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Sediment Problems and Solutions for the Minnesota River

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A Minnesota River Prognosis

The Minnesota River is in poor health. Like a heart patient's veins and arteries, its tributaries and main stem are clogged—not with cholesterol, but with sediment, nutrients, and excessive algae growth. The river, like a heart patient, needs to go on a strict diet before its health can be restored.

The river's water, clouded by sediment and contaminated by bacteria, frequently is unfit for fishing, swimming, and other uses. In fact, the lower stretch of the river has seen violations of federal and state water quality standards for turbidity, dissolved oxygen, and fecal coliform. At periods of low flow, pollution-generated algae growth and subsequent decay remove so much dissolved oxygen from the water that many aquatic life forms can't survive. At other times, a steady supply of suspended sediments keeps the river turbid—cloudy—and far below its potential as a water resource that Minnesotans can use and enjoy. This is true of the main stem, and many of the major tributaries that drain into the Minnesota River.

The good news is, the Minnesota River can be restored to health. Measures already underway promise to result in reductions of the major pollutants spoiling the river—bacteria, sediment, phosphorus, and nitrogen. Farmers are upgrading feedlots and leaving more residue on their fields. Towns and cities are reducing storm water runoff and industrial discharges while upgrading wastewater treatment plants and septic systems. New techniques for reducing sediment losses through open tile inlets are also being tested.

Sediment: A Priority Pollutant

A significant part of the Minnesota River's water quality problems comes from sediment that enters the river and its tributaries throughout its 10-million-acre watershed. Approximately 625,000 tons per year of total suspended solids, largely sediment, are transported by the Minnesota River at its mouth at Fort Snelling, according to the Metropolitan Council. That's 86 20-ton truckloads a day.

Sediment is a pollutant in its own right, causing turbidity in the water that limits light penetration and prohibits healthy plant growth on the river bed. Sediment also covers much of the river bed with a blanket of silt that smothers life. By covering up gravel and cobble, sediment destroys the spawning grounds and habitat of desirable fish species such as bass and bluegills. Instead, less desirable species such as carp are favored by the sediment-enriched habitat.

Finally, sediment is an important carrier of a critical pollutant: phosphorus. This nutrient stimulates excessive algae growth in the water column. When the algae decomposes, it depletes dissolved oxygen from the water, reducing the quality of life forms that are able to survive.

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Sediment Sources

Sediment originates from many sources within the Minnesota River basin: stream banks, construction sites, lawns and streets, and agricultural fields. Each of these sources is being addressed as part of the river restoration effort. However, given the prevalence of row-crop agriculture throughout the basin, this source generally outweighs the others, and must be significantly reduced to improve the river's water quality.

Substantial water quality improvements can result from the use of economically achievable sediment-reduction practices on farmland. One of these practices is conservation tillage, defined as tillage systems that leave at least 30 percent of the field surface area covered by crop residue after planting. Leaving the surface rough and partially covered with crop residue reduces sedimentation at its origin by preventing the detachment of soil particles by raindrops, and retarding their transport across the field surface by water runoff. Soil erosion reduction does not translate into equal reductions of sediment entering surface waters, however. Erosion refers to the transport of soil over the field by water or wind, while sedimentation refers to the deposition of soil particles into surface water. Reductions in erosion usually correspond to much smaller reductions in sedimentation.

An example illustrates the point. Switching from clean tillage to a system that leaves at least 30 percent residue cover on the surface after planting can reduce soil erosion by 50 to 65 percent. Thus, if the original average annual erosion rate on a field was 4 tons per acre, conservation tillage would result in a 2-ton reduction in soil erosion. But only a fraction of this 2 tons would translate into reduced sedimentation. On a gently sloping, typical row-cropped field in the south-central part of the Minnesota River basin, the Natural Resources Conservation Service (NRCS) estimates that about 10 to 20 percent of eroded soil typically is delivered to a surface water channel such as a drainage ditch or surface tile intake or directly into a stream. Thus, a 2-ton per acre reduction in erosion may translate into a reduction of 400 to 800 pounds of sediment entering surface water.

These sediment losses are much lower than the so-called "tolerable" level of soil loss that can be sustained without sacrificing long-term productivity — the "T" level of approximately 5 tons per acre. But sediment losses of several hundred pounds multiplied over hundreds of thousands of acres of cropland can contribute to chronic water quality problems in the Minnesota River system. This is especially true of sediment composed of fine particles from the clayey soils so prevalent in the basin. These particles may stay in suspension for days, degrading water quality for hundreds of miles before settling out.

The relative proportions of the total sediment in the river contributed by cropland, streambanks and other sources still are not well understood. Very likely, these proportions vary widely within the basin. But according to an evaluation by the NRCS, the widespread adoption of conservation tillage practices within the south-central part of the basin could reduce sediment losses by approximately 45 percent. Since conservation tillage can be practiced with minimal effect on crop yields and often at lower production costs than conventional tillage, it offers a low-risk means of achieving substantial reductions in sediment losses from cropland.

Minnesotans can aim high in their efforts to restore the quality of their namesake river. However, we need to be realistic. Even substantial reductions in sediment and other pollutants won't restore the Minnesota River to its pre-settlement state of quality, as described by early explorers and settlers. For one thing, highly productive row-crop agriculture is the dominant land use throughout most of the basin. This intensive form of land use inevitably entails sediment losses. In addition, the prairie soils throughout the Minnesota River basin are generally of a fine texture that dislodge easily, carry substantial quantities of phosphorus, and cause a high degree of turbidity.

The Benefits of a 40 Percent Sediment Reduction

The Minnesota Pollution Control Agency has established a basinwide goal of a 40 percent reduction in sediment losses. This is economically achievable throughout much of the basin, and would lead to substantial improvements in water quality.

During high-flow periods, typically in the spring, the river would begin to cleanse itself by scouring deposits from years of sediment loading. As the small spaces between pebbles on the river bed cleared out, spawning by popular game fish would increase. Species such as bluegills and largemouth bass would begin to increase in population in the lower reaches of major tributaries and in parts of the main stem.

During the rest of the year, at medium and low flow, the river and tributaries would become less turbid. A child could see his or her feet after wading in knee-deep, for example, versus only shin-deep today. But actually, light would penetrate much farther than that, all the way to the river bed of tributary streams, and up to a grown man's height in the main stem. As a result, plant growth would shift from algea at the surface to large aquatic plants at the bottom, becoming a healthy part of the biological community rather than a nuisance. Dissolved oxygen levels would rise as phosphorus levels and surface algae growth declined. The Minnesota River would be on its way to achieving the level of quality that Minnesotans expect from their major water resources.

Achieving these water quality gains through land-use changes that are consistent with a productive, profitable agriculture is the goal of the Sediment Reduction Initiative, a basinwide effort involving state and local government agencies, private businesses, landowners and nonprofit organizations. As the first stage of this initiative, the University of Minnesota has developed conservation tillage guidelines for specific soils, climate zones, and crop rotations within the basin.

Reduced Tillage Guidelines for the Minnesota River Basin

Sediment from cropland can be reduced through a variety of measures including reduced tillage, crop rotation, waterways and terraces, grassed buffers at the field edge, and catch basins. In many situations, residue management through reduced tillage can be the primary means of sediment reduction. By preventing sediment losses at the source, surface residue management reduces the need for secondary measures. Where such measures are required for secondary protection, residue management makes them less costly, more effective, and longer lasting.

Overview of Tillage Systems

A variety of tillage systems can be used in a corn-soybean rotation, or rotations including a small grain, to achieve an average surface residue cover of approximately 30 percent after planting, the goal of conservation tillage.

• Chisel plowing with straight shanks followed by very limited secondary tillage is the system most broadly applicable throughout the basin that can achieve this goal without sacrificing yield potential.

• On well-drained soils, a single pass in the spring with a disk or field cultivator can achieve still more sediment reduction, but at the possible cost of delayed planting in wet springs due to slower field drying and warm-up. Following a high-residue crop like corn or small grains, two passes may be necessary.

• Ridge-till achieves still more sediment reduction, usually at reduced operating costs and with no yield penalty. However, on poorly drained soils in wet years, reduced yields may occur.

• The same is true of no-till, but with greater potential for substantially reduced yields on poorly drained fields in wet, cool springs.

A Three-Stage Implementation Sequence

The Natural Resources Conservation Service (formerly Soil Conservation Service) has recommended that sediment reductions on farmland in the Minnesota River basin be pursued by introducing residue management on cropland through a three-stage process:

• First, cropland eroding at a rate higher than T, or the rate at which soil can replace itself naturally, should be treated with appropriate conservation tillage practices.

• Second, if the sediment reduction achieved through the first step is inadequate, suitable conservation tillage methods should be extended to fields adjacent to streams and field ditches—so-called riparian areas where eroded soil directly enters surface water channels.

• Third, if these two measures prove insufficient, suitable conservation tillage practices should be extended to fairly level terrain where sediment losses occur. Priority should be placed on fields with surface tile inlets, side inlets, or plow drains leading to ditches, or comparable surface drainage conduits. A range of methods can be used to reduce sediment losses through such conduits, depending on the situation. These include conservation tillage, alternative tile inlet designs, vegetative buffer zones, wetland restoration, or closer pattern tiling in areas that pond but are not classified as protected wetlands.

Critical Management Factors

The performance of reduced tillage systems depends on a wide variety of management factors that differ from those used under clean-till systems. Crop rotation, equipment selection and adjustment, fertility management, weed control, and drainage are among the critical factors required for successful use of reduced tillage systems.

The degree of management changes required depends on the extent of tillage reduction. Farmers who substitute the chisel plow for the moldboard plow face minor management changes, while those adopting no-till face systematic adjustments touching many aspects of crop management. Farmers in the eastern part of the Minnesota River basin, where annual precipitation averages 28 inches or more, will often face higher management requirements than those in the western part of the basin where rainfall is lower. Similarly, farmers with poorly drained, fairly level fields face greater challenges than those farming better drained, sloping fields.

• Crop Rotation

Each crop rotation presents distinct opportunities and challenges for residue management:

• Continuous corn and continuous small grains are the most restrictive cropping sequences for residue management. This is because of the high quantities of residue produced, increased potential for disease transmission and insect problems, and the loss of rotational advantages such as yield stimulus and improved weed control. Chisel plowing and ridge tillage are best suited to residue management under continuous cropping, but moldboard plowing may be required under high-stress conditions such as compaction. Crop residue should be removed from the seed furrow at planting.

• The corn-soybean rotation, the most prevalent cropping system in the Minnesota River basin, is much more flexible than continuous corn. Properly managed, and used in an appropriate soil and climate zone, reduced tillage systems of all types can be successful. On well-drained soils, corn can be planted into soybean residue with little risk of yield reduction if residue is evenly distributed by the combines and is cleared from the rows before or at planting, and if P and K are banded near the rows. Soybeans can be planted or drilled into fairly heavy corn residue without a yield penalty on well-drained fields. In poorly drained fields, chisel plowing often promotes higher corn and soybean yields by aerating and warming the soil, especially in cool, wet springs or in compacted soil.

• Small grain following soybeans can perform well under a wide range of tillage systems, from chisel-plowing to no-till. However, some yield reductions may occur on heavier, poorly drained soils unless full-width deep (6"-8") tillage is used. Moisture saving can be an added benefit of reduced tillage in the western part of the basin in years when soil moisture is limited. To avoid disease problems, wheat and barley should not follow corn in the rotation. Winter wheat seeded no-till into barley stubble is a promising rotation for west central Minnesota, thanks to the winter protection afforded by stubble-trapped snow cover.

• Drainage

• Choose well-drained fields for high-residue systems. Either natural or artificial drainage is a must. On soils that are naturally tight and poorly drained, tile drainage is a prerequisite to successful high-residue farming.

• Artificial drainage activity must not violate wetland preservation laws, however, and might need to be accompanied by such practices as vegetative riparian buffers around surface inlets and drainage ditches, and possibly temporary impoundment of drainage water.

• Planting

• Use planters and drills designed for heavy crop residue—not older, lightweight units designed for moldboard-plowed fields. Some modern planters and drills are flexible, designed for conventional and reduced tillage and no-till.

• For soybeans, choose varieties that are resistant to phytophthora root rot, and avoid planting when fields are too wet.

• Clear residue from the corn row or small grain furrow before or at planting, using coulters, finger wheels, and other such toolbar attachments.

• Avoid planting through piles of residue or chaff left by the combine. Use chaff spreaders and choppers to avoid residue piling.

• Fertilization

• Soil testing should be used to correct low P and K fertility problems before introducing high-residue farming systems. In addition, it should be used to manage P and K levels for optimal crop performance and minimal pollutant loading from any sediment that leaves the field. Move toward a medium to high soil test for phosphorus (about 15 to 20 parts per million). Limiting the concentration of phosphorus in the soil will reduce the pollutant content of sedimentation without limiting yield potential.

• Starter fertilizer: Band-apply starter fertilizer next to corn rows where full-width deep tillage is not used.

Either apply the full P-K requirement, or the first 20 to 30 pounds.

• Nitrogen: Inject, rather than broadcast, nitrogen fertilizer. Best options are injecting anhydrous ammonia, or injecting or incorporating 28 percent liquid nitrogen at early cultivation. If urea is broadcast, incorporate within three days.

• Weed Control

• Avoid starting very-reduced tillage systems on weed-infested fields.

• Perennial weed problems often increase with no-till or ridge-till. Be prepared to control a shifting spectrum through crop rotation, mechanical controls, and timely treatments of carefully chosen herbicides.

• Herbicide timing and choice become more critical as you rely less on tillage to control weeds. However, with today's wide choice of herbicides, excellent control with little or no tillage is highly feasible, often at little or no additional weed control cost compared with conventional tillage.

• Producers in the western part of the basin should not rely on rainfall to activate herbicides applied at or after planting time. Early pre-emergence treatments generally are activated, but may be difficult to schedule.

• Total post programs are feasible, and pre-post combinations including residual and contact products offer a range of reliable options.

• Soybeans planted into heavy corn residue generally require a burn-down treatment. This is not usually necessary for corn planted into soybean stubble in late April or early May.

• Banding of herbicides provides effective weed control with many tillage systems.

• Mechanical weed control, using the rotary hoe or cultivator, is a best management practice for corn and soybeans, and can be an economical choice under many situations.

Performance Summary of Tillage Systems

For purposes of evaluating tillage systems, the Minnesota River basin can be divided into four regions based on soil parent material and rainfall. The two soil parent materials are lacustrine and glacial till. Lacustrine soils, which are fine-textured and poorly drained, are found south of Mankato, in the Blue Earth basin, as well as to the northwest of New Ulm in Renville, Chippewa, and northern Lac Qui Parle counties, and in isolated pockets elsewhere. Most of the rest of the soils are classed as glacial till. The east-west dividing line is formed by the 28-inch annual precipitation line, which runs roughly north-to-south between Highways 71 and 15. Based on these distinctions, the following four regions have been delineated:

Lacustrine, High Rainfall (L-HR)
Lacustrine, Low Rainfall (L-HR)
Glacial Till, High Rainfall (G-HR)
Glacial Till, Low Rainfall (G-LR)

Each of the five tillage systems identified earlier are evaluated using the following four performance indicators:

1) ***Inadequate residue for sediment control*** — considerably less than 30 percent of surface covered after planting. Highest yields may be obtained, however, on poorly drained, fine-textured, high organic matter soils.

2) ***Recommended with good management*** — If the above management guidelines are observed, no yield penalty is expected, and surface residue should be 30 percent or more.

3) ***Excellent management required*** — Surface residue should be adequate for erosion control, but a slight yield penalty is possible, even if all recommended management practices are observed. Above average crop management, especially weed control without excessive herbicide use, will be needed to ensure profitability.

4) ***Reduced yield potential*** — Surface residue should be adequate for erosion control, but the potential exists for substantially reduced yields in wet years on poorly drained sites.

Soybeans Following Corn

	Lacustrine Soils		Glacial Till Soils	
	HR	LR	HR	LR
MB Plow	1	1	1	1
Chisel Plus	2	2	2	2
1 or 2 Passes	3	3	2	2
Ridge Till	3	2	2	2
No Till	3	3	3	3

Corn Following Soybeans

	Lacustrine Soils		Glacial Till Soils	
	HR	LR	HR	LR
MB Plow	1	1	1	1
Chisel Plus*	2	2	2	
1or 2 Passes	2	2	2	2
Ridge Till	3	3	2	2
No Till	4	4	3/2	3/2

* Even if straight shanks are used, this system cannot reliably achieve the 30 percent surface residue target, and must be used in a rotation where corn residue levels are at least 40 percent after planting.

Continuous Grain Corn

	Lacustrine Soils		Glacial Till Soils	
	HR	LR	HR	LR
MB Plow	1	1	1	1
Chisel Plus	3	2	2	2
1or 2 Passes	4	4	4	4
Ridge Till	3	3	2	2
No Till	4	4	4	4

Small Grain Following Soybeans

Tillage System	Glacial till Soils	Lacustrine Soils
MB Plow	1	1
Chisel Plus	2	2
1or 2 Passes	2	3
No Till	2	3

This set of publications was the result of a joint effort between Minnesota Extension Service, Minnesota Agricultural Experiment Station, and Minnesota Pollution Control Agency. This information was first presented February of 1995 at the Sediment Control Solutions Conferences in Mankato and Montevideo, MN.

To order other publications in this series, contact your Minnesota County Extension Office or, outside of Minnesota, contact the Distribution Center at (612) 625-8173. Titles in this series include:

- *Tillage Best Management Practices for Continuous Corn in the Minnesota River Basin* (FO-6672).
- *Description of the Minnesota River Basin and General Recommendations of Residue Management Systems for Sediment Control* (FO-6673).
- *Tillage Best Management Practices for Small Grain Production in the Upper Minnesota River Basin* (FO-6674).
- *Economic Comparison of Incremental Changes in Tillage Systems in the Minnesota River Basin* (FO-6675).
- *Tillage Best Management Practices for Corn-Soybean Rotations in the Minnesota River Basin* (FO-6676).

The six publications are also available as a package:

- *Tillage Best Management Practices for the Minnesota River Basin Based on Soils, Landscape, Climate, Crops, and Economics* (BU-6644)

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