Appendix L – Near Channel Erosion

Near Channel Erosion Section - Blue Earth County Water Management Plan

Relationship to Other Plans
Erosion Hazard Areas
Near Channel Erosion – Glacial History and Influence
Streambanks
Bluffs
Landslides
Ravines
Near-Channel Erosion Goals and Strategies
Stream channel migration and bluff erosion are natural processes in river systems. Due to its glacial history, Blue Earth County is in an area predisposed to near channel erosion and landslides. Near channel erosion includes eroding stream banks, bluffs and ravines along river channels. Scenic areas near river channels and ravines in the county are attractive for residential development. These same areas are often vulnerable to near channel erosion, and in some cases runoff from development causes or worsens near channel erosion. Dwellings, other structures and infrastructure often constructed decades ago are threatened by near channel erosion hazards in all watersheds in the county.

**Relationship to Other Plans**
This plan relates to the *Blue Earth County All-Hazard Mitigation Plan 2013 Update* and includes goals and strategies that can be addressed in future updates of the hazard mitigation plan and local stormwater management and watershed plans to address near channel erosion to achieve water quality and hazard mitigation goals.

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**Erosion Hazard Area**

“Erosion hazard area means, based on erosion rate information and other historic data available, an area of erosion or avulsion is likely to result in damage or loss of property or infrastructure within a 60 year period.”

Source: 1999 FEMA Riverine Erosion Hazard Mapping Feasibility Study, erosion hazard area is defined by Section 577 of National Flood Insurance Reform Act (NIFRA)

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**Near Channel Erosion - Glacial History and Influence**

The sources for this section are numerous and include published papers by Stephanie Day, Karen Gran, Carrie Jennings, Patrick Belmont, and Peter Wilcox.

Clay-rich soils were left behind by glacial lakes Agassiz, Benson, and Minnesota. The lakes are shown here at their maximum extents, but were present at different times. (Source: MNDNR)

Tributaries of the Minnesota River are adjusting to a profound 230 foot base level fall at the end of the most recent period of glaciation, the Pleistocene.

*Base level* is the elevation of the surface of the water body into which a river ultimately drains. A drop in base level causes a response by the river system to carve into the landscape. This incision begins at the formation of a knickpoint, and its upstream migration depends heavily...
upon the drainage area (and so the discharge of the river), material through which it cuts, and how large the drop in base level was.

**Knickpoint** is a term in geomorphology to describe a location of a river or channel where there is a sharp change in channel slope, such as a waterfall or lake. Knickpoints reflect different conditions and processes on the river often caused by previous erosion due to glaciation or variance in lithology. Glaciations resulting in hanging valleys are often prime spots for knickpoints. If lithology of the rock varies, such as shale amongst igneous rock, erosion will occur more steadily in the softer rock than the surrounding, tougher rock.

Base level fall in the Blue Earth, Le Sueur, Watonwan and Minnesota River Basin was caused by drainage of glacial Lake Agassiz through glacial River Warren. The resulting glacial River Warren channel is the valley of the modern Minnesota River. Glacial River Warren played an important role in shaping the Blue Earth, Le Sueur and Watonwan. The river scoured 213 feet below the till surface at the mouth of the Blue Earth River, initiating channel incision towards the lower base level. Incision moves upstream on the Blue Earth, Le Sueur and Watonwan channels as a knickpoint. Currently, the knickpoint is 21 to 39 river miles upstream of the Minnesota River on the three major tributaries: the Blue Earth, Watonwan and Le Sueur. Fluvial adjustment of the Blue Earth, Le Sueur and Watonwan to base level fall appears to prime these rivers for high near-channel erosion rates.

Knickpoints divide the basin into two distinct regions. Below knickpoints, channel gradients are steep, channels are deeply incised below the upland surface, and they flow through narrow valleys lined in bluffs and ravines. Above knickpoints, streams flow through a low-gradient landscape dominated by agricultural fields. The steep landscape below knickpoints is the result of watershed adjustment to knickpoint migration. About half of the Blue Earth, Le Sueur and Watonwan sediment load comes from reaches below knickpoints where response to base level fall drives erosion of near-channel features like bluffs.

**Streambanks**

Banks are the boundaries of stream channel networks which are low enough that the river can overtop them during floods. Near-channel sediment sources erode by a variety of mechanisms but are fundamentally driven by excess energy on the banks. Erosion occurs when bank sediments cannot resist the force of water in the channel. High bedload supply, low bank strength and high stream power promote lateral migration and can lead to high erosion rates.

Channel widening is a further source of channel-derived sediment. Flows have increased in many Minnesota watersheds in the last-half century. When annual discharges increase, channel geometry changes in order to move more water. Channels may widen, deepen, straighten or steepen to accommodate higher discharge rates. MNR tributaries have widened since 1975 to accommodate increased annual discharge relative to the period from 1940–1974.

Below the knickpoints, channels in the Blue Earth, Le Sueur and Watonwan are incising rapidly. This has implications for the movement of sediment in the channel. First, channel incision itself becomes a sediment source. Because the river is down-cutting through the landscape below the knickpoints, meander migration is not balanced by floodplain deposition. Incision deepens the channels to the point that floodwaters are not able to access the floodplain, and sediment is transported downstream rather than deposited back onto floodplains.

**Bluffs**

Bluffs can be impressive features: the largest in the county have nearly vertical faces up to 230 feet high and 1,640 feet long, and they line about 50% of the lower parts of Blue Earth, Le Sueur and Watonwan River valleys. Bluffs are most often composed of glacial till, but when they are not the full height of the river valley they are capped with thin layers (usually < 10 feet) of alluvial sediment. Many bluffs in the Blue Earth, Le Sueur and Watonwan are recently stranded terraces
and stand just a few yards above the modern channel and floodplain. In contrast to banks, bluffs are out of reach of typical annual floods and purely erosional features.

Bluff erosion is driven by a number of factors. Researchers have found no statistically significant correlations between decadal bluff retreat rates and parameters such as bluff vegetative cover, slope, size, aspect, sediment texture or stream power. Bluff erosion is primarily driven by fluvial incision, sapping, and freeze thaw.

**Sapping or erosion by groundwater seeping**
Groundwater flow from the bluff face increases pore pressure and can cause erosion at and below the seep. Groundwater sapping from the face of a bluff, is visible on the Blue Earth, Le Sueur and Watonwan bluffs.

**Freeze-thaw**
Aspect is well-correlated to bluff retreat rates along some tributaries of the Le Sueur, suggesting the importance of freeze-thaw to bluff erosion. Bluffs composed of overconsolidated tills appear to be more resistant to fluvial erosion than normally-consolidated bluffs, but overconsolidated bluffs have joint patterns that may make them more susceptible to frost wedging.

Sediment that erodes from a bluff will often collect in a fan at the bluff toe. This material is less dense and less cohesive than its parent material, and probably does not remain in place for long. Even low flows are able to easily entrain such material. The erodibility of colluvial bluff toes and of bluff parent material is influenced by moisture content. Higher flows that saturate channel materials are strongly correlated with high bluff erosion in the Le Sueur and in other watersheds.

Toe erosion occurs when a stream channel migrates into a bluff toe. Erosion of the bluff toe oversteepens the bluff face and reduces support for material above leading to mass wasting.

Vegetation can play a role in stabilizing river banks, but bluffs in the Blue Earth, Le Sueur and Watonwan are generally too tall for tree roots to have any influence on erosional processes near the channel. If a bluff has been spared from lateral channel migration for decades, it will trend towards a gentle angle of repose. Often inactive bluffs have dense tree cover on their slopes right down to the channel. However, even in this seemingly stable configuration, bluffs become rapidly steepened again when the river resumes migration into their toes.

A map showing some of the extent of near channel bluffs in the Blue Earth, Le Sueur and Watonwan watershed is on the following page. Two photos of the same bluff eight days apart show an example of a bluff failure on the Le Sueur River.
Blue Earth County is located in one of the few areas of Minnesota the USGS has mapped with greater than a low susceptibility of landslides. The USGS Landslide Overview Map of the Conterminous United States shows the Blue Earth, Le Sueur and Minnesota River watersheds have a “moderate susceptibility” of landslides.

The USGS definition of landslides includes a wide range of ground movement, such as rock falls, deep failure of slopes, and shallow debris flows. Although gravity acting on an over-steepened slope is the primary reason for a landslide, there are other contributing factors:

- erosion by rivers create over-steepened slopes
- rock and soil slopes are weakened through saturation by snowmelt or heavy rains
- excess weight from accumulation of rain or snow, or from man-made structures may stress weak slopes to failure and other structures

Slope material that becomes saturated with water may develop a debris flow or mud flow. The resulting slurry of rock and mud may pick up trees, houses, and cars, thus blocking bridges and tributaries causing flooding along its path.

The erosional processes associated with mass wasting include two primary types:

- shallow, fast movements of debris avalanche/debris torrents and mudflows that generally move only once
- slow, deep-seated slump/earthflow erosional processes that move intermittently over varying time scales in response to infrequent events and/or disturbance factors

According to the USGS the following areas are generally prone to landslide hazards:

- On existing old landslides.
- On or at the base of slopes.
- In or at the base of minor drainage hollows.
- At the base or top of an old fill slope.
- At the base or top of a steep cut slope.
- Developed hillsides where leach field septic systems are used.

According to the USGS, the Landslide Warning Signs are:

- Springs, seeps, or saturated ground in areas that have not typically been wet before.
- New cracks or unusual bulges in the ground, street pavements or sidewalks.
- Soil moving away from foundations.

Mass wasting

“Erosion associated with mass wasting processes is extremely difficult to predict due to the episodic nature of climatic events that initiate movement. Often landslides occur many years following vegetation and land use changes due to complex interactions of root mass decay and soil saturation from major storms.”

Source: EPA, Hillslope Processes: Mass Wasting
• Ancillary structures such as decks and patios tilting and/or moving relative to the main house.
• Tilting or cracking of concrete floors and foundations.
• Broken water lines and other underground utilities.
• Leaning telephone poles, trees, retaining walls or fences.

It is suspected that landslides in the county are common and have historically been attributed exclusively to riverine erosion. Many of the landslide warning signs have been observed near river channels and bluffs in the county. For example: new sites of groundwater sapping or seeps are observed or are changing, and large, newly-formed cracks in the ground within feet of the top of bluffs and the edge of ravines and leaning trees and retaining walls. Areas downslope of septic systems and footing drain tiles near channels and ravines appear to increase sapping in some locations.

**Jurisdictions with near channel erosion hazard areas**

Most of local government jurisdictions in the county are affected by near channel erosion hazards. Only three of 23 townships and five of 11 municipalities are not affected by ravine or near channel erosion. A list of jurisdictions is shown to the left.

### List of Jurisdictions in Blue Earth County with Potential Near Channel Erosion Hazard Areas

<table>
<thead>
<tr>
<th>6 Municipalities</th>
<th>20 Townships</th>
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<tbody>
<tr>
<td>Good Thunder</td>
<td>Beauford</td>
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<tr>
<td>Mankato</td>
<td>Cambria</td>
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<tr>
<td>Pemberton</td>
<td>Ceresco</td>
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<tr>
<td>Skyline</td>
<td>Danville</td>
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<tr>
<td>St. Clair</td>
<td>Decoria</td>
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<td>Vernon Center</td>
<td>Garden City</td>
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<td>Le Ray</td>
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<td>South Bend</td>
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<td>Sterling</td>
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<td>Vernon Center</td>
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</table>
Ravines

Ravines are steep, deep, incised gullies at the tips of a drainage channel network. Seeps may occur on steep or near-vertical slopes. Ravines connect the uplands to the river valleys, and are often formed by ephemeral streams with only seasonal discharge. Such sites in the Blue Earth, Le Sueur and Watonwan display a diverse array of sizes and relief. Erosion in ravines proceeds by a combination of fluvial and hillslope processes. Channel incision and migration leads to over-steepened slopes and mass wasting.

A significant factor in ravine bluff and bank erosion is the presence or absence of subsurface tile drain and other stormwater outlets at the head of a ravine. Tile drains often accumulate flow from a large area before exiting into a ravine. This drained area is often greater than the surface drainage area draining to the ravine, leading to increased erosion.

Ravine discharges and sediment loads are highly variable. Ravine discharges also vary seasonally. Since most of the discharge in a ravine comes from the upland above it, flow depends on seasonal variation in precipitation, infiltration and evapotranspiration. Ravines are most active in the spring, when the upland landscape has little or no crop cover and may quickly route precipitation to ravines. Ravines often dry up in mid-summer when crop evapotranspiration is highest and precipitation is low.

Sediment from ravines is a small fraction of the Le Sueur sediment budget. In dry years ravines are responsible for as little as 2% of the Le Sueur sediment budget. However, ravine loads are very nonlinear. In a wet year, ravines can be responsible for as much as 15% of the Le Sueur sediment yield. They can have very high sediment load concentrations and can locally add a lot of sediment to the system. Sandbars at ravine mouths, probably deposited during spring floods, can persist in the Blue Earth, Le Sueur and Watonwan river channels throughout the summer.
**Local Ravine Assessment**

Ravines are a significant source of sediment in nearly all local watersheds. In addition to steepness and elevation differences, there are many factors contributing to ravine erosion. Based on local staff observations and knowledge, ravine erosion can be attributed to groundwater sapping, groundwater seeps, and altered hydrology in the ravine watershed. Altered hydrology in a ravine catchment can be the result of grading and filling or impervious surfaces changing the rate or volume of drainage to the ravine, decreased water storage and increased subsurface tile drainage.

Comparing 2012 LiDAR with 2005 LiDAR, the County identified more than 300 ravines with more than five feet of erosion in the seven years between LiDAR data. The map on the previous page shows the ravines identified and the areas of the county that were assessed with LiDAR comparison.

Subsurface tile drainage outlets to ravines increase the ravine watershed area as they often drain a much larger area than the surface drainage area. Drainage ditches in the county drain about 52% of the land area in the county. Much of the remaining area is drained directly to ravines, rivers, streams, lakes and wetlands.

Heavy rain events in 2010, 2014 and 2016 worsened erosion problems in many ravines in the county.

Some of the worst ravine erosion is in Middle Minnesota and Le Sueur River subwatersheds near Mankato where there is a relatively high density of single family dwellings and large ravine systems.

**Mitigation Actions**

*Prevention:* Government, administrative, or regulatory actions or processes that influence the way land and buildings are developed and built. These actions also include public activities to reduce hazard losses. Examples include planning and zoning, building codes, capital improvement programs, open space preservation, and stormwater management regulations.

*Property Protection:* Actions that involve the modification of existing buildings or structures to protect them from a hazard or removal from the hazard area. Examples include acquisition, elevation, structural retrofits, storm shutters, and shatter-resistant glass.

*Public Education and Awareness:* Actions to inform and educate citizens, elected officials, and property owners about the hazards and potential ways to mitigate them.

*Natural Resource Protection:* Actions that, in addition to minimizing hazard losses, preserve or restore the functions of natural systems. These actions include sediment and erosion control, stream corridor restoration, watershed management, forest and vegetation management, and wetland restoration and preservation.

*Emergency Services:* Actions that protect people and property during and immediately after a disaster or hazard event. Services include warning systems, emergency response services, and protection of critical facilities.

*Structural Improvements:* Actions that involve the construction of structures to reduce the impact of a hazard. Such structures include dams, levees, floodwalls, seawalls, retaining walls, and safe rooms.
Near Channel Erosion Goals and Strategies

**Goal:** Minimize near channel erosion, erosion hazards and mitigation costs throughout the county.

Near channel erosion includes ravines, landslides and stream bank and bluff erosion. Strategies include planning and prioritizing, land use management, prevention,

**Planning**

There are many local, state and federal agencies responsible for near channel erosion depending on whether the goal is prevention, natural resource protection, structural practices or elimination of an erosion hazard. A coordinated assessment and a planned unified response to near channel erosion hazards is needed.

**Strategy: Prioritizing and Targeting.**

**Action:** The County will continue to address near channel erosion hazards in the *Blue Earth County All Hazard Mitigation Plan* update.

**Action:** The County will work with partners to assess and prioritize ravine and near channel erosion hazards for prevention, natural resource protection and structural practices in an ongoing local plan that involves multiple local and state partners. Blue Earth County Emergency Management, Public Works and Environmental Services, City of Mankato Public Works, Mankato Township, the SWCD, and the other six municipalities and 20 townships affected by near channel erosion in the county, and the MNDNR.

**Action:** The County and other partners will seek funds for technical analysis of soils, geology, engineering and other engineering and technical support.

**Land Use Strategies**

**Strategic Prevention – Structure Setbacks.**

Increase structure and other setbacks to prevent future erosion hazards and reduce mitigation costs.

**Action:** Blue Earth County, Mankato Township and other jurisdictions affected by near channel erosion will work together with technical support to develop science-based methods for increasing structure setbacks based on geology, soils and historic trends.

**Action:** Support the Minnesota Army Corps of Engineers Silver Jackets partnership with the MNDNR in the development of science-based methods for determining structure setbacks.

**Action:** Seek funds to support development of information and technical papers for elected officials, conservation, planning and zoning staff, and landowners making land use decisions in areas of near channel erosion hazards.

**Action:** Local government units in the county may consider requiring ground assessment and site specific analysis of vulnerability prior to land development and alterations in potential hazard areas.

**Potential Partners:** Affected planning and zoning authorities: Blue Earth County, Mankato Township, City of Mankato and Lime Township.
**Strategy: Prevention - Stormwater Regulations.**

**Action:** Review and revise stormwater management and land use ordinances and policies to decrease surface runoff and subsurface tile drainage water discharges directed to streambanks, bluffs and ravines to reduce erosion with stormwater management practices.

**Strategy: Prevention and Natural Resources Protection:**

**Action:** Restore wetlands and construct water storage practices in areas contributing runoff directly to bluffs streambanks, bluffs and ravines.

**Education and Outreach Strategies**

There are hundreds of actively eroding ravines in the county. Landowner reports and requests for technical and financial assistance increase dramatically after major storms. LGUs in the county lack the organizational capacity to provide technical assistance to landowners. Landowners frequently mismanage ravines with unsuccessful fixes that worsen the problem.

**Strategy: Education and Prevention:**

**Action:** Seek funds and develop funding mechanisms to provide technical information for landowners about preventing and managing ravine erosion.

**Education and Research Strategies**

**Strategy: Studies and Information.**

**Action:** Support continued investigation of near channel erosion caused by groundwater sapping and landslides.

**Action:** Support studies “*Predicting which other landscape features will erode at high rates.*” “Air photo analysis has identified bluffs that have eroded rapidly over the past 60 years, although this is not a guarantee that these bluffs will continue to erode at a high rate in the future (e.g., the bluff erosion may have resulted after only one or two large events). Further analysis is needed to indicate the combination of bluff composition, geometry, and aspect that are most likely to produce large erosion rates in the future as well as the hydrologic (seepage and undercutting) and thermal (freeze-thaw) conditions that accelerate bluff failure (Gran et al. 2011).” (Source: Sediment Reduction Strategy for the Minnesota River Basin and South Metro Mississippi River, January 2015, MPCA)

**Action:** Support “*Monitoring at knickpoints.*” “Monitoring above and below these features can help to identify sediment sources and constrain sediment loading. Monitoring the erosive features directly using ground-based LiDAR, fingerprinting, and/or field surveys provides significant benefits. Load monitoring at the watershed
outlets alone is insufficient to identify and ultimately target the appropriate areas for sediment reducing BMPs. Hence there is a need to keep many of the intermediate monitoring stations in place.” (MPCA 2012a) (Source: Sediment Reduction Strategy for the Minnesota River Basin and South Metro Mississippi River, January 2015, MPCA)

**Project Strategies**

**STRATEGY: NATURAL RESOURCE PROTECTION.**

**Action:** Implement low cost, natural resource protection projects to preserve the function of natural systems in addition to minimizing losses. Low cost options might include toe wood, bend way weirs, live willow staking, and turf reinforcement mats.

**Action:** Affected landowners will implement projects that reduce near-channel erosion and restore stream corridors and vegetation in areas with erosion hazards.

**STRATEGY: NATURAL RESOURCE PROTECTION - WATER STORAGE.**

**Action:** Control stormwater runoff to prevent convergence of surface water to prevent channelized flow and the formation of gullies.

**Action:** Restore wetlands, construct targeted stormwater retention projects and manage sub-surface discharges to reduce runoff to stream banks, bluffs, and ravines in priority areas identified in the Blue Earth County Water Management Plan, local engineering studies, stormwater management plans and other plans that address water storage.

**Action:** Establish or maintain deep rooted, permanent vegetation in shore impact zone and along stream channel bluffs.

**STRATEGY: STRUCTURAL IMPROVEMENTS AND NATURAL RESOURCE PROTECTION.**

**Action:** Stabilize and protect streambanks outlining the surficial sands aquifer and City of Mankato’s public water supply wells at the confluence of the Minnesota and Blue Earth Rivers in Land of Memories Park.

**Action:** Restore and stabilize streambanks to protect existing roadways, bridges and infrastructure in the Blue Earth, Le Sueur, Middle Minnesota and Watonwan watersheds.

**Action:** Restore and stabilize streambanks to protect public parklands affected by near channel erosion.

**STRATEGY: PROPERTY PROTECTION – REMOVE STRUCTURES.**

**Action:** Landowners will remove structures threatened by near channel erosion or in hazard areas.

**Action:** When eligible for state and federal assistance for acquisition, appropriate local units of government will assist landowners with applications for state and federal agency acquisition programs. ($12,000 per site x 4 sites in ten-year planning period)

**Watershed Management Strategies**

**STRATEGY: PLANNING.**

**Action:** Work with counties and SWCDs upstream in the Blue Earth River, Le Sueur River, Middle Minnesota and Watonwan River watersheds to identify and prioritize sites and establish water storage projects to reduce peak flows.
Ravine Implementation Goals and Strategies

**Goal:** Minimize ravine and gully erosion by managing hydrology and restoring stream channels in ravine watersheds.

Ravines are natural drainage ways located in every watershed in the county. There are hundreds of ravines in the county. Some ravines are relatively stable while others can contribute massive amounts of sediment to surface waters. Managing the flow of water to a ravine with conveyance and water retention practices can reduce ravine erosion.

**Priority watersheds include:**
- Watersheds and ravines identified in ongoing local ravine and watershed assessments
- City of Mankato – Minnesota River, HUC 070200071102, Indian Creek Watershed, Thompson Creek watershed, and other unnamed stream/ravine systems in the City of Mankato and Mankato Township
- Le Sueur River, HUC 070200110607, Mankato Township, Decoria Township and City of Mankato
- City of St. Clair – Le Sueur River, HUC 070200110604
- Eagle Lake, HUC 070200110606
- Cobb River, HUC 070200110305
- Maple River, HUC 070200110509
- Blue Earth River, HUC 070200091103
- City of Vernon Center-Blue Earth River, HUC 070200091102
- County Ditch No 24 Blue Earth River, HUC 070200091101
- City of Madelia – Watonwan River, HUC 070200100604
- Watonwan River, HUC 070200100606
- Little Cottonwood, HUC 070200070704
- City of Courtland – Minnesota River, HUC 070200071002

**ONGOING STRATEGY: PRIORITIZING AND TARGETING RAVINES.**

**Action:** Identify, assess and prioritize ravine erosion, hazards and potential projects to facilitate coordination and implementation.

**STATEGY: STRUCTURAL AND NATURAL RESOURCE PROTECTION.**

**Action:** Reduce drainage to ravines in priority areas with targeted wetland restoration and construction of water storage practices.

**Action:** Stabilize ravines in priority areas with channel restoration, water storage, grade control structures and other conveyance systems that manage water draining to ravines.

**Action:** Restore vegetation in ravine stream channels and side slopes.

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**Indian Creek Watershed**

The Indian Creek watershed is located in the Middle Minnesota River watershed. Indian Creek is the drainage outlet for many ravines draining farmland, urbanized upland areas and stormwater ponds. A Clean Water Partnership in 2003 showed erosion in Indian Creek ravine systems to be a major source of sediment in the Indian Creek watershed. The Indian Creek Watershed contains water storage and flood control systems designed by the Army Corps of Engineers to store water during major floods. The City of Mankato is responsible for maintaining water storage in Rasmussen Park in the city limits and a stormwater basin along Indian Lake Road. To maintain the required water storage, the City must remove sediment from these water storage areas every one or two years. Township and County roads in the Indian Creek watershed are also affected by flooding and ravine erosion.
**Strategy: Indian Creek Watershed Ravines Structural Natural Resource Protection:**

**Action:** Restore wetlands and increase water storage in the uplands draining to ravines in the Indian Creek Watershed.

**Action:** Increase water storage to reduce runoff from Minnesota State University Mankato MS4 draining to ravines and steep slopes in the Indian Creek Watershed.

**Action:** Restore wetlands and increase water storage in the County Ditch 69 and County Ditch 98 watersheds in areas identified in the Priority Areas for Protection and Restoration section of this plan, the City of Mankato Park and Open Space Plan, the Indian Creek watershed assessment or the Indian Creek Clean Water Partnership.

**Action:** Construct channel restoration and slope stabilization in ravines to reduce erosion in the Indian Creek Watershed as identified in the Indian Creek watershed assessment, the County’s ravine assessment, Mankato Township or the City of Skyline.

**Action:** Enhance regional stormwater ponds to reduce discharges to ravines in the Indian Creek watershed.

**Thompson Creek Watershed**

**Strategy: Structural and Natural Resource Protection:**

**Action:** Construct channel restoration, bluff protection and grade stabilization to reduce erosion in the Thompson Creek watershed as identified in the Thompson Creek watershed assessment and Thompson Creek Clean Water Partnership and City of Mankato stormwater plans.

**Wilson Creek Watershed**

The Wilson Creek watershed is located in the Le Sueur River watershed. There are significant erosion problems in the meandering stream channel/ravine locally-named Wilson Creek. The watershed is drained by extensive urban stormwater systems and a county ditch.

Urban land use and soil types with low infiltration capability in the Wilson Creek watershed are a challenge for managing hydrology to reduce erosion in this watershed.

**Strategy: Structural and Natural Resource Protection:**

**Action:** Protect and restore wetlands and increase water storage in the County Ditch 12 watershed in areas identified in the Blue Earth County Water Management Plan, City of Mankato Park and Open Space Plan or City of Mankato Wilson Creek Stormwater Master plan.

**Action:** Construct channel and slope stabilization practices in the Wilson Creek ravine as identified in the City of Mankato Wilson Creek Stormwater Master Plan.