STAYING CONNECTED IN THE NORTHERN APPALACHIANS

NORTHEAST KINGDOM TO NORTHERN NEW HAMPSHIRE LINKAGE: IMPLEMENTATION PLAN TO MAINTAIN AND ENHANCE LANDSCAPE CONNECTIVITY FOR WILDLIFE

February 2013
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Cover photo: Culvert under NH Route 110 in Milan, New Hampshire (P. Steckler).
Table of Contents

Executive Summary .......................................................................................................................................................... 2
Acknowledgements ........................................................................................................................................................... 3

Introduction ................................................................................................................................................................... 4
    Northeast Kingdom to Northern New Hampshire Linkage ........................................................................... 5
    A Look Back: Understanding the Context of the Linkage’s Landscape ..................................................... 6
    Project Goal ......................................................................................................................................................... 8

Methodology ................................................................................................................................................................ 9
    Modeling Overview ............................................................................................................................................... 9
    Roadside Winter Tracking Survey ..................................................................................................................... 10
    Manual Refinements ....................................................................................................................................... 10

Results ........................................................................................................................................................................ 12
    Roadside Winter Tracking Results ..................................................................................................................... 12
    Moving Forward ............................................................................................................................................... 13

Land Protection Strategies ........................................................................................................................................... 14
    Prioritizing Land Protection Sites .................................................................................................................... 14
    Land Protection Options .................................................................................................................................. 16
    Compatible Land Uses and Management for Connectivity Conservation ................................................ 17
    Implementation Strategy .................................................................................................................................. 17

Road Barrier Mitigation Strategies ............................................................................................................................ 31
    Roads as Barriers ............................................................................................................................................... 31
    Priority Road Segments .................................................................................................................................... 31
    Assessment of Wildlife Vehicle Collision (WVC) and Road Kill Data ....................................................... 32
    Assessment of the Roadside Winter Tracking Data ....................................................................................... 33
    Types of Road Barrier Mitigation ..................................................................................................................... 34

Restoration Strategies .................................................................................................................................................... 56
    Introduction ......................................................................................................................................................... 56
    Specific Restoration Actions, Needs, and Opportunities .............................................................................. 57
    General Linkage Wide Restoration Opportunities ......................................................................................... 58

Next Steps .................................................................................................................................................................. 70

References ...................................................................................................................................................................... 72

Appendices:
A. Detailed Structural Pathway Modeling Methods
B. Roadside Wildlife Tracking Survey Methods
C. Model Conservation Easement Language for Connectivity

Addendum:
A. Parcel-Based Land Protection Strategy
**Executive Summary**

The Staying Connected Initiative is a multi-state and bi-national partnership with a goal to maintain and enhance landscape connections for wide-ranging wildlife species across the Northern Appalachian Region. The focus of this report is to develop specific strategies that, when implemented, will maintain and enhance landscape connections in the Northeast Kingdom to Northern New Hampshire (NEK-NNH) Linkage, which includes the northeast portion of Vermont, the bulk of northern New Hampshire north of the White Mountains, and the lands connecting to Mount Megantic in southern Quebec.

Conservation organizations and public agencies working with private landowners have made great progress protecting landscape-scale conservation areas in the NEK-NNH Linkage, including natural areas and their surrounding working forests. However, there are impediments to the free flowing dispersal of wide ranging mammals between these large contiguous blocks of conservation land. For instance, the Connecticut River valley, with its relatively intense transportation, development, and agriculture land uses, poses east-west connectivity challenges to a variety of species, including many Species of Greatest Conservation Need. This report identifies, based on computer modeling and field verification, pathways for wildlife to move between the landscape-scale conservation areas in the Linkage. These pathways, referred to as “structural pathways,” represent areas with sufficient connected habitat to support wildlife movement over the long-term.

This report includes three strategies to maintain and enhance wildlife connectivity within structural pathways in the NEK-NNH Linkage: land protection, road barrier mitigation, and restoration. The land protection strategy includes a framework that prioritizes specific locations to effectively and efficiently protect landscape permeability.

This report identifies twenty three road barrier mitigation sites within the Linkage and recommends strategies for each. Road barrier mitigation strategies focus on areas within the right-of-way of major roads in the Linkage. The report also identifies seventeen sites for potential restoration and includes a brief implementation strategy for each. The restoration opportunities are on both private and public lands where altering land management will improve landscape permeability for wildlife. Landowners have not been contacted to explore restoration opportunities; their willing cooperation will be necessary to advance restoration at any given site.

This report is not only a resource for advancing wildlife connectivity strategies, it is also an implementation plan to maintain and enhance wildlife connectivity within the NEK-NNH Linkage and if successfully implemented, it will contribute significantly to connectivity across the entire Northern Appalachian Region.
Acknowledgements

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The work that this report represents was accomplished truly as a team effort. Over the last three years, the Northeast Kingdom to Northern New Hampshire Linkage workgroup has guided the efforts we’ve undertaken every step of the way. Thank you to workgroup members Emily Brunkhurst, Katie Callahan, Jad Daley, Dan Farrell, Carol Foss, Steve Fuller, Cathy Goodmen, Louise Gratton, Jens Hawkins-Hilke, Heidi Holman, Phil Huffman, Jill Kilborn, Paul Marangelo, Rose Paul, Will Staats, Elizabeth Thompson, Kate Wanner, Lindsay Webb and Tracy Zchau for all of your contributions. And thank you to the workgroup members’ organizations for supporting their staff’s participation and contributions to this project.

On two occasions we conducted field days with partners to review land protection priorities and to identify and discuss road barrier mitigation and restoration opportunities throughout the Linkage. In addition to the workgroup members that spent one or both of those days in the field with us, thank you to Gina Campoli, Mike Dugas, Christine Perron, Brian Schutt, and Chris Slezar for your participation, thoughts, and ideas.

Many of the workgroup members provided valuable comments and editorial review of this report as it took shape. In addition to you all, thanks also to Joan Allen, Duane Hyde, Ray Konisky, and Jan McClure for all of your good ideas and editing that have greatly improved the report.

Finally, thanks to Mark Zankel for spearheading this work both at the regional partnership level and at the Northeast Kingdom to Northern New Hampshire Linkage level. It’s fair to say that we wouldn’t be where we are today with this work without Mark’s vision and leadership.
Introduction

The Northern Appalachian Region, also known as the Northern Forest in the US, spans 80-million acres across the U.S. and Canada including four states and four provinces. The region includes the Tug Hill Plateau and Adirondack Mountains in New York, northern Vermont and New Hampshire, the majority of Maine, southeastern Quebec, New Brunswick, Prince Edward Island, and Nova Scotia (Figure 1). As one of the most intact temperate broadleaf forests in the world, extending from sea-level to alpine tundra, the Northern Forest supports a rich diversity of both flora and fauna and is home to more than five million people.

Wide ranging mammals, including top level predators and Species of Greatest Conservation Need (SGCN) such as black bear, bobcat, and American marten, currently have the opportunity to roam freely across much of the region. However, landscape fragmentation caused by land development and transportation corridors, in addition to climate change, threaten the long term sustainability of healthy wildlife populations (New Hampshire Fish and Game Department, 2005; Kart, et al., 2005).

The need for landscape connectivity is explicitly reflected in Vermont’s and New Hampshire’s State Wildlife Action Plans. For example, the Vermont Wildlife Action Plan states that regional connectivity (i.e., Linkages to NY, NH, and Canada) must be maintained through the re-establishment of forest and linkages in the more fragmented biophysical regions (Kart, et al., 2005). Recent scientific analysis coordinated by the Two Countries-One Forest collaborative (2C1F) identified the Northern Appalachians as a region at risk of separation into a series of disconnected ecological islands. This risk increases isolation of wildlife populations thereby limiting their ability to migrate in response to habitat fragmentation and climate change.

Figure 1: The Northern Appalachian Region and the eight Staying Connected Initiative Linkages.
The Staying Connected Initiative emerged to focus on ensuring the continued persistence of SGCN in the face of impacts from habitat fragmentation and climate change. The Initiative uses a collaborative, regional approach to maintain and enhance wildlife connectivity at local scales. Project partners identified eight study areas, or “Linkages,” where specific connectivity strategies would most improve landscape connectivity (Figure 1). The Northeast Kingdom to Northern New Hampshire Linkage is the focus of this report.

Northeast Kingdom to Northern New Hampshire Linkage

The Northeast Kingdom to Northern New Hampshire (NEK-NNH) Linkage is broadly defined to include the northeast corner of Vermont, the bulk of northern New Hampshire north of the White Mountains, and the lands connecting to Mount Megantic in southern Quebec (Figure 2). To the east is the relatively unbroken forest of western Maine and to the south is the heart of the White Mountain National Forest. To the west a similar Staying Connected effort is working to maintain and enhance wildlife connectivity between the Green Mountains and the Northeast Kingdom; to the north and northeast the landscape is dominated by agricultural use.

There is a long history of conservation accomplishments protecting “core areas” in the Linkage (conserved lands where natural processes and disturbances proceed without interference or are mimicked through management), and to maintain surrounding landscape integrity through large-scale working forest conservation easements. The extensive habitat protection in these areas supports diverse wildlife populations. To sustain healthy populations of wide-ranging mammals and other wildlife in the face of fragmentation and climate change, a network of connecting lands must be maintained over the long-term to facilitate species movement between core areas (Kart, et al., 2005).

Currently, the NEK-NNH Linkage consists predominantly of unfragmented forest that is largely permeable to wildlife movement. There are over half a million acres of protected land within the Linkage in federal, state, non-governmental organization, and private ownership including several large-scale core areas.

Figure 2: NEK-NNH Linkage highlighting the eight existing landscape-scale conservation areas.
Eight landscape-scale conservation areas within the Linkage serve as source areas for species to move between for the purpose of this project (Figure 2). Each has over 20,000 acres of contiguous conservation land:

- **Nulhegan Basin (VT):** >125,000 acres including the Nulhegan Basin Division of the Silvio O. Conte National Fish and Wildlife Refuge (26,000 acres), the Plumb Creek Timber Company Working Forest Easement (56,000 acres), and The Kingdom State Forest (21,000 acres).
- **West Mountain (VT):** >60,000 acres including the West Mountain Wildlife Management Area (24,000 acres) and the Plumb Creek Timber Company Working Forest Easement (32,000 acres).
- **Victory Basin (VT):** >25,000 acres including Victory State Forest (17,000 acres) and Victory Basin Wildlife Management Area (5,000 acres).
- **Connecticut Lakes (NH):** >200,000 acres including the Connecticut Lakes Natural Area (25,000 acres), and the Connecticut Lakes Working Forest Easement (145,000 acres).
- **Bunnell-Nash Stream Forests (NH):** >64,000 acres including the Nash Stream State Forest (40,000 acres), TNC’s Vickie Bunnell Preserve (10,700 acres), and the Bunting Family Forest Legacy Easement (8,200 acres).
- **WMNF Kilkenny (NH):** >90,000 acres including the Kilkenny section of the White Mountain National Forest (70,000 acres), the Randolph Community Forest (10,000 acres) and the Jericho Mountain State Park (5,800 acres).
- **Lake Umbagog (NH):** >28,000 acres in two major blocks, including the Lake Umbagog National Wildlife Refuge (20,900 ac) and the 13 Mile Woods Community Forest (8,000 acres).
- **Mount Megantic (QC):** >28,000 acres in Southern Quebec, Canada.

The Connecticut River valley includes the most significant fragmenting features that threaten landscape connectivity in the NEK-NNH Linkage, and is therefore a major focus for the project. With its relatively flat terrain and rich alluvial soils, the valley accommodates major north-south transportation corridors, extensive agricultural uses, and the most populous towns in the Linkage. The river valley lies between Nulhegan Basin, West Mountain, and Victory Basin in Vermont, and the Connecticut Lakes Headwaters, Bunnell-Nash Stream Forests, and the WMNF Kilkenny section in New Hampshire. To a lesser extent, river valleys of major tributaries to the Connecticut River, including the Nulhegan River in Vermont and the Mohawk and Upper Ammonoosuc Rivers in New Hampshire, support transportation corridors and land uses that threaten north-south connectivity between several of the landscape-scale conservation areas.

The NEK-NNH Linkage is sparsely populated, with populations concentrated in small towns and villages throughout the river valleys. Today, the local economy within the Linkage is driven primarily by the forest products industry, agriculture, and outdoor recreation. Energy, in the form of wind facilities and transmission, is an emerging market.

**A Look Back: Understanding the Context of the Linkage's Landscape**

The Northern Forest has a history of land use that has supported its residents’ livelihoods and industries for centuries. The story of the region provides the context for why the landscape has remained intact despite its long history of human use. More critical to our interests, the story
illustrates the threat of habitat fragmentation facing the landscape today, which has broad implications for the region’s wildlife populations.

Some 300 years ago colonists began harvesting the old-growth timber resources of the region for both domestic use and export. Up until the 1850s, loggers felled and dragged logs with oxen or horses to the rivers whose spring flows would carry the logs downstream to water powered sawmills. Over time, almost all of the tall softwood trees within hauling distance of the rivers were taken. More remote stands came within reach of logging operations in the 1870s with the advent of new technologies including logging railroads and portable steam-powered sawmills. Before long, most of the large trees were gone and the lumber boom collapsed. Logging companies moved on to virgin forests in the south and west (Dobbs & Ober, 1995).

Following the initial boom for saw logs, other industries, including tanneries, clapboard mills, and boxboard factories came and went to make use of the second-growth forest. In the 1880s, the wood pulp and paper industry took hold as it was able to take advantage of the harvested landscape by using smaller diameter trees than required for sawlogs. This was a transformative development in the region as paper companies purchased vast areas of the Northern Forest from logging companies and from farmers who were leaving the region. Through the end of the 19th century and into the middle of the 20th century widespread reforestation of the region occurred under the ownership of the paper industry (Dobbs & Ober, 1995).

The growing demand for paper in the 1960s and 1970s, in addition to newer technologies for both harvesting and paper making, resulted in a renewed appetite for timber. Road construction provided access to previously inaccessible timber resources, and whole-tree harvesters and skidders greatly improved the efficiency of clearing and moving logs to the more efficient mills. By the 1980s, timber harvests strained to keep pace with the mills (Dobbs & Ober, 1995). Large multinational industrial landowners controlled more than half of the Northern Forest in the U.S. and were beginning to view some of their more marginal timberlands and waterfront holdings as corporate assets rather than timber resources necessary for long-term operational sustainability (Hagenstien, 1987 referenced in Dobbs & Ober, 1995). The timber industry realized an annual rate of return of about six percent from their most productive lands. For double or even triple-digit returns the industry could carve off and sell their less productive lands, especially those with higher development potential or those furthest away from their mills (Harper, et al., 1990).

The sale of timberland for development became a reality in the late 1980s when approximately 90,000 acres of former industrial timberland in Vermont and New Hampshire alone were sold to developers. The developers carved up the land for resale in a booming real estate market that catered to second home owners and the growing recreation and tourism industry. Although some great conservation outcomes resulted from this newly available 90,000 acres, the Northern Forest Lands Study (Harper, et al., 1990) confirmed that fragmentation of the forest was occurring through the parcelization and re-sale of tens of thousands of acres across the region. Historically, large land ownerships passed between timberland owners, which meant at an ownership level the landscape remained largely intact. The newer trend of smaller, private ownership that we see today in the Linkage presents significant threats to wildlife connectivity.

A likely outcome of the availability of relatively small parcels in the NEK-NNH Linkage is the continued development of the first and second home market. Should another real-estate boom cycle
arrive, these pressures will increase traffic volumes on roads, create the need for more road capacity upgrades, and increase construction of roads and subdivisions. The result would further fragment the landscape, making it increasingly difficult for wildlife to meet their basic life needs, to disperse from natal areas, and to migrate and adapt in response to a changing climate.

**Project Goal**

The long-term goal for the NEK-NNH Linkage is to ensure the continued persistence of wildlife SGCN in the face of impacts from habitat fragmentation and climate change. This project’s purpose is to determine the best pathways for wildlife movement between the landscape-scale conservation areas in the Linkage and to develop strategies to maintain or enhance them. This will be accomplished by (1) identifying the key habitats needed for protection to promote landscape connectivity, (2) increasing the permeability of major barriers by establishing wildlife crossings on existing roads, enhancing road management and maintenance practices, and influencing the planning of new roads, and (3) identifying and restoring areas necessary to enhance landscape connectivity.
Methodology

Modeling Overview

We used Computer models to identify structural pathways that represent the most intact dispersal corridors for eleven focal species between the eight landscape-scale conservation areas in the NEK-NNH Linkage. The Staying Connected Initiative defines a structural pathway as “an area with sufficient structural [habitat] connectivity to function as a habitat corridor”.

The eleven focal species include American marten, black bear, bobcat, Canada lynx, fisher, long-tailed weasel, mink, otter, porcupine, snowshoe hare, and wood turtle. These species are identified as “umbrella [species] for connectivity analysis” (NH Audubon & NHFG, Draft 2010), thus representing the dispersal needs of a broader suite of wide ranging animals that occur or might occur in the future within the Linkage.

The computer models take into account the focal species’ dispersal habitat preferences including land cover, proximity to roads and riparian areas, slopes, and for some species, ridgelines. These preferences were incorporated into individual species cost surfaces that serve as the basis for structural pathway mapping. In the context of this project, a cost surface can be defined as a spatial data layer that differentiates dispersal preferences for a particular species. Preferred dispersal habitats have low costs and avoided habitats have high costs.

The methodology for developing species cost surfaces and corridors largely follow the process implemented by the New Hampshire Fish and Game Department and New Hampshire Audubon in their Connectivity Model for New Hampshire (2010). The NEK-NNH project team developed a prioritization process to identify structural pathways. Figure 3 conceptually depicts the structural pathway development process. Structural pathways were verified using important wildlife use areas identified by a NH Fish and Game Department wildlife biologist, the results of a roadside winter tracking survey completed for the project, and field reconnaissance.

Appendix A includes a detailed methodology of the computer modeling process.

Figure 3: A conceptual depiction of the structural pathway development process. The top row represents developing species cost surfaces. The bottom row represents determining start/end destinations of the modeling. The middle row represents the process of mapping species corridors and developing structural pathways.
**Roadside Winter Tracking Survey**

Over the winter of 2011-2012 a wildlife tracker was hired to complete a roadside winter tracking survey along approximately 52 miles of roads in the Linkage. The purpose of the wildlife tracking survey was to test and inform the results of the structural pathway mapping. Detailed methods for the survey are provided in Appendix B.

**Manual Refinements**

We made numerous manual adjustments to the draft structural pathways that emerged from the modeling process. Manual adjustments were based on basic clean-up of polygon boundaries, ensuring focal species' most permeable corridors are represented by structural pathways, aerial photography review, and through discussions with the project team including an in-depth review by a regional NH Fish and Game wildlife biologist.

As part of the initial clean-up, we removed structural pathway fragments such as dead ends, filled holes, and smoothed boundaries to eliminate unnecessary twists and turns in the mapping. We made additional refinements to make sure that structural pathways would encompass a connection for each of the focal species' corridors. We selected the most permeable 10% of the modeling areas between the landscape-scale conservation areas to represent each species' corridors. In some cases, to accommodate a connection for one species a completely new structural pathway connection would need to be added. In these cases, rather than creating a new connection for just one species, we looked at the next most permeable 10 to 15% corridor area to determine whether existing structural pathways would accommodate the species or if minor refinements to existing structural pathways would make a connection. In each of these situations structural pathways either accommodated the species or minor refinements accommodated the species at the higher permeability level.

We did not include snowshoe hare, porcupine, and wood turtle corridors in the prioritization process that determined locations of structural pathways. For snowshoe hare and porcupine, this is because their movement behavior is not defined by a strong preference for ridgeline or riparian habitats. See Appendix A for detail on how we treated wood turtle connectivity. Through the manual refinement process, we did make sure that snowshoe hare, porcupine, and wood turtle corridors are well represented in the structural pathways.

The manual refinement process also took into consideration conditions on the ground based on aerial photography. In general we removed more densely developed areas from structural pathways in favor of connections with less development. We used the most currently available aerial photography (USDA/FSA, 2011) to check nearly every manual adjustment.

Even though it did not emerge from the models, the NEK-NNH project team decided to include the Connecticut River and its floodplain as a structural pathway because of its importance to riparian species and migratory birds. Riparian species use the river and floodplain for dispersal heading north or south, with east or west connectivity at each tributary confluence. The river provides important stopover habitat for migratory birds, particularly in spring, when insects emerge earlier at lower elevations and agricultural fields are flooded.
Finally, we conducted an in-depth review of the structural pathways with NH Fish and Game wildlife biologist Will Staats. The goal of the review was to revise, update, and corroborate structural pathways with wildlife occurrence and habitat information. In addition to a wildlife biologist on the New Hampshire side of the Linkage, W. Staats is an avid hunter and outdoorsman who resides on the Vermont side of the Linkage. The information gathered from W. Staats proved to be exceedingly valuable over the course of the project.

We reviewed structural pathways with W. Staats and recorded his comments, including species and habitat information, directly into a GIS dataset. In many cases the structural pathways identified by the model coincide with areas where W. Staats has documented wildlife use. In some cases W. Staats identified important wildlife areas not included in the structural pathways. Where practical, we added or expanded modeled structural pathways to include some of these areas. Some examples of the type of information provided by W. Staats included black bear and bobcat habitats and road crossings, American marten occurrences and habitats, deer yards, lowland spruce/fir habitats, and moose collision areas and wallows, among others.
Results

Structural pathways represent the connected habitats in the Linkage that most effectively and efficiently connect the eight landscape-scale conservation areas for the focal species. The location and configuration of structural pathways will direct efforts to maintain and enhance permeability of the NEK-NNH Linkage. We generated structural pathways that are specific and narrow enough to support feasible conservation efforts, while sufficiently broad to ensure wildlife usage. Structural pathway maps are located at the end of the Land Protection Strategy section.

Roadside Winter Tracking Results

We recorded wildlife activity at almost 1,300 data points during the roadside winter tracking survey. Some of these data points reflect multiple individuals of the same species crossing at the same location (Table 1).

<table>
<thead>
<tr>
<th>Species</th>
<th>Count</th>
<th>% of Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Otter</td>
<td>1</td>
<td>0.08%</td>
</tr>
<tr>
<td>Porcupine</td>
<td>1</td>
<td>0.08%</td>
</tr>
<tr>
<td>Unknown</td>
<td>2</td>
<td>0.15%</td>
</tr>
<tr>
<td>Bear</td>
<td>3</td>
<td>0.2%</td>
</tr>
<tr>
<td>Unidentified Large-Medium Weasel</td>
<td>4</td>
<td>0.3%</td>
</tr>
<tr>
<td>Ermine</td>
<td>7</td>
<td>0.5%</td>
</tr>
<tr>
<td>Unidentified Small-Medium Weasel</td>
<td>12</td>
<td>0.9%</td>
</tr>
<tr>
<td>Fisher</td>
<td>14</td>
<td>1.1%</td>
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<tr>
<td>Bobcat</td>
<td>20</td>
<td>1.5%</td>
</tr>
<tr>
<td>Mink</td>
<td>31</td>
<td>2.4%</td>
</tr>
<tr>
<td>Unidentified Canid</td>
<td>101</td>
<td>7.8%</td>
</tr>
<tr>
<td>Moose</td>
<td>124</td>
<td>9.6%</td>
</tr>
<tr>
<td>Snowshoe Hare</td>
<td>177</td>
<td>13.7%</td>
</tr>
<tr>
<td>Deer</td>
<td>223</td>
<td>17.3%</td>
</tr>
<tr>
<td>Fox</td>
<td>266</td>
<td>20.6%</td>
</tr>
<tr>
<td>Coyote</td>
<td>306</td>
<td>23.7%</td>
</tr>
</tbody>
</table>

Total 1292

The roadside winter tracking survey results were useful to inform and verify structural pathways, and to assist in the development of connectivity strategies. However, we recognize the following limitations of the survey results:

- Survey results represent wildlife movement patterns for just one winter and not movement patterns during other seasons or over multiple years.
• The winter of 2011-2012 was very mild with generally poor tracking conditions. Rivers that typically freeze, allowing for easy crossing opportunities, did not present such opportunities. 2011-2012 tracking results might not represent typical winter movement patterns.

• Not all species are appropriately represented during a winter tracking survey (e.g. black bear), and conclusions regarding species movement patterns should be avoided for scarce species in the dataset.

Additional analysis of the roadside winter tracking results is included in the Road Barrier Mitigation Strategy section.

**Moving Forward**

We developed three strategies to maintain and enhance landscape permeability within the NEK-NNH Linkage, with a focus on areas delineated as structural pathways. The strategies include land protection, road barrier mitigation, and restoration. In combination, implementing these three strategies will conserve important locations for wildlife movement while improving landscape permeability.
Land Protection Strategies

Structural pathways represent a connected network of lands within the Linkage where wildlife are most likely to move between the landscape-scale conservation areas now, and with successful implementation of conservation strategies, over the long-term. Additional land protection to build out the protected lands network across the structural pathways, and the resulting management of those lands, is among the most direct and feasible way to permanently secure the Linkage’s connected landscape for wildlife. This section of the report provides guidance to prioritize land protection sites for wildlife connectivity within structural pathways, an overview of land protection options, and an overview of compatible land uses and management to structure connectivity conservation around.

The set of maps at the end of this section illustrate the structural pathway network at the Linkage scale (index map) and between landscape-scale conservation areas (maps 1 through 12). The maps also show the overlap of structural pathways with road barrier mitigation and restoration sites, which are further detailed in their respective sections of the report.

Prioritizing Land Protection Sites

We recommend using four considerations for prioritizing land protection sites within structural pathways. These considerations provide partners and conservation professionals with a framework to strategically develop a long-term approach for protecting permeability within structural pathways. This approach includes developing a range of land protection priorities, from short-term where a site has high connectivity value but is also currently highly threatened, to longer-term where the connectivity value of a site is not threatened. The considerations are discussed in more detail below and include assessments of:

- Functional connectivity
- Threats to connectivity values
- Land ownership patterns and feasibility
- Valuable wildlife habitat features

Functional Connectivity

Places where wildlife use is documented are considered functionally connected. In these areas we have the highest level of confidence that the habitat is suitable for dispersal because of confirmation through field observations. In areas where functional connectivity overlaps with structural pathway modeling
results, we feel strongly that investments in land protection will be effective at maintaining permeability for wildlife. These places, when combined with high threat by development, represent the highest priorities for initiating land protection. Partner organizations and agencies have started to compile functional connectivity datasets including wildlife tracking data, roadkill locations, and wildlife use areas, all of which can be used in concert with the structural pathway mapping.

**Threat**

We define threat in terms of a parcel’s potential to be converted (i.e. developed) from its current condition to a condition less permeable to wildlife movement. Threat assessments should take into consideration parcel location, which includes proximity to roads by road class, and the area and distribution of steep slopes and wetlands, among other development constraints and appealing site attributes.

The NEK-NNH Linkage is sparsely populated outside of town and village centers and has limited highway networks, making undeveloped parcels with frontage on federal or state roads good options for easy access and development. Roads, especially those that accommodate high speeds and traffic volumes, are significant habitat fragmenting features and barriers for wildlife (see Road Barrier Mitigation Strategies). Undeveloped road frontage lots, with their higher threat of conversion and mitigating effect to the barrier of roads, are especially important to prioritize for land protection. Other site characteristics such as steep slopes and wetlands are generally more difficult to develop and reduce the threat of development.

An example of a highly threatened tract might be one that is undeveloped, relatively flat, and well drained, with road frontage along a major road. An example of a low-threat parcel is one that is located along a mountain side, landlocked by other parcels, and has no roads that lead to it. In general, the threat level diminishes upslope and away from the major transportation corridors in the Linkage’s river valleys. Investing conservation resources in the highly threatened tracts in the near-term is more likely to ensure connectivity across the Linkage over the long-term.

**Land Ownership Patterns & Feasibility**

The configuration of parcels can significantly influence the feasibility of securing a protected network of lands within a structural pathway. For example, if a 100-acre priority area is composed of two or three tracts, the feasibility of protecting those tracts is much higher than if that same area has a larger number of tracts. This is because of variations in landowners’ willingness toward conservation, higher per-acreage costs for smaller tracts, and higher transaction costs and investments in staff time to complete many projects. Some smaller parcels are critical to completing a network of connecting lands so parcel size and configuration should be assessed on a site by site basis rather than excluding smaller parcels from consideration all together. Overlaying parcel boundaries with structural pathways allows for evaluating land ownership patterns and parcel configuration.

**Valuable Wildlife Habitat Features**

Multiple structural pathway areas coincide with valuable wildlife habitat features identified in natural resource studies or planning efforts. Parcels that include such habitat features should be appropriately prioritized when taken into account with other prioritization measures, such as proximity to roads, development pressure, and land ownership patterns. For example, if there is an immediate opportunity
to protect two tracts of land and both tracts are very similar in their connectivity value, a tract with a valuable wildlife habitat feature such as a lowland spruce-fir forest should be prioritized for its unique habitat value.

Sources of information and locations of valuable wildlife habitat features include areas identified by wildlife experts, Wildlife Action Plan priority areas (New Hampshire Fish and Game Department, 2010), deer wintering areas (Vermont Fish & Wildlife Department, 2010 and New Hampshire Fish and Game Department, 2012), locations of intact and restorable floodplain forest priority areas along the Connecticut River (Marks, 2010), and the Natural Heritage databases in both Vermont and New Hampshire.

**Land Protection Options**

We discuss three common land protection options for protecting structural pathway areas for wildlife connectivity. These include fee simple interest, conservation easement, and management agreement. These options are more fully detailed in a publication titled “Conserving Your Land, Options for New Hampshire Landowners” (Lind, 2005).

**Fee Simple Interest**

Fee simple interest refers to ownership of the entire set of rights in a parcel of land. A fee simple interest involves the ownership of the parcel by a conservation mission based organization or agency to protect the natural features of the parcel that provide wildlife habitat and connectivity. Enhancing and maintaining wildlife connectivity should be a high priority for the management of fee simple interest parcels acquired for conservation purposes within a structural pathway.

**Conservation Easement**

A conservation easement is a legal agreement between a landowner (the grantor) and a conservation organization (the grantee). Through a conservation easement, the grantor voluntarily restricts some of their land ownership rights (e.g., development, mining, agriculture, forestry) for the purpose of conserving the land’s conservation and/or resource values. The grantee is then responsible for monitoring and enforcement to ensure that the land is managed in accordance with the terms of the easement. Conservation easements are held in perpetuity and endure through changes in the underlying fee ownership of the land.

Wildlife connectivity focused conservation easements can provide the necessary safeguards for landscape permeability, while allowing the private landowner to control many other rights. Model conservation easement language for landscape connectivity is located in Appendix C.

**Management Agreement**

A management agreement is a non-binding agreement between a landowner and a party interested in management of the land owned by the first party. The terms, conditions, and duration of the agreements are flexible and designed to address the management goals mutually agreed upon by both parties. While they can be effective in the short-term, management agreements are not permanent.
Compatible Land Uses and Management for Connectivity Conservation

Conserving an area for the purpose of wildlife connectivity might only provide such benefits if the connectivity values of the property are specifically identified and protected. For example, acquiring a conservation easement on a forested parcel for the purpose of wildlife connectivity will likely not achieve the desired outcome if the landowner is allowed to, and chooses to convert the property to row crops. Maintaining a permeable landscape is not solely the result of conserving land, it is more importantly the result of restricting incompatible land uses and specifying allowed compatible uses and management.

Forest cover, which is the region’s predominant natural land cover, provides ideal conditions for landscape permeability and wildlife connectivity. Conversion of forest land to active fields or agriculture reduces wildlife connectivity and should be limited in areas where wildlife connectivity is a primary focus. Timber and agricultural management should similarly be limited within and along riparian areas, which are important wildlife travel corridors. The construction and widening of roads, as well as land development, should also be limited in important connectivity areas. Forest management operations are acceptable uses of some connectivity focused conservation lands if in compliance with stewardship plans that specifically reference habitat connectivity. Habitat restoration and enhancement activities might be appropriate and beneficial in certain situations too. See Appendix C for more detail about compatible uses.

Implementation Strategy

Land protection is expensive and time-consuming. To be effective at building a network of protected lands for wildlife, a long-term commitment is required to build out that network to completion. To discontinue efforts after some progress is made might compromise that progress if development patterns or road construction disconnect secured areas in the future. Carefully choosing locations and investing in long-term efforts is the best way to insure investments in completed projects and realize wildlife permeability at meaningful scales.

We recommend initiating a strategic outreach campaign to landowners of high priority parcels to discuss conservation options and whether they are interested in pursuing permanent conservation of their land. The connectivity value of protecting one priority parcel depends strongly on continuing to protect adjacent tracts to complete the network of connecting parcels. We expect that over time, and as we demonstrate success, additional landowners will learn the benefits of this work and will be more likely to agree to protect their lands.

Addendum A provides locations of specific land protection priorities based on a parcel analysis completed for this project. This information is considered confidential and is not included in the body of the report to respect landowner sensitivities. The Nature Conservancy fully respects the rights and wishes of private landowners and only works on conservation initiatives on a voluntary basis with willing landowners. Information in Addendum A will only be distributed to The Nature Conservancy (report author), Staying Connected Initiative partners, and the project funders.
Structural Pathways Index Map
Staying Connected Initiative: NEK-NNH Linkage

Legend
- Structural Pathway Map Number
- Cut-Sheet Focal Area
- Structural Pathway
- Landscape-Scale Conservation Area
- Linkage Area

Map created 2/20/2013 by the NH Chapter of The Nature Conservancy. This is not a survey and should not be construed as one.
Map 1: Structural Pathways

NULHEGAN BASIN TO WEST MOUNTAIN

Staying Connected Initiative: NEK-NNH Linkage

Legend
- Structural Pathway
- Road Barrier Mitigation Site ID
- Restoration Site ID
- Conservation/Public Land
- GAP 1 & 2 Protected Area (natural or some management)
- GAP 1 & 2 Protected Area (multi-use)
- Landscape scale Conservation Area
- State/Federal Highway
- Stream
- Open Water
- Political Boundary

Notes:
Map created 2/22/2013. This is not a survey and should not be construed as one. Property boundaries are approximate. Aerial photo captured in 2011 by NAIP.
Map 3: Structural Pathways

Nulhegan Basin to Bunnell-Nash Stream (N)

Staying Connected Initiative: NEK-NNH Linkage

Legend
- Structural Pathway
- Road Barrier Mitigation Site ID
- Restoration Site ID
- Conservation/Public Land
  - GAP 1 & 2 Protected Area (natural or some management)
  - GAP 3 Protected Area (multi-use)
- Landscape-scale Conservation Area
- State/Federal Highway
- Stream
- Open Water
- Political Boundary

Notes:
Map created 2/22/2013. This is not a survey and should not be construed as one. Property boundaries are approximate. Aerial photo captured in 2011 by NAIP.
Map 4: Structural Pathways

Nulhegan Basin to Bunnell-Nash Stream (s)

Staying Connected Initiative: NEK-NNH Linkage

Notes:
Map created 2/22/2013. This is not a survey and should not be construed as one. Property boundaries are approximate. Aerial photo captured in 2011 by NAIP.
Map 5:
Structural Pathways

West Mountain to Bunnell/Nash Stream

Staying Connected Initiative:
NEK-NNH Linkage

Legend
- Structural Pathway
- Road Barrier Mitigation Site ID
- Restoration Site ID
- Conservation/Public Land
- GAP 1 & 2 Protected Area (natural or some management)
- GAP 3 Protected Area (multi-use)
- Landscape-scale Conservation Area
- State/Federal Highway
- Stream
- Open Water
- Political Boundary

Notes:
Map created 2/22/2013. This is not a survey and should not be construed as one. Property boundaries are approximate. Aerial photo captured in 2011 by NAIP.
Map 6: Structural Pathways
MAIDSTONE BENDS

Staying Connected Initiative: NEK-NNH Linkage

New Hampshire Chapter
24 Bridge Street, Fourth Floor
Concord, New Hampshire 03301

Legend
Structural Pathway
Road Barrier Mitigation Site ID
Restoration Site ID
Conservation/Public Land
GAP 1 & 2 Protected Area (natural or some management)
GAP 3 Protected Area (multi-use)
Landscape scale Conservation Area
State/Federal Highway
Stream
Open Water
Political Boundary

Map created 2/22/2013. This is not a survey and should not be construed as one. Property boundaries are approximate. Aerial photo captured in 2011 by NAIP. Approximate.
Map 7: Structural Pathways

BUNNELL-NASH STREAM TO WMNF KILKENNY

Staying Connected Initiative: NEK-NNH Linkage

Legend
- Structural Pathway
- Road Barrier Mitigation Site ID
- Restoration Site ID
- Conservation/Public Land
  - GAP 1 Protected Area (natural or some management)
  - GAP 2 Protected Area (multi-use)
- Landscape-scale Conservation Area
- State/Federal Highway
- Stream
- Open Water
- Political Boundary

Notes:
Map created 2/22/2013. This is not a survey and should not be construed as one. Property boundaries are approximate. Aerial photo captured in 2011 by NAIP.
Approximate. Aerial photo captured in 2011 by NAIP. Notes:

Map created 2/22/2013. This is not a survey and should not be construed as one. Property boundaries are approximate. Aerial photo captured in 2011 by NAIP.
Map 9: Structural Pathways

BUNNELL-NASH STREAM TO LAKE UMBAGOG

Staying Connected Initiative:
NEK-NNH Linkage

GAP 1 & 2 Protected Area (natural or some management)
GAP 3 Protected Area (multi-use)
Landscape-scale Conservation Area
State/Federal Highway
Stream
Open Water
Political Boundary

Legend

Structural Pathway
Road Barrier Mitigation Site ID 1
Restoration Site ID

Conservation/Public Land

Approximate. Aerial photo captured in 2011 by NAIP.

Concord, New Hampshire 03301
22 Bridge Street, Fourth Floor

New Hampshire Chapter
The Nature Conservancy
Map 11:
Structural Pathways
LAKE UMBAGOG TO CT LAKES
Staying Connected Initiative:
NEK-NH Linkage

Legend
- Structural Pathway
- Road Barrier Mitigation Site ID
- Restoration Site ID

Conservation/Public Land
- GAP 1 & 2 Protected Area (natural or some management)
- GAP 3 Protected Area (multi-use)
- Landscape-scale Conservation Area
- State/Federal Highway
- Stream
- Open Water
- Political Boundary

Notes:

Approximate. Aerial photo captured in 2011 by NAIP. Property boundaries are not to be construed as one. Map created 2/22/2013. This is not a survey and should not be considered accurate. Property boundaries are approximate. aerial photo captured 2011 by NAIP.
Map 12: Structural Pathways
CT Lakes to Mount Megantic
Staying Connected Initiative: NEK-NNH Linkage

Legend
- Structural Pathway
- Road Barrier Mitigation Site ID
- Restoration Site ID
- Conservation/Public Land
  - GAP 1 & 2 Protected Area (natural or some management)
  - GAP 3 Protected Area (multi-use)
- Landscape-scale Conservation Area
- State/Federal Highway
- Stream
- Open Water
- Political Boundary

Notes:
Map created 2/22/2013. This is not a survey and should not be construed as one. Property boundaries are approximate. Aerial photo captured in 2011 by NAIP.
Road Barrier Mitigation Strategies

Vermont Agency of Transportation Mission (2012)
“…to provide for the safe movement of people and goods in a reliable, cost-effective and environmentally responsible manner”

New Hampshire Department of Transportation Mission (2012)
“Transportation excellence enhancing the quality of life in New Hampshire”

Roads as Barriers

Roads are major fragmenting features of landscapes. Where roads are constructed, other fragmenting features such as residences, agriculture, businesses, and industry typically follow. As human communities build out, roads are often upgraded to accommodate higher traffic volumes that allow goods, services, residents, and tourists to more quickly and efficiently move from place to place.

For wildlife, roads represent physical and biological barriers (Forman & Alexander, 1998). Physically, a road may present a barrier to species because of wildlife-vehicle collisions (WVCs), habitat avoidance, steep cut or fill slopes, traffic noise, lights, fencing, guardrails, or curbs, among others. For example, the extirpation of Canada lynx in New Hampshire is thought to be in part due to WVCs (Brocke, et al., 1993 cited in Charry & Jones, 2009). However, the physical footprint of roads constitutes a small percentage of their potential ecological and biological impact (Forman & Alexander, 1998).

Biologically, roads may threaten the long-term survival of a local or regional wildlife population (Huijser, et al., 2008) not just through WVCs, but by isolating populations. In a study of turtles in central New York, populations in areas of high road density were associated with male-biased sex ratios, presumably because females are affected disproportionately by road mortalities as they seek nesting sites (Steen & Gibbs, 2004). Similarly, bobcat’s ability to cross roads is in part based on sex, age, and individual tolerance. Males seem more likely to cross open areas, which might put them at higher risk of WVC mortality and prevent females from dispersing across certain types of roads (Staats, personal communication 2012).

Of roadway variables, traffic volume has been found to have a greater impact on wildlife than speed limits or road width (Jaeger, et al., 2005). Relatively low traffic volumes (less than 500 vehicles per day) can have substantial impacts on reptiles and amphibians. Ungulates experience substantial impacts at 1,500 to 3,000 vehicles per day and carnivores at 3,000 to 6,000 vehicles per day (Charry & Jones, 2009), although volumes as low as 300 to 500 vehicles per day may significantly reduce the frequency of carnivore road crossings (Alexander, et al., 2005).

Priority Road Segments

Well-traveled roads will always present some level of physical or biological barrier to certain wildlife species. Implementation of road barrier mitigation measures along strategic road segments is the most
feasible strategy to reduce the impacts of existing roads on wildlife populations. The NEK-NNH modeled structural pathways represent wildlife movement corridors for the study’s focal species, and field observations have confirmed wildlife use of many of these modeled areas. Therefore, the focus of road barrier mitigation strategies is within the structural pathways where such efforts will contribute to the broader network of permeable lands. Road barrier mitigation measures proposed here can, and ideally will, be applied to road segments throughout the Linkage to improve overall landscape permeability for wildlife.

A priority road segment consists of the intersection of a public road right-of-way and a modeled structural pathway. In this report, priority road segments are limited to federal and state roads, as these roads accommodate the highest traffic volumes and present the most significant barriers to wildlife movements.

We identified specific road barrier mitigation sites along priority road segments during site visits. Supporting datasets used to identify road barrier mitigation sites include the roadside winter tracking survey results, WVC data (New Hampshire), road kill data (Vermont), and wildlife use areas (Staats, personal communication 2012).

Assessment of Wildlife Vehicle Collision (WVC) and Road Kill Data

In New Hampshire the only WVC data available is from an accident dataset compiled by NH DOT. Data is collected by state troopers and local police officers, and does not record species involved in the collision. Vermont has collected road kill specific data, which includes species information and carcass locations in more recent years. In Vermont, data points are collected by both the Vermont Department of Fish and Wildlife and the Vermont Agency of Transportation. For this reason the New Hampshire dataset is referred to as WVC and the Vermont dataset is referred to as road kill. In both the New Hampshire and Vermont datasets, collection methodology and time period vary widely. Given the data limitations and inconsistencies, we did not combine the two datasets nor complete a more robust analysis of the data points.

It is well understood that WVC and road kill data reflect only reported incidents of wildlife being struck by vehicles, not locations where wildlife are crossing roads successfully. In some cases high concentrations of WVCs or road kills relate more to road layout and design than to roads intersecting wildlife corridors. Furthermore, WVCs are reported primarily when large animals cause property damage; data for smaller animals are un-reported or under-reported and thus do not provide data on the broader suite of species struck by vehicles. Vermont’s road kill dataset, though more inclusive than the New Hampshire WVC dataset, shares additional shortcomings in that is does not account for animals that are struck but survive, animals that move beyond the roadway before dying, or animals that are scavenged.

Despite the pitfalls of relying on WVC and road kill data for wildlife corridor planning, a comparison of WVC data with roadside tracking data shows a positive relationship between the datasets. The correlation in New Hampshire suggests that at least in some areas WVC hotspots coincide with heavily used crossings. In many cases these mortality hotspots overlap modeled structural pathways, providing additional support that the geographic focus of our land protection, road barrier mitigation, and restoration strategies coincides with functioning wildlife travel corridors. Roadkill data in Vermont was
not included in the analysis because the roadside winter tracking study did not consistently survey a state highway in Vermont for comparison.

**Assessment of the Roadside Winter Tracking Data**

A primary use of the roadside winter tracking survey results is to evaluate characteristics patterns of wildlife crossing locations to inform the development and implementation of conservation strategies. We focused on three general questions with respect to roadside winter tracking data: (1) what are the most common adjacent land cover categories? (2) are crossings more frequent where there is forest cover on both sides of the road? and (3) does the presence of guardrails affect the frequency of wildlife crossings? It is important to note that the majority of tracking records are likely to be more indicative of home-range habitat use than dispersal behavior. Regardless, the information is informative in terms of where a species is willing to attempt a road crossing.

We did not attempt statistical analyses of tracking data (see results section). Qualitative review of the data suggests the following trends and tendencies.

Overall, the Connecticut River valley (US Route 3) and the Androscoggin River valley (NH Route 16) differ noticeably in the diversity of identified animals crossing roads. In the Connecticut River valley the tracks identified are almost exclusively white-tailed deer and canids (fox, coyote). In the Androscoggin River valley, we recorded higher wildlife diversity including bobcat, canids, ermine, fisher, mink, moose, snowshoe hare, unidentified weasels, and white-tailed deer. In addition, where NH Route 16, which is otherwise surrounded by optimal wildlife habitat, passes through residential areas in Dummer and Errol, species diversity drops sharply to mostly white-tailed deer, canids, and some moose, similar to the survey results throughout the Connecticut River valley. We present two possible explanations for these observations. First, the more dominant spruce/fir forest along the Androscoggin River contributes to the added species diversity there, and second, that species other than white-tailed deer and canids tend to avoid fragmenting features such as residential development.

Areas with forest cover on both sides of the road appear to support higher densities of road crossings for focal species. Fisher crossings were observed almost exclusively in areas with unfragmented forest cover on both sides of the road. Bobcat crossing patterns were similar to fisher, but were also observed along sections of road with adjacent clearings where snowshoe hare were also detected. Presumably, this is because bobcat prey on snowshoe hare, which were observed along hayfields and early successional habitats, but like bobcat, were observed more often where forest cover is intact on both sides of the road. Moose crossings were abundant where forest cover occurs on both sides of the road, but tracks were recorded in clearings and some residential areas as well. Mink crossings were exclusively associated with riparian areas. White-tailed deer and canids tracks occurred throughout the study area with little association to habitat. In the Connecticut River valley, white-tailed deer and to a lesser extent canids, often approached roadsides along perpendicular forested edges.

Based on the track data, guardrails did not appear to be significant barriers for wildlife movement. Black bear, which is not well represented in the dataset, is considered to be negatively affected by guardrails (Hawkins-Hilke, personal communication 2012), as are moose (Shilling, et al., 2012, Barnum, et al., 2007).
Types of Road Barrier Mitigation

Road barrier mitigation strategies are typically divided into two categories: those that attempt to influence driver behavior and those that attempt to influence wildlife behavior. Influencing driver behavior includes measures such as posting wildlife crossing signs, lowering speed limits, and adding lighting to the roadway for better driver visibility. Influencing wildlife behavior includes the installation of road crossing structures such as culverts, underpasses, or the installation of fences, and alteration of roadside habitat features (Glista, et al., 2009).

The goal for road barrier mitigation is to improve the permeability of roads for wildlife, which includes reducing collision mortality. In a national report to Congress, Huijser et al. (2008) reports that of the 34 mitigation measures they reviewed to reduce WVCs, wildlife fencing, animal detection systems, and long tunnels or bridges were found to be the most effective. Furthermore, wildlife fencing was among the most cost effective measures to reduce WVCs.

Reducing WVCs should not be a singular goal. Fencing can be a more difficult barrier for wildlife than roads. Fences can be very effective at reducing WVCs, but they can also decrease landscape permeability if not combined with additional and expensive road crossing structures. Therefore, wildlife crossing enhancement measures must be implemented based on site specific conditions and objectives.

We conducted three field assessments of priority road segments to identify road barrier mitigation opportunities. Vermont and New Hampshire transportation and wildlife agency staff participated in the field reviews to help identify and discuss mitigation sites, strategies, and feasibility. The Road Barrier Mitigation Sites Index Map and Table 2 at the end of this section detail the twenty three road barrier mitigation sites that were identified.

We carefully considered public safety and risk to existing infrastructure for each road barrier mitigation site and strategy. Successful implementation of mitigation measures will require the engagement of transportation safety experts and structural and maintenance engineers to ensure protections to motorists and infrastructure, respectively.

Measures that Influence Wildlife Behavior

The majority of road barrier mitigation measures we propose focus on influencing wildlife behavior (see Table 2). These include simple measures such as maintaining important connectivity features during infrastructure upgrades and re-vegetating roadside clearings; larger investment measures such as removing, retrofitting, or replacing guardrails and retrofitting culverts and bridges with terrestrial passage; and significant investment measures such as replacing undersized culverts with larger structures that accommodate terrestrial wildlife passage. A review of these and other potential measures that influence wildlife behavior are provided below.

*Maintain Connectivity Features*

Maintaining wildlife passage features during infrastructure upgrades is a measure that preserves road permeability where it already exists. Road Barrier Mitigation (RBM) Site 5 is a good example of this, where a bridge with excellent terrestrial passage is in disrepair and will require maintenance or replacement in the near future. RBM Site 9 is another example of a priority road segment with an old cable guardrail along one side of the road, which has a gap...
between sections. Cable guardrails are less of a barrier to wildlife than the more recently used w-beam guardrails, and gaps in guardrails are thought to lessen the barrier effect (more information is provided on guardrails below).

Re-Vegetate Roadside Clearings

Roadside mowing and brush-cutting is a maintenance measure conducted by transportation agencies to increase sight lines and driver visibility (Rea, 2003). It is also used to reduce shading of the road surface, which in winter months enables solar melting of snow and ice covered roadways (Schutt, personal communication 2012). Hawkins-Hilke (personal communication 2012) recommends restoring tree or shrub cover in close proximity to the road edge to allow wildlife to approach roadsides unexposed. This allows animals to safely wait for a good opportunity to attempt a road crossing.

The roadside winter tracking data indicated that narrow road cuts between forest canopy cover corresponds with denser focal species crossings. Conversely, along roadways where canopy cover is further away from the road edge, an animal will be forced to risk not only the road crossing, but additional time and space in the open where they are most vulnerable. Reducing or discontinuing roadside mowing would mitigate the barrier effects of open road edges.

An added benefit of roadside re-vegetation is a reduction of early successional browse from brush-cut areas that attract moose and other herbivores to the roadside (Rea, 2003). As a general practice, we recommend planting or managing for evergreen re-vegetation for the year-round cover they provide. In addition to wildlife crossing benefits, transportation agencies will realize cost savings in annual maintenance of road edges by reducing mowing and brush-cutting maintenance.

We acknowledge the potential risk to motorists that reducing sight lines (visibility) presents. However, across the hundreds of miles of well-traveled roads in the Linkage, roadside cover varies widely from conditions where forest cover is in close proximity to the road edge, to conditions where clearings and residential development are directly adjacent to roads. Driver visibility varies widely with these changing roadside characteristics. We encourage roadside re-vegetation within structural pathways, and especially in areas with documented wildlife use. As re-vegetation progresses, reduced speed limits, warning signs, and/or wildlife detection systems (all described in more detail below), should be incorporated to enhance motorist safety as deemed appropriate.

Mitigating Guardrails

Guardrails are typically installed to protect errant motor vehicles from steep roadside slopes or other hazards along the road edge (Dugas, personal communication 2012). W-beam guardrails (Figure 4) are the standard type installed in the Linkage, which can present a barrier to the movement of black bear (Hawkins-Hilke, personal communication 2012) and moose movement (Shilling, et al., 2012, Barnum, et al., 2007). W. Staats (personal communication, 2012) has observed black bear crossing under w-beam guardrails on numerous occasions, but agrees that a less obstructive structure would be preferable. W-beam guardrails are greater barriers to wildlife movement than cable and other guardrails types, as they can prevent certain animals from crossing roads, or even trap them on the road until they either escape or are struck by a
vehicle (Shilling, et al., 2012, Hawkins-Hilke, personal communication 2012). Cable guardrails present along some NH highways are old installations that no longer meet safety standards, and are under review for eventual replacement.

The 1999 Vermont Guardrail Study Committee (referenced in Shilling, et al., 2012) recommended four other types of suitable guardrails beside the w-beam. Three of these types could replace w-beam guardrails to mitigate road barrier effects on wildlife. These include box beam barriers (Figure 5), 3-cable barriers, and steel-backed timber. According to Shilling, et al., (2012), all wildlife species can cross and see through these structures more effectively than w-beam guardrails.

The best option, if available, is simply to remove unnecessary guardrails. Where long stretches of guardrail are necessary for motorist safety, breaks in the guardrail should be considered to allow crossing and escape locations for wildlife. Creating gaps in guardrails introduces blunt guardrail ends within the crash zone and can expose motorists to roadside hazards. Alternative guardrail end treatments or impact attenuators could be implemented in these locations to maintain safety conditions for motorists.

**Retrofitting Road-Stream Crossings**

Existing culverts and bridges, with some modifications, may be enhanced as wildlife crossings. Such enhancements include habitat modifications at entrances, addition of fencing to funnel wildlife under the roadway, and incorporating stepping stones or dry ledges in culverts frequently inundated with water (Glista, et al., 2009, Figure 6).

For species to utilize road-stream crossing structures, they must have adequate visibility through the structure. Dense vegetation that blocks light and visibility at either end of the structure will act as a deterrent, so vegetation should be maintained at appropriate levels (Figure 7). Additionally, the stream grade should smoothly transition between the upstream grade, the in-structure grade, and the downstream grade (Shilling, et al., 2012). Deep pools at the structure inlet and/or outlet, which are indicative of an improperly sized or positioned structure, should be restored. Similarly, perched structures may be barriers to wildlife and should be restored or replaced.
Road-stream crossings, if adequately sized, can be retrofitted to include dry upland passage. For example, RBM Site 13 includes a newly constructed bridge with rip-rap lining the abutments at approximately 30-degree slopes. The rip-rap substrate alone is a barrier for larger animals (especially ungulates). Reconfiguring the rip-rap as in Figure 8 to include a high shelf along the abutment, and adding a suitable substrate of soil and vegetation, would greatly enhance under-road wildlife passage. At RBM site 23 there is no opportunity to reconfigure rip-rap to create a dry upland shelf. Deep water conditions span from abutment to abutment. In this situation we recommend installing stepping stones for under-road passage if a poured concrete shelf isn’t feasible.

**Replacing Road-Stream Crossings**

Where opportunities exist, road-stream crossings that are either too small or otherwise pose barriers should be replaced with properly or oversized structures to accommodate wildlife passage, including dry upland passage.

**Figure 6**: A road-stream crossing with an incorporated “sidewalk”. Additionally, note the stepping stones in the foreground. These types of stepping stones could be placed within road-stream crossing structures along the length of the crossing for some terrestrial species to use.

**Figure 7**: Appropriate vegetation cover leading to a road-stream crossing structure, which does not impede use of the crossing. Source: Shilling, et al., 2012.

**Figure 8**: Under-bridge dirt ledge for terrestrial species passage. Source: Shilling, et al., 2012.
shelves. The road-stream crossing at RBM Site 10 is an example where an overly narrow arch culvert has created a plunge pool that most wildlife are unlikely to traverse. Similarly, the slope, perched outlet, and small size of the culvert at RBM Site 4 render it impassable to most terrestrial wildlife.

**Scheduled Infrastructure Upgrades**

Opportunities to implement wildlife crossing enhancements along roadways exist when improvements, such as culvert or bridge replacements, or road relocation and expansion are already on a transportation agency’s near-term work plan. Most transportation agencies use long term plans to schedule major infrastructure projects. We hope to provide information that can inform transportation partners so that wildlife connectivity becomes an important planning component. Projects that are within structural pathway areas “should be designed to allow safe passage for animals, promote habitat connectivity, be accessible, and encourage natural movements” (Glista, et al., 2009).

**Fencing**

Wildlife fencing is an effective measure to reduce WVCs (Huijser, et al., 2008, Glista, et al., 2009, TransportCanada, 2003). According to M. Dugas at NHDOT (personal communication 2012), existing right-of-way (ROW) fencing along New Hampshire roadways in the Linkage is intended more for delineating the ROW than for keeping wildlife out of it. There is a high cost associated with maintaining ROW fencing from a time and resource standpoint (Schutt, personal communication 2012).

Wildlife commonly find and navigate through fencing deficiencies, including those from improper installation, crawl holes, damage from tree falls, vehicular accidents, and vandalism (Foster & Humphrey, 1995). Fences also pose challenges to wildlife. Species can become trapped within the fencing after they breach it (Bissonette & Hammer, 2000, TransportCanada, 2003), and they can affect important seasonal movements and breeding behavior (Staats, personal communication 2012).

Fences can provide road crossing opportunities for wildlife, but only when other crossing measures are present. For example, fencing that directs wildlife under a road through an underpass structure can be very effective. The federal and state roads in the Linkage are dotted with residences and businesses where driveways and developed road frontage will result in a large number of breaks in the fencing, making the measure largely ineffective as a general practice.

We recommend using fencing very locally to funnel species into appropriately sized road crossing structures. Because a fence is effective at blocking wildlife movement, in some cases we recommend removing fences entirely.

**Measures that Influence Driver Behavior**

Some road barrier mitigation measures focus on influencing driver behavior (see Table 2). These include speed limit reductions, installing wildlife crossing signs, traffic calming measures, and enhancing driver awareness.
Reduced Speed Limits

In a WVC study at Yellowstone National Park, roads with higher speed limits had more WVCs (Figure 9). Roads with posted speed limits of 45 mph averaged less than five road kills per mile. At speed limits of 55 mph, a sharp rise to nearly 20 road kills per mile was recorded (Gunther, et al., 1998 referenced in Huijser, et al., 2008). Reduced vehicle speed also reduces the severity of personal injury and property damage associated with WVCs (National Research Council, 1998 referenced in Huijser, et al., 2008).

![Figure 9: Roadkill by posted speed limit at Yellowstone.](image)

The majority of priority road segments in the Linkage have 50 mph speed limits. Instituting speed zones in certain locations along priority road segments to reduce WVCs would increase both motorist and wildlife safety. However, reducing posted speed limits much below the designed operational speed of the road should be implemented in conjunction with “traffic calming” measures. According to Mike Dugas at NHDOT (personal communication 2012), studies have shown that drivers tend to drive at speeds that are comfortable to them based on the roadway’s design and conditions.

Reduced speed limits can lead to greater speed variation. Unreasonably low speed limits can lead to large speed differentials between those vehicles obeying the speed limit and those driving at a speed they feel is safe and reasonable. Speed variation has been shown to result in increased crash rates among motorists. On two lane rural roads, similar to those within the NEK-NNH Linkage, speed variation can be especially dangerous because of increasing numbers of vehicles passing in unsafe conditions. For reduced speed limits to be effective, implementing consistent speed enforcement must be a priority (Huijser, et al., 2008).

As an example, we propose speed limit reduction at RBM Site 7 where US Route 3 approaches the village of Groveton. Presently, speed limits change from 50 mph to 30 mph just north of Groveton. Our recommendation is to step the speed limit down to 40 mph 1.25 miles ahead of the 30 mph zone as the road enters a priority road segment and a high moose collision area (Schutt, personal communication 2012). At other RBM sites, we propose wildlife crossing speed reduction warning zones that extend across much shorter distances. These areas are associated with horizontal and vertical curves that reduce sight distances and reaction times. RBM Site 2 is an example of this proposed strategy.
Nighttime speed reduction is another measure that is likely to reduce WVCs. Ungulate related WVCs are tied very closely to times between dusk and dawn when these species typically forage under the protective cover of darkness (Rea, 2003). Because of this, and other nocturnal species movements when driver visibility is sub-optimal between dusk and dawn, reduced speed limits at these times should be most effective without disrupting day time speed limits when traffic volumes increase. While it may seem counterintuitive to reduce speed limits at night when traffic volumes are low, this approach warrants further study and consideration by transportation agencies for its potential to improve safety for both motorists and wildlife.

Speed feedback signs (Figure 10) are an effective speed reduction measure in rural areas (Federal Highway Administration, 2009). Due to the relatively high cost of speed feedback signs, they should be placed at the most strategic locations with pre- and post-installation monitoring of WVCs to assess effectiveness.

**Wildlife Crossing Signs**

Many states have installed wildlife crossing signs and have implemented public awareness programs to reduce WVCs. Effectiveness of such programs is largely unknown (Romin & Bissonette, 1996). In New Hampshire, the “Brake for Moose” campaign has been an effective awareness raising campaign to help safeguard motorists and moose. Hawkins-Hilke (personal communication 2012) suggests that wildlife crossing signs are among the least effective strategies to enhance road permeability and reduce WVCs. Since installing signs is a low cost measure, we propose the use of wildlife crossing signs in association with speed reduction zones at several RBM sites. Ideally, the effectiveness of the signs and speed zones will be measured.

**Traffic Calming**

Traffic calming is a term that describes physical measures implemented along roadways that reduce the impacts of motor vehicle use on other users. The impacts of motor vehicle use are typically thought of in terms of non-motorized street users such as pedestrians and cyclists (Federal Highway Administration, 2013). For this project we hope to apply traffic calming concepts to benefit wildlife.

Changing the look and feel of the road by installing traffic calming treatments can be an effective way to effect driver behavior (Federal Highway Administration, 2013). At two RBM sites we propose re-vegetating the roadside in close proximity to the road edge to narrow the look and feel of the roadway. Re-vegetation is an added benefit to wildlife that allows them to move closer to the road edge under cover. The risk of implementing this type of traffic calming measure is reduced driver visibility and reaction time to avoid animals that suddenly appear on the road. This risk should be mitigated in part by slower driving speeds to provide safer
crossing conditions for wildlife and motorists. Re-
vegetation of the roadside should be limited to shrubs 
(ideally evergreens), which do not pose as high a risk to 
errant motorists as trees do. Wildlife crossing signs, 
including flashing lights and animal detection systems, 
should be incorporated in conjunction with these kinds 
of measures. Other measures such as speed limit 
reduction and speed feedback signs should be 
considered with the transportation agency on a site by 
site basis as well.

Animal Detection Systems

Animal detection systems (Figure 11) use sensors to 
detect if large animals are on or approaching a section 
of road. The detection system triggers a sign with 
flashing lights that informs motorist that a large 
animal is in the vicinity of the roadway. The two most 
common types of systems in use are passive infrared 
and video detection, both of which have to distinguish 
between the movements of animals and vehicles. In 
experimental studies these systems reduced WVCs by 
82 percent on average (Huijser, et al., 2008).

This type of system, though still experimental, is a promising and unobtrusive technology that 
enhances road permeability by making the road safer to cross for wildlife. It also provides a 
great benefit to motorists by effectively reducing WVCs. Estimated costs for these systems are 
between $65,000 and $154,000 per mile (Huijser, et al., 2008).

Figure 11: Animal detection system. 
Source: Huijser et al., 2008.
Road Barrier Mitigation Sites Index Map
Staying Connected Initiative: NEK-NNH Linkage

Legend
- Road Barrier Mitigation Site ID
- Structural Pathway
- Landscape-Scale Conservation Area
- Surface Water
- Highway
- Linkage Area

Map created 2/22/2013 by the NH Chapter of The Nature Conservancy. This is not a survey and should not be construed as one.
Table 2: Sites identified for road barrier mitigation to enhance landscape permeability for wildlife. To implement any of the site strategies, transportation safety experts must be engaged to assess and balance public safety needs and requirements. Additionally, roadway and structural engineers must guide design, maintenance, and feasibility.

<table>
<thead>
<tr>
<th>Road Barrier Mitigation Site 1</th>
<th>Site Photo (IMG_486)</th>
<th>Site Map (1” = 150’)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Site Strategy:</strong> The US Route 3 bridge over Lyman Brook in Columbia, NH provides excellent passage for riparian species. Modification of the substrate under the bridge to incorporate a dry ledge or dry stepping stones will enhance this crossing for terrestrial species.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Road Barrier Mitigation Site 2</th>
<th>Site Photo (IMG_486)</th>
<th>Site Map (1” = 200’)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Site Strategy:</strong> The highlighted road segment includes the most intact roadside habitat along US Route 3 within the structural pathway between Nulhegan Basin and Bunnell-Nash Stream Forests in the town of Columbia, NH. The curve has a vertical component as it traverses a ridge feature extending across the road segment northwest to the Connecticut River floodplain. The horizontal and vertical curves introduce sight distance limitations for drivers. The roadside wildlife tracking survey identifies a local concentration of wildlife crossings within this road segment. We recommend a speed limit reduction through the 1,000-foot road segment.</td>
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</tbody>
</table>
### Road Barrier Mitigation Site 3

**Site Photos (100_5849, 100_5850, 100_5854)**

![Site Photos](image)

**Site Map (1" = 150')**

![Site Map](image)

**Site Strategy:**
The US Route 3 crossing of Bissell Brook in Stratford, NH lies within a structural pathway between West Mountain and Bunnell-Nash Stream Forests. Bissell Brook is an important 3rd order stream that connects the Connecticut River valley well into the Bunnell-Nash Stream Forests conservation area. In the short-term, we recommend reducing mowing practices to allow for re-vegetation along a pull-off area on the northeast side of the six-foot corrugated metal culvert (below left). Over the long-term, this culvert is undersized and backs water up during high flow events nearly to road level. The culvert should be upgraded to a structure that includes aquatic and upland passage under normal flow conditions.
<table>
<thead>
<tr>
<th>Site Photo</th>
<th>Site Map (1” = 200’)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="100_5844" alt="Site Photo" /></td>
<td><img src="Stratford" alt="Site Map" /></td>
</tr>
</tbody>
</table>

**Site Strategy:** This crossing is located along a wet swale and intermittent stream system between West Mountain and Bunnell-Nash Stream Forests in Stratford, NH. The 16” concrete culvert slopes steeply to a deep gully on the west side of US Route 3. The culvert is too small to pass medium and larger sized mammals, leaving over-road travel as the only alternative for crossing the road. This crossing, with its intact riparian cover, offers a good opportunity to install a wildlife underpass structure for large mammals, such as black bear. Such a structure should also incorporate grade control at the outlet to reduce further erosion and deepening of the gully on the west side of the road.

<table>
<thead>
<tr>
<th>Site Photo</th>
<th>Site Map (1” = 200’)</th>
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</thead>
<tbody>
<tr>
<td><img src="IMG_0502" alt="Site Photo" /></td>
<td><img src="Brunswick" alt="Site Map" /></td>
</tr>
</tbody>
</table>

**Site Strategy:** The VT Route 102 crossing of the fourth order Paul Stream between West Mountain and Bunnell-Nash Stream Forests in Brunswick, VT consists of a bridge in disrepair immediately north of documented black bear habitat. The bridge includes under-road terrestrial passage on both sides of the river, with evidence of wildlife use by observation of tracks in the floodplain sediment. A similar design with under-road terrestrial passage should be maintained when this structure requires replacement.
### Site Strategy:

US Route 3 crosses this unnamed perennial stream between West Mountain and Bunnell-Nash Stream Forests in Stratford, NH. The stream extends from the Connecticut River nearly to the Bunnell-Nash Stream conservation area, almost entirely through a locally significant, high mast producing northern red oak forest that is valuable wildlife habitat. The roadside winter tracking survey identified wildlife crossings in close proximity to the stream crossing to the north and south. The road layout includes a northbound curve to the west just beyond the extent of the site map and a vertical curve associated with the stream crossing. Both curves introduce WVC hazards by reducing sight distances, reaction times, and braking distances. We recommend a wildlife crossing speed reduction zone of 45 mph or less through the stream crossing area and around the corner to the north. Additionally, a pull-off on the northwest side of the culvert should be allowed to re-vegetate.

In the longer-term, the 3’x5’ concrete box culvert should be enlarged to include dry terrestrial species passage. The upstream concrete headwall is deteriorating so some maintenance will be required to the structure in the near-term. At its outlet, the culvert is perched by approximately two feet.
Table 2, continued

<table>
<thead>
<tr>
<th>Road Barrier Mitigation Site 7</th>
<th>Site Map (1” = 1,000’)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Site Strategy:</strong> As US Route 3 southbound approaches the village of Groveton (town of Northumberland), it crosses a structural pathway connecting West Mountain, Victory Basin, Bunnell-Nash Stream Forests, and the WMNF Kilkenny section. This area was identified by Brian Schutt (personal communication 2012), NHDOT Maintenance Engineer as a high moose collision area. Additionally, this site has the most intact habitat within the structural pathway north of Groveton. The US Route 3 speed limit reduces to 30 mph further south as it approaches the densely settled area of Groveton. We recommend an incremental speed limit reduction southbound and increase northbound from 50 mph to 40 mph for an additional 1.25 miles north of the 30mph speed zone.</td>
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<table>
<thead>
<tr>
<th>Road Barrier Mitigation Site 8</th>
<th>Site Photo (IMG_0508)</th>
<th>Site Map (1” = 200’)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Site Strategy:</strong> VT Route 102 crosses this unnamed first order perennial stream between West Mountain, Victory Basin, Bunnell-Nash Stream Forests, and the WMNF Kilkenny section in Maidstone, Vermont. The stream passes through a 36” concrete culvert that has an outlet perch of approximately three feet. The riparian corridor provides excellent habitat for wildlife travel with the exception of the steep road fill slope. The site is located at the northern extent of a black bear travel corridor that connects across the Connecticut River valley. We recommend upgrading this culvert to include under-road terrestrial passage.</td>
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<tr>
<td>Site</td>
<td>Site Photo</td>
<td>Site Map (1’ = 600’)</td>
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</tr>
<tr>
<td>Site 9</td>
<td><img src="IMG_o469" alt="Site Photo" /></td>
<td>![Site Map](1” = 600’)</td>
</tr>
<tr>
<td><strong>Site Strategy:</strong></td>
<td>This site in Northumberland, NH is one of the most intact US Route 3 road crossings with natural land cover on both sides of the road. It lies between West Mountain, Victory Basin, and the WMNF Kilkenny section. It is within a known black bear crossing area, and it has a local concentration of wildlife-vehicle collisions. Two separate sections of cable guardrail abut the slope on the west side of the road. When these guardrails are replaced the gap in the guardrail should be maintained for wildlife passage. If opportunities exist to reduce the length of guardrail, or use a type of guardrail that is less of a barrier such as a box-beam type, such measures should be implemented to enhance wildlife passage. Beyond the guardrail on the west side of the road (right side of picture) mowing should be discontinued to improve cover for wildlife passage.</td>
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</table>

<p>| Site 10 | <img src="100_5869" alt="Site Photo" /> | ![Site Map](1” = 150’) |
| <strong>Site Strategy:</strong> | The VT Route 102 crossing of the second order Emery Brook lies between Victory Basin and the WMNF Kilkenny section in Guildhall, Vermont. The associated Emery Brook riparian area provides excellent wildlife habitat. The crossing structure is an arched concrete culvert with prohibitively steep slopes on both sides of the road. The too-narrow culvert has resulted in a large blow-out pool at its outlet. The upstream headwall of the structure is degrading; maintenance will be required in the near future. The existing structure should be replaced with one that is appropriately sized and includes upland passage for wildlife. |</p>
<table>
<thead>
<tr>
<th>Road Barrier Mitigation Site 11</th>
<th>Site Photo (IMG_0462)</th>
<th>Site Map (1&quot; = 400')</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Site Strategy:</strong> This segment of US Route 3 between Victory Basin and the WMNF Kilkenny section has intact forest cover along both sides of the road. The guardrail abuts a moderate slope on the west side of road (right side of picture) and trees along a slope on the east side of the road. These guardrails should be assessed to determine if they are necessary or if they can be replaced with a box beam or other more permeable guardrail type.</td>
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<thead>
<tr>
<th>Road Barrier Mitigation Site 12</th>
<th>Site Photo (100_5831)</th>
<th>Site Map (1&quot; = 200')</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Site Strategy:</strong> US Route 3 crosses this unnamed first order perennial stream between Victory Basin and the WMNF Kilkenny section in Lancaster, NH. Upon field inspection of the stream crossing, black bear scat was observed, providing direct evidence of wildlife use. A w-beam guardrail on the west side of the road is a barrier for some species passage and should be replaced with a box beam or other more permeable guardrail type.</td>
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</tbody>
</table>
### Road Barrier Mitigation Site 13

**Site Strategy:** This stretch of NH Route 26 between Bunnell-Nash Stream Forests and the Connecticut Lakes Headwaters in Colebrook, NH was recently reconfigured and improved. The road shoulders and cut slopes are covered in low grassy vegetation. We recommend discontinuing mowing of these areas to reestablish canopy cover along the roadside. The roadside winter tracking data shows relatively low concentrations of crossings in the pink outlined stretch of road compared to sections to the east and west that have canopy cover in closer proximity to the road.

At the bottom right side of the site map, NH Route 26 crosses the Mohawk River. The new bridge crossing has sloping rip-rap lined abutments on both sides of the river. We recommend that the rip-rap under the bridge be reconfigured and chinked with smaller stones and material to create a level shelf with a suitable substrate for wildlife passage along one or both sides of the river.

### Road Barrier Mitigation Site 14

**Site Strategy:** NH Route 110 crosses this unnamed first order perennial stream between Bunnell-Nash Stream Forests and the WMNF Kilkenny section in Stark, NH. The stream provides good riparian and edge habitat along the field to the north of the road for dispersal. However, an old right of way fence paralleling the road is a likely barrier for medium and large mammals. We recommend removing the fencing.
<table>
<thead>
<tr>
<th>Road Barrier Mitigation Site 15</th>
<th>Site Photo (IMG_0523)</th>
<th>Site Map (1” = 300’)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Site Strategy:</strong> NH Route 110 crosses this unnamed first order perennial stream between Bunnell-Nash Stream Forests and the WMNF Kilkenny section in Stark, NH. Mowing of the roadside should be discontinued to allow cover to reestablish in closer proximity to the road. A power line parallels the south side of the road. Shrubby vegetation should be encouraged between the side of the road and the forest canopy cover on the south side of the power line.</td>
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</table>

<table>
<thead>
<tr>
<th>Road Barrier Mitigation Site 16</th>
<th>Reference Road Segment Photo (IMG_0510)</th>
<th>Site Map (1” = 1,500’)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Site Strategy:</strong> This stretch of NH Route 110 is between the Bunnell-Nash Stream Forests and the WMNF Kilkenny section in Stark, NH. Roadside mowing throughout this section increases the barrier effect of the roadway for wildlife by widening the road’s profile. Discontinuing mowing will reestablish cover in closer proximity of the roadway, and would also have a traffic calming effect by narrowing the feel of the roadway (see reference photo above). Wildlife crossing signs, flashing warning lights, and/or wildlife detection systems should be installed to enhance motorist safety, if necessary.</td>
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</table>
### Road Barrier Mitigation Site 17

**Site Strategy:** This stretch of NH Route 110 is between the WMNF Kilkenny section and Lake Umbagog in Stark, NH. This site is very similar to RBM 16; re-vegetating the road edge will enhance road crossings for wildlife and have traffic calming effects. Wildlife crossing signs, flashing warning lights, and/or wildlife detection systems should be installed to enhance motorist safety, if necessary.

### Road Barrier Mitigation Site 18

**Site Strategy:** NHDOT is planning to reconstruct and possibly relocate portions of NH Route 16 along the Androscoggin River between the WMNF Kilkenny section and Lake Umbagog in Dummer, NH. The improvements will take place in an area with abundant wildlife crossing activity based on the roadside winter tracking survey, which included observations of mink, snowshoe hare, canids, moose, and deer tracks. Moving the road away from the river would benefit wildlife dispersing along the river. We recommend fully restoring the existing roadway using native vegetation. The new roadway should be designed with a narrow cross-section between forest canopy cover, and it should include oversized drainage structures to accommodate dry under-road wildlife passage. A non-barrier guardrail type, such as box beam, should be used if guardrails are necessary.
**Table 2, continued**

<table>
<thead>
<tr>
<th>Road Barrier Mitigation Site</th>
<th>Site Photo (IMG_0554)</th>
<th>Site Map (1” = 250’)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Site Strategy:</strong> NH Route 16 crosses this unnamed intermittent stream between the WMNF Kilkenny section and Lake Umbagog in Milan, NH. From the south vehicles approach the stream crossing over a rise and around a corner, followed by a dip into the riparian corridor. Because of the horizontal and vertical curves at this site, sight distances, reaction times, and braking distances are impaired. We recommend a speed reduction zone of 40 mph in this area for approximately 600 feet using signs similar to those proposed in RBM 2. Additionally, the downstream side of the crossing (pictured above) should be allowed to re-vegetate with shrubby vegetation, and the mowing directly adjacent to the stream channel should be discontinued.</td>
<td><img src="IMG_0554" alt="Site Photo" /></td>
<td><img src="map" alt="Site Map" /></td>
</tr>
</tbody>
</table>
### Road Barrier Mitigation Site 20

**Site Strategy:** NH Route 16 crosses this unnamed second order perennial stream between the WMNF Kilkenny section and Lake Umbagog in Milan, NH. The crossing is located just south of the densely settled village and has good quality riparian dispersal habitat. During a field inspection of the crossing, both fox and deer tracks were observed.

The curve to the north of the crossing is rather sharp and cuts between a farmhouse and barn that are directly adjacent to the road. We recommend a northbound speed reduction zone of 40 mph south of the riparian crossing and maintained around the curve to the north. A lower speed limit will increase reaction times to avoid WVCs. Pull-off areas on the east side of the road should be re-vegetated with native shrub cover.

### Road Barrier Mitigation Site 21

**Site Strategy:** These sites are located along NH Route 16 between the WMNF Kilkenny section and Lake Umbagog in Milan, NH. Relatively wide clearings are maintained in these two areas. We recommend that the maintenance of these clearings be discontinued to reestablish cover along the roadside.
### Road Barrier Mitigation Site 22

<table>
<thead>
<tr>
<th>Site Photo (IMG_0538)</th>
<th>Site Map (1&quot; = 600')</th>
</tr>
</thead>
</table>

**Site Strategy:** This site is located along NH Route 110 between the WMNF Kilkenny section and Lake Umbagog in Berlin, NH. We recommend that the maintenance of this clearing be discontinued to reestablish cover along the roadside.

### Road Barrier Mitigation Site 23

<table>
<thead>
<tr>
<th>Site Photo (IMG_0540)</th>
<th>Site Map (1&quot; = 150')</th>
</tr>
</thead>
</table>

**Site Strategy:** NH Route 110 crosses the third order Jericho Brook between the WMNF Kilkenny section and Lake Umbagog in Berlin, NH. The bridge provides excellent aquatic passage, but lacks upland terrestrial passage. We recommend reconfiguring the under-bridge substrate to include stepping stones or a dry ledge for terrestrial passage.
Restoration Strategies

Introduction

In addition to focusing on land protection of intact habitats and barrier mitigation strategies along roads, there are also opportunities with willing landowners to restore connections where land use has degraded landscape permeability. In this section, we identify locations and suggest strategies where habitat restoration will increase landscape permeability for wildlife within mapped structural pathways. Willing cooperation with private landowners will be necessary to advance restoration at any given site.

The primary restoration need is to restore natural land cover in locations where native vegetation has been removed or altered. Wildlife are most likely to disperse across relatively intact habitats where they can effectively move, rest, hunt, and/or forage. Many wildlife species, especially the focal species, are likely to avoid highly fragmented areas, particularly those caused by development (see Road Barrier Mitigation section). Most wildlife species prefer natural land cover to agricultural lands, but agricultural lands pose less of a barrier than development and may provide excellent cover depending on the season (i.e. mature corn fields, high grass meadows, or hay fields).

Restoration strategies are focused mostly in the Connecticut River valley where threats to wildlife passage are greatest. The Connecticut River valley, with its relatively high conversion from natural to agriculture and developed land, combined with continuing development threats, presents the greatest opportunities for improving connectivity.

Restoration sites, which are located on the Restoration Sites Index Map and detailed in Table 3 at the end of this section, include agricultural lands with extensive river frontage, disturbed riparian and wetland areas, abandoned lots, gravel pits, and roadside landscaped areas within structural pathways. In some cases relatively minor changes to land management practices on private lands can significantly enhance wildlife movement corridors. For example, re-vegetating a section of cleared area adjacent to an important riparian corridor is a low-cost strategy that can enhance connectivity. An added benefit is the engagement of local stakeholders to foster wildlife connectivity stewardship values.

More complex restoration sites require site-specific analysis and design. Site characteristics must be assessed to determine whether restoration will be feasible and beneficial. For example, Restoration Site 13 in Table 3 is a gravel pit with extensive road front disturbance that is a significant barrier for east-west wildlife movement. The reconfiguration of a cleared area on the site to reduce the amount of road front disturbance will greatly improve suitable dispersal habitat on both sides of NH Route 3, thus creating a natural land cover connection to habitats to the east.

These complex restoration sites might prescribe tree planting, soil remediation, site grading, culvert restoration, or other enhancements that improve dispersal habitat. In some cases this type of restoration is already underway (Figure 12).
Specific Restoration Actions, Needs, and Opportunities

Through field and GIS review we have identified seventeen sites where restoration strategies will enhance landscape permeability for wildlife (Table 3). We relied on input from wildlife professionals and the results of the roadside winter tracking survey, which indicate that reducing the distance an animal has to travel across open or dangerous terrain (such as a road) increases their chance of successfully navigating that barrier.

The recommendations detailed in Table 3 are also relevant to similar conditions throughout the Linkage. That is, landowners and land managers can use the restoration sites we’ve identified as examples for how they can apply restoration in similar conditions, which will help to improve overall landscape permeability for wildlife. Following is a description of the types of restoration strategies proposed in Table 3.

Re-Vegetation

The primary restoration strategy we recommend is planting native vegetation or allowing native vegetation to regrow in locations where natural cover has been eliminated and/or is currently managed in a way that reduces connectivity for wildlife. There are roughly four situations where re-vegetation would increase wildlife connectivity: roadsides (outside of the road’s right-of-way), riparian areas, field edges, or other locations where lands have been cleared. As a general practice, we recommend planting or managing for evergreens because they provide cover year-round.

We recommend roadside re-vegetation to allow animals to approach a road edge under natural cover and to reduce the distance they must travel across the right-of-way. Some landowners maintain cleared areas along their road frontage, a practice that compounds the habitat fragmentation effect of the roadway. Roadside re-vegetation can include reducing or altering mowing or brush-hogging schedules, increasing the width of tree cover adjacent to the right-of-way, or simply allowing shrubs and trees to recover along road edges beyond the right-of-way. In some case, allowing small roadside areas to grow back to natural cover will provide great benefits for wildlife movement, such as adjacent to a stream crossing (see Restoration Site 14). Some landowners maintain a row of trees parallel to the road as a buffer between their property and the road (see Restoration Site 8). Increasing the width to two or three trees, or allowing shrubs to grow up under the tree canopies would provide additional cover for animals to approach or travel parallel to the road until they can cross safely. Other landowners maintain yards up to the edge of roads (see Restoration Site 6), which can present roadside re-vegetation opportunities especially if habitat across the road is intact in an otherwise fragmented area.

Re-vegetation of riparian areas enhances habitat for animals that use these areas for dispersal. Many species prefer to move along rivers, streams, or wetland edges because they typically provide protective cover, are generally lower in elevation without hazardous terrain, and provide food and water. Riparian
species such as mink, otter, and wood turtle are largely restricted to riparian areas for both their habitat and dispersal needs. In many cases development and agriculture have reduced natural riparian buffers to one tree width or less (see Restoration Site 10). For riparian buffer widths, we recommend as a minimum implementing No Harvest Zones in accordance with those recommended in Good Forestry in the Granite State: Recommended Voluntary Forest Management Practices for New Hampshire (New Hampshire Department of Resources and Economic Development, 2010), which include 25-foot buffers for all perennial streams (50-foot buffers for 3rd order streams). Restoring riparian buffers provide many other benefits including stormwater retention and stream bank stabilization.

There are several ways that re-vegetation in agricultural settings will improve connectivity. We recommend increasing the natural cover along field edges, farm roads, drainage ditches, and other edges, where feasible. There are other creative ways to create permanent or rotating natural corridors through fields, such as passively allowing narrow corridors to recover and remain untilled or unmanaged for one to several years; creating hedgerows between hay and row-crop management; and/or identifying specific places for active or passive restoration that do not unduly interfere with agricultural goals. Creating multi-season, long rotations of fallow fields in a mosaic pattern across larger fields may also be an option for some locations.

In addition to respecting traditional agricultural uses, restoration should consider grassland bird habitat needs. Eastern meadowlark, bobolink, and northern harrier are all important species that require open habitat and the Connecticut River valley supports some of the best populations of these and other grassland birds. State and Federal grant and technical assistance programs (i.e. NRCS) can provide guidance and funding for wildlife habitat improvements of the kind mentioned here.

**Restore or Recover Natural Land Cover**

At some sites restoring natural cover will be more expensive and complex. Structures, converted lots, and sand and gravel pits that are no longer in use are primary candidates for active restoration. In these cases, removing pavement, fill, and/or structures would be the first step, and actively or passively restoring natural cover would occur in subsequent steps. These kinds of restoration projects will require a higher level of landowner participation, planning, funding, permitting, and site work. As such, these kinds of restoration projects should be undertaken at the highest priority locations with the expectation that they will require time, resources, and a long-term land protection outcome. We have identified several specific locations where this kind of restoration project would yield the highest connectivity benefits.

**General Linkage Wide Restoration Opportunities**

In addition to the restoration opportunities within structural pathways that are detailed in Table 3, other restoration opportunities to enhance wildlife connectivity across the Linkage are plentiful. For example, thousands of acres of active agriculture, particularly along the Connecticut River and its tributaries, pose challenges for wildlife moving up, down, and across the river valley. Improved natural streamside buffers, strips of native vegetation along roads, and intact wetland buffers would enhance wildlife habitat across the Linkage.

Outreach and education with partners and private landowners is essential to broaden the implementation of best practices for landscape permeability. By improving awareness, landowners and
land managers can change practices in ways that result in benefits to wildlife movement through relatively low or no-cost changes in land management practices. Publically owned lands provide good opportunities for restoration and habitat enhancements. For example, NH Fish and Game leases some of its lands to private land managers. Balancing lease-holder needs with wider road- and stream-side buffers on these lands would maintain traditional uses while improving wildlife habitat. Town and conservation organization owned parcels could implement similar practices.
Map created 2/22/2013 by the NH Chapter of The Nature Conservancy. This is not a survey and should not be construed as one.
Table 3: Sites identified for restoration and strategies to enhance landscape permeability for wildlife. Landowners have not been contacted to explore restoration opportunities; their willing cooperation will be necessary to advance restoration at any given site.

<table>
<thead>
<tr>
<th>Restoration Site 1</th>
<th>Site Photo (IMG_0487* &amp; _0488)</th>
<th>Site Map (1&quot; = 200’)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Site Strategy:</strong> In Cannan, VT, between Nulhegan Basin and the Connecticut Lakes Headwaters, Keyer Brook provides good wildlife movement opportunities between the Connecticut River, its associated high quality floodplain forest, and intact forested uplands. The VT Route 102 bridge provides good terrestrial species passage under the road. Expanding the natural streamside buffer on both upstream sides of the river and reducing the guardrail on the southeastern side of the crossing will enhance the connectivity value of this site.</td>
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<thead>
<tr>
<th>Restoration Site 2</th>
<th>Site Photo (IMG_0490 to _0497)</th>
<th>Site Map (1” = 1,500’)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Site Strategy:</strong> Two large fields on either side of the Connecticut River in Lemington, VT and Columbia, NH, reduce wildlife connectivity value at this location (between Nulhegan Basin and Bunnell-Nash Stream Forests). There is a deer wintering area in VT on the west side of Route 102 and frequent moose collisions on US Route 3 in this area. At the northern limit of the VT cornfield and the southern limit of the NH cornfield we recommend creating hedgerows and enhancing the CT River riparian buffer to promoted cross-river habitat and connectivity.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site Strategy</td>
<td>Site Map (1” = 500’)</td>
<td></td>
</tr>
<tr>
<td>---------------</td>
<td>----------------------</td>
<td></td>
</tr>
<tr>
<td><strong>Restoration Site 3</strong></td>
<td><img src="image" alt="Site Map" /></td>
<td></td>
</tr>
<tr>
<td><strong>Site Strategy</strong>: This site in Stratford and Columbia, NH, lies between Nulhegan Basin, West Mountain, and Bunnell-Nash Stream Forests. A deer wintering area is east of the site. Restoring native vegetation along gravel pit edges (especially the northern edge) and reconfiguring the livestock fence to the north to reduce its pinching effect would improve wildlife connectivity value within this narrow east-west structural pathway.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site Strategy</th>
<th>Site Map (1” = 400’)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Restoration Site 4</strong></td>
<td><img src="image" alt="Site Map" /></td>
</tr>
<tr>
<td><strong>Site Strategy</strong>: This large field in Stratford, NH between Bunnell-Nash Stream Forests and West Mountain, has extensive roadside frontage on both sides of NH Route 3. There is a large deer wintering area on the upslope side to the east. Improving natural cover on the road edges would increase connectivity value and additional opportunities for road crossings.</td>
<td></td>
</tr>
</tbody>
</table>
**Site Strategy:** In Brunswick, VT, between West Mountain and Bunnell-Nash Stream Forests, a large corn and hayfield complex features restorable wildlife connectivity including extensive road and river frontage. This site is adjacent to extensive bear habitat. Improving natural cover and buffer width along field edges, roadsides, and river banks, would all increase connectivity value. In the short-term we recommend working with the landowner to focus on the north and south cornfield edges, which should have minimal effects on crop yield.

**Site Strategy:** In Stratford, NH, between West Mountain and Bunnell-Nash Stream Forests, this crossing area features deer wintering habitat to the east, adjacent black bear habitat, and deer and coyote tracks along the highway. We recommend increasing roadside natural cover along the west side of US Route 3. This would provide natural vegetation on both sides of the highway. Restoring this pinch point along the highway will provide connected habitat from the Connecticut River to the unfragmented forest east of the road.
<table>
<thead>
<tr>
<th>Restoration Site 7</th>
<th>Site Strategy: This active gravel pit and fill dump (road material and concrete culverts) is located between West Mountain and Bunnell-Nash Stream Forest in Stratford, NH. It is owned and operated by NH DOT. Restoring inactive portions of the property to native vegetation would improve connectivity value for this functionally connected crossing area of NH Route 3. Confirmed deer, coyote, and bear habitat occur here, and restoring this pinch point along the highway would provide connected habitat from the Connecticut River to the unfragmented forest east of the road.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Site Strategy: This site in Northumberland, NH is at the center of multiple pathways between West Mountain, Victory Basin, the WMNF Kilkenny section, and Bunnell-Nash Stream Forests. The east side of NH Route 3 offers quality connecting habitat with extensive deer wintering area just to the east. To the west and southwest lies excellent Connecticut River floodplain forest habitat. Restoring native vegetation along the southwestern roadside would increase the connectivity value for animals moving east and west.</td>
</tr>
</tbody>
</table>
Table 3, continued

<table>
<thead>
<tr>
<th>Restoration Site 9</th>
<th>Site Photo (IMG_0506)</th>
<th>Site Map (1” = 1,500’)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Site Strategy:</strong> At this site in Maidstone, VT, we recommend re-vegetation on both sides of the highway (VT Route 102), especially at the northern corner of the fields to widen the intact forest cover pinch point. The site lies at the center of multiple pathways between West Mountain, Victory Basin, the WMNF Kilkenny section, and Bunnell-Nash Stream Forests.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Restoration Site 10</th>
<th>Site Photo (100_4368)</th>
<th>Site Map (1” = 1,500’)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Site Strategy:</strong> Both sides of the Connecticut River in Maidstone, VT and Groveton, NH provide opportunities to restore native floodplain forest, which provides cover and habitat values for multiple wildlife species. The floodplain here has been recognized as a high priority for protection and restoration. Restoring native vegetation along both sides of the river, particularly along the river bank, is recommended. The race track is a significant fragmenting feature and interferes with the dynamic nature of the floodplain system. In addition, we recommend a long-term approach of balancing hayfield management with increased native cover along riparian and wetland edges.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 3, continued

<table>
<thead>
<tr>
<th>Restoration Site 11</th>
<th>Site Photo (IMG_0464)</th>
<th>Site Map (1&quot; = 200')</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Site Strategy</strong>:</td>
<td>This derelict house in Northumberland, NH, appears to be abandoned. The landowner should be contacted to explore their plans for the property. If the landowner has no interest in restoring the house and is interested in restoration for wildlife connectivity, this site is an ideal candidate. Removing the structure and restoring the site to native vegetation would provide habitat on both sides of NH Route 3. The site lies at the center of multiple pathways between West Mountain, Victory Basin, the WMNF Kilkenny section, and Bunnell-Nash Stream Forests. Just downslope of this location there is extensive and high quality floodplain wetlands and low terrace hayfields that provide cross-river connectivity. The floodplain has been recognized as a high priority for protection and restoration for its uncommon habitat type. Additionally, this area was identified as an important black bear crossing.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Restoration Site 12</th>
<th>Site Photo (100_5836)</th>
<th>Site Map (1&quot; = 500')</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Site Strategy</strong>:</td>
<td>Dean Brook in Northumberland, NH, provides a narrow riparian dispersal corridor through this developed pinch point between the Connecticut River and the WMNF Kilkenny section. The US Route 3 bridge over the brook offers good aquatic and terrestrial wildlife passage. This site provides an opportunity to monitor wildlife movement with motion capture photography. Based on the species utilizing the corridor, restoration strategies to enhance permeability can be developed, such as stream buffer enhancements.</td>
<td></td>
</tr>
</tbody>
</table>
### Table 3, continued

<table>
<thead>
<tr>
<th>Restoration Site 13</th>
<th>Site Photo (IMG_0458)</th>
<th>Site Map (1” = 400’)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Site Strategy:</strong></td>
<td>This large, active gravel pit in Lancaster, NH, is a significant fragmenting feature between Victory Basin and the WMNF Kilkenny section. Natural land cover on the west side of NH Route 3 provides good cover for wildlife. Restoring the northern road front portion of the site would provide cross-road connected habitat, which connects to forested habitat to the east.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Restoration Site 14</th>
<th>Site Photo (IMG_0581, (representative))</th>
<th>Site Map (1” = 150’)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Site Strategy:</strong></td>
<td>This narrow riparian drainage is within an identified bear and bobcat crossing area between Victory Basin and the WMNF Kilkenny section in Guildhall, VT. Stream segments such as this, when restored with natural riparian cover, provide conductive habitat for wildlife dispersal. Connectivity between the uplands to the west and the Connecticut River to the east would be enhanced by widening the riparian buffer and re-vegetating the riparian corridor with native trees and shrubs either through active planting or passive re-growth.</td>
<td></td>
</tr>
</tbody>
</table>
### Table 3, continued

<table>
<thead>
<tr>
<th>Restoration Site 15</th>
<th>Site Photo (IMG_0457)</th>
<th>Site Map (1&quot; = 250')</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Site Strategy:</strong></td>
<td>This private staging and parking area for trucks and heavy equipment in Lancaster, NH between Victory Basin and the WMNF Kilkenny section, includes a relatively large area of mowed and open road-side. Bear and bobcat are known to cross through the western section of this site. Re-vegetation through reduced mowing or active planting along the roadside, or at the property edges, would provide natural vegetation to match natural cover on the west side of the road, and provide a good connection directly to the Connecticut River.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Restoration Site 16</th>
<th>Site Photo (IMG_0561)</th>
<th>Site Map (1&quot; = 700')</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Site Strategy:</strong></td>
<td>Upland forests to the west of NH Route 16 in Dummer, NH (between the WMNF Kilkenny section and Lake Umbagog) provide excellent habitat, whereas east of Route 16, the habitat is more dispersed and fragmented. To provide connectivity to the Androscoggin River, re-vegetation, particularly along roadsides and wet swales and drainages, would improve wildlife movement opportunities to the east and west. Establishing wider riparian buffers would increase north-south connecting habitats for wildlife movement while also reducing erosion and improving water quality, particularly during storms.</td>
<td></td>
</tr>
<tr>
<td>Restoration Site 17</td>
<td>Site Photo (IMG_0556)</td>
<td>Site Map (1” = 4,000’)</td>
</tr>
<tr>
<td>-------------------</td>
<td>-----------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td><strong>Site Strategy</strong>: Similar to Site 16, upland forests to the west of NH Route 16 in Milan, NH (between the WMNF Kilkenny section and Lake Umbagog) provide excellent habitat, whereas east of Route 16, the habitat is more dispersed and fragmented. To provide connectivity to the Androscoggin River, re-vegetation, particularly along roadsides and wet swales and drainages, would improve wildlife movement to the east and west. Establishing wider riparian buffers would increase north-south connecting habitats for wildlife movement while also reducing erosion and improving water quality, particularly during storms.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Next Steps

The next step is to transition from site identification and recommendations to strategy implementation. Implementation will depend on project funding, partner collaboration, and landowner participation. Moving forward it will also be very important to develop ways to measure the effectiveness of implemented strategies to ensure we learn from our efforts and to guide and enhance future connectivity focused conservation.

Land Protection

The land protection strategy will depend on available funding and willing landowners. The first step will be to initiate a strategic outreach campaign to communities and landowners of high priority parcels to discuss conservation options and to gauge interest. As promising land protection projects emerge, funding opportunities will be sought to undertake the projects. As the land protection building blocks for connectivity are completed the focus will expand to work with adjacent landowners to begin assembling the network of connecting parcels.

Road Barrier Mitigation

The road barrier mitigation strategy will require strong partnership building and collaboration with state transportation agencies. Staff from both Vermont and New Hampshire transportation departments helped to identify road barrier mitigation sites and we hope to build on that initial collaboration. The immediate next step is to work with the transportation agencies to cooperatively implement select road barrier mitigation measures identified in this report. Also a high priority is to conduct outreach to transportation and planning partners to raise awareness of wildlife connectivity opportunities and to identify ways of working together on such opportunities.

Another near term priority is to implement a comprehensive wildlife-vehicle collision reporting system and database with the transportation agencies. A good quality dataset, which includes GPS positions of road-killed wildlife carcasses by species, will be helpful in numerous ways. Developing and populating such a database will establish a baseline to help measure success and change over time. The dataset will also be useful to focus future road barrier mitigation efforts at roadkill hotspot locations. Lastly, such a dataset will provide data and statistics that can be used in outreach and education messaging to raise awareness of wildlife mortality on roads.

Restoration

Implementation of restoration strategies will require willing and cooperative landowners. Targeted landowner outreach will be the first step to identify property owners who are interested in managing their land to benefit wildlife connectivity and then work with those landowners to develop restoration plans. Sites that call for re-vegetation can be inexpensively restored by allowing natural recruitment to occur. As restoration strategies increase in complexity, so will the need to be creative about funding opportunities. Landowner focused outreach and education opportunities should be offered to private landowners to generate interest and awareness in land management practices that benefit wildlife connectivity.
Measuring Effectiveness

Finally, the implementation of connectivity strategies should incorporate methods to measure their effectiveness. Ideally these measures will document wildlife use (functional connectivity) pre- and post-implementation to determine how the strategies influence wildlife crossing and movement behavior. These measures will hopefully bolster the strategies put forward in pursuit of the long-term goal to ensure the continued persistence of wildlife Species of Greatest Conservation Need, and will provide rigorous data to justify changing course and methods as needed. We are optimistic that the strategies put forward in this report will move us in the right direction for wildlife connectivity.
References


New Hampshire Fish and Game Department, 2012. *Coos County Deer Wintering Areas*, Lancaster, NH: New Hampshire Fish and Game Department.


Appendix A: Detailed Structural Pathway Modeling Methods

Modeling Overview

Computer models were used to identify structural pathways that represent the most intact dispersal corridors for eleven focal species between the eight landscape-scale conservation areas in the NEK-NNH Linkage. The Staying Connected Initiative defines a structural pathway as “an area with sufficient structural [habitat] connectivity to function as a habitat corridor”.

The computer models take into account the focal species’ dispersal habitat preferences including land cover, proximity to roads and riparian areas, slopes, and for some species, ridgelines. These preferences were incorporated into individual species cost surfaces that serve as the basis for structural pathway mapping. In the context of this project, a cost surface can be defined as a spatial data layer that differentiates dispersal habitat preferences for a particular species. Preferred dispersal habitats have low costs and avoided habitats have high costs.

The methodology for developing species cost surfaces and corridors largely follow the process implemented in the Connectivity Model for New Hampshire (NH Audubon & NHFG, Draft 2010). The NEK-NNH project team developed a prioritization process to identify structural pathways. Figure 3 in the report conceptually depicts the structural pathway development process. Structural pathways were verified using functional connectivity areas identified by a NH Fish and Game Department wildlife biologist, the results of a roadside winter tracking survey completed for the project, and field reconnaissance.

Focal Species

Eleven species included in the Connectivity Model for New Hampshire are the focus of the NEK-NNH Linkage’s modeling and analysis. These species are identified as “umbrella [species] for connectivity analysis” (NH Audubon & NHFG, Draft 2010), thus representing the dispersal needs of a broader suite of wide ranging animals that occur or might occur in the future within the linkage. Following is a list of focal species separated by ridgeline or riparian dispersal preference and the habitat categories (in parenthesis) that they fall into based on the Connectivity Model for New Hampshire:

**Ridgeline using species:**
- American marten (habitat specialist, area sensitive)
- Black bear (habitat generalist)
- Bobcat (area sensitive)
- Canada lynx (habitat specialist, area sensitive)
- Fisher (habitat generalist)

**Riparian dependent species:**
- Long-tailed weasel (habitat generalist)
- Mink (habitat specialist)
- Otter (habitat specialist)
- Wood turtle (barrier sensitive)
Other Species:
Porcupine (habitat generalist, barrier sensitive)
Snowshoe hare (habitat specialist)

Developing Species Cost Surfaces

A cost surface for the NEK-NNH linkage area was created for each species listed above. Four landscape factors were combined to create species cost surfaces based on relevance to dispersal behavior and data availability. Table A-1 details the four landscape factors and the data sources used:

Table A-1: Landscape factors by geography and data source used to generate species cost surfaces.

<table>
<thead>
<tr>
<th>Landscape Factor</th>
<th>Linkage Geography</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land Cover</td>
<td>United States</td>
<td>2006 National Land Cover Data (NOAA, 2007)</td>
</tr>
<tr>
<td></td>
<td>Canada</td>
<td>Land Cover, circa 2000-Vector (Government of Canada, 2009)</td>
</tr>
<tr>
<td>Roads (distance to)</td>
<td>Vermont</td>
<td>Road Centerline data layer (Vermont Agency of Transportation, 2009)</td>
</tr>
<tr>
<td></td>
<td>New Hampshire</td>
<td>Roads 2010 (New Hampshire Department of Transportation, 2010)</td>
</tr>
<tr>
<td></td>
<td>Maine</td>
<td>Maine Public Roads (Maine Department of Transportation, 2009)</td>
</tr>
<tr>
<td></td>
<td>Quebec</td>
<td>National Road Network - Quebec (Government of Canada, 2007)</td>
</tr>
<tr>
<td></td>
<td>Canada</td>
<td>National Hydro Network (Government of Canada, 2009), Wetland classes from Land Cover, circa 2000-Vector (Government of Canada, 2009)</td>
</tr>
<tr>
<td>Slope</td>
<td>United States &amp; Canada</td>
<td>30-meter National Elevation Dataset (USGS 2005)</td>
</tr>
</tbody>
</table>

Processing was required for most of the data inputs to create the landscape factors included in the species cost surfaces. The Connectivity Model for New Hampshire project assigned costs to the factor variables for each focal species, which were peer reviewed by biologists familiar with the species. The data processing completed is outlined in the following sections.

Land Cover

The land cover dataset originally used in the Connectivity Model for New Hampshire was the 2001 NH Land Cover Assessment. That dataset has slightly different land cover classes than those in the 2006 NLCD dataset requiring some cross-walking of land cover classes. Table A-2 details the land cover class cost assignments for each of the focal species. The table predicts, on a scale of one (prefer) to ten (avoid), which land cover types each species is likely to utilize or avoid as it moves across the landscape.

Appendix A-2
For example, black bear is predicted to disperse through all natural land cover types, while American marten is predicted to favor conifer and mixed forest cover, as well as forested wetlands. All species are predicted to avoid moderately and densely developed areas.

Table A-2: Land cover cost assignments by focal species.

<table>
<thead>
<tr>
<th>Land Cover (2006 National Land Cover Dataset)</th>
<th>American Marten</th>
<th>Black Bear</th>
<th>Bobcat</th>
<th>Canada Lynx</th>
<th>Fisher</th>
<th>Long-tailed Weasel</th>
<th>Mink</th>
<th>Otter</th>
<th>Porcupine</th>
<th>Snowshoe Hare</th>
<th>Wood Turtle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developed – Low</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>Developed – Medium</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Developed – High</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Agriculture</td>
<td>9</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>6</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>Deciduous Forest</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Evergreen Forest</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Mixed forest</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Open water</td>
<td>8</td>
<td>5</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>2</td>
<td>1</td>
<td>10</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Forested wetland</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Open wetland</td>
<td>9</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>8</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Disturbed/ Other Cleared/ Scrub-Shrub</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>2</td>
</tr>
</tbody>
</table>

A land cover factor surface, which substitutes the land cover type with the land cover cost assignment, was created for each of the focal species based on the cost assignments in Table A-2.

**Distance to Roads**

Road centerline data was collected from the three states and one Canadian province within the Linkage. Annual Average Daily Traffic (AADT) volumes provide the best data for predicting road impacts on wildlife movement. However, AADT data were not available throughout the linkage area when the cost surface assembly process began. Instead, federal road classifications, which were fairly consistent across the Linkage, were used to predict road impacts on wildlife (Table A-3).
Table A-3: Federal road class groups used to predict road impacts on wildlife movement.

<table>
<thead>
<tr>
<th>Road Class Group</th>
<th>Functional Class Code</th>
<th>Functional Class Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interstate</td>
<td>1</td>
<td>Principal Arterial - Interstate</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>Principal Arterial - Interstate</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>Principal Arterial - Other</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Freeways and Expressways</td>
</tr>
<tr>
<td>Arterial</td>
<td>2</td>
<td>Principal Arterial - Other</td>
</tr>
<tr>
<td></td>
<td>6, 16</td>
<td>Minor Arterial</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>Principal Arterial - Other</td>
</tr>
<tr>
<td>Collector</td>
<td>7</td>
<td>Major Collector</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Minor Collector</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>Collector</td>
</tr>
<tr>
<td>Local or Private</td>
<td>0</td>
<td>Non-Public Roads</td>
</tr>
<tr>
<td></td>
<td>9, 19</td>
<td>Local</td>
</tr>
</tbody>
</table>

Resistance curves were developed by NH Fish and Game and NH Audubon to predict the impact on wildlife movements based on the distance from various road classes. The road classes used include (1) interstate and arterial (US routes, some state and provincial highways), (2) collector and paved local (some state and provincial highways, paved municipal roads), and (3) unpaved and private roads. Railroads constituted a fourth class. Table A-4 details the resistance curves assigned to each species by road class, and Figures A-1 through A-3 provide the resistance curve equations and graphical depictions of the curves.

Table A-4: Distance to roads resistance curves assigned to each species by road class group. “h” represents intense road effects (Figure A-1), “m” represents moderate road effects (Figure A-2), and “l” represents mild road effects (Figure A-3). The number code represents the curve number, listed both at the end of the curve name before the equation and on the graph in the figures.
Distance from major roads (Fclass Interstate and Arterial)

Cost is decreasing as you move away from the road.
Actual high cost equations used in Raster Calculator:

\[ C:\text{Templintart\_h1} = \frac{10}{1 + (0.01 \times (\exp(0.09 \times ([\text{dist\_intart\_m}]))))} \]

\[ C:\text{Templintart\_h2} = \frac{10}{1 + (0.001 \times (\exp(0.06 \times ([\text{dist\_intart\_m}]))))} \]

\[ C:\text{Templintart\_h3} = \frac{10}{1 + (0.0025 \times (\exp(0.02 \times ([\text{dist\_intart\_m}]))))} \]

\[ C:\text{Templintart\_h4} = \frac{10}{1 + (0.009 \times (\exp(0.006 \times ([\text{dist\_intart\_m}]))))} \]

Figure A-1: Resistance curve equations and graph for major roads.
Distance from collector and paved local roads

Cost is decreasing as you move away from the road. Actual moderate cost equations used in Raster Calculator:

C:\Temp\collect_m1 = 6 / (1 + (0.08 * (exp(0.09 * ([dist_coll_m])))))
C:\Temp\collect_m2 = 6 / (1 + (0.04 * (exp(0.06 * ([dist_coll_m])))))
C:\Temp\collect_m3 = 6 / (1 + (0.001 * (exp(0.06 * ([dist_coll_m])))))
C:\Temp\collect_m4 = 6 / (1 + (0.004 * (exp(0.02 * ([dist_coll_m])))))
C:\Temp\collect_h3 = 10 / (1 + (0.0025 * (exp(0.02 * ([dist_coll_m])))))  Lynx only
C:\Temp\gravel_m1 = 6 / (1 + (0.08 * (exp(0.09 * ([dist_gravel_m])))))  Snakes, Turtles

Figure A-2: Resistance curve equations and graph for collector and paved local roads.
Appendix A-7

Figure A-8: Resistance curve equations and graph for unpaved roads, private roads, and railroads. Source: NH Audubon & NHFG, Draft 2010.
Applying a resistance curve to a road centerline creates a raster dataset with higher costs directly adjacent to the road that diminish at specified rates moving away from the road until no road effects are predicted on wildlife movement. This is illustrated in the graph of Figure A-1, where the cost at the road edge is at the highest level (cell value = 10), trailing off to no effect (cell value = 0) at different rates and at different distances from the road. The curves reflect that some species’ movements are primarily affected in close proximity to roads (such as curve h1, which is assigned to porcupine, snowshoe hare, and wood turtle), while other species are sensitive to roads even when they are far away from them (curve h4, assigned to Canada lynx).

Distance from road factors were compiled for each focal species based on the road class curves assigned to them by wildlife professionals who participated in the Connectivity Model for New Hampshire project (Table A-4).

**Distance to Riparian Areas**

Riparian areas were compiled from hydrography and wetland datasets from across the linkage, merged and further buffered to 50-meters. Resistance curves were assigned for each species by wildlife professionals who participated in the Connectivity Model for New Hampshire project to predict where each species is most likely to disperse across the landscape in relation to riparian areas. Figure A-4 provides the resistance curve equations and graphical depictions of the distance to riparian curves. Table A-5 provides the curve assignments for each species. Some species are only likely to disperse in close proximity to riparian areas (curve 2, wood turtle). Species assigned curve 5 are predicted to have a slight preference for traveling through riparian areas, but they are not restricted to them.

![Resistance Curve Equations and Graph for Riparian Effects](image)

**Figure A-4:** Resistance curve equations and graph for riparian effects.

Table A-5: Distance to riparian curve assignments for the focal species. The resistance curve equations and graph are shown in Figure A-4.

<table>
<thead>
<tr>
<th>Distance to Riparian Curve Number</th>
<th>American Marten</th>
<th>Black Bear</th>
<th>Bobcat</th>
<th>Canada Lynx</th>
<th>Fisher</th>
<th>LT Weasel</th>
<th>Mink</th>
<th>Otter</th>
<th>Porcupine</th>
<th>SSH</th>
<th>Wood Turtle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>2</td>
</tr>
</tbody>
</table>

Distance to riparian factors were built for each of the resistance curves in Figure A-4 by applying the curve equation to the linkage wide riparian surface. Wide surface water features were predicted to be barriers for wildlife movement in the Connectivity Model for New Hampshire. Areas of lakes and ponds greater than a quarter mile wide were attributed as having a high cost (cell value equal to 10). In the Connectivity Model for New Hampshire these areas were differentiated in the land cover factor, not the riparian factor.

**Slope**

In the Connectivity Model for New Hampshire, wildlife professionals predicted the effects of slopes on the dispersal of the focal species. Figure A-5 provides the resistance curve equations and graphical depictions of the slope curves and Table A-6 provides the curve assignments for each species. Some species are much more sensitive to slopes when dispersing than others, which is represented by the curves. For example, the curves indicate that wood turtle (curve 1) is very slope sensitive, while most of the other species, with the exception of snowshoe hare and porcupine (curves 2 and 3, respectively), are quite tolerant of steep slopes when dispersing.

**Figure A-5: Resistance curve equations and graph for slope effects.**

Table A-6: Slope curve assignments for the focal species.

<table>
<thead>
<tr>
<th>SLOPE (percent)</th>
<th>American Marten</th>
<th>Black Bear</th>
<th>Bobcat</th>
<th>Canada Lynx</th>
<th>Fisher</th>
<th>LT Weasel</th>
<th>Mink</th>
<th>Otter</th>
<th>Porcupine</th>
<th>SSH</th>
<th>Wood Turtle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>
A slope surface was generated from the linkage-wide 30-meter digital elevation model. Slope factors were built for each species by applying their assigned slope resistance curve to the linkage wide slope surface.

### Combining Factors into Species Cost Surfaces

The landscape factors described above were combined in ArcGIS using the Weighted Sum tool to create species cost surfaces. The focal species were categorized based on their dispersal habitat preference for ridgelines, riparian areas, or neither. Within these groups we assigned relative influences to each of the landscape factors. The relative influences of the factors are listed in Table A-7. The determinations of relative influences are based on literature reviews (NH Audubon & NHFG, Draft 2010) and peer review.

#### Table A-7: Relative influences of cost surface factors.

<table>
<thead>
<tr>
<th>Species</th>
<th>Relative Influences of Cost Surface Factors</th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Bear</td>
<td>40% Land Cover, 10% Riparian, 40% Roads, 10% Slope, Apply 5 Point Ridgeline Modifier</td>
<td>Ridgeline</td>
</tr>
<tr>
<td>Bobcat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fisher</td>
<td>50% Land Cover, 30% Riparian, 30% Roads, 10% Slope, &quot;Non-Ridgeline/ Non-Riparian Dependent&quot;</td>
<td>Riparian</td>
</tr>
<tr>
<td>Lynx</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marten</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long-tailed Weasel</td>
<td>50% Land Cover, 30% Riparian, 30% Roads, 10% Slope, &quot;Non-Ridgeline/ Non-Riparian Dependent&quot;</td>
<td>&quot;Non-Ridgeline/ Non-Riparian Dependent&quot;</td>
</tr>
<tr>
<td>Mink</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Otter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Porcupine</td>
<td>40% Land Cover, 10% Riparian, 40% Roads, 10% Slope</td>
<td></td>
</tr>
<tr>
<td>Snowshoe Hare</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Applying the Ridgeline Modifier

A ridgeline modifier (Figure A-6) was developed to identify generalized ridge features on the landscape. The intention of applying a ridgeline modifier was to slightly lower the cost surface values within ridge areas. As a result, the corridor modeling tool is more likely to route predicted species movements through these lower cost ridge features if they provide a lower cost alternative to the non-ridge surrounding landscape. The ridgeline modifier reduced cost surface values by five points (5%) within ridge areas and it had no effect on the rest of the cost surface.

To develop the ridgeline modifier, the topographic position tool from the Corridor Designer modeling package was run in ArcGIS. The tool was run using a 100 x 100 cell window to identify those cells whose elevations are more than 8 cell values, or meters, higher than

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**Figure A-6: The ridgeline modifier shaded in orange.**
the average cell value within the analysis window based on the 30-meter National Elevation Dataset. The resulting ridge feature cells were used to modify the cost surfaces of the ridge using species.

**Start/End Locations for Corridors**

There are eight landscape-scale conservation areas within the linkage with structural pathways making connections between fourteen combinations of them. The connections, shown on Figure A-7, include:

1. Nulhegan Basin to West Mountain
2. Nulhegan Basin to Bunnell/Nash Stream Forests
3. Nulhegan Basin to Connecticut Lakes
4. West Mountain to Victory Basin
5. West Mountain to Bunnell/Nash Stream Forests
6. West Mountain to WMNF Kilkenny
7. Victory Basin to Bunnell/Nash Stream Forests
8. Victory Basin to WMNF Kilkenny
9. Bunnell/Nash Stream Forests to WMNF Kilkenny
10. Bunnell/Nash Stream Forests to Lake Umbagog
12. WMNF Kilkenny to Lake Umbagog
13. Lake Umbagog to Connecticut Lakes

To execute corridor models following the Connectivity Model for New Hampshire approach, start and end locations must be specified to determine the areas that the models seek to connect. Ideally, these start and end locations would be determined by known species occurrences within the eight landscape-scale conservation areas, but there is a lack of species occurrence data in the NEK-NNH Linkage. As a surrogate for occurrence data, model start and end locations were determined using low-cost patches of each species’ cost surface within the eight landscape-scale conservation areas. These patches represent suitable habitat for the species.

To complicate matters, there are many low-cost patches within each of the landscape-scale conservation areas. To simplify the number of model runs required between any two given landscape-scale conservation areas, a straight line was drawn to connect the low-cost patches within one area at an angle approximately perpendicular to the direction of travel to the second area. In the second landscape-scale conservation area, a straight line was drawn to connect the low-cost patches parallel to the straight line drawn in the first area (Figure A-8). This method was followed for each of the species in each of the landscape-scale conservation area connections where corridors were identified.

The creation of species corridors takes into account the least accumulative cost distance for each cell to the nearest “source” over a cost surface. In this case the source is one of the start/end lines within one of the eight landscape-scale conservation areas. The least accumulative cost distance takes into account two factors for each cell: (1) the other cell values between the cell and the source and (2) the distance, or
number of other cells, between the cell and the source. Therefore, a long corridor over low cost cells and a short corridor over high cost cells could have the same score. The use of straight, parallel lines as start/end locations was implemented to avoid bias in the modeling where short corridors across poor quality dispersal habitat would be selected over longer, better quality dispersal habitat. Start/end lines are consistently the same distance apart from each other, as opposed to using the leading edge of a conservation area boundary, or an inside buffer of that boundary for start and end locations.

Mapping Species Corridors

Once start and end location lines were determined, corridors were created by running the cost distance function in ArcGIS based on each species’ cost surface first to a start line and then to an end line. The corridor function sums the two opposing direction cost distance surfaces. The lowest value cells represent the most permeable connecting lands between the two destinations. The corridor surfaces were classified to represent the most permeable 10% of the modeling extent for each species. This process was completed for all species between each of the 14 landscape-scale conservation area connections.

Corridor Prioritization Process to Identify Structural Pathways

To prioritize species corridors a multi-step process was developed. The prioritization process starts at the conservation area to conservation area scale, and later in the analysis is expanded to the entire linkage scale.

Conservation area to conservation area steps:

Each of the species’ corridors was assigned a score based on Table A-8, where the most permeable 1% of the modeling extent scored 10 points, 2% scored 9 points, and so on. All corridor values greater than the most permeable 10% were not included in the prioritization in an attempt to focus the results of the analysis on the most connected dispersal habitats.

Co-occurrences were run separately for ridge species and riparian species, with results reclassified to a 1 to 100 scale. This step was important because there are five ridge species and three riparian species. Had the initial co-occurrence been run with all of the species or just the ridge and riparian species, the

Table A-8: Reclassification from species corridor permeability to co-occurrence scores.

<table>
<thead>
<tr>
<th>Corridor’s Most Permeable (%)</th>
<th>Co-Occurrence Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>&gt;10</td>
<td>0</td>
</tr>
</tbody>
</table>
results would be biased toward the ridge species habitat dispersal preferences because they are better represented in the sample.

The reclassified ridge and riparian co-occurrences were then summed together. Results were reclassified based on standard deviation classes, shown in Table A-9, where cell values less than one standard deviation above the mean, one to two standard deviations above the mean, two to three standard deviations above the mean, and greater than three standard deviations above the mean received scores of 0, 1, 2, and 4 points respectively.

**Linkage wide steps:**

Each of the 14 reclassified conservation area to conservation area scale co-occurrence surfaces were summed together to create a linkage wide co-occurrence surface based on the standard deviation scores. Any value greater than two in the linkage wide co-occurrence was selected to be included as a draft structural pathway.

**Alternative Approach for Wood Turtle**

The corridor modeling approach described above was determined to be inappropriate for predicting the dispersal of wood turtle. Wood turtle is the most riparian dependent of the focal species. Conceptually, the corridor modeling approach could force wood turtle corridors outside of riparian areas and across watershed divides when a less costly riparian route is not available. In reality this wouldn’t best reflect how wood turtles disperse. Also, the bulk of some of the landscape-scale conservation areas are too high in elevation to provide critical core habitat for wood turtle, which makes using these areas as corridor destinations of little value.

An alternate resistant kernel estimator approach was used for wood turtle. Katie Callahan from the New Hampshire Fish and Game Department ran the analysis based on draft model parameters developed by Michael Jones, PhD, of the Massachusetts Division of Fisheries and Wildlife (Jones, Draft 2009). Stream gradient and stream order are the two primary components of the model, which were parameterized using home range data from 170 adult wood turtles in the Connecticut and Housatonic watersheds. Stream segments for wood turtle below a 550–meter elevation threshold and meeting the following size and slope combinations are considered “optimal” habitat:

<table>
<thead>
<tr>
<th>Size</th>
<th>Gradient</th>
</tr>
</thead>
<tbody>
<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt; order</td>
<td>&lt;1.75%</td>
</tr>
<tr>
<td>2&lt;sup&gt;nd&lt;/sup&gt; order</td>
<td>&lt;1.75%</td>
</tr>
<tr>
<td>3&lt;sup&gt;rd&lt;/sup&gt; order</td>
<td>&lt;1.1%</td>
</tr>
<tr>
<td>4&lt;sup&gt;th&lt;/sup&gt; order</td>
<td>&lt;0.85%</td>
</tr>
<tr>
<td>5&lt;sup&gt;th&lt;/sup&gt; order</td>
<td>&lt;0.5%</td>
</tr>
<tr>
<td>6&lt;sup&gt;th&lt;/sup&gt; order</td>
<td>&lt;0.35%</td>
</tr>
<tr>
<td>7&lt;sup&gt;th&lt;/sup&gt; order</td>
<td>&lt;0%</td>
</tr>
</tbody>
</table>

Table A-9: Reclassification from conservation area to conservation area co-occurrence scores by standard deviations above the mean, to co-occurrence scores to be used in the linkage-wide co-occurrence.
To create the resistant kernel estimator (Figure A-9), the kernel density of optimal streams was applied to the wood turtle cost surface. The estimator surface represents how connected the optimal habitats are, and therefore how connected the habitats are for dispersal. Structural pathways were compared to the resistant kernel estimator. The structural pathways have good overlap with directionally congruent wood turtle habitat between most of the landscape-scale conservation areas. This means that the protection and enhancement of landscape permeability within many of the riparian-based structural pathways will also facilitate wood turtle dispersal.

Figure A-9: The kernel density of optimal streams (left) was applied to wood turtle’s cost surface, resulting in the resistant kernel estimator. Source: NHFG.

References


NH Audubon & NHFG. (Draft 2010). *Connectivity Model for New Hampshire*. Concord, New Hampshire: NH Fish & Game Department, GIS Program.
Appendix B: Roadside Wildlife Tracking Survey Methods
Northeast Kingdom-Northern New Hampshire Staying Connected Field Methods (by Jesse Mohr, Native Geographic, LLC)

The methods used for this study are similar to other regional Staying Connected Projects (Mohr et al., 2010; Leoniak et al., 2009) and other road crossing and landscape permeability studies. Based on the consultant’s experience with similar projects, feedback from prior Staying Connected projects, and the desire to increase scientific rigor and repeatability, methodologies utilized for this study were clearly documented and vetted prior to implementation.

1. WINTER ROADSIDE FIELD ASSESSMENT

Winter tracking was performed to help identify active wildlife road crossings, ascertain the value of modeled structural pathways, and to support continued connectivity modeling across the project area. During the winter surveys, the surveyor followed a suite of specific methodologies and guidelines, including specifics on the timing, duration, techniques and recording of site visits, target species, and roadside wildlife observations. See below subsections for specific methods.

Initially, five Monitoring Zones across 58.2 road miles were identified for the project by The Nature Conservancy New Hampshire using remote and landscape analysis. These zones were scheduled to be visited by Native Geographic, LLC during the winter of 2011-2012. After the first round of survey, 6.9 road miles were removed from future monitoring. The remaining 51.3 road miles were monitored an additional three times. Monitoring dates are included below.

<table>
<thead>
<tr>
<th>Zone</th>
<th>Cycle 1 Date(s)</th>
<th>Cycle 2 Date(s)</th>
<th>Cycle 3 Date(s)</th>
<th>Cycle 4 Date(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rt 3 (north of Stratford)</td>
<td>12/10/11</td>
<td>1/7/12</td>
<td>2/6/12, 2/7/12</td>
<td>3/2/12</td>
</tr>
<tr>
<td>Rt 3 (around Stratford)</td>
<td>11/27/11, 12/10/11</td>
<td>Not surveyed this cycle</td>
<td>Not surveyed this cycle</td>
<td>Not surveyed this cycle</td>
</tr>
<tr>
<td>Rt 3 (south of Stratford)</td>
<td>11/27/11</td>
<td>1/7/12</td>
<td>2/7/12</td>
<td>3/2/12</td>
</tr>
<tr>
<td>Rt 102</td>
<td>11/27/11</td>
<td>Not surveyed this cycle</td>
<td>Not surveyed this cycle</td>
<td>Not surveyed this cycle</td>
</tr>
<tr>
<td>Rt 27</td>
<td>11/27/11, 11/28/11, 12/12/11</td>
<td>1/7/12, 1/9/12</td>
<td>2/5/12, 2/6/12</td>
<td>2/29/12</td>
</tr>
<tr>
<td>Rt 16</td>
<td>11/28/11, 12/13/11</td>
<td>1/8/12</td>
<td>2/5/12</td>
<td>2/29/12, 3/6/12</td>
</tr>
<tr>
<td>Granby Rd</td>
<td>12/10/11</td>
<td>12/30,11</td>
<td>2/10/12</td>
<td>2/19/12</td>
</tr>
</tbody>
</table>
Atmospheric and snow conditions can greatly affect the probability of detection and interpretation of tracks and sign. As a whole, in this consultant's experience, the winter of 2011-2012 conditions were generally poor for tracking in snowy substrates. Tracking conditions, however, were spatially and temporally variable throughout the project area and project duration. This variability is indirectly accounted for within the “Confidence” field of the GIS data (see Roadside Wildlife Observation Methods and Guidelines section). Lower confidence levels generally reflect poorer site-specific conditions. In some instances, however, the consultant was able to make a highly confident determination of species regardless of tracking condition. In addition to this indirect, observation-specific measure of tracking conditions, daily tracking conditions were categorically (Good, Moderate, Poor) averaged across the day's survey area; these are also included below.

<table>
<thead>
<tr>
<th>Date</th>
<th>Conditions</th>
<th>Date</th>
<th>Conditions</th>
<th>Date</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>11/27/11</td>
<td>Poor</td>
<td>1/8/12</td>
<td>Moderate</td>
<td>2/29/12</td>
<td>Good</td>
</tr>
<tr>
<td>11/28/11</td>
<td>Poor</td>
<td>1/9/12</td>
<td>Poor</td>
<td>3/2/12</td>
<td>Good</td>
</tr>
<tr>
<td>12/10/11</td>
<td>Poor</td>
<td>2/5/12</td>
<td>Good</td>
<td>3/6/12</td>
<td>Moderate</td>
</tr>
<tr>
<td>12/12/11</td>
<td>Poor</td>
<td>2/6/12</td>
<td>Moderate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12/13/11</td>
<td>Poor</td>
<td>2/7/12</td>
<td>Poor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12/30/11</td>
<td>Moderate</td>
<td>2/10/12</td>
<td>Poor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/7/12</td>
<td>Moderate</td>
<td>2/19/12</td>
<td>Moderate</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Geographic and attribute data were recorded using one of two methods: directly into a checked-out ArcGIS geodatabase using Arc Pad 10.0 (ESRI, 2010) on a Trimble Recon with a Garmin 10 GPS Receiver; or on standalone Garmin GPSMAP 76csx GPS unit with geographic data linked to an excel spreadsheet for later import into ArcGIS. At a 95% confidence interval, both GPS receivers’ base positional accuracy is < 15 meters.

**SITE VISIT METHODS AND GUIDELINES**

All site visits were conducted in accordance with the following:

- Each monitoring zone was surveyed on four separate occasions, following different snow events.
- Through a combination of slowly driving and walking the road shoulder, both sides of the road were surveyed.
- All transportation structures capable of supporting wildlife passage, such as bridges and large culverts, were closely inspected. For this inspection, the surveyor left the vehicle to better examine the structure.
- Field time was maximized by attempting to allow an average of two nights or more after snow events before conducting the field assessment. Due to the poor snow conditions, some monitoring did occur on just one night of snow.
TARGET SPECIES METHODS AND GUIDELINES

All species were not of equal interest. The primary target species included: lynx, bobcat, otter, fisher, marten, mink, long-tailed weasel, ermine, porcupine, snowshoe hare, and bear. Secondary target species included: coyote, fox, moose and deer.

The surveyor attempted to individually map all primary target species observations (i.e. each observation should have its own GPS point.) Snowshoe hare was one exception. Where this species approached or utilized the roadside in relatively high numbers, the surveyor recorded clusters of track observations using a single GPS point to denote a high (greater than 10 observations in 100 ft), medium (between 5-10 observation in 100 ft) or low density (less than 5 observations in 100 ft) observation.

The surveyor also attempted to individually map all secondary target species observations. As with hare, in many locales, moose, deer, coyote, and fox approached or utilized the roadside in relatively high numbers; here the surveyor recorded clusters of track observations using a single GPS point to denote a high (greater than 10 observations in 100 ft), medium (between 5-10 observation in 100 ft) or low density (less than 5 observations in 100 ft) observation.

ROADSIDE WILDLIFE OBSERVATION METHODS AND GUIDELINES

The surveyor gathered data on individual wildlife crossings or activity at the roadside. Each data point was recorded as a Roadside Wildlife Observation within the “RoadsideWildlifeObservation” dataset. GPS locations were taken where species came onto or approached the roadway.

At each GPS point, the surveyor collected the following data:
<table>
<thead>
<tr>
<th>Field</th>
<th>Field Description</th>
<th>Field Values</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>Date of Observation</td>
<td></td>
<td>Required field</td>
</tr>
<tr>
<td>Track Nights</td>
<td>Number of Nights Since Last Snowfall Capable of Recording the Track (may be species-specific)</td>
<td></td>
<td>Field used for track observations</td>
</tr>
<tr>
<td>Sign</td>
<td>Type of Roadside Wildlife Sign Observed</td>
<td></td>
<td>Required Field</td>
</tr>
<tr>
<td></td>
<td>Track</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Scat</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hair</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sighting</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Roadkill</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Species</td>
<td>Species Associated with Observation</td>
<td></td>
<td>Required field</td>
</tr>
<tr>
<td></td>
<td>Bear</td>
<td><em>Ursus americanus</em>. Primary species</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bobcat</td>
<td><em>Lynx rufus</em>. Primary species</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lynx</td>
<td><em>Lynx canadensis</em>. Primary species</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Otter</td>
<td><em>Lontra canadensis</em>. Primary species</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fisher</td>
<td><em>Martes pennanti</em>. Primary species</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Marten</td>
<td><em>Martes americana</em>. Primary species</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mink</td>
<td><em>Neovison vison</em>. Primary species</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Long-tailed Weasel</td>
<td><em>Mustela frenata</em>. Primary species</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ermine</td>
<td><em>Mustela erminea</em>. Primary species</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unidentified Large to Medium Weasel</td>
<td>Species could not be determined. May include Marten, Fisher, Male Mink or Male Long-tailed Weasel</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unidentified Small to Medium Weasel</td>
<td>Species could not be determined. May include Female Long-tailed, Female Mink, or Ermine</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Porcupine</td>
<td><em>Erethizon dorsatum</em>. Primary species</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Snowshoe Hare</td>
<td><em>Lepus americanus</em>. Primary species</td>
<td></td>
</tr>
</tbody>
</table>

Appendix B-5
<table>
<thead>
<tr>
<th>Confidence of Species Determination</th>
<th>Required field</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Field used when a crossing attempt could be verified</td>
</tr>
<tr>
<td>Medium</td>
<td>Successful crossing attempt</td>
</tr>
<tr>
<td>Low</td>
<td>Turned back at roadside or on road</td>
</tr>
<tr>
<td>Unidentified Canid</td>
<td>Unknown if crossing attempt was successful or occurred</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RoadsideTravel</th>
<th>Direction of Travel Relative to Road</th>
<th>Field used when a crossing attempt could be verified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct</td>
<td>Approached and departed road or roadside in less than 200 linear ft of roadway</td>
<td></td>
</tr>
<tr>
<td>Parallel</td>
<td>Traveled parallel to or down road for greater than 200 ft</td>
<td></td>
</tr>
<tr>
<td>Unknown</td>
<td>Travel relative to roadside could not be interpreted</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location</th>
<th>Crossing Location Relative to Road Surface</th>
<th>Field used when a crossing was successful</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road</td>
<td>Crossed at road surface</td>
<td></td>
</tr>
<tr>
<td>Bridge</td>
<td>Crossed under road surface using a bridge</td>
<td></td>
</tr>
<tr>
<td>Culvert</td>
<td>Crossed under road surface using a culvert</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Density</th>
<th>Density of Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Field used when secondary species or</td>
</tr>
</tbody>
</table>

**Species**

- **Moose** (*Alces alces*). Secondary species
- **Deer** (*Odocoileus virginianus*). Secondary species
- **Coyote** (*Canis latrans*). Secondary species
- **Fox** (*Vulpes vulpes*). Secondary species
- **Unidentified Canid**. Species could not be determined. May include domestic dog, fox, or coyote.
snowshoe hare sign was abundant and recording of individual track observations was not possible

<table>
<thead>
<tr>
<th>Direction</th>
<th>Direction of Travel at Roadside</th>
<th>Field used when track sign allowed for interpretation of travel direction at roadside</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Greater than 10 observations in 100 ft</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>5-10 observations in 100 ft</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>3-4 observations in 100 ft</td>
<td></td>
</tr>
<tr>
<td>One Individual</td>
<td>One individual</td>
<td></td>
</tr>
<tr>
<td>North</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northeast</td>
<td></td>
<td></td>
</tr>
<tr>
<td>East</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southeast</td>
<td></td>
<td></td>
</tr>
<tr>
<td>South</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southwest</td>
<td></td>
<td></td>
</tr>
<tr>
<td>West</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northwest</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unknown</td>
<td>Direction of travel could not be interpreted</td>
<td></td>
</tr>
<tr>
<td>Variable</td>
<td>Direction of travel varied or changed at roadside</td>
<td></td>
</tr>
</tbody>
</table>
Appendix C: Model Conservation Easement Language for Connectivity
In this document, we put forward sample conservation easement language designed to explicitly address issues of habitat connectivity. The information is organized according to general conservation easement sections including: Recitals/Whereas Clauses; Conservation Values; Purposes; Use Limitations; and Forest Management Plans. In each section, we overview the types of easement provisions that may be considered and the rationale for each, and offer sample easement language. We don’t expect, and would not necessarily recommend, that sample language be used as “boilerplate”, but rather that these provisions facilitate the drafting of connectivity language appropriate to the particular circumstances of a specific conservation easement property.

**Terminology**

The Staying Connected initiative has identified and defined a set of key technical terms relevant to connectivity. Among these, the following may be of value in drafting a conservation easement where connectivity is an important and recognized conservation attribute. These definitions may be included in a definitions section of the easement, or they may need to be included where the corresponding term is initially used in the easement.

**Landscape connectivity:** The degree to which similar landscape elements, such as habitat patches or natural vegetation, are connected to each other so as to facilitate the movements of target organisms and ecological processes between them.

**Habitat corridor:** Components of the landscape that provide a continuous or near continuous pathway that may facilitate the movement of target organisms or ecological processes between areas of suitable habitat.

**Landscape permeability:** The degree to which a regional landscape, encompassing a variety of natural, semi-natural and developed land cover types, sustains natural ecological processes and is conducive to the movement of many types of organisms. Landscape permeability is a function of the connectedness of natural cover, the hardness of barriers, and the spatial arrangement of land uses.

I. **Recitals / Whereas Clauses**

Recitals, or “Whereas” clauses, are often included as preamble to conservation easements, and are an important place to specifically recognize the habitat values and significant ecological resources known to occur on the property. According to The Conservation Easement Handbook:\(^1\):

- Recitals “[set] forth background information essential for understanding both the legal and factual basis for its creation.”
- Recitals often include description of the “protected conservation values” of the property.
- “The recitation of the protected conservation values gives the term defining content. The purpose of reciting the qualitative values of the property... is to lay the foundation for the

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easement by summarizing, concisely, the characteristics of the subject property that have been identified for protection and the rationale for protecting them.”

- “[They] will function as a primary reference point for determining the purposes of the easement.”

- “Each resource... should be clearly described... so that the parties, their successors, and if necessary, the courts – however they may differ under a given set of circumstances on how the purpose should be achieved – will always be able to determine with some certainty the underlying purpose of the easement.”

Sample EASEMENT RECITAL/WHEREAS clauses related to connectivity:

1) **Whereas, the Northern Appalachians ecoregion (aka Northern Forest), spanning (in the United States) the Tug Hill Plateau and Adirondacks in New York, northern Vermont, northern New Hampshire, and western and northern Maine, is a largely forested region where wildlife still have the opportunity to roam freely across much of the landscape, and which has been identified as a largely intact forested region significant for wildlife in ________________________ (ADD REFERENCE TO ONE OR MORE STUDIES/PLANS SUCH AS STATE WILDLIFE ACTION PLAN). [THIS COULD BE TAILORED TO A SPECIFIC STATE OR AN ALTERNATE GEOGRAPHY]

When and why to include such a clause? This recital helps to frame the ecological context for the property by connecting the property to the larger landscape/ecoregion. The recital indicates that, currently, the ecoregion is largely connected for wildlife. This clause could be used for any property located in the largely forested and intact Northern Appalachians ecoregion, where connectivity is one of the property’s conservation values.

2) **Whereas, there is increasing scientific consensus that an essential strategy for sustaining regional wildlife populations and counteracting the negative consequences of habitat loss, fragmentation, and climate change on wildlife is to maintain landscape connectivity sufficient to sustain natural patterns of wildlife movement and allow for species migration, relocation, movement, and other forms of adaptation. [IF APPLICABLE, REFERENCE CURRENT STATE WILDLIFE ACTION PLAN OR OTHER GOVERNMENTAL POLICIES OR PROGRAMS THAT PROMOTE CONNECTIVITY]

When and why include such a clause? The recital specifically references “maintaining landscape connectivity” as a conservation strategy, and identifies how the property may contribute to maintaining regional wildlife populations (a public benefit). Referencing the state wildlife action plan or other relevant governmental program or policy strengthens the public benefit rationale.

3) **Whereas, the Property is located within an area that has been identified as important for regional landscape connectivity by [ADD RELEVANT STUDIES/PLANS AND/OR AGENCIES THAT HAVE IDENTIFIED THE AREA AS SIGNIFICANT FOR CONNECTIVITY]

When and why include such a clause? This recital indicates the property is set within an important area for connectivity, and may be appropriate if the property and/or area have been specifically identified as important for connectivity through science-based studies or plans.

Appendix C-3
4) Whereas, state wildlife agencies and conservation organizations [ADD OTHER ENTITIES SUCH AS MUNICIPALITIES IF APPROPRIATE] are working together to identify and conserve important regional wildlife habitat corridors that still support suitable habitat necessary to connect existing core forest habitats together for wildlife movement region-wide, including through the protection of land.

Why include such a clause? This clause ties the project to a regional connectivity conservation initiative involving public agencies. Such language may be appropriate if a property has been identified as a connectivity conservation priority through a science-based planning analysis endorsed by public and/or private conservation entities.

II. Conservation Values/Attributes

This is the area of the easement in which the property’s specific conservation values or attributes are identified. In some easement formats these are embedded in Recitals/Whereas clauses, sometimes in the Purposes, and sometimes they are specifically identified elsewhere. We believe that in most cases connectivity will be an additive conservation value, and not the exclusive conservation. In this way, referencing connectivity as an additional conservation value bolsters future opportunities to interpret the easement, but does not narrowly define the easement in a manner that could potentially undermine its validity should the connectivity value diminish over time.

Sample CONSERVATION VALUES/ATTRIBUTES clauses:

1) The Property includes suitable habitat for [LIST SPECIES, IF KNOWN] and other wildlife that provides a habitat corridor that helps to connect the [LIST CONSERVATION AREAS OR INTACT CORE HABITAT AREAS THAT YOU ARE TRYING TO CONNECT] so that wildlife populations are not isolated by developed land. [IF NOT ALREADY DEFINED, YOU MAY WISH TO DEFINE HABITAT CORRIDOR HERE: “A habitat corridor consists of components of the landscape that provide a continuous or near continuous pathway that may facilitate the movement of target organisms or ecological processes between areas of suitable habitat.”]

Why include such a clause? Explicitly identifies the connectivity conservation value of the property, with a focus here on the property’s role in area-to-area connectivity. Such language may be appropriate if a property has been identified as providing suitable habitat that facilitates connectivity for species of interest, and if the property helps to create a habitat corridor linking currently protected lands.

2) In its forested, relatively natural, and unfragmented condition, the Property contributes to maintenance of a permeable and connected landscape [IN THE ________________ REGION]. [IF NOT ALREADY DEFINED, YOU MAY WISH TO DEFINE LANDSCAPE PERMEABILITY HERE: Landscape permeability is the degree to which a region, encompassing a variety of natural, semi-natural and developed land cover types, sustains natural ecological processes and is conducive to the movement of many types of organisms. Landscape permeability is a function of the connectedness of natural cover, the hardness of barriers, and the spatial arrangement of land uses.]

Appendix C-4
Why include such a clause? Explicitly identifies the connectivity conservation value of the property, with a focus here on landscape permeability. Such language may be appropriate if a property is largely forested and in a natural condition, and is located within a linkage or other region identified as important for connectivity.

III. Easement Purposes

The Purposes section is an extremely important section of the easement. It memorializes the intentions of the parties, and defines the vision for the property and its conservation values over time. According to The Conservation Easement Handbook, the Purposes “clause is, in fact, the touchstone of the easement.” Language can be included that makes it clear that conserving the connectivity values of the property is a specific, unambiguous purpose of the easement. However, as with the conservation values/attributes section, inserting connectivity into the easement Purposes should be additive rather than exclusive, to avoid the potential of weakening the easement rationale in the event that connectivity values do not persist due to external forces or circumstances.

Sample EASEMENT PURPOSES clauses:

1) To help conserve an important habitat corridor, including the Property’s wildlife habitats [MAY WISH TO LIST WHICH ONES: such as forests, wetlands, riparian areas, streams, rivers, ponds, and/or other habitat features supporting connectivity], that facilitates the movement of organisms [MAY WISH TO MENTION SPECIFIC FOCAL SPECIES, BUT REALIZE THAT BY NAMING SPECIES THIS COULD OVER TIME PUT THE PURPOSE AT RISK IF THE SPECIES BECOMES REGIONALLY EXTIRPATED; IF LISTING SPECIES, THERE SHOULD BE DATA DOCUMENTING THAT THE SPECIES IS PRESENT AND THE PROPERTY’S HABITAT IS SUITABLE, AND BEST TO LIST SPECIES IN THE FORM OF: “such as..., ..., and ...” or “including but not necessarily limited to ..., ..., and ....”]. between [LIST CONSERVATION AREAS OR INTACT CORE HABITAT AREAS THAT YOU ARE TRYING TO CONNECT].

Why include such a clause? This clause clearly establishes conservation of the property’s area-to-area connectivity values for species movement as a purpose of the easement. Consequently, future uses of the property may be evaluated for consistency with this purpose.

2) To help maintain a permeable landscape and physical habitat connection between [LIST CONSERVATION AREAS OR INTACT CORE HABITAT AREAS THAT YOU ARE TRYING TO CONNECT] for [POSSIBLY LIST SPECIES] by conserving and managing the [forests, wetlands, riparian areas, streams, rivers, ponds, and/or other habitat features supporting connectivity] on the Property so that it is conducive to wildlife movement.

Why include such a clause? Similar to the above, but more focused on the property’s contribution to overall landscape permeability. This purpose may be appropriate if the property’s protection clearly helps to link existing protected areas.
IV. Use Restrictions

In this section, we include categories of use restrictions that may be included or tailored to reflect connectivity considerations. For each, we offer sample language that may be useful in drafting an appropriate use restriction clause for a specific property. We recommend careful consideration of the relevance and appropriateness of each restriction provision, based on the specific values and circumstances of a property, when deciding whether to include a given restriction.

**CONVERSION:** Restrictions on clearing/conversion of forest land to (re-)establish fields for agricultural [OR OTHER OPEN LAND] uses.

*Why include such a clause?* If the property’s connectivity conservation values are related to its forested habitats, the easement holder may wish to specifically restrict conversion of forest land to agricultural or other open land uses.

Sample CONVERSION language:

**Land Conversion.** *There shall be no conversion of land that was in a forested condition at the time of the granting of this Conservation Easement to a non-forested condition, except temporarily as a result of natural disturbances or as part of a silvicultural treatment prescribed in the Stewardship Plan. Exceptions to this restriction may be granted by the Easement Holder, in its sole discretion, to advance the habitat connectivity [AND MAY ALSO WANT TO REFERENCE OTHER] purposes of the easement.*

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**RIPARIAN AREAS:** Restrictions on forest and agricultural management in riparian areas (no-harvest or light-management) to protect travel corridors.

*Why include such a clause?* Amongst many ecological values, riparian areas are known to provide important habitat and travel corridors for many wildlife species. Incompatible management in riparian areas may have detrimental impacts on connectivity. Restrictions on management in riparian areas may help to preclude or limit management practices that could be detrimental to connectivity. Including such restrictions will have easement monitoring implications for the easement holder, and may have financial ramifications for the landowner.

Sample RIPARIAN language:

**Riparian Areas.** *The following riparian management zones shall apply for tree cutting and removal operations [CAN ALSO APPLY TO AGRICULTURAL MANAGEMENT OPERATIONS] adjacent to streams, rivers, ponds, and non-forested wetlands, hereinafter referred to collectively as “water body”.*

- ___ feet from each side of USGS mapped intermittent, 1st and 2nd order streams and along shores of ponds and non-forested wetlands less than 10 acres in size.
- ___ feet from each side of 3rd and higher order rivers and streams and along shores of ponds and non-forested wetlands greater than 10 acres in size.
- Riparian buffer zones shall be expanded as necessary to encompass all vegetative
communities subject to flooding, slopes greater than 35%, or soils classified as highly erodible that are adjacent to the water body or wetland.

Streams, ponds, and rivers shall be identified as those shown on 7.5 minute United States Geologic Survey Quadrangle maps. Non-forested wetlands shall include those emergent and shrub wetlands shown on National Wetlands Inventory maps, Town wetlands inventory maps, and other sources mutually agreed to by the Fee Owner and the Easement Holder.

The distance of the riparian management zone shall be measured from the edge of normal high water mark of the water body or wetland. In areas where there are wetlands contiguous to a stream, river, or pond: 1) the widest applicable riparian management zone shall apply; and 2) the starting point for the area shall be the upland edge of the normal high water mark of the water body or wetland.

- [IF NO HARVEST ZONES ARE DESIRED] Within the riparian management zone there shall be no tree harvesting within the first ___’ from the normal high water mark or wetland edge as defined above.
- [WHERE LIGHT HARVEST MANAGEMENT IS DESIRED] Within the (remainder of) the riparian buffer zone, tree harvesting methods shall be in accordance with the recommended practices in [INSERT APPROPRIATE BMP REFERENCE].
- Within the riparian buffer zone there shall be no application of pesticides or herbicides.

Proposed exceptions to these limitations, such as cutting and dropping trees into streams for the purpose of restoring aquatic habitat, shall be described in the Forest Management (or Stewardship) Plan and may be granted at the sole discretion of the Easement Holder.

ROADS: Restrictions on the development of new and widened roads. Landowner needs to clearly demonstrate that the existing road network is inadequate for management of the property in accordance with easement purpose and restrictions, thereby justifying any new/widened road.

Why include such a clause? Roads can serve as impediments or barriers to species movement, amongst other ecological impacts. While any road could have impacts, risks to connectivity increase with wider roads, with paved and gravel roads (as compared to unimproved woods roads), and with increasing intensity of use. The intent of a roads restriction clause is not to preclude the existence or use of roads on the property, but rather to establish standards for development of new roads.

Sample ROADS language: (ADAPTED FROM VLT LARGE WORKING FOREST EASEMENT)

**New Roads.** The Fee Owner may construct new roads and associated improvements necessary for forestry [AND/OR AGRICULTURE] with the written approval of the Easement Holder, provided that Fee Owner shall describe all such new roads and associated improvements in the Stewardship Plan described in Section 5 below. New (improved, paved, or gravel) roads and associated improvements shall only be constructed if Fee Owner demonstrates that:

i. such construction is consistent with the Purposes of this Conservation Easement;

ii. the system of existing roads is not adequate and additional road improvements are necessary to provide reasonable access to the Property for forestry; and

iii. any such road improvements do not significantly impair surface water quality, wildlife
**FENCING:** Fencing restrictions to reduce potential impacts of fencing as barriers

*Why include such a clause?* Fencing could serve as an impediment or barrier to movement for certain species. Note, however, that fencing restrictions may be problematic in areas dominated by livestock agriculture, and may be in conflict with other natural resource conservation goals such as water quality protection.

We do not offer sample fencing language. Restrictions on fencing could be included in existing clauses related to structures, or as a discrete type of structure with a separate use limitation clause.

**V. Forest Management [aka Stewardship] Plan**

Conservation easements on working lands typically include provisions requiring preparation of a forest management or stewardship plan, laying out the necessary elements of said plan, and mandating that management be undertaken in accordance with the plan.

*Why include such a clause?* Forest Management plans, or Stewardship plans, are an essential mechanism for translating easement purposes and provisions into more detailed land management practices. Most conservation easements today require the preparation and periodic update of management plans to guide on-the-ground management practices. The sample provisions listed below are intended to direct the landowner and the easement holder to give due consideration to the impacts of management on habitat connectivity. Because management plans will be updated over time, and therefore can and should be adapted in response to new information and circumstances.

Sample MANAGEMENT PLAN clauses specifying required elements of a plan related to connectivity [among other required elements]:

*Plant and wildlife considerations; specifically, prescribed timber management activities must be compatible with, and performed in support of the goals of conserving and enhancing wildlife habitat values, including those pertaining to feeding, travel corridor cover, and travel corridor connectivity.*

*Analysis of how roads and stream crossings may affect wildlife connectivity and what types of mitigation management will be followed, such as maintaining forest canopy across a road or making sure stream culverts are sized and located in a manner that does not impede fish movement.*

Appendix C-8