Climate Change Trends and Action Plan

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Minnesota Board of Water and Soil Resources

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Table of Contents

List of Figures

List of Tables

Executive Summary

The mission of the Minnesota Board of Water and Soil Resources is to improve and protect Minnesota's water and soil resources by working in partnership with local organizations and private landowners. Climate change affects BWSR's ability to fulfill its mission. The extreme weather patterns and disrupted natural cycles associated with climate change reduce program effectiveness and threaten the environmental and economic benefits that Minnesota's landscapes provide. However, BWSR's programs, while focused on improving water quality and soil health, also work to mitigate the impacts of climate change and to increase landscape and habitat resiliency.

This report identifies the benefits provided by agricultural conservation practices, retirement of marginal agricultural lands, and wetland conservation and restoration. These benefits fall into two broad categories: 1) mitigation; and 2) adaptation (see "A note on terminology" below).

Mitigation: Soil and water conservation programs mitigate the effects of climate change by storing carbon in the soil and by reducing the amount of fertilizers, fuel, and other inputs needed for agriculture. This report estimates the reductions in greenhouse gas emissions that result from conservation practices such as nutrient management, cover crops, reduced tillage, filter strips and riparian buffers. Estimates are based on formulas developed in a comprehensive study by the Minnesota Pollution Control Agency (MPCA) of over 20 such conservation practices, matching these to practices that BWSR systematically tracks for cost-share, grants, and easement programs. Results of this analysis include the following:

- Soil and water conservation grants have resulted in conservation practices across more than 500,000 acres and are estimated to reduce greenhouse gas (GHG) emissions by about **300,000 metric tons per year**, measured as CO_2 equivalents.
- Conservation easement through the Reinvest in Minnesota Reserve (RIM) program have restored almost 290,000 acres of land, much of it marginal farmland, to grassland, wetlands, or forest, since the program began in 1987. Conservation practices have been tracked on about 180,000 acres and are estimated to have reduced GHG emission by **about 232,400 metric tons per year.**
- Minnesota's wetland banking program has created over 380 wetland banks, covering 42,000 acres, including both existing and restored wetlands. Wetland restoration can enhance carbon sequestration but also result in methane emission. By weighing these impacts, accounting for wetland type (permanently or seasonally inundated), we estimate that the **11,800 acres in restored wetland banks** result in GHG emission reductions of about **13,500 metric tons per year**. In addition, preservation of existing high-quality wetlands can avert the increased emissions that would result from conversion to agriculture or urban development.

Adaptation: Landscape resiliency can be defined as the ability of natural and working landscapes to adapt to a changing climate, and specifically to extreme weather events and other stressors. Programs that promote integrated water resources management, multipurpose drainage management, and adaptive landscape management all increase landscape resiliency. Moreover, the same soil and water conservation programs that contribute to mitigation also increase resiliency by reducing runoff and nutrient loss, reducing erosion and flooding, and maintaining agricultural productivity.

The combined total GHG reductions of BWSR's programs are approximately **550,100 CO_2-equivalent metric tons**, or **606,400 U.S. CO_2 e-tons**. The estimated emissions of the agriculture and forestry sector are estimated by the MPCA at about **34.5 million CO_2 e-tons**, of which almost **27 million e-tons** are

emitted from cropland. Using the estimates outlined above, the combined impacts of BWSR's conservation and easement programs on the emissions of the agricultural-forestry-land use sector are clearly quite small – **1.7 percent of total emissions, or 2.2 percent of cropland emissions**. However, this assessment does not include the impacts of related state and federal programs and of voluntary practices. By continuing to assess and quantify the benefits of these programs, we can gain a clearer picture of the contributions of the agricultural sector to climate change mitigation and the potential for increasing those efforts.

Action steps to guide future direction

BWSR will continue emphasizing the role of its conservation programs in mitigating and adapting to the effects of climate change. In addition, the following are priority initiatives to increase landscape resiliency:

- **Emphasize and seek additional incentives for the implementation of climate mitigation and adaptation practices** in conjunction with existing soil and water conservation programs. Recognizing and incentivizing the multiple environmental and economic benefits provided by these programs can encourage their successful adoption.
- Guide the implementation of plan content requirements for **One Watershed One Plan** with a focus on climate mitigation and adaptation.
- Increase the focus on restoration of **high-quality pollinator habitat** to support declining pollinator populations, through BWSR's new Lawns to Legumes program, the Habitat Friendly Solar Program, and related initiatives.
- Emphasize and promote practices that provide **year-round cover on agricultural fields**, including perennial and winter annual cover crops, conservation crop rotations, and reduced tillage practices.
- Continue updating information in BWSR's **Native Vegetation Establishment and Enhancement Guidelines** about **plant selection, establishment and management considerations** to maximize climate adaptation and mitigation.

A note on terminology

This report uses several terms commonly used in climate science that are similar but not interchangeable:

- Carbon sequestration: Carbon sequestration is the process of capturing and storing atmospheric carbon dioxide. It is one method of reducing the amount of carbon dioxide in the atmosphere with the goal of reducing global climate change. Soil that sequesters carbon is referred to as a "carbon sink."
- Greenhouse gas (GHG) emission reduction: reduction of the quantity of greenhouse gases (carbon dioxide, nitrous oxide, and methane) being emitted into the atmosphere. GHG emission reduction is achieved both through carbon sequestration (offsetting emissions) and through reduction in emission-producing activities such as fertilizer use and fossil fuel consumption associated with agricultural production. GHG reduction is expressed in this report in terms of metric tons of carbon dioxide equivalents (see Appendix C for details).
- Adaptation and Mitigation: Climate adaptation is defined as developing and implementing strategies, initiatives, and measures to help human and natural systems prepare for and address climate change impacts. Climate change mitigation, the focus of this report, emphasizes reducing greenhouse gas emissions with the goal of limiting the magnitude or progression of climate change (ICAT 2017)

Lakeshore restoration in Carver County.

Forested bog in northern Minnesota.

Why does climate change matter to BWSR?

The mission of the Minnesota Board of Water and Soil Resources (BWSR) is to improve and protect Minnesota's water and soil resources by working in partnership with local organizations and private landowners. The extreme weather patterns and disrupted natural cycles associated with climate change may decrease the ability of Minnesota landscapes to sustainably provide important environmental and economic benefits. Therefore, BWSR recognizes the existing and potential effects of climate change in our conservation programs and practices. Our programs are focused on private lands, which make up approximately 75% of Minnesota's land area, through wetland protection, conservation easements (retirement of marginal agricultural lands), and providing soil and water conservation grants. These programs play an important role in mitigating the impacts of climate change by reducing emissions of greenhouse gases, diversifying the agricultural economy, and increasing landscape and habitat resiliency.

The following primary BWSR programs play significant roles in climate mitigation and adaptation.

Soil and Water Conservation Grants

BWSR's soil and water conservation grant programs provide funding to local government units for the implementation of targeted conservation projects and practices in rural and urban landscapes. A wide variety of conservation practices sequester carbon and decrease nitrous oxide emissions from fertilizer, including tree planting, grass planting, prairie and wetland restoration, windbreaks/shelterbelts, grassed waterways, contour buffer strips, filter strips, riparian buffers, critical area planting, and cover crops. These practices also increase landscape resiliency and often help protect productive agricultural fields from extreme weather events. Grants also fund nutrient management plans that decrease nitrous oxide and methane emissions.

Wetland restoration in Wright County

Conservation Easements (Reinvest in Minnesota Reserve)

BWSR's RIM program is focused on the acquisition and enhancement of critical habitat in the predominantly agricultural areas of the state by converting marginal croplands to permanent native vegetative cover, thereby storing increasing amounts of carbon in soil, plant roots, and other biomass. The retirement of marginal agricultual lands also decreases emissions from machinery and nitrous oxide emissions from fertilizers. Restoration activities, such as restoring wetlands, establishing riparian buffers, protecting sensitive groundwater areas, planting critical winter cover for wildlife, preserving habitat for rare plant and animal species, increasing pollinator habitat, and preserving spawning and reproduction areas for fish, also increase resiliency to climate change.

Wetland Protection (administration of the Minnesota Wetland Conservation Act)

The primary goal of the Minnesota Wetland Conservation Act is to achieve no net loss in the quantity, quality, and biological diversity of Minnesota's 10.6 million acres of existing wetlands. This is accomplished through avoiding direct or indirect impacts from activities that destroy or diminish wetlands and replacing wetlands where avoidance of such activity is not feasible and prudent. Minnesota's wetland banking program includes both private and state-sponsored wetland banks which have "credits" that are used to offset (mitigate) authorized wetland impacts.

Wetlands effectively sequester large amounts of carbon but are also sources of methane, particularly if they are continuously inundated. However, the majority of land in the wetland banking program consists of seasonally inundated wetland or adjacent upland, creating a net reduction in emissions (see Appendix C).

How do soil and water conservation programs mitigate the effects of climate change?

Soils contain vast quantities of carbon -- more than double the amount in the atmosphere. Carbon levels in soil vary depending on climate, soil parent material, vegetation type, landscape position, and human activities. Healthy soil holds the carbon that plants absorb from the air and incorporate into their root systems. Carbon is stored in the soil as roots, root exudates, and decomposed plant matter. Repeated plowing and chemical fertilizer use can reduce soil carbon, as well as soil fertility and water-holding capacity. Wetland drainage also leads to reduced soil carbon.

The same practices that are known to improve soil health and water quality can also increase carbon sequestration. These include conservation practices that keep soil covered year-round, such as cover crops, reduced tillage, or perennial vegetation, thereby reinvigorating soil biology and increasing carbon sequestration. Conservation practices can also reduce the amount of fertilizers, fuel, and other inputs needed for agriculture, thus reducing greenhouse gas emissions while reducing costs.

Grass waterway eroded from extreme precipitation

What are potential long-term trends and impacts from climate change?

The following section draws from the 2017 Interagency Climate Adaptation Team (ICAT) report "Adapting to Climate Change in Minnesota".

Minnesota's climate background

Minnesota's position near the center of North America, halfway between the Equator and the North Pole, brings with it an exceptional variety of weather. In a single year, most Minnesotans will experience blinding snow, bitter wind chills, howling winds, pounding thunderstorms, torrential rains, and heat waves, as well as dozens of bright and sunny days. Given the high variability that we expect from Minnesota's climate, it can be difficult to discern where, when, and how climatic conditions have changed in our state.

The conditions, however, have changed rapidly, and an overwhelming base of scientific evidence projects that Minnesota's climate will see additional significant changes through the end of the 21st century. Over the last several decades, the state has experienced substantial warming during winter and at night, with increased precipitation throughout the year, often from larger and more frequent heavy rainfall events. These changes alone have damaged buildings and infrastructure, limited recreational opportunities, altered our growing seasons, impacted natural resources, and affected the conditions of lakes, rivers, wetlands, and our groundwater aquifers that provide water for drinking and irrigation. The years and decades ahead in Minnesota will bring even warmer winters and nights, and even larger rainfalls, in addition to other climatic changes not yet experienced in the state.

Climate observations and trends in Minnesota: What has changed and what has not?

In 2014, the U.S. Global Change Research Program completed its third National Climate Assessment. This comprehensive scientific review of the state of climate change science demonstrated that the U.S. is already seeing increasing temperatures, larger rainfalls with increased flash-flooding, heavier snowstorms, more severe heatwaves, and worsening drought conditions in some areas. Within particular regions of the U.S., some of these observed changes are more intense, some are less intense, and some are negligible or not yet occurring.

Both the science summarized in the National Climate Assessment and high-quality climatic data show that in Minnesota and the Midwest, rising temperatures have been driven by a dramatic warming of winter and also nights, with both the frequency and the severity of extreme cold conditions declining rapidly. Annual precipitation increases have been punctuated by more frequent and more intense heavy rainfall events. The heaviest snowstorms have also become larger, even as winter has warmed (see Figure 1).

Changes in temperature also affect lake temperatures, particularly on the Great Lakes. According to Minnesota Sea Grant, since 1980 surface water temperatures on Lake Superior in summer has warmed twice as much as the air above it. Over the winter, the area of the lake covered by ice is decreasing by about .5% per year. Ice cover in Lake Superior has decreased from 23% to 12% over the last century.

Several other changes noted elsewhere in the U.S. and the world have not yet been observed in Minnesota. For instance, summer high temperatures have not increased in several decades, and heat waves have not worsened when compared to historical patterns. Droughts in Minnesota also have shown no long-term increase in magnitude, duration, or geographic coverage. Tornadoes, large hail, and damaging thunderstorm winds are difficult to compare historically but show a complex tendency toward more “outbreaks” consisting of multiple events at a time, though no increases in overall numbers or severity.

Figure 1

Hazard	Observed Trend	Confidence Change is Occurring
Extreme cold	Rapid decline in severity & frequency	Highest
Extreme rainfall	Becoming larger and more frequent	
Heavy snowfall	Large events more frequent	High
Severe thunderstorms & tornadoes	Overall numbers not changing but tendency toward more “outbreaks”	Moderately Low
Heat waves	No recent increases or worsening	Lowest
Drought		

Confidence Scale

Lowest	Low	Moderately Low	Moderately High	High	Highest

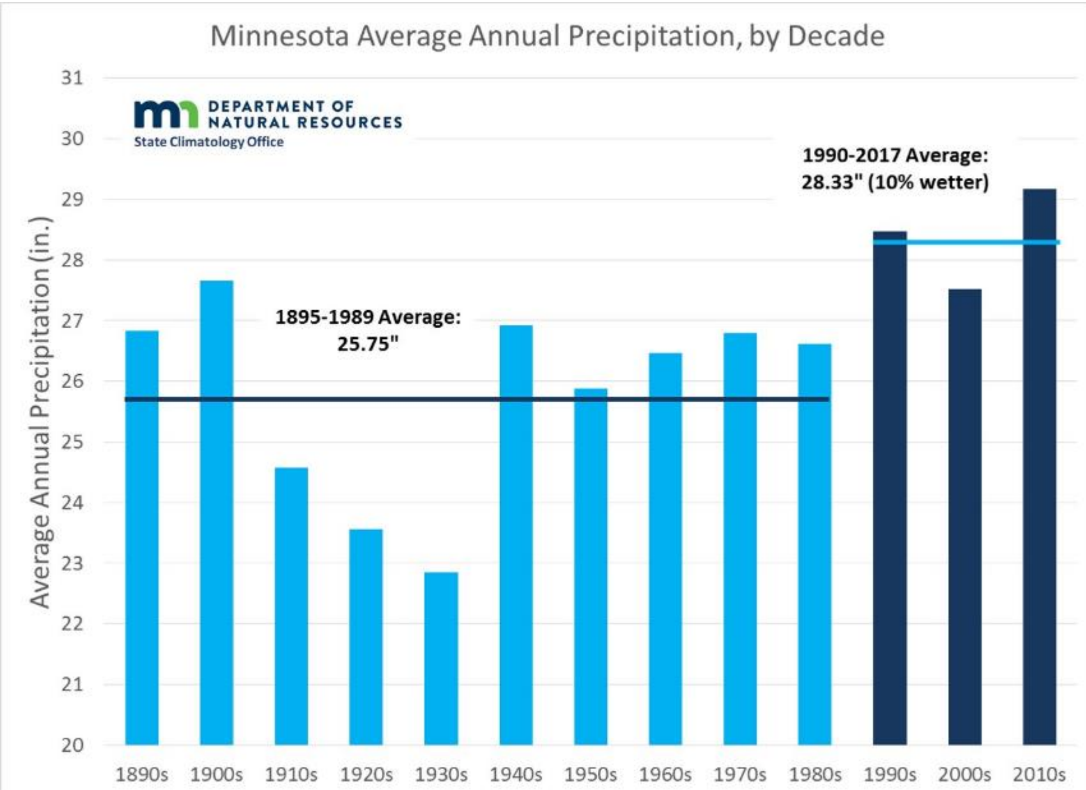
Snapshot of observed trends among common weather hazards in Minnesota, and confidence that those hazards are changing in response to climate change. Graphic based on information from 2014 National Climate Assessment and data analyzed by the Minnesota DNR State Climatology Office.

Increased precipitation

Higher temperatures globally have evaporated more surface and ocean water into the atmosphere, which in turn has provided more potential moisture for precipitating weather systems. This has resulted in more precipitation for Minnesota, which now finds itself in its wettest period in over 125 years of record. Since 1990, Minnesota has been 10% wetter on average than period 1895 to 1989 (see Figure 2).

This precipitation increase is found in all seasons, but spring and summer are becoming wetter at faster rates than fall and winter. Whereas temperature increases have been greatest in the northern parts of the state, precipitation increases have been well distributed geographically, and have somewhat favored southern Minnesota, which has better access to moisture from the Gulf of Mexico, and is more frequently near the “low-level jet” airflow (a relatively fast-moving zone of winds in the lower atmosphere) that influences precipitation production.

Figure 2



Statewide average annual precipitation, by decade, for the period 1895-2017. Please note that the 1890s and 2010s have fewer than 10 years of record. Source: Minnesota DNR State Climatology Office and National Oceanic and Atmospheric Administration (NOAA) Climate at a Glance

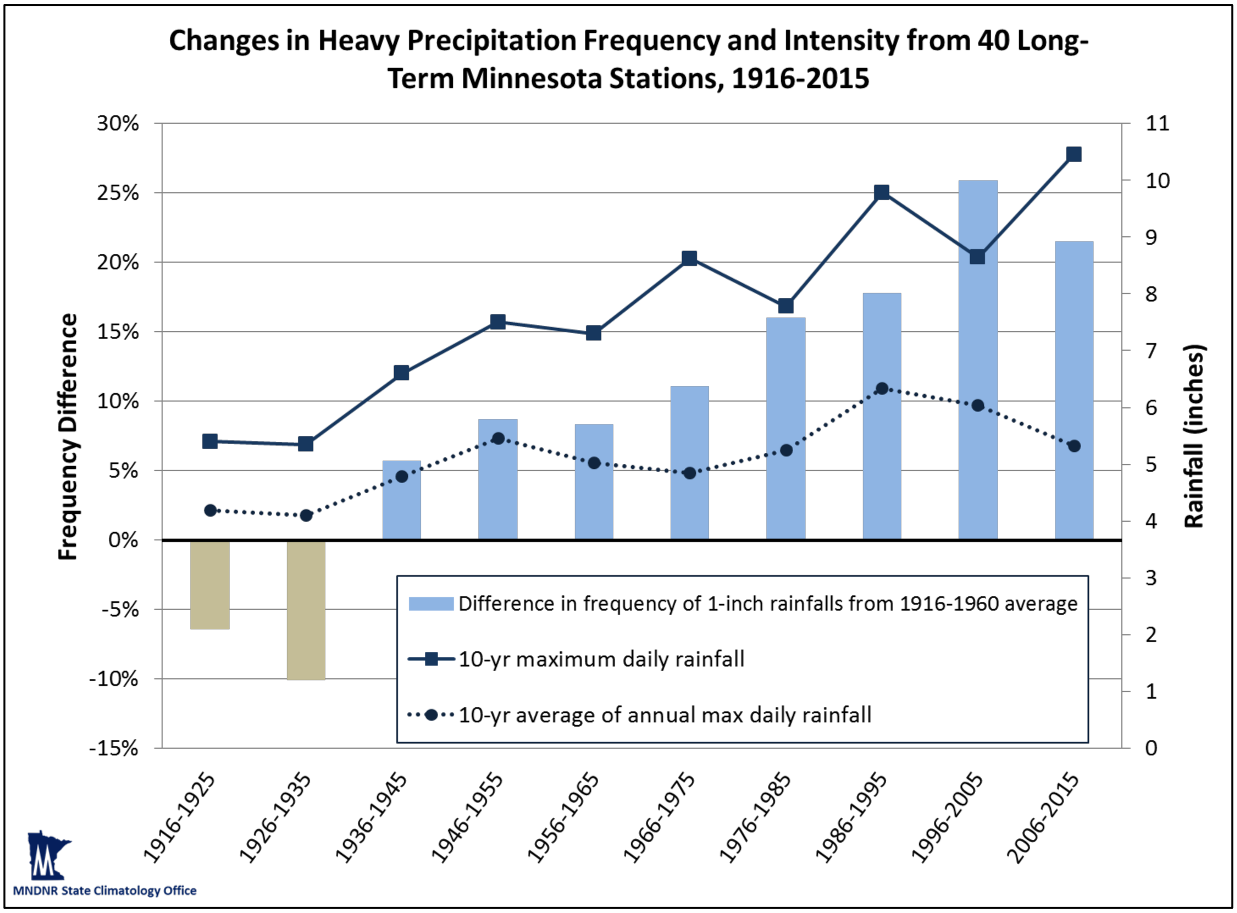
Heavy rainfall and unprecedented extremes

Heavy rainfall events in Minnesota are already becoming larger and more common and have been contributing to an increasing share of annual precipitation in Minnesota. The state has 40 daily weather observing sites whose records stretch back more than 100 years. These long-term stations have shown a 20% increase in the annual number of 1-inch daily rainfalls, a 65% increase in the number of 3-inch rainfalls, and a 13% increase in the size of the heaviest rainfall of the year. Additionally, the single heaviest rainfall amount recorded per 10-year interval at those 40 sites has roughly doubled (from just over five inches to just over 10 inches) during that same period (see Figure 3).

New National Oceanic and Atmospheric Administration rainfall frequency data (NOAA Atlas 14) has shown that the amount of rainfall for given storm frequencies (5-yr., 10-yr. etc.) has risen substantially in many areas of the U.S. in recent decades. This rainfall increase could generate approximately one third more runoff volume than estimated using the old data. The previous 100-year 24-hour event that generated approximately six inches of rainfall will now have a probability of occurring two to three times in 100 years (rather than once per 100 years).

Research specific to the Upper Midwest indicates that the physical mechanisms supporting heavy rainfall events in Minnesota are likely to have begun intensifying in response to climate change. This research also shows that these major events may be taking place earlier during the growing season than the historical average. Thus, in addition to increases in the frequency and intensity of heavy rainfall, its seasonal timing may be expanding across the calendar.

Figure 3



Changes in the frequency of one-inch rainfalls relative to the 1916-1960 average (vertical bars), from 40 long-term stations in Minnesota. Also shown are the 10-year average (lower dotted line, right axis) and 10-year maximum values (upper solid line, right axis) of the heaviest single rainfall amount recorded each year at any of the 40 stations. Note that the 10-year maximum value has doubled from just over five inches at the beginning of the record, to just over 10 inches at the end of the record. Courtesy of Minnesota State Climatology Office.

In addition to increases in the frequency and magnitude of heavy rain, Minnesota has also seen a dramatic increase in large-coverage flash floods events in recent years. Since the year 2000, the state has had eight catastrophic "mega-rain events" — when at least six inches of rain falls on an area greater than 1,000 square miles. The years 2002 and 2016 both had two of these damaging rainstorms. By contrast, the 30 years from 1970 through 1999 saw only four. Incidentally, the mega-rains since 2000 have included the largest, earliest, and latest on record, suggesting that we are seeing not just an intensification, but also a lengthening of our heavy and extreme rainfall season.

Projected continued enhancement of extreme precipitation

In the years and decades ahead, winter warming and increased extreme rainfall will continue to be Minnesota's two leading symptoms of climate change (see Figure 4).

Figure 4

Hazard	Projections through century	Confidence in projected changes
Extreme cold	Continued loss of cold extremes and dramatic warming of coldest conditions	**Highest**
Extreme rainfall	Continued increase in frequency and magnitude; unprecedented flash-floods	
Heat waves	More hot days with increases in severity, coverage, and duration of heat waves	**High**
Drought	More days between precipitation events, leading to increased drought severity, coverage, and duration	**Moderately High**
Heavy snowfall	Large events less frequent as winter warms, but occasional very large snowfalls	**Moderately low**
Severe thunderstorms & tornadoes	More "super events" possible, even if frequency decreases	

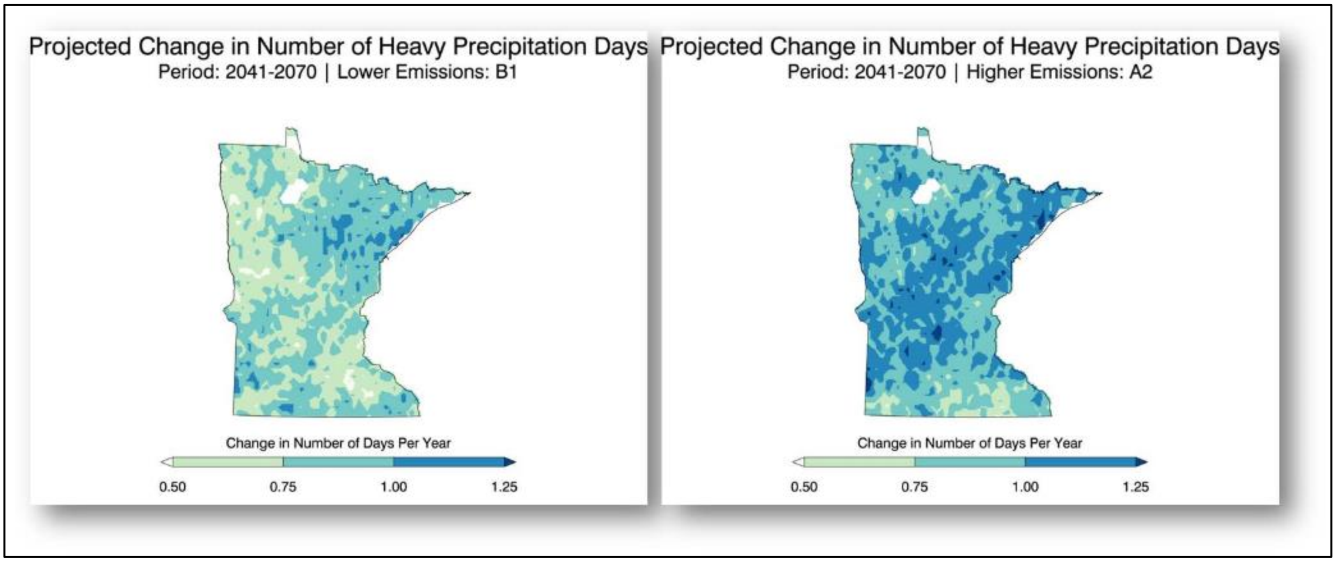
Lowest	**Low**	**Moderately Low**	**Moderately High**	**High**	**Highest**

Confidence Scale

Snapshot of projected and expected trends among common weather hazards in Minnesota, and confidence that those hazards will change (further) through the year 2099 in response to climate change. Graphic based on information from 2014 National Climate Assessment, and data analyzed by the Minnesota DNR State Climatology Office.

Greenhouse gas concentrations will continue rising through the century, and the air's ability to trap heat from the earth's surface will increase accordingly. As a result, winters, and cold conditions in particular, will continue warming well beyond historical bounds. Continued warming of the atmosphere will evaporate even more water into the air, further limiting the amount of cooling Minnesota will be able to achieve at night and during the winter. This increased water vapor will also enhance precipitating weather systems, continuing the trend toward more – and larger – heavy rainfall events (see Figure 5). Minnesota can expect unprecedented rainfall events during the remainder of the 21st century.

Figure 5



Projected changes by mid-century in number of days annually with heavy rainfall, defined as the upper 2% of daily precipitation for the 1971-2000 climate period. Left image is the "ensemble" or model average for a lower emissions scenario. The right image is the same, but for a higher emissions scenario. Images derived from output used for the 2014 National Climate Assessment, courtesy of GLISA (Great Lakes Integrated Science + Assessments).

Impacts of climate change and extreme weather events in Minnesota

The observed measurements and future projections described by the National Climate Assessment and the Minnesota State Climatology Office provide insight into climate trends that are impacting Minnesota now as well as those anticipated in the future. Complicating the varied impacts of climate change is that these changes also interact with and reinforce each other. For example, drought and heat may both contribute to wildfires, which may in turn lead to changes in plant and animal populations as well as other ecological shifts. Extreme precipitation may increase flooding, along with the potential for runoff or combined-sewer overflow and contamination of recreational and drinking water sources, which may already be in short supply due to drought. In addition, climate change will amplify the effects of existing public health and environmental challenges, such as impaired air quality, loss of wildlife habitat, invasive species, and limitations to clean water supplies.

As informed by climate data and trends, Minnesota state agencies have identified significant current and future climate change-related impacts. These impacts, including variable and considerable changes in temperature and precipitation, are expected to have substantial effects on public health, community infrastructure, ecosystem health, environmental quality, and natural resource-based economies.

Both observed climate data as well as future projections indicate increases in very heavy precipitation in Minnesota. Heavy precipitation events, storms, and flooding have significant impacts on Minnesota's communities and ecosystems. These include effects on water and soil resources, agriculture, drainage infrastructure, human health, stormwater management, wastewater treatment, solid waste management, and emergency response.

Extreme weather events have the potential to impact the **quality of water and soil resources** throughout Minnesota.

- More frequent, heavier, or longer-duration rainfall events will **increase soil erosion and runoff**, thereby increasing deposition of sediment and contaminants in water bodies.
- More frequent extreme weather events will impact Minnesota agriculture, resulting in **increased runoff of fertilizers, pesticides, and sediment**, particularly from agricultural fields that do not have best management practices in place such as buffers, grassed waterways, and crop residue left on the fields. Field flooding can result. There are also costs to the state for disaster assistance, (e.g., the DNR's Flood Damage Reduction grant program) which will likely increase as a result of climate change.
- Damage to feed crops from extreme weather also affects livestock. Greater precipitation increases **challenges for applying manure** in an environmentally safe manner to fields. Flooding can also cause **overflow of manure storage basins** which have inadequate storage capacity, leading to contamination of nearby water bodies and death of aquatic organisms.
- Increased extreme weather events put additional pressure on the state's **drainage infrastructure**. There is a potential for more erosion within older drainage systems that do not have adequate outlets or erosion controls in place.
- Flash flooding from extreme precipitation can **damage the built environment**, affecting commercial and residential buildings, roads, parks, and stormwater infrastructure. Water-saturated soils can destabilize bluffs, trees, and utility poles.
- Changes in amount, frequency, and intensity of precipitation impact **stormwater management,** potentially exceeding the design capacity of stormwater treatment structures or impacting future structure design. Extreme weather also adds to challenges in monitoring water quality.
- **Populations particularly vulnerable to flooding and extreme weather events** include the elderly and those without the ability to evacuate when necessary. Farm families and rural communities are also particularly vulnerable to the financial and emotional stresses that result from damages to land and equipment. Community infrastructure (cohesion, relationships, ability to respond as a whole) should be considered just as much as environmental and built infrastructure.

Observed threats and projected impacts to Minnesota's natural resources and BWSR programs

Soil and Water Conservation Grants

- There have been increased requests for assistance to repair and replace structures installed to manage water and improve habitat.
- Flooding has caused significant damage to private lands and conservation practice infrastructure in Minnesota.
- Conservation practices such as grassed waterways, filter strips, vegetated buffers, etc. have helped farmers retain topsoil and agricultural productivity during extreme weather events.
- Emissions of the greenhouse gas nitrous oxide (N_2O) from agricultural activities, primarily fertilizer application and other agricultural practices that increase nitrogen availability in the soil, increased by 12% between 2005 and 2016, (U.S. EPA 2018).
- Water quality in streams, rivers, wetlands, and lakes will likely degrade and/or be more challenging to restore, due to runoff from heavy rainfall, particularly in agricultural lands that are prone to erosion.
- Soil productivity and crop yields may decrease due to increased soil erosion and loss of organic content.

Wetland impacted by water level variation

Invasive buckthorn changing the structure of a forest.

Conservation Easements (Reinvest in Minnesota Reserve)

- State easements with aquatic systems may degrade due to changing hydrology conditions.
- Combinations of extreme storms, flooding, harmful insects, and invasive species will further degrade natural wetlands, prairies and forests.
- With climate change, the National Wildlife Federation concludes that there will be diminished numbers of migratory waterfowl, pheasants, moose, walleyes, northern pike and brook trout, and fish kills will likely become more prevalent (National Wildlife Federation 2013).
- Upland and wetland northern forests could significantly change in structure from the spread of woody invasive species such as common and glossy buckthorn and invasive honeysuckles, invasive insects, and changes in dominant tree species. Some areas may transition from northern coniferous forest to savanna (Frelich & Reich 2010)

Large storm events and variable climate increase erosion and affect agricultural productivity.

Wetland Protection (administration of the Minnesota Wetland Conservation Act)

- Wetland health has been impacted due to more frequent extreme water fluctuations and prolonged inundation of vegetation that favors invasive species and disrupts the life-cycle of aquatic organisms.
- Northern black ash swamps covering about one million acres in Minnesota may significantly change in structure due to emerald ash borer and the loss of black ash trees.
- Extreme precipitation may be overwhelming stormwater systems around high quality wetlands, changing their hydrology. For example, invasive cattail species are moving into intact sedge meadows.

Climate change may lead to the transition from coniferous trees to deciduous trees in northern forests.

How do BWSR's current programs help reduce greenhouse gas emissions and mitigate climate change?

Conservation practices designed to improve water quality, reduce soil erosion, reduce flood damage and enhance habitat also have significant climate benefits by fostering carbon sequestration and decreasing greenhouse gas emissions. BWSR's grants programs support agricultural conservation practices, its easement programs support retirement of marginal agricultural land, and its wetlands programs support conservation and restoration of wetlands. The following programs are significant contributors to greenhouse gas (GHG) emissions reduction.

GHG reduction estimates represent the average impact of a conservation practice compared to baseline conditions, generally defined as standard cropland management practices. However, we recognize that there is a high degree of uncertainty in estimates of GHG emissions due to variation in local climate, land use, and the duration and effectiveness of conservation practices. See Appendix A for a description of how the estimates used in this report were developed.

Soil and Water Conservation Grants for conservation practices

BWSR's grant and cost-share programs fund a broad range of conservation practices. Conservation practices sequester carbon and decrease nitrous oxide emissions from fertilizer by promoting cover crops, nutrient management, conservation tillage, conservation cover, and other soil health initiatives.

The primary programs supporting such practices are:

- Clean Water Fund grants: Projects and Practices: This grant makes an investment in on-the-ground projects and practices that will protect or restore water quality in lakes, rivers or streams, or will protect groundwater or drinking water. Examples include stormwater practices, agricultural conservation practices, livestock waste management, lakeshore and stream bank stabilization, stream restoration, and SSTS upgrades.
- Erosion Control and Water Management (State Cost Share Program): Funds are granted to SWCDs to assist with structural, vegetative, or nonstructural land management practices to correct existing problems. Vegetative practices include establishment of permanent vegetation through practices such as critical area planting and filter strips. Nonstructural land management practices include cover crops, residue management, and nutrient management practices that are incorporated into a farm management plan and have erosion control or water quality improvement benefits.

Restored grassland

Conservation practices are tracked in BWSR's eLINK conservation tracking system. The most widely implemented practices include conversion of cropland to grassland, installation of riparian buffers, field borders and filter strips, reduced tillage, and improved fertilizer management. To date, conservation practices have been implemented across **more than 500,000 acres** and are estimated to reduce greenhouse gas emissions by about **300,000 metric tons per year**, measured as CO_2 equivalents.

Conservation Easements (Reinvest in Minnesota Reserve)

Since the program began in 1987, almost 290,000 acres of land, much of it marginal farmland, have been restored to grasslands, wetlands, or forestland (or CRP conversion to agriculture has been prevented) through easement programs. Reduction of nitrous oxide and carbon dioxide entering the atmosphere from fertilization, fertilizer production, and consumption of fossil fuels for farming marginal agricultural fields also contribute to total emission reductions.

While not all easements incorporate conservation practices, and the database of conservation practices on existing easements is incomplete, practices can be tracked on **180,281 acres** and are estimated to have reduced GHG emission reductions by **about 232,437 metric tons per year** (measured as CO_2 equivalents). Appendix C describes the process used in developing these estimates.

BWSR, working with local partners, continues to secure easements on approximately 5,000 - 8,000 acres per year. Current activity is focused on securing easements through the Conservation Reserve Enhancement Program (CREP), a federal-state partnership targeting environmentally sensitive land in 54 counties in southern and western Minnesota. This program will enroll up to 60,000 acres of marginal cropland often associated with buffer areas and drained or altered wetlands in the Conservation Reserve Program, followed by a perpetual conservation easement.

Re-enrollment of lands in CRP into conservation programs prevents loss of landscapes where carbon sequestration has been occurring for many years. Easement programs also promote GHG reduction through the following activities:

- Promoting restoration of high functioning and sustainable conservation prairies and wetlands in key corridors and complexes informed by the *Minnesota Prairie Conservation Plan* and other key plans.
- Preserving natural shoreline forest lands around shallow wild rice production lakes through permanent riparian easements in northern Minnesota forest regions.
- Converting floodplain lands in frequently flooded areas from crop production to permanent native floodplain forest cover.

Wetland Protection (administration of the Minnesota Wetland Conservation Act)

The Minnesota Wetland Conservation Act has been in place since 1991 and has significantly reduced the loss of wetland acres. Wetlands contain significant amounts of carbon that can be released to the atmosphere with wetland losses. Drainage of wetlands and conversion to cropland can release significant amounts of long-stored carbon through organic matter decomposition. However, wetlands also emit methane, making it difficult to assess their role relative to GHG emissions. Methane emissions are highest in wetlands that are permanently or frequently inundated, while less frequently inundated wetland types such as wet meadows appear to sequester more GHGs than they emit.

Minnesota's wetland banking program includes both private and state-sponsored wetland banks which have “credits” that are used to offset (mitigate) authorized wetland impacts. To date, over 380 wetland banks have been established, covering 42,000 acres These sites include both existing wetlands that are preserved and previously drained wetlands that have been restored. BWSR wetlands staff developed a GIS-based process for assessing the acreage and estimating the net impacts on GHG reduction and emissions, using the National Wetlands Inventory (NWI). The process is described in Appendix C. Results of the analysis, accounting for methane emission as well as carbon sequestration, show that the **11,800 acres in restored wetland banks** result in GHG emission reductions of about **13,500 metric tons per year**.

Other BWSR initiatives also contribute to wetland protection and enhancement:

- Restoration of high quality, diverse, and resilient wetlands to replace wetland losses can mitigate the increased emissions that result from conversion of wetlands to agriculture or urban development. Evidence suggests more carbon is sequestered by a richer mix of native species (such mixed forests) and that such communities are more stable over time. BWSR has developed technical resources to help practitioners restore diverse and resilient landscapes, such as the Minnesota Wetland Restoration Guide and Native Vegetation Establishment and Enhancement Guidelines.
- Restoration of forested wetlands (particularly white cedar and tamarack swamps) through planting and hydrology restoration in northern Minnesota maintain and enhance natural communities with high potential for carbon sequestration.

Multiple benefits of conservation programs

These conservation programs have many benefits to Minnesotans. In addition to mitigating climate change, programs provide important recreational opportunities such as hunting, fishing, bird watching, boating and swimming. Conservation projects also provide jobs in areas such as restoration planning and design, native seed production, construction, native seeding, vegetation management and regulatory and conservation program administration.

Lakeshore buffer in Washington County.

Grant/Information Links:

Wetland Protection (Administration of the Minnesota Wetland Conservation Act): https://bwsr.state.mn.us/wca-program-guidance-and-information
Wetland Banking: https://bwsr.state.mn.us/wetland-bank-credits-and-fees
Conservation Easements (Reinvest in Minnesota): https://bwsr.state.mn.us/reinvest-minnesota-overview
Soil and Water Conservation Grants: https://bwsr.state.mn.us/grants
Disaster Recovery Assistance: http://www.bwsr.state.mn.us/grants/DRAP.html

How do BWSR's current programs help with adaptation to climate change?

Local water management planning

Restored wetland with diverse wet meadow plantings.

BWSR supports and promotes integrated water resources management that uses a watershed approach to solve soil and water resource issues and considers the potential for more extreme weather events and their implications for the water and land resources. This includes the use of design standards for stormwater and conservation projects that address larger precipitation events. A new white paper on "Building Resiliency to Extreme Precipitation in Minnesota" has been developed by the Interagency Climate Adaptation Team.

Wetland protection and restoration

Wetland and upland buffer restoration and protection conducted through the Reinvest in Minnesota (RIM) Reserve Program and federal partnerships, Wetlands Conservation Act implementation, and Clean Water Fund projects, help to restore and maintain water retention, runoff reduction, wildlife habitat, and water quality in Minnesota. This, in turn, enhances adaptation to climate change. The ecosystem services provided by wetlands also protect against intense storm events and periods of drought. Associated upland buffers protect wetland ecosystems and provide landscape connectivity and other functions that promote landscape resiliency. Restoration projects also increase infiltration rates and store water on the landscape.

Cover crops play an important role in improving water quality

Agricultural conservation practices

BWSR promotes a variety of conservation practices in agricultural areas that promote soil health and the ability of soils to capture and store rainfall, store carbon and decrease heat absorption from tilled ground. Examples of conservation practices that minimize impacts from larger storms include cover crops, field terraces, no-till farming, buffer strips, retention areas, and constructed wetlands.

Multipurpose drainage management

BWSR promotes and supports implementation of traditional and new conservation practices for multiple purposes, including conservation drainage and drainage water management practices. These practices help reduce runoff and nutrient loss, avoid runoff concentration, protect areas where runoff concentrates, reduce peak flows to reduce erosion, maintain agricultural productivity, improve water quality and habitat, and reduce flooding. Multipurpose drainage practices help make working lands as well as artificial and natural drainage systems more resilient to high intensity rainfall.

Flood damage in southeastern Minnesota

Increasing landscape resiliency

A variety of restoration and land management strategies are promoted to increase the resiliency of conservation projects to extreme storms and other landscape stressors. Some basic principles for increased resiliency include:

1) Restoring healthy natural systems where they can have the greatest landscape benefits.
2) Decreasing fragmentation of intact plant communities and creating habitat corridors.
3) Restoring plant communities and vegetation that fit current and expected project site conditions.
4) Promoting individual species for projects that can handle expected conditions and provide ecological functions.
5) Promoting species diversity to increase resiliency and promote habitat for a wide range of wildlife species including pollinators.
6) Using deep rooted plants to promote infiltration and groundwater recharge.
7) Restoring high quality habitat for pollinators and other beneficial insects.
8) Managing invasive species across geographic and ownership boundaries to minimize their competitive advantage.
9) Adapting project design, implementation and management approaches based on project experience.
10) Taking a long-term view to the management of natural resources.

See the web-based Landscape Resiliency Toolbox for further details. BWSR's Native Vegetation Establishment and Enhancement Guidelines includes specific guidance on seed sourcing in relation to climate change.

Adaptive landscape management

Disturbances associated with climate change can give invasive species a competitive advantage over native species. BWSR's Cooperative Weed Management Area (CWMA) program is focused on forming local organizations that share invasive species management expertise and resources across ownership boundaries. CWMAs are also focusing on controlling emerging weed threats that benefit from warming climate such as woody invasive species that are invading northern forests. By promoting adaptive landscape management practices such as forest management and prescribed burning, BWSR is also working to increase the landscape's ability to sequester carbon and withstand large rain events.

Northern forest management

BWSR is working through partnerships to protect the integrity of northern forests. Recent efforts include the protection of wild rice lakes and surrounding forests through the RIM Program, an effort to protect and restore white cedar wetlands that are becoming less common, and support of CWMAs in northern Minnesota to address emerging weed threats. BWSR also promotes managing forests for high diversity to adapt to climate variation, large storms, diseases, and pathogens.

Disaster response

Flooding has caused significant damage to private lands and conservation practice infrastructure in Minnesota. Since 2000, BWSR has provided $53 million for flooding in southeast, northeast and northwest Minnesota through the Disaster Recovery Assistance Program, with a focus on rebuilding infrastructure that will be resilient to future storms.

BWSR action steps to guide future direction

Priority initiatives in 2019

1. **Emphasize and seek additional incentives for the implementation of climate mitigation and adaptation practices** in conjunction with existing soil and water conservation programs. Recognizing and incentivizing the multiple environmental and economic benefits provided by these programs can encourage their successful adoption.
2. Further guide the implementation of plan content requirements for **One Watershed, One Plan** with a focus on climate mitigation and adaptation.
   - BWSR guidance for plan development includes language that states: "Planning partners are strongly encouraged to consider the potential for more extreme weather events and their implications for the water and land resources of the watershed in the analysis and prioritization of issues. While these events cannot be predicted with certainty as to time and occurrence, the meteorological record shows increased frequency and severity of extreme weather events, which has a direct effect on issues in local water planning".
   - Continue to work with partners developing plans in new watersheds to incorporate climate adaptation planning for landscape resiliency to more extreme precipitation events. BWSR will develop sample language to be included in plans and will conduct outreach about resiliency strategies summarized in the white paper "Building Resiliency to Extreme Precipitation in Minnesota".

Flooding following an extreme weather event

3. Through BWSR's **Pollinator Initiative**, increase focus on **maximizing benefits to pollinators** through all BWSR conservation programs. Pollinators play a key role in supporting landscape resiliency by pollinating about 30% of crops and 70% of native plants that in turn provide many landscape functions. As a land cover type, pollinator habitat is largely identical to restored prairie or grassland

in its carbon sequestration and emission reductions benefits. BWSR's Pollinator Initiative includes several programs designed to incentivize and guide creation of pollinator habitat.

- Through **Lawns to Legumes**, a new program established by the Legislature in 2019, BWSR is working with other agencies and organizations to offer landowners incentives and technical assistance to plant residential lawns with native vegetation and pollinator friendly forbs and legumes. Funded through the Environment and Natural Resources Trust Fund (ENRTF), the program is anticipated to result in establishment of pollinator habitat on about 600 acres.
- BWSR's **Habitat Friendly Solar Program** promotes the plantings of diverse native vegetation on solar projects. State legislation allows solar developers to claim that they are "Habitat Friendly" if they meet standards defined in BWSR's Assessment forms. These projects add habitat value as well as increased carbon sequestration on solar installations. It is estimated that about 1,000 acres of solar sites are being developed annually in Minnesota.
- Also recommended by the Legislative-Citizen Commission on Minnesota Resources for funding beginning in 2020 is a **Pollinator and Beneficial Insect Strategic Habitat Program** that would restore and enhance approximately 1,000 acres of diverse native habitat across 100 projects. Projects could be located on public and private lands, including parks and existing easements, selected to address the habitat needs of a wide diversity of insects, including at-risk species.

4. **Emphasize and promote practices that provide year-round cover on agricultural fields**, including perennial and winter annual cover crops, conservation crop rotations, and reduced tillage practices to promote soil health and the ability of soils to capture and store carbon, reduce runoff and erosion, protect groundwater, and decrease heat absorption from tilled ground. BWSR will emphasize the value of these practices in guidance materials for One Watershed One Plan and other local water planning efforts.
    - In the past few years, cover crops have been recognized as a new cost share-eligible practice. BWSR will continue to promote their use and assess their benefits.
    - Drawing on BWSR's 2018 Working Lands Watershed Restoration Feasibility Study, BWSR will continue to promote transition of marginal lands to harvestable perennial crops such as alfalfa and Kernza (intermediate wheat grass), with a focus on source water protection areas.
    - Promote the Minnesota Agricultural Water Quality Certification Program, a voluntary program designed to accelerate adaption of on-farm conservation practices that protect soils and restore water quality in Minnesota's lakes and rivers. Producers who implement and maintain approved farm management practices are certified and assured that their operation meets the state's water quality goals and standards for a 10-year period.
5. Continue updating information in BWSR's **Native Vegetation Establishment and Enhancement Guidelines** about **plant selection, establishment and management considerations** to maximize climate adaptation and mitigation. The Guidelines have been updated to focus on promoting plant species diversity to increase landscape resiliency and enhance habitat for a wide range of wildlife species, including pollinators.
    - The Guidelines also identify the types of plant species that can handle expected conditions at project sites, such as drought-adapted prairie species and rhizomatous emergent plants for fluctuating water levels.

Ongoing Activities

1. Continue **tracking of carbon sequestration and emission reductions** of BWSR-funded conservation projects using eLINK and other tools. Greenhouse gas reductions resulting from conservation programs are summarized in this report and will continue to be updated annually. BWSR, with agency partners, is also working with the U.S. Climate Alliance to improve statewide inventories of natural and working lands and their role in greenhouse gas reductions.

2. Use the Minnesota Prairie Conservation Plan, the Nature Conservancy's Resilient Landscapes Tool, and other key landscape ecology planning documents when selecting **conservation and restoration practices in habitat complexes and corridors** to promote resiliency to landscape stressors and to provide refuge for wildlife species. These documents will help guide the development of planting plans for RIM easements and other conservation lands.

3. **Provide information to local governments** about practices, policies and programs they can promote to address climate mitigation and adaptation, including design standards and approaches to assessing sites and updating water plans.
    - BWSR's Landscape Resiliency Toolbox and Landscape Resiliency and Climate Change webpage have been updated to guide local government partners about key practices, policies and programs.

Urban stormwater practices

4. Continue to focus on **tree planting in urban areas and previously forested areas** to sequester carbon, improve air quality, reduce stormwater runoff, decrease the heat island effect in urban areas, control erosion, promote biodiversity and stabilize watersheds.

5. Promote and support implementation of **conservation drainage and drainage water management practices,** as well as water storage at various scales, that help reduce runoff and nutrient loss, avoid runoff concentration, protect concentrated flow areas, reduce peak flows to reduce erosion, maintain agricultural productivity, improve water quality and habitat, and reduce flooding.
    - Provide outreach about the updated **Minnesota Public Drainage Manual** and redesigned BWSR Drainage webpage, as well as the Clean Water Fund Multipurpose Drainage Management Program and other potential sources of technical and financial assistance.

6. Investigate and implement methods to **restore wetlands and lakes that are more resilient to landscape stressors,** with improved site assessment, installation and maintenance techniques.
    - Refine and increase the use of BWSR's Wetland Resiliency Calculator.
    - In northern Minnesota, protect stored carbon by preserving natural shorelines around shallow wild rice production lakes via permanent riparian easements.

- Focus on restoration of high quality, diverse, and resilient wetlands to replace wetland losses. Evidence suggests that more carbon is sequestered by a richer mix of native species (such as mixed forests) and communities are more stable over time.

7. Use **adaptive management strategies** to maintain landscapes in a way that will increase landscape resiliency and increase climate mitigation.
   - Promote long-term monitoring and management of wetlands to control invasive species and promote plant diversity and study the long-term resiliency of restored wetlands and how wetland functions change over time.
   - Promote Cooperative Weed Management Areas (CWMAs), local organizations that provide a mechanism for sharing invasive species management expertise and resources across jurisdictional boundaries in order to achieve widespread invasive species prevention and control in a broader geographic region.
   - Increase focus on controlling emerging weed threats that are benefitting from a warming climate, such as woody invasive species that are starting to invade northern forests.
   - Promote landscape management practices such as forest management and prescribed burning that can increase the landscape's ability to store carbon. Soils rich in organic carbon are better able to withstand large rain events.

Native prairie sequesters large quantities of carbon in soil, perennial vegetation and deep plant roots.

Appendix A: Summary of Recent Climate Reports

NOAA Atlas 14 – New National Oceanic and Atmospheric Administration rainfall frequency data (NOAA Atlas 14) show that the amount of rainfall for given frequencies has risen substantially.

Minnesota Environment and Energy Report Card (2017) – Minnesota's climate is changing rapidly with increasing temperatures, especially in winter and at night, and with increasing frequency of extreme precipitation. Winter lows in northern Minnesota have increased 40% faster than in southern Minnesota.

U.S. Global Change Research Program. Fourth National Climate Assessment (2018) – Concludes that by mid-century, the average temperature of the Midwest Region will increase by 4.21^{o}F under a lower-emissions scenario to 5.29 ^{o}F under a higher emissions scenario, relative to the average for 1976 to 2005. Increasing heavy rains are leading to more soil erosion and nutrient loss on Midwestern cropland. The frequency and intensity of heavy precipitation events are projected to continue to increase over the 21st century.

Intergovernmental Panel on Climate Change. Special Report: Global Warming of 1.5^{o}C. (2018) – Human activities are estimated to have caused approximately 1.0^{o}C of global warming above pre-industrial levels, and global warming is likely to reach 1.5 C at mid-century if it continues at the current rate. At continental, regional and ocean basin scales, numerous long-term changes in climate have been observed. These include changes in arctic temperatures and ice, widespread changes in precipitation amounts, ocean salinity, wind patterns and aspects of extreme weather including droughts, heavy precipitation, heat waves and the intensity of tropical cyclones.

Intergovernmental Panel on Climate Change. Special Report on Climate Change and Land. (2019) – Agriculture, forestry, and other land use activities accounted for around 13% of CO_2, 44% of methane (CH_4), and 82% of nitrous oxide (N_2O) emissions from human activities globally during 2007-2016, representing 23% (of total net anthropogenic emissions of GHGs. Climate change creates additional stresses on land, exacerbating existing risks to livelihoods, biodiversity, human and ecosystem health, infrastructure, and food systems.

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Appendix C. Greenhouse Gas Reduction Estimation Methodology

Since 2009, BWSR has been estimating carbon storage from a variety of conservation practices, ranging from wetland restoration to establishment of cover crops and field windbreaks, documented in the eLINK reporting system and through the RIM easement program. Those estimates, based on a 2008 study (Anderson, et. al.), were due for an update in light of recent research advances. This report updates the estimates, with a number of changes from the previous ones:

- It includes all the major greenhouse gases (GHGs): carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4).
    - Carbon dioxide (CO_2) is the most abundant GHG and has the largest effect on our climate. Fossil fuel combustion is responsible for most CO_2 emissions in the U.S. Total GHG emissions are measured in CO_2-equivalents.
    - Nitrous oxide (N_2O) is emitted during agricultural and industrial activities, combustion of fossil fuels and solid waste, as well as during treatment of wastewater.
    - Methane (CH_4) is emitted from livestock and other agricultural practices, production and transport of fossil fuels, and from the decay of organic waste in municipal solid waste landfills, as well as certain wetlands and water bodies.
- Where previous assessments focused on carbon sequestration in soils and plant materials, this assessment estimates greenhouse gas emissions – that is, how GHG emissions are reduced under conservation practices, compared to conventional cropping practices.

A primary source for the analysis is a draft report prepared by the MPCA's Air Policy Unit, "Greenhouse Gas Reduction Potential of Agricultural Best Management Practices," referred to below as the "MPCA GHG Reduction Study." The report provides a comprehensive synthesis of the methodologies used to estimate greenhouse gas emissions reduction potential from 21 practices related to changing land use, cropping practices, and nutrient reduction.

A secondary source is the COMET-Planner tool and planning documents developed by USDA to estimate GHG reductions from NRCS conservation practices. We relied on COMET estimates for a few practices not included in the MPCA report.

How are emissions estimated?

Different GHGs can have different effects on the Earth's warming. Two key ways in which these gases differ from each other are their ability to absorb energy (their "radiative efficiency"), and how long they stay in the atmosphere (also known as their "lifetime").

The Global Warming Potential (GWP) metric was developed to allow comparisons of the global warming impacts of different gases. Specifically, it is a measure of how much energy the emissions of 1 ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of carbon dioxide (CO_2). The larger the GWP, the more that a given gas warms the Earth compared to CO_2 over that time period. The time period usually used for GWPs is 100 years. GWPs provide a common unit of measure, which allows analysts to add up emissions estimates of different gases (e.g., to compile a national GHG inventory), and allows policymakers to compare emissions reduction opportunities across sectors and gases.[1]

The MPCA prepares a report to the Minnesota Legislature every two years on state greenhouse gas emissions. The most recent report (January 2019), Greenhouse Gas Emissions in Minnesota: 1990-2016, identifies emissions by sector – transportation, electricity generation, agriculture/forestry/land use, residential, commercial, and waste. The 2019 report identified a decline in emissions from the agriculture and forestry sector compared to 2005, but also a high degree of variability in emissions. Animal agriculture is identified as the largest source of methane emissions. However, the report does not quantify the GHG reductions provided by agricultural conservation practices. One goal of this BWSR report is to improve the ability to quantify these "working lands" benefits.

The MPCA's GHG Reduction Study addresses GHG emissions from soils (N_2O, CH_4 and CO_2), surface waters (N_2O), fuel use in field machinery in crop production (CO_2, N_2O), and mostly out-of-state manufacture of agricultural chemicals and fuels (mostly CO_2 and CH_4). The MPCA study also addresses terrestrial carbon sequestration, during which atmospheric CO_2 is withdrawn from the atmosphere and stored in terrestrial soil and biomass. To the degree that CO_2 is withdrawn from the atmosphere through photosynthesis, terrestrial carbon sequestration acts to lower atmospheric CO_2 levels, offsetting surface emissions of GHGs to the atmosphere.

The amount of offset from terrestrial carbon sequestration depends on how long the CO_2 that has been removed from the atmosphere is stored in terrestrial carbon pools before re-release to the atmosphere. To fully offset 1 ton of CO_2 emitted from the combustion of fossil fuels like coal, one ton of CO_2 removed from the atmosphere would need to be retained in soils and standing biomass for roughly 50 years. To offset about one-half of a ton of emitted CO_2, carbon removed from the atmosphere would need to remain stored in soils and biomass for about 25 years.

The MPCA's GHG Reduction Study assumes that CO_2, once removed from the atmosphere, will remain in storage for 20 years, offsetting about 0.4 tons of emitted GHGs for each ton sequestered. In the language of climate science, this is equivalent to a GWP of 0.4.

The MPCA uses a 20-year time period for reasonably certain future storage of sequestered carbon for several reasons:

- 20 years is considered a reasonable assumption for the duration of agricultural and forestry practices. Some practices, such as cover crops and conservation tillage can have relatively short durations, based on changes in land ownership, program funding, or other economic considerations. Others, such as conservation cover planted through an easement program, are theoretically permanent. Therefore, the 20-year timeframe provides a common denominator across practices and programs.
- Climate change itself can affect the feasibility and effectiveness of many conservation practices, e.g., increasing wildfires changing the composition and health of forests, flooding affecting perennial crops, drought affecting wetlands, etc. Looking beyond a 20-year horizon would increase the uncertainty on practice effectiveness.

[1] https://www.epa.gov/ghgemissions/understanding-global-warming-potentials

For internal consistency, the MPCA applied the GWP value of 0.4 to all instances of terrestrial sequestration in all practices. However, it is important to note that most of BWSR's easement programs provide permanent protection, which can increase the effectiveness of carbon sequestration over as much as 40 or 50 years, or substantially longer than the 20 years assumed in the MPCA study.

Conservation practices tracked in eLINK

We assessed the conservation practices tracked in eLINK and selected those that have are directly comparable to the practices assessed in the MPCA GHG Reduction Study, or to practices identified in COMET-Planner. We then created a crosswalk table (Table 2) that compares all the assessed practices. Table 2 is a compilation of acreage in each practice as of 2018, and the estimated metric tons per acre of GHG reduction, in CO_2 equivalents. Note:

- Where dimensions of a practice are recorded in linear feet – windbreaks, for example – we used an estimate of average width to derive acres – generally 30 to 50 feet, depending on the practice.
- In a few instances where practices are simply counted, such as water and sediment control basins, we estimated an acreage likely to be vegetated – for example, one acre of perennial vegetation was assigned for each basin.
- For wetlands, we made several assumptions, based on discussions with MPCA staff and related research:
  - Methane emissions are highest in wetlands that are permanently or frequently inundated, while seasonally inundated wetland types such as wet meadows seem to sequester more GHGs than they emit.
  - About two-thirds of restored or created wetlands appear to consist of wet meadows and other areas that are seasonally inundated. These wetland types seem to act more like riparian buffers. The remaining one-third are permanently inundated, making them net sources of methane.
  - Using this ratio, we estimated net GHG emissions from all restored and created wetlands. Combining these estimates, net carbon sequestration is greater than methane emissions.
  - Additional research and geospatial analysis of wetland types and their respective emissions profiles would help refine these and other estimates.
- Another major assumption is that practices, once installed, remain in place. Grant requirements generally require that structural practices remain in place for at least 10 years, while non-structural practices vary in duration. Land management practices such as cover crops are required to remain in place for three years under current grant policies. We are unable to verify the current status of installed practices.

Conservation practices on RIM easements

RIM easements are managed through development of a conservation plan that identifies the acreage on each easement property to be protected or restored through a variety of conservation practices. We tracked the following conservation practices applied to RIM easements:

- Conservation Cover
- Diversion
- Windbreak/Shelterbelt Establishment

- Grassed Waterway
- Tree/Shrub Establishment
- Water and Sediment Control Basin
- Restoration and Management of Declining Habitats
- Wetland Restoration
- Wetland Creation

As with the eLINK data, practices were equated to the MPCA-identified conservation practices and the same estimates were used.

Several easement categories were not included in the estimates. Army Compatible Use Buffers (ACUB) easements, used to limit development around Camp Ripley, were not included since most do not require conservation practices. Wetland bank easements were not included since they were calculated separately.

Due to changes in the database and recording practices, easements recorded between 1987 and 2003 show discrepancies between total acreage and the acreage in the conservation plan, leading to substantial overcounting. Parcels with minimal discrepancies – 2.5 acres or less – are included in the acreage totals. Parcels with larger discrepancies are excluded; these comprise about 75,000 acres, or about one-third of the pre-2004 easement acres.

Easements including already established practices are also included in the analysis, since most “established” acres were converted from cropland under previous programs, generally CRP, before they were placed under easement. The results of this analysis are shown in Table 4.

Wetland restoration through wetland banking

Minnesota's wetland banking program includes both private and state-sponsored wetland banks which have “credits” that are used to offset (mitigate) authorized wetland impacts. To date, over 380 wetland banks have been established, covering 42,000 acres. These sites include both existing wetlands that are preserved and previously drained wetlands that have been restored, as well as associated upland buffers. BWSR wetlands staff developed a GIS-based process for assessing the acreage and estimating the net impacts on GHG reduction and emissions, using the National Wetlands Inventory (NWI):

- Removed the “preservation” bank sites, where restoration did not occur or was a minimal component
- Selected the NWI features that were within the wetland bank boundary layer
- Assigned wetland types, using the Simplified Plant Community classification system in the NWI, to two general categories:
  - Inundated
  - Seasonally Inundated
- Calculated the wetland bank acreages within the two categories.
- Calculated upland acreage by identifying bank areas not included in the NWI (adjacent upland areas are typically included as buffers in wetland bank sites).

- Applied the same assumptions described above under "Conservation Practices Tracked in eLINK" to the inundated and seasonally inundated categories:
  - Inundated wetlands are treated as "wetlands" in terms of their higher methane emissions
  - Seasonally inundated wetlands are treated as "grassland riparian buffers"
  - The upland category is treated as "grassland"

Table 1 below shows the classification and the acreage in each wetland category.

Table 1: Wetland Classifications and Acreage

SPCC Description	Broad Category for Duration of Hydrology	Sum of acres
Artificially Flooded Deep Marsh	Inundated	693
Artificially Flooded Shallow Marsh	Inundated	1,561
Artificially Flooded Shrub Wetland	Seasonal	135
Coniferous Bog	Seasonal	46
Deep Marsh	Inundated	9
Hardwood Wetland	Seasonal	354
Non-Vegetated Aquatic Community	Inundated	1,018
Open Bog	Seasonal	55
Seasonally Flooded/Saturated Emergent Wetland	Seasonal	3,973
Shallow Marsh	Inundated	2,673
Shallow Open Water Community	Inundated	276
Shrub Wetland	Seasonal	1,012
	TOTAL	**11,805**

Summary	Acres	CO2-e MT/ac/yr	Total MT change ac/yr
Inundated	6,230	-0.60	-3,738
Seasonal	5,575	0.70	3,902
Upland	9,099	1.47	13,376
		TOTAL	**13,541**

Conclusions: impacts of BWSR programs on the agricultural sector

The combined total GHG reductions of BWSR's programs are approximately **550,100 CO_2-equivalent metric tons**, or **606,400 U.S. CO_2 e-tons**. The estimated emissions of the agriculture and forestry sector are estimated by the MPCA at about **34.5 million CO_2 e-tons**, of which almost **27 million e-tons** are emitted from cropland. Using the estimates outlined above, the combined impacts of BWSR's conservation and easement programs on the emissions of the agricultural-forestry-land use sector are clearly quite small – **1.7 percent of total emissions, or 2.2 percent of cropland emissions**. However, this assessment does not include the impacts of related state and federal programs and of voluntary practices:

- **NRCS programs** such as EQIP and CSP are used to support conservation practices on thousands of acres in Minnesota, including the same practices that BWSR supports and tracks in eLINK. Quantifying the extent and GHG mitigation benefits of those federally-supported acres is an important next step.
- Likewise, the benefits provided by the roughly 1.13 million acres in the **Conservation Reserve Program** in 2018 have not been quantified. While CRP acreage has declined in the past decade, the 2018 farm bill increases the nationwide cap on CRP acreage from 24 million to 27 million acres, and includes practices such as grassed waterways, filter strips, riparian buffers, and wetland restoration.
- The **Minnesota Agricultural Water Quality Certification Program**, a voluntary program administered by the Minnesota Department of Agriculture, tracks the GHG mitigation benefits of practices adopted by participating producers – currently almost 800 producers on over 500,000 acres participate, with estimated GHG reductions of over 30,000 CO_2-e tons per year.
- **Minnesota's Buffer Law**, enacted in 2015, requires a continuous riparian buffer of perennial vegetation along public waters (a 50-foot average width and 30-foot minimum width) and public drainage ditches (16.5-foot minimum). It is estimated that over 100,000 acres of new buffers are being installed to comply with the law, with related GHG reduction benefits.
- In addition, many farmers and landowners adopt conservation practices independent of any federal or state program. The **2017 Census of Agriculture** shows increases in the acreage in many GHG-reducing conservation practices:
  - Acreage in no-till practices increased from 818,754 in 2012 to 1,091,337 in 2017, or about 33%
  - Acreage in other conservation tillage practices increased from 6.1 million in 2012 to 8.2 million in 2017, or about 34%
  - Cover crop acreage increased from 408,190 to 579,147, or 41%

By continuing to assess and quantify the benefits of these programs, we can gain a clearer picture of the contributions of the agricultural sector to climate change mitigation and the potential for increasing those efforts.

Table 2: Comparison of Conservation Practices Between eLINK, RIM, MPCA and COMET

eLINK BMPs	NRCS Code	RIM Practices	MPCA "Top 20"	CO_2-e tons/ 100,000 ac/yr	Convert to MT ac/yr	COMET Tool Equivalent	CO_2 MT ac/yr	N_2O (CO_2 eq) MT ac/yr
Channel Vegetation		RR14 - Existing Watercourse/drainage ditch	Forested and Multispecies Riparian Buffers	203,251	1.84	Riparian Restoration (woody)	2.19	n/a
Conservation Cover	327	RR1, RR2 - Native Grasses	Cropland Idling: Grassland Restoration	162,411	1.47	Conservation Cover	0.98	0.28
Conservation Cover Easement	327	RR1, RR2 - Native Grasses	Cropland Idling: Grassland Restoration	162,411	1.47	Conservation Cover	0.98	0.28
Conservation Crop Rotation	328		Add Perennial Grass to Crop Rotation	49,685	0.45	Conservation Crop Rotation	0.21	0.01
Conservation Tillage	329A		No-Till	13,807	0.125	Conventional Tillage to No-Till	0.42	-0.11
Conservation Tillage	345		Reduced Tillage	14,543	0.132	Conventional Tillage to Reduced Till	0.13	0.07
Contour Buffer Strips	332		Field Borders, Filter Strips, etc.	161,038	1.46	Contour Buffer Strips	0.98	0.28
Cover Crop - incorp. in rowcrops	340		Winter Cover Crop/Catch Crop	20,474	0.19	Cover Crops	0.32	0.05
Critical Area Planting (sites w/ high erosion)	342	RR2 - Native Grasses	Cropland Idling: Grassland Restoration	162,411	1.47	Critical Area Planting (disturbed areas)	1.90	n/a
Critical or Sensitive Area Protection	342		Cropland Idling: Grassland Restoration	162,411	1.47	Critical Area Planting (disturbed areas)	1.90	n/a
Diversion	638	RR5 - Diversion	Field Borders, Filter Strips, etc.	161,038	1.46			
Field Border	386		Field Borders, Filter Strips, etc.	161,038	1.46	Field Border	0.98	0.28
Field Windbreak	380	RR4 - Field Windbreak	Shelterbelts, Hedgerows	269,265	2.44	Windbreak/Shelterbelt Establishment	1.81	0.28
Filter Strip - herbaceous, capture overland flow	386/393		Field Borders, Filter Strips, etc.	161,038	1.46	Filter Strip	0.98	0.28
Forage and Biomass Planting	512	RR1 or RR2	Cropland Idling: Grassland Restoration	162,411	1.47			
Grassed Waterway	412	RR7 - Grass Waterway	Field Borders, Filter Strips, etc.	161,038	1.46	Grassed Waterway	0.98	0.28
Hedgerow planting	422		Shelterbelts, Hedgerows	269,265	2.44	Hedgerow Planting	1.42	0.28
Introduced Grasses - to be established	327	RR1 - Introduced Grasses & Legumes	Cropland Idling: Grassland Restoration	162,411	1.47	Conservation Cover	0.98	0.28
Native Grasses - to be established	327	RR2 - Native Grasses	Cropland Idling: Grassland Restoration	162,411	1.47	Conservation Cover	0.98	0.28
	327	RRFB - Native Grasses with Forbs	Cropland Idling: Grassland Restoration	162,411	1.47	Conservation Cover	0.98	0.28
Nutrient Management (590)			15% Fertilizer Use Reduction	5,878	0.06	Improved N Fertilizer Mgmnt (590)	n/a	0.11
Pasture and Hayland Planting	512		Cropland to Hayland	121,339	1.10	Forage and Biomass Planting - full	0.27	0.19
Restoration and Mgmnt of Declining Habitats:	643							
Grass (native terrestrial/aquatic ecosystem)	643, 342	RR2, RR2PP - Pollinator Planting	Cropland Idling: Grassland Restoration	162,411	1.47	Critical Area Planting (disturbed areas)	1.90	n/a
Trees (native terrestrial/aquatic ecosystem)	643, 612	RR3 - Tree and/or Shrub Planting	Cropland Idling: Afforestation	262,611	2.38	Tree/Shrub Establishment	1.98	0.28
Riparian Forest Buffer	391	RR3 - Tree and/or Shrub Planting	Forested and Multispecies Riparian Buffers	203,251	1.84	Riparian Forest Buffer	2.19	0.28
Riparian Herbaceous Cover (flood-tolerant)	390	RR2 - Native Grasses	Grassland Riparian Buffers	77,299	0.70	Riparian Herbaceous Cover	0.98	0.28
Saturated Buffer	604	RR2 - Native Grasses	Grassland Riparian Buffers	77,299	0.70	Riparian Herbaceous Cover	0.98	0.28
Sediment Basin	350	RR6 - Erosion Control Structure						
Stormwater Retention Basin	155M?	RR6 - Erosion Control Structure						
Streambank and Shoreline Protection	155M?	RR2 - Native Grasses	Grassland Riparian Buffers	77,299	0.70	Riparian Herbaceous Cover	0.98	0.28

Stripcropping	585		No-Till	13,807	0.125	Stripcropping (585)	0.11	0.13
Terrace	600		Field Borders, Filter Strips, etc.					
Tree/Shrub establishment	612	RR3 - Tree and/or Shrub Planting	Cropland Idling: Afforestation	262,611	2.38	Tree/Shrub establishment	1.98	0.28
Upland Wildlife Habitat Management	644	RR2b						
Water and Sediment Control Basin	638, 639M	RR6 - Erosion Control Structure						
Wetland Creation (constructed/treatment)	658	RR12 - Wetland Creation	Constructed and Restored Wetlands	-66,517	-0.60			
Wetland Restoration (to natural conditions)	657, 133M	RR8 - Wetland Restoration	(assumes deep water wetlands)					
Wetland Restoration - crop cessation	657	RR8 - Wetland Restoration	(wet meadow = riparian buffer)					
Windbreak/Shelterbelt establishment	380		Shelterbelts, Hedgerows	269,265	2.44			
farmstead shelterbelt	380	RR4 - Field Windbreak	Shelterbelts, Hedgerows	269,265	2.44			
field windbreak	380	RR4 - Field Windbreak	Shelterbelts, Hedgerows	269,265	2.44			
living snowfence	380	RR11 - Highway Windbreak (Living Snowfence)	Shelterbelts, Hedgerows	269,265	2.44			
			Other Practices					
			MPCA			**COMET Tool**		
			Biochar	119,713	1.17	Replacing Syn. N Fertilizer w/ Soil Amend. (590)	1.75	n/a
			Nitrification and Urease Inhibitors	24,033	0.23	Mulching (484)	0.32	n/a
			Controlled Release Fertilizers	27,369	0.27	Prescribed Grazing (528)	0.26	n/a
			Corn-Soybean Replacing Cont. Corn	-39,830	-0.39	Combustion System Improvement (Imp. Fuel Eff.) (372)	0.01	n/a
			Split Fertilizer Application	13,455	0.13			
			15% Fertilizer Use Reduction	5,878	0.06			
			Spring Fertilizer Application	-2,115	-0.02			
			Subsurface Fertilizer Placement	-31,060	-0.30			

Table 3: Summary of Conservation Practices Tracked in eLINK and GHG Emissions in Metric Tons per Acre

ELINK BMP	NRCS CODE	TOTAL ACRES	TOTAL FEET	TOTAL COUNT	CORRECT FEATURE TYPE	TOTAL # PRACTICES	MPCA Practice or Equivalent	Multiplier (for linear ft)	MT/acre	Total MT Reduction/ ac/yr
327 - Conservation Cover	327	3,161	1,500	1	Polygon	2,401	Cropland to grassland		1.47	4,647
327M - Conservation Easement	327M	5,772			Polygon	450	Cropland to grassland		1.47	8,485
328 - Conservation Crop Rotation	328	475			Polygon	5	Perennial added to annual		0.45	214
329B - Conservation Tillage (No-Till, Strip-Till, Reduced Tillage)	329B, 345, 346	28,460			Polygon	323	No-till or Reduced Tillage		0.132	3,757
332 - Contour Buffer Strips	332	660			Polygon	47	Field Borders, Filter Strips, etc.		1.46	964
340 - Cover Crop	340	66,357			Polygon	4,382	Winter cover crop/Catch crop		0.19	12,608
342 - Critical Area Planting	342	42,093	31,582	10	Polygon	14,038	Cropland to grassland		1.47	61,876
362 – Diversion	362	132	114,865	0	Line	1,458	Field Borders, Filter Strips, etc.	50'	1.46	192
380 - Windbreak/Shelterbelt Establishment	380	4,109	5,965,685	1,657	Line	6,678	Shelterbelts, Hedgerows	30'	2.44	10,025
390 - Riparian Herbaceous Cover	390	383	40	1	Polygon	90	Grassland Riparian Buffers		0.7	268
391 - Riparian Forest Buffer	391	4,394			Polygon	1,008	Forested and Multispecies Riparian Buffers		1.84	8,084
393 - Filter Strip	393	31,881	4,871	22	Polygon	6,964	Field Borders, Filter Strips, etc.		1.46	46,546
412 - Grassed Waterway and Swales	412	13,362	64,712	4	Polygon	12,221	Field Borders, Filter Strips, etc.		1.46	19,508
512 - Forage and Biomass Planting	512	514			Polygon	116	Cropland to grassland		1.47	756
528 - Prescribed Grazing	528	8,233			Polygon	131	Prescribed Grazing (COMET)		0.26	2,141
543 - Land Reclamation, Abandoned Mined Land	543	2			Polygon	1	Cropland to grassland		1.47	3
580 - Streambank and Shoreline Protection	580	1,104	1,602,882	17	Line	13,557	Grassland Riparian Buffers	30	0.59	651
585 – Stripcropping	585	1,281			Polygon	32	No-till or Reduced Tillage		0.132	169
590 - Nutrient Management	590	224,568		1	Polygon	1,544	15% Fertilizer Use Reduction		0.06	13,474
600 - Terrace	600	14,118	5,700	3	Polygon	856	Field Borders, Filter Strips		1.46	20,612
604 - Saturated Buffer	604	112			Polygon	3	Grassland Riparian Buffers		0.7	78
612 - Tree/Shrub Establishment	612	30,874	13,625	2,674	Polygon	4,472	Cropland Idling: Afforestation		2.38	73,481
638 - Water and Sediment Control Basin	638	6,685	7,466	6,685	Point	40,885	Grassland Riparian Buffers		0.59	3,944
643 - Restoration and Management of Declining Habitats	643	6,652			Polygon	1,547	Cropland to grassland		1.47	9,778
650 - Windbreak/Shelterbelt Renovation	650	99	143,387		Line	144	Shelterbelts, Hedgerows	30'	2.44	241
657 - Wetland Restoration	657	6,522		15	Polygon	339	Wetland		-0.60/0.70	1,683
658 - Wetland Creation	658	49			Polygon	18	Wetland		-0.60/0.70	13
		502,001							**TOTAL**	**304,186**

CODING
Generally accepted practices for GHG reductions
Practices in need of further research
4,109 - acres derived from linear feet * width

Link to spreadsheet with detailed calculations.

Table 4: Summary of RIM Easement Conservation Practices and GHG Emissions

RIM PRACTICE	NRCS CODE	PRACTICE DESCRIPTION	MPCA EQUIVALENT	PRACTICE ACRES	MT/ACRE	TOTAL MT
RR2 - Native Grasses	327	Conservation Cover	Cropland Idling: Grassland Restoration	41,148	1.47	60,487
RRFB - Native Grasses with Forbs	327	Conservation Cover	Cropland Idling: Grassland Restoration	32,695	1.47	48,061
RR1 - Introduced Grasses and Legumes	327	Conservation Cover	Cropland Idling: Grassland Restoration	7,542	1.47	11,087
RR9 - Vegetative Cover Already Established	327AE	Conservation Cover Already Established	Field Borders, Filter Strips, etc.	27,481	1.47	40,397
RR5 - Diversion	362	Diversion	Shelterbelts, Hedgerows	2	1.46	4
RR4 - Field Windbreak	380	Windbreak/Shelterbelt Establishment	Shelterbelts, Hedgerows	94	2.44	230
RR11 - Highway Windbreak (Living Snowfence)	380	Windbreak/Shelterbelt Establishment	Grassland Riparian Buffers	34	2.44	82
RR14 - Existing Watercourse/drainage ditch	390AE	Riparian Herbaceous Cover Already Established	Field Borders, Filter Strips, etc.	1,072	0.7	750
RR7 - Grass Waterway	412	Grassed Waterway	Cropland Idling: Afforestation	1	1.46	2
RR3 - Tree and/or Shrub Planting	612	Tree/Shrub Establishment	Cropland Idling: Afforestation	9,313	2.38	22,164
RR10 - Trees and/or Shrubs- Already Established	612AE	Tree/Shrub Already Established	Grassland Riparian Buffers	15,623	2.38	37,183
RR6 - Erosion Control Structure	638	Water and Sediment Control Basin	Cropland Idling: Grassland Restoration	3	0.59	2
RR2PP - Pollinator Planting	643	Restoration and Management of Declining Habitats	Constructed and Restored Wetlands	255	1.47	375
RR8 - Wetland Restoration	657	Wetland Restoration	Constructed and Restored Wetlands	34,196	0.6/0.7	8,822
RR13 - Existing Wetland/Waterbody	657AE	Wetland Restoration Already Established	Constructed and Restored Wetlands	10,780	0.6/0.7	2,781
RR12 - Wetland Creation	658	Wetland Creation		44	0.6/0.7	11
			TOTAL	**180,281**		**232,437**

Link to spreadsheet with detailed calculations