Replumbing Minnesota's Landscape

How Agricultural Drainage Alters Rivers and Degrades Water Quality

MCEA

EXECUTIVE SUMMARY

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The artificial drainage of Minnesota's agricultural land has increased over the past several decades, with profound costs to the quality of our lakes and streams, fish and aquatic species, recreation, and downstream infrastructure. Beginning around the mid-1970s, corn and soybeans, which require relatively dry soil conditions to thrive, became dominant crops among Minnesota growers. Because Minnesota was naturally home to many wetlands, prairie potholes, and low-lying saturated areas, farmers needed to drain their fields to achieve dry soil conditions. As a result, many agricultural fields in Minnesota are now underlain by perforated plastic pipes (referred to as "drain tile"), which collect and deliver water to public and private ditches and ultimately to our lakes, rivers, and streams.

These drainage systems negatively impact water quality in two main ways. First, the increased volume of water delivered from below agricultural fields to our waterbodies causes dramatic physical alterations of watercourses and surrounding infrastructure. This increased volume of water causes riverbanks to erode, sediment to build up in downstream waters, and floods that are more common and severe. Agricultural drainage has nearly doubled the total flow of river systems like the Minnesota River, exacerbating downstream flooding and increasing damage to infrastructure in and along the river.

Second, agricultural drainage harms aquatic life and water quality in downstream waters. Increased erosion results in more turbidity—or amount of suspended sediment—in rivers and streams, which degrades aquatic habitat and can make waters unsuitable to fish or swim in. Nutrients like nitrogen and phosphorus in chemical fertilizer and manure escape the farm through the drainage network, bypassing nature's filtration systems and polluting many streams, rivers, and lakes. The effects of agricultural drainage on water quality are particularly pronounced in the Minnesota River Basin, where many waters do not meet state standards for maintaining a healthy aquatic ecosystem and supporting aquatic recreation.

The harms to water quality caused by agricultural drainage are exacerbated by the added influence of climate change on our water resources. The changes in water flows over time are not due solely to changes in precipitation patterns caused by climate change. However, the increased likelihood of severe rainfall events due to climate change compounds the negative impacts from agricultural drainage.

The good news is that there are known practices that can help reduce the consequences of agricultural drainage. We need a combination of best management practices that include changes in land use, changes in nutrient use, and edge-of-field practices to ultimately make Minnesota's waters fishable, swimmable, and drinkable again. Retaining water on fields before it enters lakes and streams is the most effective way to reduce erosion caused by the increased volume of water due to drainage. And there are other practices that help to "treat" drainage water (i.e. allow pollutants to naturally filter out) or slow it down. But despite knowing the consequences of agricultural drainage and the means to mitigate those consequences, the promotion of voluntary practices has not resulted in the widespread adoption needed to make a difference.

We recommend four policy changes that can begin to mitigate the harms to water quality from agricultural drainage. First, we support efforts to quantify and include the externalized economic costs of drainage projects in the information considered by drainage authorities when evaluating petitions for new or improved public drainage systems. Second, we recommend a more robust process for considering the environmental effects of drainage projects, which could also aid the state in determining how to meet its nutrient reduction goals. Third, cap-and-trade systems have been successfully used to reduce other pollutants in Minnesota and could be used to reduce nitrate and sediment pollution from drainage. Last, we recommend that the Minnesota Pollution Control Agency ("MPCA") develop a permitting system for new and improved drainage projects. The water quality issues caused by agricultural drainage are similar to stormwater management problems observed as a result of intensive development in the 1950s, which eventually resulted in the development of a robust and effective stormwater management permit program at the national and state levels. MPCA could implement a similar system to mitigate water quality harms for agricultural drainage projects through a state permit.

Minnesota values its lakes, rivers, and streams. Yet many are impaired to the point that we cannot swim or fish in them or the water is not safe for drinking. MPCA and other state agencies recognize that agricultural drainage is one of our biggest hurdles to improving our waters in intensively-drained watersheds. We need to address this hurdle if we hope to have water that is fishable, swimmable, and drinkable again.

Agricultural drainage systems are found throughout Minnesota and have been in use for more than 100 years.

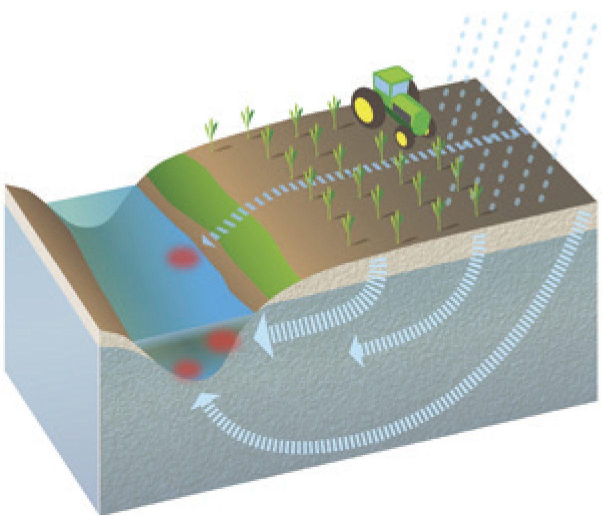
SECTION ONE

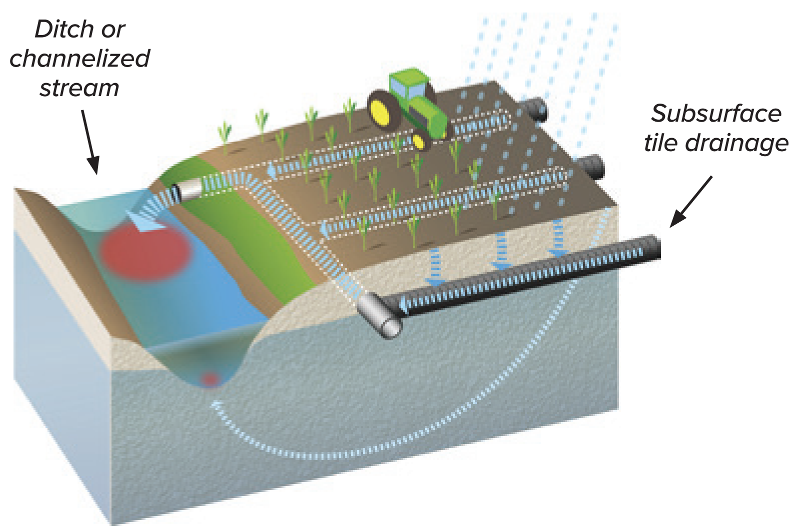
The Drainage Landscape in Minnesota

How does agricultural drainage work, and what are its positive and negative impacts? What is the legal framework for agricultural drainage in Minnesota, and where are the gaps?

If you have driven around in farm county, you have likely noticed ditches that parallel the road and crisscross the landscape. You may also have noticed formerly natural streams that have been dredged and channelized to accommodate drainage runoff. In addition to these visible landscape alterations, below the surface there are countless miles of perforated plastic pipe that play a hugely important role in modern agriculture. Farmers install these pipes below the soil to help lower the water table below cultivated fields, which allows crops to grow in unsaturated soils to maximize yield. But this comes at a cost. Water from rain and snowmelt quickly moves off the field and into a network of private and public drainage systems. This "short circuits" the natural hydrological cycle, and shuttles water from below fields and into Minnesota's lakes, streams, and rivers at rates that dramatically increase downstream flows, scour riverbanks, and artificially accelerate erosion. This drainage water is also rich in nitrogen and phosphorus, two of the primary nutrients in fertilizer and manure, which at elevated levels can harm aquatic life and make rivers unsuitable for fishing, swimming, or for drinking water. Artificial agricultural drainage is a major reason why many Minnesota waterbodies are listed as "impaired" or below state water quality standards.

Artificial agricultural drainage refers to surface and subsurface components that work together to remove excess water from farmland to maximize crop production. Below the surface, perforated pipes buried under cultivated fields funnel water





The Effects of Artificial Agricultural Drainage *In cropland without tile drainage (left), most rainwater flows through the ground to get to surface waters. As it travels through the earth, some of the nitrates are removed, resulting in less nitrates reaching our streams and rivers. In tiled cropland (right), most of the rainwater that ends up in surface water (ditches, streams, wetlands) flows through the tile drainage. This water can be high in nitrates.*
Images reprinted with permission from the Minnesota Pollution Control Agency.

Replumbed

Channelized streams are natural streams that have been artificially straightened, deepened, or widened. The effect of channelization can be seen in these aerial photographs of Lower Brush Creek in the Blue Earth River Watershed.

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from the soil profile into a network of larger pipes that direct water to discharge points. This part of the drainage system is often referred to as "drain tile" or "pattern tile" because in the early days of agriculture farmers used clay tiles rather than plastic pipes to drain their fields. The water from the underground pipes typically outlets into an **altered watercourse**, which is either a ditch or a channelized stream designed to convey water away from agricultural land. **Ditches** on private land are often excavated channels where no channel previously existed, and **channelized streams** are natural streams that have been artificially straightened, deepened, or widened to function more like a ditch. Altered watercourses ultimately outlet into larger bodies of water, such as rivers or lakes.

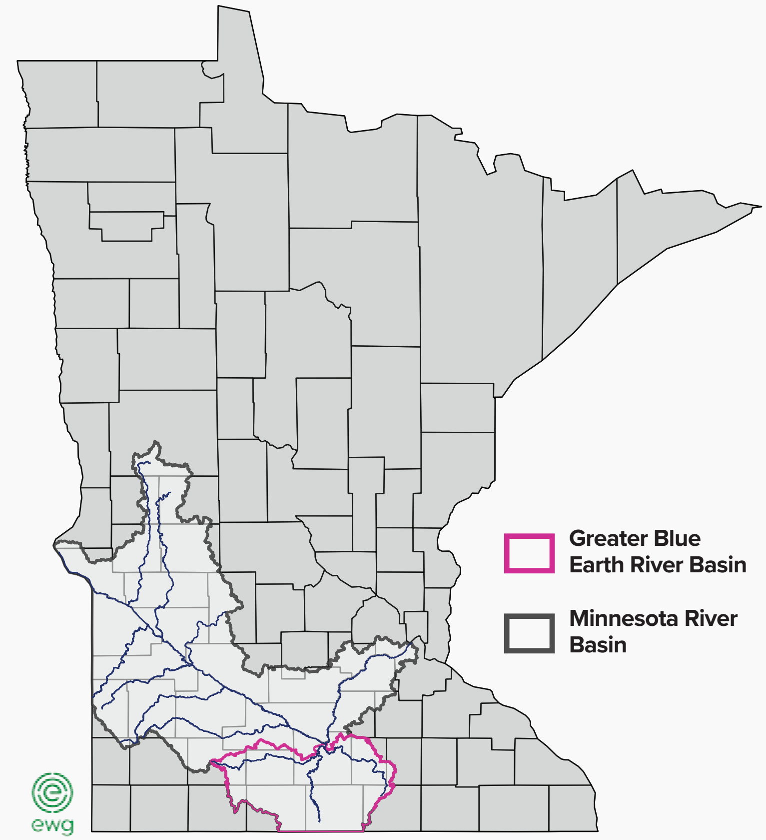
Artificial agricultural drainage is comprised of privately and publicly owned components. Much of the drain tile, or perforated pipes under cultivated land, are privately owned and not subject to regulation. A farmer who wishes to install drain tile below their fields does not need a permit or permission to do so. Privately owned drain tile usually outlets into a public drainage system, a network of larger subsurface pipes and county ditches (usually channelized streams) within a defined boundary that is overseen by elected officials in their role as county drainage authorities. If a landowner is within the defined area of a public drainage system, they do not need a permit or permission to discharge water from their privately owned fields into the public drainage system.

Public drainage systems were created under **Minnesota's Drainage Code**, a series of laws enacted over a century ago to help facilitate the drainage of wetlands, swamps, and low-lying areas for agricultural development. Today, there are 100 public drainage authorities across Minnesota. These bodies of government are controlled by county boards of commissioners or watershed districts, and they have broad authority to establish new drainage systems, authorize an existing drainage system to be enlarged, extended, straightened, or deepened, or order the repair or restoration of an existing drainage system.

Artificial agricultural drainage has "replumbed" much of Minnesota. Gone are most of the wetlands, prairie potholes, and other landscape features endemic to Minnesota that absorb and retain water. In their place are acres of monoculture crops like corn and soybeans with vast networks of perforated plastic pipes laid below the surface. This practice is widespread; approximately 50% of the land in Blue Earth County, for example, drains to a county ditch, and Minnesota farmers continue to add over 100 million feet of subsurface drainage pipe each year. The result is drier soil, fewer isolated wet spots in low-lying areas, and a dramatic increase in the amount and speed at which water, and associated agricultural pollutants, are funneled into natural streams, rivers, and lakes. These drainage systems are one of the reasons why water quality in streams, rivers, and lakes across the state are impaired or in decline.

Southern Minnesota is one of the most heavily drained regions of the state. In the Minnesota River Basin, agricultural drainage is why our state's namesake river is one of Minnesota's most polluted. Altered watercourses are common in this region: meandering streams have been channelized and straightened to better move water off the landscape, ditches have been constructed to collect water draining off fields, and each year miles of channelized streams and ditches are excavated to restore flow to its constructed condition. More producers are installing "pattern tiling"—laying dense concentrations of pipe in a large grid system under every acre under cultivation. This practice has increased alongside the shift to corn and soybean production, and the newer plastic pipes are easier to install and are better at removing water from the landscape than the clay or concrete tile of yesterday. These changes have greatly increased the volume of water carried into ditches, streams, or lakes, which can raise water levels by five feet or more. These newer practices also increase pressure on the existing drainage system, and landowners are petitioning drainage authorities for permission to increase the water capacity of public drainage systems through larger subsurface pipe sizes and wider and deeper ditches.

A History of Land Management *Clay drain tile pipes were once laid by hand as shown in this historic photo (left) of early Minnesota farming. (Ayer, Harry Darius, circa 1910, Minnesota Historical Society) Modern equipment (right) like excavators and tile plows allows farmers to install perforated plastic piping quicker and easier.*



The Minnesota River Basin

This report focuses on the Minnesota River Basin, one of the areas of the state most impacted by agricultural drainage. This report includes case studies from the Greater Blue Earth River Basin—which includes the Le Sueur, Watonwan, and Blue Earth River watersheds—and the mainstem Minnesota River downstream from its confluence with the Blue Earth River. To help policymakers take corrective action to restore the ecological and biological integrity of Minnesota's waters, we need to understand the baseline environmental consequences of artificial agricultural drainage in heavily drained watersheds like the Minnesota River Basin.

Regulatory Framework

The environmental impacts from agricultural drainage are largely unregulated in Minnesota. Here is a snapshot of the legal landscape for agricultural drainage.

The Drainage Code is a chapter of Minnesota laws that explain the process for establishing, improving, or repairing public drainage systems. These statutes were developed over a century ago to legally allow wetlands, swamps, and other landscape features to be drained to permit agricultural expansion. The limited environmental considerations in the Drainage Code have been ineffective at slowing or preventing water quality deterioration from agricultural drainage.

The Minnesota Pollution Control Agency monitors environmental quality and helps prevent and reduce air, land, and water pollution through permitting programs and regulations. The agency does not have a permit program for agricultural drainage and does not currently evaluate drainage projects for environmental effects.

The Minnesota Department of Natural Resources manages the state's aquatic resources. The agency can require a permit for a proposed drainage project if the project may impact public waters. However, this authority has limited application; in Blue Earth and Martin counties, two of the most extensively drained counties in the state, the department has required a permit in six instances in the past fourteen years. In addition, the public waters permit program is designed to address changes to the course, current, or cross-section of public waters rather than cumulative water quality impacts.

The Clean Water Act is designed to address and prevent water pollution. Agricultural drainage largely falls outside the sweep of this law.

SECTION TWO

Muddy Waters: the Role of Drainage in Altered Hyrology

How has agricultural drainage transformed water flow and sediment transport across the Minnesota River Basin?

In the Minnesota River Basin, decades of artificial agricultural drainage and the recent expansion of many agricultural drainage systems have physically altered surface waters and are a key contributor to the poor water quality in the region. More specifically, artificial agricultural drainage has increased the flow and velocity of surface waters in this region. That additional flow and velocity exacerbate streambank erosion and channel scour, which means more sediment clouds our waters and degrades aquatic habitat.

Background: The Minnesota River Basin covers approximately 16,770 square miles in southwestern Minnesota and drains into the Mississippi River. It includes three watersheds—Blue Earth River, Le Sueur River, and Watonwan River—which together drain land from 14 counties in southern Minnesota and northern Iowa. Historically dominated by tall grass prairie and wetlands and characterized by fine-grained, slowly drained soils, the region is now mainly used to grow corn and soybeans (often referred to as "row-crop" agriculture). This change in land use has been accompanied by the extensive installation of subsurface drainage pipes and ditch systems, which began in the late 19th century. Over the past several decades, farmers in this region have increasingly requested permission from public drainage authorities to expand the capacity of public drainage systems (i.e. increase pipe size and ditch width to allow them to carry more water) in order to improve crop productivity. Expanded drainage has contributed to significant increases in streamflow, which has degraded water quality and aquatic habitats. These impacts are the most profound in the Blue Earth and Le Sueur River watersheds that make up the Greater Blue Earth River Basin. These impacts can also be seen in most tributaries to the Minnesota River and many other watersheds throughout the Upper Midwest.

The Minnesota River Basin was largely shaped by glacial events nearly 11,500 years ago that lowered the elevation of the Minnesota River by up to 250 feet. As a result of this glacial history, the basin is highly sensitive to erosion and changes in hydrology, and its rivers have some of the fastest rates of incision in the world.

The Minnesota River Basin is vulnerable to erosion because of its unique geologic history, but land-use decisions have exacerbated rather than protected it from this vulnerability. The instability and erosion of the lower reaches of Minnesota River tributaries and the mainstem Minnesota River have been accelerated by the extensive expansion of agricultural drainage systems, which has contributed to excessively high river flows. The expansion of drainage systems in Minnesota dates back to the late 19th century, when European settlement first began to transform Minnesota from a wetland-rich prairie landscape to one dominated by monoculture row-crop agriculture. This transformation was accomplished through the installation of drainage ditches and the channelization of natural streams to better accommodate water drained from agricultural land.

The most dramatic transition in the Minnesota River Basin came with the shift from hay and small-grain production to corn and soybeans from the mid-1970s through the early 1990s. This transition from diverse perennial land cover to annual monoculture systems was accompanied by an increased reliance on subsurface drainage systems to lower the water table. This further altered the natural hydrology of the Minnesota River Basin. With perennial cover, excess water infiltrates further down into the soil, aided by deep prairie roots, where it either eventually becomes groundwater or flows through the sediment to nearby wetlands, streams, and lakes. In contrast, crops like corn and soybeans only grow for part of the year (typically between late May and late August) and do not have deep root structures. This reduces water infiltration in the soil and causes more "flashy" peaks in water volume delivered to streams, rivers, and lakes.

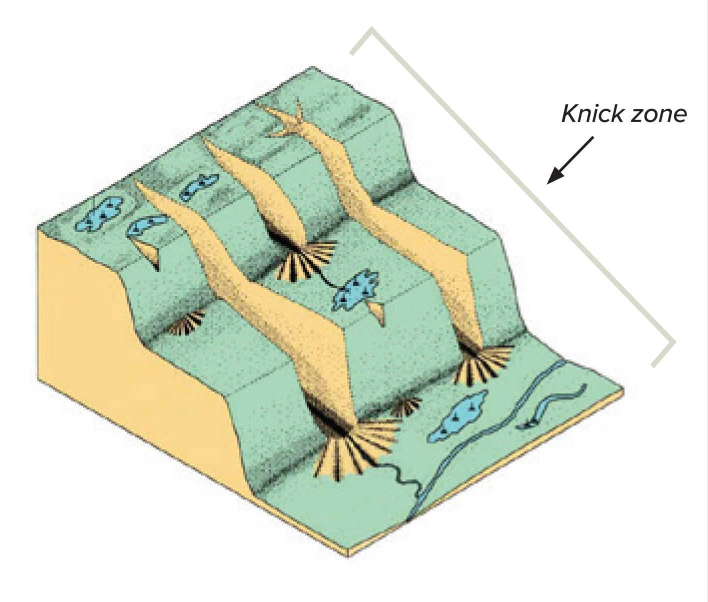
Agricultural drainage systems rapidly convey water to streams, which leads to faster and more intense streamflow events than would occur with the natural infiltration of water through the soil in the absence of extensive drainage. In urban and suburban landscapes, impermeable surfaces like pavement and concrete have a similar effect on the hydrological cycle, but federal and state laws address this through permit requirements as well as research and grant opportunities for stormwater-design innovation to remain compliant with state and federal rules. We have yet to develop the same permit requirements and level of grant support for innovation in agricultural drainage system design.

Hydrological impacts

Artificial agricultural drainage networks alter natural hydrology in ways that increase the flow and velocity of water in stream and river networks. This additional flow and velocity exacerbates streambank erosion and degrades channel stability. Ditch channels artificially extend the network of streams that drain into a mainstem river further upstream and increase the amount of water drained to downstream areas, while channelized natural streams send water downstream faster.

Glacial History

The landscape and extensive network of streams and rivers in the Minnesota River Basin are geologically young, shaped by events that occurred during the most recent glacial period that ended around 11,500 years ago. The most consequential of these events was the catastrophic drainage of Glacial Lake Agassiz, which carved out the Minnesota River Valley and lowered the elevation of the Minnesota River by as much as 250 feet. This caused tributary streams and rivers to **incise**, or downcut their channels with the steep increase in slope and energy gradient as they dropped in elevation to meet the Minnesota River. The area where rivers steeply drop in elevation from their original floodplain to the carved-out Minnesota River Valley is called the **"knick zone."**



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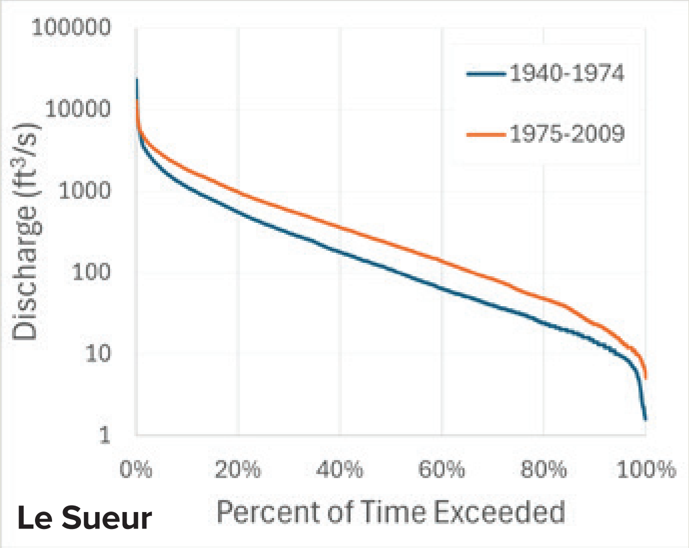
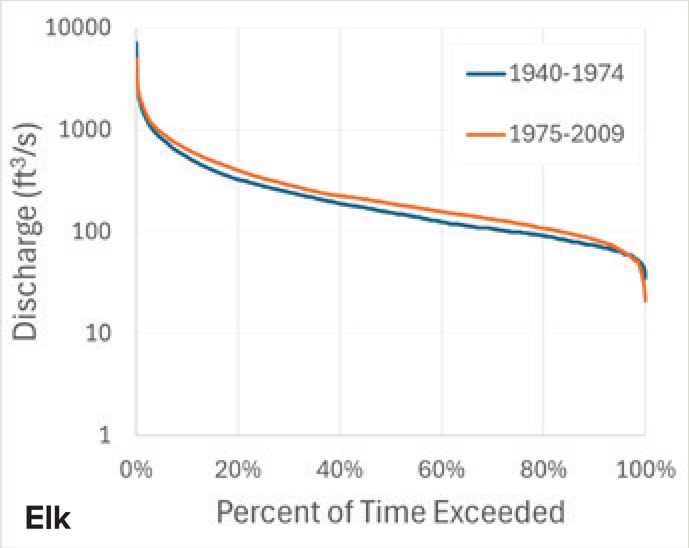
Finally, artificial drainage networks bypass historic stormwater storage areas such as wetlands, lakes, and side-channel oxbows of rivers. In the Minnesota River Basin, the net impact of these hydrological changes is that drainage networks have increased the **total flow volume** of the Minnesota River and its major tributaries. The total flow volume of a river, or the discharge, is the volume of water that passes a given point within a specific amount of time. The increase in flows due to artificial drainage are large and unambiguous.

For evidence of this change, we can look at **flow duration curves**, a tool that hydrologists use to evaluate changes in a river system across low, moderate, and high flows. Flow duration curves for the extensively drained Blue Earth and Le Sueur rivers were examined for the period of 1940 to 2009. These curves show that the volume of water that flowed from these rivers into the Minnesota River increased dramatically beginning around 1976. This increase in total flow volume correlates with the shift from hay and small-grain production to corn and soybeans, and the expansion of subsurface tile drainage throughout the Minnesota River Basin. Flow increases in tributaries like the Blue Earth and Le Sueur rivers have a large cumulative impact on the mainstem Minnesota River. In fact, research shows that the installation and expansion of artificial agricultural drainage systems in the Minnesota River Basin have caused a 2- to 4-fold increase in low flows and a 1.5- to 3-fold increase in high flows, which includes floods.

Increases of flow of this magnitude are exceedingly rare in the world for such a large river system and cannot be attributed to climate change-induced shifts in precipitation alone. A study of Minnesota watersheds found that heavily drained watersheds had more than a 50% increase in annual water yields since 1940, and that artificial drainage and the loss of water storage on the landscape accounted for more than one-half of the increase, on average. Streamflow analysis in the Minnesota River Basin shows that, while precipitation has increased slightly in recent decades from November to February, streamflow has increased over time in every month of the





Flow duration curves *allow us to compare the full range of flows for any two time periods. These plots show that the entire range of flows has increased in magnitude (i.e., the entire curve shifted up) for the 1975-2009 time period in the watershed that has been extensively tiled (Le Sueur, shown at left) much more dramatically than the watershed that has minimal tiling (Elk, shown at right).*

year. There has also been no discernable change in precipitation in May and June over time, but there has been a large increase in streamflow during these months; this is the time when subsurface tile drains are the most active. Notably, researchers have not observed such a hydrological change in river basins that have not been extensively drained, such as the Chippewa River Basin of Wisconsin.

In addition to increased river flows, artificial agricultural drainage has increased the **"flashiness"** of the Minnesota River and its tributaries, or how quickly peaks in streamflow rise and fall after precipitation events. This is because drainage systems are designed to accelerate the drainage of water below crop roots, whereas under natural conditions this underground water would drain to nearby lakes and streams very slowly through the intricate labyrinth of pore spaces between sand, silt, and clay particles. Because drainage systems alter natural water retention patterns in the soil and on the landscape, they contribute to larger peak discharges after storms.

In extensively drained river systems like the Minnesota River, hydrologists have studied the rate of streamflow rise and fall over time. What they have found is that streamflow is "flashier" in these river basins after the historical land use conversion from small grains to corn and soybeans—and the associated installation of sub-surface drainage that accompanied this shift in crop production.

The net impact of excessively high and flashy flows caused by the expansion of artificial agricultural drainage systems can be seen in the cloudy waters of the Minnesota River and its tributaries. Increased high flows due to artificial agricultural drainage have more quickly eroded riverbanks and bluffs, which has dramatically increased sediment loads in the Minnesota River Basin. This is especially pronounced in the "knick zones," or the geologically vulnerable river reaches throughout the Minnesota River Basin. In these areas, artificial agricultural drainage has accelerated natural erosion and made

Climate Change Increases the Challenge

The observed increases in streamflow across the Minnesota River Basin over the past 30+ years are not the result of changes in precipitation alone. But increases in precipitation due to climate change exacerbate the problem, and heavily drained watersheds are less resilient to these intense precipitation events. For example, the Minnesota State Climate Office reports that, since the early 20th century, the frequency of 3-inch rainfall events has increased by 65%, and rain events that dump more than six inches of rain have spiked dramatically, with eleven such events recorded in the last two decades. The increased water volume from these rain events overwhelms the rate of soil absorption, even with the increased drainage capacity of pattern-tiled landscapes, which leads to heavy volumes of surface runoff in addition to subsurface water delivery through drainage pipes. And without adequate water storage on the landscape, heavily drained watersheds cannot buffer the impact of these intense precipitation events.

river channels wider, deeper, and more prone to move within their floodplain (a process called lateral migration).

A study of Minnesota watersheds found that, on average, rivers with increased flows because of agricultural drainage have widened by 10 to 40% in a process driven by more frequent erosive flood events. In one dramatic example, a study in the Le Sueur River found that the river's channel area increased by 60% from 2008 to 2015. The mainstem Minnesota River has also increased in channel width between Mankato and Jordan. Downstream from Jordan, where the geology changes, the Minnesota River has increased in flow but has not widened or deepened to the same extent, which means that towns along the riverbanks have been more frequently flooded in this area.

These flashy flows have resulted in considerably increased risks and damage to downstream infrastructure built near riverways, at a great cost to the people of Minnesota. For example, artificial agricultural drainage played a role in the partial failure of the Rapidan Dam in June 2024. Heavy rainfall and excessive sedimentation in the reservoir triggered the dam failure, both of which were amplified by artificial agricultural drainage. This breach caused severe erosion, destroyed a nearby home, and led to the demolition of the historic Rapidan Dam Store. The adjacent County Road 9 bridge suffered irreparable damage, with erosion that compromised its structural integrity.

Erosion Due to Increased Flow *Over the past few decades, erosion of river-channel beds, banks, and bluffs has increased due to increased flows exacerbated by pervasive artificial agricultural drainage. This photo illustrates bank erosion along Hawk Creek in Renville County.*

Preliminary assessments found that the County Road 9 bridge is "likely not repairable or not economically feasible to do repairs" and that costs to replace the bridge would be at least $15 million, with some estimates as high as $80 million if you include the loss of use of the road for three years.

These costs extend beyond single catastrophic events like the Rapidan Dam's failure and include significant infrastructure improvement costs over the years. In the last 15 years, the Minnesota Department of Transportation spent over $35 million on four roadway and bridge projects in the Mankato area to address riverbank stabilization and flood resiliency.

In the Greater Blue Earth River Basin, increased flows caused by agricultural drainage in upstream counties like Blue Earth, Martin, Faribault, and Waseca cause widespread erosion in downstream locations. Erosion of river-channel beds, banks, ravines, and bluffs has dramatically increased **sediment loads** in our streams and rivers and directly caused or contributed to the degradation of aquatic habitat and increase in suspended solids (soils) in the water. Sediment sources that are derived from river banks, ravines, and bluffs (referred to as **"near-channel sources"**) can be traced to increased flows from artificial drainage. Studies show that while soil health practices and riparian buffers have reduced sediment that runs directly off farm fields, those gains have been offset by increased sediment from near-channel sources like bluffs.

In the Minnesota River Basin, sediment pollution is primarily from near-channel sources like bluffs that can definitively be traced to increased flows from agricultural drainage. In the Le Sueur River Watershed and the Greater Blue Earth River Watershed, scientists compared natural background rates of erosion and deposition before and after the onset of intensive row-crop agriculture. What they found is that recent bluff erosion rates were more than double the natural background rates of erosion. A key insight from these studies is that erosion rates were elevated due in large part to increased flows that erode downstream banks, ravines, and bluffs, rather than directly from farm field runoff. In fact, increased flows correlated with the expansion of agricultural drainage have more than doubled bluff erosion rates in Blue Earth County and elsewhere in the Minnesota River Basin.

Significant Changes

Extensive agricultural drainage has resulted in significant changes to hydrology in the Minnesota River Basin, including:

Increased total flow volume through increased hydrologic connectivity that amplifies recent increases in precipitation

More "flashy" river flows that quickly rise and fall after precipitation events and cause increased flood damage

Increased sediment loads from the accelerated erosion of river banks, ravines, and bluffs that degrade aquaitc habitat and damage downstream infrastructure

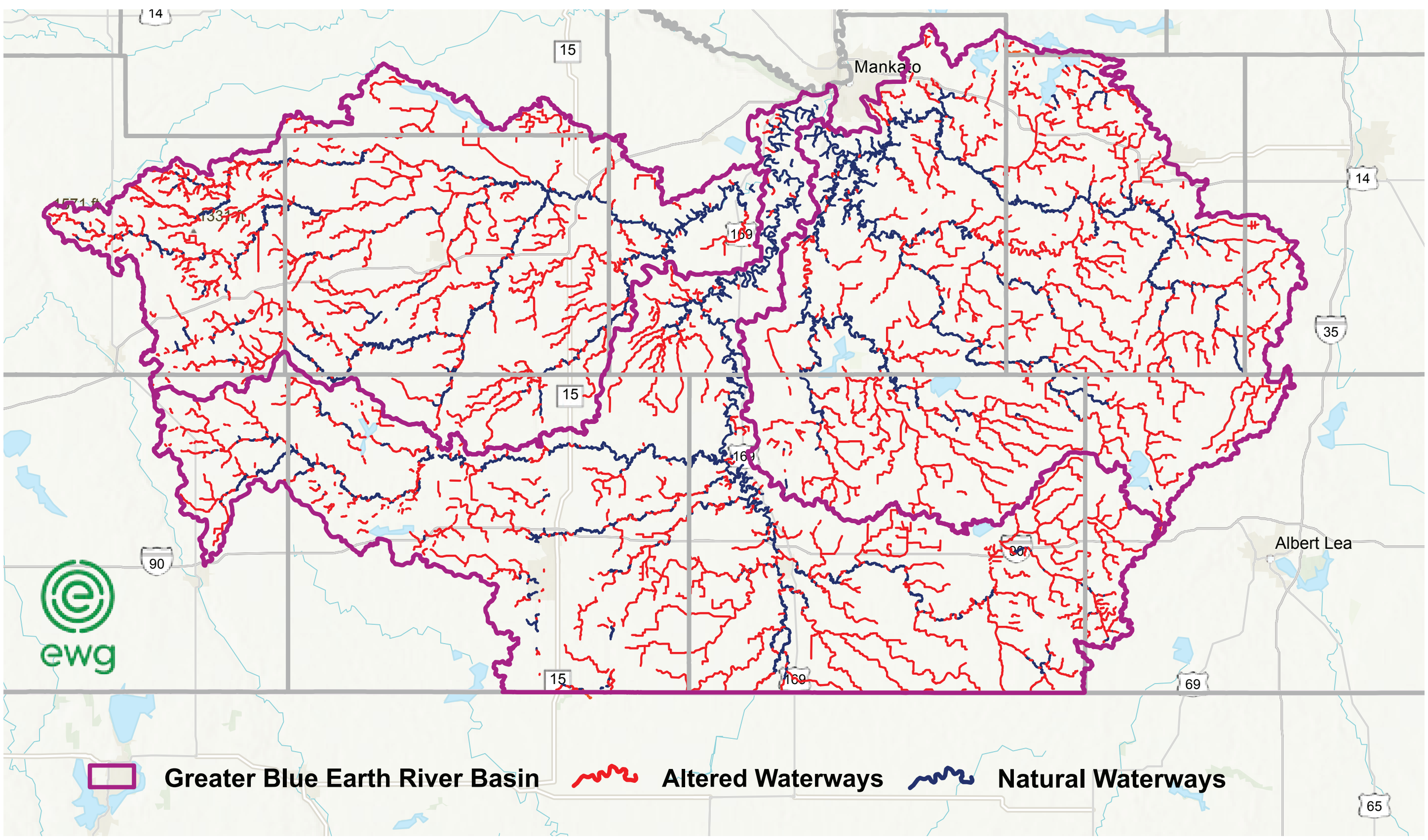
These changes have, in turn, impacted water quality and ecology, with serious implications for aquatic life, recreation, and human health.

SECTION THREE

Fishable, Swimmable, and Drinkable: the Role of Drainage Systems in Water Quality and Ecology

How do the hydrological changes outlined above connect to Minnesota's framework for impaired waters? How does agricultural drainage cause or contribute to individual water quality impairments in the Minnesota River Basin and beyond?

The cumulative impact of the hydrological changes outlined in the previous section is widespread water quality impairments and the degradation of ecological habitat throughout the Minnesota River and Greater Blue Earth River Basin. These impairments occur primarily in **altered watercourses** like county ditches, or formerly natural, meandered streams that were channelized to better accommodate increased runoff from agricultural drainage systems. Impairments are also widespread in the downstream waterbodies that receive runoff from



Altered Watercourses in the Greater Blue Earth River Basin

An "altered watercourse" is defined as any stream whose habitat has been compromised through hydrological alteration. This includes artificially constructed ditches as well as natural streams and rivers whose channels are visibly modified.

these altered watercourses, such as the Minnesota River. These impairments make waterbodies unsuitable for activities like boating, fishing, and swimming, and can impact drinking water sources. Other negative impacts include the loss of fish habitat and biodiversity, increased sediment, eutrophication, and elevated nitrates.

Loss of habitat and biodiversity: Watercourses that are altered to function as ditches are often dredged deeply to allow subsurface drainage tile outlets to drain into the ditch and not flood adjacent farmland. But this practice also eliminates important ecosystems. Fish rely on stream-side floodplain habitats as a refuge to escape the strong currents during high flows and to spawn, and the natural meander of a waterway through its floodplain dissipates the speed of the flow and allows riparian vegetation to remove excess sediment and nutrients.

Excavated ditches and channelized streams are often dredged to be unnaturally wide and uniform in depth. A natural stream widens, narrows, and alternately flows through deep pools and broad shallows. This creates habitat diversity to support large and small and older and younger fish, and a diversity of insects, mussels, and other aquatic species that each have a habitat niche. Watercourses altered for drainage typically lack this habitat diversity and are not able to support the existence of as many fish and invertebrate species as a natural stream with a similar drainage area.

Increased sediment: Increased sediment carried from farm fields and created through downstream erosion clouds the water (turbidity) and reduces the amount of sunlight that reaches the bottom of the stream. This limits the growth of plants and diatoms (single-celled beneficial algae) on rocks that fish and insects use for food. Soil and other organic matter suspended in the water can make it hard for fish and aquatic insects to breathe and locate food. When the suspended sediment settles to the bottom of the stream, it can bury streambed habitat and affect the quality of the gravel used by fish for spawning. In the Greater Blue Earth River Basin, levels of total suspended solids were two to seven times over state standards between 2000-2008.

Eutrophication: Nutrients applied to agricultural fields that aren't absorbed by the crops are carried by drainage systems into waterways in concentrations much higher than occur in those waters naturally. This can lead to eutrophication, which refers to an increase or accumulation of nutrients (such as nitrogen and phosphorous) that sets off a chain reaction of algal blooms, dissolved oxygen loss, and ultimately species loss in an aquatic ecosystem. Algal blooms can also make waters unsuitable for recreational activities like boating or swimming.

Elevated Nitrates: High nitrate levels endanger the safety of drinking water and cause stress to sensitive fish and aquatic insects. Nitrogen fertilizers are often applied to cropland in excess of what the crop needs; the excess remains in and on the soil after application and the nitrogen converts to nitrate, which is harmful to human and aquatic health. Snowmelt or rainwater then moves the nitrate into the drainage system and ultimately to nearby streams or rivers. Because of the artificial drainage system, this water has little opportunity for soil biology to remove harmful pollutants, which magnifies the nitrate delivered to ditches and streams. MPCA estimates that 76% of the nitrogen delivered to the surface waters in the Blue Earth River Watershed is from cropland drainage.

While most of Minnesota draws its public drinking water from groundwater sources, the cities of Mankato and Fairmont, both in the Greater Blue Earth River Basin, draw their drinking water from lakes or shallow groundwater connected to rivers. The Minnesota Department of Health ("MDH") has identified nitrate as a contaminant of concern for these cities, and in 2016 Fairmont had levels of nitrate in the city water supply that exceeded the human health standard of 10 mg/L. The MDH acknowledged the role of artificial agricultural drainage in the nitrate exceedance and stated that for both cities, high concentrations of nitrate were **"likely to recur each spring and fall due to tile drainage and agricultural runoff through upstream watersheds."** The City of Mankato has had to blend water from the contaminated wells with deeper groundwater to keep the city's drinking water below the 10mg/L threshold, and Fairmont has at times had to draw its water from a backup well. Without regulatory controls to mandate nitrate treatment at drainage system outlets, cleanup costs to protect drinking water supplies are left to the public: the Martin Soil and Water Conservation District has received approximately $400,000 in state and federal grants to pay landowners to adopt best management practices like saturated buffers, water and sediment control basins, and conservation easements that take marginal lands out of agricultural production.

Water Quality Impairments in the Greater Blue Earth River Basin

The Greater Blue Earth River Basin has been studied extensively due to the large amount of sediment and nutrients that the Blue Earth River and tributaries produce and send downstream to the Minnesota River, Lake Pepin, and ultimately the Gulf of Mexico. More than 62% of the stream miles in the Blue Earth River, LeSueur River, and Watonwan River watersheds have been altered for drainage, which includes both ditches that have been artificially constructed as well as natural streams and rivers that have been channelized to better accommodate runoff from drainage systems. According to the Department of Natural Resources, only 2.2% of the Blue Earth River watershed has surface water storage features like wetlands and lakes, and approximately 85% of the formerly abundant wetlands in the watershed have been lost due to drainage. In another example, wetlands in the Watonwan River Watershed have decreased by roughly 92%.

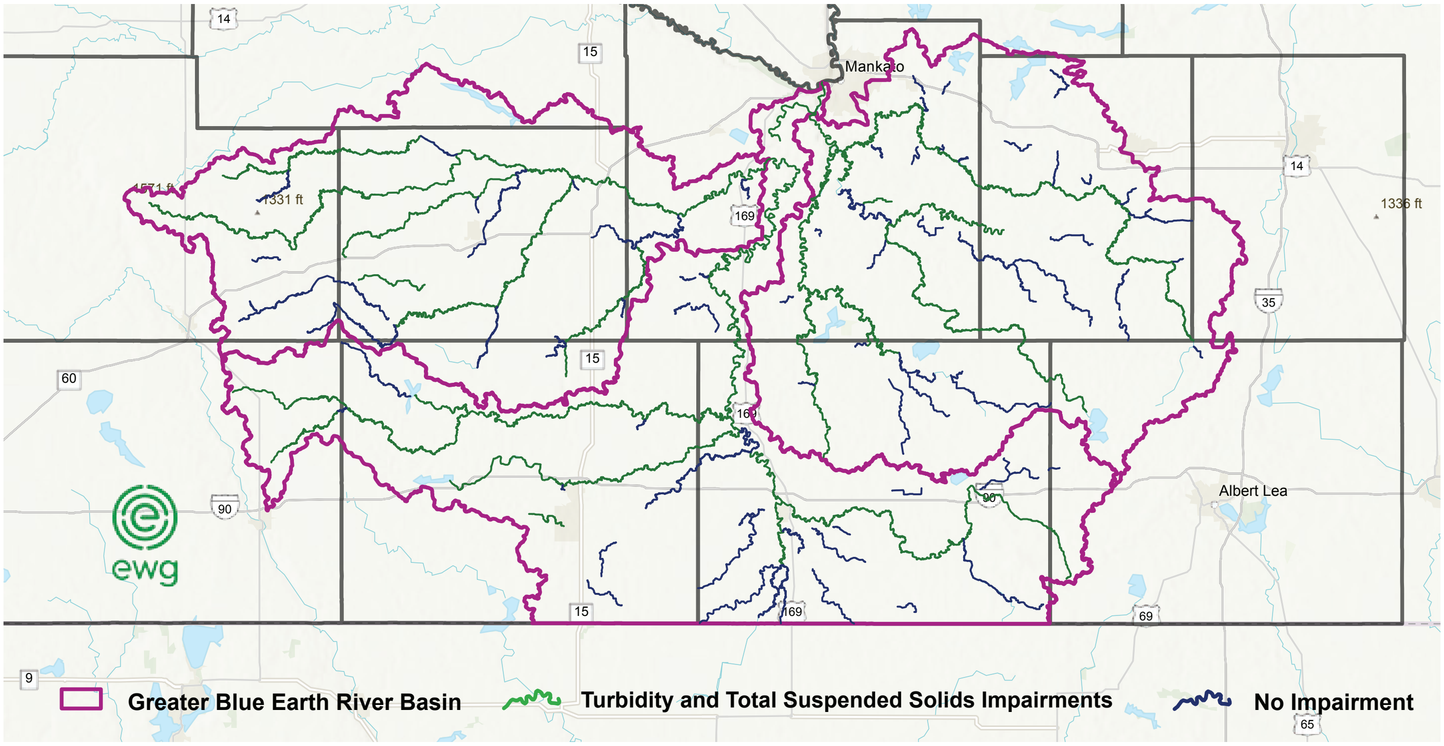
In the Greater Blue Earth River Basin watershed alone, there are 168 impaired waterbodies. These impairments are for both aquatic life (the water is too polluted to support the type of aquatic life it should) and aquatic recreation (the water is too polluted for aquatic recreation). Altered hydrology, or changes in the amount of and way that water

What is an Impairment?

There are seven classes of water in Minnesota that include **Class 1 (drinking water)** and **Class 2 (aquatic life and recreation)**. Nearly all surface waters are Class 2, which is further subdivided into subclasses based on habitat type.

For each use classification, the state establishes "**water quality standards**," expressed as the allowable pollutant concentration that will maintain the water's designated use. Every two years, MPCA assesses which waters do not meet the water quality standards for that waterbody's designated use class. Waters that do not meet water quality standards are considered **impaired**.

Once a waterbody has been assessed as impaired, MPCA takes a series of steps to determine the 'probable cause' of the impairment and prepares a clean-up plan (referred to as a Total Maximum Daily Load) to identify pollution-reduction measures needed to restore the waterbody.



Turbidity and Total Suspended Solids Impairments in the Greater Blue Earth River Basin

The total maximum daily load for the Greater Blue Earth River Basin found that near-channel sources of sediment account for approximately 75% of the total suspended solids load in the Blue Earth, Le Sueur, and Watonwan River watersheds and that subsurface tile drainage exacerbates sediment erosion in near-channel areas.

moves through the landscape, has been shown to be the main cause of most aquatic life impairments in the basin. More specifically, state agencies and the University of Minnesota have attributed these impairments to the expansive network of drainage ditches and tile drainage, loss of wetlands, changes in vegetation from perennial to annual row crops, and changes in speed and volume of stormwater delivery to surface waters.

The Total Maximum Daily Load ("TMDL") for the Minnesota River and Greater Blue Earth River Basin lists a total of 61 total suspended solids ("TSS") impairments along the Minnesota River and its tributaries. The report found that near-channel sources of sediment (such as bank and bluff erosion) comprise approximately 75% of the TSS loads in the Blue Earth, Le Sueur, and Minnesota (at Mankato) rivers. By comparison, less than one percent of the sediment loads in each of these watersheds came from urban stormwater sources. These results affirm the conclusion that increased flows, amplified by artificial agricultural drainage, have directly increased erosion rates and sediment loading from river bluffs and banks in these watersheds. Ultimately, we cannot feasibly reduce excessive flows in and meet sediment reduction targets for the Blue Earth, Le Sueur, and Minnesota rivers unless we mitigate the impacts of artificial agricultural drainage.

"Minnesota failed to meet its goal to have reduced sediment pollution in the Minnesota River by 25% by 2020 and has no viable plan to achieve the 50% reduction by 2030 goal established by the MPCA. If we want to have any hope to meet our goals to reduce sediment pollution in this region, the state of Minnesota must address how agricultural drainage has altered the physical and biological integrity of waters of the state."

- Geomorphologist and report co-author Patrick Belmont

SECTION FOUR

We Can Do Better: Innovation in Drainage Design

What are the proven effective measures to address this problem?

The good news is there are best management practices that can help fix the consequences of altered hydrology in the Minnesota River Basin and the entire Mississippi River Basin. There is widespread recognition across Minnesota and other Upper Midwest states that to meet water pollution goals, we need a combination of best management practices that include changes in land use, changes in nutrient use or crops, and edge-of-field practices such as saturated buffers, wetlands, and bioreactors. These types of practices are often referred to as "conservation drainage" or "controlled drainage." The need to adopt these types of practices has been emphasized repeatedly by MPCA.

So, what are some examples of conservation drainage and controlled drainage practices and how can we increase their adoption across heavily drained watersheds like the Blue Earth River Watershed? Below are some of the key practices that experts recommend and their pollution-reduction benefits.

Water Retention & Storage

Retaining water on the land before it enters a waterway such as a stream or river is a primary intervention to reduce flow volumes and velocity, sediment, and nitrate contamination from artificial agricultural drainage. Water storage can look like wetlands, ponds, water and sediment control basins,

Gains Erased

In-field agricultural soil erosion has decreased over the past several decades due to improved tillage and other conservation practices, but the extensive installation of agricultural drainage simultaneously exacerbated erosion of Minnesota River tributaries. This explains why sediment in the Minnesota River and Lake Pepin continues to be a problem in recent decades, despite considerable public investments and efforts by agricultural producers to reduce soil erosion. Unless appropriate investments are made in drainage practices to mitigate the impacts of artificial agricultural drainage and specifically hold more water back on the landscape, we will continue to waste large public investments in stream restoration, agricultural management, and soil health practices, and the State of Minnesota will not be able to provide reasonable assurance that state water quality standards will be met.

“Many within the agricultural community are open to water storage practices, especially when activities that increase water holding capacity of productive farmlands are combined with targeted practices such as sediment basins and wetlands.”

- The stakeholder group Collaborative for Sediment Source Reduction that met from 2011-2017 to discuss solutions for sediment pollution in the Blue Earth River.

or adding perennial cover or cover crops to cropland which allows for more water storage in the soil.

Reducing flow velocity by adding water storage capacity near the headwaters of a river system helps reduce bank erosion and the resulting sedimentation, accelerating the aquatic ecosystem's return to stability. Water retention measures have been found to be the most favorable approach to reducing sediment pollution because they address the cause of erosion rather than measures that only address the symptoms (such as hardening streambanks with concrete or riprap to stabilize the streambank), and because water retention also reduces nutrient pollution and protects ecological habitat. Water retention does not require removal of artificial agricultural drainage, but rather management of the excess water added to streams, rivers, and lakes from drainage through controls on drainage outlets and creating water storage to slow delivery of water to the river system.

Water Storage

Even modest water storage can have a big impact: **model predictions estimate a 40% reduction of sediment in the Le Sueur watershed if 4% of the landscape—using existing, natural depressions—is used for temporary water storage.** These marginal lands converted to storage sites could still potentially be used to grow hay or other crops. However, the inclusion of water storage is largely discretionary when public drainage systems are repaired or expanded, and there has been limited voluntary incorporation of water storage in many areas of the state.

Conservation Drainage Practices

Conservation drainage refers to "edge-of-field" practices that remove nutrients from subsurface drainage water before it enters streams, rivers, or lakes. It includes practices such as saturated buffers, bioreactors, and treatment wetlands.

Minnesota requires vegetative "buffers" between agricultural fields and waterways to help reduce water pollution. And there is a very high rate of buffer implementation in the state (approximately 99% of the appropriate land area has buffers). But buffers will not solve the problems caused by drainage. Stream destabilization, sediment overload, and nitrate contamination caused by drainage are not prevented or intercepted by riparian buffers because the water passes under the buffers via subsurface drain tile, and sediment erosion from increased river flows magnified by drainage happens within the river channel itself. But unlike riparian buffers, **saturated buffers** can be used to reduce nutrients and sediment in water from subsurface drainage. Saturated buffers perform similarly to treatment wetlands (about 50% nitrate removal effectiveness) but have lower installation costs and require less management.

Bioreactors are another edge-of-field practice that can be used to effectively treat subsurface drainage water. In the context of drainage, a bioreactor is a buried trench on the edge of a farm field that is traditionally filled with woodchips. Bacteria in the woodchips convert the nitrate in tile water into nitrogen gas. Bioreactors have a small footprint, which makes them well-suited to retrofit current drainage system outlets. Bioreactors require little-to-no land to be taken out of production and fit into grassy edge-of-field areas. They can reduce nitrate loads by 20-50% dependent on site-specific conditions.

Finally, **treatment wetlands** are constructed wetlands that are designed and strategically located to reduce pollutant loads and improve water quality. Treatment wetlands can reduce nitrate loads by up to 50% and can treat large drainage areas, which makes them well-suited to public drainage systems. While wetland restoration in the upper third of a watershed helps provide water-storage benefits, as described in the Water Retention and Storage section above, treatment wetlands are often located near the outlet of a drainage system to help with nutrient and sediment removal. Treatment wetlands can take substantial amounts of land out of production but are effective for watershed-scale treatment. Wetlands provide a variety of additional ecosystem services beyond nutrient removal, such as wildlife habitat and recreation.

Bioreactors *(shown here) are edge-of-field practices used to filter nutrients from drainage systems.* *Photo by Purdue University.*

Controlled Drainage Practices

Controlled drainage is complementary but distinct from the water retention and storage practices outlined above, which use or modify existing depressions in the landscape to hold water on the land surface. Controlled drainage modifies the drainage system design itself to control water table depth and flow volume to reduce erosion and sediment loads.

Controlled drainage practices include two-stage ditches, peat filters, and gravel or blind inlets. Controlled drainage is expensive and generally more difficult than edge-of-field practices like bioreactors to retrofit to current drainage systems. But drainage system improvements provide an opportunity to include both controlled drainage and conservation drainage practices in the project design. Several controlled drainage practices are outlined below:

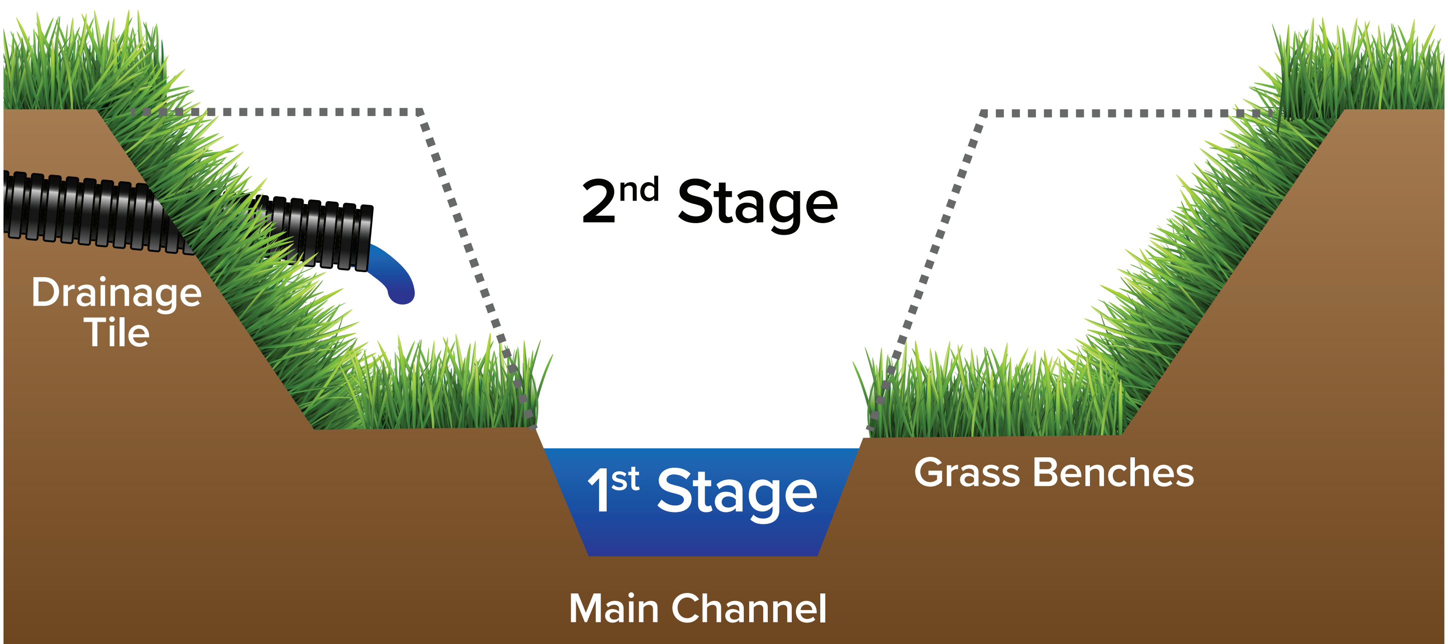
Two-Stage Ditches

Once water reaches the drainage ditches, water control structures that mimic natural hydrology patterns can help reduce negative impacts from drainage. Two-stage ditches are constructed with a deep, narrow channel beneath a shallower, wider channel and can help mitigate bank erosion and nitrate contamination. The narrow inner channel can meander and have space to overflow. This mimics a more stable, natural stream structure, reducing bank erosion and providing better habitat for fish and other wildlife. The inset floodplain of a two-stage ditch can also allow nitrates to be taken up by plants and hold water long enough to allow bacteria to reduce the nitrates.

Similar to upstream wetland restoration and water storage areas, restoring streamside riparian zones (the area next to a stream) can lead to a reduction in peak discharge and nitrate removal. Water control structures such as two-stage ditches or other features that allow flows to more easily access the floodplain and reconnect side channels to hold water and sediment will help reduce bank erosion and restore aquatic ecosystem stability. This can be one of the most cost-effective ways to meet water quality targets.

Elimination/Reduction of Ditch Clean Outs

When ditches are re-dredged due to sediment build-up and erosion, the ground is once again



Two-Stage Ditches *are designed to mitigate bank erosion and nitrate contamination.*

disturbed, which deposits loose soil along the banks and the bottom of the channel. This causes more sediment production from banks, creating a repeating cycle of sediment production and clean-outs. Drainage authorities can reduce the need to re-dredge ditches through alternatives such as localized waterway restoration, two-stage ditches, or water storage basins, and limiting the re-dredging of ditches helps improve water quality. Some formerly dredged ditches have evolved to resemble constructed two-stage ditches; for these, additional dredging may not be necessary.

The 2021 Blue Earth River Watershed Stressor Identification Report focused on the need to eliminate or reduce ditch clean outs when ditches are functioning as they need to be. It also emphasized the need to transform shallow, wide, and homogenous channelized ditches into two-stage ditches to dissipate stream energy, reduce stream fragmentation, increase habitat availability, increase denitrification rates, and reduce eutrophic growth.

Despite the many co-benefits of conservation drainage and controlled drainage practices, we have not made adequate progress in the adoption of these practices to slow down water from heavily drained landscapes or otherwise treat drainage runoff to reduce nutrients. Statewide, as of 2025 we have approximately 34,000 acres using water retention and treatment practices such as wetland restoration and controlled drainage management. In comparison, over 1.3 million acres are engaged in best management practices for cropland erosion control and about 900,000 acres use continuous living cover.

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In Blue Earth County

County Ditch 57 in Blue Earth County incorporated a multi-benefit approach using storage basins (ponds), water control structures, and two-stage ditch construction to reduce peak flow volume, stabilize the ditch for less maintenance, reduce nutrient (phosphorous and nitrate) and sediment reduction, and provide more diverse wildlife habitat. From annual reports of monitoring data, the flow volume, sediment load, and nitrate concentrations were reduced in most flow events. Additional interventions in the upland cropland areas, such as adjusting fertilizer application timing and amount and planting cover crops would help further sequester the land-applied nitrate fertilizer before it enters the tile lines and flows into the ditch.

Vulnerable Landscape

Lake Pepin in southeastern Minnesota continues to be subject to sediment pollution that is filling in the lake at a much faster rate than would occur naturally.

SECTION FIVE

A Path Forward: Policy Recommendations

What are policy measures that would help to mitigate this problem?

Artificial agricultural drainage dramatically changes river-basin hydrology with significant impacts to water quality. As discussed, agricultural drainage in the Greater Blue Earth River Basin has significantly increased flow volumes, velocity, and flashiness in the Minnesota River and its tributaries. This, in turn, has caused significant increases in streambank and bluff erosion, which has undermined progress we have made to reduce cropland erosion and has significantly increased the amount of sediment and nutrients in the Minnesota River and ultimately the upper Mississippi River. These pollutants cloud our rivers, degrade aquatic habitat, jeopardize infrastructure, and impact human health. And Minnesota's drainage law and other environmental statutes have done little to slow the rapid expansion of artificial agricultural drainage and its attendant environmental consequences. **Minnesota cannot provide reasonable assurance that water quality targets in the Minnesota River Basin will be met unless and until it addresses the pollution caused by artificial agricultural drainage.**

Given the important crop-production benefits that agricultural drainage provides to Minnesota farmers, what are the potential pathways forward? Below are four policy measures that would help mitigate this problem and better balance agricultural production with environmental protection.

ECONOMICS
Quantify economic value for downstream damages attributable to upstream agricultural drainage

When drainage authorities consider a proposed drainage project, they are required under Minnesota law to determine whether the estimated benefits of the project are greater than the estimated costs. This is supposed to include an estimation of "damages," but we currently lack consistent methods to estimate the in-system and downstream damages to water resources from artificial agricultural drainage. Economists have begun to estimate the public costs of different types of pollution, such as nitrogen, carbon, and sediment. But none of these studies have specifically looked at the role of agricultural drainage systems in these damages. We support proposed studies that would use watershed models and economic analysis to develop a way to calculate economic damages from changes in the level of sediment, pollutants, and annual flow that are attributable to drainage systems. For example, externalized economic costs could include increased public expenditures for flood resiliency and riverbank stabilization projects, or the installation of treatment systems at public water treatment plants to remove nutrients. These values can then be used by local drainage authorities to include the cost of downstream damages in their evaluation of proposed drainage projects.

ENVIRONMENTAL REVIEW
Adequately capture cumulative water quality impacts in environmental review

Minnesota law requires a review of projects that may have the potential for significant environmental effects. But despite the stark evidence that artificial agricultural drainage negatively impacts water quality in the Minnesota River Basin and other watersheds throughout the state, these impacts are not adequately reviewed. In the past, the environmental impacts of some drainage projects have been studied because of their impact on public waters. However, state environmental rules lack a tool to more holistically evaluate cumulative water quality impacts in heavily drained watersheds, such as stream channel instability and the associated negative impacts on aquatic habitat. The Environmental Quality Board ("EQB") should add a requirement to review drainage projects for cumulative water quality impacts. The EQB could do this through a new mandatory category in the state rules for environmental review. The thresholds for a new category of this type should focus on increases in flow volume and annual peak flows, because these are critical measures to capture how much hydrological change a watershed can endure before physical and biological degradation starts to occur. Like the mandatory environmental review category for animal feedlots in state rule, this could include a general threshold that applies across the state and a more conservative threshold that applies to sensitive areas, such as waterbodies impaired for turbidity and total suspended solids. Environmental review would also better inform decision makers about whether the costs of the drainage project exceed its benefit.

Alternatively, Minnesota could conduct a generic environmental review for drainage improvements in the Minnesota River Basin. A Generic Environmental Impact Statement would help the state assess how to reach its water quality goals. In 2015, MPCA's Sediment Reduction Strategy for the Minnesota River Basin and South Metro Mississippi River set out to reduce sediment in the Minnesota River by 25% in 2020, which it did not achieve, and by 50-60% in 2030, which it is not on track to achieve. Furthermore, the Nitrogen in Minnesota Surface Waters Report outlines that agricultural drainage accounts for an estimated 67% of nitrogen in the Minnesota River. These reports make clear that to meet our state water quality goals, we must study and mitigate the cumulative water quality impacts from agricultural drainage.

MARKET-BASED STRATEGIES
A cap-and-trade system would share the burden of meeting pollution targets with the wastewater sector

Another approach to mitigate the cumulative impact of artificial agricultural drainage in the Minnesota River Basin for specific pollutants would be a cap-and-trade system where pollution sources could trade pollution allowances with one another to achieve established pollution-reduction goals. This may be a necessary step for the state to implement a nitrate water quality standard for aquatic life, which is on MPCA's Work Plan for 2025-2027. Statewide, the wastewater sector only accounts for about 9% of the total nitrogen load in Minnesota waters, and even less in intensively tile-drained watersheds like the Minnesota River Basin. However, while wastewater treatment plants are required to meet certain pollution reduction targets in their permits, agricultural drainage systems are not required to meet pollution limits. To enforce a nitrate water quality standard for aquatic life, MPCA could use a cap-and-trade system to ensure that the burden to meet pollution targets is shared between permitted "point sources" like wastewater treatment plants and other pollution sources like agricultural drainage systems. This has been done successfully for other pollutants and for impaired waters in Minnesota, such as the Lower Minnesota River dissolved oxygen TMDL. This TMDL addressed a dissolved oxygen impairment in the Lower Minnesota River caused by excess phosphorus. The TMDL required the development of the Minnesota River Basin General Phosphorus Permit – Phase 1, which gave wastewater treatment plants the option to buy or sell phosphorus credits with un-permitted sources to reach their pollutant reduction targets under the permit.

REGULATORY PROGRAMS
Permit system for drainage projects

State regulators should develop a permit system for drainage projects to require the integration of appropriate water storage, conservation drainage practices, and/or controlled drainage practices when drainage systems are expanded (i.e. designed to hold more water) or new drainage systems are built. This would not need to include the repair of drainage systems that already exist. A permit system of this type could be modeled after the stormwater permit system, which refers to a manual that sets minimum design requirements for runoff retention, sediment reduction, and/or peak flow requirements. In the case of agricultural drainage management, the design manual could be informed by the Watershed Restoration and Protection Strategies and One Watershed One Plan studies, which have been completed for nearly every major watershed in the state as of this report's publication.

As a model, the stormwater permit system is designed to give permittees the flexibility to select from best management practice options and adapt the requirements to their local circumstances. The guidance can vary based on the character of the waterbody that will receive the runoff, such as whether it has trout stream protection, if it falls within a source water protection area, and whether it drains to an impaired water. A similarly structured permit system for agricultural drainage projects could be piloted in a specific watershed to help establish the effectiveness and scalability of water storage, conservation drainage practices, and controlled drainage practices at the watershed scale.

Conclusion

Minnesota has ambitious watershed pollution reduction targets that that will not be met unless we account for the cumulative impact of agricultural drainage systems. Within Minnesota River Basin tributaries like the Blue Earth River Watershed, MPCA acknowledges that the "drainage network has replaced prairies and wetland and created a 'short circuit' in hydrologic conditions that can increase the volume of water delivered and decrease the amount of time water would remain on the landscape." These changes are a primary driver of increases in the volume and duration of stream flow which "have in turn increased nutrient and sediment loads to the watershed." Watershed pollution reduction targets for the Blue Earth River Watershed include a 25% reduction in stream flow, a 45% reduction in nitrogen stream concentrations and loads, and a 60% reduction in sediment loads.

In a February 2024 letter, MPCA outlined priority issues and concerns to be addressed in the Blue Earth River Watershed. The top priority was drainage watershed management, followed by the closely related issues of aquatic life, altered hydrology, sediments and nutrients. Given the extensive impairments throughout the watershed, it will not be able to meet the ambitious goals laid out for it unless and until Minnesota takes serious steps to address agricultural drainage as a primary driver of altered hydrology and associated sediment, nutrient, and aquatic life impairments. As this report has outlined, there are ways to do that and continue to realize the benefits of drainage for agricultural production.

The Risks of Increased Flow

The June 2024 partial failure of the Rapidan Dam on the Blue Earth River is a drastic example of how increased flows from agricultural drainage decrease climate resiliency and can affect public infrastructure. Photo © Ben Brewer

Sources

Shubham Aggarwal et al., Managing nitrate-nitrogen in the intensively drained upper Mississippi River Basin, USA under uncertainty: A Perennial Path Forward, 194 Environmental Monitoring and Assessment (Aug. 2022).

Dennis Anderson, Unregulated farm tiling puts state's waters at risk, The Minnesota Star Tribune (Mar. 2018).

Wayne P. Anderson et al., Minnesota Nutrient Reduction Strategy, Minnesota Pollution Control Agency (Sept. 2104).

Erin Andrews, Jacquelyn Bacigalupi, & Kevin Mott, Watonwan River Watershed Stressor Identification Report, Minnesota Pollution Control Agency (Jul. 2018).

Brenda Asmus et al., Physical Integrity: the missing link in biological monitoring and TMDLs, 159 Environmental Monitoring and Assessment 443-463 (Jan. 2009).

Breeanna Bateman, Blue Earth River Watershed Stressor Identification Report, Minnesota Pollution Control Agency (Aug. 2021).

Patrick Belmont et al., Large shift in source of fine sediment in the Upper Mississippi River, 45(20) Environmental Science & Technology 8804-8810 (2011).

Patrick Belmont & Efi Foufoula-Georgiou, Solving water quality problems in agricultural landscapes: New approaches for these nonlinear, multiprocess, multiscale systems, 53(4) Water Resources Research 2585-2590 (2017).

Kristen L. Blann et al., Effects of Agricultural Drainage on Aquatic Ecosystems: A Review, 39(11) Critical Reviews in Environmental Science and Technology, 909-1001 (Nov. 2009).

Bruce C. Call et al., Changes in floodplain inundation under nonstationary hydrology for an adjustable, alluvial river channel, 53(5) Water Resources Research 3811-3834 (2017).

Laura Christianson, John Tyndall, & Matthew Helmers, Financial Comparison of seven nitrate reduction strategies for Midwestern agricultural drainage, 2-3 Water Resources and Economics 30-56 (Oct. 2013).

Paul Davis & Kimberly Musser, Blue Earth River Watershed Restoration and Protection Strategy Report, Minnesota Pollution Control Agency (Jul. 2023).

Brenda DeZiel et al., Habitat Improvements and Fish Community Response Associated with an Agricultural Two-Stage Ditch in Mower County, Minnesota, 55(1) Journal of the American Water Resources Association (Feb. 2019).

Gary W. Feyereisen et al., Frontier: Eating the Metaphorical Elephant: Meeting Nitrogen Reduction Goals in Upper Mississippi River Basin States, 65(3) American Society of Agricultural and Biological Engineers 621-631 (2022).

Efi Foufoula-Georgiou et al., The change of nature and the nature of change in agricultural landscapes: Hydrologic regime shifts modulate ecological transitions, 51(8) Water Resources Research 6649-6671 (2015).

Greater Blue Earth River Basin Alliance, Le Sueur Watershed, available at https://gberba.org/le-sueur-watershed/.

Amy T. Hansen et al., Integrated assessment modeling reveals near-channel management as cost-effective to improve water quality in agricultural watersheds, 118(28) Proceedings of the National Academy of Sciences (2021).

Leroy Hansen & Marc Ribaudo, Economic Measures of Soil Conservation Benefits: Regional Values for Policy Assessment, United States Department of Agriculture (Jan. 2008).

Bonnie L. Keeler et al., The social costs of nitrogen, 2(10) Science Advances (Oct 2016).

Sara A. Kelly et al., Human amplified changes in precipitation–runoff patterns in large river basins of the Midwestern United States, 21(10) Hydrology and Earth System Sciences 5065-5088 (2017).

Sara A. Kelly, Doctoral dissertation, River hydrology, morphology, and dynamics in an intensively managed, transient landscape, Utah State University (2019).

Kimberly Laing, LeSueur River Watershed Biotic Stressor Identification, Minnesota Pollution Control Agency (May 2014).

C. Lenhart et al, Attenuating Excessive Sediment and Loss of Biotic Habitat in an Intensively Managed Midwestern Agricultural Watershed, Watershed Management (2010).

Joe Magner & S.C. Alexander, Geochemical and isotopic tracing of water in nested southern Minnesota corn-belt watersheds, 45 Water Science and Technology, 37-42 (2002).

Joe Magner, G. A. Payne, & L. J. Steffen, Drainage effects on stream nitrate-N and hydrology in south-central Minnesota (USA), Environ. Monit. Assess. (Feb. 2004).

Joe Magner et al., Channel evolution of southern Minnesota ditches, 67 Environmental Earth Sciences 2359-2369 (May 2012).

Joe Magner & Lyle Steffen, Stream Morphological Response to Climate and Land-Use in the Minnesota River Basin, ASCE Joint Conference on Water Res. Engineering and Water Res. Planning and Management (June 2000).

Joe Magner, Agricultural Drainage, Water Pollution, and Biotic Health in the USA Cornbelt, 4(1) Glob Scient Res Env Sci 1-4 (June 2024).

Minnesota Board of Water and Soil Resources, Producers' work with Martin SWCD targets Fairmont city drinking water, Medium (May 2025).

Minnesota Board of Water and Soil Resources, Minnesota Buffer Law, available at https://bwsr.state.mn.us/minnesota-buffer-law.

Minnesota Department of Health, 2019 Source Water Assessment – City of Fairmont Public Water System (2019).

Minnesota Department of Health, 2021 Source Water Assessment – City of Mankato Public Water System (2021).

Minnesota Department of Natural Resources, Blue Earth River Watershed Characterization Report, Minnesota Digital Water Research Library (May 2021).

Minnesota Department of Natural Resources, Climate Change and Minnesota, available at https://www.dnr.state.mn.us/climate/climate_change_info/index.html.

Minnesota Geospatial Information Office, Altered Watercourse Determination Methodology, Minnesota Pollution Control Agency (2013).

Minnesota Pollution Control Agency, Minnesota River - Greater Blue Earth River Basin TMDL for TSS Report Summary (July, 2019).

Minnesota Pollution Control Agency, Minnesota River Turbidity Total Maximum Daily Load Draft Report (Feb. 2012).

Minnesota Pollution Control Agency, New Acres of Best Management Practices (BMPs), available at https://data.pca.state.mn.us/views/Statewidebestmanagementpracticeadoptionsummary/MinnesotaNutrientReductionStrategyBMPSummary

Sources (continued)

Minnesota Pollution Control Agency, Sediment Reduction Strategy for the Minnesota River Basin and South Metro Mississippi River (Jan. 2015).

Minnesota Pollution Control Agency, The Use of the Tiered Aquatic Use (TALU) Framework to Designate Beneficial Life Uses for Drainage Ditches and Altered Watercourses (Aug. 2016).

Minnesota Pollution Control Agency, Blue Earth River Watershed Restoration and Protection Strategies Report (Jul. 2023).

Minnesota Pollution Control Agency, Minnesota Wastewater Nitrogen Reduction and Implementation Strategy – Summary (2024).

Minnesota Pollution Control Agency, Class 2: Aquatic life and recreation beneficial uses, https://www.pca.state.mn.us/business-with-us/class-2-aquatic-life-and-recreation-beneficial-uses.

Minnesota Pollution Control Agency, Nitrogen, https://www.pca.state.mn.us/pollutants-and-contaminants/nitrogen.

William J. Mitsch et al., Nitrate-nitrogen retention in wetlands in the Mississippi River Basin, 24(4) Ecological Engineering 267-278 (Apr. 2005).

Andrea Plevin et. al, Minnesota River and Greater Blue Earth River Basin Total Suspended Solids Total Maximum Daily Load Study, Tetra Tech (Jan. 2020).

B. L. Rhoads & K. D. Massey, Flow structure and channel change in a sinuous grass-lined stream within an agricultural drainage ditch: Implications for ditch stability and aquatic habitat, 28(1) River Research and Applications 39-52 (Jan. 2012).

Gary R. Sands, How agricultural drainage works, University of Minnesota Extension (2018).

Keelin R. Schaffrath, Patrick Belmont, & Joseph M. Wheaton, Landscape-scale geomorphic change detection: Quantifying spatially variable uncertainty and circumventing legacy data issues, 250 Geomorphology 334-348 (2015).

Shawn P. Schottler et al., Twentieth century agricultural drainage creates more erosive rivers, 28(4) Hydrological Processes, (2014).

Soil and Water Conservation Society, Bioreactor Facts, Conservation Media Library (2025).

Gail Swaine & Terry Bovee, City of Fairmont Source Water Assessment, Minnesota Department of Health (2003).

David Wall, Nitrogen in Minnesota Surface Waters: Conditions, trends, sources, and reductions, Minnesota Pollution Control Agency (Jun. 2013).

Peter Wilcock et al., CSSR: Collaborative for sediment source reduction greater Blue Earth River Basin Final Report (Oct. 2016).

Peter Wilcock & the Collaborative for Sediment Source Reduction, Collaborative for Sediment Source Reduction – Greater Blue Earth River Basin Summary of Findings (2017).

Limeimei Xu, Kerry Holmberg, & Joe Magner, The Evaluation of a Novel Denitrifying Woodchip Bioreactor: Fairmont, MN, USA, 5(1) Nitrogen 152-162 (Feb. 2024).

Hannah Yang, County Road 9 bridge closed indefinitely, Blue Earth County discusses possible replacement project, Minnesota Public Radio News (Jul. 2024).

A publication of Minnesota Center for Environmental Advocacy
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Maps were created by the **Environmental Working Group** using public data.

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