# Valuing state investments in clean water

## An analysis of Minnesota's Clean Water Fund through the lens of ecosystem services, equity, and climate change

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Authors: Bonnie Keeler, Olena Boiko, Taylor Hohensee, Rachel Nichols, Erin Niehoff

Affiliations: Center for Science, Technology, and Environmental Policy, Humphrey School of Public Affairs, University of Minnesota

CENTER FOR SCIENCE, TECHNOLOGY, AND ENVIRONMENTAL POLICY
UNIVERSITY OF MINNESOTA

*Legislative Request: (MN Laws 2021, 1st Special Session, Chapter 1):*
*(c) $95,000 the first year and $95,000 the second year are for a report that quantifies the multiple benefits of clean water investments, for a review of equity considerations in clean water fund spending, and for proposing climate considerations in comprehensive watershed management plans. The Board of Regents must submit the report to the Clean Water Council and the chairs and ranking minority members of the house of representatives and senate committees and divisions with jurisdiction over environment and natural resources and the clean water fund no later than June 30, 2024.*

Per the requirements set forth in Minn. Stat. §3.197, the cost to prepare this report was $190,000.

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# Introduction and Report Summary

## Dedicated funding for clean water: Minnesota's Clean Water Land and Legacy Amendment

Voters in the state of Minnesota passed a constitutional amendment in 2008 that created a dedicated fund for the protection and restoration of water quality. In 2009, the Clean Water Council was assigned the task of recommending how to spend the Clean Water Fund, which comprises one-third of the dedicated sales tax revenue generated from the amendment. Decisions are made biennially on the appropriate investment strategies for the fund with final approval for expenditures made by the Minnesota legislature and signed by the Governor.

Projects approved to receive fund investments must comply with statutory guidance *"to protect, enhance, and restore water quality in lakes, rivers, and streams and to protect groundwater and drinking water from degradation."* Projects are given priority if they meet more than one of these stated objectives. The authorizing legislation also requires that investments are expended to balance the distribution of benefits across the state.

Since 2010, over $1.8 billion in funding from the Clean Water, Land and Legacy Amendment has been appropriated to water quality projects and planning in Minnesota (Figure 1). Assuming a linear extrapolation of funds into the future, there is an estimated $1-1.6 billion in funding available through the expiration of the amendment in 2034 (Figure 1).

In 2023, legislators modified the statutory guidance to require projects financed by the Clean Water fund to include *"an assessment of whether the funding celebrates cultural diversity or reaches diverse communities in Minnesota, including reaching low-and moderate-income households."* In accordance with this guidance, the Clean Water Council began requesting agencies and applicants to incorporate principles for diversity, equity, inclusion, and/or environmental justice into Clean Water Fund-supported programs. The Council also requests that applications articulate how programs align with the state's Climate Action Framework.

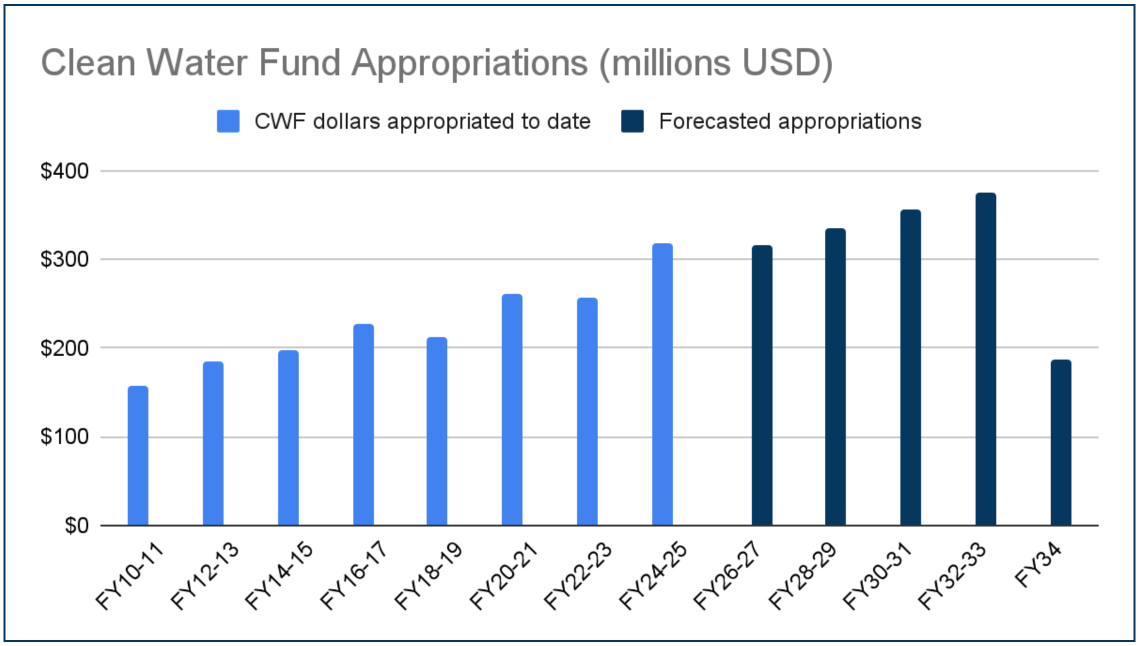


Figure 1: Funding appropriated in each biennium from the Clean Water Fund and forecasted appropriations assuming a linear extrapolation of historical data.

## Communicating the value of clean water investments

The establishment of a long-term dedicated fund for clean water allows the state to make significant investments in water quality planning, monitoring, restoration, and protection. Dollars available through the fund are required to supplement, not substitute, other investments in clean water and can be used to leverage additional state and federal resources. The Clean Water Council (Council) produces biennial reports on progress made towards multiple water quality goals and strategic targets that align with the 2014 Clean Water Roadmap.

Communicating the impacts of the Clean Water Fund to the public is necessary to maintain transparency about the expenditures of public dollars. State-mandated performance reports and agency documentation contribute to this goal. However, it is both expensive and challenging to conduct systematic monitoring and evaluation of water quality programs and expenditures. Further challenges arise when attempting to connect changes in water quality outcomes to social and economic metrics.

Beyond the quantification and communication of water quality impacts, emerging issues such as climate change and environmental justice have raised additional considerations in how water quality funds are distributed and prioritized. Climate change will affect both the quality and quantity of Minnesota waters and affect the implementation and efficacy of best management practices. Attention to the equitable distribution of water resources at both state and federal levels requires additional data on how state investments may differentially benefit or burden particular communities. These are important considerations in watershed planning and management, but place additional burdens on Council and agency staff in estimating and reporting on the impacts of funds across multiple social, economic, and environmental objectives.

## Report aim and scope

This report aims to support strategic planning through the duration of the Clean Water Land and Legacy amendment. Our goal is to provide insights to the Council and legislature to help inform remaining years of the fund, prioritize future allocations, and suggest recommendations for more efficient and equitable management. To address these gaps, we aligned our research with the following three objectives:

1. Estimating ecosystem service benefits of clean water investments,
2. Reviewing integration of climate and equity consideration in watershed planning, and
3. Evaluating potential costs of achieving multiple water quality goals through the expiration of the Clean Water Fund.

Work under each objective included review of primary and secondary literatures, spatial data analysis and modeling, review and analysis of watershed plans, and assessment and synthesis of agency and academic data and reports to distill key insights and recommendations relevant for clean water planning and management.

## Findings and recommendations

We present the main insights and recommendations from our research as contributing insight to the following four questions:

### 1. Have Clean Water Fund investments led to multiple benefits?

Our research, along with agency investments in modeling and reporting, suggests that clean water funding leads to a flow of benefits valued by Minnesota residents. Using ecosystem service models, we illustrate how investments in water quality in different regions of the state are associated with seven potential benefits: drinking water quality, lake recreation, nutrient export, trout angling, lakeshore property value, wild rice production, and wetland bird conservation. For each water-related ecosystem service, maps identify watersheds where past Clean Water Fund investments have targeted watersheds that scored highly for the provision of particular services. For some services, such as drinking water quality and nutrient export, we observed a high degree of alignment between past Clean Water Fund investments and potential returns. There are also areas where Clean Water Fund investments have not prioritized watersheds with the greatest potential to provide particular benefits, most notably for wetland bird conservation and wild rice production.

Investment decisions that consider the demand for water quality-related benefits, in addition to biophysical factors, are more likely to target areas with greater potential to deliver valued ecosystem services. Existing spatial datasets, such as those we present in this report, can assist decision makers in prioritization of implementation activities and in the evaluation of multiple benefits.

### 2. Are Clean Water Fund projects being implemented equitably?

To evaluate the distribution of Clean Water Fund investments we compared county-level data on investments from 2010 to 2022 with federal data on the location of designated disadvantaged communities. The greatest cumulative investments tend to have been allocated to central and southern Minnesota counties, whereas counties with the greatest area designated as disadvantaged tend to be in the northern parts of the state, especially where Tribal lands make up a significant proportion of county area. Federal data on the location of disadvantaged communities provides an opportunity for agencies to evaluate the distribution of funds and consider differential impacts of alternative funding models.

Our review of watershed planning documents also suggested a lack of consideration of equity and environmental justice considerations in implementation planning. Very few watershed plans considered distributional or environmental justice impacts in assessment of threats or prioritization of goals and actions. We observed notable gaps in the consideration of Tribal nations in some watersheds where Tribal lands and ceded territories make up a significant proportion of the watershed. Non-indigenous minority populations in Minnesota were not considered in any plans. Prioritizing engagement with Tribes and other federally-recognized disadvantaged communities will continue to be an important implementation strategy to ensure that clean water programming is attentive to multiple equity goals, including capacity building, meaningful participation, and equitable distribution of clean water investments.

### 3. Is watershed planning adequately considering potential impacts of climate change?

We reviewed all approved watershed plans submitted for agency review for their consideration of climate change and extreme weather. All reviewed plans included some mention of climate change or climate trends and most plans integrated climate impacts into specified goals and actions. Our review suggests an increase in the consideration of climate impacts in watershed planning over time. However, there were notable gaps in the level of specificity and rigor in consideration of climate change in watershed planning. For example, only a few plans took advantage of publicly available high resolution downscaled climate projections and no reviewed plans integrated climate projections developed specifically for Minnesota. Most plans considered climate change in very general terms, without connecting plan implementation goals or actions to specific anticipated climatic changes.

We also reviewed the literature to identify potential climate impacts on agricultural best management practices. We noted how climate change is likely to change the effectiveness of many common practices. For example, increased temperatures and shifting precipitation regimes may reduce the effectiveness of conservation tillage, filter strips, and other water management practices. Given the potential direct and indirect impacts of climate change on Minnesota watersheds, our review points to multiple areas where the consequences of climate change for planning and implementation warrant greater consideration in watershed management.

### 4. Does the Clean Water Fund have sufficient resources to accomplish multiple water quality related goals?

We compared remaining funding available through the expiration of the Clean Water Land and Legacy Amendment through 2034 with the anticipated costs of achieving multiple stated water quality goals. For a subset of goals that could be estimated with existing data, we calculated potential costs of achieving these goals at over $6 billion, representing 375% of available funding. Clearly, the funding remaining through the expiration of the Legacy amendment is insufficient to meet all stated goals. Agencies and watershed planners will have to continue to leverage additional funding, while also prioritizing investments given limited resources and many competing objectives.

Cost projections are meant to be illustrations of potential expenditures and subject to uncertainties and simplifying assumptions. Our work suggests that consideration of ecosystem services, more intentional integration of climate change impacts, and an attention to equity and distribution considerations remain important focal areas as the Council prioritizes future planning and implementation decisions.

## Report outline

The remaining sections of the report provide additional context and background for how we arrived at our findings and associated recommendations. The report is organized into the following sections. Section I applies an ecosystem services approach to estimate the multiple benefits of water quality investments. This section presents data on the past and current distribution of clean water investments and evaluates how the spatial pattern of investments aligns with priority watersheds for multiple ecosystem services and equity considerations. Section II addresses climate change and equity as emerging issues in watershed planning. This section presents a review of watershed planning documents supported by the Clean Water Fund. Plans are evaluated for their consideration of climate change and equity. We also consider how climate change will affect best management practices recommended in watershed plans. Section III addresses the funding remaining in the Clean Water Fund and evaluates potential cost scenarios associated with achieving multiple stated goals.

# Section I: Multiple benefits of clean water investments

Minnesota's Clean Water Fund supports investments in programs and practices designed to improve water quality. Adoption of best management practices or converting lands from row-crop agriculture to perennial cover can result in a stream of public benefits including reduced treatment costs for community water suppliers and reduced risk of diseases associated with exposure to contaminated drinking water. Water quality investments can also lead to benefits beyond drinking water quality such as improved recreation or habitat for fish and wildlife.

Annual reporting by the Clean Water Council and agency partners provides useful insights into how Clean Water Fund dollars are allocated among water quality monitoring, planning, and implementation. Data are also provided on the spatial distribution of investments by county or watershed. To estimate the water quality benefits of these investments, agencies rely on models such as BWSR's Pollution Reduction Estimator Tool (Minnesota Board of Water, and Soil Resources [BWSR], 2021).

Estimated benefits from these tools represent generalized relationships between adoption of land management practices and estimates of reduced sediment or nutrients. These simplified models provide useful illustrations of potential benefits. However, modeled estimates should not be confused for actual measured changes in water quality. Quantifying the realized benefits of implemented management practices requires investments in monitoring equipment, time-consuming data collection, and detailed studies that account for variations in soil conditions, climate, and other variables. As such, a persistent challenge in the oversight of water quality expenditure programs is the difficulty in demonstrating clear relationships between investments in management practices and robust and measurable outcomes in improved water quality.

## From water quality metrics to ecosystem services

Connecting expected changes in water quality to ecosystem services or metrics of human wellbeing requires a completely different set of integrated models and assumptions. Changes in water quality can be translated into changes in ecosystem services based on presumed relationships between water quality attributes and designated uses. Further conversion of ecosystem service values into monetary values requires economic models that estimate the values households place on changes in the supply of goods or services.

Ecosystem service models can help inform the prioritization of water quality investments, developing spatial maps of locations where investments in restoration or protection are likely to yield higher returns across a suite of objectives. Ecosystem service models can also be used in the assessment of tradeoffs, investigating how alternative portfolios of investments affect multiple benefits and where additional investments may lead to diminishing returns. Valuation research is an important input into policy analysis and can be used to inform benefit-cost assessments or regulatory impact analyses. As agencies and managers are challenged to conserve resources, demonstrate the value of environmental protection, and provide the greatest return on investment in limited public funding, approaches that translate environmental outcomes into ecosystem services or values can better target investments across multiple objectives, aid in prioritization decisions, and build support for future restoration and protection activities.

In recent years, a proliferation of web-based spatial data repositories and dashboards at the state level (see the Minnesota Natural Resources Atlas) or federal level (EPA EnviroAtlas) allow users to access social and environmental data that can be integrated into spatially explicit models or facilitate spatial prioritization or mapping exercises. As with all modeling efforts, ecosystem service models rely on simplifying assumptions and are constrained by data availability and underlying science. Selection of the most appropriate model for a given application requires consideration of time, data availability, and the intended decision context (Figure 2). Reviews of ecosystem service models and tools as they are applied to water quality benefits are summarized in Brauman et al. 2007, Keeler et al. 2012, and Guswa et al. 2014.

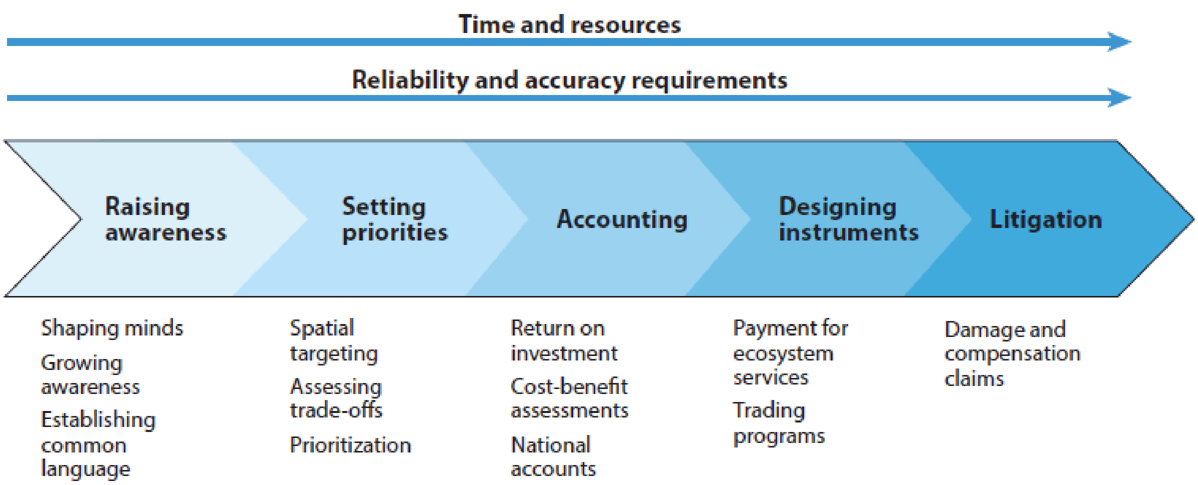


Figure 2. Selection of the most appropriate ecosystem services model depends on the intended use case or decision context. Simple overlays or benefits calculators may be sufficient if the goal is to raise awareness of potential water quality benefits. For policy design or formal evaluation, models of greater complexity and accuracy are required, increasing the time and resources required to conduct the analysis. Figure adapted from Keeler, 2020.

## Using an ecosystem services approach to prioritize investments

As noted above, applying an ecosystem services approach allows decision makers to consider how water quality investments affect a variety of potential benefits and designed uses. The distribution and value of ecosystem services will vary spatially depending on the factors that affect both the supply and demand for that particular service. For example, investments in improving the quality of drinking water will yield greater potential benefits in locations where geologic conditions facilitate the transport of pollutants from surface to groundwater and where a large number of households drink untreated groundwater.

We applied an ecosystem services approach to illustrate how investments in water quality in different regions of the state may lead to varied outcomes across a range of water-related benefits. We focused on seven potential benefits of water quality improvements: drinking water quality, lake recreation, nutrient export, trout angling, lakeshore property value, wild rice production, and wetland bird conservation. For each benefit we combined data on the provision of the ecosystem service, including biophysical data that determine how a given water quality improvement may affect endpoints of interest (trout streams, groundwater aquifers, recreational lakes) and social data on the demand for each service (population data and information on the location and preferences of users). Metrics on ecosystem service supply and demand were combined to form indicators and normalized to rank watersheds based on low to high potential to provide each service (Figure 3). We then compared these prioritization maps with spatial data on investments in water quality under the Clean Water Fund. Details on data and methods used to estimate each ecosystem services metric are described in Appendix A.

For each water-related ecosystem service, maps identify watersheds where past Clean Water Fund investments have targeted watersheds that scored highly for the provision of particular services. Similarly, the maps also identify watersheds that score highly for ecosystem service provision, but have received relatively lower levels of Clean Water Fund investments. As the supply and demand for water-related services varies spatially, there will be tradeoffs in the allocation of funds across multiple objectives. These maps indicate that for some services, such as drinking water quality and nutrient export, there is good alignment between past investments and potential returns to these two ecosystem services. There are also areas where investments have not prioritized watersheds with the greatest potential to provide particular benefits, most notably for wetland bird conservation and wild rice protection.

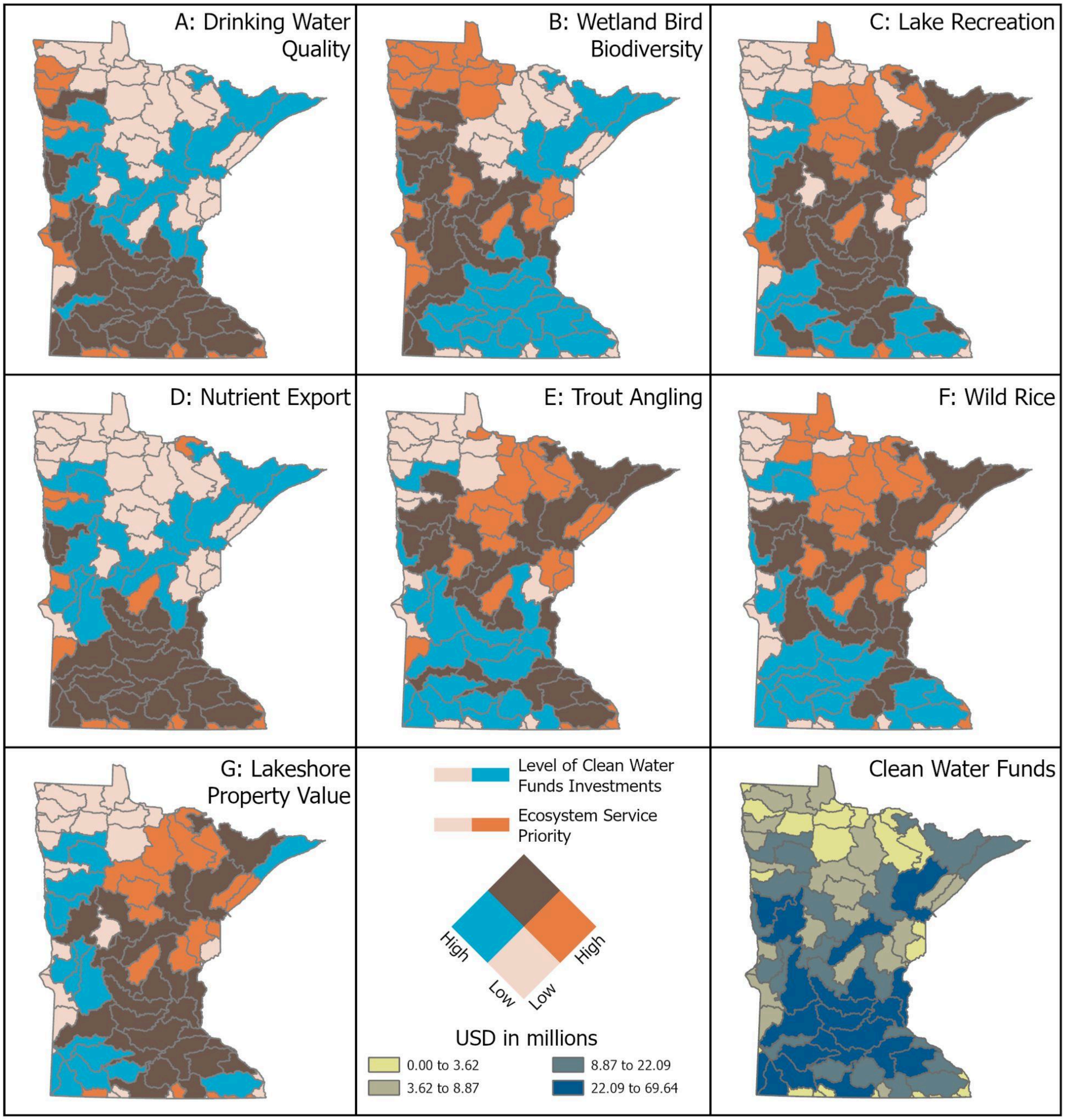


Figure 3. Lower right map visualizes total state spending on implementation projects by watershed from 2010 to 2022 for the programs managed by the Minnesota Board of Water & Soil Resources, Minnesota Department of Agriculture, and Minnesota Public Facilities Authority. The remaining map panels combine investment data with ecosystem service metrics. Dark brown watersheds indicate areas where investments are likely to yield the greatest relative returns to that ecosystem service and where there has historically been relatively high levels of clean water fund investments. Methods used to estimate ecosystem service metrics are described in Appendix A.

## Equitable distribution of Clean Water Fund investments

Updated guidance for expenditures under the Clean Water Fund now requires "an assessment of whether the funding celebrates cultural diversity or reaches diverse communities in Minnesota, including reaching low- and moderate-income households." This revised statutory language, adopted in 2023, reflects growing awareness of the equity and distributional impacts of environmental investments. In addition to state guidance, the Biden Administration has instructed federal agencies to ensure that 40% of federal investments flow to disadvantaged communities (Executive Order 14008, 2021). To support agencies in this evaluation, the administration has released a variety of tools to identify federally-designated disadvantaged communities and support the analysis and reporting of environmental justice impacts of federal programs and policies (Council on Environmental Quality, n.d.).To evaluate the distribution of Clean Water Fund investments we compared county-level data on investments from 2010 to 2022 with federal data on the location of designated disadvantaged communities (Figure 4). Federally-designated disadvantaged communities reflect communities that face both socioeconomic burdens and environmental burdens.

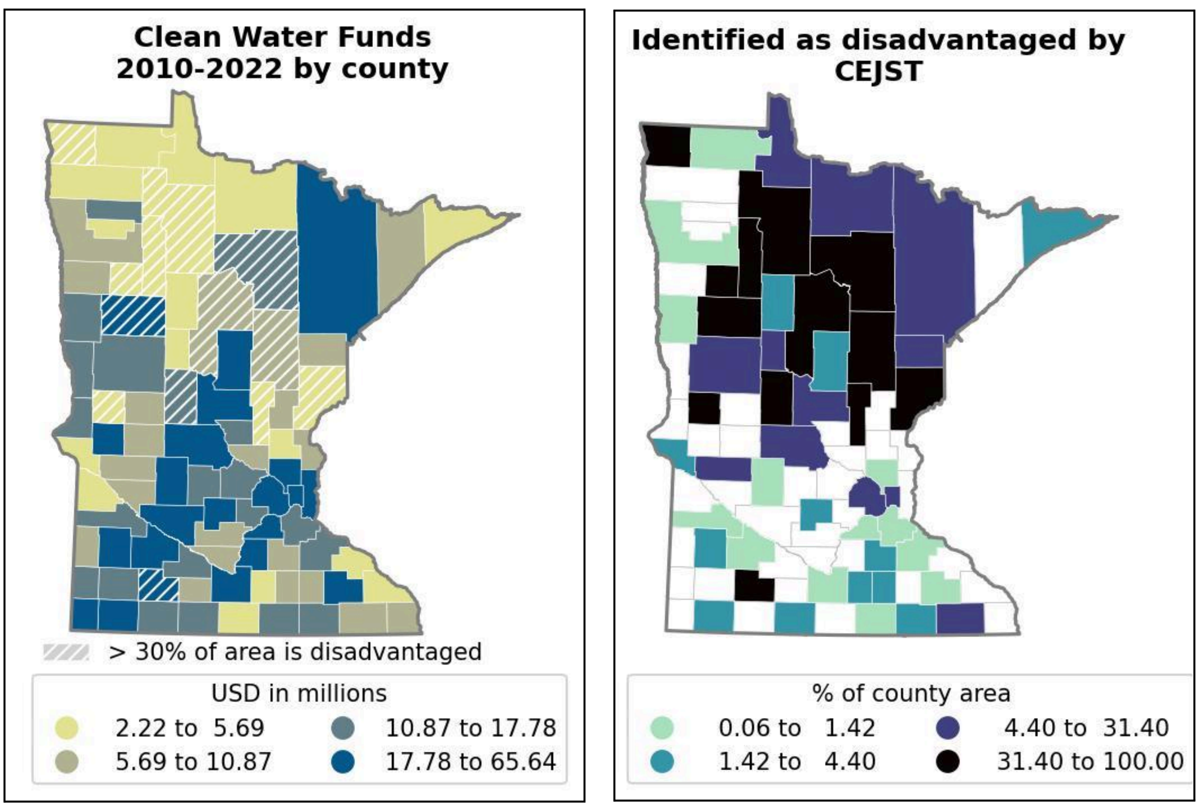


Figure 4: Clean Water Fund investments from 2010 to 2022 visualized by county and compared with spatial data on disadvantaged communities provided by the Climate and Economic Justice Screening Tool (CEJST). The tool defines the communities as disadvantaged if they are in census tracts that meet the thresholds for at least one of the categories of burden, or if they are on lands within the boundaries of Federally Recognized Tribes. We aggregated fully or partially disadvantaged census tracts to a county level by quantifying the fraction of county areas that contain disadvantaged tracts.

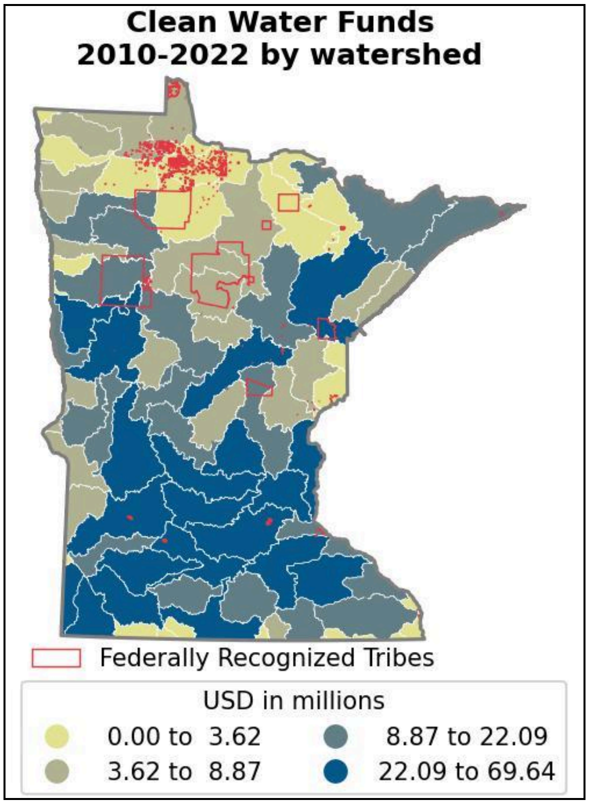


Figure 5: Clean Water Fund investments by watershed overlaid with the boundaries of federally recognized tribes within Minnesota.

Rural and remote communities, those with limited language proficiencies, and low income communities are designated as disadvantaged. Counties with significant immigrant populations and that share geographies with federally designated Tribes are more likely to have greater area designated as disadvantaged.

The greatest cumulative investments tend to have been allocated to central and southern Minnesota counties, whereas counties with the greatest area designated as disadvantaged tend to be in the northern parts of the state, especially where Tribal lands make up a significant proportion of county area (Figure 5). As decisions are made about future allocations of funds, spatial data on disadvantaged communities can support decision makers seeking more equitable distribution of water-related investments.

To further explore the distribution of Clean Water Fund investments across the state, we sorted counties by their share of past Clean Water Fund investments and share of the state population. Figure 6 shows that approximately 50% of the state population received approximately 90% of state Clean Water Fund investments.

We were interested in how clean water funding was allocated across urban and rural regions of the state. Table 1 presents the total amount of Clean Water Fund investments allocated to counties associated with rural or urban classifications and the percent share of total Clean Water Fund dollars. Almost 70% of Clean

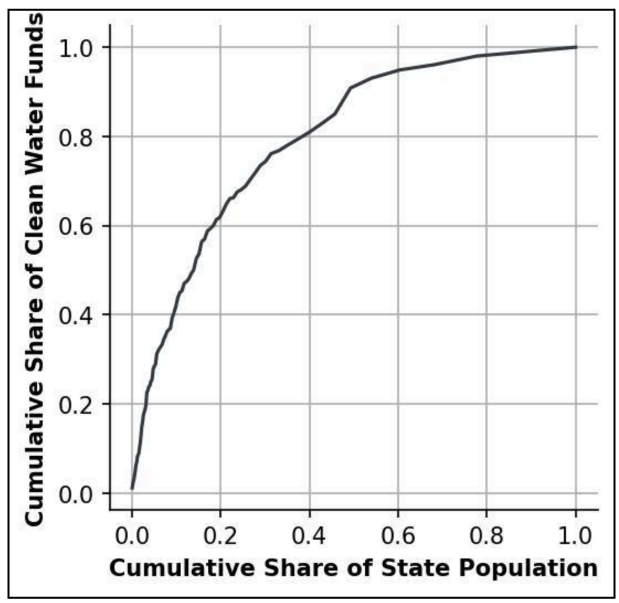


Figure 6. Data on the cumulative share of Clean Water Fund investments by county compared to cumulative share of the state population by county. Population data are from the 2022 American Community Survey: 5-Year Data.

| Rural-Urban Commuting Areas (RUCA) | Number of counties | Population | Population, % | Clean Water Funds, USD | Clean Water Funds, % |
|---|---|---|---|---|---|
| Entirely rural | 14 | 95,045 | 1.67% | 116,430,354 | 10.31% |
| Town/rural mix | 35 | 802,412 | 14.09% | 451,710,162 | 39.99% |
| Urban/town/rural mix | 25 | 1,177,192 | 20.67% | 340,849,254 | 30.17% |
| Entirely urban | 13 | 3,620,643 | 63.57% | 220,621,120 | 19.53% |
| **Total** | **87** | **5,695,292** | **100.00%** | **1,129,610,890** | **100.00%** |

Table 1: County population compared to cumulative clean water fund investments with counties allocated to corresponding rural-urban commuting areas. Population data from the 2022 American Community Survey: 5-Year Data and Rural-Urban Commuting Areas from https://www.ruralmn.org/rural-urban-commuting-areas-explanation-of-county-categories/.

Water Fund investments were made in counties designated as “town/rural mix” or “urban/town/rural mix” with the remaining allocated to “entirely rural” and “entirely urban” counties.

Demographic data are available at finer resolutions statewide, but investment data were only available at the county level making it difficult to attribute investments to particular demographic groups. Agency staff seeking to consider distributional considerations in Clean Water Fund prioritization or evaluation can take advantage of federal and state demographic data to continue to track how investments are distributed, with particular emphasis on communities designated as disadvantaged. These communities may be eligible for additional state and federal support due to this designation.

# Section II: Review of watershed plans for climate and equity considerations

## Collaborative watershed planning

The One Watershed, One Plan (1W1P) is a program administered by the Minnesota Board of Water and Soil Resources (BWSR) with the purpose of facilitating diverse partnerships for Comprehensive Watershed Management Plans (CWMP) based on watershed boundaries. The 1W1P is voluntary, but fulfills the requirements outlined in Minnesota Statutes §103B.801. These plans draw on existing local government services, agencies, and resources to implement targeted actions that address surface water and groundwater quality at the watershed level. Approved plans are eligible for watershed-based implementation funding from the Clean Water Land & Legacy Amendment if they meet set criteria for CWMPs (BWSR, n.d.).

Watershed plans offer a unique window into the priorities of local watershed partners, including water quality issues of concern, identified future threats to water quality, and goals and strategies for addressing threats. The 1W1P program has benefited from funding and support through the Clean Water Fund and is a key strategy in allocation of water restoration or protection strategies financed by Clean Water Fund implementation dollars.

Minnesota Statutes §103B.101 subd.16 requires BWSR to incorporate conservation practices, including climate adaptation, resiliency, and mitigation, into planning efforts. The plans must, at a minimum, include the following content outlined in 103B.801 Subd. 4:

- Surface water and ground water quality protection, restoration, and improvement, including prevention of erosion and soil transport into surface water systems;
- Restoration, protection, and preservation of drinking water sources and natural surface water and groundwater storage and retention systems;
- Promotion of groundwater recharge;
- Minimization of public capital expenditures needed to correct flooding and water quality problems;
- Wetland enhancement, restoration, and establishment;
- Identification of priority areas for riparian zone management and buffers; and
- Protection and enhancement of fish and wildlife habitat and water recreational facilities.

In addition to these requirements, Section B. “Other Topics” encourages plans to consider climate impacts on water resources, ecosystem health and resilience, contaminants of emerging concern, and equity and environmental justice. Climate impacts are also mentioned in the guidance under Section C. “Special Consideration: Extreme Weather” where plans can address the impacts of extreme weather events on their water and land resources (BWSR, 2022).

## Emerging issues in watershed planning: Climate change

Climate change has the potential to affect water resources in multiple ways, with implications for watershed planning. The 2020 State Water Plan for Minnesota focused on the interaction between climate change and water resources, noting that a changing climate will affect the amount and timing of precipitation, the availability and demand for water, the timing of snowmelt, the duration of ice cover on lakes and streams, the beginning and end of Minnesota's growing season, as well as chemical, physical and biological processes that shape aquatic resources (Environmental Quality Board, 2020).

Information on expected changes in future climate are readily available via state and regional investments in predictive climate science. The USGS National Climate Change Viewer provides public access to climate projections by state or county (US Geological Survey, 2013). Additionally, Minnesota researchers have invested in the development of high resolution dynamically downscaled climate projections specifically for Minnesota (Liess et al, 2023). Climate projection data are designed to help planners and decision makers consider future climate in management decisions.

According to high resolution climate projections by the University of Minnesota, the future climate in Minnesota is expected to be both wetter and warmer  (Liess et al, 2023). Average growing season temperature is expected to increase statewide (Figure 7). Changes in precipitation patterns are more variable, with the majority of the state seeing increases of at least an inch in annual precipitation (Figure 7). These temperature and precipitation deviations from historical data represent modest emissions scenarios under a mid-century time frame.

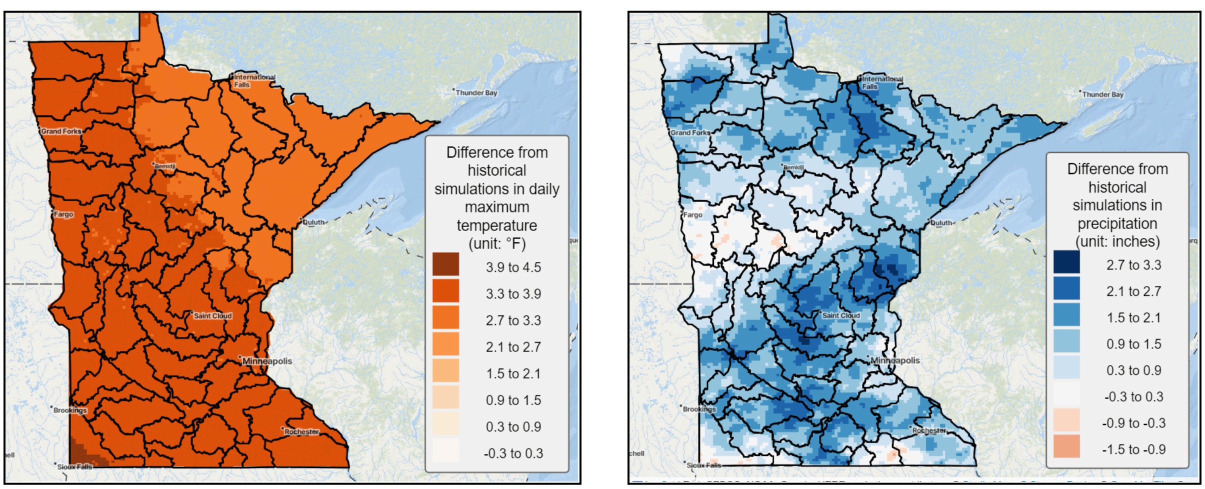


Figure 7. Differences between future growing season high temperatures (left) and annual precipitation (right) from historical simulations for mid century (2040-2059) under an intermediate emissions scenario (SSP 245). Boundaries represent 1W1P watershed planning areas. Data downloaded from the Minnesota Climate Adaptation Partnership's Minnesota CliMAT tool (Liess et al, 2023)

The 2022 Minnesota Climate Action Framework established a goal that all state funded or sponsored land, water, and species management plans identify actions to increase adaptation to a changing climate (Climate Change Subcabinet, 2022). Given both the guidance to incorporate climate considerations, and the availability of free publicly available and high quality climate projections for Minnesota, we were interested in seeing if and how climate science was being integrated into watershed planning.

## Emerging issues in watershed planning: Equity and environmental justice

In addition to consideration of climate change, we were also interested in documenting how watershed plans integrated topics related to equity or environmental justice. Equity is mentioned as a potential "Other Topic" to include in watershed planning. Furthermore, state guidance documents, including the 2020 State Water Plan and the Clean Water Fund Strategic Plan, encourage the consideration of distributional and equity consideration in water-related planning and implementation. As noted in Section I, equity and environmental justice have grown in prominence in both state and federal policy. Watershed planning touches on several aspects of environmental justice, including procedural, distributive, and recognitional justice (Agyeman et al. 2016). Planning processes provide an opportunity to consider how decisions are made, how communities are engaged in watershed planning, and how resources are distributed.

For this report, we were interested in how watershed plans considered procedural dimensions of equity including the participation and involvement of diverse communities in watershed planning. We also explored how plans assessed potential distributional considerations, including assessments of the distribution of water related benefits and burdens within a watershed and how implementation activities could be targeted to enhance equity, especially in designated disadvantaged communities.

## Review of watershed plans

As of June 2024, 48 watershed plans were either completed and approved or submitted as drafts for review. Nine watersheds are currently in the planning stage, with an additional six watersheds without a defined planning process. We reviewed all approved and draft plans for the inclusion of climate change and equity information, representing 76% of all possible plans.

We searched each plan to identify text associated with the themes of climate change and equity. To facilitate consistent analysis of large volumes of text, we used SciSpace, an AI tool that can search documents for keywords and flag associated text (SciSpace, 2022). ChatGPT was used where 1W1P documents were not readable in SciSpace because of document formatting (5 documents) (OpenAI, 2024). If documents could not be analyzed by either, reviewers manually read the documents (2 documents).

Within SciSpace, we used commands to search for keywords related to climate change, extreme weather, and equity (Table 2). If any of the keywords were present in a plan document, then SciSpace indicated which keyword and included a link to the page of the document where it was used. From there, we manually read through the section, noted important context, and identified illustrative quotes for inclusion in our analysis. We tracked our findings in a spreadsheet, with results shown in Table 3.

| Theme | Keyword Command |
|---|---|
| Equity | Search for mentions of the following words or phrases: equity, equality, diversity, underrepresented, income, low income, indigenous, tribe, tribal, tribal communities, women, non-english speakers, people of color, black, hispanic, justice, minority, marginalized, underserved, poverty |
| Climate Change | Search for mentions of the following words or phrases: climate, climate change, global warming. |
| Extreme Weather | Search for mentions of the following words or phrases: changing precipitation patterns, precipitation patterns, extreme weather, drought, floods, increase, decrease (related to weather in any section on goals). |
| Climate Modeling | Search for mentions of the following words or phrases: climate modeling, predict, prediction, predictive, future, projections, projected, NOAA Atlas, Atlas 14, 2040, 2050, 2070, 2100, years, scenario. |

Table 2: Themes and associated keywords used to analyze 48 1W1Ps.

We were also interested in how integration of climate change and equity information has changed over time. We consulted a 2022 report conducted by University of Minnesota Humphrey School students in partnership with BWSR that evaluated twenty-five approved and drafted 1W1P (Cullen et al, 2022). We adopted similar methods to the 2022 report, increasing the number of plans reviewed and expanding the scope of our analysis to explore how plans incorporated equity or distributional considerations. In the discussion section, we compare our findings with this 2022 report with particular attention to challenges related to the integration of climate information over time.

## Findings: Consideration of climate change

All reviewed watershed plans included some mention of climate change or climate trends (Table 3). Climate change was most frequently considered under the “emerging issue” section (58% of plans). A majority of plans addressed climate change generally, rather than associating climate change with noted action items or goals. For example, plans included language such as “Minnesota’s climate is already changing and will continue to do so in the future; therefore, it should be considered in a long-term planning effort” (Wild Rice-Marsh River, p. 64).

Just under half of plans considered climate change in articulated “goals or actions”. For example, plans specified how watersheds can integrate climate resiliency through investments in carbon sequestration or water storage. Other climate-related goals included evaluation of the impact of climate change on watershed resources and infrastructure such as potential flood risks to infrastructure. In comparing the plans from 2016 to 2020 and then 2021 to present, there is an increase in the number of plans that are integrating climate change into their goals or actions, from 42% to 52% respectively.

All but one plan included text related to changing precipitation patterns and/or “extreme weather events.” The text associated with mentions of extreme events included statements such as “the impact of extreme climate and precipitation events must be considered” (Sauk River p. 3-8) or are likely to “impact water resources and their management” (Root River p. 2-36, North Fork Crow River p. 2-35, Lake of the Woods p. 2-28, Missouri River Watershed p. 2-12, Watonwan River p. 4-8, Buffalo Red River p. 2-16). All consulted watershed plans used modeling programs like the Hydrologic Simulation Program-FORTRAN-Scenario Application Manager (HSPF-SAM), Soil & Water Assessment Tool (SWAT), or NOAA’s Atlas 14 to simulate changes in precipitation and land use and associated impacts on water quality. Several plans integrated data on future changes in precipitation into their modeling to evaluate the effectiveness of hydrological management decisions based on changing precipitation regimes.

More than half of plans addressed extreme weather in their “goals or actions” section including reference to “mitigating increases in peak flow” (Greater Zumbro p. 5-7) or “increase the number of volunteer rain gauge readers to evaluate short and long-term trends and their relationship to groundwater supplies and lake levels” (North Fork Crow River p. 4-8). In comparing the plans from 2016 to 2020 and then 2021 to present, more plans are integrating extreme weather into their goals or actions, from 42% to 69% respectively.

While many plans considered climate impacts generally, only three plans incorporated data derived from climate projection models in their analysis. The St. Louis River 1W1P referenced the *Climate Change Vulnerability Assessment and Adaptation Plan* for the 1854 Ceded Territory (Stults, 2016*)* which integrates dynamically downscaled regional climate projections based on alternative emissions scenarios. The Lake Superior North plan references the Lake Superior Lakewide Action and Management Plan which models changes in climate based on a range of future emission scenarios through the 21st century for the region (Huff, 2014, p. 14). The Rainy Headwaters-Vermillion 1W1P WRAPS report includes climate change scenario modeling based on linear projections of historical climate trends based on national models.

In the 2022 University of Minnesota report on 1W1P conducted in collaboration with BWSR, researchers surveyed planners and watershed managers who participated in 1W1P efforts.

Over 40% of surveyed respondents indicated that they did not have the necessary information about climate change to account for climate impacts in their watershed planning (Cullen et al, 2022, p. 21). Survey respondents had mixed reactions to a survey question about their receptivity to agency mandates requiring integration of climate change information in watershed planning. 66% of respondents indicated support for mandated consideration of climate change, whereas 33% of respondents were opposed, often noting a perceived resistance to discussions of climate change in their communities.

Our review suggests an increase in the consideration of climate impacts in watershed planning over time, perhaps reflective of broadening public acceptance or awareness of climate change. At the same time, very few plans take advantage of publicly available climate projections for their watersheds, and most plans consider climate change in very general terms, without connecting plan implementation goals or actions to specific anticipated climatic changes. As the state invests in future rounds of watershed planning, we encourage watershed planners to take advantage of high resolution climate information and consider how climate may affect water quality and quantity and the associated effectiveness of restoration or protection goals.

## Findings: Consideration of equity and environmental justice

The 2023 updated guidance for expenditures under the Clean Water Fund now requires "an assessment of whether the funding celebrates cultural diversity or reaches diverse communities in Minnesota, including reaching low- and moderate-income households." The Clean Water Council also requests that all agencies incorporate their stated principles for diversity, equity, inclusion, and/or environmental justice into Clean Water Fund-supported programs. We assessed approved plans and plans under review for topics related to cultural diversity or diverse communities and considerations of impacts to low-income households. Of the 48 plans that are currently approved or under draft review, 19 (40%) include at least one keyword related to equity (Table 3). In comparing the plans from 2016 to 2020 and then 2021 to present, more plans are integrating mentions of equity, from 26% to 48% respectively.

A majority of plans address equity in the context of plan implementation. In these plans, equity is most frequently mentioned as a general goal associated with sustainability, resilience, or community (Root River p. 2-10). The following text excerpt provides an example of how one plan discusses equity as it relates to plan implementation:

*“Equity throughout communities and in larger geographies is important because of global climate change and the development of sustainable and resilient communities. Addressing equity at a watershed scale is a way of exploring, delineating, and prescribing actions for addressing the equitable management of natural resources for the welfare of all people in those communities within the plan boundaries. Though particular goals or actions directly addressing equity are not specifically prescribed in this plan, it is encouraged to be considered during plan Implementation” (The Kettle River/ Upper St. Croix p. 13-11).*

Several plans suggest identifying areas of high value and cultural resources as part of the plan implementation (Lower Minnesota River East p. 98; Rum River p. 132). Other plans include a definition of  environmental justice and provide maps that reflect environmental justice areas within the watershed (Otter Tail River p. 134; Mississippi River - Brainerd p. 84; South Fork Crow River p. 34-35; Chippewa River p. 2-19; Lower Minnesota East p. 59; Leaf-Wing-Red Eye, p. 114; Nemadji p. 130).

A few plans mention goals of protecting water-based cultural activities including protecting streams for recreation, for subsistence fishing, for culturally significant species, for wild rice production, and for drinking water (Mississippi River -Brainerd p. 33; Leaf-Wing-Red Eye p. 114). The St. Louis River plan considers how the watershed planning process can "*reduce historic and current inequities through meaningful involvement, support for cultural ties and heritage, acknowledgement of treaty rights, consideration of economic constraints, protection of public access, and support for human health including food access and consumption, protection from pollution, employment, and water quality*" (p. 33). Several plans describe how watershed goals impact cultural resources and equity, diversity, and inclusion (Rainy Headwaters Vermillion p. 36-37, 59-85; Sand Hill River p. 67-82; St Louis River p. 35-197).

Of the 48 watersheds that currently have approved plans or plans under draft review, 14 cover areas that overlap with federal Tribal Nation reservation land. Watersheds that overlap with tribal boundaries vary in the degree to which they engage with tribes and/or consider tribal priorities in watershed planning and implementation. A few plans include only a brief mention that tribal land exists within the boundaries of the watershed (Snake, Clearwater, Yellow Medicine, Lake Superior North, Red Lake River) and one makes no mention of equity or of Tribal Nations within their boundaries (Buffalo-Red River).

Several watershed planning efforts indicated outreach and collaboration with Tribal Nations. The Kettle River planners worked with Tribal partners to prioritize recreationally/culturally important lakes and streams within the watershed boundaries (p. 4-4). The Leech Lake River plan described connections with the Leech Lake Band of Ojibwe (LLBO) and highlighted the importance of water for the subsistence, cultural, and spiritual benefits of Tribal members (Leech Lake River p. 22). The Rainy Headwaters Vermillion Watershed Plan mentions working with the 1854 Treaty Authority in addition to the Bois Forte Nation (p. 12).

Aside from Tribal partners, there were no mentions of Black, Hispanic, non-English speakers, people of color, or other minority marginalized populations in any of our reviewed plans outside of environmental justice definitions. If plans included actions or goals for low-income households, all but two stated that pre-existing programs provide qualifying households with low-interest loans to replace septic systems. The first intended to review the watershed's population and income distribution to aid in equal outreach (Snake River p. 4-1). Notably, the second included statements throughout the plan describing how actions accomplish watershed equity goals (St. Louis River p. 44, p. 138, etc). We did not otherwise observe any plans that indicated implementation funds should be preferentially directed towards underserved or disadvantaged populations, and rarely did plans explicitly state priority actions or goals around protection or restoration of culturally significant streams or lakes.

Beyond these distributional considerations, it was difficult to evaluate the procedural aspects of environmental justice represented in watershed planning processes. Tribal involvement on advisory committees or as stakeholders was mentioned in a few plans. However, we could not evaluate if planners followed best practices in community engagement or adhered to new federal guidelines on Indigenous Knowledge (Prabhakar, 2022).

Similar to climate considerations, our review suggests a trend towards greater consideration of equity implications in watershed plans in more recent years. However, there remain notable gaps in the consideration of Tribal nations in some watersheds where Tribal lands and ceded territories make up a significant proportion of the watershed. Non-indigenous minority populations in Minnesota are not considered in any plans. Low income populations, immigrant communities, and communities in flood prone areas may bear disproportionate risks associated with climate change. Future interactions of watershed planning could do more to integrate social and demographic data in climate-related risk assessments and in the prioritization of watershed implementation funding.

| Watershed | Adoption date | Equity | Climate change goals/ action items/ intent | Climate change classified as an emerging issue | Changing precipitation patterns and extreme weather events | Precip/ Weather goals/ action items/ intent |
|---|---|---|---|---|---|---|
| Root River | 12/14/2016 | x | x | x | x | |
| Yellow Medicine River | 12/14/2016 | | | x | x | |
| Lake Superior North | 1/25/2017 | | x | | x | x |
| Red Lake River | 4/26/2017 | | | | | |
| North Fork Crow River | 6/27/2018 | | | x | x | x |
| Leech Lake River | 3/27/2019 | x | x | | x | |
| Lake of the Woods | 9/25/2019 | | | x | x | |
| Pine River Watershed | 9/25/2019 | | | x | x | |
| Missouri River Watershed | 10/23/2019 | | | | x | |
| Cedar - Wapsipinicon | 12/18/2019 | | | | x | |
| Thief River | 3/25/2020 | | | x | x | x |
| Cannon River | 6/24/2020 | | x | | x | |
| Pomme de Terre River | 8/26/2020 | | | | x | |
| Leaf, Wing, Redeye | 8/26/2020 | x | x | | x | |

| Watershed | Adoption date | Equity | Climate change goals/ action items/ intent | Climate change classified as an emerging issue | Changing precipitation patterns and extreme weather events | Precip/ Weather goals/ action items/ intent |
|---|---|---|---|---|---|---|
| Buffalo-Red River | 10/28/2020 | | | x | x | x |
| Lower St. Croix | 10/28/2020 | | x | | x | x |
| Nemadji | 12/17/2020 | x | x | | x | x |
| Wild Rice - Marsh River | 12/17/2020 | x | x | x | x | x |
| Watonwan River | 12/17/2020 | | | x | x | x |
| Bois de Sioux and Mustinka | 1/21/2021 | | | x | x | |
| Two Rivers Plus | 6/23/2021 | | x | x | x | |
| Sauk River | 8/26/2021 | | | x | x | |
| Mississippi Headwaters Watershed | 9/22/2021 | x | | | x | |
| Greater Zumbro | 10/27/2021 | | x | | x | x |
| Hawk Creek - Middle Minnesota | 1/26/2022 | | x | | x | |
| Shell Rock - Winnebago | 4/27/2022 | | | x | x | x |
| Rum River | 5/25/2022 | x | x | x | x | x |
| Middle-Snake-Tamarac Rivers | 8/25/2022 | | | x | x | x |
| Long Prairie River | 10/26/2022 | x | x | x | x | x |
| Clearwater River | 10/26/2022 | | x | | x | x |
| Snake River | 1/25/2023 | | | | x | x |
| Otter Tail River | 1/25/2023 | x | x | x | x | x |
| St. Louis River | 3/22/2023 | x | x | | x | x |
| Des Moines River | 3/22/2023 | | x | x | x | x |
| La qui Parle Yellow Bank | 3/22/2023 | | | x | x | |
| Lower Minnesota River West | 3/22/2023 | | x | | x | x |
| Mississippi River Winona / La Crescent | 3/22/2023 | | | | x | x |
| Roseau River | 4/26/2023 | | | x | x | x |
| Rainy-Rapid | 5/24/2023 | x | x | x | x | x |
| Le Sueur River | 8/24/2023 | | | | x | x |
| Mississippi River - Brainerd | 12/14/2023 | x | x | x | x | x |
| Sand Hill River | 1/24/2024 | x | x | x | x | x |

| Watershed | Adoption date | Equity | Climate change goals/ action items/ intent | Climate change classified as an emerging issue | Changing precipitation patterns and extreme weather events | Precip/ Weather goals/ action items/ intent |
|---|---|---|---|---|---|---|
| **Upper Minnesota River** | 3/27/2024 | x | | x | x | |
| **South Fork Crow River** | 3/27/2024 | x | | | x | x |
| **Rainy Headwaters-Vermillion** | 4/24/2024 | x | x | x | x | x |
| **Kettle River / Upper St. Croix** | Under final review | x | x | x | x | x |
| **Chippewa River** | Under final review | x | | x | x | |
| **Lower Minnesota River East** | Under draft review | x | | x | x | |
| | | **19** | **23** | **28** | **47** | **28** |
| | | **39.6%** | **47.9%** | **58.3%** | **97.9%** | **58.3%** |

Table 3: Climate change and equity considerations for 48 One Watershed, One Plan (1W1P) documents. As of April 2024, 45 plans were approved and 3 were in draft review. 1W1P document names listed in the left column. Cells marked with an “x” indicate that the plan contained information on subject matter listed in the column header as defined by the keywords noted in Table 2.

## Climate and the effectiveness of best management practices

Implementation follows watershed planning, with plans providing guidance around key threats to water quality, stressors of concern, target areas for investments, and identified activities to improve water quality. Given the prevalence of non-point source pollutants and water retention as key watershed goals, the implementation of best management practices (BMPs) to improve water quality is a core strategy for watershed managers. As noted above, climate change will affect temperature, plant productivity, and the timing, frequency, and intensity of precipitation statewide. BMP effectiveness will also be influenced by changes in climate. Watershed planners and managers would be wise to consider the impact of climatic changes on the effectiveness of BMPs. However, our review of 1W1P documents suggests a gap between the availability of climate data and integration of those data into planning and implementation processes.

This section of the report aims to assess how the effectiveness of BMPs may increase or decrease under climate change. Minnesota’s Nutrient Reduction Strategy (NRS) identifies over 25 best management practices that can be used to mitigate the effects of agricultural sediment and nutrient pollution into waterways (Minnesota Pollution Control Agency [MPCA], 2014, appendix C). From 2010 to 2022 over 4.5 million acres of these practices were installed in Minnesota. Of these, nearly 1.5 million acres were funded by Clean Water Fund programs (BWSR: Competitive Grant Program, RIM/ Wetlands Reserve Program, MDA: Agricultural BMP Loan Program, and Water Quality Certification Program) (MPCA, 2023).

We focused on best management practices outlined in Minnesota's nutrient reduction strategy and identified on the MPCA's Nutrient Reduction Strategy BMP dashboard (MPCA, 2023). For each BMP, we searched Google Scholar with keywords focused on the name of the practice i.e. "cover crop" or "no-till", and regional keywords such as "climate change" and "midwest". We prioritized insights from research in Minnesota and surrounding geographies where available. We found three key references related to climate impacts of BMPs in the midwest. These three papers were then uploaded to the literature AI mapping tool *Research Rabbit* (Research Rabbit, 2021). Research Rabbit used these three papers to search for similar works based on author citations and relevant content, expanding our literature total to 18 papers. We supplemented papers identified by AI with additional searching using variations of the keywords above in Google Scholar. Twelve BMPs were found to have a significant body of research on the impacts of climate change to their effectiveness.

Research suggests that climate change may have positive, negative, or neutral impacts on BMP effectiveness (Table 4). We identified several key climate-related considerations in our research:

- Increased precipitation that results in stronger spring flooding and more intense rainfall events may provide more frequent flow pathways for circumventing BMPs, resulting in more opportunities for pollutant transport and loss.
- Changes in atmospheric carbon availability, warmer weather, and extended growing seasons could improve growing conditions for plants increasing the filtering ability of cover crops and other plant-based BMPs. Warmer weather also expands the geographies of invasive species and pests and might change the plant communities of the BMPs.
- Reduced snow and ice cover, and greater precipitation falling as rain may increase in the volume of water flowing through tile drains, resulting in more nutrients by-passing field surface level BMPs.
- Warmer temperatures and longer growing seasons may provide better conditions for denitrifying bacteria and increase rates of crop residue decay.
- Overall changes to precipitation patterns and temperature are likely to increase sediment and nutrient loading which may overwhelm individual BMPs, making it difficult to meet nutrient and sediment reduction targets.

In summary, climate change may increase effectiveness of some BMPs, but more dominant effects associated with increased frequency and intensity of precipitation events will likely decrease effectiveness of many BMPs. Despite potential reductions in on-field efficiencies of different practices, BMPs will remain important for climate adaptation due to estimated increases in sediment and nutrient loading. Changes in BMP efficiency will affect currently installed practices as well as future BMP investments. Future systems may need to be installed differently and established systems may need retrofits as a result of expected climatic changes. Watershed planning and implementation should take into consideration both how future climate changes may increase the need for BMPs, as well as how BMP implementation and estimated effectiveness will shift under changing temperature and precipitation regimes.

| Best Management Practice | Improve | Status quo | Reduce | Improvements in BMP Efficiency Rationale | Reductions in BMP Efficiency Rationale |
|---|---|---|---|---|---|
| **No Till & Reduced Till** | ▲ (blue) | | ▼ (black)<br>▼ (orange)<br>▼ (red) | • Model results show no-till as the most effective individual BMP at reducing multiple pollutant loads in future climate scenarios[4] | • Higher rate of decay and nutrient cycling hinder crop growth and limit biomass production[1,2]<br>• More residue movement will result from an increase in higher precipitation events[1,2]<br>• Warmer winters result in more flow in tile drainage or infiltrating groundwater avoiding surface pathway[3] |
| **Grassed Waterway** | | • (blue) | ▼ (black) | • Carbon and temp. increases could increase plant vigor[1] | • More intense precipitation events will increase concentrated flow erosion and exceed treatment capacity[1] |
| **Terrace & Contour Farming** | ▲ (gold) | | ▼ (black) | • Model results show BMPs as effective at reducing multiple pollutant loads[5] | • More intense precipitation events will increase concentrated flow erosion and exceed treatment capacity[1] |
| **Perennial Cropping** | | • (black) | | • Extended growing season<br>• Increased plant growth rates [1] | • Changes in plant species composition<br>• Exposure to different pests and disease[1] |
| **Drainage Water Management (control drainage)** | ▲ (black) | • (purple) | ▼ (orange) | • Higher winter temps lead to more soil activity and denitrification[1] | • More intense precipitation events will increase phosphorus loading in non-tile drainage flows[2] |
| **Saturated Buffer** | | • (orange) | ▼ (black) | | • More intense precipitation events will increase concentrated flow erosion and exceed treatment capacity[1]<br>• Changes in plant species composition |
| **Winter Cover Crops** | ▲ (black)<br>▲ (orange)<br>▲ (green) | • (blue) | ▼ (black)<br>▼ (red) | • Warmer temperatures and atmospheric carbon may increase plant biomass and timing of fall establishment[1,2,6] | • Extended growing season for primary crops, increasing competition with cover crops for nutrients and water[1]<br>• Warmer winters result in more tile drainage or groundwater infiltration reducing nutrient uptake by cover crops[3]<br>• Warmer temperatures result in faster breakdown of cover crop plant residue |
| **Filter Strips** | | • (blue) • (gold) | ▼ (orange)<br>▼ (red) | | • Stronger spring precipitation will increase likelihood for filter strips to be inundated with runoff carrying sediment and nutrients[2,3] |
| **Riparian Buffers (Forest and Herbaceous)** | ▲ (black) | | ▼ (black) | • Extended growing season improve filtration capacity | • More frequent intense precipitation events will impact streambank stability |
| **Nutrient Management Plans** | | • (orange) • (blue) | ▼ (black) | | • Increasingly unpredictable weather patterns could impact timing of nutrient application[1]<br>• Temperature and moisture changes will alter nutrient |

| | |
|---|---|
| | uptake[1] |

■[1] Johnson, 2022
■[2] Schmidt, 2019
■[3] Bosch, 2014
■[4] Wallace, 2017
■[5] Woznicki, 2011
■[6] Lee, 2017; Malone, 2020; Gupta, 2023
■ Pease, 2017

Table 4: Future BMP effectiveness under changing climate. Each shape (▲•▼) represents potential impacts to Best Management Practice (BMP) effectiveness in response to climate change. The primary conclusions driving the changes in effectiveness are listed under rationale, with citations to the source material shown with variations in color. The twelve listed agricultural BMP represent practices mentioned in Minnesota's nutrient reduction strategy with more than one academic paper on their response to changing climate. Two BMPs relied solely on Johnson, 2022, due to the breadth and scope of their literature review on this topic.

# Section III: Cost of meeting water quality targets

## Clean water investments through 2034

The $1.8 billion in funding from the Clean Water, Land and Legacy Amendment has yielded investments in planning, monitoring, research, and implementation statewide. We estimate that approximately half of total funds remain, approximately $1.6 billion through the expiration of the amendment in 2034 (Figure 1). As the state considers strategies for the duration of the fund under the current amendment timeline, we set out to estimate the potential costs associated with meeting a variety of stated clean water goals.

We consulted the most recent Clean Water Council Strategic Plan released in 2024 for quantifiable goals where reasonable cost estimates for meeting each goal could be obtained with available data. The cost of achieving goals associated with capacity building, monitoring, or outreach are not as easily quantifiable, whereas goals that specify acreage targets for protection or best management practices can be estimated based on a set of reasonable assumptions. For each selected goal, we obtained data on past investments associated with each goal, estimated state or federal payments associated with particular practices, cost estimates for restoration or implementation of best management practices, and estimated costs of land protection based on spatially-explicit parcel land value datasets.

Importantly, these estimates were designed to establish reasonable expectations for the costs associated with achieving specific goals as compared to the total remaining funds through the expiration of the legacy amendment. Cost estimates are subject to assumptions and data limitations. Where possible, we captured reasonable uncertainty estimates around cost projections.

## Goal: Drinking water is safe for everyone, everywhere in Minnesota.

*Selected Measure: Approximately 400,000 acres of vulnerable land surrounding drinking water wellhead areas statewide are protected by 2034. (Final Clean Water Council Strategic Plan for 2024-2028, p. 5)*

To estimate the costs of protecting lands in source water protection areas, we relied on a 2022 University of Minnesota report commissioned by the Legislative Citizen Commission on Minnesota Resources (Noe, 2021). In this report, authors obtained high resolution parcel-specific land value data (Nolte, 2020) and combined these data with spatial data on the boundaries of drinking water supply management areas. Land value data were combined with data on land management to identify unprotected and unbuilt parcels that could, in theory, be acquired by the state and protected from future development. The report estimated that the total area of unprotected and unbuilt land in source water protection areas was over 634,000 acres, with an estimated cost of protection of $8.8 billion. Targeting a subset of the lowest value, highest vulnerability land reduced the cost substantially. However, the report estimated that even protecting 15% of low value, high vulnerability parcels in drinking water supply management areas would cost over $100 million.

To apply these calculations to the Clean Water Fund goal of protecting 400,000 acres of vulnerable lands in drinking water supply management areas, we averaged parcel land values obtained through the report, arriving at an estimated cost per acre of $14,400. Applying this per acre estimate, we calculate that the cost of meeting the stated Clean Water Fund goal of protecting 400,000 acres to be approximately $5.7 billion.

## Goal: Surface water protection and restoration

*Selected Measure: Protection of 100,000 acres and restoration of 100,000 acres in the Upper Mississippi River headwaters basin by 2034 (Final Clean Water Council Strategic Plan for 2024-2028, p. 9)*

The Council does not specify if targeted acres for restoration and protection are additive or inclusive of existing lands in public protection as of 2024. Here we assume that meeting this goal requires 100,000 additional acres of protection and restoration in the headwaters basin. We assume that 100,000 acres of existing unprotected unbuilt land will need to be acquired to meet the protection goal and assume no additional cost of land acquisition for acres that need to be restored.

To estimate the costs of protecting lands in the headwaters basin we used high resolution land value data and data on protected status, this time querying land values within the Mississippi Headwaters Basin (Figure 8). To estimate the least cost approach to protecting 100,000 acres of unprotected land, we identified the least cost parcels equivalent to 100,000 acres (average values for these parcels ranged from $562 to $2,431 per hectare) and summed their values. The total cost of 100,000 acres of the least expensive unprotected non-built land within the Mississippi Headwaters Basin is approximately $84 million. If we instead assume a median per hectare value of unprotected non-built land within the area of interest ($6,281 per hectare), then the total cost of acquiring 100,000 acres within the Mississippi Headwaters Basin increases to $254 million.

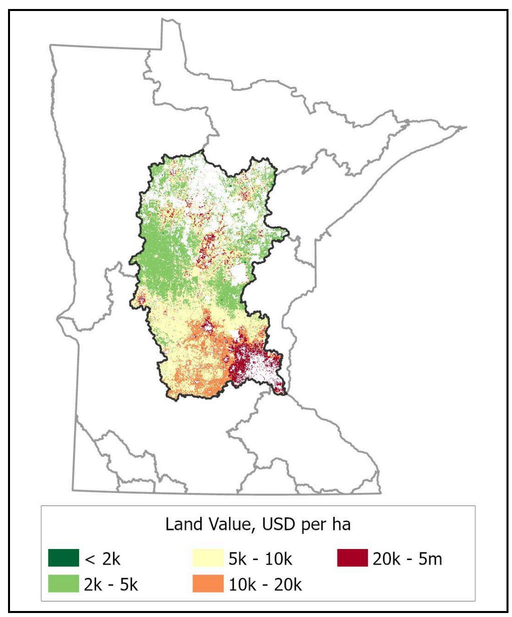


Figure 8. Land values in US dollars per hectare within the Mississippi River Headwaters basin. Land value data are from Nolte (2020).

To estimate the potential costs associated with 100,000 acres of restoration in the basin, we consulted a 2015 study that reviewed costs associated with different types of habitat restoration in Minnesota, as well as portions of Wisconsin, Iowa, North Dakota, and South Dakota. These researchers administered a survey to restoration practitioners, using 16 different restoration scenarios for grassland ecoregions. Reported restoration costs ranged from $527 (crop field to moderately diverse prairie used for grazing or hay) to $2,285 per acre (degraded meadow to species-rich, high quality habitat) (Phillips-Mao, 2015). Applying these per acre costs to 100,000 acres of restoration would cost anywhere from $52.7 million to $228.5 million. These are assumed to be one-time costs and do not include annual maintenance costs of restored lands.

## Goal: All Minnesotans value water and take actions to sustain and protect it

*Selected Measure: Number of farmers and acres enrolled in Minnesota Agricultural Water Quality Certification Program, with a target of 5,100 farms and 6.5 million acres by 2030 (Final Clean Water Council Strategic Plan for 2024-2028, p. 9)*

The Minnesota Agricultural Water Quality Certification program is a voluntary program that encourages farmers to adopt conservation practices designed to improve water quality. As of 2023, over 1,400 producers and 1 million acres have been certified, representing approximately 3.9% of all farmland in Minnesota. To achieve a target of 6.5 million enrolled acres, an additional 5.46 million acres are needed by 2030.

The costs associated with water quality certification in Minnesota has dropped from $541 per acre in FY2014 to a low of $24 per acre in FY2021 as the program has trained staff and increased efficiencies in program design and implementation. We assumed an estimated per acre cost of certification of $25 (Redlin,2022, p. 17). Applying this cost to the target of achieving an additional 5.46 million certified acres is estimated to be $137 million. This estimate includes only the one-time cost of certification. Once enrolled in the program, farmers are eligible to apply for up to $5,000 per year in cost-share grants to implement best management practices and there are additional annual costs associated with assessing program compliance and farmer outreach and engagement. If we assume that each additional farm needed to reach the 5,100 farm goal received a $5,000 grant for one year, then this would incur additional costs of $18.5 million.

*Selected Measure: Achieve a goal of five million acres of row crop agriculture that use cover crops or continuous living cover by 2034 (Final Clean Water Council Strategic Plan for 2024-2028, p. 9)*

According to the Census of Agriculture, there were 760,423 acres of cover crops in Minnesota in 2022 (Bryant, 2024). The costs of implementing cover crops in row crop agriculture include the cost of purchasing seed, chemicals, fertilizer, fuel and oil costs associated with planting and managing crops, as well as costs associated with equipment repairs and custom hire cost categories.

We obtained average cost data for installing cover crops from a 2022 report on the Economics of Cover Crops on Minnesota Farms (Nurden et al, 2022). Estimates presented in this report are based on 2022 dollars and reflect costs and conditions specific to Minnesota row crop agriculture. The report estimates costs ranging from $14 - $310 per acre, with an average cost per acre of $74 annually. If we assume that existing funding is supporting the annual cost of implementing current cover crops (760,423 acres as of 2022), then an additional 4,239,577 acres of cover crops needed to meet the 5 million acre target would cost an estimated $314 million per year.

## Goal: Groundwater is clean and available to all in Minnesota

*Selected Measure: Targets for nutrients in the state's Nutrient Reduction Strategy*
*Selected Measure: Nitrogen Fertilizer Management Plan implemented on 80% of row crop acres excluding soybean by year 2030, and implemented in all remaining townships by year 2034.*
*(Final Clean Water Council Strategic Plan for 2024-2028, p. 9)*

To estimate costs associated with compliance with the state's Nutrient Reduction Strategy and implementation of best management practices, we consulted Minnesota's Nutrient Reduction Strategy 5-Year Progress Report (MPCA, 2020). The report lists milestone goals for the year 2025 and final goals for 2040 that include achieving a 45% reduction in phosphorus for the Mississippi River Basin and a 50% reduction in Minnesota's Red River portion of the Lake Winnipeg Basin by 2040, and achieving a 45% reduction in nitrogen for the Mississippi River Basin and a 50% reduction in the Red River Basin (MPCA, 2020).

Agency staff have developed science-based scenarios to estimate compliance with the Nutrient Reduction Strategy and associated goals. Here we estimate costs associated with the best management scenarios included in the 2014 Nutrient Reduction Strategy Report (MPCA, 2014). These scenarios serve as examples of the level of best management practice (BMP) adoption needed to achieve the nutrient reduction goals in major river basins, when combined with point source nutrient reductions and other reductions (MPCA 2020, p. 34)

We estimated costs associated with five BMP scenarios that are collectively needed to reach the 2014 NRS milestones (MPCA, 2020, table 9). These include 4.9 million acres of field erosion control, 6.8 million acres of increased fertilizer use efficiency, 620,000 acres of drainage water retention and treatment, 440,000 acres of perennials, and 1.9 million acres of cover crops. We used NRCS data on the subsidies associated with each practice for our cost estimates (United States Department of Agriculture: Natural Resources Conservation Service, 2024). NRCS estimates refer to the cost the government is willing to pay a producer for a given practice and does not necessarily include the full cost associated with implementation of a given practice.

| Practice | Target Acres | Cost per acre | Included practices | Annual cost |
|---|---|---|---|---|
| **Field Erosion Control** | 4.9 million | $4.19 | Average of no till to reduce soil erosion ($3.59/acre) and reduced tillage to reduce soil erosion ($4.78/acre) practices. | $20.53 million |
| **Fertilizer Use Efficiencies** | 6.8 million | $6.40 | Average of nutrient management ($4.04/acre), precision nutrient application ($8.72/acre), and prescription nutrient efficiency ($6.43/acre) practices. | $43.52 million |
| **Drainage Water Retention** | 620,000 | $1.56 | Drainage water management ($1.56/acre). | $0.97 million |
| **Perennials** | 440,000 | $6.66 | Short term perennials ($6.66/acre). | $2.93 million |
| **Cover Crops** | 1.9 million | $9.27 | Average for cover crop - basic ($8.24/acre) and cover crop - multiple species ($10.30/acre). | $17.61 million |
| **Summed Annual Cost** | | | | **$85.56 million** |

Table 5: Estimated annual costs associated with five BMP scenarios as articulated in the Minnesota State Nutrient Reduction Strategy report. Table includes acreage totals associated with each scenario and estimated per acre payments based on listed practices drawn from NRCS subsidy databases.

In Table 5 we summarize costs associated with each best management practice based on NRCS estimates and apply these costs to the targeted acreage totals. The most expensive goal is increased fertilizer use efficiency at $43.52 million, followed by compliance with field erosion control ($20.53 million), cover crops ($17.61 million), perennials ($2.93 million), and drainage water retention ($0.97 million). Assuming these are annual costs, the total cost of achieving all five BMPs goals is $85.56 million per year.

## Findings: Total costs of meeting selected clean water goals

As noted above, cost estimates are limited by available data and subject to simplifying assumptions. Where possible we selected conservative estimates of costs, noting where costs may underestimate the total expenses associated with acquisition and management of lands. We also acknowledge that funding provided by the Clean Water Fund is meant to leverage other state and federal funds for conservation and restoration, and therefore is not representative of full purchasing power of the amendment dollars.

We estimated the cost of protecting 400,000 acres of vulnerable lands in drinking water supply management areas, protecting 100,000 acres and restoring 100,000 acres in the Mississippi

River Headwaters Basin, and certifying 6.5 million acres in voluntary water quality programs to total $6 to 6.4 billion. In addition to these costs, achieving 5 million acres of cover crops and meeting state nutrient reduction strategy goals through best management practices will add an additional $400 million annually. When comparing the costs of just these selected measures to the estimated $1.6 billion in total funds remaining in the Clean Water Legacy fund, it is clear that available funds alone will be insufficient to meet all stated water quality goals in the Council's strategic plan.

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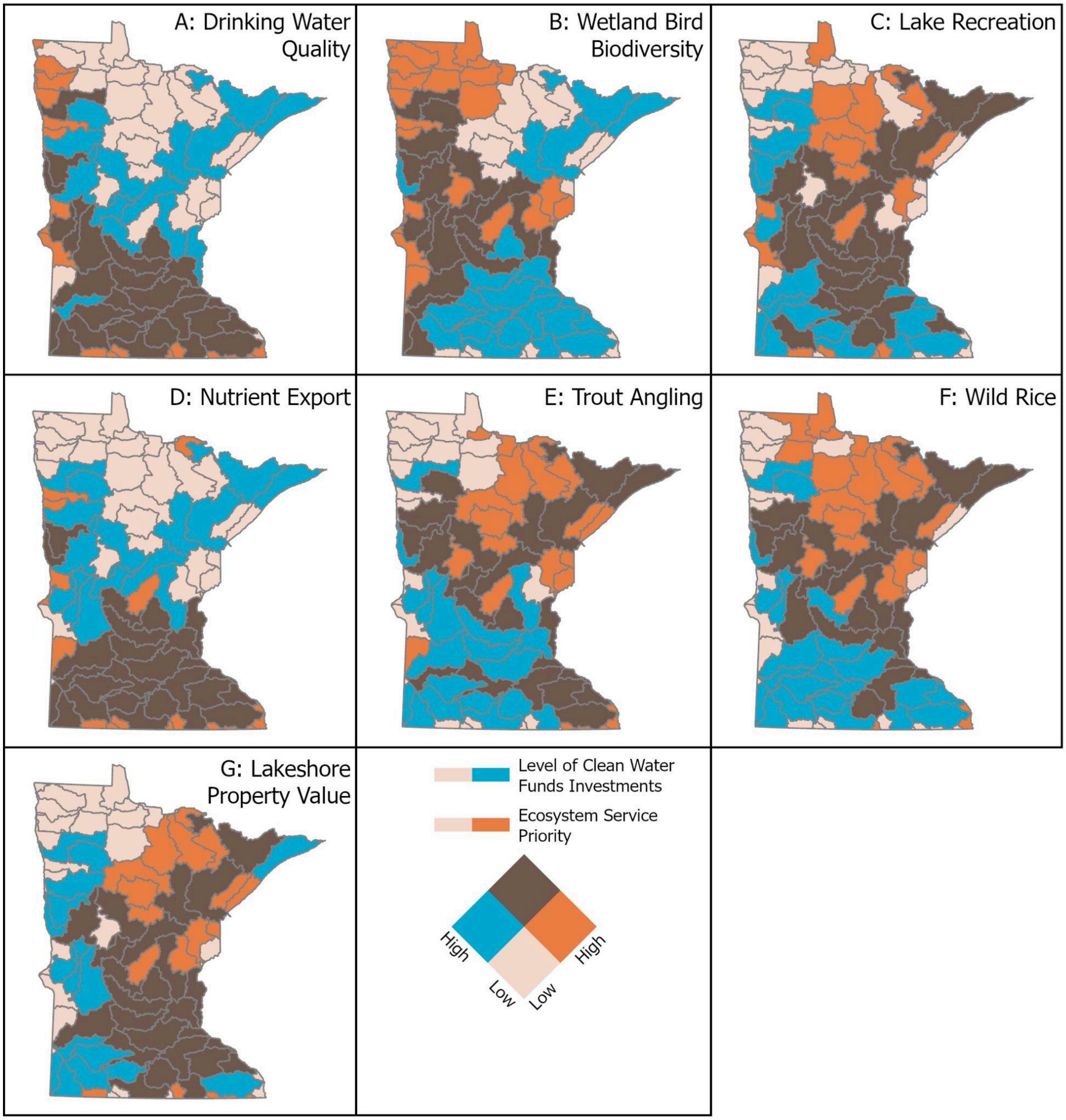
## Appendix A: Methods used to generate watershed-level ecosystem service metrics




**Bivariate Maps** above illustrate agreement and disagreement between Clean Water Funds data and HUC8 watershed priorities data

The bivariate maps above allow us to capture the spatial variability of the relationship between the two variables of interest. The first variable (Clean Water Funds) is the same for all maps, and the second variable corresponds to one of the watershed priority metrics described in sections A-G. To generate the first variable, we exported data from the Minnesota Pollution

Control Agency (MPCA) Data Services and summed up the state funding from 2010 to 2022 and for the programs of interest. To compare the two variables, we started by classifying them separately using the quantile classification method to identify 40 watersheds with High and 40 watersheds with Low values. The resulting map is created by overlaying the two intermediate classified maps to show the agreement (Low-Low, High-High) and disagreement (Low-High, High-Low) between the two variables.

**A: Drinking water quality**

The drinking water quality metric is composed of three components: geologic vulnerability of groundwater to surface contamination, amount of agriculture in the HUC8 as a proxy for nitrate contamination exposure, and population consuming groundwater in each HUC8.

We defined geologic vulnerability using a statewide map[1] with low, medium, and high classification. We re-classified those classes to vulnerability scores of 1, 2, and 3 respectively, and calculated the average vulnerability score of each HUC8. To create a proxy for nitrate contamination threat, we calculated the proportion of each HUC8 that was in the 'cultivated crops' land cover according to the 2019 National Land Cover Dataset[2].

Estimating the population of groundwater consumers in each HUC8 required using two datasets and multiple processing steps. First we calculated the total population using the US EPA's 30m dasymetric population allocation raster[3] because traditional census data does not conform to HUC8 boundaries. Next, we estimated the number of people that are served by surface water because nitrate concentrations from agricultural runoff are primarily an issue for groundwater consumers, thus we needed to subtract surface water consumers in each HUC8. We joined data from the Minnesota Department of Health's Drinking Water Query tool[4] as reported in Appendix A of Noe et al. 2021[5] to the centroid of municipality boundaries[6]. We aggregated the population served by surface water to the HUC8 level and subtracted this estimate from the total population of the HUC8.

To combine the disperate units of the three components, we converted each to an index by mapping the lowest scoring HUC8 to 0, the highest scoring to 1, and scaling the remaining HUC8 scores proportionally between them. We then summed the three indices to create the final metric.

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[5] Noe, R., Keeler, B., Mayer, T., 2021. Source Water Protection Challenges and Co-benefits. https://hdl.handle.net/11299/227195.

[6] Four of the 42 public water supplies using surface water, which serve a total of 15,512 people, did not join to a municipality. Inspection of individual records showed that over 12,000 of those people were associated with a public water supply that uses both surface and groundwater. Because of the relatively small population served and the use of some groundwater, we did not attempt to exclude these four public water supplies from this metric.

**B: Wetland Bird Biodiversity**
The wetland bird biodiversity metric is based on a habitat suitability model generated using data from the Minnesota Breeding Bird Atlas (MNBBA). Data from the MNBBA documented the statewide distribution and abundance of breeding birds over a five-year period (2009-2013) using volunteer-based sampling and systematic point counts.[7] Dominant and subdominant cover types of the survey locations were determined using the National Land Cover Database (2001).[8] Primary habitat types were identified at a scale of 30 m resolution. Habitat suitability models were developed using one of three modeling approaches (MaxEnt, glms, glms with QPAD offset)[9] for all breeding bird species[10,11,12] and can be viewed online at mnbirdatlas.org.

Using the MNBBA, we developed a habitat suitability metric for birds that depend on wetland habitat for breeding. We combined the individual species habitat models for American Bittern, Black Tern, Sedge Wren, and Yellow-headed Blackbird. These species were selected because they have been identified as Species in Greatest Conservation Need (SGCN) by the Minnesota Department of Natural Resources because they are rare, have populations that are declining, or are under threats that may cause them to decline.[13] The model output ranged from ~0 to 1, 1 being the highest "habitat suitability" value.

We then masked out urban land and water, and divided the remaining cells into quartiles based on their habitat suitability. We reclassified cells to 1 for those in the top quartile and 0 for the remainder. We aggregated the binary habitat suitability map to the HUC8 level, producing the proportion of each HUC8 that is in the highest quality class for wetland bird habitat potential.

**C: Lake recreation**
The lake recreation metric prioritizes land that influences the water quality of lakes important for public recreation. It applies to the catchments of lakes with a publicly accessible water access site. Land outside of these catchments receives a score of zero for lake recreation. Among lakes with public access, prioritization is based on three attributes; the sensitivity of the lake's clarity to additional phosphorus runoff,[14] the public amenities (e.g., dock, boat ramp, restrooms) of the lake,[15] and a proxy for lake visitation.[16] Catchments with publicly accessible lakes receive

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a minimum score of 0.2. The rest of the score is equally divided between a physical measure of the lake's sensitivity to phosphorus, and measures of the social benefit of the lake as measured by access amenities and a proxy for visitation. We aggregated this metric to the HUC8 level by averaging the recreation quality score in a watershed.

**D: Nutrient export**
Nutrient export uses estimates from 2012 USGS SPARROW modeling.[17] Specifically, we used the 'Total Nitrogen, Delivered aggregated yield (kg/km2)' variable aggregated to the HUC8 level. This includes Nitrogen from all sources (e.g., fertilizer, manure, municipal wastewater). To score each watershed we scaled nutrient export values from 0 to 1.

**E: Trout streams**
Land within the catchment of trout stream receives a score of 1 and land outside receives a score of 0. Trout streams were defined as State of Minnesota legally designated trout streams.[18] We do not differentiate among trout streams, nor does the metric account for the impact of management on trout habitat. To score each HUC8 we calculated the proportion of the area of each HUC8 with a score of 1.

**F: Wild rice sites**
Land within the catchment of a wild rice site receives a score of 1 and land outside receives a score of 0. Wild rice sites were defined as current (i.e., not prehistoric) wild rice sites identified by the DNR.[19] We do not differentiate among wild rice sites, nor does the metric account for the impact of management on wild rice habitat or water quality. To score each HUC8 we calculated the proportion of the area of each HUC8 with a score of 1.

**G: Lakeshore property value**
We used land value estimates[20] described in Nolte 2020.[21] We extracted all cells within a 50m buffer of lakes, converted them to dollars per hectare, and averaged the resulting estimates at the HUC8 level.

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