Northwest Sands Habitat Corridor Plan

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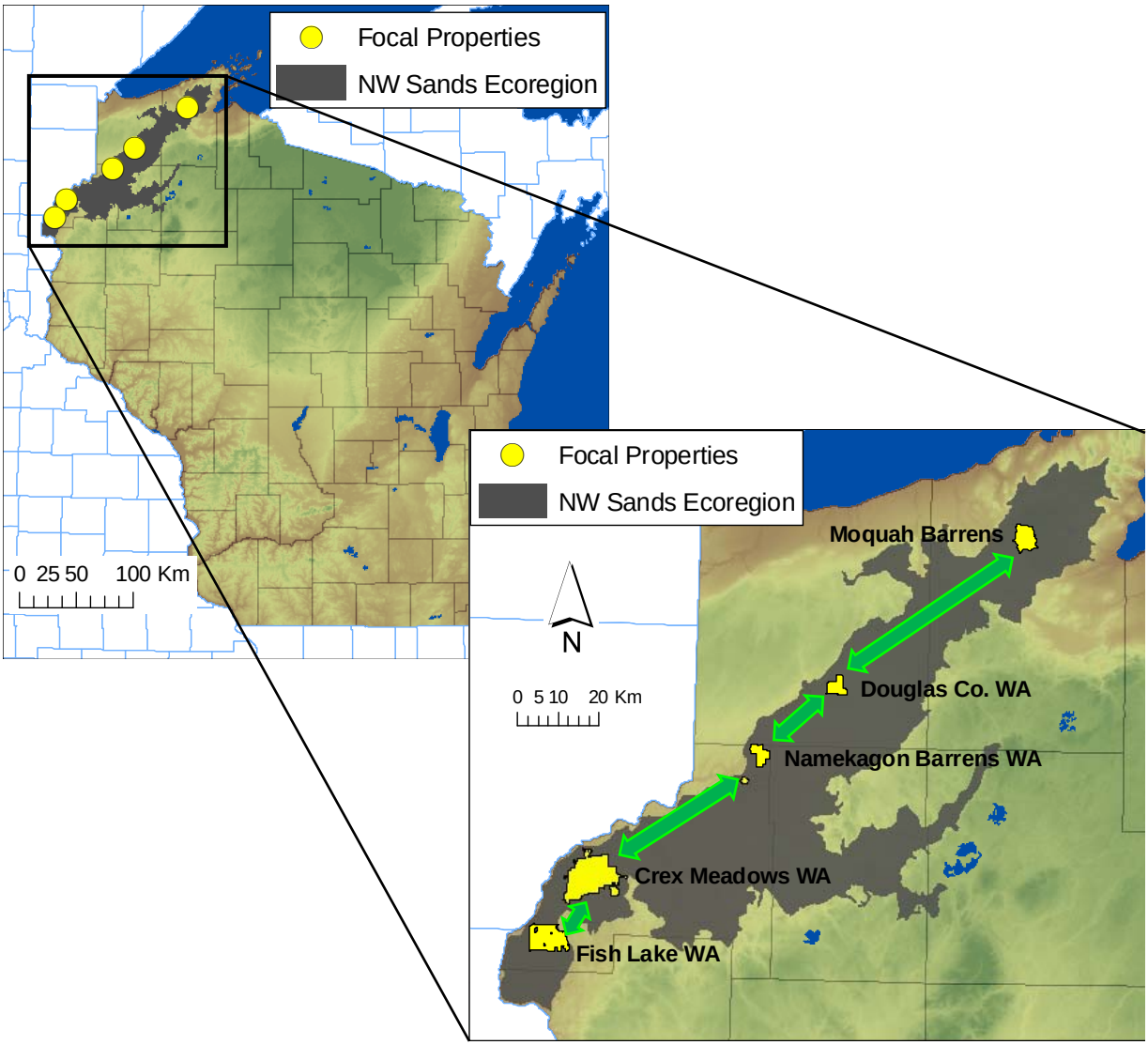

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Table of Contents

Acknowledgments i
Executive Summary ii
List of Tables iv
List of Figures v

1. Introduction: The Barrens Community, Land Use and History in the Northwest Sands 1

2. Project Justification and Goals 3
   a. Limited Distribution and Connectivity of Barrens Habitats 3
   b. Integration of Barrens Habitat Management with SGCNs 4
   c. Sharp-tailed Grouse as a Model for Long-term Management of Barrens Communities 4
   d. Overall Habitat Corridor Plan Objective 5

3. Conservation Linkage Design 7
   a. Introduction 7
   b. Land Ownership, Land Cover and Linkage Opportunities in the Northwest Sands 7
   c. Focal Properties 8
      i. Fish Lake and Crex Meadows Wildlife Areas 12
      ii. Crex Meadows and Namekagon Barrens Wildlife Areas 16
      iii. Namekagon Barrens and Douglas County Wildlife Areas 19
      iv. Douglas County Wildlife Area and Moquah Barrens 21

4. Priority Corridor Actions 27
   a. Prioritization 27
   b. Specific Management Recommendations 29
      i. Management Block Sizes 29
      ii. Distances Among Managed Blocks 30
   c. Implementation 31

Appendix A. NW Sands Species of Greatest Conservation Need 37

Appendix B. Details of the Corridor Model 38
   a. Overview of Corridor Design Toolbox 38
   b. Habitat Suitability Model 38
   c. Identifying Potential Breeding and Population Patches 46
   d. Identifying Best Corridor Options 49
   e. Sensitivity Analyses 53

Appendix C. Minimum Model Corridors 60

Literature Cited 65

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Executive Summary

Pine and Oak Barrens were once widespread in Wisconsin but are presently considered a globally significant ecosystem under the Wisconsin Wildlife Action Plan (WAP). Many wildlife Species of Greatest Conservation Need (SGCN) that depend on these habitats have experienced population declines and range contractions within the barrens ecosystem largely as a result of habitat loss, land-use change, fire suppression and habitat fragmentation. As a result, several exist in a series of largely unconnected subpopulations within the Northwest Sands Ecological Landscape of northwestern Wisconsin.

Protection and management of traditional Pine and Oak Barrens habitat largely has been maximized within the boundaries of DNR-controlled properties within the Northwest Sands. However, remaining Pine and Oak Barrens fragments in northwestern Wisconsin are potentially too small and isolated to ensure the long-term viability of species native or characteristic of this ecosystem. Maintenance of viable wildlife populations within the barrens community requires a landscape-scale approach and opportunities for the development of habitat corridors or stepping stones to facilitate dispersal between existing barrens habitat patches.

Plan Objective

This project uses biologically-driven data to identify barrens habitat restoration opportunities within the Northwest Sands and potential habitat corridors or stepping stones between existing barrens habitat patches, with the ultimate goal of benefitting barrens-dependent SGCNs.

Plan Structure

This plan has three main components. The first describes the natural history of the Northwest Sands, the need for the plan, and our specific objectives. The second component describes the basis of the linkage design, landscape characteristics relevant to the model, choice of model species, and basic corridor output. The third component includes recommendations for priority management areas and actions (size and location of potential habitat blocks) to improve linkage in the Northwest Sands. The plan also includes appendices that provide supporting information for plan goals and specific details on corridor model output and development.

Plan Methodology

We used ArcGIS and the program Corridor Design Toolbox to develop a habitat corridor model to identify potential linkages among five globally important Barrens Conservation Opportunity Areas (COA) in the Northwest Sands as identified by the Wisconsin WAP. Our habitat corridor plan was built around the habitat needs and configuration of sharp-tailed grouse (*Tympanuchus phasianellus campestris*) using available data from the literature. Because of their area sensitivity and requirements of large blocks of habitat, focusing a habitat corridor model on the needs of sharp-tailed grouse should also provide suitable habitat for most other SGCNs.

We used three GIS raster vegetation data layers from the LANDFIRE mapping program to develop a habitat suitability model by determining the quality of individual classifications in

each data layer to sharp-tailed grouse. Classifications were based on sharp-tailed grouse literature and expert opinion. The resulting habitat suitability model was used to locate potential habitat patches large enough to support breeding or year-round populations of sharp-tailed grouse. The habitat suitability model was also used to generate a cost grid that represented the permeability of the landscape to movement by sharp-tailed grouse. This grid was used to generate corridor slices between pairs of COAs. Recommended corridors were chosen based on corridor slices that met habitat requirements of sharp-tailed grouse. We present corridors and describe property management patterns, soil characteristics and potential barriers to movement for each pair of COAs. Finally, results of a sensitivity analysis suggested that our model was robust to uncertainty in factor weights and that parameterization of our original model was appropriate.

Plan Action Items

Our model produced corridor options for linking pairs of focal properties in the Northwest Sands using the best biological information available. We classified three priority tiers for habitat corridor actions based on size and status of sharp-tailed grouse subpopulations, distance between core populations, and likelihood of creating additional habitat between core properties. Tier A includes the area between Namekagon Barrens (NBWA) and Douglas County (DCWA) Wildlife Areas. Tier B includes the areas between 1) Crex Meadows Wildlife Area (CMWA) and NBWA, and 2) Bayfield County Rolling Barrens (BCRB) and DCWA. Tier C includes the areas between 1) Fish Lake Wildlife Area and CMWA, and 2) Moquah Barrens and BCRB. Work in all areas is encouraged but we recommend resources, if limited, be concentrated in Tier A with continued barrens management within all focal property boundaries.

We developed recommendations for two habitat block options: 1) permanent barrens habitat patches ≥1280 acres, and 2) temporarily-open rolling barrens habitat patches made up of a 500-1000 acre core surrounded by 500-1000 acres of rolling barrens. We recommend a 5 km (3.1 miles) distance between habitat patches or stepping stones within a larger habitat corridor design. Habitat work should first focus on management opportunities nearest core properties. Additional habitat stepping stones may then be established farther along the corridor between property pairs until linkage is achieved.

Determining where to focus limited financial and logistical resources will be paramount to successful conservation of sharp-tailed grouse, barrens-dependent species, and the Pine Barrens habitats. Our corridor models represent an important step and useful tool in determining important foci for management resources in the Northwest Sands. This habitat corridor plan also addresses specific habitat components in the statewide Sharp-tailed Grouse Conservation and Management Plan.

List of Tables

TABLE 3-1. Summary of metrics of recommended corridors for pairs of focal properties 25

TABLE 3-2. Percent of vegetation classifications within recommended corridors between focal property pairs 25

TABLE 3-3. Amount of land in recommended corridors occurring outside of focal properties (matrix) and percent of each corridor in public management. 26

TABLE 3-4. Percent of SSURGO soil drainage types in recommended corridors 26

TABLE B-1. Suitability scores of LANDFIRE Existing Vegetation Type classifications for sharp-tailed grouse. 56

TABLE B-2. Suitability scores of LANDFIRE Existing Vegetation Cover classifications for sharp-tailed grouse 57

TABLE B-3. Suitability scores of LANDFIRE Existing Vegetation Height classifications for sharp-tailed grouse 58

TABLE B-4. Weights for LANDFIRE habitat factors input in the habitat suitability model 58

TABLE B-5. Summary statistics of recommended corridors for sharp-tailed grouse to link NW Sands focal properties. 59

TABLE C-1. Summary of metrics of minimum corridors for pairs of focal properties. Length and width is given in meters 63

TABLE C-2. Percent of vegetation classifications within minimum corridors between focal property pairs 63

TABLE C-3. Amount of land in minimum corridors occurring outside of focal properties (matrix) and percent of each corridor in public management. 64

TABLE C-4. Percent of SSURGO soil drainage types in minimum corridors 64

List of Figures

FIGURE 2-1: Pine-Oak Barrens Conservation Opportunity Areas in the Northwest Sands. 6

FIGURE 3-1. Location of select focal properties in the Northwest Sands..... 8

FIGURE 3-2. Existing public property management, topography, water bodies, and roads between Fish Lake and Crex Meadows Wildlife Areas. 9

FIGURE 3-3. Existing public property management, topography, water bodies, and roads between Crex Meadows and Namekagon Barrens Wildlife Areas. 10

FIGURE 3-4. Existing public property management, topography, water bodies, and roads between Namekagon Barrens and Douglas County Wildlife Areas. 10

FIGURE 3-5. Existing public property management, topography, water bodies, and roads between Douglas County Wildlife Area and Moquah Barrens. 11

FIGURE 3-6. LANDFIRE vegetation type classifications within the recommended corridor between Fish Lake and Crex Meadows Wildlife Areas 13

FIGURE 3-7. Recommended linkage between Fish Lake and Crex Meadows Wildlife Areas showing all publicly-managed properties in the map area 14

FIGURE 3-8. SSURGO soil drainage classifications within the recommended corridor between Crex Fish Lake and Crex Meadows Wildlife Areas. 15

FIGURE 3-9. LANDFIRE vegetation type classifications within the recommended corridor between Crex Meadows and Namekagon Barrens Wildlife Areas. 16

FIGURE 3-10. Recommended linkage between Crex Meadows and Namekagon Barrens Wildlife Areas showing all publicly-managed properties in the map area. 17

FIGURE 3-11. SSURGO soil drainage classifications within the recommended corridor between Crex Meadows Wildlife and Namekagon Barrens Wildlife Areas 18

FIGURE 3-12. LANDFIRE vegetation type classifications within the recommended corridor between Namekagon Barrens and Douglas County Wildlife Areas. 19

FIGURE 3-13. Recommended linkage between Namekagon Barrens and Douglas County Wildlife Areas showing all publicly-managed properties in the map area. 20

FIGURE 3-14. SSURGO soil drainage classifications within the recommended corridor between Namekagon Barrens and Douglas County Wildlife Areas 21

FIGURE 3-15. LANDFIRE vegetation type classifications within the recommended corridor between Douglas County Wildlife Area and Moquah Barrens. 22

FIGURE 3-16. Recommended linkage between Douglas County Wildlife Area and Moquah Barrens showing all publicly-managed properties in the map area. 23

FIGURE 3-17. SSURGO soil drainage classifications within the recommended corridor between Douglas County Wildlife Area and Moquah Barrens 24

FIGURE 4-1. Prioritization of linkage opportunities in the Northwest Sands. 27

FIGURE 4-2. Location of Barnes Barrens Management Area (Bayfield Rolling Barrens) between Douglas County Wildlife Area and Moquah Barrens. 30

FIGURE 4-3. Hypothetical management blocks or "stepping stones" in the Priority A area between Namekagon Barrens and Douglas County Wildlife Areas 32

FIGURE 4-4. Hypothetical management blocks or "stepping stones" in the Priority B area between Crex Meadows and Namekagon Barrens Wildlife Areas. 33

FIGURE 4-5. Hypothetical management blocks or "stepping stones" in the Priority B area between Douglas County Wildlife Area and the Bayfield Rolling Barrens 34

FIGURE 4-6. Hypothetical management blocks or "stepping stones" in the Priority C area between Bayfield Rolling Barrens and Moquah Barrens 35

FIGURE 4-7. Location of storm damage from July 1, 2011 in Douglas County. 36

FIGURE B-1. LANDFIRE Existing Landcover Type for the Northwest Sands 40

FIGURE B-2. LANDFIRE Existing Vegetation Cover for the Northwest Sands. 41

FIGURE B-3. LANDFIRE Existing Vegetation Height for the Northwest Sands 42

FIGURE B-4. Habitat suitability for Fish Lake and Crex Meadows Wildlife Areas. 44

FIGURE B-5. Habitat suitability for Crex Meadows and Namekagon Barrens Wildlife Areas. 45

FIGURE B-6. Habitat suitability for Namekagon Barrens and Douglas County Wildlife Areas. ... 45

FIGURE B-7. Habitat suitability for Douglas County Wildlife Area and Moquah Barrens. 46

FIGURE B-8. Potential habitat patches between Fish Lake and Crex Meadows Wildlife Areas. . 47

FIGURE B-9. Potential habitat patches between Crex Meadows and Namekagon Barrens Wildlife Areas. 48

FIGURE B-10. Potential habitat patches between Namekagon Barrens and Douglas County Wildlife Areas. 48

FIGURE B-11. Potential habitat patches between Douglas County Wildlife Area and Moquah Barrens. 49

FIGURE B-12. Cost grid layer for Crex Meadows and Fish Lake Wildlife Areas. 50

FIGURE B-13. Cost grid layer for Crex Meadows and Namekagon Barrens Wildlife Areas 50

FIGURE B-14. Cost grid layer for Namekagon Barrens and Douglas County Wildlife Areas..... 51

FIGURE B-15. Cost grid layer for Douglas County Wildlife Area and Moquah Barrens 51

FIGURE B-16. Cost grid map within the corridor representing the most permeable 2.0% of the landscape from A) Crex Meadows to Namekagon Barrens and B) Namekagon Barrens to Douglas County Wildlife Areas..... 52

FIGURE B-17. Example of four corridor slices between Namekagon Barrens and Douglas County Wildlife Areas 53

FIGURE B-18. Results of sensitivity analysis for alternative corridor models..... 54

FIGURE C-1. Minimum linkage between Fish Lake and Crex Meadows Wildlife Areas showing all publicly-managed properties in the map area..... 60

FIGURE C-2. Minimum linkage between Crex Meadows and Namekagon Barrens Wildlife Areas showing all publicly-managed properties in the map area. 61

FIGURE C-3. Minimum linkage between Namekagon Barrens and Douglas County Wildlife Areas showing all publicly-managed properties in the map area. 61

FIGURE C-4. Minimum linkage between Douglas County Wildlife Area and Moquah Barrens showing all publicly-managed properties in the map area. 62

1. Introduction: The Barrens Community, Land Use and History in the Northwest Sands

Pine and oak barrens historically covered nearly one million hectares in Wisconsin (2.3 million acres), or 7% of the state's pre-European settlement landscape (Curtis 1959, WDNR *in prep*). In addition, other early successional habitats at this time were much more widespread and were estimated to cover more than 13% of northern Wisconsin. However, today barrens are uncommon and isolated, with 1995 estimates of approximately 4,000 hectares (10,000 acres) of quality pine and oak barrens remaining at 65 sites (WDNR *in prep*), with another 20,240 hectares (50,000 acres) of severely degraded barrens (Mossman et al. 1991, Eckstein and Moss 1995, WDNR *in prep*). Other estimates indicate that ultimately less than 1% of the original barrens distribution remains; as a result, these pine and oak barrens ecosystems are now considered a ***globally significant ecosystem*** under the Wisconsin Wildlife Action Plan (WDNR 2005). With this designation, the WDNR has made the pine and oak barrens a priority for landscape-scale management (Borgerding et al. 1995).

Pine and Oak Barrens ecosystems are fire-adapted savanna systems typically occurring on poor-quality, sandy, glacial outwash soils and dominated by grasses, low-growing shrubs and trees, and scattered large trees (Curtis 1959, WDNR 2005) with canopy cover typically between 5 and 60%, with or without a shrub layer (Kost et al. 2007). Barrens communities, such as those found in northwestern Wisconsin, are dynamic in nature and often variable in species composition and vegetative structure; as a result, they are often difficult to classify.

A consistent historical element in the barrens communities was the dependence on fire as a major disturbance mechanism that maintained the integrity as well as the structural and compositional variability of the barrens ecosystem. Many of the plants and animals inhabiting the barrens landscape have evolved to live within this fire-dependent ecosystem, but have nevertheless also experienced declines with the disappearance of barrens over time. Today, there is great concern that most of the remaining pine and oak barrens fragments are simply too small and isolated to ensure the long-term viability of all species native or characteristic of this ecosystem.

Geographically, the larger barrens complexes historically were concentrated in northwestern, northeastern, north central, and central Wisconsin. In the late 1800s, European

settlers began logging white and red pine across the northern third of Wisconsin. Cleared lands were often converted to agricultural production. Early on, slash from timber harvest operations fueled extensive fires. Until the 1930s, these fires, logging operations, and farm settlement were responsible for opening the landscape. As timber resources became scarce and farmers abandoned their nutrient-drained fields, much of the land was abandoned and began to revert back to forest. Land often fell into county, federal (U.S. Forest Service) or private industrial forest ownership/management. Fire suppression and tree planting practices soon also took hold, as did increases in housing development pressures and second/recreation homes (Radeloff 1999). Today, pine and oak barrens ecosystems in Wisconsin are quite rare and extremely fragmented. Those that persist often do so deliberately via management by prescribed fire or timber harvest, or accidentally via the occasional wildfire, wind/blowdown event, or disease outbreak. However, as Niemuth and Boyce (1997) noted: "Whether created by prescribed fire or timber harvest, virtually all openings within the region are sharply bounded by standing timber," which continues to pose significant, long-term management challenges for this globally important ecosystem.

2. Project Justification and Goals

a. Limited Distribution and Connectivity of Barrens Habitats

While preserving existing and increasing the amount of barrens habitat is needed in NW Wisconsin to maintain viable wildlife populations, there is also a pressing need to develop habitat corridors or stepping stones to facilitate dispersal between existing barrens habitat patches (WDNR 2005, Fandel and Hull 2011). However, relatively little is known about the minimum patch size and distribution required by many barrens Species of Greatest Conservation Need (SGCN) in order to provide effective dispersal corridors between core Pine Barrens habitat areas (PBHA), especially for sharp-tailed grouse. This gap in knowledge becomes even more complex when considering the habitat needs and patch size for the many SGCN that this project targets.

Traditional Pine Barrens habitat has been maximized within the boundaries of DNR-controlled properties within the Northwest Sand, particularly in Douglas and Bayfield Counties. This leaves the potential for some SGCN to become genetically isolated. This project attempted to use biologically-driven data to help identify and prioritize where additional barrens-focused management should take place on the landscape, with the ultimate goal of benefitting barrens-dependent SGCN. A key strategy used in the development of this plan was identifying likely linkages between existing barrens habitats, thereby providing habitat corridors between currently managed barrens properties.

In addition, The Wisconsin Wildlife Action Plan – Implementation Plan has identified several statewide priorities related to Pine Barrens ecosystems in the NW Sands. These include:

1. *Implement the Northwest Sands Integrated Ecosystem Management Plan to manage the full range of barrens succession stages and diverse habitats in a landscape context. A comprehensive landscape plan requires identification and management of early succession cores. The "barrens" also needs to have places managed in a shifting mosaic of timber harvest with many clearcuts, some older than rotation-age stands, some thinning of stands for savanna structure and a few protected groves. Many stands should be thinned to a safe amount of*

residual standing timber then burned for stand regeneration while leaving charred legacies. Manage shallow publicly-owned lakes by maintaining open shorelines. To enhance landscape attributes, red pine plantations can be applied to appropriate sites where the historic fire regime indicates groves occurred.

2. *Identify additional sites containing high quality or restorable barrens.*
3. *Integrate planning efforts across federal, state, county, local and industrial ownership boundaries.*

b. Integration of Barrens Habitat Management with SGCNs

Several wildlife species are dependent on the Pine Barrens Ecosystem in the Northwest Sands Ecological Landscape. We focus on 24 Species of Greatest Conservation Need identified in the Wisconsin Wildlife Action Plan (WDNR 2005) in the Northwest Sands Ecological Landscape (Appendix A) that are dependent on Pine-Oak Barrens ecosystems for most or all for their life-cycles.

Many of these species have experienced population declines and range contractions with the Pine-Oak Barrens ecosystem largely as a result of habitat loss, land-use change, fire suppression and habitat fragmentation (WDNR, *in prep*). As a result, several of these species exist in a series of largely unconnected patches or subpopulations within the Northwest Sands Ecological Landscape. This further exacerbates population declines, range contractions, and may lead some species into a phenomenon known as the extinction vortex (Lande et al. 2003).

c. Sharp-tailed Grouse as a Model for Long-term Management of Barrens Communities

One example of a species experiencing significant population challenges is the sharp-tailed grouse (*Tympanuchus phasianellus campestris*). As a result of landscape scale changes in barrens habitat availability and configuration sharp-tailed grouse have exhibited severe population declines and range contractions throughout Wisconsin but particularly in the Northwest Sands.

Sharp-tailed grouse use a variety of habitat types in Wisconsin including brush prairie, barrens, cut or burned-over forestland, wet meadows, pine/oak savannah, mixed deciduous-

conifer forest, and abandoned farmland (Sample and Mossman 1997, Evrard et al. 2000, Gregg and Niemuth 2000, Niemuth 2006). However, they are area-sensitive and require large open blocks of early successional habitat to support viable populations (Gregg 1987, Temple 1992, Sample and Mossman 1997, Connelly et al. 1998, Niemuth and Boyce 2004, Niemuth 2006). In Minnesota, blocks of contiguous habitat must be at least 5 km^2, and complexes of inter-connected smaller areas must contain parcels of at least 0.15 km^2 (Berg 1997). However, the exact amount of habitat needed to sustain a viable population likely varies by ecological landscape and state.

Prior to European settlement, habitat for sharp-tailed grouse in the Upper Great Lakes region included Pine Barrens, burned forest areas, brushy grasslands in the prairie-to-forest transition zone and non-forested wetlands. Sharp-tailed grouse populations expanded and contracted in response to natural disturbance events such as fire (Ammann 1957, Sjogren and Corace 2006). At this time early successional habitat was widespread.

Since sharp-tailed grouse is an area-sensitive species, there is concern that many of the remaining habitat patches are not large enough to sustain a viable grouse population in the long-term. Additionally, the scattered distribution of remaining suitable habitat limits the dispersal and movement of sharp-tailed grouse among habitat patches. As a result, sharp-tailed grouse dispersal appears to be limited by significant habitat barriers, additionally impacting any genetic exchange among subpopulations. Dispersal among habitat patches and colonization of new habitat is likely necessary to maintain overall population size and genetic viability in the long-term (Fandel and Hull 2011). Given that there are multiple landowners across the landscape, there is a significant challenge in managing for sharp-tailed grouse habitat on the landscape scale.

d. Overall Habitat Corridor Plan Objective

The objectives of this project are to identify barrens habitat restoration opportunities within the Northwest Sands Ecological Landscape and to identify opportunities to create habitat corridors or stepping stones between existing barrens habitat patches.

Further, the Wisconsin WAP (WDNR 2005) has also identified five globally important Barrens Conservation Opportunity Areas (COA; Figure 2-1). This habitat corridor plan will

identify specific strategies and opportunities for linking those COAs and provide corridors that facilitate movement and gene flow between COAs for several SGCNs but focusing on sharp-tailed grouse.

This habitat corridor plan is built around the habitat needs and configuration of sharp-tailed grouse and is data-based. Because of their area sensitivity and requirements of large blocks of habitat, focusing a habitat corridor model on the needs of sharp-tailed grouse should also provide suitable habitat for most other SGCNs (for additional discussions see part 3d). This habitat corridor plan also addresses specific habitat components in the Statewide Sharp-tailed Grouse Conservation and Management Plan (Fandel and Hull 2011).

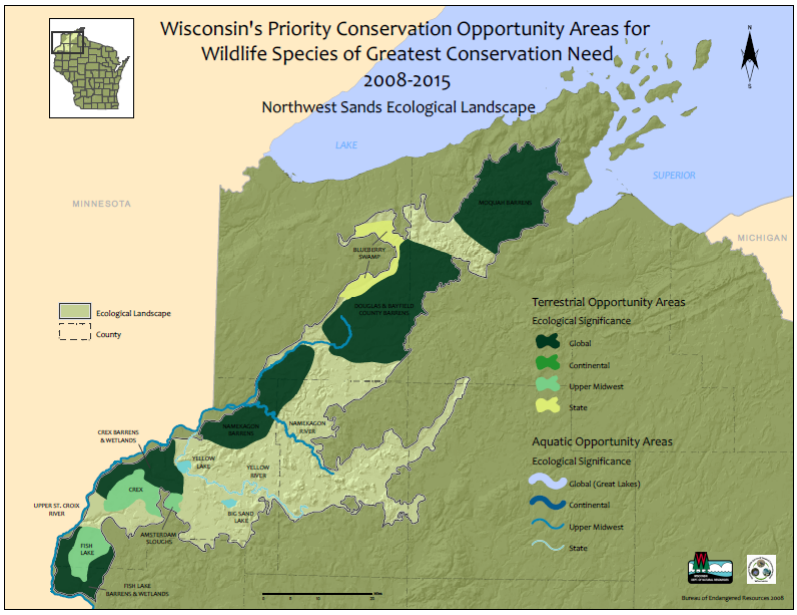

FIGURE 2-1: Pine-Oak Barrens Conservation Opportunity Areas within the Northwest Sands Ecological Landscape.

3. Conservation Linkage Design

a. Introduction

We discuss corridor linkages developed using a GIS-based habitat model that is data-based. Our model does not represent an absolute solution to habitat linkage challenges in the Northwest Sands and we recognize that restoring and managing all of land along a corridor's path is not possible. Rather, our corridor models represent an important step and useful tool in determining important foci for management resources in the Northwest Sands. The model aims at linking properties for all barrens-dependent species by using sharp-tailed grouse as an umbrella species (see below). We are focusing on distinct issues for sharp-tailed grouse in another research project by using GIS and historical grouse survey data to describe relationships between landscape patterns (i.e., fires, clearcutting) and lek persistence at large scales. Therefore, the corridor plan we describe merges with ongoing research because we are addressing two key areas related to conservation of sharp-tailed grouse: improving habitat availability and linkages (corridor plan) and determining how landscape patterns predict sharp-tailed grouse persistence (ongoing research). We focus on the corridor model in this report in describing potential opportunities for improving linkage in the Northwest Sands to benefit all barrens-dependent species.

b. Land Ownership, Land Cover and Linkage Opportunities in the Northwest Sands

Approximately 730,000 acres of the more than 1,250,000 acres of the Northwest Sands are privately-owned (USGS 2011). However, there are many opportunities for conservation and linkage of populations of barrens-dependent species in the Northwest Sands. For instance, approximately 507,000 acres (40.5%) of the Northwest Sands is owned by county, state, federal or public entities, with county forests currently constituting the highest proportion (23%). Some of these county forests do not currently represent quality barrens habitat for many of the Northwest Sands species, yet represent excellent opportunities for the linkage of properties where barrens habitat is actively managed. Indeed, the best remaining barrens habitat consistently occurs on state-owned or managed properties. These properties provide important habitat for many SGCNs in Wisconsin. Therefore, our corridor design focuses on

select state-managed properties in the Northwest Sands to provide the best opportunities for conserving and facilitating movement for barrens-dependent species.

Landcover in the Northwest Sands (Figure B-1, Table B-1) is dominated by hardwood and conifer forests, particularly Northern Hardwoods Forests (29%), Laurentian-Acadian Northern Pine Forest (8.7%), and Boreal White Spruce-Fir-Hardwood Forest (5.3%). Laurentian Pine-Oak Barrens are also well-represented in the landscape (29.1%), particularly between state-managed wildlife areas. Furthermore, northwestern Wisconsin has comparatively fewer developed areas than other regions of the state that could further impede movement or reduce opportunities for habitat management. As a result, the Northwest Sands provides a unique opportunity to improve linkage of populations of barrens-dependent species.

c. Focal Properties

We chose to model linkages in the Northwest Sands between five focal properties (Figure 3-1) where habitat is managed for open barrens and savanna habitats. Four of the areas

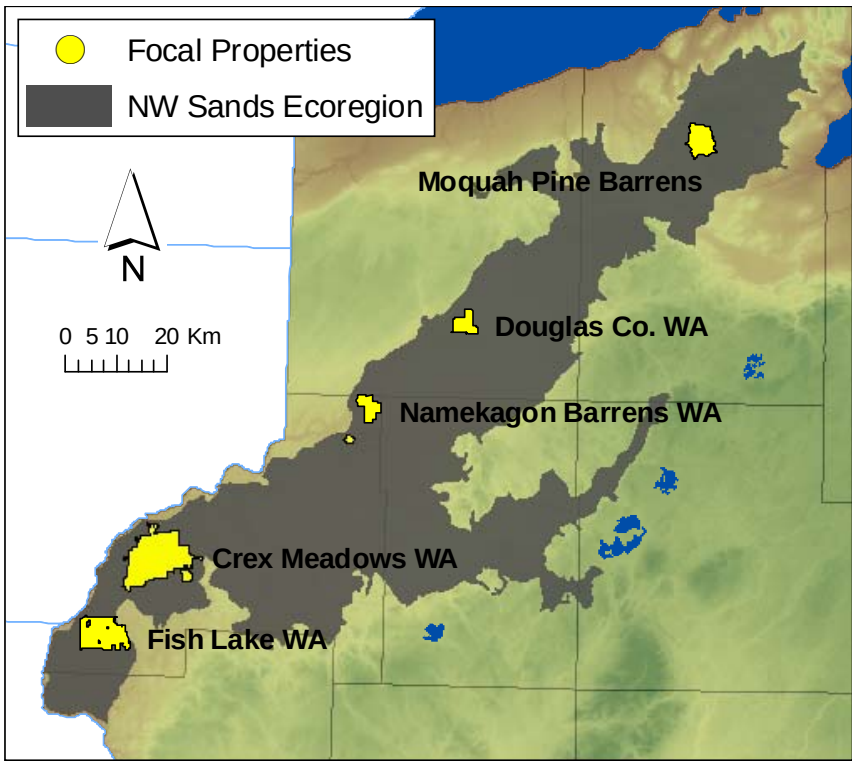

FIGURE 3-1. Location of select focal properties in the Northwest Sands Ecological Landscape.

are managed by the Wisconsin DNR while Moquah Barrens is managed by the U.S. Forest Service. These properties contain habitat for many of the remaining populations of sharp-tailed grouse in the state of Wisconsin. Focal properties included are (from west to east): Fish Lake Wildlife Area, Crex Meadows Wildlife Area, Namekagon Barrens Wildlife Area, Douglas County Wildlife Area and Moquah Barrens. Three of these properties currently hold year-round populations of sharp-tailed grouse. Fish Lake has had infrequent observations of dancing sharp-tailed grouse but no consistent leks. Sharp-tailed grouse once were fairly common at Moquah Barrens in the 1980s-90s but populations have since declined precipitously. Corridors were developed for pairs of neighboring properties. Opportunities for linkage vary between focal property pairs (Figures 3-2 to 3-5) based on land ownership and management, landcover, proximity, movement barriers, and other factors that may affect 1) permeability of the landscape to sharp-tailed grouse movement (see Appendix B) and 2) opportunities for barrens habitat management outside of focal properties to improve habitat connectivity in the Northwest Sands.

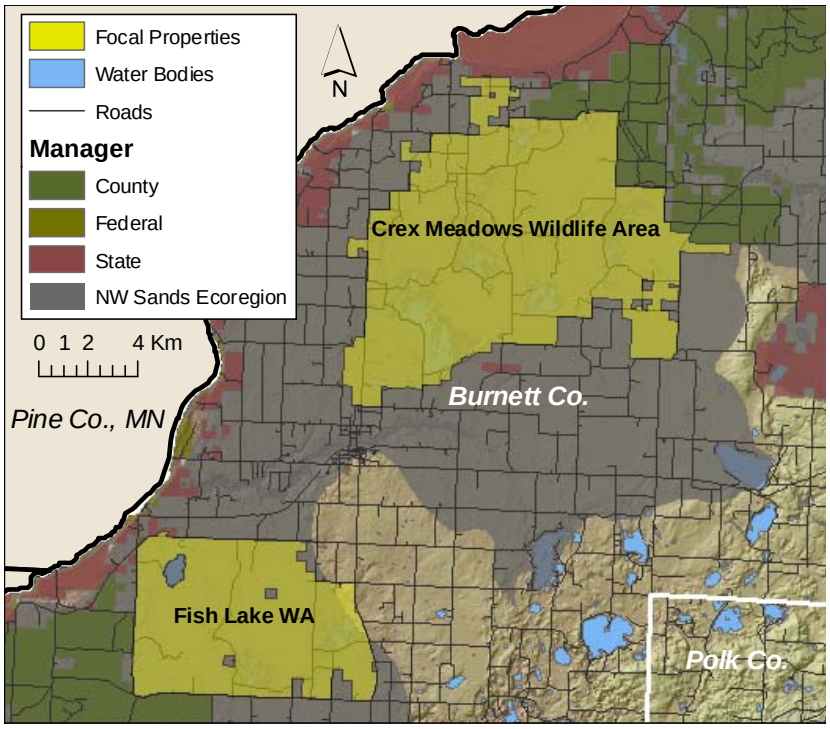

FIGURE 3-2. Existing public property management, topography, water bodies, and roads between Fish Lake and Crex Meadows Wildlife Areas.

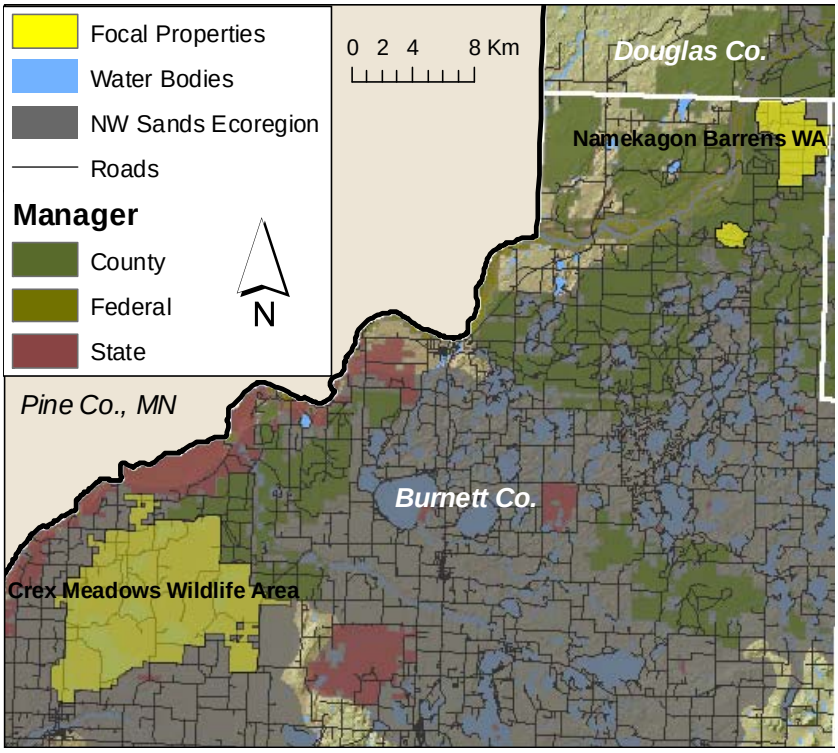

FIGURE 3-3. Existing public property management, topography, water bodies, and roads between Crex Meadows and Namekagon Barrens Wildlife Areas.

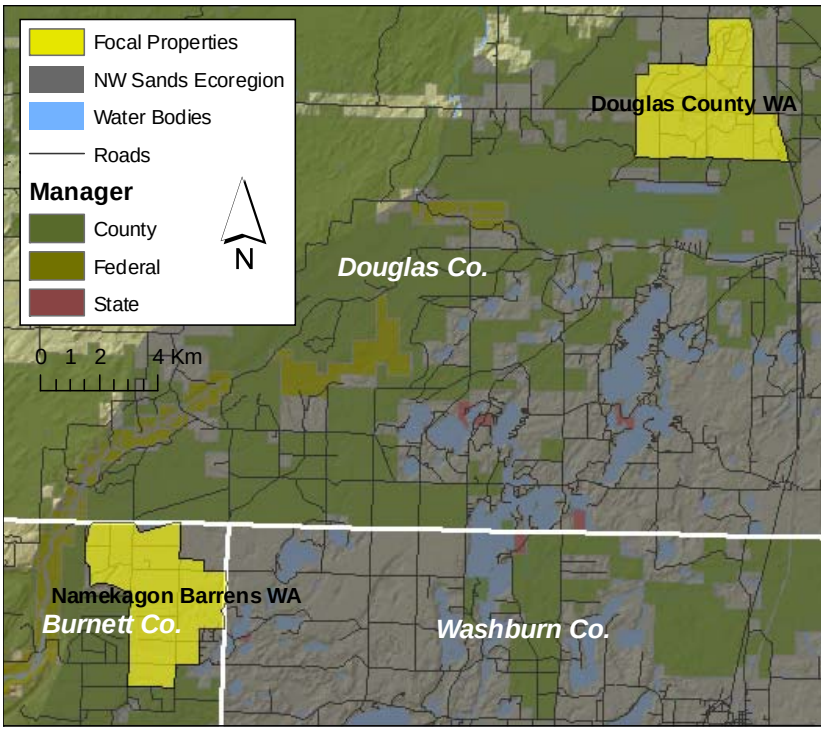

FIGURE 3-4. Existing public property management, topography, water bodies, and roads between Namekagon Barrens and Douglas County Wildlife Areas.

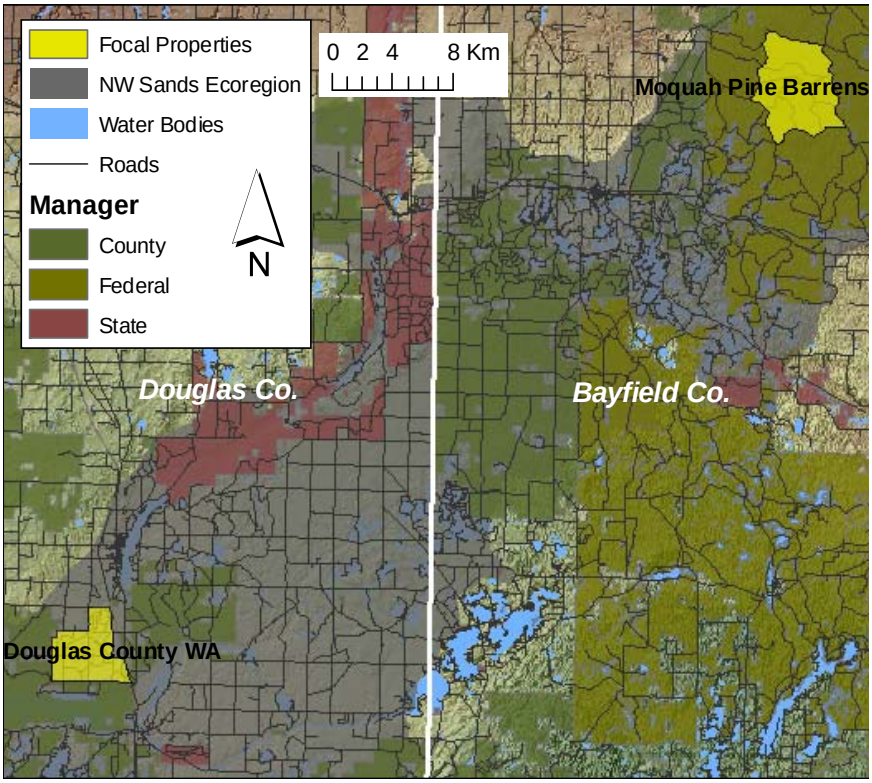

FIGURE 3-5. Existing public property management, topography, water bodies, and roads between Douglas County Wildlife Area and Moquah Barrens.

d. Choice of Model Species

We used sharp-tailed grouse as an "umbrella" species (Caro and O'Doherty 1999) to represent the barrens-dependent species of northwestern Wisconsin in our corridor model. We chose sharp-tailed grouse for many reasons: 1) it is listed as a Species of Greatest Conservation in Wisconsin, 2) it uses multiple habitat types within the ecological landscape depending on the season 3) its range is large compared to other barrens-dependent species and thus is more susceptible to changes in barrens habitat availability, 4) it has experienced declines and range reduction over the past century, and 5) it has shown to be experiencing genetic isolation in addition to range contraction (Fandel and Hull 2011), likely due to lack of immigration and emigration among subpopulations. Therefore, sharp-tailed grouse requires large or well-connected landscapes to maintain long-term population viability.

Various subspecies of sharp-tailed grouse have been found to fly long distances over short time periods (Snyder 1935, Baumgartner 1939, Hamerstrom 1939, Aldous 1943, Meints 1991). However, most records are of historical grouse populations. We have noted no long distance movements from May 2010 to present of 39 radio-collared birds at Namekagon Barrens and Crex Meadows Wildlife Areas (S. Hull, unpubl. data.). Furthermore, sharp-tailed grouse are likely similar to other bird species that are strongly affected by the composition of the landscape matrix that is located between habitat patches (Bush et al. 2011, Kennedy et al. 2011). Therefore, we believe that due to their larger habitat needs and the factors listed above, effective conservation of sharp-tailed grouse will also protect the community of barrens-dependent species of the Northwest Sands.

e. Habitat Linkage Designs for Focal Properties

For each property pair we present a recommended linkage. Corridors provide movement and potential stable habitat patches for sharp-tailed grouse. Our recommended corridor between each focal property pair has a width that meets the recommended habitat block size (5.2km^2 or 1280ac) for sharp-tailed grouse (Berg 1997, USDA 1999; Table B-5). This recommended block size corresponds to a corridor that is 2275m wide. Corridors extend from suitable habitat patches within each focal property through the joining matrix. Therefore, corridors do not simply extend from the edge of one focal property to the next, but have termini capped with appropriate habitat for sharp-tailed grouse. We also describe property management patterns, soil characteristics and potential barriers to movement for each pair. Where relevant we discuss the potential for establishment of temporary or permanent pine-barrens habitats along corridors.

i. **Fish Lake and Crex Meadows Wildlife Areas**

The model produced a recommended corridor between Fish Lake Wildlife Area (FLWA) and Crex Meadows Wildlife Area (CMWA) that is relatively short, small and straight (Table 3-1). It includes 1320ac of the northernmost portion of FLWA and extends north-northeast into the southeastern 3882ac of CMWA.

The recommended corridor is primarily composed of Laurentian Pine-Oak Barrens (38.7%), Laurentian-Acadian Shrub-Herbaceous Wetland (18.5%), Laurentian-Acadian Northern Hardwoods Forest (9.1%), Laurentian-Acadian Northern Pine Forest (6.1%) and Recently Logged Herb and Grass Cover (4.6%; Table 3-2). The Pine-Oak Barrens are located in large blocks throughout the corridor (Figure 3-6). Hardwood habitats are scattered within the corridor but likely do not occur in significant blocks to limit movement of barrens-dependent species.

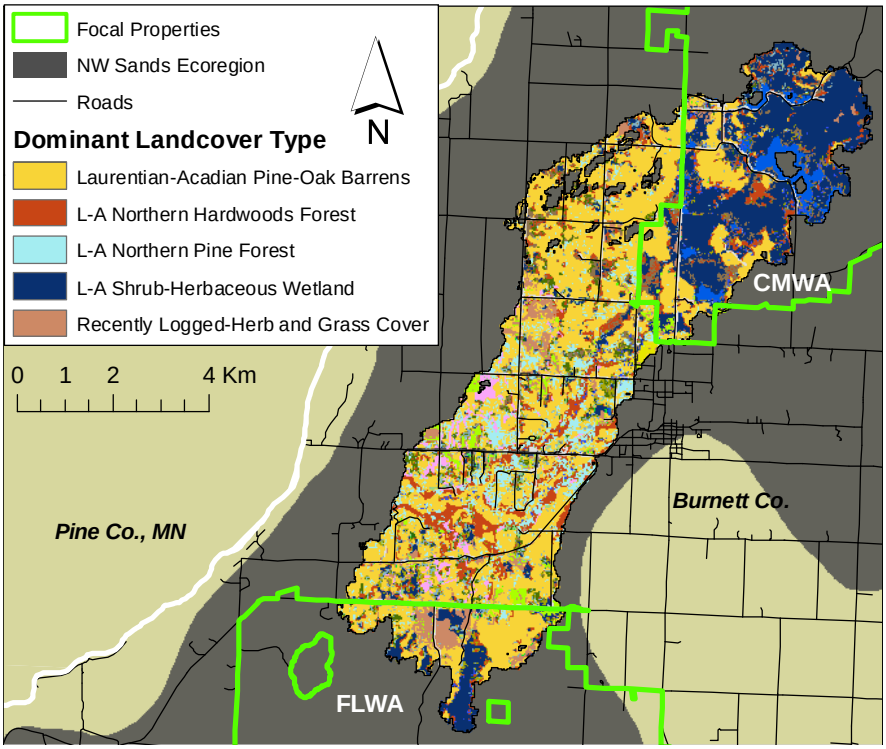

FIGURE 3-6. LANDFIRE vegetation type classifications within the recommended corridor between Fish Lake and Crex Meadows Wildlife Areas. Only the five most abundant vegetation classifications are given in the legend. See Figure B-1 for all classifications.

There are no significant barriers to movement in the corridor. It incorporates relatively few small one-and two-lane county roads with only semi-major road: State Highway 70, a two-lane highway running east-west. In addition, the modeled corridor does not move through any major populated areas, but is just west of the city of Grantsburg (population 1328) where some residential housing is found. There are no major water bodies or other potentially significant movement barriers. There are no potential

bottlenecks along the route of the corridor. Only one section (139m long) of the corridor is less than the width (2275m) for recommended sharp-tailed grouse habitat block sizes ($5.2km^2$ or 1280ac) that we specified in our model.

The recommended corridor encompasses significant areas that are state owned and managed (Table 3-3). However, all publicly-managed acreage occurs within FLWA and CMWA focal property boundaries. All lands included within the corridor that are outside of the focal properties are privately-owned (Figure 3-7). Interestingly, despite the relatively

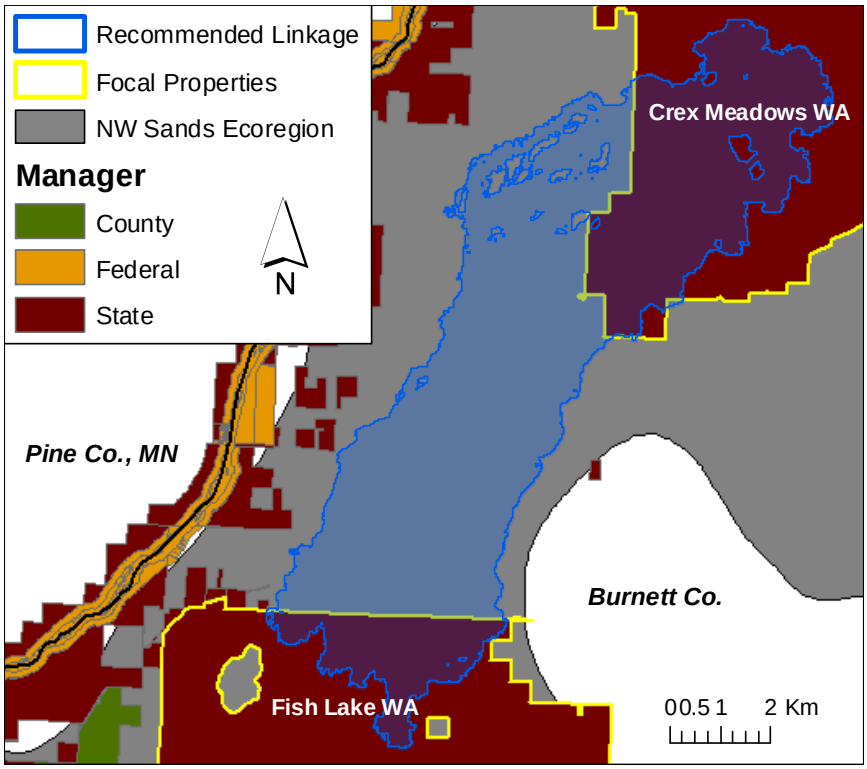

FIGURE 3-7. Recommended linkage between Fish Lake and Crex Meadows Wildlife Areas showing all publicly-managed properties in the map area

short distance between FLWA and CMWA and the seemingly similar habitats within each, few sharp-tailed grouse have been observed using Fish Lake during winter, and even less so during summer breeding. The recommended corridor does include significantly more area to the west of CMWA that approaches some state-owned property farther west and includes more private property that is classified as barrens habitat.

Despite public ownership being limited to FLWA and CMWA and no management of corridor lands outside of focal properties, much of the land between FLWA and CMWA is very well-drained soil that is indicative of current and potential Pine Barrens habitat (Figure 3-8). The area of the recommended corridor is made up of 74.3% of excessively drained

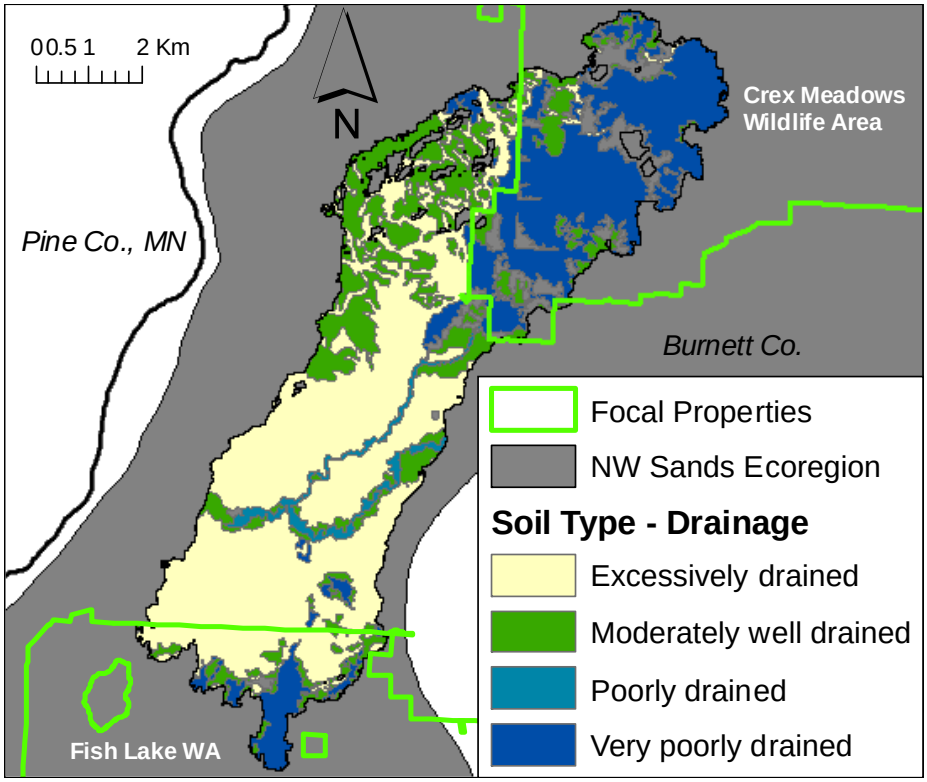

FIGURE 3-8. SSURGO soil drainage classifications within the recommended corridor between Crex Fish Lake and Crex Meadows Wildlife Areas. The legend only shows soil drainage types representing greater than 1% of the corridor.

soils (Table 3-4) as categorized by the Soil Survey Geographic (SSURGO) Database (Soil Survey Staff 2011). The availability of barrens-appropriate soil, and potential barrens habitat to the west and south of CMWA may provide some opportunity for land acquisition and management to create suitable habitat for barrens species that may also facilitate movement between FLWA and CMWA.

ii. **Crex Meadows and Namekagon Barrens Wildlife Areas**

The model produced a recommended corridor between CMWA and Namekagon Barrens Wildlife Area (NBWA) that is long and varies significantly in width (Table 3-1). It includes 542ac of the northeastern portion of CMWA and extends northeast into the southern 3104ac of the north unit of NBWA.

The recommended corridor is primarily composed of Laurentian Pine-Oak Barrens (31.9%), Laurentian-Acadian Northern Pine Forest (16.3%), Laurentian-Acadian Northern Hardwoods Forest (17.6%), Boreal Acidic Peatland Systems (7.6%), and Recently Logged Herb and Grass Cover (5.4%; Table 3-2). Significant Pine and Hardwood Forest habitats occur throughout the corridor but are concentrated in the southwestern end (Figure 3-9).

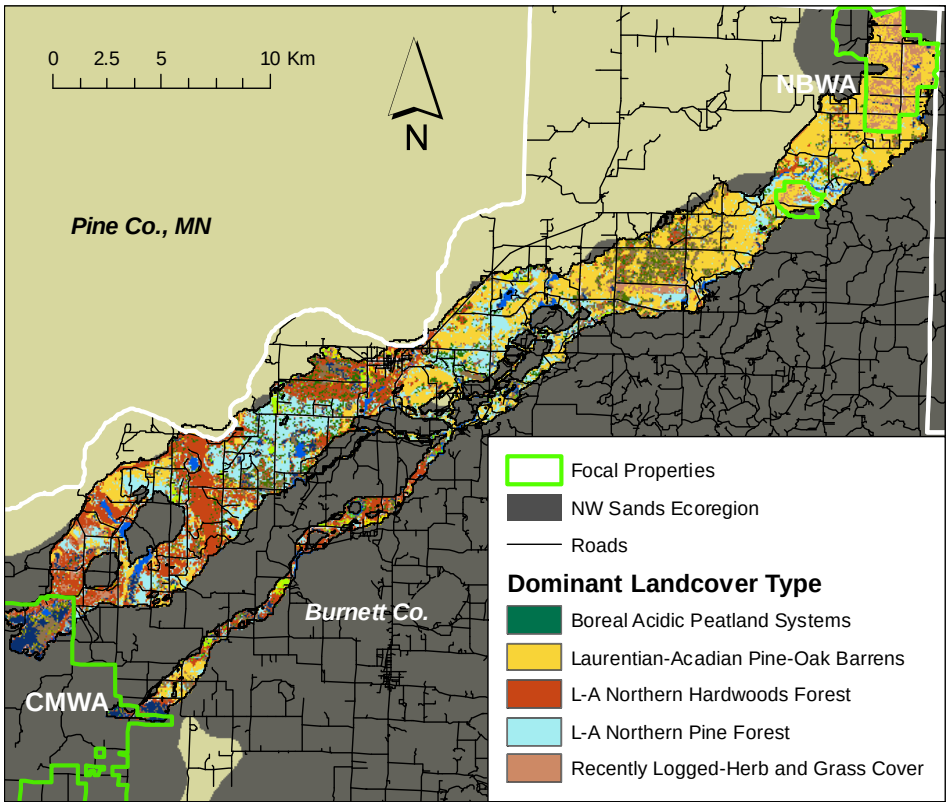

FIGURE 3-9. The five most abundant LANDFIRE vegetation type classifications within the recommended corridor between Crex Meadows and Namekagon Barrens Wildlife Areas.

Large blocks of Pine-Oak Barrens are found on the northeastern end of the corridor. Much of the habitat considered Pine-Oak Barrens is likely pine-planted county forest and not ideal habitat for sharp-tailed grouse. However, our model attempted to correct for this bias by

including vegetation layers that discriminate poor from high quality barrens habitat (see Appendix B). For example, although some landcover data indicated that an area was Pine-Oak Barrens, other data indicated high tree density that would be unsuitable for grouse.

There are no significant barriers to movement in the corridor. It incorporates few small one-and two-lane county roads with only semi-major two-lane road: State Highway 77 running east-west. In addition, the corridor does not move through major populated areas except the small city of Danbury (population 2851). Finally, a potential issue with the recommended corridor is the presence of potential bottlenecks along the route. Six sections (between 397m to 7893m long) are less than the width (2275m) for recommended sharp-tailed grouse habitat block sizes (5.2km^2 or 1280ac) that we specified in our model.

The long distance between CMWA and NBWA is probably the most important factor affecting potential movement. However, the corridor encompasses significant areas that are publicly owned and managed (Table 3-3), most which is in county forest (Figure 3-10).

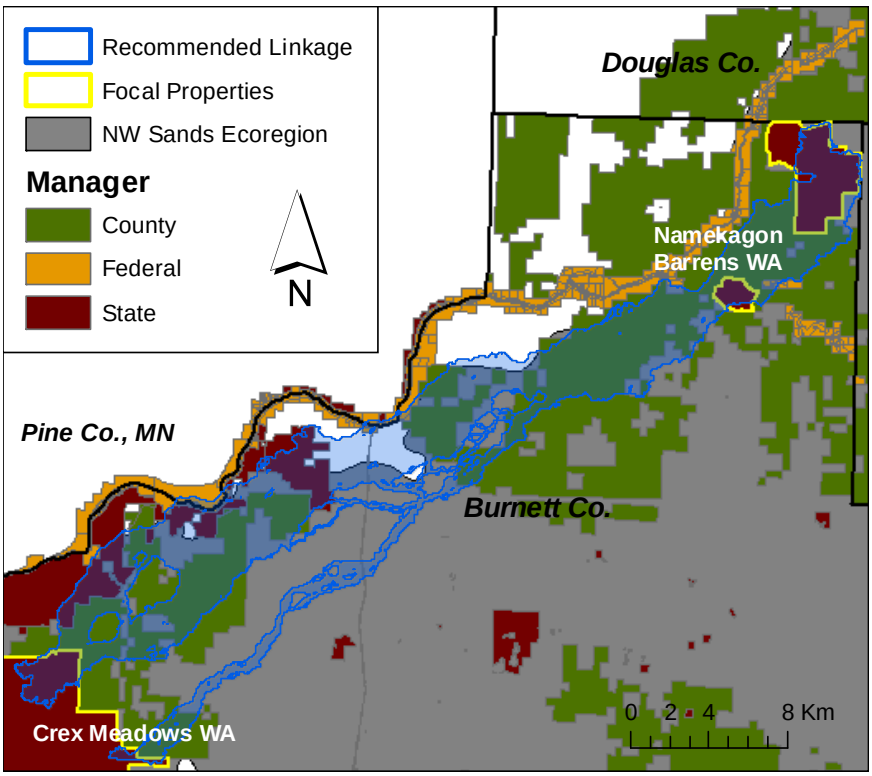

FIGURE 3-10. Recommended linkage between Crex Meadows and Namekagon Barrens Wildlife Areas showing all publicly-managed properties in the map area.

The area within the recommended corridor that is publicly-managed is 80.5%. Some of this area is within CMWA and NBWA, but the vast majority occurs within the matrix between focal properties. Large blocks of Burnett County Forest occur along the corridor, and at the midpoint between focal properties, that provide potential opportunities for Pine Barrens restoration that may improve linkage between CMWA and NBWA.

The recommended corridor encompasses primarily very well-drained soil that is indicative of current and potential Pine Barrens habitat (Figure 3-11). The corridor is made

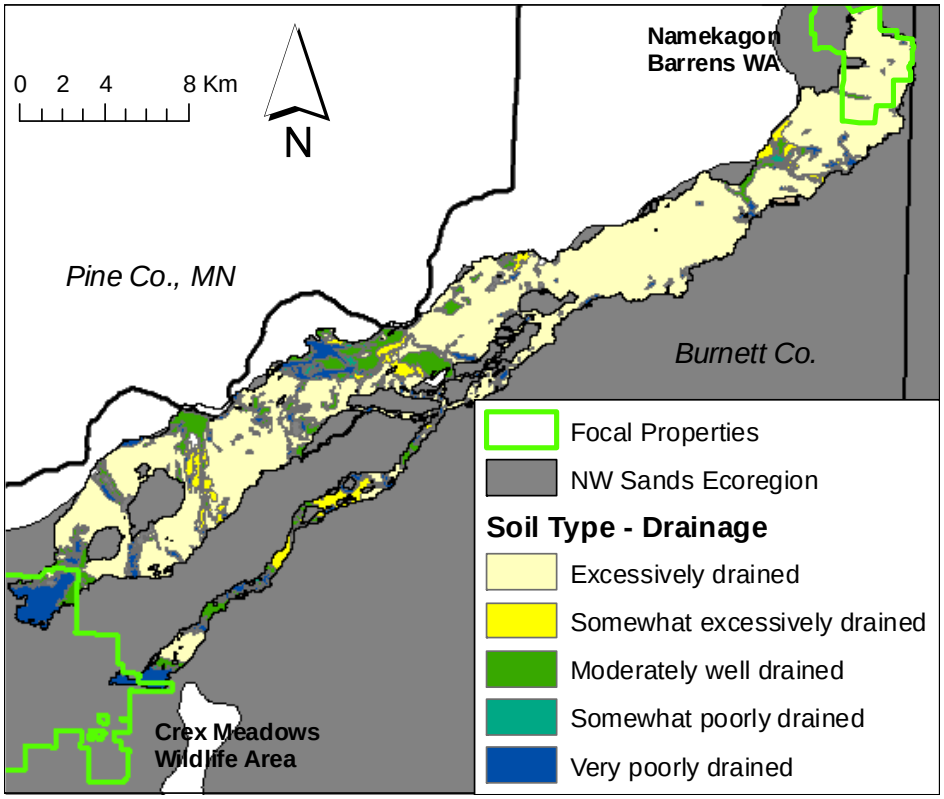

FIGURE 3-11. SSURGO soil drainage classifications within the recommended corridor between Crex Meadows Wildlife and Namekagon Barrens Wildlife Areas. The legend only shows soil drainage types representing greater than 1% of the corridor.

up of 73.3% of excessively-drained soils (Table 3-4) as categorized by SSURGO. The availability of barrens-appropriate soil and publicly owned and managed properties provide significant opportunities for land acquisition or cooperation with Burnett County Forest managers to create suitable habitat for barrens species that may also facilitate movement between CMWA and NBWA.

iii. **Namekagon Barrens and Douglas County Wildlife Areas**

The model produced a recommended corridor between NBWA and Douglas County Wildlife Area (DWMA) that includes 2917ac of the northeastern portion of NBWA and extends northeast into the southern 3278ac of DWMA.

The recommended corridor is primarily composed of Laurentian Pine-Oak Barrens (62.7%), Recently Logged Herb and Grass Cover (8.0%), Boreal Acidic Peatland Systems (6.4%), Laurentian-Acadian Northern Hardwoods Forest (4.8%), and Boreal Jack Pine-Black Spruce Forest (2.5%; Table 3-2). Pine Barrens habitat is found throughout the corridor (Figure 3-12). Much of this land is regenerating pine forest following a large wildfire in 1977

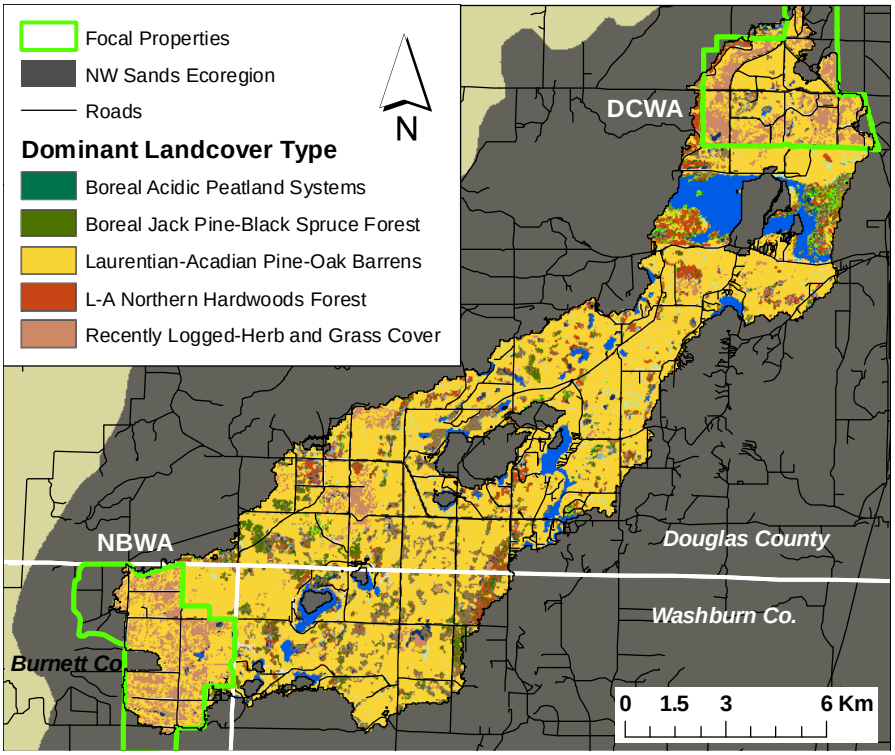

FIGURE 3-12. LANDFIRE vegetation type classifications within the recommended corridor between Namekagon Barrens and Douglas County Wildlife Areas. Only the five most abundant vegetation classifications are given in the legend.

and clearcuts from spruce budworm outbreaks in the 1980s and 1990s. Therefore, suitability of these Pine Barrens as sharp-tailed grouse habitat has declined and resulted in steady reductions in male lek attendance and lek extinction between NBWA and DCWA.

However, historical presence of grouse in areas incorporated by the corridors indicates that restoration of habitats would likely recreate suitable habitats for sharp-tailed grouse.

There are no significant developed areas that provide barriers to movement in the corridor. It incorporates relatively few small one-and two-lane county roads and no major roads. In addition, the corridor does not move through any major populated areas. One major potential problem is that the corridor links to DWMA by extending over the St. Croix River and flowage, the latter of which is approximately 1500m wide at center. Potential bottlenecks also occur along the corridor. Three segments (146m, 2213m, and 4462m long) are less than the width for recommended habitat block sizes specified in our model.

The recommended corridor encompasses significant areas that are publicly owned and managed (Table 3-3), most which is in county forest (Figure 3-13). The area of the

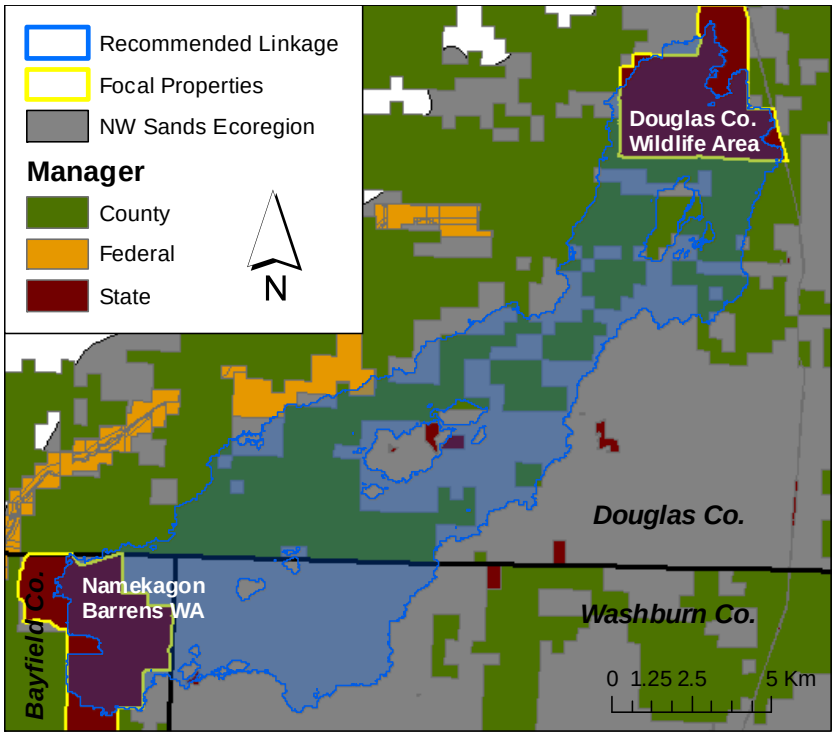

FIGURE 3-13. Recommended linkage between Namekagon Barrens and Douglas County Wildlife Areas showing all publicly-managed properties in the map area.

corridor that is publicly-managed is 56.4%. Some of this area is within NBWA and DCWA, but the vast majority occurs within the area outside of the boundaries of the focal properties. Large blocks of Douglas County Forest occur along almost the entire lengths of

the corridor that provide potential opportunities for Barrens restoration that may improve linkage between NBWA and DCWA.

The corridor between NBWA and DCWA encompasses primarily very well-drained soil that is indicative of current and potential Pine Barrens habitat (Figure 3-14). It is made

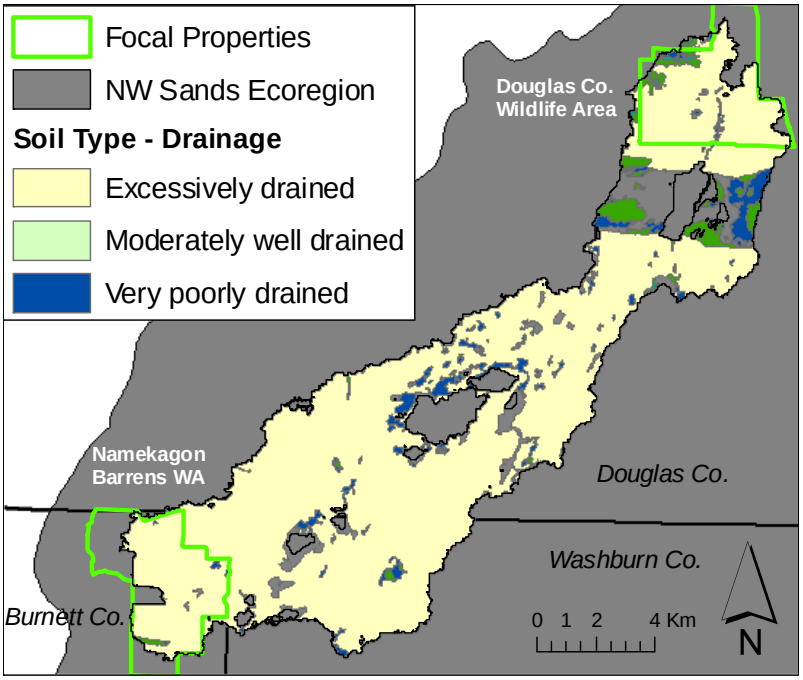

FIGURE 3-14. SSURGO soil drainage classifications within the recommended corridor between Namekagon Barrens and Douglas County Wildlife Areas. The legend only shows soil drainage types representing greater than 1% of the corridor

up of 90.4% of excessively-drained soils (Table 3-4) as categorized by SSURGO. The availability of barrens-appropriate soil and publicly owned and managed properties provide opportunities for land acquisition or cooperation with county foresters to create suitable habitat for barrens species that may also facilitate movement between CMWA and NBWA.

iv. Douglas County Wildlife Area and Moquah Barrens

The model produced a recommended corridor between DCWA and Moquah Barrens that is the longest of any developed with our model. It varies significantly in width and shape along its lengths (Table 3-1). It includes 2575ac of DCWA and extends northeast into the southeastern 576ac of Moquah Barrens.

The recommended corridor is primarily composed of Laurentian Pine-Oak Barrens (69.1%), Laurentian-Acadian Northern Pine Forest (8.8%), Laurentian-Acadian Northern Hardwoods Forest (7.2%), Recently Logged Herb and Grass Cover (3.7%) and Low Intensity Developed Land (3.5%; Table 3-2). Pine Barrens habitat dominates the corridor but is primarily found in the southwestern section of the corridors to the northeast of DCWA (Figure 3-15). Much of this land is regenerating pine forest following clearcuts from jack

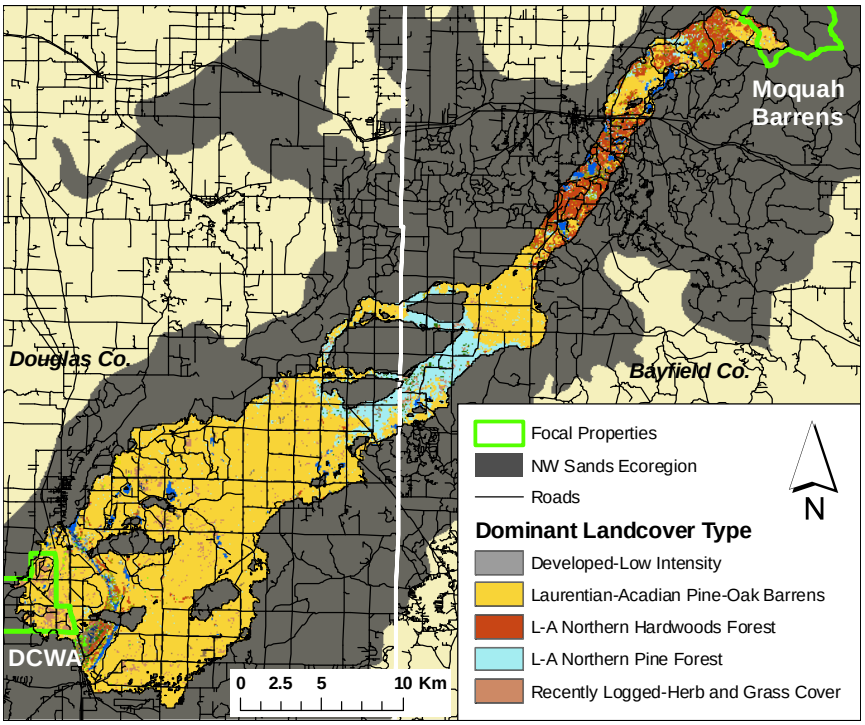

FIGURE 3-15. LANDFIRE vegetation type classifications within the recommended corridor between Douglas County Wildlife Area and Moquah Barrens. Only the five most abundant vegetation classifications are given in the legend.

pine budworm outbreaks in the 1980s and 1990s. Therefore, suitability of these Pine Barrens as sharp-tailed grouse habitat has declined and resulted in steady reductions in male lek attendance and lek extinction. However, recent and historical presence of grouse in areas incorporated by the corridor indicates that restoration of habitats would likely recreate suitable habitats between focal properties. Habitats in the northeastern section of the corridor are largely hardwoods that are not ideal sharp-tailed grouse habitat.

There are no significant developed areas that provide barriers to movement in the corridor. It incorporates relatively few small one-and two-lane county roads and State Highway 2, a major two-lane road that runs east-west. It does not move through any major populated areas but is just east of Iron River (population 2087). The corridor is long and narrow in the northwestern section as it approaches MB, creating potential bottlenecks. Seven segments (between 1085m to 9224m long) of the corridor are less than the width for recommended habitat block sizes specified in our model. Despite high potential suitability of habitats in the southwestern portion, the northeastern portion presents a significant problem for linking DCWA and MB, particularly given its landscape composition.

The recommended corridor encompasses some areas that are publicly owned and managed (Table 3-3), most which is in Douglas and Bayfield County Forest (Figure 3-16).

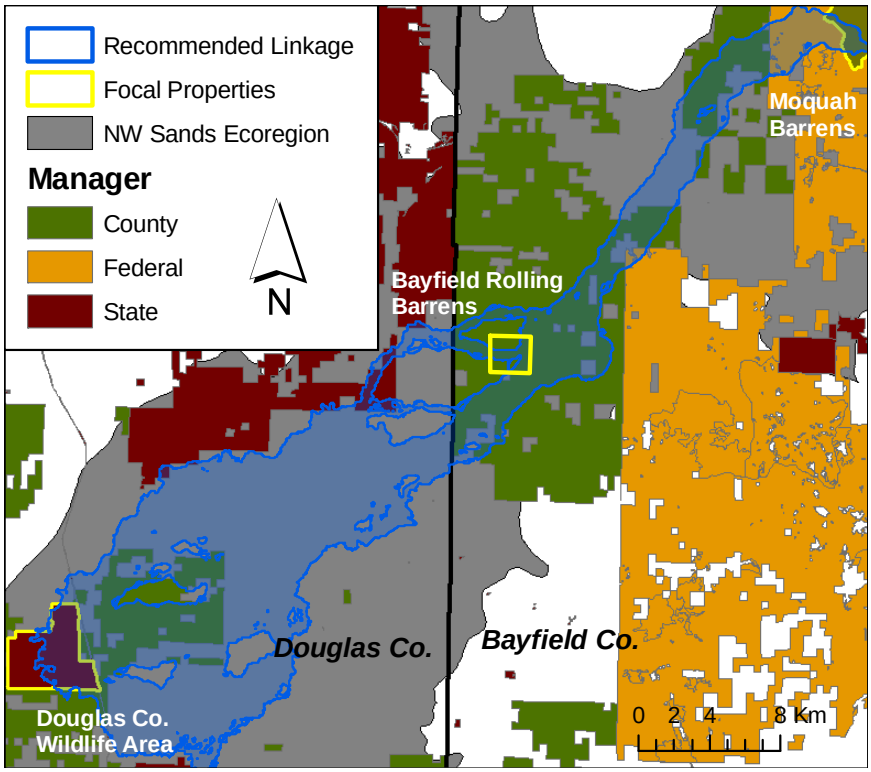

FIGURE 3-16. Recommended linkage between Douglas County Wildlife Area and Moquah Barrens showing all publicly-managed properties in the map area including the location of the Bayfield Rolling Barrens.

The area of the corridors that is publicly-managed is 39.2%. Large blocks of Douglas County Forest occur to the northeast of DCMA and Bayfield County Forest occurs along the

midpoint and toward the northwestern portion of the corridor. These areas provide potential opportunities for Pine Barrens restoration that may improve linkage between DCWA and Moquah Barrens. Indeed, many of these areas have historically had sharp-tailed grouse dancing grounds that have since become extinct. There is a large expanse of the corridor that is private property that may prevent problems for management.

The corridor between NBWA and DCWA encompasses primarily very well-drained soil that is indicative of current and potential Pine Barrens habitat (Figure 3-17). It is made

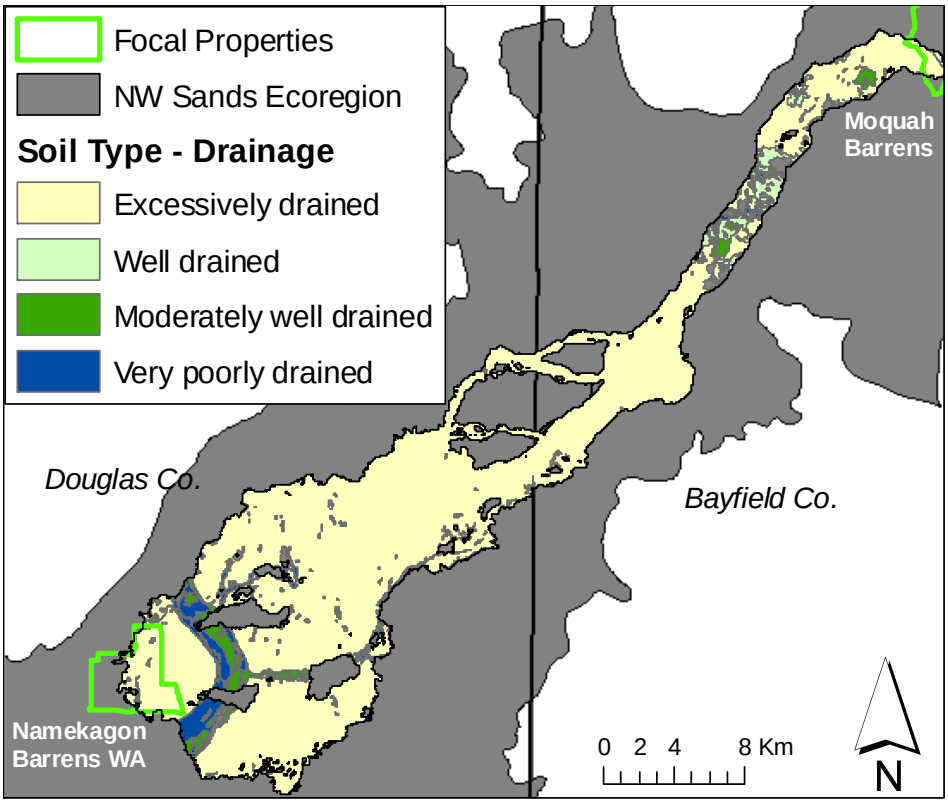

FIGURE 3-17. SSURGO soil drainage classifications within the recommended corridor between Douglas County Wildlife Area and Moquah Barrens. The legend only shows soil drainage types representing greater than 1% of the corridor.

up of 88.9% of excessively-drained soils (Table 3-4) as categorized by SSURGO. The availability of barrens-appropriate soil and publicly owned and managed properties provide significant opportunities for land acquisition or cooperation with Douglas and Bayfield County Forest managers to create suitable habitat for barrens species that may also facilitate movement between DCWA and Moquah Barrens.

TABLE 3-1. Summary of metrics of recommended corridors for pairs of focal properties. Length and width is given in meters. FL=Fish Lake Wildlife Area, CM=Crex Meadows Wildlife Area, NB=Namekagon Barrens Wildlife Area, DC=Douglas County Wildlife Area, MB=Moquah Barrens.

	Size (ac)	Length	Mean Width	Median Width	Min Width	Max Width
FL to CM	13088	8365	3040	2878	2243	4093
CM to NB	47962	47281	2361	2481	722	3773
NB to DC	38834	26791	2543	2454	1686	3847
DC to MB	78276	63659	2867	2301	1114	6813

TABLE 3-2. Percent of vegetation classifications within recommended corridors between focal property pairs. Open water and vegetation classifications <1.0% in all corridors are not included in the table.

Vegetation Classification	FL to CM	CM to NB	NB to DC	DC to MB
Conifer				
Boreal Acidic Peatland Systems	4.1	7.6	6.4	1.2
Boreal Jack Pine-Black Spruce Forest	2.1	2.2	2.5	0.1
Laurentian Pine-Oak Barrens	38.7	31.9	62.7	69.1
Laurentian-Acadian (L-A) Northern Pine	6.1	16.3	0.9	8.8
Conifer-Hardwood				
Boreal White Spruce-Fir-Hardwood Forest	2.2	1.3	1.0	2.1
Hardwood				
Boreal Aspen-Birch Forest	0.1	4.3	1.0	0.6
L-A Northern Hardwoods Forest	9.1	17.6	4.8	7.2
N. Central Interior Dry Oak Forest/Woodland	1.8	0	0	.
Grassland				
Recently Logged-Herb and Grass Cover	4.6	5.4	8.0	3.7
Riparian				
L-A Alkaline Conifer-Hardwood Swamp	3.3	1.2	1.4	0.3
L-A Floodplain Systems	1.1	0.1	0	0
L-A Shrub-Herbaceous Wetland Systems	18.5	4.1	1.2	0.3
Agriculture				
Cultivated Crops and Irrigated Agriculture	1.5	0.7	<0.1	<0.1
Pasture and Hay	0.3	0.8	<0.1	0.1
Developed				
Low Intensity	0.2	0.4	2.1	3.5
Open Space	2.7	3.4	2.1	0.8

TABLE 3-3. Amount of land (ac) in recommended corridors occurring outside of focal properties (matrix) and percent of each corridor in public management. Area within the entire corridor (which includes parts of corridors within focal properties) is in Table 3-1.

		Percent of Corridor in Public Management					Percent of Matrix in Public Management				
	Matrix (ac)	County	Federal	State	Tribal	Total	County	Federal	State	Tribal	Total
FL to CM	5332	0	0	39.7	0	39.7	0	0	0	0	0
CM to NB	19815	55.6	0.4	23.4	1.1	80.5	61.9	0.5	14.6	1.2	78.2
NB to DC	14876	43.5	0	12.9	0	56.4	51.1	0	0	0	51.1
DC to MB	38264	30.8	5.4	3.0	0	39.2	31.9	4.9	0.1	0	36.7

TABLE 3-4. Percent of SSURGO soil drainage types in recommended corridors. Percent is given only for the area between focal properties and not for corridors occurring within property boundaries.

	Soil Drainage Type						
	Excessively drained	Somewhat excessively drained	Well drained	Moderately well-drained	Somewhat poorly drained	Poorly drained	Very poorly drained
FL to CM	67.0	0.1	0.0	24.1	1.0	3.9	3.9
CM to NB	73.3	5.3	0.0	11.1	1.3	0.3	8.8
NB to DC	90.4	0.0	0.0	3.5	0.2	0	5.9
DC to MB	88.9	0.5	2.6	3.5	0.2	0.1	4.3

4. Priority Corridor Actions

a. Prioritization

Our model produced corridor options for linking pairs of focal properties in the Northwest Sands using the best biological information available. Determining where to focus limited financial and logistical resources will be paramount to successful conservation of sharp-tailed grouse, barrens-dependent species, and the Pine Barrens habitats.

We classified three tiers, or priorities, of habitat corridor actions (Figure 4-1) based on the current size of the sharp-tailed grouse subpopulations being connected, the distance between core populations, the risk of extirpation of local subpopulations, the likelihood of creating additional habitat between core properties, and the overall contribution to the sharp-tailed grouse metapopulation within Northwest Wisconsin.

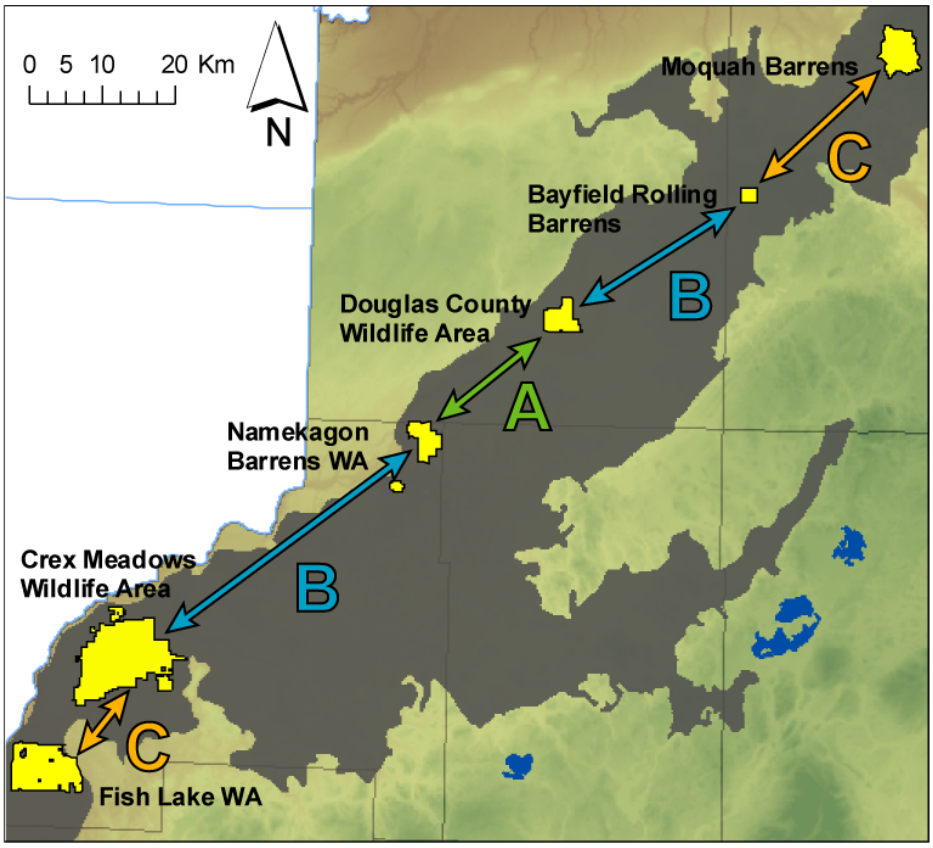

FIGURE 4-1. Prioritization of linkage opportunities in the Northwest Sands. Tier *A* represents the area of highest overall probability of success.

Tier A:

- Namekagon Barrens to Douglas County Wildlife Area

Tier B:

- Douglas County Wildlife Area to Bayfield County Rolling Barrens (see below)
- Namekagon Wildlife Area to Crex Meadows Wildlife Area

Tier C:

- Crex Meadows Wildlife Area to Fish Lake Wildlife Areas
- Bayfield County Rolling Barrens to Moquah Barrens

We classified the Namekagon Barrens – Douglas County Wildlife Area pair as a Tier A priority because the distance between the two core properties is relatively short, the sharp-tailed grouse subpopulations are the most stable within the NW Sands (Fandel and Hull 2011) and management opportunities are likely high in this area. In addition, there is considerable evidence that working to preserve the core of a metapopulation is the most efficient and successful conservation action, as opposed to working on the fringes of the population where costs are higher and success is often lower (Chauvenet et al. 2010, Wilson et al. 2010). A similar approach was used with the Greater Prairie-chicken translocation efforts in Wisconsin (Bouzat et al. 2005a, b). Finally, budworm clear cutting in the 1980s and 1990s to the east of DCWA areas created large areas of sharp-tailed grouse barrens habitat that resulted in an increase in dancing grounds and strong grouse populations over the past two decades. However, forest regeneration has reduced habitat suitability for grouse in these areas and there has been a recent stark decline in dancing grounds and male attendance. Management of habitats along the corridor between NBWA and DCWA may provide alternative habitat patches for birds leaving those areas of dwindling quality.

These types of decisions do not preclude working in Tiers B or C, either in combination with priority work in Tier A, or as a separate initiative. If resources are the limiting factor; however, it is highly recommended that they be directed toward work in Tier A as a priority,

followed by B then C. If resources are not limiting then a conceivable course of action would be to simultaneously work in Tiers A, B and possibly C. However, working in Tier C alone or as a priority will likely have the least amount of impact on the entire sharp-tailed grouse metapopulation within the Northwest Sands. We emphasize that focal wildlife properties should continue to be managed as a top tier priority to conserve existing habitats for barrens species such as sharp-tailed grouse.

b. Specific Management Recommendations

i. **Management Block Sizes**

We have modeled corridors linking focal properties using the best data available for sharp-tailed grouse. Based on the literature and model output we recommend two options for habitat blocks that incorporate potential logistical constraints and management feasibility.

Option 1: Permanent barrens habitat patches at least 1280 acres in size based on recommended habitat block sizes for sharp-tailed grouse we used to parameterize the corridor model. These blocks should be within a given proximity to existing core areas with grouse (see Section 4.b.ii below)

Option 2: Rolling barrens habitat patches that are temporarily open made up of a 500-1000 acre core surrounded by 500-1000 acres of rolling barrens resulting in approximately 1000-2000 acres open at any given time.

Option 2 is based on the rolling barrens concept outlined in the Barnes Barrens Management Plan (BBMP). The BBMP describes the habitat management of a large parcel of land (Bayfield Rolling Barrens) in Bayfield County (Figure 4-2) in which a core area of permanent barrens habitat is surrounded by management zones planted with pine forests and harvested on a rotating schedule. This results in a core barrens area surrounded by

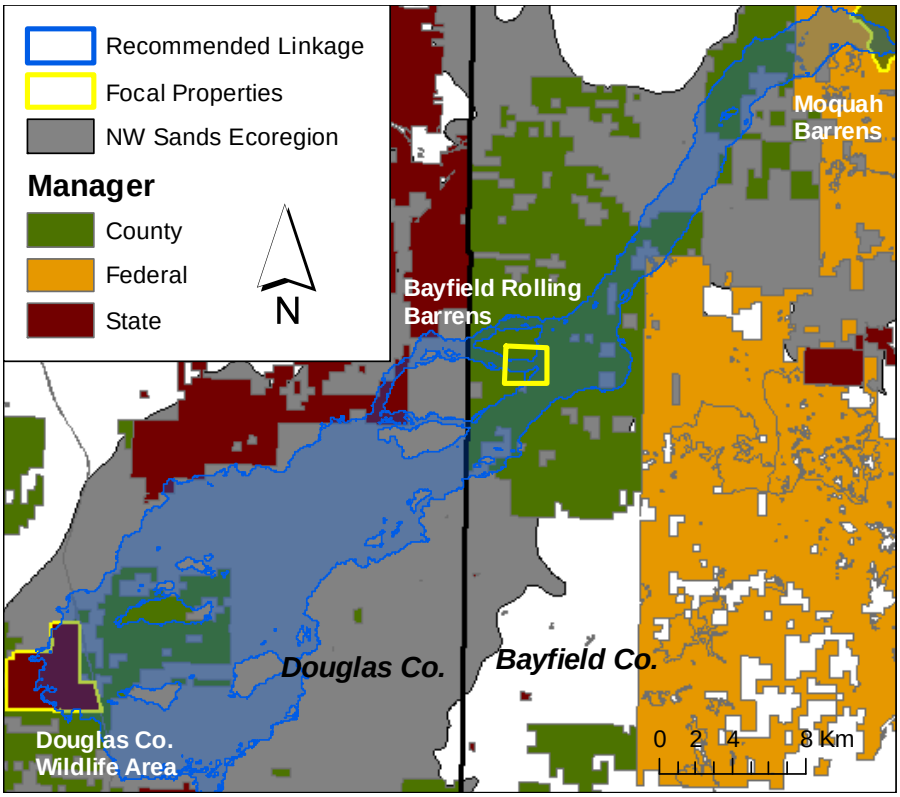

FIGURE 4-2. Location of Barnes Barrens Management Area (Bayfield Rolling Barrens) between Douglas County Wildlife Area and Moquah Barrens.

rolling or floating barrens of suitable habitat. Because the Bayfield Rolling Barrens will establish a core area of permanent habitat, we recommended establishing linkages between it and Douglas County Wildlife Area as a Tier B priority.

We do not address configuration of blocks (e.g., square versus round) because overall size is likely more important than shape of habitat blocks. Our recommended block sizes should provide ample suitable habitat for the suite of barrens-dependent species.

ii. Distances Among Managed Blocks

Sharp-tailed grouse were traditionally thought to have great dispersal abilities based in part on records of rare, long-distance dispersal events or apparent seasonal migrations/shifts. These records were/are often from the western, or plains, region of the continental sharp-tailed grouse range (Connelly et al. 1998). Generally, however, the majority of dispersal distances are much shorter. Maximum dispersal events based on banded and/or radio-collared birds have been as great as 21 miles (~34 km) in Michigan and

Wisconsin (Hamerstrom and Hamerstrom 1951, Sjogren 2006). In a 7-year study in Central Wisconsin Hamerstrom and Hamerstrom (1951) reported that 81% of banded birds were recaptured within 2 miles (3.25 km) of their original banding location. Fandel and Hull (2011) summarized that broods typically disperse <6 km (3.7 mi) from the natal site. Juveniles tend to disperse greater distances than adults, and juvenile females tend to move farther than juvenile males. Adult females also tend to disperse farther than adult males (Connelly et al. 1998). An ongoing study of radio-collared birds at Namekagon Barrens and Crex Meadows Wildlife Areas in northwestern Wisconsin has not recorded any dispersal from core properties and limited home range size of adults (S. Hull pers. comm.). However, modern genetic diversity assessments reported in Fandel and Hull (2011) showing eroded allelic diversity and isolation amongst subpopulations further demonstrates that sharp-tailed grouse dispersal between subpopulations in Wisconsin is uncommon/infrequent. However, infrequent dispersal between patches (and thus genetic isolation) may be a result of unsuitable habitat between patches and not necessarily a behavioral characteristic of the birds themselves.

Based on the literature and current knowledge of sharp-tailed grouse dispersal, genetic diversity, and habitat availability, we recommend 5 km (3.1 miles) as a reasonable/suitable dispersal distance between habitat patches or stepping stones within a larger habitat corridor design/matrix. We anticipate that a landscape scale corridor design with sharp-tailed grouse dispersal and habitat use in mind will not only connect subpopulations of sharp-tailed grouse, but also benefit other pine-barrens-dependent species.

c. Implementation

Habitat work should be initially focused on management opportunities nearest core properties. We recommend that some portion of a proposed habitat block be approximately 5km from the nearest edge of a core property and within recommended corridor boundaries. Therefore, proposed blocks that do not include this distance may be either too far from or too near to core properties to maximize linkage given logistical constraints. However, we do not discourage opportunities to acquire or manage properties that are near to the 5km distance

from core properties or that do not fall entirely within recommended corridors. Once suitable habitat blocks are established near focal properties, additional habitat stepping stones may be established farther along the corridor between property pairs until linkage is achieved (Figures 4-3 to 4-6). We did not create potential stepping stones for the Priority C pair of Fish Lake and Namekagon Barrens because any new management block would occur within 5km of both properties.

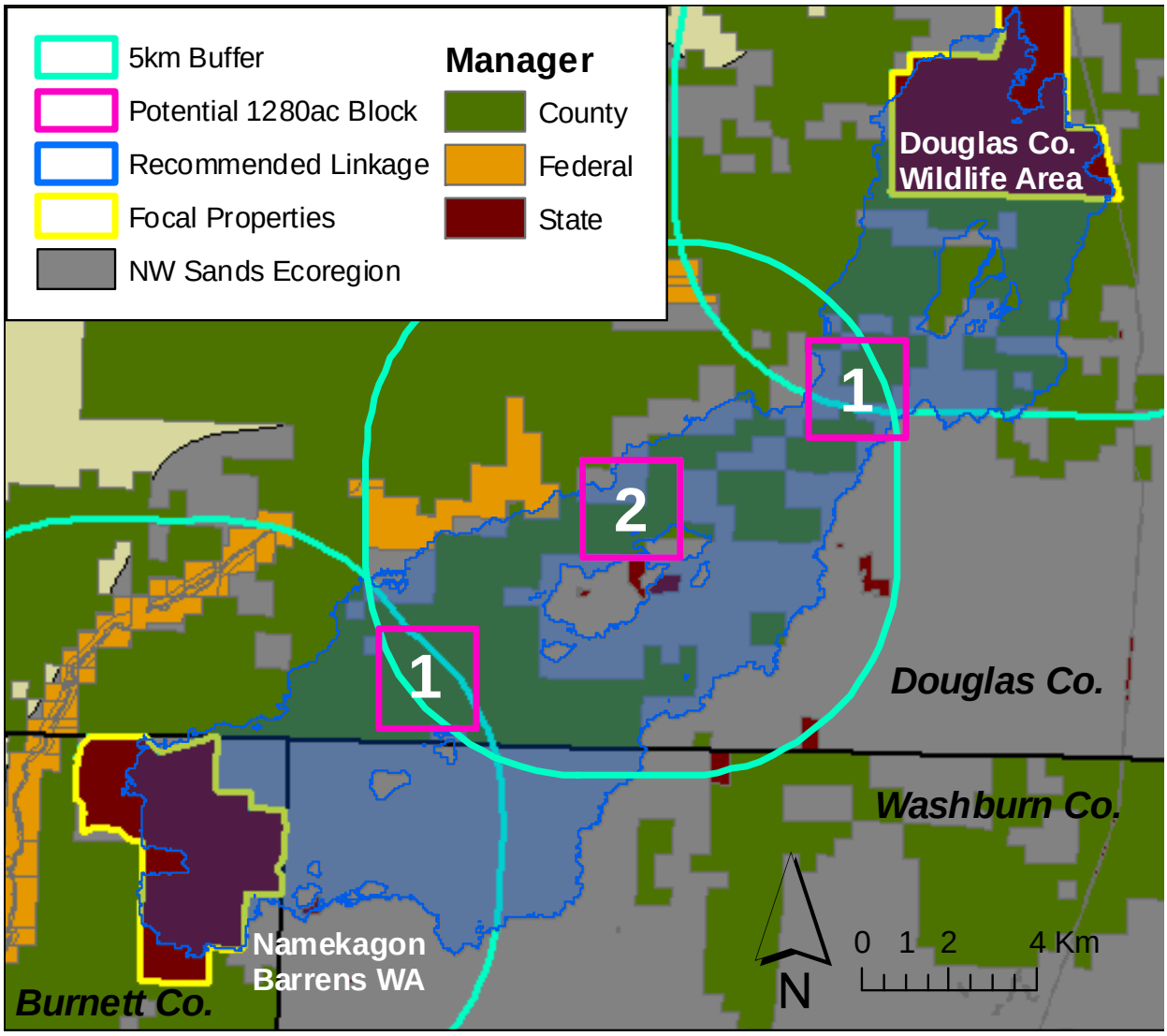

FIGURE 4-3. Hypothetical management blocks or "stepping stones" in the Priority A (Figure 4-1) area between Namekagon Barrens and Douglas County Wildlife Areas. Numbers in blocks represent order of priority for establishment of core habitats. Blocks should be located approximately 5km from edges of focal properties (circular buffer).

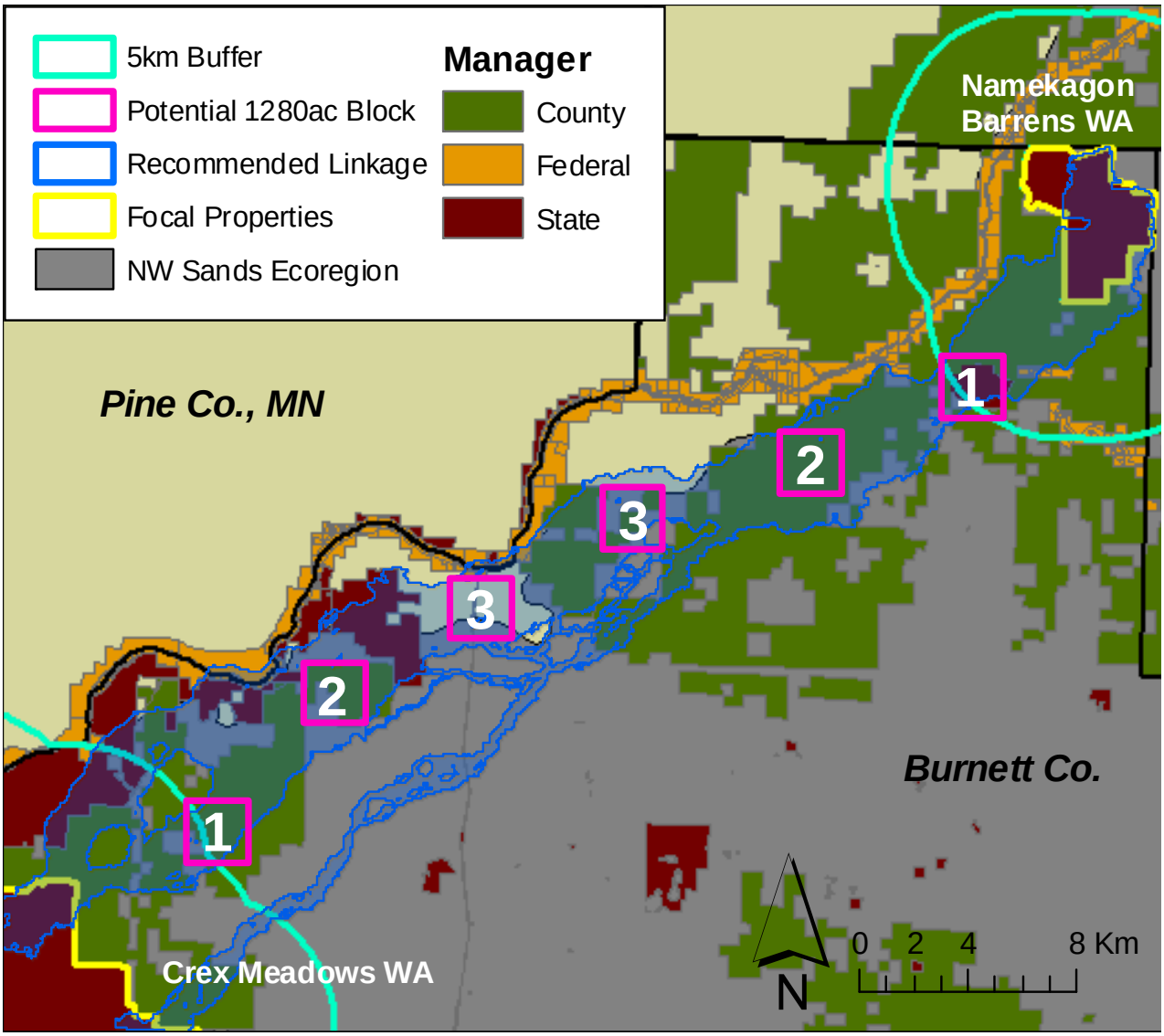

FIGURE 4-4. Hypothetical management blocks or "stepping stones" in the Priority B area between Crex Meadows and Namekagon Barrens Wildlife Areas. All potential management blocks are within 5km of each other. The northeastern Priority 1 block overlaps the south unit of Namekagon Barrens; additional acreage surrounding the south unit would be required to meet our recommendations.

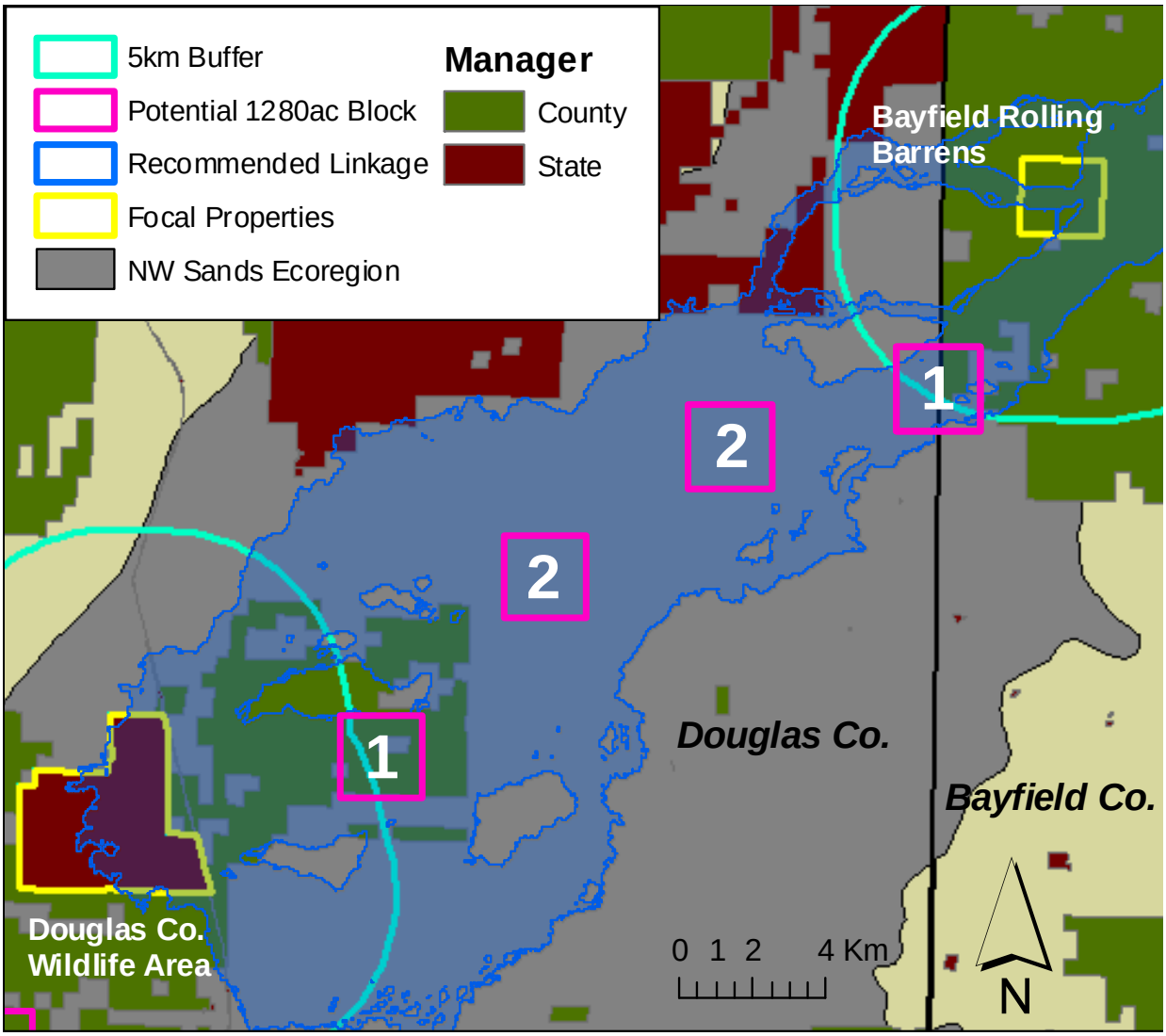

FIGURE 4-5. Hypothetical management blocks or "stepping stones" in the Priority B area between Douglas County Wildlife Area and the Bayfield Rolling Barrens. All potential management blocks are within 5km of each other.

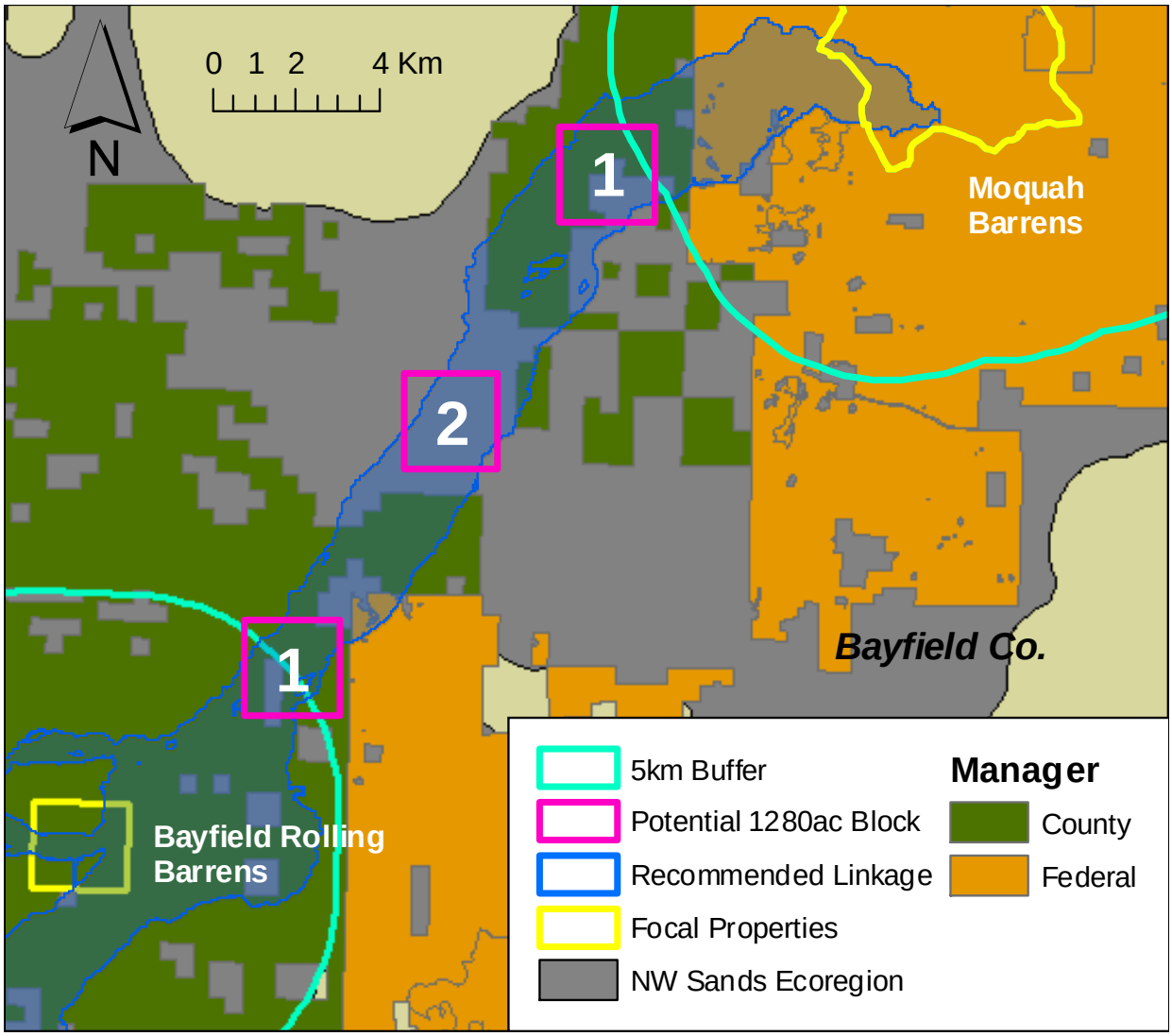

FIGURE 4-6. Hypothetical management blocks or "stepping stones" in the Priority C area between Bayfield Rolling Barrens and Moquah Barrens. All potential management blocks are within 5km of each other.

Our model identified recommended corridors using a variety of landscape layers and best biological information. The paths they followed are based on landscape permeability and location of suitable patches. However, we recognize there are other potential opportunities for management that may benefit sharp-tailed grouse, SGCNs and other barrens-dependent species in the Northwest Sands. In particular, severe winds from a storm on July 1, 2011 caused significant blowdown of trees throughout the region. Large swaths of downed planted pine are being harvested. Some of these areas occur within our corridor boundaries but many do not (Figure 4-7). Nevertheless, depending on the severity of the storm damage and the area of trees that are harvested, many potential opportunities exist for creation of barrens habitats in the blowdown region that may improve linkage in the Northwest Sands.

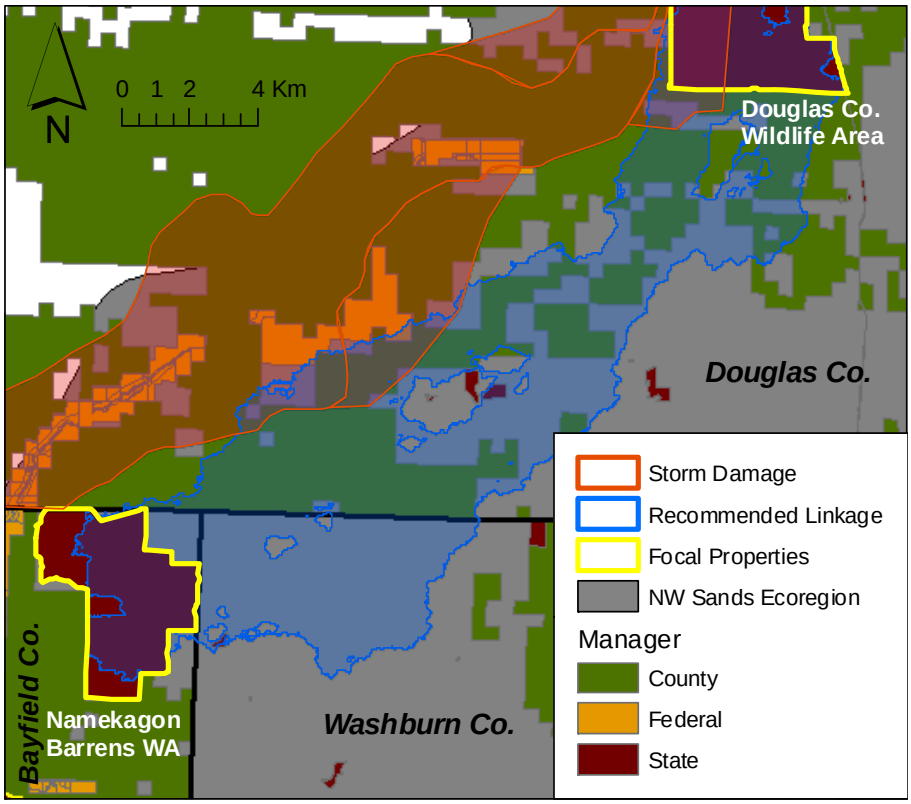

FIGURE 4-7. Location of storm damage from July 1, 2011 in Douglas County.

Appendix A. NW Sands Species of Greatest Conservation Need

Select barrens-dependent SGCN (birds, reptiles and invertebrates only) listed by WDNR's Wisconsin Wildlife Action Plan (http://dnr.wi.gov/landscapes/index.asp?mode=detail&Landscape=2&Section=species).

Reptiles & Amphibians

Bullsnake

Northern Prairie Skink

Birds

Black-billed Cuckoo

Bobolink

Brown Thrasher

Eastern Meadowlark

Field Sparrow

Golden-winged Warbler

Northern Harrier

Red-headed Woodpecker

Sharp-tailed Grouse

Upland Sandpiper

Vesper Sparrow

Invertebrates

Karner Blue Butterfly

Gorgone Checkerspot

Tawny Crescent

Henry's Elfin

Olympia Marble

Dusted Skipper

Mottled Dusky-wing

Cobweb Skipper

Indian Skipper

Phlox Moth

Graceful Clearwing

Appendix B. Details of the Corridor Model

a. Overview of Corridor Design Toolbox

We used the GIS program ArcMap (ver. 9.3; ESRI 1999-2008) and Corridor Design Toolbox (CDT; Majka et al. 2007) to identify continuous corridors between focal wildlife management areas and public properties in the Northwest Sands. CDT is an ArcGIS toolbox that creates habitat and corridor models that we used to find optimal links between designated areas. CDT has been used to generate numerous reports and recommendations for improving wildlife connectivity as part of the Arizona Missing Links Project (AMLP; http://corridordesign.org/linkages/arizona). To explain how we created our corridor model, our appendix generally follows the format of AMLP report Appendices because they were created by the designers of CDT. To determine potential corridors among focal properties, we followed the steps outlined by Beier et al. (2008) for creating a GIS-based linkage design and which were used in developing the Corridor Design Toolbox. We followed five general steps:

1. Define landscape to be analyzed and select focal species (addressed above). Our analysis area included a large area in northwestern Wisconsin and eastern Minnesota, but our model is focused on the Northwest Sands.
2. Create a habitat suitability model for sharp-tailed grouse in the defined landscape by assigning suitability values to different vegetation characteristics.
3. Identify potential patches that could support breeding or year-round populations for at least a decade by joining pixels of suitable habitat.
4. Identify corridor options between focal properties that would facilitate movement of sharp-tailed grouse and other species.
5. Conduct sensitivity analyses on model input parameters

b. Habitat Suitability Model

We used GIS raster data layers from the LANDFIRE mapping program (www.landfire.gov) to develop our habitat suitability model. LANDFIRE is a government-sponsored program that provides mapped data products to support strategic resource

management. Vegetation layers were mapped by LANDFIRE using 1999-2003 Landsat images, digital elevation models, field reference data, decision trees and post-hoc error correction to ascribe the dominant characteristic of each digital landscape pixel at a 30-m resolution. Due to the limited topography in the region, we did not use digital elevation model layers to develop habitat suitability. We recognize that the dynamic landscape in the Northwest Sands has changed since 2003. The Multi-Resolution Land Characteristics Consortium has released the provisional National Landcover Database for 2006 based on more recent imagery. However, NLCD 2006 data were not deemed appropriate because comparison of digital data with satellite imagery and knowledge of sites indicated important errors in landcover classifications, particularly of shrub-dominated barrens habitats (M. Reetz, pers. comm.).

We used three LANDFIRE vegetation raster data layers to estimate the quality of the landscape to sharp-tailed grouse.

- *Existing Vegetation Type*(EVT): represents the dominant type of vegetation for each 30-m grid cell. Classification of vegetation map units is based on NatureServe Ecological Systems (Comer et al. 2003) which represents a nationally standardized vegetation classification system. 30 vegetation type classifications were represented in the analysis area, with 28 in the Northwest Sands (Figure B-1). The EVT layer used was version 1.00 that was part of the original LANDFIRE release.
- *Existing Vegetation Cover* (EVC): represents the average percent cover of existing dominant vegetation for each 30-m grid cell. 46 vegetation cover classifications were represented in the analysis area, with 45 in the Northwest Sands (Figure B-2). We used the Refresh 2008 (ver. 1.10) EVC layer in our model. This update to original EVC LANDFIRE layer incorporated managed and natural disturbance (e.g., fire, vegetation management, weather, insect and disease) that occurred on the landscape after 2001.
- *Existing Vegetation Height* (EVH): represents the average height of the dominant vegetation for each 30-m grid cell. 32 vegetation height classifications were represented in the analysis area, with 30 in the Northwest Sands (Figure B-3). We used the Refresh 2008 (ver. 1.10) EVH layer in our model.

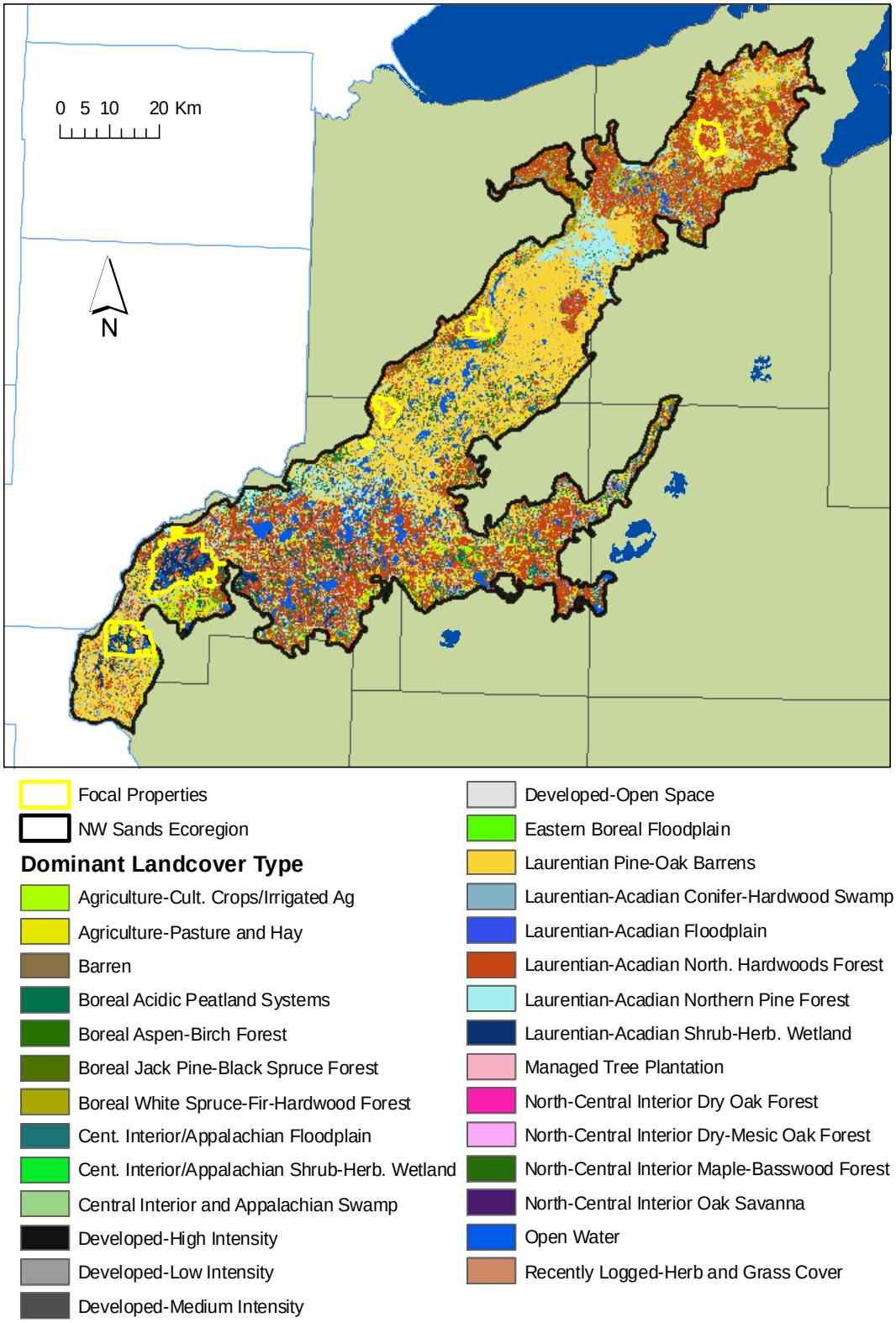

FIGURE B-1. LANDFIRE Existing Landcover Type for the Northwest Sands Ecological Landscape of Wisconsin.

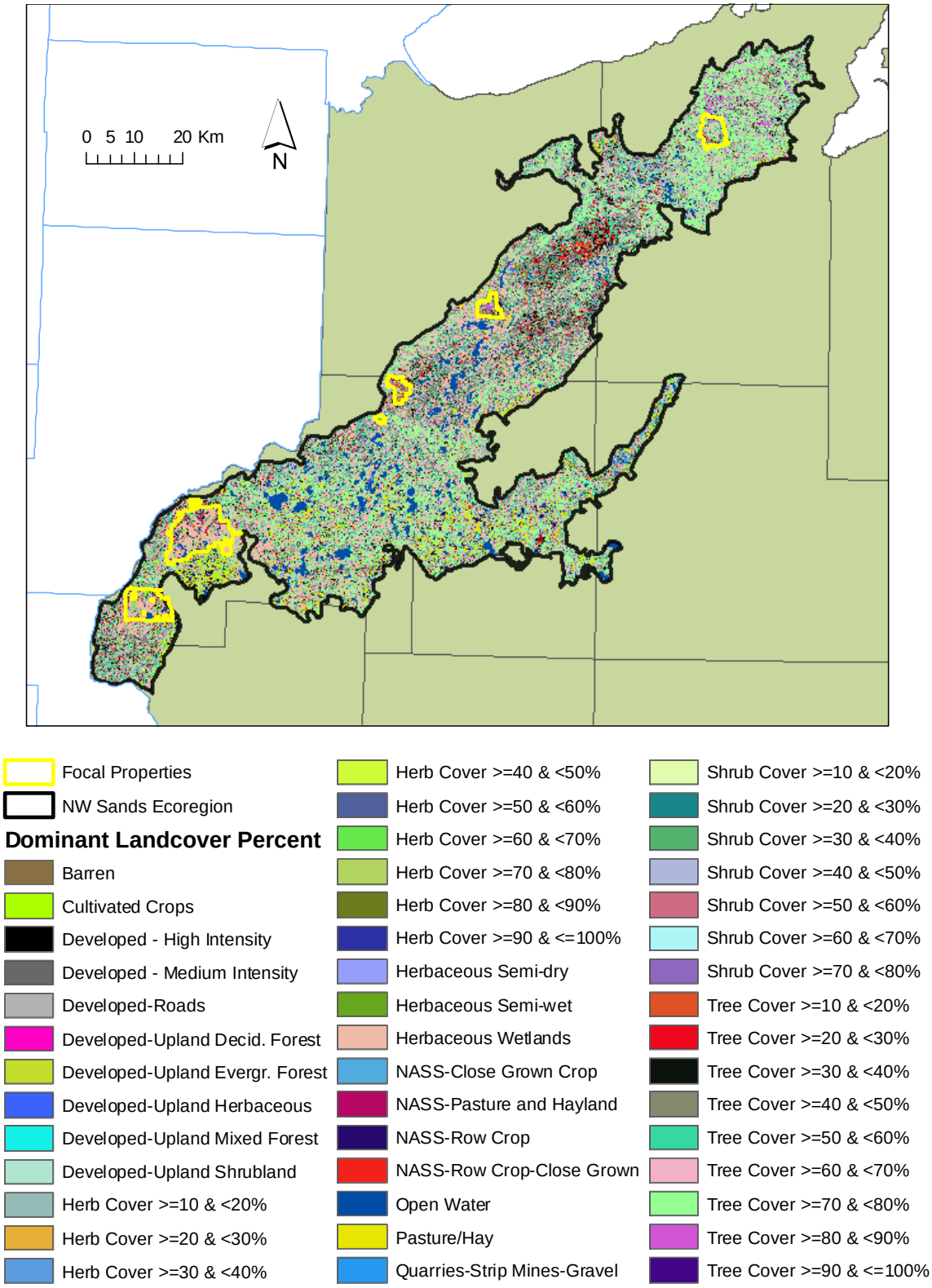

FIGURE B-2. LANDFIRE Existing Vegetation Cover for the Northwest Sands Ecological Landscape of Wisconsin. .

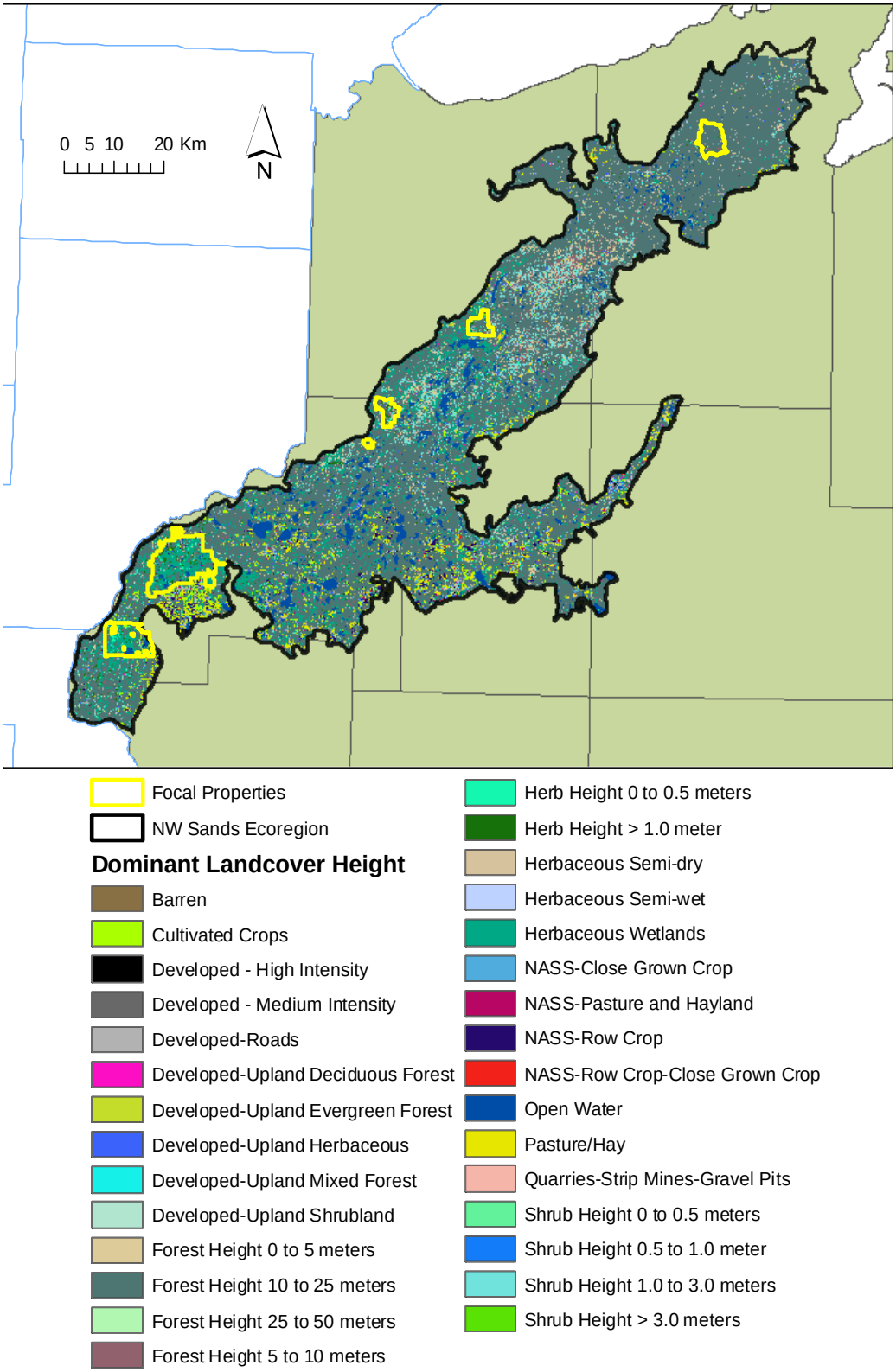

FIGURE B-3. LANDFIRE Existing Vegetation Height for the Northwest Sands Ecological Landscape of Wisconsin.

We created a habitat suitability model by determining the quality to sharp-tailed grouse of individual classifications in each data layer. Each classification was scored from 0 (unsuitable) to 100 (most suitable) using both the literature (primary) and expert opinion (secondary) on preferred grouse habitat. Literature included both natural history accounts and statistical analyses of habitat use. Main literature sources were Amman (1957), Artmann(1970), Baumgartner (1939), Connolly (2001), Gratson (1983, 1988), Grange (1948), Hamerstrom (1939, 1963), Niemuth and Boyce (2004), Ramharter (1976), Sjogren (1996), Sjogren and Corace (2006), and USDA (1999). Scores for classifications in each layer are given in Tables B-1, B-2, and B-3. Each of the three habitat factors (type, cover, height) were then weighted from 0-100% based on their relative contribution to overall suitability according to authors of this report (Table B-4). Incorporation of all three layers was important to developing habitat suitability models that reflected actual landscape conditions for sharp-tailed grouse. For example, the LANDFIRE existing vegetation layer indicates a high occurrence of the Laurentian-Acadian Pine-Oak Barrens (Table B-1) that we expect sharp-tailed grouse to prefer. However, this classification represents all areas with sparse coniferous tree cover, some of which is known to be county forest planted with red and jack pine. These areas of high tree density are revealed by the EVC layer and are not ideal habitats for sharp-tailed grouse, but would be selected as the most suitable if only vegetation type was considered in the model. Therefore, existing cover (e.g., percent of coniferous tree canopy) and vegetation height layers assist in identifying habitats that represent quality, sparsely treed areas most suitable for sharp-tailed grouse in the model.

Habitat suitability for each pixel was determined by calculating a weighted geometric (multiplicative) mean in CDT. The geometric mean determines suitability by raising each factor by its weight, and multiplying the three factors according to the formula:

Overall Suitability Value = $(Slcov^{Wlcov})$* $(Scov\%^{Wcov\%})$ *$(Shgt^{Whgt})$,where

S = suitability score,

W=factor weight, and

lcov, cov%, and hgt = the three landscape factor layers.

The use of weighted geometric mean method results in overall suitability values of zero if any of the pixel classifications contain zero scores. As a consequence, classifications deemed completely unsuitable for sharp-tailed grouse such as open water or urban areas were given scores of zero because they were unsuitable at any level. However, pixels representing unsuitable habitat in one layer (e.g., tree cover >60%) may represent suitable habitat in others (e.g., Pine Barrens vegetation type). Therefore, classifications deemed highly unsuitable in these cases were given a score of 1 so they did not overly influence final suitability scores for each pixel. Figures B-4 to B-7 show habitat suitability model maps for paired focal properties and the area between them.

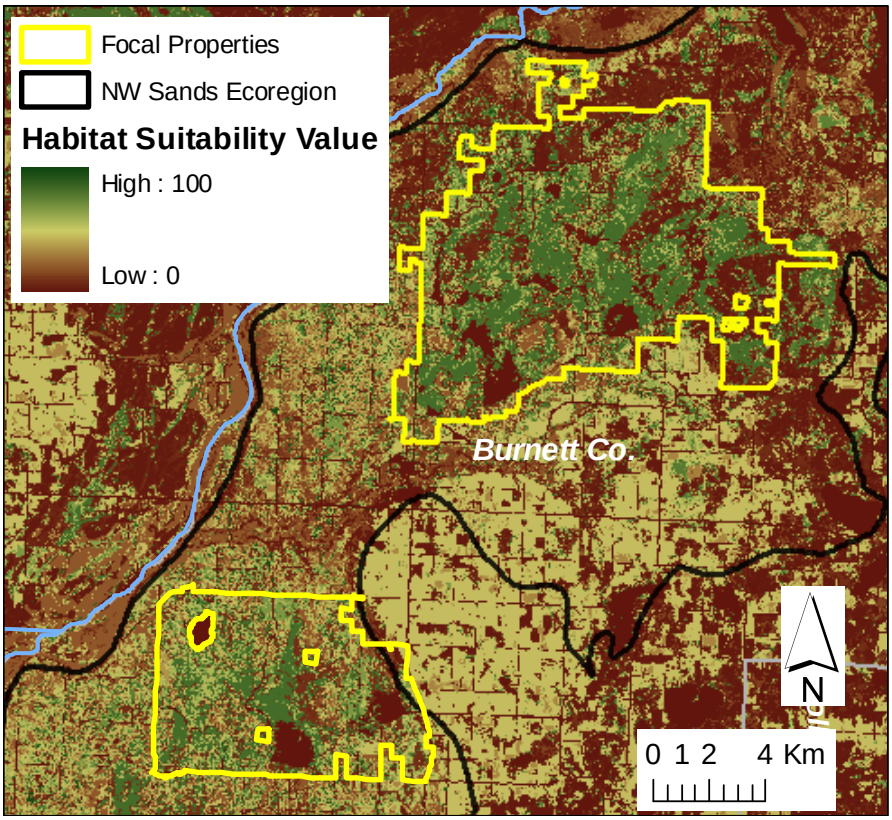

FIGURE B-4. Habitat suitability for sharp-tailed grouse at Fish Lake and Crex Meadows Wildlife Areas.

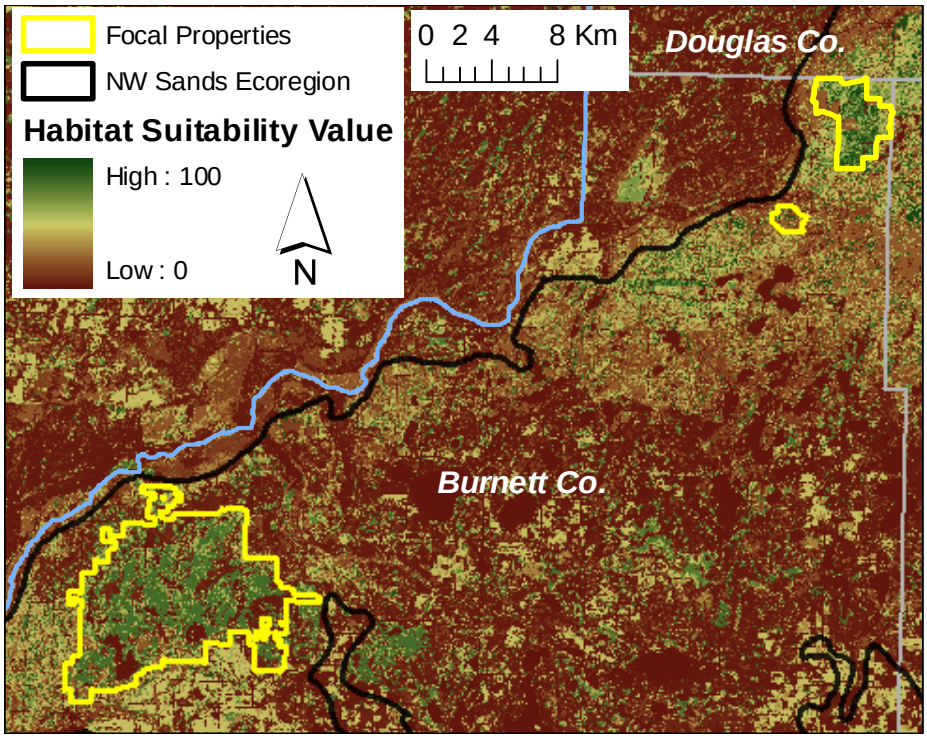

FIGURE B-5. Habitat suitability for Crex Meadows and Namekagon Barrens Wildlife Areas.

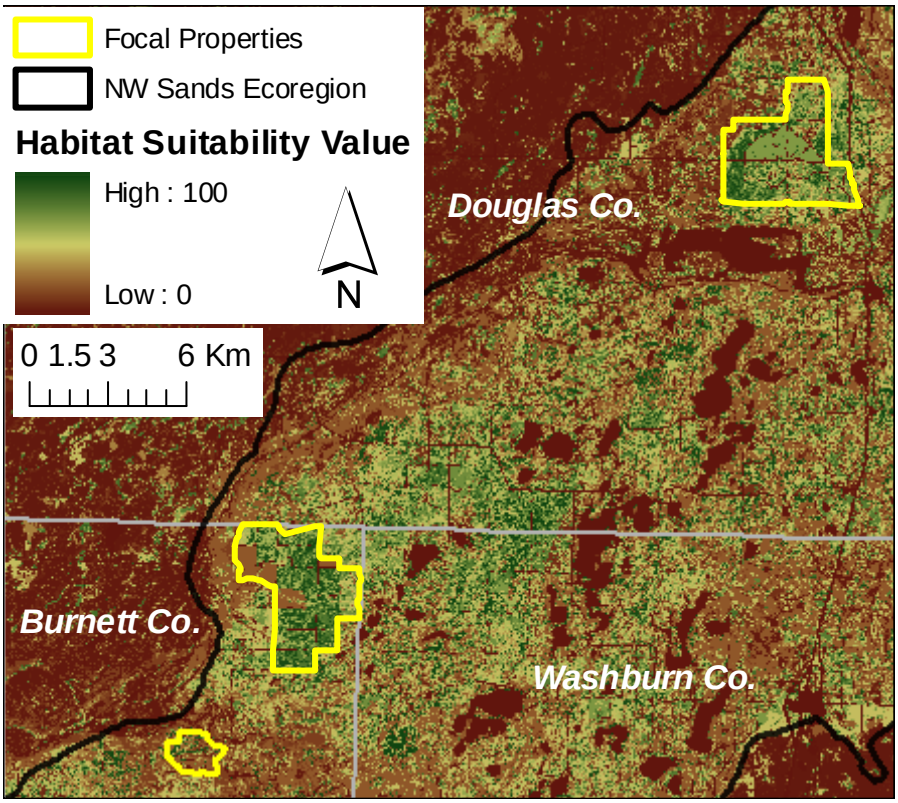

FIGURE B-6. Habitat suitability for Namekagon Barrens and Douglas County Wildlife Areas.

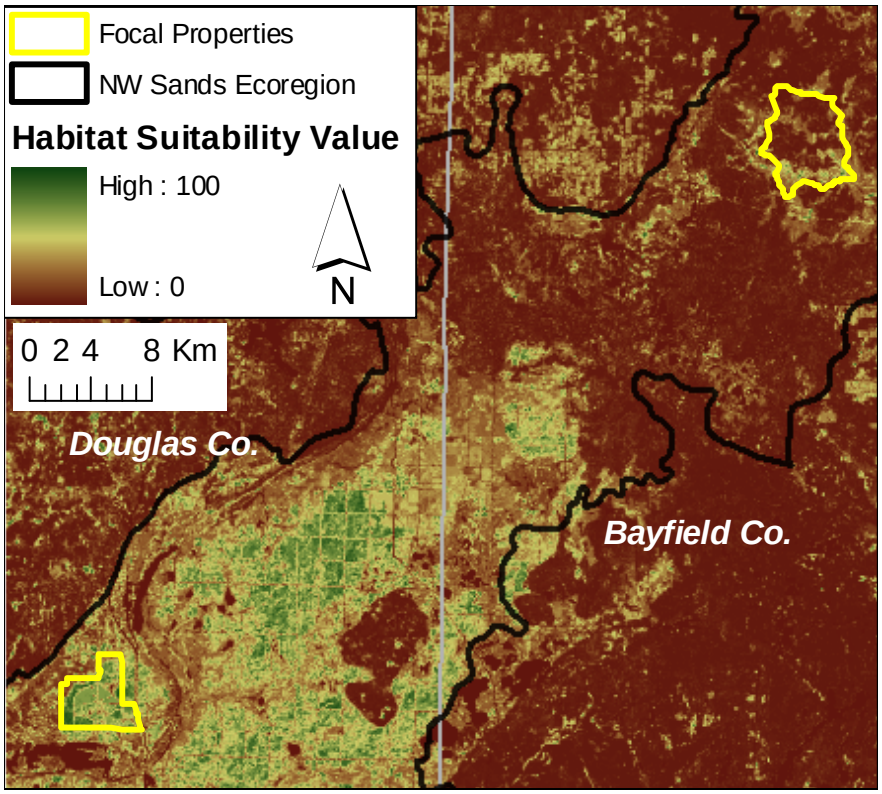

FIGURE B-7. Habitat suitability for Douglas County Wildlife Area and Moquah Barrens.

c. Identifying Potential Breeding and Population Patches

Our habitat suitability model produced scores for each pixel based on our classification scores and factor weights. This model was used to locate potential areas of grouse habitat large enough to support either breeding or year-round populations, both of which could facilitate movement among focal properties in the Northwest Sands. According to CDT:

- *potential breeding patches* are areas large enough to support reproduction (dancing ground, nesting, and brooding) for at least one breeding season.
- *potential population cores* are areas large enough to support both breeding and wintering grouse for a period of about ten years.

CDT uses a moving window that replaces suitability scores derived for each pixel with the average score from its 8 surrounding neighbors. Suitability for patch identification is determined based on user-defined thresholds for moving window size, habitat quality, and patch sizes for breeding and population persistence. A moving window size of 200m was

determined based on recommendations by Majka et al. (2007) for mobile species modeled in CDT. We determined the habitat quality threshold by examining the habitat suitability model and determining locations surrounding focal properties where grouse have been seen displaying or gathering during the breeding season extremely infrequently, but where breeding does not occur with any regularity (e.g., the landscape between Fish Lake and Crex Meadows Wildlife Areas). Therefore, areas below this threshold likely represent occasionally occupied habitat not typically used for breeding. Areas just above this threshold represent suboptimal, but usable habitat. We used a suitability score of 51 as our threshold value. We conservatively defined patch sizes of 890ac for breeding patches and 1465ac for population core patches based on sharp-tailed grouse seasonal and annual home range values reviewed by Sjogren and Corace (1996). Figures B-8 to B-11 show habitat patch maps for areas within and between paired focal properties. For three of the four pairs, potential breeding patches were not identified (Figure B-8 to B-10). However, they did identify population core patches that can sustain sharp-tailed grouse year-round and therefore also include breeding areas.

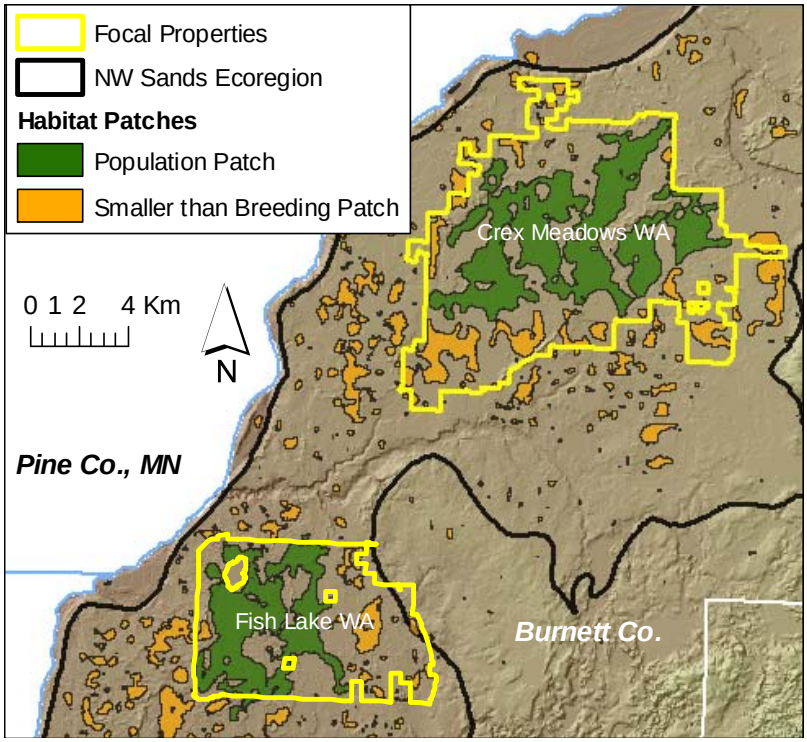

FIGURE B-8. Potential habitat patches between Fish Lake and Crex Meadows Wildlife Areas.

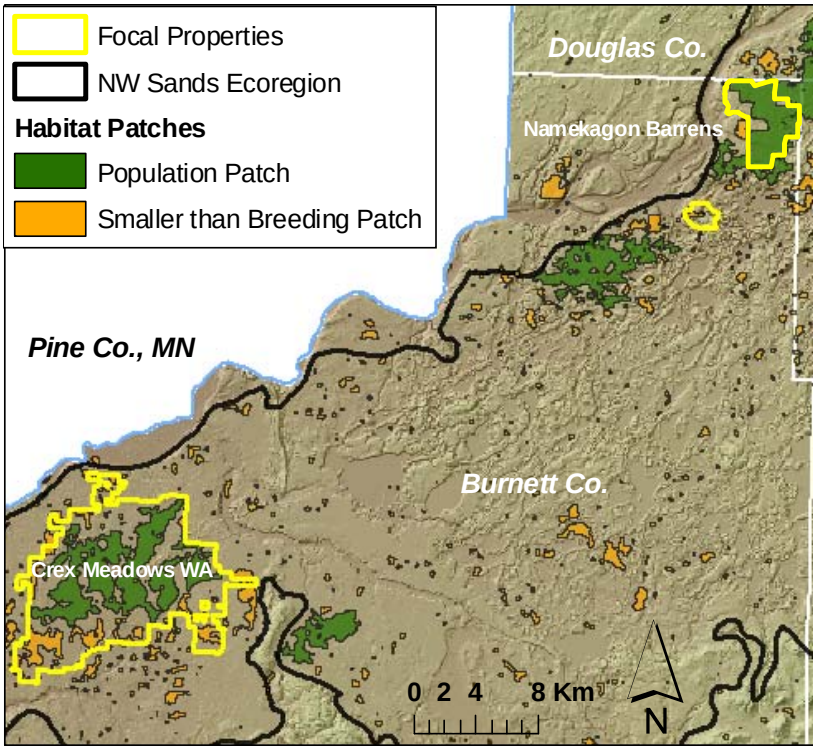

FIGURE B-9. Potential habitat patches between Crex Meadows and Namekagon Barrens Wildlife Areas.

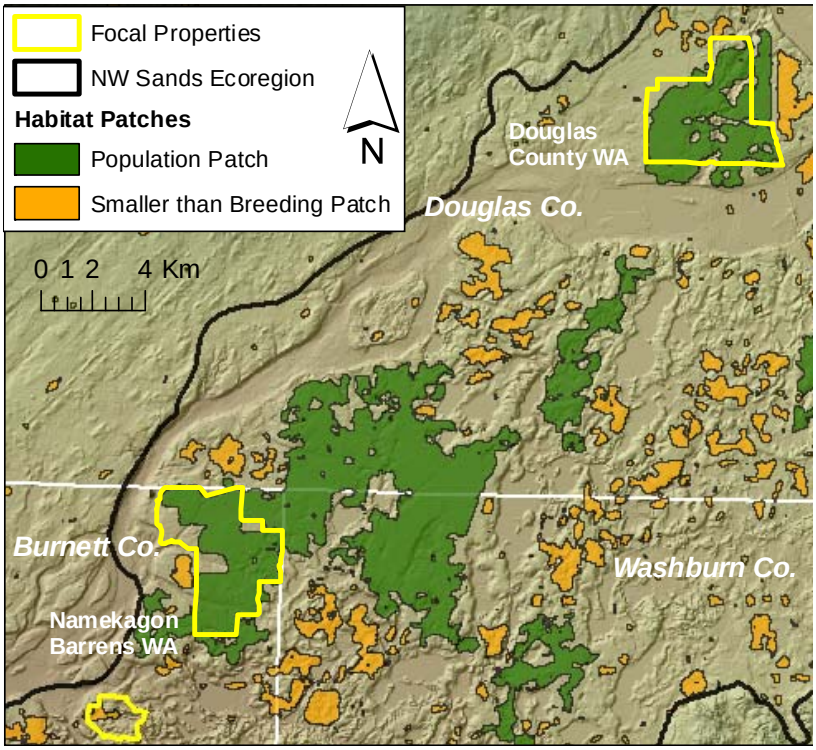

FIGURE B-10. Potential habitat patches between Namekagon Barrens and Douglas County Wildlife Areas.

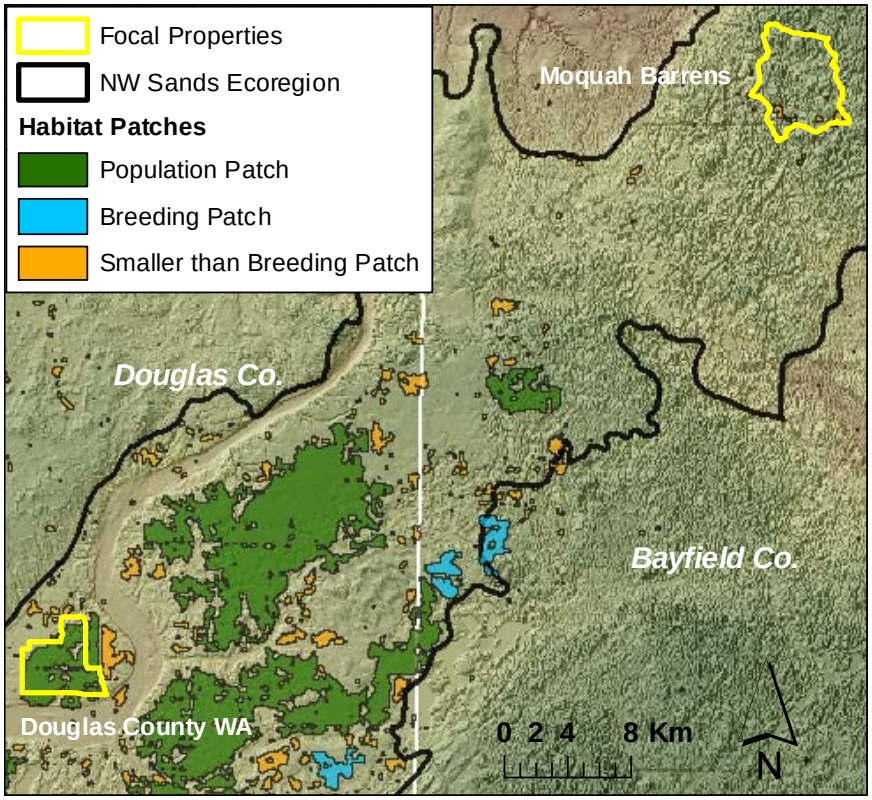

FIGURE B-11. Potential habitat patches between Douglas County Wildlife Area and Moquah Barrens.

d. Identifying Best Corridor Options

CDT uses a habitat suitability model and user parameters specific to target species to develop corridor slices between focal properties. To do so, it first generated a cost distance for each pixel that represents the inverse of suitability, selects for population and breeding patches, and results in a cost raster grid (Figures B-12 to B-15). These grids represent the permeability of the landscape to movement by target species, specifically sharp-tailed grouse, where high values represent the most permeable portions of the landscape.

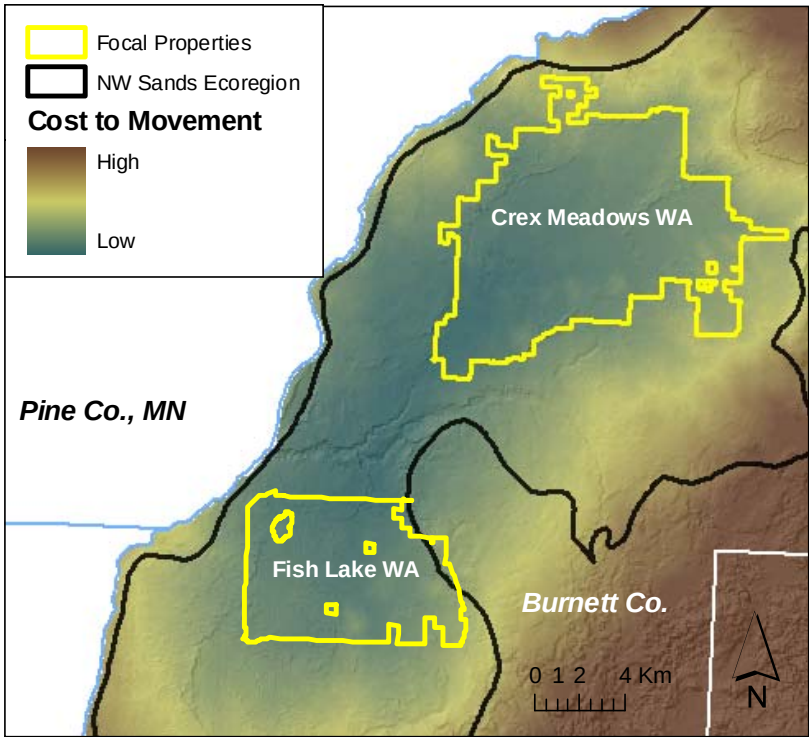

FIGURE B-12. Cost grid layer for Crex Meadows and Fish Lake Wildlife Areas. Low cost values represent the most permeable portions of the landscape.

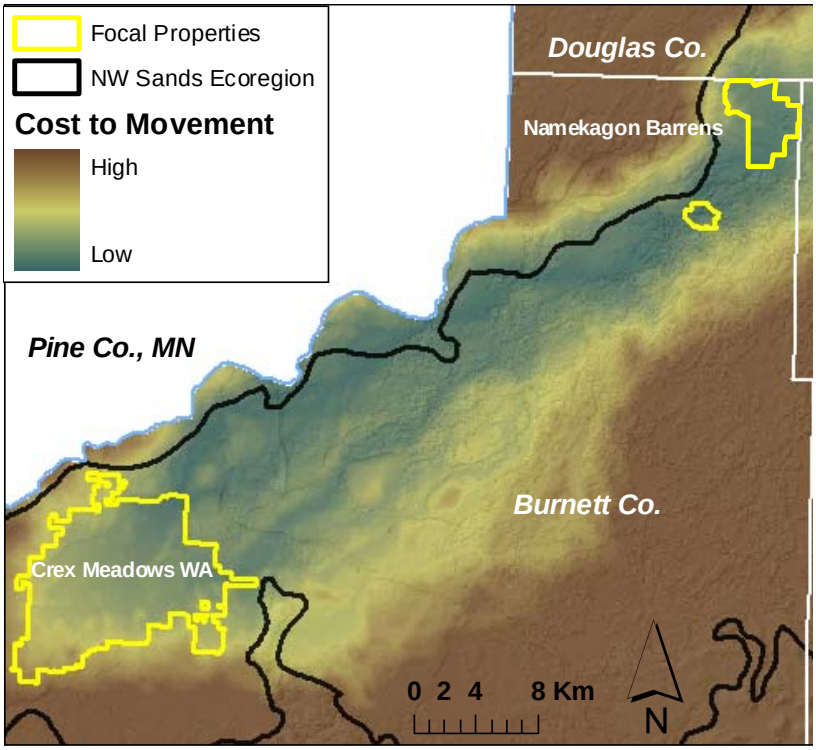

FIGURE B-13. Cost grid layer for Crex Meadows and Namekagon Barrens Wildlife Areas. Low cost values represent the most permeable portions of the landscape.

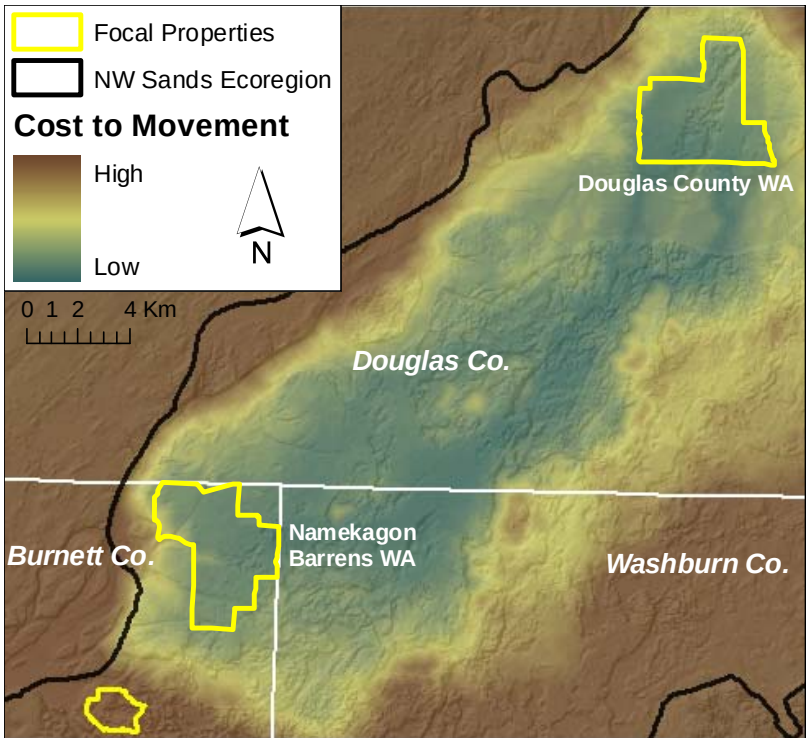

FIGURE B-14. Cost grid layer for Namekagon Barrens and Douglas County Wildlife Areas. Low cost values represent the most permeable portions of the landscape.

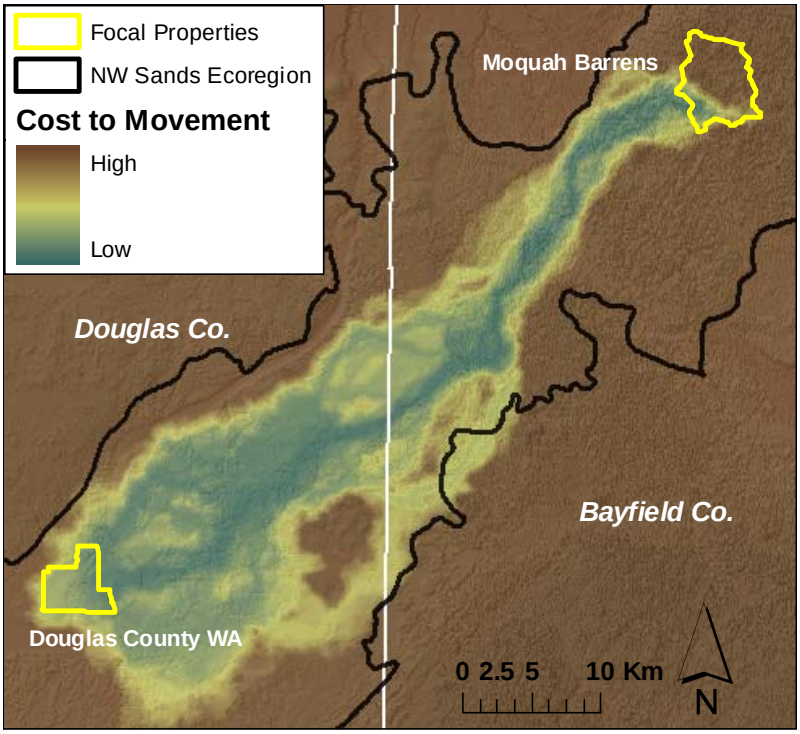

FIGURE B-15. Cost grid layer for Douglas County Wildlife Area and Moquah Barrens. Low cost values represent the most permeable portions of the landscape.

Corridor slices were then generated that represent continuous swaths of permeable pixels. Multiple corridors were generated that represented the most permeable fractions (presented in percent) of the landscape (e.g., the cost grid). Therefore, corridors representing the most permeable 1% of the landscape, for example, will differ in size, width, and location depending on the level of permeability between focal properties (Figure B-16). We generated corridor slices every 0.1% between 0 and 10% of the most permeable portion of the landscape (Figure B-17).

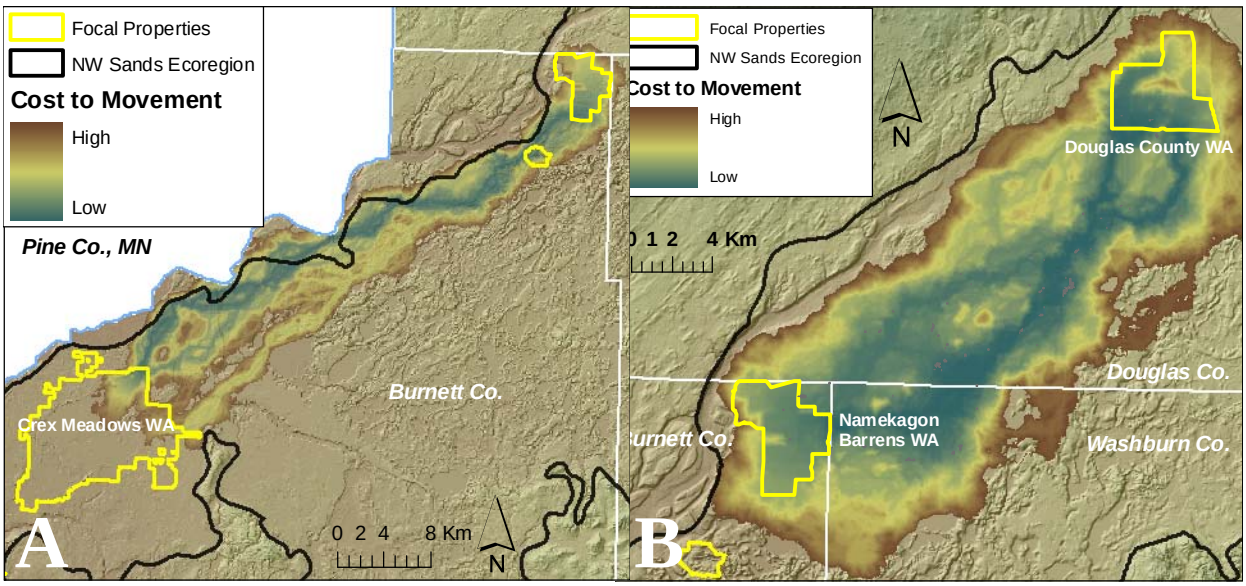

FIGURE B-16. Cost grid map within the corridor representing the most permeable 2.0% of the landscape from A) Crex Meadows to Namekagon Barrens and B) Namekagon Barrens to Douglas County Wildlife Areas. Note the difference in map scale. Permeability is significantly higher in B.

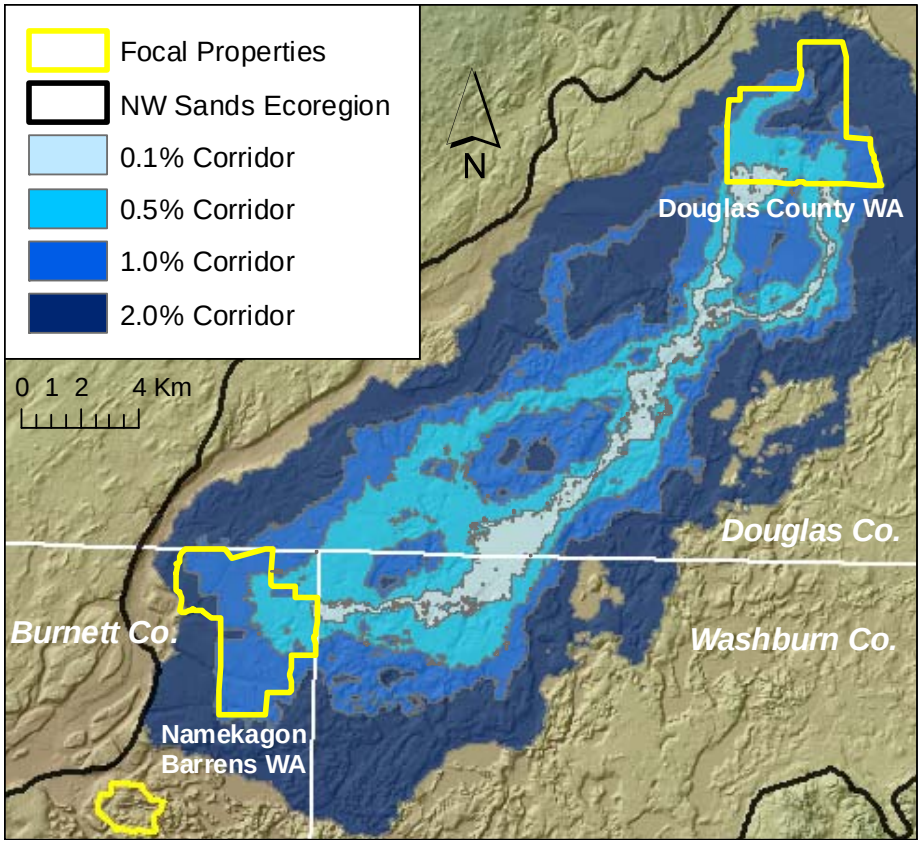

FIGURE B-17. Example of four corridor slices between Namekagon Barrens and Douglas County Wildlife Areas. Corridor slices represent different values for the most permeable percentage of the landscape.

We determined a recommended corridor from the slices generated. Slices that were large (e.g., >2%) were not considered due logistical infeasibility for land acquisition or management. We defined a recommended corridor as the smallest corridor slice (to the nearest 0.1% of the most permeable landscape) with a mean width of2275m and with at least 50% of the corridor above this threshold (Table B-5). This width is based on a recommended habitat block size of 1280ac for sharp-tailed grouse (USDA 1999). Corridor slices that moved through areas with appropriate soil types for barrens restoration and which contained significant publicly-owned property (i.e., county forests, state and federal properties) were chosen over those that did not.

e. Sensitivity Analyses

The corridor model we developed is merely that; a model. We recognize that user inputs or assumptions can potentially bias an outcome. To determine how sensitive our final

model was to factors used to parameterize the model, we conducted a sensitivity analysis by comparing our model with new models created with different inputs. Specifically, we were interested in our factor weights. In our original model, we weighted the factors of landcover vegetation type, landcover vegetation percent, and landcover vegetation height as 50%, 25%, and 25%, respectively. We ran two additional corridor models using respective weights of 25, 50, 25 (Alternative A) and 25, 25, 50 (Alternative B) for the factors and compared the corridors produced between focal properties. We then compared the percent overlap of corridor slices representing the same percentage of the landscape.

Alternative corridors produced by altered factor weights produced corridors of similar shape and width to those by the proposed corridor model. For corridor slices of 0.1%, 0.5%, 1.0%, and 2.0% of the most permeable landscape, we compared the percentage of the alternative corridors that were captured by the proposed corridors between each pair of focal properties. Proposed corridors captured a high percentage of the alternative corridors (Figure B-18; mean 87.2%).

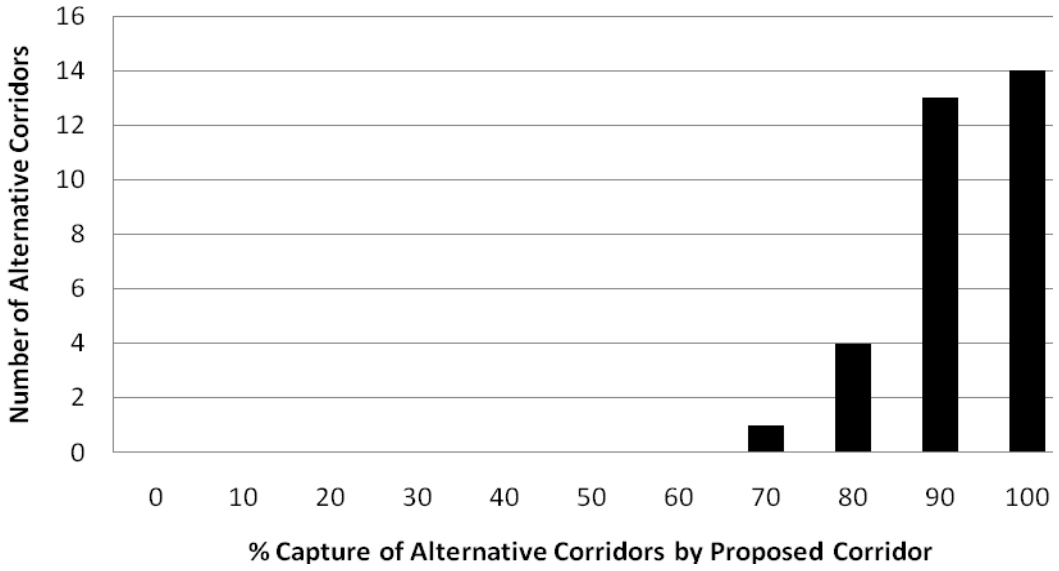

FIGURE B-18. Results of sensitivity analysis for alternative corridor models. Bars indicate the number of corridors by overlap percentage. Corridors with 100% overlap indicate extreme insensitivity to alternative model inputs. Results indicate strong parameterization of the original corridor model.

Alternative A and B performed similarly with respect to the proposed model. The proposed corridors captured Alternative A corridors between 66.8% and 99.9% (mean 86.4%) and Alternative B between 71.4% and 94.8% (mean 87.94%). Results suggest that our model was robust to uncertainty in factor weights and that parameterization of our original model was appropriate. We did not run sensitivity analyses by altering scores for classifications in the three landcover layers. It is likely that lowering scores for known crucial habitats like Pine Barrens would significantly affect model outcome. Indeed, our sensitivity analysis of factor weights likely indicates the importance of barrens habitat to habitat suitability and landscape permeability for sharp-tailed grouse. Therefore, we chose to assume high scores for barrens habitat (and other habitats with high classification scores) were important to creating suitable models for sharp-tailed grouse, and we therefore did not manipulate them.

TABLE B-1. Suitability scores (*S*) of LANDFIRE Existing Vegetation Type classifications for sharp-tailed grouse. Scores range from 0 (unsuitable) to 100 (highly suitable). Percent (%) represents the proportion of the Northwest Sands landscape in each vegetation type.

S	**Vegetation Type Class Level 1**	**Vegetation Type Class Level 2**	**%**
50	Agriculture-Cultivated Crops and Irrigated Ag	Ag-Cult. Crops and Irrigated Ag	1.8
50	Agriculture-Pasture and Hay	Agriculture-Pasture and Hay	2.6
0	Barren (Bare Land)	Barren (Bare Land)	0.0
75	Boreal Acidic Peatland Systems	Peatland Forests	4.0
40	Boreal Aspen-Birch Forest	Aspen-Birch Forest	1.1
40	Boreal Jack Pine-Black Spruce Forest	Jack Pine Forest	0.8
1	Boreal White Spruce-Fir-Hardwood Forest	Spruce-Fir-Hardwood Forest	5.5
1	Central Interior/Appalachian (CIA) Floodplain	Eastern Floodplain Forests	0.0
1	Cent. Int./Appal. Shrub-Herbaceous Wetland	Inland Marshes and Prairies	0.2
1	Central Interior and Appalachian Swamp	Atlantic Swamp Forests	0.3
0	Developed-High Intensity	Developed-High Intensity	0.0
0	Developed-Low Intensity	Developed-Low Intensity	1.4
0	Developed-Medium Intensity	Developed-Medium Intensity	0.1
0	Developed-Open Space	Developed-Open Space	2.4
1	Eastern Boreal Floodplain	Eastern Floodplain Forests	0.3
25	Laur.-Acad. Alkaline Conifer-Hardwood Swamp	Atlantic Swamp Forests	1.9
1	Laurentian-Acadian Floodplain Systems	Eastern Floodplain Forests	0.2
1	Laurentian-Acadian Northern Hardwoods Forest	Yellow Birch-Sugar Maple Forest	29.0
40	Laurentian-Acadian Northern Pine(-Oak) Forest	Red/White Pine Forest/Woodland	8.7
100	Laurentian-Acadian Pine-Oak Barrens	Jack Pine Forest	29.1
85	Laurentian-Acadian Shrub-Herbaceous Wetland	Inland Marshes and Prairies	2.9
1	Northern/Central Hardwood/Conifer Plantation	Managed Tree Plantation	0.0
25	North-Central Interior Dry Oak Forest/Woodland	Black Oak Woodland/Savanna	0.1
1	N.-Cent. Inter. Dry-Mesic Oak Forest/Woodland	Oak-Hickory Forest/Woodland	0.0
1	North-Central Interior Maple-Basswood Forest	Beech-Maple-Basswood Forest	0.2
85	North-Central Interior Oak Savanna	Bur Oak Woodland and Savanna	0.0
0	Open Water	Open Water	5.3
60	Recently Logged-Herb and Grass Cover	Transitional Herbaceous Vegetation	2.0

TABLE B-2. Suitability scores (*S*) of LANDFIRE Existing Vegetation Cover classifications for sharp-tailed grouse. Scores range from 0 (unsuitable) to 100 (highly suitable).

S	**Vegetation Cover Class**
0	Barren
50	Cultivated Crops
0	Developed-High Intensity
0	Developed-Medium Intensity
0	Developed-Roads
0	Developed-Upland Deciduous Forest
0	Developed-Upland Evergreen Forest
0	Developed-Upland Herbaceous
0	Developed-Upland Mixed Forest
0	Developed-Upland Shrubland
25	Herb Cover >=10 and <20%
60	Herb Cover >=20 and <30%
75	Herb Cover >=30 and <40%
90	Herb Cover >=40 and <50%
40	Herb Cover >=50 and <60%
25	Herb Cover >=60 and <70%
10	Herb Cover >=70 and <80%
1	Herb Cover >=80 and <90%
1	Herb Cover >=90 and <=100%
85	Herbaceous Semi-dry
85	Herbaceous Semi-wet
85	Herbaceous Wetlands
25	NASS-Close Grown Crop

S	**Vegetation Cover Class (cont'd.)**
50	NASS-Pasture and Hayland
50	NASS-Pasture and Hayland
50	NASS-Row Crop
25	NASS-Row Crop-Close Grown
0	Open Water
50	Pasture/Hay
0	Quarries-Strip Mines -Gravel Pits
50	Shrub Cover >=10 and <20%
90	Shrub Cover >=20 and <30%
100	Shrub Cover >=30 and <40%
75	Shrub Cover >=40 and <50%
50	Shrub Cover >=50 and <60%
25	Shrub Cover >=60 and <70%
10	Shrub Cover >=70 and <80%
75	Tree Cover >=10 and <20%
60	Tree Cover >=20 and <30%
50	Tree Cover >=30 and <40%
25	Tree Cover >=40 and <50%
1	Tree Cover >=50 and <60%
1	Tree Cover >=60 and <70%
1	Tree Cover >=70 and <80%
1	Tree Cover >=80 and <90%
1	Tree Cover >=90 and <=100%

TABLE B-3. Suitability scores (*S*) of LANDFIRE Existing Vegetation Height classifications for sharp-tailed grouse. Scores range from 0 (unsuitable) to 100 (highly suitable).

S	Vegetation Height Class
0	Barren
50	Cultivated Crops
0	Developed - High Intensity
0	Developed - Medium Intensity
0	Developed-Roads
0	Developed-Upland Deciduous Forest
0	Developed-Upland Evergreen Forest
0	Developed-Upland Herbaceous
0	Developed-Upland Mixed Forest
0	Developed-Upland Shrubland
60	Forest Height 0 to 5 meters
25	Forest Height 10 to 25 meters
1	Forest Height 25 to 50 meters
50	Forest Height 5 to 10 meters
100	Herb Height > 1.0 meter
75	Herb Height 0 to 0.5 meters

S	Vegetation Height Class (cont'd.)
75	Herb Height 0.5 to 1.0 meters
85	Herbaceous Semi-dry
85	Herbaceous Semi-wet
85	Herbaceous Wetlands
25	NASS-Close Grown Crop
50	NASS-Pasture and Hayland
50	NASS-Pasture and Hayland
50	NASS-Row Crop
25	NASS-Row Crop-Close Grown Crop
0	Open Water
50	Pasture/Hay
0	Quarries-Strip Mines-Gravel Pits
50	Shrub Height > 3.0 meters
25	Shrub Height 0 to 0.5 meters
75	Shrub Height 0.5 to 1.0 meter
100	Shrub Height 1.0 to 3.0 meters

TABLE B-4. Weights for LANDFIRE habitat factors input in the habitat suitability model. Weights are percentages (that sum to 100) and represent the relative influence of each habitat factor on the overall suitability of the landscape.

LANDFIRE Raster Data	Factor Weight
Vegetation Type Class	50
Vegetation Cover Class	25
Vegetation Height Class	25

TABLE B-5. Summary statistics of recommended corridors for sharp-tailed grouse to link NW Sands focal properties. FL=Fish Lake Wildlife Area, CM=Crex Meadows Wildlife Area, NB=Namekagon Barrens Wildlife Area, DC=Douglas County Wildlife Area, MB=Moquah Barrens. Threshold (*T*) width for recommended corridor is 2275m.

	Focal Property Pairs			
	FL to CM	CM to NB	NB to DC	DC to MB
Corridor %	0.3	1.1	0.8	1.8
Mean Width (m)	3040	2361	2543	2867
% of Corridor >*T*	98.3	55.8	58.7	51.5

Appendix C. Minimum Model Corridors

Above we presented recommended corridors that were based on the preferable habitat block sizes for sharp-tailed grouse in the northern Midwest (USDA 1999). In order to provide a minimally acceptable corridor size, we also developed minimum corridor sizes based on baseline habitat size requirements of sharp-tailed grouse. We defined a minimum corridor as the smallest corridor slice (to the nearest 0.1% of the most permeable landscape) with a mean width of1135mwith at least 50% of the corridor above this threshold. This width is based on a minimum habitat block size recommendation of 1.3km^2 or 320ac for sharp-tailed grouse (USDA 1999). Minimum slices were developed for all focal property pairs. Figures of corridors between focal pairs and summary tables are given below.

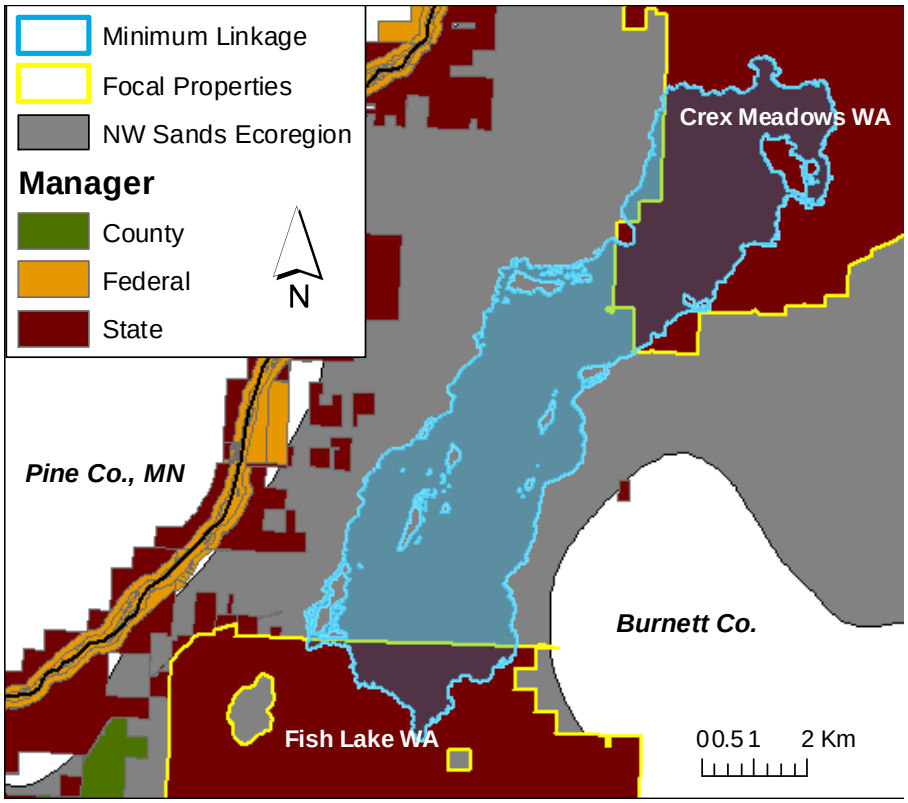

FIGURE C-1. Minimum linkage between Fish Lake and Crex Meadows Wildlife Areas showing all publicly-managed properties in the map area.

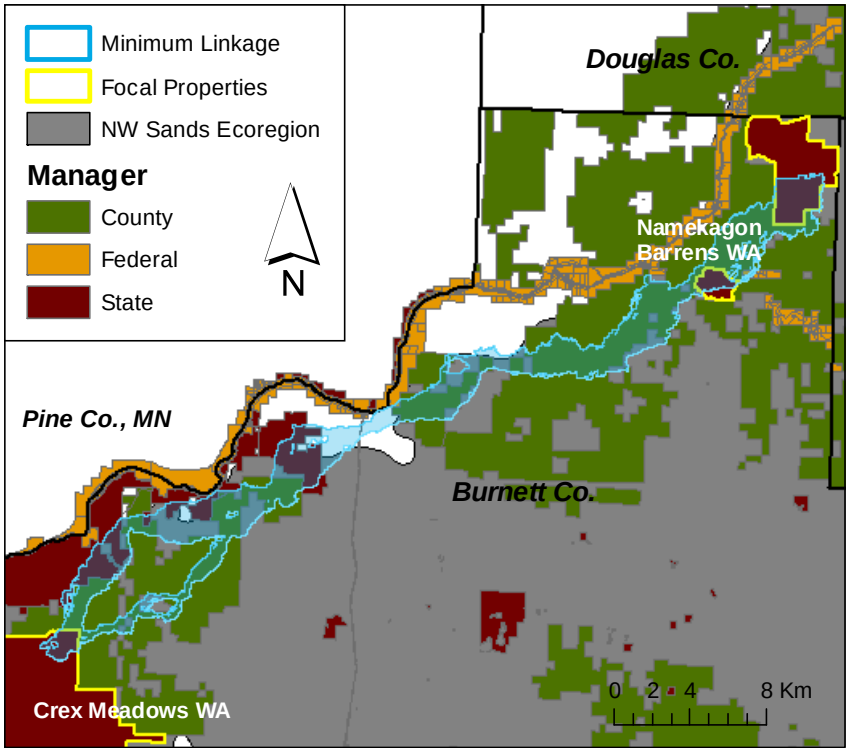

FIGURE C-2. Minimum linkage between Crex Meadows and Namekagon Barrens Wildlife Areas showing all publicly-managed properties in the map area.

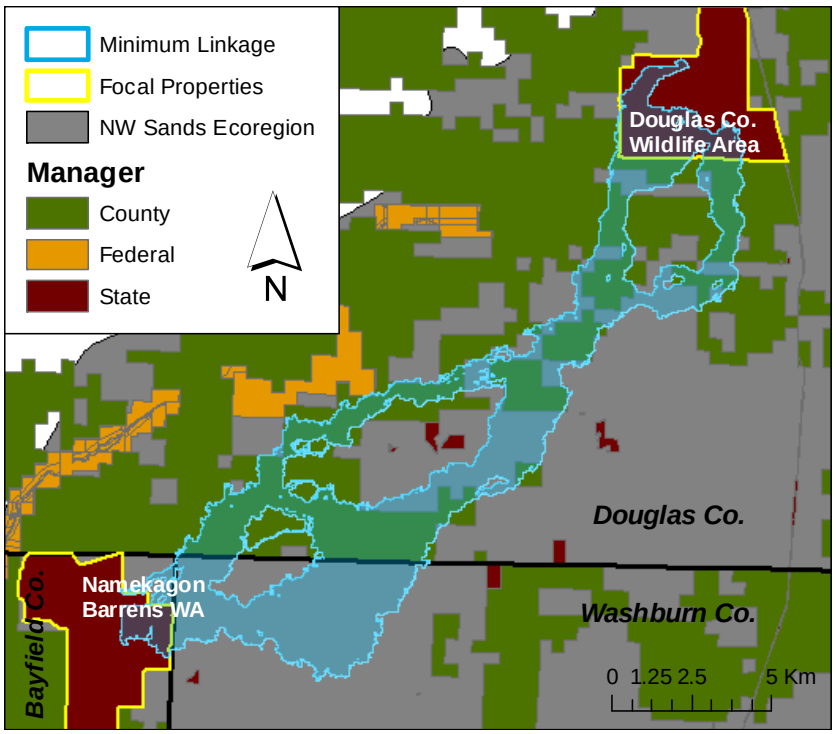

FIGURE C-3. Minimum linkage between Namekagon Barrens and Douglas County Wildlife Areas showing all publicly-managed properties in the map area.

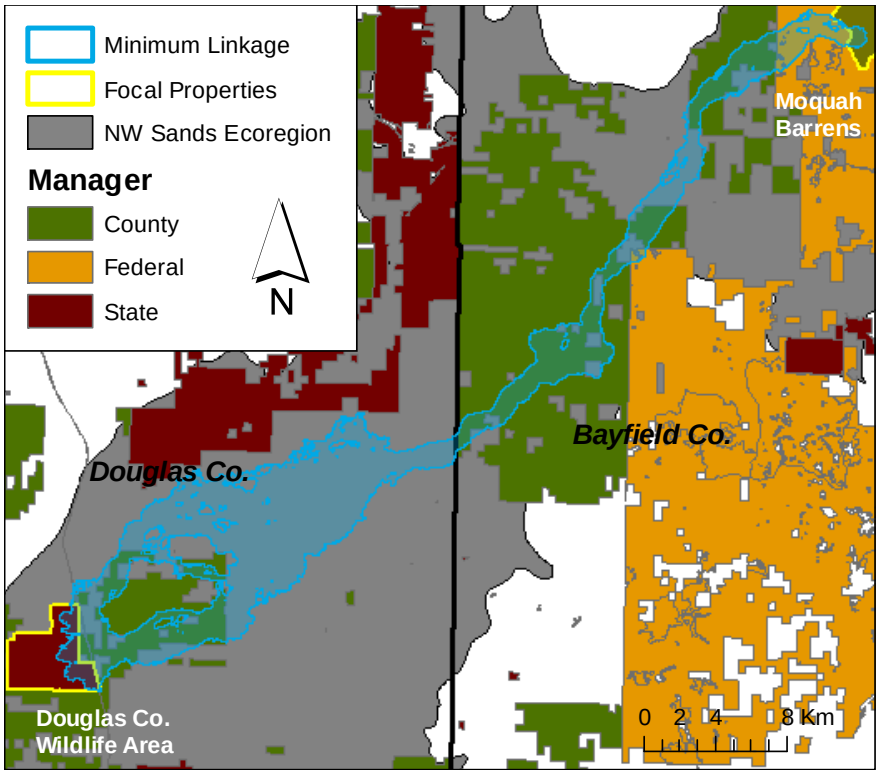

FIGURE C-4. Minimum linkage between Douglas County Wildlife Area and Moquah Barrens showing all publicly-managed properties in the map area.

TABLE C-1. Summary of metrics of minimum corridors for pairs of focal properties. Length and width is given in meters. FL=Fish Lake Wildlife Area, CM=Crex Meadows Wildlife Area, NB=Namekagon Barrens Wildlife Area, DC=Douglas County Wildlife Area, MB=Moquah Barrens.

	Size (ac)	Length	Mean Width	Median Width	Min Width	Max Width
FL to CM	8858	8540	1743	1622	1241	3093
CM to NB	22057	49074	1264	1265	487	2168
NB to DC	17481	25150	1421	1235	605	3006
DC to MB	39639	64524	1584	1395	446	4697

TABLE C-2. Percent of vegetation classifications within minimum corridors between focal property pairs. Open water and vegetation classifications <1.0% in all corridors are not included in the table.

Vegetation Classification	FL to CM	CM to NB	NB to DC	DC to MB
Conifer				
Boreal Acidic Peatland Systems	4.2	7.4	7.9	0.8
Boreal Jack Pine-Black Spruce Forest	1.9	2.2	2.0	<0.1
Laurentian Pine-Oak Barrens	35.9	35.1	66.9	71.0
Laurentian-Acadian (L-A) Northern Pine	6.5	16.6	1.0	7.3
Conifer-Hardwood				
Boreal White Spruce-Fir-Hardwood Forest	2.4	1.0	0.8	2.3
Hardwood				
Boreal Aspen-Birch Forest	0.1	4.2	1.0	0.5
L-A Northern Hardwoods Forest	9.4	15.4	4.0	7.6
N. Central Interior Dry Oak Forest/Woodland	2.0	0	0	0
Grassland				
Recently Logged-Herb and Grass Cover	5.3	6.9	6.9	4.4
Riparian				
L-A Alkaline Conifer-Hardwood Swamp	3.6	1.1	1.4	0.3
L-A Floodplain Systems	1.1	<0.1	0	<0.1
L-A Shrub-Herbaceous Wetland Systems	19.6	3.4	1.3	0.2
Agriculture				
Cultivated Crops and Irrigated Agriculture	1.7	0.5	<0.1	0.1
Pasture and Hay	0.2	0.5	0.1	0.11
Developed				
Low Intensity	0.2	0.5	2.0	3.4
Open Space	2.9	3.6	1.3	0.6

TABLE C-3. Amount of land (ac) in minimum corridors occurring outside of focal properties (matrix) and percent of each corridor in public management. Area within the entire corridor (which includes parts of corridors within focal properties) is in Table 3-1.

		Percent of Corridor in Public Management					Percent of Matrix in Public Management				
	Matrix (ac)	County	Federal	State	Tribal	Total	County	Federal	State	Tribal	Total
FL to CM	7883	0	0	39.7	0	39.7	0	0	0	0	0
CM to NB	19815	55.6	0.4	23.4	1.1	80.5	61.9	0.5	14.6	1.2	78.2
NB to DC	14876	43.5	0	12.9	0	56.4	51.1	0	0	0	51.1
DC to MB	38264	30.8	5.4	3.0	0	39.2	31.9	4.9	0.1	0	36.7

TABLE C-4. Percent of SSURGO soil drainage types in minimum corridors. Percent is given only for the matrix between focal properties.

	Soil Drainage Type						
	Excessively drained	Somewhat excessively drained	Well drained	Moderately well-drained	Somewhat poorly drained	Poorly drained	Very poorly drained
FL to CM	74.3	0.2	0.0	14.6	1.4	5.1	4.4
CM to NB	77.9	3.7	0.0	9.2	1.5	0.2	7.5
NB to DC	93.3	1.9	0.0	0.8	4.0	0.0	0.0
DC to MB	90.1	0.3	3.1	3.2	<0.1	0.1	3.2

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