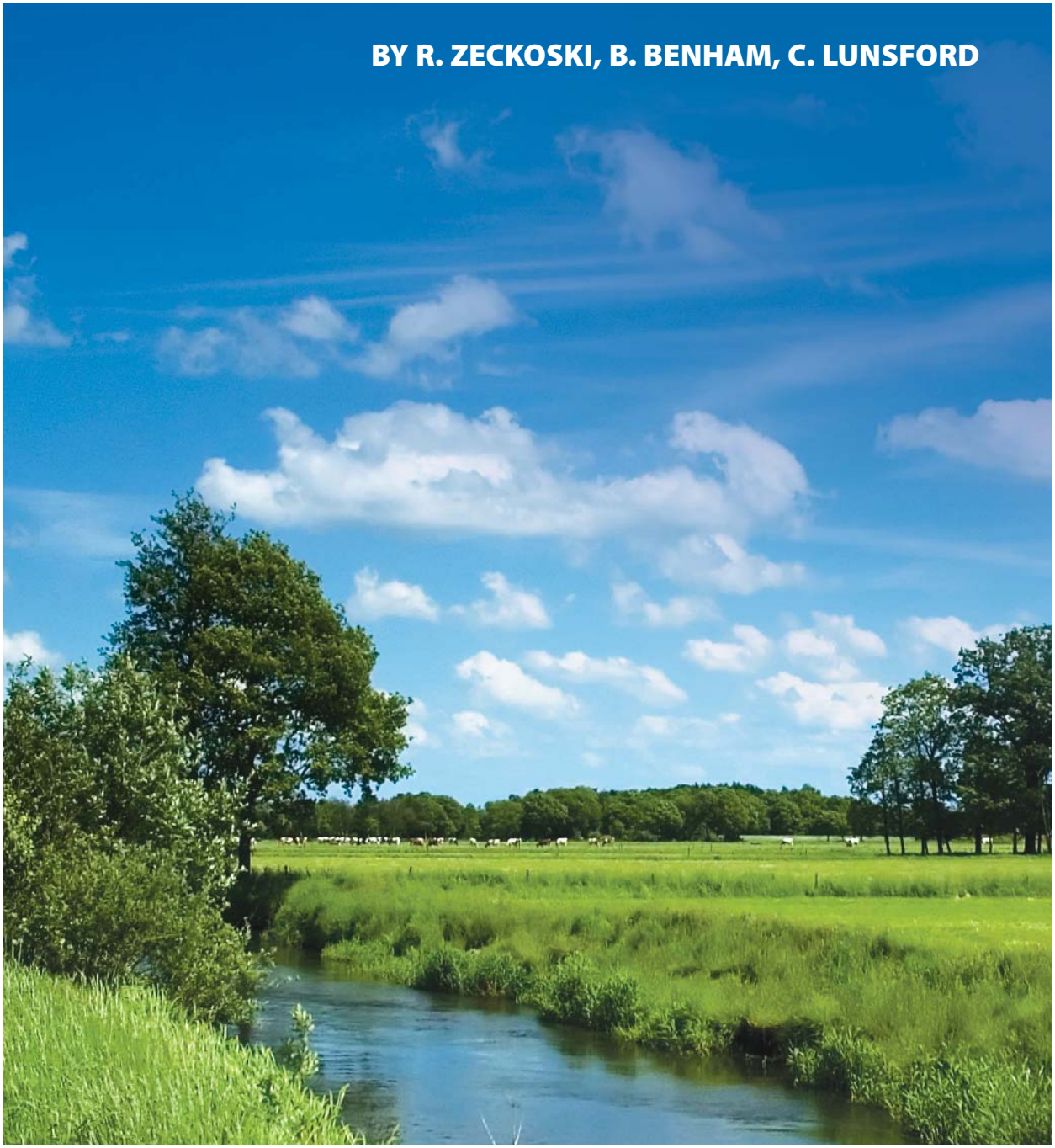
STREAMSIDE LIVESTOCK EXCLUSION:

A tool for increasing farm income and improving water quality

BY R. ZECKOSKI, B. BENHAM, C. LUNSFORD



Introduction

Did you know that livestock, like humans, prefer a clean water source and are healthier and more productive when they drink clean water? Virginia producers who have restricted or eliminated livestock access to streams and farm ponds and converted to a clean, alternative water source have observed increased livestock productivity, improved water quality, and restored stream banks on their farms. As a consequence, livestock stream exclusion practices are gaining popularity across Virginia. This publication, produced through the cooperation of Virginia Cooperative Extension and the Virginia Department of Conservation and Recreation, describes the findings, experiences, and successes of individual producers who are limiting livestock stream access.

Two sources of information were used to develop this publication. First, a literature review was conducted to compile data related to restricted livestock stream access; these data included production, herd health, economic, and water quality benefits. The literature review yielded data related to both complete livestock exclusion and partial restriction through the use of off-stream waterers to lure cattle from the stream. Second, 20 producers from across Virginia who had restricted livestock stream access on their farms were interviewed. During the interviews, producers provided information related to their positive as well as some negative experiences with livestock exclusion systems.

Several watersheds in Virginia are highlighted in this publication where livestock exclusion from streams has resulted in significant water quality improvements. Significant reductions in the violation rate of the bacteria water quality standard are evident as agricultural producers fenced stream access areas and provided alternative sources of water. Livestock were fenced from the stream through voluntary conservation actions on the part of landowners as well as through government cost-share assistance programs.

**Use of trade names in this publication does not imply a product endorsement.*

Why limit livestock access to streams?

Reason 1: Increased Productivity

Restricting livestock access to streams and providing an alternative watering system improves drinking water quality for the animals. Some of the producers interviewed for this publication noticed that their livestock preferentially drank from a water trough even when stream access was available. Research literature also indicates that cattle will preferentially drink from a trough rather than from a stream[3,11,18,26]. Potential explanations suggested for this preference include:

- improved water quality[45]
- better footing
- improved visibility
- a more desirable water temperature[26]

> "I have seen weight gain increases of 5-10% over 9-10 months since removing my beef cattle from the stream and providing water from springs and wells."
>
> **Scott Campbell**
> **Augusta County**

Potential benefits from livestock ingesting greater quantities of cleaner water include increased milk and butterfat production[3, 21] and increased weight gain. A dairy producer in Rockingham County observed increases in milk quality and production after restricting stream access and providing alternative water sources. Beef producers in Augusta, Rockingham, and Washington Counties have also reported increased weight gains after providing alternative water sources. Studies have shown the following weight gains as a result of providing cleaner water to cattle:

- 0.2 lb/day - 0.4 lb/day for cows[5, 44]
- 1 lb/day for steers[44]
- 0.6 - 1.8 lb/day for heifers[38]
- 0.1 lb/day for heifer calves[5]
- 0.2 lb/day - 0.3 lb/day for calves[12, 44]

Increased weight-gain translates into more money per head (Table 1).

Table 1. Example of increased revenue due to installing off-stream waterers[35].

Typical calf sale weight	Additional weight gain due to off-stream waterer	Price	Increased revenue due to off-stream waterer
500 lb/calf	5 % or 25 lb	$0.60 per lb	$15 per calf

The weight gains illustrated in the above example are conservative.

A recent watershed implementation plan completed in the Big Otter River basin of Virginia indicates that the average cost to the producer to install a grazing land protection system (which includes off-stream waterers as well as stream fencing and cross fencing) is $2,325 (assuming 75% cost-share and a 25% tax credit), based on an average system cost of $12,400[4]. Using the example above (Table 1), a producer would recover the fencing-related capital costs after selling 155 of the heavier calves.

Reason 2: Fewer Incidents of Disease

Learn more

The bacteria that cause foot rot dwell in the intestines of cows; therefore, allowing cows in the stream is doubly bad, as they deposit the disease-causing bacteria in the stream, and then contract the disease while they're standing in the contaminated water[3,16,18,31].

Potentially harmful organisms can be present in streams, including bacteria and viruses that cause foot rot[3, 16, 18, 31], environmental mastitis[2,3,16,19,31], jaundice, fever[2, 16, 31], red nose, bovine virus diarrhea, and tuberculosis[31]. Restricting livestock access (cattle and equine) to the stream and providing an alternative water source limits contact with these pathogens. Producers indicated that they believed that overall herd-health improved as a direct result of restricting livestock access; many found that incidences of sores decreased after removing their cattle from the stream and providing off-stream waterers. One producer commented that his veterinarian bills decreased after excluding his livestock from streams. Excluding cattle from streams also decreases leg injuries associated with traversing muddy and/or steep banks[3]. Additionally, stream exclusion and interior fencing may reduce calving losses because cows are unable to calve in wet areas or near unstable stream banks. Weather stress (i.e., cold and wind) can be lethal to calves and the combination of wet conditions can have a greater impact.

Reason 3: Pasture Management Benefits

> "It [the overall stream exclusion system] takes a little bit of management, but it's all worth it," and "everything's been a positive."
>
> **Jack Shutte**
> **Clarke County**

Installing streamside exclusion fencing along with an alternate water supply also improves pasture quality. Distributing waterers throughout the pasture increases forage utilization[6,12,21]. Many interviewed producers located waterers according to a desired pasture utilization scheme and were pleased with the results. If waterers are coupled with a managed rotational grazing system, even greater forage utilization can result. Additionally, rotational grazing distributes livestock manure, and nutrients, more evenly throughout the pasture[13]. Some beef producers who converted to rotational grazing systems have not only increased forage utilization but also decreased fertilizer usage. Because livestock will bunch together not only for water, but also for minerals and shade[12,13], strategic placement of mineral blocks and shade in a pasture can also help distribute manure throughout the grazed area[37]. Many producers cautioned against locating waterers near natural shade. Cattle tend to gather under shade. If a water source is also there, an

undesirable trampled, muddy depression can result.
Several producers noted that rotational grazing also saved time, as cattle quickly adapted to the rotational grazing system. One producer reported using rotational grazing paddocks to separate mares from stallions and to gather horses for trips or veterinary visits. Another finds gathering cattle for veterinary procedures simpler with a rotational grazing system.

"The benefit to my public image is worth far more than any money received from cost-share."

Dave Johnson
Washington County

Figure 1. Rotational grazing system in Washington County, Virginia.

Reason 4: Alternative Riparian Area Uses

The buffer established between the stream and the streamside livestock exclusion fence can be utilized for agroforestry opportunities. Forested riparian buffers are also eligible for cost-share payments through the Conservation Reserve Enhancement Program (CREP)[23]. For some Virginia producers, CREP payments more than compensate for the labor and maintenance associated with streamside livestock exclusion fencing systems. In addition, farm income can benefit by harvesting lumber and firewood[13,23].

In addition to potential agroforestry income[33,46], riparian buffers provide numerous environmental benefits, including erosion control, streambank and stream channel stability, stream temperature moderation, flood control, wildlife habitat, and interception of nonpoint source pollution originating from up-slope areas. Many of these benefits (e.g., pollution prevention and stream stability) are cheaper to achieve with riparian buffers than with constructed best management practices[1].

Reason 5: Improved Water Quality

"I enjoy going by and seeing the water so clean."

Nick Dunning
Clarke County

Unrestricted livestock access to streams is associated with many negative environmental effects. Livestock defecating in streams may deposit harmful pathogens in the stream[2,38]. Poorly managed riparian grazing can lead to elevated stream water temperatures and increased nutrients and sediment in the stream[26]. Grazing in the riparian zone and unrestricted stream access increases streambank instability and erosion[25] and can potentially lead to changes in stream flow patterns[20]. Excluding livestock from the stream stabilizes streambanks[26,34] and improves riparian vegetation and the quality of fish and wildlife habitat in and near the stream[20]. Additionally, aquatic life habitat and diversity increases after livestock are excluded from the stream[36].

Where a concerted effort to install streamside exclusion fencing has occurred, including many areas in Virginia, water quality improved[34,36,41,42]. In the Muddy Creek and Lower Dry River watersheds in Rockingham County (see page 11) where many producers are Old Order Mennonites, water quality improved after the community voluntarily installed polywire or single strand high-tensile fencing rather than more expensive fencing required by cost-share programs. Studies report that streamside exclusion fencing reduced sediment concentrations in storm runoff and total sediment transport by 60% and 40%, respectively, compared to pre-fenced conditions[30].

How do you limit livestock access to streams?

Learn more

Research suggests waterers be located so that dairy cattle do not have to walk more than 500-600 feet[43], beef cattle no more than 700-900 feet[31], and other livestock no more than 1000-1200 feet[43] to minimize energy expenditure.

Component 1: Off-stream watering

There are several options for off-stream watering systems. The choice of system will depend on the availability of an energy source, the water source, the required water volume, pasture layout, reliability, cost, and personal preference[6,18]. Potential sources of water include springs, wells, ponds, and the stream itself[2,43]. Each of these water sources was used by at least one producer interviewed for this publication. Almost all the producers used an electric pump to deliver water. The most popular types of troughs were Ritchies and MiraFounts, although some used concrete troughs or tire troughs. One producer with horses used troughs specifically designed for horses. For more information on watering systems, refer to page 13.

Component 2: Livestock comfort

To maintain highly productive livestock, or to lure animals away from streams where streamside exclusion fencing is not installed, salt blocks, scratching posts, dusters, windbreaks, shade, and other shelters should be located as far away from the stream as practical without producing excessive travel distances[2] and typically not in the same location as waterers.

There are times when the riparian buffer width required to receive cost-share funds for streamside exclusion fencing installation will eliminate the only sources of natural shade in the pasture. In these

Figure 2. Permanent shade structure, Augusta County, Virginia.

cases, producers might consider providing alternative sources of shade. Studies have shown that shade will improve milk production for dairy cows and weight gain for beef cows[37]. Approximately 40-60 square-feet of shade is needed per head for mature dairy cows[37]. Insufficient shade may be detrimental as animals will bunch together to try and fit under the undersized shade[37]. Options for off-stream shade include portable shade structures, permanent shade structures (Figure 2), and trees. Portable structures may be a viable solution if a rotational grazing system is employed. Such structures can be moved in and among paddocks[37]. Two of the producers interviewed for this publication located their waterers on covered concrete or stone pads, providing permanent, artificial shade. Natural shade created using trees must be carefully planned, as too many animals gathering under any given tree may actually kill the tree[37] (Figure 3). Producers reported using cedars, hedge apples (also known as Osage-orange), and sycamores to provide natural shade.

Figure 3. Recently planted shade trees, Clarke County, Virginia. Trees are protected from grazing by animals during establishement.

Learn more

Multiple options are available for livestock exclusion fencing whether done voluntarily or funded through state and federal agricultural cost-share programs and tax credits. Contact your local Soil and Water Conservation District office for more information.

Component 3: Stream Fencing

There are several options for streamside livestock exclusion fencing and several issues to consider when choosing fencing materials. Common fence types include woven wire, barbed wire, rail or board, cable wire, high-tensile wire, and electric[8,14,47]. The recommended fencing material for various livestock can be found in the Virginia Cooperative Extension Publication Fencing Materials for Livestock Systems[14] (see "For More Information" on page 13). Producers who participate in BMP incentive programs are required to follow specific design and installation guidelines to qualify for cost-share or tax credits[28,40]. Information about available federal and state BMP incentive programs can be obtained from your local Soil and Water Conservation District office.

Component 4: Stream Crossings

When pasture is present on both sides of a stream, it may be necessary to install a hardened crossing to allow cattle to move between pastures while restricting access to the stream. The width of hardened crossing is typically limited to discourage cattle from loitering in the stream. However, NRCS guidelines require a six-foot minimum width for cattle crossings and 10 feet for vehicular crossings[29]. A fenced lane may also require additional maintenance, as debris can get trapped during high flows and the fence may be damaged during flood events[2]. The most common fencing losses due to flooding reported by the producers interviewed occurred at stream crossings. Interviewed producers also reported that hardened crossings were a good water source in addition to allowing cattle access to pastures on both sides of streams.

Figure 4. Examples of hardened stream-crossing, Augusta County, Virginia.

Component 5: Buffer Strips

Learn more

Studies have shown a 30-95% reduction in pollutants when runoff passes through a buffer strip[1].

If sufficient distance is allowed between the fence and the stream, it is possible to develop a buffer strip to intercept runoff from the up-slope pasture. Studies have found that riparian vegetation will filter sediment, nutrients, and other contaminants from runoff before it reaches the stream[2,9,26] and stabilize stream banks and reduce erosion[1,9]. Additionally, including a buffer strip between the stream and the fence makes it less likely that a streamside fence will be damaged in a flood. A Maryland Cooperative Extension publication recommends a buffer of at least 35 feet to allow for the flooding and changes in stream meanders that characterize the 'floodway'[24].

Figure 5. Riparian buffer, Augusta County, Virginia.

Create the stream access limiting system that works for your operation.

Every livestock stream exclusion system will be unique. Livestock comfort and controlled movement must be a consideration when designing any system. It is possible to have multiple design and component combinations– studies have shown that off-stream watering without fencing can be an effective management tool in some areas; other areas may only need a fence where an alternative source of water is already available; and many areas will likely need a combination of a fence and off-stream watering supply. One should also determine whether supplemental shade and/or hardened crossings are needed.

Learn more

Cows prefer to drink from a trough rather than from a stream and may walk farther distances to do so[3,18,26,27,38,44].

Providing an alternative source of water even without fencing may reduce the time livestock spend in the stream by 80 - 99%[3,15,26,27,34].

Figure 6. Polywire fencing, Rockingham County, Virginia.

Are there negative aspects to limiting livestock stream access?

Although all the producers interviewed for this publication were pleased with their stream exclusion systems, they did raise a few concerns. The most common complaint was nuisance vegetation in the riparian area. However, many producers felt that proper planning for the riparian area could prevent noxious weeds from becoming a problem. Other less common complaints included the need to clean waterers periodically, the need to have someone available to ensure waterers are functioning properly, more complicated fertilizer applications if a rotational grazing system is used, and nuisance wildlife living in riparian buffers. However, all producers felt that the production benefits, reduced disease incidence, CREP payments, time savings, benefits to their public images, and water quality benefits more than compensated for any negative aspects.

What programs are available to help pay for limiting livestock stream access?

There are many cost-share opportunities available through Virginia's Agricultural BMP Cost-Share Program and CREP. Tax credits are also available through Virginia's Agricultural BMP Tax Credit Program[39]. Contact your local Soil and Water Conservation District (www.dcr.virginia.gov/sw/swcds.htm) to ask about opportunities for your individual farm. Other cost-share programs available to Virginians for the establishment of riparian forest buffers include the Conservation Reserve Program, Natural Resources Conservation Service (NRCS); Forestry Incentives Program, NRCS and U.S. Forestry Service (USFS); Stewardship Incentive Program (USFS); Environmental Quality Incentives Program (NRCS), and the Wetlands Reserve Program (NRCS)[1]. Conservation Easements are also available and may provide tax incentives[1].

Does water quality improve if livestock stream access is limited?

Producers are responding to the need to improve water quality by installing stream exclusion fencing and limiting livestock stream access. Muddy Creek and Lower Dry River in Rockingham County; Hutton Creek, Hall/Byers Creek, and Cedar Creek (Three Creeks) in Washington County; and Page Brook in Clarke County are examples of watersheds where water quality is improving (Figure 7).

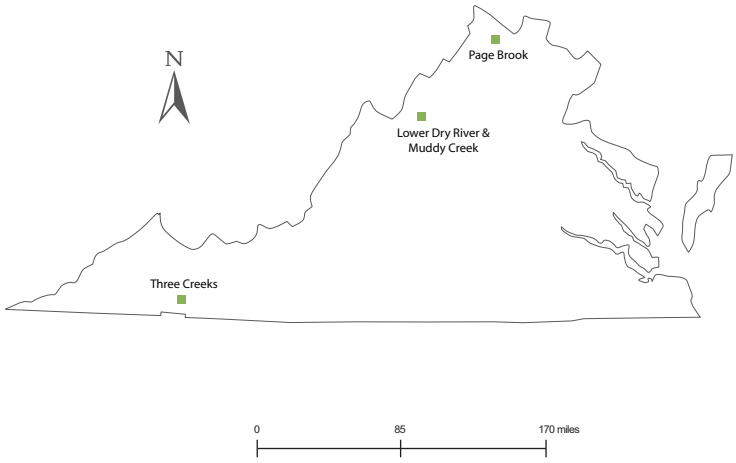


Figure 7. Locations of the Lower Dry River & Muddy Creek, Three Creeks, and Page Brook watersheds.

In the Lower Dry River and Muddy Creek watersheds, a community of Old Order Mennonites is implementing best management practices (BMPs) without cost-share incentives. In fact, 8.3 miles of the 10 miles of stream exclusion fencing installed in these watersheds since 2001 was installed without cost-share. Water quality in both Muddy Creek and Lower Dry River has improved. The number of samples violating the state's fecal coliform bacteria standard dropped from 77% in 1999 to 50% in 2006 for Muddy Creek. Similar improvements were observed in Lower Dry River where the number of samples violating the state's fecal coliform bacteria standard dropped from 50% in 2003 to 17% in 2006.

In the Hutton Creek, Hall/Byers Creek, and Cedar Creek watersheds, BMP implementation to address bacteria and aquatic life use water quality impairments began in 2001. Producers in these watersheds have installed 20 miles of stream exclusion fencing. Comparing data from 2001 and 2006, the number of samples violating the state's fecal coliform bacteria standard dropped from 100% to 17% for

Cedar Creek, from 33% to 0% for Hall/Byers Creek, and from 75% to 17% for Hutton Creek.

In the Page Brook watershed, implementation of stream exclusion fencing began in 1996[17]. Following a five year implementation period, Virginia's Department of Environmental Quality sampled Page Brook from 2001 to 2003 and the number of samples violating the state's fecal coliform bacteria standard dropped from 67% in 2001 to 0% in 2003.

While the evidence from these watersheds is promising, year-to-year variability is expected. Long-term water quality monitoring is needed to accurately detect and verify water quality improvement trends from installing and maintaining stream exclusion fencing and other BMPs. Monitoring in these and other watersheds will continue to track water quality improvement as additional miles of fencing and other BMPs are implemented.

Learn more

Water quality standards are intended to protect all state waters, for recreation, wildlife, the growth of a balanced population of aquatic life, and the production of fish and shellfish.

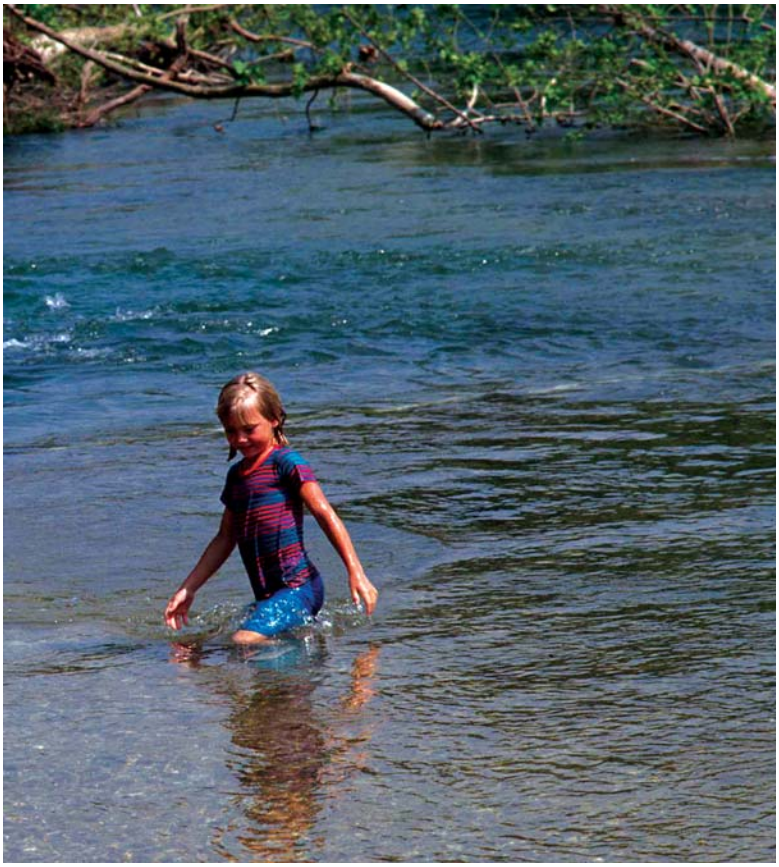


Photo courtesy of USDA Natural Resources Conservation Service.

For More Information

FOR MORE INFORMATION ON…	REFER TO…
Riparian Buffers and Agroforestry	Chesapeake Bay riparian handbook: a guide for establishing and maintaining riparian forest buffers www.chesapeakebay.net/pubs/subcommittee/nsc/forest/handbook.htm Evaluation of potential gross income from non-timber products in a model riparian forest for the Chesapeake Bay watershed – Robles-Diaz-de-Leon and Kangas[33]
Watering Systems	Selection of Alternative Livestock Watering Systems[7] www.utextension.utk.edu/publications/pbfiles/PB1641.pdf (University of Tennessee Extension) Selection of Beef Watering Systems[6] http://wastemgmt.ag.utk.edu/ExtensionProjects/beef%20waterers.pdf (University of Tennessee Extension) Alternatives to Direct Access Livestock Watering[18] www.agr.gc.ca/pfra/water/facts/directace.pdf (Agriculture and Agri-Food Canada) Pumps and Watering Systems for Managed Beef Grazing[31] http://muextension.missouri.edu/explore/envqual/eq0380.htm (Missouri State Extension)
Fencing	Fencing Materials for Livestock Systems[14] www.ext.vt.edu/pubs/bse/442-131/442-131.html (Virginia Cooperative Extension) NRCS Virginia Conservation Practice Standard: FENCE (Section IV, Conservation Practice, Code 382)[28] http://efotg.nrcs.usda.gov/efotg_locator.aspx?map=VA (Natural Resources Conservation Service)
Portable Shade Structures	Shade Options for Grazing Cattle[37] www.bae.uky.edu/Publications/AEUs/aeu-91.pdf (University of Kentucky Extension)
Shade Trees	Trees for Horse Pastures[22] www.omafra.gov.on.ca/english/livestock/horses/facts/info_livestock_pastures_trees.htm (The Ontario Ministry of Agriculture, Food, and Rural Affairs)
BMPs	Your local Soil & Water Conservation District www.dcr.virginia.gov/sw/swcds.htm or the Virginia Agricultural BMP Manual[40]

References

1. Section XII - Economics of riparian forest buffers. In Chesapeake Bay riparian handbook: a guide for establishing and maintaining riparian forest buffers. NA-TP-02-97. Palone, R. S., and A. H. Todd, Eds. USDA Forest Service: Radnor, PA, 1997. Available at: www.chesapeakebay.net/pubs/subcommittee/nsc/forest/handbook.htm. Accessed 25 May 2006.
2. Adams, E. B. 1994. Riparian Grazing. Washington State University Extension. Report EB1775. Available at: http://cru.cahe.wsu.edu/CEPublications/eb1775/eb1775.html.
3. Bendfeldt, E. S. 2004. Cattle behavior and stream water quality: what are the cattle trying to tell us? Virginia Cooperative Extension. Available at: http://info.ag.vt.edu/vce/offices/newsletters/Cattle_Behavior.pdf. Accessed 10 May 2006.
4 Big Otter IP Steering Committee. 2006. Big Otter Watershed TMDL Implementation Plan Summary. Virginia Department of Environmental Quality, Virginia Department of Conservation and Recreation. Available at: www.deq.state.va.us/tmdl/implans/otterip.pdf. Accessed 23 October 2006.
5. Buchanan, B. 1996. Clean Water Boosts Cattle Performance. Prairie Water News. 6(1). Available at: www.quantumlynx.com/water/back/vol6no1/story2.html. Accessed 25 May 2006.
6. Burns, R. T. 2001. Selection of Beef Watering Systems. University of Tennessee Agricultural Extension Service. Report WQS-01-01. Available at: http://wastemgmt.ag.utk.edu/ExtensionProjects/beef%20waterers.pdf.
7. Burns, R. T., and M. J. Buschermohle. 2000. Selection of alternative livestock watering systems. The University of Tennessee Agricultural Extension Service. Report PG1641. Available at: www.utextension.utk.edu/publications/pbfiles/PB1641.pdf. Accessed 25 May 2006.
8. Buschermohle, M. J., J. B. Wills, W. W. Gill, and C. D. Lane. 2001. Planning & Building Fences on the Farm. University of Tennessee Agricultural Extension Service. Report PB1541. Available at: www.utextension.utk.edu/publications/pbfiles/PB1541.pdf. Accessed 25 May 2006.
9. Chalmers, L. 2000. Livestock management: fence location and grazing controls. Water and Rivers Commission, Government of Western Australia. Report WN18.
10. Chesapeake Bay Local Assistance Department. 2001. Chesapeake Bay Protection Act Regulations. Available at: www.cblad.state.va.us/docs/Regs3-01-02.pdf. Accessed 25 October 2006.
11. Clawson, J. 1993. The use of off-stream water developments and various water gap configurations to modify the watering behavior of grazing cattle. M.S. Thesis. Oregon State University, Corvallis, OR.
12. Dickard, M. L. 1998. Management strategies for improved cattle distribution and subsequent riparian health. M.S. Thesis. University of Idaho.
13. Fanatico, A., R. Morrow, and A. Wells. 1999. Sustainable beef production: livestock production guide. National Center for Appropriate Technology: Appropriate Technology Transfer for Rural Areas (ATTRA). Report IP018/18. Available at: www.attra.org/attra-pub/PDF/sustbeef.pdf. Accessed 25 May 2006.
14. Gay, S. W., and R. D. Heidel. 2003. Fencing materials for livestock systems. Virginia Cooperative Extension. Report 442-131.
15. Godwin, D. C., and J. R. Miner. 1996. The potential of off-stream livestock watering to reduce water quality impacts. Bioresource Technology. 58:285-290.
16. Grove, M. B. 2003. Cows, streams, and ponds...should they mix? Penn State College of Agricultural Sciences, Cooperative Extension in Lancaster County. Available at: http://lancaster.extension.psu.edu/Agriculture/DairyProgram/DairyManagementInfo/Environment/CowsStreamsPonds.htm. Accessed 25 May 2006.
17. Hagedorn, C., S. L. Robinson, J. R. Filtz, S. M. Grubbs, T. A. Angier, and R. B. Reneau, Jr. 1999. Determining Sources of Fecal Pollution in a Rural Virginia Watershed with Antibiotic Resistance Patterns in Fecal Streptococci. Applied and Environmental Microbiology. 65(12):5522-5531.

18. Hilliard, C., and S. Reedyk. 2001. Alternatives to Direct Access Livestock Watering. Water Quality Matters. Agriculture and Agri-Food Canada, Prairie Farm Rehabilitation Administration. Available at: www.agr.gc.ca/pfra/water/facts/directace.pdf. Accessed 25 May 2006.
19. Jones, G. M., and J. J. M. Swisher. 1998. Environmental streptococcal and coliform mastitis. Virginia Cooperative Extension. Report 404-234. Available at: www.ext.vt.edu/pubs/dairy/404-234/404-234.html. Accessed 25 May 2006.
20. Kauffman, J. B., and W. C. Krueger. 1984. Livestock impacts on riparian ecosystems and streamside management implications...a review. Journal of Range Management. 37(5):430-438.
21. Landefeld, M., and J. Bettinger. 2002. Water effects on livestock performance. Ohio State University Agriculture and Natural Resources. Report ANR-13-02. Columbus, Ohio. Available at: http://ohioline.osu.edu/anr-fact/0013.html.
22. Leuty, T., and B. Wright. 2002. Trees for Horse Pastures. Ontario Ministry of Agriculture, Food and Rural Affairs. Available at: www.omafra.gov.on.ca/english/livestock/horses/facts/info_livestock_pastures_trees.htm. Accessed 22 August 2006.
23. Lynch, L., and B. Tjaden. 2000. When a landowner adopts a riparian buffer - benefits and costs. University of Maryland - Maryland Cooperative Extension. Report FS774. Available at: http://www.riparianbuffers.umd.edu/fact/FS774.html. Accessed 25 May 2006.
24. Lynch, L., and R. Tjaden. 2002. Riparian buffer financial assistance opportunities. University of Maryland: Maryland Cooperative Extension. Report FS769. Available at: www.riparianbuffers.umd.edu/fact/FS769.html. Accessed 25 May 2006.
25. McInnis, M. L., and J. McIver. 2001. Influence of off-stream supplements on streambanks of riparian pastures. Journal of Range Management. 54(6):648-652.
26. McIver, S. 2004. Using off-stream water sources as a beneficial management practice in riparian areas - a literature review. Agriculture and Agri-Food Canada, Prairie Farm Rehabilitation Administration.
27. Miner, J. R., J. C. Buckhouse, and J. A. Moore. 1992. Will a water trough reduce the amount of time hay-fed livestock spend in the stream (and therefore improve water quality)? Rangelands. 14(1):35-38.
28. Natural Resources Conservation Service. 2001. Natural Resources Conservation Service Conservation Practice Standard: Fence (Code 382). p 21. Available at: www.nrcs.usda.gov/technical/etofg.
29. Natural Resources Conservation Service. 2003. Natural Resources Conservation Service Conservation Practice Standard: Stream Crossing (Code 578). p 3. Available at: http://www.nrcs.usda.gov/technical/efotg/.
30. Owens, L. B., W. M. Edwards, and R. W. V. Keuren. 1996. Sediment losses from a pastured watershed before and after stream fencing. Journal of Soil and Water Conservation. 51(1):90-94.
31. Pfost, D., J. Gerrish, M. Davis, and M. Kennedy. 2000. Pumps and watering systems for managed beef grazing. Missouri State Extension. Report EQ380. Available at: http://muextension.missouri.edu/explore/envqual/eq0380.htm. Accessed 25 May 2006.
32. Powell, J. R. 1998. Water quality and ecological impacts of watering cattle adjacent to a small middle Tennessee stream. M.S. Thesis. The University of Tennessee, Knoxville, TN.
33. Robles-Diaz-de-Leon, L. F., and P. Kangas. 1999. Evaluation of potential gross income from non-timber products in a model riparian forest for the Chesapeake Bay watershed. Agroforestry Systems. 44:215-225.
34. Sheffield, R. E., S. Mostaghimi, D. H. Vaughan, J. E. R. Collins, and V. G. Allen. 1997. Off-stream water sources for grazing cattle as a stream bank stabilization and water quality BMP. Transactions of the ASAE. 40(3):595-604.
35. Surber, G., K. Williams, and M. Manoukian. 2005. Drinking water quality for beef cattle: an environmentally friendly and production management enhancement technique. Animal & Range Sciences, Extension Service, Montana State University. Available at:

http://www.animalrangeextension.montana.edu/articles/NatResourc/Drinking%20Water%20Quality%20for%20Beef%20Cattle.pdf. Accessed 25 May 2006.
36. Thomas, Z., D. Radcliffe, M. Cabrera, and J. Meyer. Restoring water quality to a stream in Putnam County, Georgia. Stream Restoration Success Stories. National River Restoration Science Synthesis (NRRSS). Available at: www.nrrss.umd.edu/Success_Stories/Success_Story_No_2_WQ_SE_Node.pdf. Accessed 25 May 2006.
37. Turner, L. W. 2000. Shade options for grazing cattle. University of Kentucky College of Agriculture Cooperative Extension Service. Report AEU-91. Available at: www.bae.uky.edu/Publications/AEUs/aeu-91.pdf. Accessed 25 May 2006.
38 Veira, D. M. 2003. Livestock water: impacts on production and behavior. Western Range Seminar, Medicine Hat.
39. Virginia Department of Conservation and Recreation. 2004. Cost-Share and Tax Credit for Virginia Agricultural BMPs. Available at: www.dcr.virginia.gov/sw/docs/bmpsbro2.pdf. Accessed 25 May 2006.
40. Virginia Department of Conservation and Recreation. 2005. Virginia Agricultural BMP Manual. Available at: www.dcr.virginia.gov/sw/costshar.htm. Accessed 25 May 2006.
41. Virginia Department of Environmental Quality. 2006. Spotlight on water quality improvements in DEQ's Valley Region. Available at: www.deq.state.va.us/tmdl/tmdlimprove.html. Accessed 6 October 2006.
42. Virginia Department of Environmental Quality. 2005. TMDL Program Five Year Progress Report. Available at: www.deq.virginia.gov/tmdl/pdf/04prgrpt.pdf. Accessed 6 October 2006.
43. White, H. E., and D. D. Wolf. 2000. Controlled Grazing of Virginia's Pastures. Virginia Cooperative Extension. Report 418-012. Available at: www.ext.vt.edu/pubs/livestock/418-012/418-012.html. Accessed 25 May 2006.
44. Willms, W., D. Colwell, and O. Kenzie. 1994. Water from dugouts can reduce livestock performance. Prairie Water News. 4(1). Available at: www.quantumlynx.com/water/back/vol4no1/v41_st1.html. Accessed 26 May 2006.
45. Willms, W. D., O. R. Kenzie, T. A. McAllister, D. Colwell, D. Veira, J. F. Wilmshurst, T. Entz, and M. E. Olson. 2002. Effects of water quality on cattle performance. Journal of Range Management. 55:452-460.
46. Workman, S. W., and S. C. Allen. 2004. The practice and potential of agroforestry in the southeastern United States. University of Florida Institute of Food and Agricultural Sciences. Report CIR 1446. Available at: http://edis.ifas.ufl.edu/pdffiles/FR/FR14600.pdf. Accessed 25 May 2006.
47. Worley, J. W. 2000. Fences for the farm. The University of Georgia College of Agricultural and Environmental Sciences Cooperative Extension Service. Report Circular 774.

Acknowledgements

The authors would like to gratefully acknowledge the following producers who were interviewed as part of this effort:

Mr. Slate, Horse Breeder, Washington County
Mr. Ben Fore, Beef Producer, Washington County
Mr. Andy Wallace, Dairyman, Washington County
Mr. Dave Johnson, Dairyman, Washington County
Mr. Craig Hammond, Beef Producer, Washington County
Mr. Eddie Copenhaver, Beef Producer, Washington County
Mr. Gene Copenhaver, Beef Producer, Washington County
Mr. Charlie Clark, Beef Producer, Washington County
Mr. Nick Dunning, Horse Boarder and Beef Producer, Clarke County
Mr. Jack Shutte, Beef Producer, Clarke County
Mr. Ray Showalter, Beef Producer, Rockingham County
Mr. Scott Campbell, Beef Producer, Augusta County
Mr. Kenneth Earman, Beef Producer, Augusta County
Mr. Richard Shiflet, Beef Producer, Augusta County
Ms. Tipton, Horse Owner, Prince William County
Mr. Guy Sturt, Beef Producer, Dinwiddie County

Additionally, we would like to thank the four producers who wished to remain anonymous – their names have been altered here:

Mr. Jones, Beef Producer, Washington County
Mr. Smith, Beef Producer, Washington County
Mr. Brown, Dairyman, Rockingham County
Mr. Williams, Dairyman, Rockingham County

And finally, the authors would like to acknowledge the efforts made by:

Mr. Anthony Summitt, Mr. Mike Phillips, Ms. Alison Teetor in facilitating the producer interviews and Ms. Esther Zabronsky in publiction layout.

Virginia Cooperative Extension

VCE number 442-766 issued in furtherance of Cooperative Extension work, Virginia Polytechnic Institute and State University, Virginia State University, and the U.S. Department of Agriculture cooperating. Mark McCann, Director, Virginia Cooperative Extension, Virginia Tech, Blacksburg; Alma C. Hobbs, Administrator, 1890 Extension Program, Virginia State, Petersburg.

Printed with U.S. EPA, section 319 funds.
September 2007