National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Devils Tower National Monument

Natural Resource Condition Assessment

Natural Resource Report NPS/DETO/NRTR—2011/479

ON THE COVER
A view of Devils Tower from Red Beds Trail.
Photograph by: (Michael Komp, SMUMN GSS, 2009)

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Acronyms and Abbreviations

AOA - Area of Analysis

BCR - Bird Conservation Regions

BLM - Bureau of Land Management

CAA - Clean Air Act of 1977

CBC - Christmas Bird Count

CDC - Center for Disease Control

CFU - Coliform Forming Unit

CWD - Chronic Wasting Disease

DETO - Devils Tower National Monument

DO - Dissolved Oxygen

EA - Environmental Assessment

EPA - Environmental Protection Agency

GIS - Geographic Information Systems

GLEI - Great Lakes Environmental Indicators Project

IPM - Integrated Pest Management

NABCI - North American Bird Conservation Initiative

NEPA - National Environmental Policy Act

NGP EPMT - Northern Great Plains Exotic Plant Management Team

NGPN - Northern Great Plains Inventory and Monitoring Network

NPS - National Park Service

NRCA - Natural Resource Condition Assessment

PIF - Partners in Flight

PSU - University of Idaho Park Studies Research Unit

RMBO - Rocky Mountain Bird Observatory

Acronyms and Abbreviations (continued)

RSS - Resource Stewardship Strategy

SMUMN GSS – Saint Mary's University of Minnesota, Geospatial Services

STORET - EPA Storage and Retrieval Database

USCB - U.S. Census Bureau

USFS - U.S. Forest Service

USGS - U.S. Geological Survey

WICA - Wind Cave National Park

WRD - Water Resources Division

WYDEQ - Wyoming Department of Environmental Quality

WYNDD - Wyoming Natural Diversity Database

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Saint Mary's University of Minnesota, GeoSpatial Services, provided all non-cited photographs in the body of the report.

Executive Summary

As a unit in the National Park System, Devils Tower National Monument (DETO) is responsible for the management and conservation of its natural resources. This mandate is supported by the National Park Service Organic Act of 1916, which directs the Park Service to

> conserve the scenery and natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such a manner and by such means as will leave them unimpaired for the enjoyment of future generations.

In 2003, the National Park Service (NPS) Water Resources Division received funding through the Natural Resource Challenge program to systematically assess watershed resource conditions in NPS units, thus establishing the Watershed Condition Assessment Program. This program, now titled the Natural Resource Condition Assessment (NRCA) Program, aims to provide documentation about the current conditions of important park resources through a spatially explicit, multidisciplinary synthesis of existing scientific data and knowledge. Findings from the NRCA, including the report and accompanying map products, will help DETO 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)
- report program performance (e.g., Department of Interior's Strategic Plan "land health" goals, Government Performance and Results Act).

Specific project expectations and outcomes for the DETO NRCA are listed in Chapter 3.

For the purpose of this NRCA, NPS staff identified key resources, referred to as components in the project framework and throughout the assessment. The components selected include natural resources and processes that are currently of the greatest concern to park management at DETO. The final project framework contains 13 resource components, along with measures, stressors, and reference conditions for each.

This study involved reviewing existing literature and data for each of the components in the framework, and, where appropriate, analyzing the data to provide summaries or to create new spatial or statistical representations. After gathering data regarding current condition of component measures, those data were compared to reference conditions (when possible), and a qualitative statement of condition was developed. The discussions in Chapter 4 represent a comprehensive summary of available information regarding the current condition of these resources. These discussions represent not only the most current published literature, but also unpublished park information and, most important, the perspectives of park experts.

There were data gaps for all components analyzed in this assessment. The measures analyzed for most resource components in the park indicate a condition of good or moderate concern. In addition, most measures indicate that components are in a stable condition. Only one key resource component condition, Dark Night Skies, could not be defined.

Chapter 1 NRCA Background Information

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

NRCAs represent a relatively new approach to assessing and reporting 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 multidisciplinary in scope[1]
- employ hierarchical component frameworks[2]
- identify or develop logical reference conditions and values as a comparison for current conditions[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.

[1] The breadth of natural resources and number and type of indicators evaluated will vary by park.
[2] Frameworks help guide a multidisciplinary 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 and 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 to be avoided or those that require a follow-on response (e.g., ecological thresholds or management "triggers").
[5] When 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 indicator-level conditions, investigators are asked to take a more holistic view and summarize overall findings and provide suggestions to managers on a area-by-area basis: (1) by park ecosystem or habitat types or watersheds, and (2) for other park areas as requested.

Although current condition reporting relative to logical forms of reference conditions and values is the primary objective, NRCAs also report trends for any study components 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 park resource conditions. It also includes present-day condition influences (threats and stressors) that are best interpreted at park, watershed, or landscape scales, although 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.

Important NRCA Success Factors …

Obtaining valuable 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

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 component 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 to (1) assist selection of study components; (2) recommend study datasets, methods, and reference conditions and values to use; and (3) help provide a multidisciplinary 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 components. They can also bring in relevant non-NPS data to help evaluate current conditions for those same Vital Signs. In some cases, NPS inventory datasets 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 datasets developed by NRCAs will be useful for subsequent park-level climate change studies and planning efforts.

NRCAs do not establish management targets for study components. 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 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 component, 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 prioritize near-term workload, frame data and study needs for important park resources, and communicate messages about current park resource conditions to various audiences. A successful NRCA delivers credible science-based information and provides practical uses for a variety of park decision making, planning, and partnership activities.

Over the next several years, the NPS plans to fund an 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, Congress, and the general public ***("resource condition status" reporting)***

[7] NRCAs are an especially useful lead-in to park Resource Stewardship Strategies (RSSs), but the 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

Enabling Legislation

In 1906, Congress passed the American Antiquities Act (16 USC, 431–433), granting the President the power

> to declare by public proclamation historic landmarks, historic and prehistoric structures, and other objects of historic or scientific interest that are situated upon the lands owned or controlled by the Government of the United States to be national monuments, and may reserve as a part thereof parcels of land, the limits of which in all cases shall be confined to the smallest area compatible with proper care and management of the objects to be protected.

On 24 September 1906, Theodore Roosevelt signed a proclamation that established Devils Tower National Monument (DETO) as the nation's first National Monument:

> Whereas, the lofty and isolated rock in the State of Wyoming, known as the 'Devils Tower', situated upon the public lands owned and controlled by the United States is such an extraordinary example of the effect of erosion in the higher mountains as to be a natural wonder and an object of historic and great scientific interest and it appears that the public good would be promoted by reserving this tower as a National Monument with as much land as may be necessary for the proper protection thereof;
>
> Now, therefore, I, THEODORE ROOSEVELT, President of the United States of America, by virtue of the power in me vested by section two of the aforesaid act of congress, do hereby set aside as the Devils Tower National Monument, the lofty and isolated rock situated in Crook County, Wyoming, more particularly located and described as follows, to wit:
>
> Section seven, and the north half of the northeast quarter, the northeast quarter of the northwest quarter and lot number one of section eighteen, in township fifty-three north, range sixty-six, all west of the Sixth Principal Meridian, as shown upon the map hereto attached and made a part of this proclamation.
>
> Warning is hereby expressly given to all unauthorized persons not to appropriate, injure or destroy any feature of the natural tower hereby declared to be a National Monument or to locate or settle upon any of the lands reserved and made a part of said monument by this proclamation.

Geographic Setting

DETO is a 545 ha (1,347 ac) National Park in Crook County, located in northeastern Wyoming, on the northwest edge of the Black Hills (NPS 2001). Crook County has the fifth lowest human population density of all Wyoming counties at 0.81 individuals per square kilometer (USCB 2010). The Black Hills, a mountain range in western South Dakota and northeastern Wyoming roughly 200 km long by 100 km wide (62 by 124 mi) (Marriot et al. 1999), is named for the dark ponderosa pines (*Pinus ponderosa*) that cover most of the Hills (Marriot et al. 1999). The geology of the area consists of igneous and sedimentary rock and loamy soils (Salas and Pucherelli 1998). The Belle Fourche River flows through the eastern portion of DETO and forms part of its southern boundary.

The 264 m (867 foot) high Devils Tower (Tower) was formed by the intrusion of igneous material into softer sedimentary rocks, which later eroded to expose the Tower. The formation consists of numerous hexagonal columns separated by vertical cracks that attract thousands of rock climbers each year. It is composed of a crystallized rock type called phonolite porphyry, a light to dark-gray or greenish-gray rock with conspicuous crystals of white feldspar (NPS 2010b).

DETO has a continental climate with hot summers and cold winters. Snow pack is usually light and temporary, although severe winters with long periods of snow cover occur periodically. Multiyear droughts are also a regular occurrence (Gitzen et al. 2010). Temperature and precipitation normals (defined as the arithmetic mean computed over three consecutive decades) are available for DETO from 1971–2000 (Table 1).

Table 1. Monthly temperature and precipitation normals for DETO, 1971–2000 (Western Region Climatic Data Center).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Temperature (°C)													
Max	1.2	4.6	9.6	15.3	20.7	26.0	30.1	29.9	24.2	16.7	6.7	1.9	15.7
Min	-15.1	-11.7	-6.8	-2.1	3.4	8.4	11.2	10.1	4.3	-2.1	-8.7	-13.8	-1.8
Average Precipitation (cm)													
Total	1.5	1.6	2.6	4.5	6.6	7.7	5.	4.1	3.5	3.6	1.9	1.9	45.1

Visitation Statistics

Since 1980, 358,175 people on average have visited DETO each year. Most visitors come to DETO to observe the Tower during day trips, and a small percentage stay overnight at the park's campground near the Belle Fourche River (NPS 2010a). Other activities that attract visitors include hiking, cross-country skiing, and rock climbing. Park staff also offer interpretive talks, guided walks, and various evening programs, as well as hosting cultural gatherings (DETO 2010b).

2.2 Natural Resources

Ecological Units and Watersheds

DETO is part of the Environmental Protection Agency's (EPA) Middle Rockies Level III Ecoregion.

> The climate of the Middle Rockies lacks the strong maritime influence of the Northern Rockies. Mountains have Douglas-fir, subalpine fir, and Engelmann spruce forests, as well as some large alpine areas. Pacific tree species are never

> dominant, and forests can have open canopies. Foothills are partly wooded or shrub- and grass-covered. Intermontane valleys are grass- and/or shrub-covered and contain a mosaic of terrestrial and aquatic fauna that is distinct from the nearby mountains. Many mountain-fed, perennial streams occur and differentiate the intermontane valleys from the Northwestern Great Plains. Granitics and associated management problems are less extensive than in the Idaho Batholith. Recreation, logging, mining, and summer livestock grazing are common land uses (USGS-EPA 2010).

The EPA divides Level III Ecoregions into smaller Level IV Ecoregions. The Black Hills consists of three Level IV Ecoregions: the Black Hills Foothills, Black Hills Plateau, and Black Hills Core Highlands (Plate 1). DETO is located in the Black Hills Foothills Level IV Ecoregion. The U.S. Geological Society (USGS) Northern Prairie Wildlife Research Center offers the following description of this geographic area:

> Two contrasting landscapes, the Hogback Ridge and the Red Valley (or Racetrack), compose the Black Hills Foothills ecoregion. Each forms a concentric ring around the mountainous core of the Black Hills…Ponderosa pine cover the crest of the hogback and the interior foothills. Buffalo, antelope, deer, and elk still graze the Red Valley grasslands in Custer State Park (USGS-EPA 2010).

DETO is located in the Belle Fourche River Watershed. This watershed is approximately 1,821,000 ha (4,500,000 ac) in size, with about half located in Wyoming and half located in South Dakota. The Belle Fourche River flows from central Wyoming to northwest South Dakota to the Cheyenne River in Meade County, South Dakota. Within the park, the river averages 6.1 m (20 ft) in width and is generally 1 m or less. The Keyhole Reservoir is an impoundment on the Belle Fourche River, roughly 28 km (17 mi) upstream of DETO, which became operational in 1952.

Resource Descriptions

Ponderosa pine forest covers approximately 62% of the area in DETO. Plant species found in ponderosa pine forests include common juniper (*Juniperus communis*), Oregon grape (*Mahonia aquifolium)*, and various grasses. Six types of prairie grasslands occupy roughly 29% of DETO in small patches within the more dominant ponderosa pine forests. Although deciduous forests are rare in DETO (only about 5% of the park's area), common species in this community include bur oak (*Quercus macrocarpa*), green ash (*Fraxinus pennsylvanica*), chokecherry (*Prunus virginiana*) and hawthorn (*Crataegus* spp.). Large cottonwoods (*Populus deltoides* Marshal Subsp. *monilifera*) are located in the Belle Fourche floodplain (NPS 2001).

Common terrestrial vertebrates at the park include black-tailed prairie dog (*Cynomys ludovicianus*), white-tailed deer (*Odocoileus virginianus*), red squirrel (*Tamiasciurus hudsonicus*), least chipmunk (*Tamias minimus*), deer mouse (*Peromyscus maniculatus*), yellow-bellied racer (*Coluber constrictor*), and bullsnake (*Pituophis catenifer*) (NPS 2001). Breeding birds are numerous (NPS 2001; Panjabi 2005) (see list of species in Chapter 4.4). The Tower is likely one of the prime nesting locations for prairie falcons (*Falco mexicanus*) in the area; because of this, the prairie falcon is the only avian species described as a management priority for DETO (Panjabi 2005). The Wyoming Department of Environmental Quality classifies the

Belle Fourche River as a class II river because it can support game fish. The river is a warm-water fishery with a poor aquatic food supply (NPS 1992). White et al. (2002) found nine different species of fish in the Belle Fourche River: flathead chub (*Platygobio gracilis*), sand shiner (*Notropis stramineus*), shorthead redhorse (*Moxostoma macrolepidotum*), white sucker (*Catostomus commersoni*), stonecat (*Noturus flavus*), green sunfish (L*epomis cyanellus*), smallmouth bass (*Micropterus dolomieu*), black bullhead (*Ameiurus melas*), and channel catfish (*Ictalurus punctatus*).

Resource Issues Overview

Installation of the Keyhole Dam in 1952 altered the landscape at DETO (NPS 2007), resulting in the loss of the natural flood regime required for cottonwood regeneration. Today, there are many old, dead, or dying cottonwoods in the floodplain of the park. Young cottonwoods and willows (*Salix* spp.) are not replacing the older trees, allowing exotic species a greater opportunity to establish. The National Park Service (NPS) is attempting to restore cottonwoods and willows in the floodplain through supplemental planting (NPS 2007).

Black-tailed prairie dogs thrived in western prairies in the early 1900s, but human control and sylvatic plague (*Yersnia pestis*) decimated populations through the 20th century (Cully and Williams 2001). The prairie dog population at DETO is intact, with no evidence of decline. The DETO colony occupies 12 to 16 ha (30 to 40 ac) in the southeastern corner of the park and has been expanding; however, NPS manages this expansion because of concerns regarding plague (NPS 2007).

Fire, both natural and prescribed, is one of the most important resource issues in the Northern Great Plains and in DETO. Historically, wild fires occurred every 15 to 30 years in ponderosa pine forests. Following European settlement, humans suppressed many wild fires, resulting in increased fuel loads and frequency of high severity wild fires. Today, NPS utilizes prescribed fire as a tool to encourage biological diversity. At DETO, burned trees are not logged; instead, they are left as habitat for birds, insects, and other animals (NPS 2007).

Exotic species also affect DETO ecosystems. The park has at least 56 nonnative plant species. NPS utilizes multiple techniques to control exotics: manual, biological, and mechanical (NPS 2007). The exotic plant species in DETO affect native park species in different ways. Many of these plants are unpalatable and provide poor nutrition for animals, and lack of grazing pressure allows the plants to reproduce and spread quickly. Exotic plants also out-compete native species by taking available sunlight and growing space (NPS 2007).

Climate change could have dramatic impacts on the ecosystems within DETO (Gitzen et al. 2010). Temperatures in the Northern Great Plains have risen more than 1.1°C (2 °F) over the past century, and models predict an increase of 2.7 to 6.7 °C (5 to 12 °F) during this century. While precipitation is also expected to increase, evapotranspiration will increase with higher temperatures and longer growing seasons, perhaps resulting in an overall drier climate (National Assessment Synthesis Team 2000).

2.3 Resource Stewardship

Management Directives and Planning Guidance

DETO's General Management Plan (NPS 2001) describes four management goals, based on the park's mission:

- Restore and maintain the health and diversity of DETO's natural systems
- Preserve archeological, historic, and ethnographic values at DETO
- Interpret the significant and varied themes of DETO
- Balance educational, spiritual, and recreational uses of DETO and its surrounding landscape to provide meaningful visitor experience

DETO's General Management Plan (NPS 2001) also offers goals regarding the desired future condition of key park resources:

- Regarding Water Resources, Floodplains, and Wetlands
  - Surface water and groundwater will be restored or enhanced.
  - NPS and NPS-permitted programs and facilities will be maintained and operated to avoid pollution of surface water and groundwater.
  - Natural floodplain values will be preserved or restored.
  - The natural and beneficial values of wetlands will be preserved and enhanced.
  - Long-term and short-term environmental effects associated with the occupancy and modification of floodplains will be avoided.
- Regarding Species of Special Concern
  - Federally listed and state-listed threatened and endangered species and their habitats will be sustained.
  - Native species populations that have been severely reduced in or extirpated from DETO will be restored where feasible and sustainable.
  - The management of populations of exotic plant and animal species, up to and including eradication, will be undertaken wherever such species threaten DETO resources or public health and when control is prudent and feasible.
- Regarding Wildland Fire
  - Fire management programs will be designed to meet resource management objectives prescribed for the various areas of DETO and to ensure that the safety of firefighters and the public are not compromised. Until a fire management plan is approved, all wildland fires will be aggressively suppressed, taking into account the resource to be protected and the safety of firefighters and the public.
- Regarding Night Sky
  - NPS will cooperate with DETO neighbors and local government agencies to seek ways to minimize the intrusion of artificial light into the night scene in the

monument. In natural areas, artificial outdoor lighting will be limited to basic safety requirements and will be shielded when possible.

- Regarding Natural Sounds
    - NPS will preserve the natural ambient soundscapes to the natural ambient condition wherever possible, and protect natural soundscapes from degradation due to human-caused noise. Disruption from recreational uses will be managed to provide a high quality visitor experience in an effort to preserve or restore the natural quiet and natural sounds.

Status of Supporting Science

The Northern Great Plains Inventory and Monitory 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 Vital Signs. In 2010, the NGPN completed and released a Vital Signs Monitoring Plan (Gitzen et al. 2010), a subset of which were selected for monitoring in DETO (Table 2).

Table 2. NGPN Vital Signs selected for monitoring in DETO (Gitzen et al. 2010). Those in bold are already monitored by the park or another NPS program; those in italics will likely be monitored in the future, but there are currently no plans to develop a program.

Category	NGPN Vital Signs
Air and Climate	**Ozone**, *wet and dry deposition*, **weather and climate**
Geology and Soils	Stream and river channel characteristics
Water	**Groundwater dynamics, surface water dynamics,** surface water chemistry, aquatic contaminants, aquatic microorganisms and macroinvertebrates
Biological Integrity	Exotic plant early detection, **forest insects and diseases**, riparian lowland plant communities, upland plant communities, land birds, **raptors**, **prairie dogs**
Human Use	**Treatments of exotic infestations, visitor use**
Landscapes (ecosystem pattern and process)	**Fire and fuel dynamics,** land cover and use, extreme disturbances, soundscape, *viewscape, night sky*

Despite the small size of the park, there is a relatively large body of scientific literature regarding park natural resources. Research topics at the park have included deer browsing, prairie dog abundance and health, cottonwood regeneration, natural spring and river water quality, air quality, soundscapes, and night skies.

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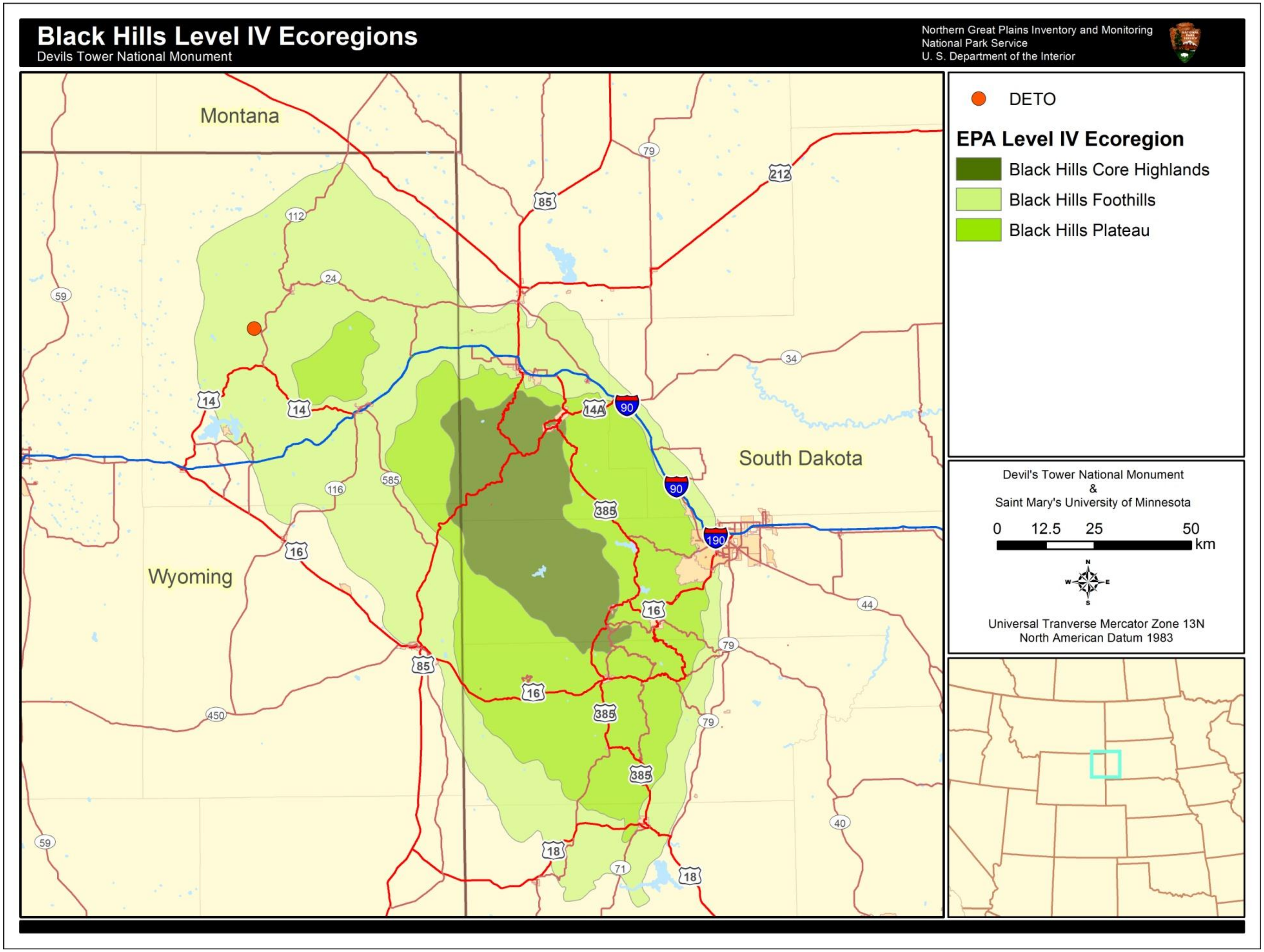

Plate 1. Black Hills Level IV Ecoregions.

Chapter 3 Study Scoping and Design

This National Resource Condition Assessment (NRCA) was a collaborative effort between the National Park Service (NPS) and Saint Mary's University of Minnesota GeoSpatial Services (SMUMN GSS). Stakeholders in this project include Devils Tower National Monument (DETO) park resource staff and the Northern Great Plains Inventory and Monitoring Network (NGPN) staff. Before embarking on the project, specific roles of the NPS and SMUMN GSS were identified. Preliminary scoping meetings were held, and both a task agreement and a detailed scope of work document were collaboratively created by NPS and SMUMN GSS.

3.1 Preliminary Scoping

A preliminary scoping meeting was held 21 October 2009 with SMUMN GSS and NPS staff to determine the purpose of the DETO NRCA, which is to evaluate and report the current conditions of key park resources, to evaluate critical data and knowledge gaps, and to highlight selected existing and emerging resource condition influences of concern to DETO managers.

The National NRCA Program Office provided specific guidance requirements regarding this NRCA:

- The NRCA would be conducted using existing data and information
- Identification of data needs and gaps would be driven by the framework categories
- The analysis of natural resource conditions would include a strong geospatial component
- Resource focus and priorities would be driven primarily by DETO park resource management

This condition assessment provides a "snapshot-in-time" evaluation of resource condition status for a select set of park natural resources, identified and agreed to by the project team. Project findings will aid DETO resource managers in the following objectives:

- Developing near-term management priorities
- Engaging in watershed or landscape scale partnership and education efforts
- Conducting park planning (e.g., General Management Plan, Resource Stewardship Strategy) Reporting program performance (e.g., Department of Interior Strategic Plan "land health" goals).

NPS Involvement

Expectations for DETO staff involvement were detailed during project scoping. Park staff participated in project development and planning, reviewed interim and final products, and participated in condition assessments. They were also expected to participate and collaborate with SMUMN GSS to identify sources of information; to define an appropriate resource assessment structure; to identify appropriately scaled resources, threats, and stressors; and to identify measures for these resources.

DETO park staff helped identify other NPS staff that could provide guidance, technical assistance, and logistical coordination for site visits and discussions with the primary investigator, analysts, and graduate research assistants. Park staff collaborated with the SMUMN GSS Principle Investigator during data mining and status assessment to ensure the synthesis was consistent with the project goals. Additionally, DETO natural resource staff assisted in developing recommendations for additional analyses to fulfill information needs that would aid in the assessment of park resource conditions. DETO staff was also expected to review and comment on draft reports and all publishable material submitted from this project in a timely fashion. Involvement of DETO staff in this project ensured that SMUMN GSS efforts met the true needs of the park.

The NPS was responsible for informing the SMUMN GSS Principle Investigator of the specific activities required to comply with the "NPS Interim Guidance Document Governing Code of Conduct, Peer Review, and Information Quality Correction for NPS Cultural and Natural Resource Disciplines" or any subsequent guidance issued by the NPS Director to replace this interim document.

3.2 Study Design

Component Framework, Focal Study Resources and Components

Selection of Resources and Measures

As defined by SMUMN GSS in the NRCA process, a "framework" is developed for a park. This framework is a way of organizing, in a hierarchical fashion, biogeophysical 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., bison), ecological processes or patterns (e.g., natural fire regime or land cover change), or specific natural features or values (e.g., geological formation, dark night skies, or viewshed) 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 an 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," any agent that imposes adverse changes to a component, and thus are considered during assessment. 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 DETO 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 comprehensive for all park resources, it includes resources and processes unique to the park in some way, of greatest concern, or of highest management priority in DETO. Several measures for each component, as well as known or potential stressors, were also identified in collaboration with DETO resource staff.

Selection of Reference Conditions

A reference condition is a benchmark against which SMUMN GSS compares current values of a given component's measures to determine the present 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 or objective (e.g., a bison herd no larger than 700 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 were not major drivers of ecological populations and processes, such as “pre-exotic invasions” or “pre-1908 establishment.” In other cases, peer-reviewed literature and ecological thresholds helped define appropriate 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” framework (Heinz 2008). Key resources for the park were gleaned from the NGPN Vital Signs Monitoring Plan (Gitzen et al. 2010) and publically available informational materials from DETO. 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 resource to be assessed.

The NRCA framework was finalized in March 2010 following acceptance from DETO resource staff. It contains 13 components (Table 3) and was used to drive analysis in this NRCA. This framework outlines the resources (components), most appropriate measures, known or perceived stressors and threats to the resources, and the reference conditions for each resource to compare to current conditions.

Table 3. Final DETO NRCA framework.

Devils Tower National Monument
Natural Resource Condition Assessment Framework

Components	Measures	Stressors & Emerging Threats	Reference Condition
Extent and Pattern			
Landscape Composition			
Landcover Extent	Landcover change	Fire suppression, exotics, and invasives	Pre cattle and sheep grazing, natural and healthy environment
	Plant species richness	Ponderosa pine, exotics	Pre cattle and sheep grazing, natural and healthy environment
Biological Components			
Ecosystem and Community			
Native plant communities	Change in Ponderosa Pine density and distribution	Ponderosa pine is a competitor with native plant communities	Pre fire supression
	Exotic Plant Distribution and Density	Fire regime, climate changes, moisture patterns, potential atmospheric nitrogen deposition, visitation	pre-exotic species
	Cottonwood Regeneration	Loss of natural hydrograph via Dam operations	Pre cattle and sheep grazing and pre dam, natural and healthy environment
Biotic Composition			
Prairie Falcon	Change in nesting or population status	Land cover change, development and disturbance	Successful nesting within monument
Birds	Species Richness, Density, and Abundance	Land cover change	Current diversity, richness, and distribution
Prairie Dog	Population number and distribution	White Hoarhound, drought, Bubonic Plague, human interactions	Current population at reference levels
White-Tailed and Mule Deer	Population and distribution	Chronic Wasting Disease	Historic natural and healthy population
Chemical and Physical Characteristics			
Water Quality	Temperature	Vegetation change, Dam operations	EPA Water Quality Criterion
	pH	Disruption of natural hydrograph (dam operation)	EPA Water Quality Criterion
	Conductivity	Disruption of natural hydrograph (dam operation)	EPA Water Quality Criterion
	Dissolved Oxygen	Turbidity, nutrients	EPA Water Quality Criterion
	Coliform Bacteria	Livestock grazing, development	EPA Water Quality Criterion
	Turbidity	Livestock grazing, bank erosion	EPA Water Quality Criterion
Air Quality	Mercury	Atmospheric deposition from powerplant operations	EPA Standards
	Nitrogen	Atmospheric deposition from agricultural operations	EPA Standards
	Ozone	Fossil fuel combustion	EPA Standards
Hydrology	Annual hydrograph (changes in natural flow)	Climatic changes, dam operations,	Pre dam construction
Goods and Services			
Non-Consumptive			
Soundscape	Decibel levels and distribution of non-natural sound character (e.g. engines	Development, trails, roads, aircraft	Undeveloped and "natural" park experience
Viewshed	Natural undeveloped viewsheds, both near and distant views	Development, visibility	Undeveloped and "natural" park experience
Dark Night Skies	V Magnitude, night sky program standard	Point source light pollution, air quality and particulates	Undeveloped and "natural" park experience
Tower usage	Climber numbers, Native American significance, visitor appreciation, local connectivity	Cultural and natural sensitivities	Current usage and practices (balanced)

Reporting Areas
Reporting areas were not used in this assessment.

General Approach and Methods
This study involved gathering and reviewing all 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 analyzed to provide summaries of condition for resources 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.

Individual Component Assessments

Data Mining
The data mining process (acquiring as much relevant data about key resources as possible) began at the first scoping meeting, where DETO 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, nongovernmental organization reports, databases, tabular data, and charts. Geographic information system (GIS) data were provided by NGPN and by DETO staff. Access was also granted to various NPS online data and literature sources, such as NatureBib and NPSpecies. 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 on the topic and analysis recommendations from DETO staff. Specific approaches to data development and analysis can be found within the respective component assessment sections located in Chapter 4 of this report.

Preparation and Review of Component Rough Draft Assessments (Phase I Documents)
The process of developing draft documents for each component began with a detailed phone or conference call with individuals considered resource components to verify the most relevant data and literature sources and to formulate ideas about current condition with respect to the experts' opinions. Information gained in these initial conversations was important for rough draft development, which used the data gathered through the data mining process as well as the insights provided by component experts. Documents were then forwarded to component experts for initial review and comments.

The preparation of rough draft assessments for each component was a cooperative process involving SMUMN GSS analysts and DETO and NGPN staff. Although SMUMN GSS analysts relied heavily on peer-reviewed literature and existing data in conducting the assessment, the expertise of NPS resource staff also played an invaluable role in providing insights into the appropriate direction for analysis and assessment of each component, especially when data or literature were limited.

Development and Review of Final Component Assessments (Phase II Documents)
Following review of the component rough drafts (Phase I documents), analysts used the review feedback from resource experts to compile the final component assessments (Phase II documents). Consistent contact with experts was maintained throughout this process to adequately address questions and comments pertaining to rough draft reviews and to ensure accurate representation of DETO and NGPN staff knowledge. Completed Phase II documents were sent back to expert reviewers for a second thorough review to allow incorporations of additional comments or feedback into the assessment document. As a result of the feedback process and recommendations and insight provided by DETO resource staff and other experts, the final component assessments (Phase II documents) represent the most relevant and current data available for each component and the sentiments of park resource staff and resource experts.

All resource component assessments are presented in a standard format in the final report (described below).

<u>Format of Component Assessment Documents</u>

Description
Each resource component is described for relevance, context, and importance to the park setting, For example, a component may represent a unique feature of the park, may be a key process or resource in park ecology, or may be a resource of high management priority in the park. Any interrelationships that occur among a given component and other resource components included in the broader assessment are also emphasized.

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

Reference Conditions and Values
Reference conditions were determined for each resource component as defined in the framework, including an explanation of why specific reference conditions are appropriate or logical. Available data and literature that explain and elaborate on the designated reference conditions are included, and the development of conditions or values that originated with the park experts or SMUMN GSS analysts are explained.

Data and Methods
Data sets used to evaluate each component were adjusted or processed as a lead-up to analysis (descriptions of extensive or highly technical processes are included in an appendix for the reader at the end of the document). A discussion of how the data were evaluated and analyzed to determine current condition (and trend when appropriate) is included.

Current Condition and Trend
In-depth key findings regarding the current condition of the resource component and trends (when available) is presented primarily in the 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. All relevant data and information for a component are presented and interpreted in this section.

Threats and Stressor Factors
A summary of the threats and stressors that may affect resources and influence, to varying degrees, the current condition of a resource component are presented. Relevant stressors were described in the scoping process and are outlined in the NRCA framework. Threats and stressors are elaborated in this section to create a summary based on a combination of available data and literature as well as discussions with experts and park natural resources staff.

Data Needs and Gaps
Critical data needs or gaps for each resource component are outlined. Specifically, SMUMN GSS discusses how these data needs and gaps, if addressed, would help determine the current condition of a given component in future assessments. In some cases, the data needs and gaps are significant enough to make it inappropriate or impossible to determine the condition of the resource component. In these cases, stating the data needs and gaps will help natural resources staff prioritize monitoring or data gathering efforts.

Overall Condition
A qualitative summary statement of the current condition was determined for each resource component. Condition is determined after a thorough review of available literature, data, and any insights from park 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.

Initial designations of current condition for a component (i.e., made by the authors during component rough draft preparation) were subject to review from resource experts during the review process and amended when appropriate to provide a more accurate representation of park staff and experts' interpretation of condition. When applicable, condition designations were made with respect to the defined reference condition; when reference conditions were not available, the opinions of park staff and experts were relied on more heavily to determine condition.

Condition Graphic

Graphic representations of the condition of the component (and trend when appropriate) are presented to provide readers a visual interpretation of the assessed condition but are not intended to replace the written statements of condition, which provide an in-depth discussion of and justification for the condition attributed by analysts to the resource component.

An example of a condition graphic used to represent the assessed condition of a component (Figure 1) uses colored circles to indicate a component's condition expressed by level of concern. Red circles signify a resource of "significant" concern to park management. Yellow circles signify a resource is of "moderate" concern to park management. Green circles indicate the condition of a component is of "low" concern. Gray circles signify that data are currently insufficient to make a statement about concern or condition of the component.

Arrows nested inside the circles indicate the trend of the condition of a resource component. Up arrows indicate the condition of the component is improving from reference condition, right arrows indicate a stable trend in condition, and down arrows indicate a decline in the condition of a component from reference condition. These are only used when it is appropriate to comment on the trend of condition of a component. A triple-pointed arrow indicates the trend of the component's condition is currently unknown.

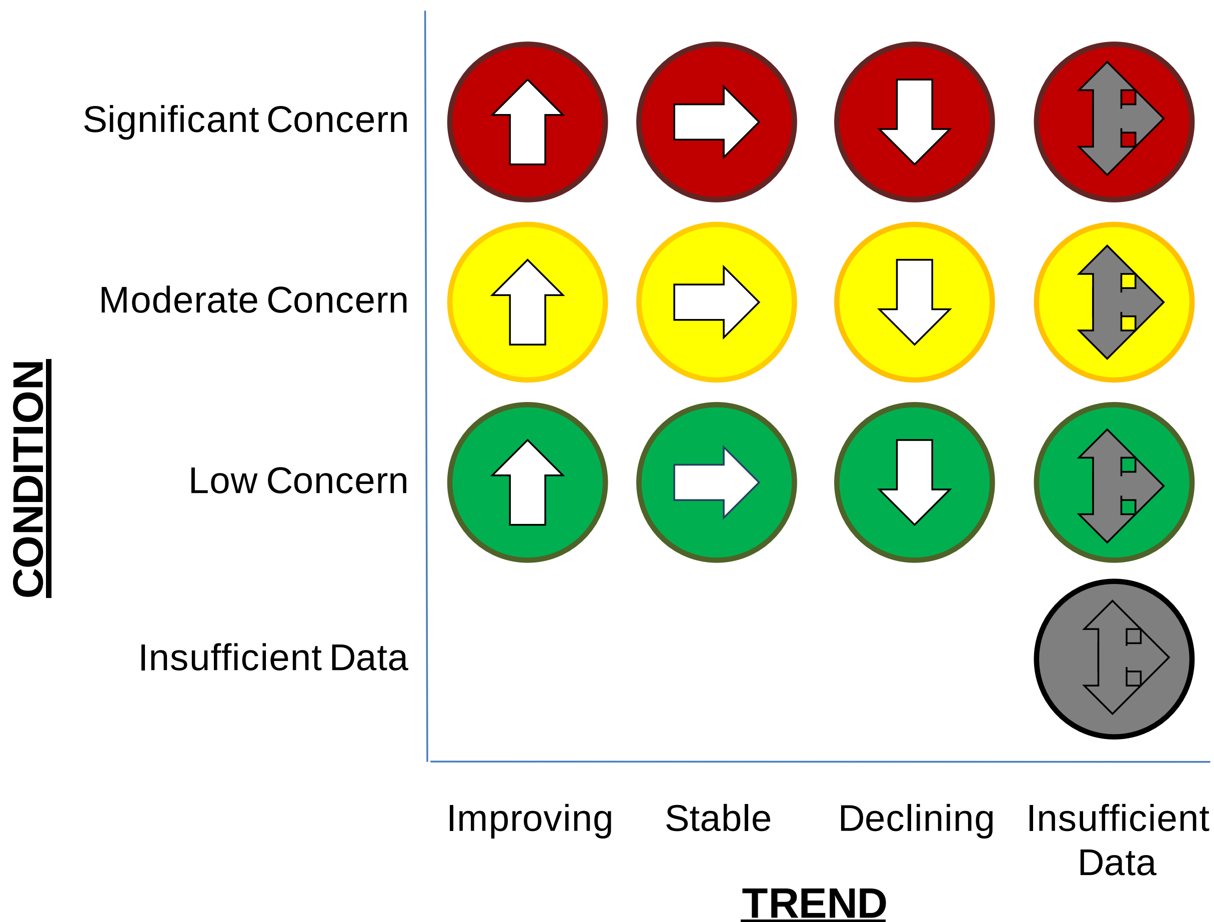

Figure 1. Graphic representation of current condition and trend of a component.

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

Literature Cited
Formal citations for literature or datasets used in the analysis and assessment of condition for the resource component are provided.

Literature Cited

Gitzen, R. A., M. Wilson, J. Brumm, M. Bynum, J. Wrede, J. Millspaugh, and K. Paintner. 2010. Northern Great Plains Network Vital Signs Monitoring Plan. Natural Resource Report NPS/NGPN/NRR—2010/186. National Park Service, Fort Collins, CO.

Great Lakes Environmental Indicators Project (GLEI). 2010. Glossary, Stressor. Online. (http://glei.nrri.umn.edu/default/glossary.htm). Accessed 9 December 2010.

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 Component Summaries

The background, analysis, and condition summaries for the 13 key resource components in the project framework were compiled. The following sections discuss the key resources and their measures, stressors, and reference conditions. The order of components follows the project framework (Table 3):

1. Land Cover Extent

2. Native Plant Communities

3. Prairie Falcon

4. Birds

5. Prairie Dog

6. White-Tailed and Mule Deer

7. Water Quality

8. Air Quality

9. Hydrology

10. Soundscape

11. Viewshed

12. Dark Night Skies

13. Tower Usage

4.1 Land Cover

Description

Land cover is the physical surface of the earth, described using classes of vegetation and land use classifications (e.g., agriculture, developed, transportation). Land cover is portrayed in maps created through field surveys and/or analysis of remotely sensed imagery (Comber et al. 2005). The Northern Great Plains Inventory and Monitoring Network (NGPN) recognizes land cover and land use (LCLU) as a Vital Sign because natural disturbances, stressors, and management cause large-scale changes to the general ecosystem composition of the National Park Service (NPS) units, altering the land cover of a park. In addition, the type, amount, and arrangement of vegetative structural types in park units partially determine the composition and abundance of vertebrate and invertebrate communities in those units (Vinton and Collins 1997).The protocol for monitoring this Vital Sign will be developed over the next 1–5 years.

Land cover in Devils Tower National Monument (DETO) is primarily a mix of ponderosa pine woodlands and short- and mixed-grass upland meadows. DETO also contains cottonwood and willow riparian areas, green ash and American elm forests (*Ulmus americana*), wolfberry (*Symphoricarpos occidentalis*) forests, and bare exposed rock. Disturbed and converted areas include vegetation influenced by nonnative plants in the prairie dog towns and some relatively small areas classified by the Anderson Level II LCLU (Anderson et al. 1976) as “residential” and “commercial services” (park roads and infrastructure areas).

Measures

- Land cover change

Reference Condition and Values

<u>Land Cover Change</u>

For this assessment, the reference condition for land cover is defined as a historical reference to a time when the environment was natural and healthy, before disturbances caused by cattle and sheep grazing in the area and before the introduction of nonnative plants.

Historic human use and land management significantly changed the landscape in and around the DETO. Most of the surrounding land has been used for livestock grazing, timber production, and agricultural crop production. In addition to livestock grazing and nonnative plant introductions, humans have altered the landscape through the suppression of wildfires during the last century. This “significantly changed the vegetation succession pattern and species composition” (NPS 2004, p. 13). The DETO Fire Management Plan suggests that lasting effects from years of fire suppression and cattle and sheep grazing may have significantly changed the land cover in the area (NPS 2004). Invasive plants have also changed plant community composition in and around present day DETO since European settlement, although no precise date identifies the first arrival of nonnative plants (NPS 2004).

Extensive grazing of cattle, sheep, and goats occurred in the late 1800s and early 1900s. Daugherty (1984) noted that livestock foraged on land surrounding DETO, and often within DETO, during the 1930s. In 1932, as many as 1,000 head of cattle were fed within 1 mile of

DETO's boundary, and as many as 25 head of cattle were driven off DETO per day. In 1933, as many as 50 head were driven off each day (Daugherty 1984).

Land cover is a dynamic aspect of any ecosystem and is driven by both natural and human factors. Natural disturbances such as fire, wind-throw, and insect and disease infestations can reset vegetation successional trajectories. Another natural driver of vegetation and land cover is native ungulate grazing. For example, bison (*Bison bison*) were a keystone species of the Great Plains for approximately 10,000 years. Humans eliminated them from the area by the mid-1870s (Brown and Seig 1996). Quantitative information describing land cover before cattle and sheep grazing in the area around DETO is unavailable. The primary change in land cover (at least at a mapable scale through most LCLU mapping efforts) described in the literature is the increase in density and expansion of ponderosa pines into the grasslands (Covington and Moore 1994; Brown and Sieg 1996; Brown et al. 2001; Brown and Cook 2005). Some of the major factors that have affected land cover on a regional or landscape scale are discussed in the subsequent section.

Fire Regime and Land Cover

Fires are important, naturally occurring events in the Black Hills and Great Plains. A generally accepted ecological concept in western North American ponderosa pine forests is that frequent surface fires maintained open forest stands dominated by large, old trees (Covington and Moore 1994; Brown et al. 2001, as cited in Brown and Cook 2005). The natural fire regime, specifically the fire return interval, has changed since European settlement due to fire suppression, grazing, logging, and fragmentation from human development.

Stambaugh et al. (2008) found that the fire regime (i.e., frequency, severity, seasonality, and temporal variability) in DETO was similar to fire regimes in other fire history studies in the Black Hills and Northern Great Plains. The mean fire return interval (timing between fires) ranged from 11 to 32 years before European settlement (from 1312 to 1850). For a relatively short time in the late 19th century (1850–1880), mean fire return intervals shortened to 5.7 years. Following settlement in the area of present day DETO, there was a fire-free interval of 119 years, four times the long term mean from 1312 to 2001 (Stambaugh et al. 2008).

Brown and Sieg (1996, 1999) identify reasons for longer fire intervals after major European settlement, including fire suppression policies and reduced fine-fuel loads because of livestock grazing, logging, and fragmentation. Fire suppression resulted in increases in woody vegetation density, allowing encroachment into prairie areas (NPS 2004). The reduction in fire frequency (or increases in mean fire return intervals) also raised concern for abnormally severe fires. In the absence of frequent fires, increases in fuel accumulation, and increased tree density, Stambaugh et al. (2008) suggest that a severe fire with "historically unprecedented fire effects" (p. 184) may occur near DETO.

A fire history study completed in 1984 found that three types of fires occurred in DETO: lightning strikes, regional fires, and area-wide fires (NPS 2004). Lightning strikes were the most common cause of fire, but they were often extinguished by rain or by discontinuous fuels (NPS 2004). Regional fires were those that started outside DETO's boundaries and often burned one-third to two-thirds of DETO's area in a single fire event; from 1600 to 1983 there were 14 of these fires (NPS 2004). Finally, area-wide fires began in DETO and expanded over the entire area; 15 of these fires occurred from 1600 to 1937 (NPS 2004).

As discussed in the native plant communities section of this document (Chapter 4.2), prescribed fires are now set to reduce fuel loads (pine density) and the risk of severe wildfires. Prescribed fires, defined as any fire ignited by management actions to meet a specific objective, began in 1982 in DETO. Most of the land surface of DETO has experienced fire at least once from 1981 to 2009 (Table 4, Plate 2), and according to NPS fire perimeter (polygon) and point GIS data, the vast majority (>90%) of the area burned in DETO was through prescribed burns. According to GIS perimeter (polygon) data, larger fires (>14 ha [33 ac]) in DETO did not begin until 1993. Averaging all years from 1993 through 2009, both wildfire and prescribed fires burned an average of 34.7 ha (85 ac) per year (Figure 2; Table 4).

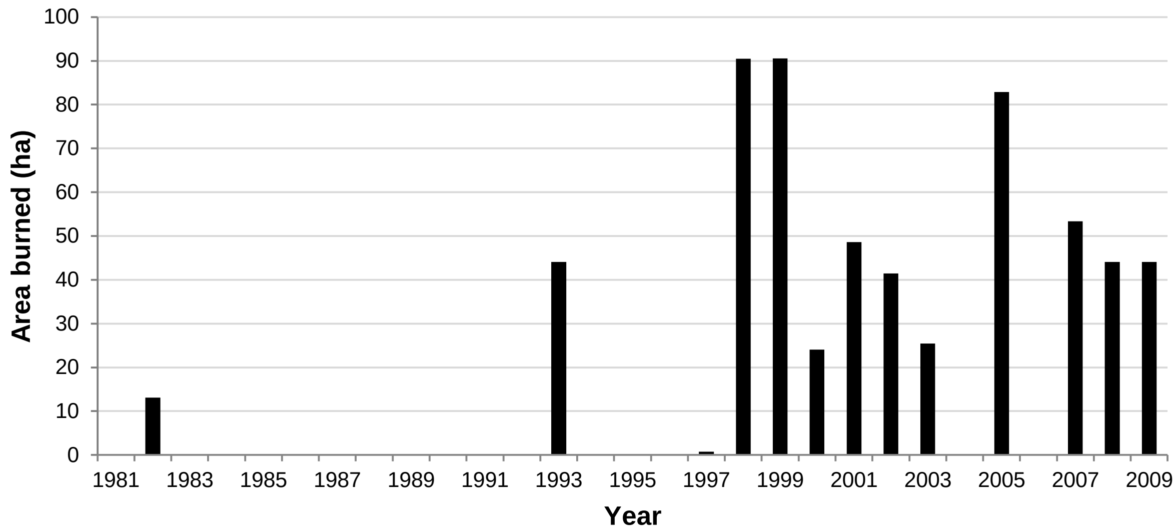

Figure 2. Burn area by year, all fire types, within the boundaries of DETO, 1986–2009 (NPS GIS data). Notes: During this period of record, more than 90% of the fire area burned in DETO was through prescribed fires, and in several years small areas were burned (Table 1). Areas for 1981–1985 come from fire-point GIS data, whereas all subsequent years come from polygon GIS data.

Table 4. Annual burn area, all fire types, within the boundaries of DETO, 1981–2009 (NPS GIS data). During this period of record, more than 90% of the fire area burned in DETO was prescribed fires.1981–1985 data are from GIS point data; all subsequent data are from GIS polygon data.

Year	Area burned		Year	Area burned	
	ac	ha		ac	ha
1981	0.1	0.0	1996	0.0	0.0
1982	32.3	13.1	1997	1.8	0.7
1983	0.0	0.0	1998	1.8	0.7
1984	0.1	0.0	1995	223.8	90.6
1985	0.0	0.0	1999	59.4	24.1
1986	0.0	0.0	2000	120.1	48.6
1987	0.0	0.0	2001	102.4	41.4
1988	0.3	0.1	2002	63.0	25.5
1989	0.0	0.0	2003	0.1	0.1
1990	0.1	0.1	2004	204.7	82.9
1991	0.0	0.0	2005	0.3	0.1
1992	0.0	0.0	2006	131.9	53.4
1993	108.9	44.1	2007	108.9	44.1
1994	0.0	0.0	2008	108.9	44.1
1995	0.0	0.0	2009	0.0	0.0

Recent fire effects monitoring data suggest that prescribed fire is opening up the midstory and overstory size classes within the ponderosa pine stands, significantly reducing fuel loading on the ground (D. Swanson, pers. comm., 2011). Most prescribed fire objectives are being met for each implemented burn unit in the forest or prairie. Those objectives include increasing cover of native grasses and forbs while decreasing cover of nonnative grasses. For most burn units and monitoring types, native grass cover and sedges are increasing following one prescribed burn. Most of this increase is from western wheatgrass (*Pascopyrum smithii*), big bluestem (*Andropogon gerardii*), and the grama grasses (*Grama* spp.). Kentucky bluegrass (*Poa pratensis*) is the predominant nonnative grass in the forest and prairie and generally decreases following prescribed burning, especially spring burns. Generally, native and nonnative forb cover has not significantly changed following one prescribed burn.

Grazing and Land Cover

Bison were once a keystone herbivore that grazed in the central grasslands of North America (Meagher 1986). Along with fire, their grazing habits played a role in vegetation succession and plant species composition, thus affecting overall land cover composition. Today, the primary grazers in the area around DETO are livestock, such as cattle and sheep. In addition to fire suppression and logging in the Black Hills, past livestock grazing affected pine density. Livestock selectively grazed on perennial grasses, reducing competitive exclusion. The removal of the herbaceous layer represented the loss of fine fuel burned by natural, frequent, low-intensity fire that killed tree seedlings (Belsky and Blumenthal 1997; Covington et al. 1997). Overgrazing occurred specifically within DETO during the 1930s from wandering cattle that, at times, impacted vegetation and caused erosion (Daugherty 1984). Cattle entered DETO because of poor fences, and the Belle Fourche River bottom served as a natural route for them (Daugherty 1984).

Human Disturbance and Land Cover

The “long history of human settlement in the Black Hills has resulted in a highly fragmented land ownership pattern” (Fertig and Obald 2000). Most of the public lands have

> well-established multiple use mandates (logging, mining, and livestock grazing). Until recently, few areas have been designated for natural resource protection, and most of these were established for recreation or to preserve unique geological or cultural features rather than native biological diversity (Fertig and Oblad 2000, p. 13).

Fertig and Oblad (2000) also suggest that the road density in the Black Hills might prevent many areas from being preserved at a broad landscape level.

DETO is located in Crook County, Wyoming, which at 0.81 individuals/km^2 is the fifth lowest human population density of all counties in the state. Although high human population densities are often associated with significant land cover changes (e.g., conversion from vegetative cover to impervious surfaces), land uses such as mining, logging, and livestock grazing (both historic and present) create lasting effects on plant communities and on overall land cover. While logging and surface mining may have more visible effects to land cover types, ecological costs are also associated with livestock grazing (Fleischner 1994).

Data and Methods

NGPN does not yet have a protocol for monitoring the LCLU Vital Signs; however, the expected approach includes the acquisition and analysis of fine-scale satellite imagery and measuring land use and coarse vegetation cover within NPS units and within an undetermined buffer of the NPS units. This protocol will be developed over the next 1 to 5 years.

Salas and Pucherelli (1998) provide the most recent, detailed vegetation map (also considered an LCLU map) in an area covering DETO. The map was derived from 1993 color infrared aerial photographs and field sampling at a scale of 1:16,000. In addition to the land within DETO boundaries, Salas and Pucherelli (1998) mapped an area of approximately 1 to 1.5 km (0.6 to 0.9 mi) surrounding the boundaries. The map categorizes vegetation associations (land cover) and Anderson Level II land use categories using GIS polygons. The imagery used to create this land cover map is now more than 17 years old. No information is available quantifying the extent of changes that have occurred to these LCLU classifications. While some changes have occurred due to effects of prescribed fire since the imagery used to create the Salas and Pucherelli (1998) map, the data are still considered to be moderately accurate.

The National Land Cover Database (NLCD) 1992/2001 Retrofit Land Cover Change Data Product (Fry et al. 2009), provides a coarse representation of LCLU (Anderson et al. 1976, Level I) change from 1992 and 2001 in and around DETO. These data are intended for regional scales with a minimum mapping unit of 0.4 ha (1 ac) and a final mapping accuracy of 70 to 80%. More recent LCLU change data (2001 to 2006) have recently become available (Fry et al. 2011); however, MRLC states that these data are provisional to date.

NPScape is a project created by the NPS Natural Resource Program Center, Inventory and Monitoring Division that monitors landscape dynamics and delivers a suite of landscape-scale datasets, maps, reports, and other products to NPS units (NPS 2011). NPScape project analyses outputs provide information regarding land cover and landscape dynamics on a regional scale (i.e., 30 km within and surrounding DETO).

The NPScape project created a conceptual framework that describes two major factors affecting landscape scale dynamics: natural systems and human drivers. Together these help define the "conservation context" of a given NPS unit (Figure 3) (NPS 2010d). As one of the standard outputs, the project provides 2001 LCLU data in a 30-m cell size within a 30-km buffer of DETO from NLCD (NPS 2010a), a coarser resolution than the Salas and Pucherelli (1998) vegetation map. The NPScape project also provides several other land cover related datasets, developed using Python® scripts in GIS, including natural versus converted land cover, land cover change, and landscape pattern. These Python® scripts can be used on other datasets (e.g., updated LULC datasets at finer scales than offered datasets such as the NLCD) to derive similar GIS products. The project also examines human drivers including population, road density, impervious surfaces, and categorizations of conservation status metrics (NPS 2010b, 2010c).

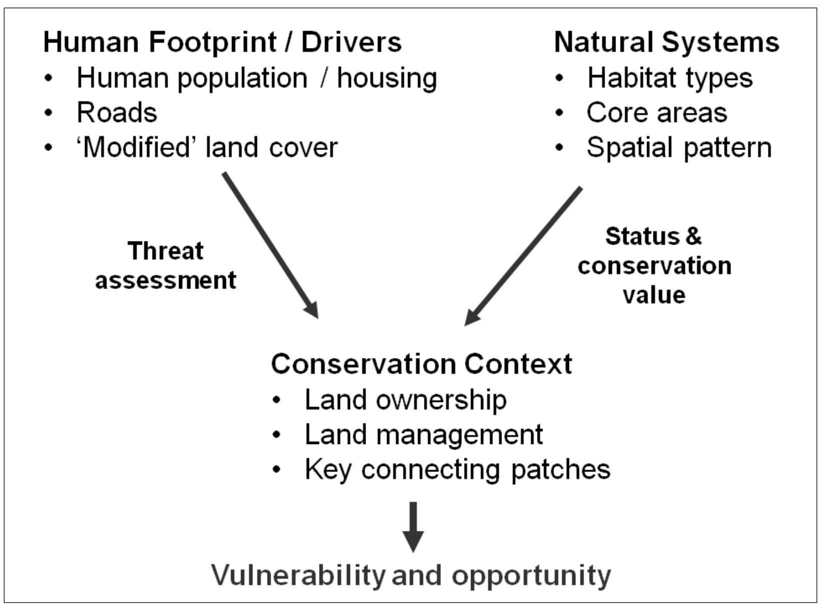

Figure 3. NPScape conceptual framework (NPS 2010d).

The GIS outputs, namely those derived from NLCD, produced by the NPScape project are not immediately comparable to those in Salas and Pucherelli (1998).

Current Condition and Trend

<u>Land Cover Change</u>
Current vegetation or land cover in DETO consists of a mosaic of ponderosa pine woodlands, forests, and mixed grass prairie, with the majority of the land cover (62%) being ponderosa pine woodlands and forests (Stambaugh et al. 2008). Salas and Pucherelli (1998) provide the most current high-resolution, field-verified vegetation map (LCLU) (Plate 3) at this scale. The

majority of land cover for the entire study area (within DETO and approximately 1.5 mi outside DETO) was considered Grassland Complex (41%), Ponderosa Pine Complex I (30%), or Ponderosa Pine Complex II (11%). Refer to Salas and Pucherelli (1998) for a detailed description of these classified map units, and to Table 9 in the native plant communities section (Chapter 4.2) for a breakdown of the 17 different vegetation associations identified in the mapping project. Appendix A displays total area of each mapping unit in the Salas and Pucherelli (1998) study area, including both vegetation associations and Anderson Level II land cover/use categories.

Since this mapping effort, prescribed burns have created some relatively small changes in the extent and relative composition of land cover classifications in DETO. One specific area that has experienced change is the 94 ha (232 ac) Belle Fourche prescribed burn in April 1998. Some localized high fire intensities resulted in ponderosa pine overstory mortality, increased canopy openness, and increased grass cover (Figure 4). At a park-wide level, these changes are relatively small. Fire effects monitoring data indicate overall decreases in midstory and overstory size classes within ponderosa pine stands (D. Swanson, pers. comm., 2011). Some subtle changes may have also occurred due to small expansions or contractions of the prairie dog towns and from relatively small alterations, on a park-wide scale, to vegetative cover through nonnative plant control efforts and native plant restoration efforts. Therefore, despite these changes, the Salas and Pucherelli (1998) map is still largely representative of the current extent and relative composition of land cover and land use classes across DETO.

Figure 4. Belle Fourche prescribed burn photos. The image on the left was taken 26 April 1998, 4 weeks after the burn. The image on the left was taken 7 July 2008. (Photos from Northern Great Plains Fire Ecology Program).

The NLCD 1992/2001 Retrofit Change Product (Fry et al. 2009) provides an indication of land cover change in and immediately surrounding DETO (Plate 4). The only change (LCLU class to class) within the boundaries of DETO was open water to forest (Table 5). This represents a classification error, likely categorizing as open water a shadow in the Satellite image caused by the Devils Tower. Using the NPScape Area of Analysis (AOA), a 30-km buffer of DETO, the primary changes of LCLU class to class from 1992 to 2001 were grassland/shrub to open water (33% of total change area), wetlands to grassland/shrub (27% of total change area), forest to grassland/shrub (14% of total change area), and agriculture to grassland /shrub (11% of total change area) (Table 6; Plate 5).

Table 5. Land cover change, 1992 to 2001 in DETO (within boundaries) (Fry et al. 2009).

Modified Anderson Land Cover Class	Land Cover Change (class to class)	area (ha)	area (ac)	% composition
Open Water*		0.9	2.2	0.2
Urban		15.1	37.4	2.8
Barren		2.7	6.7	0.5
Forest		239.3	591.3	44.0
Grassland/Shrub		276.3	682.7	50.9
Agriculture		1.1	2.7	0.2
Wetlands		7.0	17.3	1.3
	Open Water to Forest*	0.9	2.2	0.2
	Totals:	**543.3**	**1342.6**	

*This is an erroneous classification, likely caused by the tower's shadow in satellite imagery.

Table 6. Land cover change, 1992 to 2001 in DETO AOA (30 km buffer of DETO) (Fry et al. 2009).

Modified Anderson Land Cover Class	**Land Cover Change (class to class)**	**area (ha)**	**area (ac)**	**% composition**	**% of change**
Open Water		1,667.7	4,121.0	0.54	NA
Urban		1,262.9	3,120.6	0.41	NA
Barren		261.7	646.7	0.08	NA
Forest		93,987.3	232,246.7	30.16	NA
Grassland/Shrub		206,090.7	509,259.3	66.12	NA
Agriculture		2,206.0	5,451.1	0.71	NA
Wetlands		1,906.0	4,709.9	0.61	NA
	Open Water to Barren	0.6	1.6	0.00	0.01
	Open Water to Forest	0.9	2.2	0.00	0.02
	Open Water to Grassland/Shrub	132.3	326.9	0.04	3.08
	Open Water to Agriculture	1.7	4.2	0.00	0.04
	Open Water to Wetlands	13.1	32.5	0.00	0.31
	Barren to Forest	0.5	1.3	0.00	0.01
	Barren to Grassland/Shrub	66.4	164.1	0.02	1.55
	Barren to Agriculture	6.0	14.9	0.00	0.14
	Barren to Wetlands	5.4	13.3	0.00	0.13
	Forest to Open Water	0.5	1.3	0.00	0.01
	Forest to Urban	1.4	3.3	0.00	0.03
	Forest to Barren	0.6	1.6	0.00	0.01
	Forest to Grassland/Shrub	613.7	1,516.5	0.20	14.30
	Forest to Agriculture	44.6	110.3	0.01	1.04
	Forest to Wetlands	24.5	60.5	0.01	0.57
	Grassland/Shrub to Open Water	1,397.1	3,452.2	0.45	32.55
	Grassland/Shrub to Urban	10.1	24.9	0.00	0.23
	Grassland/Shrub to Barren	19.1	47.1	0.01	0.44
	Grassland/Shrub to Forest	29.1	71.8	0.01	0.68
	Grassland/Shrub to Agriculture	69.7	172.1	0.02	1.62
	Grassland/Shrub to Wetlands	19.7	48.7	0.01	0.46
	Agriculture to Urban	0.5	1.1	0.00	0.01
	Agriculture to Forest	2.3	5.8	0.00	0.05
	Agriculture to Grassland/Shrub	460.4	1,137.5	0.15	10.72
	Agriculture to Wetlands	1.0	2.4	0.00	0.02
	Wetlands to Open Water	22.1	54.7	0.01	0.52

*Total change area in the AOA (30 km buffer of DETO) is 4,292.7 ha (10,607.5 ac).

Table 6. Land cover change, 1992 to 2001 in DETO AOA (30 km buffer of DETO) (Fry et al. 2009). (continued)

Modified Anderson Land Cover Class	Land Cover Change (class to class)	area (ha)	area (ac)	% composition	% of change
	Wetlands to Urban	2.8	6.9	0.00	0.06
	Wetlands to Forest	15.8	38.9	0.01	0.37
	Wetlands to Grassland/Shrub	1,161.5	2,870.2	0.37	27.06
	Wetlands to Agriculture	169.3	418.3	0.05	3.94
	Totals:	**311,675.0**	**770,162.7**		

*Total change area in the AOA (30 km buffer of DETO) is 4,292.7 ha (10,607.5 ac).

Through the NPScape project, NPS 2010a also offers a representation of regional scale (30 km area surrounding DETO) LCLU (Plate 6), and a representation of regional land cover change using a reclassification of the 2001 NLCD. These coarse resolution land cover data indicate general changes in land cover surrounding DETO. NPS 2010a defined “natural” land cover as areas that are predominantly vegetated and “converted” land cover as areas influenced by impervious surfaces, such as urban areas and roads (Plate 7). Two further points bear consideration: (1) the “natural” categorization does not take into account important ecological changes that may have occurred, such as changes in plant species diversity, plant community composition and structure, and plant species nativity (i.e., native vs. nonnative plant species); (2) NLCD does not identify livestock grazing as a land use and therefore does not capture pasture as converted land, thus missing any associated ecological costs of this particular land use. LCLU categories were reclassified for this analysis (Table 7).

Table 7. 2001 NLCD reclassification to NPScape land cover natural vs. converted classes (NPS 2010a).

NLCD Land Cover Class	NPScape Land Cover Class
11 Open Water	2 Natural
12 Perennial Ice/Snow	2 Natural
21 Developed, Open Space	1 Converted
22 Developed, Low Intensity	1 Converted
23 Developed, Medium Intensity	1 Converted
24 Developed, High Intensity	1 Converted
31 Barren Land	2 Natural
32 Unconsolidated Shore	2 Natural
41 Deciduous Forest	2 Natural
42 Evergreen Forest	2 Natural
43 Mixed Forest	2 Natural
51 Dwarf Scrub	2 Natural
52 Scrub/Shrub	2 Natural
71 Grassland/Herbaceous	2 Natural
72 Sedge Herbaceous	2 Natural
73 Lichens	2 Natural
74 Moss	2 Natural
81 Pasture/Hay	1 Converted
82 Cultivated Crops	1 Converted
90 Woody Wetlands	2 Natural
95 Emergent Herbaceous Wetland	2 Natural

Another NPScape analysis displays categories of LCLU change from 1992 to 2001 using the NLCD change product (Plate 8) (NPS 2010a). The map reveals some areas changed from natural to agriculture (areas in pink on the map) and from converted to natural land cover classifications (areas in blue on the map). The composition of this change classification within DETO and a 30-km^2 area surrounding DETO was calculated (Table 8).

Table 8. Land cover change in and around DETO (NPS 2010a).

Class Name	Total Area		% Composition
	ha	ac	
Converted	3,469	8,571.7	9.9%
Natural	30,744	75,968.9	87.9%
Natural to Agriculture	291	719.9	0.8%
Natural to Urban	142	35.1	<0.1%
Agriculture to Urban	<1	1.1	<0.1%
Converted to Natural	464	1,145.8	1.3%

Threats and Stressor Factors

NPS identified fire suppression, past and present land use practices, and invasive plants as the main stressors or factors that have contributed to land cover change in and around DETO. Past fire suppression and land use practices such as livestock (cattle, sheep, and goat) grazing prior to the park establishment and continued grazing of wandering of cattle from outside DETO have negatively altered the native land cover in DETO by decreasing native grass and herbaceous plant cover and increasing woody species cover via succession (NPS 2004). Invasive plants continue to establish within DETO's boundaries and require repeated treatments to prevent continued spread into native plant communities. However, nonnative plants have not invaded at such a scale as to change land cover classes in DETO.

The suppression of wildfires during the last century in and around DETO "significantly changed the vegetation succession pattern and species composition" (NPS 2004, p. 13). As of 2004, the fire management plan indicated that the densities of overstory ponderosa pine trees in savanna and ponderosa pine forests in DETO should be reduced (NPS 2004). Although wildland fire suppression continues in DETO, the NPS has been conducting prescribed burns since 1982. Each prescribed fire has its own set of management objectives, but many of the fires are used, in part, to control nonnative plants and stimulate the growth of native species. "Desired future conditions" identified in the DETO Fire Management Plan (NPS 2004, p. 6) that relate to land cover are as follows:

- Fuel load levels consistent with low intensity fires
- Open-canopy ponderosa pine stands with overstory (diameter at breast height [dbh] > 15 cm) tree density in a range of 150–250 stems/ha (60–100 stems/ac) for ponderosa pine/mixed-grass savanna, and in a range of 200–350 stems/ha (80–140 stems/ac) for ponderosa pine forest
- Nonnative plant cover reduction with a relative increase in the native plant cover of grasses and forbs
- Meadow and forest area in various diverse stages of development
- Mosaic within stands of ponderosa pines promoting habitat diversity

NPS scientists in the NGPN Fire Ecology Program measure the effects of prescribed fires on vegetation on a plot-by-plot basis. Over time, the effects of prescribed burns may be detectable on a landscape scale (i.e., a scale often examined through land cover or vegetation mapping efforts, such as those used by Salas and Pucherelli 1998). Current fire effects plot data summaries that measure the number of stems per acre or trees per acre by dbh size class generally indicate reductions in pine densities, especially in the midstory and overstory size classes of ponderosa pine stands. This pine reduction has significantly reduced ground-level fuel loading (D. Swanson, pers. comm., 2011).

Past land uses, especially livestock grazing caused changes to plant communities in DETO. Daugherty (1984) noted that significant livestock foraging, especially cattle, sheep, and goats, occurred on land surrounding DETO and often within DETO during the 1930s. During 1932, as many as 1,000 head of cattle were fed within 1 mile of DETO's boundary, and as many as 25 head of cattle were driven off DETO per day. In 1933, as many as 50 head were driven off per day (Daugherty 1984).

The ecological effects of cattle grazing across a landscape are particularly difficult to assess due to a lack of "clear ecological benchmarks" (Fleischner 1994, p. 630). Fleischner (1994) notes that ungrazed land is extremely rare in the western United States; therefore, predicting the potential natural vegetation is difficult. Fleischner (1994) summarizes the documented ecological costs of cattle grazing as (1) alteration of species composition of communities (including decreases in density and biomass of individual species, reduction of species richness, and changing community organization); (2) disruption of ecosystem functioning (including interference in nutrient cycling and ecological succession); and (3) alteration of ecosystem structure (including changing vegetation stratification, contributing to soil erosion, and decreasing availability of water to biotic communities). If these effects are considered difficult to assess then it follows that any effects of present day land use surrounding DETO on the overall land cover (vegetative communities) in DETO are also difficult to assess.

Invasive plants that become prevalent and sufficiently dense could warrant a different vegetation classification. A recent example, assuming a minimum mapping unit of 0.5 ha (1.2 ac) (used in Salas and Pucherelli 1998), is leafy spurge (*Euphorbia esula*), which has occurred in large dense patches in DETO. Parker Williams and Hunt (2004) achieved 90% accuracy using hyperspectral image analysis to detect leafy spruge in DETO in July 1999, a method that could be used in the future to detect the extent of other invasive species (Jay et al. 2009). Recent reports from the Northern Great Plain Exotic Plant Management Team (NGP EPMT) indicate that treatments of leafy spurge are beginning to have the desired effect (i.e., reduction in density and extent). Although not currently found in DETO, white horehound (*Marrubium vulgare*), another example of a species that could warrant its own vegetation classification in other park units, has established itself in large, dense patches around many of the prairie dog towns in Wind Cave National Park (WICA).

An NPScape examination of all roads within 30 km of DETO using Environmental Systems Research Institute, Inc. (ESRI) Streetmap data reveals a dense network of roads (NPS 2010b). A subsequent analysis using this road layer shows patch area between roads (>500 km from the nearest road), illustrating that road density may prevent landscape-level land preservation, as suggested by Fertig and Oblad (2000) (Plate 9) (NPS 2010b). Note that this analysis treated all roads equally when creating the roadless patch areas; however, roads vary widely in size and use intensity, and therefore would likely vary in their effects related to habitat fragmentation. Despite this diversity, roads still cause fragmentation of natural landscapes and are viewed here as stressors to land cover in the area surrounding DETO.

Possible future development of DETO infrastructure is another potential threat to land cover, more specifically to native plants communities, at a localized scale. The current facilities at DETO were built during the 1930s and in 1955 to accommodate a yearly visitor capacity of about 20,000. Present-day visitor totals are now nearly 400,000 annually (NPS 2007) A new structure is proposed near the base of Devils Tower, and the parking will be moved to the lower lot to accommodate the visitors (NPS 2007). Construction of this infrastructure may require the conversion of natural areas to impermeable surfaces (e.g., pavement or buildings). Construction projects can also create soil disturbances and seed beds for the establishment of early seral nonnative and invasive plant species.

Other current stressors or anticipated threats to ecosystem health (landscape scale) in DETO and in other NGPN parks include nonnative plant control methods (e.g., chemical plant controls), nitrogen deposition, increased atmospheric carbon dioxide concentrations, and climate change

(Symstad et al. 2006). These stressors may alter the composition, structure, and distribution of plant species and communities, which in turn could alter landscape scale patterns, and therefore land cover. Stambaugh et al. (2008) suggests "climate change, invasive species, and land use changes will significantly impact ecosystems and possibly determine future range of variability" in DETO (p. 184).

Data Needs and Gaps

No quantitative data were available for this assessment to examine land cover changes from a time before fire suppression and livestock grazing in the area. Quantifiable information of historic land cover composition before cattle and sheep grazing and the introduction of nonnative plants in the area would promote a more detailed understanding of the land cover changes that have occurred.

Ranching and grazing history of DETO and the surrounding area is not quantified beyond reports from a past park manager noting the number of cattle driven off DETO lands. An examination of this grazing history may provide more context to the current condition of land cover and native plant communities in DETO, however, and allow identification of reference sites with little or no grazing.

A protocol for reporting and measuring LCLU as a Vital Sign is not yet developed. A fully developed protocol would provide LCLU consistency and specificity for network park units. It could also be used for management within DETO and, in some cases, provide valuable information for coordinating conservation efforts with outside groups, especially those managing surrounding lands.

An updated land cover map comparable to the Salas and Pucherelli (1998) map would provide much higher resolution land cover change information than offered by datasets such as the NLCD. In addition to remapping the area, an assessment of severe fire risk for adjacent land may be prudent according to Stambaugh et al. (2008), who were concerned with a potentially severe fire spreading into DETO. The NLCD 1992/2001 change product indicates some regional LCLU change, but at the park-scale does not indicate LCLU change outside of the erroneous open water change classification.

Information regarding levels of invasive plant infestations outside DETO boundaries may help management understand seed sources and vectors of spread for some plant invasive species, which can be considered a stressor to native plant communities and their associated land cover classifications.

Overall Condition

Given past factors and current stressors, land cover is of moderate concern within DETO's boundaries. Historic fire suppression, logging, mining, and livestock grazing have caused changes in the landscape in and around DETO (NPS 2004). Fire suppression, logging, and cattle grazing continue on lands surrounding DETO, and NPS staff recently report livestock entering park lands. However, not all of the changes associated with land uses are quantified, and their effects may not be quantifiable using common landscape scale LCLU mapping classification methods.

Little evidence suggests that current land cover composition (i.e., broad vegetation classifications) within DETO would be vastly different than it was prior to sheep and cattle grazing in the area, although quantifiable historic land cover data in DETO are unavailable to confirm this. With the reintroduction of fire to the landscape through prescribed burns, ongoing nonnative and invasive plant control efforts, and intensive restoration efforts (e.g., reseeding areas to native plant species), land cover may mirror historic land cover before cattle and sheep grazing in the area. Some obvious exceptions to this are areas of more intense human influence such as administrative areas, areas near DETO's road, and heavily used trails.

Two habitats related to land cover in DETO are of particular concern. Merrill et al. (2003) suggest that native deciduous woodlands in the Black Hills are a concern because they seem to be declining in the portion of the landscape where they occur, about 18% of DETO (Boldt et al. 1978, as cited in Merrill et al. 2003). Merrill et al. (2003) suggest that these woodlands are critical habitats for wildlife and that the remaining woodlands in DETO are important for the conservation of these plant communities (Salas and Pucherelli 1998). Another specific habitat of concern in DETO is cottonwood and willow communities along the Belle Fourche River. The natural hydrograph of the river has changed due to the construction and operation of the upstream Keyhole Dam in Moorcroft, Wyoming, and cottonwood regeneration along the river in DETO has decreased (Tinker 2008). More information about cottonwood communities is available in the native plant communities section of this document (Chapter 4.2).

Sources of Expertise

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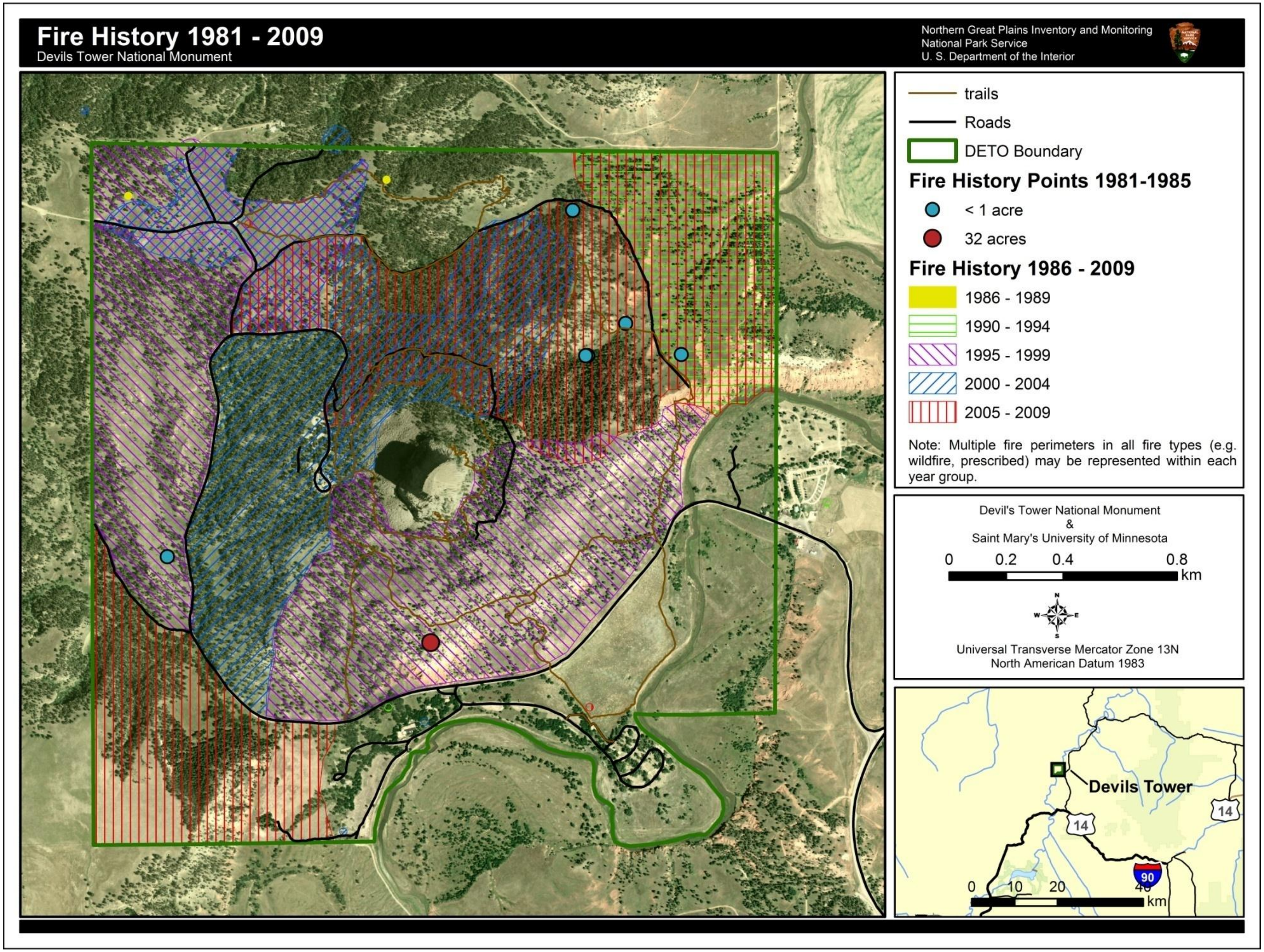

Plate 2. Fire perimeters, all fire types, DETO, 1981-2009.

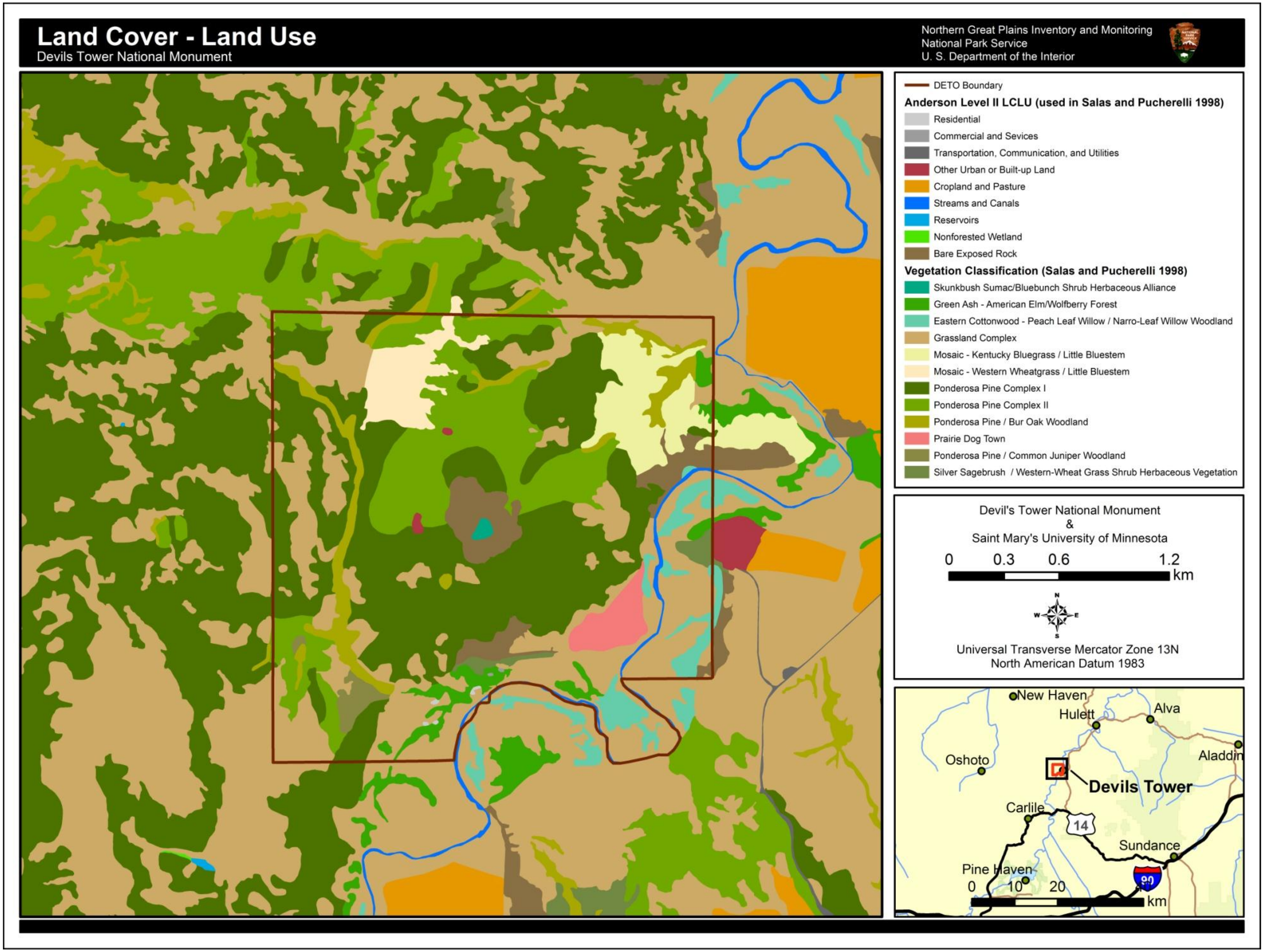

Plate 3. Land cover and land use (LCLU) in DETO and immediate surrounding area (Salas and Pucherelli 1998).

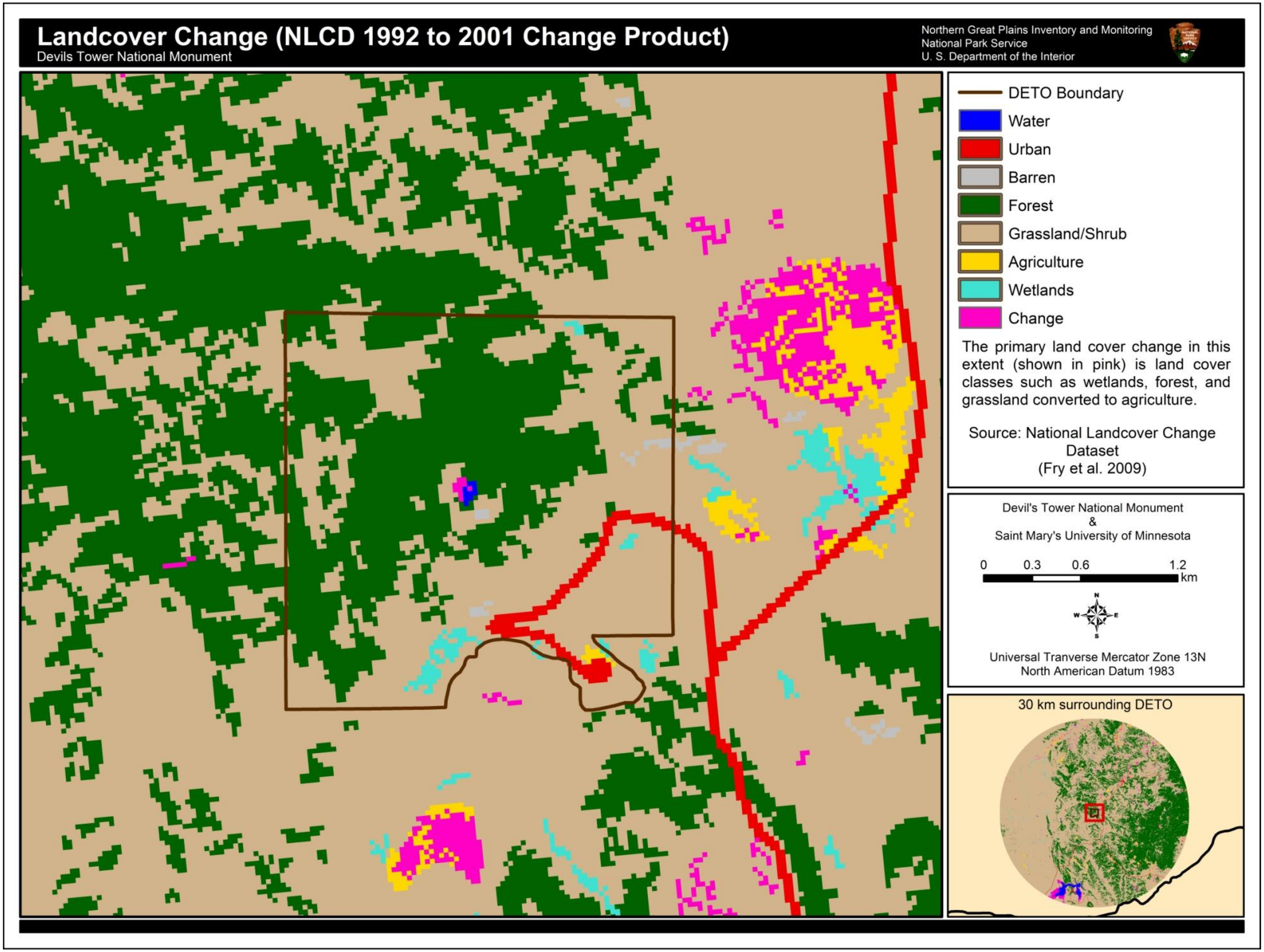

Plate 4. Land cover change, NLCD 1992 to 2001 Change Product (Fry et al. 2009).

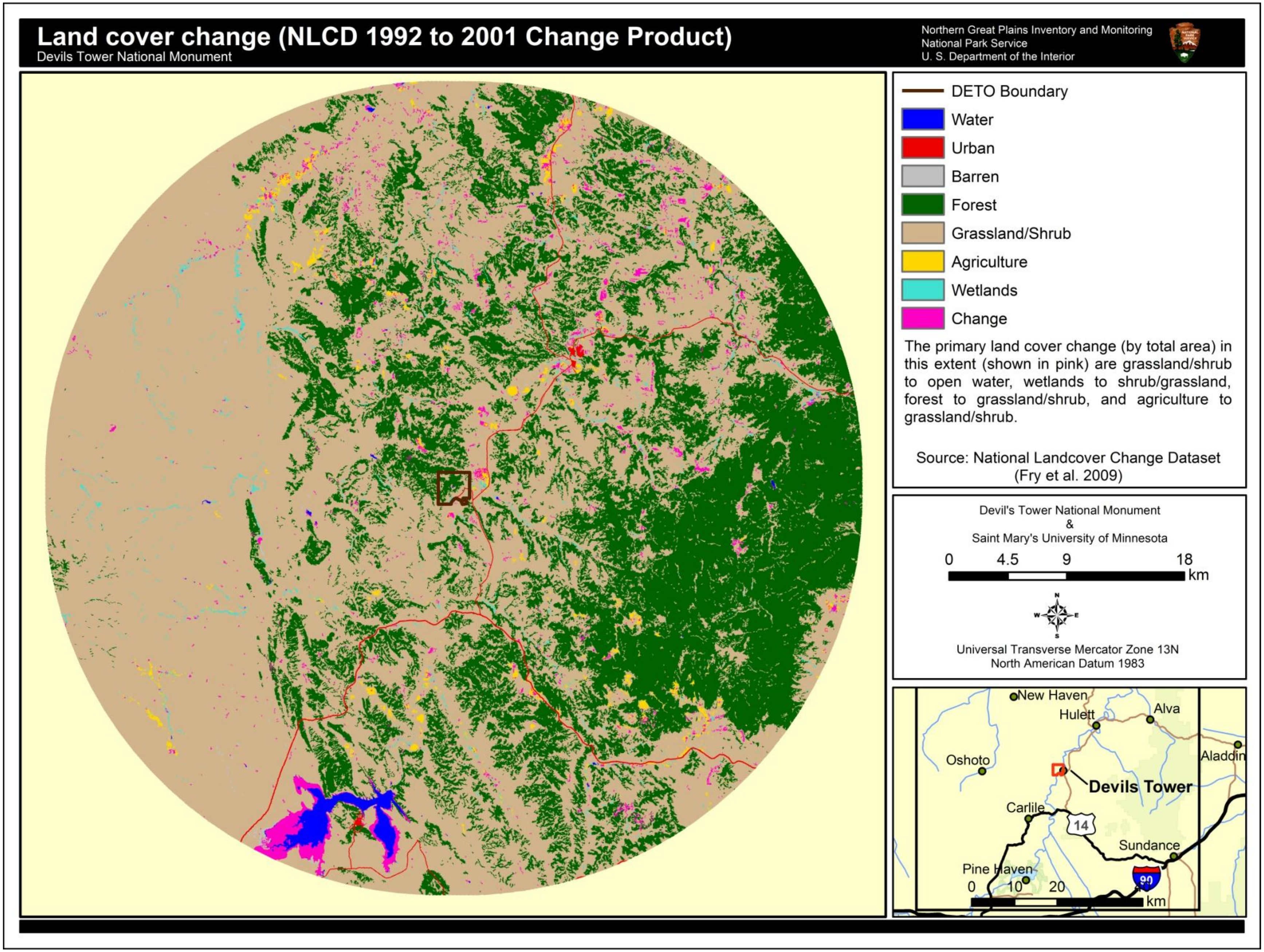

Plate 5. Land cover change, NLCD Change Product in the DETO AOA (30 km buffer of DETO) (Fry et al. 2009).

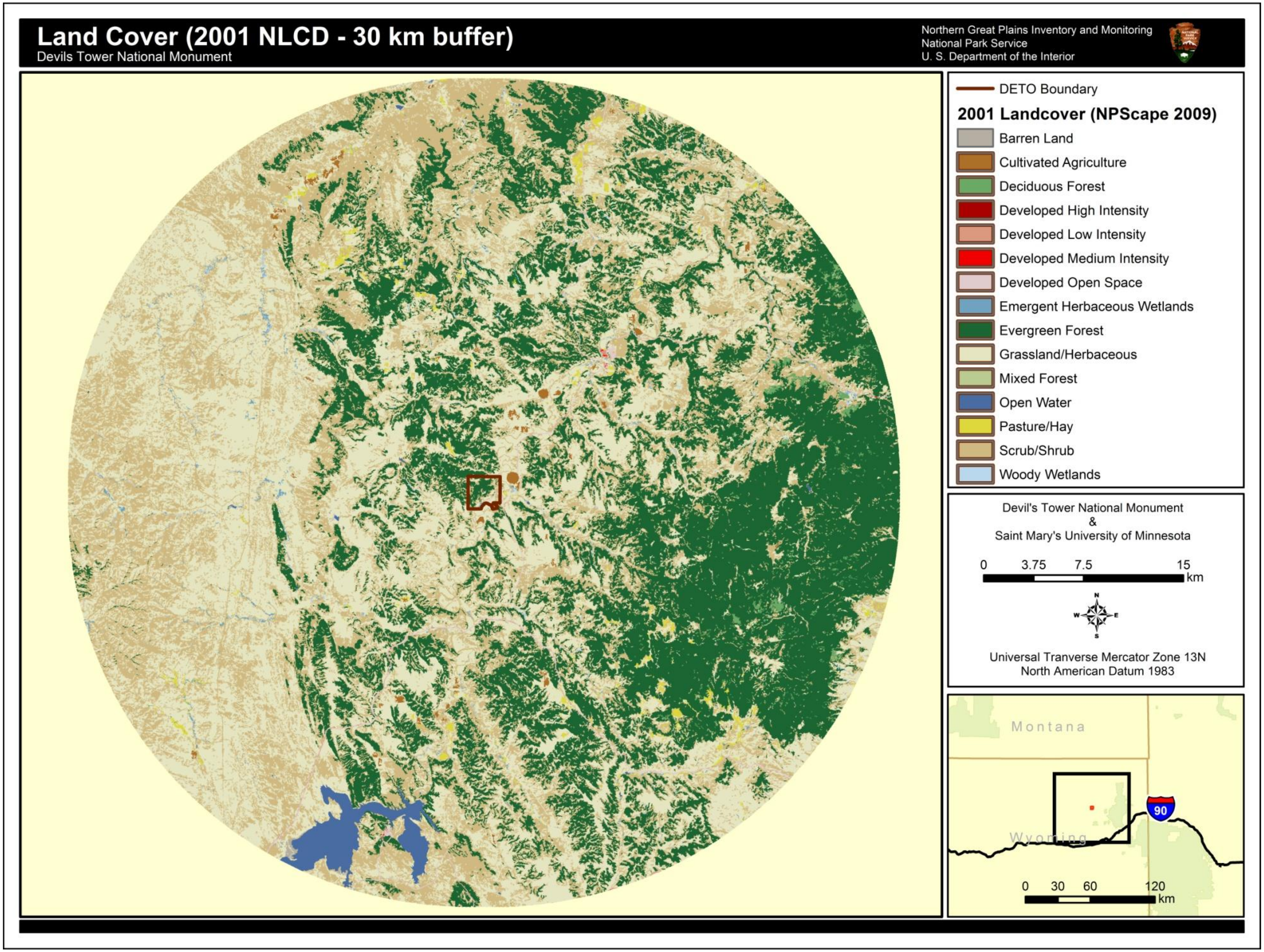

Plate 6. Land cover within a 30 km buffer of DETO (NLCD 2001, NPS 2010a).

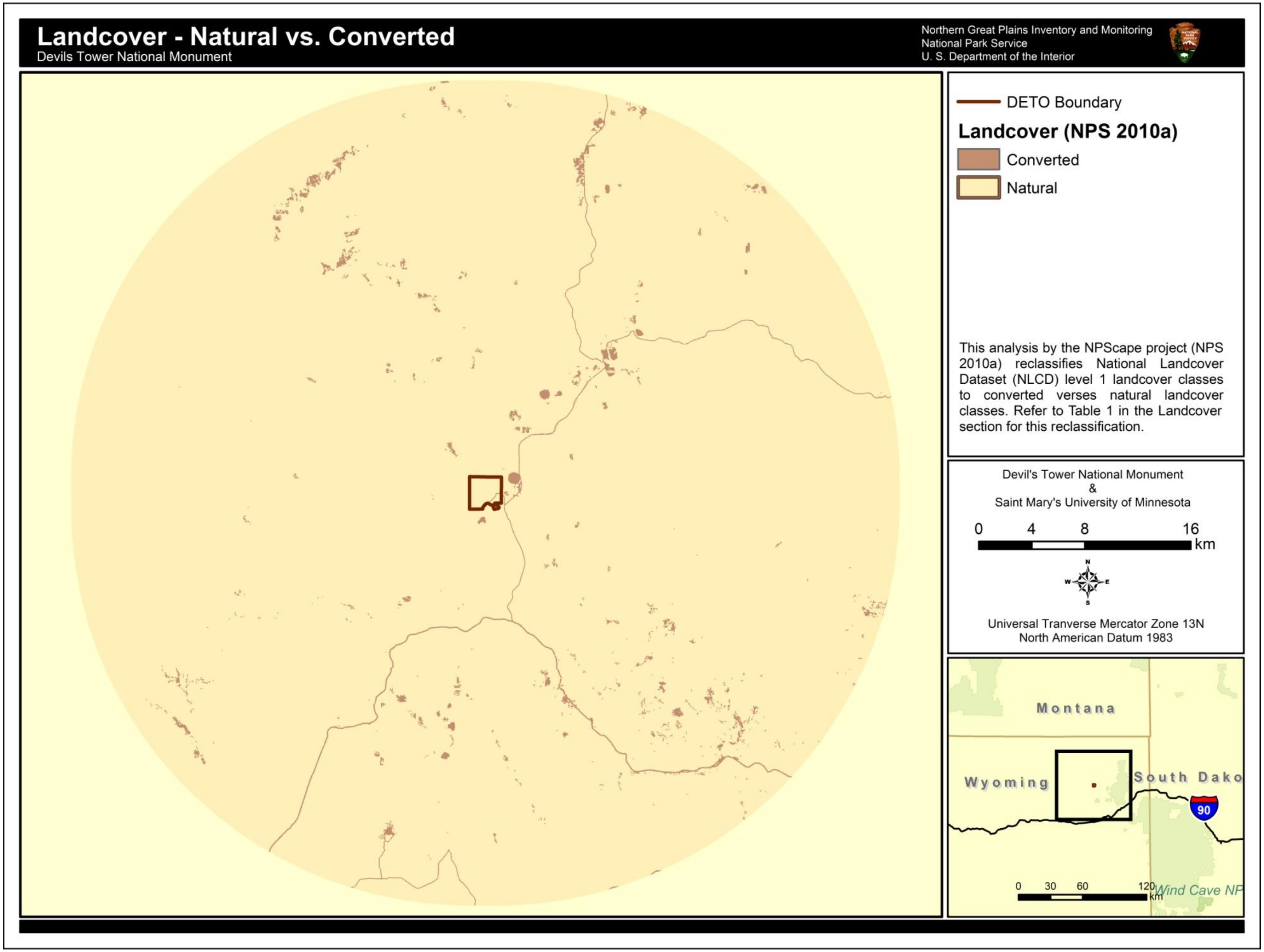

Plate 7. Land cover, natural vs. converted in and around DETO (NPS 2010a).

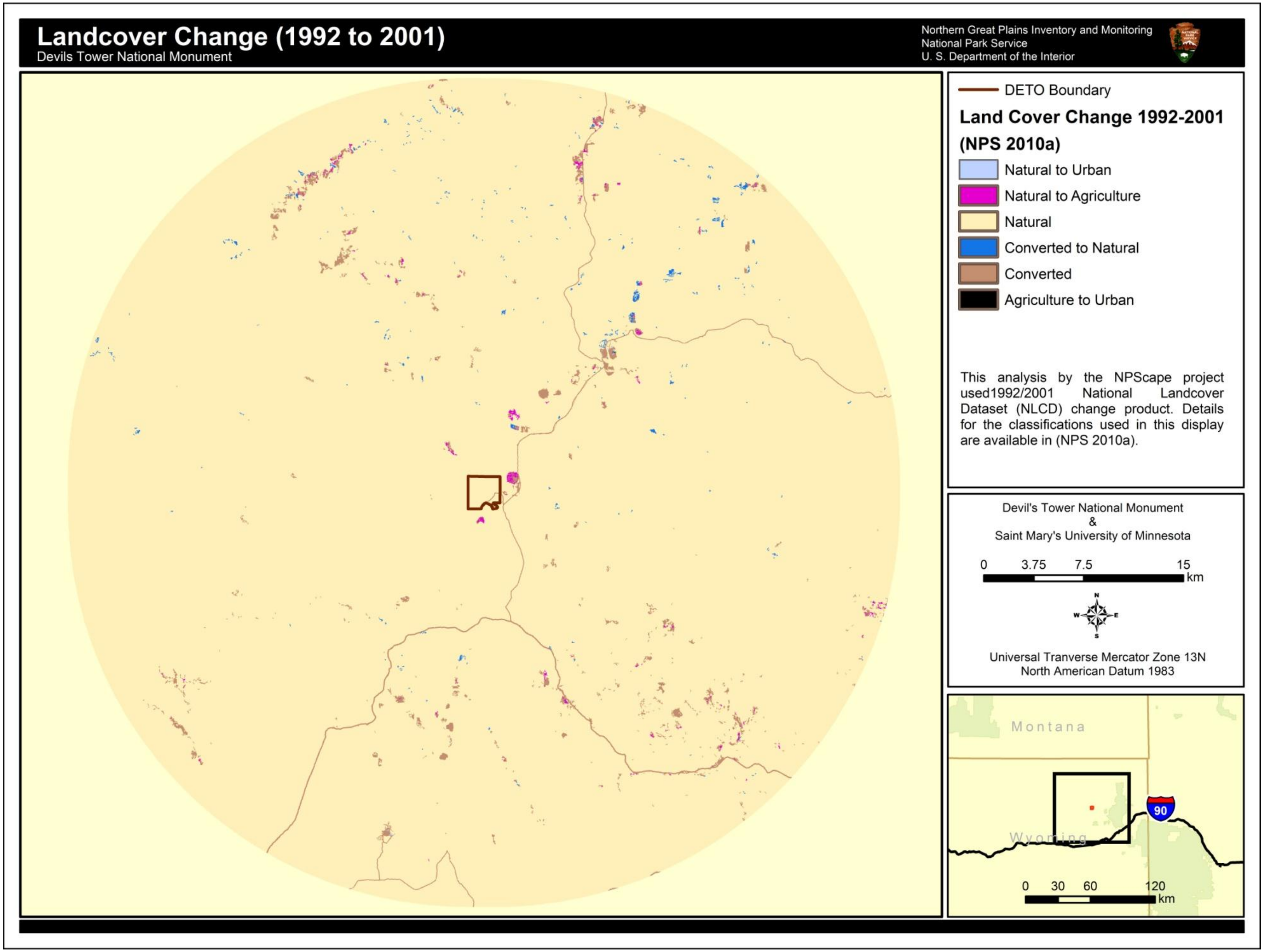

Plate 8. Land cover change, DETO area, 1992-2001 (NPS 2010a).

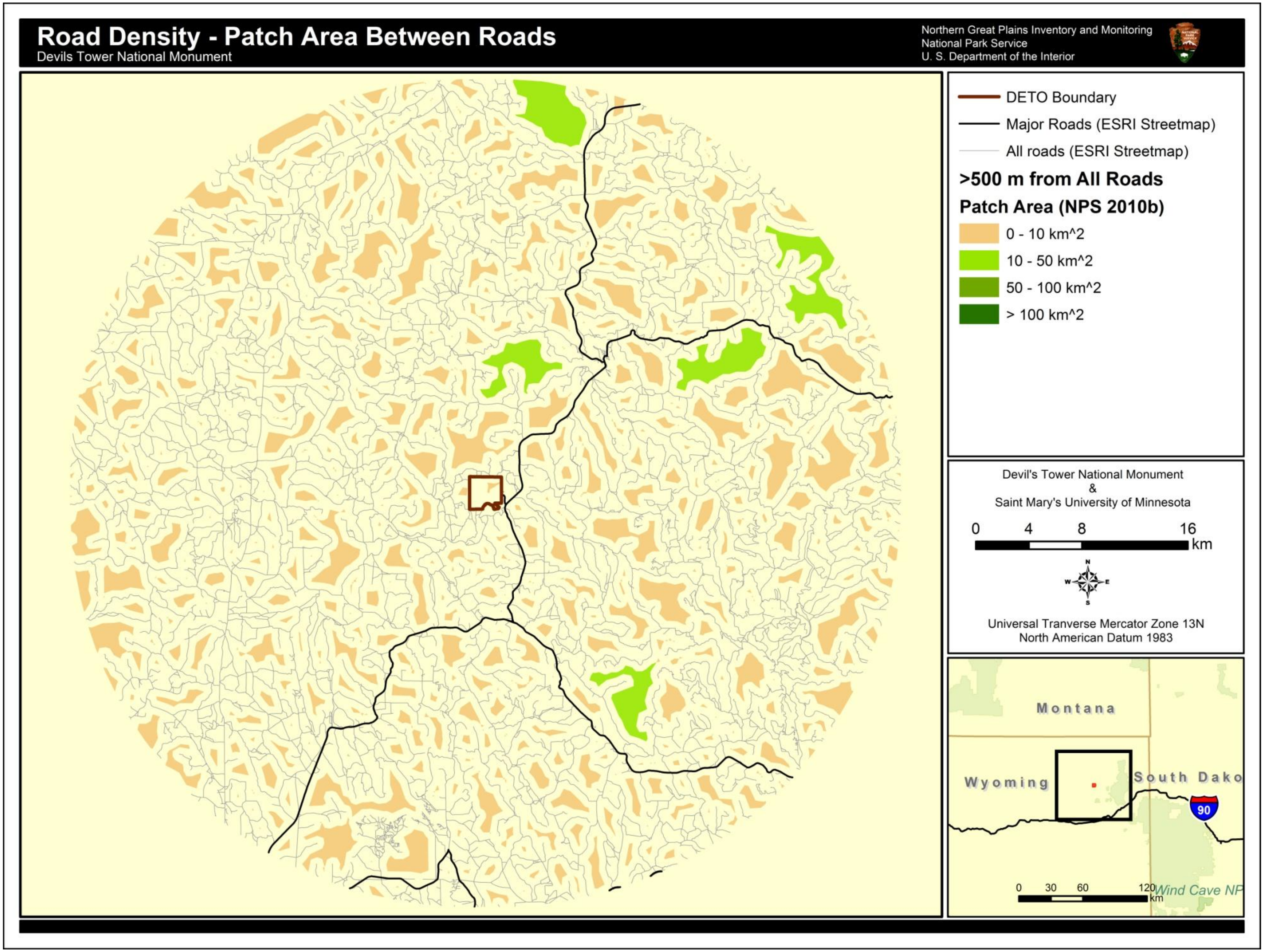

Plate 9. Roadless patch area, >500 m from nearest road (NPS 2010b).

4.2 Native Plant Communities

Description

The NGPN identifies native plant communities as a high priority resource and a Vital Sign. Plant community composition is affected by many of the stressors acting on terrestrial and riparian ecosystems, and therefore acts as an indicator of broad ecological health (Symstad. 2004). NGPN has developed a protocol for monitoring plant community composition in which frequency and percent cover of all species and select functional groups, species richness and diversity, forest structure, and herbaceous layer vegetation height will be measured (Symstad et al. 2011); however, this protocol was not implemented until 2011. Therefore, measures examined in this assessment are ponderosa pine density and distribution, exotic plant density and distribution, cottonwood regeneration, and plant species richness.

DETO is located in two Level III Ecoregions: Northwestern Great Plains and Middle Rockies. Because of this, the 545 ha (1,347 ac) park contains a diverse group of plant species typified by ponderosa pine woodlands and mixed-grass upland meadows. In addition, some drainages support bur oak stands and green ash trees, and a portion of the floodplain of the Belle Fourche River within DETO contains cottonwood and willow (Wood and Rew 2005). Park management is particularly concerned about the regeneration of cottonwood as well as the persistence of the populations of a select list of plant species of special concern identified by Heidel (2008).

Salas and Pucherelli (1998) define 17 specific vegetation associations in DETO, including two forest associations, five woodland associations, eight herbaceous associations (two of which are disturbed), and two sparsely vegetated associations (Table 9) (Salas and Pucherelli 1998). The two disturbed vegetation associations are unique because one is dominated by nonnative plants (Kentucky bluegrass disturbed community) and the other has resulted from extensive prairie dog disturbance (prairie dog town) (Salas and Pucherelli 1998). Refer to Appendix A for an area representation of each vegetation association within DETO and entire mapped area, plus disturbed landcover classes using an Anderson et al. (1976) Level II classification (e.g., residential, commercial) and other nonvegetated classes (e.g., bare rock).

Table 9. Vegetation associations within DETO. (Salas and Pucherelli 1998)

Vegetation Associations
Skunkbush Sumac / Bluebunch Wheatgrass Shrub Herbaceous Alliance
Silver Sagebrush / Western-Wheat Grass Shrub Herbaceous Vegetation
Green Ash - American Elm / Wolfberry Forest
Eastern Cottonwood - Peach Leaf Willow / Narrow-Leaf Willow Woodland
Little Bluestem - Grama (Side-Oats, Blue) - Threadleaf Sedge Herbaceous Vegetation
Western-Wheatgrass - Blue Grama - Threadleaf Sedge Herbaceous Vegetation
Prairie Cordgrass - Three-square Bulrush Herbaceous Vegetation
Kentucky Bluegrass Disturbed Community
Ponderosa Pine / Bur Oak Woodland
Ponderosa Pine / Common Juniper Woodland
Ponderosa Pine / Little Bluestem Wooded Herbaceous Vegetation
Ponderosa Pine / Sun Sedge Woodland
Ponderosa Pine / Oregon Grape Forest
Ponderosa Pine / Bluebunch Wheatgrass Woodland
Prairie Dog Town
Phonolite Porphyry Sparse
Redbeds Sparse Vegetation

Measures

- Ponderosa pine density and distribution
- Exotic plant density and distribution
- Cottonwood regeneration
- Plant species richness

Reference Conditions and Values

<u>Ponderosa Pine Density and Distribution</u>
Prefire suppression is the historic reference condition for ponderosa pine density and extent for this assessment. Fire suppression began in the area during the late 1800s.

Measuring the change in historic fire return intervals is one way to discern the changes in ponderosa pine density and distribution over the last century. Fire return intervals before 1770 were between 15 and 27 years (Fisher et al. 1987). From 1770 to approximately 1900, fires set by Native Americans reduced this to 8 to 14 years (NPS 2004). Since 1900, the fire return interval has increased due to suppression and is now 28 to 42 years (NPS 2004). It is unclear exactly what pine density and distribution would have been specifically in DETO with fire intervals of 15 to 27 years verses fire intervals of 8 to 14 years. Brown and Cook (2006) examined early settlement forest structure in the Black Hills region and provided a description of ponderosa pine stand structure, stating that ponderosa pine forests historically consisted of "a diverse landscape mosaic that varied from forested patches and open stands of very few large trees to quite dense stands with many trees" (p. 288). The authors also found that most of the forest was open, but dense patches were also present, contributing to spatial heterogeneity.

The increased time between fires has allowed ponderosa pines to expand into adjacent prairie plant communities and increase in density. While no precise measures of pine extent and densities are available for DETO for the time period before major fire suppression began in the late 1800s to early 1900s, a comparison of photographs from 1874 and 1974 reveal "dramatic increases in pine densities and invasion into meadows in the Black Hills over the past 100 years" (Progulske 1974). In addition to fire suppression and logging, past livestock grazing affected pine density because livestock selectively grazed on perennial grasses, allowing a reduction in competitive exclusion; this removal of the herbaceous layer represents the loss of fine fuel burned by natural frequent low-intensity fire that would kill tree seedlings (Belsky and Blumenthal 1997, Covington et al. 1997).

<u>Nonnative and Invasive Plant Density and Distribution</u>
The reference condition for this assessment is a historic reference to a landscape prior to the introduction of nonnative species. A landscape completely free of nonnative plants is an unrealistic expectation for management, although zero nonnative plants can act as a baseline for comparison of current conditions and serve as a comparison for future conditions.

Monitoring and control of nonnative plant species is important because nonnatives can become invasive and replace native plant communities. Invasive species will often negatively alter wildlife habitat, reduce biological diversity, and alter natural processes such as fire regimes, nutrient cycling, hydrology, and successional patterns (NPS 2005). Symstad (2004) states that the abundance and diversity of nonnative plant species plants, both absolute and relative to native species, is one of the greatest management concerns in nearly all NGPN parks.

<u>Cottonwood Regeneration</u>
The historic reference for cottonwood regeneration in DETO is a time before the construction of the Keyhole Dam (located 25.7 km [17.8 mi] upstream from DETO) and before cattle and sheep grazing in the area. No data or literature sources define the natural variation in regeneration that occurred during this time; however, the current average age for cottonwood trees in DETO suggest that cottonwoods are failing to produce enough seedlings to replace older trees.

<u>Plant Species Richness</u>
For this assessment, the historic reference for plant species richness is also identified as a time before cattle and sheep grazing in the area. Although cattle and sheep grazing contributed to dramatic shifts in plant species composition over the last century in much of the western United States, DETO represents an area where domestic animal use was limited in the past and therefore "many native species occur in healthy stands" (Redente 1993, p. F-1). The first plant species inventory in DETO occurred in 1982 (Marriott 1982). Subsequently, the list of plant species known to occur in DETO was reviewed and certified by Hollis Marriott and entered into the NPSpecies database. Heidel (2008) found additional plant species in DETO incidental to a survey for plant species of concern and suggested that because only a relatively small number of additional species were found in the survey, the original species inventory conducted by Hollis Marriott (Marriott 1982) was quite rigorous, and that the likelihood of finding many additional

species in the future was low. The additions and adjustments to the most recent (2004) certified plant list are under review by NGPN staff.

Data and Methods

Fire effects monitoring data provide estimates of ponderosa pine density, while distribution information comes from the landcover map developed by Salas and Pucherelli (1998). These data were not manipulated during analysis.

Nonnative plant species information from the NGP Exotic Plant Management Team (EPMT) provides summary information on control efforts of recent years in DETO. In addition, spatial GIS data from the NPS DataStore were exported to Microsoft Excel to summarize total area by control type (6). The following spatial file titles, obtained through the NPS DataStore, (no metadata available) were used for this summary: 'survey_2002_2006.shp', mapping_2002_2006.shp', 'manual_2002_2006.shp', 'chemical_2002_2006.shp', 'deto_chemical_08.shp', and 'biocontrol_2002_2006.shp'.

A cottonwood study by Tinker (2008) provides information regarding cottonwood regeneration and conditions in DETO. The study examined the feasibility of proposed restoration actions and characterized the condition of mature cottonwoods in the Belle Fourche campground in DETO.

Data collected in DETO as part of a protocol development for sampling herbaceous plant communities for various community characteristics (Symstad et al. 2006) provide information about plant species richness in some plant communities. Primary data contributing to current plant species lists come from Marriott (1982) and Heidel (2008).

DETO staff, along with seasonal weed crews and the NGP EPMT, conducts nonnative and invasive plant control efforts in DETO. Primary data available for this assessment were NPS GIS data and NGP EPMT annual reports. The Park staff conducted significant nonnative and invasive plant control efforts using integrated pest management strategies, and their control efforts are summarized in internal, unpublished annual resource management field season reports. This information is not included in this assessment because the data are currently not summarized.

Current Condition and Trend

<u>Ponderosa Pine Density and Distribution</u>

Historically, frequent, low-intensity fires acted as a community maintenance process, helping to shape the landscape and local ecosystems. Recognizing that "prescribed fire is essential to restore the natural scene," the goal of current fire management is to restore fire to DETO's ecosystems where possible through prescribed fires (NPS 2005). However, "people, modern-day human developments, and cultural and historic resources in and adjacent to DETO require that the protection of life and property be primary" (NPS 2004, p. 4–5).

Vegetation monitoring following prescribed fires examines percent change in grass cover, fuel load, stand structure, species richness, shrub density, and native versus nonnative relative cover on permanent plots within DETO (NPS 2004). The DETO Fire Management Plan states that current densities indicate a need to reduce overstory ponderosa pine. The plan also contains five key goals regarding desired future conditions at DETO:

- fuel load levels consistent with low intensity fires
- open-canopy ponderosa pine stands with overstory (dbh > 15cm) tree density in a range of 150 to 250 stems/ha (60 to 100 stems/ac) for ponderosa pine/mixed–grass savanna, and in a range of 200 to 350 stems/ha (80 to 140 stems/ac) for ponderosa pine forest
- nonnative plant cover reduction with a relative increase in the native plant cover of grasses and forbs
- meadow and forest areas in various diverse stages of development
- mosaic within stands of ponderosa pines promoting habitat diversity (NPS 2004)

The current extent of ponderosa pine is best illustrated in a map developed by Salas and Pucherelli (1998). The authors' map represents the most current land cover/use map of DETO (Plate 10).

Salas and Pucherelli (1998) provide estimates of ponderosa pine density (Table 10). Presumably, these densities are estimated tree canopy densities, conducted thorough aerial photography interpretation and ground-truthing during the mapping process. More precise measurements of ponderosa pine density, measured as stems per acre or trees per acre by dbh size class, come from fire effects monitoring via permanent plots across DETO.

Table 10. Area of ponderosa associations by canopy density categories in DETO. From spatial data in (Salas and Pucherelli 1998)

Association		Ponderosa Pine Canopy Density Category*					
	Area	**0**	**1**	**2**	**3**	**4**	**Totals**
Ponderosa Pine Complex 1	ha	-	17.6	87.3	72.5	-	96.5
	ac	-	43.6	215.7	179.2	-	238.4
Ponderosa Pine Complex 2	ha	56.3	24.4	-	-	-	80.7
	ac	139.1	60.4	-	-	-	199.5
Ponderosa Pine / Burr Oak Woodland	ha	-	28.2	-	-	-	28.2
	ac	-	69.7	-	-	-	69.7
Ponderosa Pine / Common Juniper Woodland	ha		4.8				4.8
	ac	-	11.8	-	-	-	11.8
Totals:	ha	56.3	57.4	87.3	72.5	-	384.9
	ac	139.1	141.9	215.7	179.2	-	951.1

*Density: 0 = undefined, 1 = closed continuous (>60%), 2 = discontinuous (40-60%), 3 = dispersed (25 to 40%), 4 = sparse (10-25%)

Fire effects monitoring plot data indicate that prescribed fire is successfully decreasing the basal area and tree density (stems/ac) of ponderosa pine forests in DETO, especially smaller overstory trees, generally <25.4 cm (10 inches) dbh (Figure 5 and Figure **6**). A 34% decrease in density was realized for all trees at one year post-burn, with most of the mortality occurring in the 2.5 to 10.1 cm (1 to 4 inch) and 10.1 to 15.2 cm (4 to 6 inch) dbh classes. This is reducing canopy densities to mimic historical stand structure, set by the Fire Management Plan (NPS 2004).

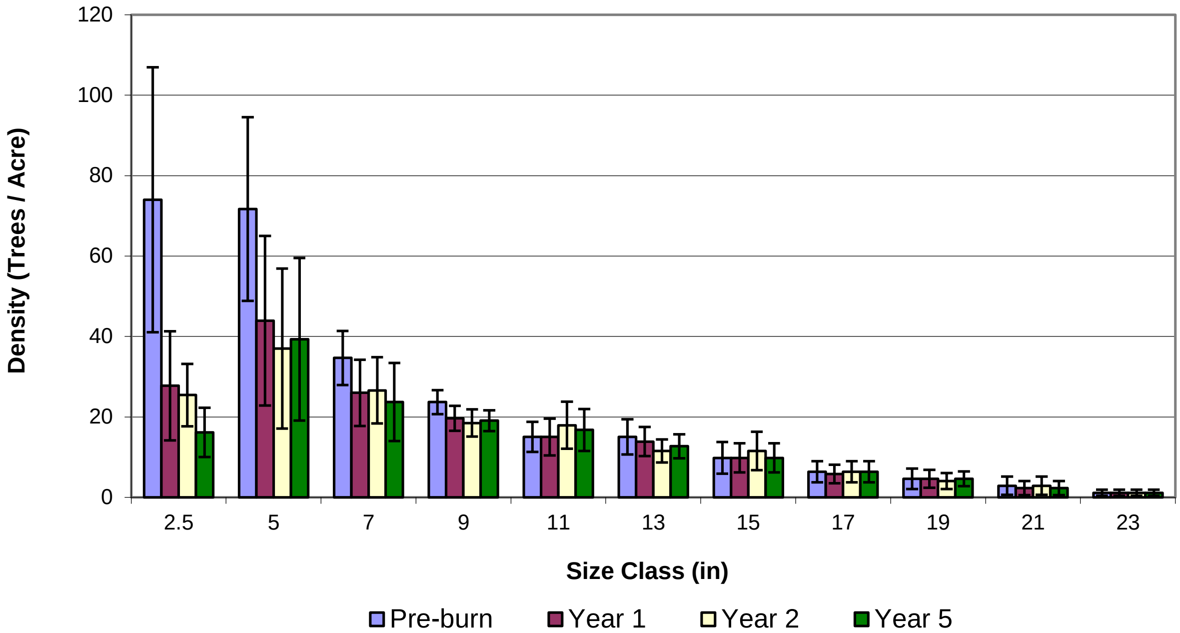

Figure 5. Mean ponderosa pine densities (stems/ac) by size class for seven fire monitoring plots: pre-burn and 1, 2, and 5 years post-burn located in DETO. Note the size classes (in) displayed represent the mean of the size class range (e.g., 5 inches falls within the 4–6 inch size class).

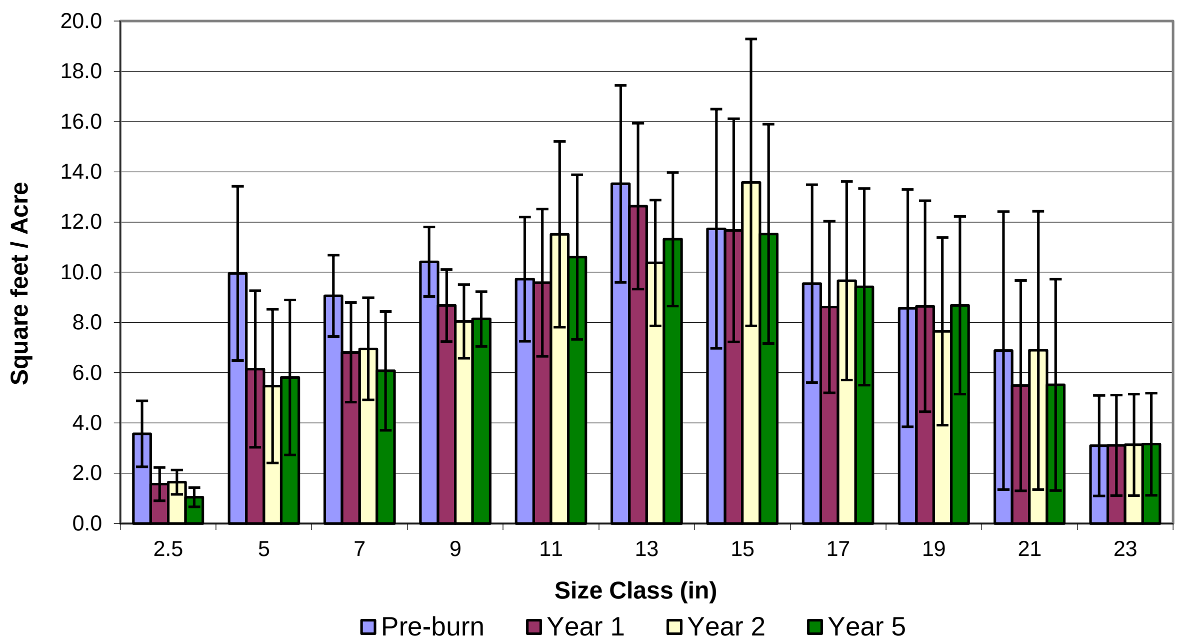

Figure 6. Mean basal areas of ponderosa pines by size class for seven fire monitoring plots: pre-burn and 1, 2, and 5 year post-burn located in DETO. Note the size classes (in) displayed represent the mean of the size class range (e.g., 5 inches falls within the 4–6 inch size class).

Plant Species Richness

Plant species richness is a descriptive measure of plant community composition, usually measured on a plot sample basis, where more species present in a sample indicates higher species richness. Existing data available for this assessment do not allow calculation of species richness on a community basis. The NGPN recognizes plant community composition as one of its Vital Signs and is in the process of implementing a monitoring protocol, starting in 2011; plots will be read in summer 2011. As part of protocol development, Symstad et al. (2006) compared two methods of vegetation sampling in NPS units to determine an effective sampling strategy for assessing herbaceous plant community composition. One of the main objectives of this research was to determine the number of subsamples necessary to adequately measure site parameters such as native species cover, nonnative species cover, and native species richness. The researchers examined sites in the following vegetation types in DETO: prairie dog town, ponderosa pine forest/woodland, and riparian forest. Appendix B presents means and ranges of percent cover and species richness for the vegetation types sampled in DETO (Symstad et al. 2006). For more information on other vegetation types examined in the various NGPN park units refer to Appendix C.

According to the certified plant list for DETO, 376 species are present in the park, 46 probably present in the park, and 41 unconfirmed species in park (NPS 2007b). Nonnative plant species (49 total) represent 12.5% of the total species present in the park. However, 24 native and 22 nonnative plant species are considered probably present in park. There are 30 native species, 5 nonnative species and 6 species of unknown nativity unconfirmed in the park. NGPN staff is in the process of making some adjustments and additions to the plant species. Ten additional species found during a survey for plant species of concern (Heidel 2008) are in the process of being certified, and other species' statuses may change from unconfirmed to present in park and from probably present in park to present in park.

Heidel (2008) originally conducted a botanical survey to locate plant species of special concern on the Wyoming state species of concern list in DETO (Table 11). The surveys found four of the targeted species and added one other species of concern not originally targeted, rabbit tobacco (*Filago prolifera*). During the survey for the species of special concern, Heidel (2008) found 12 additional species. Heidel (2008) suggests that DETO contains "an exceptionally rich flora that complements its recognition as a national monument" (p. 11). DETO contained 59.6% of the 1,023 species known from Crook County, Wyoming, in 2001. The author also suggests that the eight target species of concern represent "potentially vulnerable components of its flora" and that failure to relocate two species, prairie violet (*Viola pedatifida*) and whorled milkweed (*Asclepias verticillata*) "is significant" (Heidel 2008). Prairie violet may have been eliminated from its original DETO location by encroachment of leafy spurge, natural succession, or management efforts such as chemical herbicide spot treatments (Heidel 2008).

Table 11. Plant species of special concern at DETO. (Reproduced from Heidel 2008). This includes both Heidel (2008) targeted species and previous target species.

Scientific Name	Common Name	Tracked[1]	Relocated	Heritage Rank	Fed. Status	County(s)	Managed Area
Asclepias verticillata	Whorled milkweed	Yes	No	G5/S1	None	Crook	DETO
Carex emoryi	Emory's sedge	Yes	Yes	G5/S1	None	Crook, Goshen, Platte?	DETO Fort Laramie NM, Rawhide Wildlife Management Area
Dichanthelium wilcoxianum	Wilcox's panic grass	No	NA	G5/S2	None	Crook, Weston	Black Hills National Forest, DETO, Newcastle BLM
Elymus villosus	Hairy wild-rye	Yes	Yes	G5/S1	None	Crook	Black Hills NF, DETO, Newcastle BLM
Filago prolifera	Rabbit tobacco	Yes	Yes -New	G5/S1	None	Crook, Natrona Platte	DETO
Glandularia bipinnatifida	Dakota vervain	Yes	Yes	G5/S1	None	Crook, Fremont	DETO
Helianthemum bicknellii	Plains frostweed	Yes	Yes	G5/S1	None	Crook	Black Hills National Forest, DETO, Newcastle BLM
Oenothera laciniata	Cut-leaved evening-primrose	Yes	Yes	G5/S1	None	Campbell, Crook	Black Hills NF, DETO
Verbesina encelioides	Cowpen crownbeard	No	NA	G5/S2	None	Albany, Campbell, Converse, Crook Goshen, Platte, Sweetwater	
Viola pedatifida	Prairie violet	Yes	No	G5/S1	None	Crook	Black Hills National Forest, DETO, Newcastle BLM?

[1] Plant species that are currently tracked as species of concern (Heidel 2007) are indicated by "Yes" in the "Tracked"' column.

Heritage Rank Codes and definitions

C - uncommon; apparently secure in state but warrants monitoring; may be localized or declining. (1986)
U - status undetermined; possible rare, declining or extirpated in state; more information needed. (1986)
(p) - peripheral: a species whose occurrence in SD represents the edge of its natural range. (1986)
S3 - vulnerable - Vulnerable in the nation or state due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors making it vulnerable to extirpation.
S4 – Apparently secure (2011)
SNR – not ranked by state (2011)

G5 - Demonstrably secure, though it may be quite rare in parts of its range, especially at the periphery All species ranked S1 are known from 5 or fewer extant, well-documented occurrences and are potentially vulnerable in the state.

The abundance and diversity of nonnative plants (both absolute and relative to native species) relate to plant species richness and are discussed in the “Nonnative plant density and distribution” section (see below). The increase in the abundance and diversity of nonnative plants affect plant species richness, initially creating a biased or misrepresented overall richness of the native plant community.

Nonnative Plant Density and Distribution

The overall density of nonnative invasive plants was categorized primarily as light density (25 to 50% cover) during NGP EPMT fieldwork in 2008 (NPS 2008). However, some species were widely distributed across DETO. Wood and Rew (2005) surveyed 420 ha (1,039 ac) (77% of DETO) in 2003 and found that 59 to 67% of the surveyed area was infested with at least one, sometimes several, targeted nonnative species (Table 12). A list of targeted species as categorized by Wood and Rew (2005) is highlighted in Appendix D.

Table 12. Land area surveyed, infested, and uninfested with at least one of the eight targeted nonnative plant species in DETO. (Wood and Rew 2005)

	Estimated ha (ac)	**Estimated ha (ac) low***	**Estimated ha (ac) high***
Survey area	529.7 (1,308.9)	--	--
Cumulative infested area	504.4 (1,246.3)	375.0 (962.7)	652.4 (1,612.2)
Total infested area	333.7 (824.7)	313.6 (774.9)	354.4 (875.8)
Uninfested area	196.0 (484.3)	216.1 (534.0)	175.3 (433.1)

*Low and high ranges are based on standard error calculations, accounting for potential uncertainty in area associated with mapping. The original data were reported in acres; hectares added and rounded to the nearest tenth ha.

According to the NGP EPMT, the highest priority nonnative species for control in 2008 in DETO were leafy spurge, Canada thistle (*Cirsium arvense*), houndstongue (*Cynoglossum officinale*), common mullein (*Verbascum thapsus*), Russian thistle (*Salsola tragus*), biennial thistles [Scotch thistle (*Onopordum acanthium*) and musk thistle (*Carduus nutans*)], bull thistle (*Cirsium vulgare*), cheatgrass (*Bromus tectorum*), smooth brome (*Bromus inermis*), Kentucky bluegrass, and tumbling mustard (*Sisymbrium altissimum* L.) (NPS 2008). Wood and Rew (2005) found extensive areas of leafy spurge and houndstongue as well as other widespread nonnative species including cheatgrass, Canada thistle, and smooth brome (Table 13).

Table 13. Nonnative plant composition of survey area in DETO. (Wood and Rew 2005)

Species (scientific)	Species (common)	Estimated ha (ac)	Estimated ha (ac) Low[1]	Estimated ha (ac) High[1]
Bromus inermis	smooth brome	13.3 (32.8)	7.3 (18.0)	22.2 (54.8)
Bromus tectorum and B. japonicus	cheat grass and Japanese brome	104.5 (258.2)	84.1 (207.8)	131.3 (324.5)
**Carduus nutans*	musk thistle	1.7 (4.2)	1.1 (2.8)	2.8 (6.9)
**Cirsium arvense*	Canada thistle	23.5 (58.1)	15.0 (37.1)	34.9 (86.3)
Cirsium vulgare	bull thistle	0.2 (0.4)	0.2 (0.4)	0.2 (0.5)
**Cynoglossum officinale*	houndstongue	50.0 (123.5)	29.9 (73.8)	77.1 (190.5)
Euphorbia esula	leafy spurge	281.8 (696.8)	229.9 (568.5)	344.7 (852.4)
**Onopordum acanthium*	scotch thistle	0.3 (0.7)	0.3 (0.7)	0.3 (0.7)
Salsola tragus	Russian thistle	0.0 (0.1)	0.0 (0.1)	0.0 (0.1)
Verbascum thapsus	common mullein	28.9 (71.5)	21.6 (53.4)	38.5 (95.2)
	Totals:	504.2 (1,243.3)	389.4 (926.7)	652.1 (1,612.2)

*Currently on the State of Wyoming Designated Noxious Weeds List.

[1]Low and high ranges are based on standard error calculations, accounting for potential uncertainty in area associated with mapping. The original data were in acres and were converted to hectares rounding up to the nearest tenth ha.

In 2009, the NGP EPMT inventoried 53.9 ha (133 ac) and along with park resource staff sprayed 14.2 ha (35 ac) of leafy spurge at DETO, focusing efforts along the Belle Fourche River, the campground, and along the road to the maintenance shop (NPS 2009). NPS (2009) noted that the area had significantly reduced densities of mature leafy spurge plants along the riparian area compared with the past several years. Then, in 2010, the NGP EPMT and a crew from the Conservation Corps of Minnesota treated over 43.7 ha (108 ac) of leafy spurge and cheatgrass (NPS 2010) on the same areas as the 2009 inventory and treatment and also along the Tower Trail.

A total of 376 plant species have been certified as present in the park (NPS 2004). Of this total, 49 plant species are nonnative (13% of the total species). However, many are unconfirmed species and species considered probably present in the most recent certified plant list for DETO. There are 5 nonnative and 30 native unconfirmed plant species and 22 nonnative and 24 native species considered probably present. Adding the number of the probably present and unconfirmed species to the number of species present in park, there are 76 nonnative species (17% of the total 456 species) and 380 native species (83% of the total 456 species). DETO management considers 12 of the nonnative plant species found in the monument to be management priority species; all except common burdock (*Arctium minus*) are considered weedy (i.e., invasive; Table 14) (NPS 2010).

DETO managers utilize multiple methods to treat nonnative, invasive plants, including chemical, biological, manual, and cultural controls (NPS 2004). Biological controls began in 1998 with the release of flea beetles (*Aphthona* spp.) over several years to control leafy spurge. In 2002 and 2003, more than one million beetles were released each year. Chemical spray treatments began in 2000 and continue today along with manual and mechanical treatments (Table 14). DETO resource staff and seasonal weed crews also treated areas with fire, chemical, mechanical, and biological methods; these data are not reflected Table 14.

Table 14. Area of invasive plant survey and control treatments in DETO, 2000–2010 (years 2000–2008 GIS data from NPS data store, 2009 from NPS 2009, 2010 from NPS 2010).

Year	Surveyed area ha (ac)	Hectares (ac) by control measure				% of Area Treated vs. Surveyed*
		Biological	Manual	Chemical	Total	
2000	unknown	--	--	28 (70)	28 (70)	--
2001	--	--	--	--	--	--
2002	80 (197)	23 (57)	--	32 (79)	55 (136)	69
2003	119 (295)	21 (53)	0.4 (1)	160 (395)	182 (449)	152
2004	247 (610)	--	--	150 (370)	150 (370)	61
2005	154 (380)	--	39 (96)	78 (192)	116 (288)	76
2006	303 (748)	--	4 (10)	116 (287)	120 (297)	40
2007	--	--	--	--	--	--
2008	225 (556)	--	--	48 (118)	48 (118)	21
2009	54 (133)	--	--	14 (35)	14 (35)	26
2010	89 (221)	--	--	44 (108)	44 (108)	49

*Some areas receive multiple control methods, therefore this number may exceed 100% in years where multiple treatment methods were employed. Note: "unknown" refers to evidence that some unknown acreage of control or survey activity occurred that year and a dash (--) indicates that no activity occurred that year as indicated by data.

A majority of the 48 ha (118 ac) was treated with chemicals in 2008 to target leafy spurge (Table 15). In 2009, the NGP EPMT and DETO staff focused all of its efforts on leafy spurge, spraying plants along the eastern side of the Belle Fourche River, the campground, and along the road to the maintenance shop (NPS 2009). In 2009, the NGP EPMT noted a significant reduction in mature plant densities along the riparian area. In 2010, more than 43 ha (106 ac) of leafy spurge were treated by NGP EPMT. DETO resource staff and seasonal weed crews also treated a large area of invasive plants in 2010(302 ha [748 ac]). These efforts were primarily treatments of leafy spurge using chemicals but also included mechanical removal, biological introductions, and the introduction of fire for other invasive plants species in DETO. In addition, DETO staff focused on Canada thistle, hounds tongue, common mullein, bull thistle, and musk thistle along roads, trails, riparian areas, and heavily used areas.

Table 15. Area of chemically treated nonnative plants by species and density. (NPS 2008).

Nonnative species		Density: Trace (0-25%)	Light (25-50%)	Moderate (50-75%)	Heavy (75-100%)	Total
bull thistle	ha	0.002	0.004	--	--	0.004
	ac	0.006	0.011	--	--	0.011
Canada thistle	ha	--	--	0.019	0.015	0.033
	ac	--	--	0.047	0.037	0.084
common mullein	ha	0.006	--	0.005	--	0.038
	ac	0.006	--	0.012	--	0.094
houndstongue	ha	0.010	0.002	0.072	0.075	0.148
	ac	0.024	0.004	0.178	0.183	0.365
leafy spurge	ha	1.444	45.030	1.224	0.027	46.281
	ac	3.569	111.272	3.024	0.067	114.363
Scotch thistle	ha	0.005	--	--	--	0.005
	ac	0.012	--	--	--	0.012
Totals:	ha	1.464	45.036	1.320	0.116	46.510
	ac	3.617	111.287	3.261	0.286	207.948

Leafy spurge was first documented in Massachusetts in 1827 and then made its way to Wyoming circa the 1970s (Anderson et al. 2000). One of the most abundant invasive species in the Northern Great Plains, it creates dense stands that displace native plants (Anderson et al. 2000). Anderson et al. (2000) state that “Leafy spurge will never go away in the U.S.” and “the best we can hope to do is reduce its impact below ecologically and economically significant levels” (p. 10). However, the authors suggest that a broad set of measures, including biological, ecological, scientific, economic, political, and social, can define control success, and the most success will be obtained by using biologically based, integrated pest management (IPM) strategies.

In July 1999, researchers examined hyperspectral images to detect areas of leafy spurge in DETO (Parker, Williams, and Hunt 2004). Jay et al. (2009) suggest that low cost hyperspectral image analysis techniques are promising in the detection (remote sensing) of invasive species.

Cottonwood Regeneration

Tinker (2008) conducted a study to assess the current condition of riparian areas in DETO, specifically focusing on the regeneration of the native plains cottonwood. The author examined 152 cottonwoods in the campground area of DETO. Core samples were taken from 59 mature trees, but only 21 cores were free enough from rot to measure tree age. Tinker (2008) found the average tree age was 112 years, and 14 trees were older than 100 (range 51 to 209). Tinker (2008) concluded that, with this high average age and the amount of core rot, many of the trees in the campground “may die in the near future” (Tinker 2008, p. 8). The author also categorized the condition of the trees using classes one (best) to three (worst) (Table 16). The majority of trees, 74%, were determined to be in class two, 15% were categorized as class one, and 11% categorized as class three.

Table 16. Tree condition ranking criteria for each mature cottonwood tree measured in the Belle Fourche Campground. Trees ranked as condition class 1 were considered to be in the best condition, those ranked as class 3 were considered to be in the worst condition. (Tinker 2008)

Tree condition	Branching pattern	Crown depth	Crown width
1	Complex	>50% of tree height	>75% of tree height
2	Moderate	25–50% of tree height	50–75% of tree height
3	Minimal	<25% of tree height	<50% of tree height

Planting efforts to increase cottonwood abundance along the Belle Fourche River have been mostly unsuccessful. Tinker (2008) noted that plantings of seedling and sapling sized trees outside the floodplain may not have enough subsurface water to develop, and other trees planted in the floodplain were not sufficiently enclosed to prevent browsing and experienced high nonnative plant competition.

Threats and Stressor Factors

Ponderosa pine density and distribution increased directly due to years of fire suppression and indirectly due to past cattle and sheep grazing in the area. In addition to these broad plant community changes, high tree stocking levels and high stand density indexes of ponderosa pines (especially larger diameter trees) are of concern because they reduce tree vigor (Negrón and Popp 2004). The reduced tree vigor creates an opportune situation for insect development and spread, specifically increasing the potential for higher levels of tree mortality caused by bark beetles (*Dendroctonus* spp.) (Negrón and Popp 2004). Today, managers using prescribed burns seek to mimic natural forest and prairie fire regimes, keeping the ponderosa pine expansion in check over time and reducing the risk of broad insect infestations, such as those caused by bark beetles.

Cottonwood regeneration is nearly nonexistent along the Belle Fourche River in DETO. A large earthen dam constructed on the Belle Fourche River in 1950–1952 created the 9,000-acre Keyhole Reservoir approximately 30 km upstream of DETO (Bureau of Reclamation 2010). This changed the Belle Fourche River's hydrograph, suppressing high-water events that cottonwood trees rely on for new seedling establishment (Tinker 2008). In addition, Tinker (2008) determined that some natural factors, such as periods of drought and river channel movement over time, may be limiting cottonwood regeneration in DETO. Drought inhibits the ability of cottonwoods to regenerate, and river channel movement removes current stands from areas where flooding could occur, subsequently leaving established trees without access to high water tables found within current floodplains (Tinker 2008).

Nonnative plants, particularly invasives, are stressors to native plant communities. Nonnatives replace native species and thereby alter community composition and diversity (taxonomic and genetic), vegetation structure, fuel dynamics, and, therefore, fire regime. Given the current suite of invasive species and native vegetation at DETO, the effect of invasive species on native plant communities is more likely due to changes in community composition and diversity rather than the others.

Data Needs and Gaps

Species richness at a plot scale is a parameter that will be measured as part of an herbaceous plant community composition monitoring protocol by the NGPN. However, this protocol is in its early stages of implementation, with plots being read starting in summer 2011. Existing data do not indicate whether richness is increasing, decreasing, or stable, or indicate the suitable reference condition for this parameter.

DETO has an ongoing program attempting to replace large stands of nonnative grasses (especially smooth brome) with native species via prairie plantings. An assessment or reporting of the results of various efforts, including those recommended by Redente (1993), will help create a better understanding of condition of native plant communities and future restoration activities to engage in by DETO resource management.

In 2003, Wood and Rew (2005) noted extensive infestations of annual brome grasses and houndstongue in their 2003 survey; although houndstongue is treated by management practices, no management currently targets annual brome grasses. Most effort, in terms of inventory and control is focused on highly invasive, nonnative plant species, while other species are not treated or inventoried. Therefore, the relative density and diversity of nonnative plants is not understood across the landscape.

Overall Condition

Ponderosa pine conditions (density and distribution) are of low to moderate concern in the park primarily because dramatic changes have been observed in ponderosa pine densities and landscape coverage from 1874 to 1974 in the Black Hills (Progulske 1974). McAdams (1995) showed that trees 1 to 20 cm (0.4 to 7.9 inches) diameter increased in density and basal area in Black Hills forests from 1874 to 1995. Specific historic measurements of pine density and extent are uncalculated within DETO, so quantitative comparison is not possible. Efforts to reduce overstory ponderosa pine density are ongoing, primarily with the use of prescribed fires and some mechanical thinning. Fire effects monitoring indicate that prescribed fires have reduced density and basal area of trees in smaller diameter classes (generally <25.4 cm [10 inches] dbh), but they have had little effect on overstory density. Based on rough canopy density categorization by the mapping unit in Salas and Pucherelli (1998), approximately 17 ha (43 ac), or 41%, of the ponderosa pine forest is considered to be a closed canopy. However, a significant portion of the ponderosa pine map units in Salas and Pucherelli (1998) have an undefined canopy density (Plate 10), thereby complicating the assessment of pine densities compared to reference condition.

Symstad and Bynum (2007) provide a comparison of 1900 Black Hills forest structure across a wide range of locations with recent (2004) stand structure measured in stand level examinations in Mount Rushmore National Monument. Symstad and Bynum (2007, Figure 3) provide tree density by diameter class from Brown and Cook’s (2006) 1900 Black Hills information. The density of trees in various size classes described by the fire effects monitoring data (Figure 5) appears to be roughly similar to that of the historic (pre-fire-suppression) forest structure displayed by these data. This may suggest that current DETO forest structure, at least in areas that have had prescribed fire treatments, may be similar to historic forest structure used as the reference condition for this assessment.

The condition of plant species richness across DETO is unknown, given limited park-wide data. Also, many species on the currently list of native and nonnative plants are considered probably present or unconfirmed, complicating the understanding of current plant species richness across the monument. However, an indication of species richness in DETO is provided in Heidel (2008) with a statement that DETO “has an exceptionally rich flora.”

The condition of nonnative plant species density and distribution is of moderate concern. While a return to a landscape completely free of nonnative plant species in DETO is an unrealistic expectation, invasive nonnative plant control efforts continue every season. Eleven nonnative species are considered to be weedy by DETO resource management (NPS 2010). Leafy spurge is currently the most widespread and significant invasive plant in DETO, based on the relative number of acres where it is found and the number of acres treated with biological, chemical, and manual methods. The NGP EPMT noted significant declines in mature leafy spurge plants in the riparian areas of the DETO during 2009 (NPS 2009), and in 2010 a significant area (>100 ac) of leafy spurge was chemically treated. However, evidence for reductions of other nonnative invasive species is scarce. Heidel (2008) believes the expansion of leafy spurge in DETO is one possible reason for not finding (relocating) prairie violet, a species of special concern in DETO.

According to the most recent certified plant list for DETO, 49 nonnative species of the total 376 plant species are considered present in park (NPS 2007b); 24 native and 22 nonnative plant species are considered probably present in park (NPS 2007b); and 30 native species, 5 nonnative species, and 6 species of unknown nativity are unconfirmed in the park (NPS 2007b). Finally, 5 nonnative species and 9 unknown nativity species are considered false reports or historic species (NPS 2007b). NGPN staff is in the process of making adjustments and additions to the plant species. Ten additional species are in the process of being certified, and park statuses of other species may change from unconfirmed to present in park and from probably present in park to present in park.

The condition of cottonwood habitat in DETO based on cottonwood regeneration is a significant concern in DETO. Regeneration is nearly nonexistent in and around the campground areas of the monument (along the Belle Fourche River). Most of the cottonwoods are very old; recent examination by Tinker (2008) indicated an average age of 112 years, with many trees having moderate or advanced rot in core samples. Restoration efforts have largely failed in past years, and Tinker (2008) recommends that future restoration efforts include planting trees within the existing floodplain of the river, watering them for the first 3 to 4 years, removing nonnative plant species (especially leafy spurge), reducing damage and mortality by animal browsing by installing tall exclosures, and potentially monitoring residual levels of Tordon® in the soil.

Sources of Expertise
Mark Biel, DETO Chief of Resource Management

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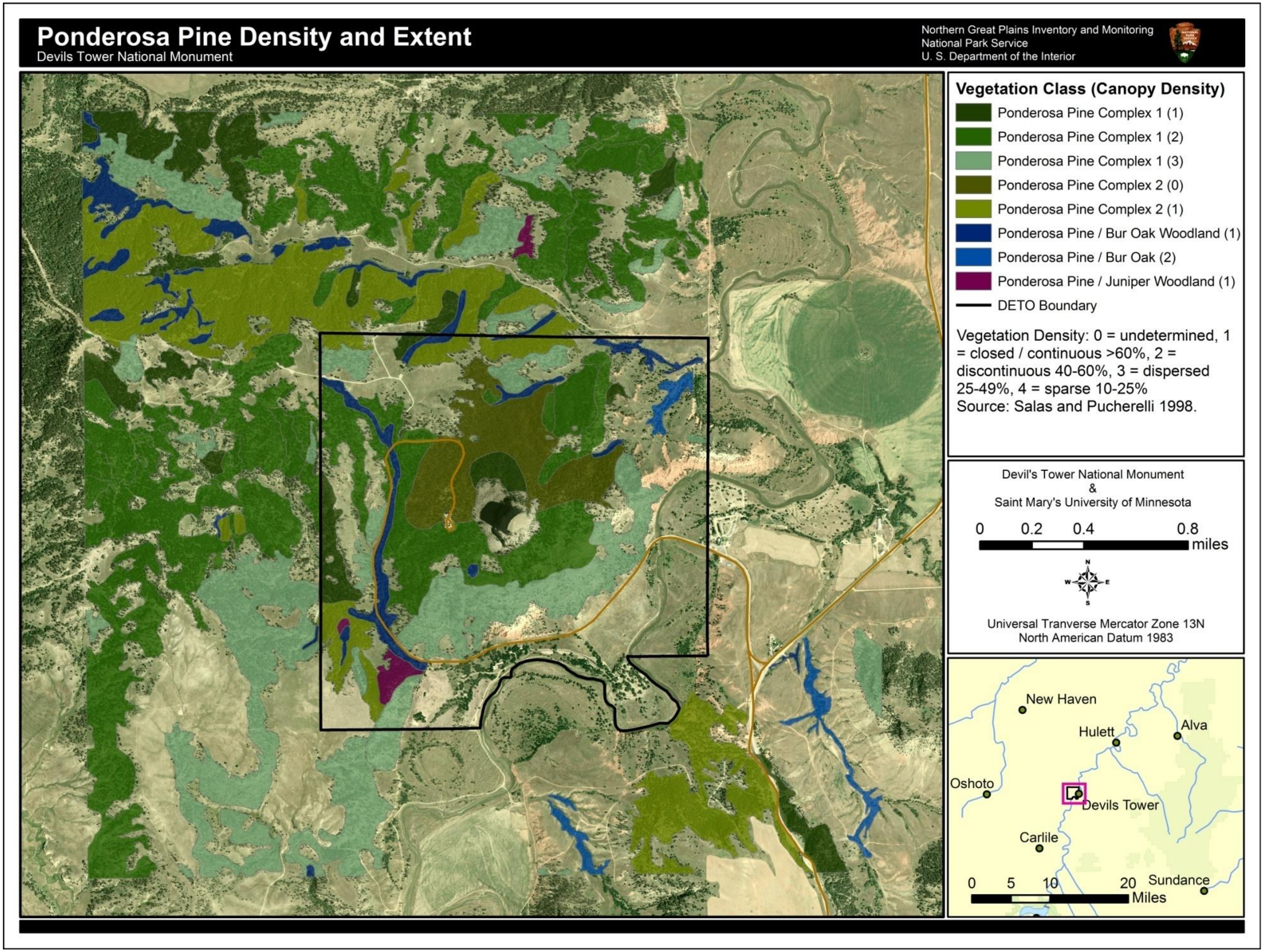

Plate 10. Pondera pine extent and density (estimated canopy density) (Salas and Pucherelli 1998).

4.3 Prairie Falcon

Description

The prairie falcon is a medium-sized, migrating raptor. In Wyoming, this species nests in April with clutch sizes of four to five. Incubation is roughly 1 month, mostly conducted by the female; males gather food. At DETO, falcons nest on ledges or in crevasses on Devils Tower, with no affinity to aspect. They also nest in the sandstone cliffs around the base of Devils Tower.

Measures

- Changes in nesting activities
- Nesting success and/or population status

Reference Conditions and Values

The reference condition for prairie falcons within DETO is successful nesting and fledging. The extent of prairie falcon use at DETO prior to settlement in the area is unknown.

Data and Methods

DETO staff provided the literature for this assessment, although sources were limited. No datasets were available regarding this species. Expert knowledge was used to supplement the data and literature deficiency for this species.

Current Condition and Trend

Nesting and Population Status

Devils Tower is likely one of the prime nesting locations for prairie falcons in the area (Panjabi 2005). Climbing routes in the immediate vicinity of the active nest on Devils Tower are closed during the nesting season to protect the nesting falcons as well as to protect climbers that may venture too close to the nest, as the falcons are known to aggressively dive and attack to protect their site. Britten (1993) noted that the earliest record of prairie falcons nesting on Devils Tower was 1972 or 1973. Between 1972 and 2005, various records indicate prairie falcon nesting at Devils Tower (Britten 1993). Since 2005, one prairie falcon nest has been confirmed at DETO each year (M. Biel, pers. comm., 2010).

Threats and Stressor Factors

Land cover change, development, and increased recreational use stress prairie falcons both locally and range-wide. Disturbance is a stressor that specifically applies to DETO. As mentioned previously, DETO staff alleviates disturbance by closing specific climbing routes near active nest sites. However, people using hiking trails around DETO on a daily basis may have some effect.

Data Needs and Gaps

Because prairie falcon use at DETO is minimal, there are few data needs. Examining the relationship between human presence and prairie falcon nesting habits could help develop ideas to encourage expanded nesting use and improve the park's ability to co-manage recreation and resource needs in the future.

Overall Condition

Prairie falcon nesting at DETO is minimal, but one nesting pair has been documented each year since 2005. How this compares to historical use is unclear. Panjabi (2005) suggests that DETO is prime nesting habitat for the geographical area and the limited use is discouraging. However, it is unknown if Devils Tower is large enough to support more than one nesting pair of prairie falcons per breeding season (M. Biel, pers. comm., 2010).

Sources of Expertise

Mark Biel, DETO Chief of Resource Management

Literature Cited

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4.4 Birds

Description

Bird populations often act as 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 exist (Blakesley et al. 2010). The 545 ha (1,347 ac) of DETO are covered with pine forests, woodlands, grasslands, prairie dog towns, and the 386 m (1,267 ft) tall Devils Tower (NPS 2010). This gradient of habitats and landforms across the park provide the birds of DETO with several unique niches. Monitoring avian population health and diversity in these habitats will be important for detecting ecosystem change.

Measures

- Species richness
- Density
- Abundance

Reference Conditions and Values

Reference condition for DETO birds is defined as the current diversity, richness, and distribution.

Data and Methods

The NPS Certified Species List for DETO (available online through NPSpecies, NPS 2007) was used for this assessment. Limited northern goshawk (*Accipiter gentilis*) data for this assessment were also provided by Mark Biel, DETO Chief of Resource Management.

<u>Rocky Mountain Bird Observatory (RMBO) Monitoring</u>

From 2002 to 2004, RMBO staff established a 6-point transect in a ponderosa pine forest along Tower Trail to determine density estimates for trend monitoring in DETO (Panjabi 2005). In 2003, this transect was reconfigured and extended to 15 points. The transect started at the northwest corner of the park and systematically covered the pine forest habitat, making frequent turns to survey the forest irrespective of roads and trails (Panjabi 2005).

Current Condition and Trend

<u>Species Richness</u>

Currently, there are no data regarding species richness in DETO. Without established annual surveys and monitoring programs this measure cannot be described.

Species of Conservation Concern

The Wyoming Partners in Flight (PIF) developed the current list of priority bird species in the state based on a combination of criteria in the national PIF priority database (Carter et al. 1997). A Level I Priority Species is defined by Nicholoff (2003) as a species that

> …clearly needs conservation action. Declining population trend and/or habitat loss may be significant. Includes species of which Wyoming has a high percentage of and

responsibility for the breeding population, monitoring, and the need for additional knowledge through research into basic natural history, distribution, etc.

In DETO, there are five level I Priority Species confirmed in the park (Table 17).

The Wyoming Natural Diversity Database (WYNDD) (Keinath et al. 2003) also developed a list of animal species of concern in Wyoming. This list summarized information on species in Wyoming that are rare, endemic, disjunct, threatened, or otherwise biologically sensitive (WYNDD 2008). In DETO, six species are listed on the WYNDD species of concern list (Table 17).

Beginning in 1991, PIF began assessing species to provide consistent, scientific evaluations of conservation status across all bird species (RMBO 2005). The assessments look at a species' population size, distribution, population trend, threats, and regional abundance to generate numerical scores that rank the species in terms of its biological vulnerability and regional status. The RMBO maintains PIF assessment data and organizes the species on a geographic scale using Bird Conservation Regions (BCRs), the accepted planning unit for updated regional bird conservation assessments under the North American Bird Conservation Initiative (NABCI) (RMBO 2005). DETO is part of BCR 17 (The Badlands and Prairies), and 16 species are listed by the PIF as Species of Regional Importance (Table 17).

Table 17. Status designation for bird species of conservation concern confirmed in DETO.

Species	Level I [1]	WYNDD SC [2]	PIF SRI [3]
Northern goshawk	x	x	x
Golden eagle			x
Swainson's hawk	x		x
Northern harrier			x
Bald eagle	x	x	
White-throated swift			x
Pinyon jay			x
Black-billed magpie			x
Peregrine falcon	x	x	
Vesper sparrow			x
Western meadowlark			x
Northern rough-winged swallow			x
Mountain bluebird			x
Sharp-tailed grouse	x		x
Red-headed woodpecker			x
Lewis's woodpecker		x	x
Black-backed woodpecker		x	x
Three-toed woodpecker		x	
Say's phoebe			x

[1] Level 1 = Wyoming Partners in Flight Level 1 Priority Species (Nicholoff 2003)

[2] WYNDD SC = Wyoming Natural Diversity Database Species of Concern (Keinath et al. 2003)

[3] PIF SRI = Partners in Flight Species of Regional Importance (http://www.rmbo.org)

Species of Management Concern

As described in the NPS Certified Species List, only the prairie falcon is a primary management concern for DETO. At DETO, falcons nest on ledges or in crevasses on Devils Tower, with no affinity to aspect. They also nest in the sandstone cliffs around the base of the Tower.

Climbing routes in the immediate vicinity of the active nest on Devils Tower are closed during the nesting season to protect the nesting falcons as well as to protect climbers that may venture too close to the nest because the falcons are known to aggressively dive and attack to protect their site. Since 2005, one prairie falcon nest has been confirmed at DETO each year; prior to 2005, reports of prairie falcon nesting are sparse (M. Biel, pers. comm. 2010).

Density

RMBO staff used point-transect survey routes during three annual surveys from 2002 through 2004 to estimate density of birds in DETO (Panjabi 2005). Of the 65 species detected, three species were observed frequently enough to generate estimates of density for trend monitoring (Panjabi 2005). Number of observed birds per year ranged from 104 to 209 individuals. This large fluctuation in recorded number of birds is likely due to the reconfiguring of routes in 2003 to accommodate for more off-trail survey transects (Table 18).

Table 18. Density estimates for three DETO bird species during RMBO bird surveys from 2002–2004 (Panjabi 2005).

Species	Year	Density Estimate (birds/ha)
American robin (*Turdus migratorius*)	2002	1.00
	2003	1.14
	2004	1.31
Yellow-rumped warbler (*Dendroica coronata*)	2002	0.34
	2003	0.47
	2004	0.54
Chipping sparrow (*Spizella passerina*)	2002	0.23
	2003	0.59
	2004	0.55
All birds	2002	7.98
	2003	6.48
	2004	8.48

Determining trends in density patterns is difficult because surveys only occurred once a year for 3 years. However, the average annual density of all breeding birds combined provides an index for monitoring the overall health of the avifauna at DETO. The estimates gathered by RMBO suggested that 12 to 14 years of annual sampling should be adequate to identify discernable trends in species density (Hanni and Panjabi 2004; Panjabi 2005).

Abundance

Currently, there are no data regarding species abundance in DETO. Without established annual surveys and monitoring programs, this measure cannot be accurately described.

Expected Bird Species

According to the NPS Certified Species List, 155 species from 36 families have been reported in DETO, and 120 of those species are confirmed sightings within DETO boundaries (NPS 2007) (Figure 7).

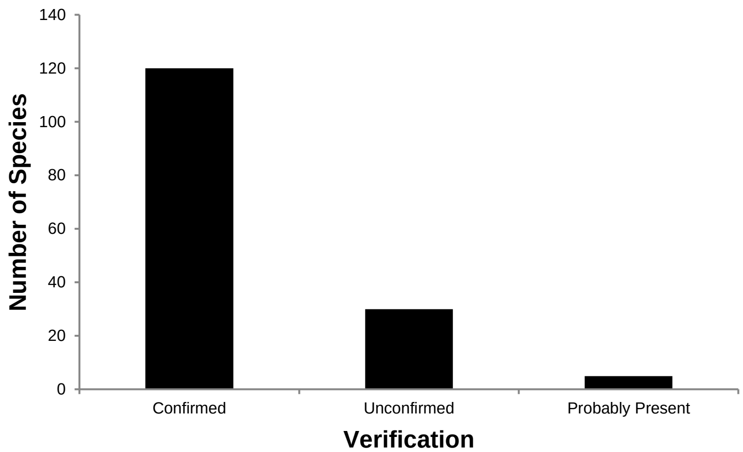

Figure 7. Status of bird species in DETO based on the NPS Certified Species List (NPS 2007).

Northern Goshawk Monitoring

During the 2007 nesting season, DETO attempted to monitor northern goshawk nest locations and reproductive success. NPS staff used a broadcast acoustical survey to elicit a response from goshawks by broadcasting a recording of an alarm or distress call. In addition to acoustical surveys, intensive nest searches were also performed that documented a single juvenile bird near DETO's west boundary, but the sex of the bird was not determined (John Wrede, pers. comm., 2010).

Reports of annual goshawk observations and potential nest sites in the northwest quadrant of the park near Joyner Trail have been fairly consistent; however, prescribed burns in the park have altered potential habitat sites in DETO. The northwest quadrant of the park had a prescribed burn that opened the canopy and created secondary and tertiary habitat.

Threats and Stressor Factors

One of the major threats facing bird populations across all habitat types is land cover change (Morrison 1986). Altered habitat can compromise the reproductive success or survival rates of species adapted to that habitat. Being home to a wide-array of habitat types, DETO may offer refuge to several habitat-specific species. Land cover change could alter the species composition of the park.

Data Needs and Gaps

Annual bird surveys, such as breeding bird surveys (BBS), Christmas bird counts (CBC), or continuation of the RMBO survey transects would allow initial assessment of current species richness, density, and abundance. Without monitoring in the park, these measures cannot be determined. Annual surveys would also help to monitor the current abundance of priority species within park boundaries. NGPN sampling and monitoring of birds in the NPS units will also help to assess the current condition and trends of the birds in DETO.

Overall Condition

DETO is home to one of the most diverse birding areas in the area due to absence of development and agriculture activities. All birds, whether breeding or migratory, use the park lands (M. Biel, pers. comm., 2010); however, because no annual bird surveys have been conducted in the park, a quantitative evaluation of condition of birds in DETO cannot be completed at this time. While the NPS has an exhaustive record of confirmed species in the park, this list does not allow estimates of current species richness, density, or abundance, which are the NPS-specified measures for birds in DETO. Annual monitoring of the populations in the park will provide a more accurate assessment of these parameters.

Sources of Expertise

Mark Biel, DETO Chief of Resource Management
John Wrede, NGPN Biological Science Technician

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4.5 Prairie Dogs

Description

Black-tailed prairie dogs, hereafter prairie dogs, are stout, burrowing rodents that occupy approximately 12.1 to 16.2 ha (30 to 40 ac) in southeastern DETO (NPS 2000a). Many species depend on prairie dogs for food, use of their burrows, and other reasons (Antolin et al. 2002). From 1989 to 1999, the estimated prairie dog population in DETO increased from 61 to 995 individuals (NPS 2009b, 2009c). This population increase caused concern for public health because prairie dogs are known to carry sylvatic plague, which can be transferred to humans through contact with an infected individual or their fleas (NPS 2000a). An environmental assessment of the issue determined that removal of prairie dogs from high visitor use areas was the best course of action to alleviate health risks (NPS 2000b).

Measures

- Population number and distribution

Reference Conditions and Values

The reference condition for the DETO prairie dog colony is the size of the colony in the recent era. This is interpreted as prairie dog populations following natural variance, unimpacted by plague or other stressors.

Data and Methods

DETO staff provided data for this assessment, including spatial data (GIS shapefiles) and spreadsheets with population information. They also provided literature explaining the management practices at the park. In some instances, data were compiled for analysis, otherwise data were not manipulated.

Current Condition and Trend

<u>Population Number and Distribution</u>

DETO contains one prairie dog town, located in the southeast. The prairie dog town is a popular stop for DETO visitors because of its easy access (the entrance road approximately bisects the prairie dog town) and the abundance of animals. The prairie dog town is bordered on the west and south by DETO and its access road. The size of the prairie dog town, sampled on 12 occasions using both GPS and aerial imagery, has ranged from 4.49 to 20.8 ha (11.1 to 51.4 ac) (NPS 2009a, Plate 11–Plate 23). The most recent estimate in 2010 was 16.7 ha (41.4 ac) (Table 19).

DETO staff members perform weekly prairie dog population trend counts yearly. From 1989 to 1999, the estimated size of the prairie dog population increased from 61 to 995 individuals. Since 1999, the prairie dog population estimates have fluctuated but seem stable ($\overline{x}$ = 762, range 285–1187). The most recent population estimate in 2009 was 573 (Figure 8).

Table 19. DETO prairie dog town size for all sampled years, 1974–2007 (NPS 2009a).

Year	Area (ac)	Area(ha)
1974	51.4	20.8
1985	42.9	17.4
1992	11.1	4.5
1995	22.5	9.1
1996	30.3	12.3
1999	34.8	14.1
2001	40.2	16.3
2002	37.0	14.9
2003	39.9	16.1
2004	40.7	16.4
2006	38.0	15.3
2007	35.0	14.1
2008	42.8	17.3
2009	41.3	16.7
2010	41.4	16.7
Average	36.6	14.8

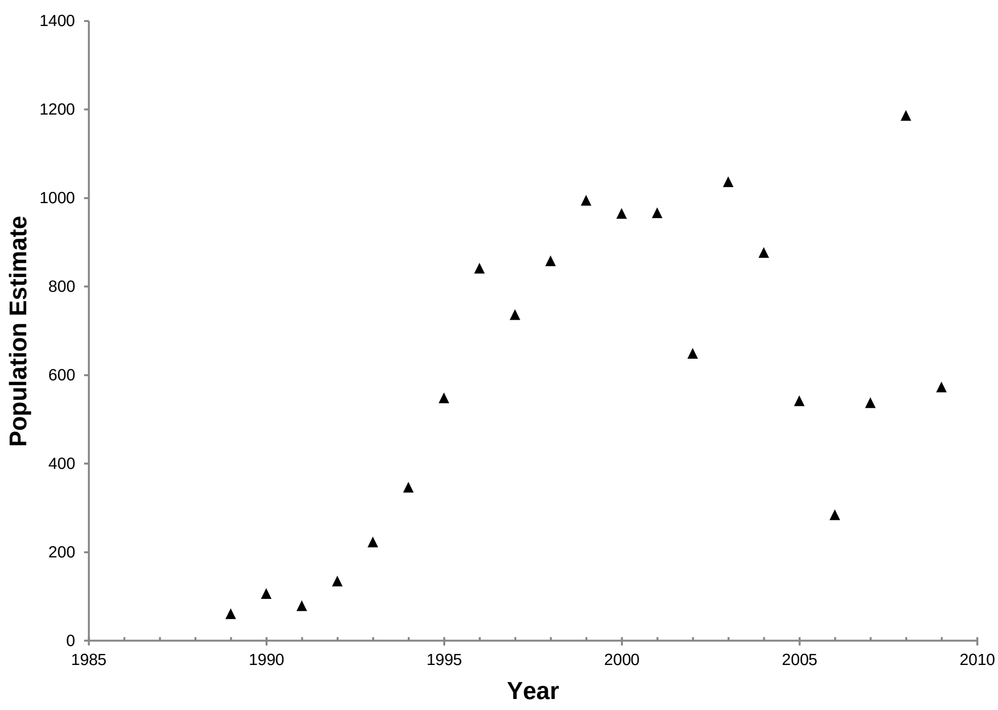

Figure 8. Prairie dog population estimates for the prairie dog town in DETO (NPS 2009b, 2009c).

Management

In the late 1990s, an increase of the DETO prairie dog town's area and population caused concerns over visitor health and safety (NPS 2000c); in response, an Environmental Assessment (EA) was performed that offered three management alternatives to control the DETO prairie dog town: Alternative A, no action; Alternative B, live trap black-tailed prairie dogs and provide them to the black-footed ferret (*Mustela nigripes)* reintroduction program; and Alternative C, eradicate encroaching black-tailed prairie dog population (NPS 2000a). Alternative B was the accepted management strategy because it offered a long-term and more humane solution than the other alternatives (NPS 2000c).

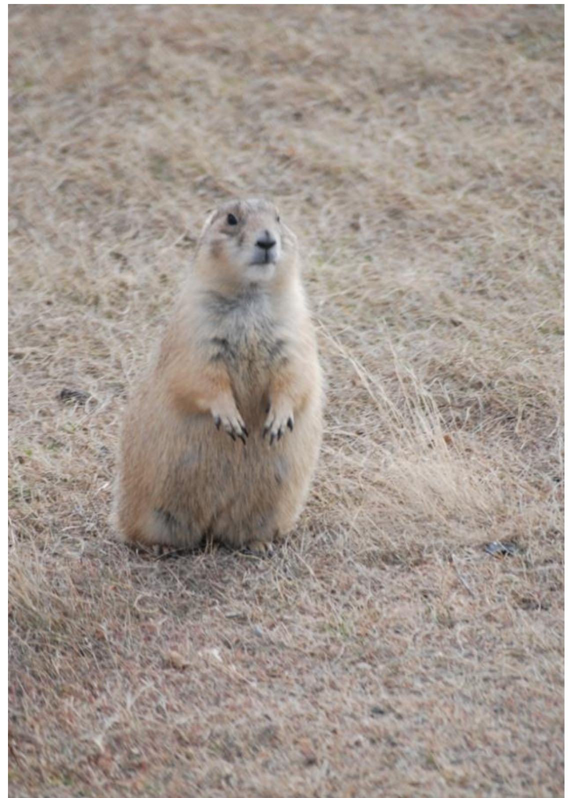

Photo 1. Black-tailed prairie dog (*Cynomys ludovicianus*) (GeoSpatial Services 2009).

Implementation of the management strategy began immediately after its acceptance. Memorandums from 2001 through 2006 outline prairie dog management accomplishments:

2001 (NPS 2001)

- Construction of a visual barrier between administration and the existing prairie dog town began. Skunkbush (*Rhus trilobata*), rubber rabbitbrush (*Chrysothamnus nauseosus*), and shrubby cinquefoil (*Potentilla fruticosa*) (145 plants) were planted and a game fence was put around them for protection.

- A silt fence was erected at the proposed site for the permanent visual/physical barrier.

- Three areas were mowed to enhance desirable prairie dog habitat and ease population pressure from the campground and picnic area.

- Open holes in Loop A of the campground were closed with a mix of gravel and dirt and campground mowing was stopped to deter the prairie dogs.

2002 (NPS 2002)

- The town was monitored for evidence of any massive die-offs, an indication of sylvatic or bubonic plague (*Yersinia pestis*).

- Construction of a permanent barrier between the administration building and the existing prairie dog town was suspended pending an EA.

2003 (NPS 2003)

- Areas mowed in 2001 to enhance desirable prairie dog habitat were mowed again.

- The town was monitored for evidence of any massive die-offs, an indication of sylvatic or bubonic plague.

2004 (NPS 2004)

- The silt fence was removed in spring of 2004, which resulted in three holes in the trailer drop area.

- The town was monitored for evidence of any massive die-offs, an indication of sylvatic or bubonic plague.

2005 (NPS 2005)

- 26 prairie dog burrows were closed, 24 in the amphitheatre area and two in Loop A of the campground.

- The town was monitored for evidence of any massive die-offs, an indication of sylvatic or bubonic plague.

2006 (NPS 2006)

- To accommodate for DETO centennial events, many areas adjacent to roads were mowed, and trapping and relocation was necessary to keep prairie dogs out of these areas.

- The town was monitored for evidence of any massive die-offs, an indication of sylvatic or bubonic plague.

Photo 2. The DETO prairie dog town.

Current management efforts include monitoring the population and distribution, and prairie dog eradication regularly takes place in the amphitheater, sculpture, and picnic areas and in the park campground on a less frequent, as-needed basis. A new prairie dog management plan is in development and scheduled for completion in December 2011. The new management plan will address different management techniques that inhibit prairie dog colony expansion and will look at alternatives to in-park lethal control activities to remove and control the colony size. The newly developed plan will be subject to the National Environmental Policy Act (NEPA) process in the form of an EA, as was the 2000 management plan. (M. Biel, pers. comm., 2010)

Threats and Stressor Factors

Sylvatic plague, caused by the bacterium *pestis*, is the most well known stressor to prairie dog populations and the primary cause for the rangewide decline in prairie dog distribution and abundance (Pauli et al. 2006). The plague is the only major limiting factor to 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 reduce genetic variability through inbreeding and genetic drift (Trudeau et al. 2004).

Human interaction also plays a role in the health and behavior of prairie dog populations (Antolin et al. 2002; Johnson and Collinge 2004; Magle et al. 2005). Prairie dogs in DETO experience human interaction on a regular basis because the prairie dog town is close to the entrance road. A study in Colorado found that black-tailed prairie dogs exhibited increased responsiveness in concealment behavior, returning to burrows faster with repeated human disturbances (Magle et al. 2005). The same study found that repeated human disturbance led to prairie dogs barking with less frequency as part of their avoidance response (Magle et al. 2005). Magle et al. (2005) speculate that the loss of barking behavior could reduce a prairie dog colony's ability to protect themselves from predators, such as humans, pets, and native carnivores.

Data Needs and Gaps

Mark Biel (pers. comm., 2010) stated that an in-depth study examining population density, genetics, food habits, and basic ecology would be beneficial to prairie dog management at DETO because the colony is isolated.

Overall Condition

The DETO prairie dog population is in good condition. Currently, plague does not affect DETO prairie dogs, and the population level has neither decreased nor increased at an unexpected rate since the re-establishment of the population in the late 1990s. The population distribution area is also stable at roughly 14.2 ha (35 ac). The population is stable because the park provides protected intact habitat compared to adjacent areas of higher agricultural land use (M. Biel, pers. comm., 2010)

Sources of Expertise

Mark Biel, DETO Chief of Resource Management

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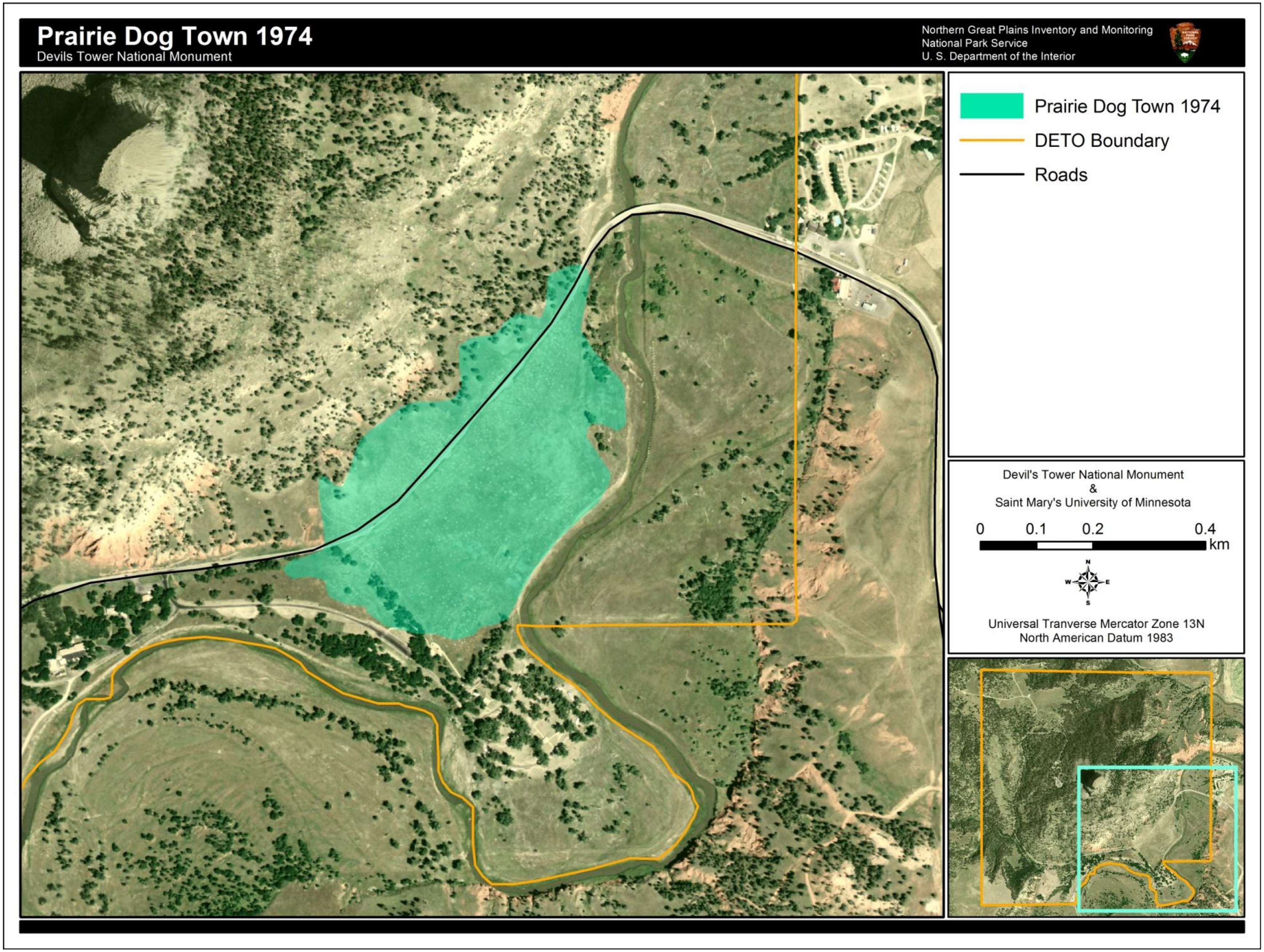

Plate 11. DETO Prairie Dog Town extent, 1974 (NPS 2009d).

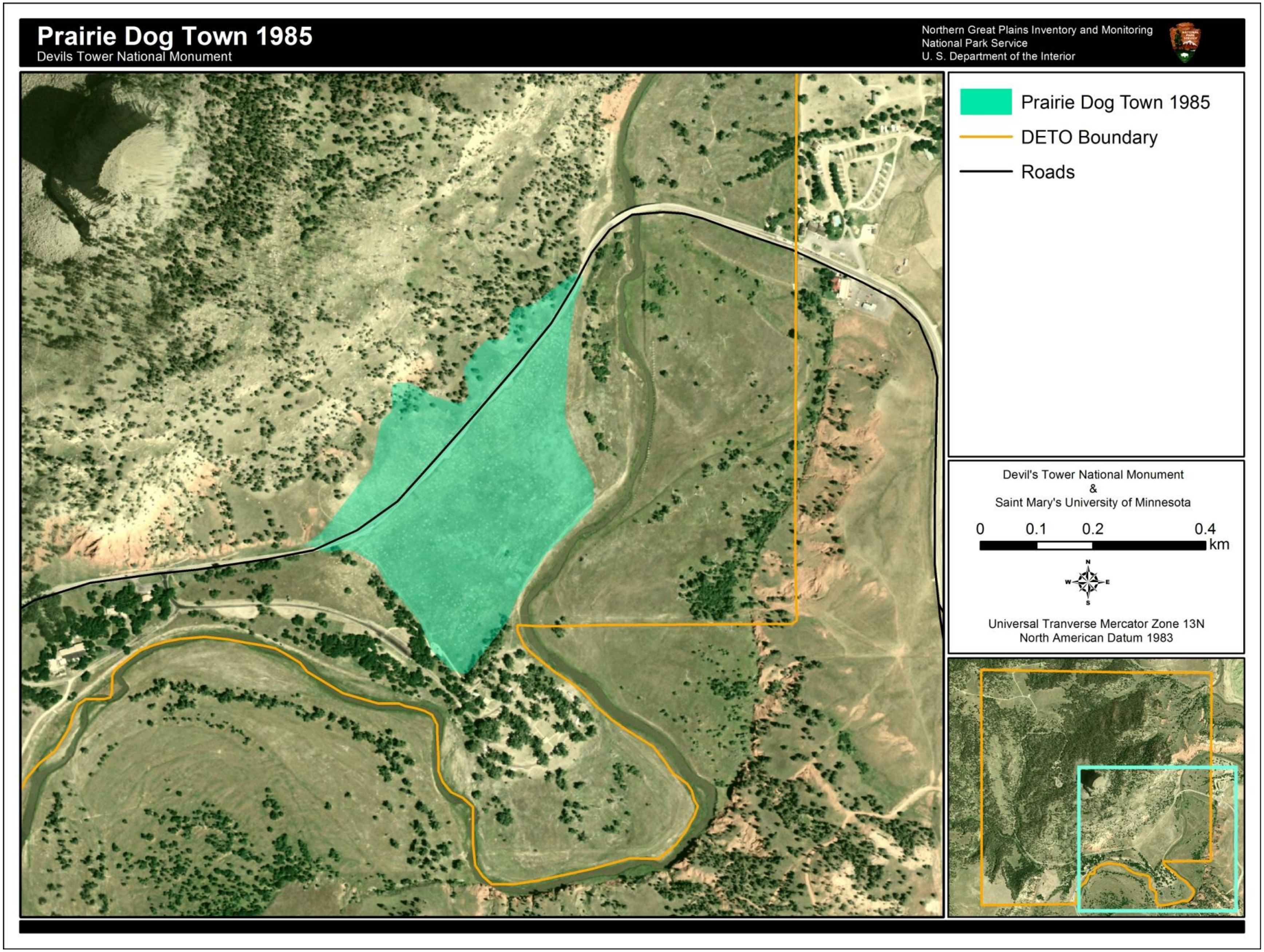

Plate 12. DETO Prairie Dog Town extent, 1985 (NPS 2009d).

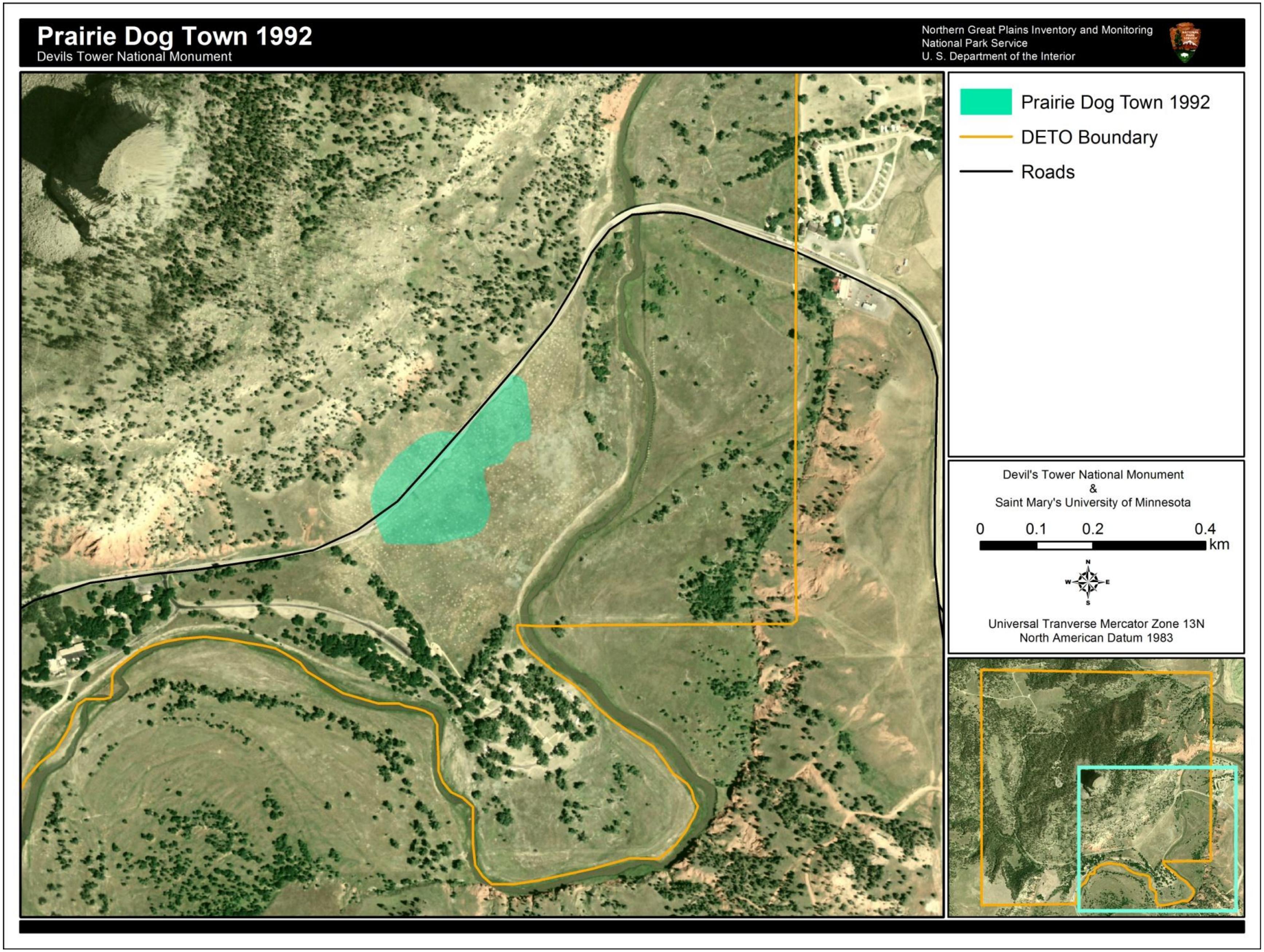

Plate 13. DETO Prairie Dog Town extent, 1992 (NPS 2009d).

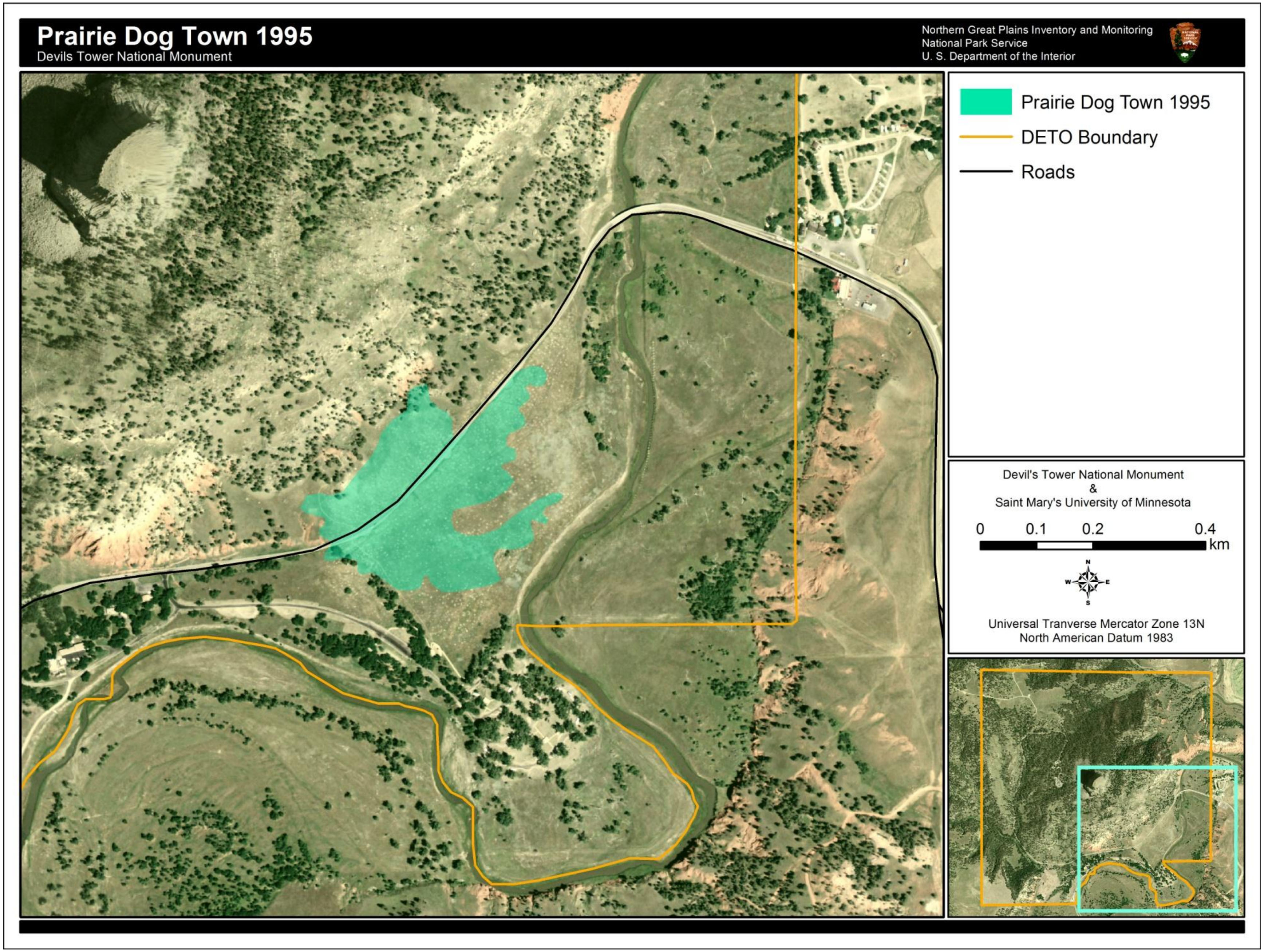

Plate 14. DETO Prairie Dog Town extent, 1995 (NPS 2009d).

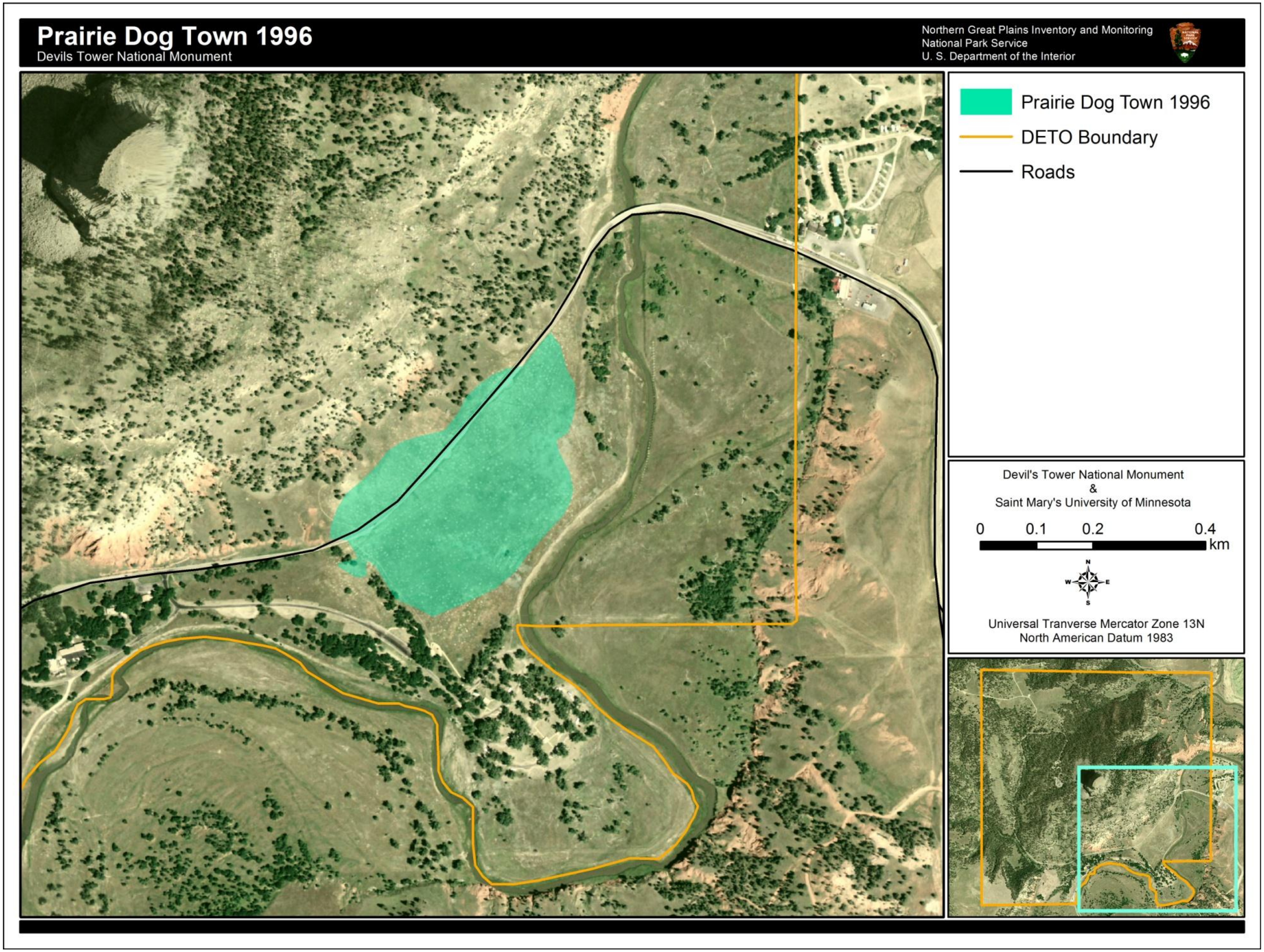

Plate 15. DETO Prairie Dog Town extent, 1996 (NPS 2009d).

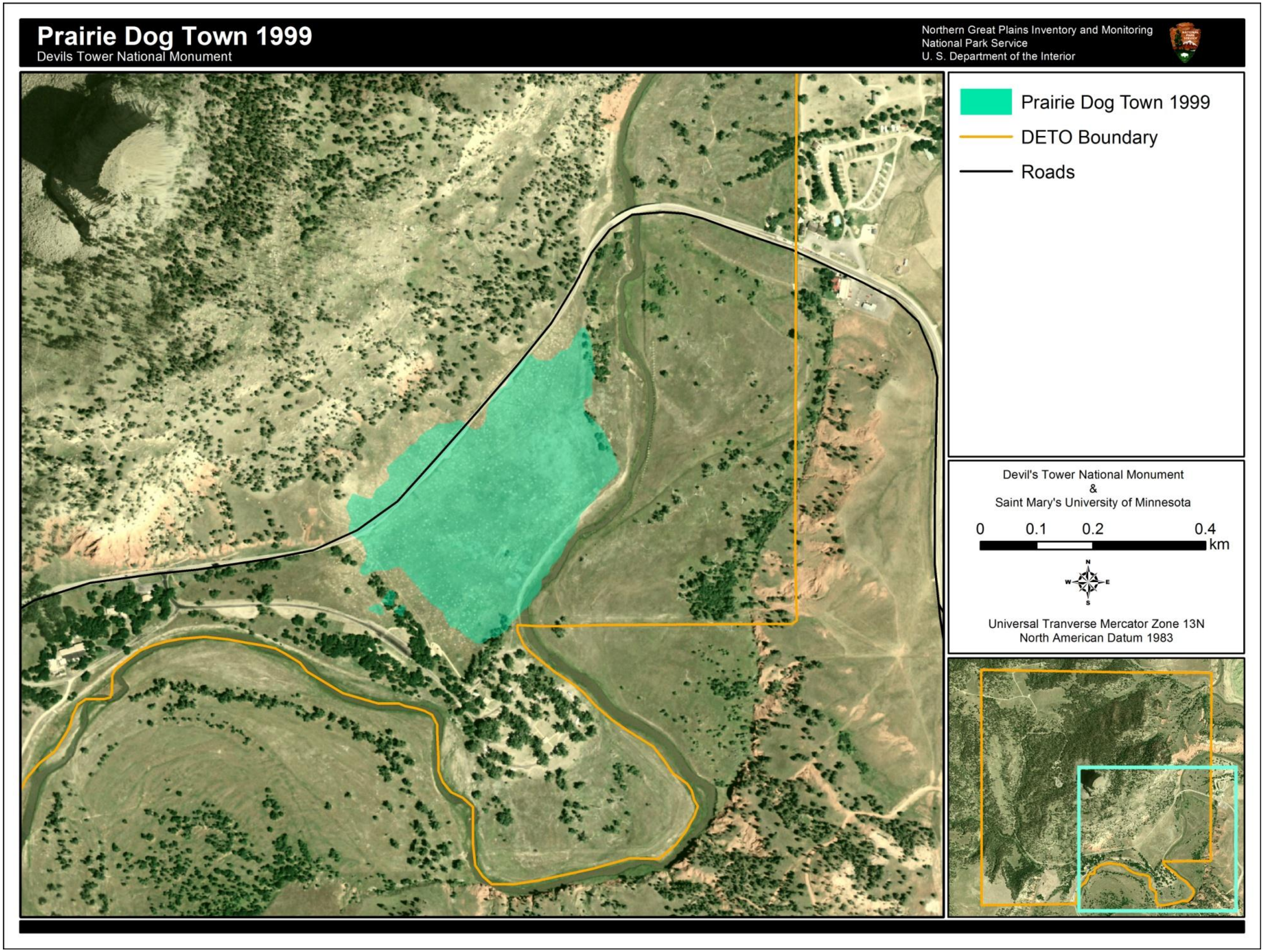

Plate 16. DETO Prairie Dog Town extent, 1999 (NPS 2009d).

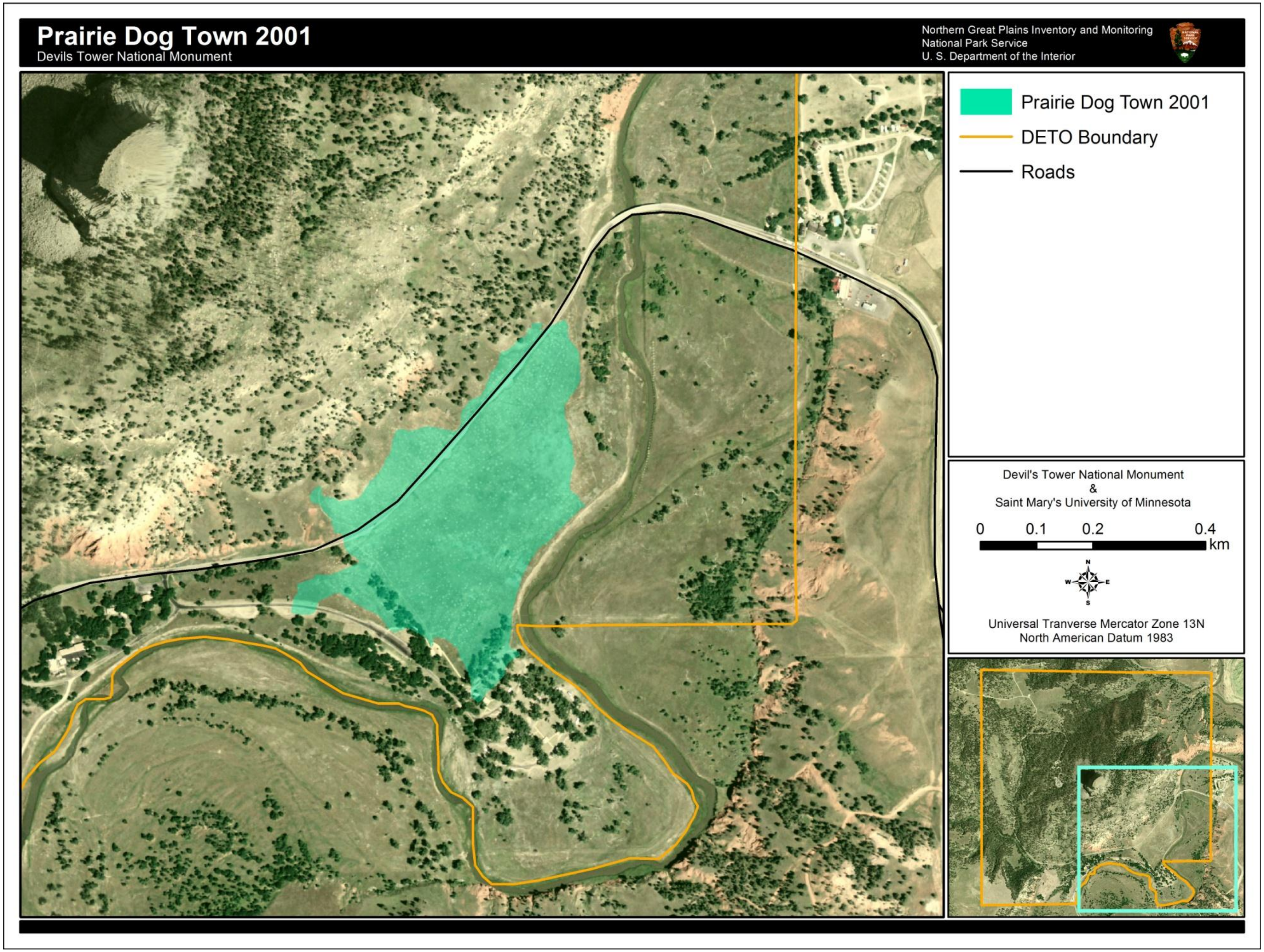

Plate 17. DETO Prairie Dog Town extent, 2001 (NPS 2009d).

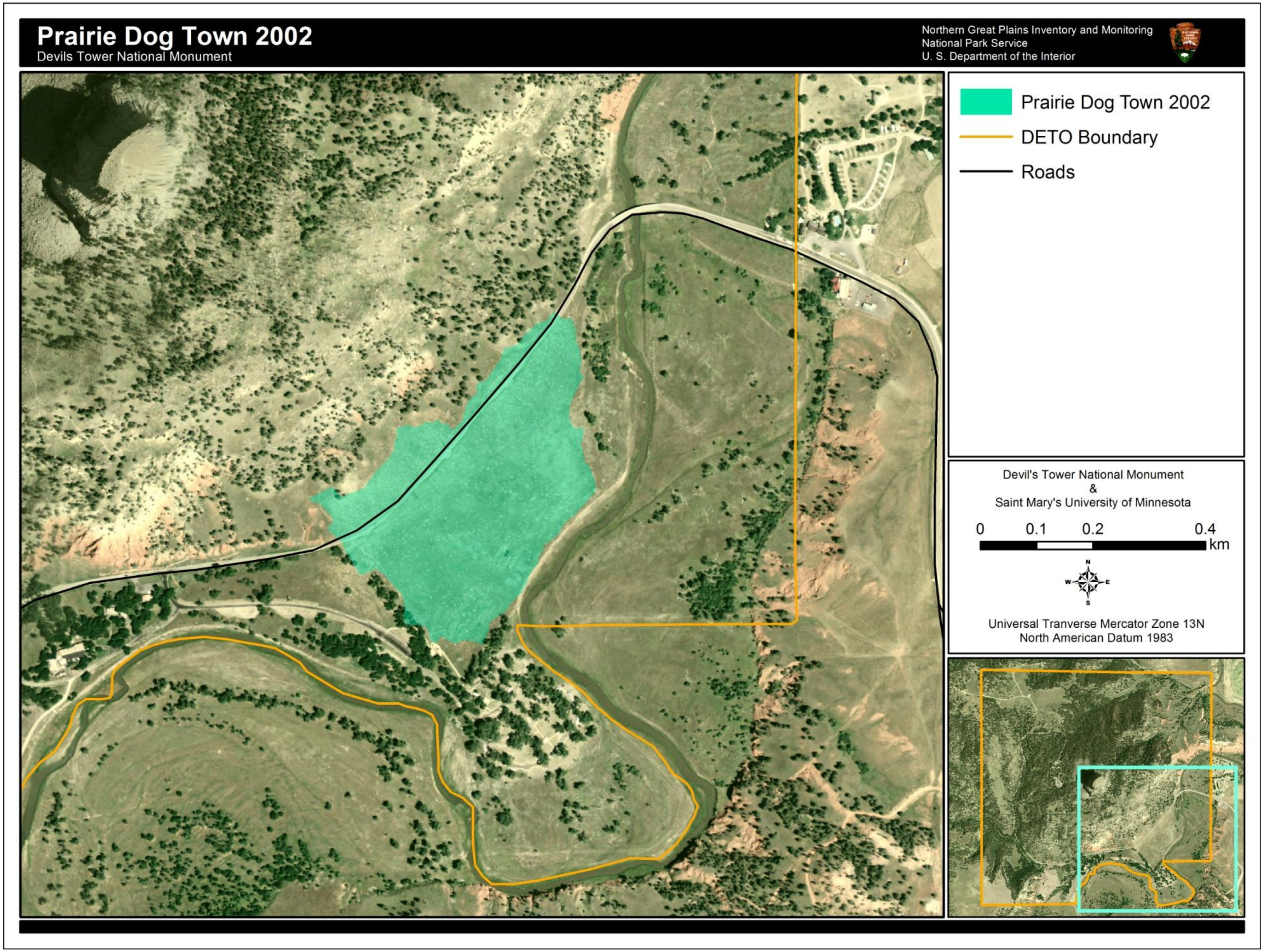

Plate 18. DETO Prairie Dog Town extent, 2002 (NPS 2009d).

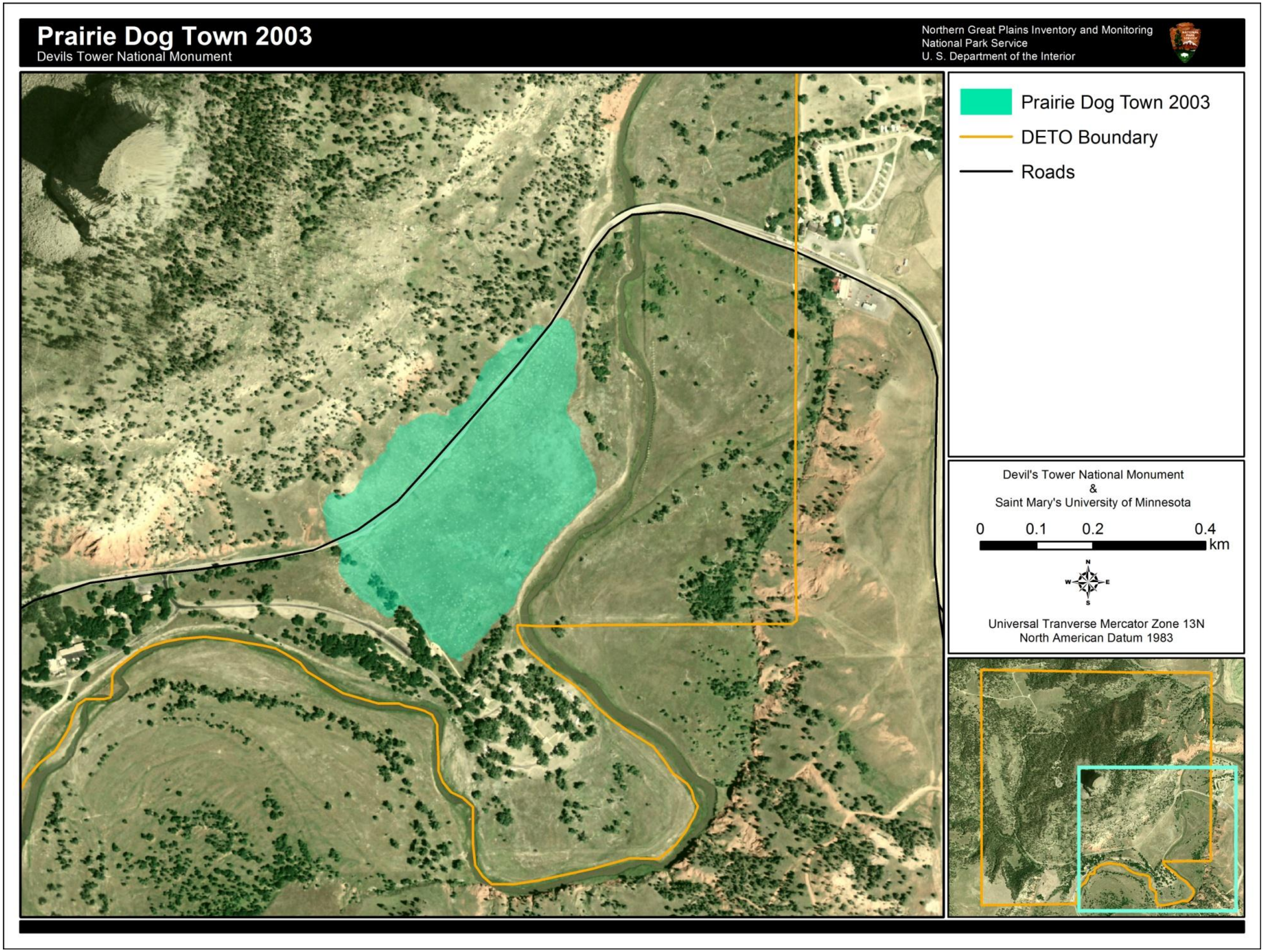

Plate 19. DETO Prairie Dog Town extent, 2003 (NPS 2009d).

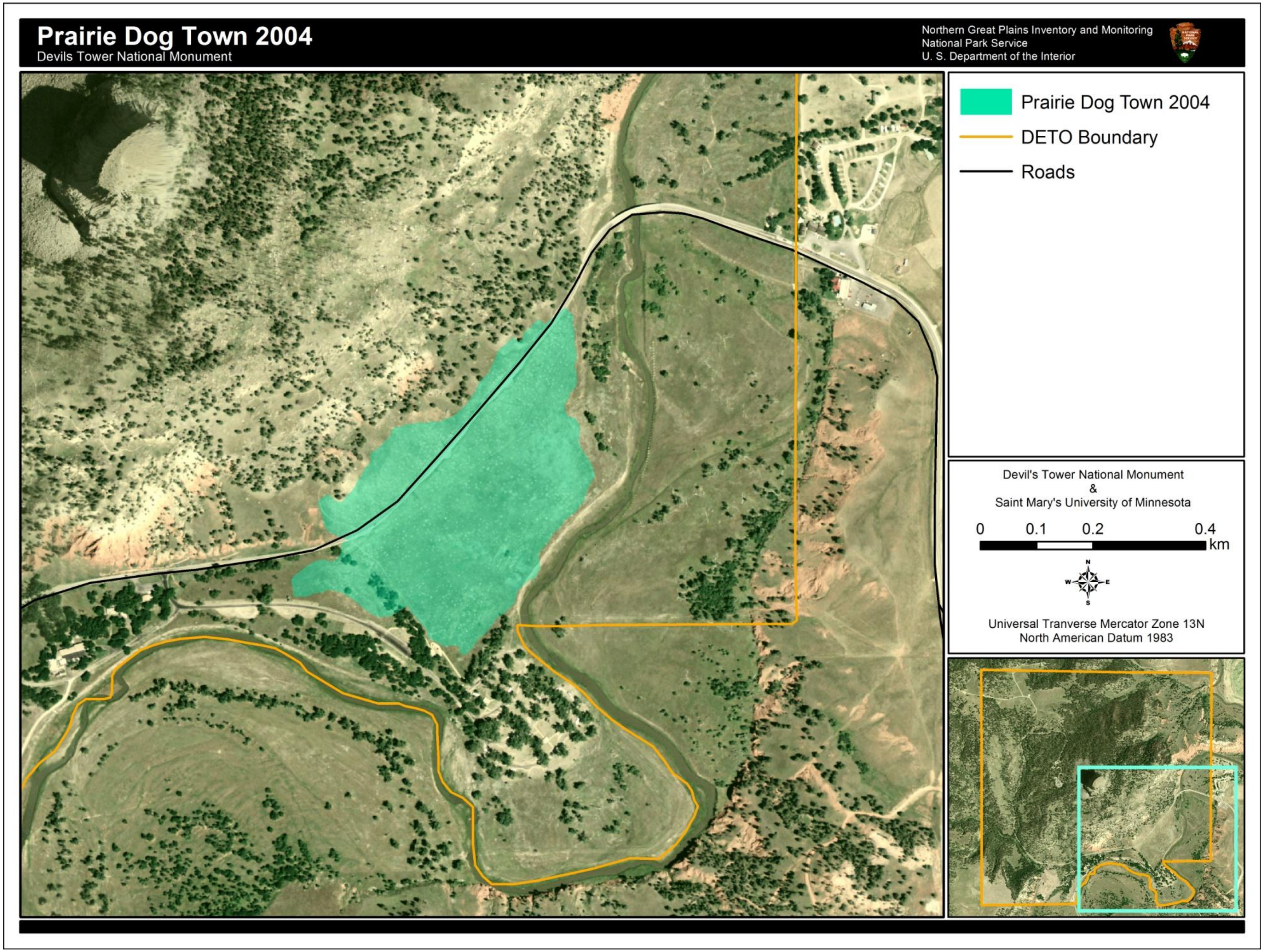

Plate 20. DETO Prairie Dog Town extent, 2004 (NPS 2009d).

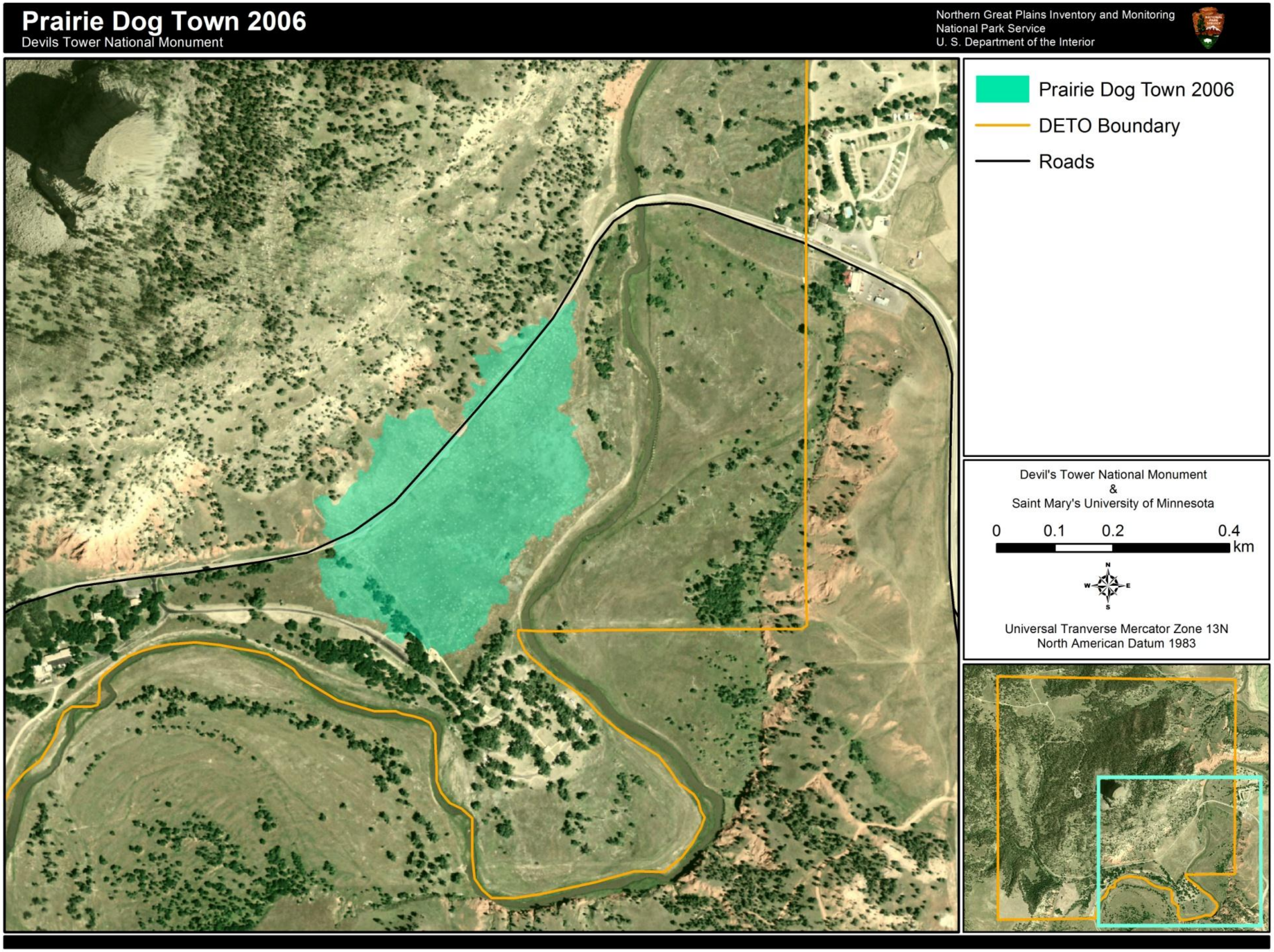

Plate 21. DETO Prairie Dog Town extent, 2006 (NPS 2009d).

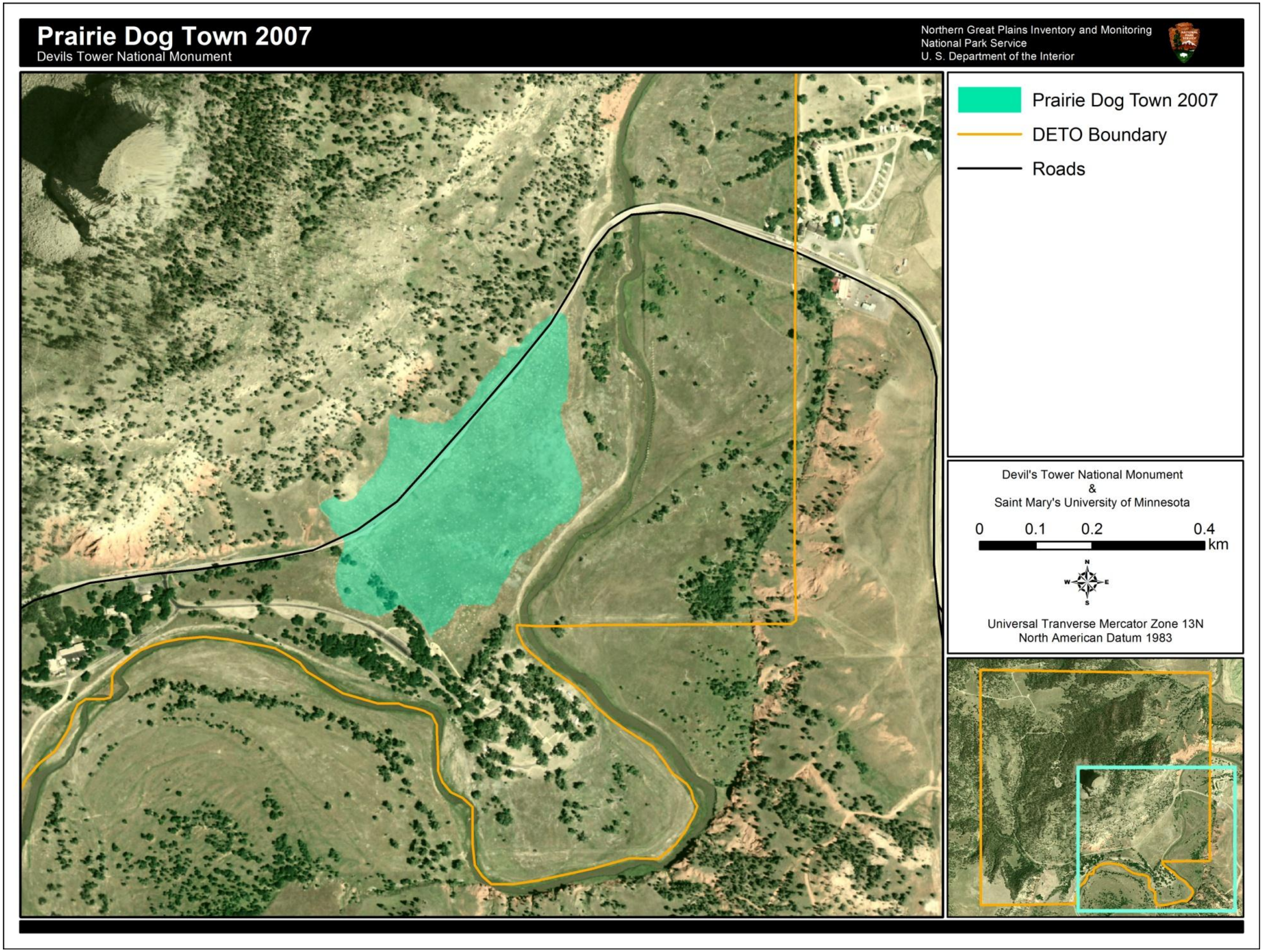

Plate 22. DETO Prairie Dog Town extent, 2007 (NPS 2009d).

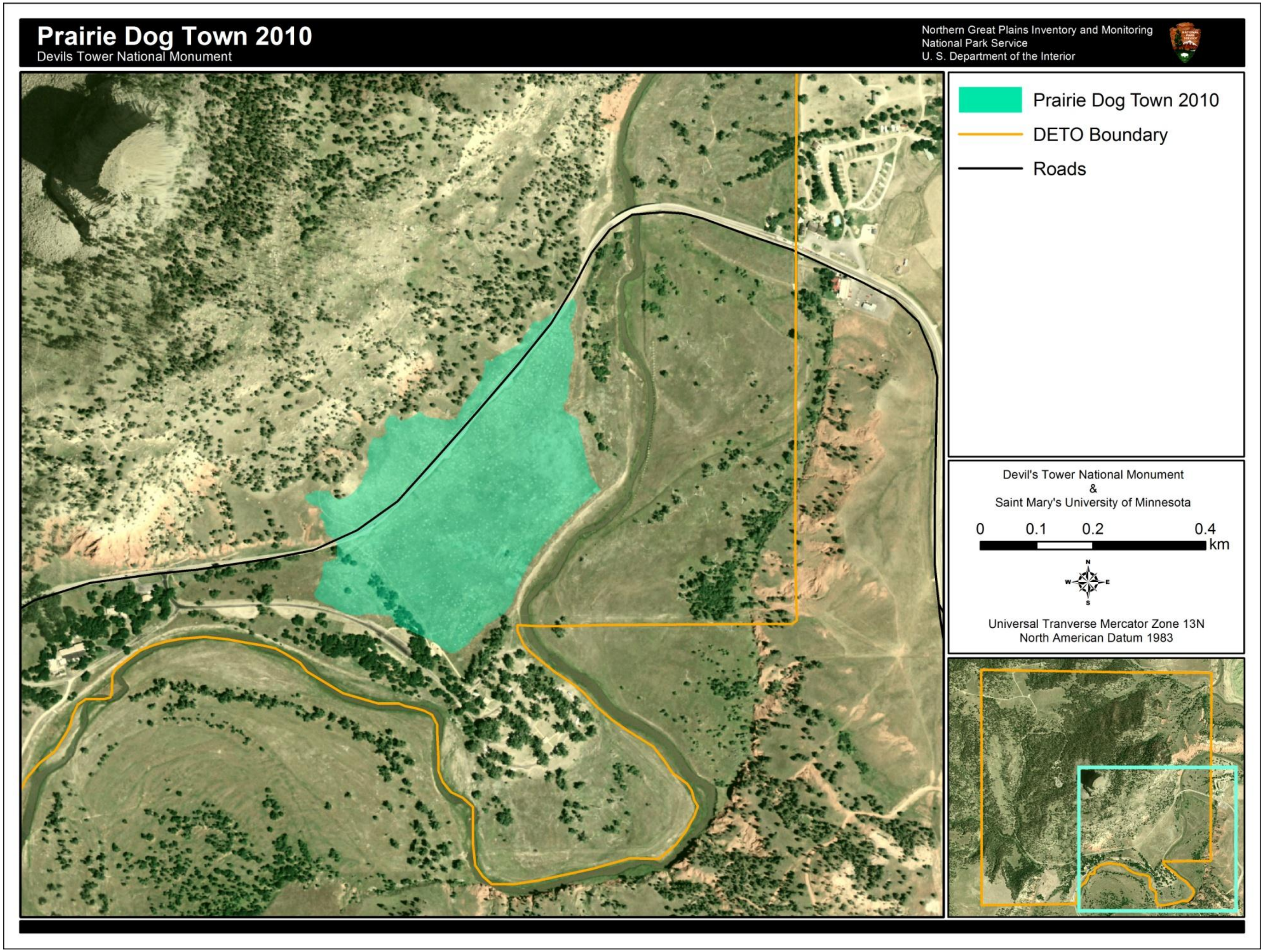

Plate 23. DETO Prairie Dog Town extent, 2010 (NPS 2009d).

4.6 White-Tailed Deer and Mule Deer

Description

White-tailed and mule (*Odocoileus hemionus*) deer use DETO and adjacent lands year round (McDaniel and Merrill 1992). Deer are important both at park and landscape levels. Although less than 5% of the Black Hills and northern plains vegetation is native deciduous woodlands, native woodlands cover 18% of DETO (Merrill et al. 2003). Over the past four decades, deer populations have increased along with heavy browsing on native forests in National Parks (Merrill et al. 2003), creating a conservation concern for native plant communities in parks with high browse levels.

Measures

- Population and distribution

Reference Conditions and Values

The reference condition for these species is natural and healthy populations. The earliest population data for deer in DETO are from the early 1990s, but whether these data are representative of a natural and healthy population is unclear. Because of this, quantitative comparison to the determined reference condition is not possible.

Data and Methods

DETO staff provided literature for this assessment. No datasets were available for this component. Expert knowledge supplemented gaps in the literature.

Current Condition and Trend

Population and Distribution

McDaniel and Merrill (1992) conducted a deer population and habitat ecology study at DETO, the only study to date to provide a population estimate for deer in the park. Population estimates were derived from deer drive counts, pellet group counts, and line-transects. They analyzed movement patterns and habitat use through telemetry and vegetation sampling and determined forage habits by sampling pellet groups.

McDaniel and Merrill (1992) performed their first deer drive count on 25 April 1992. Thirty-three participants counted 181 total deer, 162 white-tailed, 12 mule, and 7 unclassified. Twenty-five of the participants were “drivers,” positioned approximately 100 m apart. Drivers walked through the monument, pushing deer past “observers” who counted animals as they crossed their line of sight. During the second deer drive count on 10 October 1992, 129 white-tailed, 5 mule, and 1 unclassified deer were counted. Pellet group counts for October 1991 to April 1992 provided an estimate of 122 deer in DETO, with a coefficient of variation of 16%. Line-transect indices were too variable to determine monthly population estimates; however, they indicated that more deer used the park in the summer than in the spring.

Deer Browse

Merrill et al. (2003) monitored the effects of deer browse on native vegetation regimes in DETO from 1989 to 1996 and found that deer herbivory had little direct effect on the herbaceous understory because of the presence of graminoids. They also found no major shift in shrub

Photo 3. White-tailed deer in DETO (SMUMN GSS 2009).

composition, compared to less severely browsed woodland communities in the Black Hills. Browsing did reduce tree and tall-shrub regeneration, but once browsing ceased (by enclosure), these plants grew rapidly into taller shrub classes. If heavy browsing by deer continues, the shrub seed bank could be lost, leading to a shift in woodland community composition.

Threats and Stressor Factors

Chronic wasting disease (CWD) is an always-fatal, neurological disease that affects North American cervids, including white-tailed and mule deer. This disease is a transmissible spongiform encephalopathy (TSE) resulting from an accumulation of misfolded proteins called prions. Other TSEs include mad-cow disease in cattle and Cruetzfeldt-Jacobs disease in humans. Infected cervids experience many behavioral and anatomical changes, including altered social interaction, loss of fear, and progressive weight loss (USGS 2007). CWD exists in free-ranging populations of cervids in Crook County, Wyoming (CDC 2011).

Other stressors outside the park include hunting, habitat loss and modification, and road kill. How these stressors affect deer populations in DETO is unexplored.

Data Needs and Gaps

Merrill et al. (2003) performed a comprehensive deer browse study at DETO. Many deer exclosures from this study still exist, and repetition of the study would not be difficult (M. Biel pers. comm., 2010). The effects of climate change on vegetation regimes and the associated effects on deer browsing behavior is unexplored (M. Biel, pers. comm., 2010). Finally, habitat use and distribution of most species in the park is unknown; researching this would guide future deer management decisions.

Overall Condition

Deer populations in DETO appear to be normal; however, quantitative data that substantiate or refute this claim do not exist. Current nonscientific observations of deer populations within DETO and in the immediate area indicate that the population is stable. Numerous deer (mule and white-tailed) utilize DETO throughout the year with no apparent significant negative impacts to vegetation or deer populations (M. Biel, pers. comm., 2010). Based on these anecdotal observations and knowledge of these species, the populations are assumed to be stable and in no immediate danger of declining, absent CWD or other diseases (M. Biel, pers. comm., 2010).

Sources of Expertise

Mark Biel, DETO Chief of Resource Management

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4.7 Water Quality

Description

Water quality was selected as one of two high-priority Vital Signs by the NGPN (Gitzen et al. 2010). Likewise, park managers consider water quality a key resource component in DETO. Dissolved oxygen (DO), fecal coliform, pH, specific conductance, water temperature, and an estimate of flow are core water-quality parameters required by the NPS Water Resource Division for long-term monitoring in NGPN parks (NPS 2002). In addition, the level of fecal coliform in the Belle Fourche River is of concern since Wyoming has listed the section of the Belle Fourche River from the confluence with Arch Creek to Hulett as impaired under section 303(d) of the Clean Water Act for fecal coliform (WYDEQ 2010). The Belle Fourche River flows through or forms the border of DETO for approximately 3.78 km (2.35 mi).

Dissolved oxygen is critical for aquatic organisms because fish and zooplankton filter out or "breathe" DO from the water to survive (EPA 2010c; USGS 2010a). Oxygen enters water from the atmosphere or through ground water discharge, and as the amount of DO decreases it becomes more difficult for aquatic organisms to survive (USGS 2010a). The concentration of DO in a water body is closely related to water temperature; cold water holds more DO than does warm water, which creates seasonal fluctuations as lower temperatures in winter and spring hold more oxygen and warmer temperatures in summer and fall hold less (USGS 2010a).

Fecal coliform is measured to assess the level of fecal contamination in water from homeothermic (warm-blooded) animals (USGS 2009). The presence of fecal coliform bacteria colonies can suggest that other pathogenic (disease-causing) bacteria, viruses, and protozoans that live in human and animal digestive systems may also be present in the waterway, which could present a significant health risk for swimming or eating fish and shellfish from the affected waters (EPA 2011).

Acidity or alkalinity of water and is measured on a pH scale from 0 to 14, with 7 being neutral. Water with a pH of less than 7.0 indicates acidity; a pH greater than 7.0 indicates alkalinity. Chemicals in water can change the pH and harm aquatic animals and plants; thus, monitoring pH is useful for detecting natural and human-caused changes in water chemistry (USGS 2010a).

Specific conductance measures the ability of water to conduct electrical current, which depends largely on the amount of dissolved solids in the water. Specific conductance is low in water with low amounts of dissolved solids (such as purified or distilled water) and high in water with high amounts of dissolved solids (such as sea water) (USGS 2010a). 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 2010a).

Water temperature greatly influences water chemistry and aquatic organisms. Not only can it affect the ability of water to hold oxygen, water temperature also affects biological activity and growth within water systems (USGS 2010a). All aquatic organisms have a preferred temperature range for existence. As temperatures increase or decrease past this range, the population declines. In addition, higher temperatures allow some compounds or pollutants to dissolve more easily in water and become toxic to aquatic life (USGS 2010a).

Turbidity assesses the amount of fine particulate matter, such as clay, silt, or microscopic organisms, suspended in water by measuring the scattering effect that solids have on light that passes through water (USGS 2010a). The more light is scattered, the higher the turbidity measurement will be. Suspended materials can absorb heat from sunlight and thus increase water temperature, decrease photosynthesis and thus decrease DO concentrations in the water, and clog the gill structures of fish and amphibians, making it difficult to thrive (USGS 2010a).

Measures

- Dissolved oxygen
- Fecal coliform
- pH
- Specific conductance
- Water temperature
- Turbidity

Reference Conditions and Values

The reference condition set for water quality in DETO follows the EPA water quality criteria for surface waters deemed safe for freshwater aquatic life and freshwater bathing, and the NPS Water Resources Division (WRD) water quality screening criteria for safe freshwater bathing and aquatic life (NPS 1997). These benchmarks were specific to DO, fecal coliform bacteria, pH, and turbidity; no standards were in place for specific conductance. The Wyoming Department of Environmental Quality (WYDEQ) water quality criteria were also used when evaluating existing data for DETO (WYDEQ 2011). The water quality standards for each measure are as follows:

- DO: WRD criterion = ≥4 mg/L.
- Fecal Coliform, in Colony Forming Units (CFU): WRD criterion = 200 CFU/100 mL; WYDEQ criterion = 126 CFU/100 mL for primary contact (recreation in summer months) and 630 CFU/100 mL secondary contact (recreation in winter months)
- pH: EPA and WYDEQ criterion = between 6.5 and 9.0
- Specific Conductance: no standards in place
- Water Temperature: WYDEQ criterion = <30 °C
- Turbidity: WRD criterion = 50 NTU; WYDEQ criterion = <15 NTU increase from background due to human influence

Data and Methods

In 1997, NPS published the results of surface-water quality data retrievals for DETO 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). The retrieval resulted in 5,669 observations for various parameters at two monitoring stations (one operated by USGS, the other operated by WYDEQ) from 1967 to 1992 (NPS 1997). Both stations were at the same location on the Belle Fourche River within the park boundary (NPS 1997). No data have been collected at these monitoring sites since 1992 (USGS 2010b).

A number of water quality parameters were sampled in the Belle Fourche River at DETO as part of an aquatic resource study conducted in 2004–2005. Rust (2006) collected water quality samples along one reach of the Belle Fourche River (Plate 24) and at three springs in June 2004, July 2004, and June 2005.

NGPN conducted a pilot project at DETO in 2009 from the first part of May through the third week in October. Network staff deployed a multiparameter sonde that recorded water temperature, DO, pH, and specific conductance data continuously at 15 minute intervals. The raw data have not yet been corrected.

Current Condition and Trend

Dissolved Oxygen

The EPA considers DO levels ≥4 mg/L to be protective of freshwater aquatic life. The NPS Baseline Water Quality Inventory and Analysis (NPS 1997) summarized all DO measurements obtained from the USGS monitoring site within DETO. In total, 36 observations were made from 1973 to 1981. During this sampling period, DO levels on the Belle Fourche River in DETO ranged from 6.8 to 12.0 mg/L (NPS 1997). The mean and median DO levels during this time were 9.28 and 9.30 mg/L, respectively. These observations are not below the EPA minimum level protective of freshwater aquatic life.

DO levels were assessed by Rust (2006) from 2004 to 2005. Thirty samples were obtained for the 10 transects along the Belle Fourche River (EPA 2010a). During this sampling, DO levels ranged from 8.4 to 14.3 mg/L. The mean and median DO levels during this time were 11.4 and 11.1 mg/L respectively. These measurements are well within EPA criterion for protection of freshwater aquatic life.

Rust (2006) also included DO measurements for three natural springs in DETO (see Plate 24 for location of springs). Each spring was sampled at least three times (June and July 2004 and June 2005) with the exception of the northernmost spring, which was sampled twice (July 2004 and June 2005) (EPA 2010a). The northernmost spring had DO levels of 10.0 mg/L in July 2004 and 6.2 mg/L in June 2005. The spring along Red Beds Trail just south of the DETO visitors center had DO levels of 10.7 and 8.8 mg/L for June and July 2004 respectively, and a DO level of 10.1 in June 2005. The westernmost spring, just west of Highway 110 near the DETO western boundary, had substantially lower DO levels: 6.9 mg/L (June 2004), 5.4 mg/L (July 2004), and 6.4 mg/L (June 2005). Despite lower DO levels in the westernmost spring, DO levels for all three natural springs are within the EPA criterion for protection of freshwater aquatic life.

Fecal Coliform

As of 2010, the stretch of the Belle Fourche River between Arch Creek and Hulett, Wyoming is listed as 303(d) impaired for fecal coliform for the stretch of river flowing along the eastern boundary of DETO (WDEQ 2010, EPA 2010b).

Fecal coliform concentrations were measured 28 times at the USGS monitoring site in DETO from 1973 to 1976 (NPS 1997). Concentrations were 1 to 700 CFU/100 mL; mean and median concentrations were 76.3 and 41.0 CFU, respectively (NPS 1997). Of the 28 observations, two were found to exceed the WRD screening criteria (200 CFU/100 mL) for safe bathing water at 400 and 700 CFU/100 mL in July and August 1974, respectively (NPS 1997). These measurements also exceed the Wyoming State water quality criterion of 126 CFU/100 mL for primary contact (recreation in summer months).

Rust (2006) recorded three fecal coliform concentrations in the Belle Fourche River in 2004 and 2005. Two of these samples exceeded the WRD screening criteria and WYDEQ criteria for safe bathing at 810 CFU in June 2004 and 400 CFU in July 2004 (EPA 2010a).

Rust (2006) also included measurements for three springs in DETO. Springs were sampled seven times for fecal coliform during the study period. Both the northernmost spring and the spring along Red Beds Trail just south of the DETO visitor center had fecal coliform concentrations of 60 CFU (EPA 2010a). The westernmost spring, just west of Hwy 110 near the DETO western boundary, had a fecal coliform concentration of 140 CFU (EPA 2010a). All springs are within the WRD screening criteria for fecal coliform contamination for safe bathing. The westernmost spring, however, exceeded the WYDEQ criteria for primary contact in summer months.

<u>pH</u>

The EPA criterion for pH that supports freshwater aquatic life and sustains wildlife is between 6.5 and 9.0 standard units (EPA 2002). From 1967 to 1981, 135 pH measurements were taken from Belle Fourche River and ranged from 6.8 to 8.5, with a mean and median of 7.95 and 8.0, respectively (NPS 1997). All measurements fell within the EPA and WYDEQ criteria range for protection of aquatic life.

Rust (2006) also collected pH measurements along the Belle Fourche River and three springs from 2004 to 2005. Three samples taken at each of 10 transects along the river had pH levels ranging from 8.4 to 9.4 (EPA 2010a), with mean and median 8.8 and 8.6, respectively (EPA 2010a). All samples collected in June 2005 exceeded the EPA criteria (from 9.1 to 9.4); however, because so few samples were collected during a short time period, conclusions cannot be made regarding potential pH impairment.

The NGPN pilot study listed pH values from 7.9 to 8.5 from May through October of 2009. These values were collected every 15 minutes for a total of 15,895 data points (M. Wilson, pers. comm., 2010).

<u>Specific Conductance</u>

Specific conductance was measured 142 times at the USGS monitoring site in DETO from 1967 to 1981 (NPS 1997). Measurements ranged from 184 to 2400 µS/cm, with a mean and median of 1476 and 1500 µS/cm respectively (NPS 1997). The mean and median measurements indicate an elevated level of dissolved solids in the Belle Fourche River.

Rust (2006) measured specific conductance from three samples taken at each of the 10 transects along the river. Measurements ranged from 1632 to 1861 µS/cm, with a mean and median of 1719.4 and 1709.5 µS/cm, respectively (EPA 2010a). Specific conductance measurements were also taken at each natural spring on three different dates (June and July 2004, June 2005) with the exception of the northernmost spring, which was sampled twice (July 2004 and June 2005).

Specific conductance at the northernmost spring measured 1217 µS/cm in 2004 and 1204 µS/cm in 2005 (EPA 2010a). Specific conductance at the spring along Red Beds Trail south of the DETO visitor center ranged from 175 to 242 µS/cm, indicating low levels of dissolved solids (EPA 2010a). Measurements at the spring west of Hwy 110 near the western boundary of DETO ranged from 2803 to 2926 µS/cm (EPA 2010a).

The NGPN pilot study listed specific conductance values from 1127 uS/cm to 2013 uS/cm from May through October 2009. These values were collected every 15 minutes for a total of 15,895 data points (M. Wilson, pers. comm., 2010).

Temperature

There were 212 temperature records on the river from 1967 to 1992 (NPS 1997). Temperature measurements ranged from 0 °C (due to some sampling occurring in winter months) to 29 °C (NPS 1997).

Rust (2006) collected temperature measurements at 10 transects in one reach on the Belle Fourche River and from three natural springs in DETO from 2004 to 2005. During this sampling, temperature measurements ranged from 12.9 to 28.7 °C with mean and median temperatures of 23.8 and 24.2 °C respectively (EPA 2010a). Temperature trends on Belle Fourche River are difficult to determine because measurements from 1967 to 1992 were collected throughout the four seasons, while data collected by Rust (2006) were sampled exclusively in the summer months; thus, a comparison of data from these studies would be inappropriate. Temperature measurements were also taken at each natural spring on three different dates (June and July 2004, June 2005) with the exception of the northernmost spring, which was sampled twice (July 2004 and June 2005). Temperature at the northernmost spring measured 8.9 °C in 2004 and 14.7 °C in 2005. Temperature at the spring along Red Beds Trail south of the DETO visitor center ranged from 10.1 to 11.9 °C, and at the spring west of Hwy 110 near the western boundary of DETO from 7.2 to 8.5 °C (EPA 2010a).

The Network pilot study listed specific conductance values that ranged from 0 °C in October 2009 to 28.8 °C in mid-July. These values were collected every 15 minutes for a total of 15,895 data points (M. Wilson, pers. comm., 2010).

Turbidity

From 1973 to 1982, 74 turbidity observations were collected at the USGS monitoring site in DETO (NPS 1997), ranging from 1 to 350 Nephelometric Turbidity Units (NTU), with a mean and median of 32 and 10 NTU respectively (NPS 1997). Eight of the observations during this time period were found to exceed the WRD screening criteria for protection of freshwater aquatic life (WRD criteria = 50 NTU) (NPS 1997).

Turbidity measurements were also collected by Rust (2006) in 2004 and 2005. All three samples were <3 NTU (EPA 2010a), suggesting that the Belle Fourche River is relatively clear. Nevertheless, in a 2002 fish inventory of the stretch of the Belle Fourche River within DETO, researchers found the turbidity of the water to be too high for electrofishing equipment to be effective (White et al. 2002); however, no water samples were collected in this study to quantify this observation. Fluctuations in turbidity may be common due to rain and weather events or increases in activities (agriculture or recreation) that add solid materials to the water along the upper reaches of a watercourse. Without consistent monitoring of water quality parameters, assessing trends in turbidity throughout a single year, as well as over the course of many years, is difficult.

Rust (2006) also collected turbidity measurements at each spring in June and July 2004, June 2005. Turbidity at the northernmost spring measured 13.3 and 3.3 NTU. Turbidity at the spring along Red Beds Trail south of the DETO visitor center ranged from 14.6 to 18.7 NTU, and measurements at the spring west of Hwy 110 near the western boundary of DETO were 1.15 to 5.05 NTU (EPA 2010a).

Threats and Stressor Factors

Cattle can negatively affect streams by altering sedimentation regimes, morphology, temperature, stability, and nutrient loads, which can lead to eutrophication (Hoorman and McCutcheon 2010). Numerous livestock ranches operate on private lands surrounding DETO. A number of these ranches have direct access to the Belle Fourche River, and livestock are commonly viewed in the river or grazing along the riverbank (M. Biel, pers. comm., 2010). This practice not only encourages riverbank erosion, which introduces suspended solids into the water (which can increase turbidity), but it also increases the probability of water contamination by fecal coliform (*Escherichia coli*) bacteria.

Mineral development in the region may also affect water quality (NPS 1997). Several active energy and mineral mining operations, as well as two active coal-fired power plants, are located to the south and southwest of DETO near the upper reaches of the Belle Fourche River. The close proximity of the operations to the Belle Fourche River increases the probability that water runoff containing heavy metals and atmospheric deposition of air pollutants can enter the river and adversely impact water quality. In addition, acreage around the park (but not adjacent) being explored for uranium mining has increased substantially. The in-situ method of drilling is the proposed method of extraction, which raises significant concerns over groundwater contamination for many landowners in the region (M. Biel, pers. comm., 2010).

The Keyhole Dam is located on the Belle Fourche River approximately 17 mi upriver from DETO (NPS 1997; WYDEQ 2010). Construction of the 168-foot earthen dam began in 1950 and was completed in 1952; impoundment of water began shortly after (Bureau of Reclamation 2010). Summer water releases from the Keyhole Dam influence stream flows in the Belle Fourche River within DETO (NPS 1997). Anecdotal observations indicate the dam has changed the characteristics of the river from a cold, clear, and fast-moving waterway into a warm, sluggish waterway with considerably higher turbidity and elevated levels of suspended solids (M. Biel, pers. comm., 2010).

Photo 4. Cattle grazing in and around the Belle Fourche River, just upstream of DETO.

Data Needs and Gaps

Long-term monitoring of specific conductance, DO, pH, temperature, and flow/discharge is needed to determine trends in water quality. In 2012, NGPN will initiate long-term water quality monitoring protocol of the Belle Fourche River. Core water quality parameters will be monitored initially and fecal coliform may be examined in the future (M. Wilson, pers. comm., 2010). These data will allow future detection of trends and determine if park water quality adheres to EPA criteria considered safe and healthy for aquatic life and human health. The most recent data included in the NPS (1997) study are nearly 20 years old.

The presence and composition of macroinvertebrate species in waterways can be useful in determining water quality and the overall health of water bodies (USGS 2011). To date, only one survey was conducted of the benthic macroinvertebrate community in the section of the Belle Fourche River that runs through DETO (Rust 2006). Recently, a researcher with the WYNDD received funding from the NGPN to conduct a second macroinvertebrate survey at DETO in 2011.

Overall Condition

A few considerations should be made in examining these data. First, most data used in this assessment are more than 20 years old, and more recent information (in addition to the small number of 2004–2005 samples) would better assess water quality parameters. Second, the water samples collected at the USGS monitoring location were obtained at various times during each year, including every season, but water samples collected by Rust (2006) in 2004–2005 were obtained in summer. Water quality parameters can vary with seasonal changes, making it difficult and inappropriate to compare the NGPN results with the USGS results to determine any definitive trends for the different water quality parameters.

Assigning a definitive condition is difficult due to the inconsistencies in sampling methods for the data, inability to directly compare datasets to uncover trends in water quality, and discrepancies among results for certain water quality parameters from different datasets. A strict protocol and establishment of a long-term monitoring program would greatly benefit the assessment of water quality condition and trends in the future. Although assigning a condition is difficult, water quality in DETO elicits some level of concern based on the excess of fecal coliform in the stretch of the Belle Fourche River that borders DETO. The lack of consistent monitoring prevents managers from understanding if certain water quality parameters have become compromised and warrant additional concern. Because of this, and based on the historical and recent data available, the overall condition for water quality at DETO is of moderate concern.

Sources of Expertise
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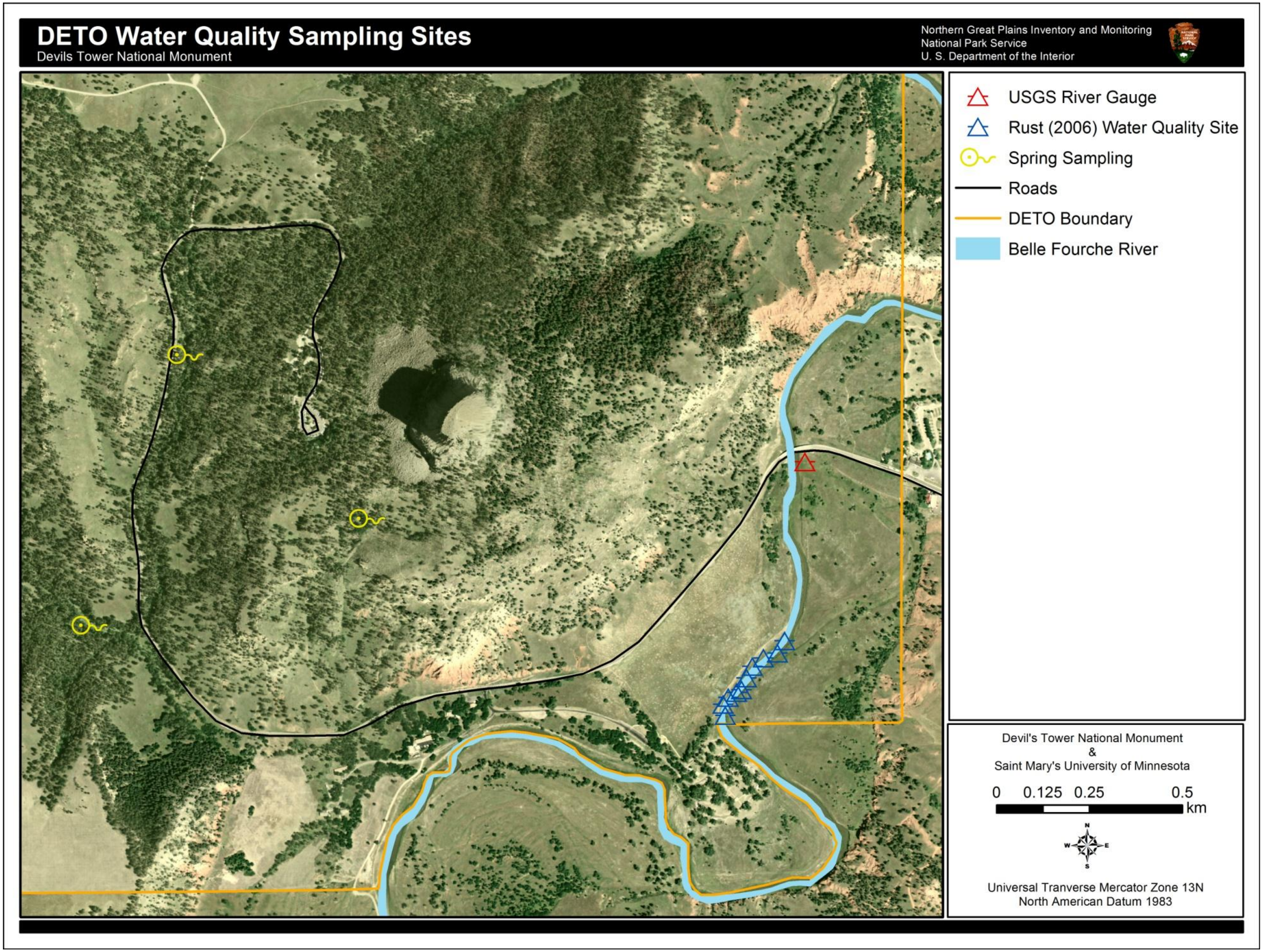

Plate 24. Water quality sampling sites in DETO, in Rust (2006).

4.8 Air Quality

Description

Air pollution can significantly affect natural resources and their associated ecological processes. In particular, air pollution can influence water quality and soil pH, compromise plant health and distribution, accelerate the decay of geologic or cultural features, and impair visibility and air quality within parks (NPS 2007a). 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 its subsequent amendments (NPS 2006). The prevention of significant deterioration (PSD) title of the CAA outlines specific authority in protecting the natural and cultural resources of parks (EPA 2008). This title defines two distinct categories of protection for natural areas, Class I and Class II air sheds, which classified all lands managed by the Department of Interior in 1977. Class I air sheds, which receive the highest level of air quality protection as offered through the CAA, permit only a small amount of additional air pollution in the air shed above baseline levels. For Class II air sheds, the increment ceilings for additional air pollution above baseline levels are slightly greater than for Class I areas and allows for moderate development (EPA 2008). However, new and modified sources of air pollution must be analyzed for potential impacts to ambient air quality and visibility prior to development. Parks designated as Class I and II air sheds typically use the EPA National Ambient Air Quality Standards (NAAQS) for criteria air pollutants as the ceiling standards for allowable levels of air pollution. EPA believes that these standards, if not exceeded, protect human health and the health of natural resources (EPA 2008). The CAA also establishes that current visibility impairment in these areas must be remedied and future impairment prevented (EPA 2008). However, EPA acknowledges that the NAAQS are not necessarily protective of ecosystems and is currently developing secondary NAAQS for ozone and nitrogen and sulfur compounds to protect sensitive plants, lakes, streams, and soils (EPA 2010a, 2010b). To comply with CAA mandates, the NPS established a monitoring program that measures air quality trends in park units for key air quality indicators, including atmospheric deposition, which affects ecological health through acidification and fertilization; ozone, which affects native plant communities and human health; and visibility, which affects how well and how far visitors can see park landscapes (NPS 2009b).

The CAA designates DETO as a Class II air shed. The DETO General Management Plan (NPS 2001) states that meeting NAAQS is a priority and that no DETO activities will contribute to deterioration in air quality.

Although located in a rural part of northwest Wyoming, DETO air quality is threatened by several sources of air pollution, including oil and gas development in northwest Wyoming; smoke from wood and pellet stoves, campfires, wildland fires and prescribed burning; visitor and NPS vehicle emissions; and nearby operations and development of coal-fired power plants (Peterson et al. 1998; NPS 2001). Air pollutants of particular concern to managers at DETO include wet deposition of sulfur (S), nitrogen (N) and ammonium (NH_4^+) compounds, as well as concentration of ground-level ozone (O_3); and deposition of mercury (Hg) and concentration of suspended particulate matter ($PM_{2.5}$ and PM_{10}).

Measures

Criteria pollutants consistent with the maintenance of Class I air sheds are deposition of Hg and N, sulfur ammonium (NH_4^+) compounds, concentrations of ground-level O_3; and $PM_{2.5}$ and PM_{10}. Visibility across the park is measured in terms of Haze Index (deciviews [dv]).

Atmospheric Deposition

Atmospheric deposition of S and N can have significant effects on ecosystems through altered water quality, soils, and vegetation (NPS 2005). Emissions form compounds that acidify water and soil systems with low buffering capacities, and excess N deposition, which acts as a fertilizer and can disrupt nutrient cycling and influence plant species composition (NPS 2005). The species diversity in grassland ecosystems is particularly vulnerable to excess N deposition because native plants adapted to N-poor conditions are displaced by species that prefer high levels of N (typically nonnative grasses and other exotics) (NPS 2005; Pohlman and Maniero 2005). Over time, this shift in nutrients can result in ecosystem-wide changes, including shifts in species composition (both plants and animals), increased occurrence or likelihood of insect and disease outbreaks, and disruption of natural fire regimes (NPS 2007a).

Mercury Deposition

Mercury is a naturally occurring element in the environment, typically associated with different types of rock including coal, that can easily make its way into the air, water and soil. For instance, when coal is burned, Hg is one by-product released into the air (EPA 2010e). The burning of sulfur-containing coal in coal-fired power plants accounts for 50% of the anthropogenic Hg emissions in the atmosphere in the United States (EPA 2010e). Airborne Hg eventually falls back to the ground with raindrops or dust (deposition) and settles into water bodies or onto land where it washes into water (EPA 2010e).

Mercury in aquatic systems is a particular concern. Microorganisms digest and transform it into methylmercury, an organic Hg compound that can be highly toxic in organisms at the top of the aquatic food web (e.g., fish and birds that eat fish or aquatic insects) (NPS 2010d; EPA 2010e). Similarly, predators that eat fish-eating animals are also at risk. Fish and shellfish consumption is the main pathway for human and wildlife exposure to methylmercury (EPA 2010e). Effects of methylmercury exposure on both wildlife and humans can include reduced reproductive success, impaired growth and development (especially in the brain), behavioral abnormalities, reduced immune response, and death (EPA 2010e; NPS 2010d). Other sources of Hg in the atmosphere include utility and industrial boilers, smelting, chloralkali plants, gold extraction, fungicides containing Hg in latex paints, and the paper and pulp industry (NPS 2010d).

Ozone (O_3)

Ozone occurs naturally throughout the earth's atmosphere. In the upper atmosphere, it protects the earth's surface against ultraviolet radiation (NPS 2005). However, it also occurs at the ground level (i.e., ground-level O^3) where, at high concentration, it is harmful to plants and human health (NPS 2005). Ground-level O_3 is created by a chemical reaction between nitrogen oxides (NO_x) and volatile organic compounds (VOCs) in the presence of heat and sunlight. Major sources of ozone-forming chemicals include motor vehicle exhaust and industrial emissions, gasoline vapors, and chemical solvents (NPS 2005; Pohlman and Maniero 2005). Breathing air containing O_3 can aggravate asthma, reduce lung function, inflame lung tissue, cause acute respiratory problems, or impair the body's immune system (NPS 2005). At high concentrations, O_3 has been linked to increased susceptibility to respiratory infections in humans (EPA 2010c). This would be of particular concern for anyone engaging in strenuous aerobic activity, such as hiking in natural areas (Pohlman and Maniero 2005, EPA 2010c). Ozone is also one of the most widespread pollutants affecting vegetation in the United States. (NPS 2005). Research has indicated that some plant species are more sensitive to O_3 than humans, with some species sustaining effects or injury at concentrations that are well below the current EPA standard (NPS 2005; Pohlman and Maniero 2005). Long-term exposures can result in increased vulnerability to insects and diseases and shifts in species composition (NPS 2005).

<u>Particulate Matter (PM) and Visibility:</u>
Particulate matter is a complex mixture of extremely small particles and liquid droplets that become suspended in the atmosphere. It is made up of a number of components including nitrates and sulfates, organic chemicals, metals, and soil or dust particles (EPA 2009a). The EPA groups particle pollution into two categories: fine particles ($PM_{2.5}$), which are 2.5 µm in diameter or smaller; and inhalable coarse particles (PM_{10}), which are smaller than 10 µm (the width of a single human hair) (EPA 2009a). The size of particles is directly linked to their potential for causing human health and landscape visibility problems. PM_{10} and $PM_{2.5}$ are a concern to human health because they can easily pass through the throat and nose and enter the lungs (EPA 2009a, 2010d). Short-term exposure to these particles can cause shortness of breath, fatigue, and lung irritation, while long-term exposure can cause more serious health effects, including heart and lung diseases (EPS 2009a).

Fine particles are also the major cause of reduced visibility (haze) in many parts of the United States, including many national parks and wildernesses (EPA 2010d). $PM_{2.5}$ can be directly emitted from sources such as forest fires or they can form when gases emitted from power plants, industry and/or vehicles react in the atmosphere (EPA 2009a, 2010d). Sources of PM_{10} include grinding or crushing operations and windblown or stirred-up dust from dirt surfaces (e.g., roads, agricultural fields). These particles either absorb or scatter 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).

Reference Conditions and Values
Park resource managers have indicated EPA standards and ecosystem thresholds to be the reference condition for air quality in DETO. The NPS Air Resources Division (ARD) has developed an approach for rating air quality conditions in national parks based on the current NAAQS, ecosystem thresholds, and visibility improvement goals (Table 20) (NPS 2010a). Assessment of current condition of atmospheric deposition of N and S compounds are based on wet deposition, primarily because many parks do not collect dry deposition data. The O_3 standard established by the EPA, which was revised in 2008 to be more protective of human health, is used as the benchmark for rating current O^3 condition in parks. Visibility conditions are rated 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 µg/m^3 over a 24-hour period; this level may not be exceeded more than once per year on average over 3 years (EPA 2010d). The standard for $PM_{2.5}$ is 15.0 µg/m^3 weighted annual mean, or 35 µg/m^3 in a 24-hour period over an average of 3 years (EPA 2010d). There are no EPA standards for deposition of Hg, only emissions of Hg into the atmosphere; thus, Hg deposition in DETO is reported here but not compared to a national standard.

Table 20. NPS Air Resource Division air quality index values (NPS 2010a).

Condition	Ozone concentration (ppb)	Wet Deposition of N or S (kg/ha/yr)	Current Group 50 – Estimated Group 50 Natural (dv)
Significant Concern	≥76	>3	>8
Moderate	61–75	1–3	2–8
Good	≤60	<1	<2

Data and Methods

Many sources may be used to access air quality data specific to parks and natural areas in the United States. The Clean Air Status and Trends Network (CASTNet) database was searched for summary charts of S and N deposition for DETO. The National Atmospheric Deposition Program–National Trends Network (NADP-NTN) database was searched for summary concentration and deposition maps of sulfate, nitrate, ammonium, and deposition maps of total inorganic N from nitrate and ammonium beginning in 1985. The Interagency Monitoring of Protected Visual Environments (IMPROVE) database was searched for summary concentrations of fine particulate matter in DETO. The NPS Explore Air website was used to obtain park specific summaries of the most current (2004–2008) interpolated air quality data for DETO as well as tables of air quality estimates for 1999–2003. None of the datasets were adjusted or processed in any way.

Current Condition and Trend

The NGPN, which includes DETO, carefully monitors air quality. The CASTNet and NGPN networks monitor O_3, dry deposition, and other meteorological parameters, while NADP-NTN monitors wet deposition of sulfates, nitrates, ammonium, and a number of cations and anions, including calcium (Ca^{2+}), chloride (Cl), magnesium (Mg^{2+}), potassium (K^+), and sodium (Na^+). A portable O_3 analyzer has been operational at DETO since 2007 (NPS 2009c). Prior to 2007, the nearest O_3 monitor to DETO was located at Thunder Basin National Grassland (64 km, [40 mi] west of DETO) (Pohlman and Maniero 2005). Visibility within the NGPN is monitored through IMPROVE, with the closest visibility monitoring station to DETO located in Thunder Basin National Grassland. Sulfur dioxide (SO_2) and PM are not measured by stations within the park (NPS 2009c). Until 2009, the nearest Hg deposition monitor to DETO was located at Yellowstone National Park in Wyoming (approximately 630 km [400 mi] southeast of DETO), and had collected Hg deposition data since 2005. However, in cooperation with the South Dakota School of Mines and Technology, an Hg deposition sampling station was installed on-site in DETO and has been collecting monthly samples for Hg analysis since 2009.

<u>Atmospheric Deposition</u>

In an assessment of air pollutant data from 1984–1995 that included a number of parks located in the Northern Great Plains, Peterson et al. (1998) found that overall deposition of hydrogen ions was low, indicating that acidity of wet deposition is not of great concern in the region. The authors did not examine deposition data specific to DETO but did examine deposition for parks in relatively close proximity to DETO (Wind Cave National Park, 200 km [125 mi] southeast of DETO). Based on the most current data at the time, the authors determined that there was no apparent threat to the natural resources at WICA from acid deposition.

Estimates of the condition of most air quality parameters use 5-year averages to offset annual variations in meteorological conditions, such as heavy precipitation during one year versus drought conditions in another. The most recent 5-year average for air quality parameter estimates (2004–2008) show total wet deposition of N in DETO to be 2.3 kg/ha/yr, while total wet deposition of S was 1.0 kg/ha/yr. Relative to the NPS ratings for air quality conditions (Table 20), the amount of atmospheric N deposition in DETO falls in the middle of the range for the *Moderate Concern* category, and the amount of S deposition is on the dividing line between the *Moderate Concern* and *Good* categories. However, several factors are considered when rating deposition condition, including natural background deposition estimates and effects of deposition on different ecosystems (NPS 2010a). The estimate for natural background wet deposition in the West is roughly equivalent to 0.13 kg/ha/yr each for N and S (NPS 2010a), which means a small amount of deposition is always present regardless of air quality in the region. Nevertheless, based on the NPS process for rating air quality conditions in parks, scores for parks with ecosystems potentially sensitive to N or S deposition are typically adjusted up one condition category. In general, native grasslands can be sensitive to increased levels of N and S because these shifts in nutrients can cause shifts in species composition (Peterson et al. 1998; Pohlman and Maniero 2005). DETO supports a small amount of native grassland ecosystem, which may be at risk from excess N deposition in particular; thus, the condition for deposition of N in DETO may be considered to be of *Significant Concern*. Because the wet deposition amount for S is just below the division between *Good* and *Moderate Concern*, the condition for total S deposition likely remains classified as *Moderate Concern*.

The NPS has guidelines for rating the air quality parameters of most concern to ecosystems, including wet deposition of N and S, O_3 concentration, and visibility. The average yearly deposition data specific to DETO from 2004–2008 for sulfate, nitrate, and ammonium (Table 21) show that, when deposited in large quantities, might affect ecosystems. Trends in deposition for each compound from 2004–2008 (Figure 9) show that deposition has been fluctuating across the time period, with substantial decreases in concentrations for most compounds in 2006, followed by slight increases in concentration in 2007 and 2008.

Table 21. Annual summary of air quality deposition for DETO, 2004–2008 (NADP-NTN 2010).

	Average Annual Deposition (kg/ha/yr)				
Ambient Measure	**2004**	**2005**	**2006**	**2007**	**2008**
Ammonium (NH_4^+)	1.18	1.56	1.076	1.668	1.74
Nitrate (NO^{3-})	3.71	4.38	3.073	3.984	4.40
Sulfate (SO_4^{2-})	2.30	2.92	2.049	2.833	3.00

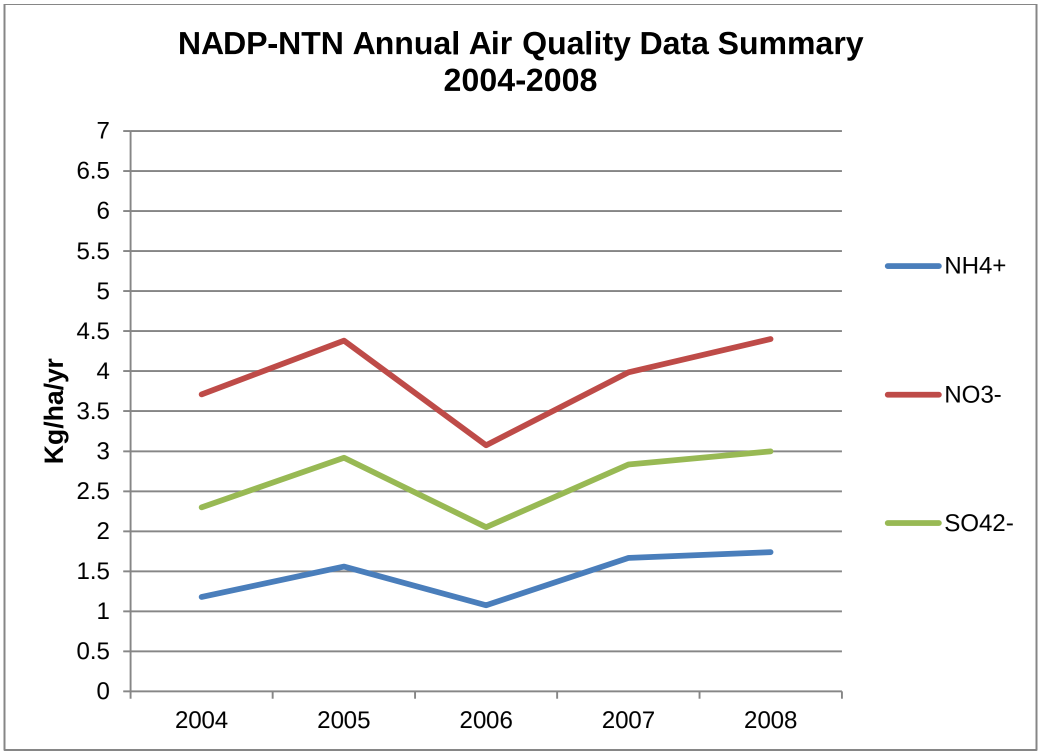

Figure 9. Trends in air quality deposition for DETO, 2004–2008 (Source: NADP-NTN 2010).

Mercury Deposition

The most recent Hg deposition data for monitoring sites across the United States (Figure 10) show that, until 2009, the nearest Hg monitoring site to DETO was located at Yellowstone National Park in the northwestern corner of Wyoming. For locations without Hg monitoring stations, deposition was interpolated from the nearest sites in areas with sufficient numbers of samplers. The most current data from the Yellowstone monitoring site (2008) suggest that Hg deposition is quite low relative to other parts of the United States (from 4–6 µg/m^2 to <4 µg/m^2). Likewise, trend data from this monitoring site indicate Hg deposition has been decreasing steadily in northern Wyoming from 2005 to present (NADP-MDN 2009). Results from data collected during 2009 from the on-site Hg sampling station in DETO are not yet available; however, preliminary analysis suggests that Hg deposition in the park falls within a range that park managers consider to be acceptable (<6 µg/m^2) (M. Biel, pers. comm., 2010).

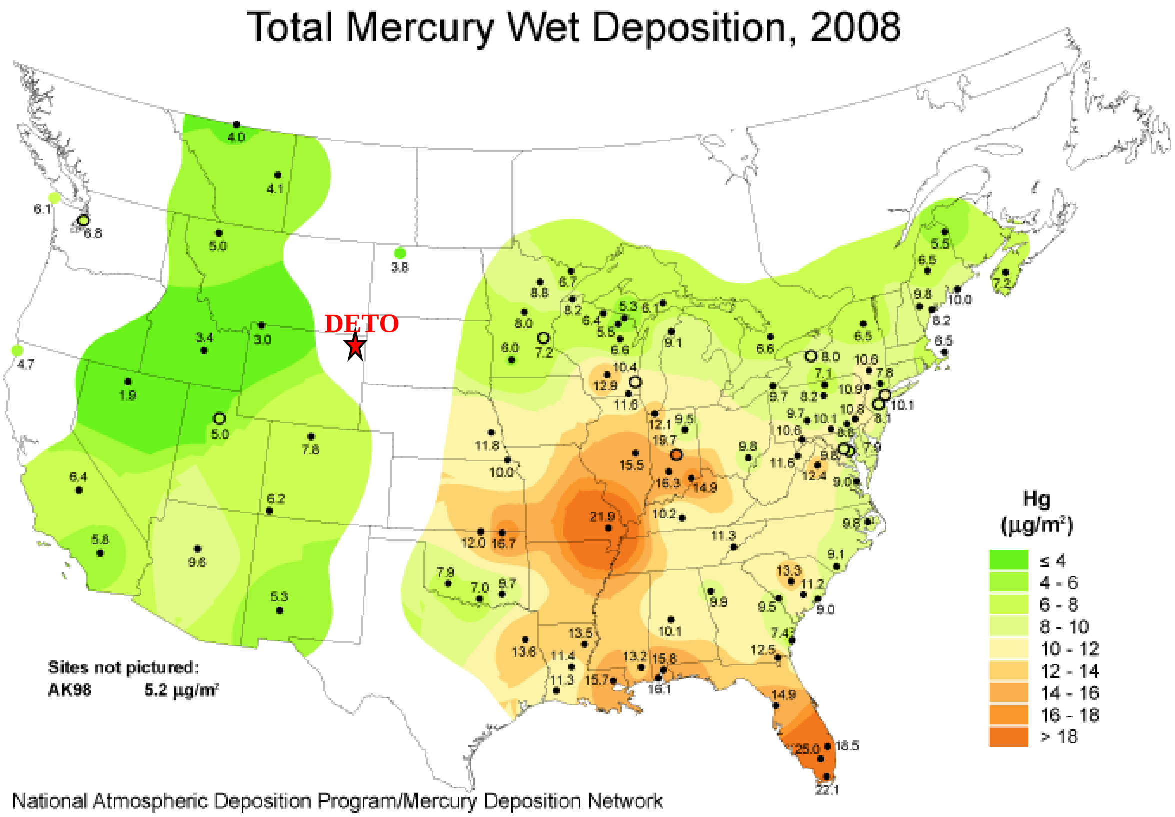

Figure 10. Total mercury deposition near DETO, 2008 (Source: NADP-MDN 2009). Red star indicates location of DETO.

<u>Ground-level Ozone</u>

Data for ground-level O_3 concentrations have been recorded in DETO since 2007. Prior to 2007, O_3 concentrations were recorded at Thunder Basin National Grassland in Campbell County, Wyoming (64 km [40 mi] west of DETO), and values were extrapolated to the park. NPS air quality condition assessment protocol uses the NAAQS for ground-level O_3 as the benchmark for rating current O_3 conditions within park units because it is a standard believed to be protective of human health. Current conditions of O_3 concentrations in NPS park units are determined by calculating the 5-year average of the fourth-highest daily maximum of 8-hour average O_3 concentrations measured at each monitor within an area over each year (NPS 2010a). From 1999–2003, the 5-year average for O_3 concentration in DETO was 69.7 ppb (NPS 2010b), and from 2003–2008, the 5-year average was 64.9 ppb (NPS 2010c). Both concentrations fall under the *Moderate Concern* category for current O_3 condition based on the NPS guidelines. The most current measurements from 2008 indicate the ground-level O_3 concentration in DETO is 62.0 ppb (NPS 2009c). These data indicate that O_3 concentrations in DETO are declining slightly, suggesting improved air quality in respect to O_3 (Figure 11).

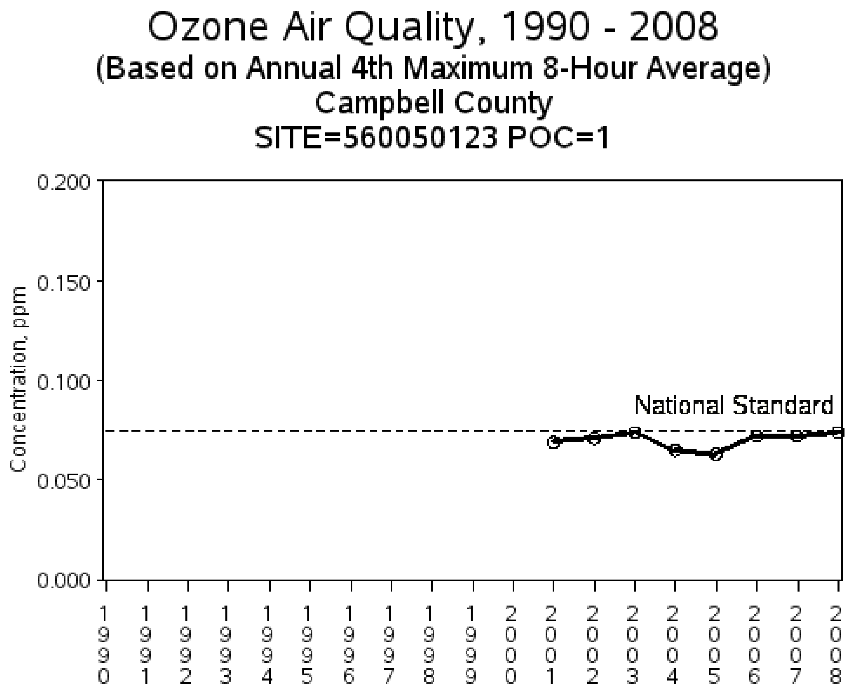

Figure 11. Average ozone (O_3) air quality for DETO, 2001–2008 (Source: EPA 2009c). Note: Site 560050123 is the monitor located at Thunder Basin National Grassland; O_3 data collection in DETO did not begin until 2007.

Pohlman and Maniero (2005) completed an air quality monitoring considerations assessment of national park units for the NGPN. Part of this assessment focused on O_3 concentrations in parks and the risk of injury to plant species sensitive to sustained O_3 exposure. Analyzing O_3 data from 1995–1999, they found that O_3 concentrations in DETO frequently exceeded 60–80 ppb for a few hours each year and sometimes, although rarely, exceeded 100 ppb. Sensitive plant species begin to experience foliar injury when exposed to O_3 concentrations of 80–120 ppb/hr for extended periods of time (8 hours or more) (Pohlman and Maniero 2005). The authors determined periodic peaks in concentration to be intermittent and the levels not likely to injure vegetation in DETO. However, if O_3 concentrations should increase in the future, the authors suggested an on-site monitoring program to assess foliar injury and growth progress would likely be necessary. Currently, no monitoring program is in place that tracks plant sensitivities to O_3 or other pollutants (M. Biel, pers. comm., 2010). Pohlman and Maniero (2005) noted that several plant species in DETO are sensitive to excessive or extended concentrations of O_3, some of which could be considered bioindicators for sustained presence of unhealthy levels of O_3. A detailed list of O_3-sensitive plant species is included in the data needs and gaps section.

Particulate Matter ($PM_{2.5}$ and PM_{10}) and Visibility

Concentrations of particulate matter ($PM_{2.5}$ and PM_{10}) are recorded at a site in nearby Campbell County (62 mi to the southwest), and values are extrapolated to DETO. Data recorded at this site from 2002 to 2006 represent the most current data on particulate matter concentrations in the area. 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 3 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 3 years (EPA 2010d). $PM_{2.5}$ concentrations have remained stable around 5 µg/m^3 from 2002 to 2006 (Figure 12). Concentrations of PM_{10} from 2004 through 2008 show an increasing trend upward until 2007, followed by a decrease in 2008 (Figure 13). These values, and those for fine particulate matter, are well within the EPA standards for levels that are protective of human health. However, these particulate matter monitoring sites are near substantial coal mining and power plant developments that likely impact particulate matter concentrations in the region and, thus, have the potential to significantly impact concentrations and visibility in DETO.

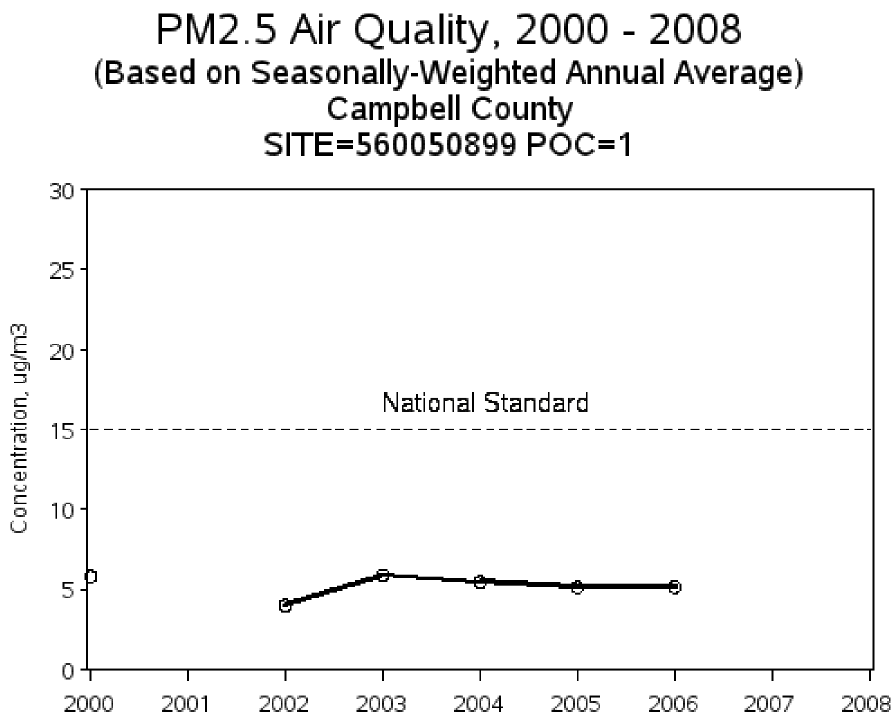

Figure 12. Trends in particulate matter ($PM_{2.5}$) near DETO, 2002–2006 (Source: EPA 2009b).

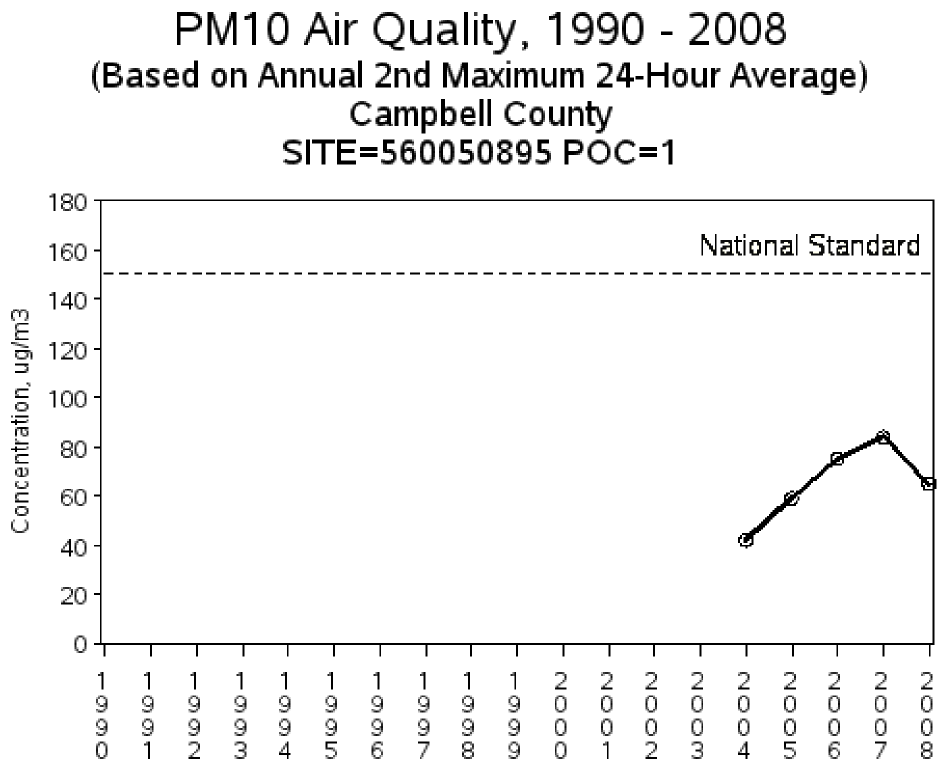

Figure 13. Trends in particulate matter (PM_{10}) near DETO, 2004–2008 (Source: EPA 2009b).

In response to the 1977 CAA mandates, Federal and regional organizations established IMPROVE in 1985 to aid in monitoring of visibility conditions in Class I air sheds (Pohlman and Maniero 2005). The goals of the program are to (1) establish current visibility conditions in Class I air sheds; (2) identify pollutants and emission sources causing existing visibility problems; and (3) document long-term trends in visibility (NPS 2009a). Based on aerosol data collected in Badlands National Park from 1996 to 1998, Pohlman and Maniero (2005) indicate that the primary sources of visibility impairment in the Northern Great Plains region are sulfates from coal combustion and oil refineries, organics from vehicle emissions and chemical manufacturing, soils (e.g., windblown dusts), light absorbing particulates (likely from wood smoke), and nitrates from coal and natural gas combustion. These particles and gases impair visibility when they scatter or absorb light; the net effect is called “light extinction,” a reduction in the amount of light from a scene that is returned to an observer (EPA 2003). The IMPROVE site nearest DETO is located in Wind Cave National Park (WICA), ~200 km (125 mi) southeast of DETO. Because weather patterns, level of industry, and land use is similar around DETO and WICA, annual visibility conditions at WICA can provide some insight into visibility conditions at DETO. Visibility (in dv) was depicted for the 20% best and 20% worst days in WICA, as well as the default natural conditions for both (Figure 14). NPS air quality estimates from 2004–2008 show that visibility in DETO on average is 5.2 dv (this is an estimate above the estimated natural conditions), which falls into the *Moderate Concern* category for NPS air quality condition assessment (NPS 2010c). However, patterns in visibility in WICA indicate that visibility on the 20% haziest and clearest days has been relatively stable since monitoring began in 2000.

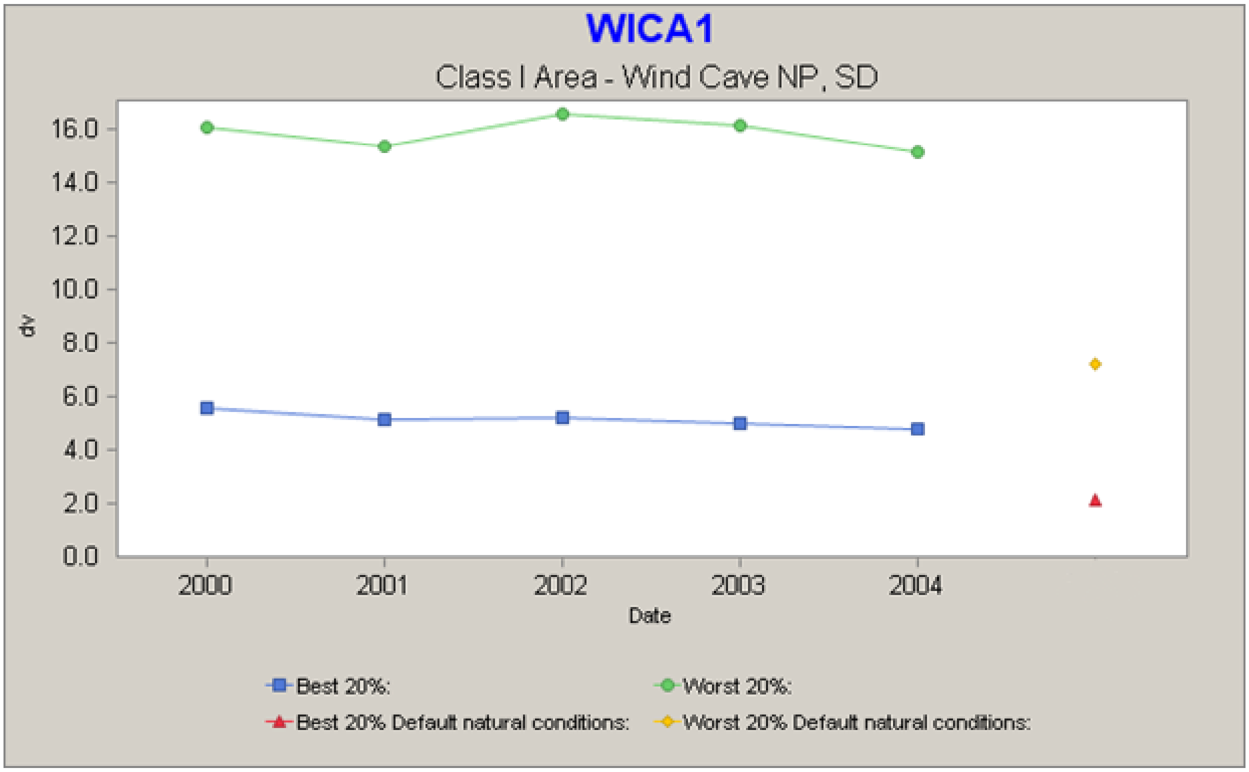

Figure 14. Annual visibility in WICA, 2000–2004 (VIEWS 2010).

<u>Threats and Stressor Factors</u>

Within DETO, threats to air quality primarily come from visitor vehicle emissions (particularly around the park entrance where vehicles may idle while waiting to gain entrance), wood smoke from campfires in the campground, and vehicle emissions from park vehicles (NPS 2001).

Emissions at the regional scale pose a greater risk to air quality at DETO. Several coal-fired power plants and mineral mining operations are located just west and south of DETO, in the eastern part of Wyoming (Peterson et al. 1998). These sources may pose a particular threat to DETO air quality because prevailing westerly winds carry nitrates, sulfates, and VOCs eastward. Peterson et al. (1998) suggest these compounds produce O_3 during warm, sunny summer months with higher levels of air moisture. Development of additional power plants in this part of Wyoming would certainly increase the emissions transported to DETO.

The smoke produced by forest and prairie fires has long been a part of the natural landscape in the Great Plains region. Although fires are not a long-term source of pollution for many parks in the eastern Rocky Mountain and Great Plains regions, if severe and substantial in extent they may result in periods of decreased visibility and increased concentrations of particulate matter (Peterson et al. 1998). Occasionally, wildfire or prescribed burning events intended to mimic low intensity wildfires occur in DETO (NPS 2008). These fires are beneficial to the natural landscape in a number of ways, including reducing the potential for catastrophic fires, eliminating excess fuel buildup, controlling disease and insect infestations, stimulating natural succession in fire dependent plant communities, and improving wildlife habitat (NPS 2008). Despite the benefits, smoke from these fires can temporarily impair air quality, primarily visibility.

Data Needs and Gaps

To date, no monitoring effort has tracked plant and animal species that are particularly sensitive to increases in certain pollutants. No direct evidence suggests current air pollution is threatening DETO vegetation, but nitrate, sulfate, and ammonium deposition, and O_3 could become a greater concern in the future if new point and area sources of pollution emerge and increase ambient pollution levels. If air pollution increases in the future, plant and trees species can be monitored to track air pollution impacts. DETO has several species sensitive to increases in O_3 (Pohlman and Maneiro 2005) that could be used as bioindicators to track potential increases in O_3 pollution as well as long-term impacts to the health of the ecosystem. A summary of the plant and tree species with known sensitivities to O_3 (Table 22) may help park staff identify key species to use as bioindicators. Peterson et al. (1998) recommend quaking aspen (*Populus tremuloides*) and ponderosa pine as bioindicators for monitoring effects of O_3 in parks in the Rocky Mountain and Northern Great Plains regions.

Table 22 Plant and tree species of DETO with sensitivities to ozone (O_3) (Adapted from Pohlman and Maniero 2005; NPS 2006b).

Scientific Name	Common Name
Amelanchier alnifolia	Saskatoon serviceberry
Apocynum androsaemifolium	Spreading dogbane
Apocynum cannabinum	Dogbane; Indian hemp
Artemisia ludoviciana	White sagebrush
Fraxinus pennsylvanica	Green ash
Pinus ponderosa	Ponderosa pine
Populus tremuloides	Quaking aspen
Prunus virginiana	Chokecherry
Rhus trilobata	Skunkbush; three-leaf sumac
Symphoricarpos albus	Common snowberry

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 N and S 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). Essentially, critical loads describe the amount of pollution that stimulates negative impacts or harmful changes to sensitive ecosystems (Porter et al. 2005; NPS 2007a). Porter et al. (2005) developed an approach for determining critical loads for N and S 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 most NPS lands, depending on available baseline information. Because plant communities in DETO are likely sensitive to increases in N, park managers at DETO 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

Based on NPS condition assessment protocol for air quality, the overall condition for air quality in DETO is of *Moderate Concern*. Nitrogen deposition in DETO falls into the *Moderate*

Concern category, but because of the sensitivity of native grasslands to increased levels of N, the park falls into the *Significant Concern* category. This suggests that, although deposition levels are not yet serious, steps should be taken to prevent significant impact to resources that are sensitive to increased levels of N. Sulfur deposition falls into the *Good* category (little concern), but due to the sensitivity of grasslands, the park falls into the *Moderate Concern* category. Data suggest that deposition of sulfate and nitrate compounds have remained stable on average between 2004 and 2008. Ground-level O_3 concentrations are of *Moderate Concern* based on NPS standards, and data suggest that O_3 concentrations in DETO are at least stable, if not declining slightly. Concentrations of both $PM_{2.5}$ and PM_{10} are well within EPA standards for allowable levels that are protective of human health; however, PM_{10} concentrations have experienced fluctuations over the last several years. Visibility in DETO is of *Moderate Concern*. Although many of the designations for air quality parameters indicate a *Moderate Concern* for air quality in the park, nearly all of the parameters are exhibiting stability or slight declines in concentrations or deposition. Overall, this suggests air quality in DETO is not deteriorating, but remaining stable.

Sources of Expertise

Mark Biel, DETO Chief of Resource Management
Mike George, NPS-ARD Air Resource Specialist
Ellen Porter, NPS-ARD Air Resource Scientist

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4.9 Hydrology

Description

The Belle Fourche River, the primary hydrological feature in DETO, flows through the eastern portion of DETO and forms part of its southern boundary. The Belle Fourche River is impounded 28 km (17 mi) upstream by Keyhole Dam, which became operational in 1952. Following its closure, the flow regime in DETO changed significantly, and seasonal flooding required for cottonwood regeneration stopped. The decline of cottonwoods in the park has compromised habitats of species that utilize the riparian areas in the park. The potential effects of climate change on flow regime are also a looming concern.

Measures

- Annual hydrograph: Annual hydrographs show seasonal fluctuations or changes in river discharge and help determine seasonal and annual water-quality variability. Discharge variability corresponds to precipitation, temperature, evapotranspiration, and drainage basin characteristics. River characteristics controlling discharge variability are width, depth, and slope (USGS 2007).

Reference Conditions

The reference condition is defined as the hydrographic conditions that existed prior to the Keyhole Dam construction in 1952. There are no specific data for flow in the park prior to 1952, but peak streamflow data for USGS gage station 06426500 below Moorcroft, Wyoming and above Keyhole dam provide some insight into pre-dam conditions.

Data and Methods

No datasets are available to evaluate the Belle Fourche River's annual hydrograph within DETO boundaries. However, a comparison of USGS gage stations 06426500 (above Keyhole Reservoir) and 06427500 (below Keyhole Reservoir) on the Belle Fourche River provides some indication of the hydrological change in the river following dam closure. Yearly peak streamflow data from these sites were extracted from the USGS National Water Information System: Web Interface and statistics and graphs were developed using Microsoft Excel.

Current Condition and Trend

In this section of the document, cubic feet per second (CFS) is used as the primary reporting unit rather than the metric cubic meters per second (CMS), as CFS is the standard convention for reporting flow by U.S. Government Agencies.

<u>Annual Hydrograph</u>

Keyhole Dam and Reservoir are situated on the Belle Fourche River in Crook County, Wyoming, 28 km (17 mi) northeast of Moorcroft, Wyoming. Normal water surface elevation is about 1,250 m (4,100 ft), and the spillway capacity at Keyhole Dam is approximately 11,000 CFS (311 CMS). DETO is located approximately 29 km (18 mi) north of Keyhole Dam and Reservoir. Within DETO boundaries, the Belle Fourche River flows approximately 100 CFS (2.83 CMS) in a northeasterly direction approximately 800 m (2,600 ft) east of DETO (Bureau of Reclamation 2010).

The Bureau of Reclamation (1997) reports that Keyhole Dam's overall safety is fair, but it is classified as a high hazard facility based on high-hazard–low-risk criteria that states overtopping of the dam will occur with floods >75% of the probable maximum flood. Dam failure, according to the Bureau of Reclamation (1997), would affect a 434-kilometer (270-mile) reach of the Belle Fourche River between Keyhole Dam and Cherry Creek, South Dakota, including DETO.

The observed peak discharges above and below Keyhole Reservoir for various years between 1924 and 2010 (Figure 15) show that following dam closure, peak discharge variability dampened below the dam. The median peak discharge above the dam is 803 CFS (22.7 CMS; 1924–2010, n = 58) and below the dam is 160 CFS (4.53 CMS; 1954–1994, n = 44). The maximum peak discharge observed below the dam is 1,410 CFS (39.9 CMS; 1978) and the maximum above the dam is 15,300 CFS (433 CMS; 1978).

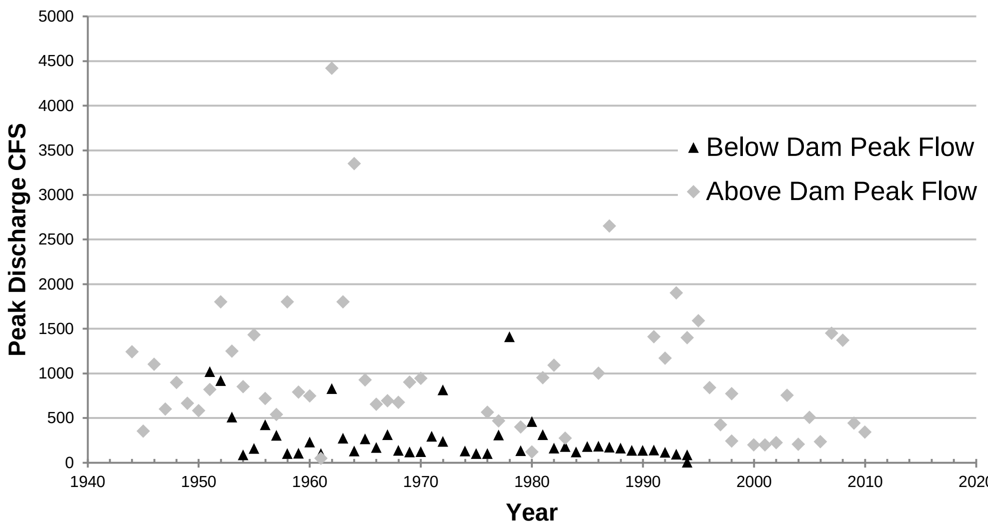

Figure 15. Peak discharge above (USGS gage 06426500) and below (USGS gage 06427500) Keyhole Reservoir on the Belle Fourche River. (Above-dam peak discharge for 1924 [12,500 CFS] and 1978 [15,300 CFS] are omitted for display purposes)

DETO has concerns with habitat loss due to flow regulation. Flooding, which is now rare in DETO area due to the flow regulation at Keyhole Dam and Reservoir (M. Biel, pers. comm., 2010), is essential for cottonwood regeneration to occur, and studies have shown that natural cottonwood regeneration is highly unlikely along rivers with flow regulation (USACE 2010). The decline of young cottonwoods available to replace older cottonwoods concerns biologists because a variety of plant and wildlife species is associated with cottonwoods (USACE 2010).

A DETO cottonwood habitat study conducted by Tinker (2008) indicates that cottonwoods are dying from old age and tree rot, and that cottonwood regeneration is difficult due to dry conditions in the past decade. Under natural conditions, the new bare substrate caused by annual runoff and seasonal flooding provided a suitable substrate for cottonwood germination. Mark Biel (NPS 2010) indicates that flow regulation of the Belle Fourche River affects cottonwood regeneration because new bare substrate for cottonwoods to germinate is absent in DETO. Cottonwood loss is associated with a decline in habitat availability for avian species that nest in cottonwoods (M. Biel, pers. comm., 2010).

Threats and Stressor Factors

Keyhole Reservoir is the primary stressor affecting the hydrology of the Belle Fourche River in DETO. Given the stability of the hydrograph below the dam, other stressors are limited; however, climate change and drought could have negative effects on the hydrology of the river in the future.

Data Needs and Gaps

DETO has a database of groundwater well monitoring data from stations along the riparian area. Some monitoring stations are equipped with data loggers that record temperature, barometric pressure, water depth, and water pressure (DETO 2010). “The purpose of the record of groundwater levels is to provide information for future efforts at the possibility of reestablishing cottonwood and willow stands along the Belle Fourche River and other projects that may occur in this area. (DETO 2010).” Future assessments should incorporate the data collected from these stations.

Overall Condition

Based on the comparison of the USGS gage stations above and below the Keyhole Reservoir, a changed hydrograph on the Belle Fourche River below Keyhole Reservoir is a cause of concern for species located in the riparian habitat in the park, especially cottonwoods. Based on the dampened flow and the effects on habitat in the park, the condition of hydrology is of significant concern.

Sources of Expertise

Mark Biel, DETO Chief of Resource Management

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4.10 Soundscape

Description
The definition of soundscape in a National Park is the total ambient sound level of the park, comprising both natural ambient sound and anthropogenic sounds (NPS 2000). The NPS mission is to preserve natural resources, including natural soundscapes, associated with the NPS units. Intrusive sounds are of concern to park visitors because they detract from their natural and cultural resource experiences (NPS 2000). NPS (2000) views soundscape preservation as an important dimension of the greater goal of preserving unimpaired park resources for present and future generations.

Measures

- Ambient sound level: ambient sounds measured in A-weighted decibels (dBA)
- Distribution of nonnatural sounds: any sound that is not part of the natural soundscape

Reference Conditions and Values
The reference condition for soundscape in DETO is an undeveloped park experience, or a soundscape not influenced by nonnatural sounds.

Data and Methods
DETO provided data and literature for this assessment. BridgeNet (2005) and Foch (1998), the two primary sources of literature, provided data and interpretation regarding the effects of aircraft on ambient sound levels in DETO. Pertinent data and conclusions from these studies are presented in this assessment.

A 30-day sound monitoring project was conducted by the NPS Natural Sounds Program, and these data are expected by the end of 2010 or early 2011. Mark Biel (Chief of Resource Management) and other park management consider the 30-day sound monitoring project a better assessment of the actual impact of Hulett Airport on the soundscape in the park. DETO and NPS Natural Sounds Program staff did not believe the BridgeNet study met NPS standards because its levels of impact were not as strict as NPS standards (M. Biel, pers. comm., 2010; NPS 2010).

The preliminary results of this sound study indicated that the existing median L50 soundscape levels exceeded 60 dBA, and most of the time was <30 dBA (V. McCusker, pers. comm., 2010). The pending results will include sound pressure levels, frequency components, continuous recordings, natural ambient sounds, and actual sounds heard with estimated anthropogenic sounds (V. McCusker, pers comm.).

Current Condition and Trend

<u>Ambient Sound Level</u>
As described in BridgeNet (2005), different frequencies (A-weighted, B-weighted, and C-weighted) are used to compute loudness levels. The most common measurement used is the A-weighted decibel scale (dBA), which approximates the sensitivity to the human ear. In this scale, everyday sounds range from 30 dBA (very quiet) to 90 dBA (very loud) (Table 23) (BridgeNet 2005).

Table 23. Examples of various A-weighted decibel sound environments (BridgeNet 2005).

dBA	Human Sensitivity	Outdoor Example
130		Military Jet Takeoff (130)
120	Uncomfortably Loud	
110		
100		Boeing 747 Takeoff (101)
90	Very Loud	Power Mower (96)
80		
70	Moderately Loud	Passenger Car @ 65 mph (77)
60		Propeller Airplane Takeoff (67)
50	Quiet	Large Transformers (50)
40		Bird Calls (44)

Foch (1998) and BridgeNet (2005) examined the ambient sound levels in DETO. Both studies explained ambient sound levels in terms of percent noise levels, the percent of the time a dB measuring device exceeds a certain level. An example is the L10 level, the sound level (dBA) exceeded over the span of multiple measurements 10% of the time. Likewise, L50 is the level exceeded 50% of the time, and L90 is the level exceeded 90% of the time.

Foch (1998) calculated percent noise levels from one location, approximately 1.6 km (1 mi) from the DETO headquarters, for 365 days between 10 June 1996 and 10 August 1997. The L10, L50, and L90 over this time were 41.1, 29.4, and 21.6 dBA, respectively (Figure 16).

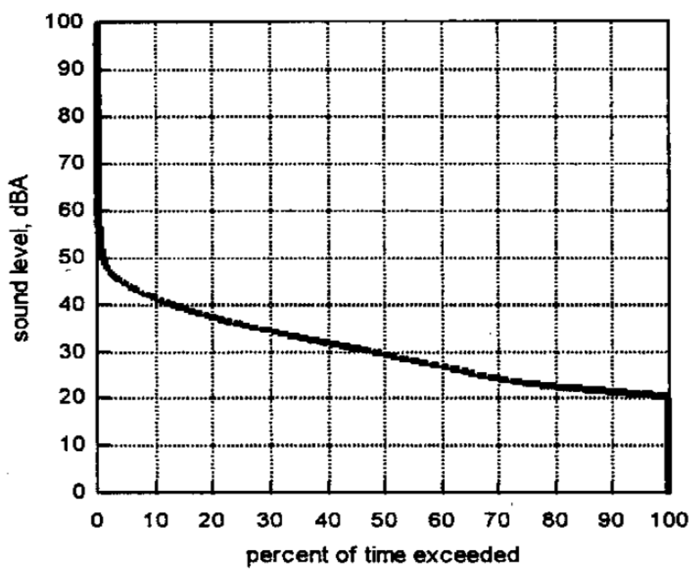

Figure 16. Percent noise levels in DETO from Foch (1998), 10 June 1996 to 10 August 1997.

BridgeNet (2005) examined percent noise levels at five locations in DETO (Plate 25) for 9 to 11 days between 11 July 2003 and 29 July 2003 (prior to the opening of the Hulett Airport) and 11 to 14 days between 15 July 2004 and 30 July 2004 (following the opening of the Hulett Airport). The L10, L50, LMIN (minimum sound level), and LMAX (maximum sound level) for each of the five study sites was recorded (Table 24). The mean L10 for all five sites prior to airport operation was 37.4 dBA and the mean L50 was 32.8 dBA. The mean L10 and L50, during airport operation, were 36.0 and 32.0 dBA, respectively. The pre- and post-Hulett Airport values from BridgeNet (2005) were slightly higher than those observed by Foch (1998).

Table 24. Ambient noise measurement results for DETO: Hulett Airport pre-opening (2003) and post-opening (2004). (Reproduced from BridgeNet 2005).

Site #	Description	LMAX 2003	LMAX 2004	L10 2003	L10 2004	L50 2003	L50 2004	LMIN 2003	LMIN 2004
1	West Side Burn Ridge	73	72	38	34	33	30	27	24
2	NW Meadows	75	70	35	32	31	29	25	23
3	NE Joyner Ridge Trail	74	72	37	34	33	29	30	22
4	NE Red Beds Trail	72	74	35	35	31	30	26	22
5	E Tower Trail	76	74	42	45	36	42	25	31

Distribution of Nonnatural Sounds

Various nonnatural sounds are present in DETO, such as development, trails, roads, and aircraft. Of these, only aircraft noise has been researched at DETO.

A technical assistance request will be submitted to NPS Natural Sounds program to conduct a noise study in future years during the annual Sturgis Motorcycle Rally, but the dates of this study are currently unknown (M. Biel, pers. comm., 2010)

Both Foch (1998) and BridgeNet (2005) examined aircraft noise levels. Foch (1998) examined the direct effects of aircraft on the ambient sound levels and found that “only aircraft overflights produce extended noise events with sound levels 30 to 40, 40 to 50, or 50 to 60 dBA above the L90,” except in the months of June, July, and August when thunderstorms occur at DETO. The 10 dBA subdivisions expressed by Foch equate, approximately, to doubling of loudness (Foch 1998).

BridgeNet (2005) examined the effects of the Hulett Airport on the soundscape at DETO. Prior to airport operation, park management was concerned that low-flying aircraft could affect the soundscape at DETO. BridgeNet measured Time Above (TA), which refers to the total time aircraft noise at a monitoring stations exceeds a certain dBA level, before and after Hulett Airport operation. Noise levels were slightly lower following the opening of the Hulett Airport (Table 25; BridgeNet 2005). BridgeNet (2005) concluded that during pre- and post-airport measuring there were “roughly 10 measureable aircraft overflights per day” and “no discernable difference” in noise measurements between their pre- and post-airport measuring periods. DETO staff and the Natural Sounds program state that this number has “increased significantly” since Hulett Airport opened. The conflicting results are likely do to more strict NPS dBA standards (M. Biel, pers. comm., 2010).

Table 25. Time Above measurements recorded by BridgeNet (2005) at DETO for 2003 and 2004. Time Above (TA) is the time in minutes per day that aircraft noise levels were greater than a specific noise level. For example, noise levels were greater than 65dBA for less than 1 minute per day.

Site #	Description	TA 65dBA	TA 60dBA	TA 55dBA	TA 50dBA	TA 45dBA
Pre-opening measurements (2003)						
1	West Side Burn Ridge	<1	1	3	11	48
2	NW Meadows	<1	1	3	12	41
3	NE Joyner Ridge Trail	<1	1	4	15	50
4	NE Red Beds Trail	<1	1	4	17	55
5	E Tower Trail	<1	3	17	65	176
Post-opening measurements (2004)						
1	West Side Burn Ridge	<1	1	2	10	38
2	NW Meadows	<1	<1	1	5	18
3	NE Joyner Ridge Trail	<1	<1	2	7	30
4	NE Red Beds Trail	1	3	8	23	72
5	E Tower Trail	<1	1	6	28	83

Threats and Stressor Factors

Development
No studies have been completed regarding development impact to soundscape in DETO.

Trails and Roads
No studies have been completed regarding trail and road impacts to soundscape in DETO. However, during the Sturgis Motorcycle Rally, motorcycles are a significant stressor to the soundscape of the park.

Aircraft
Aircraft are persistent stressors to the DETO soundscape. Miller (2008) explored visitor awareness and reactions to aircraft sounds. Across 39 parks, the survey showed that between 8 and 82% of the visitors reported hearing aircraft. Proctors asked visitors how much the noise interfered with their appreciation of the natural sounds of the park and found a positive relationship between the percent of visitors who heard aircraft in a park and the percent of visitors that reported those aircraft were interfering with their park experience (Miller 2008).

BridgeNet (2005) described the effects of aircraft flying below 914 m (3,000 ft) on the DETO soundscape. The maximum noise levels produced by these aircraft were 55 dBA in 2003 and 65 dBA in 2004, >20 dBAs above the L50 noise level. This is a cause for concern because two 10 dBA intervals equates to roughly four times the noise of the normal ambient sound level (Foch 1998).

Data Needs and Gaps
Periodic monitoring of soundscape in the future would allow trend analysis of ambient sound levels and stressors, such as development, trails and roads, and airplane over-flights.

The NPS Natural Sounds Program conducted a 30-day ambient sounds study in June–July 2010 (data currently pending) that will provide baseline soundscape data to be compared against more stringent NPS standards (M. Biel, pers. comm., 2010).

Overall Condition

Based on the examples of various A-weighted decibel sound environments (Table 23) and the two aircraft over flight studies conducted in DETO, the soundscape appears to be in *Good* condition because the sound levels remain in the quiet comfort level range most of the time. Both studies show that the mean L50 is approximately 30 dBA, and according to Foch (1998) the L90 is approximately 22 dBA.

Mark Biel (pers. comm., 2010) stated that the soundscape may seem to be in good shape, but private overflights are increasing (contrary to BridgeNet's conclusions) and may increase further with the expansion of the Powder River Training Complex by the U.S. Air Force that will incorporate airspace over Devils Tower. DETO has observed an increase in high-level military overflights (M. Biel, pers. comm., 2010).

Sources of Expertise

Mark Biel, DETO Chief of Resource Management
Vickie McCusker, NPS Sound Program 2010

Literature Cited

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Miller, N. P. 2008. U.S. National Parks and Management of Park Soundscapes: A review. Applied Acoustics 69:77-92.

National Park Service (NPS). 2000. Directors Order #47: Soundscape Preservation and Noise Management. Online. (http://www.nps.gov/policy/DOrders/DOrder47.html). Accessed 15 September 2010.

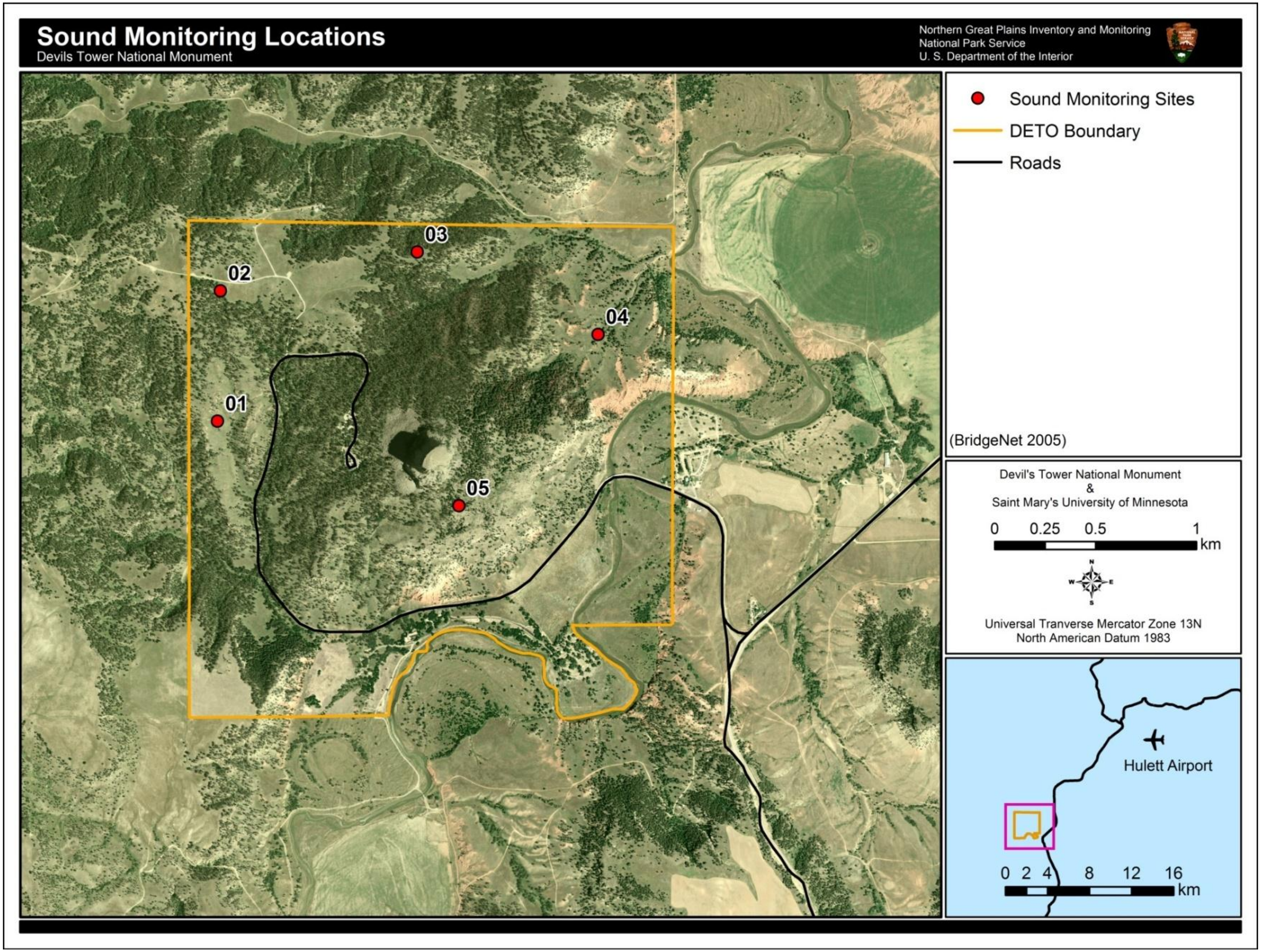

Plate 25. Sound monitoring locations (BridgeNet 2005).

4.11 Viewshed

Description

A viewshed is the area visible from a particular location. The NPS Organic Act (16 U.S.C. l) implies the need to protect the viewsheds of National Parks, Monuments, and Reservations. At DETO, viewsheds are particularly important because the primary reason for park visitation is to view the Devils Tower and the surrounding landscape. Viewsheds can be determined using GIS; specifically, a digital elevation model (DEM) is used in conjunction with a point or line to determine the visible area from that point or line. The points and lines used to calculate viewsheds often represent areas of high visitor use. The resulting viewshed layers are analyzed to determine the predominant visible characteristics within a viewshed. Important aspects to analyze are those that management or patrons of the park consider valuable. Often, nonnatural features (e.g., agriculture land, buildings, and roads) are considered detrimental to a viewshed in a National Park.

Measures

- Natural, undeveloped viewsheds

Reference Conditions and Values

The reference condition for DETO viewsheds is undeveloped, natural views.

Data and Methods

To date, viewshed monitoring data do not exist for DETO.

A viewshed analysis of DETO's Tower Trail was performed for this assessment. A visibility layer was developed using ArcGIS 9.3.1 Viewshed Tool.

Current Condition and Trend

<u>Park Viewsheds</u>

DETO, like most NPS Units, offers spectacular views (Photo 5,Photo **6**,Photo **7**, Photo 8). To maintain these views within the park, management keeps park development at a minimum; however, views across the landscape surrounding the park are significantly different from the reference condition. To the south and east of the park, agricultural development is evident, as are numerous daily flights in the area from the Hulett Airport and the Air Force's Powder River Training Complex. When looking up at the Devils Tower, these flights become especially obvious. In addition, tourist services (campground and gift shop) at the entrance to the park are visible from some of the hiking trails in the park.

Land ownership influences the quality of DETO's viewsheds. Private individuals with different land management strategies than NPS's own most neighboring lands, resulting in viewsheds with variable scenic quality when looking out from the park. However, DETO is open to partnerships with neighboring landowners (M. Biel, pers. comm., 2010).

Viewshed analysis through GIS determines areas visible from selected points or lines. For NPS units, these points and lines are typically places of high visitor use, such as trails, visitor centers, or park roads. These areas are often of high management concern because of the potential impact development may have on the visitor's park experience. Plate 27 displays a layer developed through a GIS viewshed analysis that displays the percent time a given cell (5 × 5 m area on the landscape) is visible from DETO's Tower Trail. Development in areas visible from a high percentage of the Trail could result in lower visitor appreciation during a hike. Viewshed layers are most useful when overlaid with layers that explain development or disturbance in a given area.

Photo 5. A view of Devils Tower from Red Beds Trail.

Photo 6. A view of Devils Tower, near the park administration building.

Photo 7. Looking southeast from the western portion of Tower Trail (SMUMN GSS 2009).

Photo 8. Looking east from the southern portion of Tower Trail.

Threats and Stressor Factors
Human development and resource extraction (e.g., timber or oil) outside park boundaries pose the greatest threats to the scenic quality of natural and undisturbed viewsheds. Within the park, future development of infrastructure could alter viewshed quality. Because of this, viewshed analysis is an important tool for recognizing the most crucial areas to protect. Particulate matter pollution can also deteriorate viewshed (see discussion of particulate matter pollution in Chapter 4.8).

Data Needs and Gaps
In-depth viewshed analyses could help determine areas in and around the park where development or resource extraction could deteriorate the quality of DETO's viewsheds. Specific analyses could utilize LCLU change data within different park viewsheds or fixed photopoint sites to help monitor change from a visitor's perspective.

Overall Condition
The quality of DETO's viewsheds is deteriorated in certain areas due to agriculture and developments outside of park boundaries, and future development is a concern; however, DETO works with neighboring landowners to prevent future development (M. Biel, pers. comm., 2010). Because the primary reason for park visitation is to observe the Devils Tower and surrounding landscape, continued monitoring of development in the area is an important aspect of DETO management.

Sources of Expertise
Mark Biel, DETO Chief of Resource Management

Literature Cited

National Park Service. 2009. owners.shp. GIS Shapefile. Received from DETO Staff, October 2009.

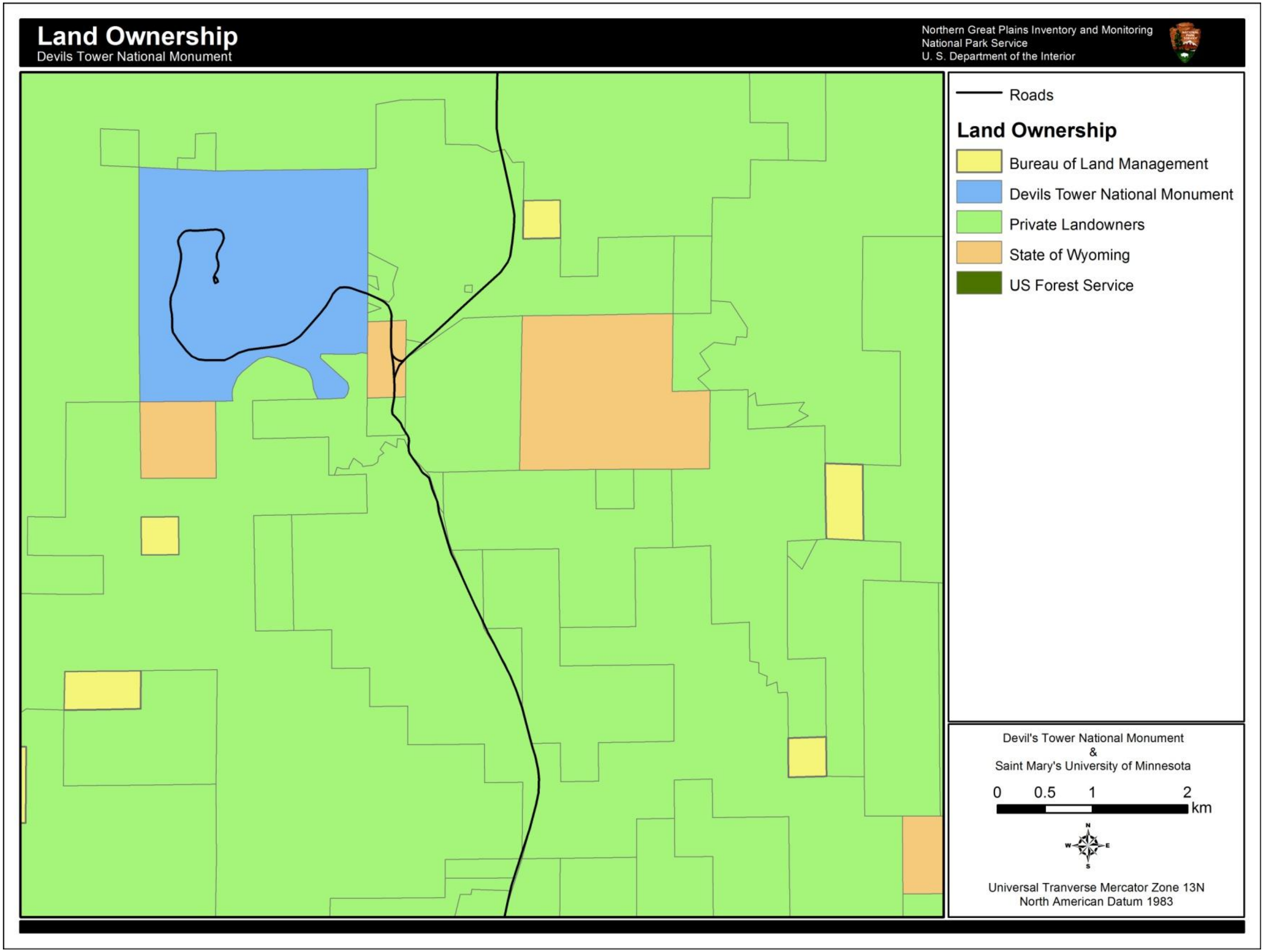

Plate 26. Land ownership, DETO area (NPS 2009).

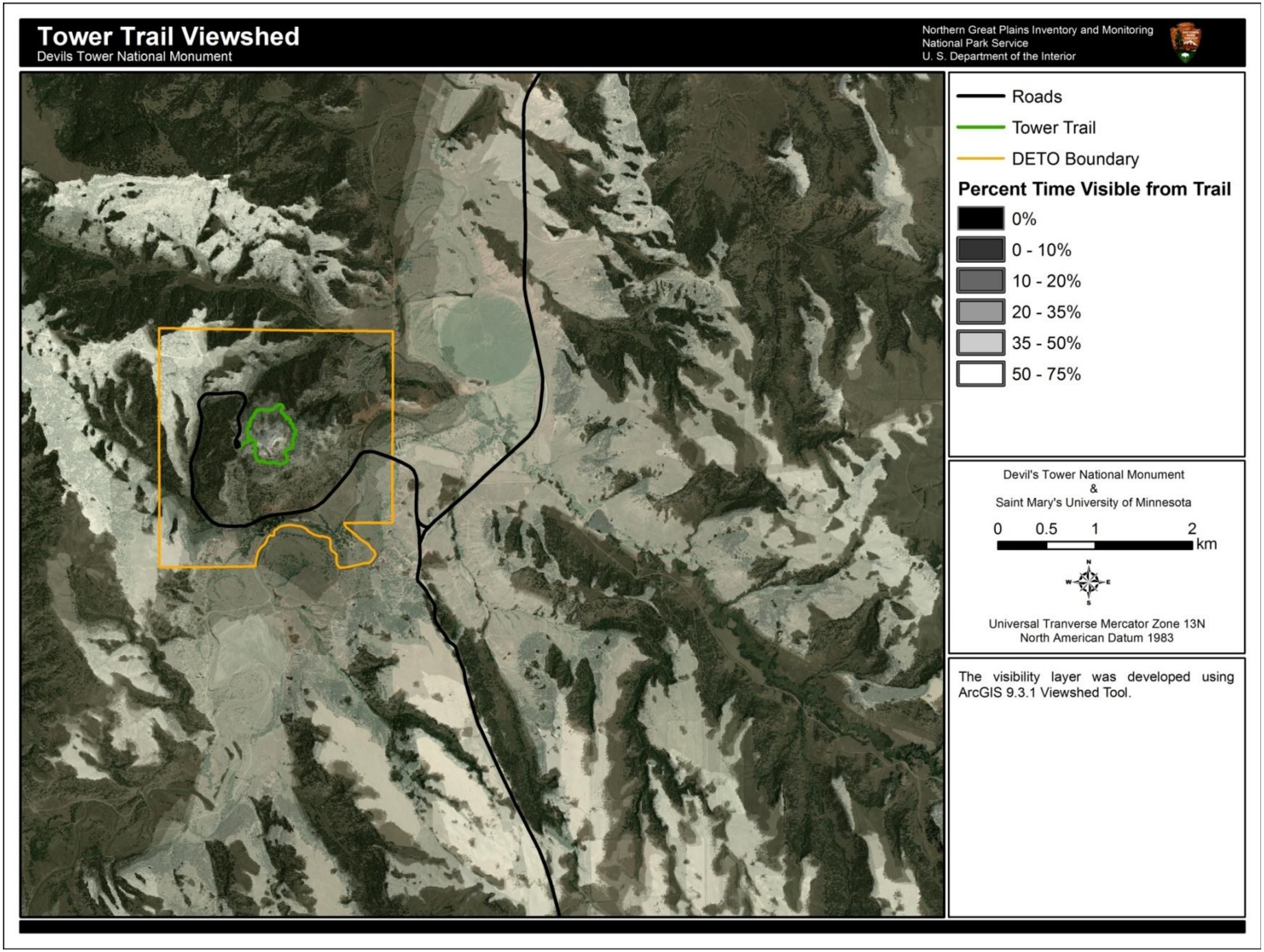

Plate 27. Tower Trail viewshed, percent time visible from trail.

4.12 Dark Night Skies

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 to allow star observation.

Measures

- Night Sky Program standard – V magnitude
- Schaff scale score

Reference Conditions and Values

The reference condition for DETO is an undeveloped and “natural” park setting. This primarily refers to the absence of anthropogenic light, which is in accordance with NPS management policies.

Data and Methods

The NPS Night Sky monitoring team visited the park in 2005 and collected baseline data regarding the condition of DETO night skies. These data remain unpublished and are currently unavailable to park managers. Albers and Duriscoe (2001) assigned a Schaff scale score to the park, but data used in this assignment were not collected in the park.

Current Condition and Trend

<u>Darkness - V Magnitude</u>

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 reported 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). An initial night sky assessment was conducted at DETO in 2005. The results of that assessment are not yet available.

<u>Schaff Scale Scores</u>

Albers and Duriscoe (2001) developed a GIS that evaluated the nighttime visibility of NPS units. This model used the Schaff scale, a 1 through 7 scale with 1 representing extreme light pollution and 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. DETO received a Schaaf score of 7.00 out of 7.00 (Albers and Duriscoe 2001); however, this value must be interpreted with caution because the original Schaff scale score maps were from

1991, and no park-specific data were used in the calculation. Also, 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 west make distant cities more visible (C. Moore, pers. comm., 2011).

Photo 9. DETO dark night sky mosaic, collected during the NPS Night Sky Team’s 2005 park visit. (NPS).

Threats and Stressor Factors
Light pollution is defined by the NPS as “the illumination of the night sky caused by artificial light sources, decreasing the visibility of stars and other natural sky phenomena” (NPS 2007). 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). In addition to human sources of light, airborne particulates can also affect night sky brightness (NPS 2007).

Several sources of anthropogenic light exist near DETO and are primarily related to areas of residential use. Of those sources, the closest to the park is a campground facility at the park border in the city of Hulett, Wyoming, 16 km (10 mi) from the park, and the city of Sundance, Wyoming, 43 km (27 mi) from the park. Additionally, park facilities may contribute to point source light pollution; preliminary discussions are underway to install light fixtures in the park to minimize point source light pollution (M. Biel, pers. comm., 2010). Chad Moore, head of the NPS Night Sky Team, also noted that the light domes of nearby Moorcroft and Gillette, Wyoming, and Rapid City and Spearfish, South Dakota, were all visible in the park during the Night Sky Team visit in 2005.

The relationship with air quality and night sky quality is complex. Poor air quality diminishes the brightness of distant cities, increases the brightness of nearby sources (like the campground facility), and dims the stars. According to Chad Moore’s professional opinion, visual ranges greater than 190 km would be considered good for DETO. A visual range of this magnitude would allow DETO to be classified as a Class I excellent star site.

Data Needs and Gaps
Quantitative dark night skies monitoring is needed in DETO to report condition. Results of the NPS Night Sky Team’s 2005 visit should help to establish a baseline for night sky conditions in DETO.

Overall Condition
Due to the lack of data, a quantitative assessment of dark night skies cannot be completed at this time. Because of the park’s relatively close proximity to residential sites, the quality of DETO’s night skies is influenced by anthropogenic light sources. Albers and Duriscoe (2001) rated the

night skies in the park as 7.00 out of 7.00, which is the only quantitative estimate of dark night skies for DETO; however, this rating must be taken with caution as no measurements were taken within DETO.

Sources of Expertise

Mark Biel, DETO Chief of Resource Management
Chad Moore, NPS Night Sky Program Manager

Literature Cited

Albers, S., and D. Duriscoe. 2001. Modeling Light Pollution from Population Data and Implications for National Park Service Lands. The George Wright FORUM 18:4, pp. 56-68.

National Park Service (NPS). 2006. Management policies 2006. ISBM 0-16-076874-8. U.S. Department of the Interior. National Park Service, Washington, D.C.

National Park Service (NPS). 2007. Air resources division – natural lightscapes. Online. (http://www.nature.nps.gov/air/lightscapes/) Accessed 9 August 2010.

4.13 Devils Tower Usage

Description

Park visitor activities can be a contentious issue at DETO. Since 1980, an average 358,175 people visit DETO each year, including 14,777 campers (Appendix F). Many stakeholders hold various viewpoints regarding the multiple uses of the Devils Tower (Tower). Native Americans regard the Tower as a sacred place; it is a focal point of many legends and rituals. Climbers regard the Tower as one of the premier climbing destinations in North America. Others hike, cross-country ski, or simply observe the Tower. Because of the diverse stakeholder group, planning processes at DETO are deliberate and take all groups' needs and expectations into consideration.

Measures

- Climber numbers: number of climber visits per year
- Native American significance: published literature and oral histories explaining the rituals and legends of tribes, and archeological evidence documenting Tribal presence associated with the Tower
- Visitor appreciation: visitor survey data in relation to Department of Interior goals

Reference Conditions and Values

The reference condition for Tower usage is the current usage and practices. Established management goals aim to balance the needs of all stakeholder groups (e.g., Native Americans, climbers, hikers, locals). DETO's general, climbing, and fire management plans define these goals.

Data and Methods

Data regarding Native American significance are from various manuscripts and NPS publications. Regarding climber use, Mark Biel, DETO Chief of Resource Management, provided climber numbers along with the DETO Climbing Management Plan (NPS 1995). The University of Idaho Park Studies Research Unit (PSU) developed visitor appreciation data, which was retrieved via their website.

Current Condition and Trend

<u>Native American Significance</u>

Currently, 24 Native American tribes have cultural affiliation with DETO (Mark Biel, pers. comm., 2010; Table 26). In addition, six tribal nations inhabited the DETO region at some time and regard it as a sacred site: Eastern Shoshone, Kiowa, Crow, Cheyenne, Arapaho, and Lakota (NPS 1995). Many of the 24 affiliated tribes still practice sacred rituals at the Tower, such as prayer offerings, sweatlodge ceremonies, vision quests, and funerals. The Lakota have performed the sacred Sun Dance at DETO since prehistoric times; this tribe recognizes the Belle Fourche River as the Sun Dance River. Many of these rituals take place in June; because of this, there is a voluntary climbing closure during June.

Table 26. Tribes with cultural affiliation to DETO (Mark Biel, pers. comm., 2010).

Apache Tribe of Oklahoma	Blackfeet Tribe	Cheyenne and Arapahoe Tribes of Oklahoma
Cheyenne River Lakota	Confederated Salish and Kootenai Tribes	Crow Creek Sioux Tribe
Crow Tribe	Flandreau Santee Lakota	Fort Belknap Tribe
Fort Peck Tribe	Kiowa Indian Tribe of Oklahoma	Lower Brule Lakota Tribe
Arapaho Tribe	Northern Cheyenne Tribe	Oglala Lakota Tribe
Rosebud Sioux Tribe	Santee Sioux Nation	Shoshone Tribe
Sisseton-Wahpeton Lakota	Standing Rock Lakota Tribe	Turtle Mountain Chippewa Tribe
Yankton Lakota	Spirit Lake Tribe	Three Affiliated Tribes

Many Native American tribes have legends regarding the origin of the Tower. Most of these legends revolve around an encounter with, and escape from, a large bear. As a result, Native American names for the Tower include "Bear's Tipi" (Arapaho), "Bear's Lodge" (Cheyenne), and "Bear's House" (Crow) (San Miguel 1994). Rogers (2008) suggests that the origin of the title "Devils Tower" could be the result of misinterpretation; the Lakota word for devil is '*wakansica*' (pronounced *wah-KON-she-cha*) and black bear is '*wahanksica*' (pronounced *wah-ON-ksee-cha*).

Photo 10. Sweatlodge at DETO.

<u>Climber Numbers</u>

Recreational climbing at DETO has increased significantly since the 1970s (NPS 1995). Hundreds of parallel cracks, which divide the Tower into large hexagonal columns, make it one of the finest traditional crack climbing areas in North America (NPS 2010b). In 1995, there were

220 named climbing routes on the tower (NPS 1995). On average, 4,230 individuals have climbed the tower each year over the past decade (NPS 2010a; Figure 17).

Devils Tower provides prime nesting habitat for prairie falcons. According to the Final Climbing Management Plan (1995), “The goal of the raptor nest protection strategy at Devils Tower is to allow falcons to freely select and establish nest sites and occupy their nests for the duration of the breeding season without being stressed by climbers on the tower.” DETO staff monitors prairie falcon nesting on DETO and close nearby routes to protect falcons and climbers. Typically, these route closures begin in mid-March and continue until young fledge.

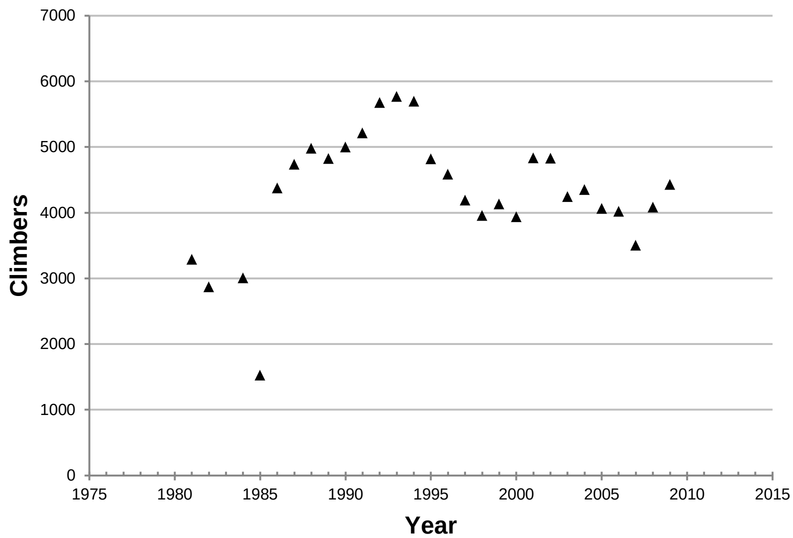

Figure 17. Yearly climbers, DETO, 1980–2009 (NPS 2010c).

Visitor Appreciation

The Department of the Interior (DOI) sets goals intended to “improve the quality and diversity of recreation experiences and visitor enjoyment on DOI lands” (DOI 2010). PSU conducts visitor surveys at NPS units to examine measures that define the DOI’s goals. In fiscal year (FY) 2009, the percent of DETO visitors satisfied with the quality of experience and the percent of customers satisfied with the value for fee paid were below the DOI target (PSU 2010; Table 27). However, PSU (2010) noted, “For most indicators, the survey data are expected to be accurate within ±6% with 95% confidence.”

Table 27. Results from 2009 PSU visitor survey and DOI FY 2009 goals (PSU 2010).

Measure	FY 2009 Final Target	DETO Actual
Percent of visitors satisfied with the quality of experience	96	93
Percent of customers satisfied with the value for fee paid	92	90

Threats and Stressor Factors

Ecological and cultural concerns can limit Tower usage. Part of DETO’s mission is to “restore and maintain the health and diversity of DETO’s natural systems” and to “Preserve archeological, historic, and ethnographic values at Devils Tower” (NPS 2001). As aforementioned, climbing routes close yearly to protect nesting prairie falcons, and an annual June voluntary climbing closure is initiated to accommodate Native American beliefs and significance. The NPS encourages input from the public, organizations, and other state and federal agencies during the NEPA planning process. Substantive comments and concerns regarding ecological and cultural concerns are then incorporated into park management documents.

Data Needs and Gaps

There are no data needs regarding Tower usage.

Overall Condition

Current Tower usage complies with DETO's mission goals. There is no significant concern regarding the allocation of Tower use.

Sources of Expertise

Mark Biel, DETO Chief of Resource Management

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Chapter 5 Discussion

5.1 Component Data Gaps

Identification of key data and information gaps is an important objective of Natural Resource Condition Assessments (NRCAs). Data gaps or needs are pieces of information that are currently unavailable but would help determine the status and the overall condition of a key resource component. Data gaps exist for all key resource components assessed in this NRCA except Tower Usage. Table 28 provides a detailed list of the key data gaps by component.

Table 28. Data gaps for DETO NRCA components.

Component	Data Gaps
Land Cover Extent	- numerical reference condition, explaining land cover composition prior to grazing and fire suppression -ranching and grazing history of DETO - protocol for reporting and measuring the land cover/land use 'Vital Sign' - an updated land cover dataset (veg. map) that is comparable to the Salas and Pucherelli 1998, veg. map
Native Plant Communities	- species richness data for the herbaceous plant communities in DETO - assessment of native plant restoration efforts - information regarding invasive species prevalence on neighboring park lands
Prairie Falcon	- examination of the relationship between prairie falcon nesting habits and human presence on and around the Tower
Birds	- annual bird surveying efforts in the park - replication of previous RMBO survey transects
Prairie Dog	- in-depth study examining population density, genetics, browsing habits, and basic ecology of the park's isolated prairie dog colony
White-tailed and Mule Deer	- climate change effects on vegetation regimes and the relationship to deer browsing behavior in the park - habitat usage and distribution in park - continued monitoring of deer exclosures used early 2000s
Water Quality	- consistent, long-term monitoring of specific conductance, fecal coliform bacteria, DO, pH, temperature, and turbidity - survey of macroinvertebrates present in the Belle Fourche River - research explaining the effects of the Keyhole Dam on water quality in DETO
Air Quality	- air pollution effects on biological park resources - "critical loads" approach for tracking and monitoring pollutants
Hydrology	- Analysis of ground water well monitoring data collected by park staff
Soundscape	- periodic monitoring of soundscape that will allow for trend analysis of ambient sound levels and stressors
Viewshed	- in-depth viewshed analysis that incorporates values of park resource management
Dark Night Skies	- quantitative dark night skies monitoring
Tower Usage	- no current data gaps

5.2 Component Condition Designations

Chapter 5 brings together and discusses the common threads in findings regarding the components featured in the assessment framework. Table 29 provides a condition graphic assigned to each resource component presented in Chapter 4. The graphic represented here is merely a symbol for the overall condition and trend assigned to each component and not intended to replace the condition section for each component. In-depth accounts and explanations of the assigned conditions are needed because the assignment of condition for most components is based on multiple factors.

Table 29. Component condition designations.

Components	Measures	Reference Condition	Condition
Extent and Pattern			
Landscape Composition			
Landcover Extent	Landcover chage	Pre-cattle and sheep grazing; natural and healthy environment	
Biological Components			
Ecosystem and Community			
Native plant communities	Change in ponderosa pine density and distribution	Pre-fire supression	
	Exotic plant distribution and density	Pre-exotic species	
	Cottonwood regeneration	Pre-cattle and sheep grazing; natural and healthy environment	
	Plant species richness	Pre-cattle and sheep grazing; natural and healthy environment	
Biotic Composition			
Prairie falcon	Change in nesting or population status	Successful nesting within monument	
Birds	Change in species richness and distribution	Current population at reference levels	
Prairie dog	Population number and distribution	Current population at reference levels	
White-tailed and mule deer	Population and distribution	Historic natural and healthy population	
Chemical and Physical Characteristics			
Water Quality	Temperature	EPA water quality criterion	
	pH	EPA water quality criterion	
	Conductivity	EPA water quality criterion	
	Dissolved Oxygen	EPA water quality criterion	
	Coliform Bacteria	EPA water quality criterion	
	Turbidity	EPA water quality criterion	

Table 29. Component condition designations. (continued)

Components	Measures	Reference Condition	Condition
Chemical and Physical Characteristics (continued)			
Air Quality	Mercury	EPA standards	
	Nitrogen	EPA standards	
	Sulfur	EPA standards	
	Ozone	EPA standards	
	Suspended particulate matter	EPA standards	
	Visibility (Haze Index)	EPA standards	
Hydrology	Annual hydrograph (changes in natural flow)	Pre-dam construction	
Goods and Services			
Non-Consumptive			
Soundscape	Decibel levels and distribution of non-natural sound character	Undeveloped and "natural" park experience	
Viewshed	Natural undeveloped viewsheds, both near and distant views	Undeveloped and "natural" park experience	
Dark night skies	V magnitude, night sky program standard	Undeveloped and "natural" park experience	
Tower usage	Climber numbers, Native American significance, visitor appreciation, local connectivity	Current usage and practices (balanced)	

5.3 Park-wide Condition Observations

Theodore Roosevelt signed a proclamation that established Devils Tower National Monument (DETO) as the nation's first National Monument in 1906 (16 USC 431-433). The 545 ha (1,346 ac) park hosts a variety of flora and fauna and offers many nonconsumptive goods and services. Yearly, more than 300,000 people visit the park for a variety of reasons other than observing the Devils Tower (Tower), such as camping, climbing, hiking, and sacred rituals, to name a few.

Ponderosa pine woodlands and short and mixed-grass upland meadows typify DETO (Salas and Pucherelli 1998). Nonnative invasive species threaten these communities; more than 50 nonnative plant species are known to exist in the park. Nonnative invasive species of particular concern include leafy spurge and smooth brome. Smooth brome is common in disturbed pasture areas within the prairie regions of the park (NPS 2004). Leafy spurge is the most widespread nonnative invasive plant in DETO, particularly prevalent in the floodplain of the Belle Fourche River. National Park Service (NPS) staff manages nonnative invasive species with a variety of methods, including fire, mowing, pulling, and chemical treatment to minimize their effects on native plant communities.

Regional land cover change, including change due to human development, is a major threat to bird populations across all habitat types, including prairie falcons that nest in the park (Morrison 1986). Private individuals who may have different land management goals and strategies than DETO own most neighboring land, which may not experience fires or invasive plant species control. Privately held lands are likely to be developed, further fragmenting habitats. However, DETO works on partnerships with neighboring landowners to minimize development of neighboring lands.

Non-NPS land management also affects the chemical and physical characteristics of the park. The Belle Fourche River, situated in the southeast portion of the park, is impounded by the Keyhole Dam roughly 27 km upstream of DETO. The dam was established in 1952, altering the natural hydrologic regime of the river, compromising cottonwood regeneration in the park (Tinker 2008). The lack of cottonwood regeneration has also resulted in a loss of avian habitat in the park (M. Biel, pers. comm., 2010).

Numerous livestock ranches operate on private lands surrounding DETO. Many of the cattle have direct access to the Belle Fourche River, and livestock graze along the riverbank and traverse the river (M. Biel, pers. comm., 2010). These practices encourage riverbank erosion, increase turbidity in the river, and enhance the probability of water contamination in the form of fecal coliform bacterium. Approximately 32 km (20 mi) of the Belle Fourche River, including the stretch that runs through DETO, is an impaired waterway (303[d]) for fecal coliform and high ammonia and chloride levels (EPA 2010).

For air quality in DETO, nitrogen deposition is of high concern, ozone of moderate concern, and mercury is currently of low concern. Threats to the park's air quality exist at multiple scales. Emissions from visitor and park vehicles along with campfire smoke in the campground are internal sources of air contaminants on a daily basis. At a regional scale, coal-fired power plants and mining operations could increase deposition of nitrates, sulfates, and volatile organic carbons. These stressors could also affect visibility, compromising some of the goods and services DETO offers. Visibility, another important air quality measure is of moderate concern.

Decreased visibility can detract from DETO's viewsheds. The views of the Devils Tower and the surrounding landscape are of high value to management because the primary reason for park visitation is to observe the Tower. Visibility is not the only stressor to viewsheds in the park; human development by neighboring landowners can alter views of the surrounding landscape, and climbers can alter natural Tower views. Many Native American tribes still perform rituals such as prayer offerings, sweatlodge ceremonies, and vision quests. Many of these rituals take place during June, and out of respect, there is a voluntary climbing closure during that month to preserve unaltered views of the Tower.

Similar to viewsheds, dark night skies are a valued resource to park visitors. The NPS aims to preserve natural dark nights unperturbed by artificial light (NPS 2007). Nearby towns and cities, park facilities, and a nearby privately owned campground could alter the natural dark night skies in the park. Quantitative dark night skies data for DETO are minimal; additional monitoring is needed to understand this resource in the park.

Soundscape of the park, another important resource for many park users, is the total ambient sound in the park, composed of both natural and anthropogenic sounds (NPS 2000), which are generally considered a negative addition to the soundscape. Currently the soundscape at DETO seems to be in good condition according to a recent study (Bridgenet International 2005), but increasing numbers of over-flights from private individuals and military operations are a concern looking forward (M. Biel, pers. comm., 2010).

Saint Mary's University of Minnesota, Geospatial Services (SMUMN GSS) observations from literature, data, and personal communications show that nearly all component measures assessed indicate stable condition, regardless of low, moderate, or high concern level. Two exceptions, nonnative plant density and distribution and the change in ponderosa pine density and distribution, show signs of improvement. For example, the Great Northern Plains Exotic Plant Management Team (NGP EPMT) and DETO nonnative plant control efforts have resulted in some leafy spurge reduction in recent years. In addition, prescribed fires are creating more canopy openness following burns in ponderosa pine burn units. Prescribed fires are also generally reducing nonnative plant densities in prairie burn units. Fauna, such as prairie dogs, birds, and deer in DETO are in stable condition. Given the limited use of the Tower based on available nesting habitat, the condition of prairie falcons is of moderate concern.

Data regarding water quality are limited, and therefore no trends in their condition are assigned. According to EPA standard. Nitrogen is of significant concern in regard to air quality measures appear to be stable at this time. The Keyhole Dam regulates the downstream flow of Belle Fourche River, the chief waterway in the park, resulting in a flow regime with reduced fluctuations in flow throughout the year. The components considered to be goods or services (i.e., soundscape, viewshed, dark night skies, and Tower usage) are also in stable condition.

In conclusion, while the condition of most of the component measures are of moderate concern, nearly all of the measures are either in a stable condition or information is insufficient to indicate a trend. Much of the concern for the different resources in the park relates directly to anthropogenic effects on the landscape. The effect of the Keyhole Dam on the hydrologic regime in the park is the most obvious example of anthropogenic effects at DETO. Other anthropogenic stressors include development on neighboring lands, past fire suppression, park infrastructure, and past grazing. However, NPS efforts to build partnerships with landowners and provide opportunities for input from multiple stakeholders, discourages anthropogenic stress on key resource components. Condition was not determined for two key resource components: birds and dark night skies. Additional data and monitoring are necessary to make any inference about the condition of these resources.

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Appendices

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Appendix A. Area of mapping units within the mapping area and within DETO (Salas and Pucherelli 1998[1]).

Map Unit	Description	Anderson Level II Code	Description	Area in ha (ac) within mapping area	Area in ha (ac) within park boundary
-	-	11	Residential	0.4 (1.0)	0.4 (1.0)
-	-	12	Commercial and Services	1.4 (3.5)	0.1 (0.2)
-	-	14	Transportation, Communications and Utilities	3.7 (9.1)	0 (0)
-	-	17	Other Urban or Built-up Land	7 (17.3)	0.8 (2.0)
-	-	21	Cropland and Pasture	117.9 (291.3)	0 (0)
-	-	51	Streams and Canals	15.9 (39.3)	3.7 (9.1)
-	-	53	Reservoirs	0.5 (1.2)	0 (0)
-	-	62	Non-forested Wetland	0.2 (0.5)	0 (0)
-	-	74	Bare Exposed Rock	52.5 (129.7)	24.3 (60.0)
BB	Wyoming Big Sagebrush / Bluebrunch Wheatgrass Shrub Herbaceous Vegetation	-	-	0.9 (2.2)	0.9 (2.2)
BU	Green Ash - American Elm / Wolfberry Forest	-	-	39.6 (97.9)	11.8 (29.2)
CP	Eastern Cottonwood Peach Leaf Willow / Narrow Leaf Willow Woodland	-	-	34.9 (86.2)	14.3 (35.3)
GH	Grassland Complex	-	-	956.4 (2363.3)	137.7 (340.3)
MK	Mosaic - Kentucky Bluegrass / Little Bluestem Grassland	-	-	36.9 (91.2)	28.3 (69.9)
MW	Mosaic - Western Wheatgrass / Little Bluestem Grassland	-	-	18.9 (46.7)	18.3 (45.2)
PB	Ponderosa Pine / Bur Oak Woodland	-	-	691.6 (1709.0)	176.9 (437.1)
PD	Prairie Dog Town	-	-	256.5 (633.8)	81.1 (200.4)
P1	Ponderosa Pine Complex 1	-	-	65.8 (162.6)	25.8 (63.8)
P2	Ponderosa Pine Complex 2	-	-	10 (24.7)	10 (24.7)
PJ	Ponderosa Pine / Common Juniper Woodland	-	-	6.6 (16.3)	4.8 (11.9)
SC	Silver Sage Brush / Western Wheatgrass Herbaceous Vegetation	-	-	12.6 (31.1)	4.6 (11.4)
			Totals:	2,330.2 (5,758.0)	543.8 (1,343.8)

[1] Salas, D. E., and M. J. Pucherelli. 1998. USGS-NPS Vegetation mapping: Devils Tower National Monument, WY.

Appendix B. Mean and range (min. and max.) of descriptive vegetation variables in DETO by vegetation type, sampled using the point intercept method in Symstad (2006[1]).

Vegetation Type		Gram Cover (%)	Shrub Cover (%)	Forb Cover (%)	Total Cover (%)	# Native Spp	# NonNative Spp	# Spp	NonNative Cover (% of Total Cover)	Plot Species Richness[a]
Prairie Dog Town*		68.5	0.0	94.5	163.0	15.0	2.0	18.0	25.7	45.0
Riparian Forest*		145.0	0.0	23.0	168.0	8.0	6.0	14.0	70.4	25.0
Ponderosa Pine Forest/Woodland	average	78.8	3.5	3.5	96.0	13.0	3.7	16.7	33.6	149.0
	min	58.0	2.0	2.0	61.0	10.0	2.0	12.0	14.0	
	max	91.5	4.5	4.5	130.0	18.0	5.0	23.0	61.1	

[1] Symstad, A. J., C. L. Wienk, and A. Thorstenson. 2006. Field-based evaluation of two herbaceous plant community sampling methods for long-term monitoring in northern Great Plains national parks. Open-File Report 2006-1282. U.S. Geological Survey: Helena, MT. 38 pp. plus 33 appendices.

[a] The species richness reported here is the total number of species found using both methods (point intercept and ocular) from the entire plot (1000m^2).

*Only one plot was used for Prairie Dog Town and Riparian Forest vegetation types using the point-intercept method in Symstad et al. (2006), whereas the Ponderosa Pine Forest/Woodland vegetation type had three different plots in DETO.

Appendix C. Mean percentage and range (in parentheses) of variables descriptive of vegetation in vegetation type sampled in Symstad et al. (2006[1]). Note: These are means and ranges for all NPS units in the study (Agate Fossil Beds National Monument, DETO, Fort Laramie National Historic Site, Theodore Roosevelt National Park, and Wind Cave National Park).

Vegetation Type	Graminoid Cover (%)	Forb Cover (%)	Shrub Cover (%)	Total Cover (%)	Nonnative Cover (% of Total Cover)	Plot Species Richness	Cover of an individual species (%)	Median Species Cover (%)
Badlands/Sparse	28 (16–36)	10 (2–19)	15 (4–33)	54 (36–70)	3 (0–14)	67 (40–88)	1.28 (0.02–23)	0.3
Prairie Dog Town	34 (6–55)	75 (16–120)	5 (0–15)	104 (71–126)	15 (0–32)	50 (45–56)	2.92 (0.02–39)	0.31
Riparian Forest	107 (80–136)	30 (2–57)	14 (0–46)	154 (83–201)	64 (31–86)	49 (25–78)	4.84 (0.02–82)	0.85
Grassland	78 (40–115)	17 (2–31)	9 (0–53)	104 (58–192)	22 (0–82)	58 (29–92)	2.88 (0.02–76)	0.44
Riparian Herbaceous Wetland	107 (79–141)	39 (14–55)	1 (0–6)	147 (134–159)	22 (7–37)	31 (21–42)	7.36 (0.02–90)	1.39
Ponderosa Pine Forest/Woodland	57 (20–79)	4 (2–7)	11 (1–43)	79 (32–125)	19 (1–50)	55 (38–69)	2.18 (0.02–64)	0.3
Shrubland	78 (29–121)	14 (8–21)	41 (30–54)	133 (75–160)	31 (4–55)	62 (41–85)	3.35 (0.02–87)	0.4

[1] Symstad, A. J., C. L. Wienk, and A. Thorstenson. 2006. Field-based evaluation of two herbaceous plant community sampling methods for long-term monitoring in northern Great Plains national parks. Open-File Report 2006-1282. U.S. Geological Survey: Helena, MT. 38 pp. plus 33 appendices.

Appendix D. List of nonnative plants targeted in the 2003 Intermountain Region weed survey (Wood and Rew 2005[1]).

Species	Common Name	Mapped in 2003	State Noxious Weed List
Acroptilon repens	Russian knapweed		MT, WY
Bromus inermis	smooth brome	X	
Bromus japonicus	Japanese brome	X	
Bromus tectorum	cheatgrass	X	
Carduus nutans	musk thistle	X	WY
Cirsium arvense	Canada thistle	X	MT, WY
Cirsium vulgare	bull thistle	X	
Cynoglossum officinale	houndstongue	X	MT, WY
Euphorbia esula	leafy spurge	X	MT, WY
Hyoscyamus niger	black henbane		
Onopordum acanthium	Scotch thistle	X	WY
Salsola tragus	Russian thistle	X	
Sisymbrium altissimum	tumbleweed mustard		
Verbascum thapsus	common mullein	X	

[1] Wood, S. D. and L. J. Rew. 2005. Non-native plant survey at Devils Tower National Monument. Department of Land Resources and Environmental Sciences, Montana State University. Bozeman, MT.

Appendix E. Certified nonnative plant abundance and management categories (weedy, pest, and management priority) by species in DETO (NPS 2010[1]).

Scientific Name	Common name	Abundance U=unknown C=common	Weedy Plant?	Pest?	Management Priority
Agropyron cristatum	crested wheatgrass	U	No	No	No
Agropyron cristatum ssp. pectinatum	crested wheatgrass	U	No	No	No
Agrostis stolonifera var. *stolonifera*	creeping bentgrass	U	No	No	No
Arctium minus	common burdock	U	No	**Yes**	**Yes**
Bromus commutatus	smooth brome	C	No	No	No
Bromus inermis	smooth brome	C	**Yes**	**Yes**	**Yes**
Bromus inermis var. *inermis*	smooth brome	U			
Bromus japonicus	Japanese brome	C	**Yes**	**Yes**	**Yes**
Bromus tectorum	cheat grass	C	**Yes**	**Yes**	**Yes**
Camelina microcarpa	smallseed falseflax	U	No	No	No
Carduus nutans	musk thistle	C	**Yes**	**Yes**	**Yes**
Ceratocephala testiculata	curve-seed-butterwort	U	No	No	No
Chorispora tenella	tenella mustard	U	No	No	No
Cirsium arvense	Canada thistle	U	**Yes**	**Yes**	**Yes**
Cirsium vulgare	bull thistle		**Yes**	**Yes**	**Yes**
Conium maculatum	poison hemlock	U	**Yes**	**Yes**	**Yes**
Convolvulus arvensis	field bindweed	U	No	No	No
Cynoglossum officinale	hounds tongue	U	**Yes**	**Yes**	**Yes**
Dactylis glomerata	orchardgrass	U	No	No	No
Elymus repens	quackgrass	U	No	No	No
Eragrostis cilianensis	stinkgrass	U	No	No	No
Erysimum cheiranthoides	wormseed wallflower	U	No	No	No
Euphorbia esula	leafy spurge		**Yes**	**Yes**	**Yes**
Euphorbia esula var. *uralensis*	Russian leafy spurge	U	No	No	No
Hesperis matronalis	dames rocket	U	No	No	No
Kochia scoparia	burningbush	U	No	No	No
Logfia arvensis	field cottonrose	U	No	No	No
Malva rotundifolia	common mallow	U	No	No	No
Matricaria discoidea	pineappleweed	U	No	No	No
Medicago lupulina	black medick	U	No	No	No
Medicago sativa	alfalfa	U	No	No	No
Melilotus alba	white sweetclover	U	No	No	No
Melilotus officinalis	yellow sweetclover	C	No	No	No
Nepeta cataria	catnip	U	No	No	No
Onopordum acanthium	scotch thistle		**Yes**	**Yes**	**Yes**
Phalaris arundinacea	reed canarygrass	U	No	No	No
Phleum pratense	timothy	C	No	No	No
Plantago major	common plantain	U	No	No	No
Poa compressa	Canada bluegrass	U	No	No	No
Poa pratensis	Kentucky bluegrass	C	**Yes**	**Yes**	**Yes**
Polygonum aviculare	prostrate knotweed	U	No	No	No

[1] National Park Service (NPS). 2010. Northern Great Plains Exotic Plant Management Team, FY 2010 annual report.

Appendix E. Certified nonnative plant abundance and management categories (weedy, pest, and management priority) by species in DETO (NPS 2010). (continued)

Scientific Name	Common name	Abundance U=unknown C=common	Weedy Plant?	Pest?	Management Priority
Polygonum convolvulus	black bindweed	U	No	No	No
Rumex crispus	curly dock	U	No	No	No
Salsola tragus	Russian thistle	U	**Yes**	**Yes**	**Yes**
Setaria viridis	green bristlegrass	U	No	No	No
Stellaria media	common chickweed	U	No	No	No
Taraxacum laevigatum	rock dandelion	U	No	No	No
Taraxacum officinale	common dandelion	U	No	No	No
Thinopyrum intermedium	intermediate wheatgrass	U	No	No	No
Thlaspi arvense	field pennycress	U	No	No	No
Tragopogon dubius	yellow salsify	U	No	No	No
Trifolium repens	white clover	U	No	No	No
Verbascum thapsus	common mullein	U	**Yes**	**Yes**	**Yes**

[1] National Park Service (NPS). 2010. Northern Great Plains Exotic Plant Management Team, FY 2010 annual report.

Appendix F. Visitor statistics, DETO, 1980–2009 (NPS 2010).

	Rec. Visits	+/-	Non-Rec. Visits	Tent Campers	RV Campers	Overnight Stays
2009	391,023	54,720	2,071	7,013	6,847	13,860
2008	336,303	14,031	2,595	7,584	9,220	16,804
2007	322,272	*-13,492*	2,621	5,583	4,581	10,164
2006	335,764	*-33,811*	1,744	4,853	4,065	8,918
2005	369,575	*-16,983*	672	5,657	5,325	10,982
2004	386,558	*-9,708*	0	6,273	5,936	12,209
2003	396,266	*-8,668*	0	6,900	5,626	12,526
2002	404,934	29,338	450	6,682	5,578	12,260
2001	375,596	*-7,872*	450	6,932	4,767	11,699
2000	383,468	*-12,424*	1,456	4,748	4,390	9,138
1999	395,892	*-3,172*	1,589	8,056	5,999	14,055
1998	399,064	9,927	1,592	6,516	5,505	12,021
1997	389,137	*-47,454*	3,106	7,982	6,201	14,183
1996	436,591	16,063	2,119	9,368	6,951	16,319
1995	420,528	*-34,248*	2,391	16,468	19,010	35,478
1994	454,776	28,319	3,013	7,551	8,782	16,333
1993	426,457	*-30,802*	2,476	6,355	7,949	14,304
1992	457,259	547	3,751	6,776	9,144	15,920
1991	456,712	27,764	2,799	6,807	8,861	15,668
1990	428,948	79,732	4,355	6,297	8,012	14,309
1989	349,216	6,069	9,637	7,341	8,124	15,465
1988	343,147	15,135	4,304	8,072	7,794	15,866
1987	328,012	37,480	6,490	8,033	8,420	16,453
1986	290,532	73,745	7,616	8,265	6,556	14,821
1985	216,787	*-3,068*	8,207	7,363	7,629	14,992
1984	219,855	*-47,421*	8,240	7,112	6,736	13,848
1983	267,276	2,973	6,989	7,825	8,602	16,427
1982	264,303	*-21,007*	6,648	6,564	7,138	13,702
1981	285,310	71,618	14,998	10,266	7,675	17,941
1980	213,692	N/A	2,288	9,862	6,787	16,649
Mean	358,175	6,115	3,822	7,503	7,274	14,777

[1]National Park Service. 2010. Devils Tower - Park Statistics. Online. (http://www.nps.gov/deto/parkmgmt/statistics.htm). Accessed 5 August 2010.

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