samples. Percentage removal rate represents the percentage difference of the influent sample and the sample taken at the further distance the runoff reached down the VFS before infiltrating into the soil.

While the maximum surface removal rate for all parameters exceeded 93 percent, the average removal rates were much more modest with high standard deviations. These results are in agreement with Edwards et. al., (1983). The negative minimum removal rates are an indication of variability of the runoff and the grab sample approach to sampling. Except for the possible exception of faecal coliform samples, the actual parameter values should not be increasing. The values could be adjusted to more accurately reflect the treatment functions of the VFS.

Site 5 involved a VFS to treat effluent from a constructed wetland. Results for the summer of 1996 are in Table IV- Even at relatively low loading rates, the VFS provided effective treatment of the waste. The VFS on this Site served to provide a polishing function, effectively improving the water quality parameters to discharge standards.

The groundwater sampling, including the farm wells, on all sites showed no increase in value for any of the tested parameters.

SUMMARY

The VFS design functioned well, however, some components require frequent monitoring and maintenance to ensure proper functioning. The surface removal rates, the soil profile results and the groundwater results when taken together, establish that the VFS system is an environmentally sound treatment system for feedlot and barnyard runoff.

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TABLE I Experimental Sites as Built

Site	Catchment Area m 2	Yard Containment Volume m 3	VFS Slope %	Length M m	Width m	VFS Design Storm	Soil Type	Infiltration Rate cm/hr	Construction Completed
1	400	32.8	0.4	101.5	4.25	2 yr 2 hr	loam	4.32	May 1995
2	2020	4.45	0.5	105	24	2 yr 2 hr	clay loam	3.05	August 1995
3	1691	61.9	4.5	140	8.5	2 yr 2 hr	loam	4.32	July 1996
4	1442	39.9	0.6	70	8.0	2 yr 2 hr	clay loam	3.05	July 1995
5	wetland system	--	0.3	180	15	--	30.5 cm, topsoil	4.95	August 1995

Table II Results of 23 Effluent Runoff Samples* Taken From Feedlots/Yards of Sites 1-4

PARAMETER	Average	Standard Deviation	Maximum	Median	Minimum
Nitrate-N (mg/L)	26.4	31.4	140.0	15.0	5.0
Ammonium (mg/L)	221.3	220.8	901.0	151.0	21.2
Total Phosphorus (mg/L)	68.7	86.8	350.0	44.0	5.0
Potassium (mg/L)	886.2	650.1	2,620.0	823.0	61.0
TDS (mg/L)	61,095	60,592	2,800,000	43,000	170,000
pH	7.4	0.58	8.3	7.4	6.2
Faecal Coliform/100 ml	3,196,435	5,321,990	19,000,000	900,000	16,000
BOD, (mg/L)	3,175	4,054	16,500	2,363	229

* 10 samples from Site 1, 2 samples from Site 2, 5 samples from Site 3, and 6 samples from Site 4

Table III VFS Percentage Removal Rates for Surface Samples From Sites 1-4

Parameter	Average	Standard Deviation	Maximum	Median	Minimum	Sample Size
Nitrate	45.2	28.5	95.0	39.1	9.1	17
Total Phosphorous	31.0	39.2	99.9	12.7	-17.6	18
Total Dissolved Solids	29.1	34.1	93.9	14.0	-10.5	17
Faecal Coliform	40.6	37.5	99.5	39.4	-25.5	14
BOD_5	51.3	34.1	99.1	50.7	-4.6	16

Table IV Average Removal Rates for VFS Treatment of Constructed Wetland Effluent on Site 5

Parameter	Wetland Effluent	VFS Effluent	Removal Rate %
Ammonia (mg/L)	2	0.5	75
TKN (mg/L)	18	1.9	89
BOD, (mg/L)	24	3.6	85
Suspended Solids (mg/L)	62	15.5	75
Total Phosphorous (mg/L)	3	0.1	97