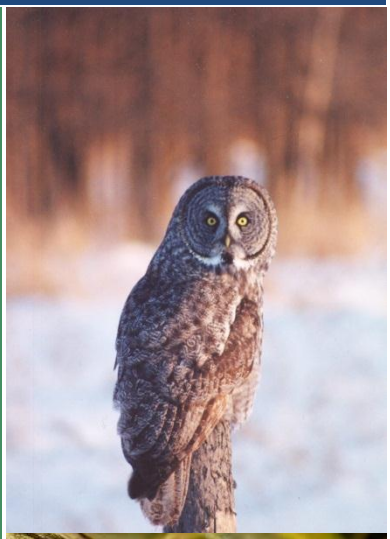
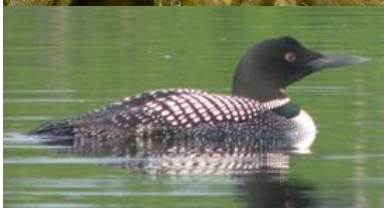
TAMARAC NATIONAL WILDLIFE REFUGE

Tamarac Wilderness

A Report on Wilderness Character Monitoring

By Morgan Gantz





2014

U.S. FISH AND WILDLIFE SERVICE

This report is part of a national initiative to establish baseline wilderness character for all the National Wildlife Refuges with designated wilderness. The measures for each wilderness were developed with refuge staff and reviewed at the national level.

Neil Powers, Refuge Manager, Tamarac NWR **Date**

Nancy Roeper, National Wilderness Coordinator, NWRS **Date**

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Tamarac Wilderness Area. Photo by Denis Mudderman.

Cover page photo credits (top right to bottom): Wayne Brininger, USFWS, USFWS, Dennis Mudermen

INTRODUCTION

The Wilderness Act of 1964 (16 U.S.C. § 1131) was passed by a nearly unanimous vote in the United States Congress to protect natural lands from the threats of "expanding settlement and growing mechanization." The primary mandate given by the Wilderness Act is to "preserve the wilderness character of the area," a responsibility given to each agency that administers any area designated as wilderness (Section 4(b)). Wilderness character was formally defined in 2006 by an interagency monitoring team – including the Department of the Interior Bureau of Land Management, U.S. Fish and Wildlife Service, National Park Service, U.S. Geological Survey, and the U.S. Forest Service (Department of Agriculture) – to establish a common understanding of wilderness character.

The definition of wilderness in The Wilderness Act describes five qualities of wilderness. Together, these qualities comprise wilderness character and are used nationwide to monitor the status and trends in wilderness (preservation or degradation) over time from stewardship actions, as well as impacts from modernization and other changes occurring outside of the wilderness itself. The five qualities apply to all wilderness areas – regardless of their size, location, administering federal agency, or other unique place-specific attributes; they are based on the legal definition of wilderness in the Act. Descriptions of the five qualities as derived from Section 2(c) of the Wilderness Act are below.

1. *Untrammeled*

   Wilderness is "*…an area where the earth and its community of life are untrammeled by man"*

   Wilderness ecological systems are essentially unhindered and free from the actions of modern human control or manipulation when the untrammeled quality is preserved.

2. *Natural*

   Wilderness "*…is protected and managed so as to preserve its natural conditions*"

   Wilderness ecological systems are substantially free from the effects of modern civilization when the natural quality is preserved.

3. *Undeveloped*

   Wilderness is "*…an area of undeveloped Federal land … without permanent improvements or human habitation*"

   Wilderness retains its primeval character and influence, and is essentially without permanent improvement or modern human occupation when the undeveloped quality is preserved.

4. *Solitude or Primitive and Unconfined Recreation*

   Wilderness "*…has outstanding opportunities for solitude or a primitive and unconfined type of recreation*"

   Wilderness provides outstanding opportunities for solitude or primitive and unconfined recreation when the quality of solitude or primitive and unconfined recreation is preserved.

5. *Other Features of Value*

Wilderness "*…may also contain ecological, geological, or other features of scientific, educational, scenic, or historical value*"

Other tangible features of scientific, educational, scenic, or historical value in wilderness preserve wilderness character when they are preserved.

In addition to the five tangible qualities of wilderness character, wilderness also has important intangible aspects that are difficult or impossible to quantify or monitor. These intangible aspects are diverse and can include the scenic beauty, spiritual experience, immensity of an area, and the opportunity for self-discovery, self-reliance, and challenge that comes from wilderness settings. Currently, these intangible aspects of wilderness can only be addressed in narrative form.

In 2008, an interagency Team published *Keeping It Wild* (Landres et al 2008), an interagency strategy for monitoring trends in wilderness character across the National Wilderness Preservation System. The framework provided in *Keeping It Wild* is based on the qualities of wilderness character defined above. Each quality is divided into a hierarchical set of monitoring questions, indicators, and measures to assess trends in wilderness character over time. Monitoring questions frame wilderness character monitoring to answer particular management questions; indicators are distinct and important elements within each monitoring question; and measures are a specific aspect of wilderness on which data are collected to assess trend of an indicator (Landres et al 2008). Expanded definitions of qualities, monitoring questions, indicators, and measures are available in Appendix D. While the qualities, monitoring questions, and indicators are nationally consistent, measures are specific and sometimes unique to individual wilderness areas (Figure 1).

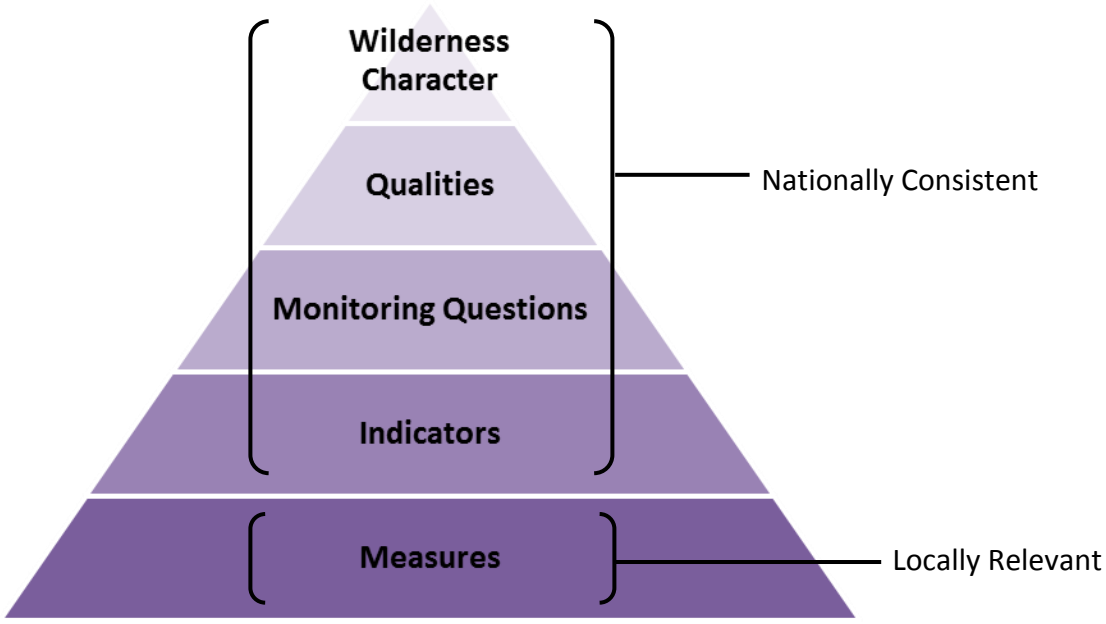

Figure 1: *Keeping It Wild* Hierarchical Framework

This framework balances national and local needs for monitoring by defining locally relevant measures whose trends can be compiled at higher levels for national or regional reporting. This interagency monitoring strategy:

- Provides on-the-ground information to assess trends and make defensible decisions;
- Provides valuable information on wilderness on regional and national scales;
- Provides a set of key wilderness stewardship goals;
- Communicates a common definition of wilderness character;
- Communicates a tangible vision of wilderness within the agency and to the public;
- Clarifies how stewardship decisions and actions influence wilderness;
- Evaluates and documents the effects of actions taken inside the wilderness and effects from threats outside the wilderness;
- Synthesizes data into a single, holistic assessment of wilderness character;
- Creates a legacy of staff experience and knowledge of a wilderness;
- Improves on-the-ground wilderness stewardship.

Under this monitoring strategy, wilderness character in a particular wilderness cannot, and will not, be compared to that of another wilderness. Each wilderness is unique in its legislative and administrative direction, and in its social and biophysical setting. Therefore, comparing wilderness character among different wildernesses is inappropriate. The purpose of this monitoring strategy is to offer a consistent means for documenting the status and trends in wilderness character and wilderness management within a wilderness, not across wildernesses. This strategy has proved to be an effective tool for wilderness managers with limited resources.

Wilderness character may show either upward or declining trends over time. The challenge of wilderness stewardship is that decisions and management actions taken to protect one aspect of wilderness character may diminish another aspect. In addition, the accumulated result of seemingly small decisions and actions may cause a significant gain or degradation of wilderness character over time. Because of this complexity, preserving wilderness character requires that refuge staff document decisions made and the impacts of those decisions.

The following report establishes a baseline condition and monitoring strategy for the Tamarac Wilderness based on the five qualities of wilderness character and measures that are specific to the Tamarac Wilderness and are indicative of local trends in wilderness character. An online Wilderness Character Monitoring Database (WCMD at https://wc.wilderness.net/) accompanies this document and includes entries for all measures and baseline data specific to this Refuge where trends in wilderness character can be monitored.

The purpose of this report and the measures of wilderness character is to improve wilderness stewardship by informing managers' understanding of the wilderness they manage, how wilderness character is changing over time, and evaluate why changes may have occurred. Trends in wilderness character cannot be used to 'rate' or 'grade' stewardship; wilderness character is a tool to holistically assess the preservation of wilderness character, not to place judgment on managers. Trends in wilderness character inform stewardship and are not meaningful when taken out of the context of this report or of WCM.

HISTORICAL AND ADMINISTRATIVE SETTING OF THE TAMARAC WILDERNESS

History of establishing the wilderness

Tamarac National Wildlife Refuge (Tamarac NWR) was established as a result of the North American waterfowl shortage during the Dust Bowl years of the early 1930's. Waterfowl populations plummeted due to drought, unsustainable farming practices and wetland drainage, which reduced the land area suitable for breeding, brood rearing and staging during migration. In response to these concerns, the Bureau of Biological Survey began the National Waterfowl Restoration Program in June 1934 to search for lands that were suitable for restoration practices that would benefit waterfowl habitat needs. The initial search indicated that Becker and Mahnomen Counties had the highest waterfowl nesting indices in the state of Minnesota. The Biological Survey viewed this area as a link in a series of migratory waterfowl refuges established in the Mississippi Flyway.

Negotiations between various land owning entities including private non-tribal individuals, county tax forfeited lands and the Bureau of Indian Affairs were made to establish the refuge. The north half of the refuge lies within the original boundary of the White Earth Reservation, which was established in 1867. For centuries Native American tribes have valued the lush beds of manoomin (wild rice) and stands of sugar maple trees. The land has provided an abundance of wild food, fish and game for the Ojibwe people and the Dakota before them. Historical sites throughout the refuge chronicle their utilization of these precious resources and the numerous battles fought over them. The Collier Agreement of 1935 guarantees that Native Americans retain their ricing and trapping privileges in perpetuity within the Refuge, including within the boundaries of the wilderness. Franklin D. Roosevelt established *Tamarac Migratory Waterfowl Refuge* by Executive Order 7902 dated May 31, 1938. Presidential Proclamation 2416 by President Roosevelt changed the name of the Refuge to Tamarac NWR in July 1940.

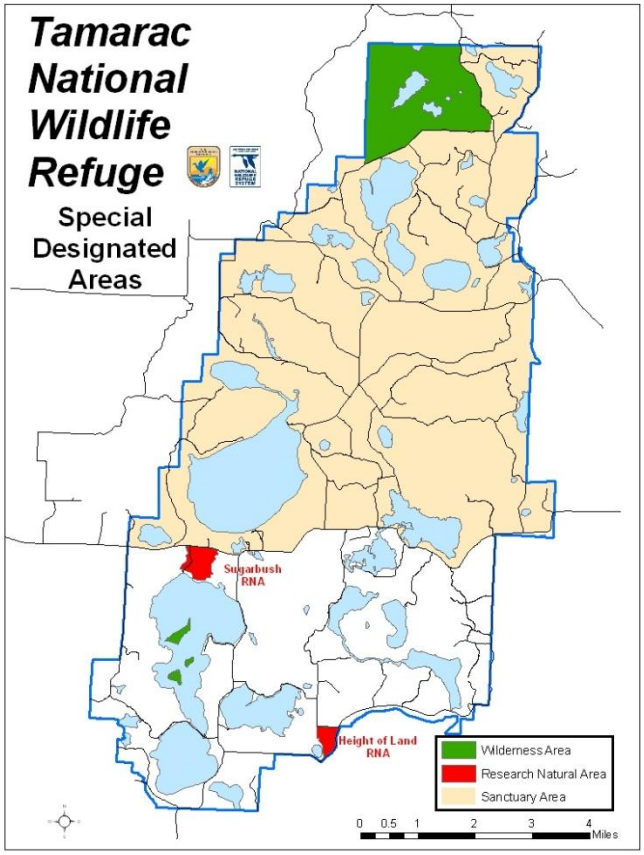

Figure 2: Map of the special designated areas within Tamarac NWR. Map produced by USFWS Region 3 Conservation Planning Office.

Following the establishment of the Refuge in 1938, the northern half of the refuge's present extent was acquired through purchases by the Migratory Bird Conservation Commission with funds from the sale of Federal Duck Stamps. Early development of the refuge was accomplished using labor contracted through the Civilian Conservation Corps (Camp 4709). In 1973, as a part of a review of all lands within the National Wildlife Refuge System, the Bureau of Sport Fisheries and Wildlife studied the lands within Tamarac NWR for potential designation as wilderness. As a result of the study, a 2,073-acre unit in the northwest corner of the refuge and the three islands in Tamarac Lake, totaling 65 acres,

were proposed for wilderness designation (Figure 2). On May 20th, 1974, the Secretary of Interior wrote to the President of the United States recommending the inclusion of the proposed Tamarac Wilderness into the National Wilderness Preservation System. The Tamarac Wilderness was included in the act "Designation of Wilderness Areas within The National Wildlife Refuge System" (16 U.S.C. § 1132 [Public Law 94-557]), passed by Congress on October 19, 1976.

Refuge purposes

National Wildlife Refuges are established under a variety of legislative acts and administrative orders and authorities. Stated in these orders and authorities are one or more specific purposes for which the refuge lands are acquired and maintained. The purposes are of key importance in refuge planning, and are the foundation for management decisions. Lands for Tamarac NWR were acquired under the original Executive Order and The Migratory Bird Conservation Act.

The establishing authorities and related purposes for Tamarac NWR and the Tamarac Wilderness include:

> *"…as a refuge and breeding ground for migratory birds and other wildlife"* (Executive Order No. 7902 signed May 31, 1938)
>
> *"…for use as an inviolate sanctuary, or for any other management purpose, for migratory birds"* 16 U.S.C. § 715d (Migratory Bird Conservation Act)
>
> "…*for the use and enjoyment of the American people such manner as will leave them unimpaired for future use and enjoyment as wilderness, and so as to provide for the protection of these areas, the preservation of their wilderness character, and for the gathering and dissemination of information regarding their use and enjoyment as wilderness*…" (16 U.S.C. § 1131 [Wilderness Act])
>
> - Wilderness designation is supplemental to refuge purposes as defined by 16 U.S.C. § 668dd (NWRS Improvement Act of 1997)

A refuge vision provides a simple statement of the desired future condition of the refuge. The vision of Tamarac NWR as stated in the Comprehensive Conservation Plan (CCP) is as follows:

> "Tamarac NWR is treasured as an ecologically and culturally rich landscape of rolling forested hills interspersed with shallow lakes, rivers and marshes that nurtures a unique and diverse assemblage of plants and animals…In the land where food grows on water, bountiful wild rice provides for future generations of wildlife and native people. From the vibrant emergence of spring woodland wildflowers to the rich colors of autumn to the quiet hush of winter, people come to revitalize their spirit and connect with a rich wildlife heritage."

Geographic setting

Tamarac NWR is located in the rolling timberlands of northwest Minnesota in Becker County, 18 miles northeast of Detroit Lakes (Figure 3). The 42,738 acre refuge is positioned just east of the eastern edge of

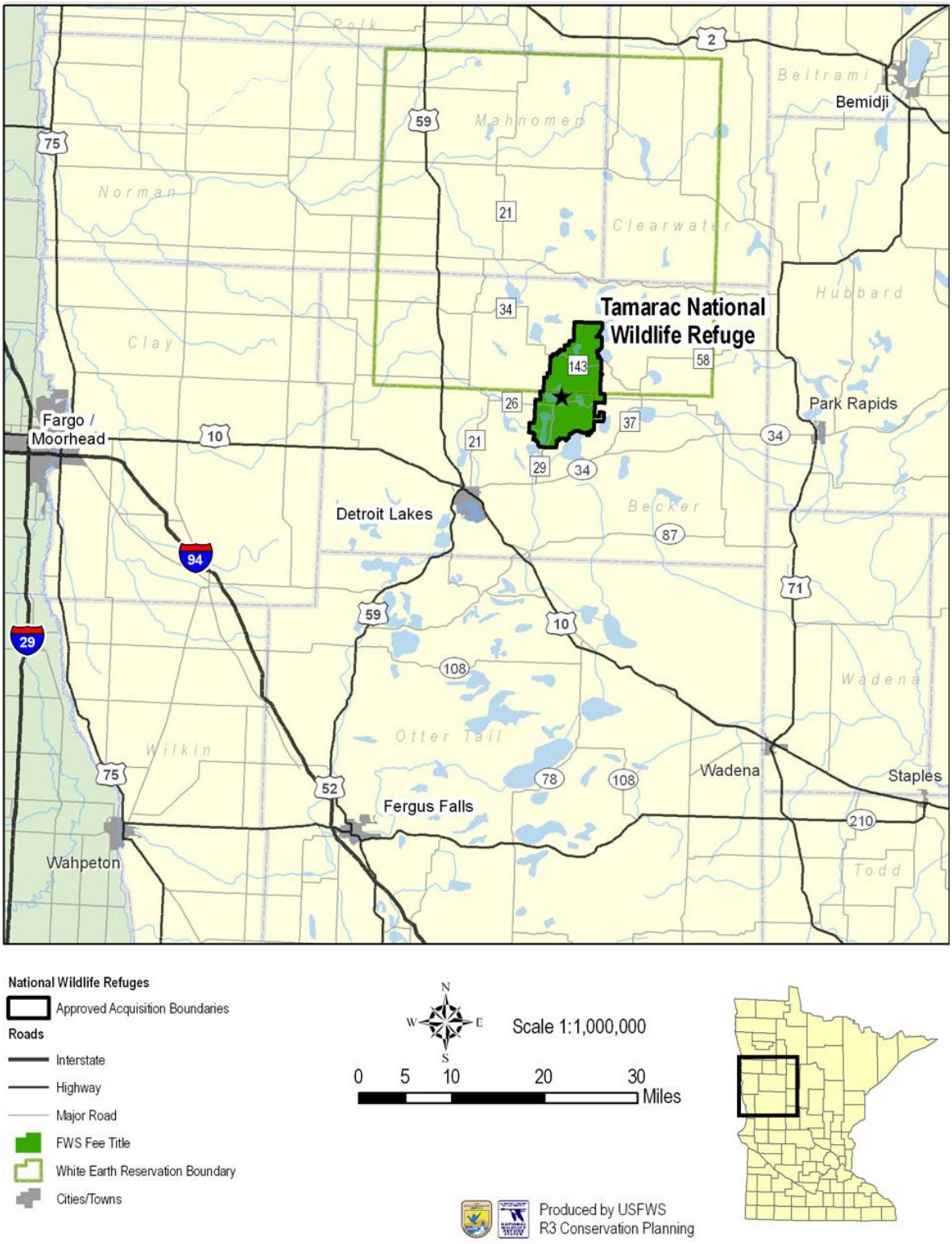

Figure 3: Location of Tamarac NWR within the state of Minnesota.

the tall grass prairie region. Tamarac NWR is in the heart of one of the most diverse ecological transition zones in North America, where northern hardwood forests, coniferous forest and tall grass prairie converge. Situated along the backbone of Minnesota, the refuge lies within a mile of the continental divide, which separates the Mississippi and Hudson Bay watersheds. Lake Itasca, the headwaters of the Mississippi River, is approximately 25 miles northeast of the refuge. The Egg River, which originates in the Tamarac Wilderness, is a tributary to the Ottertail River and is primarily contained within the refuge boundaries. The Ottertail, Egg and Buffalo Rivers drain parts of the refuge into the Red River, which runs north and ultimately empties into the Hudson Bay.

Ecological setting[1]

Between 10,000 and 10,500 years ago, receding glaciers left behind the rolling ridges and deep depressions that became a woodland area complemented by lakes, rivers, bogs and marshes. Immediately following the retreat of the Wisconsin glacier, the land was likely barren and void of vegetation; however, within a few years coniferous trees such as spruce and pine began to populate the landscape due to the cool and moist environment. These forests dominated the landscape until about 8,000 years ago, when more herbaceous species became prevalent. Warmer and drier conditions introduced a savanna with scattered oak trees and large open areas of prairie. Several thousand years later, the area became cooler and wetter again, giving rise to an expansion of the coniferous forest (primarily red and white pine) and other deciduous trees back into the area with a decrease of prairie. The history of this transition in dominant plant community types since the retreat of the Wisconsin glacier is evidenced through pollen records, which provide a testament to the range of natural variability of vegetation within the larger landscape. The transitional habitats that converge here provide for a diversity of plant and wildlife species. Tamarac NWR pre-European settlement cover types were comprised of mature stands of red and white pine, jack pine barrens, aspen-birch, mixed hardwoods, conifer bogs, swamps and numerous lakes. Between 1890 and 1930 the original stands of red and white pine were heavily logged throughout Tamarac NWR. Catastrophic fires occurred during this time period due to widespread slash piles that were left behind after logging. Several dams and ditches were also created by loggers, to transport logs down the river to the mill. Settlers followed the loggers, but farming never achieved much prominence due to the dense forest, marginal soils and numerous wetlands. A heavy mantel of glacial drift covers all of Becker County resulting in predominantly sandy moraines underlain with limey, clay loams. The soils of the northern portion of the refuge have low fertility due to poor soil structure and steep slopes.

Loggers harvesting pine trees.

Timber ready to be transported to the mill.

[1] **The descriptions provided under this heading apply to Tamarac NWR as a whole.**

According to the Minnesota Ecological Land Classification System, Tamarac NWR lies near the tallgrass prairie province but is clearly within the forest landscape of the Laurentian Mixed Forest province. Provinces are defined by major climate zones, native vegetation, and biomes; the climate at Tamarac NWR is characterized by warm summers and long, cold winters. Within each province, sections are defined by origin of glacial deposits, regional elevation, distribution of plants and regional climate. Tamarac NWR falls primarily within the Northern Drift and Lake Plains section. Each section is further broken down into subsections, which are defined using glacial deposition processes, surface bedrock formations, local climate, topographic relief and the distribution of plants, especially trees. Tamarac NWR falls primarily within the Pine Moraines and Outwash Plains subsection (Figure 4). The subsection level is the primary reference for landscape level planning.

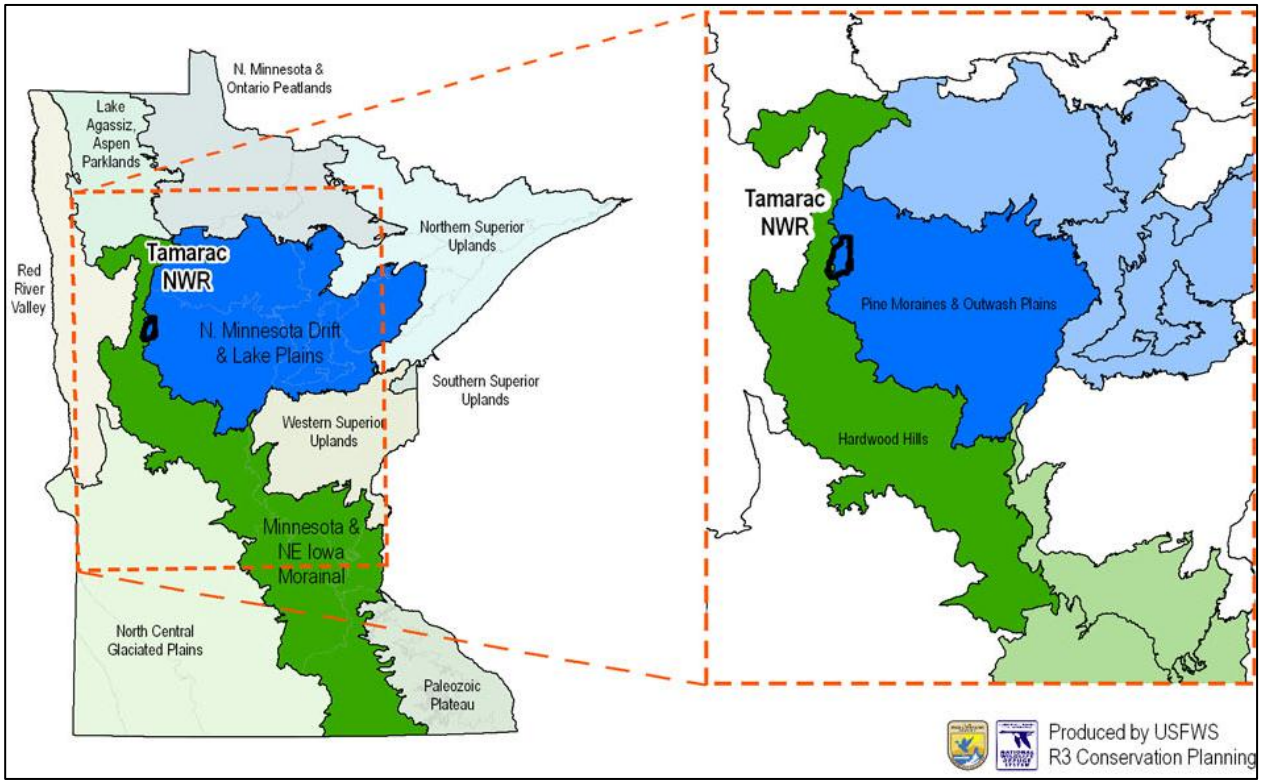

Figure 4: Tamarac NWR in relation to sections and subsections of the Minnesota Ecological Land Classification System.

Current vegetation cover types are significantly altered from pre-settlement times (92% reduction in red and white pine, 89% reduction in jack pine coverage) and increases in mixed hardwood and aspen-birch with areas of dense hazelbrush understory have occurred (Figure 5). The upland grass cover type has increased due to remnant openings that were created for farming at the time of settlement. The Tamarac Wilderness consists of open water, marsh/wetland and small pockets of almost all forest types found on the refuge: upland deciduous, mixed upland, lowland deciduous, mixed lowland, upland coniferous and lowland coniferous forests.

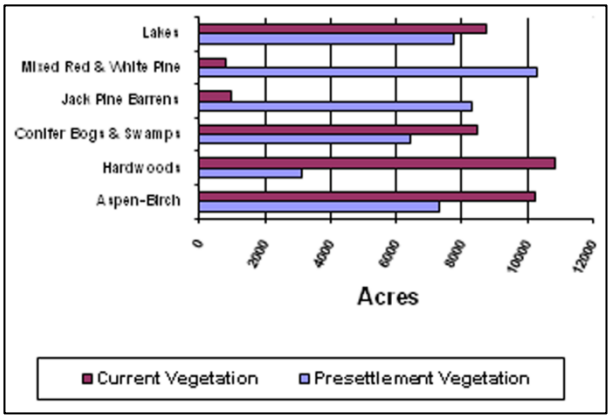

Figure 5: Tamarac NWR current versus presettlement vegetation cover types.

Tamarac NWR was initially established for the protection and production of waterfowl and migratory bird species. There are 258 species of birds that can be found on the refuge, 113 species are reported to nest here. Primary nesting waterfowl species include: mallard duck, wood duck, blue-winged teal, ring-necked duck, Canada goose, and the trumpeter swan. In addition to the breeding population, approximately 50,000 ducks migrate through the refuge each fall stopping to feed on the abundant annual wild rice. The wetlands in the refuge are ideal nesting sites particularly important to waterbirds such as: common loons, great blue herons, forster's tern, black terns, American bitterns, least bitterns, yellow rails, sora rails, Virginia rails, sedge wrens and the swamp sparrow. Resident birds or year-round species include: ruffed grouse, wild turkey, 8 species of owls and 7 species of woodpeckers. Other bird species on the refuge include: 8 species of hawks, 8 species of sandpipers, 4 species of gulls, 5 species of swallows, 23 species of warblers and 19 species of sparrows among others.

The refuge supports 53 species of resident mammals and 7 species of bats that migrate off-refuge to overwinter. Two packs of gray wolves have successfully produced young on the refuge, and a third pack's territory overlaps into the refuge. White-tailed deer, beaver, striped skunk, raccoon, muskrat, mink and red squirrels are abundant. Other furbearers, including red fox, beaver, raccoons, coyote, bobcat, fisher, otter, and long and short-tailed weasels are locally common and seen in the area on a regular basis.

Fish surveys have been conducted on select lakes and streams, sampling by various methods has documented 37 species of fish occurring within Tamarac NWR including: walleye, yellow perch, black crappie, large-mouth bass, bluegill, pumpkinseed, rock bass, brown bullhead, yellow bullhead, black bullhead, white sucker, northern pike and bowfin. Undesirable nuisance fish species, such as bullheads, common carp and fathead minnows, could become a stress upon the refuge's fishery and waterfowl. Carp are present within the Ottertail River system, but so far restricted in distribution by a box culvert structure in the Hubbel Pond Wetland Management Area, which is just south of the refuge.

Lakes, streams, ditches and other wetland basins provide aquatic habitat required for a variety of reptiles and amphibians, which are important food sources for many mammals, birds and fish. Eleven species of amphibians and 5 species of reptiles have been recorded to exist within the refuge. Frog and toad species include: spring peeper, American toad, wood, chorus, northern leopard, gray tree, Cope's gray tree and mink. Garter snakes, prairie skinks, snapping and painted turtles are all common on the refuge as well.

Tamarac Wilderness Area. Photo by Denis Mudderman.

DOCUMENTS CONSULTED

The documents listed below helped inform this report by providing background information on the Tamarac Wilderness and wilderness character monitoring. These documents, along with interviews with refuge staff, were the main sources to identify wilderness character measures. Complete citations can be found in the REFERENCES section at the end of the document.

Tamarac Wilderness

- Tamarac National Wildlife Refuge and Wetland Management District: Comprehensive Conservation Plan (2010)
- Wilderness Study Summary: Tamarac National Wildlife Refuge, Becker County, Minnesota (1974)
- Final Environmental Statement: Proposed Tamarac Wilderness Area, Minnesota (1975)
- Wilderness Record: Tamarac Wilderness Proposal (1974)
- Wilderness Management Plan. Tamarac National Wildlife Refuge, Fish and Wildlife Service (1982)

Wilderness character

- Keeping it Wild: An Interagency Strategy to Monitor Trends in Wilderness Character across the National Wilderness Preservation System. Landres, P., C. Barns, J.G. Dennis, T. Devine, P. Geissler, C.S. McCasland, L. Merigliano, J. Seastrand, and R. Swain (2008)
- Keeping it Wild 2: An Updated Interagency Strategy to Monitor Trends in Wilderness Character across the National Wilderness Preservation System. Landres, P., C. Barns, Boutcher, S., T. Devine, P. Dratch, C. Filardi, A. Lindholm, L.Merigliano, N. Roeper and E. Simpson [IN PRESS].
- Technical Guide for Monitoring Selected Conditions Related to Wilderness Character. USDA Forest Service Report WO-80. Landres, P., S. Boutcher, L. Dean, et al (2009)
- National Wildlife Refuge System Improvement Act of 1997 (16 U.S.C. § 668dd)
- Wilderness Act of 1964 (16 U.S.C. § 1131)

Other Documents

- Ecological Land Classification Handbook for the Northern Minnesota Drift & Lake Plains

STAFF CONSULTED

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Lowell Deede – Wildlife Biologist

Gina Kemper – Biological Technician

Neil Powers – Refuge Manager

Jill Webster – USFWS Air Quality Division

PROCESS USED FOR IDENTIFYING MEASURES

The process used to identify and select measures to monitor wilderness character is outlined below. All actions were carried out by the Wilderness Fellow unless otherwise specified.

1. *Gather information* – Background information was gathered to understand the wilderness and refuge including its history, ecosystems, and potential threats in the future. This information was gathered by reading background and guiding documents for the wilderness and refuge (listed in Documents Consulted), interviews with refuge staff and other individuals, visiting selected mainland units and islands, and viewing the islands from shore.
2. *Create list of possible measures* – Preliminary measures were identified and compiled for all indicators based on the information gathered and interviews with staff. Several measures were based on measures described in wilderness character monitoring documents, including the Forest Service Technical Guide, National Park Service User Guide, and the U.S. Fish and Wildlife Service (USFWS) Wilderness Character Monitoring Framework "Keeping it Wild", and refined to suit Tamarac NWR.
3. *Refine measures* – Measures were prioritized and refined through discussing measures with staff and evaluating the significance, feasibility, vulnerability, and reliability of measures (see worksheet in Appendix A). Availability of reports and scientific information was also considered.
4. *Approval of measures* – Final list of measures was developed and submitted to wilderness supervisors Nancy Roeper (National Wilderness Coordinator, USFWS), Peter Dratch (Senior Biologist, NWRS Inventory and Monitoring), and Peter Landres (ecologist, Aldo Leopold Wilderness Research Institute).
5. *Write report* – Each measure was described, including background information, collection protocol, data adequacy, measure weight, data source, and significant change. All measures were written into final report and the report was submitted to supervisors.
6. *Locate and synthesize data* – Available scientific information for each measure was collected by contacting relevant individuals and pulling information from the internet and Refuge Complex shared drive. Data was processed as necessary.
7. *Enter data*– Data was entered into the WCMD at https://wc.wilderness.net/
8. *Incorporate comments* – Changes, edits, and feedback from staff, regional Inventory and Monitoring staff, and wilderness supervisors were received by Wilderness Fellow. Edits were incorporated into the final draft.
9. *Approval of final report* – Report was finalized and approved by supervisors.

WILDERNESS CHARACTER MONITORING MEASURES

This section describes in detail the measures selected to monitor the Tamarac Wilderness. The baseline year for wilderness character monitoring in the Tamarac Wilderness is 2014. When measures have legacy data available, the baseline *for that specific measure* will be from the first year for which data are available post-wilderness designation. For the Tamarac Wilderness, designated in October of 1976, the earliest possible baseline year for a measure would be 1977. A measure's data value reported in 2014, therefore, may not necessarily be the *measure's baseline* data value. For examining trends in wilderness character for the wilderness as a whole, 2014 remains the overall baseline year.

The following aspects of each measure are described: 2014 data value, year(s) of data collection, background information, measure description & collection protocol, data source, data frequency, and significant change. The content and purpose of each section is described below.

- **2014 Data value**—specifies the value for a measure entered into the Wilderness Character Monitoring Database (WCMD) for 2014 (the baseline year for Tamarac wilderness character monitoring). Please note that the WCMD uses "year measured" to refer to the year of any given data/measure value (e.g., the "year measured" of the "2014 data value" is 2014). If a measure does not have a 2014 value, the most recent year of data is reported under each measure's heading with the respective year the data were measured.
- **Year(s) of data collection**—specifies the year(s) the data were collected. For some measures, the protocol may be to report the most recent available data, regardless of the year of data collection. For example, if data pulled from a national website is only available to the public two years after data collection, the data year corresponding with the 2014 data value would be 2012. Fiscal and water years are recorded as the secondary year—for example, the water year from October 2013 to September 2014 would be recorded as "2014 (water year)."
- **Background information** – defines the context and relevance for the measure at an individual wilderness and addresses why the measure was selected.
- **Measure description and collection protocol** – defines what is being measured and how, including the process through which data are compiled or gathered. "Collection protocol" is defined and used in this document to refer to the process by which data is gathered from existing sources and does not include in-the-field data collection instructions. If field data collection protocols are relevant to a measure and available, a location of where the protocol can be found is included. For specific data collection details refer to APPENDIX C – Data sources and protocols for all measures used.
- **Data source** – defines where baseline information for the measure can be found into the future. The intent of this section is to encourage written documentation of wilderness character so that information is accessible into the future.
- **Data frequency** – defines how often data for this measure should be entered into the WCMD. Frequency is typically determined by the time frame in which data becomes available under existing monitoring protocols and becomes available for use in wilderness monitoring purposes.
- **Data adequacy** – defines the reliability of the data to assess trends in the measure by rating the data adequacy as high, medium, or low. Data adequacy is based on data quantity and data quality.

Data quantity refers to the level of confidence that all appropriate data records have been gathered (Table 1). Data quality refers to the level of confidence about the source(s) of data and whether the data are of sufficient quality to reliably identify trends in the measure (Table 2).

Table 1: Data quantity classifications

Complete	This category indicates a high degree of confidence that all data records have been gathered. For example, to assess the occurrence of nonindigenous invasive plants, a complete inventory of the wilderness was conducted or all likely sites were visited
Partial	This category indicates that some data are available, but the data are generally considered incomplete (such as with sampling). For example, to assess the occurrence of nonindigenous invasive plants, a partial inventory was conducted or a sampling of sites was conducted where these plants are likely to occur.
Insufficient	This category indicates even less data records have been gathered or perhaps this measure is not dependent on actual field data. For example, no inventory for nonindigenous invasive plants has been conducted, and visitor use was not assessed anywhere.

Table 2: Data quality classifications

High	This category indicates a high degree of confidence that the quality of the data can reliably assess trends in the measure. For example, data on the occurrence of nonindigenous invasive plants are from ground-based inventories conducted by qualified personnel; for visitor use, data would come from visitor permit data.
Moderate	This category indicates a moderate degree of confidence about the quality of the data. For example, data on invasive plants could come from national or regional databases; for visitor use, data could come from direct visitor contacts.
Low	This category indicates a low degree of confidence about the quality of the data. For example, data on invasive plants and visitor use could come from professional judgment.

Further information on the role of data quantity and quality in WCM is available in the *FS Technical Guide* (pp. 26). Subjective evaluation of these two aspects is used to determine if data adequacy as high, medium, or low. Please note that the WCMD refers to data adequacy as 'data confidence.'

- **Significant change** – defines how much change a measure must undergo to indicate a changing trend wilderness character for a particular measure. “Significant change” is defined and used in this document differently than definitions used by other departments within USFWS and is not intended to mean “statistically significant change” nor imply use of the Environmental Impact Statement (EIS) process under the National Environmental Protection Act (NEPA).

In most cases, frequency and significant change were assigned by the Wilderness Fellow and approved by refuge staff. All measures within an indicator are weighted equally unless described otherwise.

Together, these sections provide a comprehensive overview of each measure, provide transparency into wilderness character monitoring measures selected at the refuges, and the form the basis of the wilderness character monitoring strategy of the Tamarac Wilderness.

Overview of wilderness character monitoring measures

The table below lists all 26 wilderness character measures used to monitor the Tamarac Wilderness and provides at least one measure for every indicator. Each measure is described in more detail in its respective section later in the report.

It is important to distinguish within this report that the road right-of-ways bordering the Tamarac Wilderness are not included in the wilderness boundary and should not be taken into account when completing the analyses for the following measures.

Table 3: Wilderness Character Monitoring Measures used for the Tamarac Wilderness

Quality	Indicator	Measure
Untrammeled	Actions authorized by the Federal land manager that manipulate the biophysical environment	1-1: Number of actions to manage Fire
		1-2: Number of actions to manipulate wildlife
		1-3: Number of actions to manage invasive flora and fauna species
		1-4: Number of actions to manipulate fish, pathogens, soil, or water
	Actions not authorized by the Federal land manager that manipulate the biophysical environment	1-5: Number of known unauthorized trammeling actions
Natural	Plants	2-1: Number of non-native invasive plant species
	Animals	2-2: Number of non-native fauna species
	Air and Water	2-3: Ozone concentration
		2-4: Wet deposition of nitrogen
		2-5: Wet deposition of sulfur
		2-6: Visibility
		2-7: Index of water quality
	Climate change	2-8: Annual winter minimum temperature anomaly
		2-9: Annual winter maximum temperature anomaly
		2-10: Total annual precipitation
		2-11: Annual Palmer drought severity index
	Ecological processes	2-12: Miles of wilderness boundary serving as an entry point for invasive species
		2-13: Index of connectivity

Undeveloped	Presence of non-recreational structures, installations, and developments	3-1: Number of structures, installations or developments
	Presence of recreational structures, installations, and developments	3-2: Number of recreational structures, installations, or developments
	Presence of inholdings	3-3: Acres of inholdings
	Use of motor vehicles, motorized equipment, or mechanical transport	3-4: Index of authorized administrative uses of motorized vehicles, motorized equipment, or mechanical transport
Solitude or primitive and unconfined recreation	Remoteness from sights and sounds of people inside the wilderness	4-1: Percent of wilderness away from access or travel routes
	Remoteness from occupied and modified areas outside the wilderness	4-2: Percent of wilderness not affected by adjacent travel routes and human developments
	Facilities that decrease self-reliant recreation	4-3: Number of facilities that decrease self-reliant recreation
	Management restrictions on visitor behavior	4-4: Index of management restrictions on visitor behavior

Some wilderness character monitoring measures for the Tamarac Wilderness have an associated Excel spreadsheet file where data will be recorded before updating the wilderness character monitoring online database (WCMD). The Excel file that belongs to each measure is set up to calculate index values (if required) or simply act as the repository for data. The Excel files are kept together in the wilderness character monitoring folder on the Tamarac NWR shared drive at:

S:/Wilderness Management/Wilderness Character Monitoring/ WCM data files

Within the WCM data files folder, each quality has its own folder. If applicable, the name to each measure's Excel file is found under the header, "**Data collection file**" in the measure definitions below and the electronic paths to the files for all measures can be found in APPENDIX C – Data sources and protocols for all measures used.

It is vital to use APPENDIX C – Data sources and protocols for all measures used **as a guide for all of the measures data analyses before updating the WCMD.** The information described in each of the 'measure description and collection protocol' headings are meant to briefly describe how the data value for the measure is derived, however it does not offer specific instructions and pertinent details of how to complete and replicate the analysis the exact way that the baseline value was derived. If there are variations and inconsistences in how the data value is calculated year-to-year, assigning trends over time will not be valid. This is a very important detail that must be highlighted and brought to the attention of individuals who will be responsible for data collection and analysis into the future.

Untrammeled Quality

Wilderness is essentially unhindered and free from modern human control or manipulation.

The untrammeled quality of wilderness character tracks the actions of humans in wilderness that intentionally manipulate the biophysical environment. Actions that intentionally manipulate or control ecological systems inside wilderness degrade the untrammeled quality of wilderness character. This is true regardless of what instigated the action or if benefits to other qualities of wilderness character are gained by the action. Further information on determining whether an action meets the criteria for the untrammeled quality can be found in APPENDIX E – What is a trammeling action (dated August 2014) or the latest version can be found online: http://ecos.fws.gov/ServCatFiles/Reference/Holding/26180

Table 4: Measures of the Untrammeled Quality used to monitor the Tamarac Wilderness

Indicator	Measure	Frequency	Data Adequacy	Significant Change	WCM Baseline Value
Actions authorized by the Federal land manager that manipulate the biophysical environment	1-1: Number of actions to manage Fire	5 years	High	Any	0
	1-2: Number of actions to manipulate wildlife	1 year	High	Any	0
	1-3: Number of actions to manage invasive flora and fauna species	1 year	High	Any	0
	1-4: Number of actions to manipulate plants, soil, or water	1 year	High	Any	0
Actions not authorized by the Federal manager that manipulate the biophysical environment	1-5: Number of known unauthorized trammeling actions	1 year	Low	Any	0

All trammeling actions should be recorded in the same excel spreadsheet located in the wilderness management folder on the Tamarac share drive. There are separate tabs representing authorized and unauthorized actions. Consult this data collection spreadsheet file before updating the WCMD. The file can be found at: <S:/Wilderness Management/Wilderness Character Monitoring/WCM data files/1 Untrammeled/trammeling_actions.xlsx>

Scale is an important consideration in counting trammeling actions, but only to a certain point. If it is determined that the magnitude of an action's consequences will exceed a certain threshold, the action is counted as a trammeling. All trammeling actions that cross this threshold are counted equally, regardless of the extent of their effects (e.g. the action of spraying herbicide on 100 acres is equivalent to the action of spraying herbicide on 1,000 acres). Below that threshold, however, actions are not considered significant enough to be counted as a trammeling action (e.g. hand pulling a couple of invasive plants, removing a hazard tree or two along the trail, etc.). The intent of counting trammeling actions is to track whether management programs are trending toward more or less human manipulation in the wilderness; therefore, this approach focuses on trammeling *actions*, and not on the *magnitude* of trammeling's effects. The general protocol for counting trammeling actions is outlined in Table 5, while Table 6 offers a more detailed explanation of how to report specific trammeling actions, draft from the *2009 FS Technical Guide* (pp. 55).

Table 5: General rules for counting the number of actions for the Untrammeled Quality

IN GENERAL…
▪ Only count actions that are of sufficient scale (that cross the threshold); ▪ All actions above the threshold are counted equally; ▪ Minimum requirements analyses (MRAs) or National Environmental Policy Act (NEPA) analyses can often (although not always) be used to evaluate actions in wilderness.
CLARIFICATIONS:
▪ <u>Actions approved in perpetuity</u> are counted as one action per event (e.g. if a blanket policy of complete fire suppression is approved in order to protect critical habitat or private property, each suppression event for naturally ignited fire would still count as one action). ▪ <u>Persistent structures that continue to alter wildlife distribution or movement patterns long after construction</u> (e.g. dams, water guzzlers, enclosures, exclosures, etc.) are counted as one action in the year(s) when installation actions occur. Thereafter, the *effects* of these structures are monitored as part of the natural quality. ▪ <u>Actions that are individually too small in scale to be counted as trammeling actions *will* count as trammeling actions if and when their cumulative effects cross that threshold.</u> (e.g. applying herbicide to one individual invasive plant is not significant enough to count as a trammeling, however when a significant amount of time is spent controlling one individual species, it will count as one trammeling action in the year the treatment occurred)

Table 6: Protocol for counting trammeling actions

Adapted from the *2009 Forest Service Technical Guide* (pg. 55)			
Type of action	Example	Counting rule	Reporting
Single action at a single location	Purple loosestrife is treated at a single location	Count as one action	Report one action
Single action at multiple locations	Purple loosestrife is treated with herbicide in several locations	Count as one action	Report one action for the single species regardless of the number of locations
Multiple actions at a single location	Herbicide is used to treat purple loosestrife and zebra mussels in the same location	Count as one action OR as multiple actions	Report one action AS LONG AS the actions were part of the same initiative/decision and in the same time frame; IF NOT, count as multiple actions
Multiple actions at multiple locations	Mechanical treatment is used in addition to herbicides	Count as multiple actions	Report actions based on the number of actions taken; considerations include whether the actions were part of the same initiative/decision and in the same time frame; documentation through MRA or NEPA analyses can be used to evaluate the number of actions reported
Action occurs within in a single year	Purple loosestrife is treated with herbicide from June 2011 to September 2011	Count as one action	Report one action
Action spans multiple years without interruption	Herbicide treatment begins in December 2011 and extends into March 2012	Count as one action	Report as one action in 2011
Action spans multiple years with interruption	Herbicide treatment initiated in August 2011 ends in November 2011 and is reinitiated in August 2012	Count as multiple actions	Count as one action in 2011 and one action in 2012

Measure 1-1: Number of actions to manage fire

2014 Data value: 0
Year of data collection: 2014

Background and context
Fire-dependent forests and woodlands are common across the Laurentian Mixed Forest Province of northern Minnesota. Historically, typical fire return intervals ranged from 0 – 35 years for stand maintenance at any given site within Tamarac NWR. Following the establishment of the refuge in 1938, fires in the vicinity were aggressively suppressed. In recent years, fires are typically human caused and have occurred adjacent to roads and trails open to public use. The north and west boundaries of the Tamarac Wilderness adjoin state, county and privately owned lands with no natural or man-made barriers to confine a fire. According to the Wilderness Management Plan (1982) "…any fire in a wilderness area that poses a threat to resources or facilities outside the unit will be controlled and extinguished." It also states that any natural fire on the wilderness Islands of Tamarac Lake will be allowed to burn out unless high winds threaten to spread the fire to other refuge lands. Wilderness, by definition, is land where ecological functions have been allowed to operate without human manipulation. There are certainly valid reasons behind many fire management or fire regime restoration projects. However, the purposeful manipulation of natural fire disturbance regimes by federal land managers disturbs its unadulterated state and is considered a trammeling action. Such decisions to take fire management actions within wilderness must be considered carefully in regard to their effect on wilderness character and this warrants monitoring.

Measure description and collection protocol
This measure tracks the total number of decisions to take action that influence the natural fire regime or fuel loads inside wilderness. Actions that are intended to manipulate, at a broad-scale, any component of the biophysical environment within wilderness are considered trammeling actions. Suppression of human-started fires is not considered a trammeling action as these fires are unnatural to begin with. All management decisions that involve the following actions should be included in this measure: fire ignitions, prescribed burns, natural fire suppression responses, fuel load reduction activities, or any other action involving fire management within the wilderness. Over time, an increase in the number of actions to manage fire represents a downward trend in this measure.

Data source: Fire incident reports on the share drive, Fire Management Information System, biological staff

Data adequacy: *High* –no fires have occurred in wilderness; staff will be aware of any fire, so quality is high.

Frequency: Data will be entered into the WCMD every 5 years.

Significant change: Any change in this measure is considered a significant change.

Measure 1-2: Number of actions to manipulate wildlife

2014 Data value: 0
Year of data collection: 2014

Background and context
The convergence of three biomes within Tamarac NWR provide habitat to a diversity of wildlife. Monitoring and management of these species is sometimes necessary for population or community health. Likewise, research can provide important knowledge regarding the status or presence of rare or declining species. While these projects are often initiated with the intent of improving the natural quality of wilderness character, they must be monitored for their effects on wilderness. Authorized actions to manipulate the biophysical environment in the Tamarac Wilderness are rare, but their role as trammeling actions makes them significant to wilderness character.

Measure description and collection protocol
This measure is a count of the number of actions that are intended to manipulate, at a broad-scale, any component of wildlife populations within wilderness. Authorized actions include discretionary and non-discretionary actions required to uphold other laws, as well as any independent actions authorized through special permits (i.e. research or monitoring actions that manipulates wildlife). The count should include all wildlife management actions involving the following: reintroduction, introduction, supplementation of wildlife species, predator control programs, or research or monitoring activities that involve significant disruption to wildlife populations. Significant disruption to wildlife includes, but is not limited to, actions such as: capturing, collaring, implanting transmitters, collecting blood/tissue samples, electro-shocking, and sterilizing. This measure does not include any actions involving invasive animal species, as these actions are counted under a separate measure. An "action" should be counted according to the guidelines set forth in Table 5 and Table 6. Over time, an increase in the number of authorized actions to manipulate wildlife signifies a downward trend in this measure.

Definitions
- See APPENDIX E – What is a trammeling action

Data source: Special Use Permits, biological staff

Data adequacy: *High* – no authorized trammeling actions have occurred; staff should be aware of such actions, so confidence in data quality is high.

Frequency: Data will be entered into the WCMD annually.

Significant change: Any change in this measure is considered to be a significant change.

Measure 1-3: Number of actions to manage invasive flora and fauna species

2014 Data value: 0
Year of data collection: 2014

Background and context
The natural community of the Tamarac Wilderness is at risk of invasion by non-native invasive species and trammeling may occur to combat their invasion. Authorized actions to manipulate the biophysical environment in the wilderness are rare, but their role as trammeling actions makes them significant to wilderness character. There has been no comprehensive survey for invasive species in the Tamarac Wilderness. Invasive species of concern include: invasive earth worms, gypsy moth, emerald ash borer, faucet snails, purple loosestrife and several other terrestrial and aquatic invasive plant species. A volunteer who paddled up the Egg River in the northwest unit of the Wilderness, found an individual plant of purple loosestrife in the summer of 2014. This was the first known infestation to occur within the wilderness. Staff controlled the individual plant by hand pulling and spot spraying with an herbicide; this action was not included in the baseline value as only one individual plant was treated and it does not pass the threshold protocol of counting trammeling actions. The purpose and frequency of invasive species management must be considered carefully in regard to its effect on wilderness character and this warrants monitoring.

Measure description and collection protocol
This measure is a count of the number of authorized actions that are intended to manage, at a broad-scale, any plant or animal invasive species in wilderness. Authorized actions include discretionary and non-discretionary actions required to uphold other laws, as well as any independent actions authorized through special permits. The count should include all plant management activities involving the following: biological, chemical, or mechanical control of invasive species. The count should also include all invasive animal management actions. An "action" should be counted according to the guidelines set forth in Table 5 and Table 6. Over time, an increase in the number of authorized actions to manage invasive species signifies a downward trend in this measure.

Definitions
- See APPENDIX E – What is a trammeling action

Data source: Special Use Permits, biological staff

Data adequacy: *High* – no authorized actions have occurred; staff should be aware of such actions, so confidence in data quality is high.

Frequency: Data will be entered into the WCMD annually.

Significant change: Any change in this measure is considered to be a significant change.

Measure 1-4: Number of actions to manipulate plants, soil, or water

2014 Data value: 0
Year of data collection: 2014

Background and context
Upper Egg Lake is contained within the wilderness boundary and is the origin for the Egg River. The Egg Lake Trail, a refuge service road, borders the northwest wilderness unit to the south and a water culvert is below this road to ensure the flow of the river into Big Egg Lake just across the wilderness boundary. There have been instances in the past when beavers have plugged up the culvert; management actions taken to clear the culvert would not be considered a trammeling action as the road right-of-way is not considered to be a part of the wilderness boundary. Given the amount of water resources in the wilderness, it is important to track any management actions that may occur there. Authorized actions to manipulate the biophysical environment in the Tamarac Wilderness are rare, but their role as trammeling actions makes them significant to wilderness character.

Measure description and collection protocol
This measure is a count of the number of authorized actions that are intended to manipulate, at a broad-scale, any components of the biophysical environment, specifically native plants, soil or water in wilderness. Authorized actions include discretionary and non-discretionary actions required to uphold other laws, as well as any independent actions authorized through special permits (i.e. research or monitoring actions that manipulate the biophysical environment). The count should include any native plant management activities involving the following: large scale harvesting, restoration, seeding, or research/monitoring studies. The count should also include all actions to manipulate or research soil and water components within the wilderness boundary. An "action" should be counted according to the guidelines set forth in Table 5 and Table 6. Over time, an increase in the number of authorized actions to manipulate plants, soil or water signifies a downward trend in this measure.

Definitions
- See APPENDIX E – What is a trammeling action

Data source: Special Use Permits, biological staff

Data adequacy: *High* – no authorized actions have occurred and staff should be aware of such actions, so confidence in data quality is high.

Frequency: Data will be entered into the WCMD annually.

Significant change: Any change in this measure is considered to be a significant change.

Measure 1-5: Number of known unauthorized trammeling actions

2014 Data value: 0
Year of data collection: 2014

Background and context
Unauthorized trammeling actions are fundamentally different from authorized trammeling actions in that they are usually taken with little or no consideration of the effects on the broader ecological systems within wilderness. No known unauthorized trammeling actions have occurred in the Tamarac Wilderness. It is possible for unauthorized intentional manipulations of the Tamarac Wilderness to occur without the knowledge of refuge staff given the distance between the wilderness and refuge headquarters and the lack of monitoring presence within the wilderness. The Tamarac Wilderness gets minimal use and visitors to the wilderness are typically hunters.

Measure description and collection protocol
This measure counts the number of actions not authorized by the USFWS that are taken by individuals, citizen groups, or other agencies that are intended to manipulate, at a broad-scale, any component of the biophysical environment, including plants, wildlife, insects, fish, pathogens, soil, water, or fire (i.e. cutting/thinning trees, purposely releasing non-native species). An increase in the number of unauthorized actions intended to manipulate the biophysical environment results in a downward trend in this measure.

Definitions
- See APPENDIX E – What is a trammeling action

Data source: Law Enforcement records, biological staff

Data adequacy: *Low* – no records exist, the wilderness is not patrolled or visited so confidence in data quality is low.

Frequency: Data is entered into the WCMD annually.

Significant change: Any change in this measure is considered a significant change.

Natural Quality

Wilderness ecological systems are substantially free from the effects of modern civilization.

The natural quality of wilderness assesses the integrity of local ecosystems and their freedom to change and develop without human manipulation. As a quality of wilderness character, the natural quality of wilderness tracks the effects of human actions and modern civilization on natural ecosystems (in contrast to the untrammeled quality which tracks the actions themselves). Ecosystems include all living and non-living things in an area, as well as the interactions between them. Within wilderness, changes to the natural quality can be caused directly or indirectly as well as caused intentionally or unintentionally. Monitoring ecosystem changes inside wilderness is key to understanding the unique character of each wilderness area and how it is impacted by human actions. In addition, the NWRS Improvement Act states that refuges shall "*ensure that the biological integrity, diversity, and environmental health of the System are maintained,*" complementing naturalness as quality of wilderness (16 U.S.C. § 668dd).

Table 7: Measures of the Natural Quality used to monitor the Tamarac Wilderness

Indicator	Measure	Frequency	Data Adequacy	Significant Change	WCM Baseline Value
Plants	2-1: Number of non-native invasive plant species	5 years	Low	Any	4 species
Animals	2-2: Number of non-native fauna species	5 years	Medium	Any	1 species
Air and water	2-3: Ozone concentration	5 years	High	Categorical	61.0 ppb
	2-4: Wet deposition of nitrogen	5 years	Medium	Categorical	4.9 kg/ha
	2-5: Wet deposition of sulfur	5 years	Medium	Categorical	1.8 kg/ha
	2-6: Visibility	5 years	Medium	Categorical	6.6 dV
	2-7: Index of water quality	5 years	Medium	Any	2
Climate change	2-8: Annual winter minimum temperature anomaly	1 year	Medium	P value ≤ 0.1	-10.8 ˚F
	2-9: Annual winter maximum temperature anomaly	1 year	Medium	P value ≤ 0.1	-8.5 ˚F
	2-10: Total annual precipitation	1 year	Medium	P value ≤ 0.1	29.61 inches
	2-11: Annual Palmer drought severity index	1 year	Medium	P value ≤ 0.1	0.06
Ecological processes	2-12: Miles of wilderness boundary serving as entry for invasive species	5 years	Medium	Any	4.22 miles
	2-13: Index of Connectivity	5 years	Medium	Any	0.98

Measure 2-1: Number of non-native invasive plant species

2014 data value: 4 species
Year of data collection: 2014

Background and context
The Tamarac Wilderness is home to many unique, native plant species. However, plant communities are at risk of invasion by non-native invasive species. Non-native plants have the potential to displace native vegetation, create monocultures, increase fire frequency, increase soil erosion, and decrease the quality of wildlife habitat. The wilderness is adjacent to Highway 35 and the Egg Lake Trail, a refuge service road. Several terrestrial invasive species can be found along the roads that border the wilderness. There has been no comprehensive survey for non-native invasive plant species within the Tamarac Wilderness. The baseline value consists of only plants encountered while visiting the wilderness in 2014 (Table 8). Several factors have contributed to the lack of data within the wilderness, including minimal monitoring presence, difficulty of travel due to dense stands of vegetation in certain areas, and minimal routes of access.

It is important to distinguish the vulnerability and distribution of invasive plants on each of the separate wilderness units at Tamarac. Any plants occurring on the three wilderness islands on Tamarac Lake are relatively confined to the islands and management of these systems will be different than that of the larger northwest wilderness unit. During a site visit to the large island by the Wilderness Fellow in 2014, two species of terrestrial non-native invasive species were found on the shore: Bull Thistle (*Cirsium vulgare*) and Perennial sowthistle (*Sonchus arvensis*). A vetch (*Vicia spp.*) and clover (Trifolium spp.) species in the northwest unit along an old remnant trail was also discovered. While paddling up the Egg River, in the northwest unit of the Wilderness, a volunteer found an individual plant of purple loosestrife (*Lythrum salicaria*) in the summer of 2014. This was the first known infestation to occur within the Tamarac Wilderness. Staff controlled the individual plant by hand pulling and spot spraying with an herbicide. Purple loosestrife is the first priority species of control at Tamarac NWR. Future monitoring should include a more extensive aquatic survey and a terrestrial survey along the travel routes bordering wilderness where introduction is most likely to occur.

Measure description and collection protocol
This measure is a count of the number of non-native invasive, aquatic or terrestrial, plant species present in wilderness. The count will be compiled from plant surveys and GPS records taken in wilderness. An increase in the number of non-native invasive plant species found in wilderness produces a downward trend in this measure.

Definitions

- *Invasive species* – nonnative species that: (1) causes or may cause economic or environmental harm or harm to human health; or (2) threatens or may threaten natural resources or the use of natural resources in the state. (Minnesota Statute 84D.01 subd. 9a.)

Data source: Plant survey GPS records, biological staff

Data collection file: Invasive plant spreadsheet

Data adequacy: *Low* – there has been no comprehensive plant survey within wilderness, therefore the confidence in the data is low.

Frequency: Data is entered into the WCMD annually.

Significant change: Any change in the number of species is considered significant.

Table 8: Detailed data of the non-native invasive plant species counted in the 2014 baseline value

Common Name	Scientific Name	Year Found	Location
Bull Thistle	*Cirsium vulgare*	2014	Large wilderness island
Perennial sowthistle	*Sonchus arvensis*	2014	Large wilderness island
Vetch*	*Vicia spp.*	2014	Northwest unit
Clover *	*Trifolium spp.*	2014	Northwest unit

*These species are non-native to Minnesota but staff does not consider them to be invasive at this time. Considering future changes to the environment, the status of invasiveness could change therefore they are included in the baseline value.

The non-native invasive terrestrial plant species counted in the 2014 baseline value for this measure. From bottom left, clockwise: Bull thistle (*Cirsium vulgare),* Perennial sowthistle (*Sonchus arvensis),* Clover *(Trifolium spp.),* and Vetch *(Vicia spp.).* Both plants featured on the left were found on the large wilderness island of Tamarac Lake, while both plants featured on the right were found in the large northwest unit of the Wilderness. Photos by Morgan Gantz and Denis Mudderman

Measure 2-2: Number of non-native fauna species

Emerald Ash Borer (*Agrilus planipennis*). U.S. Forest Service/APHIS photo by Dr. James E. Zablotny.

2014 Data value: 1 species
Year of data collection: 2014

Background and context

The presence of non-native fauna may significantly alter the composition, structure, and function of natural systems within wilderness. Non-indigenous species could put stress on the Tamarac Wilderness ecosystem, specifically emerald ash borer (EAB), gypsy moths and invasive earth worms. EAB is a non-native invasive insect that kills ash trees. Both black and green ash trees are a major component of the forest within the Tamarac Wilderness**.** In May 2009, EAB was confirmed as present in St. Paul, Minnesota. As of 2014, the nearest EAB to Tamarac NWR is 176 miles away (MNDA 2014). Gypsy moths are aggressive deciduous tree defoliators introduced into the U.S. from Europe. Aspen and Oak trees top the list of over 500 preferred host species for the gypsy moth; both aspen and oak are prevalent in the wilderness. Minnesota's hardwood forests developed in the absence of earthworms. Decomposing leaves create a spongy layer of organic "duff" on the forest floor. This duff layer provides habitat for ground-dwelling animals and helps prevent soil erosion. Invading earthworms eat the leaves that create the duff layer and are capable of eliminating it completely. In areas heavily infested by earthworms, soil erosion and leaching of nutrients may reduce the productivity of forests and ultimately degrade habitat. Invasive earthworms were found in the forest floor across from the Tamarac Wilderness on the east side of highway 35. Although there has been no survey, staff presumes that there are earthworms within the wilderness therefore it was counted in the baseline value for this measure.

Measure description and collection protocol

This measure counts the number of non-native fauna occurring in wilderness. The Minnesota Department of Agriculture (MNDA) sets up EAB and gypsy moth traps on the refuge to track the presence of the species. Refuge staff should monitor the status of trapping efforts and if the pest is detected, implement a more rigorous monitoring strategy to determine if the species is present within wilderness. Over time, an increase in the number of non-native fauna species occurring within wilderness produces a downward trend in this measure.

Data source: Refuge staff, traps on the refuge, MNDA online EAB GIS map: http://gis.mda.state.mn.us/eab/

Data adequacy: *Medium* – some data records have been gathered but no official survey has been completed; EAB symptoms do not appear until it has been present in an area for 2 years or more.

Frequency: Data will be entered into the WCMD every 5 years.
Significant change: Any change in this measure is considered to be a significant change.

Measure 2-3: Ozone concentration

2009 Data value: 61.0 ppb
Years of data collection: 2005 - 2009

Background and context

Tropospheric ozone is considered to be a secondary pollutant, which is formed by atmospheric reactions between volatile organic compounds (VOCs) and nitrogen oxides (NO_x) in the presence of sunlight (U.S. EPA 2006). Ozone concentration has been identified by the USFWS and other federal land management agencies as a key indicator of air pollution (USFWS et al 2010). Emissions from industrial facilities and electric utilities, motor vehicle exhaust, gasoline vapors, and chemical solvents are major sources of VOCs and NO_x. Indicated by the U.S. Clean Air Act (1970), ozone is an air pollutant regulated by National Ambient Air Quality Standards (NAAQS). Section 109(b)(2) of the Clean Air Act specifies that this standard is a level of air quality that is requisite to protect public welfare; this includes effects on the environment encompassing animals, climate, crops, soils, vegetation, water, weather, and wildlife. The current NAAQS for ozone is .075 ppm (75 ppb). The effects of ozone on an ecosystem range from sensitive plant injury and loss of species diversity to changes in habitat quality and water and nutrient cycles. When ozone enters the leaves of a plant, not only does it cause visual damage, but it can also interfere with photosynthesis, carbon sequestration, and lead to increased susceptibility to disease and damage (Fox et. al. 1989). While ozone affects plant species, it is an airborne product of urban areas and therefore is counted under this indicator.

Measure description and collection protocol

This measure tracks the average ozone concentrations within a five-year interval. The fourth highest 8-hour average ozone concentration in parts per billion (ppb) is measured. These data are compiled and interpolated for specific wilderness areas by USFWS Inventory and Monitoring Program. Since the Tamarac Wilderness consists of three separate islands and a larger unit in the northwest corner, the values provided by USFWS are averaged for reporting of this measure. This value is based on interpolated data; therefore a trend will not be assessed for this characteristic. However, this measure tracks whether the numerical value for this indicator is increasing or decreasing over the averaging periods.

Data source: National Wildlife Refuge System, Inventory and Monitoring, Branch of Air Quality

Data adequacy: *High* – all records have been collected and are provided by the USFWS.

Frequency: The 5-year average will be entered into the WCMD every 5 years.

Significant change: Any change in one condition to the next is considered a significant change (Table 9).

Table 9: Categories of significant change for ozone concentration

Condition:	**Good**	**Moderate**	**Significant Concern**
Measure value:	< 60 ppb	61-75 ppb	> 76 ppb

Measure 2-4: Wet deposition of nitrogen

2009 Data value: 4.9 kg/ha
Years of data collection: 2005-2009

Background and context
Most of the earth's nitrogen is found in solid form within the chemical structure of rock, soil and sediment. The remainder moves in a dynamic cycle involving the atmosphere, oceans, lakes, streams, plants and animals. Atmospheric nitrogen compounds cycle to the land and water through wet deposition, predominantly rain and snow. Deposition of nitrogen causes chemical changes within the water cycle and soils that can affect aquatic and terrestrial plants and animals. Wet deposition of nitrogen has been identified by the U.S. Fish and Wildlife Service and other federal land management agencies as a key indicator of air pollution and is monitored through the National Atmospheric Deposition Program (USFWS et al 2010). Sources for adding nitrogen to the cycle include combustion, agriculture, sewage plants, lightning, and industry. Human activities account for more than 90% of nitrogen emissions in the U.S. with the largest sources coming from motor vehicles, electric utilities and industrial boilers (Porter et. al. 2000).

Measure description and collection protocol
This measure tracks the concentration of wet deposition of nitrogen in the atmosphere. Wet deposition is monitored in units of kilogram per hectare (kg/ha) and values are reported as five-year averages. These data are compiled and interpolated for specific wilderness areas by USFWS Inventory and Monitoring Program. Since the Tamarac Wilderness consists of three separate islands and a larger unit in the northwest corner, the values provided by USFWS are averaged for reporting of this measure. This value is based on interpolated data; therefore a trend will not be assessed for this characteristic. However, this measure tracks whether the numerical value for this indicator is increasing or decreasing over the averaging periods.

Data source: National Wildlife Refuge System, Inventory and Monitoring, Branch of Air Quality

Data adequacy: *Medium* - all records have been collected but data are interpolated for locations where no monitors are in close proximity, therefore quality is moderate.

Frequency: The 5-year average will be entered into the WCMD every 5 years.

Significant change: Any change in one condition to the next a considered a significant change (Table 10).

Table 10: Categories of significant change for wet deposition of nitrogen

Condition:	**Good**	**Moderate**	**Significant Concern**
Measure value:	< 1 kg/ha	1-3 kg/ha	> 3 kg/ha

Measure 2-5: Wet deposition of sulfur

2009 Data value: 1.8 kg/ha
Years of data collection: 2005-2009

Background and context
Sulfur oxides emitted into the atmosphere react to form compounds that are deposited in the form of pollutants. Atmospheric sulfur compounds cycle to the land and water through wet deposition, predominantly rain and snow. Deposition of sulfur causes chemical changes within the water cycle and soils that can affect aquatic and terrestrial plants and animals. Sulfur wet deposition has been identified by the U.S. Fish and Wildlife Service and other federal land management agencies as a key indicator of air pollution and is monitored through the National Atmospheric Deposition Program (USFWS et al 2010). The major source of atmospheric sulfur is from electric utilities.

Measure description and collection protocol
This measure tracks the concentration of wet deposition of sulfur in the atmosphere. Wet deposition is monitored in units of kilogram per hectare (kg/ha) and values are reported as five-year averages. These data are compiled and interpolated for specific wilderness areas by USFWS Inventory and Monitoring Program. Since the Tamarac Wilderness consists of three separate islands and a larger unit in the northwest corner, the values provided by USFWS are averaged for reporting of this measure. This value is based on interpolated data; therefore a trend will not be assessed for this characteristic. However, this measure tracks whether the numerical value for this indicator is increasing or decreasing over the averaging periods.

Data source: National Wildlife Refuge System, Inventory and Monitoring, Branch of Air Quality

Data adequacy: *Medium* – all records have been collected but data are interpolated for locations where no monitors are in close proximity, therefore quality is moderate.

Frequency: The 5-year average will be entered into the WCMD every 5 years.

Significant change: Any change in one condition to the next is considered a significant change (Table 11).

Table 11: Categories of significant change for wet deposition of sulfur

Condition:	**Good**	**Moderate**	**Significant Concern**
Measure value:	< 1 kg/ha	1-3 kg/ha	> 3 kg/ha

Measure 2-6: Visibility

2009 Data value: 6.6 dV
Years of data collection: 2005-2009

Background and context
Sulfate, nitrate and other fine particulates in the atmosphere scatter and absorb light, contributing to visibility impairment. Visibility is used as a key indicator in air quality and is measured as a part of the Interagency Monitoring of Protected Visual Environments (IMPROVE) system. Reduced visibility increases reflective power, which can affect climate and photosynthetic activity as well as wildlife populations relying on clean air to find food sources. Visibility has been identified by the U.S. Fish and Wildlife Service and other federal land management agencies as a key indicator of air pollution and is monitored through the National Atmospheric Deposition Program (USFS et al 2010).

Measure description and collection protocol
This measure tracks visibility using the amount of fine particulates in the air in units of deciview (dV). Data values are reported as five-year averages interpolated from nearby data stations. These data are compiled and interpolated for specific wilderness areas by USFWS Inventory and Monitoring Program. Since the Tamarac Wilderness consists of three separate islands and a larger unit in the northwest corner, the values provided by USFWS are averaged for reporting of this measure. This value is based on interpolated data; therefore a trend will not be assessed for this characteristic. However, this measure tracks whether the numerical value for this indicator is increasing or decreasing over the averaging periods.

Data source: National Wildlife Refuge System, Inventory and Monitoring, Branch of Air Quality

Data adequacy: *Medium* – all records have been collected but data are interpolated for locations where no monitors are in close proximity, therefore quality is moderate.

Frequency: The 5-year average will be entered into the WCMD every 5 years.

Significant change: Any change in one condition to the next is considered a significant change (Table 12).

Table 12: Categories of significant change for visibility

Condition:	**Good**	**Moderate**	**Significant Concern**
Measure value:	< 2 dV	2-8 dV	> 8 dV

Measure 2-7: Index of water quality

2012 Data value: 2
Years of data collection: 2008 - 2012

Background and context

The Tamarac Wilderness lies within the Northern Lakes and Forests ecoregion of Minnesota. This heavily forested ecoregion is made up of steep, rolling hills interspersed with pockets of wetlands, bogs, lakes and ponds. These lakes are very sensitive to damage from atmospheric deposition of pollutants (e.g. mercury), storm water runoff from logging operations, urban and shoreland development, mining, inadequate wastewater treatment, and failing septic systems (MN Pollution Control Agency 2014). According to the Minnesota Pollution Control Agency (MPCA), typical ranges of healthy water quality metrics for streams in the Northern Lakes and Forests ecoregion are outlined in Table 13.

Table 13: Typical water quality measurements for streams in the Northern Lakes and Forests ecoregion of Minnesota (MPCA 2014)

Field pH	TSS (in mg/L)	NO_X (in mg/L)	TP (in mg/L)	Turbidity (in NTU)	FC (in # of organisms per 100 ml)	Temperature (degrees C)	BOD (in mg/L)
7.6 - 7.9	1.8 - 6	0.01 - 0.09	0.02 - 0.05	1.7 - 4.3	11 - 20	0.5 - 17	0.8 - 1.7

- TSS: Total suspended solids
- NO_X: Total nitrate and nitrite nitrogen
- TP: Total phosphorus
- FC: Fecal coliform bacteria
- BOD: Biological oxygen demand

The State of Minnesota has established numeric and narrative water quality standards (https://www.revisor.mn.gov/rules/?id=7050.0222). Tamarac NWR water bodies should be assessed as Class 2B waters (Minnesota Administrative Rules, Part 7050.0222).

For purposes of this monitoring strategy, 4 water quality parameters were chosen to represent this index value: pH, transparency, total phosphorus and chlorophyll A. These metrics were chosen by staff based on relevancy and practicality of data collection; other parameters and constituents are monitored by staff each year and data can be found on the Tamarac share drive. When analyzing the values for these 4 water quality parameters, staff should consider where the water stage and specific conductance levels are to provide a context of hydrologic conditions relative to water quality conditions.

The amount of free hydrogen and hydroxyl ions in the water are monitored when pH is measured. Water that has more free hydrogen ions is acidic, whereas water that has more free hydroxyl ions is basic. Since pH can be affected by chemicals in the water, pH is an important indicator of water that is changing chemically. pH is reported in "logarithmic units," and each number represents a 10-fold change in the acidity/basicness of the water (e.g. water with a pH of 5 is ten times more acidic than water having a pH of 6). Pollution can change a water body's pH, which in turn can harm animals or plants living in the water,

and alter chemical or biological reactions and processes. Minnesota state standards for Class 2B identify waters as 'impaired' with a pH value exceeding 9.0 or falling below 6.5 standard units (SU).

Transparency is a metric for the amount of suspended material in the water, which in many cases is an indication of the amount of algae in the water. A low transparency reading from measuring with a tube and secchi disk reflects excess sediment or other suspended material in the water. For streams and rivers in and around Tamarac NWR, consistently low transparency readings would likely indicate a decline in water quality conditions. The State of Minnesota transparency eutrophication standards for Class 2B waters in the Northern Lakes and Forest Ecoregion are "[n]ot less than 2.0 meters."

Phosphorus, as with nutrients in general, is an essential element for plant life, but in excessive quantities it can accelerate eutrophication and cause a reduction of dissolved oxygen in water bodies due to increases in mineral and organic nutrient concentrations. Excess phosphorus is released from both point and nonpoint sources of pollution. The past 100+ years of human land and water use have resulted in excessive loading of phosphorus into many freshwater systems. Phosphorus pollution into lakes and streams often results in highly eutrophic systems with symptoms such as excessive growth of algae, altering water chemistry and suffocating fish and other aquatic life in serious cases. Eutrophication standards for Class 2B rivers and streams in this ecoregion are set at 50 µg/l or less.

Chlorophyll *a* is one of several types of chlorophyll necessary for photosynthesis and is bound within the living cells of algae and other phytoplankton found in surface waters. Specifically, chlorophyll *a* absorbs most energy wavelengths from violet-blue and orange-red sunlight and, with other processes, helps to produce life-sustaining oxygen. Monitoring chlorophyll *a* levels within a given water body can serve as a direct measure of algal growth, which in turn can be an indicator of changes in nutrient concentrations or other water chemistry changes. The State of Minnesota eutrophication standards for Class 2B rivers and streams in this ecoregion are set at 7 µg/l or less.

Measure description and collection protocol

This measure tracks trends in water quality flowing from the wilderness by using an index value based on 4 water quality parameters: pH, transparency, total phosphorus, and chlorophyll A (stream stage and specific conductance should be considered for context of hydrologic conditions when analyzing these data values). The location from which data values are used is titled Egg River – North Culvert (stop #3, ID: S004-775) (Figure 6); Data

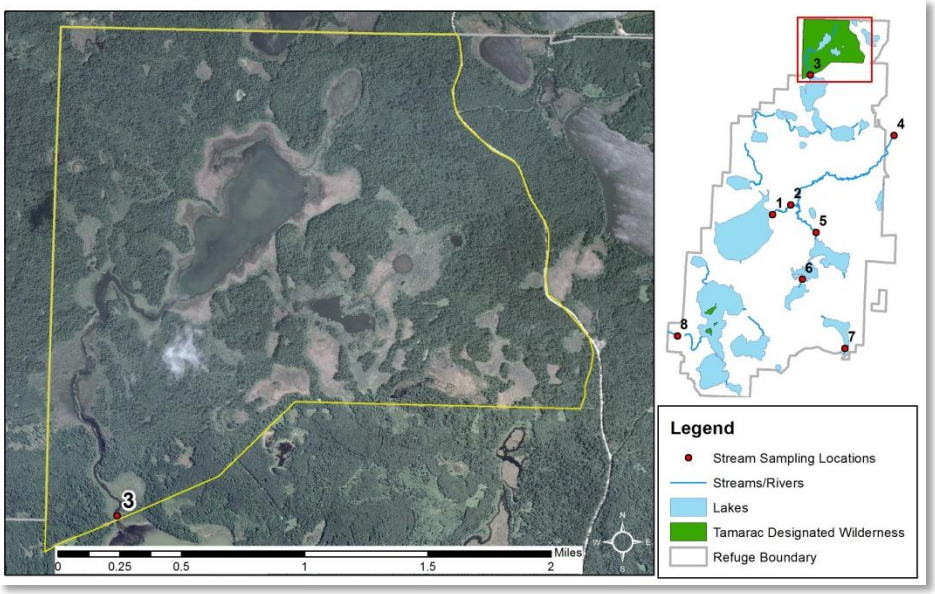


Figure 6: Map of the water quality stream monitoring locations in Tamarac NWR. The location associated with the wilderness is stop 3, Egg River - North Culvert, flowing out of the wilderness boundary.

values are assessed within a 5-year period due to the practicality of data collection and preference of staff. Data values are assigned an overall category and index point value based on where the data falls within a range that is considered good, caution, or poor (based on MN state standard conditions) (Table 14). The baseline value for this measure is assessed from 2008-2012; therefore, there is no data value for 2014 since this year falls in the middle of the 5-year monitoring cycle of this measure. Each parameters index score within a 5-year period are added up to get an overall index score for the wilderness, which will be the value entered into the WCMD (Table 15). Over time, an increase in the water quality index value represents a downward trend in this measure.

Data source: Master water quality spreadsheet <S:/Biology/Water Quality/Water Quality Monitoring>

Data collection file: WCM water quality spreadsheet (Wilderness Management folder)

Data adequacy: *Medium* – all data records have been gathered but some years have data gaps due to budget.

Frequency: Data will be entered into the WCMD every 5 years.

Significant change: Any change in this measure is considered a significant change.

Table 14: Scoring protocol for water quality metrics within a 5-year period

	Good = 0 points	**Caution = 1 point**	**Poor = 2 points**
pH	> 7.0 and < 8.0	*If 4 individual samples fall within the following range in the five year period assign this category.* ≥ 8.0 and < 8.5 ***OR*** > 6.5 and ≤ 7.0	*If 2 individual samples fall within the following range in the five year period assign this category.* ≥ 8.5 ***OR*** ≤ 6.5
Transparency (secchi tube reading)	> 60 cm	≤ 60 cm and > 40 cm	≤ 40 cm
Total P (mg/L)	≤ 0.02	*If 4 individual samples fall within the following range in the five year period assign this category.* > 0.02 and < 0.05	*If 2 individual samples fall within the following range in the five year period assign this category.* ≥ 0.05
Chlorophyll A (µg/L)	≤ 5	> 5 and < 7	≥ 7
-Transparency values are averaged for the five year period, then given a score -Chlorophyll A values are averaged for the five year period, then given a score			

Table 15: Detailed data of the baseline value for water quality in the Tamarac Wilderness

	pH	Transparency	Total P	Chlorophyll A		Overall Score
2008 - 2012	0	0	2	0		**2**
2013 - 2017						

Measure 2-9: Annual winter minimum temperature anomaly

2014 Data value: -10.8 ˚F
Year of data collection: 2013 -2014

Background and context

According to the Midwest chapter of the 2014 Climate Change Impacts in the United States: The Third National Climate Assessment, "[t]he rate of warming in the Midwest has markedly accelerated over the past few decades. Between 1900 and 2010, the average Midwest air temperature increased by more than 1.5°F. However, between 1950 and 2010, the average temperature increased twice as quickly, and between 1980 and 2010, it increased three times as quickly as it did from 1900 to 2010" (Pryor et al).

Climate change has the potential to significantly alter natural systems within wilderness. Significant changes in temperature over time may cause several impacts including changes in annual snowfall, extent of ice coverage on lakes, the timing of bird migration and nesting, forest composition and structure, changes to water temperatures causing a shift in fish species, plant phenology patterns, and increased invasions by non-native species, etc. According to the Intergovernmental Panel on Climate Change, there will be fewer cold temperature extremes and "[i]n most locations, scientists expect daily minimum temperatures – which typically occur at night – to become warmer at a faster rate than daily maximum temperatures" (as cited in EPA 2014).

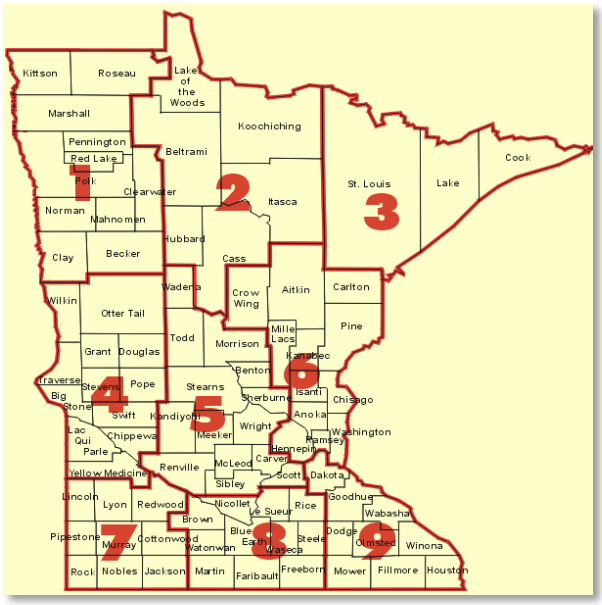


Figure 7: Climate divisions for the State of Minnesota. The Tamarac Wilderness located in Becker County and lies within the Northwest Division of the state, or Division 1.

Each state is divided into several climate divisions, defined by the National Climatic Data Center's (NCDC) Climate Monitoring Branch, to assess long-term temporal and spatial trends in climate (http://www.ncdc.noaa.gov/monitoring-references/maps/us-climate-divisions.php). The Tamarac Wilderness is located in the northwest climate division of Minnesota or climate division 1 (Figure 7). Average climate division temperature values are calculated through a 5 km grid-based interpolation technique, which ensures spatial balancing within each division. Every grid node value is calculated through this technique, and an average temperature for the entire division is calculated with each grid node value. Climate change is occurring over a much larger scale than just within the wilderness border. Climate divisions are used for measuring climate change in this monitoring strategy because it will serve as a useful tool for managers to explore and understand

temperature changes on a larger scale. NOAA also has a 'Climate at a Glance' GIS mapping tool (http://gis.ncdc.noaa.gov/map/cag/#app=cdo) that will display several climate change variables at all spatial scales: national, regional, statewide, and divisional. This tool can be used to see how patterns in climate change are occurring over time and how they relate to other parts of the country.

Measure description and collection protocol

This measure tracks the trend in annual winter minimum temperature anomalies. Meteorologically, winter is defined as the three month period from December to February (the 'year measured' value in the database will be assigned based on the year in February of the annual analysis, for example 1977 is the 'year measured' for the baseline value because it incorporates the 3-month period of December 1976 – February 1977). An average minimum winter temperature for the climate division of which the Tamarac Wilderness is located is calculated for the base period built on the current 30-year normals, and annual data values are compared to this value to calculate a temperature departure from that amount, or an anomaly (Table 16). The current climate normals period is from 1981-2010; this was the base period used in the calculation for the baseline anomaly for this measure. Climate normals are calculated every ten years; the next period will be from 1991-2020. The goal of this analysis is to illustrate how the annual minimum winter temperature is changing over time relative to long term average of what is considered to be the climate normal value (Figure 8). The base period for the calculation of anomalies in this measure will always use the 30 years of the current climate normals period. By tracking the winter minimum temperature anomaly year-to-year, any patterns of how minimum temperatures are departing from long term averages will be evident.

Although it is difficult to assess whether change in climate variables have a positive or negative impact on wilderness character, trends in this measure will be reported as either stable or significant change. A downward trend will be assigned when a significant change is detected.

Definitions

- *Climate normals* – 30-year averages of climatological variables (NOAA).
- *Climate change* – A non-random change in climate that is measured over several decades or longer. The change may be due to natural or human induced causes (NOAA).
- *Climate* – The average of weather over at least a 30-year period. Note that the climate taken over different periods of time (30 years, 1000 years) may be different. The old saying is climate is what we expect and weather is what we get (NOAA).
- *Current base period (1981 – 2010) average minimum winter temperature* = 0.4 ˚F

Data source: NOAA, National Climatic Data Center, Climate at a Glance Time Series Tool http://www.ncdc.noaa.gov/cag/time-series/us/21/01/tmin/3/02/1977-2014?base_prd=true&firstbaseyear=1981&lastbaseyear=2010&trend=true&trend_base=10&firsttrendyear=1977&lasttrendyear=2014 *

*The link provided are the results from the analysis completed in 2014. For future monitoring of this measure, simply modify the end year to reflect the current year of data collection. In the options window, you will also need to modify the base period to reflect the years of the current 30-year normal period.

Data adequacy: *Medium* – All records have been gathered for this measure but are based on a national data set; data values reflect temperatures and departures of the entire climate division that the Tamarac Wilderness is located within.

Frequency: Data will be entered into the WCMD annually.

Significant change: Perform a linear regression in Excel with α=0.1 every year for all data values since 1977 to evaluate significant change. Any significant trend is a significant change. For step-by-step instructions refer to APPENDIX F – How to perform a linear regression analysis in Excel.

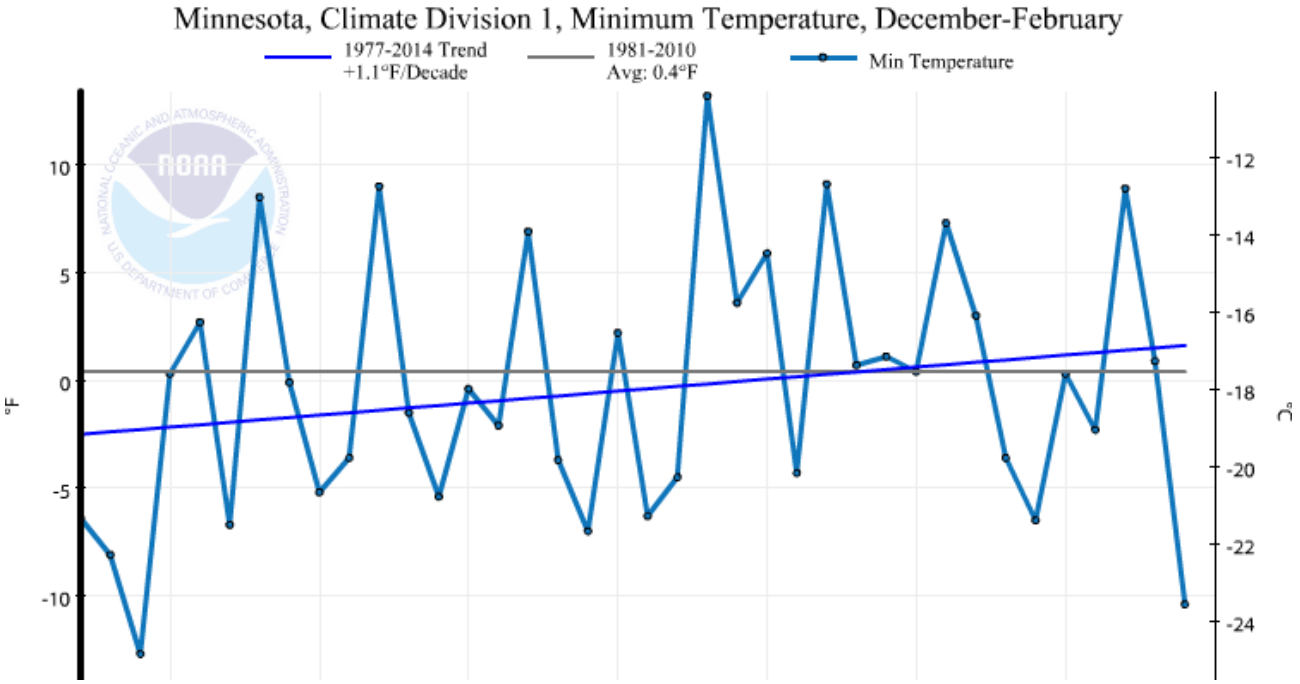


Figure 8: Minnesota Climate Division 1 observed annual minimum winter temperatures. The 1977 - 2014 trend shows an increase in minimum temperature of 1.1 ˚F per decade; there is no statistically significant trend from 1977 – 2014 (F=1.57, p-value=0.22). The graph was obtained from the link provided under this measure's heading 'data source'.

Table 16: Detailed data of the temperature anomalies entered into the WCMD for the current year and past 5 years

Base Period: 1981-2010, Average winter minimum temperature of the base period = 0.4˚F		
Year	Divisional average temperature	Anomaly
2009	-6.5 ˚F	-6.9 ˚F
2010	0.3 ˚F	- 0.1 ˚F
2011	-2.3 ˚F	- 2.7 ˚F
2012	8.9 ˚F	8.5 ˚F
2013	0.9 ˚F	0.5 ˚F
2014	-10.4 ˚F	-10.8 ˚F

Measure 2-9: Annual winter maximum temperature anomaly

2014 Data value: -8.5 ˚F
Year of data collection: 2013 - 2014

Background and context
According to the Midwest chapter of the 2014 Climate Change Impacts in the United States: The Third National Climate Assessment, "[t]he rate of warming in the Midwest has markedly accelerated over the past few decades. Between 1900 and 2010, the average Midwest air temperature increased by more than 1.5°F. However, between 1950 and 2010, the average temperature increased twice as quickly, and between 1980 and 2010, it increased three times as quickly as it did from 1900 to 2010" (Pryor et al). The President's Climate Action Plan states that 2012 was the warmest year on record in the contiguous United States and the 12 hottest years on record have all come in the last 15 years (United States 2013).

Climate change has the potential to significantly alter natural systems within wilderness. Significant changes in temperature over time may cause several impacts including changes in annual snowfall, extent of ice coverage on lakes, the timing of bird migration and nesting, forest composition and structure, changes to water temperatures causing a shift in fish species, plant phenology patterns, and increased invasions by non-native species, etc. According to the Intergovernmental Panel on Climate Change, there will be fewer cold temperature extremes and "[i]n most locations, scientists expect daily minimum temperatures – which typically occur at night – to become warmer at a faster rate than daily maximum temperatures" (as cited in EPA 2014). The purpose of this measure is to compare and contrast how changes are occurring relative to the previous measure (annual winter minimum temperature anomaly); Minnesota State Climatology personnel highly suggested tracking both trends in the minimum and maximum temperature anomalies.

Each state is divided into several climate divisions, defined by the National Climatic Data Center's (NCDC) Climate Monitoring Branch, to assess long-term temporal and spatial trends in climate (http://www.ncdc.noaa.gov/ monitoring-references/maps/us-climate-divisions.php). The Tamarac Wilderness is located in the northwest climate division of Minnesota or climate division 1 (Figure 7). Average climate division temperature values are calculated through a 5 km grid-based interpolation technique, which ensures spatial balancing within each division. Every grid node value is calculated through this technique, and an average temperature for the entire division is calculated with each grid node value. Climate change is occurring over a much larger scale than just within the wilderness border. Climate divisions are used for measuring climate change in this monitoring strategy because it will serve as a useful tool for managers to explore and understand temperature changes on a larger scale. NOAA also has a 'Climate at a Glance' mapping tool (http://gis.ncdc.noaa.gov/map/cag/#app=cdo) that will display several climate change variables at all spatial scales: national, regional, statewide, and divisional. This tool can be used to see how patterns in climate change are occurring over time and how they relate to other parts of the country.

Measure description and collection protocol

This measure tracks the trend in annual winter maximum temperature anomalies. Meteorologically, winter is defined as the three-month period from December to February (the 'year measured' value in the database will be assigned based on the year in February of the annual analysis, for example 1977 is the 'year measured' for the baseline value because it incorporates the 3-month period of December 1976 – February 1977). An average maximum winter temperature for the climate division of which the Tamarac Wilderness is located is calculated for the base period built on the current 30-year normals, and annual data values are compared to this value to calculate a temperature departure from that amount, or an anomaly (Table 17). The current climate normals period is from 1981-2010; this was the base period used in the calculation for the baseline anomaly for this measure. Climate normals are calculated every ten years; the next period will be from 1991-2020. The goal of this analysis is to illustrate how the annual maximum winter temperature is changing over time relative to the long term average of what is considered to be the climate normal value (Figure 9). The base period for the calculation of anomalies in this measure will always use the 30 years of the current climate normals period. By tracking the winter maximum temperature anomaly year-to-year, any patterns of how maximum temperatures are departing from long-term averages will be evident.

Although it is difficult to assess whether change in climate variables have a positive or negative impact on wilderness character, trends in this measure will be reported as either stable or significant change. A downward trend will be assigned when a significant change is detected.

Definitions

- *Climate normals* – 30-year averages of climatological variables (NOAA).
- *Climate change* – A non-random change in climate that is measured over several decades or longer. The change may be due to natural or human induced causes (NOAA).
- *Climate* – The average of weather over at least a 30-year period. Note that the climate taken over different periods of time (30 years, 1000 years) may be different. The old saying is climate is what we expect and weather is what we get (NOAA).
- *Current base period (1981– 2010) average maximum winter temperature* = 19.1 ˚F

Data source: NOAA, National Climatic Data Center, Climate at a Glance Time Series Tool http://www.ncdc.noaa.gov/cag/time-series/us/21/01/tmax/3/02/1977-2014?base_prd=true&firstbaseyear=1981&lastbaseyear=2010&trend=true&trend_base=10&firsttrendyear=1977&lasttrendyear=2014 *

*The link provided are the results from the analysis completed in 2014. For future monitoring of this measure, simply modify the end year to reflect the current year of data collection. In the options window, you will also need to modify the base period to reflect the years of the current 30-year normal period.

Data adequacy: *Medium* – All records have been gathered for this measure but are based on a national data set; data values reflect temperatures and departures of the entire climate division that the Tamarac Wilderness is located within.

Frequency: Data will be entered into the WCMD annually.

Significant change: Perform a linear regression in Excel with α=0.1 every year for all data values since 1977 to evaluate significant change. Any significant trend is a significant change. For step-by-step instructions refer to APPENDIX F – How to perform a linear regression analysis in Excel.

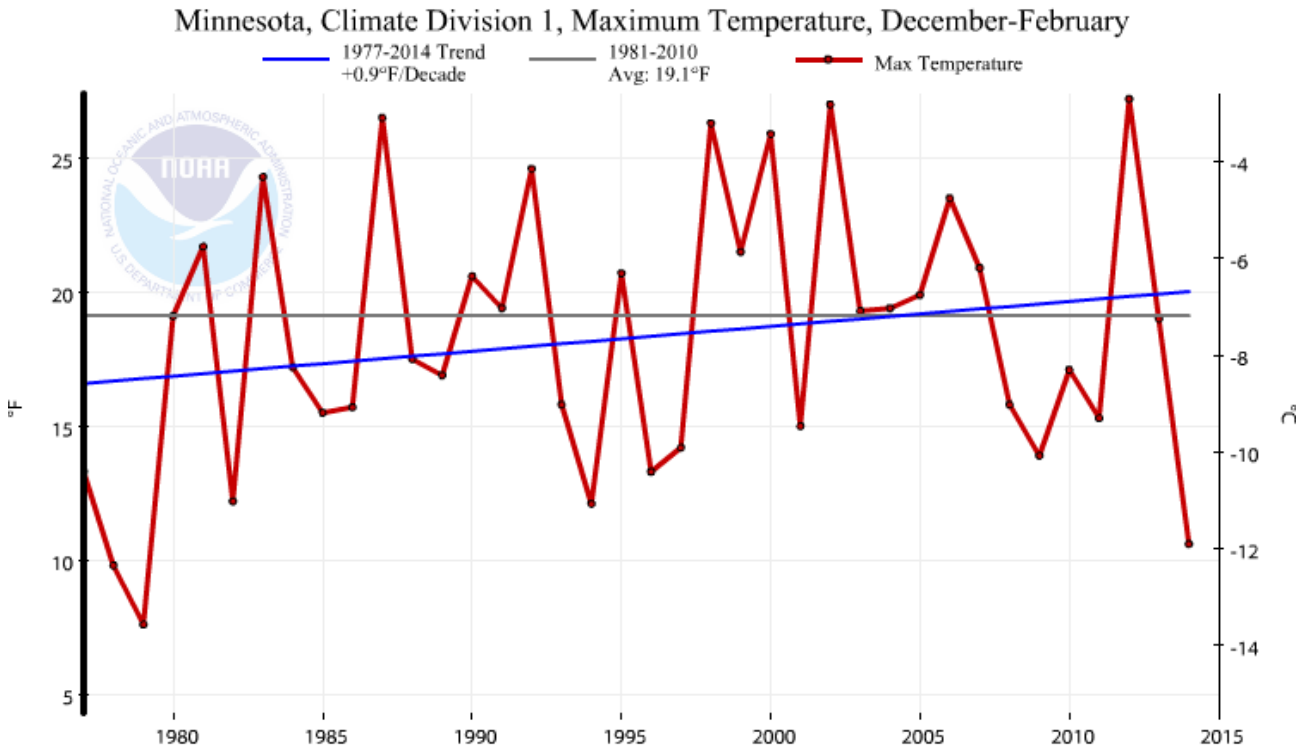


Figure 9: Minnesota climate division 1 observed annual maximum winter temperatures. The 1977 - 2014 trend shows an increase in maximum temperature of 0.9 ˚F per decade; there is no statistically significant trend from 1977 – 2014 (F=1.51, p-value=0.23). The graph was obtained from the link provided under the measure's heading 'data source'.

Table 17: Detailed data of the temperature anomalies entered into the WCMD for the current year and past 5 years

Base Period: 1981-2010, Average winter maximum temperature of the base period = 19.1 ˚F		
Year	Divisional average temperature	Anomaly
2009	13.9 ˚F	-5.2 ˚F
2010	17.1 ˚F	-2 ˚F
2011	15.3 ˚F	-3.8 ˚F
2012	27.2 ˚F	8.1 ˚F
2013	19.0 ˚F	- 0.1 ˚F
2014	10.6 ˚F	-8.5 ˚F

Measure 2-10: Total annual precipitation

2013 Data value: 29.61 inches
Year of data collection: 2013

Background and context
Precipitation is a key component to the wilderness ecosystem and can determine what types of animals and plants will survive there. Changes in precipitation can disrupt a wide-range of natural processes, particularly if these changes occur more quickly than plant and animal species can adapt. Since 1901, precipitation in the contiguous 48 states has increased at a rate of 0.5% per decade (U.S. EPA 2014).

Measure description and collection protocol
This measure tracks total annual precipitation falling in wilderness. Monthly precipitation totals are estimated for grid nodes at regularly spaced (10 km) intervals. The gridded database is derived from a monthly precipitation database maintained by the State Climatology Office; enter in the location information provided in Table 18 to retrieve data. Use Table 19 to document the condition of total annual precipitation in the WCMD. Although it is difficult to assess whether change in climate variables have a positive or negative impact on wilderness character, trends in this measure will be reported as either stable or significant change. A downward trend will be assigned when a significant change is detected.

Data source
Minnesota Climatology Working Group, Wetland Delineation Precipitation Data Retrieval from a gridded database: http://climate.umn.edu/gridded_data/precip/wetland/wetland.asp

Table 18: Detailed location information for retrieval of precipitation data

Tamarac Wilderness location coordinates to retrieve precipitation data	
Xutm: 302421	**Yutm:** 5216594
Latitude: 47.07328	Longitude: 95.60247
county: Becker	township number: 142N
township name: Eagle View	range number: 39W
nearest community: Elbow Lake Village	section number: 34

Data collection file: Precipitation spreadsheet

Data adequacy: *Medium* – All records have been gathered for this measure. Confidence is moderate as monthly precipitation totals are estimated for grid nodes and obtained using an interpolation technique called 'kriging', which makes use of the irregularly spaced data in the vicinity of the node to assign it a value.
Frequency: Data will be entered into the WCMD annually.

Significant change: Perform a linear regression in Excel with α=0.1 every year for all data values since 1977 to evaluate significant change. Any significant trend is a significant change. For step-by-step instructions refer to APPENDIX F – How to perform a linear regression analysis in Excel.

Table 19: Categories for the condition of total annual precipitation

Condition:	Low	Normal	High
Rank:	Lowest 30th percentile of the period-of-record distribution	≥ 30th and ≤ 70th percentile	Highest 30th percentile of the period-of-record distribution

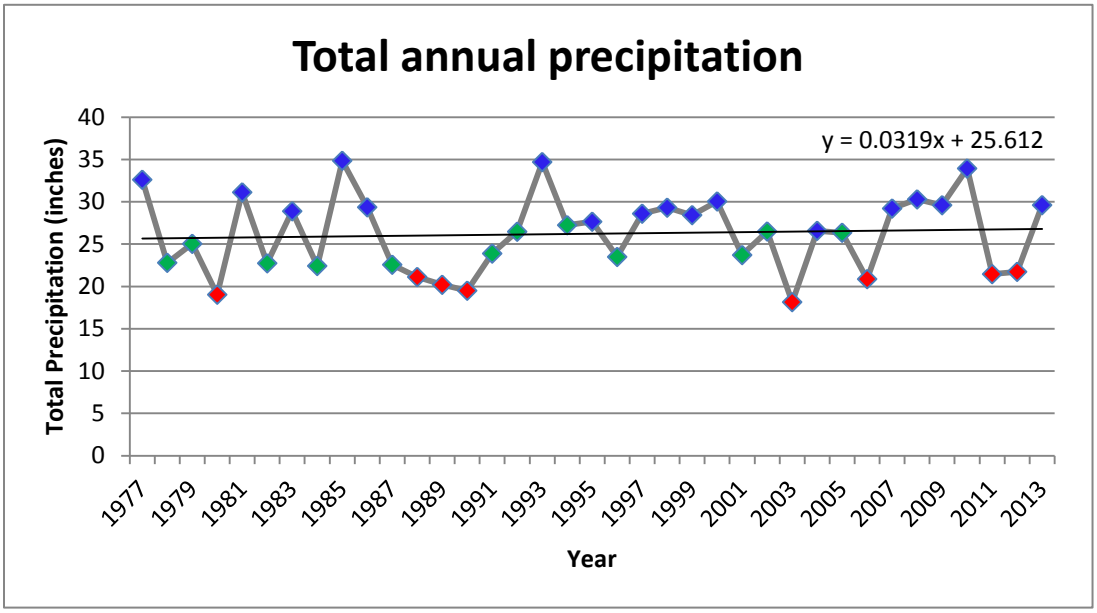
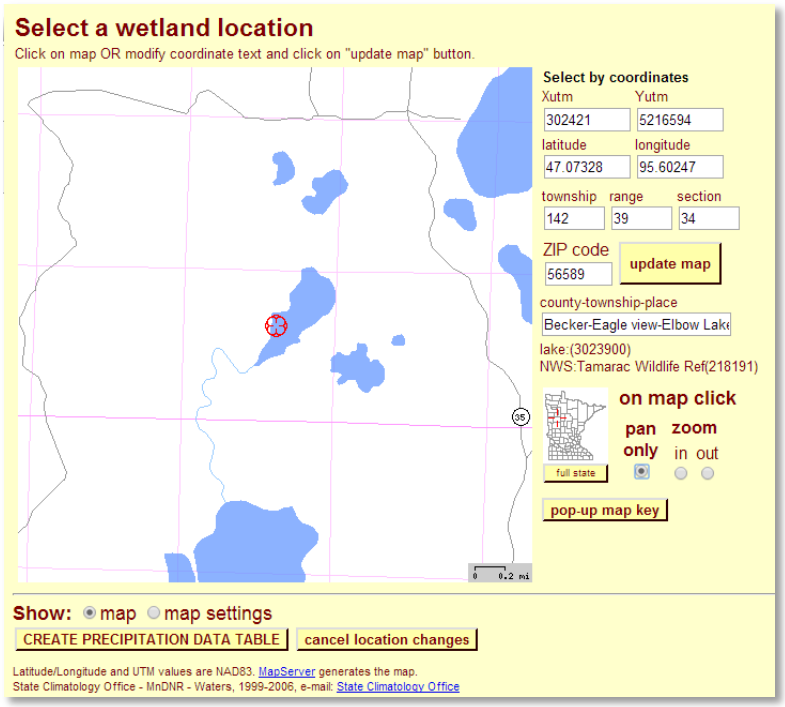


Figure 10: Total annual precipitation falling in the Tamarac Wilderness. There is no significant trend from 1977 - 2013 (F=0.20, p-value=0.65).



Precipitation data retrieval from the Minnesota Climatology Working Group Website

Measure 2-11: Annual Palmer drought severity index

2013 Data value: 0.06
Year of data collection: 2013

Background and context

Given the unique location near the center of North America, Minnesota is susceptible to diverse air masses that make up its climate resulting in a high degree of spatial and temporal variation. During the winter, cold, dry continental polar air from the north dominates, while the summer brings both hot, dry air masses from the desert southwest and warm, moist maritime air that originates from the Gulf of Mexico. Minnesota sits right on the border between the semi-humid climate regime of the eastern U.S., and the semi-arid regime to the west (Figure 11). The eastern U.S. experiences annual precipitation that exceeds average annual evapotranspiration, resulting in a net surplus of water, while in the western U.S. evapotranspiration exceeds precipitation resulting in a water deficit (MNDNR 2014).

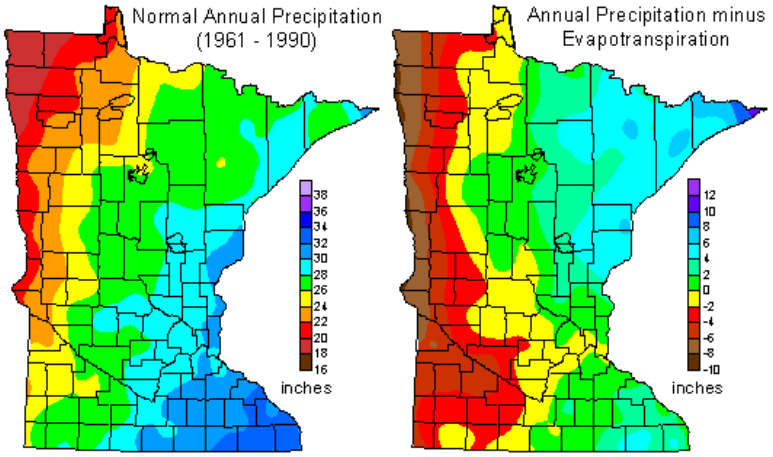


Figure 11: Depiction of how the different climate regimes intersect in Minnesota and roughly cut the state into east-west halves. Figure credit: MNDNR.

The largest source of stress upon the Tamarac Wilderness ecosystem in the future could be from a changing climate and the unknown outcome of whether the environment will become warmer and wetter or warmer and drier. In 1965 the Palmer drought severity index (PDSI) was developed as a tool to measure the cumulative departure, relative to local mean conditions, in atmospheric moisture supply and demand at the surface (Dai et al 2004). The PDSI is calculated based on precipitation, temperature, and local available water content of the soil; positive index values indicate wet conditions, while negative index values indicate dry conditions (Table 20). By using surface air temperature and a physical water balance model, the PDSI takes into account the basic effect of climate change through potential evapotranspiration. Monitoring climate patterns will provide important insight into water availability and by tracking the PDSI value, staff will be able to place annual conditions within a historical perspective. This particular measure is important within this monitoring strategy because it ties together the cumulative impact of both temperature and precipitation changes, which together influence wilderness character much more than just measuring the change in temperature and precipitation alone.

Definitions

- *Evapotranspiration* - the sum of evaporation from the land surface plus transpiration from plants; or the water lost to the atmosphere from the ground surface (evaporation from the capillary fringe of the groundwater table) and the transpiration of groundwater by plants whose roots tap the capillary fringe of the groundwater table (USGS).
- *Climate change* – A non-random change in climate that is measured over several decades or longer. The change may be due to natural or human induced causes (NOAA).
- *Climate* – The average of weather over at least a 30-year period. Note that the climate taken over different periods of time (30 years, 1000 years) may be different. The old saying is climate is what we expect and weather is what we get (NOAA).

Table 20: Palmer drought severity index value classifications

PDSI Classifications				
Wet conditions			**Dry conditions**	
≥ 4.0	extremely wet		≤ - 4.0	extreme drought
3.0 to 3.99	very wet	**Near Normal**	-3.0 to -3.99	severe drought
2.0 to 2.99	moderately wet	0.49 to -0.49	-2.0 to -2.99	moderate drought
1.0 to 1.99	slightly wet		-1.0 to -1.99	mild drought
0.5 to 0.99	Incipient wet spell		-0.5 to -0.99	incipient dry spell

Measure description and collection protocol

This measures tracks changes in the annual Palmer drought severity index (PDSI) value for the climate division of which the Tamarac Wilderness is located within, or the northwest climate division (#1) of Minnesota (Figure 7). Documenting the annual PDSI is a useful tool for refuge staff because it responds to both wet and dry conditions and accounts for long-term trends that may be occurring. This measure should be used congruently with all the other climate change measures to verify the trends that may be occurring separately within them. When accessing the data, it is important to realize that the anomaly values are not being used for the analysis in this particular measure.

Although it is difficult to assess whether change in climate variables have a positive or negative impact on wilderness character, trends in this measure will be reported as either stable or significant change. A downward trend will be assigned when a significant change is detected.

Data source: NOAA, National Climatic Data Center, Climate at a Glance Time Series tool http://www.ncdc.noaa.gov/cag/time-series/us/21/01/pdsi/ytd/12/1977-2013?base_prd=true&firstbaseyear=1977&lastbaseyear=2013&trend=true&trend_base=10&firsttrendyear=1977&lasttrendyear=2013 *

*The link provided is the results of data analysis for 2013. For future monitoring of this measure, simply modify the end year, base period, and trend period to reflect the years 1977 - present.

This measure is set up to track long-term trends but another tool for staff to use to track short term trends in drought conditions can be found here: http://droughtmonitor.unl.edu/MapsAndData/DataTables.aspx

Data collection file: Palmer drought index spreadsheet

Data adequacy: *Medium* - All records have been gathered for this measure but are based on a national data set; data values reflect the entire climate division that the Tamarac Wilderness is located within. There are also some minor limitations and assumptions of the calculation methodology for the index value.

Frequency: Data will be entered into the WCMD annually.

Significant change: Perform a linear regression in Excel with α=0.1 every year for all data values since 1977 to evaluate significant change. Any significant trend is a significant change. For step-by-step instructions refer to APPENDIX F – How to perform a linear regression analysis in Excel.

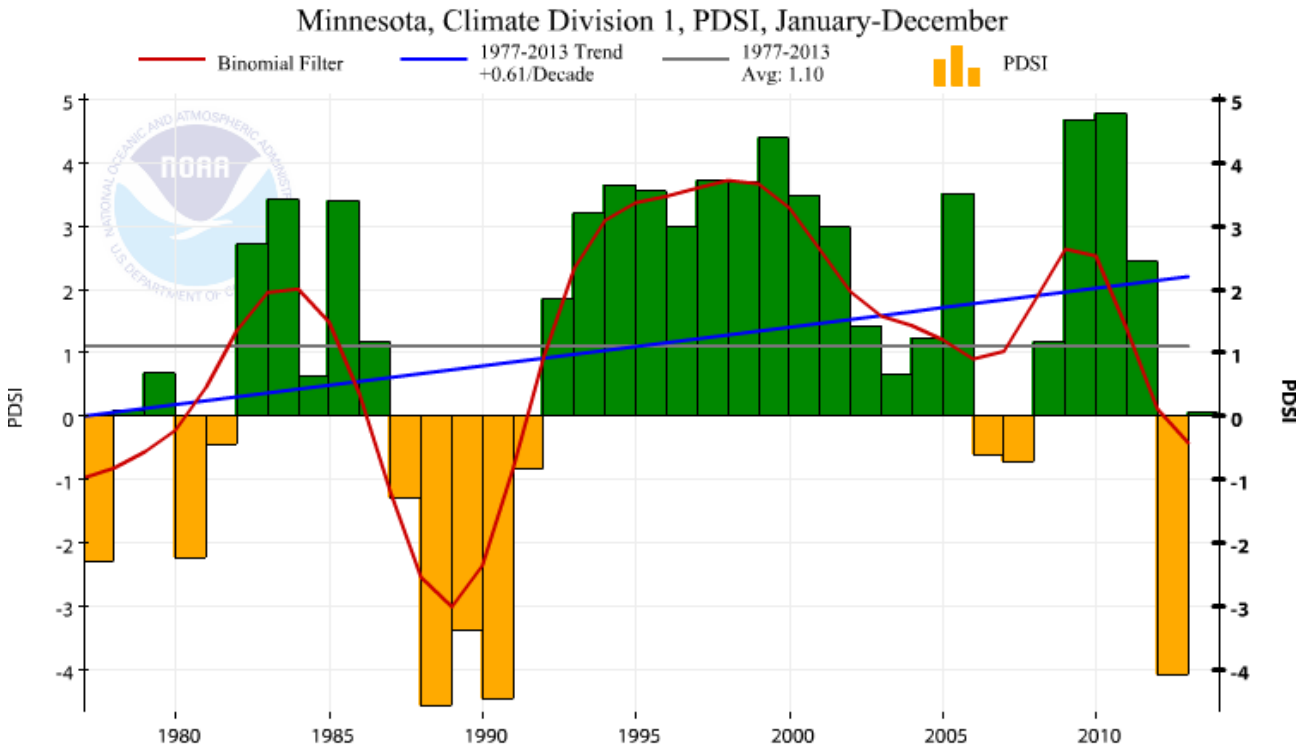


Figure 12: Minnesota Climate Division 1 annual Palmer drought severity index values (PDSI). There is a 0.61 increase in the value per decade from 1977-2013 and the average PDSI value is 1.10 from 1977-2013. There is no statistically significant trend from 1977-2013 (F=2.30, p-value=0.14).

Measure 2-12: Miles of wilderness boundary serving as an entry point for invasive species

2014 Data value: 4.22 miles
Year of data collection: 2014

Background and context
Disturbed areas adjacent to wilderness can act as corridors for the movement of invasive species. Invasive species have the potential to greatly alter the natural ecosystem of life in the Tamarac Wilderness. County highway 35 borders the wilderness to the east, while the egg lake trail refuge road is bordered to the south (Figure 13). This measure is specifically focused on the connectivity of the wilderness boundary, therefore the islands were not considered in the baseline calculation.

Measure description and collection protocol
This measure counts the total miles of wilderness boundary that are crossed by or abut disturbed areas. This includes timber management projects, trail heads, roads, and burned or otherwise disturbed areas that could act as corridors for the movement of invasive species into wilderness. The total perimeter of the northwest unit of wilderness measures 7.85 miles. The wilderness islands in Tamarac Lake are not included in the analysis for this measure because invasive species occurring there are confined and management differs from that of the northwest unit, which is connected to much larger tracts of forest. Over time, an increase in the miles of wilderness boundary serving as an entry point for invasive species produces a downward trend in this measure.

Data source: Tamarac NWR share drive for all GIS data

Data adequacy: *High* – all records have been gathered and are based on GIS locations therefore the confidence in the data is high.

Frequency: Data will be entered into the WCMD every 5 years.

Significant change
Any change is considered a significant change.

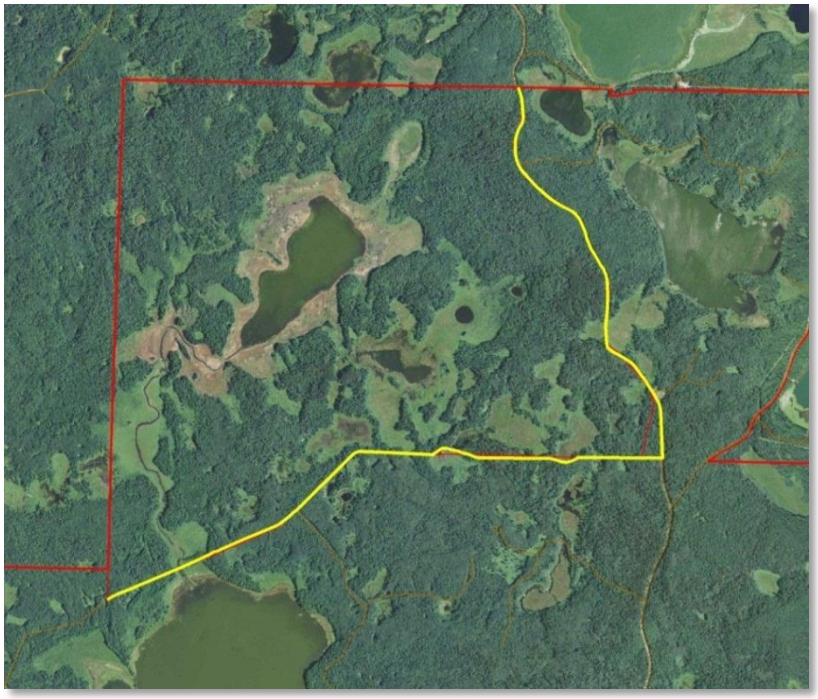


Figure 13: The perimeter of wilderness serving as an entry point for invasive species. The total perimeter of the Wilderness is 7.85 miles. 4.22 miles of that perimeter (indicated in yellow) are directly adjacent to roads and trails.

Measure 2-13: Index of Connectivity

2014 Data value: 0.98
Year of data collection: 2011

Background and context

As part of their natural functioning, ecological systems remove carbon dioxide from the air, purify surface and ground water, reduce flooding, and maintain biological diversity. These functions depend on a connected ecological framework of high-quality land (EPA). Such land provides for the movement of energy, matter, and species across the landscape. Agricultural and silvicultural practices, road development, and urban sprawl cause fragmentation and put stress upon the connectivity framework of the landscape. Maintaining ecological connectivity can help to protect the entire system. High connectivity implies high levels of interaction between or movement of animals, plants, heat energy, water, and materials among other elements. The integrity of ecological processes within wilderness is vital to preserving the Natural Quality of wilderness. About half of the surrounding landscape of the Tamarac Wilderness is protected or has similar land cover/land use classifications (Figure 14). A future source of stress to the wilderness ecosystem could be from expanding settlement from the city of Detroit Lakes; this measure will allow staff to be aware of the changing land uses that are occurring close to wilderness and offer a tool to analyze how those changes are affecting wilderness character.

Measure description and collection protocol

This measure attempts to track changes in connectivity by monitoring land uses within a twenty mile radius of wilderness. Connectivity is measured by a scoring index that categorizes all adjacent land into simple numerical categories based on the degree of difference from wilderness, multiplied by the percent of the category's land cover within a 20 mile buffer of wilderness (Table 21). A 20 mile buffer was chosen for this analysis to provide staff with a useful tool to monitor the larger framework of connectivity surrounding wilderness. The National Land Cover Database 2011 (NLCD 2011) is the most recent national land cover product created by the Multi-Resolution Land Characteristics (MRLC) Consortium. NLCD land cover products categorize land into 16-classes based on land use/cover that has been applied consistently across the United States at a spatial resolution of 30 meters. NLCD 2011 is based primarily on a decision-tree classification of circa 2011 Landsat satellite data. For step-by-step instructions refer to APPENDIX G – How to perform the analysis for measure 2-13: Index of connectivity. The connectivity spreadsheet contains built in calculations and the 16 classification definitions. For purposes of this monitoring strategy, the categories of open water, deciduous forest, evergreen forest, mixed forest, shrub/scrub, emergent herbaceous wetlands and woody wetlands are lumped into one category when calculating the scoring index because they reflect the same land cover as land within wilderness and do not have any degree of difference. An increase in the index value represents a decrease in connectivity and signifies a downward trend in this measure.

Data source: National Land Cover Database, USGS, Department of the Interior
http://www.mrlc.gov/index.php

Data collection files: Connectivity ArcMap file and the connectivity spreadsheet

Data adequacy: *Medium* – all records have been gathered for this measure but are based on a national dataset.

Frequency: Data will be entered into the WCMD every 5 years.

Significant change: Any change in this measure is considered a significant change.

Table 21: Scoring Index for connectivity

Year of WCM	Category of land use	Degree of difference from wilderness		% cover within 20 mile buffer of wilderness	Total category score
2014	Developed, high intensity	7		0.06%	0.00
Year of Data	Developed, medium intensity	6		0.20%	0.01
2011	Developed, low intensity	5		0.54%	0.03
	Developed, open space	4	x	5.77%	0.23
	Barren land	3		0.15%	0.00
	Cultivated crops	2		27.20%	0.54
	Hay/pasture	1		15.81%	0.16
	Open Water, Forest, shrub, or wetlands	0		50.28%	0.00
				Total Index score for the Tamarac Wilderness:	0.98

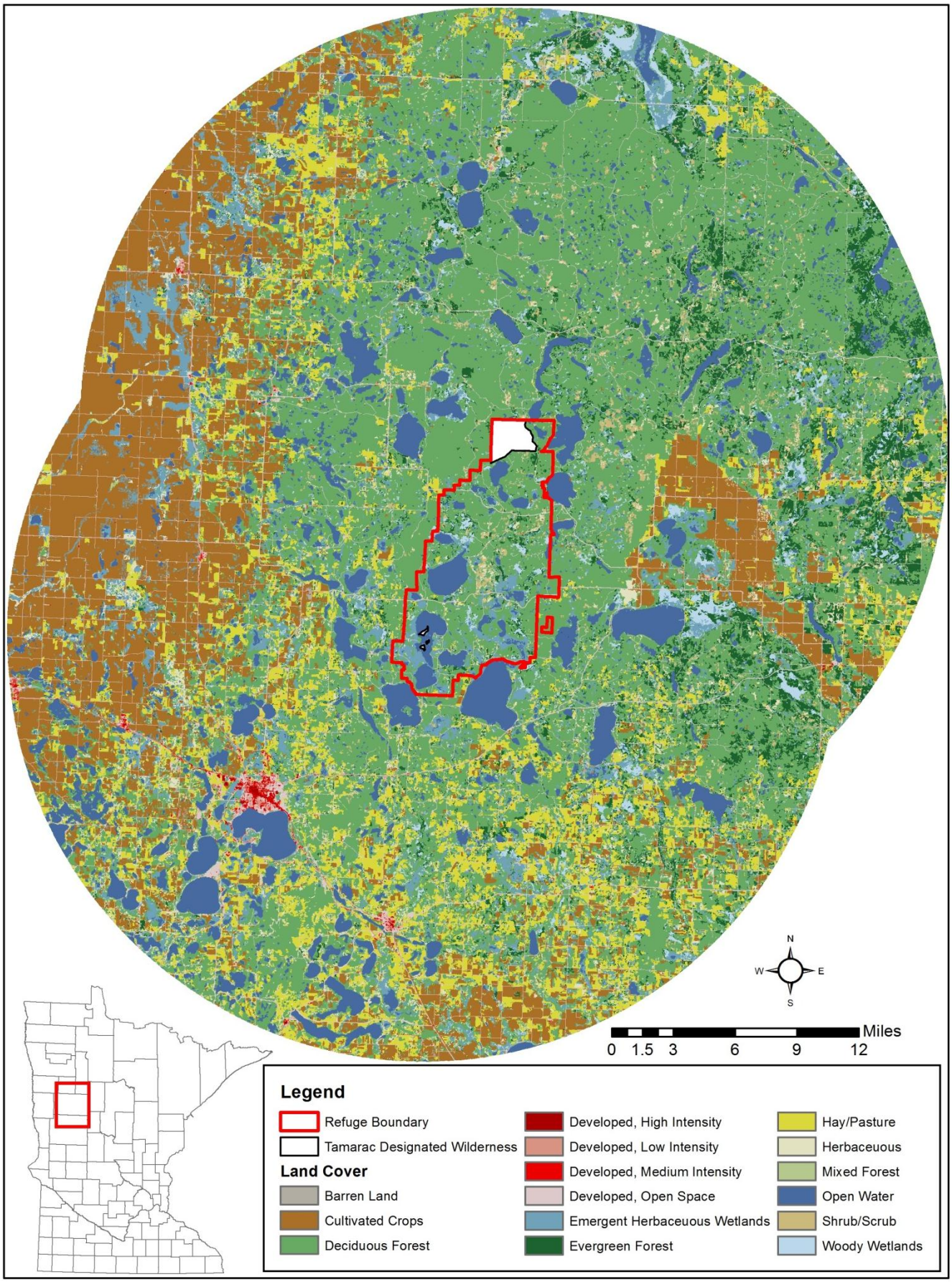


Figure 14: Map displaying surrounding land cover classifications used to calculate an index of connectivity. A 20 mile buffer was applied to the Tamarac Wilderness boundary. Data citation: U.S. Geological Survey, 20140331, NLCD 2011 Land Cover (2011 Edition), Sioux Falls, SD.

Undeveloped Quality

Wilderness retains its primeval character and influence, and is essentially without permanent improvement or modern human occupation.

The undeveloped quality of wilderness is the most familiar and recognizable quality of wilderness for many people. Without buildings, evidence of other humans, or improvements on the landscape, the undeveloped quality of wilderness speaks to "man himself as a visitor who does not remain" and the absence of lasting improvements to the landscape that would change this visitor relationship.

Table 22: Measures of the Undeveloped Quality used to monitor the Tamarac Wilderness

Indicator	Measure	Frequency	Data Adequacy	Significant Change	WCM Baseline Value
Presence of non-recreational structures, installations, and developments	3-1: Number of authorized structures, installations or developments	5 years	Medium	Any	6
Presence of recreational structures, installations, and developments	3-2: Number of recreational structures, installations, or developments	5 years	High	Any	0
Presence of inholdings	3-3: Acres of inholdings	5 years	High	Any	0 acres
Use of motor vehicles, motorized equipment, or mechanical transport	3-4: Index of authorized administrative uses of motorized vehicles, motorized equipment, or mechanical transport	1 year	High	Any	0

Measure 3-1: Number of authorized structures, installations, or developments

2014 Data value: 6
Year of data collection: 2014

Background and context

The idea that wilderness is undeveloped runs through every definition of wilderness. It affects a visitor's experience of a primitive environment, since wilderness is supposed to be a place where the evidence of human activity is substantially unnoticeable. The Tamarac Wilderness has minimal structures, installations or developments (Table 23). Some installations are for research purposes and some structures were present before wilderness designation. The presence of structures, installations or developments significantly impacts the Undeveloped Quality of wilderness character and therefore warrants monitoring.

Measure description and collection protocol

This measure counts all of the federally authorized non-recreational temporary or permanent structures, installations or developments occurring inside wilderness. Examples of features to include in this measure are water conveyance ditches and pipelines, stock tanks, mining structures, communication facilities, energy transmission facilities, road beds, instrument sites for gathering data, and refuge signs. In addition, large trash objects, such as motor vehicles, aircraft, earth moving equipment, military and mining debris, or trash dumps may be included in this measure because they are signs of modern human occupation and they have comparable impacts on wilderness character as structures, installations or developments. The total number of structures, installations or developments is reported into the WCMD. Over time, an increase in the number of structures, installations or developments produces a downward trend in this measure.

Table 23: Detailed data of the number of authorized structures, installations, or developments counted in the baseline value

Description	Location	
PVC piping in wetland sites (2)	Both in large northwest unit	
Sound meters (2)	Both in large northwest unit	
Trash dump and cement structure	Large island	
Old water well structure	Large island	
Total Number of structures, installations or developments entered into the WCMD:		6

Data source: Refuge staff

Data collection file: Structures, installations or developments spreadsheet

Data adequacy: *Medium*– All records are reported for this measure, however given the minimal monitoring presence in the wilderness, signs of human occupation before wilderness designation may exist without refuge knowledge.

Frequency: Data will be entered into the WCMD every 5 years.

Significant change: Any change in this measure is considered a significant change.

Measure 3-2: Number of recreational structures, installations, or developments

2014 Data value: 0
Year of data collection: 2014

Background and context
Recreational structures, installations and developments can be distinguished from non-recreational structures, installations or developments if they are constructed to facilitate "use and enjoyment" of the wilderness, for human safety, or to protect other wilderness resources from visitors. The Tamarac Wilderness has no recreational structures, installations or developments. The wilderness does not have official maintained trails and visitor use is minimal. Most use from visitors occurs during the hunting season.

Measure description and collection protocol
This measure counts all federally authorized and any unauthorized recreational structures, installations or developments within wilderness. Although the Tamarac Wilderness has no recreational structures, installations or developments as of 2014, examples to count in this measure include illegal deer stands, system trails, trail signs, bridges, toilets, and food storage lockers. Recreational developments are tracked under this indicator for their impact on the Undeveloped Quality, and in addition, the impact of these developments on visitors' primitive recreation experience is tracked in the Solitude or Primitive and Unconfined Recreation Quality under the indicator of facilities that decrease self-reliant recreation. Over time an increase in the number of recreational structures, installations, or developments produces a downward trend in this measure.

Data source: Refuge staff

Data collection file: Recreational structures, installations and developments spreadsheet

Data adequacy: *Medium* – All records of authorized recreational structures, installations or developments in wilderness are reported for this measure; however unauthorized recreational structures are harder to account for.

Frequency: Data is entered into the WCMD every 5 years.

Significant change: Any change in this measure is considered a significant change.

Measure 3-3: Acres of inholdings

2014 Data value: 0 acres
Year of data collection: 2014

Background and context
Since inholdings interior to wilderness boundaries are not part of the wilderness, they are not subject to wilderness laws and policies. These lands can be developed for various purposes at the discretion of the landowner, and thereby have a large impact on the surrounding wilderness. There are no inholdings within the Tamarac Wilderness. While the vulnerability of this measure is very low given the relatively small acreage of the wilderness, this measure is highly relevant to the Undeveloped Quality of wilderness character.

Measure description and collection protocol
This measure counts the total acres of inholdings occurring within the wilderness boundary. Over time, an increase in this value would signify a downward trend in this measure.

Definitions

- *Inholding* – parcels of land not owned by the federal land managing agency that are entirely surrounded by and considered to be "inside" wilderness.

Data source: Refuge Manager

Data adequacy: *High* – All records of inholdings in wilderness are reported for this measure. This data is common refuge knowledge and therefore the quality of this data is high.

Frequency: Data is entered into the WCMD every 5 years.

Significant change: Any change in this measure is considered a significant change.

Measure 3-4: Index of authorized administrative uses of motorized vehicles, motorized equipment, or mechanical transport

2014 Data value: 0
Year of data collection: 2014

Background and context

Section 4(c) of the Wilderness Act discusses three forms of mechanization: motor vehicles, motorized equipment, and mechanical transport (see definitions below). Motorized equipment and mechanical transport make it easier for people to occupy and modify the land. The use of motor vehicles, motorized equipment, or mechanical transport are included under the Undeveloped Quality because of the close association in the legislative history between motorized use, mechanical transport, and people's ability to develop, occupy, and modify wilderness. There has been no documented use of motorized vehicles, motorized equipment or mechanical transport within the Tamarac Wilderness to date. Motorized or mechanized uses for administrative purposes may be authorized for a variety of reasons but the mandate from the Wilderness Act states that such uses are allowed only when they are the minimum tool necessary to administer the area as wilderness. A Minimum Requirement Analysis may be done in the future which may authorize motorized transport, motorized equipment, and mechanical transport to eradicate invasive species or to remove unwanted structures from the wilderness.

Measure description and collection protocol

This measure tracks the use of federally authorized administrative or emergency uses of motorized vehicles, motorized equipment, or mechanical transport occurring in wilderness. Mechanized administrative purposes may be authorized for a variety of reasons but the mandate from the Wilderness Act states that such uses are allowed only when they are the minimum tool necessary to administer the area as wilderness.

Different types of motorized and mechanized equipment have different levels of impact on wilderness character. For instance, a wheelbarrow has a significantly different level of impact on wilderness than a motorized vehicle. To account for these differences, an inherent weight will be assigned to each equipment type based on its perceived impact to wilderness character (Table 24). When reporting this value, consult the data collection spreadsheet listed below. The resulting values for each motorized or mechanized use will be summed to generate a total score for the entire wilderness. This sum will be reported in the WCMD. An increase in the total index value over time produces a downward trend in this measure.

Definitions

- *Emergency* – a situation within a wilderness area that requires immediate action because of imminent danger to the health and safety of people within that wilderness area.
- *Mechanical Transport* – any device for moving people or material on, over, or through land, water, or air that has moving parts, provides a mechanical advantage to the user, and is powered by a living or nonliving power

source. (1) This includes, but is not limited to, sailboats, hang gliders, parachutes, bicycles, carts, and wagons. (2) We do not include: (a) wheelchairs when used by those whose disabilities require wheelchairs for locomotion; (b) skis, snowshoes, rafts, canoes, sleds, travois, or similar devices (FWS Wilderness Policy 610FW 1-5).

- *Minimum Tool* – the least intrusive tool, equipment, device, force, regulation, or practice determined to be necessary to achieve a refuge management activity objective in wilderness (FWS Wilderness Policy 610FW 1-5).
- *Motorized Equipment* – machines that use or are activated by a motor, engine, or other power source. (1) We include, but to not limit this to, motorized portable tools, chain saws, aircraft, snowmobiles, generators, motorboats, and motor vehicles. (2) We do not include small, handheld, portable devices such as shavers, wristwatches, flashlights, cameras, stoves, cellular telephones, radios, GPS units, or other similar small equipment. We do not include motorized wheelchairs when used by those whose disabilities require wheelchairs for locomotion (FWS Wilderness Policy 610FW 1-5).

Table 24: Scoring index for motorized vehicles, motorized equipment or mechanical transport use

Scoring Index for motorized vehicles, motorized equipment or mechanical transport use in wilderness Adapted from the *Forest Service Technical Guide (pp.170)*					
Equipment Type	Inherent Weight*		Amount of Use	Use Weight	Total
Battery-powered tool	1		One piece, 1 day	1	
Wheelbarrow	1				
Generator	2		Multiple pieces, 1 day	2	
Air compressor	2				
All-terrain vehicle	3	x	One piece, multiple days	2	
Chain saw	3				
Concrete equipment	3		Multiple pieces, multiple days	3	
Motorized watercraft	3				
Snowmachine	3				
Truck	3				
Heavy equipment	4				

***** Inherent weight is subjectively determined and best professional judgment should be used when assigning weights to those equipment types that are not listed here.

Data source: Special Use Permits, Minimum Requirement Analyses, Refuge Manager

Data collection file: Authorized mechanized use spreadsheet

Data adequacy: *High* – All records of authorized administrative uses in wilderness are reported for this measure. This data is common refuge knowledge and therefore the quality of this data is high.

Frequency: Data will be entered into the WCMD annually.

Significant change: Any change in this measure is considered a significant change.

Solitude or Primitive and Unconfined Recreation Quality

Wilderness provides outstanding opportunities for solitude or primitive and unconfined recreation.

Opportunities for solitude or primitive and unconfined recreation can be difficult to find as modernization and civilization continue to expand. In contrast, wilderness is a place where visitors can experience self-reliance, challenge, and self-discovery. When understanding this quality of wilderness, it is important to note that not all visitors will experience these features. Nonetheless, from a management perspective, the opportunity for these experiences must be preserved as part of wilderness.

Table 25: Measures of the Solitude or Primitive and Unconfined Recreation Quality of wilderness used to monitor the Tamarac Wilderness

Indicator	Measure	Frequency	Data Adequacy	Significant Change	WCM Baseline Value
Remoteness from sights and sounds of people inside the wilderness	4-1: Percent of wilderness away from access or travel routes	5 years	High	Any	87%
Remoteness from occupied and modified areas outside the wilderness	4-2: Percent of wilderness not affected by adjacent travel routes and human developments	5 years	High	5%	42%
Facilities that decrease self-reliant recreation	4-3: Number of facilities that decrease self-reliant recreation	5 years	High	Any	0 facilities
Management restrictions on visitor behavior	4-4: Index of management restrictions on visitor behavior	5 years	High	Any	13

Measure 4-1: Percent of wilderness away from access or travel routes

2014 Data value: 87%
Year of data collection: 2014

Background and context

The Tamarac Wilderness does not have any maintained access points or trails through its boundary. Pre-wilderness establishment, a road was cleared for access down to Little Egg Lake off of highway 35, bordering the wilderness to the East. Air photos from the 1930s clearly show that a travel route used to exist through this area. Today, although the vegetation has overgrown down the path, there is still evidence of where the road once existed and it offers a relatively easy trail to follow (Figure 15). Overall, the Tamarac Wilderness gets minimal use with the majority of visitors occurring during the hunting season.

Measure description and collection protocol

This measure tracks changes in the area of wilderness located away from access points or travel routes. Any remnant trails or new trails used as travel routes are buffered by ¼ mile. The three wilderness islands on Tamarac Lake were not included in this analysis because the methods of access and implications for wilderness character are very different from the rest of the wilderness area. Over time, a decrease in the area of wilderness away from access or travel routes signifies a downward trend in this measure.

Data source: GIS ArcMap data collection file and aerial photos

Data collection file: Area away from access and travel routes.mxd (ArcMap file)

Data adequacy: *Medium* – All records have been gathered for this measure but due to minimal monitoring presence in the wilderness confidence in the data is moderate.

Frequency: Data will be entered into the WCMD every 5 years.

Significant change: Any change is considered a significant change.

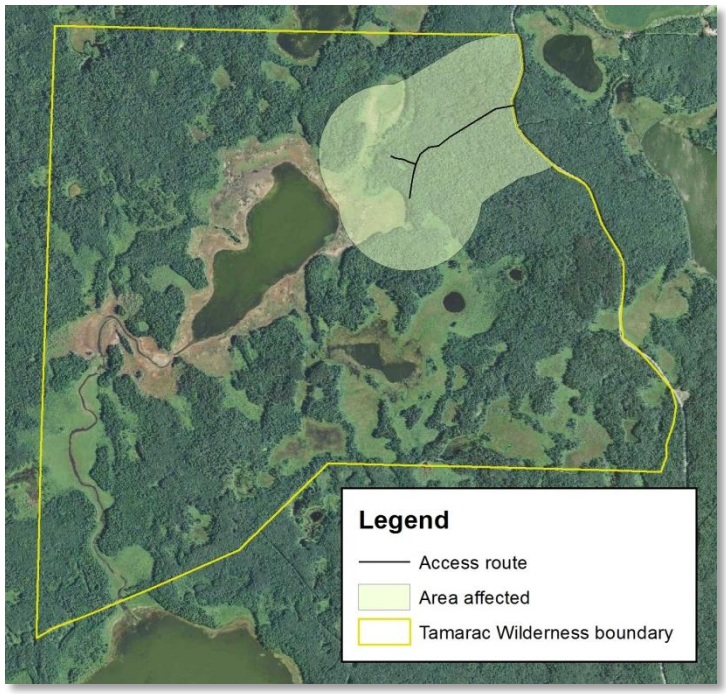


Figure 15: Area affected by (264 acres, indicated in light green) and away (1,816 acres or 87%) from access or travel routes within the Tamarac Wilderness.

Measure 4-2: Percent of wilderness not affected by adjacent travel routes and human developments

2014 Data value: 42%
Year of data collection: 2014

Background and context
This measure tracks human activity outside wilderness that is evident within wilderness. Signs of human activity and development outside wilderness may be manifested in many ways within wilderness, including sights and sounds of automobiles and off-road vehicles on nearby travel routes and private properties, airplanes, motorboats and decreased visibility from air and light pollution. This measure attempts to record the effects of development outside the wilderness on resources that are integral to the perception of wilderness character from inside the wilderness.

Measure description and collection protocol
This measure tracks the area (measured by a percent) of wilderness not affected by adjacent travel routes and human developments outside of wilderness (Figure 16). Adjacent travel routes and human developments are buffered by ½ mile for this analysis; for step-by-step instructions refer to APPENDIX H – How to perform the analysis for measure 4-2: Percent of wilderness not affected by adjacent travel routes and human developments. The wilderness Islands on Tamarac Lake were not included in the analysis for this measure due to their small size and location within Tamarac Lake; motorized boats are permitted on the lake and can often be seen and heard within wilderness especially during the hunting and fishing season. To obtain a percent divide the area of wilderness not affected by the total wilderness area of the northwest unit. Over time a decrease in the percent of wilderness not affected by adjacent travel routes and human developments results in a downward trend in this measure.

Data source: Becker County, MN GIS website http://www.co.becker.mn.us/online_services/

Data collection file: Area affected travel routes develop ArcMap file

Data adequacy: *High* – all records have been gathered for this measure and are based on GIS, so quality is high.

Frequency: Data will be entered into the WCMD every 5 years.

Significant change: A change in 5% is considered a significant change for this measure.

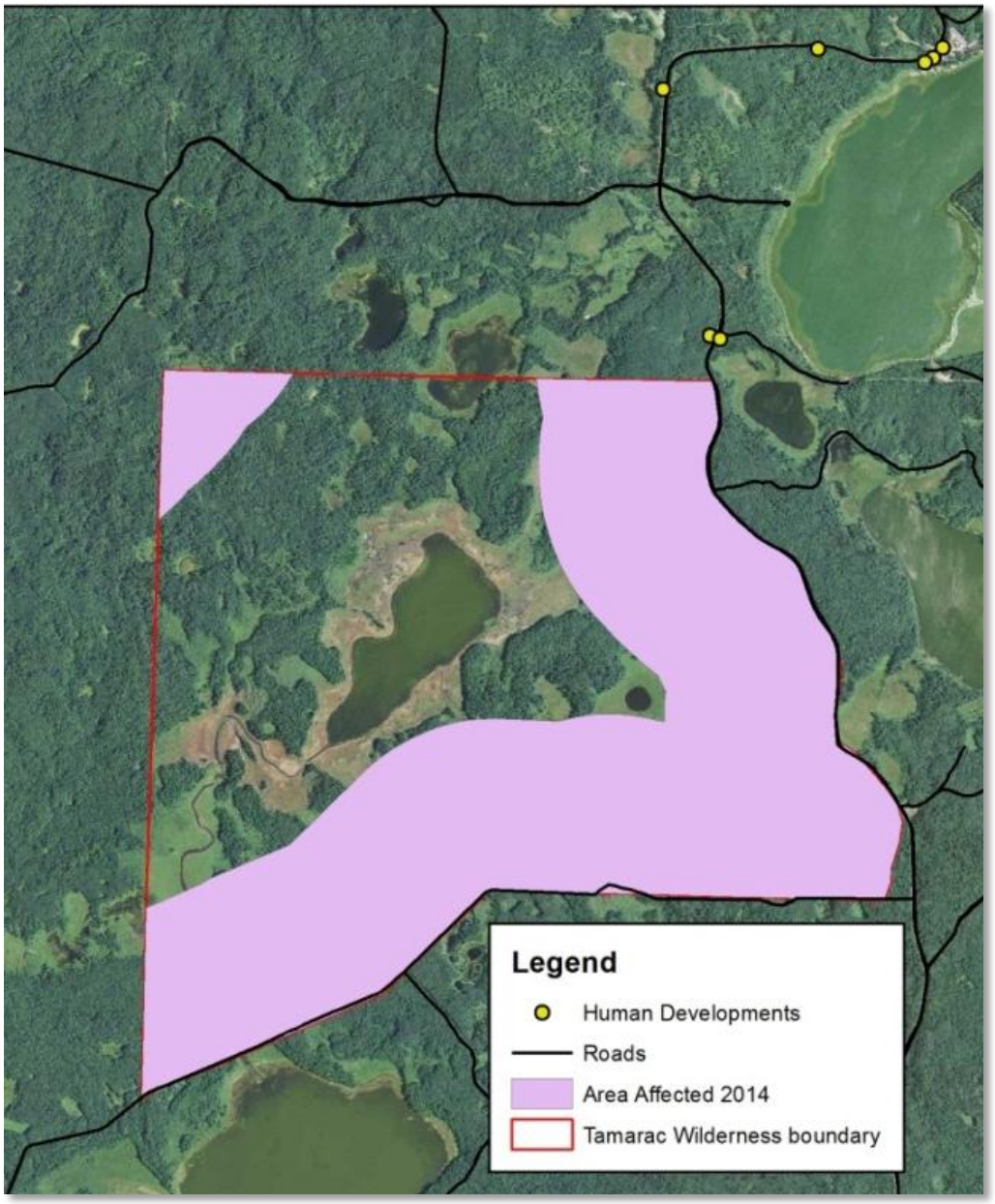


Figure 16: Map of the area of wilderness affected (1,209 acres) by adjacent travel routes and human developments. The area not affected is 871 acres, or 42% of the northwest unit of wilderness.

Measure 4-3: Number of facilities that decrease self-reliant recreation

2014 Data value: 0 facilities
Year of data collection: 2014

Background and context
Primitive recreation consists of activities that require self-reliance and no modern conveniences. Although trails and other recreation facilities in wilderness concentrate user impact and protect resources, such developments reduce the primitiveness and need to practice primitive skills. No recreational facilities are currently present within the Tamarac Wilderness. The potential for future facilities within wilderness is very low but this measure is being tracked because the presence of recreational facilities is highly relevant to wilderness character.

Measure description and Collection protocol
This measure counts the total number of permanent agency provided facilities that impact the opportunity for primitive recreation. Over time, an increase in the number of facilities that decrease self-reliant recreation signifies a downward trend in this measure.

Data source: Refuge Manager and staff

Data adequacy: *High* – all records have been gathered for this measure, no recreational facilities exist in the Tamarac Wilderness so data quality is high.

Frequency: Data will be entered into the WCMD every 5 years.

Significant change: Any change in this measure is considered a significant change.

Measure 4-4: Index of management restrictions on visitor behavior

2014 Data value: 13
Year of data collection: 2014

Background and context

Management restrictions in wilderness are often adopted to protect resources or opportunities for solitude in wilderness but such restrictions also diminish the opportunities for unconfined recreation. In the context of this monitoring strategy, management restrictions on visitor behavior in wilderness are agency regulations or policies that govern visitor behavior, travel, and/or equipment. A permit process through the state of Minnesota is required for visitors participating in a firearm hunt within the refuge.

Measure description and collection protocol

This measure assigns an index score to the restrictions on visitor behavior (Table 26). Restrictions are evaluated on the magnitude of the restriction, with a heavier weight applied to more extensive restrictions (Table 27). The index value to report in the WCMD is the sum of the total scores from all four categories: camping, campfires, permits and area closure. An increase in the index value of management restrictions on visitor behavior produces a downward trend in this measure.

Table 26: Scoring index for management restrictions on visitor behavior

Category	Type of Restriction	Tamarac Wilderness Score
Camping	Total prohibition	3
Campfires	Total prohibition	3
Fees	No fees	0
Permits	Permits required for certain user-types	1
Length of stay	Length of stay limited	1
Swimming/bathing	Prohibited	2
Area Closure	Area closed part of the year	2
Group size limits	No restriction	0
Dogs/domesticated animals	Required to be on a leash	1
	Total score reported to the WCMD:	**13**

Data source: Comprehensive Conservation Plan, Refuge Manager

Data adequacy: *High* –all refuge records have been gathered and staff knowledge is accurate and reliable.

Frequency: Data is entered into the WCMD every 5 years.

Significant change: Any change in this measure is considered a significant change.

Table 27: Weighting scheme for regulations in wilderness

Adapted from the *Forest Service Technical Guide*, page 219		
Category	**Score**	**Type of restriction**
Camping	0	No regulation
	1	Designated site; any mandatory setback
	2	Assigned sites
	3	Total prohibition
Campfires	0	No regulation
	1	Designated site or mandatory setback
	2	Total prohibition
Fees	0	No fees
	1	Fees charged of selected user type
	2	Fees charged of all visitors
Permits	0	No permit or registration
	1	Permits required for certain user-types
	2	Permits required for all users
Length of stay	0	No restriction on length of stay
	1	Length of stay limited
Swimming/bathing	0	No restrictions
	2	Prohibited
Area closure	0	No restriction
	2	Area closed part of the year
	3	Area closed to use
Group size limits	0	No restriction
	1	Group size limits in place
Dogs/domesticated animals	0	No restrictions
	1	Required to be on leash
	2	Prohibited

SUGGESTED FUTURE MEASURES

Natural Quality – Climate Change - Seasonal changes/phenology changes/soundscape

The USGS, Amphibian Research and Monitoring Initiative (ARMI) has an established partnership with the refuge for a long term research study focused on terrestrial wetland global change. Sound meters are placed throughout the refuge, with two study locations adjacent to wetlands within the Tamarac Wilderness border. The highly sensitive microphones in the meters record all sounds near the wetland for five minutes at the top of every hour. The meters are placed adjacent to wetlands seasonally to track changes in phenology of amphibian and bird species. The data could be very useful in putting local changes that may be occurring here at the refuge on a global scale. This data could be used once a data analysis and quantification methodology is created for the purposes of this monitoring strategy. More information on the USGS ARMI can be found at the following links:

http://www.umesc.usgs.gov/twgcrn.html – Terrestrial Wetland Global Change Research Network
http://www.umesc.usgs.gov/armi.html - Amphibian Research and Monitoring Initiative: Midwest Region

Natural Quality – Ecological Processes - Water level changes

Staff has indicated that one of the major threats on the Tamarac ecosystem is climate change and the unknown outcome of whether the environment will become warmer and wetter or warmer and dryer. The difference in these two outcomes will have significant impacts on the natural systems within the wilderness and the larger landscape of the entire refuge. The extent of plant species range, their distributions and abundance directly depend on the availability of water, as well as several key animal populations to this region such as waterfowl and small mammals. To monitor this potential change into the future, the USGS water level data as a part of the climate change study could be utilized for this measure.

MEASURES NOT USED FOR WILDERNESS CHARACTER MONITORING

The measures described below were considered as measures for wilderness character (a); but were ultimately not used (b). The measure and why it was excluded are described in this section.

Natural Quality – Animals - Number of frog and toad species detected

a) This measure was ranked a high priority and considered to highlight the importance of amphibian populations to the natural quality of wilderness at Tamarac. The soundscape data that is collected by USGS could be used to identify the presence of individual species by observing the frequency of their calls within the soundscape.
b) This measure was not chosen because the data is housed with USGS and has not been published yet; researchers are also still exploring the different ways to analyze the soundscape data and produce meaningful results. There is a lack of sufficient data points to accurately represent the wilderness as well. The data collection has been occurring on the refuge since 2009 and there are numerous other locations spanning the entire continent, including Canada and Alaska. This measure, or another measure related to amphibian populations, has the potential to be added in the future once a good data analysis methodology is implemented by USGS.

Natural Quality – Animals - Number of active bald eagle nests

a) This measure was ranked a medium priority and considered to try and track trends in bird populations utilizing the wilderness.
b) Legacy data exists for this measure, however staff no longer conduct this survey within the Tamarac Wilderness. Therefore, this measure was not chosen due to feasibility of data collection.

Natural Quality – Animals - Number of townships occupied with wolves

a) This measure was ranked as a medium priority and originally considered to try and highlight the importance of predator species in the natural quality of wilderness. The Tamarac NWR management plan states gray wolves are a good indicator species for regional biodiversity because they require large blocks of suitable habitat. Tamarac Staff and the MN DNR conduct wolf surveys in the area on a 5-year basis and are able to distinguish the number of townships that are within a wolf pack's territory. There has been 3 wolves collared with tracking devices on the refuge and data indicates that wolves do utilize the wilderness.
b) This measure was not chosen however, due to the lack of data specifically within wilderness and the difficultly of assessing their population. A measure focused on wolves has the potential to be added in the future if better data collection protocols are established or if population numbers become concerning and warrant further monitoring.

Natural Quality – Animals - Waterfowl richness

a) This measure was ranked as a medium priority to account for waterfowl health within wilderness, however it was not chosen for several reasons.
b) The location is difficult to access as entry up the river is dependent on water levels and whether or not a beaver dam has plugged up the river, because of this some years the survey is not completed. Lastly, this measure was not chosen because it would not be a good representation of what could be happening to waterfowl populations on a larger scale within the refuge, just because they are not detected in the wilderness on any given year, doesn't necessarily mean that they are not nesting on the lake just across the wilderness border; Tamarac is dotted with numerous marshes, lakes and ponds all conducive to waterfowl breeding sites.

Natural Quality – Animals - Number of species of concern or interest

a) This measure was ranked as a medium priority and originally considered to highlight the status of animal populations within wilderness. Appendix D in the Tamarac CCP lists the refuge species of concern and their associated habitat types.
b) This measure was not chosen because the Tamarac Wilderness represents a little of each habitat type, which would count almost all of the species on the list in this measure without accurately determining the species abundance solely within the wilderness border.

Natural Quality – Animals - Number or extirpated species

a) This measure was ranked as a medium priority and considered to highlight the importance of tracking the trend of species extinction in the area.

b) This measure was not chosen by choice of staff due to the problem of knowing how far back to consider and the exact definition of extirpated (just within the region? Within the state? etc.). For example, bison and moose used to exist in the area but are mostly non-existent here today but could occur just further north.

Natural Quality – Plants -Native plant species distribution

a) This measure was ranked a medium priority and considered because there is an extensive database of native plant community types and their distribution throughout the wilderness. A plant survey was conducted in 2010 to serve as the baseline. This is useful data to have especially with the occurrence of climate change threatening the types of plant species that will be able to survive and their distribution throughout the landscape.
b) This measure was not chosen because an adequate methodology of analyzing the data and coming up with a way to quantify the potential change over time was not looked into with enough detail. This measure has the potential to be added in the future if such a methodology is created and it is certain that future plant surveys replicating the protocol of data collection of the baseline plant distributions will be completed.

Natural Quality – Climate Change - Number of severe weather events

a) This measure was ranked as a medium priority and considered to track trends in weather patterns that could be occurring due to climate change.
b) After several discussions with the University of Minnesota State Climatologists, the data adequacy for this dataset is not sufficient to establish a measure within a monitoring strategy. Furthermore, most of the events reported in this database do not significantly impact the character of the Tamarac Wilderness.

Natural Quality – Climate Change - Average annual summer and winter temperatures

a) This measure was ranked as a medium priority and considered to track seasonal temperature changes.
b) After discussions with University of Minnesota State Climatologists, the average seasonal temperature trends do not accurately represent how climate is changing over time. They suggested tracking temperature changes within a larger landscape of climate divisions and focus on the trends in minimum and maximum temperatures, especially during the winter. Global trends are indicating a significant rise in winter minimum temperatures. The winter season is a significant defining characteristic of the natural quality within the Tamarac Wilderness. Changes in winter temperatures are more important to focus on as a measure in the climate change indicator, therefore this measure tracking average annual seasonal temperatures was not chosen.

Undeveloped Quality – Presence of recreational structures - Number of unauthorized structures

a) This measure was ranked as a medium priority and considered because there have been documented cases of illegal deer stands installed within the wilderness border. Law enforcement records document a few occasions and provide GPS locations of where the stands once stood.
b) This measure was not chosen because once such a structure is detected, it is immediately removed by refuge staff so counting the number of structures annually would not be accurate as the

structures are installed and removed in the same year. It is important to note that deer hunting is legal in the wilderness and hunters are allowed to have deer stands; it only becomes illegal when they leave the stand there overnight. This measure has the potential to be added in the future if the occurrence of illegal structures significantly increases and a better counting protocol is developed.

Other Features of Value Quality - Index of condition of protected cultural resources

a) This measure was ranked a low priority and originally considered because there is a known potential archeology site on the large wilderness island of Tamarac Lake. Historically, an old logging or hunting cabin used to exist there before wilderness designation. During a site visit to the island by the Wilderness Fellow in 2014, an old water well, cement foundation block, several tin can dump sites, and glass and other objects were found. James Myster, the regional archeologist, indicated that no comprehensive survey has been done at that site but he is aware that the site is located there.
b) Due to the fact that the archeologist has not officially surveyed the site, there is uncertainty at this time if the artifacts left behind significantly contribute to the historical or cultural features of the wilderness character at Tamarac, therefore this measure was not chosen. This measure has the potential to be added in the future once a survey is completed and the archeologist determines the significance of the stuff and the refuge can decide if it is worth preserving or it falls under the 'junk' category and should be removed to improve the undeveloped quality of wilderness character.

CONCLUSIONS

The wilderness character monitoring strategy described in this report, based on current monitoring capabilities, effectively captures the character of the Tamarac Wilderness. The measures defined in each quality of wilderness are intended to be used as a tool to help managers understand temporal changes through the lens of wilderness character. Twenty-six measures were chosen for monitoring, which epitomize the most important and locally relevant characteristics of the Tamarac Wilderness. Minnesota has only three designated and two proposed wilderness locations (Tamarac, Agassiz, and the Boundary Waters are designated while Rice Lake and Mille Lacs are proposed) covering only about 1.5% of the state. Maintaining or improving the wilderness character of this unique but isolated place among the larger natural landscape is of utmost importance. Thus, preserving the integrity of wilderness character is at the forefront of management at Tamarac NWR.

The rich resources of this north woods location has drawn people here for centuries, from the Native American tribes to the loggers, settlers, and hunters who came after them. Going forward, it will be important to heighten awareness within the surrounding community on how rare and meaningful it is to have public lands in their own backyard designated as wilderness within the National Wilderness Preservation System. Refuge staff has a limited presence in the wilderness, which helps to preserve wilderness character but also limits the information that can be used to asses and monitor its condition.

In the coming decades the Tamarac Wilderness could face significant threats to its wilderness character, most notably from climate change and expanding human settlement. Refuge staff is concerned with the potential spread of both aquatic and terrestrial invasive species, water quantity and quality, and the future capacity of refuge staff to adequately monitor the wilderness.

The Tamarac Wilderness is an asset to its surrounding landscape and community. The refuge vision that "…people come to revitalize their spirit and connect with a rich wildlife heritage" can be achieved through a wilderness experience at Tamarac. In order to ensure the refuge vision is upheld into the future, this monitoring strategy will be used as a tool by refuge management to prevent the degradation of wilderness character.

Fall landscape of the Tamarac Wilderness

REFERENCES

Almendinger, J.C. and Hanson, D.S. 1998. Ecological Land Classification Handbook for the Northern Minnesota Drift & Lake Plains. Ecological Land Classification Program, Minnesota Department of Natural Resources, Division of Forestry.

Bureau of Sport Fisheries and Wildlife. 1974. Wilderness Study Summary. United States Department of the Interior, Tamarac National Wildlife Refuge, Becker County, Minnesota.

Bureau of Sport Fisheries and Wildlife. 1974. Wilderness Record: Tamarac Wilderness Proposal. United States Department of the Interior, Tamarac National Wildlife Refuge, Becker County, Minnesota.

Dai, A., Trenberth, K.E., and Qian, T. 2004. A Global Dataset of Palmer Drought Severity Index for 1870 – 2002: Relationship with Soil Moisture and Effects of Surface Warming. *Journal of Hydrometerology*, Volume 5, 1117 – 1130.

Fox, Douglas G., Bartuska, Ann M., Byrne, James G., and others. 1989. A screening procedure to evaluate air pollution effects on Class I wilderness areas. Gen. Tech. Rep. RM-168. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 36 p. Web

Guttman, N. V. and R. G. Quayle, 1996: A historical perspective of U.S. climate divisions. Bulletin of the American Meteorological Society, Volume 77, No. 2, 293-303.

Landres, P., C. Barns, J.G. Dennis, T. Devine, P. Geissler, C.S. McCasland, L. Merigliano, J. Seastrand, and R. Swain. 2008. *Keeping It Wild*: An Interagency Strategy to Monitor Trends in Wilderness Character across the National Wilderness Preservation System. General Technical Report RMRS-GTR-212. Fort Collins, Co: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Landres, P., C. Barns, Boutcher, S., T. Devine, P. Dratch, C. Filardi, A. Lindholm, L.Merigliano, N. Roeper and E. Simpson. [IN PRESS]. *Keeping it Wild 2:* An Updated Interagency Strategy to Monitor Trends in Wilderness Character across the National Wilderness Preservation System. General Technical Report RMRS-GTR-XXX. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. XX pages.

Landres, P., S. Boutcher, L. Dean, T. Hall, T. Blett, T. Carlson, A. Mebane, C. Hardy, S. Rinehart, L. Merigliano, D. N. Cole, A. Leach, P. Wright, D. Bumpus. 2009. Technical Guide for Monitoring Selected Conditions Related to Wilderness Character. USDA Forest Service General Technical Report WO-80, 282 pp.

Minnesota Department of Agriculture (MNDA). 2014. Emerald Ash Borer Status: GIS online mapping tool. Accessed online 09/27/2014 at: http://gis.mda.state.mn.us/eab/

MN Pollution Control Agency. 2014. Environmental Data Access, Surface Water Data: Guide to Typical Minnesota Water Quality Conditions. Accessed online 10/31/2014 at: http://www.pca.state.mn.us/

index.php/data/eda-surface-water-searches/eda-guide-to-typical-minnesota-water-quality-conditions.html

Porter, E., Tonnessen, K., Sherwell, J., and R. Grant. 2000. *Nitrogen in The Nation's Rain.* Kingston, E., Bowersox, V., and G. Zorrilla Eds., National Atmospheric Deposition Program (NADP), NADP Brochure 2000-01c (revised). Accessed online from: http://nadp.sws.uiuc.edu/lib/brochures/nitrogen.pdf

Pryor, S. C., D. Scavia, C. Downer, M. Gaden, L. Iverson, R. Nordstrom, J. Patz, and G. P. Robertson. 2014. Ch. 18: Midwest. *Climate Change Impacts in the United States: The Third National Climate Assessment*, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 418-440. doi:10.7930/J0J1012N.

United States. 2013. The President's Climate Action Plan. The White House, Executive Office of the President, Washington D.C. Retrieved on July 22, 2014 online at: http://www.whitehouse.gov/sites/default/files/image/president27sclimateactionplan.pdf

U.S. EPA. 2006. Air Quality Criteria for Ozone and Related Photochemical Oxidants. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-05/004aF-cF.

U.S. Environmental Protection Agency. 2014. Climate change indicators in the United States, 2014. Third edition. EPA 430-R-14-004. www.epa.gov/climatechange/indicators.

U.S. Fish and Wildlife Service. 1975. Final Environmental Statement (FES 75-44): Proposed Tamarac Wilderness Area, Minnesota. Department of the Interior, Washington, D.C., 36 pp.

U.S. Fish and Wildlife Service. 1982. Refuge Management Plan, Chapter 5, Part III: Wilderness Management Plan. Department of the Interior, Tamarac National Wildlife Refuge, Rochert, Minnesota.

U.S. Fish and Wildlife Service. 2010. Tamarac National Wildlife Refuge and Wetland Management District: Comprehensive Conservation Plan; U.S. Department of the Interior, Midwest Region.

U.S. Forest Service, National Park Service, and U.S. Fish and Wildlife Service. 2010. Federal land Managers' air quality related values work group (FLAG): phase I report–revised (2010). Natural Resource Report NPS/NRPC/NRR–2010/232. National Park Service, Denver, Colorado. Web.

United States of America. 1970. *The Clean Air Act*. Public Law 91-604 (42 U.S.C. § 1857 *et seq.*)

United States of America. 1964. *The Wilderness Act.* Public Law 88-577 (16 U.S.C. § 1131), 88th Congress, Second Session.

United States of America. 1997. *National Wildlife Refuge System Improvement Act*. Public Law 105-57, provision of the National Wildlife Refuge System Administration Act of 1966 (16 U.S.C. § 668dd), 105th Congress.

APPENDICES

APPENDIX A – Priority ranking of all measures considered

Directions: In each row, write the potential measure in the left column under the appropriate indicator. Add or delete rows as needed. Use the criteria and ranking guide below to create an overall score for each measure. If the combined score for criteria A and B is ≤ 2, STOP and do not score criteria C and D. Those measures with the highest overall scores should be the highest priority for assessing trends in wilderness character.

A. Level of significance (the measure is highly relevant to the quality and indicator of wilderness character, and is highly useful for managing the wilderness):
High = 3 points, Medium = 2 points, Low = 1 point

B. Level of vulnerability (measures an attribute of wilderness character that currently is at risk, or might likely be at risk over 10-15 years):
High = 3 points, Medium = 2 points, Low = 1 point

C. Degree of reliability (the measure can be monitored accurately with a high degree of confidence, and would yield the same result if measured by different people at different times):
High = 3 points, Medium = 2 points, Low = 1 point

D. Degree of feasibility (the measure is related to an existing effort or could be monitored without significant additional effort):
High = 1 point, Low = 0 point (if 0 is given, do not use)

Assigning priority levels (see appendix C)**:**
Total Score ≤ 5: Low Priority Level 5.5 ≤ Total Score ≤ 8*: Medium Priority Level 8* ≤ Total Score: High Priority Level
**When the total score = 8, if the subtotal for significance and vulnerability ≥ 5 (meaning that neither were low and that at least one was high) the measure was assigned a high priority level. If the subtotal for significance and vulnerability ≤ 4 it was assigned a Medium priority.*

POTENTIAL MEASURE	Criteria for Prioritizing Potential Measures				OVERALL SCORE	Comments
	A. Significance	B. Vulnerability	C. Reliability	D. Feasibility		
UNTRAMMELED QUALITY						
Indicator: Authorized actions that manipulate the biophysical environment **Measure: Number of actions to manage fire**	3	2	3	1	9	
Indicator: Authorized actions that manipulate the biophysical environment **Measure: Number of actions to manipulate wildlife**	3	2	3	1	9	

POTENTIAL MEASURE	Criteria for Prioritizing Potential Measures				OVERALL SCORE	Comments
	A. Significance	B. Vulnerability	C. Reliability	D. Feasibility		
Indicator: Authorized actions that manipulate the biophysical environment **Measure: Number of actions to manage invasive flora and fauna species**	3	1	3	1	9	
Indicator: Authorized actions that manipulate the biophysical environment **Measure: Number of actions to manipulate fish, pathogens, soil, or water**	3	2	3	1	9	
Indicator: Unauthorized actions that manipulate the biophysical environment **Measure: Number of known unauthorized trammeling actions**	3	2	1	1	7	
NATURAL QUALITY						
Indicator: Plants **Measure: Number of non-native invasive plant species**	3	3	2	1	9	
Indicator: Plants **Measure: Native plant species distribution**	2	2	2	0	--	NOT USED, an adequate methodology for analyzing this data and quantifying change over time does not exist at this time.
Indicator: Animals **Measure: Number of non-native fauna species**	3	3	3	1	10	
Indicator: Animals **Measure: Number of frog and toad species detected**	3	2	3	1	--	NOT USED, access to USGS data and a methodology for analyzing the soundscape data did not occur this year

POTENTIAL MEASURE	Criteria for Prioritizing Potential Measures				OVERALL SCORE	Comments
	A. Significance	B. Vulnerability	C. Reliability	D. Feasibility		
Indicator: Animals **Measure: Number of active bald eagle nests**	2	2	2	0	--	NOT USED, staff no longer conduct this survey
Indicator: Animals **Measure: Number of townships occupied with wolves**	2	2	2	0	--	NOT USED, too difficult to assess population within wilderness
Indicator: Animals **Measure: Waterfowl richness**	3	2	1	1	--	NOT USED, survey only occurs once a year and is not an accurate representation
Indicator: Animals **Measure: Number of species of concern or interest**	3	2	1	1	--	NOT USED, preference of staff
Indicator: Animals **Measure: Number of extirpated species**	3	2	1	0	--	NOT USED, preference of staff
Indicator: Air and water **Measure: Ozone concentration**	3	2	2	1	8	
Indicator: Air and water **Measure: Wet deposition of nitrogen**	3	2	2	1	8	
Indicator: Air and water **Measure: Wet deposition of sulfur**	3	2	2	1	8	
Indicator: Air and water **Measure: Visibility**	3	2	2	1	8	
Indicator: Air and water **Measure: Index of water quality**	3	3	2	1	9	
Indicator: Climate change **Measure: Frequency of severe weather events**	1	2	2	1	--	NOT USED, not relevant to wilderness character, low data adequacy

POTENTIAL MEASURE	Criteria for Prioritizing Potential Measures				OVERALL SCORE	Comments
	A. Significance	B. Vulnerability	C. Reliability	D. Feasibility		
Indicator: Climate change **Measure: Average annual summer and winter temperatures**	2	2	2	1	--	NOT USED, no accurate local data source
Indicator: Climate change **Measure: Annual winter minimum temperature anomaly**	3	3	3	1	10	
Indicator: Climate change **Measure: Annual winter maximum temperature anomaly**	2	3	3	1	9	
Indicator: Climate change **Measure: Total annual precipitation**	3	2	3	1	9	
Indicator: Climate change **Measure: Annual Palmer drought severity index**	3	3	3	1	10	
Indicator: Ecosystem processes **Measure: Miles of wilderness boundary serving as an entry point for invasive species**	3	1	3	1	8	
Indicator: Ecosystem processes **Measure: Index of connectivity**	3	3	3	1	10	
UNDEVELOPED QUALITY						
Indicator: Presence of non-recreational structures, installations, or developments **Measure: Number of authorized structures, installations or developments**	3	1	3	1	8	
Indicator: Presence of recreational structures, installations, or developments **Measure: Number of recreational structures, installations or developments**	3	1	3	1	8	
Indicator: Presence of recreational structures, installations, or developments **Measure: Number of unauthorized recreational structures, installations or developments**	2	2	2	1	--	NOT USED, preference of staff

POTENTIAL MEASURE	Criteria for Prioritizing Potential Measures				OVERALL SCORE	Comments
	A. Significance	B. Vulnerability	C. Reliability	D. Feasibility		
Indicator: Presence of inholdings **Measure: Acres of inholdings**	3	1	3	1	8	
Indicator: Use of motor vehicles, motorized equipment, or mechanical transport **Measure: Index of authorized administrative uses of motorized vehicles, motorized equipment, or mechanical transport**	3	1	3	1	8	
SOLITUDE OR PRIMITIVE AND UNCONFINED RECREATION QUALITY						
Indicator: Remoteness from sights and sounds of people inside the wilderness **Measure: Percent of wilderness away from access or travel routes**	3	1	2	1	7	
Indicator: Remoteness from occupied and modified areas outside the wilderness **Measure: Percent of wilderness not affected by adjacent travel routes and human developments**	3	2	3	1	9	
Indicator: Facilities that decrease self-reliant recreation **Measure: Number of facilities that decrease self-reliant recreation**	3	1	3	1	8	
Indicator: Management restrictions on visitor behavior **Measure: Index of management restrictions on visitor behavior**	3	1	3	1	8	
Other Features Quality						
Indicator: Deterioration or loss of integral historical or cultural features **Measure: Condition of cultural resources**	1	1	2	0	--	NOT USED, no official survey to determine cultural significance to wilderness character

APPENDIX B – Summary of effort required for wilderness character monitoring

Quality	Indicator	Measure	Type of Data Source	Time spent gathering data for each measure (in whole hours)*	Comments
Untrammeled	Actions authorized by the Federal land manager that manipulate the biophysical environment	1-1: Number of actions to manage fire	Fire incident reports, biological staff	1	Fire Management Information System (FMIS) and Fire incident reports are on the share drive <S:/MANAGEMENT/Fire>
		1-2: Number of actions to manipulate wildlife	Special use permits, biological staff	1	
		1-3: Number of actions to manage invasive flora and fauna species		1	
		1-4: Number of actions to manipulate plants, soil, or water		1	
	Actions not authorized by the Federal land manager that manipulate the biophysical environment	1-5: Number of known unauthorized trammeling actions	Law enforcement records, staff	1	Law enforcement records are on the share drive <S:/LE Case Reports-Photos>

Quality	Indicator	Measure	Type of Data Source	Time spent gathering data for each measure (in whole hours)*	Comments
Natural	Plants	2-1: Number of non-native invasive plant species	GPS records, biological staff	2	Also consult with the invasive plant spreadsheet in the wilderness management folder of the share drive
	Animals	2-2: Number of non-native fauna species	Biological staff, MNDA	1	MNDA emerald ash borer online GIS map: http://gis.mda.state.mn.us/eab/
	Air and Water	2-3: Ozone concentration	NWRS, Inventory and Monitoring Branch of Air Quality	1	Data is provided upon request. The baseline values were provided by Jill Webster.
		2-4: Wet deposition of nitrogen			
		2-5: Wet deposition of sulfur			
		2-6: Visibility			
		2-7: Index of water quality	Water quality field collection data	2	Use the WCM water quality spreadsheet in the wilderness management folder on the share drive. Consult with Josh Eash, region 3 hydrologist, with any questions as he assisted with the development of this measure.

Quality	Indicator	Measure	Type of Data Source	Time spent gathering data for each measure (in whole hours)*	Comments
Natural (cont.)	Climate change	2-8: Annual winter minimum temperature anomaly	NOAA, NCDC Climate at a Glance tool	1	Consult with the University of Minnesota State Climatology Office with any questions or concerns as they assisted with the development of these measures. People I contacted for assistance were Peter Snyder, Peter Boulay and Greg Spoden. http://www.ncdc.noaa.gov/cag/
		2-9: Annual winter maximum temperature anomaly	NOAA, NCDC Climate at a Glance tool	1	
		2-10: Total annual precipitation	Gridded online database provided by the MN Climatology Working Group	2	http://climate.umn.edu/gridded_data/precip/wetland/wetland.asp
		2-11: Annual Palmer drought severity index	NOAA, NCDC Climate at a Glance tool	1	Climate at a glance: http://www.ncdc.noaa.gov/cag/ A tool to track short term trends: http://droughtmonitor.unl.edu/MapsAndData/DataTables.aspx
	Ecological processes	2-12: Miles of wilderness boundary serving as an entry point for invasive species	Tamarac share drive for all GIS data	1	An ArcMap file for this analysis is saved in the wilderness management folder on the share drive <S:/Wilderness Management/Wilderness Character Monitoring/GPS GIS MAPS>

Quality	Indicator	Measure	Type of Data Source	Time spent gathering data for each measure (in whole hours)*	Comments
		2-13: Index of connectivity	National Land Cover data, USGS	2	http://www.mrlc.gov/index.php Also consult the connectivity ArcMap and spreadsheet saved in the wilderness management folder on the share drive
Undeveloped	Presence of non-recreational structures, installations, and developments	3-1: Number of authorized structures, installations or developments	Refuge manager and/or biological staff	1	Also consult the data collection spreadsheet in the wilderness management folder on the share drive
	Presence of recreational structures, installations, and developments	3-2: Number of recreational structures, installations, or developments		1	
	Presence of inholdings	3-3: Acres of inholdings	Refuge Manager	1	
	Use of motor vehicles, motorized equipment, or mechanical transport	3-4: Index of authorized administrative uses of motorized vehicles, motorized equipment, or mechanical transport	Special use permits, biological staff and Refuge Manager	1	Also consult the authorized mechanized use data collection spreadsheet in the wilderness management folder on the share drive

Quality	Indicator	Measure	Type of Data Source	Time spent gathering data for each measure (in whole hours)*	Comments
Solitude and primitive or unconfined recreation Solitude and primitive or unconfined recreation (cont.)	Remoteness from sights and sounds of people inside the wilderness	4-1: Percent of wilderness away from access or travel routes	Aerial photos, biological staff	1	There is a ArcMap file saved in the wilderness management folder on the share drive for this analysis
	Remoteness from occupied and modified areas outside the wilderness	4-2: Percent of wilderness not affected by adjacent travel routes and human developments	Becker County GIS website	1	http://www.co.becker.mn.us/online_services/GIS_data.aspx There is also an ArcMap file saved in the wilderness management folder on the share drive for this analysis
	Facilities that decrease self-reliant recreation	4-3: Number of facilities that decrease self-reliant recreation	Refuge Manager	1	
	Management restrictions on visitor behavior	4-4: Index of management restrictions on visitor behavior	CCP, Refuge Manager	1	

* Time spent gathering data does not include time spent gaining access to the data or time spent analyzing or developing index values and counting protocols.

APPENDIX C – Data sources and protocols for all measures used

Keeping Track of Wilderness Character Monitoring Measures

Measure	Priority (H, M, L)	Detailed Description of the Data Source(s) and Protocols for How the Data Were Gathered
Untrammeled Quality		
1-1: Number of actions to manage fire	H	*Data sources:* Fire incident reports on the share drive, Fire Management Information System (FMIS), biological staff and the trammeling actions spreadsheet <S:/Wilderness Management/Wilderness Character Monitoring/ WCM data files/1 Untrammeled/trammeling_actions.xlsx> *Collection protocol:* Suppression of human-started fires is not considered a trammeling action as these fires are unnatural to begin with. All management decisions that involve the following actions should be included in this measure: fire ignitions, prescribed burns, natural fire suppression responses, fuel load reduction activities, or any other action involving fire management within the wilderness. The general protocol for counting trammeling actions is outlined in Table 5, while Table 6 offers a more detailed explanation of how to report specific trammeling actions. Report the total number of actions in the WCMD every 5 years. Over time, an increase in the number of actions to manage fire represents a downward trend in this measure. When assigning a trend (stable, upward or downward) in the database, compare the current year data value to the previous year.
1-2: Number of actions to manipulate wildlife	H	*Data sources:* Special Use Permits, biological staff and the trammeling actions spreadsheet <S:/Wilderness Management/Wilderness Character Monitoring/ WCM data files/1 Untrammeled/trammeling_actions.xlsx> *Collection protocol:* Count of the number of actions that are intended to manipulate, at a broad-scale, any component of wildlife populations within wilderness. This measure does not include any actions involving invasive animal species, as these actions are counted in another measure. The count should include all wildlife management actions involving the following: reintroduction, introduction, supplementation of wildlife species, predator control programs, or the authorization of research or monitoring activities that involve significant disruption. Significant disruption to wildlife includes, but is not limited to, actions such as: capturing, collaring, implanting transmitters, collecting blood/tissue samples, electro-shocking, sterilizing, etc. An "action" should be counted according to the guidelines set forth in Table 5 and Table 6. Over time, an increase in the number of authorized actions to manipulate wildlife signifies a downward trend in this measure. When assigning a trend (stable, upward or downward) in the database, compare the current year data value to the previous year.
1-3: Number of actions to manage	H	*Data sources:* Special Use Permits, biological staff and the trammeling actions spreadsheet <S:/Wilderness Management/Wilderness Character Monitoring/ WCM data files/1 Untrammeled/trammeling_actions.xlsx>

Measure	Priority (H, M, L)	Detailed Description of the Data Source(s) and Protocols for How the Data Were Gathered
invasive flora and fauna species		*Collection protocol:* This measure is a count of the number of authorized actions that are intended to manage, at a broad-scale, any plant or animal invasive species in wilderness. The count should include all plant management activities involving the following: biological, chemical, or mechanical control of invasive species. The count should also include all invasive animal management actions. An "action" should be counted according to the guidelines set forth in Table 5 and Table 6. Over time, an increase in the number of authorized actions to manage invasive species signifies a downward trend in this measure. When assigning a trend (stable, upward or downward) in the database, compare the current year data value to the previous year.
1-4: Number of actions to manipulate plants, soil, or water	H	*Data sources:* Special Use Permits, biological staff and the trammeling actions spreadsheet <S:/Wilderness Management/Wilderness Character Monitoring/ WCM data files/1 Untrammeled/trammeling_actions.xlsx> *Collection protocol:* This measure is a count of the number of authorized actions that are intended to manipulate, at a broad-scale, any components of the biophysical environment, specifically native plants, soil or water in wilderness. The count should include any native plant management activities involving the following: large scale harvesting, restoration, seeding, or research/monitoring studies that manipulate the biophysical environment. The count should also include all actions to manipulate or research soil and water components within the wilderness boundary that cause significant disturbance. An "action" should be counted according to the guidelines set forth in Table 5 and Table 6. Over time, an increase in the number of authorized actions to manipulate plants, soil or water signifies a downward trend in this measure. When assigning a trend (stable, upward or downward) in the database, compare the current year data value to the previous year.
1-5: Number of known unauthorized trammeling actions	M	*Data sources:* Law Enforcement, biological staff and the trammeling actions spreadsheet <S:/Wilderness Management/Wilderness Character Monitoring/ WCM data files/1 Untrammeled/trammeling_ actions.xlsx> *Collection protocol: Collection protocol:* Count the total number of unauthorized trammeling actions occurring in wilderness. An increase in the number of unauthorized actions intended to manipulate the biophysical environment results in a downward trend in this measure. Report this value annually. When assigning a trend (stable, upward or downward) in the database, compare the current year data value to the previous year.
Natural Quality		
2-1: Number of non-native invasive plant species	H	*Data sources:* Biological staff, GPS records from plant surveys, invasive plant spreadsheet <S:/Wilderness Management/Wilderness Character Monitoring/ WCM Data Files/2 Natural Quality/Plant Indicator/Invasive_Plants_ inWilderness.xlsx> *Collection protocol:* The count will be compiled from plant surveys and

Measure	Priority (H, M, L)	Detailed Description of the Data Source(s) and Protocols for How the Data Were Gathered
		GPS records taken in wilderness. No comprehensive survey has been completed in the wilderness; however the Wilderness Fellow in 2014 found 4 plant species in wilderness while visiting both the islands and the northwest unit to make up the baseline value for 2014 (Table 8). Consult the invasive plants spreadsheet when entering data into the WCMD. An increase in the number of invasive plant species found in wilderness produces a downward trend in this measure. This value is reported every 5 years. When assigning a trend (stable, upward or downward) in the database, compare the current year data value to the previous year.
2-2: Number of non-native fauna species	H	*Data sources:* Refuge staff, traps on the refuge, Minnesota Department of Agriculture (MNDA) online GIS map: http://gis.mda.state.mn.us/eab/ *Collection protocol:* Type in the search box on the MNDA's GIS map interface: Tamarac National Wildlife Refuge and monitor the closest reported location of EAB. If the invasive pest is detected on the refuge from the traps set out by the MNDA, staff should implement a more rigorous monitoring strategy to detect if it is present in wilderness. Over time, an increase in the number of non-native fauna represents a downward trend in this measure. Report this value every 5 years. When assigning a trend (stable, upward or downward) in the database, compare the current year data value to the previous year.
2-3: Ozone concentration	H	*Data source:* National Wildlife Refuge System, Inventory and Monitoring, Branch of Air Quality *Collection protocol:* Since the Tamarac Wilderness consists of three separate islands and a larger unit in the northwest corner, the values provided by USFWS are averaged for reporting of this measure. The data are provided upon request; the baseline values were provided by Jill Webster. This value is based on interpolated data; therefore a trend will not be assessed for this characteristic. However, this measure tracks whether the numerical value for this indicator is increasing or decreasing over the averaging periods. Report this value every 5 years.
2-4: Wet deposition of nitrogen	H	*Data source:* National Wildlife Refuge System, Inventory and Monitoring, Branch of Air Quality *Collection protocol:* Since the Tamarac Wilderness consists of three separate islands and a larger unit in the northwest corner, the values provided by USFWS Inventory and Monitoring Program are averaged for reporting of this measure. The data are provided upon request; the baseline values were provided by Jill Webster This value is based on interpolated data; therefore a trend will not be assessed for this characteristic. However, this measure tracks whether the numerical value for this indicator is increasing or decreasing over the averaging periods. Report this value every 5 years.
2-5: Wet deposition of sulfur	H	*Data source:* National Wildlife Refuge System, Inventory and Monitoring, Branch of Air Quality

Measure	Priority (H, M, L)	Detailed Description of the Data Source(s) and Protocols for How the Data Were Gathered
		Collection protocol: Since the Tamarac Wilderness consists of three separate islands and a larger unit in the northwest corner, the values provided by USFWS Inventory and Monitoring Program are averaged for reporting of this measure. The data are provided upon request; the baseline values were provided by Jill Webster. This value is based on interpolated data; therefore a trend will not be assessed for this characteristic. However, this measure tracks whether the numerical value for this indicator is increasing or decreasing over the averaging periods. Report this value every 5 years.
2-6: Visibility	H	*Data source:* National Wildlife Refuge System, Inventory and Monitoring, Branch of Air Quality *Collection protocol:* Since the Tamarac Wilderness consists of three separate islands and a larger unit in the northwest corner, the values provided by USFWS Inventory and Monitoring Program are averaged for reporting of this measure. The data are provided upon request; the baseline values were provided by Jill Webster. This value is based on interpolated data; therefore a trend will not be assessed for this characteristic. However, this measure tracks whether the numerical value for this indicator is increasing or decreasing over the averaging periods. Report this value every 5 years.
2-7: Index of water quality	H	*Data source:* Master water quality spreadsheet <S:/Biology/Water Quality/Water Quality Monitoring>, and the WCM water quality spreadsheet <S:/Wilderness Management/Wilderness Character Monitoring/WCM data files/2 Natural/Air and Water indicator/WCM_WaterQuality.xlsx> *Collection protocol:* This measure tracks trends in water quality from the wilderness by using an index value based on 4 water quality parameters: pH, transparency, total phosphorus, and chlorophyll A (stream stage and specific conductance should be considered for context of hydrologic conditions). Data values are assessed within a 5-year period due to the practicality of data collection and preference of staff. The associated location from which data values are used flows out of the wilderness and is titled Egg River – North Culvert (stop #3, ID: S004-775) (Figure 6). Open the master water quality spreadsheet on the share drive and copy the raw data from only stop #3, the Egg River – North Culvert, for all 5 years included in the current data analysis period and paste them into the WCM water quality spreadsheet under the heading 'RAW data'. Tease out the data from the raw data tab and only copy the values of the 4 parameters tracked in this measure to the respective years data summary tab: pH, transparency, total P, chlorophyll A (and conductance and stream stage height for context). Data values are then assigned an overall category and index point value based on where the data falls within a range that is considered good, caution, or poor (based on MN state standard conditions) (Table 14). Use the scoring protocol to rank each individual water sample for total P and chlorophyll A and change the text

Measure	Priority (H, M, L)	Detailed Description of the Data Source(s) and Protocols for How the Data Were Gathered
		color to reflect the category it falls under in the WCM water quality spreadsheet. The baseline value for this measure is assessed from 2008-2012; therefore, there is no data value for 2014 since this year falls in the middle of the 5-year monitoring cycle of this measure. Each parameters index score within a 5-year period are added up to get an overall index score for the wilderness, which will be the value entered into the WCMD (Table 15). When entering data into the WCMD, the data year (or year measured) is determined by the last year of data collection (e.g. data collected from 2008 – 2012 is assigned the 'year measured' as 2012 and data collected from 2013 – 2017 is assigned the 'year measured' as 2017 and so on) Over time, an increase in the water quality index value represents a downward trend in this measure. When assigning a trend (stable, upward or downward) in the database, compare the current year data value to the previous year.
2-8: Annual winter minimum temperature anomaly	H	*Data source:* Climate division departures spreadsheet <S:/Wilderness Management/Wilderness Character Monitoring/WCM data files/2 Natural/Climate Change indicator/Climate division departures.xlsx> and NOAA National Climatic Data Center, Climate at a Glace Time Series http://www.ncdc.noaa.gov/cag/time-series/us/21/01/tmin/3/02/1977-2014?base_prd=true&firstbaseyear=1981&lastbaseyear=2010&trend=true&trend_base=10&firsttrendyear=1977&lasttrendyear=2014*IN THE OPTIONS WINDOW YOU MUST CHANGE THE BASE PERIOD TO REFLECT THE 30 YEARS OF THE CURRENT CLIMATE NORMALS PERIOD. *Collection protocol:* This measure tracks the trend in annual winter minimum temperature anomalies. Meteorologically, winter is defined as the three month period from December to February (the 'year measured' value in the database will be assigned based on the year in February of the annual analysis, for example the winter of Dec 2013 – February 2014 is recorded in the data base under the year 2014). Visit the data source website listed above and modify the end year to the current year of data analysis. In the options window, modify the base period to reflect the 30 years of the current climate noarmals and modify the trend represent 1977 - present. The current climate normals period is from 1981-2010; this was the base period used in the calculation for the baseline anomaly for this measure. Climate normals are calculated every ten years; the next period will be from 1991-2020. The base period for the calculation of anomalies in this measure will always use the 30 years of the current climate normals period. Once the data are plotted, copy the data table provided on the website and paste the values in the climate division departures spreadsheet under the 'Min Winter' tab (if the current year is in the same climate normal period, you will only need to copy the current year of data and add it to the respective tab). You will need to create a new tab in the spreadsheet once the climate normal period has changed because the base period average temperature will have changed and therefore the calculation of anomalies will be different. Add a column to the table titled 'WCM year' and assign data rows to reflect the individual

Measure	Priority (H, M, L)	Detailed Description of the Data Source(s) and Protocols for How the Data Were Gathered
		year that will represent the 'year measured' in the WCMD (this year should be based on the year in February of the winter temperatures). Report the current year anomaly value in the WCMD; include in the measure value comment field the actual observed average winter temperature and the climate normal average temperature of the base period. Also include in the comment field the long term trend calculated by NOAA in the graph provided on the website and the results from the regression analysis (the F value, p-value, and if it is considered to be statistically significant, or if the p-value is ≤ 0.1). For step-by-step instructions refer to APPENDIX F – How to perform a linear regression analysis in Excel. Although it is difficult to assess whether change in climate variables have a positive or negative impact on wilderness character, trends in this measure will be reported as either stable or significant change. A downward trend will be assigned when a significant change is detected. Report this value annually.
2-9: Annual winter maximum temperature anomaly	H	*Data source:* Climate division departures spreadsheet <S:/Wilderness Management/Wilderness Character Monitoring/WCM data files/2 Natural/Climate Change indicator/Climate division departures.xlsx> and NOAA National Climatic Data Center, Climate at a Glace Time Series http://www.ncdc.noaa.gov/cag/time-series/us/21/01/tmax/3/02/1977-2014?base_prd=true&firstbaseyear=1981&lastbaseyear=2010&trend=true&trend_base=10&firsttrendyear=1977&lasttrendyear=2014*IN THE OPTIONS WINDOW YOU MUST CHANGE THE BASE PERIOD TO REFLECT THE 30 YEARS OF THE CURRENT CLIMATE NORMALS PERIOD. *Collection protocol:* This measure tracks the trend in annual winter maximum temperature anomalies. The purpose of this measure is to compare and contrast how changes are occurring relative to the previous measure (annual winter minimum temperature anomaly); MN State Climatology personnel highly suggested tracking both trends in the minimum and maximum temperature anomalies. Visit the data source website listed above and modify the end year to the current year of data collection. In the options window, modify the years of the base period to reflect the 30 years of the current climate normals period and modify the displayed trend to reflect 1977 - present. The current climate normals period is from 1981-2010; this was the base period used in the calculation for the baseline anomaly for this measure. Climate normals are calculated every ten years; the next period will be from 1991-2020. The base period for the calculation of anomalies in this measure will always use the 30 years of the current climate normals period. Once the data are plotted, copy the data table provided on the website and paste the values in the climate division departures spreadsheet under the 'Max Winter' tab (if the current year is in the same climate normal period, you will only need to copy the current year of data and add it to the respective tab). You will need to create a new tab in the spreadsheet once the climate normal period has changed because the base period average temperature will have changed and therefore the calculation of anomalies will be

Measure	Priority (H, M, L)	Detailed Description of the Data Source(s) and Protocols for How the Data Were Gathered
		different. Add a column to the table titled 'WCM year' and assign data rows to reflect the individual year that will represent the 'year measured' in the WCMD (this year should be based on the year in February of the winter temperatures). Report the current year anomaly value in the WCMD; include in the measure value comment field the actual observed average winter max temperature and climate normal average winter max temperature. Also include in the comment field the long term trend calculated by NOAA in the graph provided on the website and the results from the regression analysis (the F value, p-value, and if it is considered to be statistically significant, or if the p-value is $\leq$ 0.1). For step-by-step instructions refer to APPENDIX F – How to perform a linear regression analysis in Excel. Although it is difficult to assess whether change in climate variables have a positive or negative impact on wilderness character, trends in this measure will be reported as either stable or significant change. A downward trend will be assigned when a significant change is detected. Report this value annually.
2-10: Total annual precipitation	H	*Data source*: Annual Precip spreadsheet <S:/Wilderness Management/Wilderness Character Monitoring/WCM data files/2 Natural/Climate Change indicator/Annual Precip.xlsx> and the Minnesota Climatology Working Group, Wetland Delineation Precipitation Data Retrieval from a Gridded Database http://climate.umn.edu/gridded_data/precip/ wetland/wetland.asp *Collection protocol:* Visit the above website and use Table 18 to retrieve precipitation data for the Tamarac Wilderness; use the Xutm and Yutm numbers to select the location coordinates and hit the 'update map' button. Verify all of the other details match the location specified in Table 18 and choose 'create precipitation table'. The estimates are derived using an interpolation technique called "Kriging", which makes use of the irregularly spaced data in the vicinity of the node to assign it a value. A precipitation total is calculated for every grid node spaced at 10 km intervals, for every month. Once the grids are created, the calculation of long-term summary statistics such as normals and percentiles are performed on each grid node. Copy the colored data values under the Year-to-Year data table for the current year of data analysis and paste these values in the precipitation spreadsheet under the 'RAW data' tab. Copy the total annual precipitation data value indicated in the 'ANN' column of the raw data to the 'data summary' tab of the spreadsheet. When entering data into the WCMD, report the total annual precipitation value and indicate the assigned condition in the value comment field based on Table 19 or the color of the data value (Low, Normal or High); If the current year of data falls within the normal category, assign the condition within the WCMD of good, if it falls in the low or high category assign the condition as caution and if any data values are extreme outliers, assign the condition as poor. Report this value annually. Although it is difficult to assess whether change in climate variables have a positive or negative impact on wilderness character, trends in this

Measure	Priority (H, M, L)	Detailed Description of the Data Source(s) and Protocols for How the Data Were Gathered
		measure will be reported as either stable or significant change. Over time, a downward trend is assigned when a significant change has occurred. Perform a linear regression in Excel with α=0.1 every year for all data values since 1977 to evaluate significant change. Any significant trend is a significant change. For step-by-step instructions refer to APPENDIX F – How to perform a linear regression analysis in Excel.
2-11: Annual Palmer drought severity index	H	*Data source:* Palmer drought index spreadsheet <S:/Wilderness Management/Wilderness Character Monitoring/WCM data files/2 Natural/Climate Change indicator/Palmer drought index.xlsx> and NOAA National Climatic Data Center, Climate at a Glace Time Series: http://www.ncdc.noaa.gov/cag/time-series/us/21/01/pdsi/ytd/12/1977-2013?base_prd=true&firstbaseyear=1977&lastbaseyear=2013&trend=true&trend_base=10&firsttrendyear=1977&lasttrendyear=2013 *Collection protocol:* This measure tracks changes in the annual Palmer drought severity index (PDSI) value for the climate division of which the Tamarac Wilderness is located within, or the northwest climate division (#1) of Minnesota (Figure 7). This measure should be used congruently with all the other climate change measures to verify the trends that may be occurring separately within them, since this measure takes into account both temperature and precipitation. Visit the NOAA website and modify the end year to reflect the most recent full year of data. (If you want to plot the trend and average base period for comparison you will need to modify the years to reflect 1977-Present in the options window) Copy only the most recent years data in the first three columns of the data graph provided on the website (dates, value and rank) and paste the values in the Palmer drought index spreadsheet. (NOTE: the anomaly value is not the focus of this analysis, although it might be interesting to look at). Report the annual PDSI value in the database annually and document in the value comment field the assigned rank of the data. Although it is difficult to assess whether change in climate variables have a positive or negative impact on wilderness character, trends in this measure will be reported as either stable or significant change. Over time, a downward trend is assigned when a significant change has occurred. Perform a linear regression in Excel with α=0.1 every year for all data values since 1977 to evaluate significant change. Any significant trend is a significant change. For step-by-step instructions refer to APPENDIX F – How to perform a linear regression analysis in Excel.
2-12: Miles of wilderness boundary serving as an entry point for invasive species	M	*Data source:* Tamarac NWR share drive for all GIS data (timber management locations, trail heads, roads and burn locations) Miles boundary entry for invasives ArcMap file <S:/Wilderness Management/Wilderness Character Monitoring/GPS GIS Maps/Miles boundary entry for invasives.mxd> *Collection protocol:* Display all data in ArcGIS and analyze any changes in roads or trails adjacent to wilderness. Also check if any timber management or fire management projects have crossed into the

Measure	Priority (H, M, L)	Detailed Description of the Data Source(s) and Protocols for How the Data Were Gathered
		wilderness boundary. Measure the perimeter of wilderness affected by these disturbed locations in miles. If timber or fire units cross over into wilderness, perform an intersect in GIS (under geoprocessing) between the wilderness boundary and the timber or fire units. In the attribute table, add a 'length_mi' field and calculate geometry to get a number for the miles of wilderness boundary affected. Sum the total miles of wilderness boundary and report this value every 5 years. Over time, an increase in the miles of wilderness boundary serving as an entry point for invasive species produces a downward trend in this measure. When assigning a trend (stable, upward or downward) in the database, compare the current year data value to the previous year.
2-13: Index of connectivity	H	*Data source:* National Land Cover Database, USGS, Department of the Interior: http://www.mrlc.gov/index.php, connectivity ArcMap file <S:/Wilderness Management/Wilderness Character Monitoring/GPS GIS Maps/connectivity.mxd> and the connectivity spreadsheet <S:/Wilderness Management/Wilderness Character Monitoring/ WCM data files/2 Natural/Ecological Processes indicator/connectivity.xlsx> *Collection protocol:* Connectivity is measured by a scoring index that categorizes all adjacent land into simple numerical categories based on the degree of difference from wilderness, multiplied by the percent of the category's land cover within a 20 mile buffer of wilderness (Table 21). For step-by-step instructions refer to APPENDIX G – How to perform the analysis for measure 2-13: Index of connectivity to monitor this measure. The baseline year ('year measured' in the database) is 2014 but the analysis for this year is based on NLCD data from 2011. NLCD data is collected from Landsat imagery on a five year basis; the next year of data will be from 2016 imagery and the analysis should take place in 2019; 2019 will be the 'year measured' and 2016 will be the 'year of data collection' in the WCMD. An increase in the index value represents a decrease in connectivity while a decrease in the index value represents increased connectivity. Over time an increase in the index value produces a downward trend in this measure. Report this value every 5 years. When assigning a trend (stable, upward or downward) in the database, compare the current year data value to the previous year.
Undeveloped Quality		
3-1: Number of authorized structures, installations or developments	M	*Data sources:* Refuge Manager, structures, installations or developments data collection spreadsheet <S:/Wilderness Management/Wilderness Character Monitoring/ WCM data files/3 Undeveloped /struct_inst_develop.xlsx> *Collection protocol:* Count the total number non-recreational structures, installations or developments occurring in wilderness. Examples of things to include in this measure are water conveyance ditches and pipelines, stock tanks, mining structures, communication facilities, energy transmission facilities, road beds, instrument sites for gathering data, and refuge signs. In addition, large trash objects, such as motor vehicles,

Measure	Priority (H, M, L)	Detailed Description of the Data Source(s) and Protocols for How the Data Were Gathered
		aircraft, earth moving equipment, military and mining debris, or trash dumps may be included in this measure because they are signs of modern human occupation and they have comparable impacts on wilderness character as structures, installations or developments. The refuge wilderness boundary signs are not included in this measure as they are placed within the road right-of-way, which is not included in the wilderness boundary. Report this value every 5 years. An increase in the number of structures, installations or developments represents a downward trend in this measure. When assigning a trend (stable, upward or downward) in the database, compare the current year data value to the previous year.
3-2: Number of recreational structures, installations, or developments	M	*Data sources:* Refuge Manager, recreational structures, installations and developments data collection spreadsheet <S:/Wilderness Management/Wilderness Character Monitoring/ WCM data files/3 Undeveloped/recreational_struc_inst_develop.xlsx> *Collection protocol:* Count the total number of federally authorized or any unauthorized recreational structures, installations or developments occurring within wilderness. An increase in the number of recreational structures, installations or developments represents a downward trend in this measure Report this value every 5 years. When assigning a trend (stable, upward or downward) in the database, compare the current year data value to the previous year.
3-3: Acres of inholdings	M	*Data sources:* Refuge Manager *Collection protocol:* Count the total acres of inholdings within wilderness and report this value every 5 years. An increase in the number of acres represents a downward trend in this measure. This value is highly unlikely to change. When assigning a trend (stable, upward or downward) in the database, compare the current year data value to the previous year.
3-4: Index of authorized administrative uses of motorized vehicles, motorized equipment, or mechanical transport	M	*Data sources:* Special Use Permits, Refuge Manager, authorized mechanized use spreadsheet <S:/Wilderness Management/Wilderness Character Monitoring/ WCM data files/3 Undeveloped/authorized_mechanized_use. xlsx> *Collection protocol:* An inherent weight will be assigned to each equipment type based on its perceived impact to wilderness character. Motorized and mechanized equipment with a relatively low level of impact are assigned a value of "1", equipment with a moderate level of impact are assigned a value of "2", and equipment or transport with a high level of impact is assigned a value of "3". A "total use" value will be calculated for each event of motorized or mechanized use by multiplying the inherent weight of each type of equipment by the amount of use, accounting for the number of pieces and number of days used (Table 24). When reporting this value, consult the data collection spreadsheet. The resulting values for each motorized or mechanized use will be summed to generate a total score for the entire wilderness. This sum will be reported

Measure	Priority (H, M, L)	Detailed Description of the Data Source(s) and Protocols for How the Data Were Gathered
		in the WCMD on an annual basis. Over time, an increase in the index value represents a downward trend in this measure. When assigning a trend (stable, upward or downward) in the database, compare the current year data value to the previous year.
Solitude or Primitive and Unconfined Quality		
4-1: Percent of wilderness away from access or travel routes	M	*Data sources:* Aerial photos and Area away from access and travel routes ArcMap file <S:/Wilderness Management/Wilderness Character Monitoring /GPS GIS MAPS/Area way from access and travel routes.mxd> *Collection protocol:* Buffer any new or remnant trails used as travel routes within the wilderness boundary by ¼ mile. Open the area affected layer (the buffer around the travel route) and calculate the area based on acres. Subtract the area of the buffer from the total acres of wilderness, and then divide by the total acres of wilderness to obtain a percent (use 2,080 acres for the total northwest unit acreage to maintain GIS consistency). The three wilderness islands on Tamarac Lake were not included in this analysis because the methods of access and implications for wilderness character are very different from the rest of the wilderness area. Report the percent of wilderness away from access or travel routes in the WCMD every 5 years. Over time, a decrease in the percent of wilderness away from access or travel routes signifies a downward trend in this measure. When assigning a trend (stable, upward or downward) in the database, compare the current year data value to the previous year.
4-2: Percent of wilderness not affected by adjacent travel routes and human developments	H	*Data sources:* Becker County GIS website, Area affected ArcMap file <S:/Wilderness Management/Wilderness Character Monitoring/GPS GIS MAPS/Area affected travel routes Develop.mxd> *Collection protocol:* Follow the step-by-step protocol in APPENDIX H – How to perform the analysis for measure 4-2: Percent of wilderness not affected by adjacent travel routes and human developments for analysis of this measure. When calculating a percent, use a total acreage of the northwest unit of wilderness, 2,080 acres, to maintain GIS consistency. The wilderness Islands on Tamarac Lake were not included in the analysis for this measure due to their small size and location within Tamarac Lake. Over time, a decrease in the percent of wilderness not affected by adjacent travel routes and human developments represents a downward trend in this measure. Report this value every 5 years. When assigning a trend (stable, upward or downward) in the database, compare the current year data value to the previous year.
4-3: Number of facilities that decrease self-reliant recreation	M	*Data sources:* Refuge Manager and staff *Collection protocol:* Count the total number of facilities occurring within wilderness. An increase in the number of facilities represents a downward trend in this measure. Report this value every 5 years. When assigning a trend (stable, upward or downward) in the database, compare the current year data value to the previous year.

Measure	Priority (H, M, L)	Detailed Description of the Data Source(s) and Protocols for How the Data Were Gathered
4-4: Index of management restrictions on visitor behavior	M	*Data sources:* Comprehensive Conservation Plan, Refuge Manager *Collection protocol:* Consult Table 26 for the index scoring protocol and Table 27 for the weighting scheme for restrictions on visitor behavior in wilderness. Report the total index value every 5 years. An increase in the index value represents a downward trend in this quality. When assigning a trend (stable, upward or downward) in the database, compare the current year data value to the previous year.

APPENDIX D – Framework for Wilderness Character Monitoring

Framework for Wilderness Character Monitoring (excerpt from *Keeping It Wild,* pp. 16)

Overview

This interagency monitoring Framework is based on hierarchically dividing wilderness character into successively finer elements. These elements, starting from wilderness character, are:

- **Qualities**—primary elements of wilderness character that link directly to the statutory language of the 1964 Wilderness Act. In this Framework, all [five] qualities are necessary to assess trends in wilderness character and each wilderness would be required to report the trend for each quality.

- **Monitoring questions**—major elements under each quality that are significantly different from one another. Monitoring questions frame this monitoring to answer particular management questions. In this context, monitoring questions are similar to monitoring goals. Each wilderness and agency would be responsible for reporting on the trend for all eight monitoring questions.

- **Indicators**—distinct and important elements within each monitoring question. In nearly all cases, there is more than one indicator under a monitoring question. Each wilderness and agency would be responsible for reporting on the trend for all 13 indicators.

- **Measures**—a specific aspect of wilderness on which data are collected to assess trend of an indicator. In nearly all cases, there is more than one measure to provide each agency (and potentially each wilderness within an agency) a range of options for assessing trend in the indicator. Some of these measures are more accurate and precise but costly, while others are less accurate and precise but easier and less expensive to monitor. For example, under the indicator "Remoteness from sights and sounds of people inside wilderness" (see page 28 table 7), the measure "amount of visitor use" requires substantial effort and cost but is fairly precise. On the other hand, the measure "area of wilderness affected by access or travel routes" is fairly easy to compute in a Geographic Information System, but is not very precise because it doesn't assess the number of people inside the wilderness. This range of measures allows different agencies and wildernesses to choose the measure(s) that are relevant and practical. We recommend monitoring all the measures for which data are available to give the most accurate assessment possible and, if two or more measures are monitored, that they be equally weighted to prevent giving a biased trend in the indicator.

  For a few measures, the use of an "index" is recommended. In these cases, several attributes are considered simultaneously to assess trend and the different attributes may be weighted differently. For example, the index of physical development would combine the type and number of structures. Developing an index typically requires subjective judgments about the types of attributes to include, their relative weighting (for example, a dam has more impact than

an outhouse), and how they would be mathematically combined. In the detailed descriptions of the measures given in Appendix A, only the types of attributes are suggested—if this interagency strategy is implemented, each agency would need to develop these indexes based on their data capabilities and needs.

Each measure is used only once, under the quality that was deemed most relevant given the broad interagency perspective of this monitoring strategy. This approach avoids problems of double-counting some measures and the bias this would introduce. However, some measures are clearly relevant to more than one quality. Agency provided system trails, shelters, and toilets, for example, are relevant to both the undeveloped quality and the solitude or primitive and unconfined recreation quality. In such cases, different agencies (and different wildernesses if allowed by their home agency) may assign the measure to a different quality than what is presented in this framework. These differences are not nearly as important as consistency over time within an agency or wilderness because this monitoring strategy is based on assessing how wilderness character is changing only within a single wilderness.

If none of the recommended measures under a particular indicator are relevant to an agency or wilderness, other measures may be used or developed as long as the rationale is made clear for how the new measure is relevant to the indicator and how it is measurable, credible, and repeatable. For example, a wilderness may develop a measure that is relevant for assessing place-based aspects or other special features. We recommend that a wilderness character monitoring team within each agency be tasked to approve the use of such measures and communicate this use with the other wilderness management agencies.

APPENDIX E – What is a trammeling action

What is a trammeling action?

Peter Landres, Aldo Leopold Wilderness Research Institute

This appendix provides guidelines and examples to clarify what is and is not a trammeling action. These guidelines and examples are intended to capture about 90% of the cases and provide sufficient guidance for local staff to figure out the novel and rarer cases as they occur. This appendix does not discuss how to weight such actions, how to find or record the data for these actions, or any other aspect of using this information in wilderness character monitoring.

The following definitions are used in this appendix:

- *Trammeling action*: an action that intentionally manipulates "the earth and its community of life" inside a designated wilderness or inside an area that by agency policy is managed as wilderness.
- *Intentional:* done on purpose; deliberate; willful
- *Manipulation*: an action that alters, hinders, restricts, controls, or manipulates "the earth and its community of life" including the type, amount, or distribution of plants, animals, or physical resources inside a designated wilderness or inside an area that by agency policy is managed as wilderness.
- *Intentional manipulation*: an action that purposefully alters, hinders, restricts, controls, or manipulates "the earth and its community of life."

Based on these definitions, trammeling occurs when a manager makes a decision and takes action that intentionally manipulates the Natural Quality. Once action is taken the effect on the Natural Quality cannot typically be halted or stopped or reversed, and therefore the effect typically persists from the moment of the action onwards over time. Because of this persistent or permanent effect on "the earth and its community of life," managers need to think long and hard about these types of decisions.

Trammeling actions are often considered only in terms of how they degrade the Untrammeled Quality, but the agencies take such actions for many different reasons that support or sustain the other qualities of wilderness character. For example, actions taken to protect and sustain the Natural Quality include controlling or eradicating non-native species, restoring degraded habitat, or protecting species from harm such as installing gates across caves to prevent people from entering. Resource management actions in wilderness almost always involve tradeoffs, and while there may be valid and good reasons for taking trammeling actions, these actions nonetheless degrade the Untrammeled Quality. The framework of wilderness character simply allows agency staff to be transparent about these tradeoffs that might be involved in actions taken to improve the Natural Quality that degrade the Untrammeled Quality. The goal of using the framework of wilderness character is to help agency staff make the decision that is deemed best overall for preserving wilderness character.

The following sections describe three types of activities: those that are not trammeling actions, those that are trammeling actions, and those that may be trammeling actions.

Activities that are not trammeling actions

There are several types of activities that have caused considerable discussion about whether they are trammeling actions. Examples that have been discussed as possible trammeling actions include climate change, air pollutants that drift into a wilderness, escaped camp fires the burn in wilderness, and non-native species that disperse into a wilderness. Intentionality and the opportunity for management restraint are central tenets of the Untrammeled Quality, so if there is no opportunity for management restraint and no intention to manipulate the earth and its community of life, there is no impact on the Untrammeled Quality. In all of the examples cited above, there is no opportunity for management restraint and no intention to manipulate, so none of these examples would be counted as trammeling actions. There are certainly effects on the Natural Quality from these, and monitoring could track these effects.

Another group of examples have also caused lots of discussion, including installing meteorological or other science instrumentation, landing a helicopter for search and rescue operations, and removing trash. In each of these cases there is an opportunity for management restraint, but because there is no intention to manipulate the earth and its community of life, these are not considered trammeling actions. One last group of examples, including camping violations and unauthorized motorized incursions, are not considered trammeling actions because there is no opportunity for management restraint and there was no intention to manipulate the ecological system. In all of these examples there may be impacts to the other qualities of wilderness character, but not to the Untrammeled Quality.

Sport hunting has provoked an enormous amount of discussion about whether it degrades the Untrammeled Quality. The consensus view is that sport hunting is not a trammeling action because individual hunters are taking individual animals without the intention to manipulate the wildlife population. Like the other examples above, however, sport hunting, by affecting the abundance, distribution, and sex ratio of wildlife populations, may affect the Natural Quality; the presence of hunters may affect the Solitude or Primitive and Unconfined Recreation Quality; and structures built by hunters may affect the Undeveloped Quality.

Activities that are trammeling actions

There are two broad classes of activities that are trammeling actions, those that are authorized by the federal wilderness manager and those that are not. Under each of these broad classes there are several subclasses that reflect whether the action is taken on a biological resource or a physical resource, and whether the effect of the action is on a biological or physical resource. (This might seem like an unnecessary nuance but experience has shown that these distinctions help staff understand what trammeling actions are.) Almost always the concern is for actions that occur inside a designated wilderness, but one subclass provides examples of actions taken outside a designated wilderness that would be included as a trammeling action because the intention is to affect biological or physical resources inside the wilderness.

In some situations, staff may assume that they do not have the opportunity for restraint and therefore assume that their actions do not degrade the Untrammeled Quality. Examples of such situations include restoring habitat for a listed endangered species, spraying herbicides to eradicate an invasive non-native plant that is degrading wildlife habitat, transplanting an extirpated species back into the wilderness, or suppressing a naturally-ignited fire to save timber or homes adjacent to the wilderness. However, even in these situations, staff are deciding to take action as well as the type and intensity of action. In some of the examples above, staff are taking an action that supports one law (such as the Endangered Species Act) that degrades another (in this case the Wilderness Act).

Agency authorized trammeling actions. These are actions that are authorized by the federal wilderness manager as well as actions by other agencies, organizations, or individuals that have been approved or permitted by the federal land manager.

1. Actions taken inside the wilderness on vegetation or fish and wildlife to intentionally and directly affect this vegetation or fish and wildlife. Examples include:
    a. Removing or killing native vegetation or fish and wildlife
    b. Adding or restoring native vegetation or fish and wildlife
    c. Adding non-native vegetation for erosion control
    d. Adding non-native fish and wildlife
    e. Spraying chemicals to control non-native vegetation or fish and wildlife
    f. Releasing biocontrol agents to control non-native vegetation or fish and wildlife
    g. Collecting vegetation for scientific study
    h. Collecting or capturing and releasing fish and wildlife for scientific study
    i. Collecting vegetation or fish and wildlife for commercial purposes
    j. Enclosing or excluding fish and wildlife from an area to protect vegetation or to study the effects of enclosing or excluding fish and wildlife on protecting vegetation or animals
    k. Adding piscicides to water to eliminate non-native fish

2. Actions taken inside the wilderness on a physical resource to intentionally and directly affect this physical resource. Examples include:
    a. Suppressing naturally-ignited fire
    b. Lighting fire (under management prescription) to reduce fuels or for other purposes
    c. Constructing or maintaining a dam or diversion structure to alter the quantity or seasonal flow of water
    d. Constructing a road to allow access to mineral, oil, or gas leases; communication sites; or inholdings

3. Actions taken inside the wilderness on a physical resource that intentionally affects the physical resource to directly or indirectly affect vegetation or fish and wildlife. Examples include:
    a. Installing a gate across a cave that will protect bats but exclude other animals from using the cave
    b. Constructing or maintaining a range allotment fence
    c. Constructing a dam to exclude non-native species from moving up or down a stream

d. Installing guzzlers to provide water for wildlife
e. Lighting fire (under management prescription) or any other vegetation manipulation to improve wildlife habitat
f. Adding acid-buffering limestone to water to neutralize the effects of acid deposition on aquatic flora and fauna

4. Actions taken outside the wilderness on a physical or biological resource to intentionally and directly affect that resource inside a wilderness. Examples include:
   a. Cloud seeding that occurs above the wilderness, and is therefore outside it, to intentionally increase precipitation inside the wilderness
   b. Damming a river outside a wilderness to intentionally create a lake or water storage area inside the wilderness
   c. Killing fish and wildlife outside the wilderness to intentionally affect the population or distribution of this species inside the wilderness
   d. Planting or stocking fish and wildlife outside the wilderness to intentionally or foreseeably affect the population or distribution of this species inside the wilderness because of known habitat inside the wilderness

Not authorized trammeling actions. These are citable and other actions taken by other agencies, organizations, or individuals that have not been authorized, approved, or permitted by the federal wilderness land manager.

1. Actions taken inside the wilderness on vegetation or fish and wildlife to intentionally and directly affect this vegetation or fish and wildlife. Examples include:
   a. Adding vegetation or fish and wildlife by a federal agency (other than the federal land managing agency), a state agency, or the public
   b. Removing vegetation or fish and wildlife by a federal or state agency or the public
   c. Inclosing or excluding fish and wildlife to study the effects of inclosing or excluding on vegetation or fish and wildlife

2. Actions taken inside the wilderness on a physical resource to intentionally and directly affect this resource. Examples include:
   a. Modifying water flow to store water or alter the timing of water flow
   b. Setting arson fire

3. Actions taken inside the wilderness on a physical resource that intentionally affects the physical resource to intentionally (either directly or indirectly) affect vegetation or fish and wildlife. Examples include:
   a. Modifying water resources to provide water for wildlife

4. Actions taken outside the wilderness on vegetation or fish and wildlife to intentionally and directly affect the occurrence or distribution of these or other species inside a wilderness. Examples include:

a. Releasing species outside a wilderness with the intention to affect a population whose range expands into the wilderness
b. Killing wildlife outside of the wilderness with the intention to affect populations whose ranges expand into the wilderness

Activities that may be trammeling actions

In many cases deciding whether an activity is a trammeling action is straightforward, but in other cases this decision is more complex and nuanced. These nuanced cases typically involve some type of action where the intent is not to manipulate the "earth and its community of life" but some manipulation of the environment is required to produce a desired outcome, such as building a trail. These nuanced cases may be confusing because even though the primary intent is not to manipulate species or physical resources, action is intentionally being taken and this action may have a foreseeable and substantial effect on "the earth and its community of life."

In Table 28 below, several hypothetical situations illustrate how an action may or may not be a trammeling depending on the scope and scale of the action and its effects. Each bullet in the table presents a situation where the action being taken likely would, or would not, be considered a trammeling. For every real situation, agency staff need to think through whether the proposed action will have a foreseeable and substantial effect on "the earth and its community of life" and if their answer is "yes" then it's a trammeling action, and if the answer is "no" then it's not a trammeling action. Also, in this table an action may not be a trammeling but it still may affect other qualities of wilderness character. For example, installing rebar monumentation for a science project would likely not be a trammeling, but such installations would likely degrade the Undeveloped Quality.

Table 28: Examples of actions that likely are, and likely are not, trammeling actions.

ACTION	LIKELY NOT A TRAMMELING	LIKELY A TRAMMELING
Building system trail	• Routing a trail needs around a rock slide that obliterated the former trail • Building a bridge across a stream to prevent stream bank erosion • Installing a small section of corduroy across a wet area to prevent trenching • Installing in water bars • Removing rock in a trail • Building rock-cribbing to support a trail	• Routing a trail through an area of endangered alpine butterfly habitat • Building a large amount of new trail to go around a section of a river or a cliff • Building a trail that requires extensive earth movement or tree cutting
Obliterating non-system trail	• Piling vegetation or rocks at the beginning and end of trail sections that cut a switchback • Piling vegetation or rocks to block social trails around campsites	• Obliterating a large section of non-system trail that requires extensive earth movement

ACTION	LIKELY NOT A TRAMMELING	LIKELY A TRAMMELING
Restoring campsites	• Restoring a single, isolated campsite • Restoring a number of campsites (e.g., that are clustered around a lake) that doesn't require degrading the soil or vegetation in the surrounding area	• Restoring a number of campsites that does require moving a significant amount of soil or number of plants in the surrounding area
Closing caves	• Installing a bat gate across one or a few caves of many in the area	• Installing bat gates across all the caves in an area
Removing hazard trees	• Removing one or a few hazard trees that threaten designated campsites or that are along a trail	• Removing all of the hazard trees over a large area
Treating non-native invasive plants	• Hand pulling a small area of non-native invasive plants	• Spraying any herbicide
Permitting scientific activities	• Installing research plot monumentation, such as rebar stakes or nails • Installing most scientific instrumentation • Collecting a limited number of voucher specimens with no impact species distribution or abundance	• Installing enclosures or exclosures that affect the movement of fish and wildlife • Installing instrumentation that disrupts the movement or behavior of plants, or fish and wildlife • Collecting voucher specimens that does affect the species distribution or abundance

APPENDIX F – How to perform a linear regression analysis in Excel

This appendix explains how to interpret trends using a statistical regression analysis.

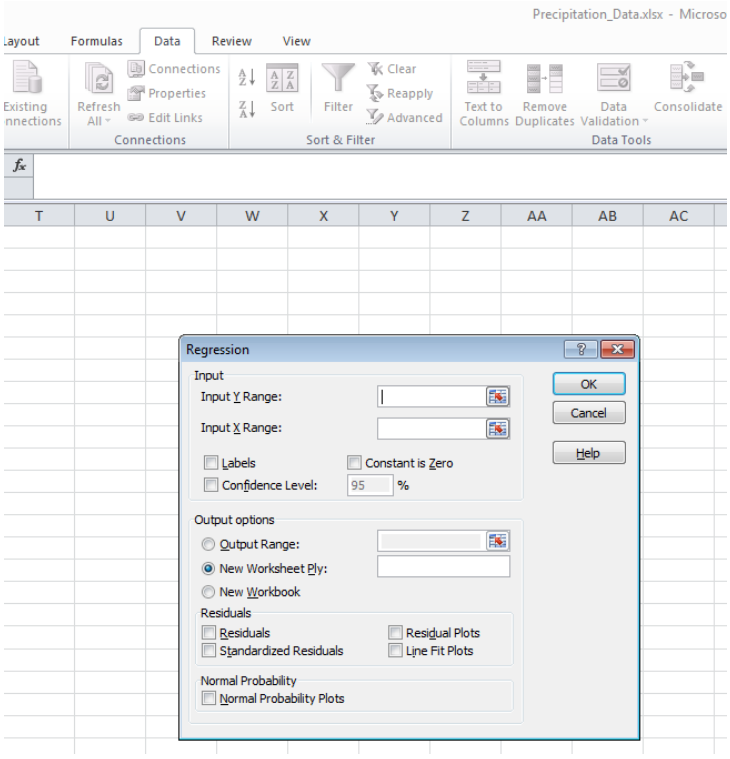
Only measures that have five or more data points can use a regression analysis. The 0.1 alpha level is suggested by the *Forest Service Technical Guide* (page 227) and has been chosen in this monitoring strategy to evaluate whether a trend in the data is significant or not. This trigger point is based on how much randomness is acceptable in identifying a significant change. For example, the 0.1 threshold means that there is a 10% chance that this trend is occurring at random and there is a 90% chance that this trend is real. This alpha level was selected because it represents an appropriate balance between the need to catch trends early enabling managers to take corrective actions sooner, while maintaining as much statistical rigor as possible in correctly identifying significant trends.

1. Make sure there is the "Analysis ToolPak" Add-In installed on the computer. Under the 'Data' tab all the way to the right should be a 'Data Analysis' button. If not, add the tool by selecting the 'File' tab, then 'Options'. Under the 'Add-Ins' section locate the "Analysis ToolPak" and click ok to add to Excel.
2. Open the spreadsheet with the data to be analyzed and click on the "Data Analysis" button under the 'Data' tab. Choose 'Regression'
3. Input the data values into the next screen that pops up:

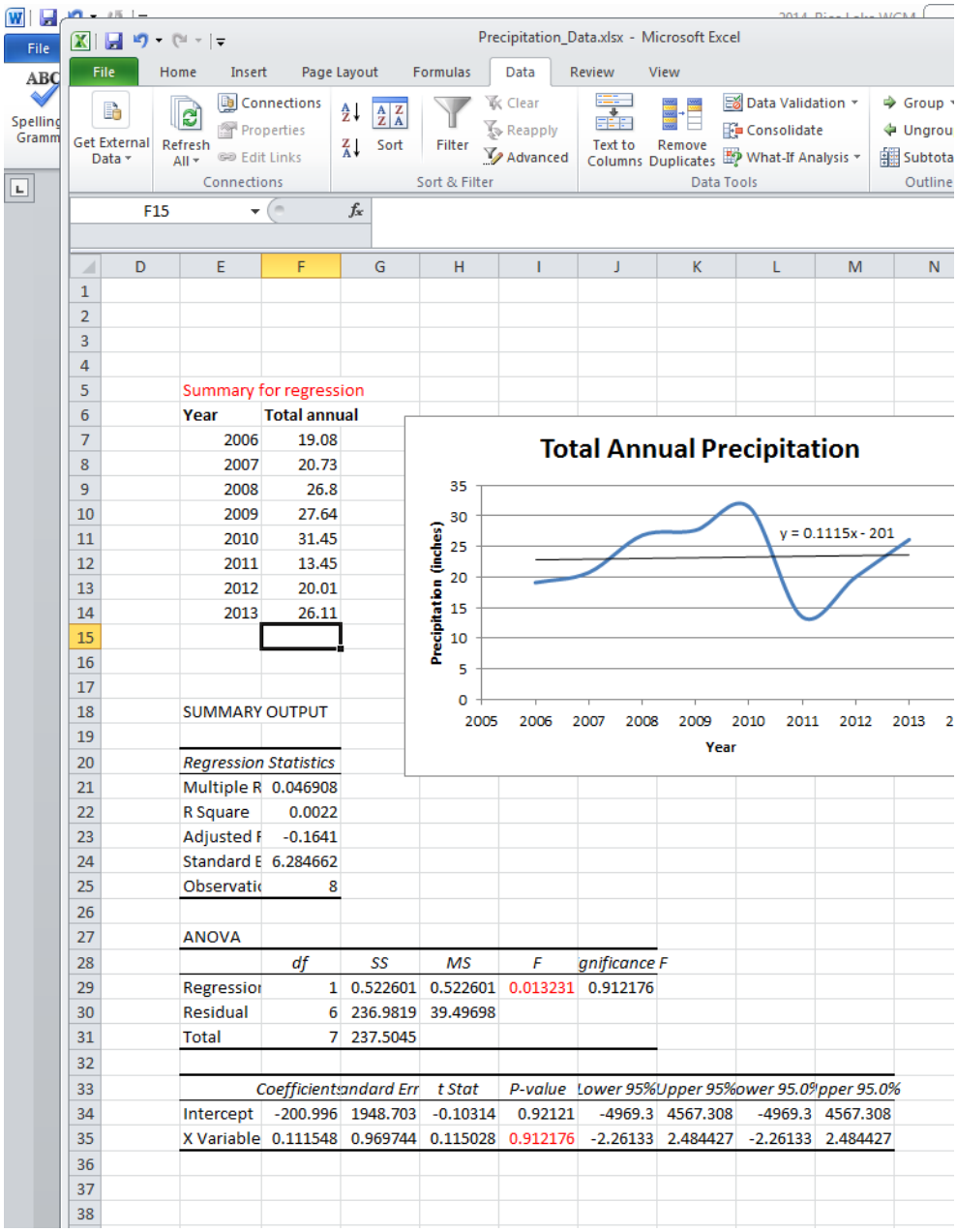
   Input Y Range: dependent variable (Y-axis data), the data value that is being measured

   Input X Range: independent variable (X-axis data), the corresponding data year

   Leave all other spaces as they are and click ok to produce results.



4. The worksheet will spit out the summary output. The two values to report include the 'F-value' under the heading ANOVA, and the p-value (X variable). These values have been highlighted in red for the baseline analysis spreadsheets. The value that determines whether you have a significant trend in the data is the p-value (x variable). If this value is less than 0.1, it is considered significant.

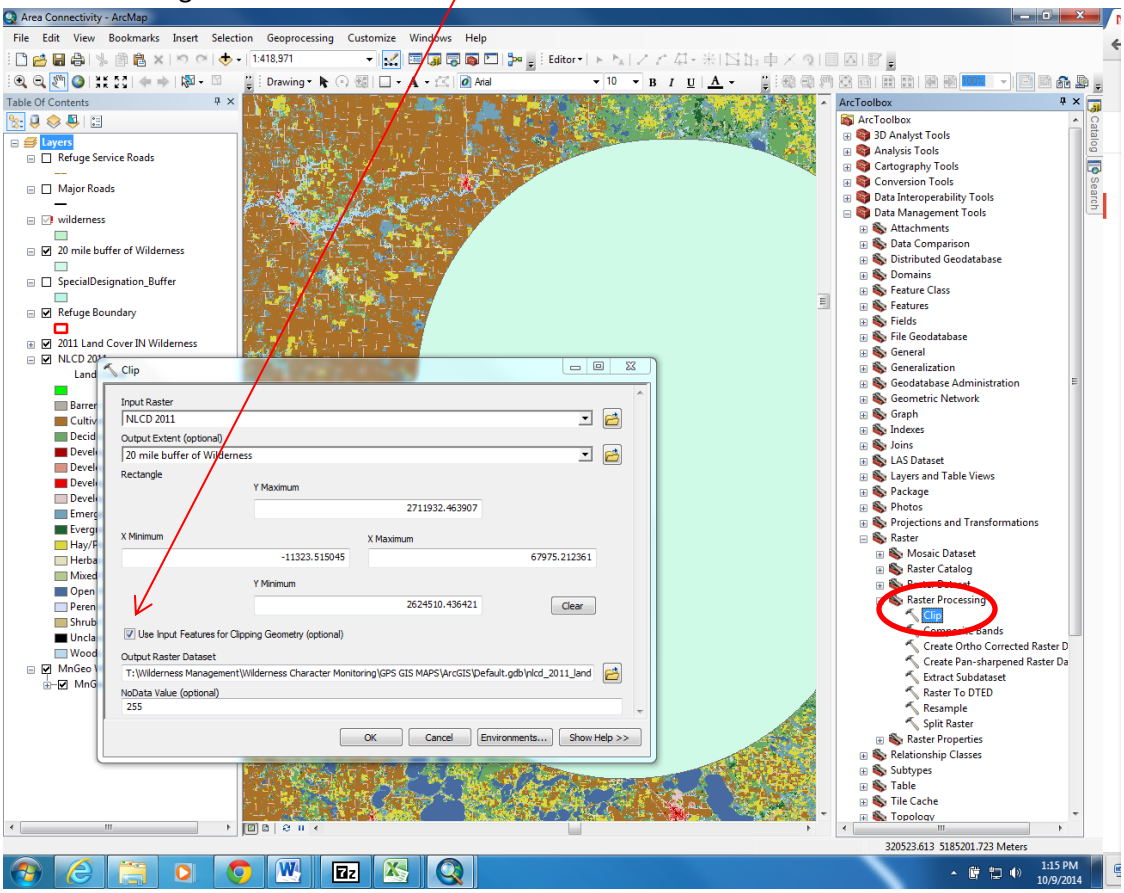


APPENDIX G – How to perform the analysis for measure 2-13: Index of connectivity

1. Download the latest version of National Land Cover Data (NLCD) from MRLC website (http://www.mrlc.gov/index.php). Save the file in the following folder under the respective year <S:/Wilderness Management/GPS GIS Maps/NLCD data>. Once the file has been downloaded, it will need to be unzipped before it can be used. After unzipping the file, add the data to the connectivity ArcMap file located at <S:/Wilderness Management/Wilderness Character Monitoring/ GPS GIS Maps/connectivity.mxd>

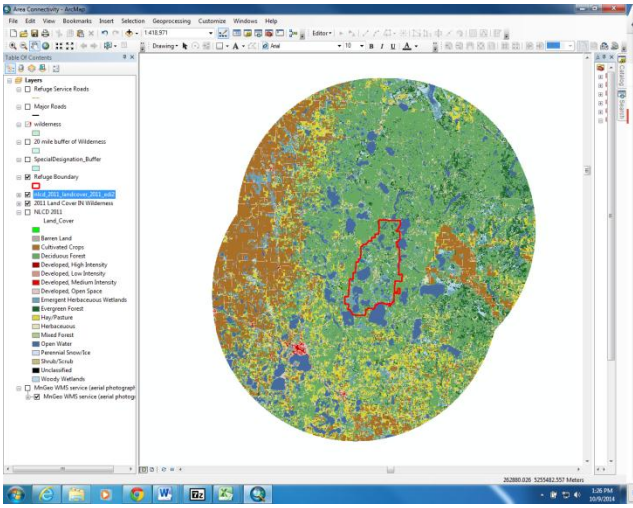
2. Make sure the '20 mile buffer of wilderness' layer is active on the map. If not, to create a 20 mile buffer, under the Geoprocessing tab select 'buffer'. The input features should be the layer 'Tamarac Wilderness'. Set the linear unit distance as 20 miles. Since the wilderness is composed of separate units, the 20 mile buffer will need to be dissolved into one contingious shape. To do this, under the Geoprocessing menu select 'dissolve' and choose the buffer layer as the inupt features.

3. The next steps will be to clip the land cover data to both the 20 mile buffer and the Tamarac Wilderness boundary. This tool will be executed TWICE. Under the Arc Toolbox navigate to the 'clip' function under the Raster Processing tool. The input raster will be the most recent Land Cover data that was just added to the map document. The output extent will be: 1) the 20 mile buffer of wilderness, and 2) the Tamarac Wilderness boundary (The tool will be executed two separate times). Make sure the box reading 'Use input features for clipping geometry (optional)' is checked before executing the tool both times.

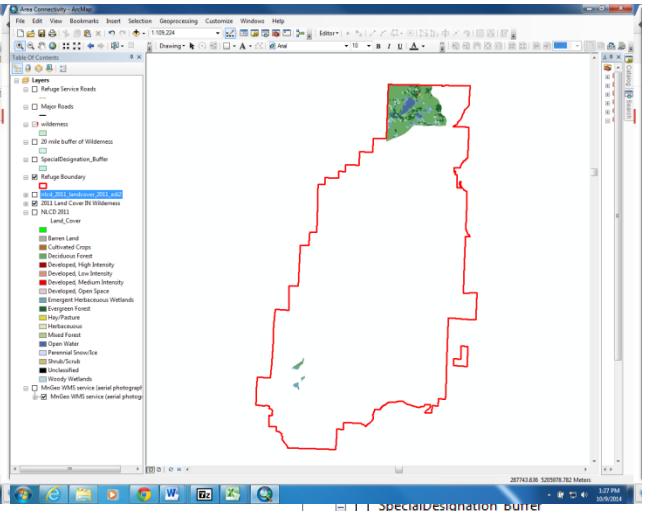


The results should look like this:

20 mile buffer of wilderness

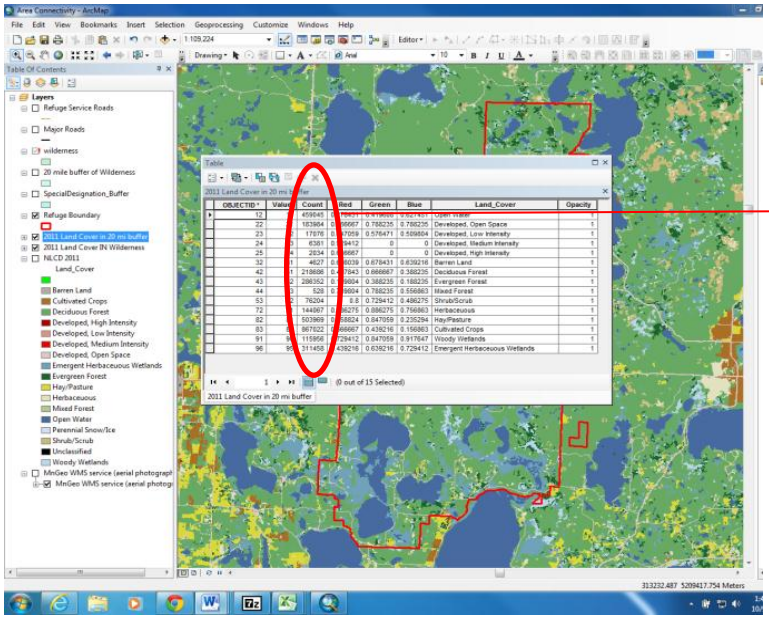


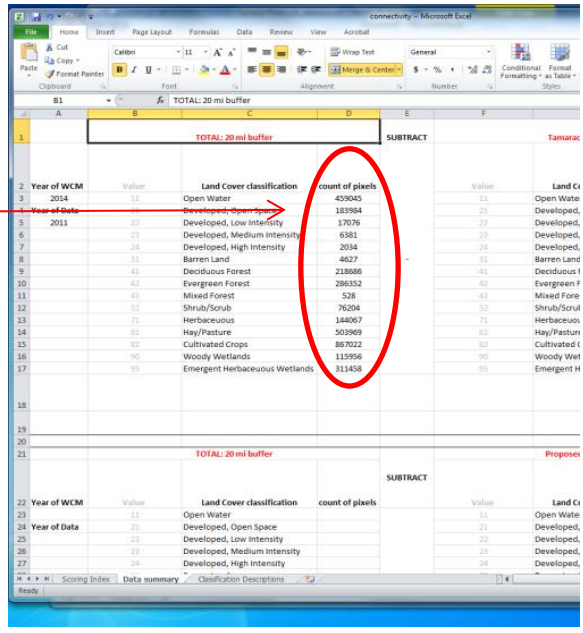
Tamarac Wilderness boundary

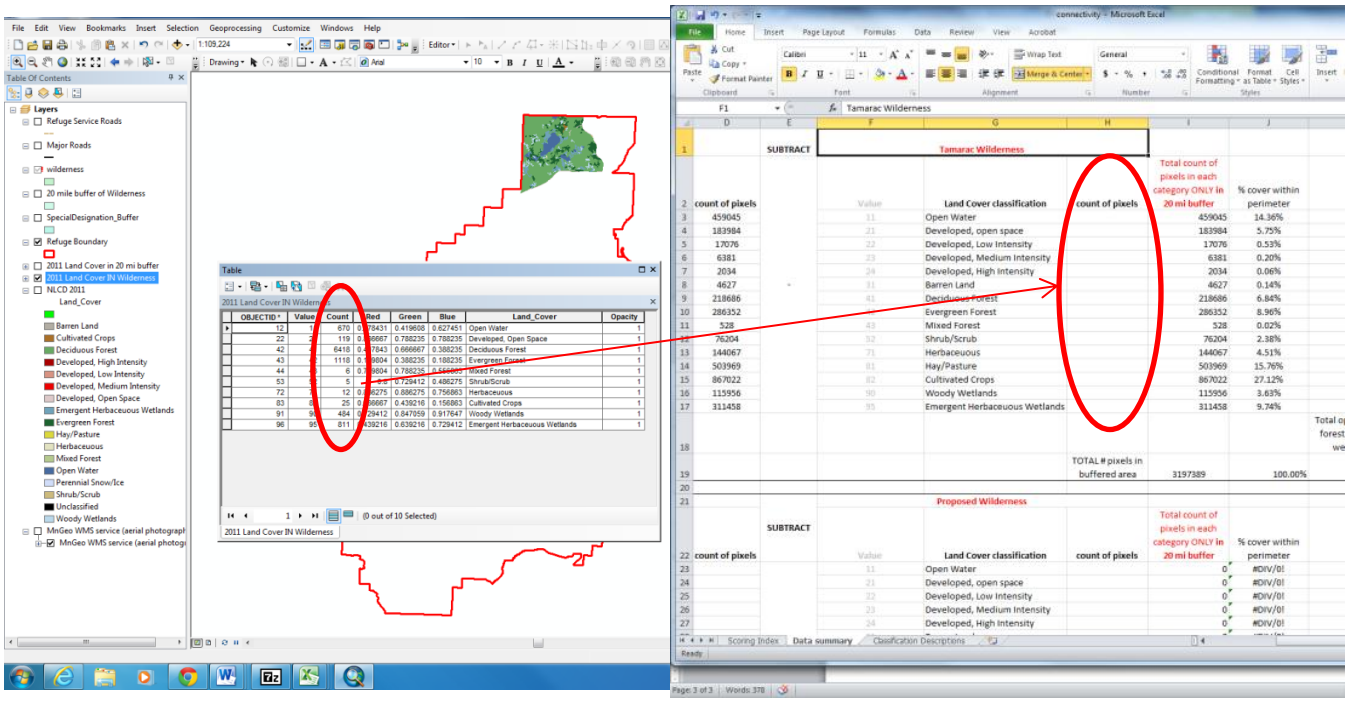


To keep order in the map document, re-name the clipped raster data to reflect what the data represents.

4. Open the connectivity spreadsheet on the share drive <S:/Wilderness Management/Wilderness Character Monitoring/WCM data files/2 Natural/Ecological Processes indicator/connectivity.xlsx> This step requires documenting the number of pixels in each land cover category in both the buffer and wilderness boundary under the 'data summary' tab of the spreadsheet. To find the number of pixels, open the attribute table of each layer: 1) the 20 mile buffer, and 2) the Tamarac Wilderness. Extract the number in the 'count' column for each category and record the numbers in the spreadsheet. Equations are already set up and built into this spreadsheet so you may notice some columns starting to populate with numbers as you are entering data.







5. The next step requires transferring the percent cover within the buffered perimeter area of each category from the 'data summary' tab to the 'scoring index' tab. To eliminate data entry errors, just reference the location of the data from one tab to the other in the form of a function in the cell. Under the '% cover within 20 mile buffer of wilderness' column of the scoring index tab enter an equals sign and navigate to the categories percent on the 'data summary' tab. You are just directing excel to connect the cells in each tab. All of the equations in this tab are also built in so as you are entering the data, cells will begin to populate.

6. For purposes of this monitoring strategy, the categories of open water, deciduous forest, evergreen forest, mixed forest, shrub/scrub, herbaceous, emergent herbaceous wetlands, and woody wetlands are lumped into one category when calculating the scoring index because they reflect the same land cover of land within wilderness and do not have any degree of difference.

   When updating the WCM online database, report the total index score for the Tamarac Wilderness. The equations are built into the connectivity spreadsheet, as numbers are entered the index score should appear. The index value score is obtained by multiplying the category of land use's degree of difference from wilderness value by the percent cover within the 20 mi buffered perimeter of wilderness. Each categories score is then summed to get the total index score. An increase in the index value represents a decrease in connectivity, while a decrease in the index value represents an increase in connectivity. Over time, an increase in the index value produces a downward trend in this measure. Report this value every 5 years.

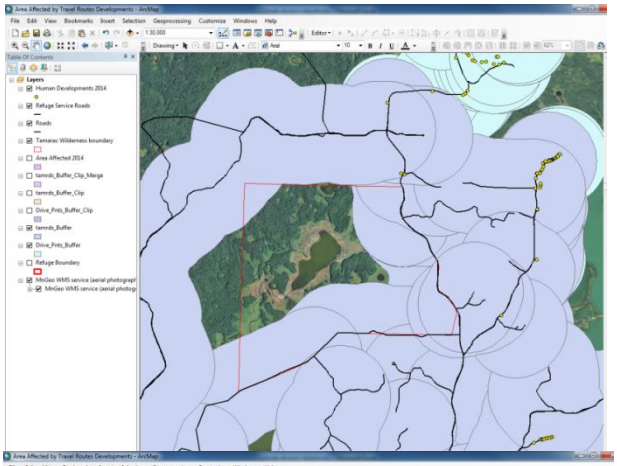
APPENDIX H – How to perform the analysis for measure 4-2: Percent of wilderness not affected by adjacent travel routes and human developments

1. Visit the Becker County GIS website http://www.co.becker.mn.us/online_services/GIS_data.aspx and download the drive points file (which indicates human developments by marking driveways) and the roads layer file. Save the data in the following folder <S:/Wilderness Management/Wilderness Character Monitoring/GPS GIS MAPS/Data downloaded from Becker County> Data will be in shapefile format. Open the associated ArcMap file on the share drive <S:/Wilderness Management/Wilderness Character Monitoring/GPS GIS MAPS/Area Affected by Travel Routes Developments.mxd>

2. The Map will already have the wilderness boundary layer and the results from the 2014 analysis in the table of contents. Add the downloaded data from the Becker County website to the map, both the drive points layer and the roads layer.

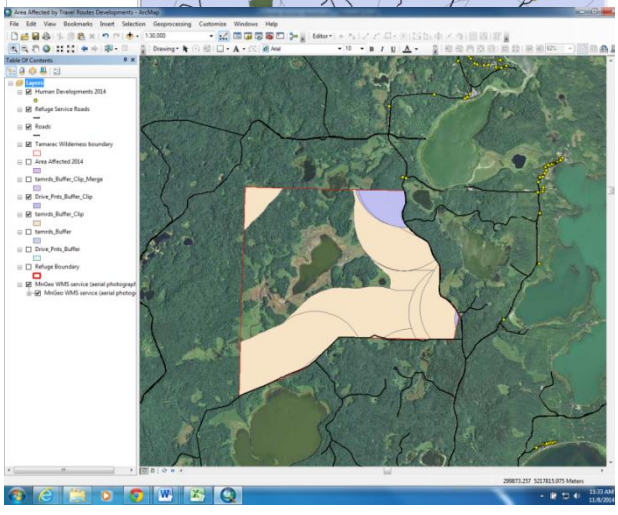
3. Buffer the drive points and roads layers by 0.5 mile. Each layer will need to be buffered separately, so perform the buffer tool twice (On the top menu, Geoprocessing, Buffer). If the buffer tool initially fails, try turning on the 'background processing' option and try the tool again (Geoprocessing, geoprocessing options, and check the box labeled enable). The input feature will be both the drive points layer and the roads layer (again the tool will be performed twice seperatly for each layer).

   The outcome should look something similar to this →



4. Once all of the layers have associated buffers, clip the buffer layers to the wilderness boundary (On the top menu, Geoprocessing, Clip). The input feature will be the buffer layers that were just created and the output feature will be the Tamarac Wilderness boundary layer. This tool will need to be run twice for each separate buffer layer as well.

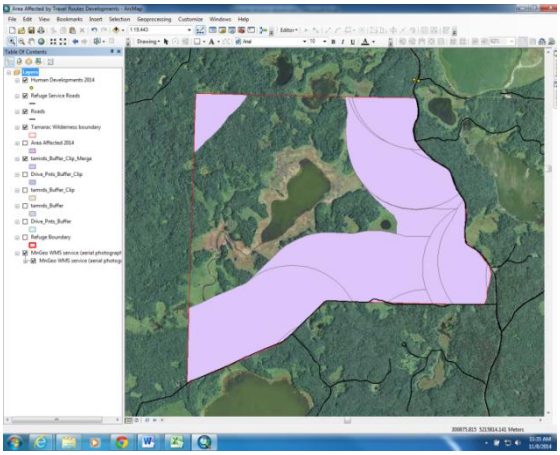
   The outcome should look something similar to this →



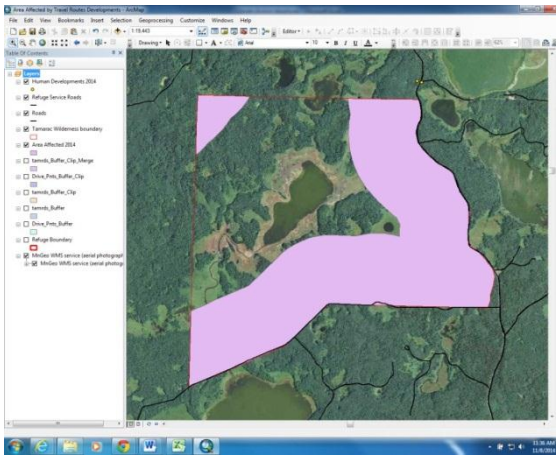
5. Once the buffers are clipped to the wilderness, merge the layers (On the top menu, geoprocessing, merge). The input data sets for the merge tool will be all of the clipped buffer layers. The final step

to obtain an area will be to dissolve the merged layer (on the top menu, geoprocessing, dissolve). The input feature will be the clipped and merged layer that was just created in the previous step.

After the merge is complete:



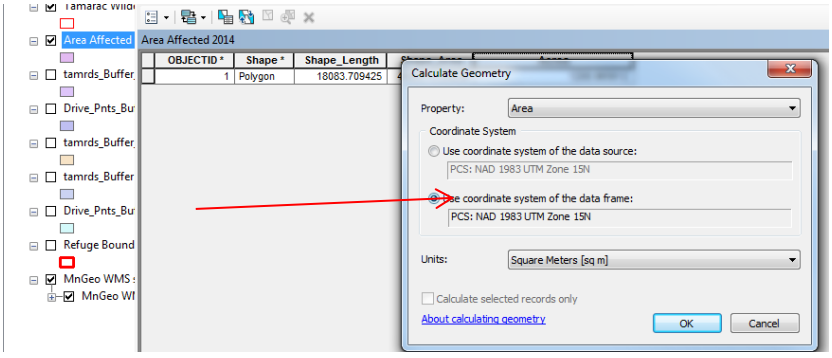
After the dissolve is complete:



6. Rename the dissolved layer that was created in the previous step 'Area affected XXXX' and fill in the X's with the year the analysis is completed.

7. Use the attribute table of the 'area affected' layer to calculate the area of wilderness in the dissolved buffer zone. To do this, right click on the layer in the table of contents and open the attribute table, then on the menu button choose add a field to the attribute table. Choose a name for the field that will be used to calculate the area affected in acres (be sure to add acres into the name so you know what the units are; the name cannot contain any spaces). Specify the type to be 'double'.

8. On the added field, right click and choose 'calculate geometry' (in acres). On the prompted window be sure to choose the option that bases the calculation on the coordinate system OF THE DATA FRAME, not the data source (this will be the second bullet option).



9. The number calculated represents the acreage of wilderness that is affected by adjacent travel routes and human developments (round the number up to the nearest whole number). Subtract this number from the total acreage of the wilderness boundary (2080 acres for GIS consistency) and then divide by the total acreage (2080) to obtain the percent of wilderness not affected. Report the percentage in the WCM database.