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Better Management Practices for Improved Profitability and Water Quality

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A. Summary

Better management practices are flexible, field-tested techniques that increase profitability and reduce the impact of agriculture and livestock production on the environment. Better management practices must be 1) cost-effective, 2) proven to reduce negative impacts, 3) realistic, and 4) compatible with an operation's culture. The purpose of this guide is to discuss the positive and negative aspects of specific better management practices. The transport of sediments, nutrients, chemicals, and bacteria from agricultural fields and livestock-producing areas to non-target areas can be reduced by the following:

a) Applying agrichemicals and manure only to areas requiring treatment.
b) Reducing runoff and erosion within a field.
c) Using livestock management practices that reduce runoff from feedlots.
d) Establishing grazing practices that promote stabilized riparian zones.

B. The Importance of Water Quality

Economic development, human health, and recreational activities are dependent on water quantity and quality. Recently, a survey of urban and rural residents from South Dakota, Montana, North Dakota, Colorado, Wyoming, and Utah was conducted. The survey sought to answer questions about perceptions on water quality (table 1). Ninety-two percent of the respondents identified clean rivers as very or extremely important. Almost 78% of respondents thought that farmers should use better management practices. Findings from the survey suggest that many peoples' perceptions about 1) water use, 2) the importance of using improved management practices, and 3) factors influencing water quality were not in harmony. These results were attributed to many people not having a clear understanding of the relationships between water quality and land management practices. These results are troubling because

- the economic development of many rural communities depends on water quality, quantity, and resource management; and
- declining rural populations make it likely that policy decisions about water quality will increasingly be made by people not connected to the rural landscape.

To minimize the risk of excessive non-point source pollution regulations, producers need to incorporate techniques into their operations that reduce the off-site transport of contaminants. Research in Minnesota and Virginia showed that adapting relatively simple techniques can greatly reduce off-site transport (Gowda and Mulla 2006). For example, in the Virginia Lower Dry River and Muddy Creek watersheds, 8.3 miles of fencing along 10 miles of stream reduced both sediment transport and the number of fecal coliform bacteria in the water (Zeckoski et al. 2007).

C. River Water Quality Assessments

Water quality assessments have shown that, in many situations, contamination can be attributed to human activity (e.g., agriculture, municipal wastewater treatment facilities, residential and golf course turf management, and industry). To develop targets for water quality improvement, the South Dakota Department of Environment and Natural Resources (SD DENR 2006) identified total maximum daily loads (TMDL) for many streams, rivers, and lakes. A TMDL is the sum of the allowable loads of a single pollutant from all contributing point and non-point sources. Point source contamination is contamination from a single identifiable localized source, such as a factory, whereas non-point source contamination comes from diffuse, non-localized sources. Agriculture is generally considered one of the largest non-point sources of water contamination. The goal of the TMDL program is to restore the full use of the water body, relative to its designated uses. Designated uses are set by states, territories, and tribes. The TMDL is not a constant value; it differs

Table 1. The importance of various aspects of water quality to respondants of North andDakota, South Dakota, Montana, Wyoming, Colorado, and Utah. (Modified from Clay et al. 2007.)

-------Topic-------	South Dakota	All States
	% of respondents providing a rating of "critical or very important"	
Clean rivers	87	92
Water for		
Livestock	79	78
Recreation	45	49
Aquatic habitats	72	79
Adopting better management practices	76	78
Improved grazing	59	65

based on the designated use. For example, the TMDL for a water body that designates uses that include swimming are more stringent than the TMDL for those designated uses that include only limited contact (e.g., a hand getting wet when fishing). Action plans are developed by the State based on the TMDL.

Different streams and lakes have different identified impairments. For example, the north-central and central portions of eastern South Dakota's Big Sioux River (Fig. 1) have impairments that are related to the following:

Sediment loading
- Impairment: Sediment covering fish spawning beds, reducing reproductive success
- Cause: Soil erosion occurring along the stream bank and/or from production fields

High bacterial counts
- Impairment: Water (from affected rivers and lakes) unsafe for drinking and recreation
- Cause: Livestock, wild animal waste, and/or poorly installed septic systems

Low oxygen concentrations
- Impairment: Reduced fish and other animal populations
- Cause: Nutrient-rich (N and P) runoff stimulating microorganism growth; subsequent death and decomposition of the microorganisms consuming dissolved oxygen

By understanding the impairments and causes, solutions to mitigate the problem can be brought to the forefront.

I. Better Nutrient Management Practices

Nitrogen (N) and phosphorus (P) are the two major nutrients added to crops as fertilizer. Unfortunately, these two nutrients, when transported to non-target water bodies, also cause the most problems. High N and P can contribute to algal blooms, excessive plant growth, low O_2 concentration, and subsequent fish kills. To decrease the possibility of off-site N and P transport, crops should be fertilized with enough nutrients for excellent growth, but not with excessive amounts. Fertilizer recommendations need to account for 1) residual nutrients and 2) nutrient credits for manure or prior crops. To account for nutrients contained in the soil, soil samples should be collected and analyzed. Details for collecting soil samples are available in Clay et al. (2002) and Gelderman et al. (2005). Details for converting soil test values into recommendations are available in Gerwing and Gelderman (2005) and Reitsma et al. (2008).

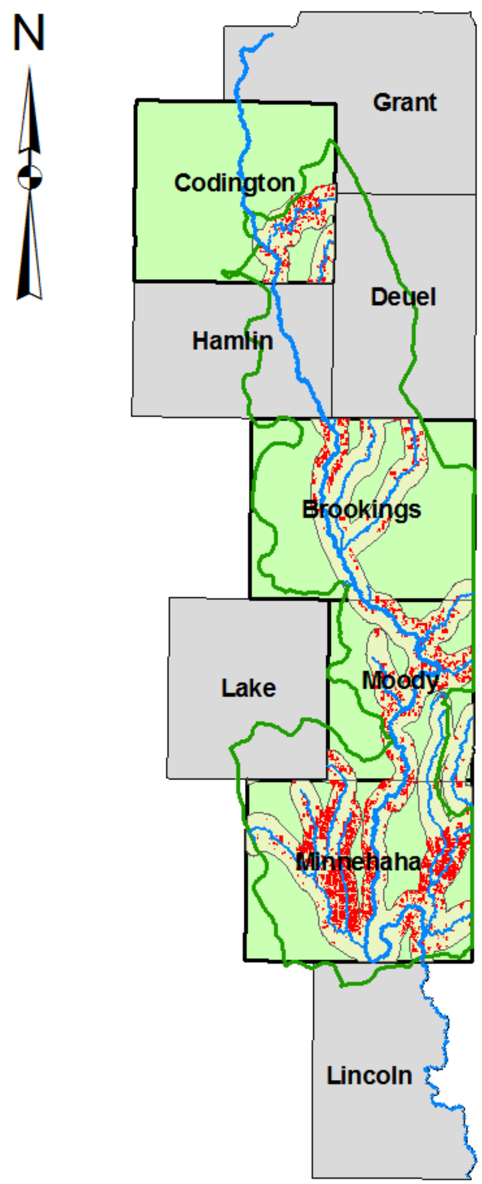
A. Develop a Nutrient Management Plan

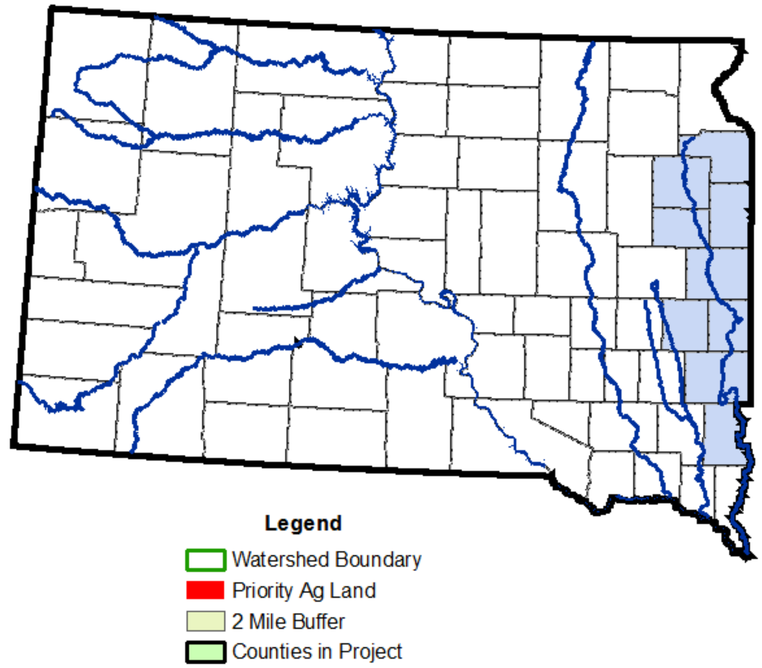
Details on developing N recommendations are available at Reitsma et al. (2008). Plans should be developed and updated annually for both manured and non-manured systems.

1) In manured systems, important considerations include the following:
   a) Determining the appropriate application rate. The rate is based on
      i) the amount of land available for manure application;
      ii) estimated concentrations of nutrients in manure and soil (Reitsma et al. 2008);
      iii) priorities within the field; and
      iv) previous applications of manure (Jokela 2005).
   b) Determining appropriate placement in the field. To minimize problems
      i) avoid applications within 100 feet of natural or man-made drainage or open tile intake structures or other conduits to surface water or groundwater;
      ii) avoid application to frozen or snow-covered ground;
      iii) apply to relatively level land (<6% slope is ideal), and avoid application to soils classified as "highly erodible";
      iv) in no-till operations, inject liquid manure to reduce inorganic N losses; and
      v) use deep manure injection to reduce P and fecal bacterial runoff, increase N efficiency, and increase energy efficiency (Fig. 2).
   c) Determining appropriate timing.
      i) Apply manures and N fertilizers as closely as possible to the time of uptake by the plant, especially on sandy soils, to reduce NO_3-N leaching.
      ii) Minimize N volatilization and P runoff by incorporating fertilizers and manure soon after application.

B. Other Important Nutrient Management Practices

1) Consider nutrient removal rates when making fertilizer or manure application decisions:
   a) Average N, P_2O_5, and K_2O removal rates by corn grain in the north-central region of the United States are 0.9 lb. N/bu, 0.38 lbs. P_2O_5/bu, and 0.27 lbs. K_2O/bu (Murrell 2005).
      i) Based on these values, a 200 bu/acre corn crop removes 180 lbs. N, 76 lbs. of P_2O_5, and 54 lbs. of K_2O.
2) Scout fields for potential nutrient deficiencies during the growing season.
3) Schedule irrigation to minimize leaching and reduce runoff.
4) Design crop rotations to improve nutrient use efficiency.
5) Consider using cover crops to utilize residual nutrients and minimize loss.

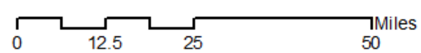




Agricultural Land Area Estimates

County	Agricultural Land (Acres)	Priority Agricultural Land (Acres)
Codington	314,000	17,000
Brookings	395,000	16,000
Moody	285,000	30,000
Minnehaha	430,000	99,000
Total	**1,424,000**	**162,000**

Agricultural land estimates are based on estimates of cropland and pastureland land use classes only. Other agricultural land uses were not considered in acreage estimates and the creation of this map.



This Map is for Planning Purposes Only

Although every effort has been made to ensure the accuracy of information, errors and conditions originating from the physical sources used to develop the database may be reflected in the data supplied. The end user must be aware of the data conditions and ultimately bear responsibility for the appropriate use of the information with respect to possible errors, original map scale, collection methodology, currency of data and other conditions specific to certain data.

Figure 1. The location of the north and central reaches of the Big Sioux River watershed in eastern South Dakota.

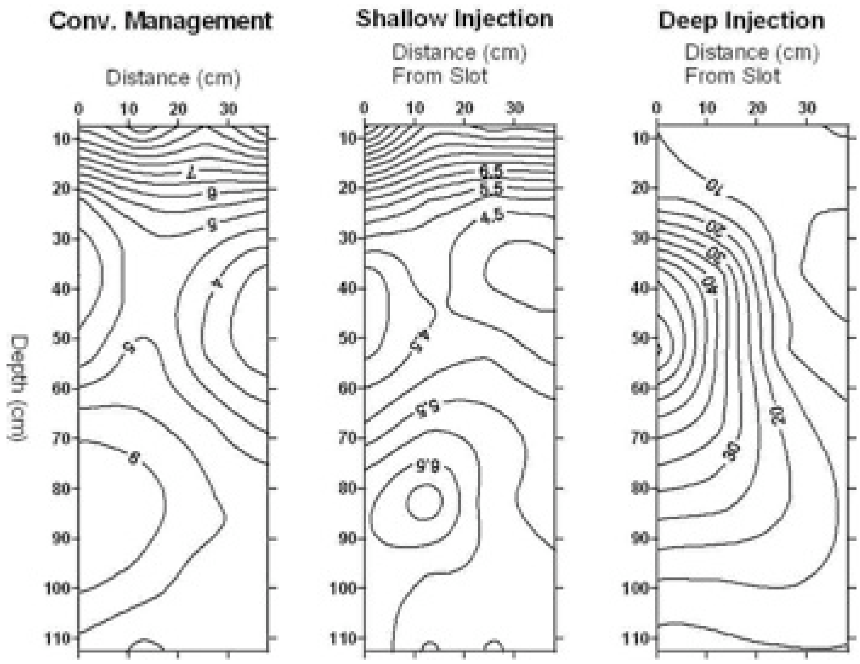


Figure 2. The influence of manure placement at Flandreau on soil nitrate-N (ppm) 12 months after application. The conventional management (surface-applied manure) and shallow injection (6 in. below the surface) treatments lost more N than the deep injection treatment (18 in. below the surface). Losses from conventional management and shallow injection treatments were attributed to higher nitrification rates near the surface where O_2 levels and microbial activity were higher.

II. Better Pest Management Practices

Herbicides and other pesticides have been reported in many surface waters of South Dakota. Most are at low levels, but even these amounts are considered impairments to water quality. Integrated Pest Management (IPM) is a science-based approach to managing pest populations. Using the IPM approach to develop improved recommendations involves combining knowledge of pest biology and site population assessments with a site's physical and biological characteristics. Using IPM methods can often lead to reduced herbicide and insecticide applications.

A. Tools of IPM

1) To maximize pesticide treatment efficiency:
   a) Frequently scout fields to correctly identify pests and to note their locations on field maps.
   b) Use economic threshold values to make treatment decisions.
   c) Use data obtained to make in-season decisions and decisions for subsequent seasons that may include rotating crops and/or planting insect- and disease-resistant plants.
   d) Apply at growth stages when pests are most susceptible.
   e) Calibrate sprayers to apply the correct rate (Wilson 2006).
   f) Plant high-quality, disease-free seed that is free of weed seeds.
   g) Prevent the mechanical spread of pathogens and pests by cleaning equipment.
   h) Read and follow label directions to know the following:
      i) proper personal protective equipment (PPE)
      ii) who to call in case of a spill
      iii) methods for the proper storage, handling, and disposal of pesticides and containers
      iv) correct application rates for
         (1) the pest[s] present
         (2) soil types
         (3) organic matter content (for preemergence application)
   i) Do not apply pesticides too close to water sources (within 50 to 100 ft. of surface water).
   j) Do not apply when windy or if inversion conditions are present.
   k) Apply pesticides with different modes of action to avoid resistance in pest populations.
   l) Avoid back-siphoning into wells by keeping airspace between the water supply hose and spray tank.
   m) Keep application records to track field histories.

III. Better Management Practices to Reduce Soil Erosion and Sediment Transport from Cropped Soils

Soil erosion attributable to water occurs on sloped lands when the intensity of rainfall exceeds the water infiltration rate. Water erosion is a two-step process. First, soil particles are detached by raindrops or flowing water. Second, these materials are transported downstream. Soil erosion is a physical process that requires energy; therefore, erosion-control techniques dissipate energy. A protective crop or residue cover of the soil typically slows rain drop impact, increases water infiltration rates, and reduces runoff rates. Soils should have a minimum of 30% residue cover after planting to be classified as a conservation tillage practice (McCarthy et al. 1993). On an average soil, 30% residue cover is an accepted value to reduce soil erosion rates by 50%, relative to leaving no residue cover. On long and steep slopes, 50 to 60% residue cover may be needed to reduce erosion by 50%. Surface residue is dependent on previous crop and tillage (table 2). Where possible, no-tillage or reduced-tillage practices should be adapted.

Table 2. Some common tillage practices applied to corn residue, and the typical residue cover percentages after planting the following season. (*Adapted from McCarthy et al., 1993.*)

	After Soybeans	After Corn
Tillage	-------% Residue Cover [1]-------	
No-till	45 to 58	65 to 77
Strip-till	24 to 35	44 to 58
Ridge-till	13 to 27	17 to 34
Field cult. or tandem disk	24 to 40	29 to 54
Disk chisel + field cult.	7 to 14	25 to 37
Tandem disk + tandem disk		20 to 43
Disk ripper + field cult.		15 to 31
Moldboard plow + field cult.		5 to 12

[1]Percent residue cover remaining after planting the following season.

A. Other Important Better Management Practices to Reduce Soil Erosion

1) Adopt appropriate tillage practices:
   a) Use contour tillage,
   b) Install terraces, and
   c) Where necessary, use deep tillage techniques to break up plow pans.
2) Adopt appropriate cropping practices:
   a) To maintain increased winter soil cover, plant a winter annual after corn silage harvest:
      i) Winter rye can be harvested for silage prior to planting corn or soybeans.
   b) To reduce erosion, plant corn and soybeans in strips with small grains or a sod-forming crop (Francis et al. 1986).
   c) Consider alternative land use for lower-yielding eroded shoulder slopes.
   d) Reduce compaction by loading grain trucks outside the field and by staying off heavy-textured soils that are wet.

B. Grassed Waterways

Installing grassed waterways (fig. 3) in areas with recurring gullies can minimize erosion that occurs during the transport of runoff both through and off the field. Grassed waterways can channel runoff water 1) into strategically placed wetlands for storage or 2) into structures that transport water from the field to the stream.

Figure 3. Example of a grassed waterway.
(*Photo courtesy of USDA-NRCS.*)

Considerations to increase grassed waterway effectiveness and maintenance after establishment include the following:

1) Grassed Waterway Maintenance (USDA–NRCS 2006a):
   a) Maintain stand by mowing (annually) and fertilizing (when necessary).
   b) Inspect each spring and following heavy rains so that sediment may be removed and damage repaired.
   c) Lift tillage equipment and shut off sprayers when crossing.
   d) Till perpendicular to grassed waterways whenever possible.
   e) Do not use as a field road.
   f) Avoid crossing with heavy equipment when the waterway is wet.
   g) And exclude livestock whenever possible, especially during wet periods.

C. Filter Strips

While grassed waterways are used within a field to minimize within-field erosion, filter strips are used to limit the movement of sediments, water, and chemicals into streams. Filter strips (fig. 4) are vegetated areas along rivers and streams that can reduce contaminant loadings into surface waters. Lee et al. (2003) reported that a 23-foot-wide buffer strip of switchgrass removed >92% of the sediment under natural rainfall conditions. In addition to benefiting water quality, filter strips also stabilize stream banks, provide hay and grazing land, straighten crop rows, and provide habitat for wildlife. The width of a filter strip depends on its purpose. The NRCS recommends filter strips ranging from 20 to 100 feet in width. Steeper slopes above the strip require a greater strip width. Strips designed to trap sediment require less width than strips designed to trap dissolved contaminants. Many cost-share programs pay up to 75% of the installation, plus county-average rent, for each year the land is put into a permanent filter strip. The following maintenance practices can increase the effectiveness of filter strips:

1) Filter Strip Maintenance (USDA–NRCS 2006b)
    a) Maintain plant vigor with the following methods:
        i) Mow or graze the filter strip every two to five years.
        ii) Mow or graze when chances for heavy rains are low. This allows sufficient time for regrowth (prior to the next typical period for heavy rains) and minimizes equipment traffic through the filter strip.
        iii) Avoid spraying herbicides that may damage the filter strip.
        iv) Use fences to control grazing, and graze with high animal densities for a short time period (5 to 6 AUs/acre for three to five days).
    b) Maintain filter strip shape with the following methods:
        i) If necessary, reshape and reseed rills and gullies that form within the filter strip.
        ii) To prevent rills and gullies and to encourage sheet flow, make a shallow furrow on the contour across the filter strip.

Figure 4. The trees and grasses in this filter strip trap sediment and other pollutants contained in runoff that could otherwise enter the stream. (*Photo courtesy of USDA-NRCS.*)

D. The Targeted Buffer Zones Alternative

Many farmers may not be willing to sacrifice the amount of land required to buffer the length of an entire stream. An alternative technique may be a Targeted Buffer Zones approach. Under such an approach, the segments of the stream that receive more runoff would have wider buffer strips than those that receive less runoff (Dosskey et al. 2005). This approach could be considered when it is obvious that the majority of the runoff is leaving the field from a small zone. Unfortunately, financial and technical support is not yet available for the Targeted Buffer Zones approach. It may be more feasible for farmers to apply a shorter-but-wider buffer strip, even though farmers that do so will receive no funding.

IV. Better Management Practices to Reduce Runoff from Feeding Facilities

Livestock in feedlots can have a large impact on the water quality of streams and lakes. Bacteria contained in manure can enter surface waters via runoff and make those waters unsafe for recreation and drinking. Nutrients contained in the manure can also impair water quality. While large feedlots are heavily regulated, smaller operations have the flexibility to choose the practices and management principles for protecting water resources that more closely meet the operation's unique needs and situations.

A. Better Management Practices to Reduce Contamination from Open Feedlots

1) Managing runon and runoff
    a) Prevent wastewater runoff from a settling basin or the lot itself from reaching surface waters.
    b) For future land application, install a retention basin to contain all wastewater from a settling basin.
    c) Install a vegetated treatment area to infiltrate wastewater, rather than a retention basin (Koelsch et al. 2006).
    d) Reduce clean water coming onto open feedlots by installing diversions, rooftop gutters, and more roofed area; fixing waterers; and reducing quantities of water for cooling, if possible.
    e) Remove snow from open lots as quickly as possible.
2) Manure handling
    a) Collect manure from the open lot frequently.
    b) Do not stockpile manure within 200 feet of natural or manmade drainage.
    c) Minimize runoff and leaching from stockpiles. Do this by covering the stockpile, by installing dikes around the stockpile, and by supplying a liner or concrete beneath the stockpile.
3) Feedlot maintenance
    a) Scrape old feedlots bare and revegetate them prior to abandonment.
    b) Locate feeding facilities away from streams or drainage channels.

V. Better Grazing Management Practices

For many producers, ponds and streams provide a convenient water supply for livestock. However, livestock grazing in pastures can reduce the water quality of streams and lakes, especially when the livestock have access to surface water. Allowing livestock access to surface water also increases the livestock's chances of being affected by foot rot. Economical alternatives to unfettered grazing are available. The following are better management practices and principles that can help to reduce the impact grazing livestock have on surface waters:

1) Cattle prefer clean water, and they can grow faster with access to it. For example:
   a) Cattle chose to drink fresh water 92% of time when a spring-fed trough was placed in a pasture with a stream flowing through the middle (Sheffield et al. 1997).
   b) Calves that drank clean water in a pasture gained 9% more weight than those drinking directly from a pond (Willms et al. 2002).
   c) Yearling heifers with access to clean water gained 20% more weight than those drinking from a trough with water pumped from a pond (Willms et al. 2002).
   d) Having troughs lessens the chances for the foot rot and leg injuries that can be associated with streams and slippery, muddy shorelines.
2) Clean water is economical.
   a) Selling fifty 500-lb. calves that had a 3% weight gain due to clean water, at $1.00 per lb., would bring an additional $750 per year (table 3).
   b) Selling fifty 500-lb. calves that had a 9% weight gain due to clean water, at $1.25 per lb., would bring an additional $2,250 per year (table 3).

Table 3. Example of increased revenue due to installing off-stream waterers.

Calf sale weight after drinking pond water	Additional weight gain due to clean water	Price	Increased revenue due to clean water
500 lb/calf	3% or 15 lbs	$1.00 per lb	$15.00
	6% or 30 lbs		$30.00
	9%[1] or 45 lb.		$45.00
	3% or 15 lbs	$1.25 per lb	$18.75
	6% or 30 lbs		$37.50
	9% or 45 lb.		$56.25

[1]Willms et al. (2002) study from Alberta.

   c) Estimated costs in eastern South Dakota:
      i) Well drilling ($90 per ft. x 30-ft. deep) = $2700
      ii) Pump with a float system = 1500
      iii) Power wire trenched to pump ($3 per ft. up to 1320 ft)= 300 to 3960
      iv) Estimated Installation cost= $4500 to $8160
   d) With improved weight gains, this system could pay for itself within five years.
   e) Installation costs could be <$1000 if water is delivered from an existing well through 1" plastic pipe.
3) Pumping water directly from stream or pond can be less expensive.
   a) Montana research shows:
      i) Tanks installed 50 to 150 ft. from stock dams resulted in 76% of cows and calves preferring the tank to the stock dam (Surber et al. 2003).
      ii) Solar-powered pumps could be used as an alternative if power line is not available
   b) Potential disadvantage:
      i) Weight gains relative to drinking directly from pond were not found in calves (Willms et al. 2002).
4) Provide shade away from riparian area.
   a) Cattle preferred wooded areas over grassed areas for lying behaviors (Zuo and Miller 2004).
   b) Cattle have exhibited increased weight gain and milk production when given shade (Turner 2000).
5) Graze riparian areas only during dry periods (see pg. 9).
6) Permanent or temporary fences can be used to control grazing.
   a) Cost-share available, and may also pay for portion of providing alternative water source.
7) Stabilize areas where the livestock routinely cross the stream (fig. 5).
8) Monitor the pasture on a regular basis for weed infestations, overgrazing, and damaged areas that may need reseeding.

Figure 5. A hardened stream crossing reduces the amount of time cattle spend in the stream. (*Photo courtesy of USDA-NRCS.*)

VI. Summary

People in the region are interested in maintaining high-quality water for its many varied uses. Sediments, fertilizers, herbicides, insecticides, and bacteria can be transported from agricultural fields to streams and rivers following rainfall. Such pollutants damage and degrade the water, making the natural resource less useable by both wildlife and humans. In some cases, these pollutants can pose a health threat to anyone using the affected waters.

The loss of sediments from production fields reduces soil productivity. The surface soil is the most productive portion of the soil. Sediments contain many of the nutrients that were purchased and applied as fertilizer. The future ability of the soil to produce high yields lies in its sediments. Therefore, to maintain the long-term sustainability of our soil and water resources, the off-site transport of sediments, chemicals, and bacteria must be reduced and kept to a minimum.

Everyone contributes to water quality problems, and everyone must be involved in the solution to those problems. Producers can assist by adopting better management practices. In many situations, the off-site transport of materials from production fields to non-target areas can be reduced by adopting relatively simple measures. For example, adopting conservation tillage, using soil testing to identify nutrient deficient zones, injecting manure rather than surface-applying manure, applying manure and fertilizer only to areas where needed, and installing grass buffer zones in areas where water leaves the field are just a few practices that can make large positive impacts in improving water quality. The pros and cons associated with the different better management practices are shown in table 5.

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Table 5. Advantages and disadvantages associated with better management practices.

BMP	Pros	Cons	Costs to Establish and Maintain	References
Attending Training Sessions	Provides up-to-date information about state-of-the-art techniques	Time required to attend training Training may not provide adequate details to implement practices	Transportation, time, and registration fees (usually <$40)	See http://sdces.sdstate.edu/events
Nutrient Management: Better Manure Application Methods	Less potential to contaminate surface water Higher nutrient availability to increase crop yields	Manure application at inconvenient times May reduce amount of land available for manure application or require longer hauling distances	Should involve few if any additional costs; just requires some consideration where and when manure is applied	http://www.state.sd.us/denr/DES/Surfacewater/IPermits/AllAnimalGPermit.pdf
Nutrient Management: Manure Testing	Coupled with results from a soil test and manure spreader calibration, a more accurate fertilizer rate can be applied	Liquid manure should be agitated 2-4 hours to obtain a good sample	$55-60 per test at SDSU Lab Fuel to agitate for 2-4 hours	Kleinman et al. (2005) http://www.sera17.ext.vt.edu/SERA_17_Publications.htm http://anserv.sdstate.edu/
Nutrient Management: Manure Spreader Calibration	Enables producer to know the approximate manure rate applied so fertilizer rates can be adjusted accordingly	Requires time Recalibration needed if application changes occur	Machinery scales are expensive Just use spreader's rated capacity or collect and weigh manure from 3 or 4 areas	Jokela (2005) http://www.sera17.ext.vt.edu/SERA_17_Publications.htm
Nutrient Management: Soil Testing	Good way to assess nutrient levels Use to make fertilizer recommendations	Requires time and a soil probe (about $85, or borrow one from Extension Educator)	$11 per sample Sample each year for NO3-N prior to planting a non-legume crop	Gelderman et al. (2005) http://agbiopubs.sdstate.edu/articles/FS935 http://plantsci.sdstate.edu/soiltest
Nutrient Management: Precision farming	Using variability to target where additional resources are needed.	Requires time to collect and analyze information May involve technological hurdles	Yield monitor costs approx. $10,000	http://plantsci.sdstate.edu/precisionfarm/
Nutrient Management: Schedule Irrigation	May save water and reduce NO3-N leaching and sediment loss in runoff	Time is required to keep the schedule and its data current	Cost of your own labor or a consultant	Werner (1993) http://agbiopubs.sdstate.edu/articles/EC897.pdf
Pest Management: Integrated Pest Management	Reduce input costs by treating pests when their populations exceed the economic threshold Avoid pest resistance	Frequent scouting and development of control tactics require your own labor or that of an Independent Crop Consultant	Crop Consuting Fee of approx. $5 per acre per year, which is typically offset by improved agronomic decisions	http://www.ncipmc.org/
Pest Management: Read and follow label instructions and keep field records	Peace of mind if there is ever a legal action threat May discover a method to increase effectiveness of pesticide. Can be used to track treatment efficiencies.	Requires time, often during very busy times	Typically less than one-hour of labor to read a pesticide instruction label and make records of the application	
Pest Management: Sprayer Calibration	Apply the desired rate from all nozzles to save money	Requires some labor, but can probably be done in a few hours	Cost of labor, new nozzles, and hoses if necessary	Wilson (2006) http://sdces.sdstate.edu/brown/CalibrationPesticideSprayingEquipFS933.pdf
Pest Management: Do not apply when offsite movement likely to occur	Lessens the chances of polluting surface and ground water	May not be able to apply certain pesticides in some areas of a field	Possibly less than desirable pest control in some areas of a field	Johnson et al. (1996) http://extension.missouri.edu/explore/agguides/crops/g04851.htm

Erosion Reduction: Double Pass Tillage Disk Chisel in fall followed by field cultivator in spring	No yield penalty expected relative to moldboard plowing Sufficient residue cover to minimize soil erosion on many soil types	Requires higher fuel, labor, and implement costs relative to no-till, strip-till, and single pass tillage systems Insufficient residue to minimize erosion on soil types with higher erosion rates	Typical fuel, labor, and implement costs of approximately $60 per acre	Randall et al. (1996) http://www.extension.umn.edu/distribution/naturalresources/DD6676.html McCarthy et al. (1993) http://extension.missouri.edu/explore/agguides/agengin/g01650.htm Schnitkey and Lattz (2006) http://www.farmdoc.uiuc.edu/manage/newsletters/fefo06_07/fefo06_07.html
Erosion Reduction: Single Pass Tillage Disk in spring if corn residue or field cultivator in spring if soybean residue	No yield penalty expected on well-drained soils with sloping landscapes Sufficient residue cover to minimize erosion on many soil types Costs are similar to no-till and strip-tillage	Possible yield penalty in continuous corn Possible yield penalty on heavy, poorly-drained soils with 0-3% slopes Insufficient residue to minimize erosion on soil types with higher erosion rates, especially after soybean residue	Costs are approximately 15% less than double pass tillage for a corn-soybean rotation	Randall et al. (1996) http://www.extension.umn.edu/distribution/naturalresources/DD6676.html Olson and Senjem (2002) http://www.extension.umn.edu/distribution/naturalresources/DD6675.html McCarthy et al. (1993) http://extension.missouri.edu/explore/agguides/agengin/g01650.htm Schnitkey and Lattz (2006) http://www.farmdoc.uiuc.edu/manage/newsletters/fefo06_07/fefo06_07.html
Erosion Reduction: Strip-Till	No yield penalty expected Lower production costs than double pass tillage Gives the seedbed drying benefits of tillage and the residue cover benefits of no-till Better option than no-till or ridge-till for continuous corn	Auto-guidance to steer tractor is highly recommended and can cost from $7,000 to 35,000 May need to purchase a Strip-Till Toolbar Erosion could be a problem if tilled strips run parallel to slope direction	Production costs of approximately 17% less than double pass tillage for a corn-soybean rotation	Randall et al. (1996) http://www.extension.umn.edu/distribution/naturalresources/DD6676.html Schnitkey and Lattz (2006) http://www.farmdoc.uiuc.edu/manage/newsletters/fefo06_07/fefo06_07.html McCarthy et al., (1993) http://extension.missouri.edu/explore/agguides/agengin/g01650.htm
Erosion Reduction: Ridge-Till	No yield penalty expected on well-drained soils with sloping landscapes Reduced fertilizer and chemical costs compared to other tillage practices Minimizes soil erosion if ridges run perpendicular to slope direction	Possible yield penalty for corn in heavy, poorly drained soils Must use rotation that utilizes the same row width each year Need expensive equipment to build ridges Ridge building is done when plants are 6-12 in high, so timeframe may be short	Production costs about 8.5 to 10% less than double pass tillage for a corn-soybean rotation Approximately $7,000 to convert planter and $11,500 for a specialized cultivator	Randall et al. (1996) http://www.extension.umn.edu/distribution/naturalresources/DD6676.html Katsvairo and Cox (2000) McCarthy et al. (1993) http://extension.missouri.edu/explore/agguides/agengin/g01650.htm Olson and Senjem (2002) http://www.extension.umn.edu/distribution/naturalresources/DD6675.html
Erosion Reduction: No-till	No yield penalty expected on well-drained soils with sloping landscapes Lower production costs Minimizes soil erosion more than any other tillage practice Increases soil quality over time	Possible yield penalty on heavy, poorly-drained soils Expected yield penalty for continuous corn on all soil types	Production costs of about 17% less than double-pass tillage for a corn-soybean rotation	Randall et al. (1996) http://www.extension.umn.edu/distribution/naturalresources/DD6676.html McCarthy et al., (1993) http://extension.missouri.edu/explore/agguides/agengin/g01650.htm Schnitkey and Lattz (2006) http://www.farmdoc.uiuc.edu/manage/newsletters/fefo06_07/fefo06_07.html
Erosion Reduction: Contour Tillage	Tilling across the slope can reduce erosion by 74% compared to tilling downslope	May require more fuel and labor on some fields	Depending on the field, costs could be more, less, or no different	Zhang et al. (2004)

Erosion Reduction: Strip Cropping	One of least costly conservation practices to install Erosion-resistant strips can provide hay Some annual crops, such as winter wheat, may be substituted for hay crops	Addition of grasses or forage legumes may alter cropping sequences Strips are more difficult to manage compared to large fields Herbicides may injure or kill crops in adjacent strips	Establishing new crops into the long-term crop rotation could reduce income	Carman (2005) http://www.sera17.ext.vt.edu/Documents/BMP_strip_cropping.pdf
Erosion Reduction: Cover crops or winter annuals, especially after corn silage	Reduce soil erosion and NO3-N leaching Suppresses weeds Can be harvested for forage or grain the following season	May not be enough time to establish in the fall Costs money for seed Cover crops must be killed the following spring	Cost for seed, planting, and harvest Crop destruction costs if not harvested Forage or grain provided may offset costs	Stute et al. (2007) http://www.uwex.edu/ces/cty/Manitowoc/ag/documents/RyeAfterCornSilage.pdf
Erosion Reduction: Unload combines at field edge to reduce compaction	Less-compacted soils are more productive	Harvesting may be less efficient if trucks must follow traffic lanes Sometimes farmers need to drive on wet soils	Extra labor to drive combine to field edge for unloading	Wortmann and Jasa (2003) Available at http://www.ianrpubs.unl.edu/epublic/pages/publicationD.jsp?publicationId=148
Reducing Runoff from the Field Edge: Filter Strips/Grassed Waterways	>70% sediment removal >50% soluble pollutant removal Can provide hay	Loss of crop land May require maintenance after large runoff events	Numerous programs can offset most of the establishment costs Hay production may offset costs	Green et al. (2005) http://www.sera17.ext.vt.edu/Documents/BMP_Filter_Strips.pdf http://www.sera17.ext.vt.edu/Documents/BMP_Grassed_Waterways.pdf
Reducing Runoff from the Field Edge: Targeted Buffer Zones	Less land sacrificed than buffering the entire stream length	May be less effective at trapping contaminants than a filter strip No funding available for this practice	Depends on amount of land taken from production May provide hay	Dosskey et al., 2005
Feedlots: Reduce runoff entering water resources by establishing clean water diversions, settling basins, and containment basins	Captures water and nutrients for potential application to cropland at appropriate times Reduces discharge of water into water resources	Installation costs Must be managed to maintain appropriate water levels in the basin	Professional design and installation required for regulated CAFOs	Wright, 2005 http://www.sera17.ext.vt.edu/Documents/BMP_barnyard_feedlot.pdf Glanville et al., 1998 http://www3.abe.iastate.edu/homestudy/open.htm
Feedlots: Reduce runoff entering water resources by establishing clean water diversions, settling basins, and vegetated treatment systems	Installation costs may be lower than containment basins May require less management time than containment basins	Lost opportunity to apply water and nutrients to higher-return grain crops	Contact local conservation office because they can provide assistance and cost-sharing for non-CAFOs	Koelsch et al., 2006 http://www.heartlandwq.iastate.edu/NR/rdonlyres/7A7E022B-D488-4673-B7BC-F98B78741749/34261/Section1Introduction.pdf
Feedlots: Relocating feeding facilities	Less threat to stream pollution Funding typically available	Feedlot may be further from the home	Farmer will likely have to pay for a portion of the cost	www.eastdakota.org
Feedlots: Contain manure stockpiles	Reduces nutrient loss Less potential to contaminate surface and ground waters	Costs money for a cover, an earthen or concrete barrier, and a concrete surface beneath the pile if necessary	<$1,000 for stockpile cover and earth moving, but could be more if concrete is needed	South Dakota Department of Environment and Natural Resources. Available at http://www.state.sd.us/denr/DES/Surfacewater/IPermits/AllAnimalGPermit.pdf

Grazing: Remote waterers in pastures	Cattle spend less time in the stream A good alternative to fencing off the stream Increased weight gain if given fresh water	May have to drill another well May need to construct a hardened crossing if stream cuts through the pasture Labor to maintain	$4,500 to 8,200 to install Could be <$1,000 if water can be piped from an existing well or rural water system	Phost et al. (2007) http://extension.missouri.edu/explore/envqual/eq0380.htm Surber et al. (2003) http://animalrangeextension.montana.edu/articles/beef/drought/water-quality.htm Zeckoski, et al. (2007) http://www.ext.vt.edu/pubs/bse/442-766/442-766.html
Grazing: Hardened stream crossings	Reduces erosion at the livestock crossing locations Reduces time cattle spend in stream Funding may be available	Installation costs Labor to maintain	Approximately $2,000-6,000 for installation costs Gravel for maintaining crossing	Zeckoski et al. (2007) http://www.ext.vt.edu/pubs/bse/442-766/442-766.html Strobel and Javid (2006) http://cleanwater.uwex.edu/pubs/pdf/farm.cattlewater.pdf
Grazing: Rotational grazing	More productive pastures More effective riparian areas when grazed at proper times More uniform soil fertility levels	Labor required to frequently move livestock Increased fencing needed to divide pasture into paddocks	$30 to 70 per acre for new fencing; fencers; water systems; and possibly livestock lanes, which will give the higher cost	Undersander et al., 2002 http://learningstore.uwex.edu/pdf/A3529.pdf
Grazing: Provide shade away from riparian area	Keep cattle away from stream Improves rate of gain and milk production during hot weather	Trees are difficult to remove if grazing is discontinued Shading structures cost money	Moveable shading structures can be built for $500 that will accommodate 5 or 6 cows	Turner, 2000 http://www.bae.uky.edu/Publications/AEUs/aeu-91.pdf Zuo and Miller-Goodman, 2004
Grazing: Streamside livestock exclusion	Improved health Less leg and foot injuries Prevents direct deposits of manure into water bodies Improves riparian areas	Reduces total feedstocks available for cattle Costs for fencing, alternative water, and labor to maintain	Funding may be available to install fencing through local conservation office	Zeckoski et al., 2007 http://www.ext.vt.edu/pubs/bse/442-766/442-766.html

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