TRAPPING

Narrow filter strip. Clay County, MN.

Filter Strips (393) and Field Borders (386)

Definition & Introduction

Filter strips are an area of vegetation planted between fields and surface waters to reduce sediment, organics, nutrients, pesticides, and other contaminants in runoff. Filter strips are one of the most common BMPs used on farms state-wide and is considered by the NRCS as part of the "Core 4" practices that have conservation impact and can be implemented on almost every farm.

Field borders are strips or bands of permanent vegetation established at the edge of or around the perimeter of a cropland field. Field borders and filter strips are linked together in this chapter because of there likely similarity in pollutant removal capacity and because they are both established with permanent herbaceous vegetation consisting of a single species or mixture of grasses, legumes and/or forbs.

Field borders can be used to connect other buffers such as grassed waterways, filter strips, and contour buffer strips providing easy access for maintenance or harvest purpose. Field borders can be strategically located to eliminate sloping end rows, headlands, and other areas that are prone to erosion.

Water Quality and Other Benefits

Field Border

Field borders protect soil from wind and water erosion, reducing deposits of nutrients that are strongly bound to sediments, such as phosphorus. There is little data showing the percent erosion reduction or contaminant removal specifically by field borders.

Filter Strips

Filter strips reduce runoff, sediments, and contaminants by settling of sediment, infiltration, and filtration (Schmitt et al., 1999). Most sediments settle upgradient of where the filter strip vegetation meets the contributing area (Jin and Romkens, 2000).

Filter strips effectively reduce runoff volume and sediments. Total phosphorus and some insecticides such as Permethrin and Chlorpyrifos are strongly bound to sediments and similarly reduced as sediments (See Figure 10). However, total phosphorus tends to adsorb to fine particles such as silt and clay, which take longer time to settle than larger sediments, and their reduction is usually less than the total sediment reduction. Dissolved contaminants such as total nitrogen, total dissolved P, atrazine, and alachlor (commonly used herbicides) are weakly bound to sediments and its reduction is associated more with infiltration. The reduction of these dissolved contaminants is usually much less than sediment bound P. Reduction efficiencies of both sediment bound and dissolved contaminants increase with width of the filter strip (Blanco-Canqui et al., 2004; Helmers et al., 2008; Schmitt et al., 1999).

Recommended width for filter strips depends on sediment load, size, and slope of contributing area. As noted above, filter strips have to be wider to remove finer particles. A very valuable Nebraska study by Schmitt et al (1999) found that doubling width from 7.5 m to 15 m significantly increased infiltration and dilution of runoff; improving the reduction of nitrate + nitrite N from 23 to 38%, and total dissolved P from 24 to 39%. TSS showed least removal improvement (from 77 to 83%) with increased width (Figure 10). Volume of outflow was also reduced significantly with increased width, contributing to the reduction of contaminant masses.

Table 25. Pollutant load reduction estimates in percent for filter strips

Pollutant	Mean	Minimum	Maximum	Number of Entries	Source
Sediment	86	76	91	6	1
Total Phosphorus	65	38	96	4	2, 3
Nitrogen	27	27	27	1	3
Atrazine	58	45	71	6	1
Metolachlor	72	68	78	6	1
Cyanazine	69	59	77	6	1

1 – Arora et al., 1996
2 – Webber et al., 2009
3 – Eghball et al., 2000

Arora et al (1996) studied filter strip removal of pesticides and sediment in a natural rainfall study in Iowa and found good removals for all substances. Eghball et al., (2000) and Webber et al. (2009) have both studied the phosphorus removal of filter strips in Iowa under natural rainfall conditions (Table 25). Buffers in general can remove nutrients from shallow groundwater (Helmers et al., 2008), and are particularly valuable on shallow soil (Dabney et al., 2006). Tile drainage beneath a filter strip bypasses the potential treatment of the strip. Kasper et al. (2007) observed no significant nitrate-N removal by gamagrass strip fields on no-till corn-soybean plots with a tile drainage system in Iowa. They suspect that the removal might have been improved if establishment of gamagrass was longer, or the width of the strip was wider.

Bhattarai et al. (2009) found increased nitrate N concentrations in a filter strip system (brome grass and annual rye grass) treating runoff from a feedlot with 130 cattle. In this study, a subsurface drainage system was installed at a depth of 1.2 m below the soil surface right underneath the filter strip. The data suggest that nitrate N was drained out of the filter strip and possibly to receiving water. They concluded that the presence of a subsurface drainage system is harmful to filter strip effectiveness and the buffer is more effective without any drainage system.

In a simulated rainfall experiment in Iowa, Arora et al. (2003) tested pesticide reduction efficiency of filter strips by applying 100mg of different pesticides per kg of soil. Filter strips retained 49.7% of Atrazine, 51.2 % of Metolachlor, and 80.0% of Chlorpyrifos for the buffers tested. Buffer area ratios in the study were between15:1 and 30:1.

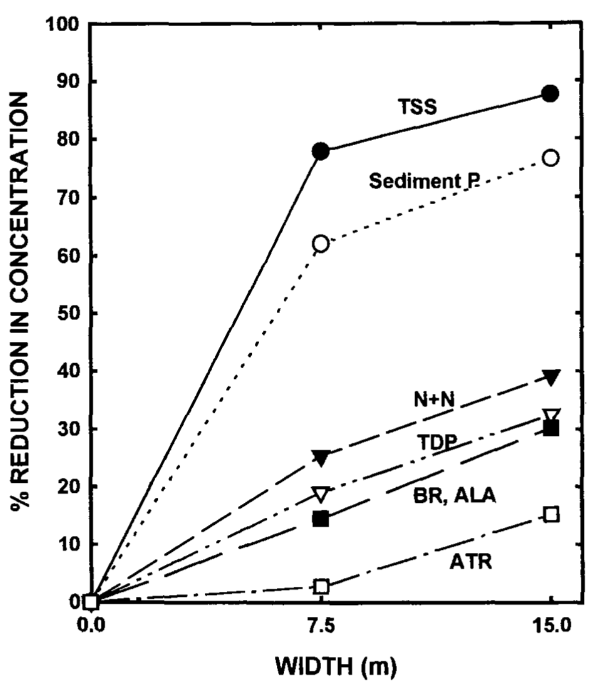

Figure 10. Percentage of reduction in concentration of contaminants in relation to width of filter strip. Plotted values represent measured averages for 2-yr-old grass and 2-yr-old-grass-shrub-tree plots at N+N, nitrate plus nitrite; TN, total nitrogen; ATR, atrazine; ALA, alachlor; TDP, total dissolved phosphorus; TSS, total suspended solids; BR, bromide (Schmitt et al., 1999)

In a study for the MN department of transportation, Nieber et al. (2011) summarized two other literature reviews showing that TSS, TP and TN removal could be shown as a function of buffer width according to the following equations:

TSS: $y = 8.5\ LN(x) + 51.3$
TP: $y = 15.84Ln(x) + 5.9$
TN: $y = 20.24Ln(x) - 13.18$.

where y = removal efficiency (%) and x = buffer width (ft).

A recent study in Wisconsin shows that 50% of mean annual runoff occurred in February and March when the ground was still frozen. Significantly high concentrations of total N and dissolved P were associated with this winter runoff. Vegetated buffers are less effective during the winter months and an alternative BMP to filter strips in winter may have to accompany filter strips to protect water quality all year around (Stuntebeck et al., 2011).

Key Design/Implementation Considerations

Field Borders

The NRCS standard (NRCS, 2007, code 386) and the MN Department of Agriculture recommend for this practice:

- ✓ Border Widths:
  - At least 16.5 feet (1 rod) or a half of the height of adjoining trees, whichever is greater

    - Enough to accommodate equipment turning, parking, loading/unloading equipment, and grain harvest operations

- ✓ Plant Species:
    - Permanent grass, legumes, and/or shrubs that have the physical characteristics necessary to control wind and water erosion on the field border area
    - At least 1 foot height during the critical wind erosion period
    - For shrub cover, plant a minimum of two rows
    - No plants listed on the noxious weed list of the state

Filter Strips

Filter strips perform well with uniform sheet flows. When the flow is concentrated in some area of strips, the concentrated flow will short-circuit the filter and inversely affect the efficiency of field strips, especially during the time of high flow rate. The combination with other buffer systems such as contour buffer strips can make the flow more evenly distributed for maximum performance (Dabney et al., 2006; Helmers et al., 2008; USDA, 1999). Other conservation measures can be used within a filter strip to improve the removal and maintenance as well (Blanco-Canqui et al., 2004). Shallow trenches and/or vegetative barriers constructed across the flow direction can retard flow and enhance infiltration and absorbance of pollutants. The trenches can be filled with porous or adsorbent material such as crushed limestone or wood products (USDA, 1999).

The age of vegetation influences the infiltration capacity in filter strips. Udawatta et al. (2002) observed runoff reduction only from the second year after the establishment of vegetation. When Schmitt et al. (1999) compared different vegetation, 25 year-old mixed grass had better performance in general than 2 year-old vegetation and this is probably due to improved infiltration with a more established root system. It seems that when vegetation becomes older, infiltration capacity improves, consequently improving the removal of soluble contaminants.

Filter strips also offer a setback required for manure and agrochemical applications. Grass can be used for haying or grazing unless prohibited by conservation program rules (Helmers et al., 2008; USDA, 1999). Although filter strips not be used as a travel lane for equipment or livestock, the strip serves as a turning and parking area, facilitating season-long access to fields (NRCS, 2010; MNDA).

Filter strips are typically designed and installed with a fixed width. However, it is unlikely that the flow rate distributions entering the upstream edge of strips are uniform. Future design of filter strips should incorporate variable-width design depending on the upland contributing area to minimize nutrient runoff to water bodies (Helmers et al., 2008).

The NRCS standard (NRCS, 2010, code 393) and the MN Department of Agriculture recommend for this practice:

- ✓ Slope of the Area Contributing Runoff to the Filter Strip:
    - Between 1% and 12% with some exceptions

✓ Strip Widths:

- A least 16.5 feet (1 rod) for strips along public drain ditches
- A least 50 feet for agricultural lands in shoreland areas adjacent to designated public waters
- Depends on the ratio of area contributing runoff to filter strip area (< 60:1) vs. % slope of contributing area and soil losses (< 8.1 tons/acre/year) from the contributing area
- Depends on hydrologic soil groups, which show infiltration capacity (Wider for C and D than for A and B)

✓ Plant Species:

- Stiff, upright stemmed vegetation is required and it depends on purpose of filter strips, soil types, existence of flood and draught, and latitude of the location.
- For removal of nitrate N, at least 50% of the cool season species shall be deep-rooted and legumes have to be all be deep rooted (≥ 3 feet)

✓ Other Requirements:

- At least 50% of overland flow entering the filter strip from the contributing area shall or shall be converted to uniform sheet flow

Cost Information

The cost of field borders and filter strips is dependent upon value of the land taken out of production, buffer installation, plant establishment, and maintenance. In Missouri, assuming a 10-year time horizon, the annualized cost of installation and taking the land out of production is $62.40 per acre (Qiu, 2003). In this scenario, installation cost is estimated to be $51.85 per acre and land opportunity cost is estimated to be $55.68 per acre. NRCS estimates filter strip establishment cost at $154 per acre. If a 33-foot filter strip is developed along 1312 feet, the distributed establishment cost, which is the cost of establishment divided by the 30 acre subwatershed area, results in the distributed cost of $5 per acre. The additional annual distributed land rent cost was estimated to be $6.50 per acre. Amortized fixed cost and total annual cost at 10% interest rate were $0.53 per acre per year and $7.00 per acre per year, respectively (Yuan et al., 2002).

Table 26. 2011 EQIP payment schedule for field borders (reproduced from MN NRCS 2011)

Component	Unit	PR/unit	HUP/unit	Payment Cap
< 2 acres introduced grasses and legumes	ac	174	190	
2 to 5 acres introduced grasses and legumes	ac	164	178	
> 5 acres introduced grasses and legumes	ac	160	173	
< 2 acres native grasses and forbs	ac	230	257	
2 to 4 acres native grasses and forbs	ac	205	227	
> 2 acres native grasses and forbs	ac	191	210	

Table 27. 2011 EQIP payment schedule filter strips (reproduced from MN NRCS 2011)

Component	Unit	PR/unit	HUP/unit	Payment Cap
Single species introduced or native grass	ac	191	210	
Single species introduced or native grass with shaping	ac	258	291	
Intorduced grasses and legumes	ac	170	185	
Intorduced grasses and legumes with shaping	ac	230	257	
Mixed native grasses with or without forbs	ac	222	247	
Mixed native grasses with or without forbs with shaping	ac	282	319	

Operation and Maintenance Considerations

The maintenance of filter strips and field borders is directly related to its performance. If proper maintenance is not practiced periodically and after storm and tillage events, the runoff flow can be altered to parallel flow, bypassing the strips (Dabney et al., 2006). Maintenance of the system is important in order to maximize water quality effects: maintaining flow direction, proper density, and continuity of the buffer (Dabney et al., 2006; Helmers et al., 2008). USDA (1999) recommends a list of maintenance work for filter strips and field borders:

- Any development of channel and rills within the must be repaired. Shallow furrows or small berms can be placed across any concentrated flow to re-establish sheet flow.
- If a concentrated flow area is not redirected, it must be treated separately. A grassed waterway, shallow impoundment, terraces, dikes, berms, trenches, or vegetative barriers can be used to stabilize the waterway and reduce water velocity.
- Sediments accumulate along the upper gradient of the strips. This sediment has to be removed before it reaches 6 inches high and diverts runoff flow around the strip. The removal can be done with tillage equipment or other machinery. Re-establishment of vegetation at the contributing area interface may be necessary.
- Mowing is important to encourage vigorous sod or filtering vegetation. If the filter strip is removing bacteria or other pathogens, mowing encourages sunlight and air movement to desiccate the entrapped pathogens. However, over-mowing and excessive vehicle traffic can lead to poor root growth, soil compaction and reduced effectiveness.
- Weeding is important to maintain the designed width and density of filter strips.

Research Gaps

No research measuring efficiency of field border erosion control was found. This may be because field borders generally accommodate other conservation practices and it is difficult to isolate its impact on erosion. In order to improve the general understanding on the benefits of having field borders to improve water quality, more research on cost and effect of field borders may be necessary.

Increasingly, saturated buffers are being promoted as a way to increase N uptake although additional study on these specialty buffers is lacking. These types of buffers are commonly being used as part of a conservation drainage system.

For filter strips, there is little data on nutrient reduction efficiency studied under unconfined flow-path conditions and more research is necessary on plots similar to actual agricultural settings. Also, most monitoring studies are short-term and there are few long-term studies to understand maintenance required to keep the maximum effects of buffers (Helmers et al., 2008).

Tile drainage is widely used practice in Minnesota; however, there are few filter strip research projects conducted to find the nutrient removal on drained fields. Research is needed to understand the mechanism of filter strips when combined with a drainage system to maximize performance.

References

Arora, K., S. K. Mickelson, and J. L. Baker. 2003. "Effectiveness of Vegetated Buffer Strips in Reducing Pesticide Transport in Simulated Runoff." *Transactions of the American Society of Agricultural Engineers* 46 (3): 635–644.

Arora, K., S. K. Mickelson, J. L. Baker, D. P. Tierney, and C. J. Peters. 1996. "Herbicide Retention by Vegetative Buffer Strips from Runoff Under Natural Rainfall." *Transactions of the American Society of Agricultural Engineers* 39 (6): 2155–2162.

Bhattarai, Rabin, Prasanta Kumar Kalita, and Mita Kanu Patel. 2009. "Nutrient Transport Through a Vegetative Filter Strip with Subsurface Drainage." *Journal of Environmental Management* 90 (5) (April): 1868–1876. doi:10.1016/j.jenvman.2008.12.010.

Blanco-Canqui, Humberto, C.J. Gantzer, S.H. Anderson, and E.E. Alberts. "Grass Barriers for Reduced Concentrated Flow Induced Soil and Nutrient Loss." *Soil Science Society of America Journal*.

Dabney, Seth M., Matthew T. Moore, and Martin A. Locke. 2006. "Integrated Management of In-field, Edge-of-field, and After-field Buffers." *Jawra* (February): 24.

Eghball, B., J.E. Gilley, L.A. Kramer, and T.B. Moorman. 2009. "Narrow Grass Hedge Effects on Phosphorus and Nitrogen in Runoff Following Manure and Fetilizer Application." *Journal of Soil and Water Conservation* 64 (2) (April): 163–171.

Helmers, Matthew J., Thomas M. Isenhart, Michael G. Dosskey, Seth M. Dabney, and Jeffrey S. Strock. 2008. "Chapter 4: Buffers and Vegetative Filter Strips." UMRSHNC (Upper Mississippi River Sub-basin Hypoxia Nutrient Committee). Final report: Gulf hypoxia and local water quality concerns workshop. American Society of Agricultural and Biological Engineers. St. Joseph, Michigan. P. 43-58.

Jin, C.-X., and J. M. Romkens. 2001. "Experimental Studies of Factors in Determining Sediment Trapping in Vegetative Filter Strips." *Transactions of the American Society of Agricultural Engineers* 44 (2): 277–288.

Kaspar, T.C., D.B. Jaynes, T.B. Parkin, and T.B. Moorman. 2007. "Rye Cover Crop and Gamagrass Strip Effects on NO3 Concentration and Load in Tile Drainage." *Journal of Environmental Quality* 36: 1503–1511.

Merriman, Katherine R., Margaret W. Gitau, and Indrajeet Chaubey. 2009. "A Tool for Estimating Best Management Practice Effectiveness in Arkansas." *Applied Engineering in Agriculture* 25 (2): 199–213.

Minnesota Natural Resource Conservation Service (MN NRCS). 2011. "2011 Minnesota Eqip Conservation Practice Payment Schedule."

Nieber, John, Caleb Arika, Chris Lenhart, and Mikhail Titov. 2011. Evaluation of Buffer Width on Hydrologic Function, Water Quality, and Ecological Integrity of Wetlands.

Qiu, Zeyuan. 2003. "A VSA-Based Strategy for Placing Conservation Buffers in Agricultural Watersheds." *Environmental Management* 32 (3) (September): 299–311. doi:10.1007/s00267-003-2910-0.

Rickerl, D. H., L. L. Janssen, and R. Woodland. 2000. "Buffered Wetlands in Agricultural Landscapes in the Prairie Pothole Region: Environmental Agronomic and Economic Evaluations." Journal of Soil and Water Conservation 55 (2): 220–225.

Schmitt, T.J., Dosskey, M.G., Hoagland, K.D. 1999. Filter strip performance and processes for different vegetation, widths, and contaminants. *Journal of Environmental Quality*. 28:1479-1489.

Stuntebeck, Todd D., Matthew J. Komiskey, Marie C. Peppler, David W. Owens, and Dennis R. Frame. 2011. *Precipitation-Runoff Relations and Water-Quality Characteristics at Edge-of-Field Stations, Discovery Farms and Pioneer Farm, Wisconsin, 2003-08*. Scientific Investigations Report 2011-5008. Wisconsin: USGS.

Udawatta, Ranjith P., J. John Krstansky, Gray S. Henderson, and Harold E. Garrett. "Agroforestry Practices, Runoff, and Nutrient Loss: A Paired Watershed Comparison."

USDA. 1999. "CORE4 Conservation Practices Training Guide The Common Sense Approach to Natural Resource Conservation". USDA.

Webber, D.F., S. K. Mickelson, T.L. Richard, and H.K. Ahn. 2009. "Effects of a Livestock Manure Windrow Composting Site with a Fly Ash Pad Surface and Vegetative Filter Strip Buffers on Sediment, Nitrate, and Phosphorus Losses with Runoff." *Journal of Soil and Water Conservation* 64 (2): 163–171.

Yuan, Y., S.M. Dabney, and R.L. Bingner. "Cost Effectiveness of Agricultural BMPs for Sediment Reduction in the Mississippi Delta."

Links

NRCS Conservation Practice Standard, Field Borders, Code 386, http://efotg.sc.egov.usda.gov/references/public/MN/386mn.pdf

NRCS Conservation Practice Standard, Filter Strips, Code 393 http://efotg.sc.egov.usda.gov/references/public/MN/393mn.pdf

MNDA Conservation Practices Minnesota Conservation Funding Guide, Field Border
http://www.mda.state.mn.us/protecting/conservation/practices/fieldborder.aspx

Minnesota Conservation Funding Guide, Grass Filter Strip, http://www.mda.state.mn.us/protecting/conservation/practices/buffergrass.aspx