OFF-STREAM WATER SOURCES FOR GRAZING CATTLE AS A STREAM BANK STABILIZATION AND WATER QUALITY BMP

R. E. Sheffield, S. Mostaghimi, D. H. Vaughan, E. R. Collins Jr., V. G. Allen

ABSTRACT. *A multi-disciplinary study was conducted to evaluate effectiveness of providing cattle with an off-stream water source (i.e., water trough) in reducing stream bank erosion and fostering water quality improvements. This study was conducted on two commercial cow-calf operations in southwest Virginia which used rotational stocking. When given the choice, cattle were observed to drink from a water trough 92% of the time, compared to the time which they spent drinking from the stream. Stream bank erosion was reduced by 77% due to installation of the alternative water source. Concentrations of total suspended solids, total nitrogen, and total phosphorus reduced by 90, 54, and 81%, respectively when an alternative water source was provided. Similar reductions were observed in concentrations of fecal coliform and fecal streptococcus. Concentrations of dissolved nutrients such as nitrate and orthophosphorus, however, were adversely affected by installation of the BMP. The study results clearly indicate that off-stream water sources for grazing cattle are effective BMPs for reducing the loss of sediment and sediment-bound pollutants to adjacent streams without resorting to stream bank fencing.* ***Keywords.*** *Water quality, Erosion, Animal behavior, BMP, Off-stream water source.*

Cattle watering and standing in streams have long been seen as an eyesore by people both inside and outside of the agricultural community. This traditional agricultural practice has also been identified as a source of nonpoint source pollution (Smolen et al., 1990). Fencing of stream banks to deny cattle access to streams has been proposed (Skovlin, 1984; Davis et al., 1991) to minimize pollution from pasture and rangelands. Debate over the economic consequences (Platts and Wagstaff, 1984), the resulting management issues, and possible regulatory involvement (Swan, 1979) have escalated concerning stream bank fencing as a general management strategy. Unfortunately, few cost-effective alternatives to stream bank fencing have been proposed.

Off-stream water sources, as suggested by Smith et al. (1992) and Marlow and Pogacnik (1986), is a water quality management practice which has been noted by farmers and conservationists to be quite effective in reducing cattle impact upon stream environments. However, little field data is available for evaluation of the impact of this practice on water quality. Water developments have traditionally been viewed solely as a farm improvement strategy. Greene (1994) observed in southwest Virginia that when water troughs were installed large stream bank vegetation, such as speckled alders (*Alnus rugosa*) and willows (*Salix* sp.), were established after a few years because cattle would spend less time in the stream.

Miner et al. (1992) observed that hay-fed cattle in Oregon preferred to drink from a trough rather than from a stream during an eight-day observation period. Cattle preference resulted in a 90% reduction in the amount of time they spent in the stream, if a stream was their sole source of drinking water. Miner et al. (1992) hypothesized that the 90% reduction in time spent in the stream would correlate to a reduction in fecal and nutrient loadings to the stream.

Clawson (1993) observed that the installation of a water trough had a significant impact on cattle use of the stream side areas. Use of a stream within a pasture dropped from 4.7 to 0.9 min, and use of a wide streamside area dropped from 8.3 to 3.9 min per cow per day after the trough was installed. This correlated to an 81% reduction in the time cattle spent drinking from the stream and a 53% reduction in the time cattle spent in an adjacent stream side area. Clawson (1993) concluded that cattle preferred to drink from a water trough rather than a stream 75% of the time.

The overall goal of this study was to evaluate the feasibility of using water troughs as a Best Management Practice (BMP) to reduce the losses of soil, nutrients, and bacteria from pasture lands. Specific objectives were: (1) to compare the behavior of cattle using streams as a primary water source to those which had access to streams as well as to off-stream water sources; (2) to estimate and compare stream bank erosion in pasture systems using rotational stocking where streams were and were not utilized as the primary water source; and (3) to estimate and compare nutrients and fecal bacteria concentrations from pasture systems where streams were and were not utilized as the primary water source.

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The Study Sites

This study was conducted on two commercial cow-calf operations in the Ridge and Valley region of southwest Virginia which used rotational stocking. One study pasture (14.2 ha) was located on the River Ridge Farm in Independence, Virginia (fig. 1), and two additional study pastures (16.6 and 22.3 ha) were located on the Bender Farm in Floyd, Virginia (fig. 2). The River Ridge Farm produces Brahma-Angus calves using high stocking density and stocking rates of 200 cows and 170 calves on eight pastures totaling 136 ha. The Bender Farm produces Angus-Hereford calves at a stocking rate of 150 cows and 60 calves on eight pastures totaling 187 ha. The Bender Farm used first-last grazing during the spring and fall, rotating yearlings onto paddocks for three days before grazing lactating cows and calves.

The three study pastures were chosen for several reasons. First, a spring-fed first-order stream originates in each pasture. Second, spring-developments provide water to a three-trough system on the River Ridge Farm, and a single-trough system provides water for cattle on each of the pastures on the Bender Farm. Lastly, tall fescue (*Festuca arundinacea* L.) was the dominant grass on both farms among a mix of orchardgrass (*Dactylis glomerata*), Kentucky bluegrass (*Poa pratensis*), red clover (*Trifolium pratense*) and white clover (*Trifolium repens*). A more detailed description of the study sites is given by Sheffield (1996).

The tall fescue present in the River Ridge and two Bender pastures was found to be highly infected (77%, 72%, and 78%, respectively) by the fungal endophyte (*Acremonium coenophialum* Morgan, James and Gams). The endophyte has long been identified with three syndromes among cattle (Ball et al., 1991). Cattle grazing toxic tall fescue and suffering from the effects of fescue toxicosis or "summer slump" have been observed to have a tendency to wallow in mud (Bowman et al., 1973) or stand in ponds or creeks during hot portions of the day. Fescue toxicosis causes the body temperature of cattle to elevate and subsequently the cattle spend more time within the stream areas. Therefore, it can be expected that the level of impact (erosion, degraded water quality) upon these areas would increase in pastures where high levels of the endophyte are present.

Methods

During the first seven months of the study (pre-BMP period: Aug. 1994 through Apr. 1995), cattle had access to only one stream in the observed pasture as their source of water. After the first seven months, water troughs were installed in the pastures and cattle had continued access to streams (post-BMP period: Apr. 1995 through Oct. 1995). To provide water for the troughs, springs were developed according to design specifications of the Natural Resources

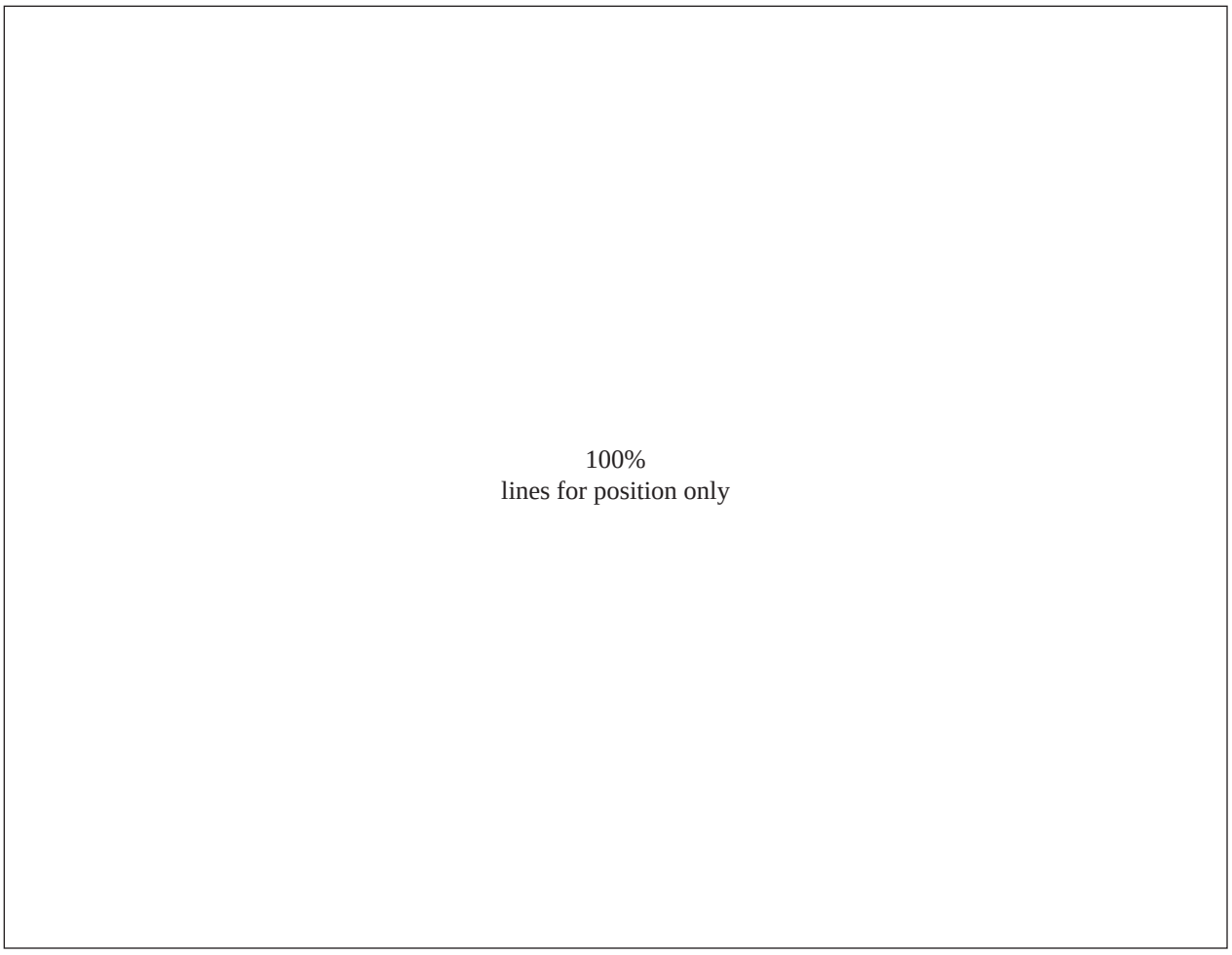


Figure 1–Location of study site at the River Ridge Farm in Independence, Virginia.

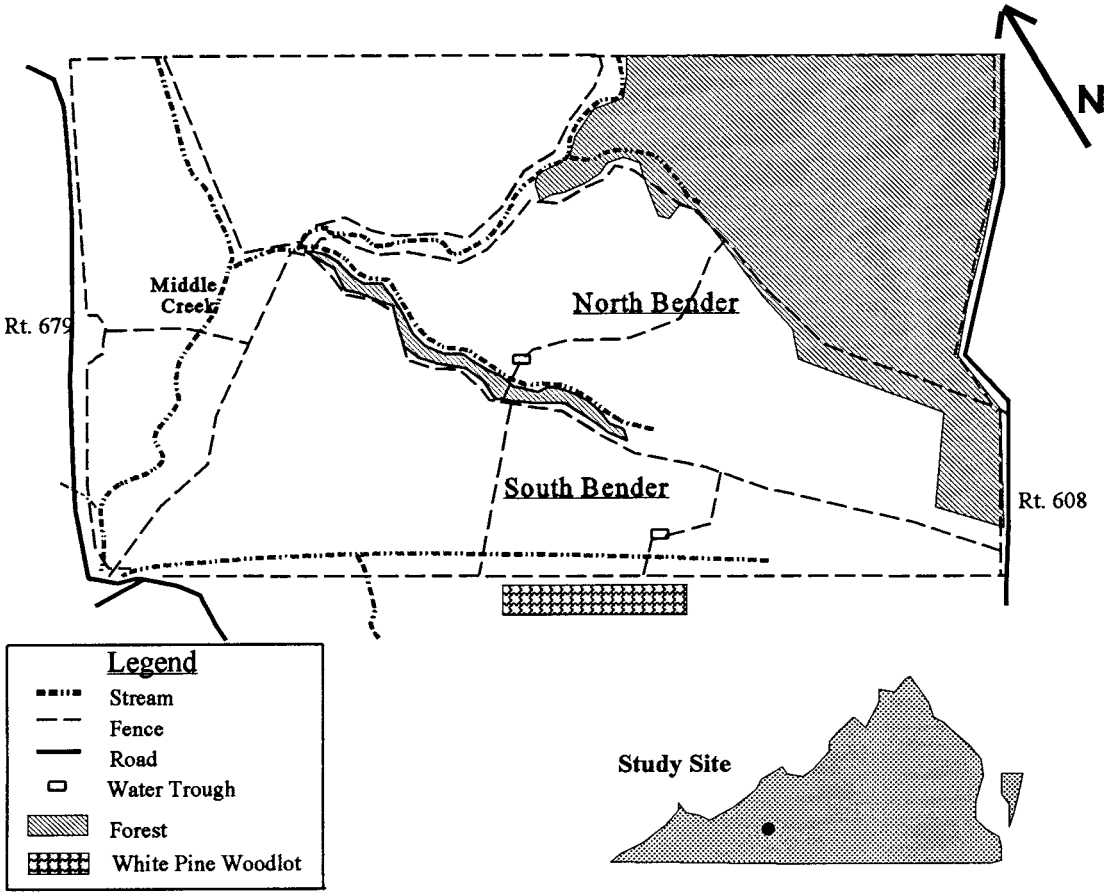


Figure 2–Location of study site at the Bender Farm in Floyd, Virginia.

Conservation Service (1992). At no time during the study were cattle excluded from the stream by fencing.

Prior to the study, various monitoring equipment were installed on the River Ridge Farm, and surveys were conducted in preparation of this project. A weighing raingauge and a standard raingauge were installed. The standard and weighing raingauges were read by the farm operator. Surveys for stream length and slope were conducted prior to the start of the project. Stream flow data were obtained by measuring the time to collect a known volume of water (3.785 L or 18.925 L) at the pond outlet (QRR 6, fig. 1).

Three day-long observations of cattle behavior were conducted during the pre-and post-BMP treatment periods on both the River Ridge and Bender farms. Cow-day observations (daybreak to dark) were made at 5-min intervals from the cab or rear of a pick-up truck parked either off pasture, if possible, or within the pasture at a distance which would not disturb the cattle. The number of cattle drinking from the stream or trough, cattle within the stream or trough areas, and the percentage of herd grazing were recorded during each time interval. Observations were also made between the 5-min intervals to describe the behavior of the herd or of individual animals. Notes were made pertaining to the extent of the area along the stream used by the cattle, size of groups watering together, distance the cattle traveled to water in relation to grazing area, closest stream or trough location, and the behavior of age/sex groups within the herd.

The stream and trough areas were defined in this study as the distance of two adult cow lengths (approximately 4.6 m) from the center of the stream or the edge of the water trough. The number of animals (cows, calves, and bulls) on the observed pasture was obtained from the farm managers prior to the day of observation. Each animal was treated as an individual unit.

Comparisons between the pre- and post-BMP observation periods were made by averaging the three observations which were conducted during both treatment periods. The observation period with the largest number of 5-min intervals (i.e., observations) was used as the reference observation period in order to have a common time scale for subsequent comparisons. The time intervals of the remaining observation periods were weighted in order to create a common time scale. The cumulative time per animal and the percentage of herd participation in each activity and observation period were averaged for the pre- and post-BMP observation phases. Lastly, the percentage difference in cumulative time per animal and the percentage of herd participation were calculated by comparing the mean and standard deviations for each activity during the pre- and post-BMP treatment periods.

Estimates of stream bank erosion in terms of sloughing or mass wasting were made before and after providing cattle with an off-stream water source. These estimates were made by installing 19 pairs of 30-cm (1-ft) long, 13-mm (½-in.) wall thickness steel pipes (stakes) along the stream on the River Ridge Farm. Stakes were placed

randomly across straight, as well as meandering, portions of the stream channel.

The side of the stream which was closest to the primary grazing area was denoted as the inside side of the stream, and the opposite side of the stream was denoted as the outside of the stream (fig. 3). The free end of a 32.8 m (100 ft) tape measure was placed on a pipe on the outside bank of the stream, referred to as the reference stake, and was stretched across the stream to the back of a stake located on the inside bank of the stream. The tape was then stretched to a predetermined known distance before measurements along the cross-section were made. The distance from the reference stake to the outside edge of the stream bank was measured to the outside edge of the stream, inside edge of the stream and the inside edge of the stream bank, using a plumb bob. All measurements of the cross-sections were made on the upstream side of the stretched tape. This procedure was conducted prior to the study, and every two months during the pre- and post-BMP periods.

Differences in the distance from each reference cross-section stake to the stream bank and to the stream edge were calculated from the most recent measurement compared to the previous measurement. Changes in distances were also calculated using the difference between the most recent measurement, to the beginning of the treatment period and to the beginning of the study period, for post-BMP measurements. The location of the edge of the stream bank was allowed only to increase (move away from center of the stream) through time. If the most recent measurement of the location of the stream bank was closer to the stream than the previous measurement, then the previous value was substituted for the most recent value. No adjustments were made to the edge of stream measurements. The average and standard deviations of loss of stream bank for all of the stream cross-sections during the pre- and post-BMP treatment periods were calculated. A Wilcoxon sign-rank test (α = 0.05) was used to detect whether a significant difference existed between the amount of stream bank loss during the pre- and post-BMP treatment periods.

Variations in water quality were evaluated prior to and after the BMP was installed. Six stations (QRR1, 2, 3, 4, 5, and 6) were located along the stream at the River Ridge Farm (fig. 1). Water quality samples were also taken at the Bender Farm. However, an insufficient number of samples were collected during the post-BMP period to make a statistical comparison and are not presented here. The following water quality parameters were measured from semi-monthly water quality samples: total suspended solids (**TSS**), nitrate-nitrogen (**NO_3-N**), ammonium (**NH_4-N**), total nitrogen (**TN**), sediment-bound nitrogen (**SBN**), ortho-phosphorus (**PO_4**), total phosphorus (**TP**), sediment-bound phosphorus (**SBP**), fecal coliform (**FC**), fecal streptococci (**FS**), and total coliform (**TC**).

The concentrations of all parameters, expressed in milligrams per liter (mg/L), were evaluated at each sampling station. The concentration of TN was calculated as the sum of the concentrations of nitrate and total Kjeldahl nitrogen. The sediment-bound nitrogen (SBN) was calculated by subtracting the total Kjeldahl nitrogen from filtered total Kjeldahl nitrogen concentrations. The sediment-bound phosphorus concentration (SBP) was calculated by subtracting the filtered total phosphorus from total phosphorus. The concentrations of the three fecal bacteria were also evaluated in terms of colonies per 100 mL of water. Due to the skewness of the data, the non-parametric Wilcoxon sign-rank sum test was used to evaluate each parameter.

The nutrient samples collected from the outlet of the stream (QRR-5) on the River Ridge Farm were also evaluated in terms of their loading and flow-weighted concentration. Pollutant loading (kg) at the stream outlet was calculated by multiplying the concentration by the flow volume measured at the time of sampling and the number of days since the last sampling date. The pollutant loadings were then divided by the amount of rainfall (cm) recorded since the last sampling date in order to remove the effect of variations in rainfall amounts during the pre-and post-BMP periods. If no rain had occurred since the last sampling date, the mass was carried over to the next sampling time where rainfall was recorded. The pollutant loadings for each treatment period were then evaluated using the non-parametric Wilcoxon sign-rank sum test. Flow-weighted concentrations (mg/L) for each treatment period were calculated by summing the mass of each pollutant (kg) and dividing it by the total stream flow volume observed during the study period (m^3). The percent differences, in loading and flow weighted concentration, which occurred due to installation of the BMPs were then calculated for each pollutant.

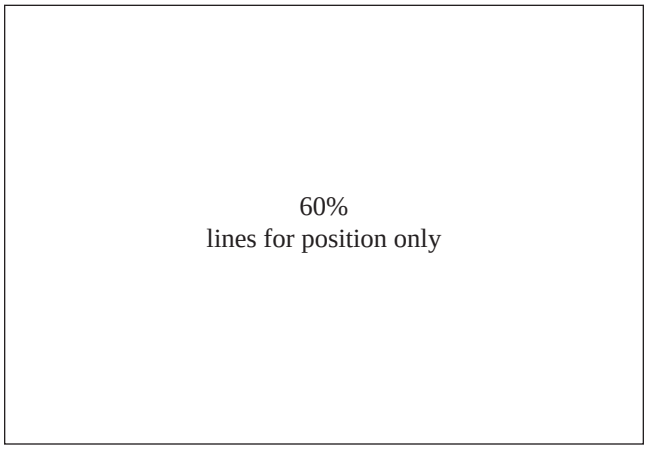


Figure 3–Schematic of the methods used for measuring a stream cross-section to estimate stream bank erosion.

Results and Discussion

Cattle Behavior

The average cumulative time each cow spent within the stream drinking, and being in the stream area are depicted in figures 4 and 5, respectively. These values are also listed for each observation period in table 1. The average length of time spent by each cow drinking from the stream was 6.7 and 0.7 min for the pre- and post-BMP periods, respectively, an 89% reduction. These reductions are similar to those reported by Clawson (1993) who observed a drop from 4.7 to 0.9 min per cow when cattle were drinking only from a stream and when an off-stream water source was available, respectively. The average length of time spent by each cow within the stream area was reduced from 12.7 min to 6.2 min during the pre- and post-BMP treatment periods, respectively. This corresponds to a

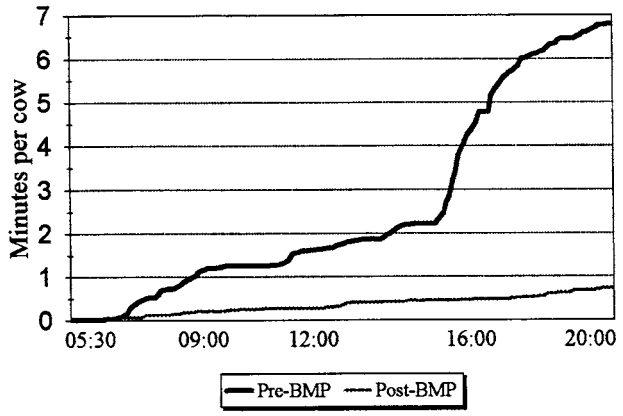


Figure 4–Cumulative time per cow spent in the stream drinking for an average cow-day.

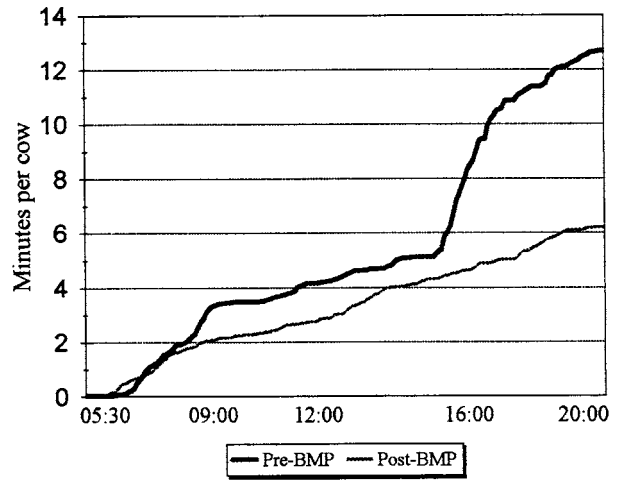


Figure 5–Cumulative time per cow spent in the stream area for an average cow-day.

Table 1. Comparison of length of time spent by each cow drinking from the stream and being in the stream area

Date	Farm	Cumulative Time per Cow Drinking from the Stream	Cumulative Time per Cow Being in the Stream Area
Pre-BMP*			
11-22-94	South Bender	6.20	13.33
12-03-94	River Ridge	6.62	12.71
1-10-95	North Bender	7.35	12.02
Mean		**6.72**	**12.69**
Post-BMP†			
6-29-95	River Ridge	0.62	3.55
8-22-95	South Bender	1.31	12.33
9-26-95	River Ridge	0.24	2.80
Mean		**0.72**	**6.19**
% Reduction in Mean		**89.4**	**51.2**

* Without water trough.
† With water trough.
NOTE: All values expressed in minutes.

reduction of 51% in the average cumulative time spent by each cow within the stream area due to the availability of an off-stream water source for grazing cattle.

The pre-BMP values for cumulative time spent by each cow drinking from the stream and being in the stream area were less variable than those observed for the post-BMP period. The differences in variability can be largely explained by the pasture conditions in the South Bender Farm on the 22 August 1995 observation. During this post-BMP observation date, the majority of the pasture was cut and baled for hay prior to cattle entering the pasture. It can be construed that the decreased amount of forage available within the main grazing area forced the cattle to seek vegetation within the stream corridor. Thus, the large value obtained for cumulative time each cow spent in the stream area on 22 August mainly reflects the effect of the farm forage management practices rather than the BMP. The moderately increased values in cumulative time each cow spent drinking from the stream on the South Bender Farm reflects increased use of the stream as a drinking water source when the adjacent stream area was used for forage, as compared to the other post-BMP observations. It is believed that with better cattle/forage management, the average cumulative time per cow spent in the stream area or drinking from the stream would be reduced. This should enhance the effectiveness of off-stream water sources in reducing the cumulative time spent within the stream area and reduce the use of the stream for drinking.

The presence of an off-stream water source for grazing cattle reduced the time spent by the cattle in the stream for drinking by an average of 92% (table 2), assuming the time which cattle spend drinking remains constant regardless of the source. This assumption seems to be reasonable since the average cumulative time each cow spent drinking from the stream and drinking from a water trough are comparable with mean values of 6.8 min and 7.2 min, respectively. Godwin (1994) also reported no significant difference between the cumulative time cattle or horses spent drinking from a stream when an off-stream water source was not provided, and the time spent drinking from an off-stream water source when it was made available. The data on the use of streams for drinking when an off-stream water source is available for grazing cattle is shown in figure 6.

Table 2. Off-stream water source preference during the post-BMP treatment period

Date	Farm	Reduction in % of Time Spent Drinking in Stream Due to Trough Installation
6-29-95	River Ridge	92
8-22-95	South Bender	90
9-26-95	North Bender	93
Average		91.7

STREAM BANK EROSION

The results of measurements taken from randomly selected cross-sections along the River Ridge Farm stream is presented in table 3. Measurements were taken three times during each treatment period in order to estimate the amount of stream bank erosion which took place due to the influence of grazing cattle and the presence of an off-stream water source.

Stream bank losses which occurred during the post-BMP period were significantly less ($\alpha = 0.05$) than those measured during the pre-BMP treatment period. Average

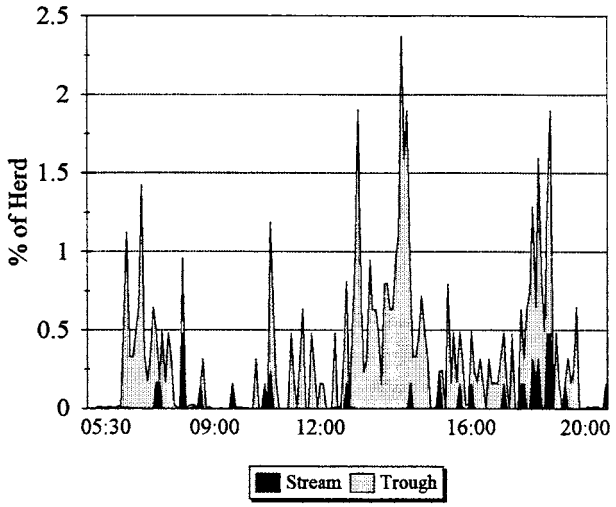


Figure 6–Cattle water source preference during the post-BMP treatment period.

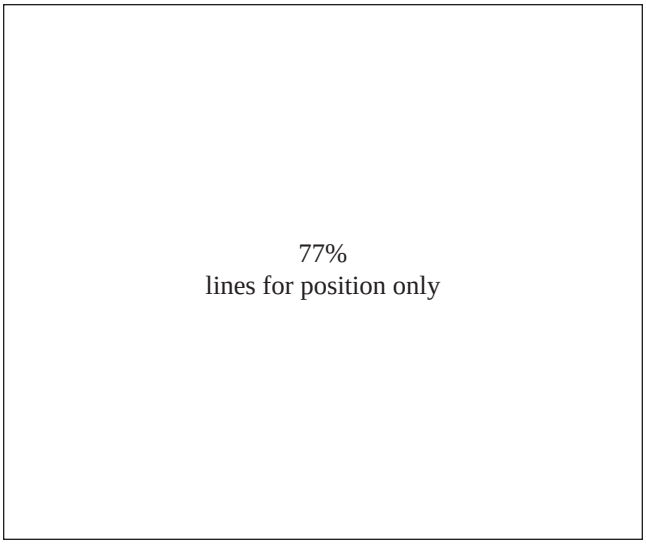


Figure 7–Average concentration of total suspended solids for all stations on the River Ridge Farm.

Table 3. Results of stream cross-sectional surveys on the River Ridge Farm

	Pre-BMP	Post-BMP	D[1*]
P -value			0.006†
Mean	0.66	0.15	0.51
Std. dev.	0.96	0.17	0.96
% reduction		**77.2**	

* D[1] = Difference between pre- and post BMP values.
† Significant at 0.05 level.
NOTE: Means and standard deviations area expressed in terms of meters of stream bank loss (erosion) due to sloughing.

stream bank loss was 0.66 m and 0.15 m on the River Ridge Farm for the pre-BMP and post-BMP periods, respectively. This resulted in a 77% reduction in the amount of stream bank loss, due to the effect of sloughing by cattle, due to installation of the BMP.

WATER QUALITY

Water quality samples were taken every two weeks from the River Ridge Farm stream. Additional samples were also taken before, after and during some of the cattle rotation activities in order to coordinate water quality sampling with cattle movement. A total of 193 samples were taken from the six water quality stations (fig. 1), of which 83 were taken during the pre-BMP treatment period (8/17/94 - 3/17/95) and 110 were taken during the post-BMP (3/18/95 - 10/15/95) phase. The spring upstream of QRR-2 was dry for long spans of time, making regular sample collection difficult. Therefore, data from QRR-2 is not included in this article.

The average concentrations of water quality parameters from all stations reflected the significant reductions in stream bank erosion discussed earlier. Significant reductions were detected in the average concentration of TSS in the River Ridge stream after BMP installation (fig. 7). The reduction in average TSS concentrations reflects the reduction in stream bank erosion due to installation of the off-stream water source. An 89% reduction in the flow-weighted concentration of TSS was observed at the watershed outlet (QRR-5) on the River Ridge Farm due to installation of the off-stream water source (table 4). At the same station, the loading of TSS per cm of rainfall during the post-BMP treatment period was reduced by 96%, compared to the pre-BMP period. These results further support the earlier findings that, when cattle have access to an off-stream water source, the total amount of suspended solids in a stream could be substantially reduced.

Average concentrations of total nitrogen, ammonium and sediment-bound nitrogen on the River Ridge Farm were generally reduced due to the installation of the BMP (fig. 8). Average concentrations of TN and SBN increased during the post-BMP period at station QRR-1. Nitrate concentrations also increased significantly after BMP installation at QRR-1 (fig. 1). It is not surprising to find increased NO_3-N levels at this station. Due to the source area up-slope of QRR-1 and the increased mean air

Table 4. Flow-weighted concentrations and loadings of water quality nutrients for the stream outlet (QRR-5) on the River Ridge Farm

	Flow-weighted Concentration (mg/L)			Loading (kg/cm rain)		
Parameter	Pre-BMP	Post-BMP	% Change	Pre-BMP	Post-BMP	% Change
Total Suspended Solids (TSS)	132.35	14.28	–89.21	292.84	11.06	–96.22*†
Total Nitrogen (TN)	1.340	1.237	–7.72	3.02	1.34	–55.63*
Ammonium (NH_4)	0.321	0.090	–72.06	0.52	0.12	–76.92*
Nitrate (NO_3)	0.167	0.229	37.05	0.31	0.35	12.90
Sediment Bound Nitrogen (SBN)	0.472	0.468	–0.66	1.05	0.55	–47.62
Total Phosphorus (TP)	0.203	0.072	–64.56	3.25	0.08	–97.54*
Ortho-phosphates (PO_4)	0.004	0.007	98.47	0.04	0.01	–75.00
Sediment Bound Phosphorus (SBP)	0.120	0.068	–42.87	0.93	0.07	–92.47*

* Significant difference between means at $\alpha = 0.05$ level.
† A negative value (–) indicates a reduction due to the installation of the BMP.

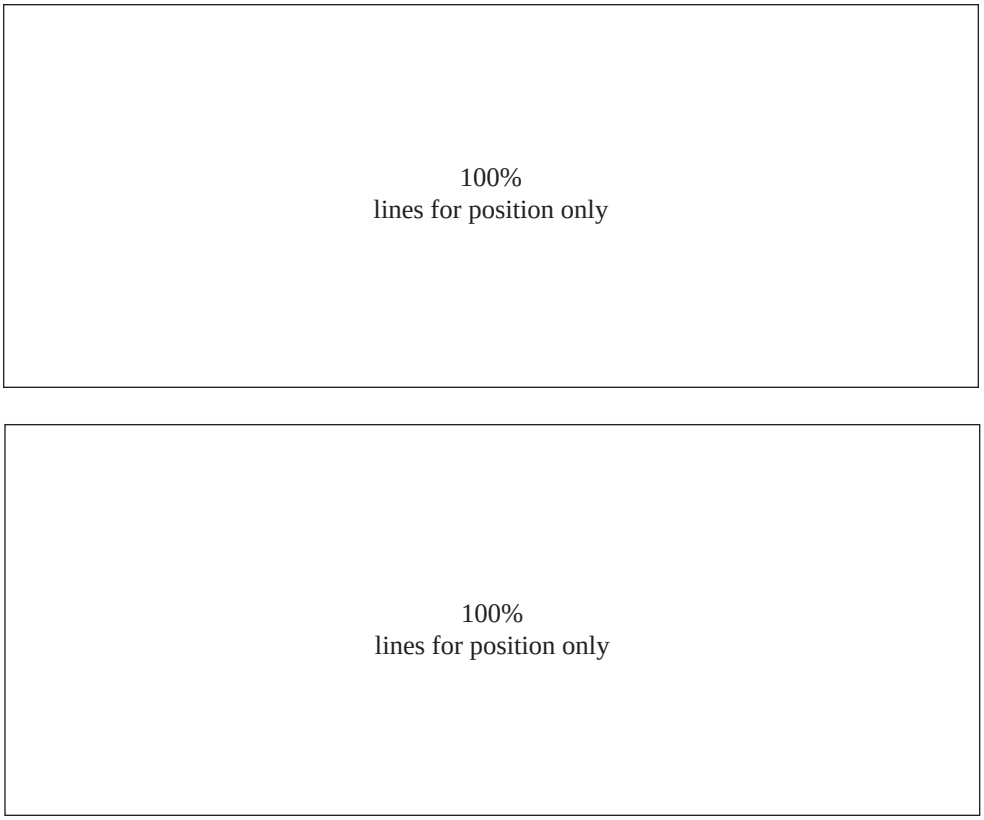


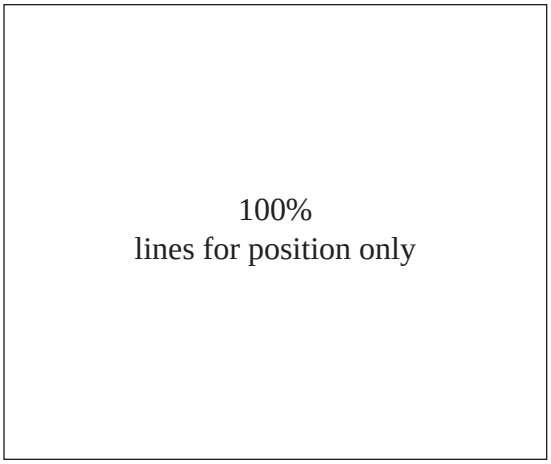
Figure 8–Average concentration of total nitrogen, ammonium, nitrate, and sediment and sediment-bound nitrogen for all stations on the River Ridge Farm.

temperatures, concentrations of the soluble nutrient (NO_3-N) would be expected to increase at the headwater station during the primarily summertime post-BMP period, as compared to the wintertime pre-BMP period. The greater soil temperature during the post-BMP period may have increased the nitrification process, thereby increasing nitrate levels. The flow-weighted concentrations and loadings of TN, NH_4, NO_3, and SBN are given in table 4. The percent change which occurred during the post-BMP treatment period, as compared to the pre-BMP period, is also reported in table 4.

The average concentrations of sediment-bound phosphorus were reduced due to the installation of the off-stream water source on the River Ridge Farm (fig. 9). Significant reductions in the average concentration of TP were obtained at QRR-1, QRR-3, QRR-4, and QRR-5 during the post-BMP treatment period. These reductions also correspond with the significant reductions reported for TSS concentrations. Significant reductions in the concentration of SBP were found at QRR-1, QRR-3, and QRR-4. A 71% reduction in the average concentration of SBP was found at QRR-5. Concentrations of soluble phosphorus, in the form of orthophosphates (PO_4), increased or remained relatively unchanged due to the installation of the off-stream water source. However, no statistically significant differences in PO_4 concentrations were detected for the samples collected from the River Ridge stream. The concentrations of PO_4 followed the same trend as those reported for NO_3.

Installation of the off-stream water source reduced the flow-weighted concentration and loading of TP and SBP on the River Ridge Farm (table 4). Reductions of 65% and 43% were found in the flow-weighted concentration of total phosphorus and sediment bound phosphorus, respectively. The loading of TP and SBP were also significantly reduced by 98% and 92%, respectively, during the post-BMP treatment period. The flow-weighted concentration of PO_4 increased by 98% while its respective loading decreased by 75% during the post-BMP treatment period.

Figure 10 presents the average concentration of total coliform, fecal coliform, and fecal streptococci for all stations on the River Ridge Farm. The total coliform, fecal coliform and fecal streptococci bacteria are used as indicators of NPS pollution, especially those directly deposited by grazing cattle. However, since the total coliform group consists of species of bacteria from soil, vegetative matter, and animals, a direct relationship between its occurrence and the presence of cattle cannot be justified (Stephenson and Street, 1978.). Since the fecal coliform and fecal streptococci groups are directly related to the feces of warm-blooded animals, they are considered a more reliable indicator of pollution from grazing cattle. Significant reductions in TC, FC, and FS were observed on the River Ridge stream due to the installation of the off-stream water sources. Significant reductions of 88%, 78%, an 86% in total coliform were found at sampling stations QRR-3, QRR-4, and QRR-5, respectively. A significant increase (61%) in TC was also observed at QRR-1. However, the increase in TC (fig. 10) can be attributed to the significant increase in TSS also found at the headwaters of this station, as discussed previously. Significant reductions of 99%, 87%, and 57% in FC were also found at



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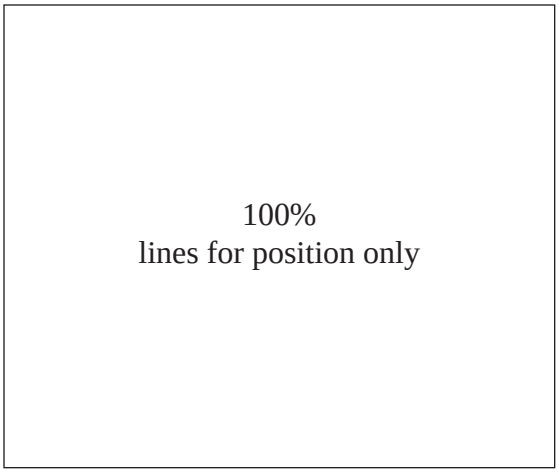
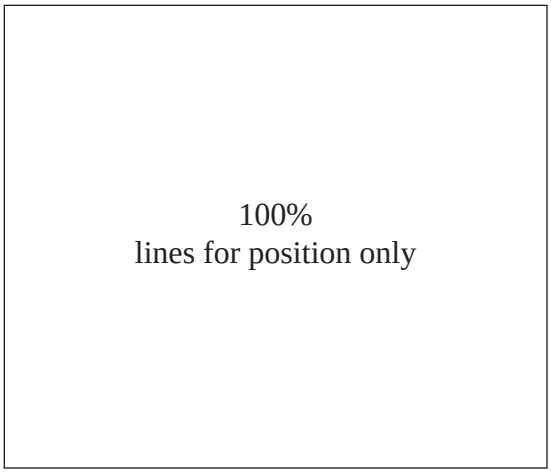
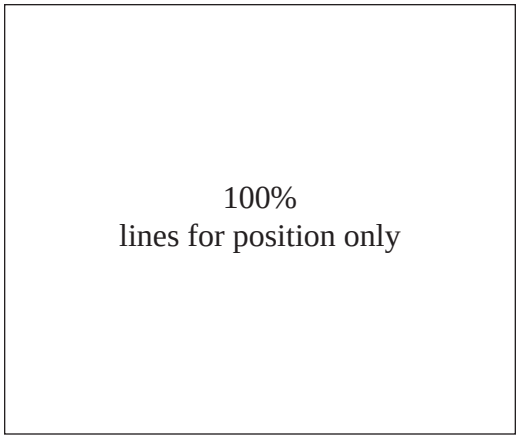


(b)

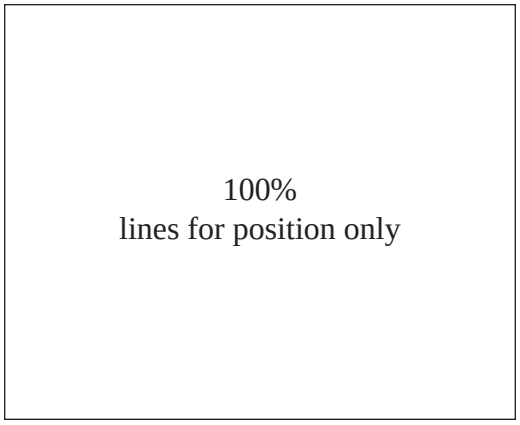


(c)

Figure 9–Average concentration of total phosphorus, orthophosphates and sediment-bound phosphorus for all stations on the River Ridge Farm.



(a)



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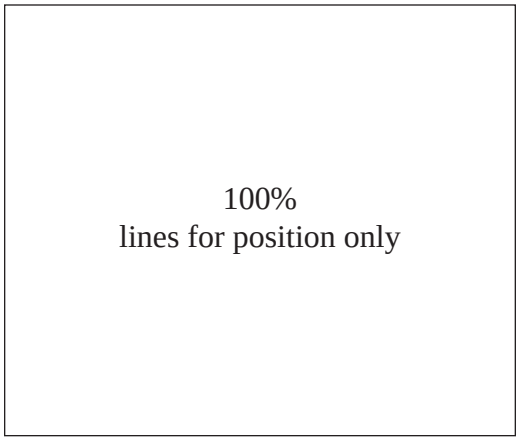

(c)

Figure 10–Average concentration of total coliform, fecal coliform, and fecal streptococci for all stations on the River Ridge Farm.

stations QRR-3, QRR-4, and QRR-5, respectively. A 53% increase in total coliform was not statistically significant at the headwater station, QRR-1. Significant reductions in FS were observed at all stations on the River Ridge stream due to the installation of the off-stream water sources. Statistically significant reductions in FS of 99%, 77%, 70%, and 84% resulted at the water monitoring stations of QRR-3, QRR-4, QRR-5, and QRR-6, respectively.

The reductions in TC, FC, and FS concentrations are directly related to the dramatic changes in cattle behavior due to the presence of the off-stream water source. It can be construed that, with the 51% reduction in cumulative

time each cow spent in the stream, the amount of fecal matter deposited by each cow was also reduced. Thus, as the water trough drew cattle away from the stream (92 % of the time), manure which would have been deposited in the stream was deposited near the off-stream water source. This study has shown that the off-stream water source is an effective BMP for reducing the concentration of sediment-bound pollutants and bacteria, while cattle access to streams remained unchanged.

Conclusions

The presence of an off-stream water source for grazing cattle reduced the time which cattle spent in the stream area as well as the time which they spent drinking from the stream. When given the choice, cattle were observed to drink from a spring-fed water trough 92% of the time, as compared to the time which they spent drinking from the stream. Cattle use of the stream area for all activities, including drinking, was reduced by 51% when an off-stream water source was made available. These results were observed on study pastures that were predominately tall fescue with a high percentage of endophyte infection. When an off-stream water source was present during the primarily summer and fall post-BMP period, cattle were not observed to spend large portions of the day standing in the streams as described by Bowman et al. (1973) of cattle grazing tall fescue with high endophyte infection levels.

Due to the dramatic reductions in time which cattle spent within the stream area, stream bank erosion and the losses of sediment and sediment-bound pollutants were also significantly reduced. Stream bank erosion was reduced by 77% on the River Ridge Farm in Independence, Virginia. The presence of an off-stream water source significantly reduced the loading of sediment, sediment-bound nutrients and fecal bacteria in a first-order stream on the River Ridge Farm. Average concentrations of total suspended solids, total nitrogen, ammonium, sediment-bound nitrogen, total phosphorus and sediment-bound phosphorus were reduced by 90%, 54%, 70%, 68%, 81%, and 75%, respectively, due to the installation of an off-stream water source. Concentrations of dissolved nutrients such as nitrate and orthophosphates, however, were adversely affected by the implementation of the BMP.

The installation of off-stream water sources was also effective in reducing the concentration of fecal bacteria as hypothesized by Miner et al. (1992). Concentrations of fecal coliform and fecal streptococci were reduced by an average of 51% and 77%, respectively, on all the River Ridge Farm sampling stations due to the use of off-stream water sources. The presence of an off-stream water source for grazing cattle greatly reduced the impact which grazing cattle had upon stream bank erosion and water quality. The results of this study indicate that off-stream water sources for grazing cattle would be effective BMPs for reducing stream bank erosion as well as sediment-bound pollutants and fecal bacteria production from smaller order streams.

The implementation of the conclusions drawn from this study are limited by several factors. First, the study was conducted for a relatively short time of about 14 months. Seasonal variation of cattle behavior, rainfall patterns, and runoff nutrient concentrations may significantly alter the conclusions drawn from this study if data were collected for longer durations. However, it must be noted that the post-BMP treatment period of this study was conducted during the warmer summer months of the year, during which greater sediment, nutrient, and bacteria concentrations are expected, thus, BMP impacts reported in this study are conservative. Had the post-BMP treatment period been conducted during the winter months, greater BMP impacts (more reductions in water quality concentrations and loadings) may have been observed. In spite of these limitations, this study has clearly shown that off-stream water sources for grazing cattle are quite effective in reducing the amount of sediment bound and fecal bacteria contributed to streams without resorting to stream bank fencing.

Future studies should compare the economic costs and environmental benefits of off-stream water sources, as a stream bank erosion and water quality BMP, to those of stream bank fencing. Water quality and stream bank erosion results of this study should be compared to those with fenced cattle from streams. Also, the scale of BMP implementation, either farm, watershed or regional, should be a major component of such an analysis. Such an analysis should address the economic feasibility of providing off-stream water sources compared with mandatory stream bank fencing in order to protect water resources.

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