National Park Service
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Natural Resource Stewardship and Science

Theodore Roosevelt National Park

Natural Resource Condition Assessment

Natural Resource Report NPS/THRO/NRR—2014/776

ON THE COVER
River Bend Overlook in the North Unit of Theodore Roosevelt National Park
Photograph by: (Shannon Amberg, SMUMN GSS)

Theodore Roosevelt National Park

Natural Resource Condition Assessment

Natural Resource Report NPS/THRO/NRR—2014/776

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Acronyms and Abbreviations

BBS – Breeding Bird Survey

BCR – Bird Conservation Region

CCC – Civilian Conservation Corps

dNBR – Differenced Normalized Burn Ratio

EAB – Emerald Ash Borer

EPA – Environmental Protection Agency

EPMT – Exotic Plant Management Team

FMP – Fire Management Plan

GIS – Geographic Information System

GPRA – Government Performance and Results Act

IMBCR – Integrated Monitoring in Bird Conservation Regions

IRMA – Integration of Resource Management Applications

LMNG – Little Missouri National Grassland

NGPN – Northern Great Plains Inventory and Monitoring Network

NPS – National Park Service

NRCA – Natural Resource Condition Assessment

RMBO – Rocky Mountain Bird Observatory

SMUMN GSS – Saint Mary's University of Minnesota GeoSpatial Services

SWE – Snow Water Equivalent

THRO – Theodore Roosevelt National Park

USFS – United Stated Forest Service

USGS – United States Geological Survey

WCS – Weighted Condition Score

WICA – Wind Cave National Park

WNDD – Wyoming Natural Diversity Database

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Executive Summary

The Natural Resource Condition Assessment (NRCA) Program aims to provide documentation about the current conditions of important park natural resources through a spatially explicit, multi-disciplinary synthesis of existing scientific data and knowledge. Findings from the NRCA, including the report and accompanying map products, will help THRO managers to develop near-term management priorities; engage in watershed or landscape scale partnership and education efforts; conduct park planning (e.g., Resource Stewardship Strategy); and report program performance (e.g., Department of the Interior's Strategic Plan "land health" goals, Government Performance and Results Act).

The objectives of this assessment are to evaluate and report on current conditions of key park resources, to evaluate critical data and knowledge gaps, and to highlight selected existing stressors and emerging threats to resources or processes. For the purpose of this NRCA, staff from the National Park Service (NPS) and Saint Mary's University of Minnesota – GeoSpatial Services (SMUMN GSS) identified key resources, referred to as "components" in the project. The selected components include natural resources and processes that are currently of the greatest concern to park management at THRO. The final project framework contains 17 resource components, each featuring discussions of measures, stressors, and reference conditions.

This study involved examining exisiting literature and short- or long-term datasets, as well as expertise from NPS and other outside agency or organization scientists to provide summaries of current condition and trends in featured resources. When possible, existing data for the established measures of each component is compared to designated reference conditions. A weighted scoring system was applied to calculate the current condition of the components. Weighted condition scores, ranging from zero to one, were divided into three categories of condition: low concern, moderate concern, and significant concern. These weighted condition scores help determine the overall current condition of each resource. The discussions for each component, found in Chapter 4 of this report, represent a comprehensive summary of current available data and information for these resources, as well as unpublished park information and perspectives of park resource managers, and present a current condition designation when appropriate. Each component assessment was subjected to review by THRO park resource managers and NPS Northern Great Plains Network Inventory and Monitoring specialists.

In a number of cases, data are unavailable or insufficient for many of the measures of the featured components in this assessment. In other instances, data that establishes reference condition were limited or unavailable for components, making comparisons with current information inappropriate or invalid. Thus, in these cases, it was not possible to assign condition for these components. Current condition was not able to be determined for 10 of the 17 components (58%) due to these significant data gaps.

For those components with more available data, the overall conditions assigned varied. For some components, enough data exist to determine a trend in condition over time; however, for others the lack of long-term or comparable data prevented the determination of trends. Several components were determined to be in good condition with a stable trend, including air quality, the prairie dog population, water quality, and fire. Flooding on the Little Missouri River in the park was determined to have a condition of moderate concern but with a stable trend, meaning the condition is not believed to be degrading or improving from past conditions. Native grasslands and woody draws were also determined to be of moderate concern, but a lack of historical data does not allow for designating a trend in condition over time. A detailed discussion of these designations is presented in Chapter 5 of this report.

Several threats and stressors were identified as park-wide influences on the condition of resources in THRO. Those of primary concern include establishment of non-native and invasive species, increased oil and gas industry development, and air pollution, especially increased emissions from nearby oil, gas, and power plant development.

Major changes in vegetation communities, from native to more non-native species, could have a significant impact on the animal species that use these communities for habitat. A more complete understanding of the prevalence of non-natives in the different vegetation communities throughout the park would help managers strategize about potential management actions.

Land development around THRO is mainly associated with the growth and expansion of the oil and gas industry. This development has increased exponentially in western North Dakota and around THRO over the last decade. Such development affects different aspects of park resources, including impacts to viewsheds with the building of new structures that can be seen from various points in the park, impacts to soundscapes with increased industrial activity and vehicle traffic at development sites, and greater stresses to air quality from increased vehicle and industrial emissions.

This assessment serves as a review and summary of available data and literature for featured components in the park. The information presented here may serve as a baseline against which any changes in condition of components in coming years may be compared. Establishing a number of monitoring programs would begin to fill in data gaps for the resources viewed as important by THRO managers and would help managers better understand the current state of these resources throughout the park. Of those components that had sufficient available information, current condition was determined to be either good or of moderate concern. Understanding this can help managers prioritize management objectives and better focus conservation strategies.

Chapter 1 NRCA Background Information

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national park units, hereafter "parks". For these condition analyses they also report on trends (as possible), critical data gaps, and general level of confidence for study findings. The resources and indicators emphasized in the project work depend on a park's resource setting, status of resource stewardship planning and science in identifying high-priority indicators for that park, and availability of data and expertise to assess current conditions for the things identified on a list of potential study resources and indicators.

NRCAs represent a relatively new approach to assessing and reporting on park resource conditions. They are meant to complement, not replace, traditional issue and threat-based resource assessments. As distinguishing characteristics, all NRCAs:

NRCAs Strive to Provide…

Credible condition reporting for a subset of important park natural resources and indicators

Useful condition summaries by broader resource categories or topics, and by park areas

- are multi-disciplinary in scope[1]
- employ hierarchical indicator frameworks[2]
- identify or develop logical reference
- conditions/values to compare current condition data against[3,4]
- emphasize spatial evaluation of conditions and GIS (map) products[5]
- summarize key findings by park areas[6]
- follow national NRCA guidelines and standards for study design and reporting products

Although current condition reporting relative to logical forms of reference conditions and values is the primary objective, NRCAs also report on trends for any study indicators where the underlying data and methods support it. Resource condition influences are also addressed. This can include past activities or conditions that provide a helpful context for understanding current

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[1] However, the breadth of natural resources and number/type of indicators evaluated will vary by park.
[2] Frameworks help guide a multi-disciplinary selection of indicators and subsequent "roll up" and reporting of data for measures ⇨ conditions for indicators ⇨ condition reporting by broader topics and park areas.
[3] NRCAs must consider ecologically-based reference conditions, must also consider applicable legal and regulatory standards, and can consider other management-specified condition objectives or targets; each study indicator can be evaluated against one or more types of logical reference conditions.
[4] Reference values can be expressed in qualitative to quantitative terms, as a single value or range of values; they represent desirable resource conditions or, alternatively, condition states that we wish to avoid or that require a follow-on response (e.g., ecological thresholds or management "triggers").
[5] As possible and appropriate, NRCAs describe condition gradients or differences across the park for important natural resources and study indicators through a set of GIS coverages and map products.
[6] In addition to reporting on indicator-level conditions, investigators are asked to take a bigger picture (more holistic) view and summarize overall findings and provide suggestions to managers on a area-by-area basis: 1) by park ecosystem/habitat types or watersheds, and 2) for other park areas as requested.

park resource conditions. It also includes present-day condition influences (threats and stressors) that are best interpreted at park, watershed, or landscape scales, though NRCAs do not judge or report on condition status per se for land areas and natural resources beyond the park's boundaries. Intensive cause and effect analyses of threats and stressors or development of detailed treatment options is outside the project scope.

Credibility for study findings derives from the data, methods, and reference values used in the project work—are they appropriate for the stated purpose and adequately documented? For each study indicator where current condition or trend is reported it is important to identify critical data gaps and describe level of confidence in at least qualitative terms. Involvement of park staff and National Park Service (NPS) subject matter experts at critical points during the project timeline is also important: 1) to assist selection of study indicators; 2) to recommend study data sets, methods, and reference conditions and values to use; and 3) to help provide a multi-disciplinary review of draft study findings and products.

NRCAs provide a useful complement to more rigorous NPS science support programs such as the NPS Inventory and Monitoring Program. For example, NRCAs can provide current condition estimates and help establish reference conditions or baseline values for some of a park's "Vital Signs" monitoring indicators. They can also bring in relevant non-NPS data to help evaluate current conditions for those same Vital Signs. In some cases, NPS inventory data sets are also incorporated into NRCA analyses and reporting products.

In-depth analysis of climate change effects on park natural resources is outside the project scope.

However, existing condition analyses and data sets developed by a NRCA will be useful for subsequent park-level climate change studies and planning efforts.

NRCAs do not establish management targets for study indicators. Decisions about management targets must be made through sanctioned park planning and management processes. NRCAs do provide science-based information that will help park managers with an ongoing, longer term effort to describe and quantify their park's desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource

Important NRCA Success Factors…

Obtaining good input from park and other NPS subjective matter experts at critical points in the project timeline

Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures ⇨ indicators ⇨ broader resource topics and park areas)

Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for indicator-level condition findings planning[7] and help parks report to government accountability measures[8].

Due to their modest funding, relatively quick timeframe for completion and reliance on existing data and information, NRCAs are not intended to be exhaustive. Study methods typically involve an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or indicator, reflecting differences in our present data and knowledge bases across these varied study components.

NRCAs can yield new insights about current park resource conditions but in many cases their greatest value may be the development of useful documentation regarding known or suspected resource conditions within parks. Reporting products can help park managers as they think about near-term workload priorities, frame data and study needs for important park resources, and communicate messages about current park resource conditions to various audiences. A successful NRCA delivers science-based information that is credible and has practical uses for a variety of park decision-making, planning, and partnership activities.

Over the next several years, the NPS plans to fund a NRCA project for each of the ~270 parks served by the NPS Inventory and Monitoring Program. Additional NRCA Program information is posted at: http://www.nature.nps.gov/water/NRCondition_Assessment_Program/Index.cfm.

NRCA Reporting Products…
Provide a credible snapshot-in-time evaluation for a subset of important park natural resources and indicators, to help park managers:

Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations
(near-term operational planning and management)
Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values
(longer-term strategic planning)
Communicate succinct messages regarding current resource conditions to government program managers, to Congress, and to the general public
("resource condition status" reporting)

[7] NRCAs are an especially useful lead-in to working on a park Resource Stewardship Strategy (RSS) but study scope can be tailored to also work well as a post-RSS project.
[8] While accountability reporting measures are subject to change, the spatial and reference-based condition data provided by NRCAs will be useful for most forms of "resource condition status" reporting as may be required by the NPS, the Department of the Interior, or the Office of Management and Budget.

Chapter 2 Introduction and Resource Setting

2.1 Introduction

2.1.1 Enabling Legislation

Theodore Roosevelt National Park (THRO) consists of three separate units: North Unit, Elkhorn Ranch, and South Unit. THRO was first protected as the Roosevelt Regional State Park in 1934, when the Civilian Conservation Corps (CCC) camps were sponsored by the North Dakota State Historical Society and the National Park System (NPS 1986). On 25 April 1947, the state park became Theodore Roosevelt National Memorial Park with the passage of Public Law 38 (61 Stat. 52) (NPS 1986). The North Unit and the land west of the Little Missouri River, including the Elkhorn Ranch Unit, the petrified forest, and some land that was earlier designated "recreation demonstration area" (RDA), were added to the park in 1948 (NPS 1986). Several years later, on 10 November 1978, the memorial park was designated Theodore Roosevelt National Park by Public Law 95-625 (92 Stat. 3467) (NPS 1986).

2.1.2 Geographic Setting

THRO encompasses 28,509 hectares (70,447 acres) (NPS 2011a), making it one of the larger national parks in the Northern Great Plains Network (NGPN) (Gitzen et al. 2010). The park consists of three units, the North Unit (9,740.91 hectares [24,070.32 acres]), the South Unit (18,679.71 hectares [46,158.57 acres]), and the Elkhorn Unit (88.22 hectares [218 acres]) (NPS 1986, NPS 2011a). All units are connected by the Little Missouri River (NPS 1986). The park contains 33.79 km of the Little Missouri River, and 432.59 km of intermittent streams (Gitzen et al. 2010). THRO is bordered on the south by the town of Medora, in Billings County with a population of 783 people (U.S. Census 2010). The Little Missouri National Grassland, managed by the U.S. Forest Service, are adjacent to THRO.

Photo 1. River Bend Overlook, North Unit of THRO (Photo by Shannon Amberg, SMUMN GSS, 2010).

The park is covered by predominantly native grassland (40%), forest (21%), barren ground (21%), and shrubland (14%) (Von Loh et al. 2000). However, over 400 species of plants and trees have been identified in the park, several of which are considered sensitive or vulnerable (NPS 2012a).

THRO is a Class I airshed authorized by the Clean Air Act, and is one of the few national parks to maintain long-term air quality monitoring stations within the park (Gitzen et al. 2010). The NPS and state agencies operate some of the monitoring stations in THRO and those found in the NGPN (Pohlman and Maniero 2005).

The geologic features within the park were formed by river and rainfall erosion, uplift, and sediment deposition from the Black Hills and the Rocky Mountains (KellerLynn 2007, Tweet et al. 2011). The soils in the Great Plains are commonly nitrogen poor and, for a majority of the year, retain little moisture (Seastedt 1995).

THRO has several geological features of interest. Most of the park is located on the unglaciated Missouri Plateau, which gives the park its appearance (including the mountains, plateaus, and badland formations) (Trimble 1993, as cited by NPS 2007a). The North Unit of the park has the "third largest concentration of petrified wood in the United States" (NPS 2011b, as stated by the superintendent, Valerie J. Naylor). The park's other geological features include concretions and cap rocks (photo 2), glacial erratics, oxbows, pediments, sheet-wash erosion, sandstone and silcrete, and terraces (NPS 2007a).

Photo 2. Concretion formations in the North Unit of THRO (Photo by Shannon Amberg, SMUMN GSS, 2010).

THRO has a variable climate with windy conditions year-round (NPS 2011c). The park experiences warm summers with high temperatures above 30°C (86°F) (May through September). In the winter months (December through February), the low temperatures have been known to drop below -18°C (0°F). The majority of precipitation occurs from mid to late spring with an annual average of 37 cm (14.6 in) a year (Table 1; NPS 2011c).

Table 1. Monthly temperature and precipitation normals (1948-2010) for THRO (Station 325813, Medora, North Dakota) (High Plains Regional Climate Center 2011).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Temperature (°C)													
Max	-2.7	1.1	6.4	14.6	21.2	26.2	30.7	30.5	23.9	16.3	6.4	-0.4	14.5
Min	-16.7	-13.1	-7.8	-1.4	4.8	9.9	12.7	11.6	5.3	-0.83	-7.5	-13.9	-0.39
Average Precipitation (cm)													
Total	0.9	0.9	1.6	3.3	5.8	7.9	5.3	3.4	3.4	2.4	1.3	0.9	37.4

2.1.3 Visitation Statistics

On average, THRO receives about 523,885 visitors annually, who come to participate in activities such as sightseeing, hiking, and camping (NPS 2011d). In 2010, the park had an annual visitor count of 623,748 (NPS 2011a). The park receives the majority of visitors during the summer months (June through August) with numbers in the 100,000s (NPS 2011a).

2.2 Natural Resources

2.2.1 Ecological Units and Watersheds

According to Griffith (2010), THRO falls into the Northwestern Great Plains ecological region. This region alone has the widest latitudinal range in North America, and it is characterized by its semiarid climate, grasslands, lack of forests, and moderately short topographic features (CEC 1997). The Great Plains region is habitat for an unusually large amount of sensitive, threatened, and endangered species (CEC 1997).

THRO is located approximately midway along the length of the Little Missouri River watershed, which stretches from northeastern Wyoming into central North Dakota; the Little Missouri River flows primarily northeast from the headwaters northeastern Wyoming into North Dakota and terminates at the Sakakawea Reservoir in central North Dakota (Berkley et a. 1998). The Little Missouri River flows through nine miles of the park's South Unit, 14 miles of the North Unit, forms the boundary of the Elkhorn Unit, and bisects the park's designated wilderness (Berkley et al. 1998). The Little Missouri River is entirely free-flowing and represents the major surface water resource throughout the park (Berkley et al. 1998).

2.2.2 Resource Descriptions

THRO is located in a grassland biome. The grasslands of the Great Plains region are also known as mixed prairie. Dominant plant species in the park include blue grama (*Bouteloua gracilis*), green needlegrass (*Nassella viridula*), western wheatgrass (*Pascopyrum smithii*), and needle-and-thread (*Hesperostipa comata*) (Von Loh et al. 2000).

The park supports 34 different species of mammal, 151 bird species, 21 fish species, and 15 herpetofauna species (NPS 2012b). Porcupine (*Erethizon dorsatum*), beaver (*Castor canadensis*), black-tailed prairie dogs (*Cynomys ludovicianus*), prairie sharptail grouse (*Pedioecetes phasianellus*), great horned owl (*Bubo virginianus*), and golden eagle (*Aquila chrysaetos*) are just a few mammal and bird species found in the park (NPS 1999, NPS 2012b). THRO is one of the few NPS-managed areas in the western United States where there is a free-roaming feral horse (*Equus* caballus) population (NPS 2011e). These feral horses have been found in western North Dakota for decades; their existence has dated back to the mid 19th century (NPS 2011e). THRO has a large variety of ungulate species, including bison (*Bison bison*), elk (*Cervus canadensis*), mule deer (*Odocoileus hemionus*), white-tailed deer (*O. virginianus*), bighorn sheep (*Ovis canadensis*), and pronghorn (*Antilocapra americana*) (NPS 1994, NPS 2012b).

2.2.3. Resource Issues Overview
Air contamination is a concern for the park staff at THRO. Serious air pollutants in the region include nitrate, sulfate, and ammonium because their levels have increased (Pohlman and Maniero 2005). The push to develop and obtain more gas and oil resources is the main factor influencing this increase in Montana, North Dakota, and Wyoming (Pohlman and Maniero 2005). In the past, the air quality in THRO has been excellent, with the exception of a few cases, which were caused by wildfires and were short-lived (NPS 2008).

Several non-native plant species have become problematic in the park. These include leafy spurge (*Euphorbia esula*), yellow sweetclover (*Melilotus officinalis*), brome grasses (*Bromus* sp.), Canada thistle (*Cirsium arvense*), Kentucky bluegrass (*Poa pratensis*) and crested wheatgrass (*Agropyron cristatum*) (NPS 1999, 2008). The spread of exotic plant species has been known to alter fire regimes by increasing leaf litter layers. When applicable, THRO managers intend to restore the fuel loads as well as the plant community and composition to ranges of natural variability using prescribed fires and various chemical and mechanical exotic plant treatment methods (NPS 2008).

<u>Managed Species</u>
Bison, elk, and feral horses are three intensively managed species in THRO. Fences surrounding each of the North and South Units of the park serve two purposes: to keep the park's bison and feral horses within park boundaries, and to keep domestic cattle on surrounding lands from entering the park (NPS 1994). Due to the management intensity, park staff has opted not to assess these species as traditional components in the NRCA.

Bison
For almost 10,000 years, plains bison (Photo 3) were a keystone element of the Great Plains, providing food and materials for Native Americans and the European settlers that arrived in the 18th and 19th centuries (NPS 2006). It is not certain how many bison were present in North America prior to European settlement, but estimates are in the millions (NPS 2009). Today, there are a few remnant wild populations in North America, but most populations occur in parks, preserves, or on private ranches. Currently only 11 bison herds exist in federally protected lands (Halbert et al. 2007). There are now two bison herds in THRO, one in the North Unit of the park and one in the South

Photo 3. Plains bison in THRO (Photo by Shannon Amberg, SMUMN GSS, 2010).

Unit. In 2000-2001, the park estimated the bison population at 312 and 371 bison in the North and South Units respectively, and population estimates for 2009 were about 300 for both the North and South Units.

Marlow et al. (1984) determined a bison carrying capacity between 200-500 animals in the South Unit of THRO and 100-250 animals in the North Unit, based on factors such as potential droughts, overgrazing, and competition with other grazing ungulates for resources. The lack of natural predators and large area of available open space has forced management to implement culling to maintain a healthy population. Bison occasionally are exported to other national parks, Native American tribal lands, or zoos, or are transferred through the Inter-Tribal Bison Cooperative and other federal, state and non-profit entities (Dratch and Gogan 2010). A total of 2,992 bison were removed from THRO between 1962 and 2008 (NPS 2009).

Roundups of the bison herds take place within each unit of the park every 3-5 years (NPS 2009, M. Oehler, pers. comm., 2011). After examination of age, weight, sex, and presence of disease, each animal is assigned an identification number, and the number of animals to remove is determined according to a forage allocation model. Genetic variability is a major management goal of the NPS as inbreeding can cause decreased heterozygosity, adaptive response (ability of herd to adapt to environmental changes), and population viability (Franklin 1980, as cited by Halbert et al. 2007). Monitoring and management of bison populations are expected to continue in THRO.

Elk

Elk (Photo 4) resided throughout the North Dakota Badlands until extirpation in the late 1800s (NPS 2010). In 1985, the NPS reintroduced 47 elk from Wind Cave National Park (WICA) to the South Unit of THRO. Following reintroduction, the elk population grew rapidly, exceeding the NPS-established maximum population threshold by 1993 (NPS 2010). In 2010, THRO developed an Elk Management Plan and Environmental Impact Statement to guide management actions of the large herd and mitigate negative effects on other park resources.

Photo 4. Bull elk with cows in THRO (NPS Photo).

The Elk Management Plan established a goal of 100-400 individuals in the elk herd. This goal allows maintenance of the mixed-grass prairie system in a lightly grazed state (NPS 2010). The estimated herd population size in 2010 in THRO was approximately 950 individuals; at this population size, many different negative outcomes become possible. High-density elk populations often exhibit poor body condition and reproductive success. In addition, added stress on plant communities causes decreased forage availability, which in turn affects other species in the population’s ecosystem. The large elk population and the looming negative effects on the THRO ecosystem prompted action in the form of a volunteer-based elk reduction effort.

From October 2010 to January 2011, park staff assisted volunteers by leading them to elk and instructing them to harvest appropriate animals (adult cow elk). The initial reduction effort resulted in the removal of 406 animals from the park. In the fall of 2011, another volunteer-based reduction resulted in the removal of 462 animals. The park intends to monitor carefully elk population numbers and demographics in the future; this information then will be used to tailor specific reduction efforts carried out by NPS employees.

Feral Horses

Modern horses (*Equus*) (Photo 5) evolved on the North American continent but became extinct nearly 10,000 years ago around the end of the Pleistocene epoch (NPS 2011d). Horses were re-introduced to North America in the 16th century by Spanish explorers; Native Americans spread these animals across the continent, with horse populations eventually numbering in the thousands of individuals (McLaughlin 1989, NPS 2011d). The herd at THRO is a small, isolated population, which is comprised of descendents of local ranch stock that either escaped captivity or were abandoned by their owners. Marlow et al. (1992) examined feral horse distribution and habitat use in the park and found that the herd generally isolated itself to the southeastern and eastern portion of the South Unit.

When THRO was established in 1947, several hundred horses were present in the park (McLaughlin 1989). Park land was used by area ranchers to graze their horses in the 1940s and 50s; during this time horses were considered a trespass livestock and removal was a priority. The park's goal was to eliminate horses from the South Unit (McLaughlin 1989). The decision was made in the late 1960s to maintain the horse population as a cultural demonstration herd at a maximum of about 40 horses (NPS 1978). In 1978, the population grew to 65-70 horses in the fenced South Unit. Marlow et al. (1992) calculated a feral horse carrying capacity of 50 to 90 individuals for the South Unit of THRO, as a larger population would possibly lead to significant decline in certain forage plant species. The feral horse herd is managed now as a cultural demonstration herd to preserve the historical context of the horses' presence in the park (NPS 2011d; Oehler, pers. comm., 2011). The current target population size is between 50-90 individuals (NPS 2011d). However, the herd currently numbers 135 individuals (Oehler, pers. comm., 2011).

Photo 5. Feral horses in the South Unit of THRO (NPS photo).

To guard against overpopulation, the herd is rounded up every 3-5 years, during which time horses are selected to be removed from the herd and sold at auction. In addition, THRO wildlife biologists have recently initiated field trials on a temporary contraception vaccination for females aged 2 years and older (Oehler, pers. comm., 2011). The park plans to continue management of feral horse populations in order to limit herd size.

Other Ungulates
Rocky Mountain bighorn populations are also present in the park; the park plans to restore bighorn population sizes, but fences for bison and feral horses may limit the bighorn to less suitable habitat (NPS 1994). Deer and pronghorn populations are also present; however, the population sizes primarily are monitored and occasionally surveyed (NPS 1994). As for the predatory mammal species, the park monitors these populations for vector-borne diseases (NPS 1994).

<u>Viewshed</u>
A viewshed is the area that is visible from a particular location. The National Park Service Organic Act (16 U.S.C. l) implies the need to protect the viewsheds of National Parks, Monuments, and Reservations. At THRO, viewsheds are of particular importance because a primary reason visitors frequent the park is to view the landscape. Views from within the park are expansive in some areas, with NPS and non-NPS lands being the primary visible features. Currently, the oil and gas industry is expanding in western North Dakota, which is a cause of concern for the viewsheds in THRO, due to rapidly expanding industrial development.

Due to the current dynamic nature of the landscape surrounding the park, a detailed viewshed analysis is not appropriate for this document. The evidence of oil and gas development is increasing in North Dakota and this makes the viewshed from the park variable in the short-term. Therefore, conducting an all-inclusive viewshed analysis at this time is not appropriate, because the data would likely be irrelevant quickly.

Even though a park-wide viewshed analysis is not appropriate at this time, THRO regularly uses viewshed analyses to provide specific data regarding anthropogenic development concerns. Developed data enrich the understanding of anthropogenic effects on the park's viewsheds. These data allow park management to make informed decisions and pursue appropriate actions regarding development.

2.3 Resource Stewardship

2.3.1 Management Directives and Planning Guidance
THRO has several management plans, including the most recent Elk Management Plan (2010), the Centennial Plan (2007), the Fire Management Plan (2008), the Water Resources Management Plan (1998), the Resource Management Plan (1994), and the General Management Plan (1987). Each plan has its own objectives and goals to improve the park's resources and increase public awareness.

The Elk Management Plan was proposed to ensure long-term preservation and protection of park resources. When the elk population increased after its reintroduction, the non-managed herd strained plant communities by over grazing; as of 2010, there were approximately 900 elk in the South Unit of the park (NPS 2010). The objectives for the elk management plan are as follows:

- Prevent negative effects to the biotic and abiotic components of the park and adjacent lands.
- Construct and execute actions parallel to the direction and limits set by the NPS Management Policies 2006.

- Determine indicators to assist and direct the management of elk.
- Maintain the long-term viability of the elk population while limiting herd manipulation in the park.
- Incorporate management flexibility to take action after obtaining information on disease or other factors that may adversely affect the elk population.
- Offer opportunities to educate the public about the challenges of elk management when limiting that management to park land.
- Collaborate with the stakeholders (e.g., federal agencies, state agencies, and private companies) by sharing data on the elk population and it management.
- When applicable, improve the hunting opportunities on the areas of land surrounding the park.

In 2007, the park celebrated its 60th anniversary. Its theme was "60 years of Preservation, Tradition, and Inspiration" (NPS 2007b). Now, the park's plan for the next decade is to revise its mission and purpose to be connected better with the American public (NPS 2007b). The goals for the centennial plan are as follows:

- Enhance the condition of the park by improving its resources and assets.
- Educate and motivate children to give back to the environment by becoming future conservationists.
- Alter park operations to minimize adverse impacts on the environment.
- Inspire the public to become environmentally conscious.
- Encourage all to participate in a shared environmental stewardship.
- Focus national, regional, and local tourism efforts to reach diverse audiences and young people and to attract visitors to lesser-known parks.
- Create stimulating media to introduce and excite youth and their families to the national parks.

The THRO Wildland Fire Management Plan (NPS 2008) was an addition to the resource management plan. Fire is an important factor that plays a large role in the development of most terrestrial ecosystems in North America (NPS 2008). This plan is becoming more intensive and of greater importance in the park; the objectives of the Wildland Fire Management Plan (NPS 2008) are:

- Decrease the frequency and severity of fires caused by humans.
- Promote the occurrence of wildland fire in ecosystems dependent on its effects.
- Control and utilize fire as a management tool.
- Protect the park components (e.g., life, property and resources) from adverse effects of unwanted fire.

- Prevent adverse effects from fire suppression on the ecosystem.

THRO created the Water Resources Management Plan in 1998 with the purpose of guiding park managers in assessing the water resources (NPS 1998). The park, being located in a semiarid ecosystem of the northern Great Plains, is particularly concerned with their water resources (Berkley et al. 1998). Maintaining plant and animal community diversity is dependent on water availability. The Water Resources Plan (1998) objectives include:

- Manage the park's water resources to maintain an optimal level of species diversity and native plant composition.
- Revive and protect the park's natural springs and developed wells for native wildlife.
- Assure that any development within the park will not negatively impact the water resources and water-dependent environments.
- Become knowledgeable about water quality to be able to actively contribute to the local and state water management plans while also striving for the optimal level of water quality standards for the park.
- Protest the water rights applications that would negatively impact the park and contribute to water rights adjudications involving the park lands so that the NPS water rights and water-related resources remain protected.
- Obtain a sufficient amount of information to adequately manage the park's water resources while also following the NPS inventory and monitoring requirements.
- Follow NPS Floodplain Management Guidelines to insure minimal damage (e.g., injury, property) while also encouraging the occurrence of natural hydrologic and geomorphic processes of floods.
- Create and update maps of the wetlands and riparian areas to make it easier to monitor and maintain ideal habitat conditions for the park's wildlife.
- Educate the public and increase their awareness of the adverse effects done on water resources due to human impacts.
- Protect the native fish species (e.g., rare, threatened, and endangered) found in the park and surrounding areas by creating and applying effort to a cooperative management plan.
- Identify and assess the NPS water-related resources and any factors outside the park that may cause an impact.
- Ensure minimal impact on surface and ground water resources when permitting oil and gas operations done on lands adjacent to the park.

The Resource Management Plan (NPS 1994) is a supporting document of the original General Management Plan (NPS 1987), so that it would include both the 83 natural and 17 cultural resources important to the park (NPS 1994). The plan identifies resources and their components and indicates measures to be taken and methods to be used in management. The park's goal is to restore and maintain the resources and processes that form the park's ecosystem (NPS 1994). The Resource Management Plan had the following objectives:

- Create a tactical plan that recognizes and establishes priorities for resource management and research needs.
- Manage the park as a natural badlands ecosystem, influenced by human activities over time, allowing natural processes to continue.
- Prevent negative impacts on essential resources of the park by bearing in mind the effects that visitors and park managers may have on the natural and cultural resources with everyday activities.
- Create an information system for the Little Missouri Badlands ecosystems to protect the natural resources and ecological processes native to each ecosystem.
- Ensure the roadways are maintained and in satisfactory condition to make resource management (e.g., natural and cultural) more efficient.
- Follow all appropriate laws, NPS guidelines, and management plans to properly manage natural and cultural resources inside the park.
- Maintain resources in the park that are historically connected with Theodore Roosevelt (e.g., his life and experience in the Badlands).
- Guarantee that a sufficient collections management program is developed for the park's natural and cultural resources.

One of the earliest management plans for THRO is its General Management Plan (NPS 1987). The General Management Plan provides the necessary strategies to guide management, use, and development of the park for the next 10 years (NPS 1987). This plan addresses resource management (e.g., flood protection, bison management, historic building preservation, and visitor use needs) (NPS 1987).

2.3.2 Status of Supporting Science

The Northern Great Plains Inventory and Monitoring Network (NGPN) identifies key resources network-wide and for each of its parks that can be used to determine the overall health of the parks. These key resources are called Vital Signs. In 2010, the NGPN completed and released a Vital Signs monitoring plan (adapted from Gitzen et al. 2010, Table 2).

Table 2. NGPN Vital Signs selected for monitoring in THRO (adapted from Gitzen et al. 2010).

Category	Vital Signs Currently Monitored by NPGN parks, Other NPS Entities, or Other Federal or State Agencies	Vital Signs for Which NGPN Will Develop and Implement Monitoring Protocols in the Future
Air and climate	• Ozone • Wet and dry deposition • Visibility and particulate matter • Air contaminants • Weather and climate	
Geology and soils		• Stream and river channel characteristics
Water	• Surface water dynamics	• Surface water chemistry • Aquatic contaminants • Aquatic microorganisms • Aquatic macroinvertebrates
Biological integrity	• Exotic plant early detection • Raptors • Prairie dogs • Ungulates • Riparian lowland plant communities • Upland plant communities	• Land birds
Human use	• Treatments of exotic infestations • Visitor use	
Landscapes (ecosystem pattern and process)	• Fire and fuel dynamics,	• Land cover and use • Extreme disturbances • Soundscape • Viewshed • Night sky

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Chapter 3 Study Scoping and Design

This NRCA is a collaborative project between the National Park Service (NPS) and Saint Mary's University of Minnesota Geospatial Services (SMUMN GSS). Project stakeholders include the THRO resource management team and NGPN Inventory and Monitoring Program staff. Before embarking on the project, it was necessary to identify the specific roles of the NPS and SMUMN GSS. Preliminary scoping meetings were held, and a task agreement and a scope of work document were created cooperatively between the NPS and SMUMN GSS.

3.1 Preliminary scoping

A preliminary scoping meeting was held on 31 August 2010. At this meeting, SMUMN GSS and NPS staff confirmed that the purpose of the THRO NRCA was to evaluate and report on current conditions, critical data and knowledge gaps, and selected existing and emerging resource condition influences of concern to THRO managers. Certain constraints were placed on this NRCA, including the following:

- Condition assessments are conducted using existing data and information.
- Identification of data needs and gaps is driven by the project framework categories.
- The analysis of natural resource conditions includes a strong geospatial component.
- Resource focus and priorities are primarily driven by THRO resource management.

This condition assessment provides a "snapshot-in-time" evaluation of the condition of a select set of park natural resources that were identified and agreed upon by the project team. Project findings will aid THRO resource managers in the following objectives:

- Develop near-term management priorities (how to allocate limited staff and funding resources);
- Engage in watershed or landscape scale partnership and education efforts;
- Consider new park planning goals and take steps to further these;
- Report program performance (e.g., Department of Interior Strategic Plan "land health" goals, Government Performance and Results Act [GPRA]).

Specific project expectations and outcomes included the following:

- For key natural resource components, consolidate available data, reports, and spatial information from appropriate sources including: THRO resource staff, IRMA (Integration of Resource Management Applications), Inventory and Monitoring Vital Signs, NGPN staff, and available third-party sources. The NRCA report will provide a resource assessment and summary of pertinent data evaluated through this project.

- When appropriate, define a reference condition so that statements of current condition may be developed. The statements will describe the current state of a particular resource with respect to an agreed upon reference point.

- Clearly identify "management critical" data (i.e., those data relevant to the key resources). This will drive the data mining and gap definition process.

- Where applicable, develop GIS products that provide spatial representation of resource data, ecological processes, resource stressors, trends, or other valuable information that can be better interpreted visually.

- Utilize "gray literature" and reports from third party research to the extent practicable.

3.2 Study Design

3.2.1 Indicator Framework, Focal Study Resources and Indicators

Selection of Resources and Measures

As defined by SMUMN GSS in the NRCA process, a "framework" is developed for a park or preserve. This framework is a way of organizing, in a hierarchical fashion, bio-geophysical resource topics considered important in park management efforts. The primary features in the framework are key resource components, measures, stressors, and reference conditions.

"Components" in this process are defined as natural resources (e.g., prairie dogs), ecological processes or patterns (e.g., natural fire regime), or specific natural features or values (e.g., geological formations) that are considered important to current park management. Each key resource component has one or more "measures" that best define the current condition of a component being assessed in the NRCA. Measures are defined as those values or characterizations that evaluate and quantify the state of ecological health or integrity of a component. In addition to measures, current condition of components may be influenced by certain "stressors" which are also considered during assessment. A "stressor" is defined as any agent that imposes adverse changes upon a component. These typically refer to anthropogenic factors that adversely affect natural ecosystems, but may also include natural processes or disturbances such as floods, fires, or predation (adapted from GLEI 2010).

During the THRO NRCA scoping process, key resource components were identified by NPS staff and are represented as "components" in the NRCA framework. While this list of components is not a comprehensive list of all the resources in the park, it includes resources and processes that are unique to the park in some way, of greatest concern or of highest management priority in THRO. Several measures for each component, as well as known or potential stressors, were also identified in collaboration with NPS resource staff.

Selection of Reference Conditions

A "reference condition" is a benchmark to which current values of a given component's measures can be compared to determine the condition of that component. A reference condition may be a historical condition (e.g., flood frequency prior to dam construction on a river), an established ecological threshold (e.g., EPA standards for air quality), or a targeted management goal/objective (e.g., an elk herd of less than 200 individuals) (adapted from Stoddard et al. 2006).

Reference conditions in this project were identified during the scoping process using input from NPS resource staff. In some cases, reference conditions represent a historical reference in which human activity and disturbance was not a major driver of ecological populations and processes, such as “pre-cattle/sheep grazing” or “pre-fire suppression.” In cases where reference conditions were less clearly defined, peer-reviewed literature, ecological thresholds, and consultation with resource staff were used to define appropriate reference conditions more clearly. In these instances, efforts were made to utilize existing research and documentation of historical conditions to identify the range of natural variation for reference conditions.

Finalizing the Framework

An initial framework was adapted from the organizational framework outlined by the H. John Heinz III Center for Science’s “State of Our Nation’s Ecosystems 2008” (Heinz Center 2008). Key resources for the park were adapted from the NGPN Vital Signs monitoring plan (Gitzen et al. 2010) and natural resource reports from THRO. This initial framework was presented to park resource staff to stimulate meaningful dialogue about key resources that should be assessed. Significant collaboration between SMUMN GSS analysts and NPS staff was needed to focus the scope of the NRCA project and finalize the framework of key resources to be assessed.

The NRCA framework was finalized in August 2011 following acceptance from NPS resource staff. It contains a total of 17 components (Table 3) and was used to drive analysis in this NRCA. This framework outlines the components (resources), most appropriate measures, known or perceived stressors and threats to the resources, and the reference conditions for each component for comparison to current conditions. The THRO framework also contains several components that are contextually important natural resource topics in the park; these include feral horses, bison, elk, and viewshed. During scoping, it was agreed that these topics would be addressed in Chapter 2 of the report.

Table 3. THRO natural resource condition assessment framework.

THRO National Park
Natural Resource Condition Assessment Framework

Component	Measures (Significance level)	Stessors	Reference Condition
Ecosystem Extent and Function			
Disturbance Regimes			
Fire	Frequency (3), severity (2), number of acres burned (2-3), fire origin (1-2)(e.g., prescribed, lightning, human-caused, etc.), intensity (2), seasonality (2)	Climate change, fire suppression, development	Management objectives for the park as stated in the fire management plan
Erosion/wind and water	Changes in landscape features (3), amount of material removed (erosion rates) (3)	Increase in frequency of heavy rain or wind events, decreased soil moisture over time, climate change	No established reference condition
Flooding (Little Missouri)	Frequency (3), magnitude (3), Snowpack (3), Duration (2), effects of upstream water withdrawal on summer flows (3)	Drought conditions, climate change, water retention in stock dams (in upriver tribs and draws), drawdown from nearby development (golf course)	Range of variation since the beginning of data collection (1904 and 1935 respectively for Medora and Watford City, ND)
Biotic Composition			
Ecological Communities			
Native grasslands	Species composition (3), distribution (3), prevalence of non-natives (3)	Non-native/exotic species, changes in fire regime, juniper encroachment, Grazing effects	Ideally, composition and distribution of grasslands prior to European settlement; Hansen et al. (1984) and Hansen and Whitman (1938)
Juniper forests (slope forests)	Density and distribution (both rated as 3)	Non-native/exotic species, fire	Ideally, composition and distribution of juniper forests prior to European settlement; Ralston (1960) and Von Loh et al. (2000)
Floodplain forests	Species composition & abundance (3), changes in species distribution (3), Cottonwood Woodland Area-Age Distribution (3), non-native species abundance (3)	Non-native/exotic species, changes in flooding regime, juniper encroachment, ice jams impacting streambanks	Ideally, composition and distribution of floodplain woodlands prior to European settlement; Girard (1989), Everitt (1968), Von Loh et al. (2000), Johnson (1994),
Woody draws	Species composition & abundance (2), distribution (3), prevalence of non-natives (2)	Non-native/exotic species, ungulate foraging, browsing/grazing effects, Disease, EAB	Ideally, composition and distribution of woody draws prior to European settlement; Hansen et al. (1984)
Upland shrubland communities	Species composition (2), distribution (including changes)(3), prevalence of non-natives (2)	Non-native/exotic species, disease (Dutch elm; Emerald ash borer), browsing/grazing effects,	Ideally, composition and distribution of these communities prior to European settlement; Hansen et al. (1984)
Aquatic communities	Diversity and abundance of native fish (3), Diversity and abundance of macroinvertebrates (2)	Non-natives/exotic species, changes in water quality	The range of abundance and diversity of native fish and macroinvertebrates in the park; cross-reference of historic fish lists

	Component	Measures (Significance level)	Stessors	Reference Condition
Grazing animals				
	Prairie dogs	Extent of dog colonies (3)	Disease (plague), food availability	No established reference condition
Birds				
	Breeding Birds	Species richness (3), number of species of conservation concern (2), raptor species richness (2)	Loss of forest habitat (cottonwoods and juniper encroachment in upland habitats)	The characteristics of the breeding bird population from the nearby Little Missouri National Grassland (LMNG), established bird routes similar to routes recently
Environmental Quality				
	Air Quality	Mercury deposition (3), ozone (3), nitrogen & sulfur deposition (3), visibility (3), particulate matter (3)	Development of coal power plants; oil and gas development; smoke from wildfires and agricultural burning	EPA standards for Class I air shed
	Water Quality	Temperature (3), turbidity (3), specific conductance (3), sensitive macroinvertebrate species (3), pH (3), fecal coliform (3)	Erosion, livestock ranching, development up stream (specifically, the effects of the golf course upstream on WQ in park), nutrients	EPA water criterion; Water Resources Division water criterion; North Dakota Department of Health water criterion
	Soundscape	Occurrence of human-caused and unnatural sounds (3), natural ambient sound levels (1)	Oil drilling and other development, road traffic (especially near wilderness and Elkhorn Ranch site)	A natural experience, or a soundscape not influenced by unnatural sounds
	Dark night skies	V magnitude (3), ambient light pollution (3)	Point source light pollution, particulates, air quality	Absence of anthropogenic light pollution in accordance with National Park Service management policies
Physical Characteristics				
Hydrologic & Geologic				
	Surface Water Availability	Precipitation (2), prevalence (locations) of seeps and springs (2), flow rates of man-made water developments (2)	Juniper encroachment, water retention in stock dams, ice jamming (impact to streambank and veg), flooding (or lack thereof),	For precipitation -- historic period of record (pre-2000) for each of the three weather stations surrounding THRO; no established reference condition for prevalence or flow
	Paleontological Features	Distribution and abundance (3), protection of collections (2)	Theft, decay due to exposure from erosion, degradation due to development	No established reference condition

3.2.2 General Approach and Methods

This study involved gathering and reviewing existing literature and data relevant to each of the key resource components included in the framework. No new data were collected for this study, however, where appropriate, existing data were further analyzed to provide summaries of resource condition or to create new spatial representations. After all data and literature relevant to the measures of each component were reviewed and considered, a qualitative statement of overall current condition was created and compared to the reference condition when possible.

Data Mining

The data mining process (acquiring as much relevant data about key resources as possible) began at the initial scoping meeting, at which time THRO staff provided data and literature in multiple forms, including: NPS reports and monitoring plans, reports from various state and federal agencies, published and unpublished research documents, databases, tabular data, and charts. GIS data were provided by NPS staff (NGPN and THRO). Access was also granted to NPS online data and literature sources, such as NatureBib, NPSpecies, and IRMA . Additional data and literature were also acquired through online bibliographic literature searches and inquiries on various state and federal government websites. Data and literature acquired throughout the data mining process were inventoried and analyzed for thoroughness, relevancy, and quality regarding the resource components identified at the scoping meeting.

Data Development and Analysis

Data development and analysis was highly specific to each component in the framework and depended largely on the amount of information and data available and recommendations from NPS reviewers and sources of expertise including NPS staff from THRO and NGPN. Specific approaches to data development and analysis can be found within the respective component assessment sections located in Chapter 4 of this report.

Scoring Methods and Assigning Condition

A set of measures are useful in describing the condition of a particular component, but all measures may not be equally important. A "significance level" represents a numeric categorization (integer of 1-3) of the importance of each measure in explaining the condition of the component; each significance level is defined in Table 4. This categorization allows measures that are more important for determining condition (higher significance level) of a component to be more heavily weighted in calculating an overall condition.

Table 4. Scale of measure significance used in determining overall condition.

Significance Level (SL)	Description
1	Measure is of low importance in defining the condition of this component.
2	Measure is of moderate importance in defining the condition of this component.
3	Measure is of high importance in defining the condition of this component.

After each component assessment is completed (including any possible data analysis), a condition level is calculated for each measure. This is based on a 0-3 integer scale and reflects the data mining efforts and communications with park experts (Table 5).

Table 5. Scale used in determining condition level of individual measures.

Condition Level (CL)	Description
0	Of **NO** concern. No net loss, degradation, negative change, or alteration.
1	Of **LOW** concern. Signs of limited and isolated degradation of the component.
2	Of **MODERATE** concern. Pronounced signs of widespread and uncontrolled degradation.
3	Of **HIGH** concern. Nearing catastrophic, complete, and irreparable degradation of the component.

After the significance levels (SL) and condition levels (CL) are assigned, a weighted condition score (WCS) is calculated via the following equation:

$$WCS = \frac{\sum_{i=1}^{\# \, of \, measures} SL_i * CL_i}{3 * \sum_{i=1}^{\# \, of \, measures} SL_i}$$

The resulting WCS value is placed into one of three possible categories: condition of low concern (WCS = 0.0 – 0.33); condition of moderate concern (WCS = 0.34 - 0.66); and condition of significant concern (WCS = 0.67 to 1.00). Figure 1 displays all of the potential graphics used to represent a component's condition in this assessment. The colored circles represent the categorized WCS; red circles signify a significant concern, yellow circles a moderate concern and green circles a condition of low concern. Gray circles are used to represent situations in which there is currently insufficient data to make a statement about the condition of a component. The arrows inside the circles indicate the trend of the condition of a resource component. An upward pointing arrow indicates the condition of the component has been improving in recent times. A right-pointing arrow indicates a stable condition or trend and an arrow pointing down indicates a decline in the condition of a component in recent times. These are only used when it is appropriate to comment on the trend of condition of a component. A gray, triple-pointed arrow is reserved for situations in which the trend of the component's condition is currently unknown.

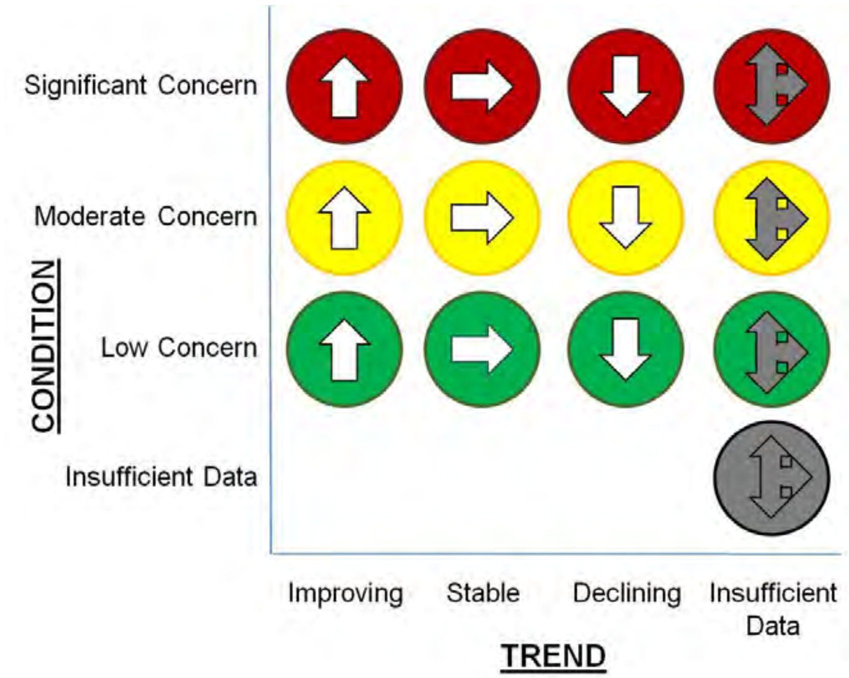

Figure 1. Symbols used for individual component assessments with condition or concern designations along the vertical axis and trend designations along the horizontal.

Preparation and Review of Component Draft Assessments
The preparation of draft assessments for each component was a highly cooperative process among SMUMN GSS analysts and THRO staff. Though SMUMN GSS analysts rely heavily on peer-reviewed literature and existing data in conducting the assessment, the expertise of NPS resource staff also plays a significant and invaluable role in providing insights into the appropriate direction for analysis and assessment of each component. This step is especially important when data or literature are limited for a resource component.

The process of developing draft documents for each component began with a detailed phone or conference call with an individual or multiple individuals considered local experts on the resource components under examination. These conversations were a way for analysts to verify the most relevant data and literature sources that should be used and also to formulate ideas about current condition with respect to the NPS staff opinions. Upon completion, draft assessment were forwarded to component experts for initial review and comments.

Development and Review of Final Component Assessments
Following review of the component draft assessments, analysts used the review feedback from resource experts to compile the final component assessments. As a result of this process, and based on the recommendations and insights provided by THRO resource staff and other experts, the final component assessments represent the most relevant and current data available for each component and the sentiments of park resource staff and resource experts.

Format of Component Assessment Documents
All resource component assessments are presented in a standard format. The format and structure of these assessments is described below.

Description
This section describes the relevance of the resource component to the park and the context within which it occurs in the park setting. For example, a component may represent a unique feature of the park, it may be a key process or resource in park ecology, or it may be a resource that is of high management priority in the park. Also emphasized are interrelationships that occur among a given component and other resource components included in the broader assessment.

Measures
Resource component measures were defined in the scoping process and refined through dialogue with resource experts. Those measures deemed most appropriate for assessing the current condition of a component are listed in this section, typically as bulleted items.

Reference Conditions/Values
This section explains the reference condition determined for each resource component as it is defined in the framework. Explanation is provided as to why specific reference conditions are appropriate or logical to use. Also included in this section is a discussion of any available data and literature that explain and elaborate on the designated reference conditions. If these conditions or values originated with the NPS experts or SMUMN GSS analysts, an explanation of how they were developed is provided.

Data and Methods
This section includes a discussion of the data sets used to evaluate the component and if or how these data sets were adjusted or processed as a lead-up to analysis. If adjustment or processing of data involved an extensive or highly technical process, these descriptions are included in an appendix for the reader or a GIS metadata file. Also discussed is how the data were evaluated and analyzed to determine current condition (and trend when appropriate).

Current Condition and Trend
This section presents and discusses in-depth key findings regarding the current condition of the resource component and trends (when available). The information is presented primarily with text but is often accompanied by detailed maps or plates that display different analyses, as well as graphs, charts, and/or tables that summarize relevant data or show interesting relationships. Due to their low importance, measures that are assigned a significance level of 1 do not receive an in-depth analysis and are not addressed in the current condition section. These measures are briefly discussed in the overall condition section of the document (see below).

Threats and Stressor Factors
This section provides a summary of the threats and stressors that may impact the resource and influence to varying degrees the current condition of a resource component. Relevant stressors were described in the scoping process and are outlined in the NRCA framework. However, these are elaborated on in this section to create a summary of threats and stressor based on a combination of available data and literature, and discussions with resource experts and NPS natural resources staff.

Data Needs/Gaps
This section outlines critical data needs or gaps for the resource component. Specifically, what is discussed is how these data needs/gaps, if addressed, would provide further insight in determining the current condition or trend of a given component in future assessments. In some cases, the data needs/gaps are significant enough to make it inappropriate or impossible to determine condition of the resource component. In these cases, stating the data needs/gaps is useful to natural resources staff that wish to prioritize monitoring or data gathering efforts.

Overall Condition
This section provides a qualitative summary statement of the current condition that was determined for the resource component using the WCS method. Condition is determined after thoughtful review of available literature, data, and any insights from NPS staff and experts, which are presented in the Current Condition and Trend section. The Overall Condition section summarizes the key findings and highlights the key elements used in determining and justifying the level of concern, if any, that analysts attribute to the condition of the resource component. Also included in this section are the graphics used to represent the component condition.

Sources of Expertise
This is a listing of the individuals (including their title and affiliation with offices or programs) who had a primary role in providing expertise, insight, and interpretation to determine current condition (and trend when appropriate) for each resource component.

Literature Cited
This is a list of formal citations for literature or datasets used in the analysis and assessment of condition for the resource component. Note, citations used in appendices and plates referenced in each section (component) of Chapter 4 are listed in that section's "Literature Cited" section.

3.3 Literature Cited

Gitzen, R., M. Wilson, J. Brumm, M. Bynum, J. Wrede, J. Millspaugh, and K. Paintner. 2010. Northern Great Plains Network vital signs monitoring plan. Appendix B: conceptual ecological models. Natural Resource Report NPS/NGPN/NRR-2010/186. National Park Service, Fort Collins, Colorado.

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The H. John Heinz III Center for Science, Economics, and the Environment. 2008. The state of the nation's ecosystems 2008: Measuring the land, waters, and living resources of the United States. Island Press, Washington, D.C.

Stoddard. J. L., D. P. Larsen, C. P. Hawkins, R. K. Johnson, and R. J. Norris. 2006. Setting expectations for the ecological condition of streams: the concept of reference condition. Ecological Applications. 16(4):1267-1276.

Chapter 4 Natural Resource Conditions

This chapter presents the background, analysis, and condition summaries for the 17 key resource components identified in the project framework. Each component assessment is organized into the following sections:

1. Description
2. Measures
3. Reference Condition
4. Data and Methods
5. Current Condition and Trend (including threats and stressor factors, data needs/gaps, and overall condition)
6. Sources of Expertise
7. Literature Cited

Components appear in the order they are listed in the project framework (Table 3):

4.1 Fire

4.2 Wind and water erosion

4.3 Flooding (Little Missouri River)

4.4 Native grasslands

4.5 Juniper forests

4.6 Floodplain forests

4.7 Woody draws

4.8 Upland shrubland communities

4.9 Aquatic communities

4.10 Prairie dogs

4.11 Breeding birds

4.12 Air quality

4.13 Water quality

4.14 Soundscape

4.15 Dark night skies

4.16 Surface water availability

4.17 Paleontological features

4.1 Fire

4.1.1 Description

Fire plays a major role in the ecological processes of North American prairies (Umbanhowar 1996), and historically, fires have been important naturally occurring events in THRO. These fires created natural disturbances that are important for maintaining healthy native plant communities in the prairie landscape. Mixed grass prairie, the primary vegetative cover in THRO, is approximately 0.61-1.22 m (2 to 4 ft) tall and grows quickly then dies back each year (NPS 2008). However, small trees and shrubs grow primarily on north aspects and within woody draws in the park. Fire in mixed grass prairie tends to limit the growth of trees and shrubs to places where finer fuels are less continuous and natural fire breaks exist (e.g., drier, rocky breaks, draws, and riparian areas) (NPS 2008).

Photo 6. Firefighters igniting a prescribed fire in THRO (NPS photo).

Fires that are naturally ignited (i.e., wildfires starting from lightning strikes) have been quickly suppressed for the majority of the park's existence (NPS 2010a). However, wildland fires are allowed to burn under certain conditions and in particular geographic areas of the park (e.g., fire management unit no. 2 in the North Unit of the park) as described in the Fire Management Plan (FMP) (NPS 2008). Fire was reintroduced to THRO in 1999 through prescribed burns, as a native plant community management strategy (NPS 2010a). Generally, THRO uses prescribed fire as a management tool for reducing fuel loads and stimulating the growth and health of native plant communities adapted to fire. However, each fire is set to accomplish individualized resource management objectives, which are identified for each fire (project) plan (NPS 2008). The rough terrain and low vegetation densities within the park, which consequently contribute to low fuel densities, limit the extent to which fire can spread (NPS 2010a). Prescribed fires account for the vast majority of the burned area in the park with approximately 93% of the total acreage burned within THRO from 1999 to 2010 (see Appendix A for information on individual fires).

4.1.2 Measures

- Frequency
- Severity
- Extent (area burned over time)
- Fire origin (e.g., prescribed, lightning, human-caused, etc.)
- Intensity
- Seasonality

- Change in native vegetation after prescribed fire

4.1.3 Reference Conditions/Values

Given that reference conditions (i.e., natural fire regime parameters) are not well established and that prescribed fire has nearly completely replaced natural fire starts in THRO, the fire management goals for the park will serve as the reference condition. As a part of fire management in THRO, the NPS can chose from multiple options: wildland fire suppression, wildland fire use, prescribed fire, and non-fire fuel treatments. The 2008 THRO fire management plan (NPS 2008) contains several objectives. The objectives relevant to the use of wildland fires to meet resource objectives include:

1) permit wildland fire use (lightning-caused) in areas where fire dependency has been scientifically proven and the fuel load and vegetation composition are within the range of natural variability,

2) use fire to restore plant community structure, composition and maintain cultural landscapes similar to those before European settlement,

3) allow wildland fire use within the constraints of policy (DO-18) and the Environmental Assessment/Assessment of Effect for the Fire Management Program of Theodore Roosevelt National Park.

Objectives relevant to the use of prescribed fires in order to meet management objectives include:

1) create and/or maintain defensible wildland fire use boundaries,

2) where applicable, restore fuel loads and plant community structure and compositions to ranges of natural variability comparable to pre-European settlement using prescribed fire and wildland fire use,

3) restore cultural landscapes similar to those present before European statement,

4) minimize the occurrence of unnaturally intense fires through reduction of hazard fuels by prescribed burning,

5) avoid prescribed fires and wildland fire use that would reduce air quality in Medora, North Dakota between Memorial Day and Labor Day,

6) train park staff and cooperators to conduct safe, objective-oriented prescribed fires and wildland fire use consistent with DO-18 requirements,

7) provide opportunities for public understanding of fire ecology principles, smoke management, and wildland fire program objectives, and

8) monitor and evaluate the effectiveness of the preserved fire program.

Generally, fire managers aim to reduce the cover and density of non-native forbs and grasses while encouraging native plant species growth; reduce the cover and density of silver sagebrush (*Artemisia cana*), and western snowberry (*Symphoricarpos occidentalis*); and reintroduce fire to fire-adapted ecosystems in the park. However, each fire is set to achieve a particular set of goals, and these may vary based on landscape position, fire history in the area, weather conditions (e.g., wind, temperature, and humidity), a variety of fuel dynamics, and availability of fire suppression resources such as trained personnel and materials.

4.1.4 Data and Methods
Fire data captured in GIS were obtained from the park for fires that occurred within and near THRO from 1946 to 2010 (NPS 2010b). The attributes from the GIS data were used to assess the past and current condition of fire. Monitoring Trends in Burn Severity (MTBS 2011) provided burn severity data for two fires, specifically highlighting the acreage burned in each severity class.

A series of prescribed fire monitoring reports were used to document the extent of most fires in THRO and the intensity and severity of each burn.

Wienk et al. (2007) provided a program review of the Northern Great Plains Fire Ecology Program, focusing on research efforts from 1997-2007. This report provided information about native and non-native vegetation responses to different fire treatments over time.

4.1.5 Current Condition and Trend
Fire in THRO is monitored and managed to achieve a number of objectives, including restoring fire-adapted ecosystems within the park (NPS 2008). The measures used to assess the current condition of THRO fire are compared to the historic fire regime and current management objectives for fire on the landscape. Fire frequency is assessed by comparing the current fire frequency with the historic frequency (prior to European settlement of the region). Historic fire frequency is often determined through examination of fire-scars on trees and stumps and by charcoal research. However, the primary vegetation type in THRO is mixed grass prairie and little fire scar data are available to determine historic fire frequency. In an investigation of fire history in Great Plains National Parks, Guyette et al. (2011) found little evidence of fire scars in juniper in the South Unit of THRO. The authors suggested that, because of reduced spread of fire on the landscape due to natural fire breaks, fire scar history methods would likely not be appropriate for describing the history of fire events in the region. Therefore, the pre-European settlement fire frequency (i.e., fire return interval), extent (area), severity, and seasonality are not well understood in THRO. Wright and Bailey (1980) estimate fire frequency in the northern mixed prairie of the Badlands to be 5 to 30 years. While most historic fires originated from lightning strikes, historic fire frequency estimates may be confounded by evidence, according to pioneer settlers' reports, that Native Americans intentionally and unintentionally set fires (NPS 1999).

Official documentation of fires did not begin in THRO until 1949 (NPS 1999). From 1949 to 1999, all fires were either accidental or caused by lightning; since 1999, the park has increasingly used prescribed fire as a management tool. Since then, resource managers and fire researchers have continued to record fire origin, frequency, area burned, and seasonality (dates) of fires. In many cases, only area burned has been recorded. These primarily have been monitored through field reconnaissance and provide a basic assessment and overview of each fire (NPS 2003). Intensity and severity are assessed during prescribed burns and by examining the post-fire effects on the plant communities.

Frequency

Guyette et al. (2011) suggest pre-European settlement human-caused fires were rare in the THRO area because of the low human population density and the variation in topography, which inhibited natural fires. Wright and Bailey (1982) estimate that fire should burn every 5 to 10 years in prairie grasslands with rolling topography, and every 20 to 30 years in topography with breaks and rivers; the latter is characteristic of the THRO landscape.

THRO began recording fire dates in 1949 (NPS 1999). Natural wildfires (lightning-caused) are permitted to burn in areas where fire dependency is proven (NPS 2008). However, management suppresses all human-caused fires (non-prescribed) and does not allow natural wildfires to burn more than a few acres if there is direct threat to human life, private property, and park cultural resources (NPS 2008). Therefore, fire frequency or fire-return interval is primarily determined by burn prescriptions. However, because of the discontinuous, patchy fuel sources and sparsely vegetated topography within THRO, some sites may have mean fire-return intervals between 150 and 400 years (NPS 2003). NPS (1999) reported 90 fires in THRO between 1949 and 1993. Since that time, (through 2010) the number of fires has increased to 157, with most fires being prescribed burns. In1999, prescribed fire was used for the first time in THRO, and since then an average of 4.1 fires occurred per year. Refer to Table 6 for fire frequency, area, and origin by major burn unit. The fire history dataset containing fire origin (cause), area, date, name, and burn unit from 1946 to 2010 is available in Appendix A.

Table 6. Number of fires and area burned in THRO by origin and park unit (1984 to 2010) (NPS 2010b).

Origin / Burn Unit	Number of fires	Percent of fires[a]	Acres burned	Hectares burned	Percent of Area
Human	**25**	**23.5**	**78.0**	**31.6**	**1.0**
North Unit	6	18.9	8.0	3.2	
South Unit	19	27.1	70.0	28.3	
Lightning	**28**	**26.4**	**760.2**	**307.6**	**8.8**
Elkhorn Ranch Unit	1	25.0	158.0	63.9	
North Unit	10	31.2	76.5	31.0	
South Unit	17	24.3	525.7	212.7	
Prescribed	**49**	**46.2**	**7,813.7**	**3,162.1**	**90.0**
Elkhorn Ranch Unit	3	75.0	18.1	7.3	
North Unit	14	43.8	3,385.9	1,370.2	
South Unit	32	45.7	4,409.8	1,784.6	
Unknown	**4**	**<0.1**	**21**	**8.5**	**0.2**
North Unit	2	0.1	19.0	7.7	
South Unit	2	<0.1	2.0	0.8	
Totals:	**106**	**100.0**	**8,672.9**	**3,509.8**	**100.0**

[a] Percentages for origins use the park-wide total and each unit is calculated by the total within that unit.

THRO uses prescribed fire to meet goals for vegetation management and to mimic the natural historic fire regime as closely as possible. However, the number of prescribed fires that can occur depends largely on the funding available each year. Thus, areas of THRO may not see fire for 100 to 200 years (R. Skalsky, pers. comm., 2011).

Severity

Fire (or burn) severity is a term used to describe the physical and chemical changes to the soil, the conversion of vegetation and fuels to inorganic carbon, and structural or compositional transformations that create new microclimates and species assemblages (Key and Benson 2006). Severity is measured by the amount of organic matter loss both above and below the surface of the ground after a fire (Keeley 2008).

One method for measuring burn severity is to compare LandSat imagery prior to and after a fire to determine a Differenced Normalized Burn Ratio (dNBR). The dNBR data, which represent continuous values, are separated into six categories. MTBS (2011b) classifies the six severity categories as unburned to low, low, moderate, high, increased greenness, and no data. According to MTBS (2011a), an analyst evaluates the dNBR data range and determines where significant thresholds exist to discriminate between severity categories. In Sorbel and Allen (2005), the accuracy of the dNBR method was tested by sampling Composite Burn Index (CBI) plots established on the ground in recently burned areas. CBI methods involve scoring burn severity based on 22 variables including soil cover/color change, duff and litter consumption, percent of colonizers, percent of altered foliage, and percent of canopy mortality (Sorbel and Allen 2005). A comparison of CBI scores and dNBRs for the same areas shows that dNBR is "a suitable measure and predictor of burn severity" (Sorbel and Allen 2005, p. 9). MTBS (2011b) provided burn severity data in which acreage of severity categories were derived for the Little Missouri II and Southeast Corner fires within THRO (Table 7).

Table 7. Burn severity for the Little Missouri II and Southeast Corner fires (MTBS 2011).

Year	Fire Name	Unburned to Low Severity	Low Severity	Moderate Severity	High Severity	Increased Greenness
2002	Little Missouri II					
Acres		369	467	505	97	7
Hectares		149	189	204	39	3
% composition		25.5	32.3	34.9	6.7	0.5
2004	SE Corner					
Acres		149	454	320	0	0
Hectares		60	184	130	0	0
% composition		16.2	49.2	34.7	0	0

Immediate post-burn severity is also measured by fire monitoring personnel. Severity for some prescribed burns can be found in THRO prescribed burn reports. The recent prescribed fire reports cite mostly "low" and "moderate" severity with fewer occurrences of "scorched" severity (which is less severe than the "low" category) (Lund 2007, Mitchell 2007, Koller and Freeman 2008, Freeman 2008). Low and moderate severity is a result of the fast-burning nature of THRO grassland fires (NPS 1999). When a fire is behaving in a manner that is counter to the management goals for the fire, the prescribed burning can be stopped, as was the circumstance for the Horse Camp fire of 2007 (Mitchell 2007).

Extent - Area Burned

NPS (1999) suggests that, in comparing the historic presence of fire on the landscape to present fire, the largest difference is probably in the area or extent of fires. Currently, large landscape fires are not allowed to burn due to widespread agricultural land use and a landscape containing many human-created firebreaks (e.g., roads). In addition to land use changes, fire that once was used commonly by Native-American cultures and in cattle ranching practices has since ceased (NPS 1999).

Wildland fires, typically caused by lightning, rarely burn more than a few acres (Appendix A) (C. Sexton, pers. comm., 2011). Where fire dependency is proven for vegetation communities, wildland fires are allowed to burn if fuel load and vegetation composition are within the range of natural variability (NPS 2008). According to the NPS (2008), the preferred strategy for managing fire in the majority of the park is to allow natural processes to occur in order to perpetuate and maintain various ecosystems to the maximum extent possible. Naturally-ignited fires may burn so long as human life and property are protected and all wildland fires are limited to burning in a manner consistent with national policy. Fire is suppressed in the Elkhorn Ranch unit and prescribed fire is implemented when it is determined that it can accomplish predetermined resource objectives (NPS 2008). Appendix A displays the areas burned in THRO from 1946 to 2010.

Fire Origin

Fires in the park are typically started by humans (non-prescribed), lightning, or are prescribed burns conducted by fire management and natural resource personnel (NPS 2003, Guyette et al. 2011) (Appendix A). Another possible ignition source exists in the form of lignite (low-grade coal seams) (NPS 1999). THRO experiences very few lightning-ignited fires (0.00075 fires/km^2/yr) (Schroeder and Buck 1970, also reviewed by Guyette et al. 2011). Higgins (1984) found that between 1949 and 1981, THRO experienced an average of 1.09 lightning-caused fires per year. Lightning-caused fires occur most frequently in July and August (Hull Sieg and Fletcher 1998). Prescribed fire now accounts for the vast majority of area burned in THRO. From 1999 to 2010, prescribed fires accounted for 49 of the 106 fires, and 90% of the area burned. However, lightning-caused fires have been allowed to burn over larger areas in the last decade and appear more frequent in recent decades (Table 8). Table 6 shows the origin of recorded fires in the park from 1999 to 2010.

Table 8. Lightning-caused fire numbers and area by decade in THRO (NPS 2010b).

Decade	No. of lightning-caused fires	Area	
		acres	hectares
1950s	15	308	125
1960s	15	45	18
1970s	11	403	163
1980s	39	699	283
1990s	39	1,185	480
2000s	50	6,746	2,730

Intensity

Fires in mixed-grass prairie ecosystems are generally fast-burning surface fires that tend to leave a mosaic of burned and unburned vegetation (NPS 1999). One goal of THRO fire management is to minimize the occurrence of unnaturally intense fires by reducing hazard fuels. Intensity is the energy or magnitude of heat produced by a fire (Key and Benson 2006, Keeley 2008). Intensity is an indicator to fire managers of the potential effects of fire on soil and vegetation (i.e., fire severity) during prescribed burns. Intensity can be measured in two ways: downward penetration to the soil, or upward spread to vegetation and the atmosphere. Both measures are dependent on residual flame time and are a function of fuel and weather conditions (Key and Benson 2006). Mineral soil surface temperatures from grassland headfires increase as the amount of uncompacted fine fuels increases (Wright and Bailey 1982). Headfires spread with the wind, sometimes uphill; these are different from backfires, which are generally low and burn back into the wind slowly (Wright and Bailey 1982). When fuel availability on grasslands in the Great Plains range from 1,685 to 7,865 kg/ha, the average soil temperature during burning ranged from 102° to 388° C (215° to 730°F). Wright and Bailey (1982) suggest that the highest soil surface temperatures occur from local accumulations of loosely arranged fuel types and strong winds created by fire. Air temperature, relative humidity, and soil moisture do not appear to affect surface soil temperature in grassland fires (Britton and Wright 1971, as cited by Wright and Bailey 1982).

Grasses have a high surface area to volume ratio and moisture is easily lost or gained as combustible material is exposed to the air. These properties result in grass fires that spread quickly and end abruptly (Anderson 1982). Grassland fuels also burn with faster rates of spread than other fuels during similar observed weather conditions (Anderson 1982). THRO contains grassland fuel model 1 (Anderson 1982), where spread of fire is controlled by cured and almost cured herbaceous fuels that are fine, porous, or continuous. As wind speed increases, model 1 develops the fastest rate of spread within grassland models based upon the fine fuels, fuel load, and fuel depth relations. The fast rates of spread produce short periods of intense heat production in THRO (NPS 1999).

Seasonality

The season in which a fire burns affects the diversity, density, and composition of the plant community (Biondini et al. 1989). Burning in different seasons can affect plants and animals differently due to their sensitivity to disturbance at various phenological or reproductive stages and seasonal differences in moisture regimes at the site (NPS 2003). Biondini et al. (1989) found plot diversity of forb species in northern mixed-grass prairies decreased after fall and spring burns and remained the same following a summer burn. This same trend was also evident in areas left unburned. However, plots left unburned and those burned in the summer showed large decreases (54% and 60%, respectively) in density. Smaller declines in density were found in plots burned in the fall and spring (9% and 19%, respectively) (Biondini et al. 1989). Across the landscape, unburned, spring, and summer burn areas had random distribution patterns of forb regrowth, while plots burned in the fall showed high forb clustering (Biondini et al. 1989).

The fire season in THRO is primarily April through September. Prescribed fires usually are conducted in either spring or fall, though fire can be used at any time of year to achieve a particular management objective (NPS 1999). Wienk et al. (2007) generally recommends late summer or fall prescribed burning for areas dominated by native plant species in NGPN park units. However, Wienk et al. (2007) suggest that for areas dominated by cool-season species (e.g., Kentucky bluegrass [*Poa pratensis*], smooth brome [*Bromus inermis*], or crested wheatgrass [*Agropyron cristatum*]) spring burning tends to be more effective in reducing non-native species cover.

Natural fires caused by lightning generally occur in the late spring to early autumn season (NPS 1999). Since prescribed fire has been used in THRO, most larger fires (≥10 acres or 4 ha) have occurred in spring (April and May) and in late summer/fall (August, September, and October) (Table 9). Smaller fires (<10 acres) occur throughout the year. Other small fires occurring outside these months are typically accidental human-caused fires and suppressed lightning-caused fires.

Table 9. Number of fires by month for fires ≥ one acre and those ≥ 10 acres in THRO (NPS 2011b).

Number of fires	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
Period of record 1949 to 2010												
≥ 1 acre	1	4	7	23	16	16	17	29	11	11	-	2
≥ 10 acres	-	-	3	18	6	3	3	10	7	6	-	-
Period of record 1984 to 2010												
≥ 1 acre	1	4	4	20	11	12	6	13	6	8	1	2
≥ 10 acres	-	-	1	16	6	1	1	4	3	6	-	-

Changes in Native Vegetation after Prescribed Fires

Management goals for prescribed fires may include to reduce 1-hour dead and down fuels, decrease cover of non-native grasses, and increase cover of native grasses, forbs, and sedges. Accomplishing vegetation goals and obtaining anticipated results from prescribed fire depends largely on such variables as weather and moisture conditions (R. Skalsky, pers. comm., 2011). In particular, managers at THRO use prescribed fire to stimulate or manage the growth of the following native species: western wheatgrass (*Pascopyrum smithii*), green needlegrass (*Nassella viridula*), needle-and-thread (*Hesperostipa comata*), grama grasses (*Bouteloua* spp.), and common yarrow (*Achillea millefolium*).

Presently, the park contains too few monitoring plots to accurately and statistically measure changes in native vegetation in response to prescribed fires. However, the monitoring plots may provide possible trend and some insight to the degree of change, though no clear, causal relationships can be surmised. Rod Skalsky (pers. comm., 2012) observes that fire clearly impacts deciduous and brush species, but it is difficult to differentiate with any degree of certainty if changes in grasslands are due to fire, to grazing post-fire, or both. While it is most likely the latter, this complex relationship is difficult to measure statistically (Skalsky, pers. comm., 2012). Since 2011, the NGP Fire Ecology Program has been installing more sample plots within burn units at THRO in ordrer to increase precision and statistical confidence (D. Swanson, pers. comm., 2012). In addition, combined monitoring efforts and data from the NGP Fire

Ecology Program and the NGP I&M Program will allow for greater statistical confidence in the future, allowing some of the variables to be statistically differentiated. For example, it is postulated that variables such as interannual total precipitation and seasonal precipitation may have the largest impact on resultant herbaceous diversity and cover. Likewise the timing of prescribed fires in terms of the park's recent precipitation levels (i.e., whether the park is in a wet, normal, or droubt cycle) may significantly impact subsequent herbaceous species composition and cover (Swanson, pers. comm., 2012).

The NGP Fire Ecology Program established fire monitoring units in 1998 and 1999 based on dominant plant species. The NGP Fire Ecology Program established individual post-fire vegetation objectives for each monitoring unit. Each unit (named by dominant plant species) may be represented in several different burn units (e.g., I-94, Jones Creek, Little Missouri, River Corridor). Likewise, some burn units may contain various vegetation types, and therefore distinct monitoring units. There are 27 fire-monitoring plots in THRO (NPS n.d.). From 1999 to 2010, 22 prescribed fires occurred, most in spring (Table 10). Wienk et al. (2007) summarized work completed by the NGP Fire Ecology Program from 1997 to 2007 for the prescribed burns in THRO and is presented in Table 10.

Table 10. Prescribed fire dates, season, and area burned in THRO (from Wienk et al. [2007] and updated using NPS [2011b]).

Unit	Date(s)	Season	Size (acres)	Size (hectares)
Little Missouri	9/21/99	Fall	650	263
SE Corner	4/19/99	Spring	475	192
SE Corner	4/11/00	Spring	331	134
NW Corner	10/18-21/01	Fall	700	283
Little Mo II	5/13/02	Spring	800	324
Peaceful Valley	5/29/02	Spring	18	7
Skyline Vista	10/9/02	Fall	534	216
I-94	10/10/02	Fall	300	121
Cottonwood CG	4/25/03	Spring	250	101
I-94	5/2/03	Spring	250	101
SE Corner	4/23/04	Spring	910	368
Monitoring results of the above prescribed fires are listed in the following section, the prescribed fires listed below are not yet reported for all monitoring unit types				
Horsecamp	4/24/07	Spring	92	37
Loop 1	4/17/07	Spring	17	7
Loop 2	4/17/07	Spring	25	10
Loop 3	4/17/07	Spring	6	2
Loop 4	4/17/07	Spring	44	18
Loop 5	4/24/07	Spring	40	16
Radiotower	10/04/07	Spring	95	38
Loop 6	4/13/08	Spring	40	16
Loop 7	4/13/08	Spring	93	38
Loop 8	4/13/08	Spring	20	8
Loop 9	4/13/08	Spring	70	28
NW Corner 1	10/09/08	Spring	70	28
NW Corner 2	10/09/08	Spring	327	132
NW Corner 3	10/09/08	Spring	297	120
Elkhorn Ranch 1	5/07/09	Spring	3	1
Elkhorn Ranch 2	5/07/09	Spring	11	4
Elkhorn Ranch 3	5/07/09	Spring	4	2
Juniper Campground	No date	Spring	150	61
Loop Unit 1	No date	Spring	11	4
North Loop Burn	5/03/09	Spring	150	61
SE Corner 6	4/22/10	Spring	250	101
Sheep	9/14/11	Fall	3641	1474
Longhorn Flats	9/16/11	Fall	460	186

D. Swanson (pers. comm., 2012) suggests that project based plot monitoring is more informative to park managers on whether objectives are met for each prescribed fire, since prescribed fires occur in both the spring and fall and occur under different temperatures and moisture conditions. Starting in 2011, the NGP Fire Ecology Program has been installing a greater number of plots within each burn unit to address changes to the vegetation composition and cover at the project level.

Crested Wheatgrass (AGCR)

Monitoring units for the non-native crested wheatgrass only exist within the Southeast Corner / I-94 prescribed burn unit. Crested wheatgrass and the invasive smooth brome are the dominant species found in this mostly non-native vegetation unit. The I-94 prescribed fire objectives were to burn 60-90% of project area and reduce fuel loads by 50-85% immediately after the burn. The goals for changes in post-burn vegetation are as follows:

Immediate post-burn:

- Burn 60-90% of project area;
- Reduce fuel load by 50-85%.

Two years post-burn:

- Reduce non-native grasses by at least 20%;
- Increase native grass cover by at least 20%;
- Keep hardwood mortality to less than 10%.

Five year post-burn:

- Maintain a reduction of non-native species;
- Maintain the increase in native species.

Two-year objectives were partially attained in that non-native grasses decreased by 43%. However, native grasses decreased by 39%. Five-year objectives were not met as non-native grasses were only 11% lower than the pre-burned state and native grasses were 5% lower than the pre-burned state. Western wheatgrass was unchanged after one year and decreased two years after the burn. Precipitation is suspected to have affected the re-growth percentages (Wienk et al. 2007).

The Southeast Corner prescribed fire of 1999 had a pre-burn objective to reduce 1-hour decadent fuels by at least 70%. Paintner and Pindel (1999) state this goal was not met and suggest that it may have been unrealistic. Thorstenson and Schmitt (2004) indicate that 70-90% of the area burned during the 2004 Southeast Corner prescribed fire and the immediate fuel load goal was met in blocks (sections of the fire) F, G, and H.

Silver sagebrush shrubland (ARCA)
Four prescribed fire units contain plots for this monitoring unit; two plots burned in 1999 and two in 2002.

Immediate post-burn objectives:

- Burn 60-90% of the available project area.

Two years post-burn:

- Reduce silver sagebrush density by 40-60%;
- Increase native herbaceous cover by 20%;
- Reduce non-native cover by 25%, and increase native perennial grass cover by at least 25%.

Five years post-burn:

- Maintain the reduction of shrub density;
- Increase native species;
- Maintain a reduction in non-native species.

The reduction of silver sagebrush density was reached for the two-year post-burn objectives, while the increase and reduction goals of native and non-native species were not met. However, five years post-burn, non-native grass cover decreased by 55%, while native grass and forb cover increased by 18% and 45%, respectively (Wienk et al. 2007).

Cottonwood/Rocky Mountain juniper forest (PODE)
Of the three plots installed for monitoring these forests, two have been burned. Post-burn vegetation objectives are:

Immediate post-burn:

- Reduce total fuel loading by 60-80%.

Two years post-burn:

- Reduce total brush density by 30-50%;
- Reduce conifers by 50-70%,
- Acceptable mortality of deciduous overstory trees was 20%.

The Little Missouri II fire decreased total fuel loads by 17% immediately post-burn and total fuel load actually increased by 38% at five-year post-burn measurements. However, significant decreases in pole-sized stems/acre (from ~90 stems/acre pre-burn to ~15 stems/acre year five) were realized at 5 years in this burn unit for cottonwood and very few overstory trees were reduced. Conifers were not evaluated in Wienk et al. (2007) for this burn unit.

Green needlegrass mixed-grass prairie (STVI)
Ten plots were installed for the monitoring of this unit; three have burned in the Southeast Corner unit and three have burned in the Northwest Corner unit. The Southeast Corner unit is dominated by Kentucky bluegrass, whereas the Northwest Corner unit is a more appropriate unit to assess the condition of green needlegrass plots, as native species are dominant (Wienk et al. 2007). Post-burn vegetation objectives are:

Immediate post-burn:

- Reduce thatch by 20-30%.

Two years post-burn:

- Reinvigorate native species and decadent vegetation;
- Reduce brush species;
- Restore and maintain native plant communities;
- Reduce non-native cover by at least 20 to 30%;
- Increase native perennial grass cover by at least 20 to 30%;

- Reduce brush by 20 to 30%;
- Increase native herbaceous and shrub cover by 20 to 30%.

Immediate visual estimates of the Northwest Corner fire in 2001 found that about 50% of the thatch was removed (Rehman and Thorstenson 2001). Based on the Northwest Corner prescribed fire monitoring report, none of the two-year objectives were met (Wienk et al. 2007). While non-native grass cover was reduced by 53%, non-native forb cover increased by 100%. Five years after burning, native grass cover had increased by 40% (Wienk et al. 2007).

Snowberry shrub land (SYOC)
As of 2007, one plot was installed to monitor this mixed-grass prairie vegetation type.

Immediate post-burn:

- Reduce silver sagebrush density by 40-60%.

Two year post-burn:

- Reduce non-native cover by at least 25%;
- Increase native perennial grass cover by at least 25%;
- Reduce silver sage by 50%;
- Reduce total fuel load by 75%.

Immediate post burn goals were inconclusive and silver sage reduction was the only two-year post burn objective attained (Wienk et al. 2007).

A park-wide summary of fire monitoring plots in THRO through 2007 indicated that 16 plots were burned and 15 of them were visited five years post-burn (Figure 2) (Wienk et al. 2007).

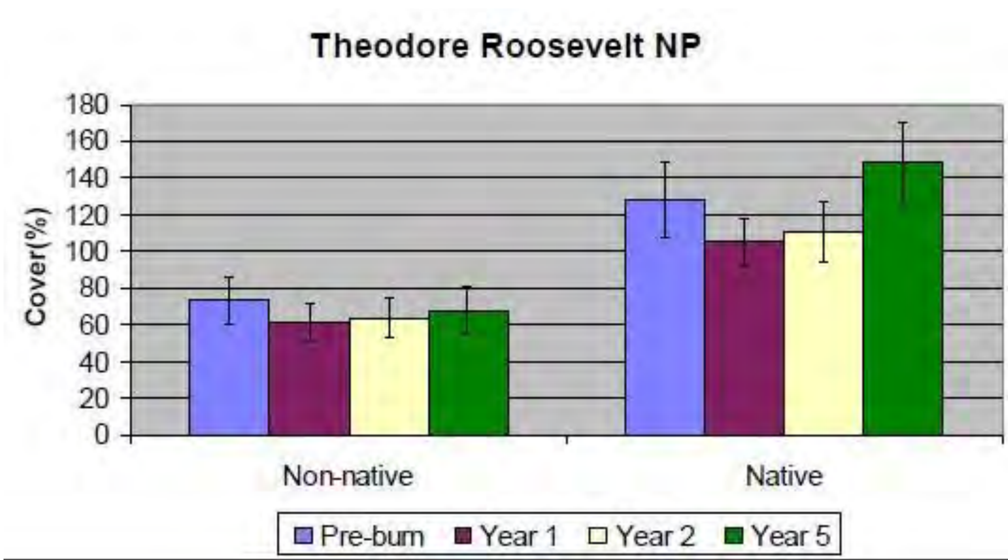


Figure 2. Pre-burn and post-burn percent cover of native and non-native plant species (average of 15 monitoring plots). Reproduced from Wienk et al. (2007).

Since Wienk et al. (2007), several treatments (fires) have been conducted in THRO. Decreases in the percent cover of nonnative grasses and increases in both native grass and sedges occurred in the Southeast Corner burn unit (which contains three green needlegrass monitoring plots) (Figure 3). Kentucky bluegrass showed the most notable decrease in cover of five major non-native grasses.

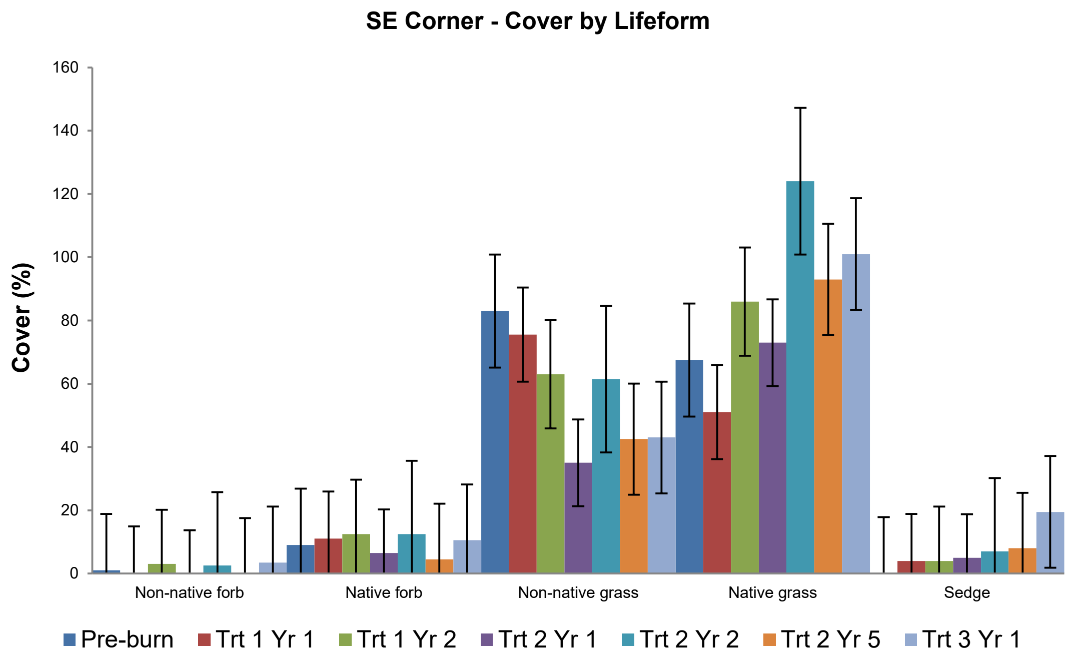


Figure 3. Southeast Corner burn unit changes in percent cover by life form following multi-year, multi-burn, prescribed fire treatments in THRO.

Similar decreases in non-native grasses and increases in native grasses and sedges also were reported in the Northwest Corner burn unit following multiple fire treatments (Figure 4). However, it is not clear how the additional influence of livestock and ungulate grazing may influence the results of any post-burn measurements.

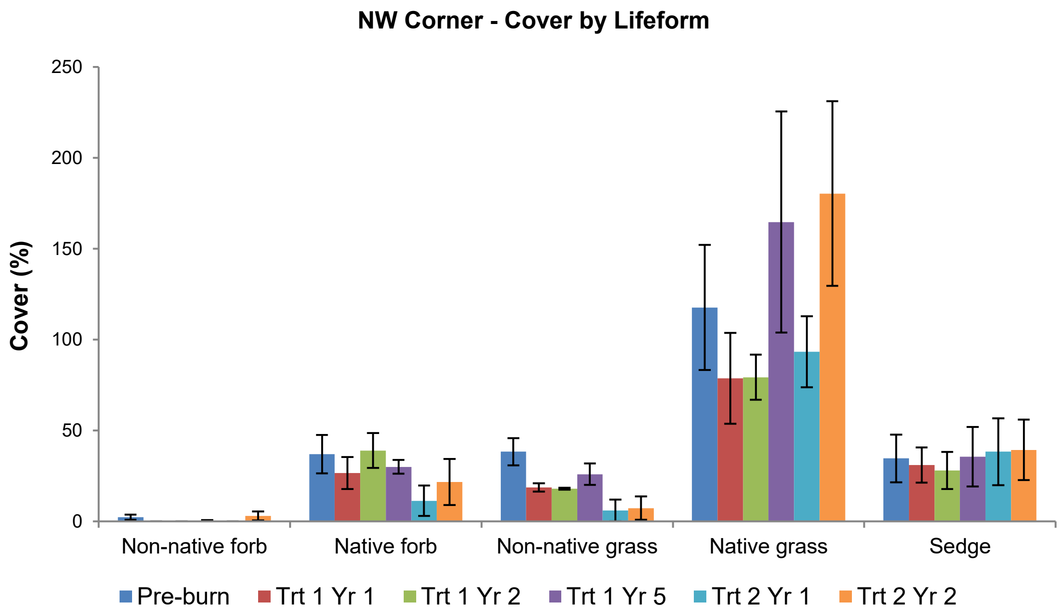


Figure 4. Northwest Corner burn unit changes in percent cover by life form following multi-year, multi-treatments (fires) in THRO.

Overall, shrub density objectives for both silver sagebrush and western snowberry were achieved in the Little Missouri burn unit, though at ten years post-burn, a slight increase occurred in silver sagebrush density from initial post-burn measurements (Figure 5).

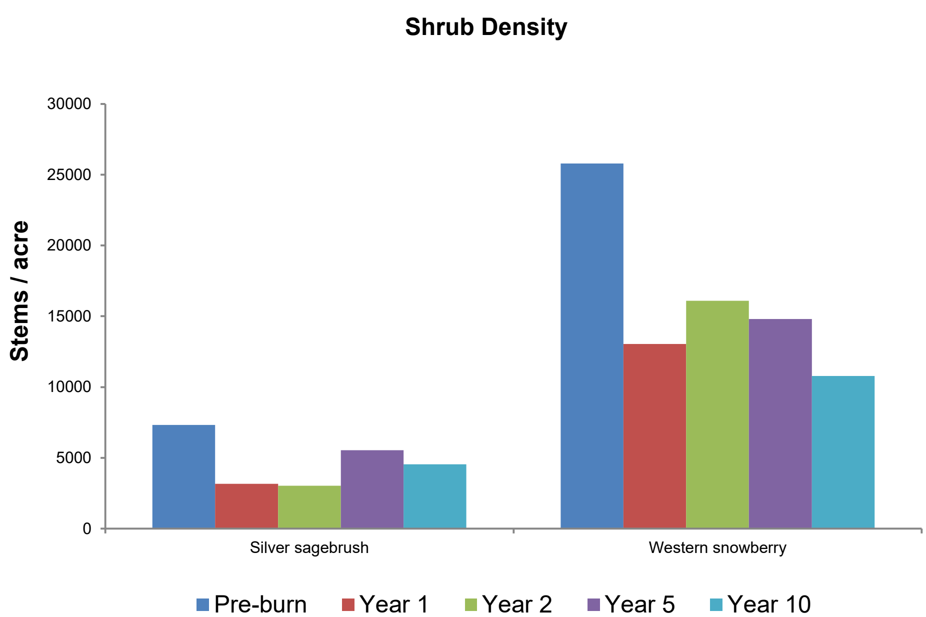


Figure 5. Shrub density changes post-fire in the Little Missouri burn unit.

Threats and Stressor Factors

Fire suppression and development adjacent to the park were identified by park managers as threats or stressors to the fire regime in THRO. Throughout the early to mid-1900s, fire suppression was practiced throughout the northern Great Plains region to protect private property and resources. This prevents the natural extent and frequency from occurring, especially in the case of large landscape-scale fires.Suppression of nearly all unplanned fires continues as a part of the THRO Fire Management Plan, creating a situation in which the fire regime is almost completely dependent upon prescribed burning and non-fire fuel treatments.

Increased development adjacent to the park increases the opportunity for fires occurring within the park to destroy private property or structures and threaten human life should a fire escape park boundaries. This increased risk to private property elevates the need to suppress natural fires and requires deliberate, careful planning of prescribed fires in the park in order to achieve fire management goals while preserving park structures and private property. As a result, large-scale fires are rare in the region and occur at a lower frequency.

Data Needs/Gaps

Immediate monitoring and reporting of burn intensity and severity will assist managers to further understand fire's effects on vegetation. Continued capture/delineation of fire perimeters using GPS data (adding to 10 years of consistent data collection) will give managers a clear understanding of fire history in each burn unit, and will illustrate areas of the park that have not experienced prescribed fire for long periods. Continued and consistent monitoring of established vegetation plots will provide a better understanding of the fire effects on vegetation as well as a way to determine if management objectives are being met. With additional plots within burn units and in combining NGP Fire Ecology Program and NGP I&M data vegetation plots may also allow managers to correlate different fire management parameters (e.g., season, fuel loads, or weather conditions) with the desired vegetation outcomes.

Overall Condition

Fire over the last several decades in THRO has been managed either through suppression (accidental fires or in some cases of lightning-caused) or through prescribed fires. While the following measures characterize the present-day fire regime in the park, prescribed fire has almost completely replaced natural-start fires. Prescribed fires are set to achieve desired effects on vegetation and soils. Therefore, the effects of fire may be considered a more important measure of fire's condition in THRO than various parameters of fire occurrence in the park. The desired effects vary by individual burn unit, monitoring unit, and by fire. Understanding how fire parameters (e.g., intensity, severity, flame length, wind) influence the effects of burning will assist park staff in meeting their management objectives.

Frequency

The *Significance Level* for frequency is a 3. A fire behavior model suggests that the park should have fire-return intervals of 5 to 30 years. However, some areas of THRO do not burn for 100 to 200 years. For this reason, *Condition Level* for frequency is a 2, indicating the component is of moderate concern.

Extent - Area Burned
The *Significance Level* for area burned is a 3. There is not a target established for number of acres to be burned annually in the park. However, some areas in the park have not experienced fire in over 200 years, and the declining fuel budget is likely to further decrease the average extent burned per year (R. Skalsky, pers. comm., 2011). Thus, the *Condition Level* for extent of area burned is a 2, indicating the condition is of moderate concern.

Intensity
The *Significance Level* for intensity is a 2. Intensity is measured by the rate of spread and flame length. Prescribed fires are heavily monitored and managed during burns and wildfires are monitored and sometimes suppressed, depending on location, suppression support, and weather conditions. Since managers extinguish fires that are behaving unfavorably, the *Condition Level* for intensity is a 0, indicating the component is of no concern.

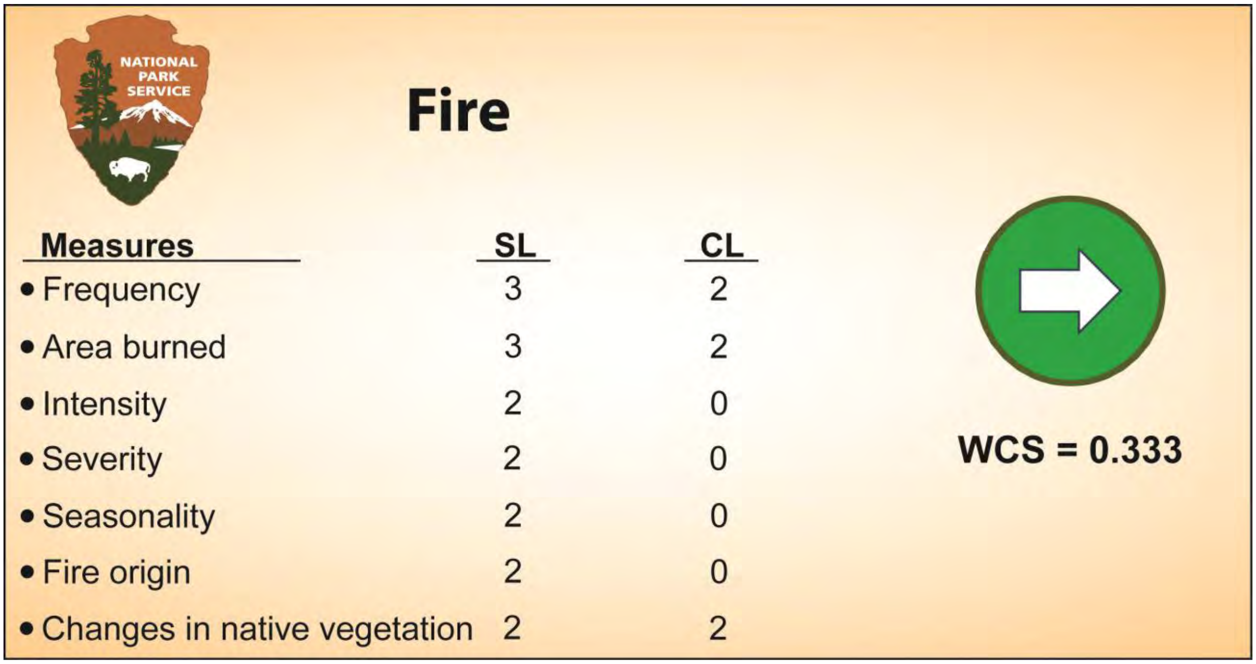
Severity
The *Significance Level* for severity is a 2. Fires that burn too hot will destroy vegetation completely and damage soils; thus, personnel will extinguish a prescribed fire that has the potential to become too severe. The majority of fires in THRO had a reported severity of "scorched", "low", or "moderate," largely due to the controlled nature of the fires. The *Condition Level* of severity is a 0, indicating the component is of no concern. This is because fire personnel generally control severity, and to date overall severity has been low.

Seasonality
The *Significance Level* for seasonality is a 2. Prescribed fires usually occur in the fall and spring but fire can be used during any season to meet management goals. Since most fires in THRO are prescribed, and wildfires only burn a few acres at a time and have minimal effects on vegetation park-wide, the *Condition Level* for seasonality is a 0, indicating no concern. The appropriate season in which to use prescribed fire to achieve a particular set of objectives (e.g., reducing non-native cool season grasses) continues to be a topic of research. Fire effects monitoring results will aid in answering this general research question.

Fire Origin
The *Significance Level* for fire origin is a 2. The *Condition Level* for fire origin is a 0, indicating no concern because 93% of the acres burned since 1984 are of prescribed origin. Since 2000, only five human-caused fires have occurred in the park, burning a total of six acres. Wildfires generally are suppressed because they are less predictable, and therefore pose threats to property within and adjacent to THRO; however, larger areas have burned from 1999 to 2010 due to natural wildfire.

Changes in Native Vegetation
The project team defined the *Significance Level* for changes in native vegetation as a 2. The *Condition Level* for changes in native vegetation is also a 2, indicating that the component is of moderate concern. Weather and moisture variables affect both the way prescribed fires burn and the results from prescribed fires. Most immediate prescribed fire goals have been met, while two-year and five-year goals are sometimes met. Some progress has been realized as is evidenced by 10-year post-fire effects (e.g., continued reductions in shrub densities).

Weighted Condition Score
The *Weighted Condition Score* (WCS) for the fire component is 0.333 indicating the condition is in good condition with a stable trend.



4.1.6 Sources of Expertise
Rod Skalsky, Fire Management Officer, THRO
Dan Swanson, Fire Ecologist, WICA
Chad Sexton, Geographic Information Systems Analyst, THRO

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4.2 Wind and Water Erosion

* During initial project scoping, project stakeholders identified wind and water erosion as important processes within the park, but little or no data exist to examine their current condition. Thus, no data will be summarized nor will the condition of erosion be assessed. Rather, a brief overview of the component and a description of potential measures, threats, and stressors are provided for the primary purpose of inclusion in a future assessment when appropriate data are available.

4.2.1 Description

Wind and water erosion are natural processes that have shaped the landscape of THRO, particularly the dramatic geological formations of the badlands. Erosion rates on the badlands slopes of western North Dakota have been estimated at 0.28-1.04 cm/year (Tinker 1970 and Bluemle 1975, as cited by Von Loh et al. 2000). Factors that influence erosion rates include lithology, slope gradient (steepness), and vegetative cover (Butler et al. 1985, KellerLynn 2007). The presence of bentonite (a clay material that swells when wet) in a rock formation increases its susceptibility to erosion. Bentonite is common in the Sentinel Butte Formation of THRO, where most landsliding occurs in the park (KellerLynn 2007). Slope gradient influences water infiltration, especially of runoff water, therefore affecting erosion rates (Butler et al. 1985). Finally, vegetative cover plays a key role in protecting surfaces from wind, rainsplash, and runoff (Wei et al. 2009, Munson et al. 2011).

One significant erosional process of concern to park managers is mass wasting, which is the downslope movement of soil and rock material by gravity (e.g., landslides, slumping, soil creep) (NPS 2003, KellerLynn 2007). This movement, sometimes sudden and dramatic, can threaten park roads, trails, and visitor facilities (NPS 1986). For example, significant slumping due to above normal precipitation in 2011 led to the closure of a portion of road in the North Unit through Cedar Canyon, as it was deemed unsafe for visitors (Laurie Richardson, THRO Botanist, e-mail communication, 2012). Mass wasting in THRO occurs primarily as landslides and soil creep (Biek and Gonzalez 2001). Evidence of landslides is common in the North Unit, where "rotational slumps" are apparent in several locations (Photo 7). Large slumps with hummocky surfaces occur along the Little Missouri River, with the largest occurring on the north flank of the Achenbach Hills near Achenbach Spring (Biek and Gonzalez 2001). Another notable rotational slump can be found north of the river between the east entrance and Juniper Campground. The largest landslides in the South Unit occur along the eastern escarpment, on the eastern flank of the Petrified Forest Plateau, and around Buck Hill. Also in the South Unit, soil creep is common on steep slopes of the Bullion Creek Formation with north or northeast aspects (Biek and Gonzalez 2001).

Photo 7. A small landslide in Sentinel Butte strata (left) and a large rotational slump in the North Unit (right) (Biek and Gonzalez 2001).

Other erosional processes in the park include rill and gully erosion, common in basal sandstone of the Sentinel Butte formation, and piping (KellerLynn 2007). Piping occurs “when surface runoff erodes vertically downward through poorly lithified sediments”, creating a network of tunnels, small caves, and pseudokarst features that channel runoff underground (Biek and Gonzalez 2001, p. 56). It is common in poorly lithified bedrock and associated colluvial, alluvial, and landslide deposits, which regularly occur at or near the bottom of steep badlands slopes (Biek and Gonzalez 2001). These pipes can eventually collapse, potentially causing subsidence or rockslides that could threaten nearby roads or structures.

Another erosion-related threat to the park is the exposure of lignite beds (also known as “brown coal”), which can ignite when exposed to air and trigger fires (Biek and Gonzalez 2001). Once ignited at the surface, lignite often burns back into the hillside or formation, creating an empty space into which overlying beds settle or collapse. Significant burning and subsidence occurred in the Buck Hill area from the early 1950s through the 1970s (Biek and Gonzalez 2001). No lignite beds were burning in THRO as of 2007, but several small fires occurred in the South Unit’s northeastern corner during the late 1980s and early 1990s (KellerLynn 2007). However, outcrops of lignite are a constant concern for the park’s fire management program and can influence park planning and management (KellerLynn 2007).

4.2.2 Measures

- Changes in landscape features

- Amount of material removed (erosion rates)

4.2.3 Reference Conditions/Values

A reference condition for wind and water erosion in the park has not been determined.

4.2.4 Data and Methods

Information regarding erosion in the park was primarily found in Biek and Gonzalez (2001) and the THRO Geologic Resources Evaluation Report (KellerLynn 2007). Numerous journal articles were consulted regarding the impact of climate on erosional processes.

4.2.5 Current Condition and Trend

Changes in Landscape Features
Wind and water erosion are constantly changing the landscape of THRO. However, no research or consistent monitoring of these changes has occurred.

Amount of Material Removed (Erosion Rates)
To date, no current or historical data are available for erosion rates in the park.

Threats and Stressor Factors
Climate is a critical factor in erosional processes, especially in semiarid regions (Kuehn 2003, Graham 2008). According to Wei et al. (2009, p. 308), "rainfall is the initial and essential driving force for natural runoff generation and erosion variation." Climate variables also impact vegetation patterns, which in turn influence erosion across the landscape. An increase in precipitation generally is thought to increase erosion rates (as reviewed by O'Neal et al. 2005). A decrease in precipitation therefore would be expected to reduce erosion rates; however, a reduction in precipitation could reduce vegetative cover, increasing the surface area exposed to rainfall and runoff (Clarke and Rendell 2010). A reduction in vegetative cover may increase the soil's exposure to wind erosion as well (Munson et al. 2011). The frequency of precipitation can also impact erosional processes. Wei et al. (2007) found that rainfall regimes with strong intensities and low frequencies induced more severe runoff and soil erosion than regimes with weak intensities and high frequencies.

In semi-arid badlands like those found at THRO, "the ephemeral nature of precipitation and runoff means that change is particularly associated with extreme events" (Faulkner 2008, p. 92). Rain often comes in sudden showers that can drop several inches per hour (Opdahl et al. 1975, as cited by KellerLynn 2007); the resulting runoff typically causes rapid erosion. Heavy downpours have increased in frequency and intensity across the U.S. over the past several decades, a trend that is expected to continue throughout this century (Karl et al. 2009).

Erosion also can be exacerbated by road construction and trail use. Movement is still occurring in landslide deposits under several roads in the park, causing buckled pavement and dips in the roads (Biek and Gonzalez 2001). For example, the North Unit's scenic drive crosses several landslide deposits between the Concretion Pullout and the Highway 85 junction. In the South Unit, the park road crosses landslides near the Ridgeline Trail trailhead and along the Buck Hill road (Biek and Gonzalez 2001, KellerLynn 2007). Disturbance caused by repair activities such as placing fill, regrading, or rerouting drainage in these deposits may actually increase instability (Biek and Gonzalez 2001, KellerLynn 2007). Intense trail use or poor trail design often result in soil erosion and trampled vegetation (NPS 1994). In some places, trails have become deep channels that actually concentrate runoff, further exacerbating erosion. The eroded material can then impact vegetation and soils in previously undisturbed areas along the trail (NPS 1994).

Data Needs/Gaps
No research has been conducted in the park regarding either changes in landscape features or erosion rates. A multi-year study of erosion rates using a variety of sampling techniques (e.g., survey stakes and pins, sediment erosion traps, photogrammetry, LiDAR) is currently underway at Badlands National Park in South Dakota (Stetler and Benton 2011). The results of this study,

which is scheduled for completion in 2012, could help THRO design an erosion survey and monitoring plan.

Overall Condition
Due to a lack of information and data regarding erosion rates and erosional landscape changes in the park, the overall condition of wind and water erosion cannot be assessed at this time.

4.2.6 Sources of Expertise
Bill Whitworth, Chief of Resources, THRO

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4.3 Flooding (Little Missouri River)

4.3.1 Description

The Little Missouri River is a tributary of the Missouri River, which begins in northeastern Wyoming and flows through all three units of THRO (through 14 km of the South Unit, 23 km of the North Unit, and through Elkhorn Ranch) (Miller 2005, KellerLynn 2007). Peak flows of the Little Missouri River in the 20th century were lower than in previous centuries; regardless, they have subsequently altered floodplain formation (Miller and Friedman 2009). These overall decreases in peak flows are postulated to be a result of climatic shifts (changes in precipitation and temperature), as the Little Missouri River is mostly unregulated (Miller and Friedman 2009). Despite the overall decrease in peak flow magnitude, several park features (Cottonwood and Juniper Campgrounds, Peaceful Valley Ranch, South Unit Park Headquarters, and portions of park roads) are located within the 100-year floodplain, leaving a 1% chance each year that these features will be in the river's inundation zone (KellerLynn 2007). In May 2011, the Little Missouri River experienced significant flooding in THRO and the surrounding area following heavy spring rain events.

Photo 8. Record flooding on the Little Missouri River in May 2011 as viewed from the MP 27 loop road in the South Unit, THRO (NPS photo).

The National Weather Service defines a flood as "any high flow, overflow, or inundation by water which causes or threatens damage (NWS 2012)." The National Weather Service defines gage heights that correspond to flooding events at certain gages. For the Little Missori River, two gages are most relevant to THRO, one at Medora and one near Watford City (Plate 1). The gage heights that represent flooding events at these sites do not correspond to flooding events in the park for all high-water events though; in 2011, a high-water event occurred that caused substantial flooding in the park, yet the gage height at Watford City did not correspond to a flood event as defined by the National Weather Service.

4.3.2 Measures

- Frequency
- Magnitude
- Duration
- Effects of upstream water withdrawal on summer low flows
- Snow pack

4.3.3 Reference Conditions/Values
The reference condition for flooding is the range of variation since the beginning of data collection (1904 and 1935 for Medora and Watford City, ND, respectively).

4.3.4 Data and Methods
Literature provided by THRO (Emerson and Macek-Rowland 1986; KellerLynn 2007; Miller 2005; Miller and Friedman 2009) and USGS stream gage statistics (USGS 2011a, b, c) were the main sources of information for this assessment. Two USGS gage sites were utilized for this assessment: Little Missouri River at Medora, ND (USGS Station No. 06336000) and Little Missouri River at Watford City, ND (USGS Station No. 06337000). The Medora gage is indicative of streamflow characteristics near the South Unit and the Watford City gage is indicative of streamflow in the North Unit; there is no stream gage near the Elkhorn Ranch Unit of THRO.

4.3.5 Current Condition and Trend

Frequency

Peak flows in the Little Missouri River occur in late March and early April of each year, with periodic summer high flows occurring in May through July. Spring peak flows are generally a result of snowmelt, but can also result from rain and the breaking up of river ice; summer high flows are generally the result of intense thunderstorms (Miller and Friedman 2009). High-flow events causing significant floodplain destruction occur every five to ten years on the Little Missouri River (Miller and Friedman 2009). Frequent flooding increases erosion and causes changes to the channel area, which is important for establishment and regeneration of cottonwoods (*Populus deltoides*).

Magnitude

Over the last century, there has been a reduction in the magnitude of peak flows on the Little Missouri River (Miller and Friedman 2009). Since the Little Missouri River is largely unregulated, climatic factors, such as temperature and precipitation, are thought to be the primary driver in the overall reduction in peak flow magnitude during the 20th century.

Photo 9. Flooding on the Little Missouri in May 2011 as viewed from the Medora Overlook in the South Unit, THRO (NPS photo).

Discharge has been monitored since 1935 (North Unit) and 1904 (South Unit), and the overall average annual peak flow of the Little Missouri River was 15,122 cfs (mean discharge = 535 cfs) (Miller 2005, Miller and Friedman 2009). However, there are many gaps in the available data for the South Unit. The largest recorded instantaneous peak flow of the

Little Missouri River occurred in 1947, with a peak discharge of 110,000 cfs (Miller and Friedman 2009). This 1947 flood was seven times larger than the average annual peak flow on the Little Missouri River, and reached a peak height of 20.5 ft at Medora, 5.5 ft above the National Weather Service 15-foot Flood Stage (USGS 2011a). The second largest recorded flood occurred in 1950, with a peak discharge of 60,000 cfs. Recently, in May of 2011, a high-water event occurred; stage height of this event reached 16.70 feet and discharge reached 30,000 cfs at the Watford City gage (USGS 2012). At the same time, the stage height exceeded the flood stage (15 ft) at Medora, reaching a height of 20.39 ft with a discharge of 35,100 cfs. For the period of recorded streamflow, "peak flows along the Little Missouri River have declined over time and the active channel area has decreased by 38% since 1939" (Miller and Freidman 2009, p. 754). Peak discharge is an important driver of erosion and channel migration (Miller 2005), which are both necessary for cottonwood establishment. Therefore, a decrease in flood magnitude could be problematic for cottonwood forests. Table 11 displays peak discharge for the Little Missouri River at the North and South Units of THRO, along with other tributaries of the Little Missouri River. Annual peak flow data recorded at the Medora, ND and Watford City, ND gages are included in Appendices A and B, respectively.

Table 11. Flood discharges for the Little Missouri River and tributaries in THRO. Discharges in cfs; maximum water-surface elevations are in feet above sea level (asl) (Emerson and Macek-Rowland 1986).

	Peak recorded discharge	Maximum water-surface elevation	Date	100-year flood discharge	500-year flood discharge
North Unit	110,000 cfs	1,953.03 ft asl	25 March 1947	78,800 cfs	113,500 cfs
South Unit	65,000 cfs	2,267.25 ft asl	23 March , 1947	65,300 cfs	99,300 cfs
Elkhorn Ranch	No data	No data	n/a	69,000 cfs	103,000 cfs
Knutson Creek	No data	No data	n/a	31,800 cfs	
Paddock Creek	No data	No data	n/a	13,500 cfs	
Squaw Creek	No data	No data	n/a	24,600 cfs	

North Unit

Figure 6 represents peak discharge at the Watford City USGS stream gage near the North Unit of THRO. This stream gage gathers continuous data, with no data gaps, making overall trends discernable. Since 1980, no higher peak discharges have occurred, such as those seen in 1947, 1950, 1952, and 1972.

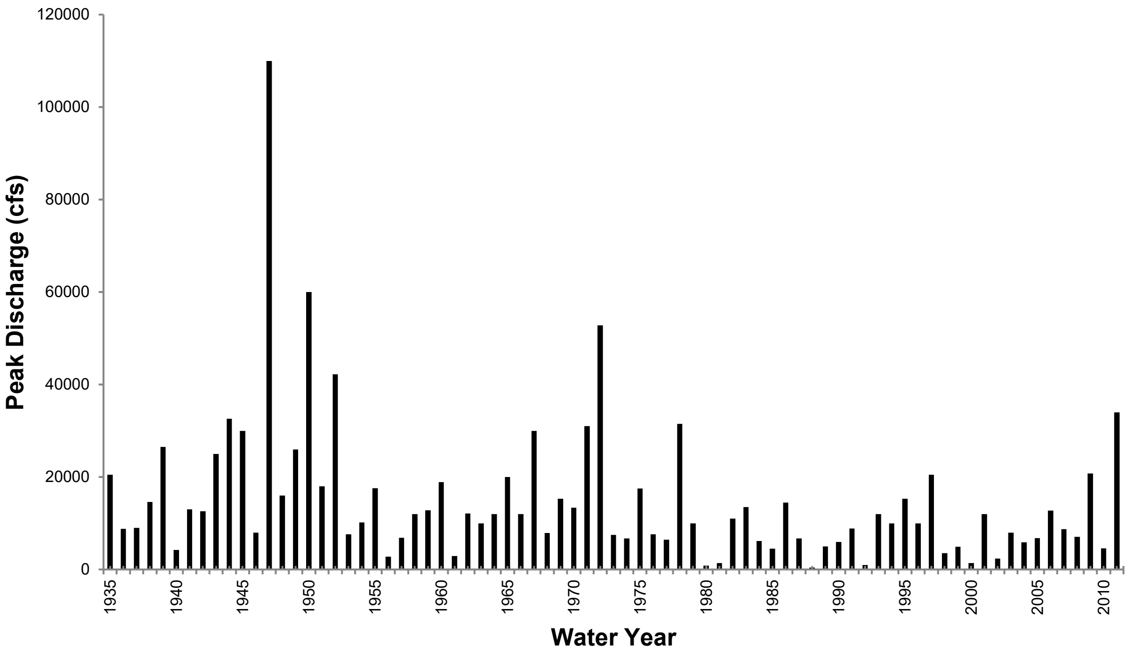


Figure 6. Peak discharge (cfs) for the Little Missouri River near Watford City, ND (USGS Station No. 06337000) from 1935-2010 (USGS 2011c, 2012).

The National Weather Service determined the flood stage at Watford City to be 20 ft (USGS 2011b). At Watford City, the Little Missouri River has only reached flood stage twice since 1935 (in 1947 and 1950) (USGS 2011b). The peak gage height for 1947 and 1950 were 24 and 21.42 ft, respectively (USGS 2011b). However, there seem to be many years with high peak gage heights, but relatively low peak discharge. J. Hughes (pers. comm.) indicated a potential reason for some of the discrepancies is that the gage near Watford City has changed location on numerous occasions.

South Unit

Figure 7 represents peak discharge at the USGS Medora stream gage near the South Unit of THRO at Medora, ND. The stream gage data for this location has many multi-year data gaps. For approximately 25 years (from the mid-1970s until 2000), there are no USGS stream gage statistics available. In addition, there are multi-year data gaps in years prior to 1945. It is difficult to draw any conclusions about peak discharge trends from the data that are available, due to the large data gaps.

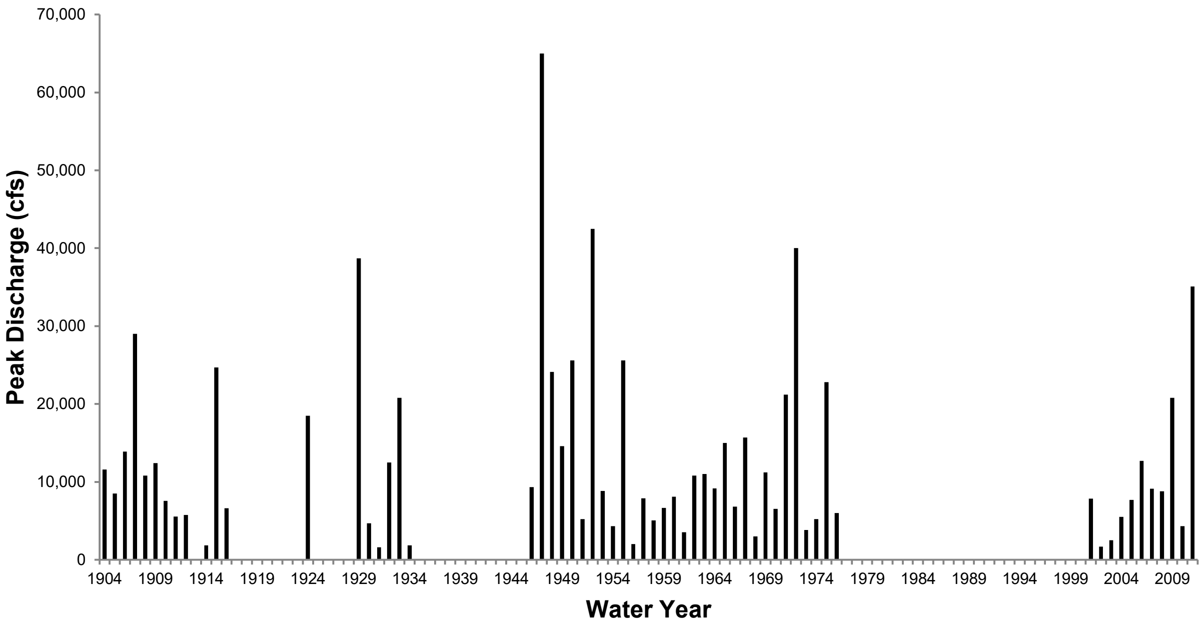


Figure 7. Peak discharge (cfs) for the Little Missouri River at Medora, ND from 1904-2010 (USGS Station No. 06336000) (USGS 2011c, 2012).

The National Weather Service determined the flood stage at Medora to be 15 ft (USGS 2011a). At Medora, the Little Missouri River has reached flood stage seven times since 1904 (in 1904, 1929, 1947, 1952, 1972, 2009, and 2011) (USGS 2011a, 2012). The peak gage heights for 1947, 2011, 1972, 1952, and 1929 were the highest recorded, with respective gage heights of 20.50, 20.39, 18.68, 18.35, and 17.20 ft (USGS 2011a). Interestingly, the 1950 peak gage height passed flood stage in Watford City, but did not in Medora. All years that passed flood stage at Medora (aside from 1947) did not pass flood stage in Watford City, which could be due to the difference in flood stage heights (15 versus 20 ft). As expected, all flow events that surpassed flood stage heights at Medora correspond to years with a higher-than-normal peak discharge; further investigation is needed to determine the actual effects of these high-water events in the park.

Snowpack

Snowpack is often measured in snow water equivalent (SWE). SWE is the water depth that would hypothetically result in the event that the entire snowpack melted at one time (NRCS 2009). This estimate is based off snow depth and snow density information, gathered from SNOTEL sampling locations. Snowpack is directly related to the amount of water entering river systems, and is therefore important to understand when analyzing flooding. The nearest SNOTEL sampling station to the Little Missouri River is located at Cole Canyon, in Sundance, Wyoming. This SNOTEL station is located approximately 60 km east of the headwaters of the Little Missouri River, and should provide a general trend of the changes in snowpack in the last 40 years. Figure 8 displays SWE averages from 1971-2000 and 2001-2009 at Cole Canyon. The 2001-2009 averages are all smaller than the 1971-2000 averages, with 2001-2009 May averages at approximately 1/3 of the 1971-2000 May averages. While it may not be appropriate to draw further conclusions, this general decreasing trend in snowpack could be associated with the conclusions of Miller and Friedman (2009), that climate is the primary driver for the recent decrease in peak flow magnitudes on the Little Missouri River.

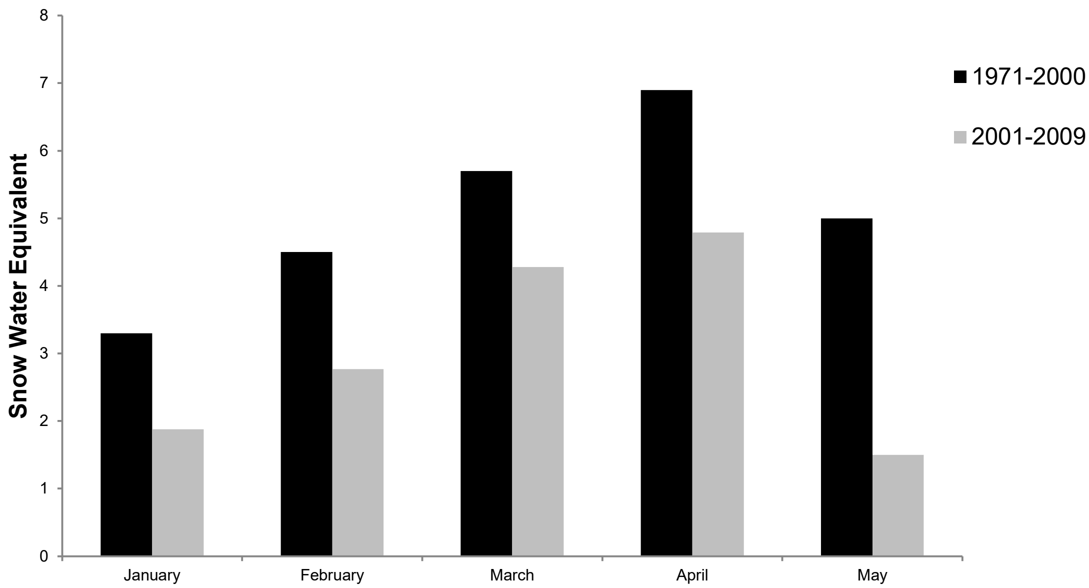


Figure 8. Snow water equivalent averages from 1971-2000 and 2001-2009 at Cole Canyon, Sundance, Wyoming (NRCS 2009).

Duration

The duration of a flood event is related largely to the volume of water received by the stream from precipitation and snowmelt events and the location of where runoff enters the stream. Spring floods are generally longer in duration than summer floods. A positive correlation between duration and magnitude exists, with larger floods having longer durations; a flood of higher magnitude will have more water, so it will take a longer period of time for the saturated soil and upstream tributaries to drain back to normal levels. Contrastingly, summer floods are much shorter, as they are generally a result of intense rain and thunderstorms. While duration appears to be important in forming the total channel area, peak magnitude appears to be the most important factor (Miller 2005).

Effects of upstream water withdrawal on summer flows

Jeff Hughes (pers. comm., 2012) indicated that he is gathering information on water rights and permits for water withdrawal on the Little Missouri River. Currently, the Theodore Roosevelt Medora Foundation has a permit to withdraw 11 cfs from the Little Missouri River (3 miles upstream of the South Unit of THRO) between 1 March and 1 July. The Medora Foundation permit and other similar operations upstream of THRO may affect flow in the Little Missouri River and the NPS Water Rights Branch is currently collecting available information on the number of water users and the amount of water diverted and withdrawn from the Little Missouri River system to determine if adverse impacts could be occurring at the park.

Threats and Stressor Factors

The climate around THRO is semi-arid, with extreme temperatures in the summer and winter months (Miller 2005). On average, the Little Missouri watershed receives 35.6 cm (14 in) of precipitation per year, and approximately 76 cm (30 in) of snowfall (average from 1939-2003) (Miller 2005). In the last 100 years, there has been a reduction in peak flows, and because the Little Missouri is largely unregulated, the cause of this reduction is thought to be related to climate. Climate is related directly to precipitation and snowpack, which directly influence the amount of water moving through the Little Missouri River system. This reduction in peak flows is correlated strongly with a reduction in erosion (Miller 2005), which poses a risk for cottonwood regeneration.

Water retention in stock dams (in upriver tributaries and draws) can change the flooding patterns of the Little Missouri River. There is no current literature explaining the effects of water retention in stock dams in upriver tributaries and draws of the Little Missouri River. Other potential concerns include upstream irrigation practices and withdrawals associated with hydraulic fracturing.

Data Needs/Gaps

Peak magnitude and peak gage height for the Medora gage has major data gaps throughout the entire period of data collection (1904-present). J. Hughes (pers. comm., 2012) indicated that the Medora and Watford City gage locations are largely similar, and statistical models (using the Watford City gage data) likely could be used to predict the missing years for the Medora gage.

J. Hughes (pers. comm., 2012) is currently investigating the amount and extent of water permits near the Little Missouri River, to get a better idea of the amount of water taken from the river. This information would be beneficial in understanding upstream drawdown statistics.

Research investigating the number, location, and extent of stock dams in the upstream tributaries of the Little Missouri River would be beneficial to get a better idea of how these might be affecting floods near THRO.

Overall Condition

Frequency

The project team defined the *Significance Level* of frequency as a 3. As a result of snowmelt, spring floods are still occurring, and summer floods from intense rain and thunderstorms are also occurring; thus, a *Condition Level* of 1 (low concern) was assigned for the frequency measure.

Magnitude

The project team defined the *Significance Level* of magnitude as a 3. While the spring and summer peak flows are still occurring on the Little Missouri, Miller and Friedman (2009) point out that the peak flows have dropped over the last century, likely due to climate change. The decrease in magnitude, coupled with concerns regarding climate change, result in a *Condition Level* of 2 (moderate concern) for the magnitude measure.

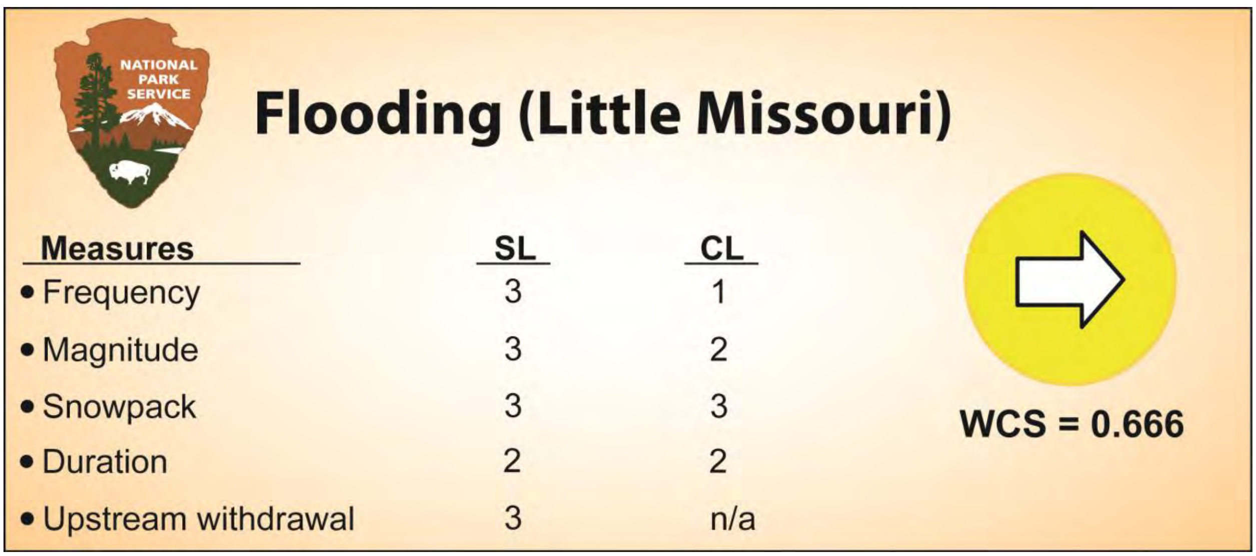
Snowpack

The project team defined the *Significance Level* of snowpack as a 3. Snowpack is the main driver of spring peak flows, and while some years still see heavy snowpack, there has been an overall decrease in SWE over the last 40 years. Snowpack was given a *Condition Level* of 3 (significant concern) because of these overall decreasing trends.

Duration
The project team defined the *Significance Level* of duration as a 2. Duration is largely a product of magnitude, meaning that a decrease in flood magnitude over the last century has contributed to a decrease in flood duration as well. The project team assigned a *Condition Level* of 2 (moderate concern) for the duration measure.

Effects of Upstream Water Withdrawal on Summer Flows
The project team defined the *Significance Level* of effects of upstream water withdrawal on summer flows as a 3. However, there are no current data on the amount of water withdrawn from the Little Missouri River. Thus, a *Condition Level* for this measure could not be determined.

Weighted Condition Score
While spring and summer peak flows are still occurring, decreases in snowpack have resulted in lower magnitude and duration of peak flows. The overall *Weighted Condition Score* of flooding was 0.666, meaning it is of moderate concern.



4.3.6 Sources of Expertise
Jeff Hughes, Hydrologist, NPS Water Resources Division

4.3.7 Literature Cited

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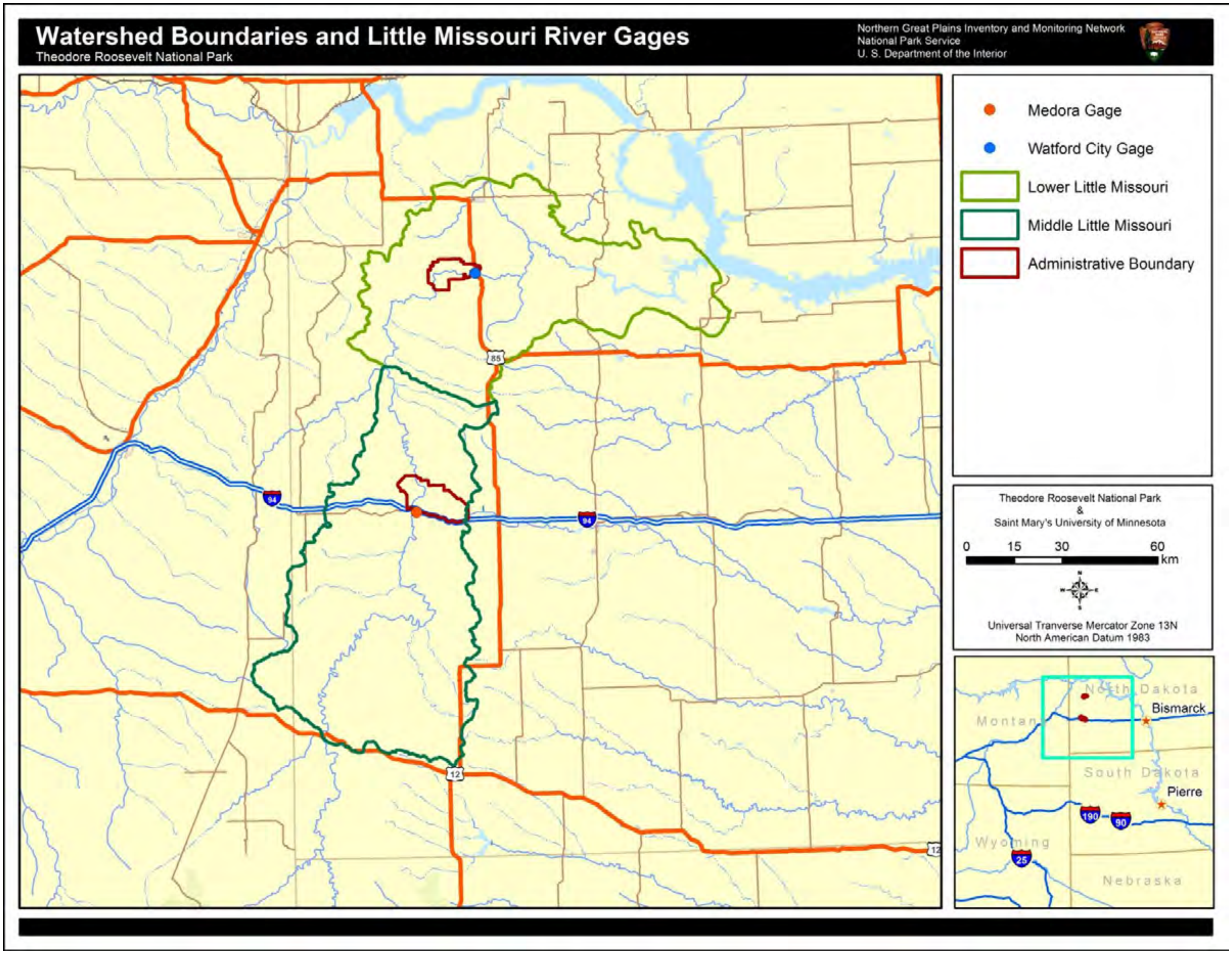

Plate 1. Watershed boundaries and Little Missouri River gages.

4.4 Native Grasslands

4.4.1 Description

Prior to the drought of the 1930s, the mixed-prairie grasslands of the northern Great Plains region were used extensively for grazing and agriculture, including the area that now makes up THRO. The establishment of THRO in 1947 allowed grassland communities within the park to revert to their natural state (Stubbendieck and Willson 1986). Today, native grasslands within THRO are widely distributed across areas with deeper soils such as plains, valleys, buttes, sand hills, and ridges. Grasslands also are interspersed with shrublands and woodlands throughout the park, and grasses sometimes comprise the understory of various woody habitats (Von Loh et al. 2000). Native grasslands support a wide variety of wildlife, from bison and elk to prairie dogs and numerous bird species (NPS 2010a). The most abundant native grass species in THRO include needle-and-thread (*Hesperostipa comata*), blue grama (*Bouteloua gracilis*), and threadleaf sedge (*Carex filifolia*). Von Loh et al. (2000) identified six grassland alliances in THRO (five native and one introduced). The native grassland communities found in the park are listed in Table 21.

Photo 10. Native grassland in the Peaceful Valley in THRO (Photo by Shannon Amberg, SMUMN GSS, 2010).

Table 12. Native grassland communities of THRO (Von Loh et al. 2000).

Common Name	NVCS Association or Complex
Needle-and-Thread Herbaceous Alliance	*Hesperostipa comata – Bouteloua gracilis – Carex filifolia* Herbaceous Vegetation
Western Wheatgrass Herbaceous Alliance	*Pascopyrum smithii – Bouteloua gracilis – Carex filifolia* Herbaceous Vegetation; *Pascopyrum smithii – Nassella viridula* Herbaceous Vegetation
Little Bluestem - Sideoats Grama Herbaceous Alliance	*Schizachyrium scoparium – Bouteloua* (*curtipendula, gracilis*) *– Carex filifolia* Herbaceous Vegetation
Prairie Sandreed Grass Herbaceous Alliance	*Calamovilfa longifolia – Carex inops* ssp. *heliophila* Herbaceous Vegetation
Prairie Cordgrass Temporarily Flooded Herbaceous Alliance	*Spartina pectinata – Carex* spp. Herbaceous Vegetation

4.4.2 Measures

- Species composition
- Distribution

- Prevalence of non-natives

4.4.3 Reference Conditions/Values

The ideal reference condition for this component is the composition and distribution of grasslands prior to European settlement. However, no information is available from this historical period. The earliest description of native grasslands within THRO comes from Hansen et al. (1984), who identified three grassland habitat types in the park: *Hesperostipa comata*/*Carex filifolia*, *Pascopyrum smithii*/*Carex filifolia*, and *Schizachyrium scoparium*/*Carex filifolia*. These descriptions will be used as reference conditions for species composition in the respective grassland types present in the park today. An earlier work by Hanson and Whitman (1938) focused on grasslands in western Northern Dakota and included these three grasslands, as well as a *Calamovilfa longifolia* grassland. Although not specific to the park, these descriptions also can be used as secondary reference conditions for species composition.

4.4.4 Data and Methods

The USGS-NPS Vegetation Mapping Program document (Von Loh et al. 2000) was a major source of information for this component. The NPS Inventory and Monitoring (I&M) Program implemented this project to map and categorize the vegetation of THRO using aerial photography GIS analysis. Multiple sources documented the occurrence of non-natives in the park's grasslands: Hansen et al. (1984), Trammell (1994), Von Loh et al. (2000), and THRO GIS data (NPS n.d.)

4.4.5 Current Condition and Trend

<u>Species Composition</u>

Many of the park's native grasslands have similar species compositions, but with variation in which species are dominant. The most common native grassland type in THRO is the Needle-and-Thread Herbaceous Alliance, which consists of Needle-and-Thread – Blue Grama – Threadleaf Sedge Herbaceous Vegetation. In addition to these three grasses, other common species include Junegrass (*Koeleria macrantha*), western wheatgrass (*Pascopyrum smithii*), prairie sagewort (*Artemisia frigida*), purple coneflower (*Echinacea angustifolia*), prairie coneflower (*Ratibida columnifera*), and the non-natives field brome (*Bromus arvensis*) and yellow sweetclover (*Melilotus officinalis*) (Von Loh et al. 2000).

The Prairie Cordgrass Temporarily Flooded Herbaceous Alliance is characterized by prairie cordgrass (*Spartina pectinata*) and sedge species (*Carex* spp.) Other species in this community include western wheatgrass, foxtail barley (*Hordeum jubatum*), and several non-native grasses. Curly-cup gumweed (*Grindelia squarrosa*), wild bergamot (*Monarda fistulosa*), and white aster (*Aster ericoides*) are commonly associated forbs, although species richness is generally low in cordgrass stands (Von Loh et al. 2000).

In THRO, the Prairie Sandreed Grass Herbaceous Alliance consists of Prairie Sandreed – Long-stolon Sedge Herbaceous Vegetation. In these grasslands, prairie sandreed (*Calamovilfa longifolia*) is associated with threadleaf sedge, little bluestem (*Schizachyrium scoparium*), needle-and-thread, and prairie sagewort. Several stands in the South Unit include porcupine grass (*Hesperostipa spartea*) as a co-dominant graminoid species (Von Loh et al. 2000).

The Little Bluestem-Sideoats Grama Herbaceous Alliance, dominated by little bluestem, is rare within the park. Other species regularly found with little bluestem include sideoats grama (*Bouteloua curtipendula*), threadleaf sedge, prairie sandreed, porcupine grass, and various forbs (Von Loh et al. 2000).

The Western Wheatgrass Alliance is divided further into two associations. The Western Wheatgrass – Blue Grama – Threadleaf Sedge Herbaceous Vegetation Association is dominated by western wheatgrass with blue grama and prairie sagewort as major secondary species on drier sites and green needlegrass (*Nasella viridula*) on more mesic sites (Von Loh et al. 2000). Silver sagebrush is also common, but typically with less than 25% coverage. In the Western Wheatgrass – Green Needlegrass Herbaceous Vegetation Association, western wheatgrass and green needlegrass are codominant, although western wheatgrass is more abundant on drier sites and green needlegrass increases on more mesic sites. Other common species include blue grama and white sagebrush (*A. ludoviciana*). The exotic species Kentucky bluegrass, yellow sweetclover, and leafy spurge are often found in both associations (Von Loh et al. 2000). Table 13 summarizes the most abundant species in each of these grassland communities.

In 2011, the Northern Great Plains Inventory & Monitoring program established and surveyed vegetation in 21 plots in THRO as part of a larger, multi-year vegetation survey (Ashton et al. 2012). Early results indicate western wheatgrass was the most common species across the plots. In $1m^2$ plots, an average of 10 and 12 species were found in the North and South Unit, respectively.

Table 13. The native grasslands of THRO and the most abundant species in each community, as surveyed by Von Loh et al. (2000).

Grassland community	Most abundant species
Needle-and-Thread Herbaceous Alliance	*Hesperostipa comata, Bouteloua gracilis, Carex filifolia*
Western Wheatgrass – Blue Grama – Threadleaf Sedge Herbaceous Vegetation	*Pascopyrum smithii, Bouteloua gracilis, Nasella viridula, Artemisia cana*
Western Wheatgrass – Green Needlegrass Herbaceous Vegetation	*Nassella viridula, Pascopyrum smithii*
Little Bluestem - Sideoats Grama Herbaceous Alliance	*Schizachyrium scoparium, Bouteloua curtipendula, Carex filifolia*
Prairie Sandreed - Long-stolon Sedge Herbaceous Vegetation	*Calamovilfa longifolia, Carex filifolia*
Prairie Cordgrass Temporarily Flooded Herbaceous Alliance	*Spartina pectinata, Pascopyrum smithii, Hordeum jubatum*

Distribution
Native grasslands cover over 10,000 ha of THRO. Their distribution is shown in Plate 2,

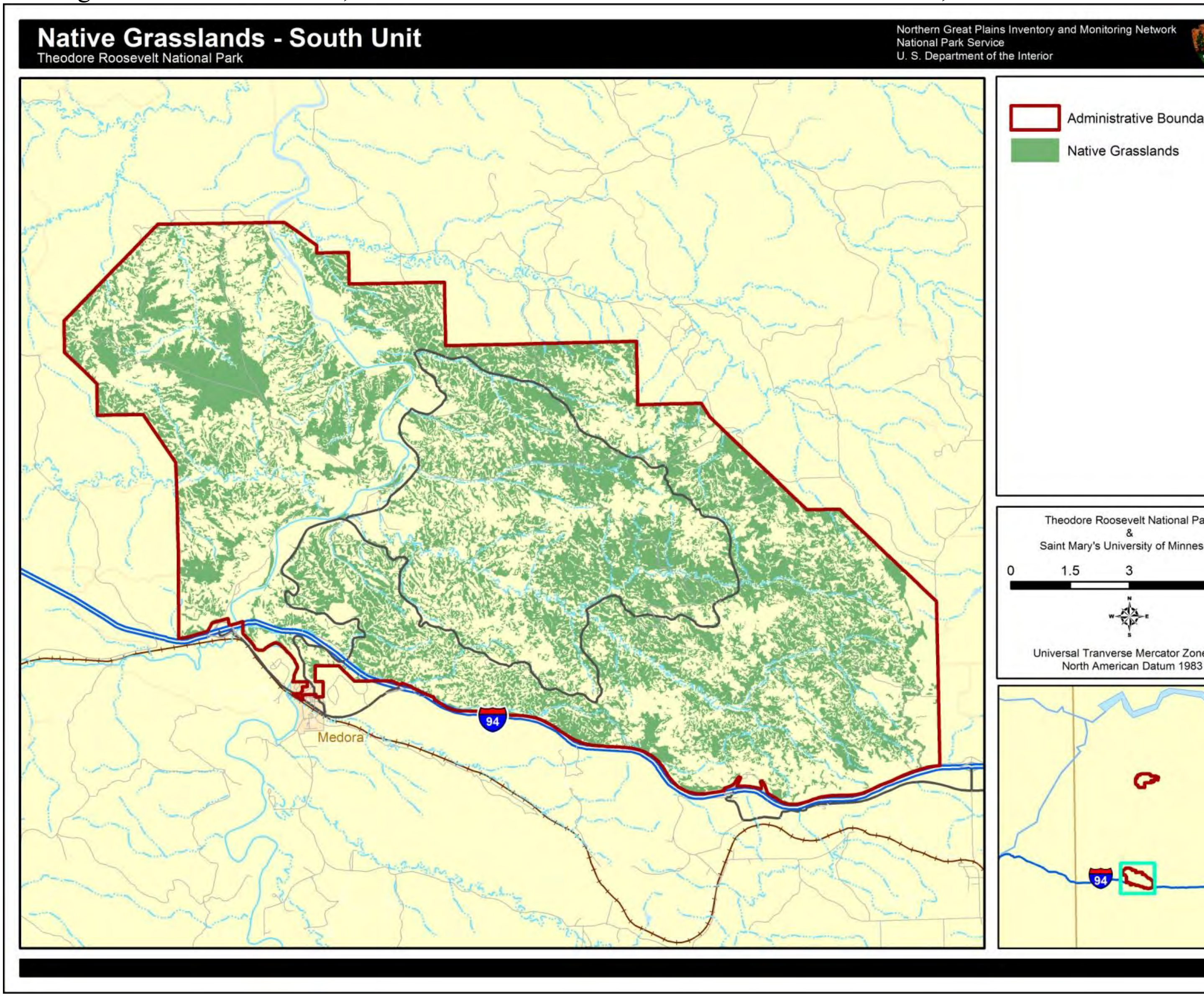

Plate 3, and Plate 4. Needle-and-thread grasslands are the most widely distributed type, with western wheatgrass grasslands a distant second. Needle-and-thread occurs in dry areas on plains, flats on buttes, plateaus, on top of mesas, and dry hillsides (Von Loh et al. 2000). Large areas of these grasslands occur on the Petrified Forest Plateau and Big Plateau in the South Unit, and on the Achenbach Hills of the North Unit. The Western Wheatgrass Herbaceous Alliance generally is found in broad floodplains, moist swales, and slopes below badland formations where runoff water is available (Von Loh et al. 2000).

The Little Bluestem-Sideoats Grama Herbaceous Alliance occurs in small patches on moist north and east facing slopes, but is also common in the understory of several shrubland types, particularly creeping juniper (*Juniperus horizontalis*) (Von Loh et al. 2000). Prairie Sandreed Grass Herbaceous Alliance grasslands occur in small stands on knolls, hilltops, slopes, and at the heads of mesic draws in both the North and South Units of THRO, often on gravelly or sandy soils. Finally, the Prairie Cordgrass Temporarily Flooded Herbaceous Alliance is found sporadically in the Little Missouri River floodplain and is most noticeable near Scenic Drive in the North Unit. This vegetation occurs in areas where the water table is close to the surface or in depressions holding water following flood events (Von Loh et al. 2000). The area covered by each grassland alliance in the park is shown in Table 14.

Table 14. Area (in hectares) covered by native grasslands in THRO. GIS data from Von Loh et. al. (2000).

Common Name	North Unit	South Unit	EHR	Total
Needle-and-Thread Herbaceous Alliance	2,182.8	7,126.4	3.5	9,312.7
Western Wheatgrass Herbaceous Alliance	369.5	832.2	0.8	1,202.5
Little Bluestem - Sideoats Grama Herbaceous Alliance	75.6	9.4	--	85.0
Prairie Sandreed Grass Herbaceous Alliance	12.8	44.6	--	57.4
Prairie Cordgrass Temporarily Flooded Herbaceous Alliance	11.6	--	--	11.6

Prevalence of Non-natives

In addition to the five native grasslands, Von Loh et al. (2000) mapped an Introduced Grassland Alliance in the park. This alliance covered 146 ha in the North Unit and 192 ha in the South Unit for a park-wide total of 338 ha (Plate 5 and Plate 6). Kentucky bluegrass is one of the most widespread exotic grasses in THRO, dominating the eastern portion of the South Unit. This species is present on many of the more moist areas in the park where western wheatgrass would be expected to occur (Von Loh et al. 2000). The other dominant non-native grasses in the park are crested wheatgrass and smooth brome. Additional non-native species documented in THRO's grasslands as of 2000 are listed in Table 15. More recent non-native plant survey efforts have not identified the plant community where each species has been found. A full list of non-native plant species in the park (many of which are likely found in native grasslands) can be found in Appendix C. Grassland areas sampled in the park during 2011 as part of an NGPN plant community monitoring program averaged 17% (±12.4%) non-native species cover in the North Unit and 16% (±15.7%) in the South Unit (Ashton et al. 2012).

Table 15. Non-native species documented in THRO grasslands (Hansen et al. 1984, Trammell 1994, Von Loh et al. 2000).

Common Name	Scientific Name
Field brome	*Bromus arvensis*
Cheatgrass	*Bromus tectorum*
Lambsquarters	*Chenopodium album*
Barnyard grass	*Echinochloa* spp.
Leafy spurge	*Euphorbia esula*
False flax	*Camelina microcarpa*
Prickly lettuce	*Lactuca serriola*
Yellow sweetclover	*Melilotus officinalis*
Alfalfa	*Medicago sativa*
Dandelion	*Taraxacum officinale*
Yellow salsify	*Tragopogon dubius*

Threats and Stressor Factors

Non-native plants have invaded the native grasslands of THRO and have become dominant in some areas of the park. In addition to altering native species composition, non-natives can alter natural processes such as fire, nutrient cycling, and erosion (Von Loh et al. 2000). As of 1994, 36 non-native plant species had been observed within the park during field surveys (Trammell 1994). By 2011, over 60 non-native species were documented in the park with many more thought to be present (Appendix C). The most problematic and aggressive non-native plants in THRO are leafy spurge and Canada thistle (*Cirsium arvense*). In 2011, THRO and EPMT staff chemically treated infestations of Canada thistle in North Unit grasslands and leafy spurge in South Unit grasslands (L. Richardson, pers. comm., 2012). Non-native grasses introduced from pasture lands include crested wheatgrass, Kentucky bluegrass, and smooth brome (Von Loh et al. 2000).

Fire suppression is another threat to the park's native grasslands. Fire is one of the most important processes in the maintenance of grassland systems (Anderson 1990), as it reduces competition from woody species. Frequent fires are important for maintaining native species diversity and also positively impact other grassland components, such as nutrient cycling and productivity (Collins and Wallace 1990). Fire suppression often leads to juniper and other woody species encroachment into native grasslands (NPS 1994, 2010b) and can favor non-native plants over native species (Whisenant and Uresk 1990). Fire was viewed as a danger to people, property, and resources for much of the 20th century and was suppressed all across the Great Plains (NPS 2010b). Fire returned to the landscape of THRO in the form of prescribed burns in the late 1990s. Further discussion of fire in THRO is found in section 4.1 of this assessment. Overgrazing is not currently a threat to the park's grasslands (L. Richardson, pers. comm., 2012).

Data Needs/Gaps

While the park is monitored annually for non-native species, Von Loh et al.'s (2000) vegetation mapping project remains the most comprehensive survey conducted in the park. In 2011, a plant community composition and structure monitoring was initiated by the NGPN and baseline data was gathered in all network parks. Twenty-one plots (16 upland and five riparian) were sampled in THRO (Ashton et al. 2012). Over time, this monitoring data will allow for a better comparison of current grassland condition to earlier reports (e.g., Hanson and Whitman 1938, Hansen et al.

1984). An updated vegetation mapping effort would also help to identify the extent of juniper and other woody encroachment into park grasslands.

Overall Condition

Species Composition
During initial scoping meetings, THRO staff assigned the measure of species composition a *Significance Level* of 3. Von Loh et al.'s (2000) grassland species composition descriptions are slightly different than those in Hansen et al. (1984) and Hanson and Whitman (1938). While Von Loh et al.'s (2000) description of the needle-and-thread herbaceous alliance is very similar to Hanson and Whitman (1938), it differs from Hansen et al. (1984) who reported very little blue grama and more western wheatgrass in the *Hesperostipa comata*/*Carex filifolia* habitat type. Hansen et al. (1984) also reported minimal blue grama and green needlegrass in the *Pascopyrum smithii*/*Carex filifolia* habitat type, two grasses that were key "secondary species" in Von Loh et al.'s (2000) descriptions. Some of these differences could be natural variation due to climate variability, fire regime, and land use shifts (e.g., grazing). These differences are worth further investigation and this measure is therefore assigned a *Condition Level* of 1 indicating low concern. In the future, data from the NGPN plant community monitoring can be used to assess this measure.

Distribution
A *Significance Level* of 3 was assigned to the measure of distribution. Since there are no historic or more recent distribution maps that are directly comparable to Von Loh et al.'s (2000) distribution data, a *Condition Level* cannot be assigned. Data from the NGPN plant community monitoring may also be useful in assessing this measure in the future.

Prevalence of Non-natives
A *Significance Level* of 3 was assigned to the prevalence of non-native species measure. Non-native grasses have become dominant in several areas within THRO and have the potential to expand further into native grasslands. Several other non-native species, particularly the aggressive leafy spurge, have been documented in the park's native grasslands. This measure was assigned a *Condition Level* of 2, indicating moderate concern.

Weighted Condition Score
The *Weighted Condition Score* (WCS) for native grasslands in THRO is 0.500, indicating moderate concern. The trend is currently unknown, although the new network vegetation monitoring program should help to fill this gap in the near future.

Native Grasslands

Measures	SL	CL
• Species composition	3	1
• Distribution	3	n/a
• Prevalence of non-natives	3	2

WCS = 0.500

4.6.1 Sources of Expertise

Laurie Richardson, Botanist, THRO

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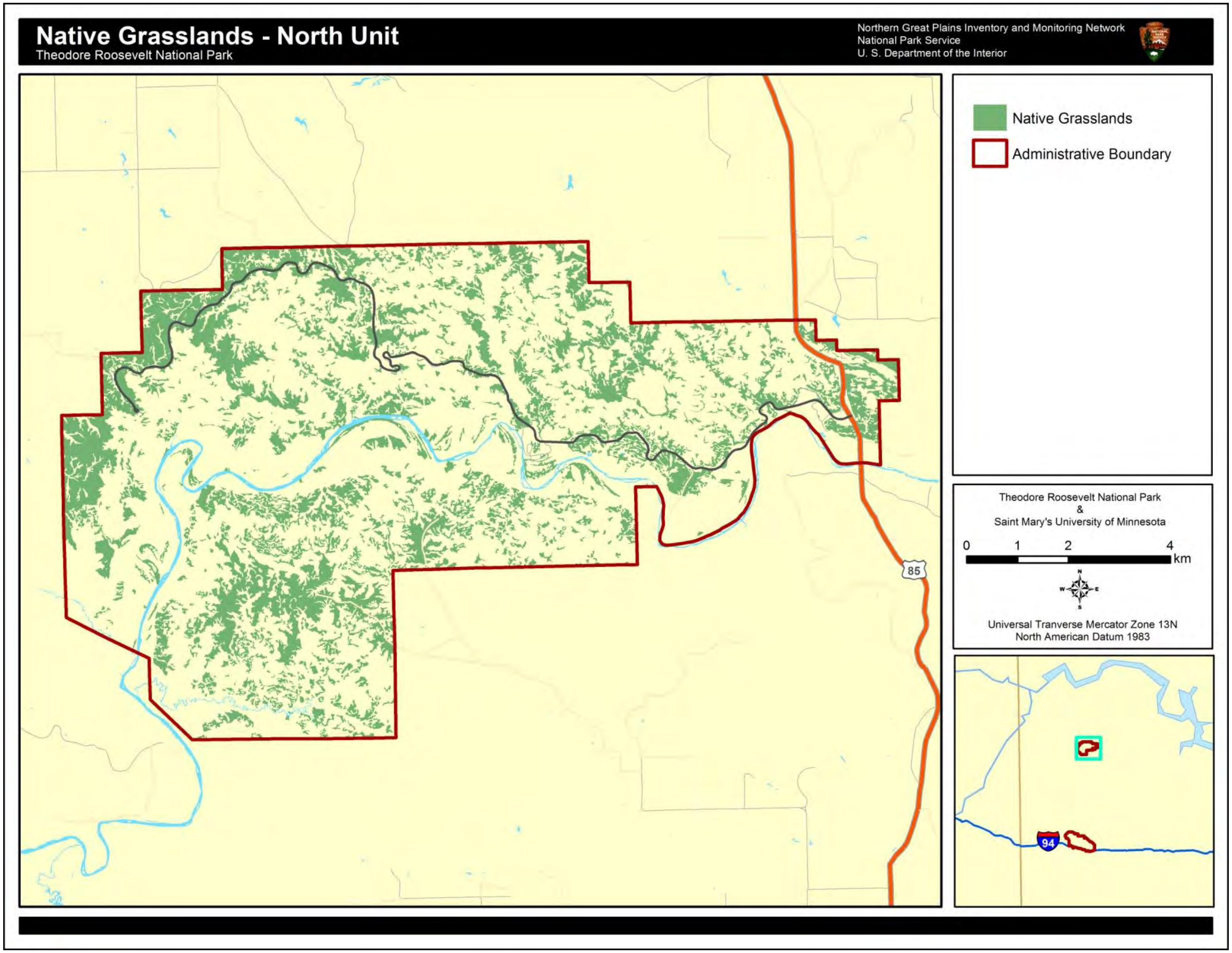


Plate 2. Native grassland alliances in the North Unit of THRO.

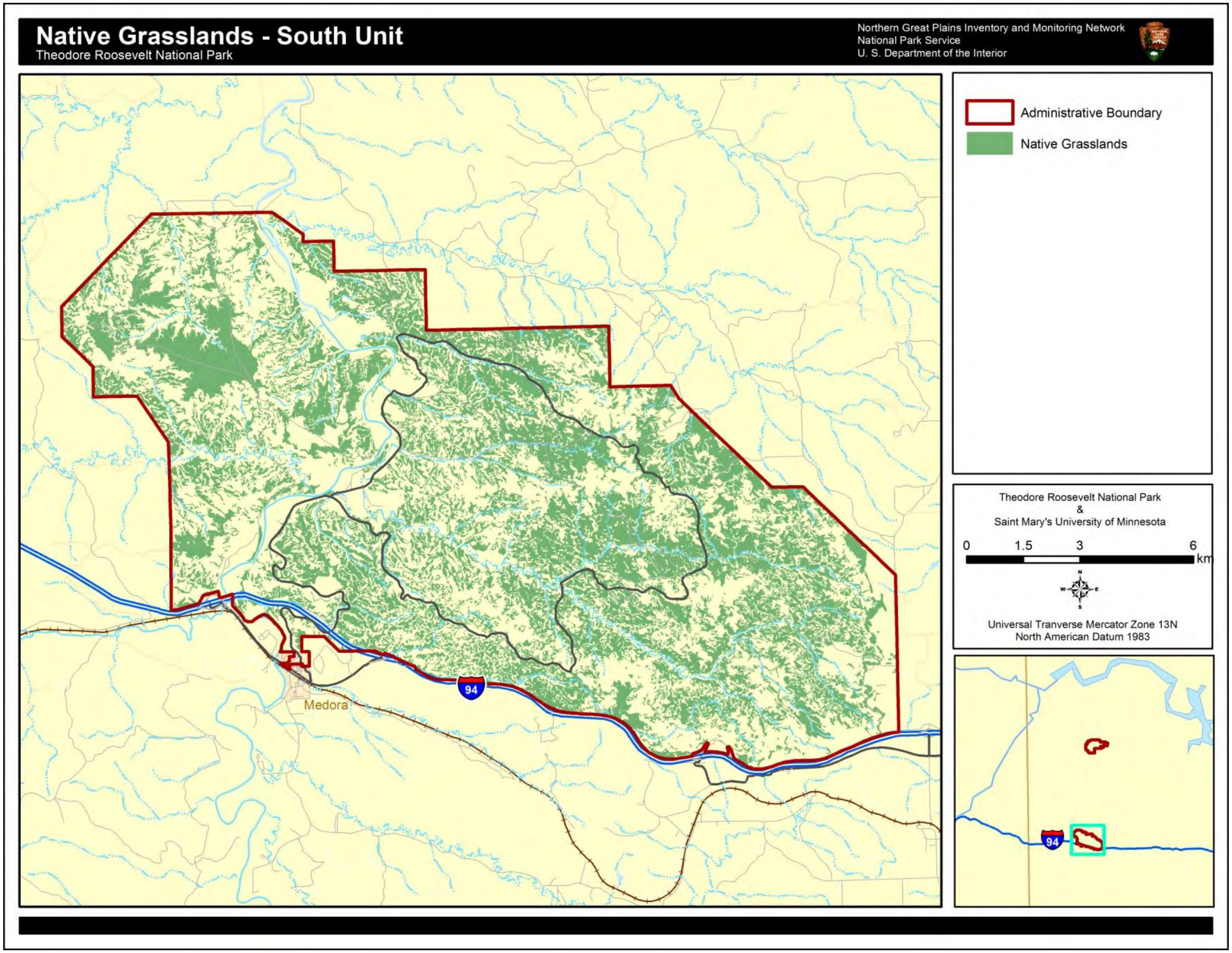


Plate 3. Native grassland alliances in the South Unit of THRO.

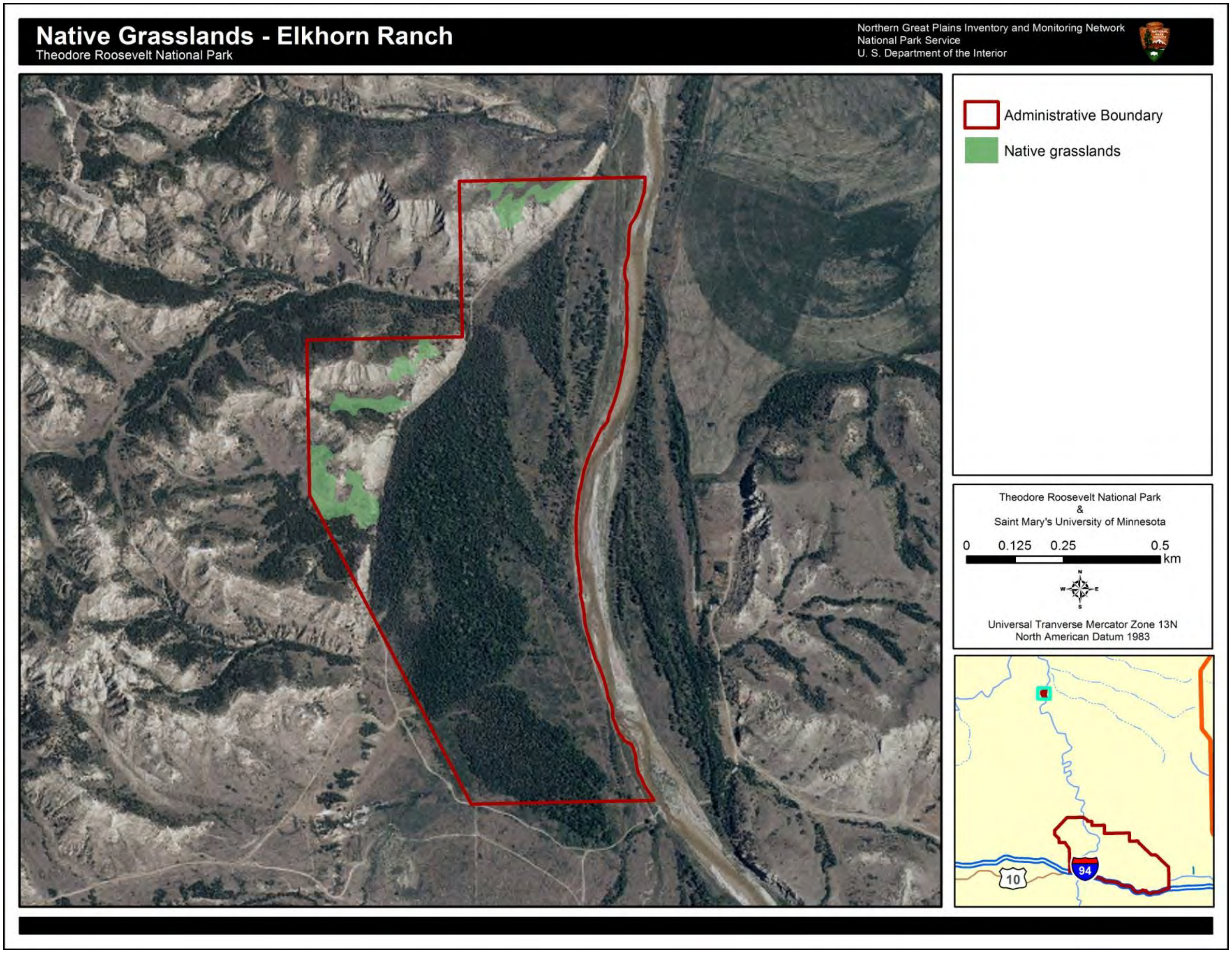


Plate 4. Native grassland alliances in the Elkhorn Ranch Unit of THRO.

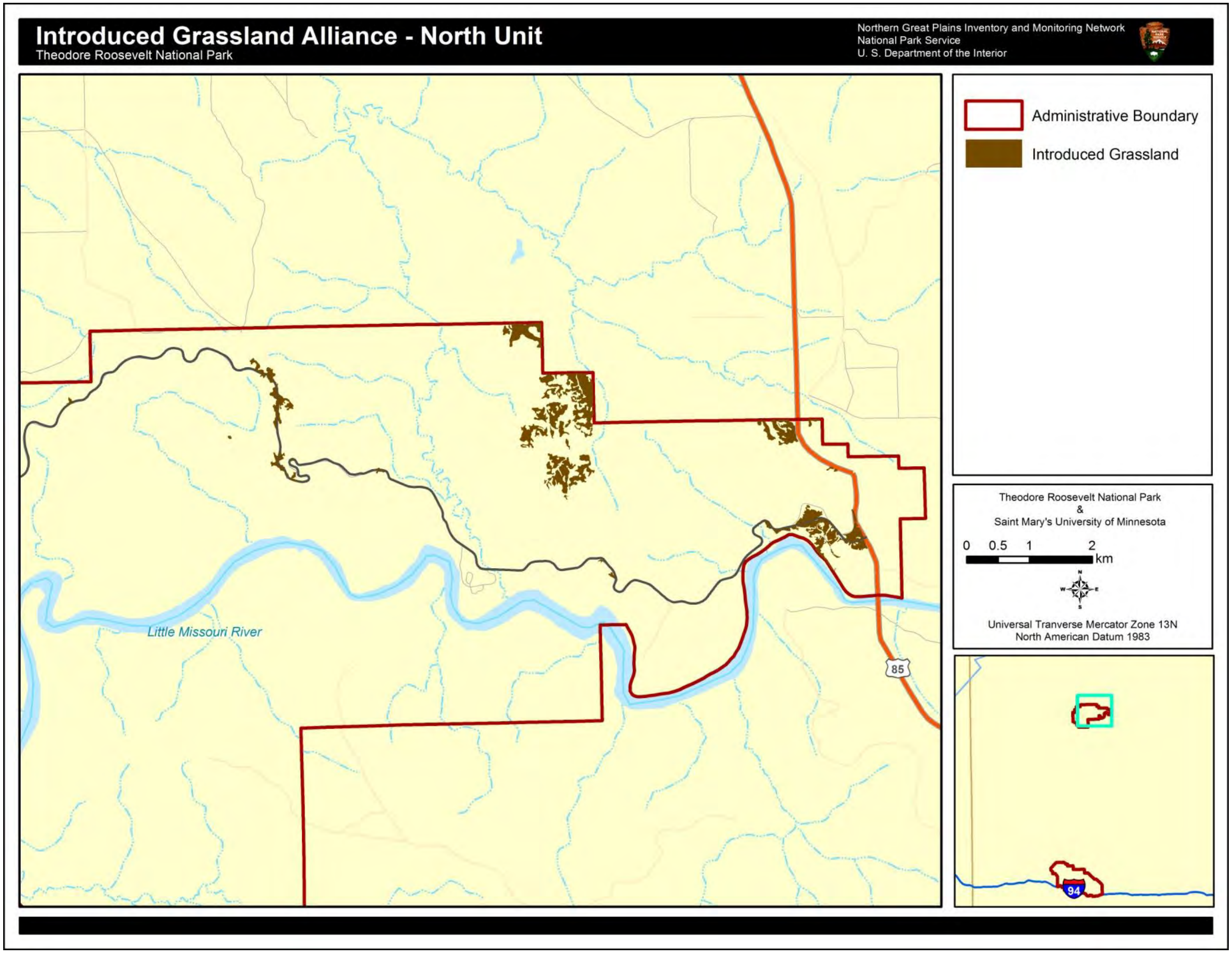


Plate 5. The introduced grassland alliance in the North Unit of THRO.

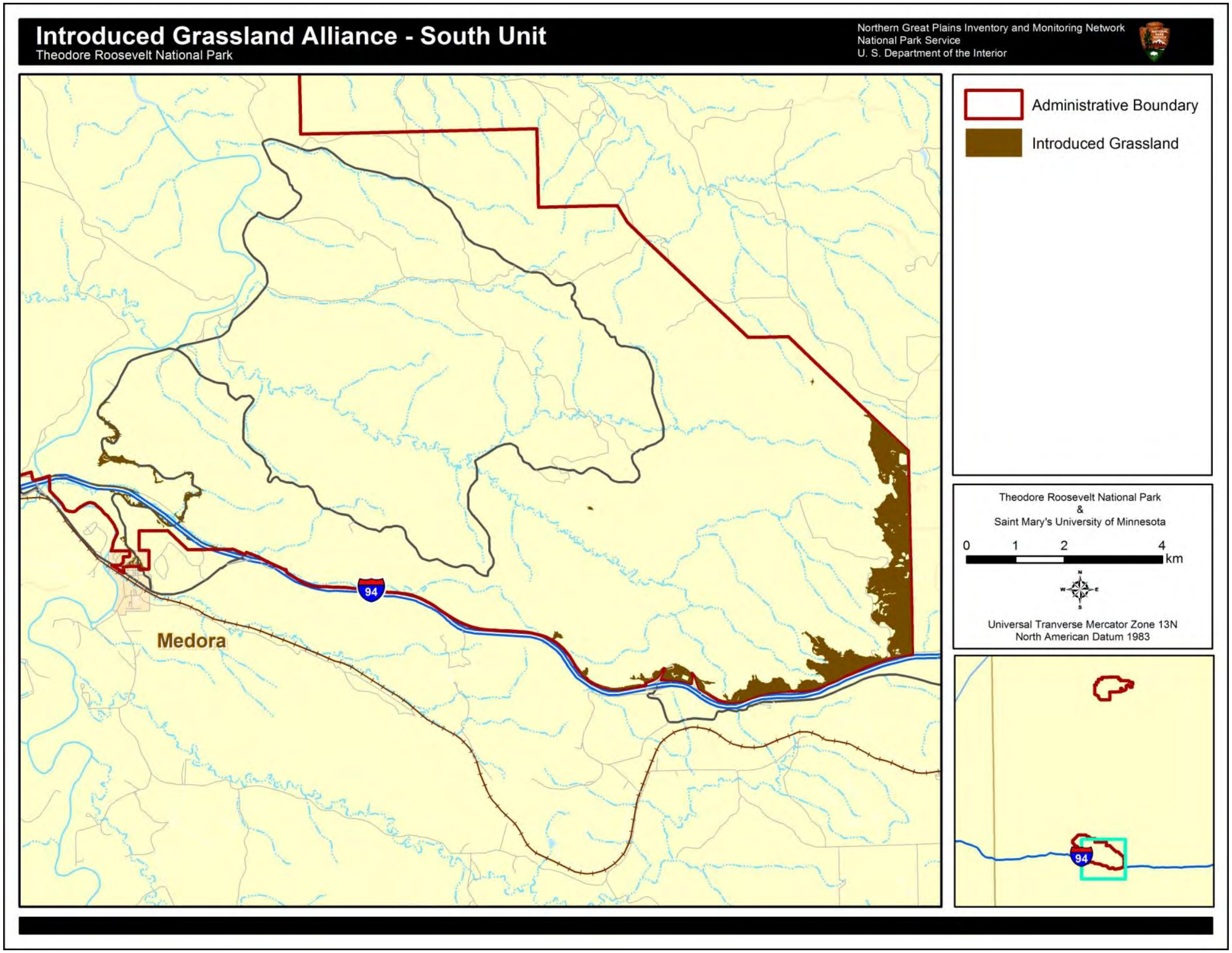


Plate 6. The introduced grassland alliance in the South Unit of THRO.

4.5 Juniper Forests

4.5.1 Description

Juniper forests are considered a distinct vegetation type in THRO and occur primarily on north-facing hill slopes in the park. This forest type, dominated by Rocky Mountain juniper (*Juniperus scopulorum*), is the most common wooded plant community in the park (NPS 2010a). Juniper forests are important for slowing erosion on slopes and are the preferred habitat for elk (*Cervus elaphus*) in THRO (NPS 2010a). Berry-like cones produced by junipers are a critical food source for several bird species in the park, including Townsend's solitaires (*Myadestes townsendi*), cedar waxwings (*Bombycilla cedrorum*), Bohemian waxwings (*B. garrulus*), and American robins (*Turdus migratorius*) (NPS 2010a).

Photo 11. Rocky Mountain juniper in THRO (Photo by Shannon Amberg, SMUMN GSS 2010)

Juniper forests in the park often are wooded densely with thick tree canopies (Von Loh et al. 2000). Green ash (*Fraxinus pennsylvanica*) and chokecherry (*Prunus virginiana*) are also common but at much lower densities. Characteristic understory species include little-seed ricegrass (*Oryzopsis micrantha*), mosses and lichens, and false Solomon's seal (*Maianthemum stellatum*) (Hansen et al. 1984, Von Loh et al. 2000).

4.5.2 Measures

- Distribution
- Density

4.5.3 Reference Conditions/Values

The ideal reference condition for this component would be the composition and distribution of juniper forests prior to European settlement. However, no information is available from this historical period. The earliest description of THRO's juniper forests comes from Ralston (1960), who studied the structure and ecology of "north slope juniper stands" in the area. This source will act as the reference condition for density in this assessment. For the distribution measure, Von Loh et al.'s (2000) 1996-97 vegetation mapping data will serve as the reference condition.

4.5.4 Data and Methods

Von Loh et al. (2000) used remote sensing to map vegetation in THRO and provided the majority of information regarding juniper forests in the park, particularly regarding distribution. Ralston (1960) also provided stand density data for several juniper forests in the park. Density measurements were calculated using the quarter method (Cottam and Curtis 1956) in 12 juniper stands in the North and South Units of THRO (Ralston 1960).

4.5.5 Current Condition and Trend

Distribution

Rocky Mountain juniper often covers steep north-facing slopes in the badlands, facing away from direct sun where there is less surface insolation, conditions are cooler, snow remains longer in the spring, and moisture evaporates less readily (Godfread 1994). It is widely distributed across THRO, most often forming dense woodlands in drainages and draws, but also occurring on ridges, hill tops, and slumps on side slopes (Von Loh et al. 2000). Nelson (1961) states that this vegetation type generally is found on slopes of scoria or clay, and that juniper will generally cover the slope from its base to the summit.

Photo 12. Juniper forests in the North Unit of THRO (Photo by Shannon Amberg, SMUMN GSS 2010).

Plate 7, Plate 8, and Plate 9 display the area covered by the Rocky Mountain juniper alliance as of 2000 in the North, South, and Elkhorn Ranch Units of THRO, respectively. Based on GIS data, this vegetation alliance is slightly more widespread in the North Unit. GIS data are also available for the distribution of the *Juniperus scopulorum*/*Oryzopsis micrantha* habitat type in the park as of 1984 (Norland 1984). Although not directly comparable due to slight methodology differences, a comparison of total juniper forest area in 1984 and 2000 suggests that these forests have expanded over time. According to 1984 GIS data, the *Juniperus scopulorum*/*Oryzopsis micrantha* habitat type covered approximately 1,000 ha of THRO (just under 500 ha in the South Unit and just over 500 ha in the North Unit). By 2000, GIS data show Rocky Mountain juniper woodland covering approximately 3,800 ha of the park (about 2,200 ha in the South Unit and 1,600 ha in the North Unit) (Von Loh et al. 2000).

Density

No recent information is available regarding the density of THRO's juniper forests specifically. Stand density data is being gathered as part of the NGPN plant community monitoring, but this monitoring has just completed its first year.

Ralston (1960) calculated densities for 12 juniper stands in THRO

Table 16). Stands with the highest density also exhibited the greatest reproduction rates. Density appeared to be related to fire intensity, with stands exposed to higher intensity fires actually showing higher densities (Ralston 1960).

Table 16. Tree densities for THRO juniper stands sampled in 1960 (Ralston 1960).

Stand	Density (trees per acre)			
	Ash	Juniper	Total	Juniper saplings (trees/m^2)
101	19.5	759	778.5	0.30
102	--	1286	1286	--
103	--	970.37	970.37	0.20
104	34.3	880.7	915.00	0.2875
105	154.8	619.6	774.4	0.325
106	134	844	978	0.1125
107	292	770	1062	--
109	11.44	903.56	915	0.25
110	1041.7	852.3	1894	--
111	134	763	897	0.162
112	23	906	926	0.10
116	177.4	1241.6	1419	--

Threats and Stressor Factors

Non-native plant species constitute a threat to the juniper forests of THRO. These species can impact native species composition and alter natural processes such as fire, nutrient cycling, and erosion (Von Loh et al. 2000; as reviewed by Brooks et al. 2004). THRO and EPMT staff have been chemically treating infestations of Canada thistle in North Unit juniper forests and leafy spurge and Canada thistle in South Unit forests annually for nearly a decade (NPS n.d.). Other non-natives documented in juniper stands are field brome, yellow sweet clover, Kentucky bluegrass, lambsquarters, dandelion, and yellow salsify (Hansen et al. 1984, Trammell 1994, Von Loh et al. 2000).

Rocky Mountain juniper generally is considered intolerant of fire. Particularly intense fires can kill all but the largest junipers in a stand (Scher 2000). However, without fire juniper woodlands will expand and eventually encroach into other native plant communities (Burkhardt and Tisdale 1976, NPS 2010b). The majority of Rocky Mountain juniper stands sampled during the THRO vegetation mapping program showed evidence of historic burns (Von Loh et al. 2000). Some evidence suggests that juniper stands that experienced fires of a certain intensity actually increased in stand density and reproduction over time (Ralston 1960).

Data Needs/Gaps

Density and other stand structure data is lacking for THRO's juniper forests and could help managers better understand the juniper encroachment occurring in the park. NGPN plant community monitoring will contribute some stand density information over time. Also, the distribution of juniper has not been mapped since 2000. Updated distribution data would help identify any vegetation changes (e.g., juniper encroachment) occurring in the park.

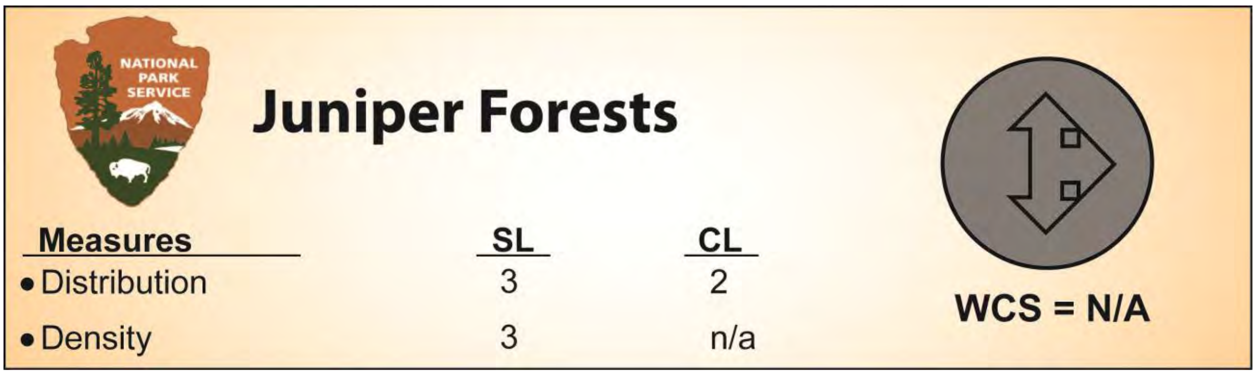
Overall Condition

Distribution

A *Significance Level* of 3 was assigned to the measure of juniper forest distribution. Evidence suggests that juniper distribution has expanded in the park over time, perhaps due to a long period of fire suppression. Junipers are encroaching on other native plant communities, which is a concern for park management. Therefore, this measure is assigned a *Condition Level* of 2, indicating moderate concern.

Density
A *Significance Level* of 3 was assigned to the measure of juniper forest density. Since no recent density information is available for the park, a *Condition Level* could not be assigned.

Weighted Condition Score
A *Weighted Condition Score* (WCS) could not be calculated for the juniper forest community in THRO, since a *Condition Level* was only assigned for one of the two measures. As a result, the condition and trend of juniper forests in the park are considered unknown.



4.5.6 Sources of Expertise
Laurie Richardson, Botanist, THRO

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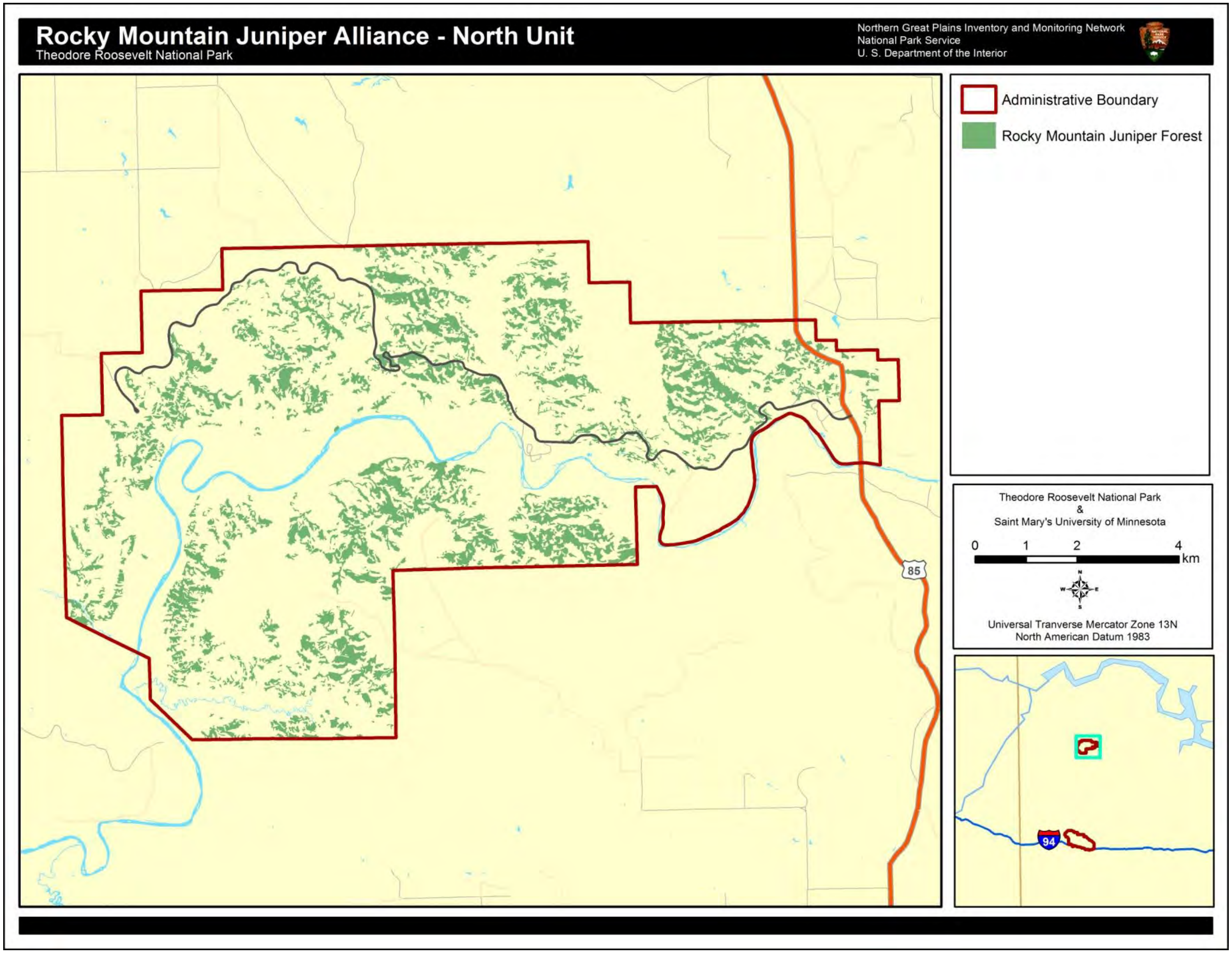


Plate 7. Rocky Mountain Juniper Alliance in the North Unit of THRO.

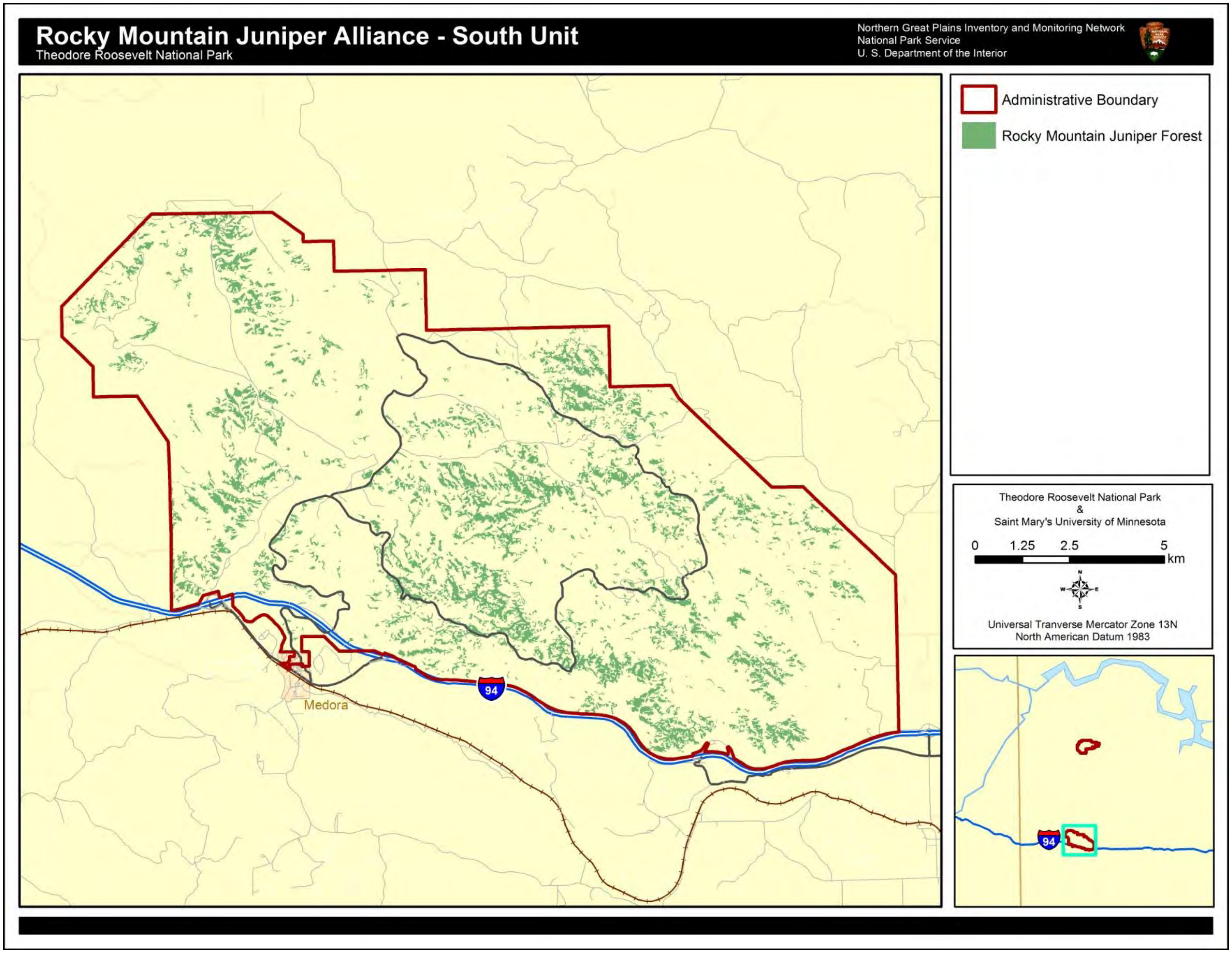


Plate 8. Rocky Mountain Juniper Alliance in the South Unit of THRO.

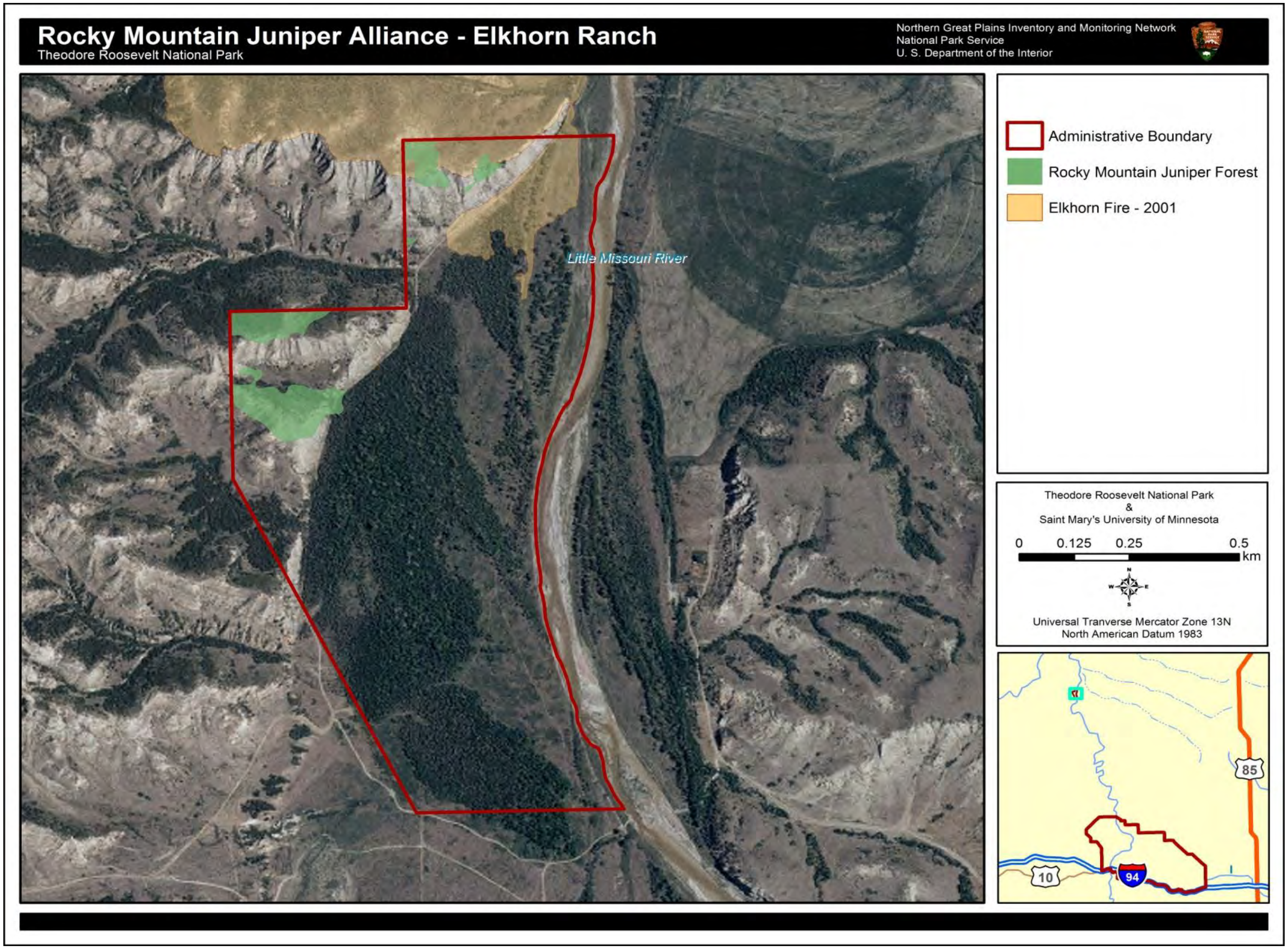


Plate 9. Rocky Mountain Juniper Alliance in the Elkhorn Ranch Unit of THRO (based on 1996 aerial imagery). Juniper stands in the northwestern corner are no longer visible in 2004 aerial photography, as this area burned in the Elkhorn wildfire that occurred in August 2001**.**

4.6 Floodplain Woodlands

4.6.1 Description

Floodplain woodlands are areas dominated by trees with less than 60% canopy cover (Von Loh et al. 2000), occurring along the banks of the Little Missouri River and its major tributaries in THRO (Miller 2005). Sometimes referred to as gallery forests (Norland 1984, Girard et al. 1989), or more broadly as bottomland forests (Nelson 1961), they are primarily characterized by cottonwood-willow (*Populus-Salix* sp.) woodlands (Miller 2005). Floodplain woodlands at THRO are dominated by plains cottonwood (*Populus deltoides* subsp. *Monilifera*).

Photo 13. Floodplain woodlands along the Little Missouri River in the North Unit of THRO (photo by Shannon Amberg, SMUMN GSS 2010).

Native woodlands represent less than 5% of the southwestern North Dakota vegetation (Jakes and Smith 1983); floodplain woodlands along the Little Missouri River represent a subset of these woodlands. The plant communities/alliances related to floodplain woodlands, along with those alliances that may succeed to or from floodplain woodlands, are listed in Table 17. According to GIS data (Von Loh et al. 2000), cottonwood woodlands and other related map units listed in Table 17 make up approximately 55% of the EHR, 7% of the North Unit, and 1% of the South Unit, and 3.4% of the total land area across the three units of THRO. Despite the small proportion on the landscape, these woodlands and associated alliances provide valuable habitat for many wildlife species in THRO including white-tailed deer (*Odocoileus virginianus*) (Nelson 1961), numerous bird species, porcupine (*Erithizon dorsatum*), and beaver (*Castor canadensis*) (NPS 2009).

Reproduction and age structure of cottonwood woodlands are controlled by river flooding and channel migration. Survival of woodland species during drought depends upon a water subsidy from the river. Reproduction and survival of these woodlands has been impaired globally by construction of dams and channel stabilization that limit flooding and channel migration, and by summer water withdrawals that cause drought mortality. The Little Missouri River in THRO is a rare example of a large river with minimal flow regulation, channel stabilization, or land clearing. As a result this forest includes the oldest known plains cottonwood trees in the world (up to 371 years, Friedman pers. comm., 2012), and the age structure and spatial patterns of cottonwood trees serve as a reference example of the natural condition for this plant community.

Table 17 Reproduction and age structure of cottonwood woodlands are controlled by river flooding and channel migration. Survival of woodland species during drought depends upon a water subsidy from the river. Reproduction and survival of these woodlands has been impaired globally by construction of dams and channel stabilization that limit flooding and channel migration, and by summer water withdrawals that cause drought mortality. The Little Missouri River in THRO is a rare example of a large river with minimal flow regulation, channel stabilization, or land clearing. As a result this forest includes the oldest known plains cottonwood trees in the world (up to 371 years, Friedman pers. comm., 2012), and the age structure and spatial patterns of cottonwood trees serve as a reference example of the natural condition for this plant community.

Table 17. Map unit descriptions and NVCS associations related to floodplain woodlands in THRO (Von Loh et al. 2000).

Map unit description	NVCS Association or Complex
Sandbar Willow Temporarily-Flooded Shrubland Alliance [a]	*Salix exigua* temporarily flooded shrubland
Cottonwood – Peachleaf Willow Floodplain Woodland	*Populus deltoides* – (*Salix amygdaloides*) / *Salix exigua* woodland
Cottonwood Temporarily Flooded Woodland Alliance	*Populus deltoides* temporarily flooded woodland
Cottonwood – Rocky Mtn. Juniper Floodplain Woodland	*Populus deltoides* / *Juniperus scopulorum* woodland
Green Ash – American Elm Temporarily-Flooded Woodland Alliance [b]	*Fraxinus pennsylvanica / Ulmus americana* temporarily flooded woodland alliance

[a] An early successional stage of cottonwood woodlands, as it contains some young cottonwoods.

[b] A late successional stage of cottonwood woodlands.

4.6.2 Measures

- Species composition and abundance
- Changes in species distribution
- Cottonwood woodland area-age distribution
- Non-native species abundance

4.6.3 Reference Conditions/Values

The ideal reference condition for this component would be the composition and distribution of floodplain woodlands prior to European settlement. Successional processes in these forest types are described in detatil in Johnson et al. (1976). Generally the authors conclude that river meandering patterns are an important determinant of horizontal and vertical distribution of the cottonwood forests, and that the rate of river meandering is a major factor in determing the composition of foodplain woodland stages (e.g., pioneer, transitional, and terminal

Photo 14. Understory view of a cottonwood woodland in the North Unit of THRO (photo by Shannon Amberg, SMUMN GSS, 2010).

forest types). However, no map information is available from this period. Everitt (1968) provides some of the oldest observations of cottonwood stand ages in a 2.4 km (1.5 mi) section of the Little Missouri River in THRO. Norland (1984) also provides some older map information regarding floodplain woodlands; however, the data and specifically map classes are not comparable to recent map data developed by Von Loh et al. (2000). Everitt (1968) described the cottonwood floodplain forests as a living record of past river channel migrations. Cottonwood establishment and survival relies on widening of the river channel after floods and narrowing during low flow periods (Everitt 1968, Johnson 1994, Friedman and Lee 2002).

Cottonwood woodlands dominate the floodplain forest of the Little Missouri River. Girard et al. (1989) found two specific community types common in the floodplain, *P. deltoides/Juniperus scopulurum* (eastern cottonwood/ Rocky Mountain juniper) and *P. deltoides/F. pennsylvanica* (eastern cottonwood/green ash). *P. deltoides/Juniperus scopulurum* occurs on more recently deposited alluvial sites and *P. deltoides/F. pennsylvanica* on more mature sites (Girard et al. 1989). Girard et al. (1989) suggest that under certain conditions (e.g., absence of disturbance), these communities will likely succeed to *F. pennyslvanica/S. occidentalis* (green ash/western snowberry). It is unclear if the Green Ash – American Elm Temporarily-Flooded Woodland Alliance identified by Von Loh et al. (2000) represents a transitional gradient of the green ash/ western snowberry community mentioned by Girard et al. (1989). According to the Von Loh et al. (2000) GIS data, the Green Ash – American Elm Temporarily Flooded Woodland Alliance is a climax community of floodplain woodlands and shrublands. The species composition, distribution, and status of cottonwood regeneration in floodplain woodlands may vary over time, depending on disturbance regimes. However, cottonwood stand ages can provide an indication of what the near future may hold for the previously mentioned measures.

The presence of non-native species, especially those considered invasive, is undesirable for the biological integrity of the floodplain woodlands, or any native vegetation community in the park. The ideal reference condition for non-native plant species, particularly those considered invasive, would be no presence in the park. However, this is an unrealistic goal, given the current density and vectors of spread.

4.6.4 Data and Methods

Two GIS datasets characterize the vegetation communities of THRO, one published in 1984 and the other in 2000. The 1984 vegetation dataset is a product of aerial-photo interpretation in Norland (1984) (a bison habitat mapping thesis), using 1:12,000 scale color-infrared photos. Map units relevant to floodplain woodlands include:

- River bottoms mapping unit: areas mapped by the author and simply defined as areas subject to frequent flooding;
- Willows mapping unit: areas dominated by densely growing willow (*Salix* spp.), with little other plant growth;
- Grassed sand floodplain habitat type, or a sandy range (bison) site;
- *Populus deltoides – Juniperus scopulorum* habitat type: identified in the thesis by Michele Girard of North Dakota State University.

The other GIS vegetation dataset in THRO is from the USGS-NPS Vegetation Mapping Program (Von Loh et al. 2000). These data are classified using the Standardized National Vegetation Classification System (NVCS), contain additional plant community types, and also combined some land use classes (e.g., transportation, communications, and utilities; mixed urban or built-up land; croplands and pasture). The map product used 1996, 1:24,000 scale aerial photography from the USFS. The overall initial accuracy was 74.3% for all mapped vegetation classes (Von Loh et al. 2000).

The Von Loh et al. (2000) data contain more detailed information than GIS data derived from the earlier study (Norland 1984). Von Loh et al. (2000) identify 39 unique map classes or map units (27 natural and semi-natural alliances and associations, two complexes, and 10 Anderson et al. [1976] land use classes). However, the two datasets are not quantitatively comparable and cannot be used to examine changes in species composition and abundance, changes in species distribution, or shifts in cottonwood area-age distribution. Von Loh et al. (2000) is used below to report current conditions of floodplain woodlands in THRO.

4.6.5 Current Condition and Trend

Species Composition and Abundance

Von Loh et al. (2000) describe five plant community associations relevant to THRO's floodplain woodlands (Table 17). However, the authors warn that many of the plant associations' compositions are variable and some confusion between associated floodplain shrublands and woodlands were revealed during map accuracy assessments. The sandbar willow temporarily flooded shrubland alliance (cottonwood seedlings are often present in this alliance) may succeed to cottonwood woodlands over time, therefore it is included in the floodplain woodland assessment. Cottonwood woodlands also succeed to cottonwood-Rocky Mountain juniper, and finally to green ash – American elm temporarily flooded woodland alliance. This alliance is the climax vegetation community of the floodplain woodlands, given enough time without flooding (Von Loh et al. 2000). The most common species by stratum in each of the map units is displayed in Table 18.

Table 18. Abundant species in floodplain shrubland and woodlands of THRO (Von Loh et al. 2000).

Common Name / Stratum	Most abundant species
Sandbar Willow Temporarily-Flooded Shrubland Alliance (map unit no. 38)	
Tree Canopy	*Populus deltoides*
Short Shrub	*Salix exigua*
Herbaceous	*Melilotus alba, Xanthium strumarium, Spartina pectinata*
Cottonwood – Peachleaf Willow Floodplain Woodland (map unit no. 41)	
Tree Canopy	*Populus deltoides, Salix amygdaloides*
Short Shrub	*Salix exigua, Symphoricarpos occidentalis*
Herbaceous	*Glycyrrhiza lepidota, Melilotus alba, M. officinalis*
Cottonwood Temporarily-Flooded Woodland (map unit no. 43)	
Tree Canopy	*Populus deltoides, Juniperus scopulorum, Fraxinus pennsylvanica*
Short Shrub	*Symphoricarpos occidentalis, Prunus virginiana*
Herbaceous	*Poa pratensis, Bromus inermis*
Cottonwood – Rocky Mountain Juniper Floodplain Woodland (map unit no. 42)	

Common Name / Stratum	Most abundant species
Tree Canopy	*Populus deltoides, Juniperus scopulorum,*
Short Shrub	*Symphoricarpos occidentalis, Prunus virginiana*
Herbaceous	*Poa pratensis, Bromus inermis*
Green Ash – American Elm Woodland Floodplain (map unit no. 45)	
Tree Canopy	*Fraxinus pennsylvanica, Ulmus pumila*
Short Shrub	*Symphoricarpos occidentalis, Artemisia cana*
Herbaceous	*Poa pratensis, Bromus inermis*

The following paragraphs describing the general species composition of the five different floodplain woodland/shrubland associations are adapted from Von Loh et al. (2000).

Sandbar willow, usually forming dense cover in the tall shrub layer, is the dominant species in the Sandbar Willow Temporarily Flooded Shrubland Alliance. Young, shrub-sized cottonwoods are also found in this alliance. Non-native white sweetclover (*Melilotus alba*), yellow sweetclover, and native Canada cocklebur (*Xanthium strumarium*) and prairie cordgrass are the most common herbaceous species.

The Cottonwood–Peachleaf Willow Floodplain Woodlands are nearly equally dominated by eastern cottonwood and peachleaf willow. These woodlands also contain other woody vegetation, including *Salix amygdaloides*, box elder (*Acer negundo*), green ash, and Rocky Mountain juniper. On dryer sites (river terraces), other shrub species are more common, such as redosier dogwood (*Cornus sericea*), golden currant (*Ribes aureum* var. *villosum*), honeysuckle (*Lonicera* spp.), western snowberry, Woods' rose (*Rosa woodsii*), skunkbush sumac (*Rhus trilobata*), and the vines western white clematis (*Clematis ligusticifolia*) and Virginia creeper (*Parthenocissus quinquefolia*) (Von Loh et al. 2000). Native herbaceous species present in this type include Canada wildrye (*Elymus canadensis*), western wheatgrass, wild licorice (*Glycyrrhiza lepidota*), northern bedstraw (*Galium boreale*), meadow-rue (*Thalictrum dasycarpum*), and smooth scouring-rush (*Equisetum laevigatum*), but many non-native herbaceous plants are also present, namely leafy spurge, Kentucky bluegrass, white sweetclover, yellow sweetclover, Canada thistle, smooth brome, and yellow salsify (Von Loh et al. 2000). This community is likely successional between the Sandbar Willow Temporarily Flooded Shrubland Alliance and the Cottonwood–Rocky Mountain Juniper Woodland (Von Loh et al. 2000).

Large and mature eastern cottonwood trees that form a distinctive tree canopy characterize the Cottonwood Temporarily Flooded Woodlands (Von Loh et al. 2000). Small cottonwood trees and secondary tree species such as green ash and Rocky Mountain juniper are sparse or sometimes absent. The alliance contains a high diversity of short shrub species, though most common are western snowberry. Yellow sweetclover and leafy spurge are very common non-native understory species in South Unit cottonwood stands. This alliance is closely associated with the Silver Sagebrush / Western Wheatgrass Shrubland Alliance, Cottonwood – Rocky Mountain Juniper Woodland, and the Cottonwood–Peachleaf Willow Woodlands (Von Loh et al. 2000).

The Cottonwood – Rocky Mountain Juniper Floodplain Woodlands are stands of old eastern cottonwood, where Rocky Mountain juniper and some green ash begin to fill in gaps.

Cottonwood trees remain the dominate species with Rocky Mountain juniper subordinate. Rocky Mountain juniper and green ash dominate the tree, tall shrub, and short shrub layers. The understory is fairly sparse and similar to the Cottonwood Temporarily Flooded Woodland Alliance (Von Loh et al. 2000).

The Green Ash – American Elm Temporarily-Flooded Woodland Alliance is the climax community of the floodplain woodlands. They exist on the oldest areas of the floodplain woodlands, areas such as meander scars and depressions or along tributaries (Von Loh et al. 2000). They are dominated by green ash and American elm trees, but many species of shrubs establish in the understory of older eastern cottonwood stands. The non-native Siberian elm (*Ulmus pumila*) is a secondary tree species in this alliance. Green ash and western snowberry are common small shrub species, along with some Rocky Mountain juniper. The most abundant herbaceous species is non-native Kentucky bluegrass (Von Loh et al. 2000).

Table 19. Floodplain shrubland and woodland area and percent composition for each THRO unit. GIS data from Von Loh et. al. (2000).

Description	no. of polygons	area (ha)	area (ac)	% composition*
Elkhorn Ranch Unit (EHR)				
Sandbar Willow Temporarily Flooded Shrubland Alliance	13	8.4	20.7	9.1
Cottonwood-Peachleaf Willow Floodplain Woodland	5	3.9	9.5	4.2
Cottonwood Temporarily Flooded Woodland Alliance	1	17.2	42.6	18.7
Cottonwood-Rocky Mountain Juniper Floodplain Woodland	1	0.1	0.3	0.1
Green Ash-American Elm Temporarily Flooded Woodland Alliance	5	21.3	52.6	23.0
North Unit (NU)				
Sandbar Willow Temporarily Flooded Shrubland Alliance	137	410.3	1013.8	4.2
Cottonwood-Peachleaf Willow Floodplain Woodland	7	9.4	23.3	0.1
Cottonwood Temporarily Flooded Woodland Alliance	0	0	0	0.0
Cottonwood-Rocky Mountain Juniper Floodplain Woodland	34	184.2	74.5	0.3
Green Ash-American Elm Temporarily Flooded Woodland Alliance	56	167.8	414.5	1.7
South Unit (SU)				
Sandbar Willow Temporarily Flooded Shrubland Alliance	192	92.9	229.6	0.5
Cottonwood-Peachleaf Willow Floodplain Woodland	30	29.1	72	0.2
Cottonwood Temporarily Flooded Woodland Alliance	28	70.4	174	0.4
Cottonwood-Rocky Mountain Juniper Floodplain Woodland	24	18.2	45.1	0.1
Green Ash-American Elm Temporarily Flooded Woodland Alliance	70	55.1	136.2	0.3
Park-wide (all units combined)				
Sandbar Willow Temporarily Flooded Shrubland Alliance	342	511.6	1264.1	1.8
Cottonwood-Peachleaf Willow Floodplain Woodland	42	42.4	104.8	0.2
Cottonwood Temporarily Flooded Woodland Alliance	29	87.6	216.6	0.3
Cottonwood-Rocky Mountain Juniper Floodplain Woodland	63	223.7	172.2	0.2
Green Ash-American Elm Temporarily Flooded Woodland Alliance	126	222.9	550.7	0.8

*calculated as a percent of total area in unit, EHR = 95.3 ha (228.2 ac), NU = 9,751.7.3 ha (24,096.9), SU = 18,635.2 ha (45,048.6 ac), total area all units = 28,479.2 ha (69,373.7 ac).

Changes in Species Distribution

Floodplain woodlands are found on alluvial soils adjacent to the Little Missouri River and along its major tributaries across southwest North Dakota (Godfread 1994). In THRO, most cottonwood woodlands are restricted to the floodplain of the Little Missouri River, though some stands exist along Box Elder, Beaver, Cherry, Paddock and Corral Creeks. Cottonwood woodlands typically are distributed along the Little Missouri River as bow-shaped stands of even-aged trees, with older stands farther away from the river channel (Miller 2005).

Changes in the distribution of cottonwood woodlands are expected over time, with channel migration and the deposition of new alluvium. However, Miller (2005) found that the high instantaneous peak flows typically occurring during spring snowmelt have decreased in magnitude over time (1939 to 2003), causing a decrease in the active channel area and an increase in the floodplain area. High flows allow for the continued establishment of cottonwood forests, as high peak discharges tend to cause more "floodplain turnover" (Miller 2005). The spring 2011 high peak flows and stage heights may have caused significant changes in successional trajectories of floodplain woodlands. In a study related to water rights issues on the Little Missouri River, Miller (2005) recommended that high flows should be protected and that reductions in summer flows should be avoided to limit drought mortality of floodplain trees.

Von Loh et al.'s (2000) GIS data provide the most current distribution and extent of cottonwood forests in THRO, based on 1996 aerial photography. All three units contain stands of cottonwood woodland types. The North Unit did not contain any Cottonwood-Rocky Mountain juniper floodplain woodlands (Plate 10), whereas the South Unit contains a significant portion of this community type (Plate 11). A mix of the various cottonwood woodlands and some Sandbar

Willow Temporarily-Flooded Shrubland Alliance areas are present in the EHR Unit (

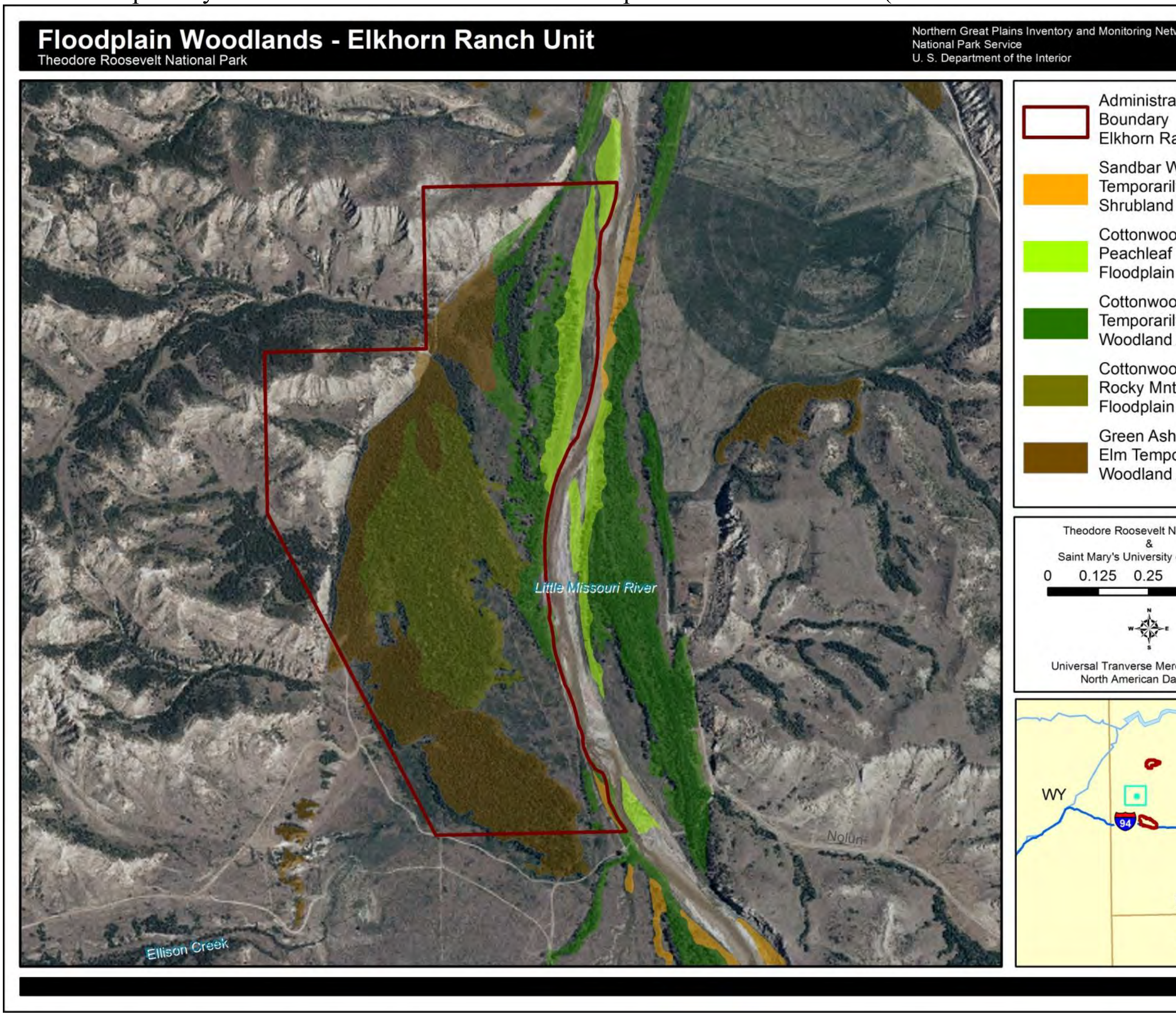


Plate 12).

Cottonwood Woodland Area-Age Distribution
The last specific assessment of cottonwood stand ages in THRO was the dendrologic work by Everitt (1968) in a small section the Little Missouri River in the North Unit of the park (Figure 9).

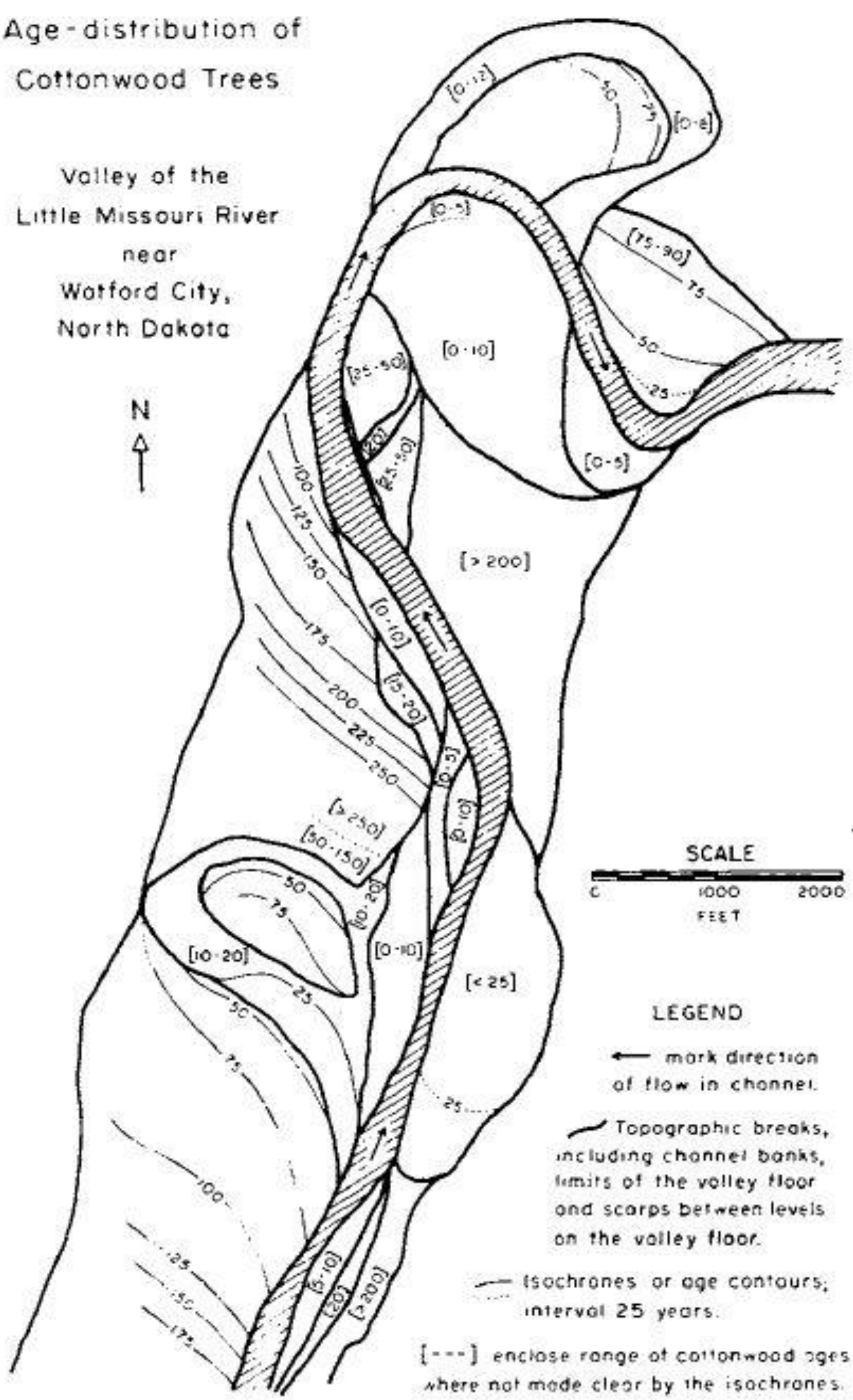


Figure 9. Age map of valley floor. Reproduced from Everitt (1968).

Floodplain riparian forest (woodland) ages are determined by the spatial and temporal variation in historic flood events (Miller 2005). This is because cottonwood seedlings require freshly deposited alluvium for establishment, as older established cottonwood woodlands do not reseed themselves in their under-stories (Everitt 1968). Cottonwood seedling survival depends on these sites being relatively safe from future flooding disturbance, which are typically rare in the riparian landscape (Scott et al. 1996). The creation of new alluvium requires transport and deposition of sediment, mainly through high river discharges, important for the establishment of new cottonwood seedlings (Miller 2005). The seedlings initially form dense stands of cottonwoods or willows on point bars in the Little Missouri River; then, as the channel migrates, narrow bands of cottonwoods mature along older abandoned channels and show an orderly increase in age moving up-valley away from the channel (Everitt 1968, Godfread 1994). Cottonwood trees along the Little Missouri typically reach approximately 90 years of age before their health begins to decline (Wali et al. 1980), after which cottonwood forests will eventually succeed to green ash-American elm woodlands in the absence of flooding (Von Loh et al. 2000).

Everitt (1968) found cottonwood stands to exhibit an age distribution similar to a steady-state exponential relation described in Merigliano et al. (2012). However, research that is more recent found instantaneous high flows have decreased on the Little Missouri, resulting in a larger floodplain area and smaller active river channel area (Miller 2005, Miller and Friedman 2009). The authors suggest the age distribution of the Little Missouri River floodplain is now far from a steady state. However, high peak flows occurring in late-May 2011 may have since reset succession of riparian vegetation in some areas with increased channel migration.

According to GIS data developed by Von Loh et al. (2000), the three aforementioned cottonwood communities, the Sandbar Willow Temporarily Flooded Shrubland Alliance, and the Green Ash-American Elm Temporarily Flooded Alliance community cover approximately 3.4% of the total park area (all units combined). Most of the floodplain woodlands were classified as Cottonwood Temporarily Flooded Woodland Alliance and a relatively large proportion of Green Ash-American Elm Temporarily Flooded Alliance. Smaller proportions were early successional floodplain vegetation stages (Sandbar Willow and Cottonwood-Peachleaf Willow) (Figure 10). This is consistent with Miller and Friedman's (2009) conclusion that old floodplain forest is more abundant than young floodplain areas. Again, this may have changed since 1996 (date of aerial photography used to create GIS data), and given the large magnitude flooding that occurred in spring 2011.

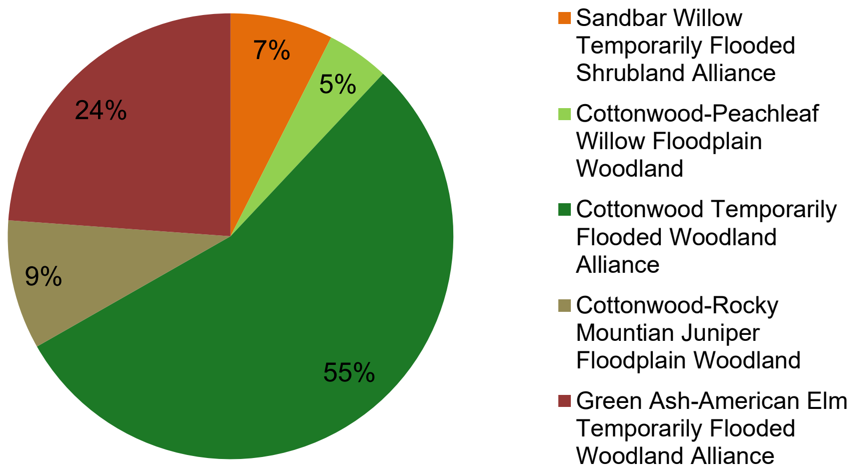


Figure 10. Relative composition of woodland and shrubland floodplain area in THRO. GIS data from Von Loh et. al. (2000).

A floodplain with very few cottonwood seedlings or young cottonwood trees could cause concern for the future of this community type in THRO. However, Friedman (pers. comm., 2012) suggests that using the relative area of young vegetation classes by itself as an index of establishment rate of floodplain woodlands is problematic since cottonwood and willow reproduction are closely linked to channel migration driven by floods, which are uncommon and unevenly distributed in time. That is, the Little Missouri River is dominated by lasting effects of infrequent flooding events (Merigiliano et al. 2012). Instead, Friedman (pers. comm., 2012) suggests that in using aerial photography or satellite imagery to detect channel migration rates along with monitoring the areas of different vegetation types, the NPS can gauge forest reproduction and survival rates. It is important to note that these measures are most valuable when used together, repeatedly, and over a long time-period.

Friedman (pers. comm., 2012) recommends protecting factors that promote channel migration, because riparian vegetation depends so heavily upon this channel migration. Examples of this type of protection include limiting construction activities on the floodplain in or near the park, limiting upstream water withdrawals, and monitoring annual variation in peak flows at the USGS gages in Watford City and Medora, North Dakota. Riparian vegetation is also dependent upon a water subsidy provided by the river. Therefore, summer low flows should be monitored at the USGS gages, upstream water withdrawals should be monitored, and instream flows should be protected during drought.

<u>Non-Native Species Abundance</u>

According to Ashton et al. (2012), non-native species are more abundant in riparian forests than the surrounding upland areas of THRO. Russian olive trees are a specific non-native woody species representing a threat to Sandbar Willow Shrublands, Cottonwood-Peachleaf Willow, and Cottonwood Woodlands in THRO. Once located by NPS invasive plant survey efforts, Russian olive seedlings are immediately removed (L. Richardson, pers. comm., 2012). Another woody species that could threaten floodplain woodlands is saltcedar.

Other abundant non-native invasive species are herbaceous. The Cottonwood–Peachleaf Willow Floodplain Woodlands of THRO contain non-native yellow sweetclover and white sweetclover (Von Loh et al. 2000). In the Cottonwood Temporarily-Flooded Woodland Alliance, common invasive plants include yellow sweetclover, leafy spurge, smooth brome, Kentucky bluegrass, and yellow salsify. Cottonwood – Rocky Mountain Juniper Floodplain Woodlands also contain leafy spurge, Kentucky bluegrass, smooth brome, white sweetclover, yellow sweetclover, and alfalfa. In the Green Ash-American Elm alliance, the primary non-native plant species is Kentucky bluegrass (Von Loh et al. 2000).

Leafy spurge, a species long noted as an aggressive invasive (Bowes and Thomas 1978), was first noted to occur in the river floodplain of THRO, followed by its spread to wooded draws and grasslands (Trammell 1994). More recently, leafy spurge and Canada thistle were found to occur at such densities and large areas as to warrant their own map units in Von Loh et al.'s (2000) mapping efforts. The Leafy Spurge Herbaceous Alliance occurs in many areas of the park, including on floodplains, especially in the South Unit. Since 2002, the EPMT and THRO park staff have utilized integrated pest management practices to reduce/eliminate invasive plant species. The primary focus of these efforts has been on species listed on the North Dakota Noxious Weed List (NPS 2010).

According to GIS data collected by the EPMT, leafy spurge and Canada thistle are the primary invasive non-native plant species in terms of treatment effort in or adjacent to the floodplain woodlands in THRO. However, other typical non-native plant species include Kentucky bluegrass and smooth brome, though less targeted by invasive plant management control efforts. In 2009, nearly 500 acres were treated for these species in or near floodplain woodlands of the park. Multiple herbicides and methods (e.g., helicopter, backpack, ATV) are employed by the EPMT and by THRO park staff. According to the NPS THRO Exotic Vegetation Program Geodatabase (GIS data), THRO staff and NGP EPMT also used biological control on Canada thistle and leafy spurge, releasing biological control agents (e.g., beetles) from 1988 to 2005 in hundreds of locations across the park. Since significant invasive plant treatments began, most of the efforts have been focused in the South Unit of the park.

Threats and Stressor Factors

Non-native Species

Non-native species, especially those considered invasive, can alter the composition and structure of native plant communities. They are considered threats in THRO "because they: 1) replace native species, 2) reduce the land's carrying capacity for livestock and grazing wildlife, 3) may be poisonous to livestock or wildlife, 4) decrease plant species diversity and can further reduce/imperil populations of rare plant species, 5) may carry detrimental insects, diseases, or parasites, 6) can alter fire patterns and intensity, 7) can increase soil nitrogen levels to be detrimental to native species, 8) can result in increased soil erosion and runoff, and 9) can generally degrade or destroy wildlife habitat" (Trammell 1994, CNAP 1999; as cited by Von Loh et al. 2000, p. 2-18).

Although it is a native species, Rocky Mountain juniper is encroaching on some of the floodplain forests (at least those on drier river terraces), along with many of the upland grassland communities. Rocky Mountain juniper forms a sub-canopy beneath larger cottonwood trees in the riparian areas along the Little Missouri River (Von Loh et al. 2000). Juniper encroachment into the floodplain forest community can replace both green ash and cottonwood trees as terraces dry (Godfread 1994, Von Loh et al. 2000). While its encroachment into floodplain woodlands is part of natural succession occurring as floodplain areas age, the increasing prevalence of this species across the park and its potential influence on other floodplain species is concerning to park staff.

Changes in Flooding Regime
In a study examining the influence of flow variability on the formation and destruction of the Little Missouri River floodplain, discharge of the highest one or two flow events of a decade were correlated most strongly with floodplain destruction (Miller and Friedman 2009). In addition, half of the suspended sand was transported via discharges that occur on average only one day per year (Miller and Friedman 2009). This suggests the geomorphological importance of peak flows in determining the amount of floodplain destruction (i.e., creation of new alluvial surfaces). This is especially true in more arid and smaller watersheds (Merigliano et al. 2012). Miller and Friedman's (2009) time sequence mapping of floodplain ages were similar to stand age maps created through dendrologic examinations (Everitt 1968), and they suggest that this confirms the concept that riparian tree establishment occurs mainly on recent channel locations in the Little Missouri River. Miller and Friedman (2009) found that, from 1939 to 2003, the magnitude of these influential instantaneous peak flows decreased, and suggested that this was primarily due to climatic conditions (i.e., precipitation and temperature patterns). This decrease generally reduced channel migration and erosion rates, thereby reducing the amount of new alluvial surfaces for the establishment of early successional shrubs (willows) and cottonwood trees.

Miller and Friedman (2009) suggest that, "the age distribution of the floodplain is far from steady state" (Miller and Friedman 2009, p. 758). However, this was found to be influenced by an uncommon increase in tree establishment from a large flood in 1947 (Merigliano et al. 2012). Miller (2005) recommended that the NPS should protect high instantaneous peak flows along the Little Missouri to support new cottonwood habitat formation. In addition, during July and August, near Watford City, North Dakota, the Little Missouri River flow can be greatly reduced and has even been known to cease (Everitt 1968). Therefore, Miller (2005) also recommended avoiding reductions in summer low flows because of the potential for drought-caused mortality of trees.

Since the Miller and Friedman (2009) study, a high spring discharge occurred on the Little Missouri in May 2011. This represented a large magnitude flood due to large snowpack in the upper reaches of the watershed. The peak discharge of 36,200 cfs on this day represented the fifth highest flow on record at the USGS gage in Medora, ND (Figure 11) and the second highest recorded gage height, at 6.21 m (20.39 ft) (Figure 12). This likely caused geomorphological changes to the river channel and the riparian vegetation. Refer to Section 4.3 for more information regarding Little Missouri River flooding.

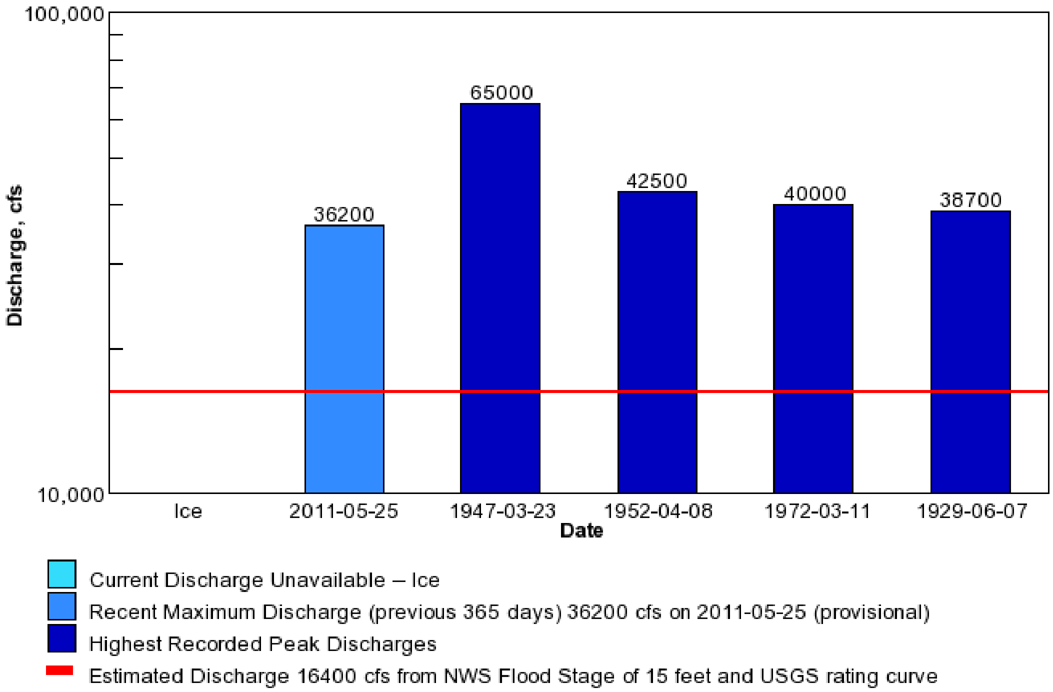


Figure 11. Highest recorded peak discharges and recent (2011) peak discharge from the USGS gage (06336000) at Medora, ND.

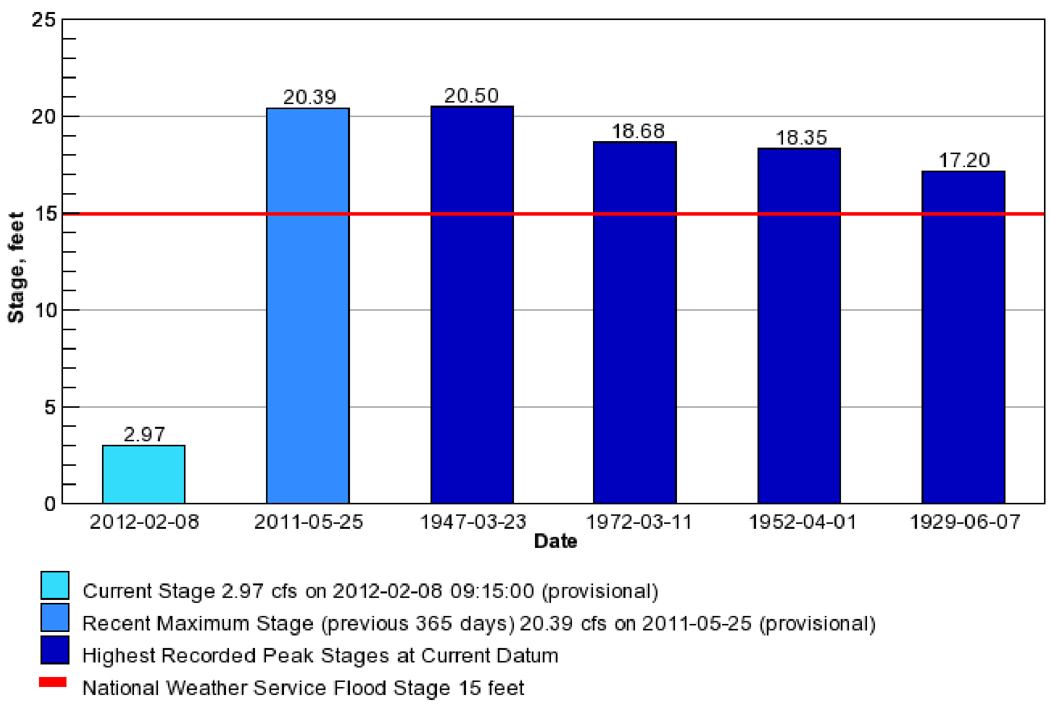


Figure 12. Highest recorded peak stage heights and recent (2011) gage height at the USGS gage (06336000) at Medora, ND.

Ice Jams
Ice jams have been witnessed by park staff in the winter months, leading to flooding that can impact streambanks (Berkeley et al. 1998). This is more typical during the spring snowmelt season (Miller 2005). Spring ice-jams are natural events that cause damage (abrasion) to cottonwood trees. They leave scars on tree trunks for years which act as references for the approximate stage height of past ice-jam floods (Miller 2005). A concern regarding ice-jam floods is the potential for climate/weather changes to alter the hydrologic regime (including the magnitude and frequency of ice-jam flooding events) of the Little Missouri, thereby possibly altering the composition and abundance of floodplain vegetation over time.

Data Needs/Gaps
No specific information is available that examines the species composition and abundance of each floodplain woodland alliance. A NGPN plant community monitoring will help address this gap. However, only five riparian plots have been sampled to date (Ashton et al. 2012). In 2015, the NGPN plant community monitoring program plans to implement a large survey of riparian forests in the park that will examine stand structure and forest health (Symstad et al. 2012).

An assessment of cottonwood woodland stand ages in THRO would give park managers a better understanding of the age composition of these woodlands in order to provide insight for the future of cottonwood forests (e.g., if regeneration is keeping pace with vegetation succession and tree mortality). This research is ongoing in both the North and South Units of the park.

The Von Loh et al. (2000) GIS data describing the extent and distribution of various floodplain woodlands across the three park units was developed using 1996 aerial photography (now nearly 16 years old). An update would provide park management a contemporary understanding of the extent and distribution of floodplain woodlands and would allow for an assessment of changes in community distribution and composition in the park. The 2011 spring flooding likely caused significant alterations to the river channel and riparian vegetation along the Little Missouri River in THRO. These interactions of the river's hydrologic regime and changes in the relative composition of floodplain vegetation classes are important to examine in order to understand the current status of the floodplain woodlands and potential trajectories.

Overall Condition

Species Composition and Abundance
The project team defined the *Significance Level* of frequency as a 3. No specific information examining species-level composition and abundance is currently available, outside of broad categorizations of dominant species for each plant community association in Von Loh et al. (2000); therefore, a *Condition Level* is not assigned. The main issue affecting native species composition and abundance is the influx and expansion of invasive plant species. In the future, data from NGPN plant community monitoring can be used to assess this measure.

Changes in Species Distribution
The project team defined the *Significance Level* of changes in species distribution as a 3. No species-level distribution information is currently available for THRO, only relatively recent community distribution information from Von Loh et al.'s (2000) GIS data. The *Condition Level*

is not assigned. Data from NGPN plant community monitoring may also be useful in assessing this measure in the future.

Cottonwood Area-Age Distribution

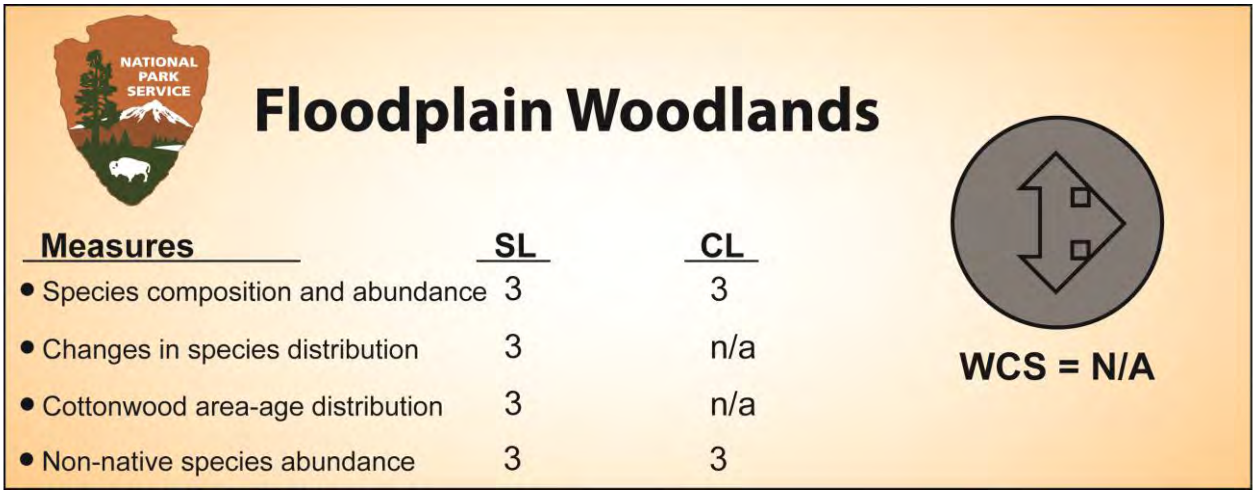
The project team defined the *Significance Level* of cottonwood area-age distribution as a 3. Unlike Everitt's (1968) assessment of stand ages in the North Unit of the park where floodplain ages more closely matched a steady-state exponential relationship, Miller and Friedman (2009) found that floodplain ages were far from a steady state, and that floodplain destruction decreased from 1939 to 2003 on the Little Missouri River. Miller and Friedman (2009) also found that the proportion of older woodlands was higher than younger woodlands. This proportion also was illustrated in examining the relative composition of various successional stages of the floodplain shrubland and woodlands in the Von Loh et al. (2000) GIS data. Merigliano et al. (2012) suggest that there is too much variability in annual peak flows because of local conditions affecting ice jams to detect climate-induced changes in peak flows. Recently, the distribution of cottonwood area-ages has likely changed following the May 2011 flooding. However, given a low level of flow regulation and land clearing, the absence of channel stabilization, the existence of record tree ages, and the natural age structure characteristics of these woodlands, the level of concern for this measure is low (J Hughs, pers. comm., 2012). A *Condition Level* for cottonwood area-age distribution is assigned a value of one, indicating low concern.

Non-native Species Abundance

The project team defined the *Significance Level* of non-native species abundance as a 3. Specific data defining the abundance of non-native species in each of the floodplain woodlands are lacking. However, a few non-native invasive plant species are abundant in many of these woodlands. Despite not having data that specifically estimate abundances, yellow and white sweetclovers, leafy spurge, and Kentucky bluegrass contribute a significant proportion of the species composition in many of the floodplain woodlands. Therefore, this measure is assigned a *Condition Level* of 3, signifying a significant concern for the biological integrity of these floodplain woodlands. Although they currently exist in very low numbers, invasive Russian olive trees present a looming threat to floodplain vegetation of the park.

Weighted Condition Score

Given the lack of information for most of the measures, a *Weighted Condition Score* is not appropriate for this component. However, Friedman (pers. comm., 2012) suggests if, for example, young woodlands decreased in area during and after a period of high river flows, it would be cause for concern especially if channel migration rates were shown to decrease during the same time-period. As another example, if large areas of mature floodplain woodlands were to die-off at a time when upstream withdrawals increased and summer low flows became more extreme, it would also be a cause for concern.



4.6.6 Sources of Expertise

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Laurie Richardson, Botanist, THRO

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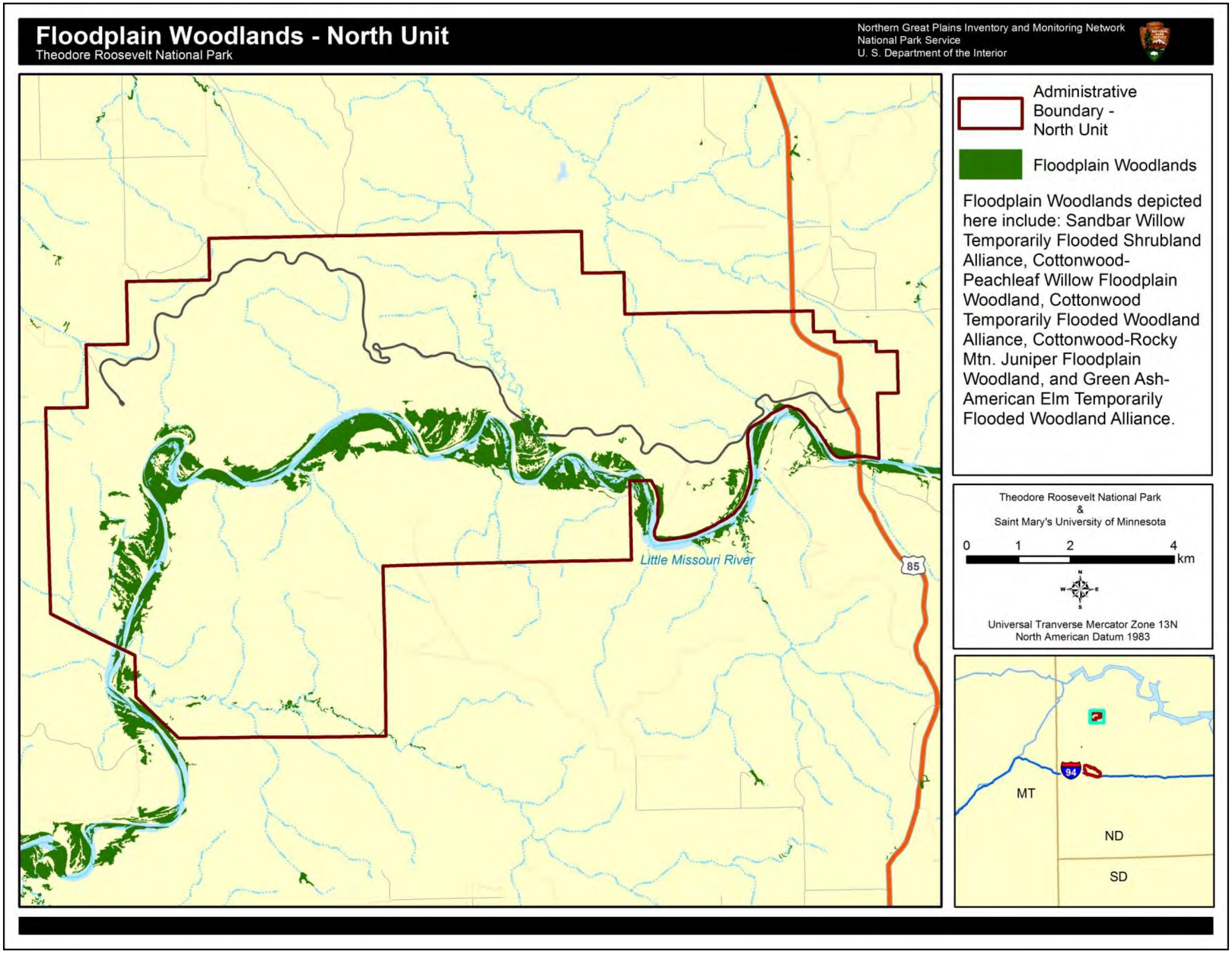

Plate 10. Floodplain woodlands in the North Unit of THRO (Von Loh et al. 2000).

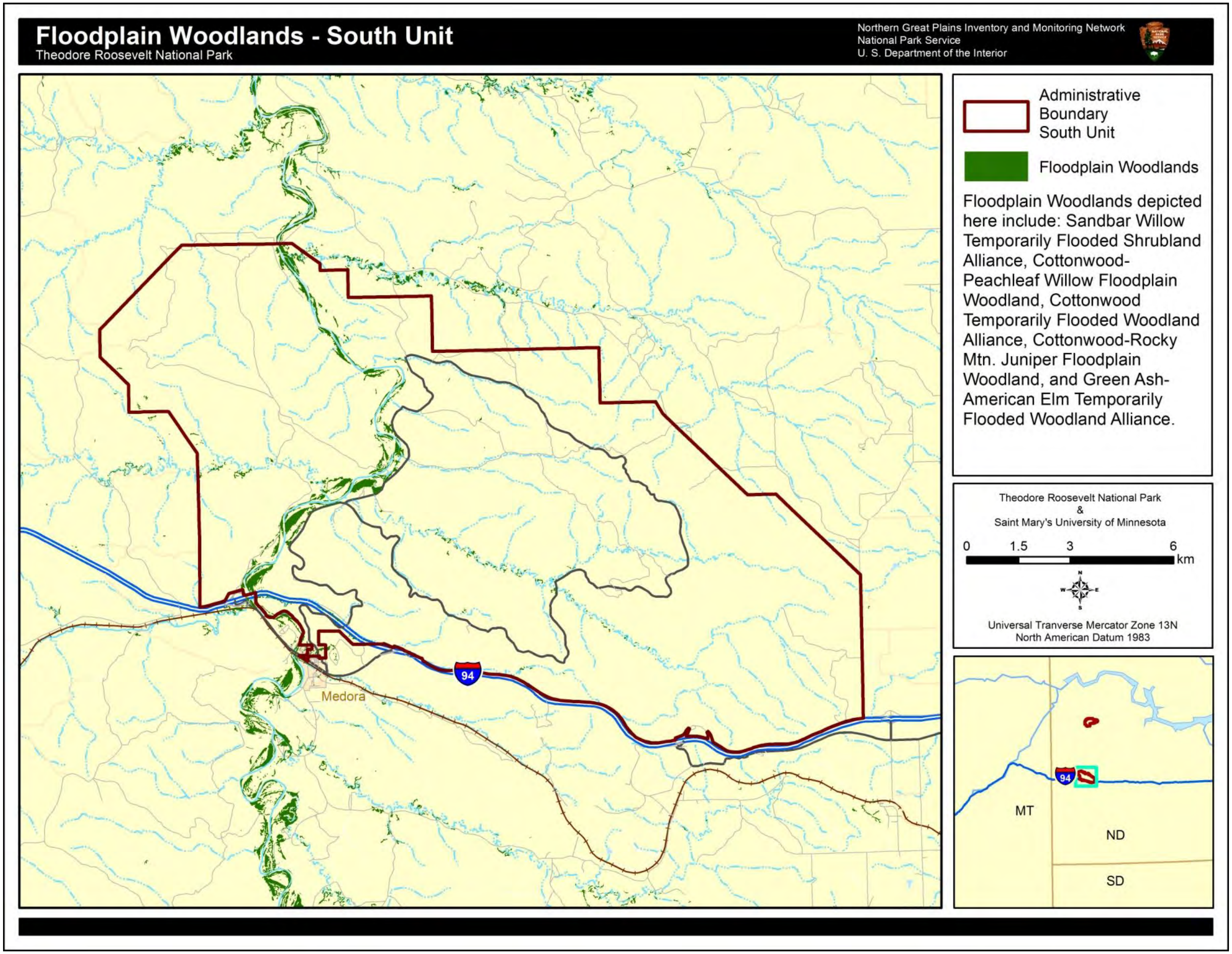

Plate 11. Floodplain woodlands in the South Unit of THRO (Von Loh et al. 2000).

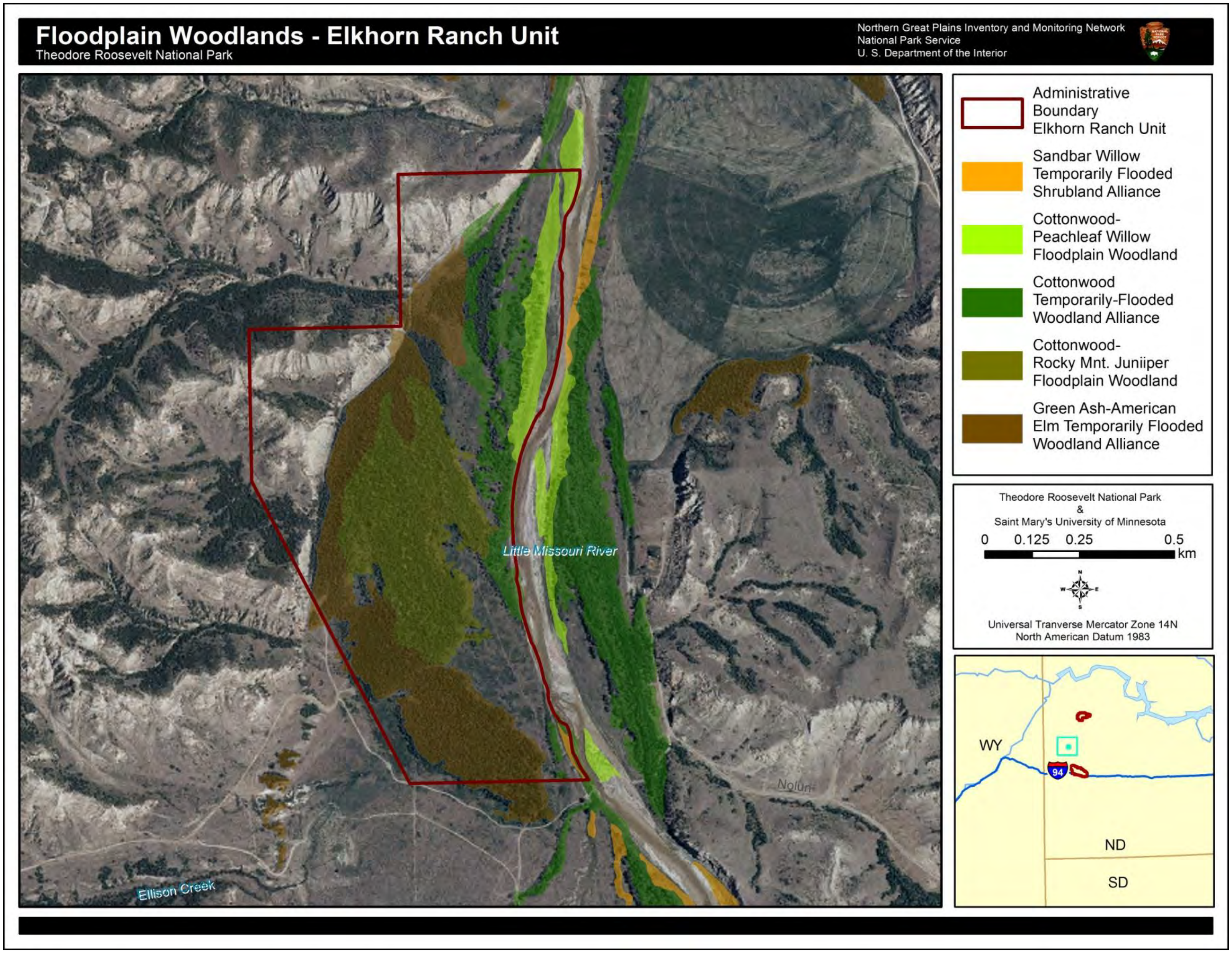

Plate 12. Floodplain woodlands in the Elkhorn Ranch Unit of THRO (Von Loh et al. 2000). Shown with 2004 USDA National Agriculture Imagery Program (NAIP) imagery.

4.7 Woody Draws

4.7.1 Description

Woody draws are small, forested areas that occur in ravines or drainage areas within the badlands landscape (Hull Sieg 1997). The hardwood communities are a small portion of the overall landscape in the northern Great Plains, but provide an important structural contrast to the surrounding grasslands and shrublands (Sullivan et al. 1989). Woody draws provide food and cover for a variety of wildlife species in THRO, including white-tailed deer, mule deer (*Odocoileus hemionus*), porcupine, and forest-dwelling birds. This plant community is dominated by green ash, and support American elm and box elder to a lesser extent (Von Loh et al. 2000).

Photo 15. Woody draw in THRO dominated by green ash with some juniper encroachment (photo by Shannon Amberg, SMUMN GSS, 2010).

4.7.2 Measures

- Species composition and abundance
- Distribution
- Prevalence of non-natives

4.7.3 Reference Conditions/Values

The ideal reference condition for this component would be the composition and distribution of woody draws prior to European settlement. However, no information is available from this historical period. The earliest description of THRO's woody draws comes from Hansen et al.'s (1984) habitat type classification of the park's vegetation. Their characterization of the *Fraxinus pennsylvanica*/*Prunus virginiana* habitat type will be used as the reference condition for species composition in this assessment.

4.7.4 Data and Methods

Irby (2000) monitored 12 green ash draws in the South Unit of THRO between 1985 and 1996 for changes in plant species composition. North Dakota green ash draws were also studied previously by Butler (1983).

Von Loh et al. (2000) used remote sensing to map vegetation in THRO and provided information regarding the composition and distribution of woody draws in the park.

Trammel (1994) surveyed the distribution and extent of exotic species throughout THRO, including in woody draws.

4.7.5 Current Condition and Trend

Species Composition and Abundance
Green ash is one of the dominant tree species found in hardwood draws of the northern Great Plains (Sullivan et al. 1989). Other tree species found in the hardwood draws of THRO include American elm and box elder (Butler 1983, Von Loh et al. 2000). Woody draws sampled by Von Loh et al. (2000) in THRO exhibited 30% mean foliar cover by green ash, followed by 12% mean foliar cover for American elm and 3% for box elder. The shrub layer is typically dominated by chokecherry but can also include Saskatoon serviceberry (*Amelanchier alnifolia*), common snowberry (*Symphoricarpos albus*), western snowberry, currants (*Ribes* spp.), skunkbush sumac, and American plum (*Prunus americana*) (Irby et al. 2000, Von Loh et al. 2000). Northern bedstraw, wild bergamot, and early meadow rue (*Thalictrum venulosum*) are forb species commonly found in these communities (Hansen et al. 1984, Godfread 1994). Common graminoids include Virginia wild-rye (*Elymus virginicus*), Sprengel sedge (*Carex sprengelii*), and Kentucky bluegrass (Butler 1983, Von Loh et al. 2000). The herbaceous layer (forbs and graminoids) in THRO woody draws averaged 45% foliar cover (Von Loh et al. 2000).

Irby et al. (2000) noted that graminoids, forbs, and invasive forbs all showed significant increases in the 12 green ash stands monitored during their 1985-1996 study. The study found a few directional changes in these communities, including a decrease in mature chokecherry and Saskatoon serviceberry and an increase in ground cover plants. These changes did not appear to be due to overuse by ungulates and may be part of natural stand succession. Green ash canopy cover showed little change over the study period (Irby et al. 2000).

Distribution
Woody species are primarily found in draws in THRO, which have greater soil moisture (Hull Sieg 1997). Woody draws rarely comprise more than 2% of the plains landscape due to a lack of moisture (Boldt et al. 1978 and Girard et al. 1989, as cited by Sullivan et al. 1989). The Green Ash-American Elm Woodland Alliance is the dominant woody plant community in THRO draws, in which green ash is the dominant species (Von Loh et al. 2000). Von Loh et al. (2000) states that green ash-American elm draws generally occur in north facing mesic draws or drainages and on moderately steep slopes, but occasionally on east-west oriented sites where moisture requirements are met.

Plate 13, Plate 14, and Plate 15 display the distribution of Green Ash-American Elm Woodland draws in the North, South, and Elkhorn Ranch Units of THRO, respectively.

Prevalence of Non-Natives
Trammel (1994) found 14 non-native plant species present in the hardwood draw vegetational class in a survey of the park. Kentucky bluegrass was the most widespread in the park, with leafy spurge occuring in many of the South Unit draws (Trammel 1994). In recent years Canada thistle has become more common in woody draws as well (L. Richardson, pers. comm., 2012). Table 20 displays non-native plant species documented in THRO hardwood draws in a 1992-1993 survey, along with their mean percent cover and quadrat frequency.

Table 20. Non-native plants documented in THRO woody draws in 1992-1993, with mean percent cover and quadrat frequencies (Trammel 1994). Nine hundred thirty-five quadrats were sampled in 1992 with 150 different quadrats sampled in 1993.

Scientific Name	Common Name	% Cover - 1992 plots	Quadrat freq. - 1992 plots	% Cover - 1993 plots	Quadrat freq. - 1993 plots
Agropyron cristatum	crested wheat grass	T*	0.7		
Bromus inermis	smooth brome	0.9	3.1	0.4	2.6
Bromus arvensis	field brome	T	0.1	0.2	2.6
Bromus tectorum	cheat grass	T	0.7		
Chenopodium album	lambsquarters			T	0.6
Convolvulus arvensis	field bindweed			0.1	4.0
Euphorbia esula	leafy spurge	8.8	29.7		
Lactuca serriola	prickly lettuce	T	0.5		
Lappula echinata	stickseed			T	0.6
Melilotus officinalis	yellow sweetclover	0.1	1.3		
Poa compressa	Canada bluegrass	T	0.5		
Poa pratensis	Kentucky bluegrass	4.8	25.2	6.0	66.6
Taraxacum officinale	dandelion	0.6	5.6	T	2.0
Tragopogon dubius	yellow salsify	0.1	1.5		

* T= Trace (cover < 0.1%)

Irby et al. (2000) found that non-native grasses increased over the 12-year study period but remained low in comparison to natives. Invasive forbs increased more than palatable forbs during this period, although invasive species were a small percentage of total ground cover. Von Loh et al. (2000) noted that Kentucky bluegrass, leafy spurge, burdock (*Arctium minus*), yellow sweetclover, and smooth brome were prevalent in THRO hardwood draws.

Threats and Stressor Factors

Non-native species are a significant threat to the native woody draw communities in THRO. Leafy spurge is a particularly aggressive non-native, which is problematic at the park. The species has proven difficult to control by conventional means (Butler and Trammell 1995), can displace native species (Trammell 1994), and is toxic or unpalatable to some wildlife (Selleck et al. 1962, as cited by Butler and Trammell 1995). Observations suggest that heavily infested areas are sometimes avoided by bison, elk, and deer (Butler and Trammell 1995); however, this has not been validated with an experimental research design. Despite an increase in non-native grasses in the 12-year Irby et al. (2000) study, invasive species remained a small percentage of ground cover in the woody draws that were sampled.

Ungulate foraging is a potential threat to woody draws in THRO if populations grow too large; however, Irby et al. (2000) found no evidence of overgrazing of the green ash woodlands sampled in the South Unit of the park. Elk and mule deer are the two most common ungulates that use woody draws for browse (Irby et al. 2000). Godfread (1994) noted that disturbance by cattle in woody draws allowed non-native plants such as burdock and dandelion (*Taraxacum officinale*) to invade; it is possible that heavy native ungulate activity in THRO could cause similar disturbances (although likely to a lesser degree) in these communities.

Several tree diseases pose a potential threat to woody draws in THRO. A variety of diseases can impact the *Fraxinus* genus, including anthracnose, scorch, ash rust, several heart rots, leafspots, and ash yellows (NDSU 1995). The *Prunus* genus is affected by black knot, plum pockets, and X disease, the latter of which has wiped out many chokecherry stands in the northern Great Plains (NDSU 1995). During a brief visit to THRO in August 2010 to investigate ash die back in several South Unit stands, NDSU researchers found evidence of several ash pathogens, including the fungus *Perenniporia fraxinophila*, wood borers, and bark beetles (Walla and Zeleznik 2010). Ash yellows damage was also observed in one tree. However, this survey was limited to just five green ash stands in the South Unit and does not necessarily reflect conditions throughout the park. Further research is needed to determine if these pathogens are impacting woody draws as a whole.

The emerald ash borer (EAB) (*Agrilus planipennis*) is an invasive insect recently introduced to North America, which has quickly spread across much of the eastern United States and Canada and is now present as far west as Minnesota (USFS et al. 2011). Emerald ash borer larvae kill ash trees by feeding on the inner bark, disrupting the tree's ability to transport water and nutrients (USFS et al. 2011). Emerald ash borer has already decimated large populations of ash trees, and could be devastating to ash trees in the woody draws of THRO if it becomes introduced to the area. The U.S. Department of Agriculture monitors for EAB in the park each summer (L. Richardson, pers. comm., 2012).

<u>Data Needs/Gaps</u>
Green ash draw sites measured by Irby (2000) could be revisited to examine changes in the plant community over time. However, it may be difficult with such a small sample size to determine if any differences represent actual changes or simply natural variation. There is no information currently available regarding the prevalence of diseases in woody draws. Non-native species abundance has not been closely examined specifically in woody draws for a number of years. Research into how these non-natives impact woody draw composition and structure would be helpful in understanding the condition of this plant community in the park.

<u>Overall Condition</u>

Species Composition and Abundance
The THRO project team assigned a *Significance Level* of 2 for species composition and abundance. The most recent description of THRO woody draw composition (Von Loh et al. 2000) is very similar to earlier reports by Butler (1983) and Hansen et al. (1984). Since there is currently no evidence of change in the composition or abundance of woody draws, this measure was assigned a *Condition Level* of 1.

Distribution
A *Significance Level* of 3 was assigned to the measure of distribution. Unfortunately, there is only one source of information addressing the distribution of woody draws in THRO (Von Loh et al. 2000). Since there is no historic or more recent distribution information for comparison, a *Condition Level* cannot be assigned for this measure.

Prevalence of Non-natives
A *Significance Level* of 2 was assigned to the measure of prevalence of non-natives. While non-native species comprised a small percentage of the ground cover in woody draws when they were last surveyed, the presence of aggressive invasives such as leafy spurge and Canada thistle makes this measure of moderate concern (*Condition Level* = 2).

Weighted Condition Score
The *Weighted Condition Score* (WCS) for woody draws in THRO is 0.500, which is of moderate concern. Since woody draws have not been surveyed in any detail over the past decade, the trend in their condition is unknown.

Woody Draws

Measures	SL	CL
• Species composition and abundance	2	1
• Distribution	3	n/a
• Prevalence of non-natives	2	2

WCS = 0.500

4.7.6 Sources of Expertise
Laurie Richardson, Botanist, THRO

4.7.7 Literature Cited

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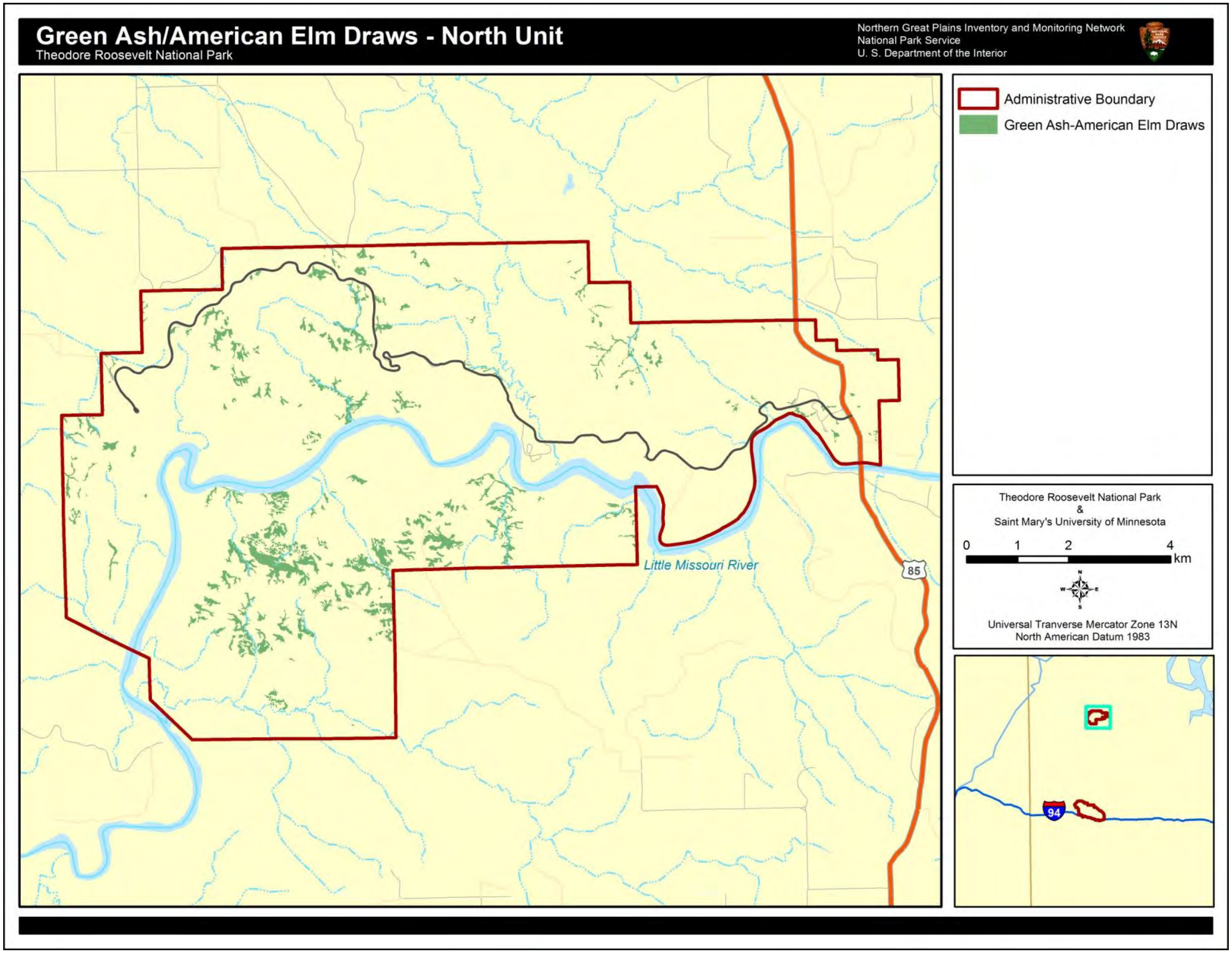


Plate 13. Green Ash-American Elm Woodland Alliance distribution in the North Unit of THRO (mapped in 2000).

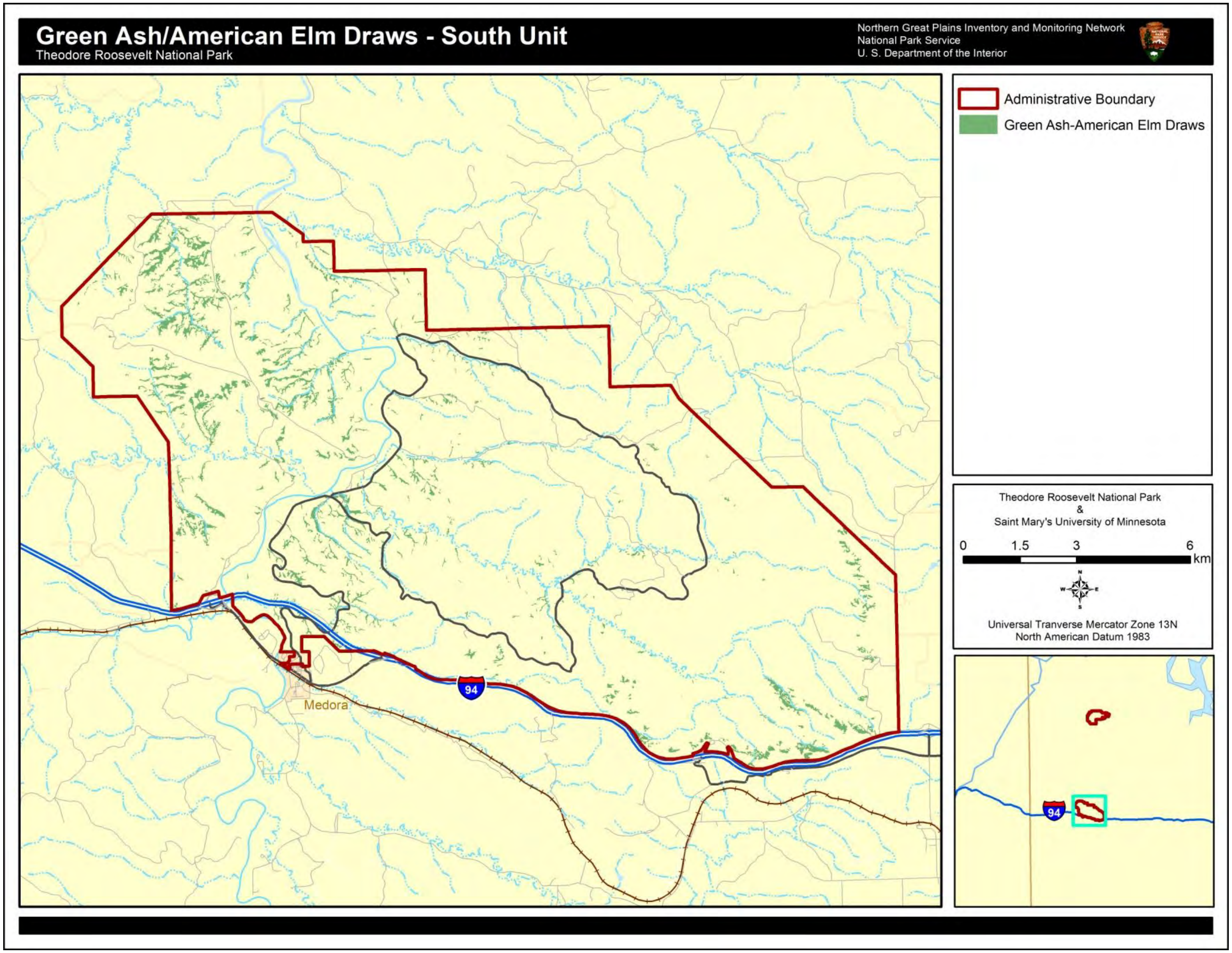


Plate 14. Green Ash-American Elm Woodland Alliance distribution in the South Unit of THRO (mapped in 2000).

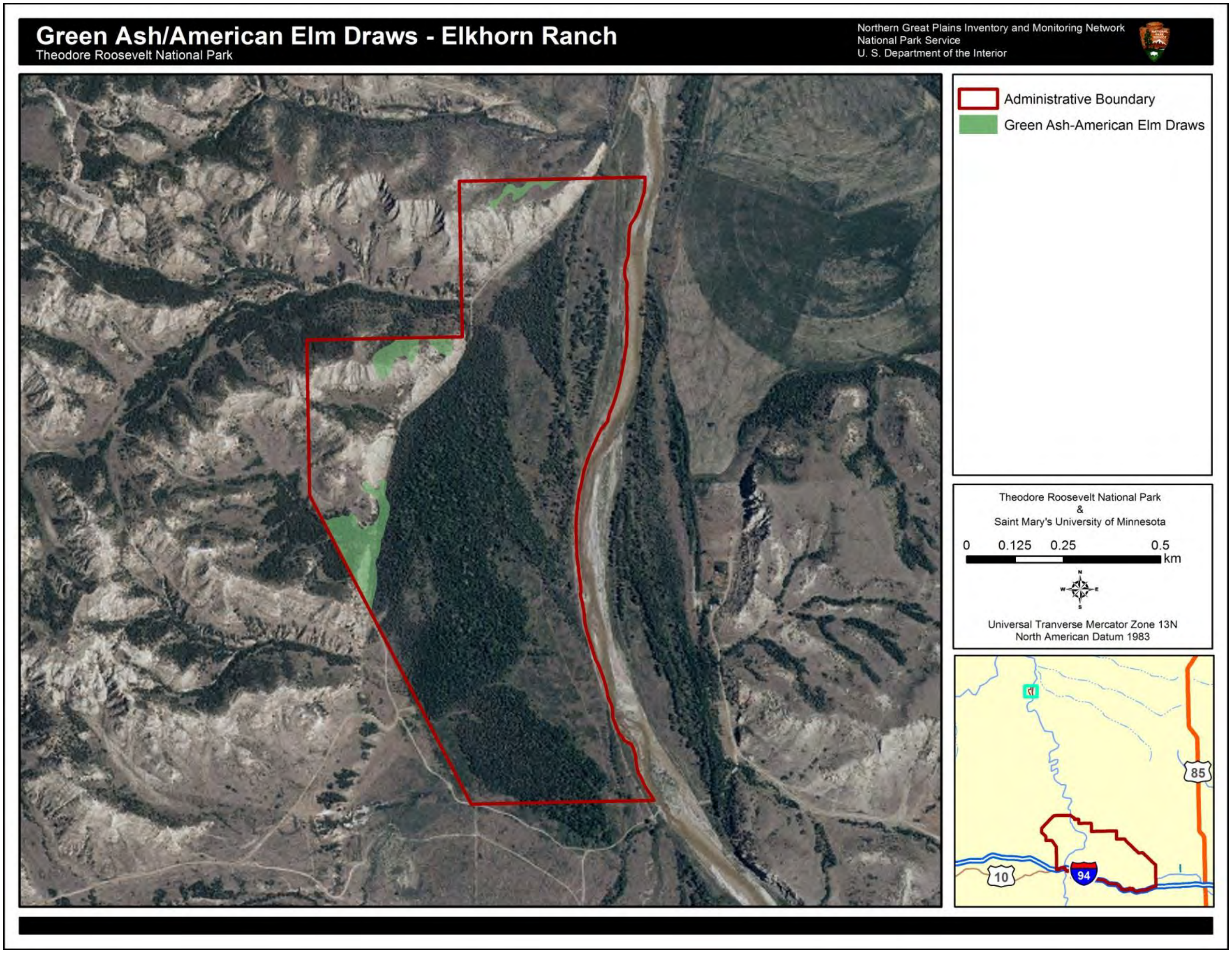


Plate 15. Green Ash-American Elm Woodland Alliance distribution in the Elkhorn Ranch Unit of THRO (mapped in 2000).

4.8 Upland Shrubland Communities

4.8.1 Description

Shrubland communities are found on a wide variety of landform types in THRO, including floodplains, flats, slopes, slumps, draws, hills, and ridges (Von Loh et al. 2000). This assessment focuses on shrubland communities found in upland habitats of the park. These areas provide important resources for wildlife, including elk and North Dakota conservation priority species such as the lark bunting (*Calamospiza melanocorys*) and black-billed cuckoo (*Coccyzus erythropthalmus*) (NPS 2010). Von Loh et al. (2000) identified nine shrubland community types that occur in the park's upland areas. These are listed in Table 21.

Table 21. Upland shrubland communities of THRO (Von Loh et al. 2000).

Common Name	NVCS Association or Complex
Silver Sagebrush / Western Wheatgrass Shrub Prairie	*Artemisia cana* / *Pascopyrum smithii* Shrubland
Wyoming Big Sagebrush - Spiny Saltbush Shrubland	*Artemisia tridentata* - *Atriplex confertifolia* Shrubland
Wyoming Big Sagebrush / Western Wheatgrass Shrubland	*Artemisia tridentata* ssp. *wyomingensis* / *Pascopyrum smithii* Shrubland
Rubber Rabbitbrush / Bluebunch Wheatgrass Shrub Prairie	*Ericameria nauseosa*/ *Pseudoroegneria spicata* Shrubland
Creeping Juniper / Little Bluestem Dwarf-shrubland	*Juniperus horizontalis* / *Schizachyrium scoparium* Dwarf-shrubland
Silver Buffaloberry Shrubland	*Shepherdia argentea* Shrubland
Western Snowberry (Buckbrush) Shrubland	*Symphoricarpos occidentalis* Shrubland
Skunkbush Sumac / Thread-leaved Sedge Shrub Prairie	*Rhus trilobata* / *Carex filifolia* Shrub Herbaceous Vegetation
Greasewood / Western Wheatgrass Shrub Prairie	*Sarcobatus vermiculatus* / *Pascopyrum smithii* - (*Elymus lanceolatus*) Shrub Herbaceous Vegetation

4.8.2 Measures

- Species composition
- Distribution (including changes)
- Prevalence of non-natives

Photo 16. Sagebrush on an upland slope in THRO (Photo by Shannon Amberg, SMUMN GSS 2010).

4.8.3 Reference Conditions/Values

The ideal reference condition for this component would be the composition and distribution of these communities prior to European settlement. However, no information is available from this historical period. The earliest description of THRO's shrubland communities comes from Hansen et al.'s (1984) habitat type classification of vegetation in the park. This report identified four shrubland community types in the park: *Artemisia tridentata/Pascopyrum smithii*, *Artemisia cana/Pascopyrum smithii*, *Juniperus horizontalis/ Schizachyrium scoparium*, and

Symphoricarpos occidentalis. These descriptions are used as the reference condition for species composition within those communities in this assessment. No reference condition could be found for the other shrublands in the park.

4.8.4 Data and Methods

In 1997-98, the USGS and NPS collaborated on a vegetation mapping program of THRO to classify the major plant community types (Von Loh et al. 2000). This report provides the majority of information on the upland shrub communities in the park. Trammel (1994) surveyed the distribution and extent of exotic species throughout THRO, including in several shrubland community types.

4.8.5 Current Condition and Trend

Photo 17. Bison grazing in an upland shrubland habitat dominated by sagebrush (Photo by Shannon Amberg, SMUMN GSS 2010).

Species Composition

One of the first scientific records of western North Dakota shrublands comes from Hanson and Whitman (1938), who described the sagebrush flat type community, in which silver sagebrush is the primary shrub species. Silver sagebrush generally occurs on floodplain terraces, but is also found on some upland flats and slopes. It is often associated with western wheatgrass and is sometimes co-dominant with or dominated by western snowberry (Von Loh et al. 2000).

Western snowberry, also known as buckbrush, is widespread throughout the park, occupying upland depressions, mesic swales and heads of mesic draws, and is an understory of all woodland types in THRO. Western snowberry forms dense thickets, typically 75-90% aerial cover. The species most commonly associated with western snowberry is the non-native Kentucky bluegrass (Von Loh et al. 2000).

Silver buffaloberry (*Shepherdia argentea*) forms very dense stands in lowland areas, but also occurs at the top of mesic draws. Major stands of buffaloberry are found near the turn-around at the west end of Scenic Drive in the North Unit and along the Wind Canyon Trail in the South Unit (Von Loh et al. 2000).

Skunkbush or three-leaved sumac stands are found on ridges, hills, and slopes that consist mostly of scoria outcrops or soils derived from scoria. This species is often associated with silver sagebrush and chokecherry, as well as a variety of herbaceous species in the understory (Von Loh et al. 2000).

Rabbitbrush (*Ericameria nauseosa*) is a dominant shrub on slumps, which are soils disturbed by sliding down steep slopes (Von Loh et al. 2000). This is an uncommon shrub in THRO; the main examples are found on the slump-slope below the Painted Canyon Overlook, the Interstate 94 right-of-way near Medora, and the slump-slope south of the Long X Trail Pullout. Rabbitbrush is often associated with silver sagebrush and western snowberry on these slump locations (Von Loh et al. 2000).

On the higher hillslopes of the park, horizontal or creeping juniper is commonly found in dense patches, sharing habitat with the silver buffaloberry and skunkbush sumac shrubland alliances, as well as the little bluestem - sideoats grama herbaceous alliance (Von Loh et al. 2000). Nelson (1961) noted that horizontal juniper was commonly found on scoria knobs and in the open prairies, and in lesser amounts in the juniper slope forests in his survey of the western North Dakota Badlands.

Wyoming big sagebrush - saltbush shrubland occurs on slopes and ridges in the park, often mixed with sparse badlands vegetation (Von Loh et al. 2000). Plants are typically short and relatively sparse, with total cover ranging from 20-40%. Spiny saltbush (*Atriplex confertifolia*) and broom snakeweed (*Gutierrezia sarothrae*) are common secondary shrubs (Von Loh et al. 2000). Wyoming big sagebrush also occurs in a shrubland community with western wheatgrass. In this community, shrubs are widely spaced with approximately 25% cover (Von Loh et al. 2000). In addition to western wheatgrass, the understory includes needle-and-thread and blue grama.

Greasewood (*Sarcobatus vermiculatus*) stands are the rarest shrub type in THRO, dominating in only two locations in the South Unit (Von Loh et al. 2000). However, the species is also found in sparse vegetation alliances or mixed with other shrubs. Greasewood forms open stands with prairie sagewort, western wheatgrass, field brome, and Canada bluegrass (*Poa compressa*). Individual greasewood shrubs are interspersed with sagebrush and saltbush shrubs on badlands formations (Von Loh et al. 2000).

Table **22** summarizes the most abundant shrub and herbaceous species in each of these shrub communities.

Table 22. The upland shrub communities of THRO and the most abundant species in each community, as surveyed by Von Loh et al. (2000).

Shrub community	Most Abundant Species	
	Shrubs	Herbaceous
Silver sagebrush/Western wheatgrass (*Artemisia cana / Pascopyrum smithii*)	*Artemisia cana, Symphoricarpos occidentalis, Prunus virginiana*	*Pascopyrum smithii, Bromus inermis, Euphorbia esula*
Wyoming big sagebrush - Spiny saltbush (*Artemisia tridentata - Atriplex confertifolia*)	*Artemisia tridentata, Atriplex confertifolia, Gutierrezia sarothrae*	*Pascopyrum smithii, Bouteloua gracilis, Muhlenbergia cuspidata*
Wyoming big sagebrush /Western wheatgrass (*Artemisia tridentata - Pascopyrum smithii*)	*Artemisia tridentata, Atriplex confertifolia, Ericameria nauseosa*	*Pascopyrum smithii, Hesperostipa comata, Bouteloua gracilis*
Rubber rabbitbrush / Bluebunch wheatgrass (*Ericameria nauseosa / Pseudoroegneria spicata*)	*Ericameria nauseosa, Prunus virginiana, Symphoricarpos occidentalis*	*Pascopyrum smithii, Elymus trachycaulus, Melilotus officinalis*
Creeping juniper / Little bluestem (*Juniperus horizontalis / Schizachyrium scoparium*)	*Juniperus horizontalis, Prunus virginiana, Dasiphora fruticosa, Rhus trilobata*	*Schizachyrium scoparium, Calamovilfa longifolia*
Silver buffaloberry (*Shepherdia argentea*)	*Shepherdia argentea, Symphoricarpos occidentalis, Prunus virginiana*	*Poa pratensis, Pascopyrum smithii*
Western snowberry (*Symphoricarpos occidentalis*)	*Symphoricarpos occidentalis, Prunus virginiana*	*Pascopyrum smithii, Poa pratensis, Nassella viridula*
Skunkbush sumac / Threadleaf sedge (*Rhus trilobata / Carex filifolia*)	*Rhus trilobata, Prunus virginiana*	*Muhlenbergia cuspidata, Melilotus officinalis*
Greasewood / Western wheatgrass (*Sarcobatus vermiculatus / Pascopyrum smithii*)	*Sarcobatus vermiculatus*	*Pascopyrum smithii*

Distribution

The distribution of shrub communities in the North and South Units of THRO are displayed in Plate 16 and Plate 17 respectively. Elkhorn Ranch Unit (EHR) shrublands are shown in Plate 18. Sandbar willow communities were excluded from these maps since they do not occur in the park's uplands (they are included in the floodplain woodland section of this report). The Wyoming big sagebrush shrublands also are not shown, as they were combined with the sparse vegetation mapping units rather than being mapped separately.

Western snowberry is the most widespread shrub species in THRO, followed by silver sagebrush and skunkbush sumac (Von Loh et al. 2000). The area covered by each mapped shrub community type in the park is shown in Table 23. Note that these areas include shrublands in both floodplains and upland locations, as these were not separated in the Von Loh et al. (2000) mapping project.

Table 23. Area (in hectares) covered by shrublands in THRO. GIS data from Von Loh et. al. (2000).

Common Name	North Unit	South Unit	EHR	Total
Western Snowberry (Buckbrush) Shrubland	735.0	846.0	11.7	1,592.7
Silver Sagebrush / Western Wheatgrass Shrub Prairie	601.8	586.8	8.7	1,197.3
Skunkbush Sumac / Thread-leaved Sedge Shrub Prairie	161.2	816.5	1.4	979.1
Creeping Juniper / Little Bluestem Dwarf-shrubland	1.7	82.4	0.5	84.6
Rubber Rabbitbrush / Bluebunch Wheatgrass Shrub Prairie	5.2	34.0	--	39.2
Silver Buffaloberry Shrubland	9.9	14.2	--	24.1
Greasewood / Western Wheatgrass Shrub Prairie	0.8	0.4	--	1.2
Total	1,515.6	2,380.3	22.3	3,918.2

Prevalence of Non-Natives

Non-native species occur in all plant communities in THRO, including upland shrubland habitats. These plants can impact native species composition and alter natural processes such as fire, nutrient cycling, and erosion (Von Loh et al. 2000). Silver sagebrush communities have been heavily invaded by leafy spurge in the South Unit of THRO, particularly along the Little Missouri River, and Knutson and Paddock Creeks (Von Loh et al. 2000). Leafy spurge has also been found in creeping juniper shrublands, where it has caused a decrease in species richness (Butler and Cogan 2004). Yellow sweetclover is often associated with the skunkbush sumac shrubland alliance on south-facing ridges. Western snowberry stands are most frequently invaded by Kentucky bluegrass (Von Loh et al. 2000). Other non-native species documented in park shrublands include field brome, field bindweed (*Convolvulus arvensis*), dandelion, yellow salsify, smooth brome, and Canada thistle (Trammel 1994, Von Loh et al. 2000). A full list of non-native plants confirmed in THRO, some of which may also be found in shrublands, is included in Appendix C.

Threats and Stressor Factors

Ungulate browsing and grazing impacts the park's upland shrub communities, as well as the distribution of non-native plants such as leafy spurge (Vitousek et al. 1996). Heavy grazing and the associated soil disturbance have been known to promote exotic grass invasion (Knight 1994). Some shrub communities may be replaced by shortgrass species in areas where grazing occurs. In the North Unit of the park, western snowberry shrublands "literally stop at the fenceline and are replaced by shortgrasses on annually grazed areas on the non-park side of the fenceline" (Von Loh et al. 2000). In big sagebrush shrublands, grazers may trample sagebrush seedlings, inhibiting reproduction. However, grazing can also reduce competition from grasses, increasing shrub density and sagebrush establishment (Beck and Mitchell 2000).

Data Needs/Gaps

THRO's shrubland communities have not been surveyed in depth since the Von Loh et al. (2000) study in 1997-98. The NGPN began a long-term monitoring program in 2011 to examine plant composition and structure in THRO. While the focus is not on shrublands in particular, all of the 21 plots visited in 2011 had a substantial shrub component (Ashton et al. 2012). These and future data should provide information on the species composition and exotic cover in shrublands. Updated information is needed on plant species composition, particularly regarding the prevalence and impact of non-native species specifically within these shrubland communities.

More recent distribution information would also help managers determine if the extent of these communities is changing.

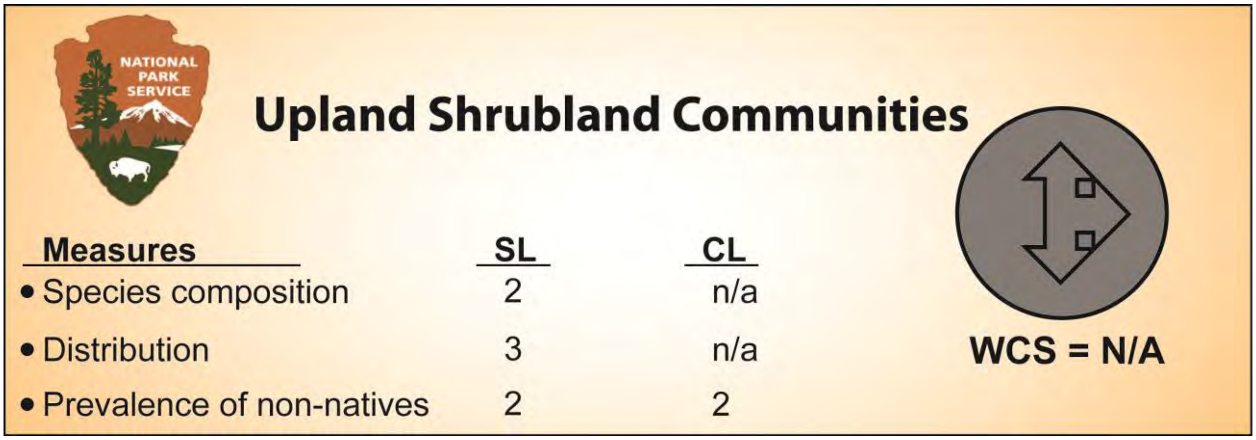
Overall Condition

Species Composition
During initial scoping meetings, THRO staff assigned the measure of species composition a *Significance Level* of 2. The species composition of the four shrubland habitat types surveyed by Hansen et al. (1984) was similar to that found by Von Loh et al. in 2000, with the exception of a few additional non-native species. No reference condition could be established for the remaining upland shrublands, so no comparisons could be made for these communities. Therefore, a *Condition Level* could not be assigned at this time for the upland shrub communities as a whole. In future assessments, data from NGPN plant community monitoring will likely be useful in evaluating this measure.

Distribution
A *Significance Level* of 3 was assigned to the measure of distribution. However, there is only one source of information addressing the distribution of all the shrubland communities in THRO (Von Loh et al. 2000). Since neither a historic or more recent distribution map is unavailable for comparison, *Condition Level* is unknown. Data from NGPN plant community monitoring may also be useful in assessing this measure in the future.

Prevalence of Non-natives
A *Significance Level* of 2 was assigned to the measure of prevalence of non-native species. Leafy spurge has severely infested several shrublands in the park, causing an apparent decrease in plant species richness (Butler and Cogan 2004). In the early 1980s, Hansen et al. (1984) found a small amount of this species in only one of their shrubland sampling plots. Numerous other non-native species have been documented in the park's upland shrublands. As a result, the *Condition Level* for this measure is a 2, signifying moderate concern.

Weighted Condition Score
Since *Condition Levels* for two of the three upland shrubland communities are unknown, a *Weighted Condition Score* (WCS) was not calculated for this component.



4.8.6 Sources of Expertise
Laurie Richardson, THRO Botanist

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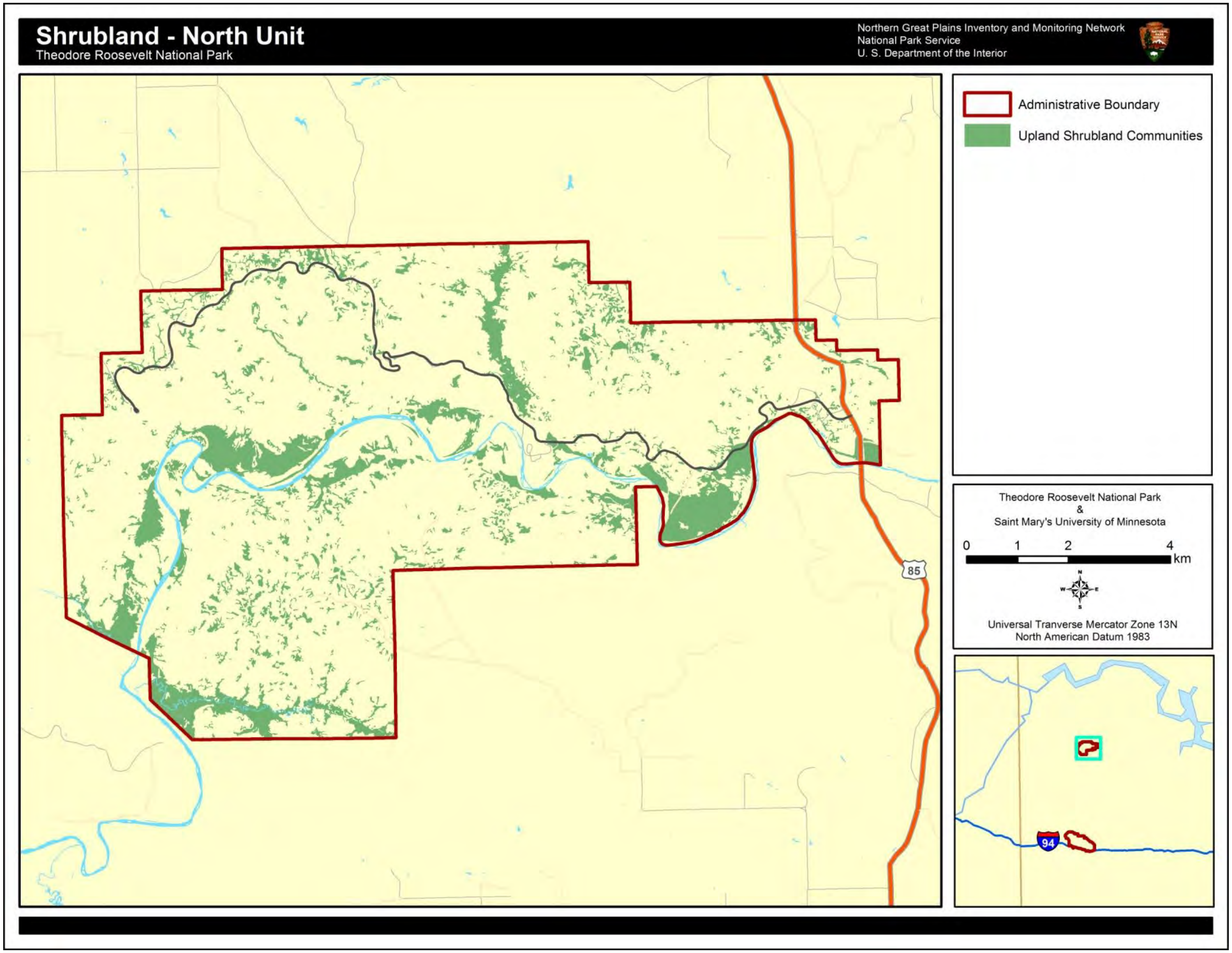


Plate 16. Shrubland alliances in the North Unit of THRO.

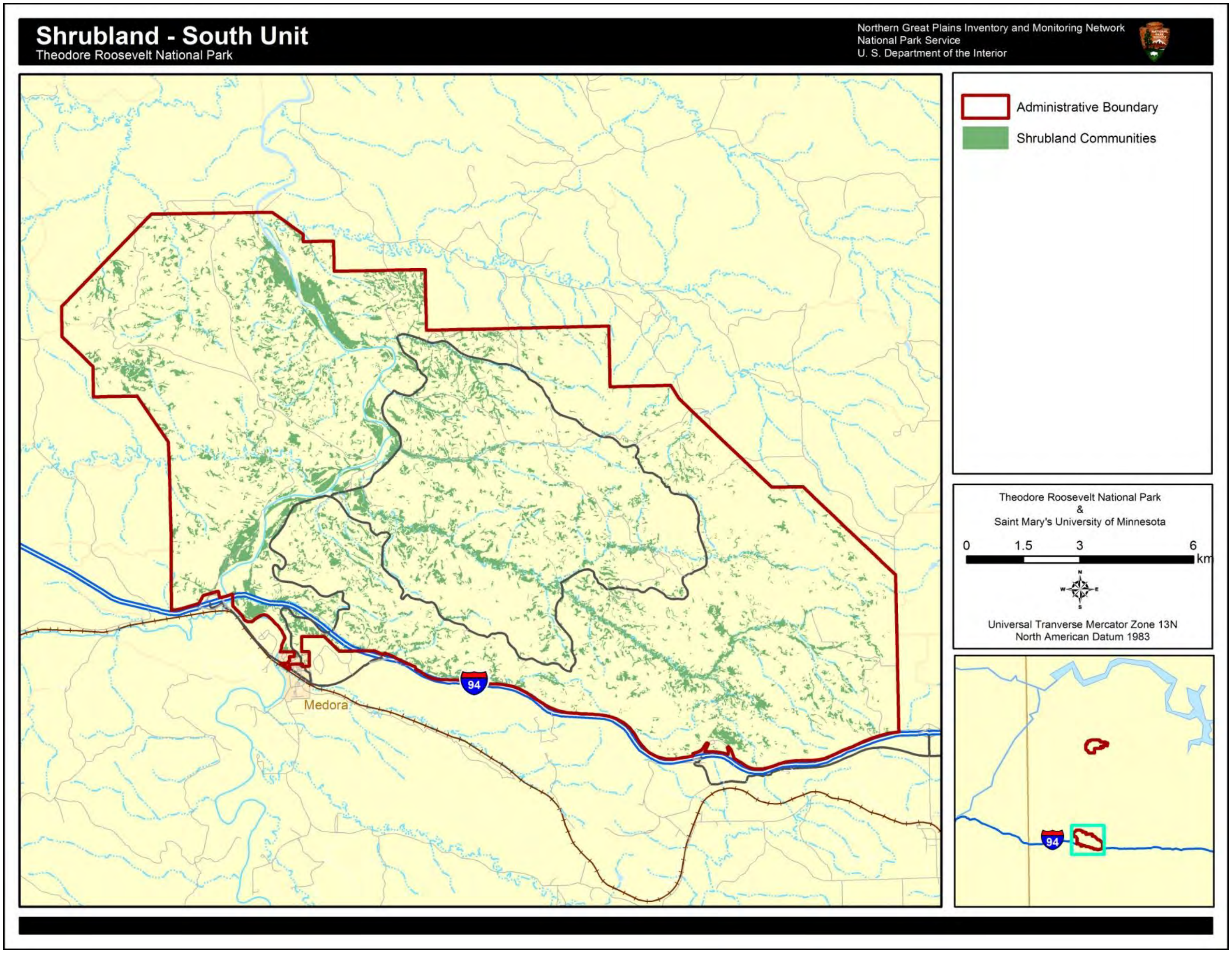


Plate 17. Shrubland alliances in the South Unit of THRO.

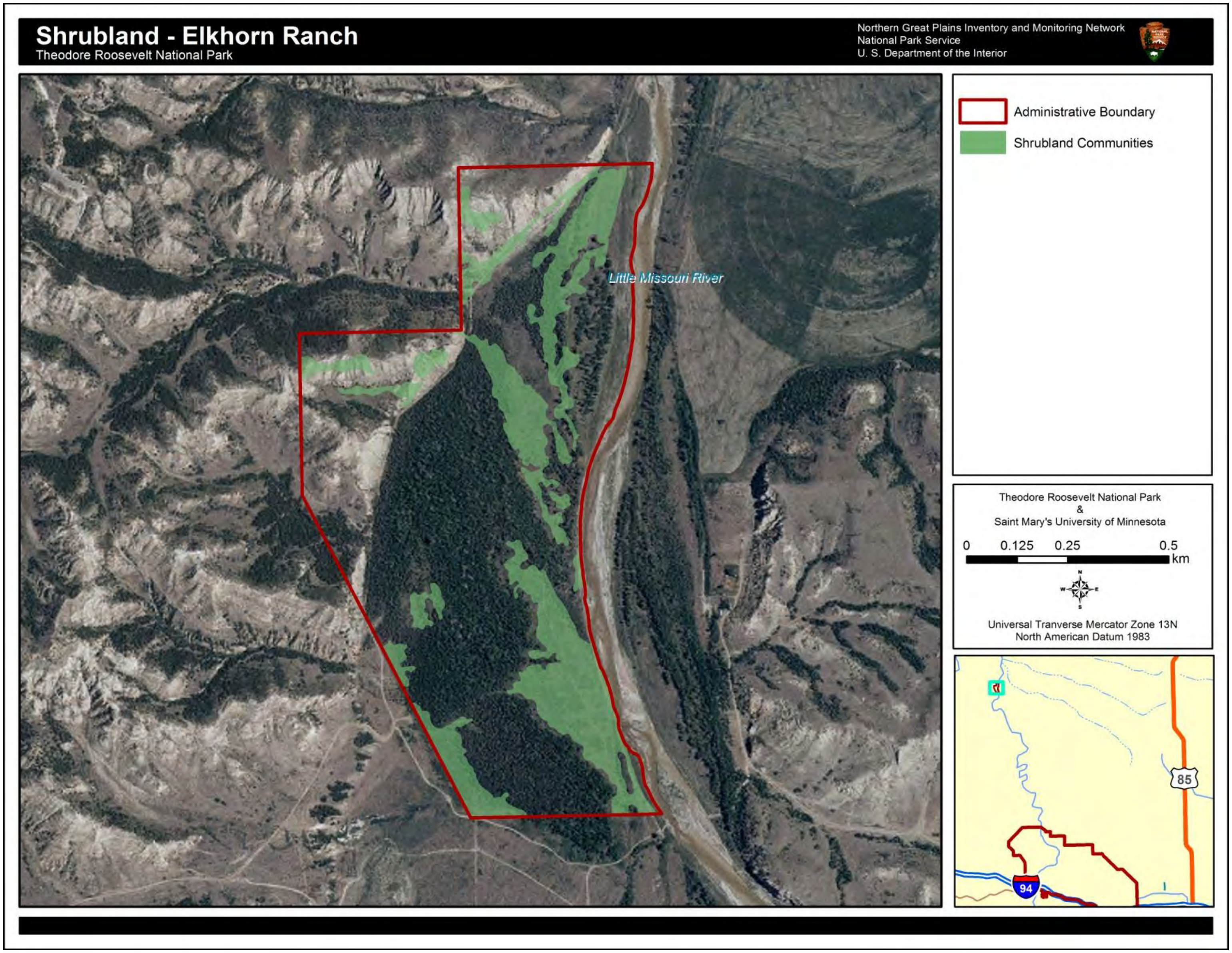


Plate 18. Shrubland alliances in the Elkhorn Ranch Unit of THRO.

4.9 Aquatic Communities

4.9.1 Description

Water is a scarce and highly valuable resource in the semi-arid landscape of THRO. While wetland and riparian areas are important habitats for some aquatic species in the park (Berkeley et al. 1998), the aquatic communities of THRO are mainly limited to the Little Missouri River, which connects all three units of the park, and tributary streams that feed into the river. The Little Missouri River is the only water body that supports a fish community in the park (NPS 2010). The river is primarily suited for small, non-game fish species; game species are more productive during wet years with high water levels (Duerre 1986, as cited in Berkley et al. 1998). There are 29 species of fish present in the Little Missouri River (NPS 2011). Little is known about the macroinvertebrate community in the Little Missouri River and other park water bodies, although limited research suggests that species diversity and abundance appear to be low in some stretches of the river (Rust 2006).

Photo 18. Longnose dace (*Rhinichthys cataractae*) (NPS photo).

4.9.2 Measures

- Native fish species composition and abundance
- Macroinvertebrate composition and abundance

4.9.3 Reference Conditions/Values

The reference condition for aquatic communities is the range of abundance and diversity of native fish and macroinvertebrate species over the duration of available survey and monitoring data. Historic fish species lists are cross-referenced to identify potential changes or shifts in abundance and diversity.

4.9.4 Data and Methods

Kelsch (1994) conducted a fish survey of the Little Missouri River at 24 sample sites between the towns of Marmarth and Medora in North Dakota in 1993.

USFWS (1999) also conducted a fish survey of the Little Missouri River in 1998 as part of the sturgeon chub (*Macrhybopsis gelida*) reintroduction project.

Rust (2006) collected water quality samples for several parameters on the Little Missouri River in THRO in 2004-2005. The objective of the research was to provide baseline descriptions of macroinvertebrate communities in the aquatic systems of national parks in the NGPN (including THRO), as well as select optimal metrics for use in future monitoring efforts by park resource managers. Chemical, physical, and habitat parameters were assessed for streams, rivers, and springs during the 2004 and 2005 summer seasons. The diversity and abundance of macroinvertebrate species was sampled at three locations on the Little Missouri River during this time.

4.9.5 Current Condition and Trend

<u>Native Fish Species Composition and Abundance</u>
Minnows (Cyprinidae), perches (Percidae), suckers (Catostomidae), and catfishes (Ictaluridae) make up 70% of the native fish fauna of the northern Great Plains region (Berkley et al. 1998). Hankinson (1929) was the first to survey fish species in the Little Missouri River, describing 17 species. Personius and Eddy (1955) reportedly identified 13 species during a survey from the headwaters in Wyoming to the junction with the Missouri River in central North Dakota. The list of fish species from Personius and Eddy (1955) is displayed in Table 24. It is important to note that this survey did not focus specifically on the stretch of river passing through THRO, but covered the entire Little Missouri River.

Table 24. Fish species documented in a 1950 survey of the Little Missouri River (Personius and Eddy 1955).

Scientific Name	Common Name
Carpiodes carpio carpio	northern river carpsucker
Catostomus commersoni commersoni	common white sucker
Cyprinus carpio	carp
Hybopsis gracilis communis	plains flathead chub
Hybopsis plumbea	northern chub
Hybopsis meeki	sickelfin chub
Rhinichthys cataclae	longnose dace
Notropis deliciosus missuriensis	plains sand shiner
Hybognathus placita	plains minnow
Pimephales promelas promelas	northern fathead minnow
Ictalurus punctatus	channel catfish
Ameiurus melas melas	northern black bullhead
Stizostedion canadense	sauger

The current NPS Certified Species List for THRO fish expands upon the list developed by Personius and Eddy (1955). Table 25 displays fish species confirmed to be present in THRO. The plains flathead chub (*Platygobio gracilis*, previously *Hybopsis gracilis communis*) was documented by Personius and Eddy (1955) but is not included on the current park species list.

Table 25. Certified species list for fish in THRO (NPS 2011).

Scientific Name	Common Name
Ameiurus melas	black bullhead
Aplodinotus grunniens	freshwater drum
Carpiodes carpio	river carpsucker/carpsucker
Catostomus commersonii	white sucker
Couesius plumbeus	lake chub
Culaea inconstans	brook stickleback
Cyprinus carpio	carp/European carp
Esox lucius	northern pike
Etheostoma exile	Iowa darter
Hiodon alosoides	goldeye
Hybognathus argyritis	western silvery minnow
Hybognathus hankinsoni	brassy minnow
Hybognathus placitus	plains minnow
Ictalurus punctatus	channel catfish
Lepomis cyanellus	green sunfish
Lepomis macrochirus	bluegill
Lota lota	burbot
Moxostoma macrolepidotum	shorthead redhorse
Notemigonus crysoleucas	golden shiner
Notropis atherinoides	emerald shiner
Notropis stramineus	sand shiner
Noturus flavus	stonecat
Phoxinus eos	northern redbelly dace
Pimephales promelas	fathead minnow, flathead minnow
Platygobio gracilis	flathead chub
Rhinichthys cataractae	longnose dace
Sander canadensis	sauger
Sander vitreus	walleye
Semotilus atromaculatus	creek chub

Kelsch (1994) surveyed the Little Missouri River in 1993 and documented 13 fish species. Three species were commonly found during the survey: flathead chub (*Platygobio gracilis*), plains minnow (*Hybognathus placitus*), and the longnose dace (*Rhinichthys cataractae*). These three species comprised 95% of individuals captured during the study; the flathead chub alone represented 72% of individuals captured. Generally, species diversity and abundance were low during the survey; only three sample sites out of 24 yielded more than five fish species (Kelsch 1994). Two species of special concern were captured during the study, the northern redbelly dace (*Phoxinus eos*) and the lake chub (*Couesius plumbeus*). The survey results may not have been representative of normal conditions on the Little Missouri River, as the study was conducted after a drought followed by unusually high flow and velocity (Kelsch 1994).

USFWS (1999) found that fish abundance in the Little Missouri River was dominated by a few species: flathead chubs, *Hybognathus* spp., sandshiners, and longnose dace comprised 90% of fish biomass in the survey. These results are quite similar to the findings of Kelsch (1994).

The sturgeon chub and sicklefin chub (*Macrhybopsis meeki*) are listed as Level I species by the North Dakota Game and Fish Department, meaning they are “species in the greatest need of conservation” within the state (NDGFD 2010). Neither species is federally-listed as threatened or endangered in the United States (Rahel and Thel 2004). The sturgeon chub and sicklefin chub now are considered extirpated from the Little Missouri River, and a sturgeon chub reintroduction effort conducted between 1998 and 2000 was unsuccessful (Rahel and Thel 2004).

Macroinvertebrate Composition and Abundance

Rust (2006) collected invertebrates in the Little Missouri River within THRO and found a low level of species diversity, with 47% of total abundance composed of the order Diptera (true flies). Twenty-four percent of macroinvertebrates in the survey were attributed to EPT (Ephemeroptera, Plecoptera, and Trichoptera) orders. Macroinvertebrate abundance in the Little Missouri River also was considered low by Rust (2006). This was the first and only study to examine the macroinvertebrate community in THRO. The Wyoming Natural Diversity Database sampled the macroinvertebrate community in THRO in 2011 (L. Tronstad, pers. comm., 2012). Data currently are being analyzed and are not yet available for comparison with Rust’s (2006) findings.

Threats and Stressor Factors

Non-native species threaten native fish and macroinvertebrate populations in the Little Missouri River, and are present in part due to habitat alterations caused by reservoir construction (Rahel and Thel 2004). Non-native fish species present in the Little Missouri River include the common carp (*Cyprinus carpio*), and piscivorous fish species such as walleye (*Zander vitreum*), striped bass (*Morone saxatilis*), and largemouth bass (*Micropterus salmoides*) that have been stocked in Little Missouri River reservoirs in an attempt to develop sport fisheries (Rahel and Thel 2004).

Habitat alterations to the Little Missouri River, including conversion of riverine habitat to standing water habitat, reduction of turbidity, and fragmentation, have altered the natural water quality (Rahel and Thel 2004). Reduction of turbidity in particular has led to the replacement of fish species tolerant of turbid water with species characteristic of clearer waters. Species such as the sturgeon chub particularly have been affected by these water quality changes, with an increase in clear water fish that often prey on the chub (Rahel and Thel 2004).

Data Needs/Gaps

Kelsch (1994) stated that additional fish surveys during periods of both normal and low flow would be necessary to truly understand diversity and abundance in the Little Missouri River. The few surveys conducted to date have been sporadic and only present a snapshot of the fish community under certain conditions. There have been no published studies on fish populations in or near THRO over the past decade.

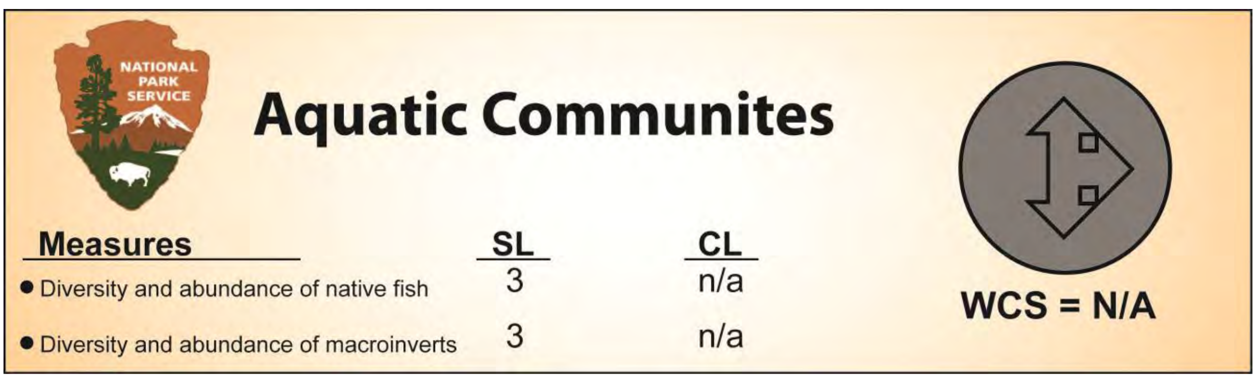
There is little data available regarding macroinvertebrate diversity and abundance. Rust (2006) provided some baseline data on the community in the Little Missouri River and the Wyoming Natural Diversity Database recently sampled the macroinvertebrate community in THRO, although this data is not yet available. Continued monitoring of macroinvertebrates could help managers identify any changes in the park's aquatic community and possibly water quality.

Overall Condition

Native Fish Species Composition and Abundance
The THRO project team defined the *Significance Level* for native fish species composition and abundance as a 3. Documented fish species diversity has increased over time in THRO, though this is likely due to more intensive sampling. There is not enough historic and current diversity and abundance data to determine a *Condition Level*.

Macroinvertebrate Composition and Abundance
A *Significance Level* of 2 was assigned for the measure of macroinvertebrate composition and abundance. Because there has only been one published study on the macroinvertebrate community in the Little Missouri River to date, there is not enough data to determine a *Condition Level* for this measure.

Weighted Condition Score
A *Weighted Condition Score* (WCS) cannot be assigned at this time due to lack of data on component measures.



4.9.6 Sources of Expertise
Steven Kelsch, Associate Professor of Biology, University of North Dakota

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4.10 Prairie Dogs

4.10.1 Description

Black-tailed prairie dogs (*Cynomys ludovicianus*), hereafter prairie dogs, are stout, burrowing rodents commonly associated with early successional vegetation (NRCS 2012). Grasses comprise a majority of their diet, but forage varies across the species' range. Prairie dogs are gregarious animals; they live in social groups called towns or colonies. Within these towns are multiple burrows connected through underground tunnels. Prairie dogs are a keystone species in their environments as they provide essential food and shelter for other prairie species. At THRO, some of the species that utilize towns include burrowing owls (*Athene cunicularia*), ferruginous hawks (*Buteo regalis*), and mountain plovers (*Charadrius montanus*); these species depend on prairie dogs for food, use of their burrows, and other reasons (Antolin et al. 2002).

4.10.2 Measures

- Extent of prairie dog colonies

4.10.3 Reference Conditions/Values

There is not an established reference condition for this component. Park management actively observes the dog colonies throughout the year to be prepared in case management action is necessary. However, the use of active management techniques by park staff is rare with this species. Future assessments should incorporate the new prairie dog management plan that is currently in development.

Photo 19. Black-tailed prairie dog (Photo by Shannon Amberg, SMUMN GSS, 2010).

4.10.4 Data and Methods

The primary source of data for this component is the THRO Wildlife Program Geodatabase. This database holds polygon feature classes with the extent of prairie dog colonies for 12 years: 1984, 1996, 1997, 1999, 2000-2003, 2005, and 2007-2011. Mike Oehler, THRO Wildlife Biologist, indicated that data gathered after 2000 is of higher quality due to adjusted methods. Attributes from this dataset used in this assessment include colony name, area (acres), and perimeter (meters). Data from the extent feature classes were extracted to an Excel table, where fields were dissolved in order to allow for easy development of tables and graphs.

4.10.5 Current Condition and Trend

<u>Extent of Prairie Dog Colonies</u>

From 1984 to 2008, the total area of prairie dog colonies in THRO increased to a maximum recorded area of 1,879 acres (Figure 13). Then, from 2009 to 2011, prairie dog acreage decreased each year, with total acreage in 2011 being 1,151 acres. In 1984, the total area occupied by prairie dogs in the South Unit was 422 acres, according to a vegetation map produced by Jack Norland of North Dakota State University. In 2008, the acreage in the South Unit was at an all-time high, since recordkeeping began, with 1,742 acres (Figure 14). The earliest date that prairie dog mapping occurred in the North Unit was 1997. In 1997, the total acreage in the North Unit was 108 acres. Since 1997, the extent of prairie dogs in the North Unit has been stable (mean = 112, range = 31-145), not showing any particular trend (Figure 15). However, the most recent occupied acreage, in 2011, was the second lowest on record at 72 acres.

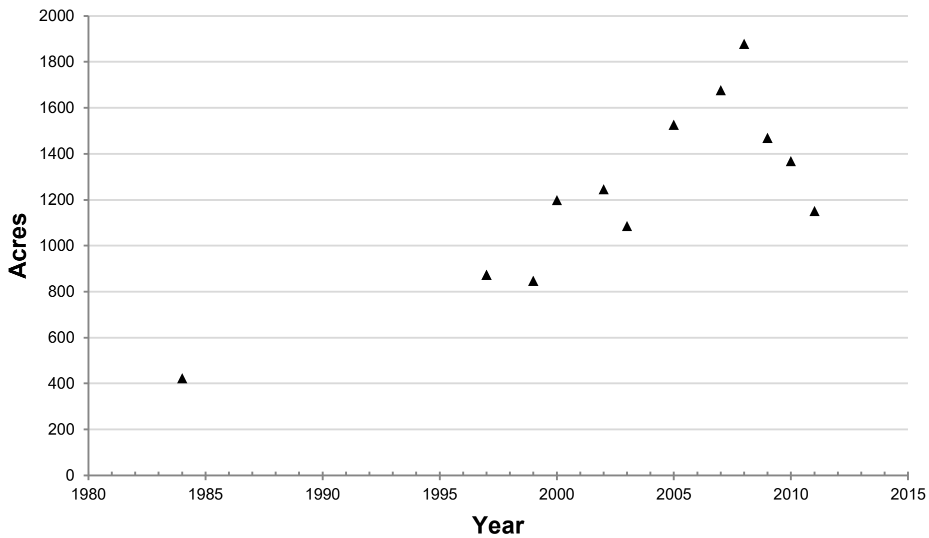


Figure 13. Total acres of prairie dog colonies in THRO, 1984-2011 (THRO 2010).

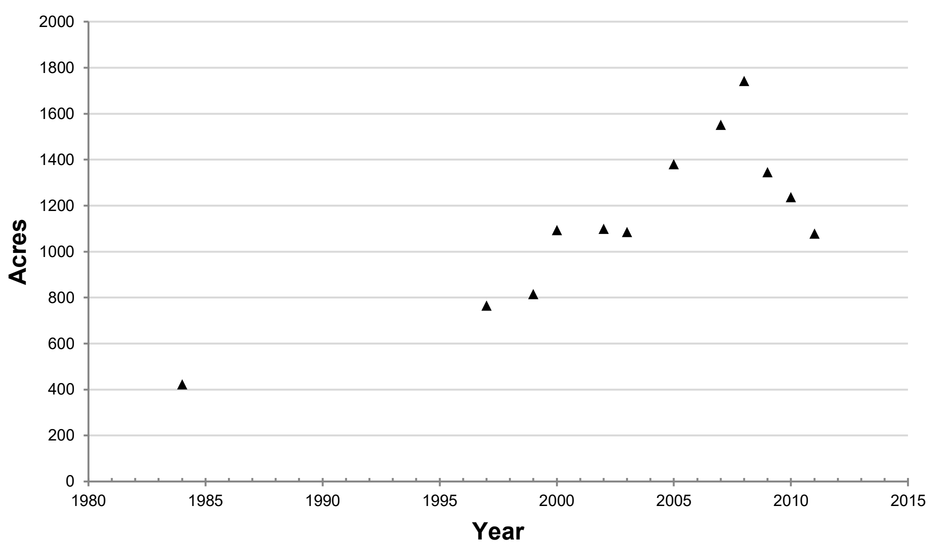


Figure 14. Total acres of prairie dog colonies in the South Unit of THRO, 1997-2011 (THRO 2010).

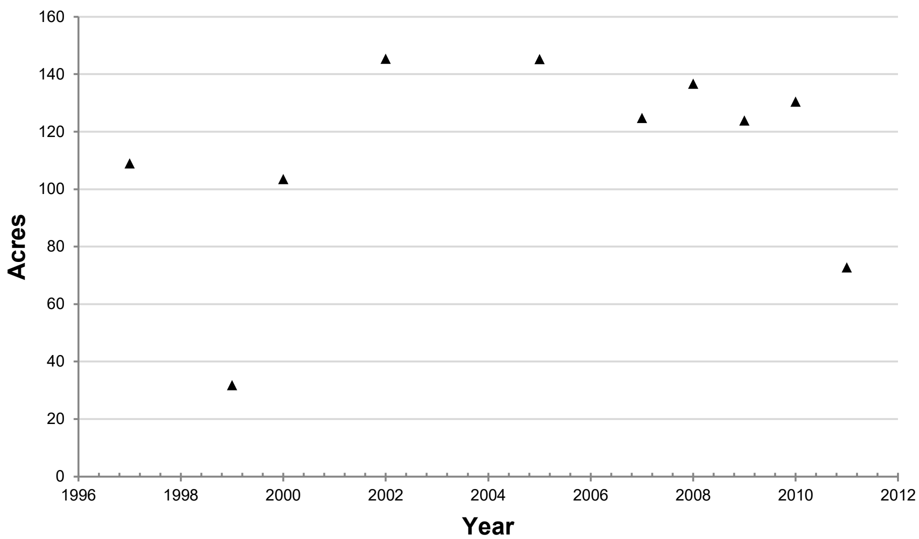


Figure 15. Total acres of prairie dog colonies in the North Unit of THRO, 1997-2011 (THRO 2010).

Increases in prairie dog acreage within the South Unit in the mid-2000s occurred during years of drought, possibly because colonies must expand to access more forage (M. Oehler, pers. comm., 2012). If this is true, even though acreage is expanding, the relative change in total population over that time is still unknown. THRO typically allows colonies to expand and contract according to natural processes. The only exception is when a colony infringes upon park infrastructure. In the North Unit of the park, prairie dog acreage is relatively stable over the duration of the available data; the reason for the stability is not described in the literature, but rough terrain and limited suitable habitat are two possibilities identified by park staff (M. Oehler, C. Sexton, pers. comm., 2012).

Threats and Stressor Factors

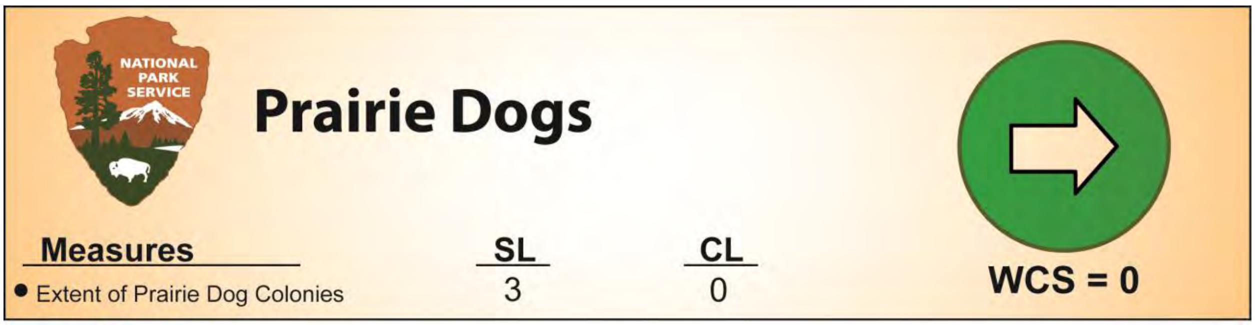
Sylvatic plague, caused by the bacterium *Yersinia pestis,* is the most well-known stressor to prairie dog populations and one of the four primary causes for the rangewide decline in prairie dog distribution and abundance over the past century (Van Putten and Miller 1999, Antolin et al. 2002, Pauli et al. 2006). It is the only major factor that limits prairie dog abundance that is beyond human control (Cully and Williams 2001). Black-tailed prairie dogs are highly susceptible to plague, exhibiting near 100% mortality, compared to approximately 85% mortality in white-tailed prairie dogs (Barnes 1993, Cully and Williams 2001). Additionally, plague results in smaller and more isolated prairie dog colonies, which reduces genetic variability through inbreeding and genetic drift (Trudeau et al. 2004). Sylvatic plague occurred in THRO in 1986, 1993, and on a few later occasions, but data are unpublished (C. Sexton, pers. comm., 2012).

Data Needs/Gaps

There are currently no data gaps for the prairie dog population at THRO. Park staff performs yearly delineations of the prairie dog colonies to inform their management.

Overall Condition

Extent of Prairie Dog Colonies
The *Significance Level* of this measure is a 3 because prairie dog management at the park focuses nearly exclusively on prairie dog acreages. THRO’s active management of the prairie dog colonies is minimal; this allows natural processes to govern the size and location of the dog towns. Currently, sylvatic plague is not present in the park and other stressors common to prairie dogs elsewhere are absent in the park. Therefore, the *Condition Level* for this component is 0, indicating minimal concern; because there is only one measure for this component, the *Weighted Condition Score* is also 0.



4.10.6 Sources of Expertise
Mike Oehler, Wildlife Biologist, THRO
Chad Sexton, Geographic Information Systems Analyst, THRO

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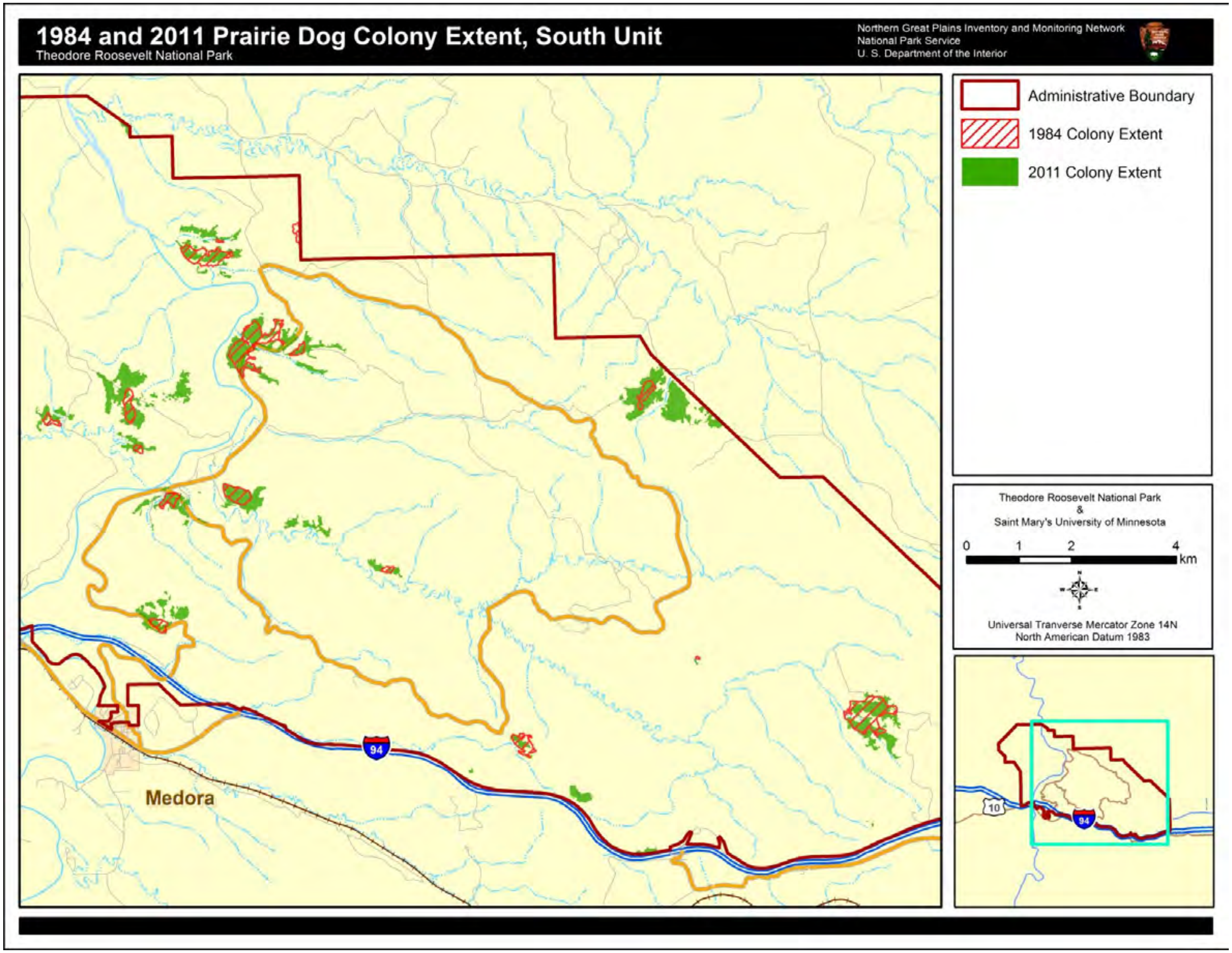

Plate 19. Prairie dog colony extent, South Unit,1984 and 2011.

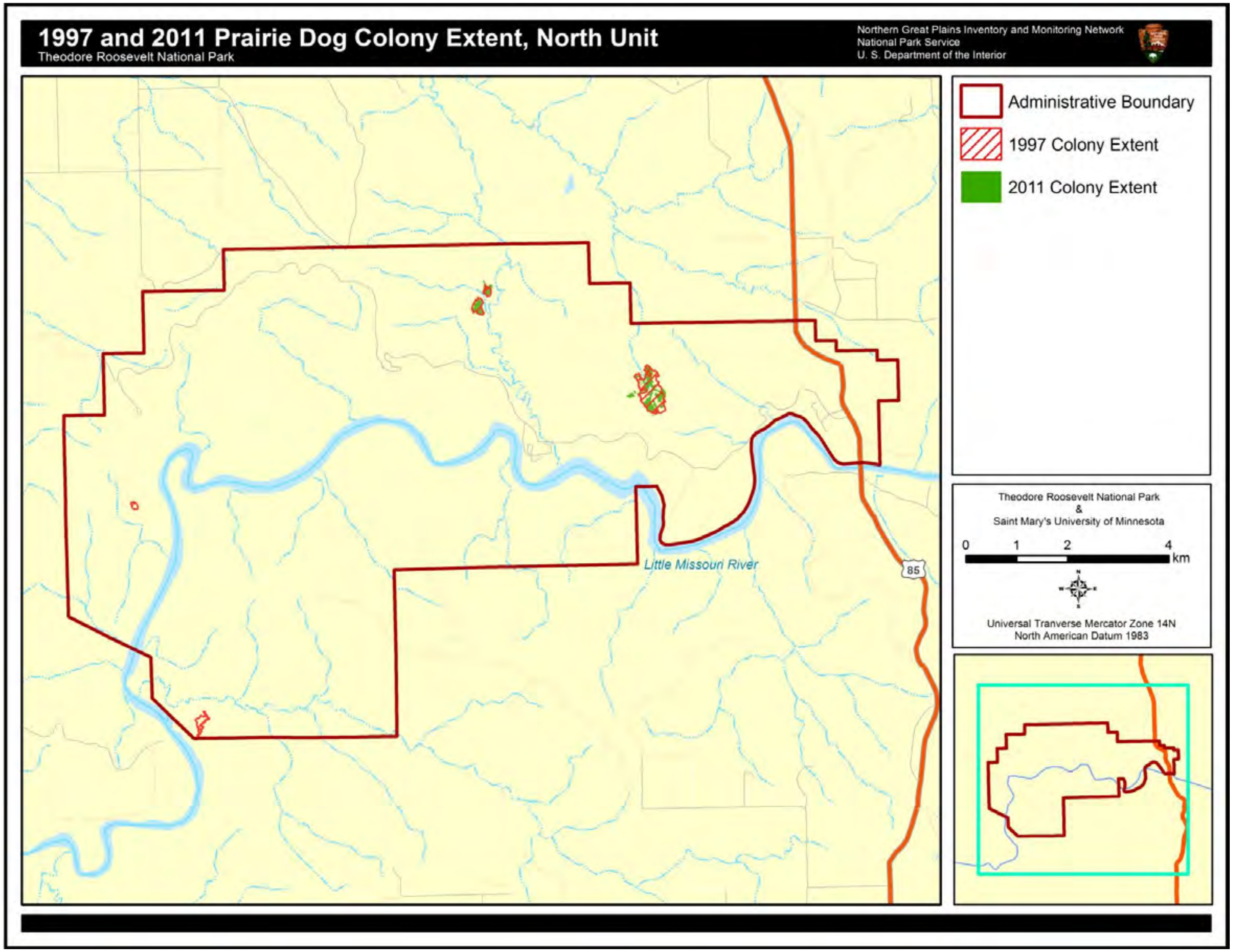

Plate 20. Prairie dog colony extent, North Unit, 1997 and 2011.

4.11 Breeding Birds

4.11.1 Description

Bird populations are excellent indicators of an ecosystem's health (Morrison 1986, Hutto 1998, NABCI 2009). Birds are typically easy to observe and identify, and bird communities often reflect the abundance and distribution of other organisms with which they co-exist (Blakesley et al. 2010).

Photo 20. Pine siskin (*Carduelis pinus*) (NPS Photo, Nathan King).

THRO is home to a unique diversity of habitats including floodplain forests, native grasslands, and juniper slope forests. These habitats provide the avian species in the park with nesting habitat and food sources. Over 185 bird species have been confirmed in the park (NPS 2011). Monitoring avian population health and diversity in these habitats will be important for detecting ecosystem change.

There has not been a formal effort to classify which species in THRO breed in the area annually. Therefore, this assessment will include all species observed during surveys conducted during the breeding season (e.g., Breeding Bird Surveys [BBS], Integrated Monitoring in Bird Conservation Regions [IMBCR] surveys).

4.11.2 Measures

- Species richness
- Number of species of conservation concern
- Raptor species richness

4.11.3 Reference Conditions/Values

There have been limited bird surveys in THRO, and because of this, the reference condition will be the characteristics of the breeding bird population from the nearby Little Missouri National Grassland (LMNG). This grassland has established IMBCR sampling grids similar to grids recently established in THRO. The LMNG grids serve as a comparison for the THRO grids. If IMBCR grid sampling is continued in THRO, the data from 2009-2012 could serve as a baseline reference condition for this component in the future.

4.11.4 Data and Methods

The NPS Certified Bird Species List (NPS 2011) for THRO was used for this assessment. This list represents all of the confirmed bird species present in the park.

In 1999, Powell (2000) began a breeding bird study at four national park units (Agate Fossil Beds National Monument, Scott's Bluff National Monument, Badlands National Park, and

THRO). The specific objective of this study was to investigate and identify the quantity of grassland-associated species in these Great Plains parks. Powell (2000) utilized fixed-radius point counts to survey breeding birds in THRO. The sample points were located in grassland habitats and were spaced 250 m apart; points were sampled for 5 minutes. All birds seen or heard within a 100 m radius were counted.

Because the objectives of Powell (2000) were specifically concerning grassland birds, the point counts focused only on the grassland habitats in THRO. Thus, these point counts may have missed breeding species that are not dependent upon grassland habitats.

The THRO breeding bird survey route is part of the large-scale North American Breeding Bird Survey (BBS), which began in 1966 and is coordinated by the USGS and the Canadian Wildlife Service (Robbins et al. 1986). The standard BBS route is approximately 40 km (25 mi) long with survey points at every 0.8 km (0.5 mi). The survey begins ½ hour before sunrise, and at each survey point the number of birds seen and heard within a 0.4-km (0.25-mi) radius during a three-minute interval is recorded. Only BBS route 64033 (Roosevelt Park Route) crosses within the park's North Unit boundaries (Plate 21). This route was surveyed annually from 1982-2009 (USGS 2011).

The Rocky Mountain Bird Observatory (RMBO) and its partners monitor land bird populations in several Bird Conservation Regions (BCRs) across North America; THRO lies within Bird Conservation Region 17 (BCR 17: Badlands and Prairies) (Figure 16) and has been monitored by RMBO and its partners since 2009 (White et al. 2011). Land bird monitoring in THRO is part of the IMBCR program, and utilizes a spatially-balanced sampling design during survey efforts (White et al. 2011).

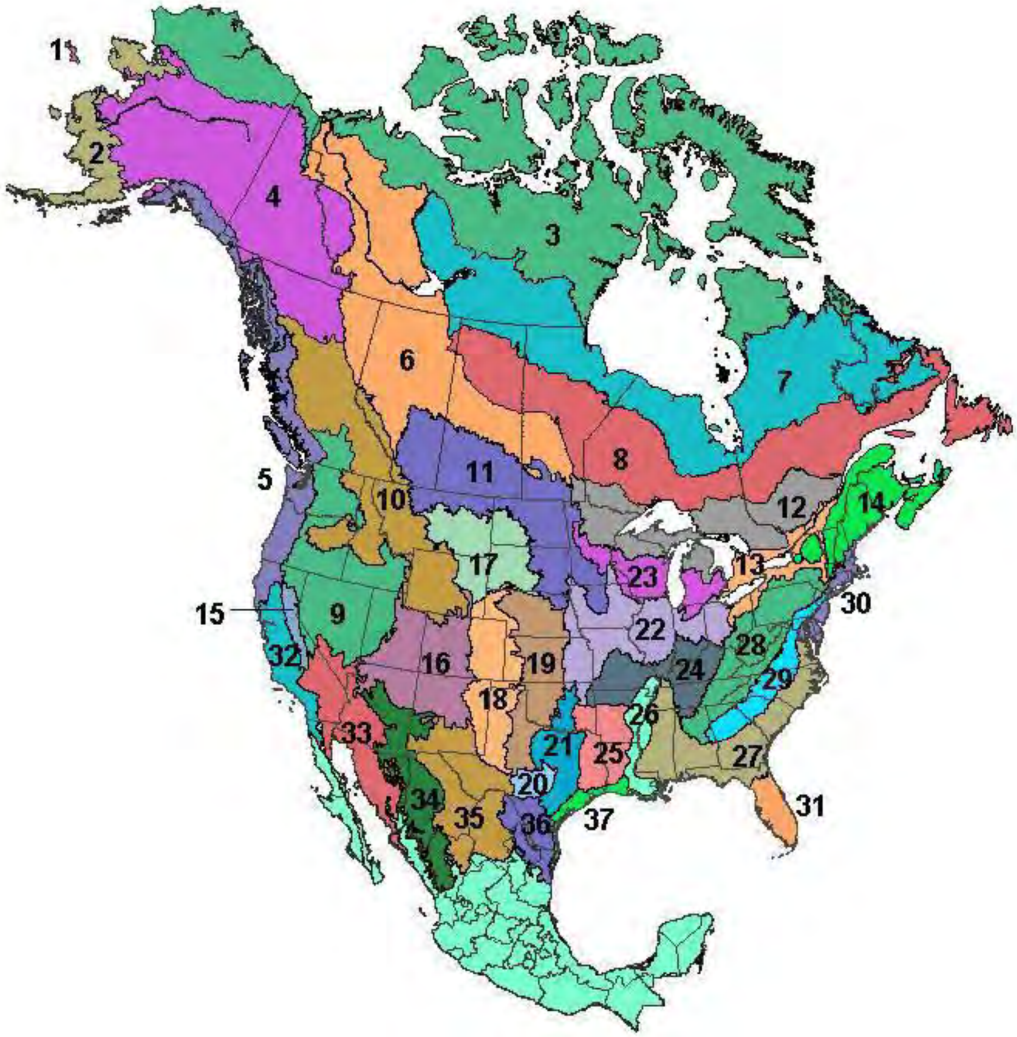

Figure 16. Bird Conservation Regions through North America. THRO lies within BCR 17. Image reproduced from (http://www.nabci-us.org/map.html).

The IMBCR land bird monitoring program established a series of strata and super-strata (White et al. 2011). Within these strata, RMBO and its partners utilized generalized random-tessellation stratification (GRTS) to select sample units (Stevens and Olson 2004, White et al. 2011). According to White et al. (2011, p. 8):

> The IMBCR design defined sampling units as 1-km^2 cells that were used to create a uniform grid over the entire BCR. Within each grid cell we established a 4 x 4 grid of 16 points spaced 250 m apart (Figure 17, Plate 22).

The IMBCR program surveys all land bird species during the typical breeding season. Data and analyses in this document represent the likely breeding landbirds.

Selected transects (Plate 22) were sampled early in the breeding season after all migratory species had returned to their breeding areas. Care was taken not to survey too early in the season, as an early survey could potentially miss migratory breeding species or could sample transient birds that are migrating through the area (Hanni et al. 2011). Each point on a transect was sampled for 6 minutes using methods that allow for estimating detection probability through the principles of distance sampling (Buckland et al. 2001, Thomas et al. 2010), removal modeling (Farnsworth et al. 2002) and occupancy estimation (MacKenzie et al. 2002, MacKenzie 2006). All bird species detected were recorded, along with several variables such as distance from the observer, habitat type, weather, and land ownership (Hanni et al. 2011).

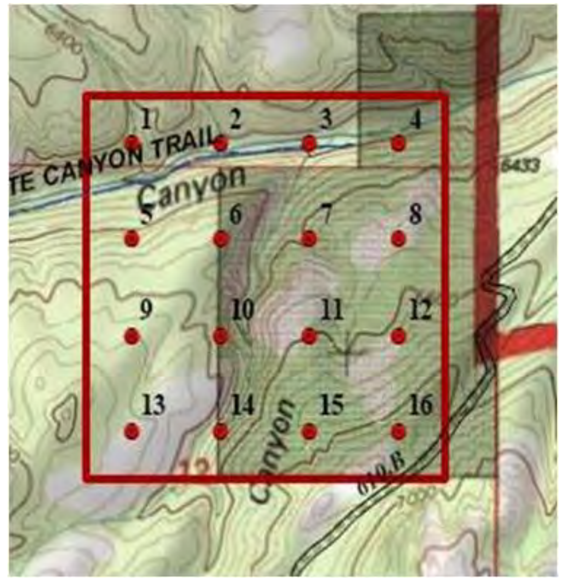

Figure 17. Example of a grid cell created by the RMBO using the IMBCR design. Reproduced from White et al. (2011).

4.11.5 Current Condition and Trend

<u>Species Richness</u>

Breeding Bird Survey

Species counts for each year of the BBS were calculated (Figure 18). The average number of species observed on the THRO BBS from 1982-2009 was 53.4 species. There does not appear to be an increasing or decreasing trend in species richness observed each year (Figure 18). However, there may be undetected changes in species richness of native species compared to non-native species, or in Neotropical migrant species compared to resident species. Such changes would not be apparent in Figure 18. The THRO BBS only surveys the North Unit of the park (Plate 21), and does not survey any part of the South Unit. Thus, species richness values shown here may not be truly indicative of the overall species richness for THRO.

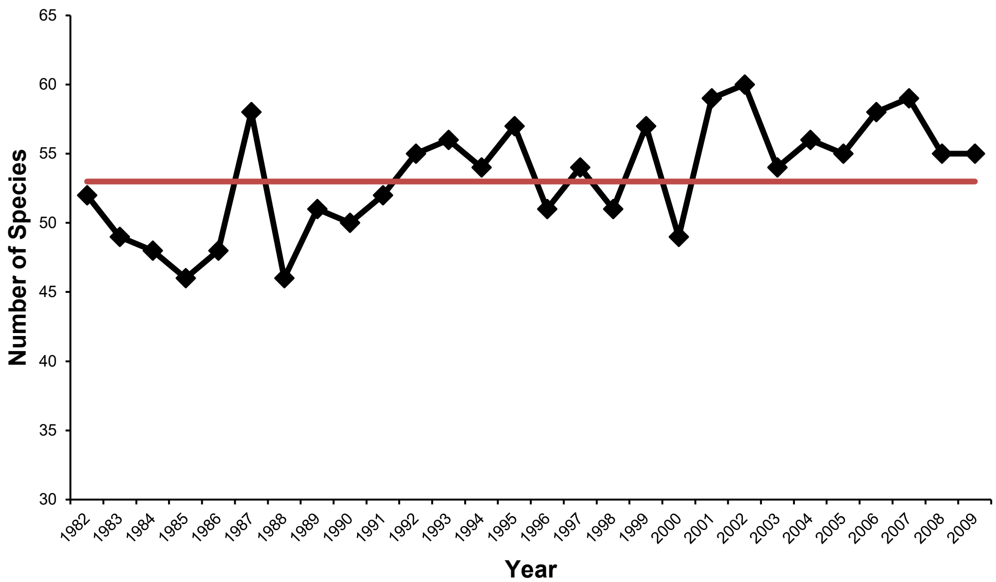

Figure 18. Species richness estimates from the annual BBS route in THRO. The solid red line indicates the 28-year average (53 species) for the survey.

Powell (2000) Grassland Bird Inventory
Powell (2000) conducted a fixed-radius point count of breeding bird species (with emphasis on the grassland species in THRO) at 18 points in the park. During this 1-year survey, Powell (2000) found 650 individuals of 49 species on point counts. When not restricted to the species observed on the point counts, Powell (2000) reported 76 species observed. Approximately 31% of the breeding species recorded were grassland-associated species; the most abundant species observed were spotted towhee (*Pipilo maculatus*), vesper sparrow (*Pooecetes gramineus*), field sparrow (*Spizella pusilla*), and yellow-breasted chat (*Icteria virens*).

IMBCR Land Bird Sampling
RMBO surveyed two grids under the IMBCR design during visits to the South Unit of THRO from 2009-2011 (ND-BCR17-NP1 and ND-BCR17-NP3) (Plate 22). In 2009, 35 bird species were observed on 21 points along both grids, while 37 species were observed at 20 points along both grids in 2010. In 2011, 39 bird species were identified at 22 points along both grids.

The IMBCR grids within THRO have been surveyed for only 3 years, and deciphering any trends from these data is not appropriate at this time. Continued monitoring with increased sampling intensity will allow for long-term species richness trend comparisons and may provide insights into the habitat availability for bird species in the park from year to year.

The IMBCR grids in THRO present an opportunity to compare the park's species richness to that of the nearby LMNG. LMNG is also part of the RMBO's IMBCR program, and has several established transects in the grassland. LMNG is in a similar habitat type as THRO, and serves as an appropriate reference condition for the breeding birds in THRO (J. Birek, pers. comm., 2012). From 2009-2011, LMNG had an average of 77.6 species observed. In 2009, 76 species were observed at 146 points, while 83 species were observed at 123 points in 2010 (Figure 19). In 2011, 74 species were identified at 83 points in LMNG (Figure 19). These estimates of species richness are higher than those reported for THRO. However, LMNG has 16 established grids while THRO only has two, which may result in some discrepancy when comparing the data.

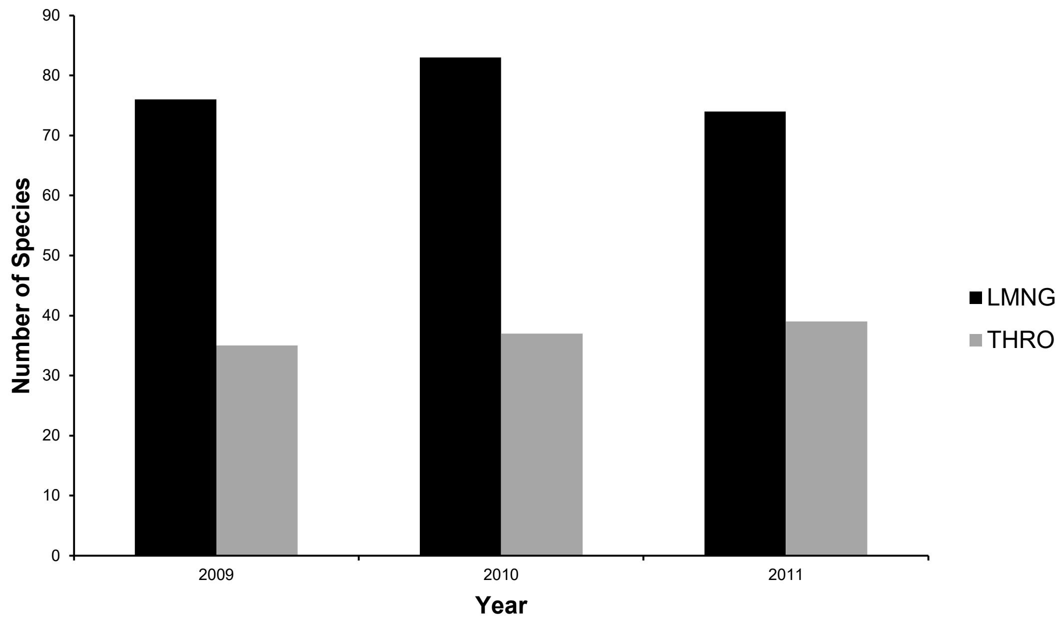

Figure 19. Species richness for IMBCR surveys in both LMNG (16 grids or transects) and THRO (two grids or transects) from 2009-2011.

Number of Species of Conservation Concern

Breeding Bird Survey

Partners in Flight (PIF) compiles a list (RMBO 2005) of species of regional importance for each BCR in North America. Seventeen species identified on this list were observed on the BBS in THRO from 1982-2009

Table 26). Similarly, the U.S. Fish and Wildlife Service (USFWS) compiles a list of birds of conservation concern for all BCRs in North America (USFWS 2008). During the THRO BBS, ten species from this list were identified within the park

Table 26).

Table 26. Species of conservation concern observed during the THRO BBS from 1982-2009.

Species	USFWS (2008)[a]	PIF SRI[b]	NDGFD (2004)[c]
sharp-tailed grouse		X	
American white pelican			X
northern harrier		X	
Swainson's hawk		X	X
golden eagle	X	X	
prairie falcon	X		
upland sandpiper	X		X
black-billed cuckoo	X	X	X
red-headed woodpecker	X	X	
Say's phoebe		X	
loggerhead shrike	X	X	
black-billed magpie		X	
northern rough-winged swallow		X	
mountain bluebird		X	
Sprague's pipit	X	X	X
vesper sparrow		X	
lark bunting		X	X
grasshopper sparrow	X	X	X
Baird's sparrow	X	X	X
chestnut-collared longspur	X	X	X

[a] = USFWS Species of Conservation Concern, 2008
[b] = Partners in Flight Species of Regional Importance for BCR 17 (RMBO 2005)
[c] = North Dakota's 100 Species of Conservation Priority

NDGFD (2004) identifies 100 species of conservation priority in North Dakota. However, the species identified in this report are not limited to only avian species. This report separates the species into three levels: Level-I, Level-II, and Level-III. For this report only avian species identified as Level-I species are considered. A Level-I species is defined by NDGFD (2004, p. 3) as:

> Species having a high level of conservation priority because of declining status either in North Dakota or across their range; or a high rate of occurrence in North Dakota constituting the core of the species' breeding range, but are at-risk range wide, and non-SWG [State Wildlife Grants] funding is not readily available to them.

Within THRO, nine Level-I species were identified on the THRO BBS route from 1982-2009 (

Table **26**).

Powell (2000) Grassland Bird Inventory
During a 1999 breeding bird inventory, Powell (2000) documented 17 species listed as species of conservation concern by USFWS (2008), 23 species of regional importance (RMBO 2005), and 11 Level-I species identified in NDGFD (2004) (Table 27).

Table 27. Species of conservation concern observed during the Powell (2000) bird survey in 1999.

Species	USFWS (2008)[a]	PIF SRI[b]	NDGFD (2004)[c]
northern goshawk		X	
golden eagle	X	X	
ferruginous hawk	X	X	X
Swainson's hawk		X	X
northern harrier		X	
bald eagle	X		
prairie falcon	X		
peregrine falcon	X		
American white pelican			X
upland sandpiper	X		X
long-billed curlew	X		
Wilson's phalarope			X
black-billed cuckoo	X	X	X
sharp-tailed grouse		X	
dickcissel	X	X	
black-billed magpie		X	
Baird's sparrow	X	X	X
grasshopper sparrow	X	X	X
lark bunting		X	X
chestnut-collared longspur	X	X	X
vesper sparrow		X	
northern rough-winged swallow		X	
western meadowlark		X	
loggerhead shrike	X	X	
Sprague's pipit	X	X	X
mountain bluebird		X	
Say's phoebe		X	
red-headed woodpecker	X	X	
short-eared owl	X	X	
burrowing owl	X	X	

[a] = USFWS Species of Conservation Concern, 2008
[b] = Partners in Flight Species of Regional Importance for BCR 17 (RMBO 2005)
[c] = North Dakota's 100 Species of Conservation Priority

On the two IMBCR transects in THRO, three species of conservation concern (USFWS 2008), 10 species of regional importance (RMBO 2005), and three species identified in NDGFD (2004) were observed (Table 28).

Table 28. Species of conservation concern observed during the IMBCR bird monitoring in THRO from 2009-2011.

Species	USFWS (2008)[a]	PIF SRI[b]	NDGFD (2004)[c]
black-billed magpie		X	
golden eagle	X	X	
grasshopper sparrow	X	X	X
lark bunting		X	X
mountain bluebird		X	
northern harrier		X	
Say's phoebe		X	
sharp-tailed grouse		X	
upland sandpiper	X		X
vesper sparrow		X	
western meadowlark		X	

[a] = USFWS Species of Conservation Concern, 2008
[b] = Partners in Flight Species of Regional Importance for BCR 17 (RMBO 2005)
[c] = North Dakota's 100 Species of Conservation Priority

Raptor Species Richness

No raptor-dedicated survey effort currently exists in THRO. The available data for raptors in the area come from the aforementioned surveys and reports.

Breeding Bird Survey

From 1982-2009, 11 raptor species were observed on the annual BBS route in THRO (Table 29). The average raptor species richness on the THRO BBS was three species per year; the highest number of raptor species was observed in 1987 (seven species), while only one species was observed in 1989, 1999, 2002, and 2007 (Figure 20).

Table 29. Raptor species observed on the THRO BBS from 1982-2009.

Common Name	Number of years observed
turkey vulture	12
northern harrier	11
sharp-shinned hawk	4
Cooper's hawk	5
Swainson's hawk	2
red-tailed hawk	9
golden eagle	3
American kestrel	25
prairie falcon	9
eastern screech-owl	1
great horned owl	2

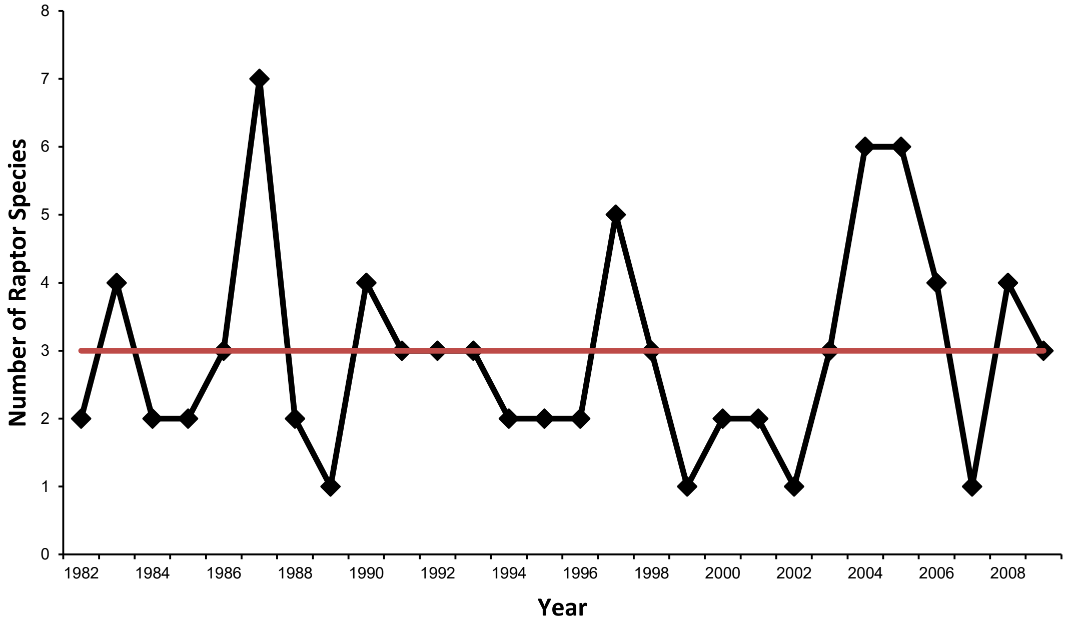

Figure 20. Raptor species richness estimates from the annual BBS route in THRO from 1982-2009. The solid red line indicates the 28-year average (three species) for the survey.

Powell (2000) Grassland Bird Inventory
The Powell (2000) grassland bird inventory only recorded the presence of species, and did not indicate the number of observations of each species. In 1999, seven raptor species were observed: sharp-shinned hawk, golden eagle, Swainson's hawk, northern harrier, turkey vulture, American kestrel, and great horned owl (Powell 2000).

IMBCR Land Bird Sampling
The two IMBCR transects in THRO have been surveyed annually since 2009. During these surveys, five raptor species have been observed. In 2009, two species were observed (northern harrier and turkey vulture), while only one raptor species was observed in 2010 (turkey vulture). 2011 had three raptor species observations (American kestrel, golden eagle, and red-tailed hawk). Table 30 represents the total number of individuals observed during the IMBCR transect surveys.

Table 30. Number of individual raptors observed from 2009-2011 during IMBCR surveys in THRO.

Species	2009	2010	2011
American kestrel			3
golden eagle			1
northern harrier	1		
red-tailed hawk			1
turkey vulture	1	1	

<u>Threats and Stressor Factors</u>
One of the major threats facing bird populations across all habitat types is land cover change (Morrison 1986). Land cover change is not restricted to breeding habitat; many species depend

on specific migratory and wintering habitat types. Altered habitats can compromise the reproductive success or wintering survival rates of species adapted to that habitat. Priority species in THRO, such as Sprague's pipit (*Anthus sprauguei*) and Baird's sparrow (*Ammodramus bairdii*), often require specific vegetative communities (e.g., tall prairie grasses and ample ground cover) for successful nesting to occur. A loss or alteration of these vegetative structures could compromise the nesting success of these species in THRO.

Another threat facing land bird populations is shifts in reproductive phenology. Several bird species depend on temperature ranges or weather cycles to cue their breeding. As global temperatures change, some bird species have adjusted by moving their home range north (Hitch and Leberg 2007). Other species have adjusted their migratory period and have begun returning to their breeding grounds earlier in the spring; American robins (*Turdus migratorius*) in the Colorado Rocky Mountains are now returning to their breeding grounds 14 days earlier compared to 1981 (NABCI 2009). A concern is that this shift in migration may be out of sync with food availability and could ultimately lead to lowered reproductive success.

The North American Bird Phenology Program (BPP) is currently analyzing the migration patterns and distribution of migratory bird species across North America (USGS 2008). Information from this analysis will provide new insights into how bird distribution, migration timing, and migratory flyways have changed since the later part of the 19th century. This information may also be applied to estimate changes in breeding initiation periods in specific habitats.

Data Needs/Gaps

Breeding bird surveys provide snapshots in time of species richness. However, only one survey/visit per year yields little information in terms of population trends. Further observation could help to remedy this data gap and could potentially help the park better understand the status of breeding bird species in the park as well. BBS route 64033 (Roosevelt Park) in the North Unit was surveyed annually from 1982-2009. Resuming this survey, despite its limited coverage of THRO, would be beneficial for future analysis.

Increased sampling under the IMBCR spatially balanced land bird protocol would allow for density and occupancy estimates to be calculated in the future. These estimates could provide baseline values that would serve as sources of comparison for future studies. Expansion of the IMBCR land bird monitoring effort would also provide a more accurate depiction of the breeding bird composition in both the North and South Units of THRO. The spatially-balanced nature of these transects would provide a more reliable assessment of current breeding bird composition. Data and results would also be directly comparable to and combinable withnearby IMBCR strata and super-strata (e.g., LMNG, BCR 17).

With so many priority species lists in existence, it is often difficult for managers to isolate which species in a park are in need of particular attention. The establishment of a priority species population monitoring program, or even just a yearly breeding survey of a few species, could provide park managers with insights into the overall breeding health of these species in THRO. A program such as this could also provide valuable information about habitat use and potentially provide new information about the overall health of high-priority habitats.

Currently, THRO does not conduct in-depth raptor-specific monitoring. The establishment of a raptor monitoring program, or an in-depth analysis of prey species composition of raptors, would not only give managers insights into the health of the THRO raptor population, but could also provide information about the health and abundance of prey species (e.g., small mammals). Although not monitored in detail, THRO staff do observe activity on the few know Golden eagle nests in the park each spring. However, systematic searches for raptor nests are not conducted. With a few modifications, the same sampling frame and sampling grids from the GRTS-based design used in the IMBCR program can be used for monitoring of raptors and other species in THRO.

Overall Condition

Species Richness
The measure species richness was assigned a *Significance Level* of 3. Data for this measure are limited to two surveys (IMBCR transects from 2009-2011, and BBS routes from 1982-2009) and one grassland bird inventory in 1999 (Powell 2000). While the data suggest that species richness has not fluctuated much and appears stable, a more comprehensive data source is needed to accurately assess the condition of this measure in THRO. Compared to the reference condition, the THRO IMBCR surveys yielded species richnesses that were just over half those of LMNG. This is likely due to the disparity in sample size and number of transects in the park, but nonetheless it highlights the need for expansion of survey efforts to accurately assess the condition of this measure in THRO. For this reason, a *Condition Level* for species richness was not assigned.

Number of Species of Conservation Concern
The number of species of conservation concern was assigned a *Significance Level* of 2. Data from all available sources indicate that several species designated as species of conservation concern exist in the park. However, no study has investigated the population trends or nesting success of these species. Such trend data would provide for a more accurate assessment of this measure. There does not appear to be particular concern in THRO for this measure, although an investigation of priority species that may be conspicuously absent could benefit managers. This measure was assigned a *Condition Level* of 1.

Raptor Species Richness
A *Significance Level* of 2 was assigned to the raptor species richness measure. There has been no raptor-specific monitoring within THRO. The data that do exist for this measure are from general bird surveys, and the number of raptor observations is sparse. This is largely affected by the large geographic ranges of raptors, the limited temporospatial extent of current sampling and a lack of raptor-specific monitoring efforts in THRO. Because of this data gap, a *Condition Level* for this measure was not assigned.

Weighted Condition Score
A *Weighted Condition Score* for breeding birds in THRO was not assigned because >50% of the measures had unknown *Condition Levels*.

Breeding Birds

Measures	SL	CL
• Species richness	3	n/a
• # of species of conservation concern	2	1
• Raptor species richness	2	n/a

WCS = N/A

4.11.6 Sources of Expertise
Jeff Birek, Outreach Biologist, Rocky Mountain Bird Observatory

4.11.7 Literature Cited

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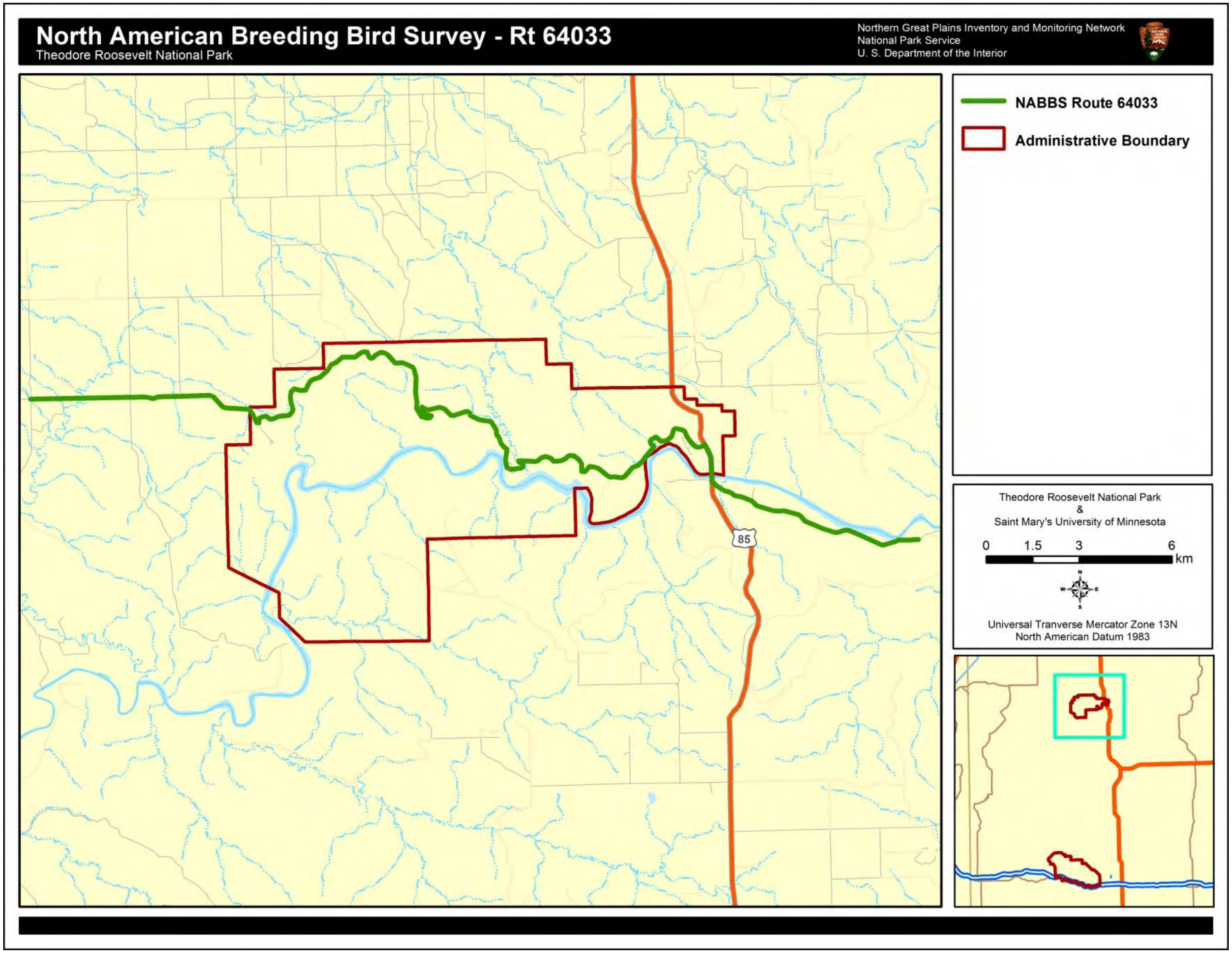


Plate 21. Breeding Bird Survey route 64033 in the North Unit of THRO.

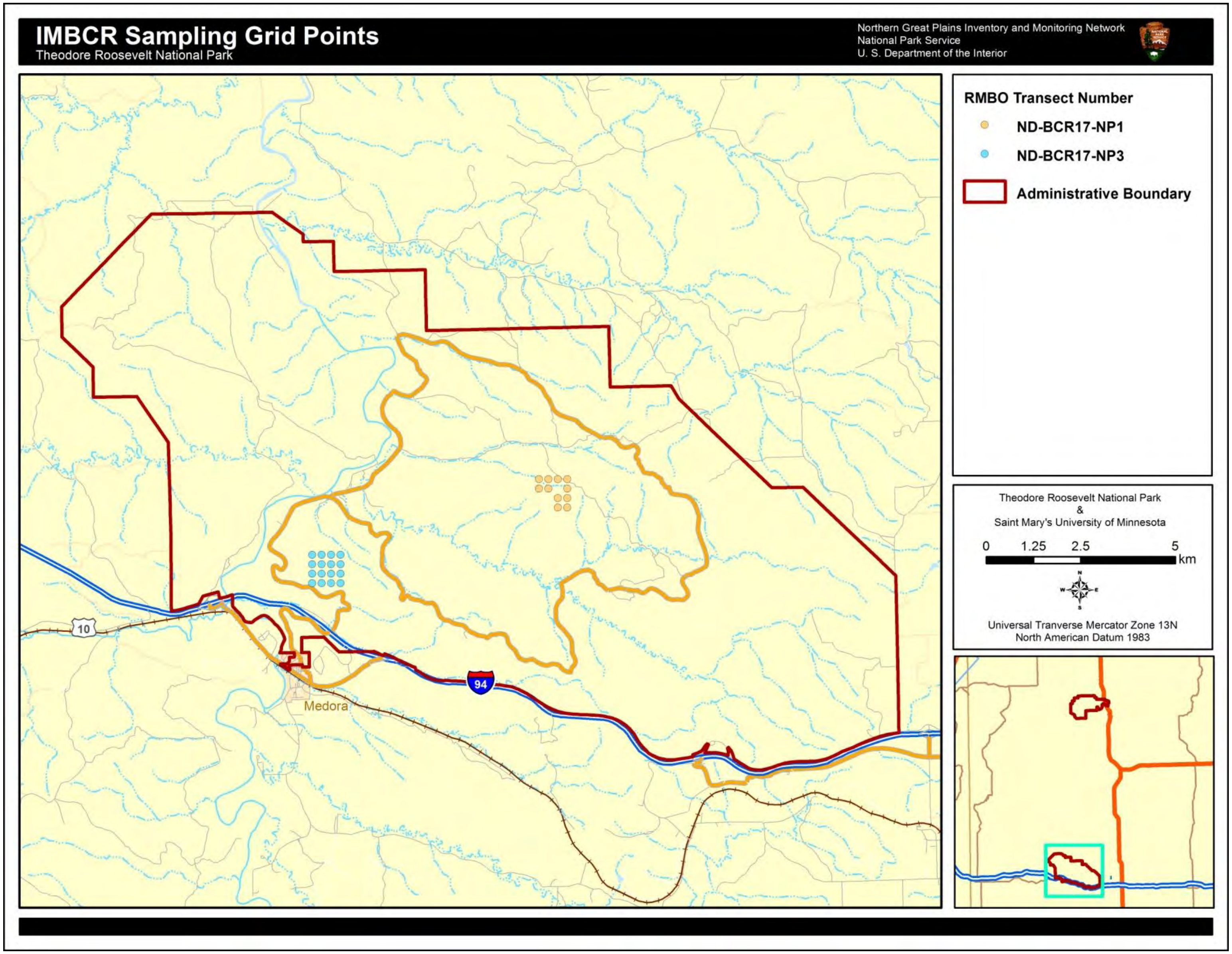


Plate 22. IMBCR points sampled in the South Unit of THRO 2009-2011.

4.12 Air Quality

4.12.1 Description

Air pollution can significantly affect natural resources and their associated ecological processes. Consequently, air quality in parks and wilderness areas is protected and regulated through the 1916 Organic Act and the Clean Air Act of 1977 (CAA) and the CAA's subsequent amendments. The CAA defines two distinct categories of protection for natural areas, Class I and Class II airsheds. Class I airsheds receive the highest level of air quality protection as offered through the CAA; only a small amount of additional air pollution is permitted in the airshed above baseline levels. For Class II airsheds, the increment ceilings for additional air pollution above baseline levels are slightly greater than for Class I areas and allow for moderate development (EPA 2008a). However, new and modified sources of air pollution must be analyzed for potential impacts to ambient air quality and visibility prior to development. THRO is designated as a Class I airshed.

Parks designated as Class I and II airsheds typically use the Environmental Protection Agency (EPA) National Ambient Air Quality Standards (NAAQS) for criteria air pollutants as the ceiling standards for allowable levels of air pollution. The EPA believes these standards, if not exceeded, protect human health and the health of natural resources (EPA 2008a). The CAA also establishes that current visibility impairment in these areas must be remedied and future impairment prevented (EPA 2008a). However, the EPA acknowledges that the NAAQS are not necessarily protective of ecosystems and is currently developing secondary NAAQS for ozone, nitrogen, and sulfur compounds to protect sensitive plants, lakes, streams, and soils (EPA 2010a, 2010b). To comply with CAA and NPS Organic Act mandates, the NPS established a monitoring program that measures air quality trends in many park units for key air quality indicators, including atmospheric deposition, ozone, and visibility (NPS 2008).

Although THRO is located in a rural part of the country, several sources of air pollution threaten the park's air quality. The more persistent and permanent sources include oil and gas development in western North Dakota, vehicle emissions, and emissions from the nearby operation and development of coal-fired power plants (Peterson et al. 1998). Smoke from wildland fires, agricultural burning, and prescribed burning can also periodically affect air quality in THRO (Peterson et al. 1998), but these are of short duration compared to more permanent sources.

4.12.2 Measures

- Nitrogen deposition
- Sulfur deposition
- Ozone concentration
- Mercury deposition/concentration
- Concentration of particulate matter (PM 2.5 and 10)
- Visibility

Atmospheric Deposition

Nitrogen and sulfur oxides are emitted into the atmosphere primarily through the burning of fossil fuels, industrial processes, and agricultural activities (EPA 2008b). While in the atmosphere, these emissions form compounds that may be transported long distances and settle out of the atmosphere in the form of pollutants such as particulate matter (e.g., sulfates, nitrates, ammonium) or gases (e.g., nitrogen dioxide, sulfur dioxide, nitric acid, ammonia) (EPA 2008b, NPS 2008). Atmospheric deposition can be in wet (i.e., pollutants dissolved in atmospheric moisture and deposited in rain, snow, low clouds, or fog) or dry (i.e., particles or gases that settle on dry surfaces as with windblown dusts) form (EPA 2008b). Deposition of sulfur and nitrogen can have significant effects on ecosystems including acidification of water and soils, excess fertilization or increased eutrophication, changes in the chemical and physical characteristics of water and soils, and accumulation of toxins in soils, water, and vegetation (NPS 2008, reviewed in Sullivan et al. 2011a and 2011b). Grassland prairie and meadow communities are sensitive to increased levels of nitrogen and may be impacted by excess nitrogen enrichment via deposition (reviewed in Sullivan 2011b); the predominant landcover in THRO is grassland and meadow (NPS 2005, Pohlman and Maniero 2005, Sullivan et al. 2011c). On the other hand, many non-natives, such as the invasive cheatgrass, prefer nitrogen rich environments and may displace native species as nitrogen deposition increases in these sensitive communities (Sullivan et al. 2011a, b, and c).

Ozone

Ozone occurs naturally in the earth's atmosphere where, in the upper atmosphere, it protects the earth's surface against ultraviolet radiation (EPA 2008b). However, it also occurs at the ground level (i.e., ground-level ozone) where it is created by a chemical reaction between nitrogen oxides and volatile organic compounds (VOCs) in the presence of heat and sunlight (NPS 2008). Ozone is also one of the most widespread pollutants affecting vegetation in the U.S. (NPS 2008). Considered phytotoxic, ozone can cause significant foliar injury and growth effects for sensitive plants in natural ecosystems (EPA 2008a, NPS 2008). Specific effects include reduced photosynthesis, premature leaf loss, and reduced biomass, and prolonged exposure can increase vulnerability to insects and diseases or other environmental stresses (NPS 2008). At high concentrations, ozone can aggravate respiratory and cardiovascular diseases, reduce lung function, cause acute respiratory problems, and increase susceptibility to respiratory infections (EPA 2008b, 2010c); this would be a concern for visitors and staff engaging in aerobic activities in the park, such as hiking.

Mercury

Sources of atmospheric mercury include fuel combustion and evaporation (especially coal-fired power plants), waste disposal, mining, industrial sources, and natural sources such as volcanoes and evaporation from enriched soils, wetlands, and oceans (EPA 2008b). Mercury deposited into rivers, lakes, and oceans can accumulate in various aquatic species, resulting in exposure to wildlife and humans that consume them (EPA 2008b).

Particulate Matter (PM) and Visibility

Particulate matter (PM) is a complex mixture of extremely small particles and liquid droplets suspended in the atmosphere. PM is categorized as fine particles ($PM_{2.5}$), which are 2.5 micrometers in diameter or smaller, and inhalable coarse particles (PM_{10}), which are smaller than 10 micrometers (the width of a single human hair) (EPA 2009a). Particulate matter largely consists of acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles (EPA 2008a, 2009a). Fine particles are a major cause of reduced visibility (haze) in many national parks and wildernesses (EPA 2010b). $PM_{2.5}$ can be directly emitted from sources such as forest fires, or they can form when gases emitted from power plants, industries, and/or vehicles react with air (EPA 2009a, 2010d). Sources of coarse particles (PM_{10}) include grinding or crushing operations and windblown or stirred up dust from dirt surfaces (e.g., roads, agricultural fields). Particulate matter either absorbs or scatters light. As a result, the clarity, color, and distance seen by humans decreases, especially during humid conditions when additional moisture is present in the air (EPA 2010d). PM_{10} and $PM_{2.5}$ are also a concern for human health as these particles can easily pass through the throat and nose and enter the lungs (EPA 2008b, 2009a, 2010d). Short-term exposure to these particles can cause shortness of breath, fatigue, and lung irritation (EPA 2008b, 2009a).

4.12.3 Reference Conditions/Values

The NPS Air Resources Division (ARD) developed an approach for rating air quality conditions in national parks, based on the current NAAQS, ecosystem thresholds, and visibility improvement goals (Table 31) (NPS 2010a). Assessment of current condition of nitrogen and sulfur atmospheric deposition is based on wet (rain and snow) deposition. Ozone condition is based on the NAAQS standard of 75 parts per billion (ppb). Visibility conditions are assessed in terms of a Haze Index, a measure of visibility derived from calculated light extinction (NPS 2010a). The NAAQS standard for PM_{10} is 150 $\mu g/m^3$ over a 24-hour period; this level may not be exceeded more than once per year on average over three years (EPA 2010d). The standard for $PM_{2.5}$ is 15.0 $\mu g/m^3$ weighted annual mean or 35 $\mu g/m^3$ in a 24-hour period over an average of three years (EPA 2010d). Currently, there is no standard or threshold established for mercury deposition. Finally, NPS ARD recommends the following values for determining air quality condition (Table 31). The "good condition" metrics may be considered the reference condition for THRO.

Table 31. National Park Service Air Resources Division air quality index values (NPS 2010a).

Condition	Ozone concentration (ppb)	Wet Deposition of N or S (kg/ha/yr)	Visibility (dv)
Significant Concern	≥ 76	> 3	> 8
Moderate	61-75	1-3	2-8
Good	≤ 60	< 1	< 2

4.12.4 Data and Methods

<u>Monitoring in the Park</u>

Substantial monitoring efforts have been ongoing in THRO since the early 1980s and, thus, monitoring data for the period of record may be examined for trends in air quality. Air quality monitoring in the park includes ozone monitoring (NPS Gaseous Pollutant Monitoring Program [GPMP]), wet deposition monitoring of atmospheric pollutants, including nitrogen, sulfur, and ammonium (National Atmospheric Deposition Program [NADP]), dry deposition monitoring of atmospheric pollutants (Clean Air Status and Trends Network [CASTNet]), and visibility monitoring (Interagency Monitoring of Protected Visual Environments Program [IMPROVE]) (Pohlman and Maniero 2005). Data from these on-site monitors are used to evaluate trends in air quality at the park, most recently for the period 1999-2008 (NPS 2010b).

NPS Data Resources

In addition, NPS ARD provides estimates of ozone, wet deposition of nitrogen and sulfur, and visibility that are based on interpolations of data from all air quality monitoring stations operated by NPS, EPA, various states, and other entities, averaged over five years (2005-2009). These estimates are available from the Explore Air website (NPS 2011) and are used to evaluate air quality conditions. Note that on-site or nearby data are needed for a statistically valid trends analysis, while a five-year average interpolated estimate is preferred for the condition assessment. NPS ARD (2010b) reports on air quality conditions and trends in an annual report for over 200 park units, including THRO.

Other Air Quality Data Resources

The National Atmospheric Deposition Program–National Trends Network (NADP) database provides access to annual average summary data for nitrogen and sulfur concentration and deposition in THRO (monitoring site ND00) (NADP 2011).

The Clean Air Status and Trends Network (CASTNet) provides access to summaries of the composition of nitrogen and sulfur deposition in THRO (site number THR422) (EPA 2012a).

The EPA Air Trends database provides access to annual average summary data for ozone concentrations in the North and South Units of THRO (North Unit monitoring site = 380530002; South Unit monitoring site = 380070002) (EPA 2012b).

The Visibility Information Exchange Web System (VIEWS) database provided average annual visibility monitoring data (in deciviews [dv]) for THRO from 2001 through 2004 (VIEWS 2010). The IMPROVE Program provided access to annual summary data for particulate matter concentrations and average visibility (in dv) in the park (IMPROVE 2011).

Special Air Quality Studies

Pohlman and Maniero (2005) reports on the estimated risk of foliar injury from ozone on native vegetation in national parks in the NGPN. Information on ozone sensitive plant species present in the parks, levels of ozone exposure, and relationships between exposure and soil moisture are synthesized into a risk assessment of foliar injury for each park, including THRO.

Sullivan et al. (2011a) assessed the relative sensitivity of national parks to the potential effects of acidification caused by acidic atmospheric deposition from nitrogen and sulfur compounds. The relative risk for each park was assessed by examining three variables: the level of exposure to emissions and deposition of nitrogen and sulfur; inherent sensitivity of park ecosystems to acidifying compounds (N and/or S) from deposition; and level of mandated park protection against air pollution degradation (i.e., Wilderness and Class I). The outcome was an overall risk assessment that estimates the relative risk of acidification impacts to park resources from atmospheric deposition of nitrogen and sulfur (Sullivan et al. 2011a). Using the same approach, Sullivan et al. (2011b) assessed the sensitivity of national parks to the effects of nutrient enrichment by atmospheric deposition of nitrogen. The outcome was an overall risk assessment that estimates the relative risk to park resources of nutrient enrichment from increased nitrogen deposition.

4.12.5 Current Condition and Trend

Atmospheric Deposition

Five-year interpolated averages are used to estimate the condition of most air quality parameters; this offsets annual variations in meteorological conditions, such as heavy precipitation one year versus drought conditions in another. The current 5-year average (2005-2009) estimates total wet deposition of nitrogen in THRO to be 2.26 kg/ha/yr, while the wet deposition of sulfur is 0.93 kg/ha/yr (NPS 2011). Overall, deposition of nitrogen and sulfur appears to be stable. Based on NPS ratings for air quality conditions, the current estimates for nitrogen deposition fall into the *Moderate Concern* category, while the current estimates for sulfur deposition fall into the *Good Condition* category (see Table 31 for ratings values). However, several factors are considered when rating the condition of atmospheric deposition, including effects of deposition on different ecosystems (NPS 2010a). Based on the NPS process for rating air quality conditions, ratings for parks with ecosystems considered potentially sensitive to nitrogen or sulfur deposition are typically adjusted up one condition category. In general, native grassland and meadow ecosystems can be sensitive to increased levels of nitrogen, as acidification and nutrient enrichment can cause shifts in native species composition and encourage encroachment of exotic species and grasses (reviewed in Sullivan et al. 2011a and 2011b). THRO comprises native grassland/prairie vegetation communities, which may be at risk from increased nitrogen deposition. Thus, the condition in THRO typically would be considered of *Significant Concern* for nitrogen deposition and *Moderate Concern* for sulfur deposition, based on natural background and current average nitrogen deposition rates. However, trend analysis of wet deposition data collected in THRO from 1999-2008 indicates nitrogen deposition is of moderate concern with a stable trend, while sulfur deposition is in good condition with a stable trend (NPS 2010b).

Concentrations (mg/L) of nitrogen, sulfur, and ammonium compounds in wet deposition can be used to evaluate trends in deposition of total nitrogen and sulfur. Since atmospheric wet deposition can vary greatly depending on the amount of precipitation that falls in any given year, it can be useful to examine concentrations of pollutants, which factor out the variation introduced by precipitation. Figure 21 shows the annual average concentrations of sulfate, nitrate, and ammonium recorded in THRO from 2000-2010. Despite a slight increase in concentrations in 2002 and 2006, annual averages indicate that sulfate and nitrate concentrations in the park have been decreasing overall, while ammonium deposition appears stable (NADP 2011).

Figure 21. Annual average precipitation-weighted concentrations of nitrate (NO_3), sulfate (SO_4), and ammonium (NH_4) (mg/L) in THRO, 2000-2010 (NADP monitoring site ND00) (Source: NADP 2011).

Dry deposition (dust, particles, and aerosols) also contributes significantly to total deposition in the region around THRO. CASTNet data indicate that dry forms contribute about one-fourth (26%) to total deposition of nitrogen, and about 30% to total sulfur deposition (EPA 2012a) (see Figure 22 and Figure 23). Figure 26 indicates that reduced forms of nitrogen (i.e., ammonium [NH_4]) contribute approximately 50% of total nitrogen deposition; this is likely an underestimate because ammonia gas is not included in the measurements.

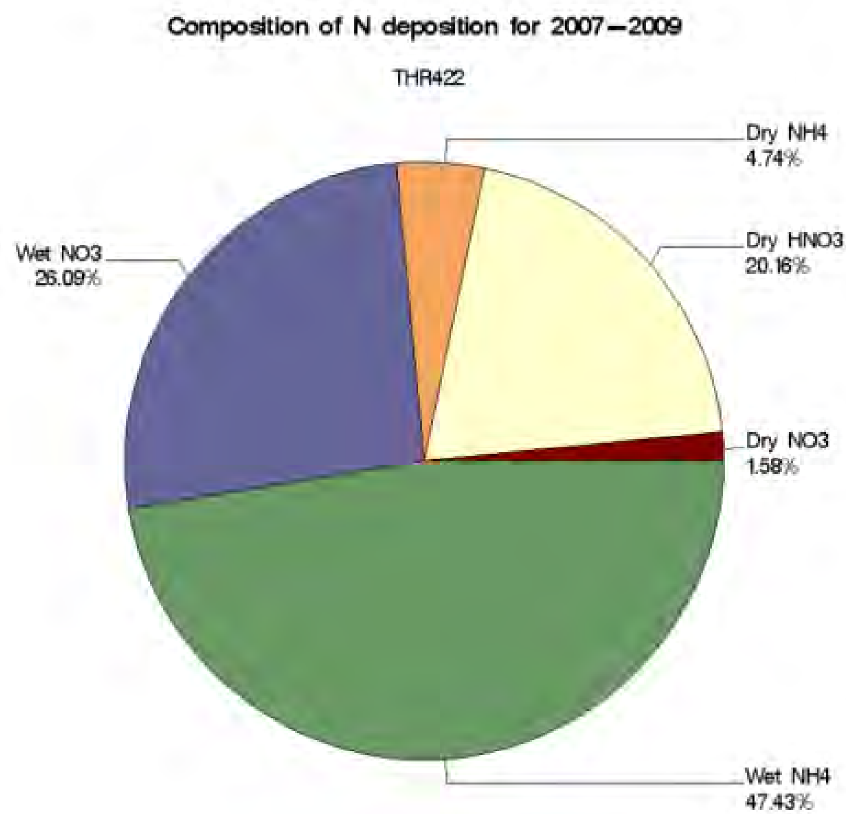


Figure 22. Composition of nitrogen deposition in THRO, 2007-2009 (Monitoring station THRO422) (EPA 2012a).

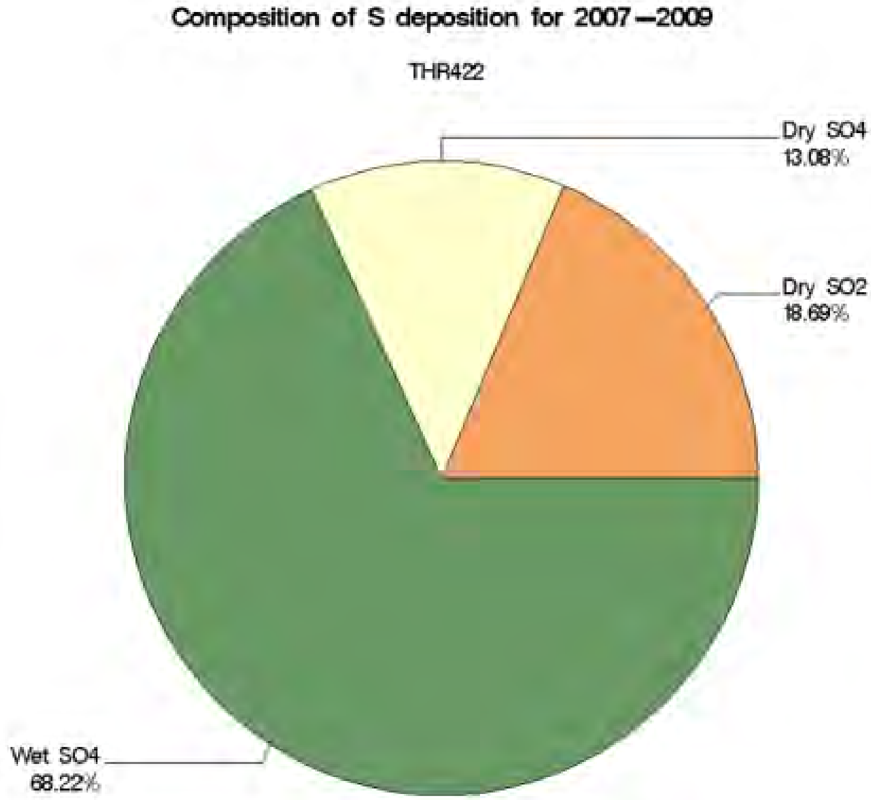


Figure 23. Composition of sulfur deposition in THRO, 2007-2009 (Monitoring station THRO422) (EPA 2012a).

Sullivan et al. (2011a) ranked THRO as having moderate acidifying (nitrogen and sulfur) pollutant exposure, moderate ecosystem sensitivity to acidification in its grassland ecosystem, and very high park protection (Class I airshed) against air pollution. The relative ranking of overall risk from acidification due to acid deposition is high relative to other parks (Sullivan et al. 2011a). In a separate examination, Sullivan et al. (2011b) used the same approach to assess the sensitivity of national parks to nutrient enrichment effects from atmospheric nitrogen deposition relative to other parks. Risk relative to other parks was assessed by examining exposure to nitrogen deposition, inherent sensitivity of park ecosystems, and mandates for park protection. THRO was ranked as being at low risk for nitrogen pollutant exposure, very high ecosystem sensitivity of grasslands and meadows, and very high park protection mandates (Class I airshed). The ranking of overall risk of effects from nutrient enrichment due to atmospheric nitrogen deposition was determined to be very high relative to other parks (Sullivan et al. 2011b).

Ozone Concentration

The NAAQS standard for ground-level ozone is the benchmark for rating current ozone conditions within park units. The condition of ozone in NPS park units is determined by calculating the 5-year average of the fourth-highest daily maximum of 8-hour average ozone concentrations measured at each monitor within an area over each year (NPS 2010a). The current 5-year average (from 2005-2009) for THRO indicates an average ground-level ozone concentration of 60.0 ppb (NPS 2011), which falls under the *Good Condition* category based on

NPS guidelines. Based on trend analysis of annual average data from 1999-2008, ozone concentrations in THRO are in good condition with a stable trend (NPS 2010b). Figure 24 and Figure 25 show the trends for average annual ozone concentrations in the South and North Units of THRO (Note: concentrations are in ppm, while NPS thresholds are in ppb) from 1991 to 2010 with respect to the national standard (EPA 2012b). Data suggest ozone concentrations vary slightly, but overall, concentrations appear to be stable and within the EPA national standard.

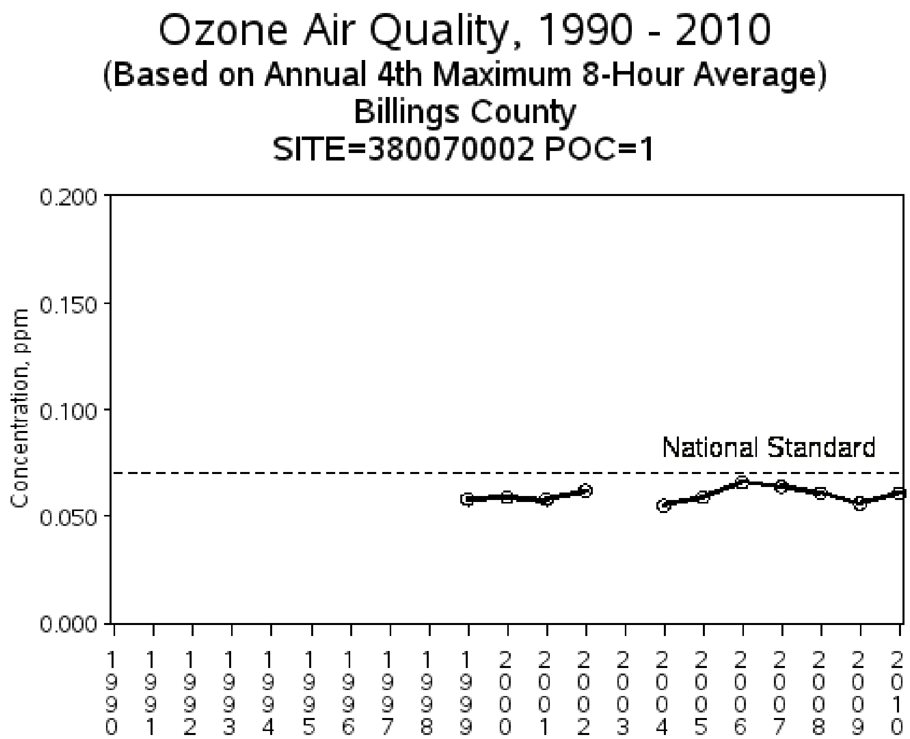


Figure 24. Average annual ozone (O_3) concentration (ppm) for the South Unit of THRO, 1999-2010 (Source: EPA 2012b).

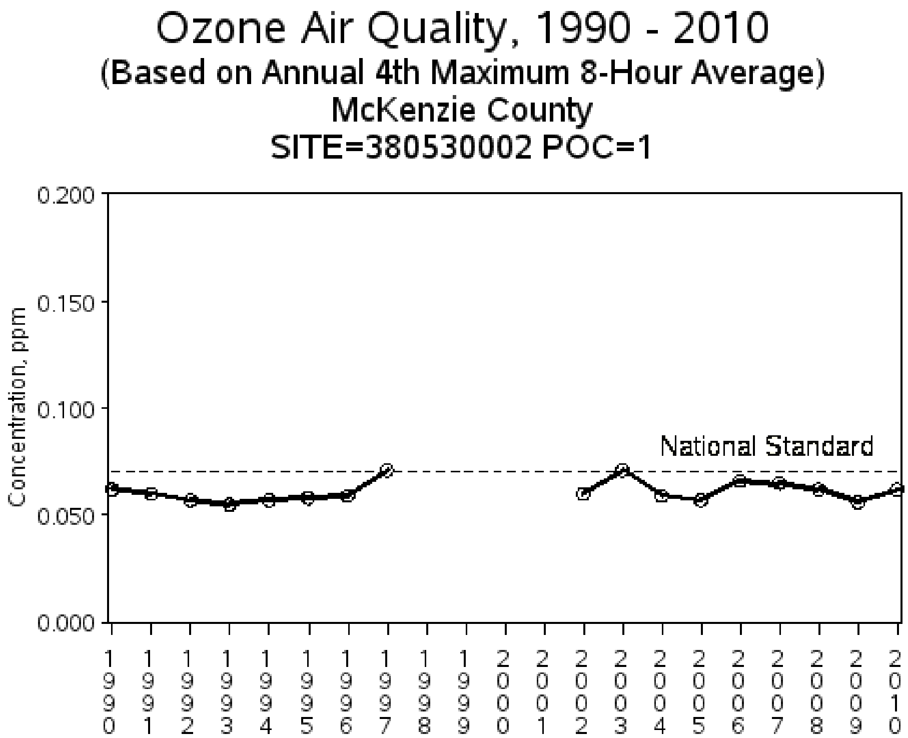


Figure 25. Average annual ozone (O_3) concentration (ppm) for the North Unit of THRO, 1990-2010 (Source: EPA 2012b).

Pohlman and Maniero (2005) assessed ozone concentrations in the NPGN and the risk of injury to plant species that are sensitive to sustained ozone exposure. Data from 1995-1999 indicate ozone concentrations in THRO during this time frequently exceeded 60 ppb for a few hours each year, but only exceeded 80 ppb a few times in one year out of the five; ozone concentrations never exceeded 100 ppb. Sensitive plant species begin to experience foliar injury when exposed to ozone concentrations of 80-120 ppb/hour for extended periods of time (8 hours or more) (Pohlman and Maniero 2005). Thus, the risk of foliar injury to plants was determined to be low (Pohlman and Maniero 2005). However, if ozone concentrations should increase in the future, an on-site monitoring program that assesses foliar injury and growth progress may be necessary (Pohlman and Maniero 2005).

Various plant and tree species are monitored to track air pollution impacts. THRO has 18 plant species known to be sensitive to excessive or extended concentrations of ozone, including a number of species that are highly sensitive. Highly sensitive species include Ponderosa pine (*Pinus ponderosa*), chokecherry, quaking aspen (*Populus tremuloides*), spreading dogbane (*Apocynum androsaemifolium*), paper birch (*Betula papyrifera*), Virginia strawberry (*Fragaria virginiana*), common snowberry, and green ash (Peterson et al. 1998, NPS 2006).

Photo 21. Chokecherry (NPS photo).

Mercury Concentration

THRO does not have a monitoring station that records mercury deposition. The nearest monitoring station is located in Eagle Butte, South Dakota. However, it is approximately 322 km (200 mi) southeast of THRO and, thus, it is inappropriate to estimate deposition rates in the park from this monitor. For locations in the U.S. that do not have mercury monitoring stations, deposition is interpolated from the nearest sites in areas with sufficient numbers of samplers; this data can be used to estimate conditions in a particular area, but should be used with caution in considering current condition or in determining trends. Figure 26 shows the most recent interpolated average mercury wet deposition for monitoring sites across the U.S. (the approximate location of THRO is marked with a yellow star). Recent average deposition data indicate wet deposition of mercury in the region of the park is approximately 4-6 µg/m^2 (NADP 2012).

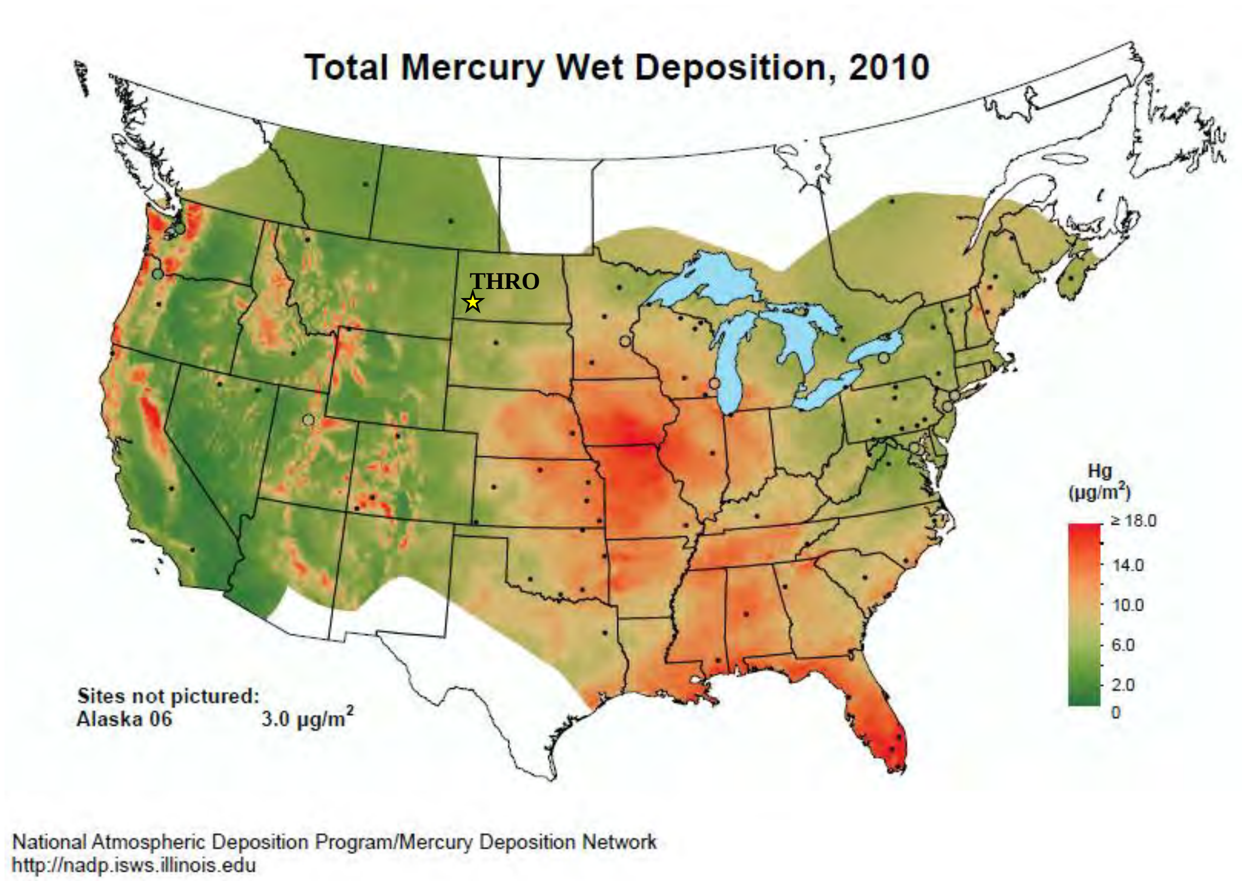


Figure 26. Total mercury deposition near THRO, 2010 (Source: NADP 2012). Yellow star indicates the approximate location of THRO.

Wet deposition of mercury can vary greatly depending on variations in the amount of precipitation that has fallen in an area across a year or several years. Mercury concentrations more accurately reflect patterns in mercury emissions. Figure 27 shows the most recent interpolated average mercury concentrations for monitoring sites across the U.S. (approximate location of THRO is marked with a yellow star). Recent average concentration data indicate mercury concentrations in the region of THRO are approximately 10-14 ng/L (NADP 2012). Reliable data for both concentration and deposition of mercury prior to 2009 are unavailable.

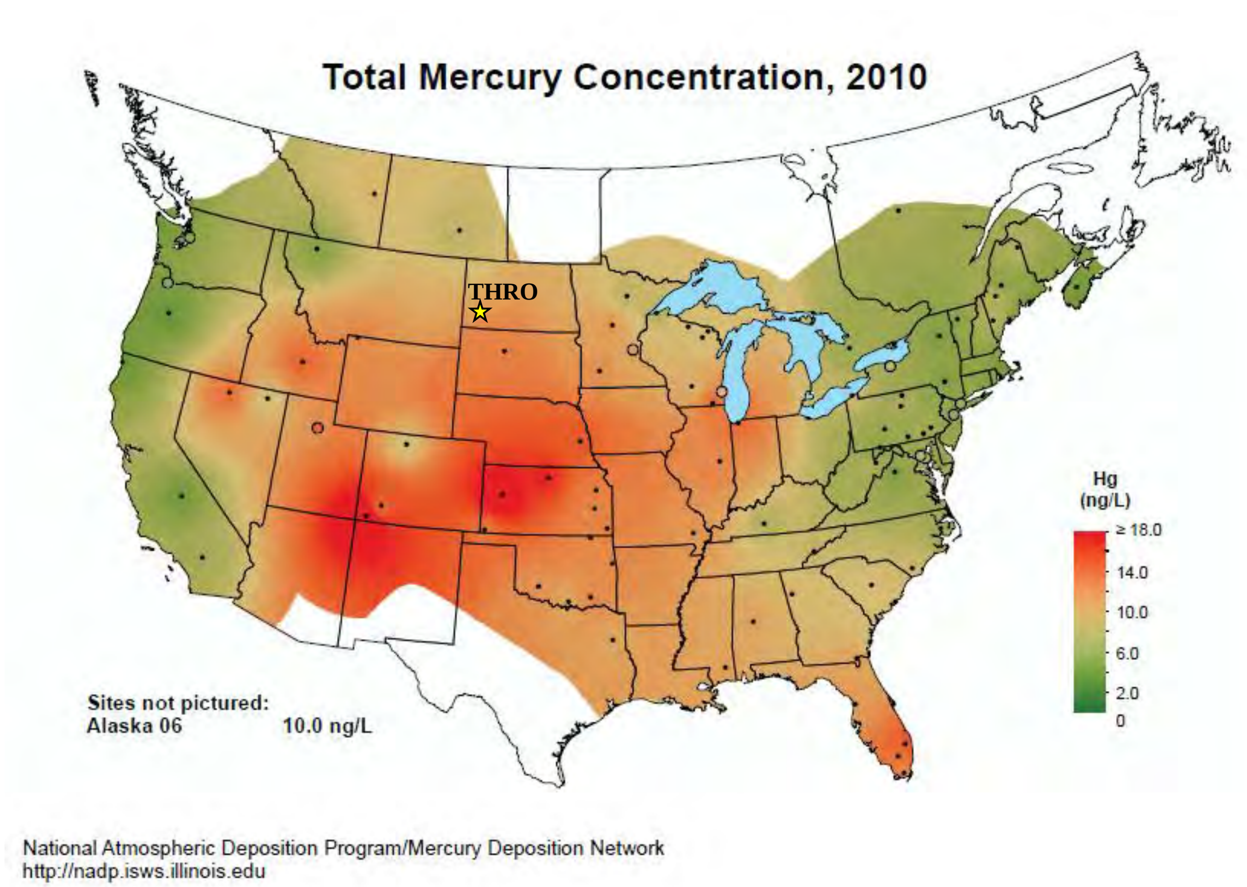


Figure 27. Total mercury concentration near THRO, 2010 (Source: NADP 2012). Yellow star indicates the approximate location of THRO.

<u>Concentration of Particulate Matter ($PM_{2.5}$ and PM_{10})</u>

Concentrations of particulate matter ($PM_{2.5}$ and PM_{10}) are recorded at an IMPROVE monitoring site located in THRO (site THRO1). Data for average concentrations in the park are available from 2001 through 2010, and are summarized as annual average concentrations (IMPROVE 2011). The NAAQS standard for PM_{10} is 150 µg/m^3 over a 24-hour period; this level may not be exceeded more than once per year on average over three years (EPA 2010d). The standard for $PM_{2.5}$ is a weighted annual mean of 15.0 µg/m^3 or 35 µg/m^3 in a 24-hour period over an average of three years (EPA 2010d). Since 2001, $PM_{2.5}$ concentrations have remained stable around 3.5-4.5 µg/m^3, while average concentrations of PM_{10} fluctuated between 8.5-11.5 µg/m^3 (Figure 28) (IMPROVE 2011). Values for both $PM_{2.5}$ and PM_{10} are well within the EPA standards for levels that are protective of human health and visibility.

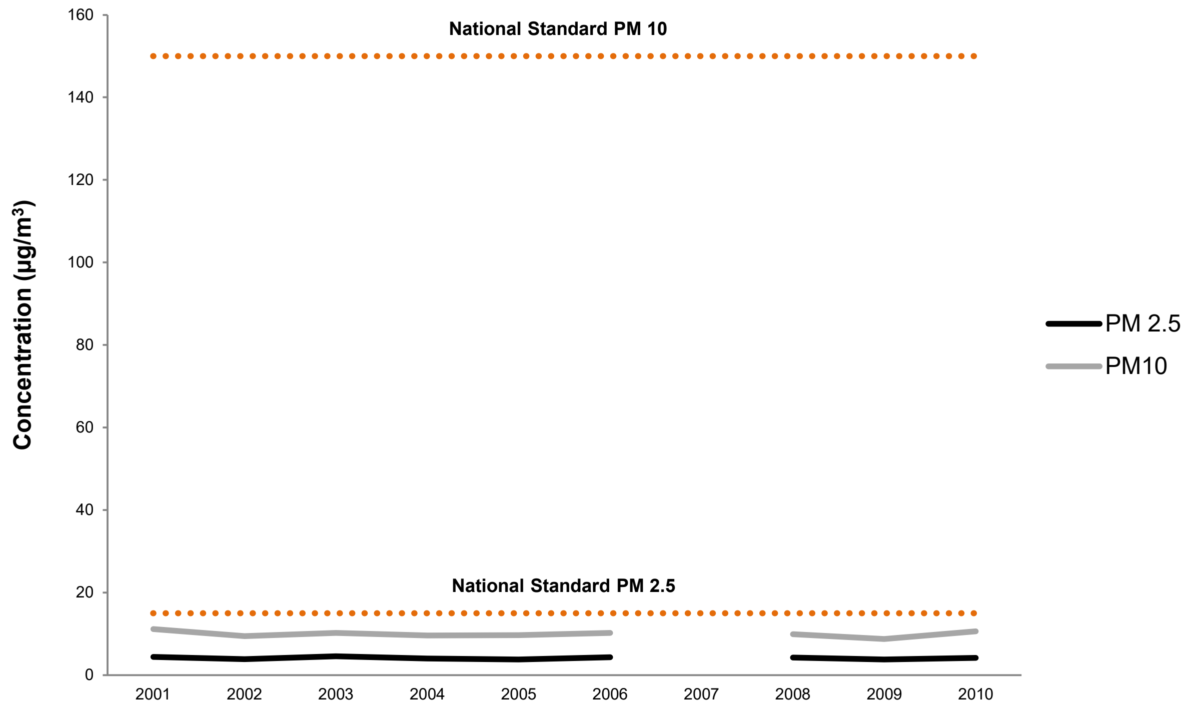


Figure 28. Average annual particulate matter concentration ($PM_{2.5}$ and PM_{10}) in THRO, 2001-2010 (IMPROVE 2011).

Visibility

Visibility impairment occurs when airborne particles and gases scatter and absorb light; the net effect is called "light extinction," which is a reduction in the amount of light from a view that is returned to an observer (EPA 2003). In response to the mandates of the CAA of 1977, federal and regional organizations established IMPROVE in 1985 to aid in monitoring of visibility conditions in Class I airsheds. The goals of the program are to 1) establish current visibility conditions in Class I airsheds; 2) identify pollutants and emission sources causing the existing visibility problems; and 3) document long-term trends in visibility (NPS 2009).

The most current 5-year average (2005-2009) estimates visibility in THRO to be 6.8 dv (this is an estimate minus the estimated natural conditions). This falls into the *Moderate Concern* category for NPS air quality condition assessment (NPS 2011).

The clearest and haziest 20% of days each year also are examined for parks. Figure 29 depicts estimated visibility conditions (in dv) for the 20% haziest and 20% clearest days in THRO. Conditions measured near 0 dv are clear and provide excellent visibility, and as deciview measurements increase, visibility conditions become hazier. Estimated visibility conditions appear relatively consistent for both the 20% haziest and clearest days over the last 10 years. Trend analysis of data from 1999-2008 indicates visibility to be of moderate concern with a stable trend (NPS 2010b).

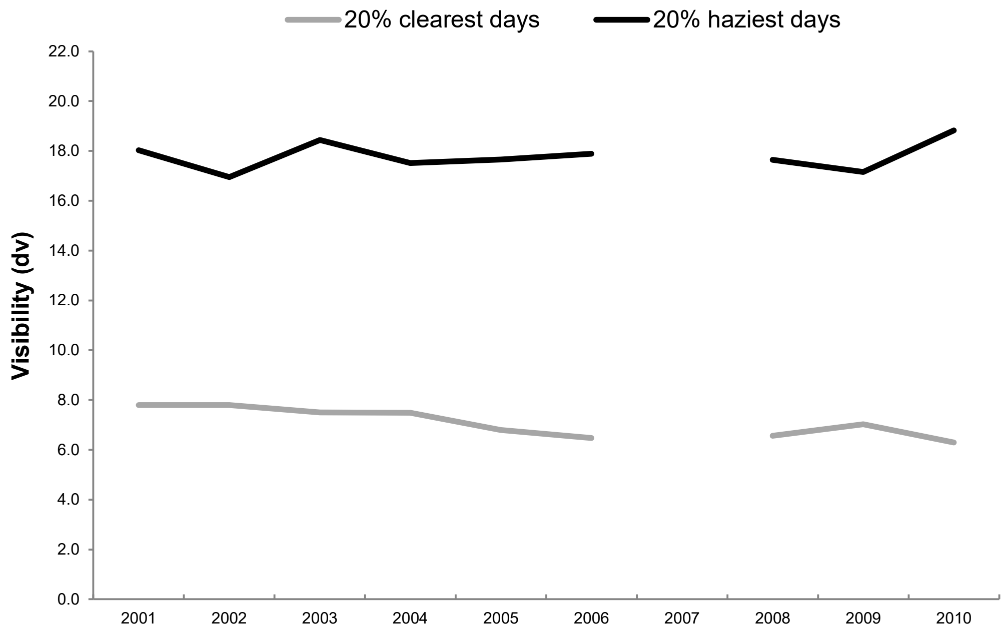


Figure 29. Visibility (in dv) on the 20% clearest and 20% haziest days in THRO, 2001-2010 (IMPROVE 2011).

Threats and Stressor Factors

The most substantial threat to air quality in THRO is energy development in the region, particularly crude oil and natural gas. Western and central North Dakota have experienced a significant increase in oil and gas development in the last two decades (Peterson et al. 1998). The major sources of pollution that could affect protected areas in this region have been associated with oil and gas operations as well as coal-fired power plants; these sources add sulfur dioxide and nitrogen oxide emissions to the air (Peterson et al. 1998). Several power plants, the largest sources of sulfur dioxide emissions in the region, are located near the park (Peterson et al. 1998), where winds can carry emissions into the park. Although THRO is unlikely to be affected by acidification from sulfur dioxide and associated sulfate deposition, these coal-burning power plants also release mercury into the atmosphere that, when transformed to toxic methylmercury in wetlands, can bioaccumulate in fish and wildlife. Nitrogen oxide emissions from oil and gas development may increase nitrogen deposition to THRO grasslands and wetlands, which could affect plant communities and promote growth of annual grasses and invasive species.

Smoke produced by wildfires or human-caused fires have long been a part of the Great Plains ecosystem. Though fires are not considered a long-term source of pollution in the northern Great Plains (including THRO), if persistent and substantial in extent, they may result in periods of decreased visibility and increased concentrations of particulate matter (Peterson et al. 1998).

Data Needs/Gaps

Though monitoring of air quality parameters is quite thorough in THRO, little emphasis has been placed on tracking the plant and animal species that are sensitive to increases in certain pollutants. Peterson et al. (1998) indicate that a primary concern in THRO is sulfur exposure and the effects of such exposure on native vegetation. Nitrate, sulfate, and ammonium deposition and ozone could become more of a concern in the future as new point and area sources of pollution emerge (e.g., increase in development of oil and gas wells, and operation of coal-fired power plants) and increase ambient pollution levels (Peterson et al. 1998). If air pollution increases in the future, plant and trees species can be monitored to track air pollution impacts.

THRO has a number of species that are quite sensitive to increases in ozone and sulfates (Peterson et al. 1998 provide a detailed list). Several of these species could be used as bioindicators to track potential increases in certain criteria air pollutants as well as long-term health of the ecosystem. Table 32 summarizes the vascular plant and tree species that have known sensitivities, either medium or high, to sulfates and ozone. While it is impractical to monitor all sensitive plant species, park staff may identify key species to use as bioindicators.

Table 32. Plant and tree species of THRO with high or moderate sensitivities to sulfates and ozone (adapted from Peterson et al. 1998; Pohlman and Maniero 2005, NPS 2006b).

Scientific Name	Common Name	SO_2 Sensitivity[1]	O_3 Sensitivity
Amelanchier alnifolia	Saskatoon serviceberry	H	M
Betula papyrifera	Paper birch	H	H
Convolvulus arvensis	Field bindweed	H	
Corylus cornuta	Beaked hazelnut	H	
Fragaria virginiana	Virginia strawberry		H
Fraxinus pennsylvanica	Green ash	M	H
Helianthus anuus	Common sunflower	H	
Pinus ponderosa	Ponderosa pine	M	H
Populus tremuloides	Quaking aspen	H	H
Prunus virginiana	Chokecherry	M	H
Rhus aromatica	Fragrant sumac	H	

[1]Sensitivity: M=medium; H=high

In an effort to quantify harmful pollution levels and set goals for resource protection on federal lands, natural resources managers are increasingly using a “critical loads” approach for tracking and monitoring a variety of pollutants, in particular nitrogen and sulfur compounds (Porter et al. 2005). Critical loads are defined as “the quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge” (Nilsson and Grennfelt 1988, as cited in Porter et al. 2005, p. 603). Essentially, critical loads describe the amount of pollution that stimulates negative impacts or harmful changes in sensitive ecosystems (Porter et al. 2005, NPS 2007). Porter et al. (2005) developed an approach for determining critical loads for nitrogen and sulfur using two national parks as case studies, and research is underway in other park units to aid in communicating resource condition. Their methodology can be tailored to fit most national park lands, depending on the baseline information that is available. Since there are a variety of plant species found in THRO that are sensitive to increases in air pollutants and because grasslands are particularly vulnerable to excess deposition of nitrogen (Peterson et al. 1998), park managers at THRO may be able to develop and implement a critical load approach for managing air pollutants and to set goals for resource protection within the park.

Overall Condition

Nitrogen Deposition
The project team defined the *Significance Level* for atmospheric deposition of nitrogen as a 3. Sullivan et al. (2011b) rate the grassland ecosystems in THRO as at very high risk of nutrient enrichment due to nitrogen deposition. NADP data suggest nitrogen deposition may be declining slightly in recent years. NPS (2010b) trend analysis from 1999-2008 indicates nitrogen deposition is of moderate concern with a stable trend. Therefore, deposition of nitrogen is of moderate concern (*Condition Level* = 2).

Sulfur Deposition
The project team defined the *Significance Level* for atmospheric deposition of sulfur as a 3. Sullivan et al. (2011a) suggest the moderate sensitivity to acidification, coupled with a moderate risk of pollutant exposure, make the grassland ecosystems in THRO at high risk of acidification by sulfur and other acids. NADP data suggest sulfur deposition may be declining slightly in recent years and has largely remained stable. Current measurements fall into the moderate concern category based on NPS criteria for rating air quality, however, NPS (2010b) trend analysis from 1999-2008 specifies that sulfate deposition is in good condition with a stable trend. Therefore, deposition of sulfur is of low concern (*Condition Level* = 1).

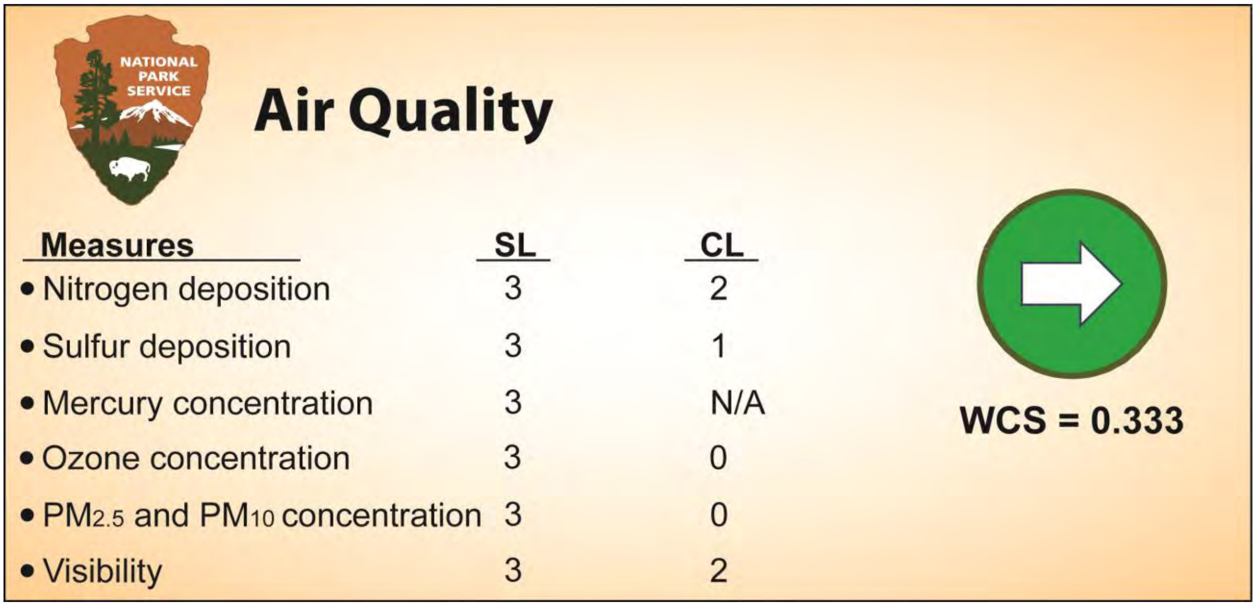
Ozone Concentration
The project team defined the *Significance Level* for ozone concentration as a 3. Current average ground-level ozone concentrations fall into the good concern category based on NPS criteria for rating air quality, with annual average concentrations (measured in ppm) indicating a stable trend. Therefore, the *Condition Level* for ozone concentration is a 0, of no concern.

Mercury Deposition/Concentration
The project team defined the *Significance Level* for mercury concentration as a 3. Current data suggest mercury deposition and concentration in the northern Great Plains are low relative to other regions of the U.S. However, these data are interpolated from monitoring stations some distance from THRO and serve only as estimates for the region versus data collected in or near the park. Limited data make it impossible to determine a *Condition Level* for this measure.

Particulate Matter Concentration (PM 2.5 and PM 10)
The project team defined the *Significance Level* as 3 for concentration of fine particulate matter (PM 2.5 and 10). Concentrations for both $PM_{2.5}$ and PM_{10} in THRO are well within the EPA standards for levels that are protective of human health. Trends in average concentrations show consistent stability over the last decade. The *Condition Level* for $PM_{2.5}$ and PM 10 is a 0, of no concern.

Visibility
The project team defined the *Significance Level* for visibility as a 3. Current average visibility falls into the moderate concern category based on NPS criteria. Average visibility conditions on the 20% clearest days are improving slightly over the last decade, while visibility for the 20% haziest days may be declining slightly. The *Condition Level* for visibility is a 2, of moderate concern.

Weighted Condition Score
The *Weighted Condition Score* (WCS) for the air quality component is 0.333, indicating the condition is of low concern with a stable trend.



4.12.6 Sources of Expertise
Ellen Porter, Biologist, National Park Service, Air Resources Division.

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4.13 Water Quality

4.13.1 Description

In recent years, water quality monitoring has been identified as a priority for NGPN parks, including THRO, for tracking ecological health in the park, assessing compliance with water quality standards, and detecting threats to human health. A core set of water quality measures will be monitored, including such parameters as dissolved oxygen, concentration of fecal coliform bacteria, pH, and water temperature (NPS 2012).

The Little Missouri River is a primary feature on the THRO landscape, running through all three units of the park. It provides support and habitat for a variety of plants, birds, terrestrial animals, and fish. For many of the park's large animals, such as bison, feral horses, and elk, the Little Missouri River provides one of the only consistent sources of water (NPS 2010). Additionally, some popular visitor activities include fishing, float trips down the river, and wildlife viewing (NPS 2010). Thus, impaired water quality could substantially affect both animals and people in the park.

4.13.2 Measures

- Dissolved oxygen (DO)
- Fecal coliform
- pH
- Macroinvertebrates
- Specific conductance
- Temperature
- Turbidity

Photo 22. Little Missouri River at Juniper Campground in the North Unit of THRO (Photo by Shannon Amberg, SMUMN GSS, 2010).

<u>Dissolved Oxygen</u>

Dissolved oxygen (DO) is critical for organisms that live in water. Fish and zooplankton filter out or "breathe" dissolved oxygen from the water to survive (USGS 2010). Oxygen enters water from the atmosphere or through ground water discharge. As the amount of DO drops, it becomes more difficult for water-based organisms to survive (USGS 2010). The concentration of DO in a water body is closely related to water temperature; cold water holds more DO than does warm water (USGS 2010). Thus, DO concentrations are subject to seasonal fluctuations as low temperatures in the winter and spring allow water to hold more oxygen, and warmer temperatures in the summer and fall allow water to hold less oxygen (USGS 2010).

<u>Fecal Coliform</u>

Fecal coliform bacteria are an accurate indicator of fecal contamination in water by warm-blooded animals. It is tested by counting colonies that grow on micron filters placed in an incubator for 22-24 hours. High numbers of fecal coliform can be an indicator of harmful bacteria as well as other disease-causing organisms such as viruses and protozoans (USGS 2011).

pH

pH is a measure of the level of acidity or alkalinity of water and is measured on a scale from 0 to 14, with 7 being neutral (USGS 2010). Water with a pH of less than 7.0 indicates acidity, whereas water with a pH greater than 7.0 indicates alkalinity. Aquatic organisms have a preferred pH range that is ideal for growth and survival (USGS 2010). Chemicals in water can change the pH and harm animals and plants living in the water; thus, monitoring pH can be useful for detecting natural and human-caused changes in water chemistry (USGS 2010).

Macroinvertebrates

Because aquatic macroinvertebrates spend most or all of their life cycles in water, they are well known as indicators of watershed health and the quality of water in aquatic systems (EPA 2011b). Some species are tolerant of pollution or poor water quality, while others are highly sensitive to it. Thus, the presence or absence of tolerant and intolerant species can be an indication of the condition of the water body and water quality (EPA 2011b). The life cycles of many macroinvertebrate species are short (sometimes one season in length), though some species live longer, and many have limited mobility; thus, in a discrete area from year to year, it can be easy to detect population fluctuations that may indicate a change (positive or negative) in water quality (EPA 2011b).

Specific Conductance

Specific conductance is a measure of the ability of water to conduct electrical current, which depends largely on the amount of dissolved solids in the water (USGS 2010). Conductivity is affected by inorganic dissolved solids that may be present, such as chloride, nitrate, sulfate, and phosphate anions (having a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (having a positive charge) (EPA 2012a). Water with low amounts of dissolved solids (such as purified or distilled water) will have a low specific conductance, while water with high amounts of dissolved solids (such as salty sea water or other minerals) will have a much higher specific conductance (USGS 2010). Specific conductance is an important water-quality parameter to monitor because high levels can indicate that water is unsuitable for drinking or aquatic life (USGS 2010).

Water Temperature

Water temperature greatly influences water chemistry and the organisms that live in aquatic systems. Not only can it affect the ability of water to hold oxygen, water temperature also affects biological activity and growth within water systems (USGS 2010). All aquatic organisms, from fish to insects to zoo- and phytoplankton, have a preferred or ideal temperature range for existence (USGS 2010). As temperature increases or decreases too far past this range, the number of individuals and species able to live there eventually decreases. In addition, higher temperatures allow some compounds or pollutants to dissolve more easily in water and can be more toxic to aquatic life (USGS 2010).

Turbidity

Turbidity assesses the amount of fine particle matter (such as clay, silt, plankton, microscopic organisms, or finely divided organic or inorganic matter) that is suspended in water by measuring the scattering effect that solids have on light that passes through water (USGS 2010a). For instance, the more light that is scattered, the higher the turbidity measurement will be. The suspended materials that make water turbid can absorb heat from sunlight, increasing the water temperature in waterways and reducing the concentration of DO in the water (USGS 2010a). The scattering of sunlight by suspended particles decreases photosynthesis by plants and algae, which contributes to decreased DO concentrations in the water (USGS 2010a). Suspended particles also irritate and clog the gill structures of many fish or amphibians, making it difficult to thrive (USGS 2010).

4.13.3 Reference Conditions/Values

The reference condition for THRO's water quality is the North Dakota Standards of Water Quality for the State for surface waters (NDDH 2001). The Little Missouri River is classified as a Class II stream by these standards, requiring that water quality be suitable for propagation or protection, or both, of resident species and other aquatic biota and for swimming, boating, and other water recreation (NDDH 2001). When state standards are unavailable, the EPA's water quality criteria for surface waters were used. The water must be safe for freshwater organisms, for human bathing, and must meet drinking water standards. Table 33 displays water quality parameter standards set by the state of North Dakota and EPA. There are no established thresholds for specific conductance at the state level, although the EPA (2012a) suggests that waterways with conductivity greater than 500 microsiemens per centimeter (µs/cm) may be unsuitable for some species of fish or macroinvertebrates.

Table 33. North Dakota water quality standards (North Dakota Department of Health 2001, EPA 2012b).

Parameter	North Dakota standard
Temperature	<85°F or 29.4°C (for Class II streams)
Dissolved oxygen	≥5 mg/L
Turbidity	50 NTU (EPA standard)
pH	≥7.0 – ≤9.0 (up to 10% of representative samples collected during any 3-year period may exceed this range provided that lethal conditions are avoided)
Fecal coliform	≤126 CFU/100 mL (for recreational waters from May 1 – September 30)

4.13.4 Data and Methods

NPS (1997) presents the results of surface-water quality data retrievals for THRO using six of the EPA national databases: Storage and Retrieval (STORET) water quality database management system, River Reach File (RF3), Industrial Facilities Discharge (IFD), Drinking Water Supplies (DRINKS), Water Gages (GAGES), and Water Impoundments (DAMS) (NPS 1999). Results located nine active or inactive USGS water gages in the study area, which includes the park and surrounding area within the same watershed. Results of the STORET query yielded 19,534 observations for various parameters collected by NPS, USGS, EPA, U.S. Army Corps of Engineers, and the North Dakota Health Department at 76 monitoring sites on the Little Missouri River, tributaries to the Little Missouri River, and ponds and springs in and around THRO. Thirty-three of these sites were located within park boundaries; however, most of these monitoring sites were either single-time or one-year intensive sampling efforts. Four stations on the Little Missouri River (THRO 0005, THRO 0006, THRO 0046, and THRO 0050) yielded the longest-term data for several parameters and accounted for approximately 89% of the total water quality observations in the study area (NPS 1997). Figure 30 and Figure 31 show the locations of all monitoring sites identified in the NPS (1997) inventory.

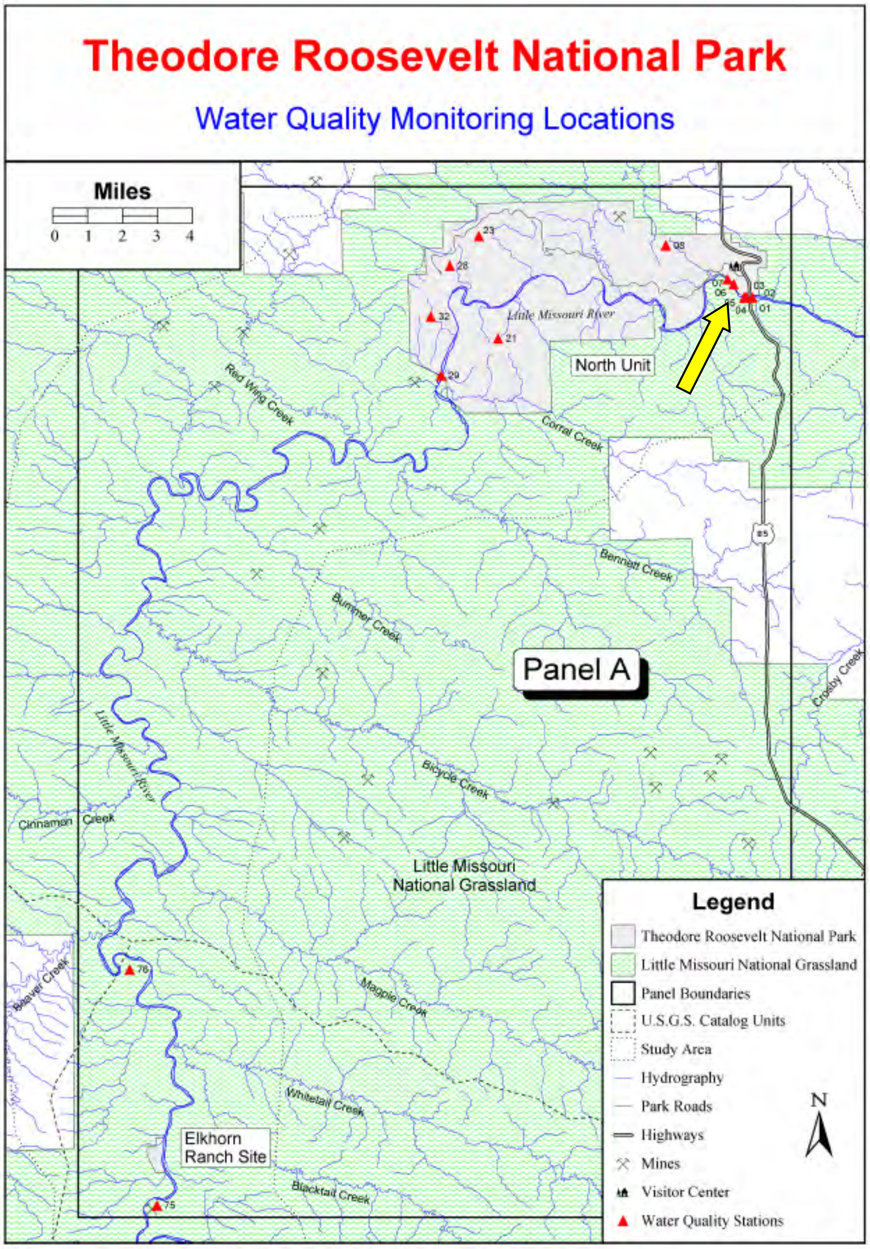

Figure 30. Water monitoring locations in the North Unit of THRO and near the Elkhorn Ranch (Source: NPS 1997). Note: yellow arrow identifies monitoring sites THRO 0005 and 0006, which provide longer-term water quality monitoring data.

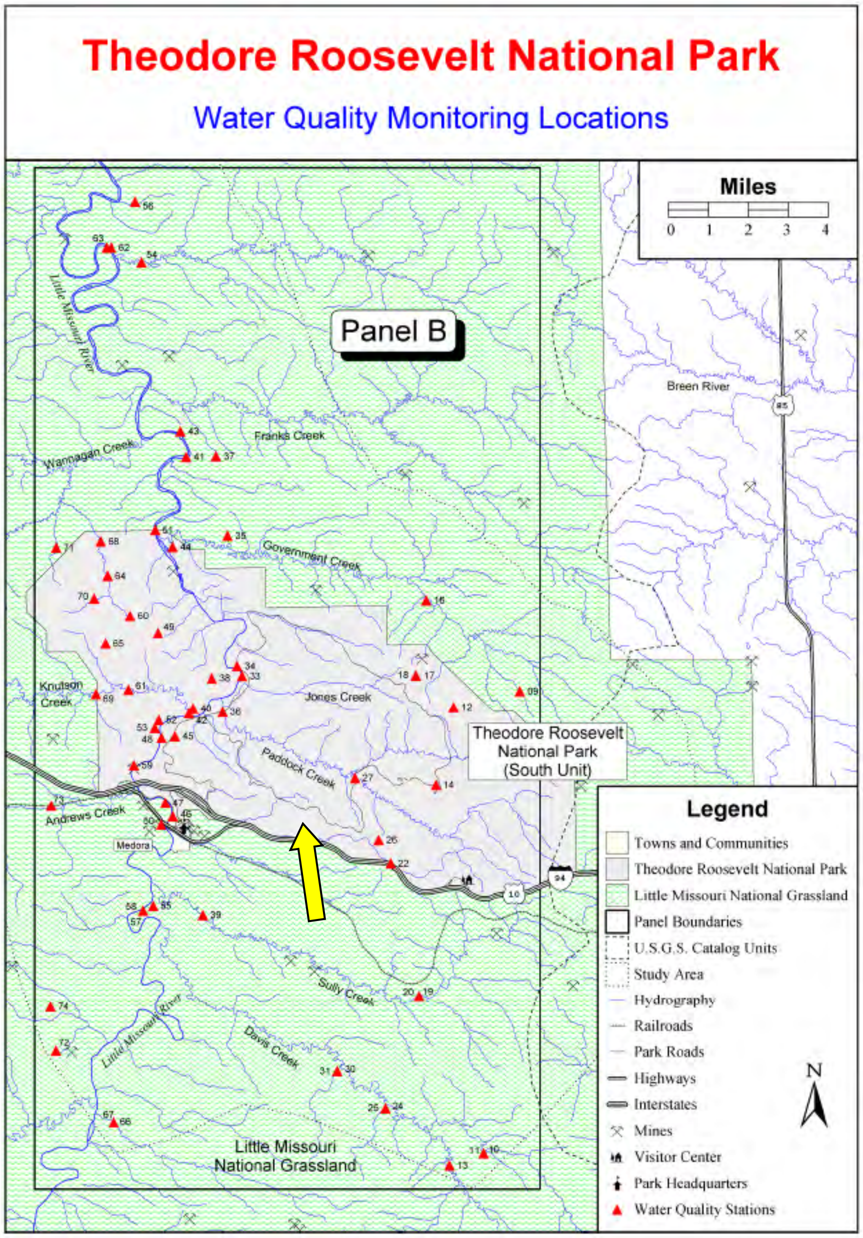

Figure 31. Water monitoring locations in and around the South Unit of THRO (Source: NPS 1997). Note: yellow arrow identifies monitoring sites THRO 0046 and 0050, which provide longer-term water quality monitoring data.

Rust (2006) collected water quality samples for several parameters on the Little Missouri River in 2004-2005. The objective of the research was to provide baseline descriptions of macroinvertebrate communities in the aquatic systems of national parks in the NGPN (including THRO), as well as select optimal metrics for use in future monitoring efforts by park resource managers. Chemical, physical, and aquatic habitat parameters were assessed for the Little Missouri River during the 2004 and 2005 field summer seasons. Water quality parameters measured in the study included dissolved oxygen, temperature, turbidity, fecal coliform concentration, pH, and diversity and abundance of macroinvertebrate species as well as other parameters.

A project to monitor macroinvertebrate communities in the Little Missouri River in THRO is currently underway and led by Dr. Lusha Tronstad, an invertebrate zoologist with the Wyoming Natural Diversity Database (WNDD). In August 2011, Dr. Tronstad collected aquatic invertebrate and water quality samples at four sites along the Little Missouri River at THRO. Parameters examined include diversity of macroinvertebrate taxa, water temperature, dissolved oxygen, specific conductance, salinity, pH, turbidity, and concentration of coliform bacteria. Preliminary results are available for chemical and physical water quality parameters; analysis of macroinvertebrate taxa is still underway (Dr. Lusha Tronstad, WNDD Invertebrate Zoologist, telephone communication, 21 May 2012).

The EPA STORET database provided water quality data recorded from 1996 through 2011 at two North Dakota Department of Health (NDDH) monitoring stations located on the Little Missouri River adjacent to THRO: NDDH station 380022 is located at Medora in the South Unit and station 380059 is located at Hwy 85 at the entrance to the North Unit (EPA 2012c). Data for the parameters of interest were summarized by range (minimum and maximum values), yearly mean, and median values where appropriate. There are two USGS gage stations located near the park, one in Medora and one in Watford City. Data collected at these two stations include measurements for water temperature, specific conductance, and pH parameters. However, only two observations have been collected each year since 2005 for each parameter. Because water quality parameters can vary largely on a daily, monthly, and seasonal basis, data from these gaging stations were determined to offer little insight for this assessment.

4.13.5 Current Condition and Trend

Dissolved Oxygen

NPS (1997) reported that dissolved oxygen was measured 794 times at five monitoring stations on the Little Missouri River from 1968 through 1994. Of these observations, three were less than the 5 mg/L state criterion for protection of freshwater aquatic life. Across five stations, DO measurements ranged from 0.9 to 13.3 mg/L. Measurement ranges are consistent for the river in both the North and South Units. Median DO concentrations were approximately 10.0 mg/L in the Little Missouri River in both units of the park.

In 2004 and 2005, Rust (2006) collected 90 DO samples along three reaches (10 transects/reach) of the Little Missouri River throughout the park; two reaches were located in the South Unit and one reach was located in the North Unit. DO levels ranged from 7.2 to 9.1 mg/L. The mean and median DO levels during this time were 8.2 and 8.3 mg/L respectively.

In August 2011, Dr. Lusha Tronstad recorded dissolved oxygen levels at four sites along the Little Missouri River; three sites were located near Medora and one site was located in the North Unit near the Hwy 85 bridge. DO levels ranged from 8.0 to 8.3 mg/L in the South Unit and 8.8 mg/L in the North Unit. These measurements, and the Rust (2006) observations, are well within EPA criterion for protection of freshwater aquatic life.

Two NDDH monitoring stations on the Little Missouri River, one in the North Unit and one in the South Unit of the park, recorded some three to eight dissolved oxygen observations per year from 1996 through 2011. Figure 32 shows the mean annual dissolved oxygen concentrations at each monitoring station for the last 15 years. During this time, mean DO concentrations ranged from 8.8 to 10.96 mg/L; observations ranged from 4.6 to 15.4 mg/L (EPA 2012c). All mean values are well above the minimum standards for protection of coldwater aquatic organisms (EPA ≥ 4 mg/L, State of North Dakota ≥ 5 mg/L).

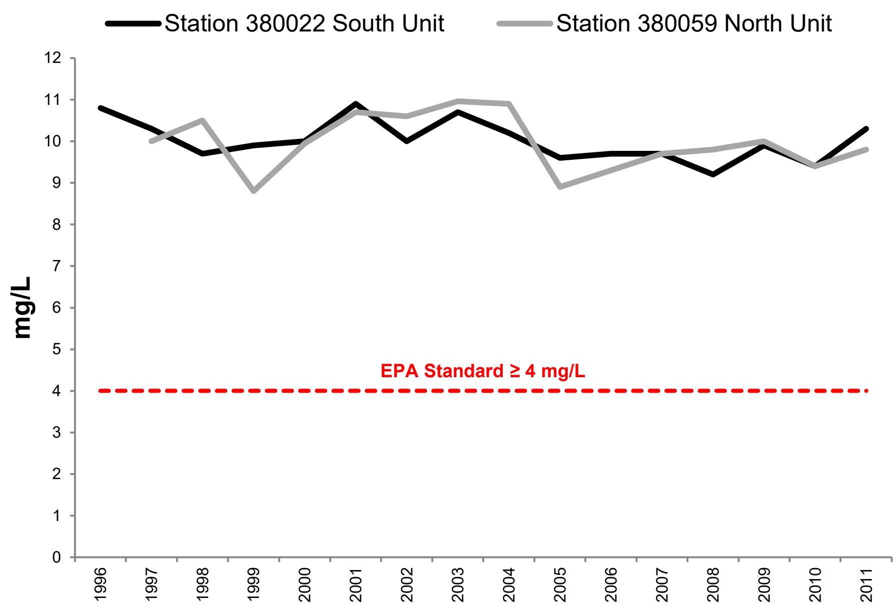

Figure 32. Mean annual dissolved oxygen concentrations (in mg/L) recorded at two monitoring stations on the Little Missouri River in the North and South Units of THRO, 1996-2011 (Source: EPA 2012c). Note: NDDH monitoring station 380022 is located at Medora (South Unit) and NDDH monitoring station 380059 is located at Hwy 85 (North Unit).

<u>Fecal Coliform</u>

NPS (1997) reported that total coliform concentrations were measured 98 times at three monitoring sites (THRO 0004, 0006, and 0050) on the Little Missouri River from 1968 through 1976. Measurements ranged from 1.0 to 300,000 CFU/100 mL; the median was 200 CFU. Thirty-seven observations at two stations (THRO 0004 [North Unit] and 0050 [South Unit]) exceeded the criteria for safe bathing (1,000 CFU/100 mL). Thirty-six of these observations were recorded in the Little Missouri River at Medora (THRO 0050) from 1969-1976.

NPS (1997) also summarized fecal coliform concentrations recorded at various locations in the park from 1971-1994. A total of 220 observations were recorded at four monitoring sites along the Little Missouri River in THRO (THRO 0004, 0005, 0006, and 0050). Measurements ranged from 2 – 46,000 CFU/100 mL; the median was 80 CFU. Fifty-four observations exceeded the WRD criteria for safe bathing water (200 CFU/100 mL). Just over 60% of exceedences, including the highest recorded value of 46,000 CFU (June 1977), occurred in the Little Missouri River at Medora (THRO 0050) from 1972-1992.

Rust (2006) collected three fecal coliform samples on the Little Missouri River in THRO in the summer months of 2004 and 2005. Two measurements were recorded in the South Unit (20 and

2,300 CFU/100 mL), the higher of which exceeded the state water quality criteria for safe bathing. A third observation was recorded in the North Unit (40 CFU/100 mL).

In August 2011, Dr. Lusha Tronstad recorded fecal coliform samples along the Little Missouri River; three sites were sampled near Medora and one site was sampled in the North Unit near the Hwy 85 bridge. Fecal coliform concentrations exceeded the maximum concentration that is measurable without dilution (L. Tronstad, pers. comm., 2012). All measurements exceeded state standards for safe bathing.

Two NDDH monitoring stations on the Little Missouri River, in both the North and South Units of the park, recorded anywhere from two to eight samples per year from 1996 through 2009 to test for presence and prevalence of fecal coliform bacteria. Figure 33 shows mean annual fecal coliform concentrations at each monitoring station from 1996 through 2009. Mean calculations are based on samples with quantifiable bacteria counts; some samples collected contained bacteria concentrations but they were present above or below the quantification limits for a specific test used (EPA 2012c). Overall, fecal coliform bacteria concentrations fluctuated widely from 1996 to 2009. During this time, individual bacterial colony concentrations ranged from 0 to 6,200 CFU/100 mL. A number of annual means exceeded the North Dakota criterion for safe bathing (EPA ≤200 CFU/100 mL). However, some years experienced as few as two observations, and thus, the data may not reflect normal conditions in the Little Missouri River.

As of 2010, a large reach of the Little Missouri River immediately upstream from Medora and bordering the South Unit of THRO was listed as 303[d] impaired for fecal coliform contamination. Likewise, a large reach of the Little Missouri flowing through the North Unit of THRO also was listed as 303[d] impaired for fecal coliform bacteria (EPA 2011a).

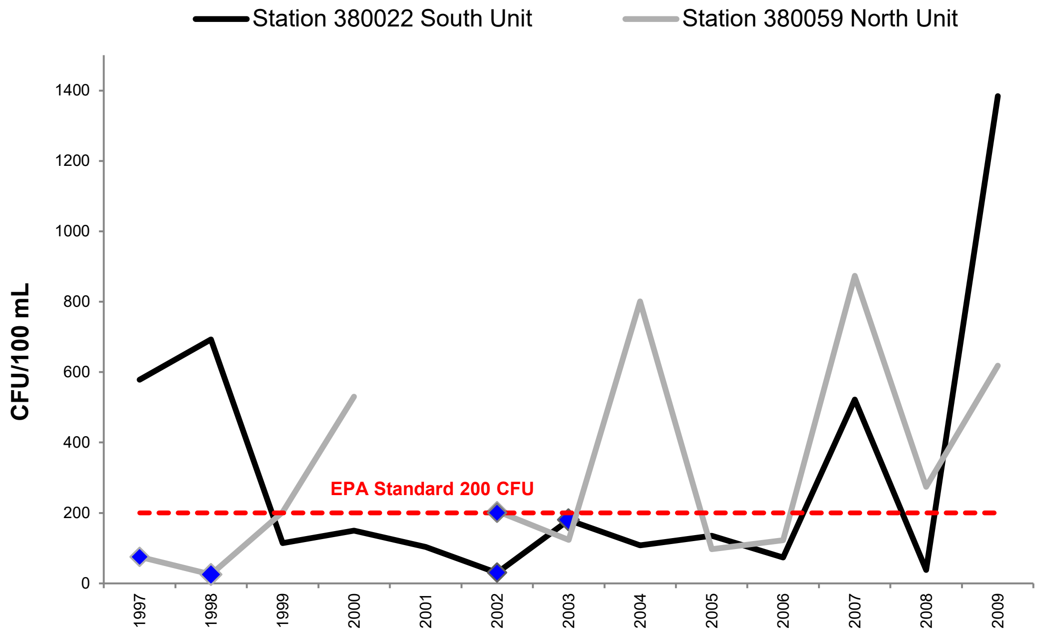

Figure 33. Mean annual fecal coliform concentrations (in CFU/100 mL) recorded at two monitoring stations in the Little Missouri River in the North and South Units of THRO, 1996-2009 (Source: EPA 2012c). Data points marked in blue represent averages based on only two observations. Note: NDDH monitoring station 380022 is located at Medora (South Unit) and NDDH monitoring station 380059 is located at Hwy 85 (North Unit).

Macroinvertebrates

In 2004 and 2005, Rust (2006) sampled benthic macroinvertebrates from five randomly chosen transects along three reaches in the Little Missouri River. Samples at each reach were pooled into one composite sample for that reach on each sample date; each reach was sampled on three different dates for a total of nine combined samples. Mean total abundance of macroinvertebrates found in the Little Missouri River in THRO was 25, with a range of 3 to 100 individuals collected across nine samples. Species richness was low, with an average of six species represented across nine samples (range = 2 to 12 species observed). The majority (47%) of these species were Diptera, while 24% represented Ephemeroptera, Plecoptera, and Trichoptera (EPT), the three pollution-sensitive orders of macroinvertebrates commonly used to assess water quality. The richness of species considered tolerant and intolerant of poor water quality was similar for all sampling in the Little Missouri during this time.

In August 2011, Dr. Lusha Tronstad collected macroinvertebrate samples at four sites along the Little Missouri River; three sites were sampled near Medora and one site was sampled in the North Unit near the Hwy 85 bridge. Examination of taxa diversity and abundance is currently underway (L. Tronstad, pers. comm., 2012).

pH

NPS (1997) reported that pH was measured 1,011 times at 52 monitoring sites throughout THRO from 1949 through 1996. Of these, three observations on the Little Missouri River were outside of the pH range (7.0-9.0) considered by state standards to be protective for freshwater aquatic life. Two observations were found to be above 9.0, while one was below 6.5. pH values in the Little Missouri River at Medora in the South Unit (monitoring sites THRO 0046 and 0050) ranged from 6.9-8.8, while values recorded in the North Unit (THRO 0005 and 0006) ranged from 4.3-9.23.

Rust (2006) collected 90 pH measurements on the Little Missouri River during the summer months of 2004 and 2005. During this sampling, pH levels ranged from 7.6 to 8.6. The median pH level during this time was 8.5 (no mean was given). All samples fell within the state criteria range for protection of aquatic life.

In August 2011, Dr. Lusha Tronstad collected pH samples at four sites along the Little Missouri River; three sites were sampled near Medora and one site was sampled in the North Unit near the Hwy 85 bridge. pH ranged from 8.41 to 8.49 (L. Tronstad, pers. comm., 2012). All samples were within the state criteria range for protection of aquatic life.

NDDH monitoring stations in the North and South Units recorded three to 10 pH measurements per year from 1996 through 2011. Figure 34 shows the mean annual pH at each monitoring station for the last 15 years. During this time, mean pH ranged from 7.8 to 8.7, and individual observations ranged from 6.9 to 10.7 (EPA 2012c). Although several individual measurements were at the lower and upper end of the thresholds protective of aquatic life, most observations and all annual mean values were well within the state criterion for protection of freshwater aquatic organisms ($\geq 7.0 - \leq 9.0$).

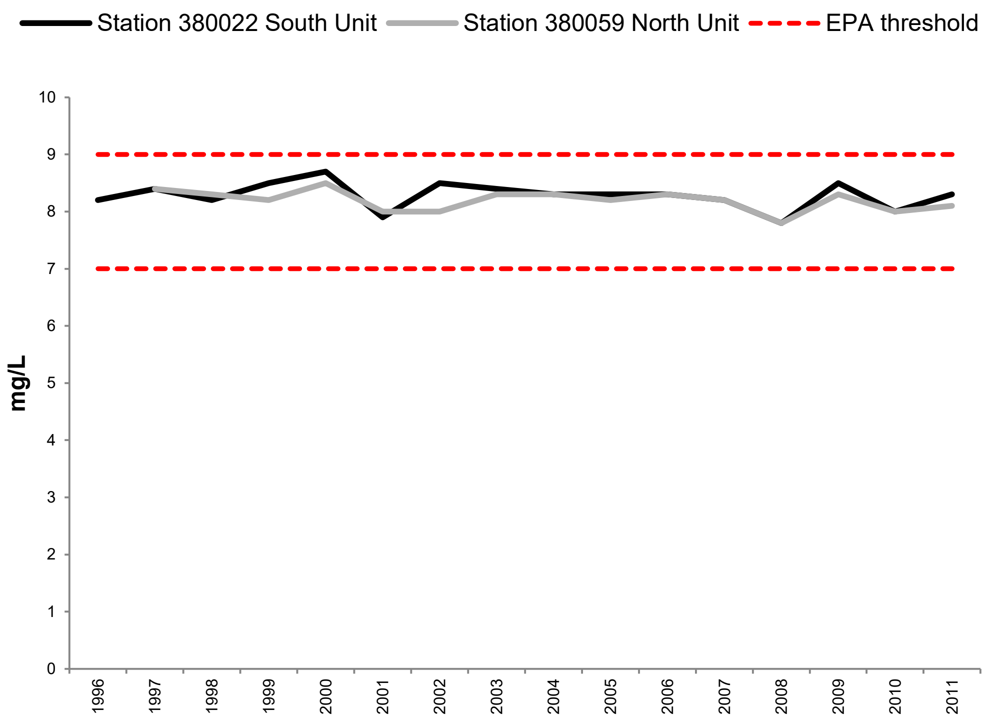

Figure 34. Mean annual pH (in Standard Units) recorded at two monitoring stations on the Little Missouri River in the North and South Units of THRO, 1996-2011 (Source: EPA 2012c). Note: NDDH monitoring station 380022 is located at Medora (South Unit) and NDDH monitoring station 380059 is located at Hwy 85 (North Unit).

<u>Specific Conductance</u>

NPS (1997) reported that specific conductance was measured 860 times at 39 monitoring sites throughout the study area from 1949 through 1996. Approximately half of these observations occurred from 1985 through 1996. Specific conductance values in the Little Missouri River measured at Medora (THRO 0046 and 0050) ranged from 300-4,200 µs/cm; median values were 1,655 µs/cm at THRO 0050 and 1,590 µs/cm at THRO 0046. Values recorded in the North Unit (THRO 0005 and 0006) ranged from 400-4,900 µs/cm; median values were 1,580 µs/cm at THRO 0005 and 1,630 µs/cm at THRO 0006.

Rust (2006) collected 90 measures for specific conductance on the Little Missouri River throughout THRO in the summer months of 2004 and 2005. Conductivity ranged from 167 to 1,684 µs/cm; mean and median conductivity were 1,289 and 1,303 µs/cm respectively. These data suggest that, during the time of sampling, the Little Missouri in THRO contained higher levels of dissolved inorganic solids.

In August 2011, Dr. Lusha Tronstad collected specific conductance samples at four sites along the Little Missouri River; three sites were sampled near Medora and one site was sampled in the North Unit near the Hwy 85 bridge. Specific conductance ranged from 2,421 to 2,617 µs/cm during this time (L. Tronstad, pers. comm., 2012), indicating higher levels of dissolved inorganic solids.

NDDH monitoring stations in the North and South Units recorded four to eight specific conductance measurements per year from 1996 through 2011. Figure 35 shows the mean annual specific conductance at each monitoring station for the last 15 years. During this time, mean conductivity ranged from 1,350 to 2,780 µs/cm, and individual observations ranged from 400 to 5,300 µs/cm (EPA 2012c). These measurements indicate high levels of dissolved inorganic solids in the Little Missouri River.

There is no established standard or threshold for specific conductance in waterways, mainly because conductivity can vary widely depending on the geology of the area through which a waterway flows as well as water temperature. Thus, high conductivity could be a natural characteristic of a waterway based on these factors. The highly erodible landscape in THRO likely contributes to the high conductivity conditions in the Little Missouri River. Despite this, the EPA suggests that waterways with conductivity greater than 500 µs/cm may be unsuitable for some species of fish or macroinvertebrates (2012a) and as a result, waterways with naturally high conductivity will likely support a different diversity of aquatic life.

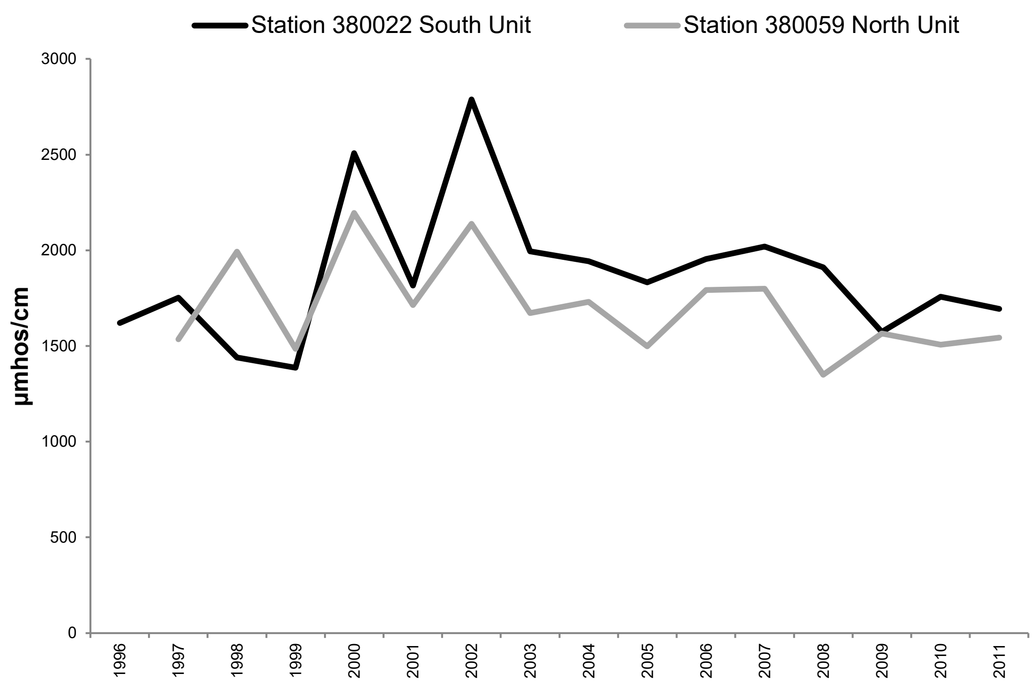

Figure 35. Mean annual specific conductance (in µmhos/cm) in the Little Missouri River in the North and South Units of THRO, 1996-2011 (Source: EPA 2012c). Note: NDDH monitoring station 380022 is located at Medora (South Unit) and NDDH monitoring station 380059 is located at Hwy 85 (North Unit).

<u>Water Temperature</u>

NPS (1997) reported that water temperature was measured 949 times at 16 monitoring sites in the study area from 1949 through 1996. Values on the Little Missouri at Medora (THRO 0046 and 0050) ranged from -1 to 30.5°C throughout sampling, while values in the North Unit (THRO 0005 and 0006) ranged from 0 to 28.5°C.

Rust (2006) collected 30 temperature measurements on the Little Missouri River in THRO during the summer months of 2004 and 2005. During this sampling, temperature measurements ranged from 12.1 to 29.2°C. Mean and median temperatures during this time were 20.5° and 20.6°C respectively.

In August 2011, Dr. Lusha Tronstad recorded water temperatures at four sites along the Little Missouri River; three sites were sampled near Medora and one site was sampled in the North Unit near the Hwy 85 bridge. Water temperatures ranged from 19.9 to 25.5°C (L. Tronstad, pers. comm., 2012). All measurements were within the state standards for Class II streams.

NDDH monitoring stations in the North and South Units recorded three to eight temperature measurements throughout each year from 1996 through 2011. In total, 182 observations were recorded: 97 observations were recorded in the South Unit at Medora and 85 were recorded in the North Unit. Temperature measurements during this time ranged from -0.2 to 28.3°C in the South Unit and -2.1 to 27.7°C in the North Unit.

It should be noted that temperature data presented here are not time-series data, meaning samples were not collected consistently on a daily or monthly basis. Thus, it can be difficult to determine the trends in high, low, and mean temperatures on a daily or monthly basis. This should be taken into account when considering overall condition.

Turbidity

NPS (1997) reported that turbidity was measured 182 times at 24 monitoring sites in the study area from 1971 through 1994. A total of 116 observations at 10 monitoring sites exceeded WRD screening criterion (50 NTU); 111 of these observations were collected on the Little Missouri River. Monitoring sites THRO 0005 and 0006 in the North Unit of the park recorded 84% of the observations that exceeded water quality criterion during this time, including the highest reported value of 15,000 NTU recorded in May 1974 at THRO 0005.

Rust (2006) collected six turbidity measurements in the Little Missouri River in THRO during the summer months of 2004 and 2005. Sample measurements ranged from 157 to 116,000 NTU. The mean and median turbidity measurements were 20,632 NTU and 1,430 NTU respectively. Rust (2006) described the Little Missouri as a turbid river based on these measurements, all of which exceeded the EPA criterion. Rust’s 2006 report represented the most recent data on turbidity for the Little Missouri River in THRO.

Threats and Stressor Factors

Runoff from agricultural, development, and ranching activities upriver from THRO can contribute to water quality impairment by increasing the concentration of various nutrients in the water (such as nitrogen, phosphorus, and ammonium) and levels of suspended sediment and dissolved solids in the waterway. Runoff from heavy precipitation events, coupled with the highly erosive badlands landscape that is characteristic of THRO, may also significantly contribute to elevated turbidity and total suspended and dissolved solids levels in the Little Missouri River.

Currently, there is a golf course located next to the Little Missouri River immediately upriver from Medora and THRO; fertilizer applications and runoff from this operation may contribute to higher than normal nutrient concentrations in the river. Rust (2006) measured concentrations of various nutrients in the Little Missouri River in THRO and found that nitrates exceeded North Dakota water quality standards in two of six samples (July 2004 and June 2005) and total phosphorus exceeded water quality standards in eight of nine samples (range=0.222-4.650 mg/L). Consistent monitoring of nutrients in the Little Missouri River would provide greater insight to managers about condition of the main water resource in the park.

Other potential anthropogenic sources of contaminants include wastewater effluent; mining and quarrying operations; and oil and natural gas development (NPS 1997).

Data Needs/Gaps

Currently, consistent monitoring of water quality parameters does not occur in THRO. The NGPN will initiate long-term monitoring of water quality and *E. coli* at the USGS Medora stream gaging station and at the USGS Watford City stream gaging station in 2013. It is possible to query (through STORET) and analyze data collected at water quality stations managed by other agencies, as was done for this assessment. While these monitors will provide access to the basic water quality parameters for understanding threats to human health, these parameters may not always meet park needs for understanding water quality for protection of freshwater aquatic organisms in THRO. Likewise, there are two active USGS stream gages adjacent to THRO, one at Medora and one located near the entrance to the North Unit on Hwy 85. However, since 2005, only one to two observations per year have been collected at these gages for temperature, specific conductance, and turbidity. Scant observations of parameters may not be representative of consistent conditions of the water quality throughout the course of each year.

In addition, consistent monitoring of aquatic macroinvertebrate populations in the park is lacking. The presence or absence of species that are tolerant and intolerant to pollution can be an indication of the condition of the water body and water quality. To date, Rust (2006) represents the most recent examination of the benthic macroinvertebrate community in the Little Missouri River in THRO that has been completed. In August 2011, Dr. Lusha Tronstad collected aquatic invertebrate samples at four sites along the Little Missouri River. Three sites were located upstream from the park entrance at Medora in the South Unit and one site was located in the North Unit at the Hwy 85 bridge. Examination of Dr. Tronstad's macroinvertebrate samples is still underway and results should be available in late 2012. Results from these two surveys could be used as baseline information to which the results from future monitoring efforts may be compared.

Overall Condition

Dissolved Oxygen

The project team defined the *Significance Level* for dissolved oxygen as a 3. Water quality monitoring data on the Little Missouri River across the last 60 years indicate that dissolved oxygen concentrations are consistently well above the EPA criterion for freshwater aquatic organisms. Thus, the condition of dissolved oxygen is currently of no concern (*Condition Level* = 0).

Fecal Coliform

The project team defined the *Significance Level* for fecal coliform as a 3. Fecal coliform measurements have fluctuated widely since 1996, with many observations far exceeding EPA and North Dakota standards for safe bathing. As of 2010, a large reach of the Little Missouri River bordering the South Unit of the park, as well as a large reach flowing through the North Unit, were listed as 303[d] impaired for fecal coliform contamination. Therefore, the condition of fecal coliform concentration is of high concern (*Condition Level* = 3).

Macroinvertebrates

The project team defined the *Significance Level* for macroinvertebrates as a 3. Rust (2006) compiled nine different composite samples from 2004 - 2005. Total abundance and total richness were both found to be low, and richness of species considered tolerant and intolerant of poor water quality were similar (Rust 2006). However, these data are nearly 10 years old and may not reflect current conditions in this stretch of river. Therefore, a *Condition Level* for macroinvertebrates was not assigned.

pH

The project team defined the *Significance Level* for pH as a 3. pH measurements consistently have remained between 7.5 and 8.5 since 1996. All but just a few observations have occurred well within the EPA and North Dakota criterion for protection of freshwater aquatic organisms. Therefore, the condition of pH is of no concern (*Condition Level* = 0).

Specific Conductance

The project team defined the *Significance Level* for specific conductance as a 3. In the last 15 years, mean conductivity ranged from 1,350 to 2,780 µs/cm, with some observations ranging as high as 5,300 µs/cm. These measurements indicate higher-than-typical levels of dissolved inorganic solids in the Little Missouri River. High conductivity can be a natural characteristic of a waterway based on the geology of the region and water temperature, and the highly erodible landscape in THRO likely contributes to the high conductivity conditions in the Little Missouri River. However, it is not clear if conductivity has always been this high or if increased development or other activities upriver from THRO contribute to the amount of dissolved solids in the river or if aquatic life in the river has been affected over time. Thus, the condition for specific conductance is of low concern (*Condition Level* = 1).

Temperature

The project team defined the *Significance Level* for temperature as a 3. Over the last 50 years, water temperature observations in the Little Missouri River have ranged from approximately 0 to 30.0°C. Temperatures fluctuate during summer and winter seasons, and some temperatures in the summer months may reach as high as 28 to 30°C for short periods of time. This may affect some fish species' ability to thrive in the Little Missouri River, but may suit other species better adapted to warmer water temperatures. Thus, the condition for water temperature is of low concern (*Condition Level* = 1).

Turbidity

The project team defined the *Significance Level* for turbidity as a 3. Turbidity observations through 1994 indicated measurements consistently above EPA criterion. Likewise, Rust's (2006) observations indicated that the Little Missouri River was highly turbid, with all observations exceeding EPA criterion. Rust's (2006) observations represent the most recent turbidity monitoring for the park and are nearing 10 years old. Thus, these measurements may not represent the current conditions for turbidity in the Little Missouri River. For these reasons, a *Condition Level* for turbidity was not assigned.

Weighted Condition Score
The *Weighted Condition Score* for water quality in THRO is 0.333, indicating water quality is in good condition with a stable trend.

Water Quality

Measures	SL	CL
Dissolved oxygen	3	0
Fecal coliform	3	3
Macroinvertebrates	3	N/A
pH	3	0
Specific conductance	3	1
Temperature	3	1
Turbidity	3	N/A

WCS = 0.333

4.13.6 Sources of Expertise
Dr. Lusha Tronstad, Invertebrate Zoologist, Wyoming Natural Diversity Database

4.13.7 Literature Cited

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4.14 Soundscape

4.14.1 Description

The definition of a soundscape in a national park is the total ambient sound level of the park, comprised of both natural ambient sound and human-made sounds (NPS 2000). The National Park Service's mission is to preserve natural resources, including the natural soundscape associated with the national park units. According to a survey conducted by the NPS, many visitors come to national parks to enjoy, equally, the natural soundscape and natural scenery. Intrusive sounds are of concern to park visitors, as they detract from their natural and cultural resource experiences (Gramann 1999). The General Management Plan for THRO identifies noise pollution as a resource management concern for the park (NPS 1986).

4.14.2 Measures

- Occurrence of human-caused and unnatural sounds
- Natural ambient sound level

4.14.3 Reference Conditions/Values

The reference condition for soundscape in THRO is a natural experience, or a soundscape not influenced by unnatural sounds.

4.14.4 Data and Methods

No quantitative soundscape data are currently available for THRO. This assessment relies on qualitative descriptions of non-natural sounds present in the park.

4.14.5 Current Condition and Trend

<u>Occurrence of Human-caused and Unnatural Sounds</u>

Oil and gas developments are very common on public and private lands around and adjacent to THRO, creating a major source of unnatural sounds in the park, which can carry for miles under favorable atmospheric conditions (NPS 1991). Drilling also creates extra vehicle traffic in the area, generating additional non-natural sounds. At lower densities, these activities can be mitigated by restricting oil drilling and trucking to periods of low visitor use and locating future oil wells and roads behind ridges or slopes (NPS 1991). However, development in the THRO area has now become so dense that mitigation may no longer be possible (C. Sexton, pers. comm., 2012).

Rosendahl et al. (2002) conducted a visitor survey at THRO in 2001, in which one question asked visitors to rate the effect of noise from outside park boundaries on their experience of the park. A total of 13.3% of respondents said that outside noise detracted from their experience, ranging from 'slightly detracted' to 'very seriously detracted'; the remaining 86.7% of respondents were unaffected by noise (Rosendahl et al. 2002).

<u>Threats and Stressor Factors</u>

Oil drilling and other forms of development are threats to the natural soundscape in THRO. The park is located in the Williston Basin, which is a highly productive oil and gas development area in western North Dakota (KellerLynn 2007). Hundreds of oil wells are located on the public and private lands surrounding the park. Drilling occurs 24 hours a day for weeks at a time, creating noise that can carry for miles and disrupt both wildlife and humans within the park (NPS 1991). Unnatural noises can arise from a variety of mining activities related to oil and gas development, including exploration, drilling, blasting, stripping (overburden removal), hauling, maintenance, and beneficiation (KellerLynn 2007).

Road traffic is another threat to the natural soundscape of THRO as Interstate 94 passes through a portion of the South Unit and Highway 85 passes through the North Unit. Trains frequently pass through the Little Missouri River valley, introducing unnatural noise into the park soundscape. The park staff is particularly concerned with traffic noise near the Elkhorn Ranch site which is historically significant as Theodore Roosevelt's "home ranch" and treasured for the peace and solitude it once offered. The soundscape of the ranch is threatened by traffic noise as well as oil development in the area (NPS 2010). Drilling recently began near Elkhorn Ranch and many development sites are now visible from the entrance roads (L. Richardson, pers. comm., 2012).

Data Needs/Gaps

Acoustic monitoring is needed in order to quantify levels of ambient and unnatural sounds in and around THRO. Visitor surveys could be repeated to determine if visitor experience has been impacted by noise from increased development outside the park. In August 2012, a park request was approved for technical assistance in monitoring energy development impacts on THRO's natural soundscapes. This assessment could provide insight into current impacts to soundscape and identify long-term needs for soundscape management in the park.

Overall Condition

Occurrence of Human-caused and Unnatural Sounds

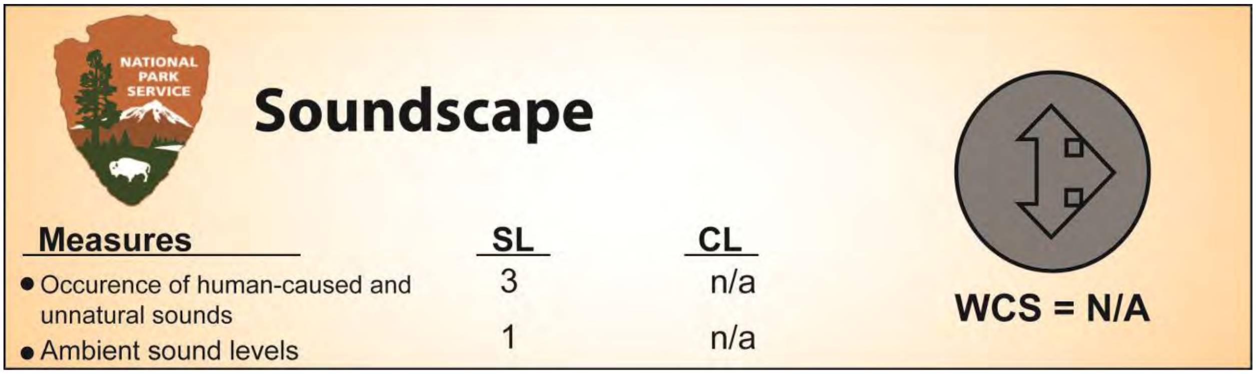
During initial scoping meetings, THRO staff assigned the measure of human-caused and unnatural sounds a *Significance Level* of 3. This indicates that the measure is vital to define condition of this component. Since no acoustic monitoring has been conducted in the park, a *Condition Level* cannot be assigned.

Natural Ambient Sound Levels

THRO staff assigned the measure of natural ambient sound levels a *Significance Level* of 1, indicating that the measure is of minimal use in defining the condition of this component. Natural ambient sound levels are not a concern related to soundscape, but rather provide a baseline from which to measure unnatural sounds. Because no data have been collected on the ambient sound levels in the park, a *Condition Level* cannot be assigned.

Overall Condition

A *Weighted Condition Score* (WCS) cannot be assigned without data on the component measures.



4.14.6 Sources of Expertise

Chad Sexton, Geographic Information Systems Analyst, THRO
Laurie Richardson, Botanist, THRO

4.14.7 Literature Cited

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4.15 Dark Night Skies

4.15.1 Description

A lightscape is a place or environment characterized by the natural rhythm of the sun and moon cycles, clean air, and of dark nights unperturbed by artificial light (NPS 2007). The NPS directs each of its units to preserve, to the greatest extent possible, these natural lightscapes (NPS 2006). Natural cycles of dark and light periods during the course of a day affect the evolution of species and other natural resource processes such as plant phenology (NPS 2006, 2007). Several species require darkness to hunt, hide their location, navigate, or reproduce (NPS 2007). In addition to the ecological importance of dark night skies, park visitors expect skies to be free of light pollution and allow for star observation.

4.15.2 Measures

- V magnitude

- Ambient light pollution

4.15.3 Reference Conditions/Values

The reference condition for THRO is the absence of anthropogenic light pollution, which is in accordance with NPS management policies.

4.15.4 Data and Methods

No dark night skies data have been summarized by the NPS in THRO. The NPS Night Sky Team visited the North Unit of the park (near the Oxbow Overlook), but no data or summary report are available. Albers and Duriscoe (2001) assigned a Schaff scale score to the park, but data used in this assignment were not collected in the park and did not utilize V magnitude measurements.

4.15.5 Current Condition and Trend

<u>Darkness - V Magnitude</u>

The NPS uses a charged coupled device (CCD) digital camera connected to a robotic mount and laptop computer to conduct night sky assessments and to determine darkness of park nightscapes (NPS 2007). A mosaic image of the entire night sky is created by stitching together multiple short exposure images (NPS 2007). The images are filtered using a green filter to approximate human night vision sensitivity, and the data are calibrated using the known brightness of certain stars. The resulting data are in units of V magnitude, which is an astronomical brightness system (NPS 2007). Weather conditions and phases of the moon limit the number of suitable nights for measuring V magnitude (NPS 2007). Data from the Night Sky Team's visit to THRO are not yet available for this assessment.

<u>Ambient Light Pollution</u>

NPS defines ambient light pollution as "the illumination of the night sky caused by artificial light sources, decreasing the visibility of stars and other natural sky phenomena" (NPS 2007). Unfortunately, ambient light pollution has not been recorded or monitored in THRO.

Schaff Scale Scores

Albers and Duriscoe (2001) developed a GIS that evaluated the nighttime visibility of NPS units. This model used the Schaaf scale, which is a 1 through 7 scale with a value of 1 representing extreme light pollution and a value of 7 representing pristine skies. Albers and Duriscoe (2001) overlaid Schaff scale score maps with park boundaries, and then extracted the mean Schaff score for the entire area of a given park. THRO received a Schaaf score of 7.00 out of 7.00; this score represents pristine night sky conditions (Albers and Duriscoe 2001). This value must be interpreted with caution though, as the original Schaff scale maps were from 1991 and no park-specific data were used in the calculation. In addition, this model is not sensitive to small amounts of light pollution and tends to over-predict sky quality in dark locations. The clear air and high altitudes of the western United States make distant cities more visible (C. Moore, pers. comm., 2011).

Threats and Stressor Factors

Light pollution is highest in areas with high human densities and can include glare, the use of light or intrusion of light in areas not requiring lighting, and any other disturbance of the natural nighttime lightscape (NPS 2007).

The major negative impact to THRO's dark night environment stems from the nearby development from oil and gas facilities (NPS 1991). THRO lies within one of the largest structural and sedimentary basins in North America. The basin has been active in oil and gas development since the mid 1970s. In the past 20-30 years, many wells have been developed outside of the park boundaries on public and private lands; some of the wells are within a few hundred feet of THRO's boundary (NPS 1991). In 2008, the National Parks Conservation Association (NPCA) identified THRO as one of ten National Parks most threatened by pollution from new coal-fired plants (NPCA 2008). The lights associated with these structures have the potential to affect THRO visitor's night sky viewing experience. KellerLynn (2007, p. 6) stated,

> Energy development on lands adjacent to the park is negatively affecting air and water quality; scenic views; dark night skies; wildlife and plants, including threatened and endangered species; cultural resources; and natural quiet.

Another threat also associated with oil and gas development is the large scale "flaring" or burning of waste natural gas and other gaseous compounds at production wells (Sexton, pers. comm., 2012). This practice has dramatically increased near the park's boundaries in the past two years and represents a major threat to the quality and integrity of the dark night skies in the park.

Another source of point-source light pollution is the city of Medora, ND. Medora is located on the South Unit's southern border and is a busy tourist hub location during the summer months. Shop lights, traffic lights, and traffic along U.S. Interstate 94 are all sources of light pollution that may influence the overall quality of darkness in THRO.

In addition to human sources of light, airborne particulates also affect night sky brightness (NPS 2007). Chapter 4.12 of this document provides detailed information about airborne particulates in THRO.

Data Needs/Gaps

There has been no collection of baseline data at THRO in regards to dark night skies. Without this data, an assessment of the condition of the night skies cannot be completed. An investigation into the effects of “flaring” operations is also necessary; Bill Whitworth, THRO Chief of Resource Management, has indicated that plans for such an investigation are currently in development (pers. comm., 2012).

Overall Condition

V Magnitude
During initial scoping meetings, THRO staff assigned the measure of V magnitude a *Significance Level* of 3. However, due to the lack of appropriate data, a *Condition Level* for V magnitude cannot be assigned at this time.

Ambient Light Pollution
Ambient light pollution was also assigned a *Significance Level* of 3. Overall, there is insufficient data describing ambient light pollution. Albers and Duriscoe (2001) rated the night skies in the park as 7.00 out of 7.00 in terms of schaff scale scores, which is the only quantitative estimate of dark night skies for THRO. However, this rating must be taken with caution as no measurements were taken within THRO. SMUMN GSS did not assign this measure a *Condition Level* as there is insufficient data for such an assessment.

Weighted Condition Score
Because SMUMN GSS could not assign condition levels to the component, no *Weighted Condition Score* was assigned.

Dark Night Skies

Measures	SL	CL
• V Magnitude	3	n/a
• Ambient Light Pollution	3	n/a

WCS = N/A

4.15.6 Sources of Expertise
Bill Whitworth, THRO Chief of Resource Management.
Chad Moore, NPS Night Sky Program Manager.
Chad Sexton, THRO GIS Analyst

4.15.7 Literature Cited

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4.16 Surface Water Availability

4.16.1 Description

THRO is located in the semi-arid region of the Northern Great Plains, which makes surface water an important and scarce resource in the park (Berkley et al. 1998). The Little Missouri River is the main surface water resource in the park, flowing through 23 km of the North Unit, 14 km of the South Unit, and along Elkhorn Ranch (NPS 1994). The river's flow varies greatly, depending on the season and weather conditions (NPS 1994). Tributaries of the Little Missouri River within THRO include Knutson, Paddock, Jones, Jules, and Squaw Creeks, many of which are intermittent streams (Berkley et al. 1998).

Seeps and springs are another source of surface water in THRO. These sources provide water for wildlife in the park's backcountry (Berkley et al. 1998, Photo 23). Flow rate and chemical characteristic data have been collected for 10 developed springs and 15 flowing wells in the park, while an innumerable number of other seeps and springs have not been inventoried or studied (NPS 1994). According to Berkley et al. (1998), little information and data is available for surface water features (springs and seeps) in THRO, including surface and ground water quantity and quality.

Photo 23. Wannagan Seeps in THRO's South Unit (photo by Nathan King).

4.16.2 Measures

- Precipitation
- Prevalence (location) of seeps and springs
- Flow rates of man-made water developments

4.16.3 Reference Conditions/Values

The reference condition for precipitation is the historic period of record (pre-2000) for the two weather stations near THRO. Reference conditions could not be established for prevalence of seeps and springs or flow rates of man-made water developments.

4.16.4 Data and Methods

Precipitation data acquired by the High Plains Regional Climate Center (HPRCC) was analyzed by decadal monthly average. Weather stations at Medora and Watford City, North Dakota (near THRO's South and North Units respectively), were analyzed to show a regional perspective of precipitation.

Many of the park's seeps and springs have been developed to provide water for wildlife. These locations were provided by the park in a GIS layer. Several additional undeveloped springs were identified on USGS topographic quad maps of the park from 1997. These locations were digitized to create a map of all known springs and seeps in the park.

4.16.5 Current Condition and Trend

<u>Precipitation</u>

The average annual precipitation in western North Dakota is 38 cm (15 in) (Berkley et al. 1998). Around THRO precipitation occurs quickly in rain showers, with some areas receiving up to several inches of rain per hour (KellerLynn 2007). About 50% of the total annual precipitation falls between May and July (Berkley et al. 1998). No significant change in precipitation has been detected at weather stations near THRO during the period of record (Figure 36 and Figure 37) (HRPCC 2011).

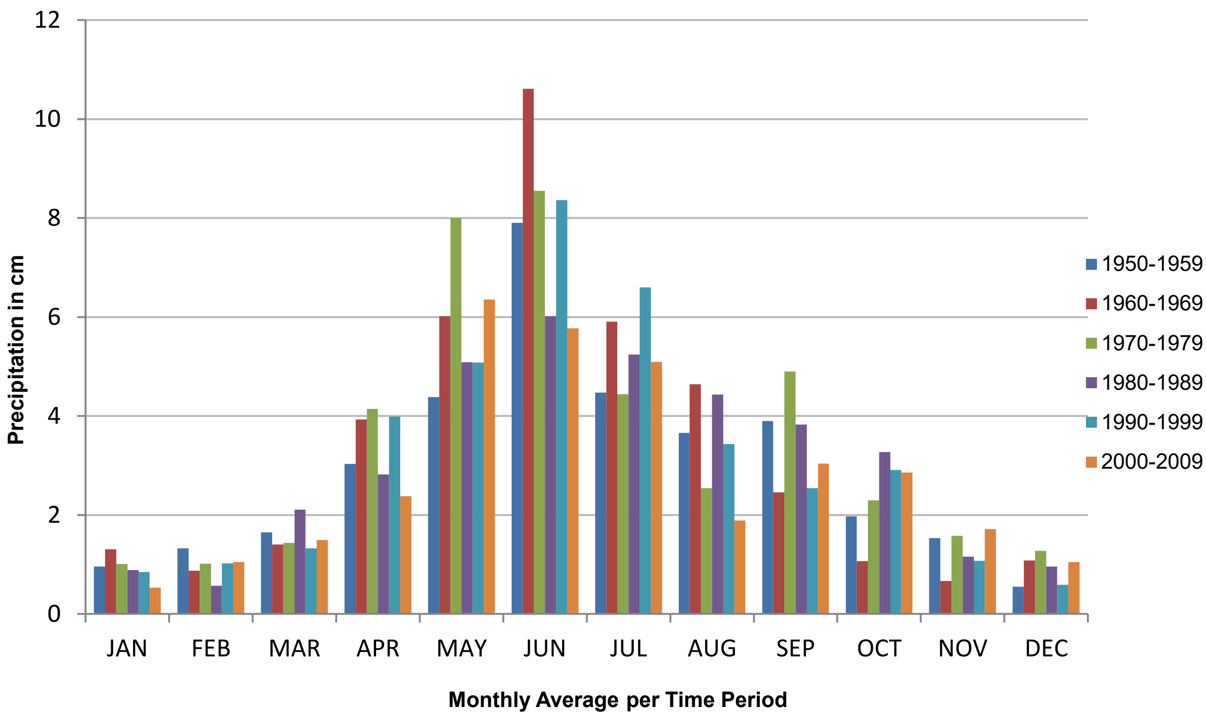


Figure 36. Monthly average precipitation at Medora, North Dakota per decade from 1950-2009 (HPRCC 2011). Months with more than five days missing were excluded from monthly averages (based on methodology from the High Plains Regional Climate Center).

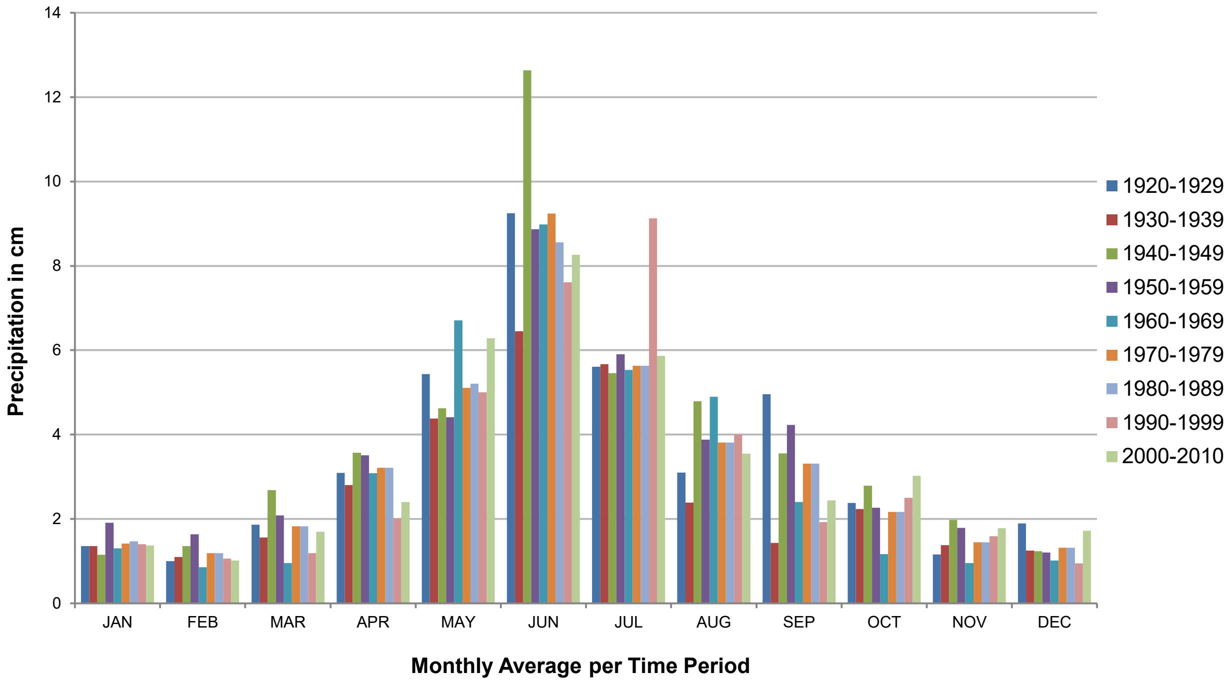


Figure 37. Monthly average precipitation at Watford City, North Dakota per decade from 1920-2010 (HPRCC 2011). Months with more than five days missing were excluded from monthly averages (based on methodology from the High Plains Regional Climate Center).

Prevalence of Seeps and Springs

The locations of 14 seeps and springs identified in park GIS data and on USGS topographic maps are shown in Plate 23 and Plate 24. Five of these springs are in the North Unit and nine are in the South Unit. Most of these water sources are in the western portions of both the North and South Units. Ground-truthing may be necessary to confirm that these springs are still producing water. The presence of water at some springs may depend on precipitation; in dry years, groundwater recharge and therefore the water table may decline, causing springs and seeps to dry up.

Flow Rates of Man-made Water Developments

Man-made water developments in the park include drilled wells and natural springs and seeps developed to capture water for animals. Most of these developments occurred before the park's establishment and were meant to provide reliable water for livestock and, in some cases, for fire protection (Oehler and Sexton 2010). Some were developed later by the NPS to provide water for wildlife. A typical spring-fed water development is shown in Figure 38.

Photo 24. Collection tank at Tomamichael Well (NPS photo).

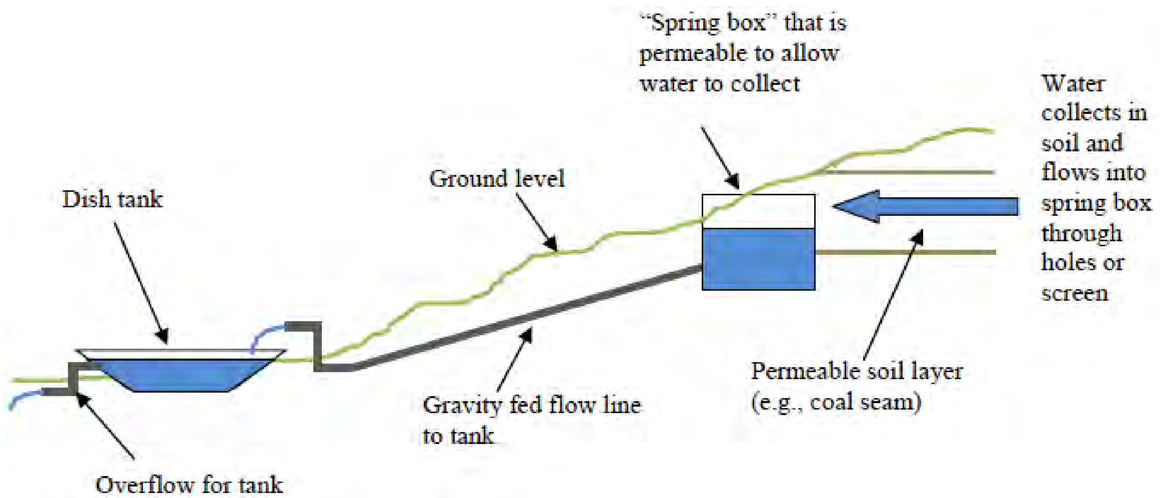


Figure 38. Diagram of a typical spring or seep fed water development in THRO (Oehler and Sexton 2010).

Flow rate data is available for several springs or wells in the park that have been developed to provide water for wildlife (Table 34). However, the majority of this data is from the 1980s, with only a few measurements taken from 2007-2009. Flow rates generally vary depending on precipitation and distance to remote water sources (Oehler and Sexton 2010). Most park water developments have not been maintained since the 1990s or earlier due to the considerable cost of maintenance, and many have fallen into disrepair. Spring boxes, pipes, and tanks may be leaking, allowing water to escape from the collection system before reaching the tank. As a result, recent measurements may not be comparable to historic data when these developments were maintained, since flow rate measurements are typically taken at collection tanks (C. Sexton, pers. comm., 2012). A number of these developments occur in the Wilderness Area of the park (Plate 23 and Plate 24) and may be removed when they stop functioning in an effort to restore the wilderness character of the park, unless they serve "a compelling need" for wildlife or visitors (M. Oehler and C. Sexton 2010, Photo 25).

Photo 25. Non-functional water developments at Sheep Pasture Spring in the South Unit's wilderness area (NPS photo).

Table 34. Flow rates (in gallons per minute) from man-made water developments in THRO over time (Berkley et al. 1998, Oehler and Sexton 2010, unpublished data).

Spring/Well	Unit	1982	1983	1985	1986	1988	1990	1992	2007	2008	2009	Status
Achenbach Spring	North		30		40					1.9	0.06	
Stevens Spring	North				15	12	9	13		0.02	0.01	
Hagen Spring	North				45	23	30	15		1.1	0.8	
Overlook Spring	North		300		300	300		300				
Ekblom Well	South		60	68		103			1.6	1.9		Operational
Tomamichael Well	South	6	6	5		5			0.01	0.1	0.08	Functional, in need of maintenance
Rough Rider Well	South	78		68	68	64						
SE Corner Spring	South	0		37		28	24	17				Seep is active, developments non-functional
Sheep Creek Well	South			152		180						
Sheep Butte Spring	South	15	75	7		10		7				Seep active, but developments non-functional
Mike Auney Well	South	138	30	42		126				0.2	0.07	Operational
Lone Tree Spring	South	30	60	35	35	16		13	0.4			Seep active, but developments non-functional
Big Plateau Spring	South	60	30	19	19	15		15				Active natural seep
Boicourt Spring	South	12	4	6	6	2		7				Operational
VA Well	South		15	11		10		6				Ceased functioning after 2004
Jones Creek Well	South	168	180	146		140				0.2	0.5	Operational
Sheep Pasture Spring	South											No apparent flow

Threats and Stressor Factors

Water Retention in Stock Dams
Water retention in stock dams (in upriver tributaries and draws) can change the flow and flooding patterns of the Missouri River. There is no current literature explaining the effects of water retention in stock dams in upriver tributaries and draws of the Missouri River.

Ice Jamming (impacts to stream banks and vegetation)
Ice jams are frequent during the spring melting season (Everitt 1968, Miller 2005) and were responsible for the spring flooding of the Little Missouri River in 2009 (Macek-Rowland and Gross 2011). The Little Missouri River is unusual in that it flows to the north. As weather to the south of North Dakota warms, snow and ice flows downstream to the colder north, where the water is still frozen (Macek-Rowland and Gross 2011). The snow and ice flowing to the north meets a frozen channel and an ice jam forms. River stage rises and the flow spills over the banks (Macek-Rowland and Gross 2011). These high spring flows can undercut the river bank, leading to channel instability (Miller 2005). Cottonwood seedlings and saplings can be destroyed by ice and major floods (Friedman et al. 1998); however, scouring and sand bar development due to flooding can also create new substrates for cottonwood development.

Changes in Flood Regime
High-flow events causing significant floodplain destruction have occurred every 5-10 years on the Little Missouri River (Miller and Friedman 2009). Over the last century, there has been a reduction in the magnitude of peak flows on the Little Missouri River (Miller and Friedman 2009). Since the Little Missouri River is largely unregulated, climatic factors such as temperature and precipitation are thought to be the primary drivers in the overall reduction of peak flow magnitude during the 20th century. Flooding is discussed further in section 4.3 of this assessment.

Data Needs/Gaps
A park-wide inventory of springs and seeps would identify additional surface water sources and regular monitoring could help to determine if spring flows are changing over time. A study of the relationship between coal seams, ground water, and surface water would also be beneficial. Research investigating the number, location, and extent of man-made developments (e.g., stock dams) in the upstream tributaries of the Little Missouri River would be a first step in better understanding how these might be affecting surface waters in THRO. Quantifying the impact of these developments upon water flow, while more difficult, would help managers understand the severity of this threat to park surface water availability. A survey of groundwater use in the region could also be helpful in understanding impacts on the water table, which may influence the supply of water for seeps and springs.

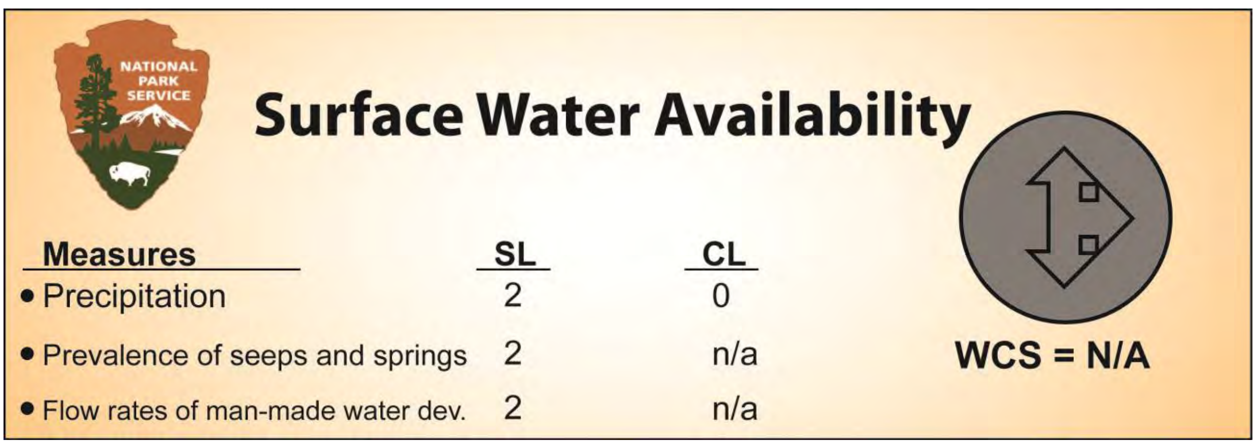
Overall Condition

Precipitation
The *Significance Level* for precipitation was a 2. No significant changes in precipitation have been observed at the two weather stations near the park. The *Condition Level* for precipitation is 0, indicating the component is of no concern.

Prevalence (locations) of Seeps and Springs
The *Significance Level* for prevalence of seeps and springs was a 2. Information regarding the locations of seeps and springs in the park is somewhat limited. The full extent of these features throughout the park may be difficult to determine, as the park's geology allows seeps to develop across the landscape (C. Sexton, pers. comm., 2012). Since the data available for spring and seep locations are not conducive to an analysis of change in prevalence over time, a *Condition Level* could not be assigned for this measure.

Flow Rates of Man-made Water Developments
The *Significance Level* for flow rates of man-made water developments was a 2. Flow rate data for the park is sporadic and recent measurements are not directly comparable to historic data since these developments are no longer maintained. Many developments, particularly those in wilderness areas, may be removed when they cease functioning. Therefore, a *Condition Level* could not be assigned.

Weighted Condition Score
Since *Condition Levels* could not be assigned for two of this component's three measures, a *Weighted Condition Score* was not calculated. The overall condition of surface water availability is unknown.



4.16.6 Sources of Expertise
Chad Sexton, Geographic Information Systems Analyst, THRO
Jeff Hughes, Hydrologist, NPS
Eleanor Griffin, Hydrologist, USGS
Jonathan Friedman, Research Hydrologist, USGS

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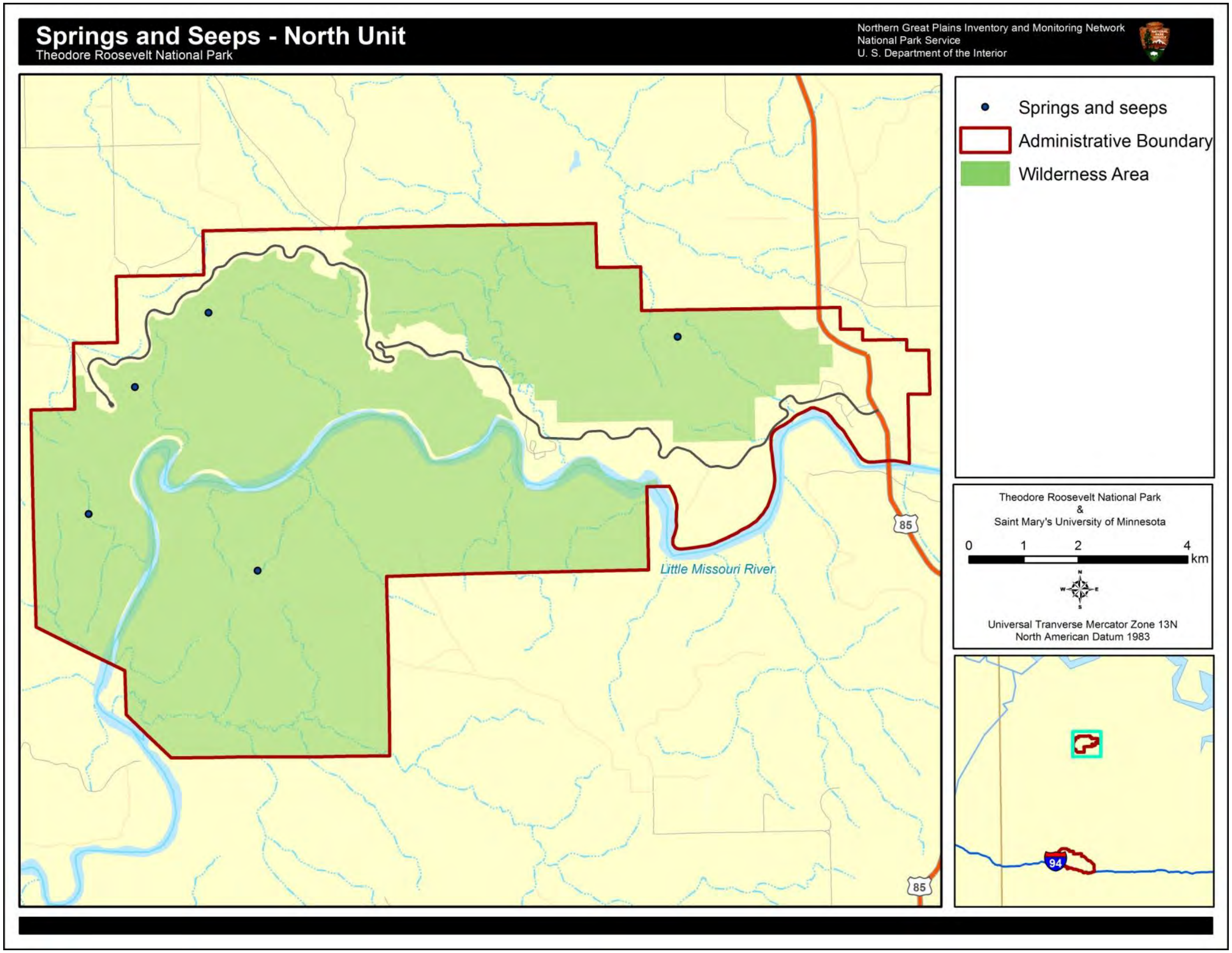

Plate 23. Known spring and seep locations in the North Unit of THRO.

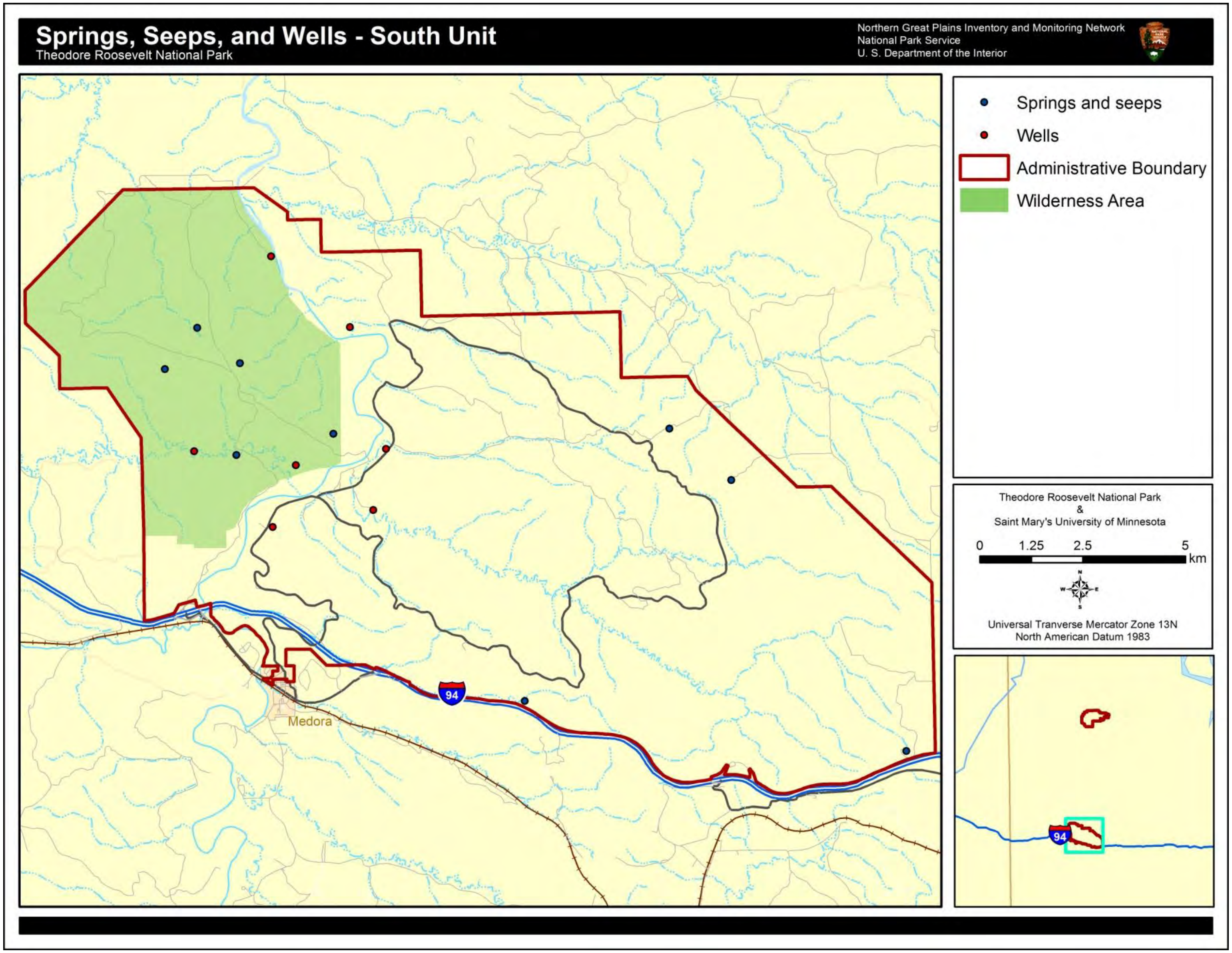

Plate 24. Known spring, seep, and well locations in the South Unit of THRO.

4.17 Paleontological Features

4.17.1 Description

Paleontological features (i.e., fossils) are "the remains, imprints and traces of once living organisms preserved in the earth's crust" (DOI 2000, p. 13). These features are vital in providing insight to the history of life on earth (e.g., mass extinctions, genealogical relationships between species), and how life responds to changing conditions, including effects of anthropological caused changes, as well as effects on biological diversity and ecological structure due to environmental changes (DOI 2000). Fossils also provide evidence of physical changes to the earth over time such as changes in the positions of continents, climate change cycles, and mountain building (DOI 2000).

Fossils are found in both of THRO's primary exposed rock formations: the Bullion Creek Formation and the overlying Sentinel Butte Formation (Hoganson and Campbell 1997). These formations were formed during the Paleocene Epoch (60-55 Ma), when sediments carried from the uplifting Rocky Mountains were deposited on the Central Plains by fluvial and lacustrine systems, forming generally flat beds (Figure 39). For example, the Bullion Creek Formation, only exposed in the South Unit of THRO, consists of poorly lithified claystones, mudstones, and siltstones, with minor amounts of fine-grained sandstone and lignite. The formation is yellow and tan in color and approximately 61 m (200 ft) thick (Hoganson and Campbell 1997). The Sentinel Butte Formation is found in both the South and North Units of the park. It is composed of similar lithologies as the Bullion Creek Formation; however, it is gray to brown in color. This formation can be greater than 213 m (700 ft) thick in the North Unit and 91 m (300 ft) thick in the South Unit. Generally, the contact between these two formations can be recognized by a pink rock layer identified as the HT Butte clinker (Hoganson and Campbell 1997).

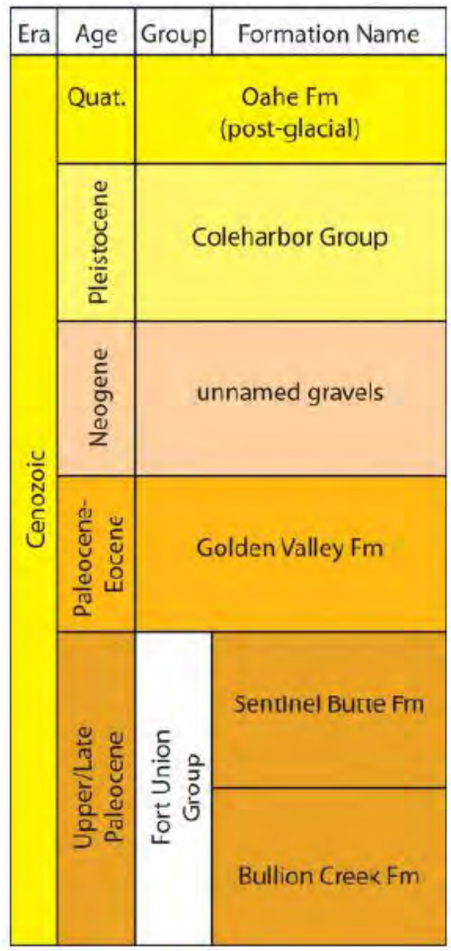

Figure 39. Schematic stratigraphic column of rock formations in THRO (from Tweet et al. 2011).

The fossils in THRO indicate that the historical (Paleocene) climate was subtropical with hot and humid swampy lowlands. There were periods with well-established forests composed of ferns, cycads, figs (*Ficus* spp.), bald cypress (*Taxodium* spp.), *Ginkgo*, katsura (*Cercidiphyllum* spp.), *Magnolia*, sycamore (*Platanus* spp.), and dawn redwoods (*Metasequoia* spp.) (Hoganson and Campbell 1997). These forests provided an extensive habitat and food source for insects and birds. Rivers, streams, ponds, and swamps provided habitat for invertebrates such as pill clams, mussels, snails, insects, and minute crustaceans, as well as predators such as crocodiles (*Borealosuchus*), alligators (genus not identified), and *Champsosaurus* (crocodile-like creatures). The swampy lowland forests supported mammals similar to present-day lemurs (Hoganson and Campbell 1997).

The NPS recognizes paleontological sites as a sensitive resource in need of protection. On 30 March 2009, the Omnibus Public Land Management Act of 2009 was passed into law. Subtitle D, the Paleontological Resources Preservation Act, mandates the Secretaries of the Interior and Agriculture to implement a paleontological resource management program on federal lands, with the requirements to increase protection, enhance management tools, and increase scientific and public understanding of fossil resources (Tweet et al. 2011).

4.17.2 Measures

- Distribution and abundance of paleontological resources
- Protection of collections

4.17.3 Reference Conditions/Values

A reference condition has not been determined for this component.

4.17.4 Data and Methods

Hoganson and Campbell (1997) conducted a detailed study of 25.9 km^2 (10 mi^2) of THRO (about 1/10 of the entire park area), and mapped 400 fossil sites. Fossils collected during this study are housed at the North Dakota Heritage Center in Bismarck and cataloged in their North Dakota State Fossil Collection (J. Hoganson, pers. comm., 2012).

The NPS Geologic Resource Evaluation (GRE) Program conducted scoping meetings with park staff and geologic experts, with the purpose of reviewing available geologic maps and discussing geologic issues, features, and processes. Then, using a GIS data model, the team converted geologic maps identified in the scoping meeting into digital data sets. Finally, a park specific report was produced (KellerLynn 2007) to provide the park with an overview of the geology and related resource management issues.

Tweet et al. (2011) prepared a paleontological resource summary report for the parks of the NGPN, based on an extensive literature review and interviews with park staff and professional geologists and paleontologists in the region.

4.17.5 Current Condition and Trend

<u>Distribution and Abundance</u>

The presence of fossils in THRO has been known for many years; however, up until the 1990s, the documented diversity was limited to the abundant petrified wood. In 1994, the park entered into a cooperative agreement with the North Dakota Geological Survey "to identify, map and assess the significance of fossils and paleontological sites in the park, for the intent to use that information in overall resource management planning" (Hoganson and Campbell 1997, p. 1). This survey effort mapped 400 fossil sites in a 26 km^2 (10 mi^2) study area of THRO, with an average of 40 fossil sites per 2.6 km^2 (1 mi^2). They concluded that the Bullion Creek and Sentinel Butte Formations were relatively fossiliferous, predominantly consisting of freshwater mollusk fossils (Hoganson and Campbell 1997). Petrified wood, located at several levels within the Bullion Creek and Sentinel Butte formations, remains the most abundant fossil in the park, and has proven impractical to map completely. Poor preservation of these remains makes it difficult to determine the original tree taxa; however, it is thought that most trees were conifers of the genus *Metasequoia* (Tweet et al. 2011). Vertebrate fossils are found throughout the park, located in both the Bullion Creek and Sentinel Butte Formations. The most abundant vertebrate fossil was the aquatic reptile *Champsosaurus* (Tweet et al. 2011). Table 35 contains a list of fossils documented in THRO, along with the formation in which they were found.

Table 35. Fossils at Theodore Roosevelt National Park (Hoganson and Campbell 1997, as cited in KellerLynn 2007).

Fossil type	Formation
Petrified wood	Bullion Creek and Sentinel Butte
Freshwater mollusks	Bullion Creek and Sentinel Butte
Ostracods (small bivalved crustaceans)	Sentinel Butte
Coleoptera (beetle)	Sentinel Butte
Leaves (e.g., angiosperms and ferns)	Bullion Creek and Sentinel Butte
Seeds (e.g., *Cercidiphyllum* [katsura tree])	Bullion Creek and Sentinel Butte
Twigs, roots, and branches	Taylor bed of the Golden Valley Formation
Champsosaurs (crocodile- like creature), including common *Champsosaurus* and extremely rare *Simoedosaurus*	Bullion Creek and Sentinel Butte
Crocodiles (probably *Borealosuchus*)	Bullion Creek and Sentinel Butte
Alligators	Sentinel Butte
Turtles (*Protochelydra* - chelydrid [snapping turtle], and *Plastomenus* - plastomenid [soft- shelled turtle])	Sentinel Butte
Fish (*Amia* [bowfin] and *Lepisosteus* gar.)	Bullion Creek and Sentinel Butte
Giant salamander (*Piceoerpeton*)	Sentinel Butte
Plesiadapis (lemur- like mammal)	Sentinel Butte
Bison	Quaternary alluvial and colluvial deposits

Photo 26. Fossils from the Sentinel Butte Formation (l-r): A leaf, a crocodile scute and tooth, and petrified wood (photos from Hoganson and Campbell 1997).

The Wannagan Creek Quarry (part of the Bullion Creek Formation), just west of the South Unit of the park, has a diverse fossil assemblage. The floral record is composed of spores, pollen (Melchior and Hall 1983, as cited in Tweet et al. 2011), and over 100 taxa including both aquatic and terrestrial plants (Erickson 1982, 1991, 1999, as cited in Tweet et al. 2011). Animal fossils include invertebrates (e.g., mollusks and insects), fish, amphibians, reptiles, and mammals (e.g., marsupials, early primate relatives) (Melchior and Hall 1983, Erickson 1991, as cited in Tweet et al. 2011).

Protection of Collections

NPS museums study, interpret, and provide visitors the opportunity to view natural and cultural resources that have been collected and preserved (Hitchcock and Floray 2006). The primary responsibility of a museum is to document the collection, and continue to collect according to its written "Scope of Collections" statement (required for each museum under Director's Order #24 – see Floray and Knapp 2003). Preservation of the collection is the second responsibility, as museum specimens lose their value if they are damaged or if their documentation is lost. The third responsibility of the museum is to provide access, use, and interpretation of the collection (Hitchcock and Floray 2006).

To meet these responsibilities, the park must consider many factors such as lighting, dust, storage, handling, fire security, and theft and/or vandalism. Light levels affect glues and preservatives; however, they do not adversely affect the fossil itself (McDonald et al. 2005). Fossils with remaining organic constituents can also be vulnerable to high humidity or ultraviolet light. The leading source of degradation is improper storage and handling of a fossil (McDonald et al. 2005). Dust can be abrasive if it settles on specimens that are not stored properly. Fossils can be damaged with gentle cleaning, so it is recommended to eliminate dust by storing specimens in enclosed areas with filtered circulating air. If a closed area is not available, dust covers should be used on open rack shelving (McDonald et al. 2005). Fossils are particularly susceptible to improper handling because most fossils cannot sustain their own weight. To prevent damage, museum staff should practice good maintenance procedures and use methods outlined in its Museum Housekeeping Plan (see NPS 1998).

Fossils are susceptible to fire damage; it is important for the museum to practice and train staff in fire prevention. All NPS museums should have an up-to-date Emergency Operations Plan, which includes information about hazardous material, and special needs of the collection (McDonald et al. 2005). All structures containing the collection should have an appropriate level of fire protection. Security is also important as many of the specimens are very valuable. Fossils are very collectible, and there are opportunities to sell fossils in a black market (McDonald et al. 2005). In particular, trilobites, dinosaur parts, amber, and shark's teeth are very popular fossils. Petrified wood also is sought after as some specimens are considered to be of gemstone quality. It is important for museums to discuss security with the regional/SO curator, park protection staff, and/or regional law enforcement specialist. To protect the collection from theft or vandalism, doors, exhibit cases, and storage cabinets should remain locked (McDonald et al. 2005).

THRO's collection consists of 55 catalog numbers for fossil objects, representing approximately 230 specimens (Tweet et al. 2011). The majority of the catalog numbers were from the Sentinel Butte Formation, with the remaining catalog numbers from the Bullion Creek Formation, the White River Formation, and Quaternary deposits. While plant fossils are most abundant in the collection, it also includes brachiopods, bivalves, gastropods, fish, reptiles, mammals, and some unknown fossils (Tweet et al. 2011).

Understanding the geology and geographic abundance, occurrence, and distribution of fossils as well as threats and stressors (e.g., erosion, human activity) is critical when managing and protecting paleontological resources (KellerLynn 2007). NPS paleontologists have established protocol to monitor baseline changes and to quantify resource loss. Park staff monitors locations of fossils through normal patrol activities. However, some areas of the park are more difficult to monitor, such as the backcountry and the Petrified Forest Plateau area, which is a particularly sensitive area (KellerLynn 2007). The locations of paleontological resources in the park differ extensively in terms of rock types, degree of preservation, geomorphic characteristics, and accessibility. A specific inventory may not be useful or appropriate at all fossil sites within the park. A combination of monitoring strategies (e.g., baseline inventory and patrols) provides a useful approach to assess or measure impacts to in situ resources in THRO (KellerLynn 2007).

Threats and Stressor Factors

Threats to paleontological features include any natural (physical, chemical, and biological) or human factor (theft or vandalism) that has the potential to cause degradation or loss (Santucci and Koch 2003). Erosion is an important natural process that aids in the discovery of paleontological resources. However, it is also a major threat because once a fossil is exposed, it can rapidly be destroyed (NPS 2004). Climatic factors such as precipitation and wind can influence weathering and erosion of paleontological resources (Santucci et al. 2009).

Precipitation (rain, snow, hail, etc.) can influence the stability of in situ paleontological resources (Santucci et al. 2009), and rainfall has been described as the initial and essential driving force for erosion variation (Wei et al. 2009). Erosion rates are directly proportional to precipitation levels and intensity. Areas with greater or intense seasonal periods of precipitation generally have higher rates of erosion (Santucci et al. 2009). Hydrologic factors such as flooding and droughts can significantly influence the stability of in situ paleontological features. Periods of flooding can increase erosion of resources located along riverbanks. Droughts may cause river levels to drop, exposing previously submerged fossils (Santucci et al. 2009).

Wind has the potential to influence the stability of in situ resources in two ways. Abrasive wind transportation (eolian) of unconsolidated sediments can smooth exposed fossils at the surface. In contrast, winds can cause sediments to accumulate in the form of dunes. Degradation can occur as the dune migrates; resources may be buried, exposed, or destroyed (Santucci et al. 2009).

Theft and vandalism are of concern at THRO (Tweet et al. 2011). Data compiled by the NPS in 1999 for 721 incidents of theft or vandalism indicate that humans pose a significant threat to paleontological resources (Santucci 1999, as cited in Santucci and Koch 2003). Fossils and fragments can have high commercial value. Many people collect fossils with the purpose of selling them to museums or private collectors (DOI 2000). Park management and adequate baseline data is critical to prevent degradation due to human causes (Santucci and Koch 2003).

Development in THRO could also pose a threat to paleontological resources if projects are not managed properly. According to the NPS (2004) Paleontological Resources Management policy, any area with the potential for paleontological resources must receive a surface assessment prior to any disturbance or development. If paleontological resources are found, then the site will be avoided or, if necessary, the resources will be collected before development begins and properly cared for. These areas also must be monitored during development (NPS 2004).

Data Needs/Gaps

There is a need for a complete park paleontological survey to aid in resource management. Prior to the 1990s, little was known about the abundance of paleontological features; only 10% of the park was surveyed by Hoganson and Campbell (1997). It is also critical for sites to be resurveyed to monitor any changes in the condition of in situ fossils.

<u>Overall Condition</u>

Distribution and Abundance
The measure of distribution and abundance was assigned a *Significance Level* of 3. Due to the limited amount of paleontological survey work that has been conducted in the park, a *Condition Level* cannot be assigned at this time.

Protection of Collections
The protection of collections measure was assigned a *Significance Level* of 2. Because it is not clear if protection of collections at THRO meets NPS standards for preservation, *Condition Level* for this measure cannot be assigned at this time.

Weighted Condition Score
A *Weighted Condition Score* (WCS) cannot be assigned at this time due to lack of data on component measures.

Paleontological Features

Measures	SL	CL
• Distribution and abundance	3	n/a
• Protection of collections	2	n/a

WCS = N/A

4.17.6 Sources of Expertise
John Hoganson, State Paleontologist, North Dakota Geological Survey.
Rachel Benton, Geologist, Badlands National Park.

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Chapter 5 Discussion

Chapter 5 provides an opportunity to summarize the assessment findings and discuss the overarching themes and common threads that have emerged for the featured components. Specifically, the data gaps and needs identified for each component are summarized and the role these play in the designation of current condition is discussed. Also discussed is how condition analysis relates to the overall natural resource management issues of the park.

5.1 Component Data Gaps

The identification of key data and information gaps is an important objective of NRCAs. Data gaps or needs are those pieces of information that are currently unavailable, but are needed to help inform the status or overall condition of a key resource component in the park. Data gaps and needs exist for most key resource components assessed in this NRCA. Table 36 provides a detailed list of the key data gaps by component. Each data gap or need is discussed in detail in the individual component assessments in Chapter 4.

Some data gaps, if addressed, would provide managers with more information for resource protection and enhancement for multiple components in the project framework. Such is the case for the vegetation communities featured in this NRCA. For all vegetation components, carrying out updated surveys of species composition, capturing the extent/distribution of the communities, and assessing the prevalence of non-native species presence in these communities would help to fill data gaps and provide a more complete understanding of the current condition of each community. In addition, the condition of several other featured components and natural resources may be affected by the health and integrity of the native vegetation communities. These include the frequency and behavior of fire on the landscape, rates of erosion by wind and water, and the health of animals such as breeding birds, prairie dogs, and grazing and browsing ungulates managed within the park (bison, elk, and feral horses, etc.). Filling in data gaps for each vegetation community would help managers determine an accurate current condition of these communities, as well as provide insight into how the health and diversity of these vegetative systems affect the organisms that depend on them for habitat. Data gaps for other featured biotic components, breeding birds and aquatic communities, include updated surveys of species diversity and abundance to understand population trends.

Data gaps vary for the chemical and physical components in THRO, including water quality, air quality, and surface water availability. Since THRO is a Class I airshed, monitoring of air quality conditions in the park is quite thorough. However, identifying and monitoring sensitive plant and tree species that serve as bioindicators for air pollutants could help managers understand, at early stages, the degree of impact from air pollution on the landscape. The Little Missouri River is a major water feature in all three units of THRO. Though much data are available on water quality parameters courtesy of outside agency monitoring stations adjacent to the park's North and South Units, very little monitoring is conducted within the park through an established NPS monitoring program. In addition, these monitoring stations do not survey the macroinvertebrate communities in the Little Missouri River within the park; macroinvertebrates can be important indicators of poor or good water quality. Any monitoring of water quality parameters that does occur within park boundaries is sporadic and does not allow for assessing long-term trends in water quality. To date, the largest data gap for water quality is a consistent survey of macroinvertebrate species diversity and abundance in the park.

Components featuring natural disturbance regimes, including fire, erosion from wind and water, and flooding on the Little Missouri River, are important in shaping the landscape both ecologically and physically. Wind and water erosion are largely responsible for shaping the dramatic badlands formation that are characteristic of the park landscape. However, no research has been conducted on the rate at which these processes affect the landscape. Regular flooding of the Little Missouri River is essential for the proliferation and health of various floodplain woodlands, particularly the regeneration of cottonwood woodlands. Currently, it is unclear how development and the extent of water draw down activities upriver from THRO or on tributaries to the river may affect the rate and magnitude of flooding and availability of surface water within the park. Fire in THRO, almost exclusively occurring as prescription burns, is monitored regularly through data collected before, during, and after burn events. Managers could continue to benefit from continual, detailed monitoring of established vegetation plots to estimate the effects of fire on desired vegetation outcomes. These data would help managers further understand the condition of fire and its usefulness in meeting management objectives for the native plant communities in the park.

Soundscape and dark night skies are components commonly thought of as “goods and services” for visitors; however, quantitative data related to these in THRO is very limited. National programs and sampling standards have been developed by NPS in order to monitor soundscape and dark night skies conditions in all parks. Currently, baseline data do not exist for dark night skies conditions or the levels of unnatural sounds in the park. Implementing the NPS protocol for these resources would provide a better understanding of the components’ conditions.

Table 36. Identified data gaps or needs for the featured components.

Component	Data Gaps/Needs
Fire	➢ Continued and consistent monitoring of established vegetation plots to characterize the effects of fire and parameters that correlate with desired vegetation outcomes ➢ Record of burn severity and intensity and its correlative effects on native vegetation
Wind and water erosion	➢ No research has been conducted on this component
Flooding (Little Missouri River)	➢ Consistent monitoring of peak magnitude and peak gage height at Medora, ND ➢ Understanding of the amount and extent of water permits near the Little Missouri River to understand drawn down statistics ➢ Summary of the amount, location, and extent of stock dams in upstream tributaries of the Little Missouri River
Native grasslands	➢ An updated vegetation mapping effort to characterize extent of juniper and other woody encroachment ➢ Updated survey of grassland composition
Juniper forests	➢ Updated data on density and stand structure ➢ Updated distribution and extent of juniper stands

Table 37. Identified data gaps or needs for the featured components. (continued)

Component	Data Gaps/Needs
Floodplain forests	➢ Specific information on the species composition and abundance of floodplain woodland alliances ➢ Cottonwood woodland stand age data to understand regeneration and mortality ➢ Updated extent and distribution data for floodplain woodlands
Woody draws	➢ Prevalence of diseases affecting species in the woody draws ➢ Data representing changes in woody draw communities over time ➢ More detailed examination of non-native species prevalence/abundance
Upland shrublands	➢ Updated information on plant species composition with an emphasis on the prevalence and impact of non-native species ➢ Updated extent and distribution of upland shrubland communities
Aquatic communities	➢ Species surveys during normal and low flow periods to understand diversity and abundance ➢ Updated survey of species diversity ➢ Updated survey of macroinvertebrate diversity and abundance in the Little Missouri River
Prairie dogs	➢ Continued monitoring efforts that include mapping of prairie dog town extents
Breeding birds	➢ Greater frequency of surveys to understand population trends ➢ Increased sampling under the IMBCR spatially balanced land bird protocol ➢ Consistent monitoring of priority species populations ➢ Raptor specific monitoring
Air quality	➢ Periodic monitoring of air pollutant sensitive plants that may act as bioindicators of declining air quality conditions
Water quality	➢ Consistent monitoring of water quality parameters within THRO, including macroinvertebrate populations
Soundscape	➢ Acoustic monitoring to quantify levels of ambient and unnatural sounds
Dark night skies	➢ Baseline data on dark night skies ➢ Study of effects of oil and gas “flaring” activities on night skies
Surface water availability	➢ Park-wide inventory of springs and seeps and regular monitoring of these features ➢ Summary of the number, location, and extent of man-made developments in the tributaries of the Little Missouri River in and around THRO
Paleontological features	➢ A complete park paleontological survey to aid resource management ➢ Resurvey of sites to monitor for changes in the condition of in situ fossils

5.2 Component Condition Designations

Table 38 displays the conditions assigned to each resource component presented in Chapter 4 (definitions of condition graphics are located in Figure 40 following Table 38). It is important to remember that the graphics represented are simple symbols for the overall condition and trend assigned to each component. Because the assigned condition of a component (as represented by the symbols used in Table 38) is based on a number of factors and an assessment of multiple literature and data sources, it is strongly recommended that the reader refer back to each specific component assessment in Chapter 4 for a detailed explanation and justification of the assigned condition. Condition designations for some components are supported by existing or long-term datasets and monitoring information and expertise by NPS and other non-NPS scientists, while other components lack historic data, a clear understanding of reference conditions (i.e., what is considered desirable or natural), or even current information.

Data are unavailable or insufficient for many of the measures of the featured components and, thus, it is not possible to define current condition for these components. In other instances, reference condition data were limited or unavailable for components, making comparisons inappropriate or invalid. Current condition was not able to be determined for 10 of the 17 components (58%) due to these significant data gaps.

For featured components with available data and fewer data gaps, assigned conditions varied. For some components, enough data exist to determine a trend in condition over time; however, for others the lack of long-term or comparable data prevented the determination of trends. Several components were determined to be in good condition with a stable trend, including air quality, water quality, fire, and the prairie dog population. Flooding on the Little Missouri River in the park was determined to have a condition of moderate concern but with a stable trend, meaning the condition is not believed to be degrading or improving from past conditions. Native grasslands and woody draws were also determined to be of moderate concern, but a lack of historical data does not allow for designating a trend in condition over time. A discussion of these designations is presented in the following section.

Table 38. Summary of current condition and condition trend for featured NRCA components.

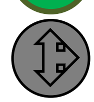
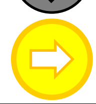
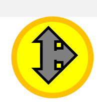
Component	WCS	Condition
Ecosystem Extent and Function		
Disturbance Regimes		
Fire	0.333	
Wind and water erosion	N/A	
Flooding (Little Missouri)	0.666	
Biological Composition		
Ecological communities		
Native grasslands	0.500	

Table 39. Summary of current condition and condition trend for featured NRCA components. (continued)

Component	WCS	Condition
Juniper forests	N/A	
Floodplain forests	N/A	
Woody draws	0.500	
Upland shrubland communities	N/A	
Aquatic communities	N/A	
Grazing animals		
Prairie dogs	0*	
Birds		
Breeding birds	N/A	
Environmental Quality		
Air quality	0.333	
Water quality	0.333	
Soundscape	N/A	
Dark night skies	N/A	
Physical Characteristics		
Hydrologic & Geologic		
Surface water availability	N/A	
Paleontological features	N/A	

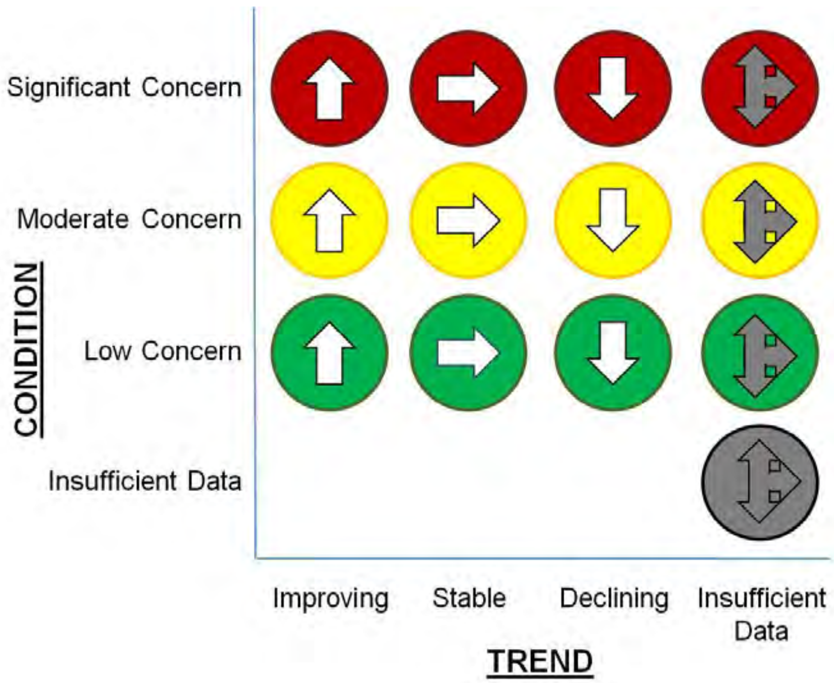


Figure 40. Symbols used for individual component assessments with condition or concern designations along the vertical axis and trend designations along the horizontal.

5.3 Park-wide Condition Observations

The landscape in THRO is rich in natural resources that are diverse and complex. As a result, a number of components featured in the NRCA are interrelated, with the condition of many being dependent on the condition and healthy functioning of others. In particular, the native vegetation communities and the natural disturbance patterns in the park (i.e., fire and flooding along the Little Missouri River) seem to be an important influence on the condition of many other biotic components in the park.

Native Vegetation Communities

THRO managers agree that the native vegetation communities within the park are integral to the healthy functioning of the overall ecological landscape and that the health of the vegetation communities can significantly influence the condition of many of the species that also reside in the park. For example, the condition of the vegetation communities in the park is an important factor in the health of ungulate populations (such as bison, elk, and feral horses), as well as small mammals and breeding birds that utilize these communities for habitat. Thus, the health and composition of the native plant communities is important for many of the species present in the park.

Data gaps for three of the five native vegetation communities featured in the NRCA prevent the determination of current condition or any trends that may be occurring over time. The juniper forests, floodplain woodlands, and upland shrublands components substantially lack data for most or all component measures to be able to determine current condition or any trends that may be occurring over time. Enough data were available to assign condition for the woody draws and native grasslands components, both of which were determined to be of moderate concern. Both native grasslands and woody draws were determined to be of moderate concern due to the presence of invasive non-native species that threaten to alter native species composition and abundance in these two communities. Particularly aggressive species, such as leafy spurge and Canada thistle, are treated actively in both native communities to limit spread and shift of native composition. Non-native grasses (e.g., field brome and cheatgrass) also threaten the composition of the native grasslands throughout the park. Unfortunately, the lack of long-term community-specific monitoring data prevents the identification of any trends in condition over time for either woody draws or native grasslands in the park.

Disturbance Regimes

Disturbance regimes (e.g., fire, flooding, or erosion) can play a signicant role in the evolution and adaptation of vegetation communities across a landscape, as well as influence the current condition of these communities. In THRO, frequent burning of the landscape, by either natural-caused wildfires or prescribed fires, is an important factor in maintaining species composition in native vegetation communities, for example, by limiting the encroachment of woody shrubs and junipers into open areas and regenerating native grasslands. However, fire suppression has significantly altered the rate at which fires historically occurred in and around THRO. As a result, in order to obtain the beneficial effects of wildfires throughout the park, fire is managed heavily, with nearly all fires occurring as prescribed burns. Because of the high degree of planning and control of location, time of year, intensity, and frequency for burning to occur in THRO, fire was determined to be in good condition with a stable trend. Although fires are not as frequent on the landscape as they once were, current prescribed burn efforts aim to distribute fire throughout the park to benefit native plant communities.

Regular flooding events on the Little Missouri River also are important, particularly for the floodplain forest communities, where regular flooding and extended periods of inundation of the floodplain are necessary for the regeneration of cottonwood stands along the Little Missouri River. Without this regeneration, the cottonwood woodlands would age and slowly die away. This would effectively contribute to a decrease in important habitat for various breeding birds and raptors, among other associated impacts. As a component, flooding events along the Little Missouri River in THRO were determined to be of moderate concern. Of particular concern is the decreased frequency of periods of inundation in the floodplains, which are necessary for the regeneration of cottonwood stands in the floodplain woodlands along the river. In May 2011, the Little Missouri River experienced a 100-year flood event that left floodplains inundated for several weeks. This event and available data indicate that the trend for flooding is stable.

Other Biotics

Animals featured as NRCA components included prairie dogs and breeding birds. Prairie dog colonies are allowed to expand and contract naturally within park boundaries and active management is required only when disease threatens individual populations or when prairie dogs move into non-tolerance areas such as leach fields and corrals. Plague has been found sporadically in the park over the last several years, however, managers have little concern about the rates of colony growth and spread of disease. To date, no action has been taken to reduce plague when it occurs. Thus, praire dogs were determined to be in good condition with a stable trend. Breeding birds are also an important resource in the park, but significant data gaps make it impossible to determine condition of populations at this time.

Environmental Quality
Environmental quality is important in maintaining healthy functioning ecosystems. The health of terrestrial and aquatic organisms in parks can be affected substantially by the condition of air and water quality. Designated as a Class I airshed, THRO closely monitors air quality in the park. Current data suggest air quality is in good condition with a stable trend; this is in part likely due to THRO's location in rural North Dakota, away from any major population center. However, recent exponential growth in energy development around the park has the potential to impact air quality in the future through increased emissions and atmospheric deposition.

With the exception of a few sporadic, short-term sampling studies conducted throughout the years, consistent monitoring of basic water quality parameters is not performed within park boundaries. To understand the state of water quality in the park, managers must rely on monitoring stations established and maintained by other agencies. Historic and current data indicate that, in the stretches of the Little Missouri River that flow through the park, water quality is in good condition with a stable trend. However, certain elements of water quality are of particular concern, such as the high concentration of fecal coliform bacteria, which have warranted EPA 303[d] impaired waters listing for large sections of the Little Missouri River flowing through the park. Also of slight concern are higher measures of specific conductance, indicating high levels of dissolved solids in the Little Missouri River. Higher specific conductance in a waterway can occur naturally as a result of geology (such as a stream running through a highly erodible landscape) and water temperature (warmer water has higher conductivity than cold water). However, it is not clear how much natural variability contributes to specific conductance measures in the Little Missouri River in THRO and what may be contributed by development, agriculture, or other activities upriver from the park.

Park-wide Threats and Stressors
Several park-wide threats and stressors will continue to influence the condition of resources in THRO. Those of primary concern include establishment of non-native and invasive species, increased oil and gas industry development, and air pollution, especially increased emissions from nearby oil, gas, and powerplant development.

The presence of non-native and invasive species, especially plants, poses a significant threat for the native vegetation communities in THRO. Some invasive plant species present in THRO, such as leafy spurge and Canada thistle, have the ability to overtake native plant communities if left unchecked. Major changes in vegetation communities, from native to more non-native species, could have a significant impact on the animal species that use these communities for habitat. A more complete understanding of the prevalence of non-natives in the different vegetation communities throughout the park would help managers strategize about potential management actions.

Land development around THRO is mainly associated with the growth and expansion of the oil and gas industry. This development has increased exponentially in western North Dakota and around THRO over the last decade. Such development affects different aspects of park resources including impacts to viewscapes with the building of new structures that can be seen from various points in the park, impacts to soundscapes with increased industrial activity and vehicle traffic at development sites, and greater stresses to air quality from increased vehicle and industrial emissions.

Overall Conclusions

This assessment serves as a review and summary of available data and literature for featured natural resources in the park. The information presented here may serve as a baseline against which any changes in condition of components in coming years may be compared. Establishing a number of monitoring programs would begin to fill in data gaps for the resources viewed as important by THRO managers and would help managers better understand the current state of these resources throughout the park. Of those components that had sufficient available information, current condition was determined to be either good or of moderate concern. Understanding this can help managers prioritize management objectives and better focus conservation strategies.

Appendices

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Appendix A: Fire History in THRO, 1946 to 2010

Fire Year	Fire Name	Fire Cause	Start Date	Park Unit[a]	Area ac	Area ha
1946	EAST_ENTRANCE	HUMAN	3/28/1946	SU	14.0	5.7
1949	EAST_ENTRANCE	HUMAN	4/22/1949	SU	11.0	4.5
1949	EAST_ENTRANCE_#2	LIGHTNING	7/16/1949	SU	200.0	80.9
1951	BUCK_HILL_#3	LIGHTNING	8/17/1951	SU	38.0	15.4
1951	COOPER_PASTURE	LIGHTNING	8/17/1951	SU	1.0	0.4
1951	EAST_BORDER	LIGHTNING	8/17/1951	SU	19.0	7.7
1952	PAINTED_CANYON	HUMAN	10/16/1952	SU	1.0	0.4
1954	DEDICATION_HILL	HUMAN	8/14/1954	SU	3.0	1.2
1954	HEADQUARTERS_DUMP	HUMAN	7/26/1954	SU	1.0	0.4
1955	BUCK_HILL	COAL_SEAM	4/10/1955	SU	36.0	14.6
1955	NORTH_PADDOCK_CREEK	LIGHTNING	8/23/1955	SU	37.0	15.0
1955	SQUAW_CREEK	HUMAN	9/30/1955	NU	110.0	44.5
1956	CEDAR_CANYON	HUMAN	5/19/1956	SU	1.0	0.4
1957	CORRAL_CREEK	LIGHTNING	7/27/1957	NU	35.0	14.2
1958	NORTH_RIM	LIGHTNING		NU	5.0	2.0
1958	RIDGELINE	HUMAN	9/21/1958	SU	17.0	6.9
1959	BIG_PLATEAU_#1	LIGHTNING	6/7/1959	SU	2.0	0.8
1959	TWO	UNKNOWN	6/7/1959	SU	2.0	0.8
1962	APPLE_BOTTOM	LIGHTNING	8/21/1962	NU	1.0	0.4
1963	BOICOURT_SPRING	LIGHTNING	7/26/1963	SU	1.0	0.4
1963	GARLAND_BOTTOM	LIGHTNING	9/10/1963	NU	1.0	0.4
1963	MILLER_BOTTOM	UNKNOWN	5/21/1963	NU	1.0	0.4
1963	PAINTED_CANYON_OVERLOOK	HUMAN	10/25/1963	SU	1.0	0.4
1966	CORRAL_CREEK_PRAIRIE_DOG_TOWN	LIGHTNING	7/8/1966	NU	1.0	0.4
1966	JOHNSON'S_PLATEAU	HUMAN	5/30/1966	SU	1.0	0.4
1966	SHEEP_BUTTE	LIGHTNING	9/12/1966	SU	15.0	6.1
1967	PEACEFUL_VALLEY_PICNIC_AREA	HUMAN	10/22/1967	SU	1.0	0.4
1967	SHEEP_CREEK_#1	HUMAN	8/1/1967	SU	1.0	0.4
1967	SHEEP_CREEK_#2	HUMAN	8/17/1967	SU	1.0	0.4
1967	SHEEP_CREEK_#3	HUMAN	8/19/1967	SU	2.0	0.8
1967	SHEEP_CREEK_#4	HUMAN	8/31/1967	SU	1.0	0.4
1967	SQUAW_CREEK_CAMPGROUND	HUMAN	8/14/1967	NU	3.0	1.2
1968	STONE_HILLS	LIGHTNING	9/14/1968	NU	14.0	5.7
1974	RIDGELINE	HUMAN	7/14/1974	SU	2.0	0.8
1976	FIREWORKS	HUMAN	7/4/1976	SU	1.0	0.4
1976	GLACIAL_NORTH	HUMAN	7/26/1976	NU	1.0	0.4
1976	GLACIAL_SOUTH	HUMAN	7/27/1976	NU	1.0	0.4
1976	OVER_SPRING	HUMAN	7/24/1976	NU	2.0	0.8

Fire Year	Fire Name	Fire Cause	Start Date	Park Unit[a]	Area ac	Area ha
1976	SPERATI_POINT	LIGHTNING	8/18/1976	NU	30.0	12.1
1977	HIGHWAY 85 WEST	HUMAN	5/13/1977	NU	1.0	0.4
1978	BUFFALO_CORRAL	HUMAN	5/22/1978	NU	9.0	3.6
1978	PLATEAU	LIGHTNING	8/22/1978	SU	275.0	111.3
1979	KNUTSON_CREEK	LIGHTNING	7/8/1979	SU	1.0	0.4
1979	TOWER_FIRE	LIGHTNING	6/30/1979	SU	80.0	32.4
1980	MAN_AND_GRASS	LIGHTNING	6/3/1980	NU	84.0	34.0
1980	PAINTED_CANYON	LIGHTNING	8/22/1980	SU	1.0	0.4
1981	PAINTED_CANYON	HUMAN	3/23/1981	SU	13.0	5.3
1981	ROUGHRIDER	HUMAN	3/13/1981	SU	8.0	3.2
1983	JOHNSON	HUMAN	8/25/1983	SU	100.0	40.5
1983	SQUAW_CREEK	HUMAN	4/24/1983	NU	1.0	0.4
1983	SQUAW_CREEK_DOG	LIGHTNING	8/28/1983	NU	1.0	0.4
1984	SQUAW_CREEK	HUMAN	8/8/1984	NU	3.0	1.2
1984	SU_ENTRANCE	PRESCRIBED		SU	0.0	0.0
1984	TUESDAY	LIGHTNING	8/14/1984	NU	10.0	4.0
1985	FATHERS_DAY	HUMAN	6/16/1985	SU	27.0	10.9
1985	NORTH_UNIT_CORRAL	PRESCRIBED	4/11/1985	NU	250.0	101.2
1988	BUCK_HILL	LIGHTNING	7/27/1988	SU	197.0	79.7
1988	SOUTH_UNIT_HEADQUARTERS	PRESCRIBED	4/19/1988	SU	2.0	0.8
1988	TR_CABIN	HUMAN	3/26/1988	SU	1.0	0.4
1989	PADDOCK_CREEK	LIGHTNING	8/30/1989	SU	1.0	0.4
1991	CHIP	LIGHTNING	6/29/1991	NU	1.0	0.4
1992	MAINTENANCE	HUMAN	7/5/1992	SU	1.0	0.4
1992	MEDIAN	HUMAN	2/25/1992	SU	1.0	0.4
1992	MEDIAN	HUMAN	2/25/1992	SU	1.0	0.4
1992	NORTH_UNIT_SLASH	PRESCRIBED	4/10/1992	NU	0.0	0.0
1992	TIMBERS	PRESCRIBED	2/14/1992	SU	0.0	0.0
1993	CORRAL	HUMAN	3/22/1993	SU	25.0	10.1
1993	RAMIREZ	HUMAN	4/17/1993	NU	1.0	0.4
1993	RESIDENCE 188C	HUMAN	12/22/1993	NU	1.0	0.4
1993	TRAP	LIGHTNING	3/3/1993	NU	6.0	2.4
1993	TRAP	LIGHTNING	3/3/1993	SU	6.0	2.4
1994	COTTON_#1	HUMAN	5/29/1994	SU	1.0	0.4
1994	COTTON_#2	HUMAN	5/29/1994	SU	1.0	0.4
1994	COTTON_#3	HUMAN	6/5/1994	SU	1.0	0.4
1994	HAYSTACK	HUMAN	4/21/1994	NU	1.0	0.4
1995	LEAVES	HUMAN	2/7/1995	SU	1.0	0.4
1995	LEAVES	HUMAN	2/7/1995	SU	1.0	0.4
1995	RESIDENCE_101	HUMAN	12/30/1995	SU	1.0	0.4

					Area	
Fire Year	**Fire Name**	**Fire Cause**	**Start Date**	**Park Unit[a]**	**ac**	**ha**
1996	INTERSTATE	LIGHTNING	6/8/1996	SU	6.0	2.4
1996	INTERSTATE	LIGHTNING	6/8/1996	SU	6.0	2.4
1996	SHUT_DOWN	HUMAN	1/13/1996	NU	1.0	0.4
1997	COTTON_#3	HUMAN	6/1/1997	SU	1.0	0.4
1997	RIVER_BEND	LIGHTNING	6/22/1997	NU	1.0	0.4
1997	RIVER_BEND	LIGHTNING	6/22/1997	NU	1.0	0.4
1997	UNKNOWN_2	HUMAN	6/20/1997	NU	1.0	0.4
1998	BOICOURT	LIGHTNING	8/10/1998	SU	15.1	6.1
1998	CHALKCLIFF	UNKNOWN	5/31/1998	NU	18.0	7.3
1998	CHASER	LIGHTNING	8/10/1998	SU	1.0	0.4
1998	NORTH_UNIT_HOUSING	LIGHTNING	8/14/1998	NU	1.0	0.4
1998	VOLUNTEER	LIGHTNING	8/10/1998	SU	2.0	0.8
1999	BURN_HILLS	HUMAN	7/30/1999	SU	1.0	0.4
1999	JOHNSON'S_PLATEAU	LIGHTNING	6/25/1999	SU	1.0	0.4
1999	LITTLE_MISSOURI	PRESCRIBED	9/21/1999	NU	504.3	204.1
1999	LITTLE_MISSOURI	PRESCRIBED	9/21/1999	NU	100.6	40.7
1999	PUMPKIN	UNKNOWN	10/23/1999	NU	1.0	0.4
1999	RAIL_CAR	LIGHTNING	6/25/1999	SU	1.0	0.4
1999	SE_CORNER	PRESCRIBED	4/19/1999	SU	304.8	123.3
1999	SE_CORNER	PRESCRIBED	4/19/1999	SU	167.6	67.8
1999	SOUTH_UNIT_HEADQUARTERS	PRESCRIBED	4/14/1999	SU	0.0	0.0
2000	BURLINGTON	HUMAN	10/10/2000	SU	2.0	0.8
2000	BURNT_TREE	LIGHTNING	9/19/2000	SU	1.0	0.4
2000	PAINTED_CANYON	LIGHTNING	8/28/2000	SU	277.6	112.3
2000	PETRIFIED	LIGHTNING	8/26/2000	SU	2.0	0.8
2000	SE_CORNER	PRESCRIBED	4/11/2000	SU	331.0	133.9
2000	WIND_CANYON	HUMAN	7/29/2000	SU	1.0	0.4
2001	ELKHORN_FIRE	LIGHTNING	8/31/2001	EHR	158.0	63.9
2001	NOTHWEST_CORNER	PRESCRIBED		NU	827.2	334.7
2002	INTERSTATE_94	PRESCRIBED	10/10/2002	SU	227.5	92.1
2002	INTERSTATE_94	PRESCRIBED	5/2/2003	SU	306.6	124.1
2002	KNUTSON_CREEK_RESEARCH	PRESCRIBED	4/24/2002	SU	0.0	0.0
2002	LITTLE_MISSOURI	PRESCRIBED	5/13/2002	NU	540.5	218.7
2002	MIX_PIT	UNKNOWN	8/16/2002	SU	1.0	0.4
2002	NORTHWEST_CORNER	PRESCRIBED		NU	160.0	64.7
2002	OLSEN_WELL_RESEARCH	PRESCRIBED	10/17/2002	SU	0.0	0.0
2002	PEACEFUL_VALLEY	PRESCRIBED	5/29/2002	SU	625.9	253.3
2002	SKYLINE_VISTA	PRESCRIBED	10/9/2002	SU	588.9	238.3
2002	SPAGHETTI	HUMAN	8/15/2002	SU	2.0	0.8
2003	BIGHORN	LIGHTNING	9/14/2003	NU	2.0	0.8

Fire Year	Fire Name	Fire Cause	Start Date	Park Unit[a]	Area	
					ac	ha
2003	COTTONWOOD_CAMPGROUND	PRESCRIBED	4/24/2003	SU	155.5	62.9
2003	FA #1	UNKNOWN	9/5/2003	SU	1.0	0.4
2003	LOST_BISON	LIGHTNING	9/9/2003	NU	50.0	20.2
2003	SMOOTH_BROME_RESEARCH	PRESCRIBED	10/22/2003	SU	0.0	0.0
2003	WIND_CANYON	HUMAN	7/22/2003	SU	1.0	0.4
2004	JULES_CREEK	LIGHTNING	7/9/2004	SU	8.0	3.2
2004	SE_CORNER	PRESCRIBED	4/22/2004	SU	910.0	368.3
2006	MILE_36	LIGHTNING	8/10/2006	SU	1.0	0.4
2007	HORSECAMP	PRESCRIBED	4/24/2007	SU	92.1	37.3
2007	LOOP_1	PRESCRIBED	4/17/2007	SU	17.2	6.9
2007	LOOP_2	PRESCRIBED	4/17/2007	SU	24.5	9.9
2007	LOOP_3	PRESCRIBED	4/17/2007	SU	5.7	2.3
2007	LOOP_4	PRESCRIBED	4/17/2007	SU	43.9	17.7
2007	LOOP_5	PRESCRIBED	4/24/2007	SU	40.3	16.3
2007	RADIOTOWER	PRESCRIBED	10/4/2007	SU	94.9	38.4
2008	CORRAL_FIRE	LIGHTNING	6/23/2008	NU	3.5	1.4
2008	LOOP_6	PRESCRIBED	4/13/2008	SU	38.8	15.7
2008	LOOP_7	PRESCRIBED	4/13/2008	SU	92.9	37.6
2008	LOOP_8	PRESCRIBED	4/13/2008	SU	19.7	8.0
2008	LOOP_9	PRESCRIBED	4/13/2008	SU	70.0	28.3
2008	NORTHWEST_CORNER_1	PRESCRIBED	10/9/2008	NU	68.9	27.9
2008	NORTHWEST_CORNER_2	PRESCRIBED	10/9/2008	NU	326.8	132.3
2008	NORTHWEST_CORNER_3	PRESCRIBED	10/9/2008	NU	296.8	120.1
2009	CAR 1	HUMAN	7/13/2009	SU	0.0	0.0
2009	ELKHORN_RANCH_1	PRESCRIBED	5/7/2009	EHR	2.9	1.2
2009	ELKHORN_RANCH_2	PRESCRIBED	5/7/2009	EHR	11.1	4.5
2009	ELKHORN_RANCH_3	PRESCRIBED	5/7/2009	EHR	4.1	1.6
2009	JUNIPER CAMPGROUND	PRESCRIBED		NU	150.0	60.7
2009	LOOP UNIT 1	PRESCRIBED		NU	10.8	4.4
2009	MUD FIRE	LIGHTNING	5/12/2009	NU	1.0	0.4
2009	NORTH_LOOP_BURN	PRESCRIBED	5/3/2009	NU	149.6	60.5
2010	SE_CORNER_6	PRESCRIBED	4/22/2010	SU	250.1	101.2
2011	SHEEP	PRESCRIBED	9/14/2011	NU	3641	1474
2011	LONGHORN FLATS	PRESCRIBED	9/16/2011	NU	460	186

[a] NU=North Unit, SU=South Unit, EHR=Elkhorn Ranch Unit

Appendix B: Peak Flow Data for the Little Missouri River at Medora, ND

Water Year	Gage Height (ft)	Streamflow (cfs)	Date of Peak Flow
1904	11.2	11,600	9-Jun-04
1905	10.2	8,500	2-Jul-05
1906	12	13,900	8-Jun-06
1907	16	29,000	24-Jun-07
1908	10.7	10,800	6-Jun-08
1909	11.5	12,400	31-May-09
1910	9.5	7,550	16-Mar-10
1911	8.6	5,540	17-May-11
1912	8.7	5,750	8-Jul-12
1913	n.d.	n.d.	n.d.
1914	6.3	1,850	3-Apr-14
1915	14.1	24,700	16-Jun-15
1916	9.1	6,630	16-Mar-16
1917	n.d.	n.d.	n.d.
1918	n.d.	n.d.	n.d.
1919	n.d.	n.d.	n.d.
1920	n.d.	n.d.	n.d.
1921	n.d.	n.d.	n.d.
1922	n.d.	n.d.	n.d.
1923	n.d.	n.d.	n.d.
1924	13.8	18,500	4-Apr-24
1925	n.d.	n.d.	n.d.
1926	n.d.	n.d.	n.d.
1927	n.d.	n.d.	n.d.
1928	n.d.	n.d.	n.d.
1929	17.2	38,700	7-Jun-29
1930	7	4,700	13-Sep-30
1931	4.52	1,610	22-Jun-31
1932	9.66	12,500	28-Apr-32
1933	12.44	20,800	24-May-33
1934	4.5	1,850	12-Jun-34
1935	n.d.	n.d.	n.d.
1936	n.d.	n.d.	n.d.
1937	n.d.	n.d.	n.d.
1938	n.d.	n.d.	n.d.
1939	n.d.	n.d.	n.d.
1940	n.d.	n.d.	n.d.
1941	n.d.	n.d.	n.d.

Water Year	Gage Height (ft)	Streamflow (cfs)	Date of Peak Flow
1942	n.d.	n.d.	n.d.
1943	n.d.	n.d.	n.d.
1944	n.d.	n.d.	n.d.
1945	n.d.	n.d.	n.d.
1946	8.75	9,310	24-Jun-46
1947	20.5	65,000	23-Mar-47
1948	13.5	24,100	23-Mar-48
1949	11.2	14,600	27-Mar-49
1950	13	25,600	8-Apr-50
1951	8.5	5,200	22-Mar-51
1952	17.32	42,500	8-Apr-52
1953	8.21	8,820	21-Jun-53
1954	5.99	4,320	7-Apr-54
1955	13.9	25,600	27-Jun-55
1956	4.05	2,030	27-Mar-56
1957	7.45	7,900	22-Jun-57
1958	5.9	5,050	4-Jul-58
1959	7.47	6,650	20-Mar-59
1960	8.72	8,100	22-Mar-60
1961	5.22	3,540	24-May-61
1962	9.85	10,800	30-May-62
1963	n.d.	11,000	3-Mar-63
1964	9.11	9,170	10-Jun-64
1965	n.d.	15,000	3-Apr-65
1966	7.98	6,800	14-Mar-66
1967	11.73	15,700	11-May-67
1968	5.35	3,000	7-Mar-68
1969	10	11,200	23-Mar-69
1970	7.31	6,550	9-May-70
1971	12.82	21,200	6-Jun-71
1972	18	40,000	11-Mar-72
1973	5.72	3,820	20-Jun-73
1974	6.9	5,230	21-May-74
1975	14	22,800	9-May-75
1976	n.d.	6,000	21-Jun-76
1977	n.d.	n.d.	n.d.
1978	n.d.	n.d.	n.d.
1979	n.d.	n.d.	n.d.
1980	n.d.	n.d.	n.d.
1981	n.d.	n.d.	n.d.

Water Year	Gage Height (ft)	Streamflow (cfs)	Date of Peak Flow
1984	n.d.	n.d.	n.d.
1985	n.d.	n.d.	n.d.
1986	n.d.	n.d.	n.d.
1987	n.d.	n.d.	n.d.
1988	n.d.	n.d.	n.d.
1989	n.d.	n.d.	n.d.
1990	n.d.	n.d.	n.d.
1991	n.d.	n.d.	n.d.
1992	n.d.	n.d.	n.d.
1993	n.d.	n.d.	n.d.
1994	n.d.	n.d.	n.d.
1995	n.d.	n.d.	n.d.
1996	n.d.	n.d.	n.d.
1997	n.d.	n.d.	n.d.
1998	n.d.	n.d.	n.d.
1999	n.d.	n.d.	n.d.
2000	n.d.	n.d.	n.d.
2001	n.d.	7,840	12-Mar-01
2002	5.62	1,680	11-Jun-02
2003	7.46	2,500	18-Mar-03
2004	9.51	5,500	10-Mar-04
2005	11.41	7,680	30-Jun-05
2006	13.61	12,700	25-Apr-06
2007	11.77	9,110	9-Jun-07
2008	11.9	8,810	10-May-08
2009	16.43	20,800	19-Apr-09
2010	8.69	4,330	24-Mar-10
2011	20.39	35,100	25-May-11

Appendix C. Peak Flow Data for the Little Missouri River at Watford City, ND

Water Year	Gage Height (ft)	Streamflow (cfs)	Date of Peak Flow
1935	10.6	20,500	11-Jul-35
1936	8	8,800	10-Mar-36
1937	7.85	8,990	15-Jun-37
1938	9.4	14,600	15-Mar-38
1939	13.05	26,500	22-Mar-39
1940	6.83	4,270	23-Sep-11
1941	9	13,000	11-Jun-41
1942	9.59	12,600	11-Mar-42
1943	n.d.	25,000	22-Feb-43
1944	14.4	32,600	8-Apr-44
1945	14.4	30,000	14-Mar-45
1946	8.75	8,000	24-Feb-46
1947	24	110,000	25-Mar-11
1948	11.56	16,000	24-Mar-11
1949	13.7	26,000	28-Mar-49
1950	21.42	60,000	9-Apr-50
1951	13.82	18,000	27-Mar-51
1952	15.53	42,200	10-Apr-52
1953	7.68	7,650	22-Jun-53
1954	8.37	10,200	14-Jun-54
1955	9.96	17,600	28-Jun-55
1956	6	2,770	30-Jul-56
1957	7.8	6,890	23-Jun-57
1958	9.94	12,000	25-Mar-58
1959	10.13	12,800	20-Mar-59
1960	9.83	18,900	22-Mar-60
1961	3.76	2,920	25-May-61
1962	6.71	12,100	31-May-62
1963	n.d.	10,000	5-Mar-63
1964	7.82	12,000	5-Jul-64
1965	n.d.	20,000	10-Apr-65
1966	7.06	12,000	12-Mar-66
1967	16.07	30,000	22-Mar-67
1968	6.38	7,900	1-Mar-68
1969	8.04	15,300	23-Mar-69
1970	7.3	13,400	9-May-70
1971	15.27	31,000	28-Mar-71
1972	14.68	52,800	13-Mar-72
1973	6.42	7,500	28-Feb-73
1974	5.45	6,750	21-May-74

Water Year	Gage Height (ft)	Streamflow (cfs)	Date of Peak Flow
1975	8.4	17,500	11-May-75
1976	6	7,600	24-Jun-76
1977	5.4	6,430	17-Jun-77
1978	11.08	31,500	30-Mar-78
1979	6.45	10,000	17-Apr-79
1980	3.09	865	14-Jun-80
1981	3.54	1,390	23-Oct-81
1982	n.d.	11,000	21-Feb-82
1983	8.41	13,500	23-Feb-83
1984	5.77	6,200	24-Jun-84
1985	5.1	4,540	24-Mar-85
1986	7.9	14,500	28-Feb-86
1987	5.47	6,740	1-Apr-87
1988	2.18	400	24-Mar-88
1989	7.44	5,000	11-Mar-89
1990	6.81	6,000	5-Mar-90
1991	8.15	8,900	15-Sep-91
1992	4.7	1,000	28-Feb-92
1993	n.d.	12,000	27-Jul-93
1994	11.79	10,000	6-Mar-94
1995	11.6	15,300	15-May-95
1996	17.23	10,000	15-Mar-96
1997	n.d.	20,500	22-Mar-97
1998	5.55	3,520	2-Apr-98
1999	6.31	4,960	16-Mar-99
2000	4.46	1,400	26-Feb-00
2001	n.d.	12,000	13-Mar-01
2002	4.91	2,360	23-Jun-02
2003	n.d.	8,000	17-Mar-03
2004	6.99	5,900	14-Mar-04
2005	8.01	6,770	2-Jul-05
2006	10.61	12,770	27-Apr-06
2007	8.21	8,710	10-Jun-07
2008	8.38	7,110	12-May-08
2009	13.68	20,800	21-Apr-09
2010	5.16	4,550	26-Mar-10
2011	16.70	34,000	27-May-11

Appendix D: Non-native Plant Species Documented in THRO

Non-native plant species documented in THRO through May 2011. A number of additional species are classified as "probably present" in the park or "unconfirmed" and are therefore not listed here. The full list can be found at http://science.nature.nps.gov/im/units/ngpn/monitor/exoticplant/docs/THRO_Park_Exotics.pdf.

Scientific Name	Common Name	Life cycle[1]	Growth form[2]	High priority?
Acroptilon repens	Russian knapweed	P	F	x
Agropyron cristatum	Crested wheatgrass	P	G	
Artemisia absinthium	Absinth wormwood	P	F-SS	x
Asparagus officinalis	Garden asparagus	P	F	
Asperugo procumbens	German-madwort	A	F	
Bassia scoparia	Burning bush	A	F	
Bromus inermis	Smooth brome	P	G	
Bromus arvensis	Field brome	A	G	
Bromus tectorum	Cheatgrass	A	G	x
Camelina microcarpa	Littlepod false flax	A-B	F	
Capsella bursa-pastoris	Shepherd's purse	A	F	
Cardaria draba	Whitetop	P	F	x
Carduus nutans	Musk thistle	B-P	F	x
Centaurea stoebe ssp. *micranthos*	Spotted knapweed	B-P	F	x
Ceratocephala testiculata	Bur buttercup	A	F	
Chenopodium album	Lambsquarters	A	F	
Chenopodium glaucum	Oakleaf goosefoot	A	F	
Cirsium arvense	Canada thistle	P	F	x
Cirsium vulgare	Bull thistle	B	F	x
Conringia orientalis	Hare's ear mustard	A	F	
Convolvulus arvensis	Field bindweed	P	F-V	x
Cynoglossum officinale	Houndstongue	B	F	x
Descurainia sophia	Flixweed	A-B	F	
Echinochloa crus-galli	Barnyard grass	A	G	
Elaeagnus angustifolia	Russian olive	P	S-T	x
Eragrostis cilianensis	Stinkgrass	A	G	
Erysimum cheiranthoides	Wormseed wallflower	A-B	F	
Euphorbia esula	Leafy spurge	P	F	x
Hyoscyamus niger	Black henbane	A-B	F	x
Lactuca serriola	Prickly lettuce	A-B	F	
Lappula squarrosa	European stickseed	A-B	F	
Lepidium perfoliatum	Clasping pepperweed	A-B	F	
Linaria vulgaris	Yellow toadflax	P	F	
Malva rotundifolia	Low mallow	A-B	F	
Medicago lupulina	Black medick	A-P	F	
Medicago sativa	Alfalfa	A-P	F	
Melilotus alba	White sweetclover	A-B-P	F	
Melilotus officinalis	Yellow sweetclover	A-B-P	F	
Nepeta cataria	Catnip	P	F	
Pennisetum glaucum	Pearl millet	A-P	G	
Poa compressa	Canada bluegrass	P	G	
Poa pratensis	Kentucky bluegrass	P	G	
Polygonum arenastrum	Oval-leaf knotweed	A-P	F	
Polygonum aviculare	Prostrate knotweed	A-P	F	
Polygonum convolvulus	Black bindweed	A	F-V	
Polygonum persicaria	Spotted ladysthumb	A-P	F	

Scientific Name	Common Name	Life cycle[1]	Growth form[2]	High priority?
Rumex crispus	Curly dock	P	F	
Rumex stenophyllus	Narrowleaf dock	P	F	
Salsola kali	Russian thistle	A	F	
Salsola tragus	Prickly Russian thistle	A	F	
Schedonorus pratensis	Meadow fescue	P	G	
Setaria viridis	Green foxtail	A	G	
Silene cserei	Balkan catchfly	B-P	F	
Silene latifolia ssp. *alba*	Bladder campion	B-P	F	
Sisymbrium altissimum	Tumbling mustard	A-B	F	
Sonchus arvensis	Perennial sowthistle	P	F	
Tamarix ramosissima	Saltcedar	P	S-T	x
Taraxacum officinale	Common dandelion	P	F	
Thlaspi arvense	Field pennycress	A	F	
Tragopogon dubius	Yellow salsify	A-B	F	
Trifolium repens	White clover	P	F	
Typha angustifolia	Narrowleaf cattail	P	F	
Ulmus pumila	Siberian elm	P	S-T	
Verbascum thapsus	Common mullein	B	F	x
Vicia sativa ssp. *nigra*	Garden vetch	A	F-V	

[1] A = Annual, B = Biennial, P = Perennial
[2] F = Forb, G = Graminoid, S = Shrub, SS = Subshrub, T = Tree, V = Vine

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