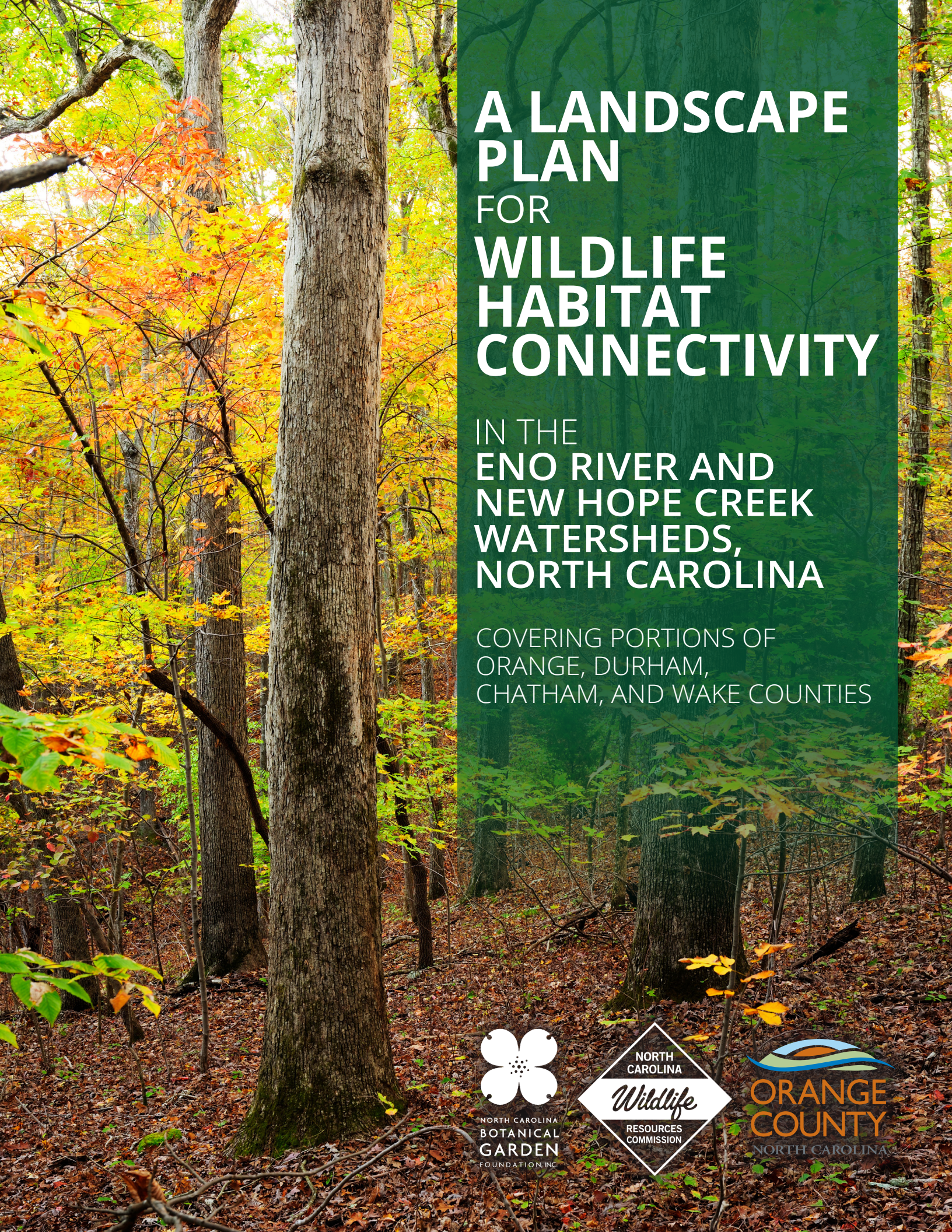

A LANDSCAPE PLAN FOR WILDLIFE HABITAT CONNECTIVITY

IN THE ENO RIVER AND NEW HOPE CREEK WATERSHEDS, NORTH CAROLINA

COVERING PORTIONS OF ORANGE, DURHAM, CHATHAM, AND WAKE COUNTIES

NORTH CAROLINA BOTANICAL GARDEN FOUNDATION, INC.

NORTH CAROLINA Wildlife RESOURCES COMMISSION

ORANGE COUNTY NORTH CAROLINA

A Partners for Green Growth project funded by the North Carolina Wildlife Resources Commission and Orange County, NC, and administered by the North Carolina Botanical Garden Foundation, Inc.

Prepared by

Julie Tuttle, Project Ecologist and Coordinator

Brooke Massa, Olivia Munzer, Rich Shaw, Sara Childs, and **Johnny Randall**

in collaboration with the steering, policy, and technical committees and members of the

Eno-New Hope Landscape Conservation Group

December 2019

Front and back cover photo credit: David Blevins

Acknowledgements

We gratefully acknowledge:

The Partners for Green Growth Program of the North Carolina Wildlife Resources Commission and Orange County, North Carolina, for funding this project.

The North Carolina Botanical Garden Foundation, Inc., for administering the project.

The North Carolina Botanical Garden for generous provision of meeting space.

Sara Childs from the Office of the Duke Forest at Duke University for generous provision of virtual space for storage and sharing of data and documents.

Members of the Eno-New Hope Landscape Conservation Group for sharing their time, expertise, insight, advice, and collaboration on all aspects of this project, especially:

- Brooke Massa and Olivia Munzer of the North Carolina Wildlife Resources Commission
- Johnny Randall of the North Carolina Botanical Garden
- Stephen Hall of the North Carolina Biodiversity Project
- Sara Childs of Duke University
- and members of the steering, technical, and policy committees (Emily Blanchard, Misty Buchanan, Celeste Burns, Sara Childs, Bo Howes, Kim Livingston, Brooke Massa, Olivia Munzer, Johnny Randall, Rich Shaw, Ron Sutherland, and Allison Weakley)

The North Carolina Natural Heritage Program, NatureServe, the North Carolina Wildlife Resources Commission, Stephen Hall, Wildlands Network, Triangle Land Conservancy, NC State Parks, Piedmont Wildlife Center, several iNaturalist citizen observers, and members of this collaborative group for sharing critical data inputs to this project.

The Counties, Towns, and other participating organizations in the project area for sharing their local GIS data, which were also important inputs to the project and interpretation of the results.

NatureServe and Michael Lee for consultation on data management for the project.

John Fay and Dean Urban of Duke University for sharing their expertise and tools for landscape corridor network modeling.

Suzanne Mason of the North Carolina Natural Heritage Program for review and helpful comments on two drafts of this report.

Michelle Benham for generous donation of her expertise and time in the design and creation of promotional and educational materials for the project.

Blake Tedder from the Office of the Duke Forest at Duke University for assistance with the promotional and educational materials for the project, and formatting of this report.

Melissa Blackburn of Orange County for graphic design of the cover of this report.

Eno-New Hope Landscape Conservation Group Members

Johnny Randall[123]	**Project Administrator**; North Carolina Botanical Garden, University of North Carolina at Chapel Hill
Julie Tuttle[23]	**Project Ecologist & Coordinator**; Consultant; University of North Carolina at Chapel Hill (research affiliate)
Emily Blanchard[2]	Wildlands Network (former)
Misty Buchanan[2]	North Carolina Natural Heritage Program
Celeste Burns[13]	Durham County Open Space & Real Estate
Sara Childs[12]	Office of the Duke Forest, Duke University; Eno River Association Board of Directors
Deborah Fowler	Wake County Parks, Recreation & Open Space
Stephen Hall	North Carolina Biodiversity Project; retired North Carolina Natural Heritage Program
Ed Harrison	New Hope Creek Corridor Advisory Committee
Bob Healy	New Hope Creek Corridor Advisory Committee; Duke University
Bo Howes[13]	Triangle Land Conservancy
John Kent	New Hope Creek Corridor Advisory Committee; StreamWatch
Jane Korest	Durham County Open Space & Real Estate
Kim Livingston[13]	Eno River Association
Brooke Massa[123]	North Carolina Wildlife Resources Commission; Chatham Conservation Partnership; PlanWake Advisory Committee
Olivia Munzer[2]	North Carolina Wildlife Resources Commission
Milo Pyne	NatureServe; Eno River Association Board of Directors
Chuck Roe	Southern Conservation Partners; Wake Open Space & Parks Advisory Committee; PlanWake Advisory Committee
Bradley Saul	Orange County Commission for the Environment
Jenna Schreiber	Office of the Duke Forest, Duke University
Pete Schubert	Eno River Association Board of Directors
Rich Shaw[3]	Orange County Natural & Cultural Resources; New Hope Creek Corridor Advisory Committee
Tom Struhsaker	Conservation Biologist; Duke University
Ron Sutherland[2]	Wildlands Network
Allison Weakley[23]	Town of Chapel Hill Stormwater Management; Chatham County Planning Board; Chatham Conservation Partnership
Travis Wilson	North Carolina Wildlife Resources Commission

1 = Steering Committee
2 = Technical Subcommittee
3 = Policy Subcommittee

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INTRODUCTION

OVERVIEW AND PROJECT OBJECTIVES

The Eno River and New Hope Creek-Jordan Lake watersheds in North Carolina are home to ecologically significant forests, wetlands, and other habitats that support a rich diversity of plant and animal species, including rare species. In these two watersheds, the North Carolina Natural Heritage Program (NCNHP) has identified over 65 Natural Heritage Natural Areas (NHNAs) (NCNHP 2019c). NHNAs are terrestrial or aquatic sites "of special biodiversity significance due to the presence of rare species, unique natural communities, important animal assemblages, or other ecological features" (NCNHP nd, 2019d). Around Jordan Lake alone, 19 NHNAs encompass approximately 8,000 of the more than 40,000 acres of the Jordan Game Land (NCNHP 2019c, NCWRC 2019).

Movement of animal species within and between these NHNAs and other priority natural communities (wildlife habitats) is necessary for their survival. In the face of increasing habitat loss and *fragmentation* from development and other threats, including climate change, wildlife species require an intact, connected network of habitat and movement corridors that maintain ecosystem functions and processes (Rudnick et al. 2012). Connecting wildlife habitats not only benefits wildlife populations but also benefits water quality, native plants, our local economy (including working farms and forests), and public health (NRCS 2004).

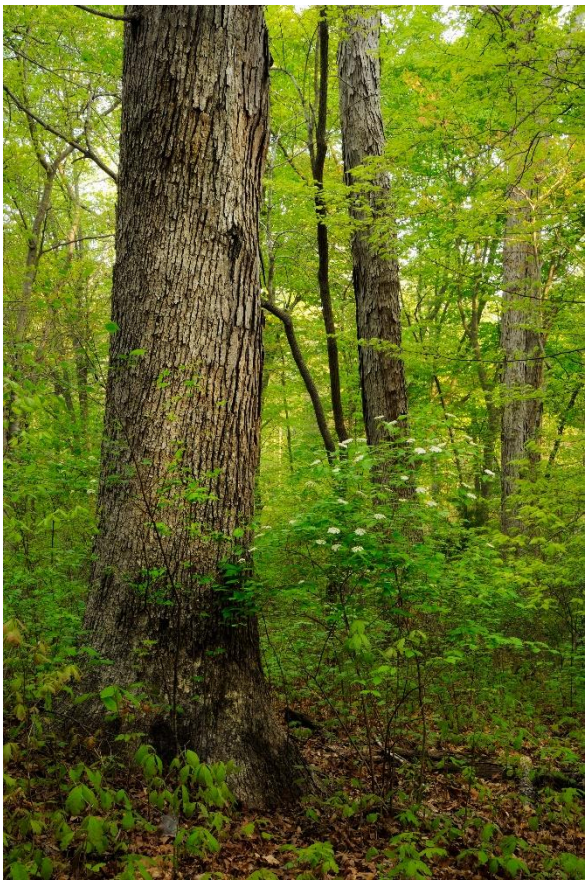

Figure 1. A protected upland hardwood forest in the project area. Photo credit David Blevins.

Important wildlife habitat anchors, including many NHNAs and other priority natural communities identified by the North Carolina Wildlife Resources Commission (NCWRC) (2015), have already been conserved in the project area by local land trusts, local government open space programs, state and national agencies, educational institutions such as Duke University and the University of North Carolina at Chapel Hill (UNC Chapel Hill), and other private and public landowners. However, the collaborators on this project recognize that existing conservation lands (such as in Figure 1) are in danger of becoming isolated by barriers to wildlife movement, such as roads and development.

Through discussions that led to the development of this project, group members articulated the need to identify places important for current and near-future landscape habitat *connectivity*, with the intention that results will help inform conservation priorities, land use decision-making, and transportation infrastructure siting and improvements. This collaboration across jurisdictions and organizations is also intended to foster coordination on shared landscape conservation goals that require planning based on ecological systems rather than jurisdictional boundaries.

The goal of this project is to provide an actionable plan for ensuring wildlife habitat connectivity across the landscape of the Eno River and New Hope Creek-Jordan Lake watersheds in North Carolina. Toward this aim, the project addresses three related objectives:

- to identify and map priority wildlife habitat and corridors connecting a network of natural communities and species populations, within and between the two watersheds (landscape corridor analysis)
- to review existing land protection priorities, policies, and ordinances related to wildlife habitat and corridor conservation (planning review), and
- to develop recommendations to drive land protection, land-use, and transportation decision-making across the project area.

This project focuses on the habitat and movement needs of development-sensitive terrestrial wildlife species that occur in the project area and are indicators of *landscape habitat integrity* (Hall 2008). Landscape habitat integrity is defined by Hall (2008) as simply the inverse of the degree of landscape fragmentation and is part of the broader concept of *ecological integrity* (ELI 2003, Parrish et al. 2003). The project species list was derived from:

- species identified in NCNHP's List of Rare Animal Species in North Carolina (NCNHP 2018), which includes species designated as rare, threatened, endangered, or on NCNHP's watch list, and
- Species of Greatest Conservation Need (SGCN), as identified by NCWRC in the North Carolina Wildlife Action Plan (NCWRC 2015), which includes species that are rare or at risk of extinction as well as species for which there are knowledge gaps and species which have received inadequate conservation attention in the past.

Planning to ensure landscape habitat connectivity and minimize the impacts of changing land uses is essential. NCWRC provides scientific guidance for conserving wildlife habitat (NCWRC 2012) and, through its Green Growth Program, offers strategies for local governance and development to enable landscape habitat conservation and connectivity. The recommendations in this plan were developed from strategies in NCWRC's Green Growth Toolbox (NCWRC 2013) and other science-based resources on best practices for ensuring landscape habitat connectivity for wildlife, and the recommendations were tailored to the project area and its jurisdictions based on the results of the corridor analysis and planning review.

PROJECT AREA

The adjacent Eno River and New Hope Creek-Jordan Lake watersheds are located in the Eastern Piedmont of North Carolina in the Upper Neuse and Cape Fear River basins, respectively (Figure 2). These watersheds include portions of Chatham, Durham, Orange, and Wake counties, the City of Durham, and the towns of Apex, Carrboro, Cary, Chapel Hill, and Hillsborough.

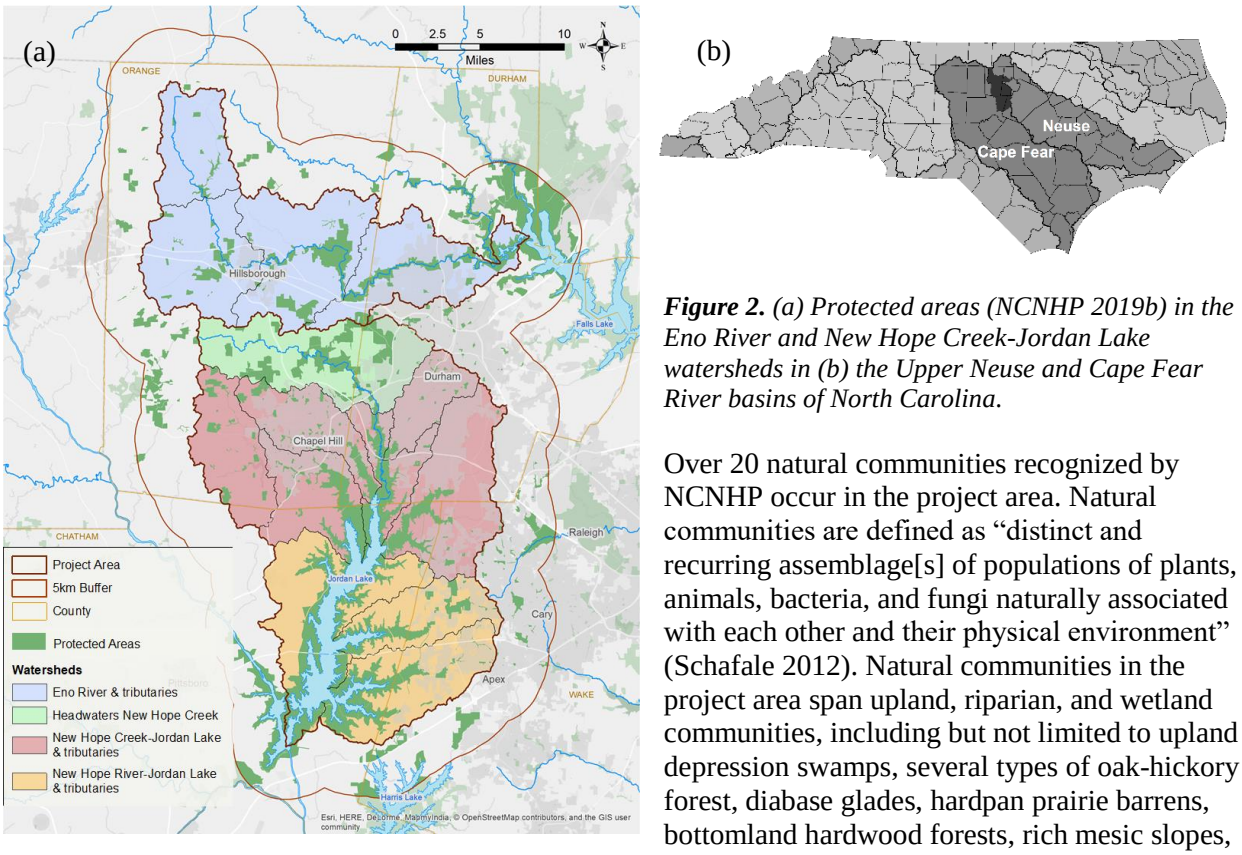

Figure 2. *(a) Protected areas (NCNHP 2019b) in the Eno River and New Hope Creek-Jordan Lake watersheds in (b) the Upper Neuse and Cape Fear River basins of North Carolina.*

Over 20 natural communities recognized by NCNHP occur in the project area. Natural communities are defined as "distinct and recurring assemblage[s] of populations of plants, animals, bacteria, and fungi naturally associated with each other and their physical environment" (Schafale 2012). Natural communities in the project area span upland, riparian, and wetland communities, including but not limited to upland depression swamps, several types of oak-hickory forest, diabase glades, hardpan prairie barrens, bottomland hardwood forests, rich mesic slopes, heath bluffs, mesic mixed hardwood forests, and numerous riparian forest variants (Schafale and Weakley 1990; Schafale 2012). These natural communities provide habitat for a number of rare plant and animal species (terrestrial and aquatic) and support a rich fauna of birds, bobcats, mink, weasels, box turtles, numerous amphibian species, (an overabundance of) white-tailed deer, the relatively recent arrival of coyotes, and many other wildlife species and taxonomic groups (North Carolina Biodiversity Project 2019).

Local, state, and national agencies, universities, land trusts, and private landowners (such as the North Carolina Plant Conservation Program, Eno River State Park, Eno River Association, North Carolina Botanical Garden Foundation, Triangle Land Conservancy, Duke University, UNC Chapel Hill, US Army Corps of Engineers, county and local governments, and others) hold thousands of acres of wildlands and natural open space in the project area (Figure 2). Connecting and preserving these areas with landscape corridors is a primary focus of this project.

Much more detail on the significant biodiversity, natural and environmental features, and history of the project area may be found in county natural area inventories conducted by NCNHP, ongoing data collected and managed by NCNHP (current data available from https://www.ncnhp.org/data), the NC Wildlife Action Plan (NCWRC 2015), county and municipal comprehensive plans, and other conservation planning and assessment documents for the region or specific sites (see References Cited section in this report).

BACKGROUND

THE EVOLUTION OF LANDSCAPE CORRIDOR PLANNING IN THE PROJECT AREA

Conservation of natural areas along the two major river corridors in the project area, the Eno River and New Hope River (now Jordan Lake), originated in the late 1960s and early 1970s. Eno River State Park was formed in 1973 with an initial purchase of 300 acres, and the Eno River Association has helped protect nearly 6000 acres along the Eno River corridor since that time (Eno River Association 2019), with ongoing efforts to complete protection of the entire river corridor. The Jordan Lake Dam on the New Hope River was completed in 1974, and Jordan Lake was filled by 1982. Greater than 32,000 acres surrounding Jordan Lake were protected from development when the lake was formed (LeGrand 1999), with protected lands now totaling more than 40,000 acres (NCWRC 2019); these lands are owned by the Federal government, administered by the US Army Corps of Engineers (USACE), and managed by various state agencies for recreation, wildlife-related activities, natural resource conservation, and education.

NATURAL AREAS INVENTORIES

From the late 1980s onward, natural areas inventories conducted and updated by NCNHP for Durham, Wake, Orange, and Chatham Counties have provided the foundation for conservation planning in the project area (Table 1). In addition, NCNHP completed an inventory of Jordan Lake (USACE land and the lake itself) in 1999 (LeGrand 1999), which includes portions of all four counties. The NCNHP inventories focus on identifying and surveying natural communities, wildlife habitat, and rare plant and animal populations throughout each county. NHNAs (formerly called Significant Natural Heritage Areas) (NCNHP 2019d) are then designed and mapped around these elements and evaluated for their biological significance based on these comprehensive biological surveys.

Table 1. Natural areas inventories completed by NCNHP for counties in the project area and Jordan Lake lands.

Natural Areas Inventory	Author, Year completed	Update Author, Year
Durham County	Sutter 1987	Hall and Sutter 1999
Wake County	LeGrand 1987	LeGrand 2003
Orange County	Sather and Hall 1988	Sorrie, Shaw, Sather, Hall 2004
Chatham County	Hall and Boyer 1992	n/a
Jordan Lake	LeGrand 1999	n/a

Each county inventory report in the project area acknowledges the importance of landscape connectivity for natural areas and wildlife habitat. The reports highlight important riparian corridors within the county, and NHNAs can be defined in part by their function as important wildlife corridors. The Durham and Orange County inventories include a broader focus on landscape-wide connectivity. The 1987 Durham County inventory (Sutter 1987) is organized "around a network structure of core refuge areas and linking movement corridors", and the 1999 update to this inventory (Hall and Sutter 1999) incorporates a more comprehensive zoological survey and assessment of wildlife movement corridors (Hall 1995). The 1999 update organizes the county into eight major riparian core refuge-corridor complexes and provides mapped corridors between these complexes, in addition to noting connectivity between core areas within each complex. The 1988 Orange County inventory (Sather and Hall 1988) provides a map showing a suggested wildlife corridor system for the entire county, organized around five riparian refuge systems and connected by four upland areas identified in the inventory. The 2004 update to the Orange County inventory (Sorrie, Shaw, Sather, and Hall 2004) organizes the landscape into macrosites (a concept used

for grouping NHNAs into larger, related conservation priority areas; no longer used by NCNHP) but does not include the suggested wildlife corridor system from the 1988 report.

REGIONAL LANDSCAPE ASSESSMENT

In 2008 NCNHP, in association with the North Carolina Ecosystem Enhancement Program (EEP), produced a "Statewide Assessment of Conservation Priorities at the Landscape Level" (Hall 2008, 2009). This assessment, which consists of a report on riparian habitats (Hall 2008) and a separate report on Eastern Piedmont upland and inter-basin habitats (Hall 2009), identifies and maps core wildlife habitat areas and linear habitat connectors between them for natural communities that represent habitat types in seven geographic regions, including the project area within the Eastern Piedmont region. The maps encompass NHNAs from the county inventories but include additional habitat areas for a broader set of indicator wildlife species beyond the rare, threatened, and endangered species tracked by NCNHP.

This statewide assessment introduced Hall's Landscape/Habitat Indicator Guild (LHIG) approach (Hall 2008) to identifying regional conservation priorities, with a focus on protecting a connected network of core habitats for guilds of indicator species that have similar habitat and movement needs and that respond in similar ways to landscape fragmentation. These indicator species collectively serve as indicators of landscape habitat integrity and, as a result, can represent the conservation needs of many species and natural communities. LHIGs as defined by Hall form the underpinning of the landscape corridor analysis in this project, and the geographic information systems (GIS) data for Hall's core-connector maps were updated for the project area in 2017-18 by Hall (unpublished) in support of this project.

CORRIDOR PLANNING

Three previous planning efforts have focused on landscape or riparian corridors in the project area: the New Hope Corridor Open Space Master Plan (Coulter Associates and New Hope Corridor Advisory Committee 1991), the Durham County Open Space Corridor System plan (Durham City-County Planning Department 1993), and the Triangle GreenPrint Regional Open Space Assessment (NC Division of Parks and Recreation et al. 2002).

In 1989 Durham County, the City of Durham, Orange County, and the Town of Chapel Hill commissioned a detailed plan for protecting open space in the New Hope Creek corridor, extending northward from the USACE lands around Jordan Lake. Following a survey and mapping of the natural areas within this corridor (Burger and Harrison 1989, Appendix E in Coulter Associates and New Hope Corridor Advisory Committee 1991), a consultant and an appointed advisory committee representing each of the four jurisdictions worked with planning staff to prepare a master plan for preserving the New Hope Creek corridor. They were charged with: "… creating an open space corridor linking the Eno River State Park, New Hope Creek, [USACE] Lands, and the growing communities of Durham and Chapel Hill for aesthetic, environmental, educational, and recreational purposes, and as a means of shaping the urban form of the area."

The resulting New Hope Corridor Open Space Master Plan (Coulter Associates and New Hope Corridor Advisory Committee 1991) identified potential recreational trails and key wildlife corridors with detailed recommendations on how to secure those areas over a 20-year period. Further, in 1993 the UNC Chapel Hill Department of City and Regional Planning worked with the Orange County Planning Department to develop the New Hope Corridor Open Space Master Plan: Proposals for Linking Duke Forest with Eno River State Park (UNC Chapel Hill Department of City and Regional Planning 1993). This study continued the work of the earlier New Hope Creek corridor plan by further defining corridor links in east central Orange County. The project identified a potential recreational trail and a separate wildlife corridor (200 feet wide) to link the Durham Division of Duke Forest and Eno River State Park. The New Hope Creek Corridor Advisory Committee remains in existence, has been active in monitoring conservation and development efforts in the New Hope Creek Corridor, and has been effective in providing expertise and

recommendations to the four local governments that have enabled the protection of 323 acres along this corridor since 1991 (Jane Korest, Durham Open Space & Real Estate Division, pers. comm.).

The Durham County Open Space Corridor System plan (Durham City-County Planning Department 1993) set the stage for completion of open space plans for individual "natural area corridors" along major streams in Durham. This plan also established policies to support the open space corridor system, including working with landowners to preserve corridor areas, supporting private and public-private efforts, cooperating with other public agencies, coordinating city and county efforts, encouraging clustered development away from natural areas, requiring inclusion of open space in new developments, and educating the public on the value of river and stream corridors.

The Triangle GreenPrint Regional Open Space Assessment (NC Division of Parks and Recreation et al. 2002) was not explicitly a landscape corridor plan. The aim of the project was to "facilitate development of a regional vision for [connected] open space in the Triangle." The plan produced a map and GIS layer of "significant open spaces for parks, greenways, historic areas, natural areas, and water quality." The resulting map represents a system of coarse-scale reserve areas (some of them already protected) connected by riparian corridors.

COUNTY LAND PROTECTION AND OPEN SPACE PLANNING

The use of NCNHP data (from county inventories and other surveys) for land use decision-making has been incorporated into county planning documents to some degree for all four counties. In addition, all four local governments involved in creation of the New Hope Corridor Open Space Master Plan (Coulter Associates and New Hope Corridor Advisory Committee 1991) endorsed the plan, and two local governments, Durham County and Orange County, incorporated the findings into their comprehensive land use plans.

Orange County specifically incorporated the mapped corridors (each 300 meters wide) from the Orange County inventory and Hall's (2008, 2009) LHIG work for the Eastern Piedmont into the county's comprehensive land use plan (as part of its Resource Protection Areas overlay) and amended its zoning and subdivision ordinances to include provisions that would help protect the areas from future development.

More recently, the Wake County Consolidated Open Space Master Plan (2003, 2006) and the Comprehensive Conservation Plan for Chatham County (Robert J. Goldstein & Associates, Inc., and Biocenosis, Inc. 2011) have identified high-priority lands for protection in Wake and Chatham counties, respectively. The Wake County plan funded and incorporated open space plans from its municipalities. The plan also maps priority open space corridors and recommends linking protected lands using corridors wide enough to protect water courses, conserve wildlife habitat, preserve historic landscapes, and beautify area roadways. Aspects of the Chatham Comprehensive Conservation Plan related to wildlife habitat conservation and connectivity have been incorporated into Plan Chatham (2017), Chatham County's recently completed comprehensive plan.

Efforts to implement landscape conservation recommendations and priorities included in the various plans are carried out by area land trusts (such as the Eno River Association, Triangle Land Conservancy, and North Carolina Botanical Garden Foundation), local government land conservation programs (such as the Orange County Lands Legacy Program, Durham County Open Space Program, and Wake County Open Space Program), and other partner entities including Duke University and UNC Chapel Hill. These land conservation programs have all worked to conserve lands within the Eno-New Hope project area, and the results of this report provide new data and a plan to build on past work and existing priorities to conserve a functional habitat-corridor network across the project area.

WHY WE NEED LANDSCAPE CORRIDORS

Movement of wildlife within and between habitats is essential for the short-term and long-term survival of individuals, species, and populations. Animals need to move across the landscape to find food, shelter, water, and mates, as well as to maintain genetic diversity and adapt to climate change (Cosgrove et al. 2018). However, as human population density increases, the natural contiguous landscape is fragmented by development into smaller, isolated patches or "islands" of natural habitat (Hilty et al. 2006) (Figure 3). Roads and development can make wildlife travel difficult or impossible (National Research Council 2005), while semi-natural landscapes such as working farms and forests are more conducive to movement by some species (NCWRC 2013). In North Carolina, as elsewhere, habitat loss and fragmentation are caused by changing human land uses from natural and semi-natural to developed land uses.

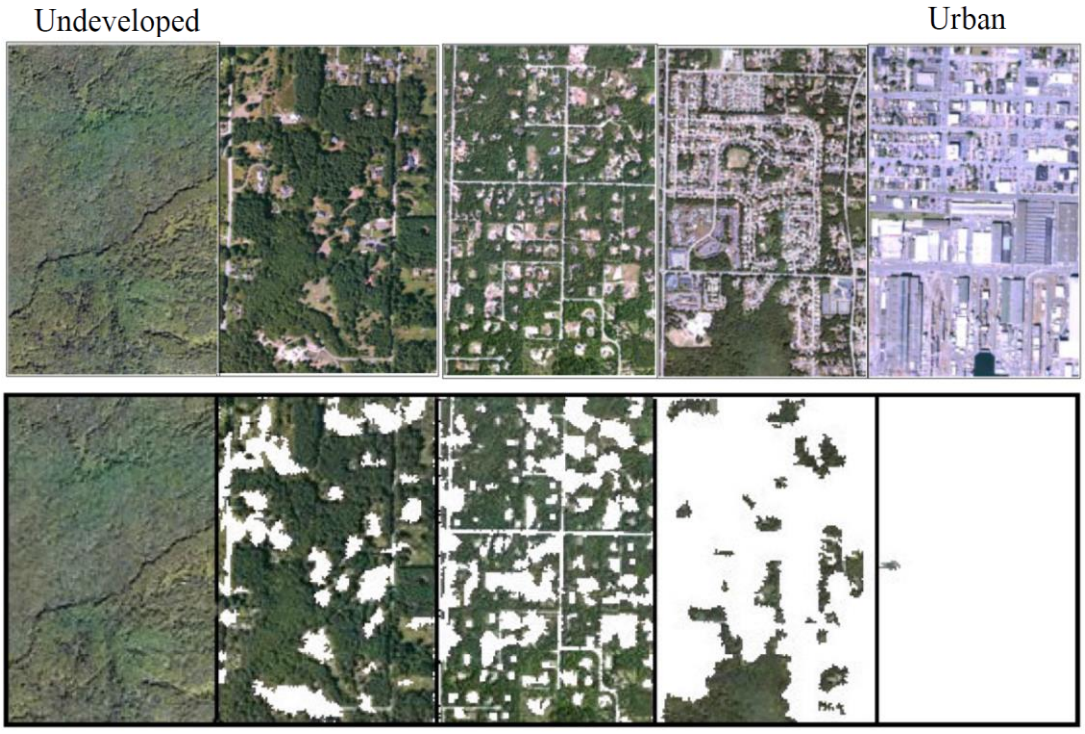

Figure 3. *Reproduced from Washington Department of Fish and Wildlife (2009): "An aerial depiction of the undeveloped to urban gradient...The bottom panel highlights how forest habitat (shown here in green) decreases, and how forest patches become smaller and more dispersed as development intensity increases."*

In addition to direct loss of wildlife populations from conversion of habitat to human land uses, development actions such as land clearing, development, and road-building (along with resulting increases in traffic volume) can be understood as stressors that negatively affect development-sensitive wildlife populations, overall biodiversity, and ecosystems (Washington Department of Fish and Wildlife 2009) (Figure 4). For example, along New Hope Creek in Durham County, habitat fragmentation caused by US Highway 15-501 creates an artificial edge to the forest that may alter or halt the movement behavior of wildlife species that are wary of open or developed areas. This *habitat edge* also contributes to habitat degradation and increased threats to wildlife (such as predation by other species) through changes in natural community composition and structure, as the road carries edge-dependent (often non-native and/or invasive) plant and animal species into the bottomland hardwood forests in the floodplain.

In addition to these and other *edge effects* of habitat fragmentation (Hilty et al. 2006, 2019), US Highway 15-501 is a direct cause of mortality for wildlife that try to cross, and the road creates a behavioral or

physical barrier for less mobile animals that will not cross a paved road or cannot cross a road with curbs or other structures (National Research Council 2005). Over time, loss and isolation of habitat, blocked animal movements, and increased mortality contribute to decline of wildlife populations (Haddad et al. 2015).

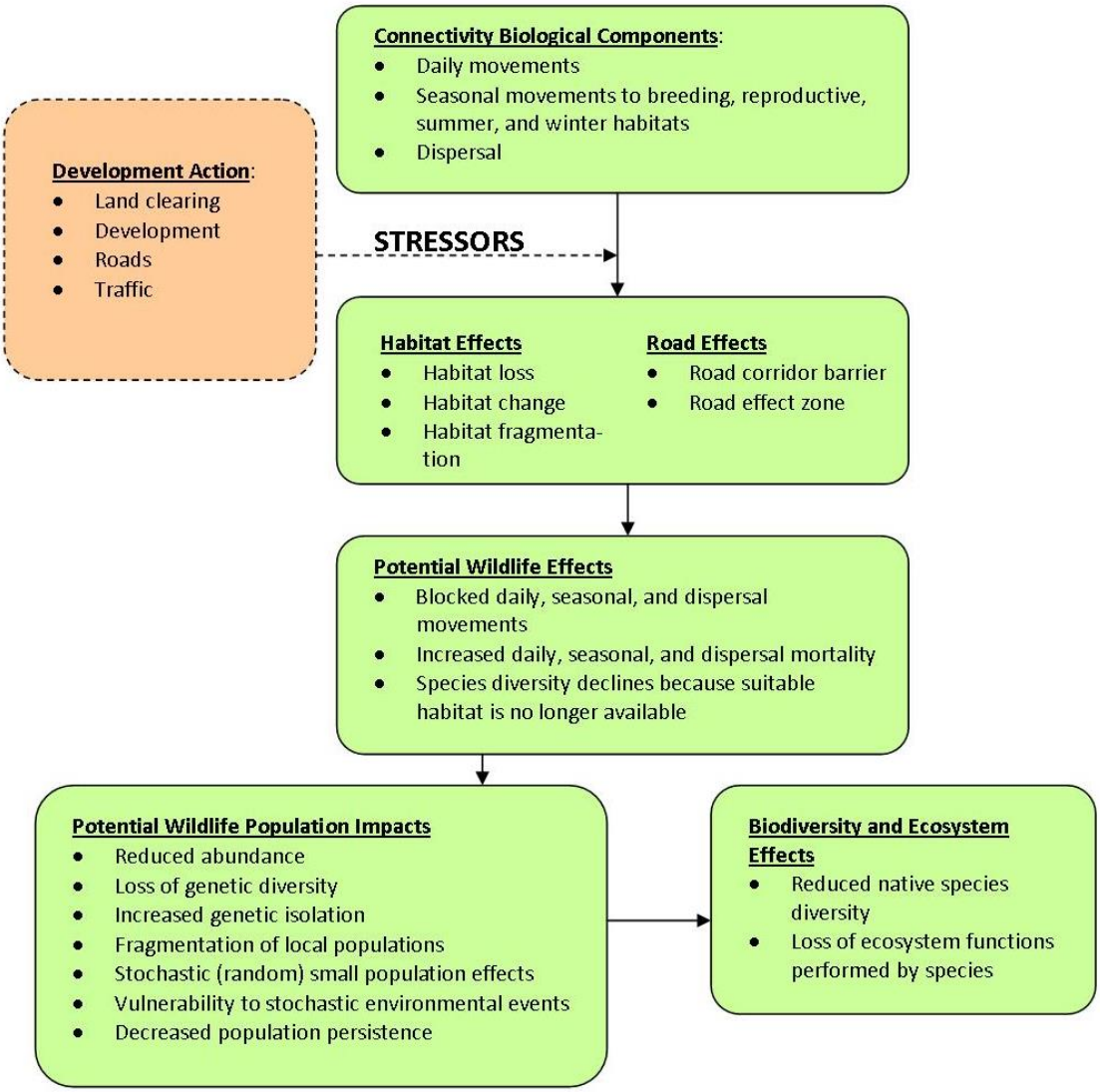

Figure 4. *Reproduced from Washington Department of Fish and Wildlife (2009): "Potential impacts to wildlife from loss of connectivity in developed landscapes. Includes impacts of the 'road effect zone,' or area of impact extending beyond the roadway and including traffic noise and lights."*

Ultimately, local wildlife populations and species diversity are not sustainable in a landscape with isolated patches of habitat (Williams 1998, Haddad et al. 2015). Interconnected networks of habitat are necessary for maintaining wildlife populations, natural communities, genetic and species diversity, and natural ecological processes (Bennett 1999, Cosgrove et al. 2018). Maintaining connectivity of natural communities and ecosystem processes also benefits humans by maintaining *ecosystem services*, such as clean water and air, native plant and pollinator diversity, carbon sequestration and climate regulation, benefits to our local economy (through working farms and forests, recreation, and tourism), benefits to public health, and more (NRCS 2004, Millennium Ecosystem Assessment 2005).

In fragmented landscapes, habitat connectivity can be achieved through naturally occurring or created habitat *corridors* (Gilbert-Norton et al. 2010), defined as "patch[es] of habitat (often linear) that link two or more other natural habitat patches, providing habitat for animals as they disperse or migrate" (NCWRC 2012) (see Appendix B: Glossary for more detailed definition). Corridors can include crossing structures that enable wildlife to cross barriers such as roads, reducing wildlife collisions with vehicles (Bennett 1999). Corridors allow wildlife populations to move to meet daily and seasonal resource needs, to interbreed with other populations, and to colonize new or former habitat areas (such as after recovery from disturbance or disease) by increasing the potential for dispersal from one habitat patch to another (NRCS 2004, Hilty et al. 2006). Maintaining habitat connectivity reduces the susceptibility of wildlife populations and species to decline and local extinction that can occur through, for example, the deleterious effects of increased predation, disease, and natural catastrophes when there are no avenues for escape or recovery through movement of individuals between populations and habitat areas (Rudnick et al. 2012).

THE IMPORTANCE OF WILDLIFE CROSSINGS

Roads contribute to wildlife habitat fragmentation and can function as barriers to wildlife movement or sources of wildlife mortality from wildlife-vehicle collisions (WVC) (National Research Council 2005) (Figure 5). In the US, over one million vertebrates are killed each day due to WVC (Bissonette and Cramer 2008 *in* Ernest and Sutherland 2017). Human safety is also at issue, with more than 61,000 wildlife-related vehicle crashes recorded in North Carolina from 2011 to 2013, causing nearly 20 human fatalities, greater than 3,400 injuries, and more than $149 million in damages (Oliver 2014 *in* Ernest and Sutherland 2017).

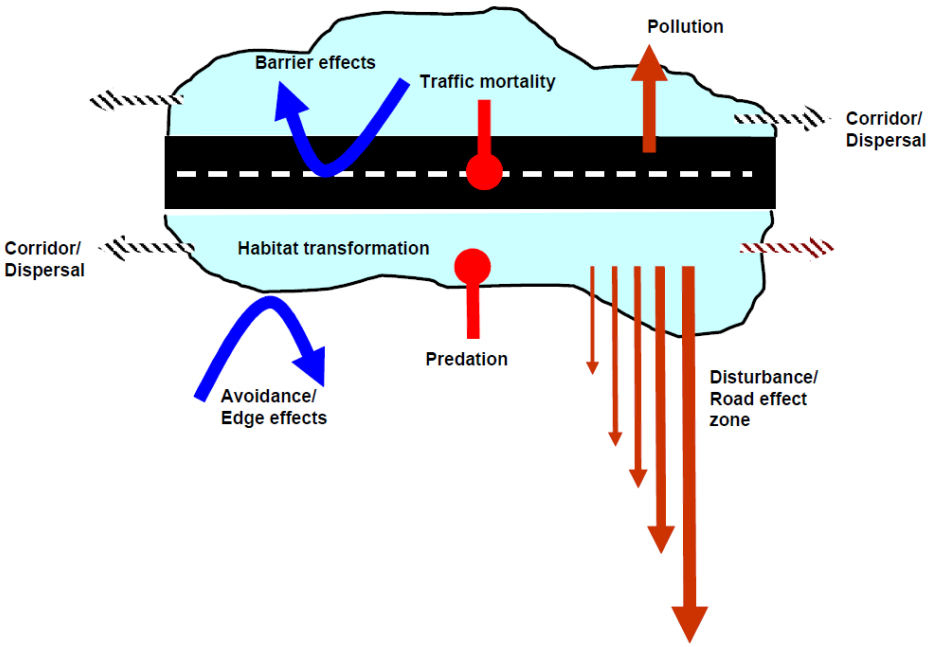

Figure 5. Schematic showing the primary effects of roads on wildlife species and populations (reproduced from National Research Council 2005).

Wildlife crossings, including underpasses, overpasses, and wildlife-friendly culverts, can facilitate wildlife movements and have been shown to reduce WVC (Clevenger et al. 2001 *in* Ernest and Sutherland 2017). Indeed, properly designed wildlife crossing structures installed or retrofitted at priority

locations within the landscape are a necessary component of a landscape habitat-corridor network that functions to maintain wildlife populations. To determine where wildlife crossings should be prioritized and what type of crossing is most suitable for a given location, knowledge of WVC, species' biological requirements, and landscape corridor data are required (Huijser et al. 2008). Other road design elements such as guard rails, fencing, and vegetation barriers are also important considerations for designing successful wildlife crossings. As our understanding of wildlife movement behavior and wildlife use of crossing structures improves, detailed structural specifications and implementation guidelines for effective crossing structures are increasingly available for different wildlife taxonomic groups (such as mammals, turtles, or salamanders) (Clevenger and Huijser 2011).

North Carolina has over 79,000 miles of roads, and the NC Department of Transportation (NCDOT) has installed or modified approximately 12 crossings for wildlife statewide (Ernest and Sutherland 2017). While most of these crossings are located in the mountains or coastal plain (such as in Jones et al. 2010), the improved US 15-501 bridge over New Hope Creek (Figure 6), installed in 2007, is an example of a transportation improvement project in the project area that included modification of the bridge height and length to improve its use as a wildlife underpass. The new bridge has increased safe passage under the highway for a variety of wildlife species (Ron Sutherland, Wildlands Network, pers. comm.).

Figure 6. The improved US 15-501 bridge over New Hope Creek in Durham County, NC. Photo credit Ron Sutherland, Wildlands Network.

Ernest and Sutherland (2017) recently produced a statewide map of roads that are high-priority candidates for wildlife crossing structures to mitigate WVC, based on data from NCDOT on traffic volume, WVC, and road structural characteristics. Their data, in combination with the results of this project and other conservation data layers, provide an opportunity for NCDOT and local governments to integrate wildlife crossing structures into transportation improvement projects at selected locations where they will be most effective for reducing WVC, promoting landscape connectivity, and helping to maintain healthy, diverse ecosystems.

PLANNING FOR CORRIDORS AND CONNECTIVITY: THE GREEN GROWTH APPROACH

NCWRC's Green Growth Program provides a framework for incorporating conservation data and principles into land use planning and development. The Green Growth approach to land use planning requires the recognition of our natural resources as fundamental to the resiliency of communities. Integrating natural resources into land use planning and policy is a critical step to ensure natural resource conservation and integrity into the future. NCWRC's Green Growth Toolbox (NCWRC 2013) is a set of resources that helps communities understand where high-quality natural areas occur and how to protect them through land use planning tools, such as plans, ordinances, and development review. To help identify conservation priorities, spatial information on natural areas, rare species locations, wildlife habitat, and other biological information collected and maintained by NCNHP is made available to planning departments and the public.

Once conservation priorities are recognized, the Green Growth Toolbox offers guidance using three basic conservation principles:

- **Protect** conservation priorities, including large natural areas and sensitive habitats.
- **Buffer** these areas from suburban and urban development.
- **Connect** these natural areas across the landscape to reduce habitat fragmentation.

As described in the Green Growth Toolbox manual (NCWRC 2013), the most direct way to maintain connectivity is to keep important natural areas in a rural context where they are typically surrounded by working farms and forests, which can act as wildlife corridors. However, in more suburban and urban environments, connectivity may be maintained for many species by protecting wildlife corridors that are 150-1000 feet wide (depending on species; NCWRC 2012), ideally with larger patches of habitat interspersed along the corridor.

In general, following the three conservation principles above using strategies outlined in the Green Growth Toolbox will encourage growth and development in areas more suitable for development. For North Carolina, the Green Growth Toolbox provides a bridge between conservation planning and development planning and, along with other science-based resources on best practices for landscape connectivity planning (such as in Appendix E), provides the framework for developing recommendations to ensure wildlife habitat connectivity across the Eno-New Hope project area.

METHODS

LANDSCAPE CORRIDOR ANALYSIS

Approach and tools

This project generally followed the steps outlined in NatureServe's Landscope America guide, "Connecting Landscapes: A Practitioner's Resource for Assessing and Planning for Habitat Connectivity" (Figure 7) (NatureServe/Landscope America 2019). The project used a spatially explicit, GIS-based approach to identify corridors and analyze connectivity in the project area. Within this broad approach, a variety of methods and tools exist to accommodate different objectives and scales of analysis (see examples at Conservation Corridor: Programs and Tools, https://conservationcorridor.org/corridor-toolbox/programs-and-tools/).

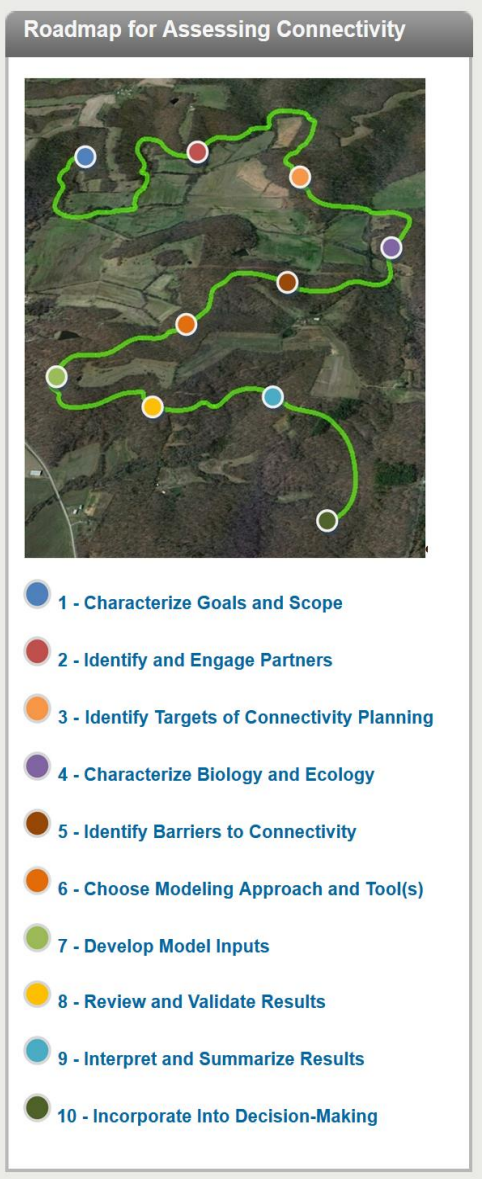

Figure 7. *An outline of the Landscope America Roadmap for Assessing Connectivity (Reproduced from NatureServe/ Landscope America 2019).*

Based on the scale of the project area, the group's objectives, and the need for compatibility with other planning tools, this project used resistance-surface-based connectivity modeling (Wade et al. 2015) to identify a *habitat-corridor network* across the project area, defined as a connected set of discrete wildlife *habitat patches* and *least cost corridors* between them (Figure 8a). Least cost corridor mapping (Wade et al. 2015, Etherington 2016) uses knowledge of species' habitat needs and movement behaviors to map pathways of different relative *movement cost* for a species across a given landscape, using a *cost surface* (or resistance surface) that excludes *movement barriers*. Rather than using the single *least cost path*, a cost threshold is used to identify the areas of lowest movement cost (least cost corridors) connecting pairs of discrete habitat areas (Wade et al. 2015) (Figure 8b).

Least cost corridors are intended to represent areas that, over time, are most hospitable or conducive to successful movement of a species between habitat areas. For example, a spotted salamander living in a moist forest habitat may typically stay within several hundred meters of its breeding pond; however, its offspring may disperse several kilometers across the landscape to find mates and new breeding ponds (NatureServe 2019c). For this *dispersal* to be successful, an individual salamander must choose a movement path that is safe (from predation by other species) and has environmental conditions it can tolerate (sufficient moisture, sufficient food and shelter for the journey, or a relative short journey between habitat patches). The salamander may actively avoid moving into or across areas that it perceives as threatening (roads with traffic) or inhospitable (open fields or dry, sunny conditions),

and will be unable to move across areas that it cannot physically traverse (a barrier across or alongside a road). A particular least cost corridor will preferentially include any areas similar to the salamander's habitat (whether small or large) and will exclude movement barriers and minimize expanses of threatening or inhospitable habitat. Over time, a connected landscape of habitat patches and functional least cost corridors can promote successful movement of individuals between a network of populations (Gilbert-Norton et al. 2010), which ultimately supports long-term persistence, health, and *resilience* of species and ecosystems.

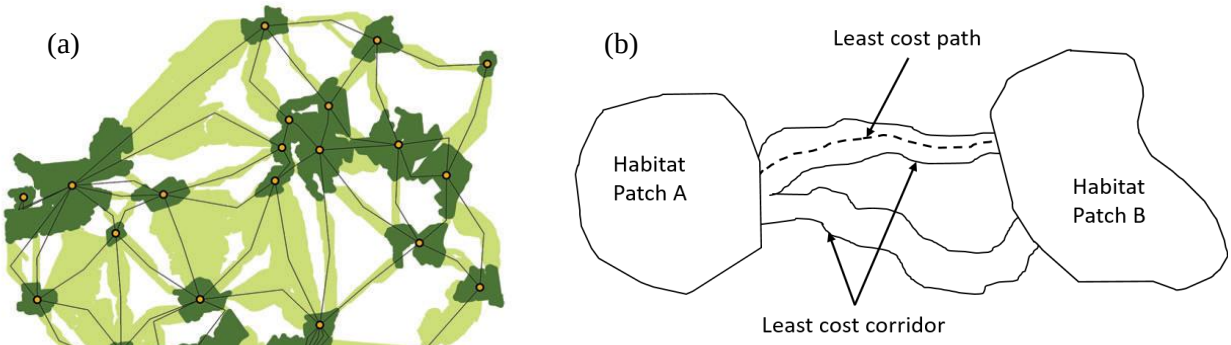

Figure 8. *(a) Depiction of a habitat-corridor network with habitat patches in dark green and corridors in light green (reproduced from Rudnick et al. 2012). (b) Two habitat patches connected by areas of lowest movement cost for a given species across a cost (or resistance) surface, defined by a threshold of maximum movement cost.*

To create the habitat-corridor network, Tuttle used ArcGIS 10.4 (ESRI 2014), the GeoHAT Toolbox for ArcGIS (Geospatial Habitat Assessment Toolkit) (Fay 2012), customized ArcGIS models and Python scripts developed by Tuttle (unpublished), and NetworkX (software for network analysis using the Python programming language) (Hagberg et al. 2008). During the analysis process, the Technical Subcommittee (and later the Policy Subcommittee) reviewed data inputs and intermediate results and provided feedback in an iterative process of refining the data inputs, parameters, and analytical approach to best represent landscape habitat connectivity for the project area in the final results.

Natural communities: species and habitats

The project focuses on connectivity for preservation of terrestrial wildlife species (and many aquatic species by inclusion of riparian areas), natural communities, and existing conservation lands. Building on biodiversity and habitat assessments developed by NCWRC and NCNHP, the group elected to focus on priority species and natural communities (or habitat types) identified in the North Carolina Wildlife Action Plan (SGCN; NCWRC 2015) and in NCNHP's List of Rare Animal Species of North Carolina (Ratcliffe 2018). Hall's previous work on LHIGs (Hall 2008, 2009, 2018) helped focus the project on the function and movement of several focal species groups (indicator guilds) within and between habitat types in a landscape network. In the LHIG framework, species are grouped into guilds by similar habitat needs and responses to habitat fragmentation and development. Because of their sensitivity to fragmentation, these indicator guilds can represent the conservation needs of many species that rely on these habitats or, put another way, that collectively embody these natural communities. Hall's work on LHIG for the Eastern Piedmont of NC (Hall 2008, 2009, 2018) informed the definition of priority habitats and species guilds for the project area, and the relationships between them.

To identify the indicator species and habitat guilds known to occur in the project area, species occurrence data were compiled from several sources:

- NCNHP's List of Rare Animal Species of North Carolina (Ratcliffe 2018)
- NCWRC's SGCN list for the Eastern Piedmont (NCWRC 2015)
- A database compiled by Hall (2017 unpublished) from various sources, including the NCNHP county inventories, the NC State Parks Natural Resources Inventory Database (NRID) (NC Division of Parks and Recreation 2015), and additional field work
- Species Element Occurrence data from NCNHP for the project area (NCNHP 2019a)
- Observation data from the Piedmont Wildlife Center (2018 unpublished), located in the City of Durham adjacent to the New Hope Creek corridor.
- Observations by Eno-New Hope Landscape Conservation Group members, Allison Weakley (Town of Chapel Hill) (2018) and Deborah Fowler (Wake County) (through 2017)
- Observations by a number of individuals as recorded on iNaturalist (iNaturalist.org 2019), an online platform for sharing species observations by date and geographic location, which can be curated, verified, and used as citizen science data inputs in scientific research projects.

The SGCN list (NCWRC 2015) does not contain specific location data but provides a list of species known to occur in the Eastern Piedmont of NC. County-level occurrence lists for NCNHP's rare and watch list animal species (Ratcliffe 2018) are available (https://www.ncnhp.org/data/species-community-search). These two species lists were combined, and inconsistent species taxonomy was corrected. This combined species list was used to filter all available georeferenced species occurrences (from the additional sources listed above) within the project area boundary (with a 5-km buffer), yielding a list of SGCN, rare, and watch list animal species known to occur in the project area. The final species list included only terrestrial species known to occur in the project area within the last 30 years and with year-round resident populations in the project area. Classification of species into habitat guilds followed the classification designated by Hall in his work on LHIG (Hall 2008, 2009).

Fifty-seven terrestrial wildlife species in more than 22 habitat indicator guilds were identified for the project area (Appendix C). Based on the group's desire to identify specific corridor areas, the availability of spatial data for mapping habitat, and other methodological constraints, corridor analysis and mapping were limited to habitat types for three guilds. The three guilds broadly encompass wet-to-mesic (moist) hardwood forests (such as in Figure 9), dry-to-wet hardwood/mixed hardwood-pine forests, and sparsely settled forested areas, including some managed forests. Collectively, they include a total of 14 terrestrial wildlife indicator species, 8 of which are non-flying species and rely on ground-based habitat connectivity.

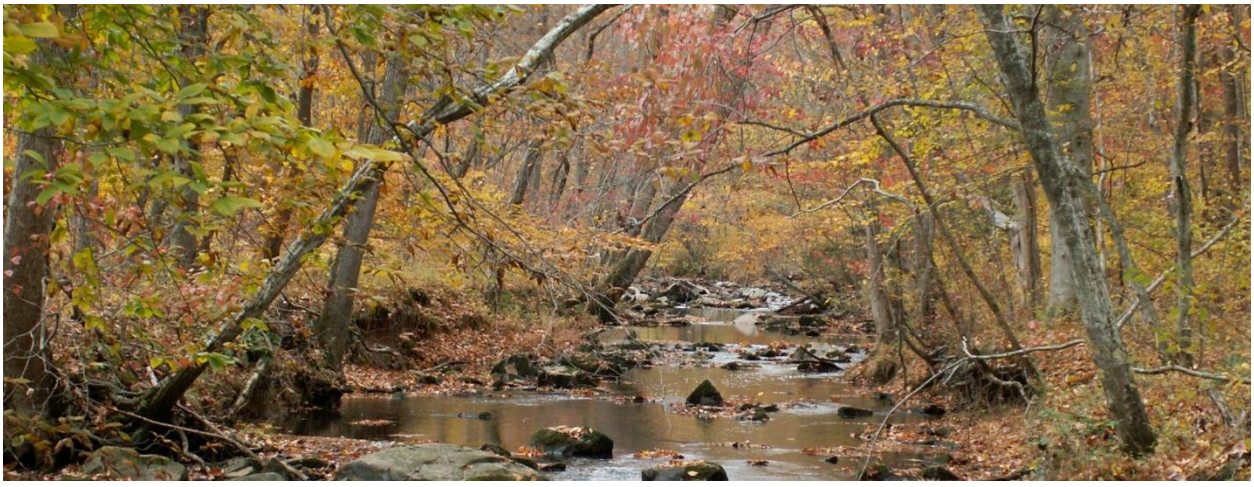

Figure 9. Riparian hardwood forest along the Eno River in North Carolina. Photo credit Kathy Lee.

The three guild habitat types are often spatially nested on the landscape (for example, as floodplain or riparian areas surrounded by adjacent upland areas) and encompass most of the remaining natural habitat in the project area as well as some managed forests that can support native wildlife populations. Additional localized habitat types are further nested within the three selected habitat types, supporting several additional priority wildlife species. As a result, conserving and maintaining connectivity for the three selected habitats will likely support persistence of several other embedded natural communities and many other wildlife species.

Biological and ecological information for species on the final list was compiled from information in Biotics, NatureServe's web-enabled biodiversity information management system (which includes NC-specific data from NCNHP) (NatureServe 2019c), the NC Wildlife Action Plan (NCWRC 2015), and the Fire Effects Information System (FEIS) (Abrahamson nd). Where species-level information was not available, information was compiled for the Element Group (NatureServe 2019d) to which the species belongs. Each Element Group represents species that are related taxonomically, functionally, or by habitat and that have similar habitat needs and movement behaviors.

Concepts, parameters, and inputs

Resistance-surface-based connectivity modeling, a common approach to GIS-based corridor analysis, involves conceptualizing the landscape as habitat, barriers to movement, and a cost surface (or resistance surface) intended to represent species' ability to move within and between habitat areas on the landscape. Types of habitat can be distinguished and assigned higher or lower movement costs, and the *cost distance* that species can move on the landscape can be specified, based on knowledge of species' habitat and movement needs, limitations, and behaviors. Potential corridors can be identified and overall landscape connectivity can be assessed from this mapping based on the quantity and arrangement of habitat types and barriers, and the ease, difficulty, or obstruction of movement over the cost surface.

Habitat. For this project, we used the concepts of suitable and unsuitable habitat used by NatureServe and the Natural Heritage Network (NatureServe 2019a, b). The landscape was divided into habitat suitable for occupancy (by individuals or populations; *suitable habitat*), habitat unsuitable for long-term occupancy but suitable for movement (*unsuitable habitat*), and barriers to movement.

Suitable habitat was further divided into habitat patches -- contiguous areas of suitable habitat above a size threshold -- and smaller fragments of suitable habitat dispersed on the landscape. Habitat patch size thresholds for each guild (Table 2) were determined from information on home range size, daily and seasonal movement behaviors, and habitat characteristics for species or Element Groups as compiled in Biotics (NatureServe 2019c), supplemented by information from FEIS (Abrahamson nd). Where habitat patch size differed for species or Element Groups within guilds, the more limiting (larger) patch size was used.

To classify the landscape of the project area into suitable and unsuitable habitat, we used the LANDFIRE 2014 Existing Vegetation Type (EVT) classification (LANDFIRE 2014) as the base land cover layer. Vegetation types representing suitable or unsuitable habitat for species in each guild in the Eastern Piedmont were identified from information in reports by Hall (2008, 2009) and in Biotics (NatureServe 2019c) (Table 2). EVT land cover classes (LANDFIRE 2016) were then matched to these vegetation types. This habitat "crosswalk" was calibrated and validated by Hall's previous mapping of guild habitat for the project area (from finer-resolution aerial photography than that used for the EVT 30 m x 30 m classification) and the locations of guild species occurrences compiled for the project area. The resulting habitat classification was refined and updated using overlays of floodplains from the NC Flood Mapping Program (2017) and wetlands from the National Wetlands Inventory (NWI) (US Fish and Wildlife Service 2017). For instance, in areas mapped as floodplain but incorrectly classified as an upland hardwood forest type (usually because of the relatively coarse scale of the EVT layer), the vegetation type was updated to floodplain hardwood forest.

***Table 2**. Guild/species biological and ecological information related to habitat and connectivity needs, derived from information in Biotics (NatureServe 2019c) or, where noted, FEIS (Abrahamson nd).*

Guild name (habitat type)	Taxonomic groups in guild	Focal species (species observation network)	Habitat and movement characteristics				Barriers to movement	Sensitivity to development and fragmentation	Primary stressors
			Patch size	*Habitat composition*	Separation distance				
					Unsuitable habitat	*Suitable habitat*			
Wet-mesic hardwood forests	amphibians, (riparian breeding birds and odonates)	Four-toed salamander	5 ha[a]	**breeding:** boggy streams, ephemeral wetlands, usually in floodplains or uplands near headwater streams **non-breeding:** mesic hardwood forests, mixed hardwood/pine near wetlands	1 km	3 km	Large streams and rivers, roads, suburban and urban development	High sensitivity	Floodplain and wetland modification, human disturbances, water pollution, roads
Dry-wet mixed hardwood/ pine forests	reptiles, amphibians, (forest breeding birds)	Box turtle	20 ha	**breeding**: upland mixed hardwood/pine, successional (herb, shrub, and woody) **non-breeding**: bottomland hardwood, successional	1 km	3-5 km (minimum of 3 km used)	High-traffic-volume roads, large rivers, urban development	Moderate sensitivity	Roads, habitat loss
Sparsely settled mixed hardwood/ pine habitats	generalist species of large and small mammals, reptiles, (birds)	Bobcat	60 ha[b]	**breeding:** upland and bottomland mixed hardwood/ pine, successional, with logs, fallen trees, or rock shelters for denning **non-breeding:** upland and bottomland mixed hardwood/pine, successional	50 km[c]	200 km[c]	None; avoidance of buildings and development	Moderate sensitivity	Roads, dense development, human disturbances

[a]Data in Biotics (NatureServe 2019c) indicate home range size of less than 1 ha; however, to avoid including spurious patches and to avoid excessive GIS computation time, the observed minimum patch size of approximately 5 ha (based on species observations in the project area) was used.
[b]Derived from minimum Bobcat home range provided in FEIS (Abrahamson nd).
[c]Derived from Bobcat dispersal information in Biotics (NatureServe 2019c). Dispersal distances for Timber rattlesnake are lower (7 and 1 km for suitable and unsuitable habitat, respectively), but species observation data do not conclusively support the current presence of Timber rattlesnake populations in the project area.

Barriers. By definition, characteristics of barriers are similar for terrestrial species within the same guild. Information in Biotics indicates that developed areas, some roads, and some water bodies are the primary barriers to movement for the focal species and habitat guilds in this project (Table 2). Developed areas were identified from developed land cover classes in the EVT layer (LANDFIRE 2014) and building footprint layers combined across the project area (Apex 2017, Carrboro 2017, Cary 2018, Chatham County 2015, Durham City-County 2017, Orange County 2010). Areas of open water (large rivers, lakes, and ponds) were identified from the EVT and NWI (US Fish and Wildlife Service 2017) layers. Streams that were not wide enough to be identified as open water in the EVT classification were not considered barriers. To classify roads as either barriers or non-barriers, the scientific literature (as compiled in Ernest & Sutherland 2017) provides details on traffic volume, road characteristics, and roadway structures that likely represent barriers to movement for large- and small-animal species groups (adapted for this project as in Table 3). Roads, road characteristics, roadway structures, and traffic volume data for the project area were obtained from NCDOT (2019a, 2017).

To represent known or potential wildlife crossing locations, barrier roads were considered *permeable* to wildlife passage via known and presumed crossing structures (such as bridges, culverts, or pipes). Bridge, culvert, and pipe location data were obtained from NCDOT (2019b). Ultimately, however, potential wildlife crossings were represented primarily as intersections between barrier roads and permanent streams from the National Hydrography Dataset (USGS 2018) because of incomplete mapping of bridge, culvert, and pipe locations throughout the project area. Bridge locations over non-barrier roads were included as potential crossing locations for the sparsely settled mixed habitats guild.

Table 3. Criteria for identifying barrier roads and potential crossing locations for each habitat guild, slightly modified from criteria provided in Ernest and Sutherland (2017) based on biological/ecological information for the species included in this project. Barrier roads were identified from data on road characteristics and roadway structures (NCDOT 2019a) and traffic volume (NCDOT 2017). Potential crossing locations were identified from barrier road—stream intersections (USGS 2018) and bridge/culvert/pipe structure locations (NCDOT 2019b).

Habitat guild	Barrier road characteristics	Potential crossing locations
General wet-mesic hardwood forests (Four-toed salamander)	Surface width ≥ 26 feet Shoulder curb present Median barrier or curb present Striped median present Traffic volume ≥ 2000	Intersections between barrier roads and streams
Dry-wet hardwood and mixed forests (Eastern box turtle, salamanders)	Surface width ≥ 26 feet Shoulder curb present Median barrier or curb present Striped median present Traffic volume ≥ 2000	Intersections between barrier roads and streams
Sparsely settled mixed habitats (medium-sized mammals, snake)	Speed limit ≥ 60 miles per hour Median barrier present Traffic volume ≥ 10,000	Intersections between barrier roads and streams Bridges over non-barrier roads

Movement cost and distance. Cost distance thresholds and the costs for movement through suitable or unsuitable habitat were derived from NatureServe's concept of *separation distance* (NatureServe nd). For NCNHP mapping of known species occurrences, the distance between two or more occurrences and the quality of the intervening habitat (suitable or unsuitable) determines whether the occurrences are mapped as distinct populations or as connected sub-populations. These separation distances for suitable and unsuitable habitat are determined from knowledge of species' biology and ecology, including typical or maximum dispersal distances within and between areas of suitable habitat (Table 2).

For each guild, separation distances for suitable and unsuitable habitat were derived from information for species or Element Groups in Biotics (NatureServe 2019c), supplemented by information from FEIS (Abrahamson nd). Where suitable or unsuitable separation distance differed for species or Element Groups within guilds, the more limiting (lower) distance was used. A guild's cost distance threshold was scaled to the unsuitable separation distance, so that each unit of distance traveled in unsuitable habitat represented a unit of cost toward the distance threshold for unsuitable habitat. The lower movement cost in suitable habitat was then calculated as the ratio of unsuitable to suitable separation distance, so that for the same cost distance threshold, the actual distance on the ground would equal the larger suitable separation distance.

Cost surface and habitat patches. The cost surface for each guild was derived by first rasterizing (where necessary), reclassifying, and combining the following GIS layers into a single raster GIS layer:

- habitat (EVT vegetation, floodplains, wetlands, and non-barrier roads)
- barriers (EVT developed areas, building footprints, open water, and barrier roads)
- potential wildlife crossing areas (barrier road—bridge/culvert/pipe intersections and barrier road—stream intersections)

The combined raster layer was then reclassified so that barriers were removed, and each unique habitat class was assigned the guild's unit movement cost value for suitable or unsuitable habitat according to a reclassification table. Potential wildlife crossing areas were also assigned the movement cost value for unsuitable habitat. Discrete areas of suitable habitat above the threshold patch size were identified and extracted as a separate habitat patch layer (shown in Figure 10 overlaid on the cost surface).

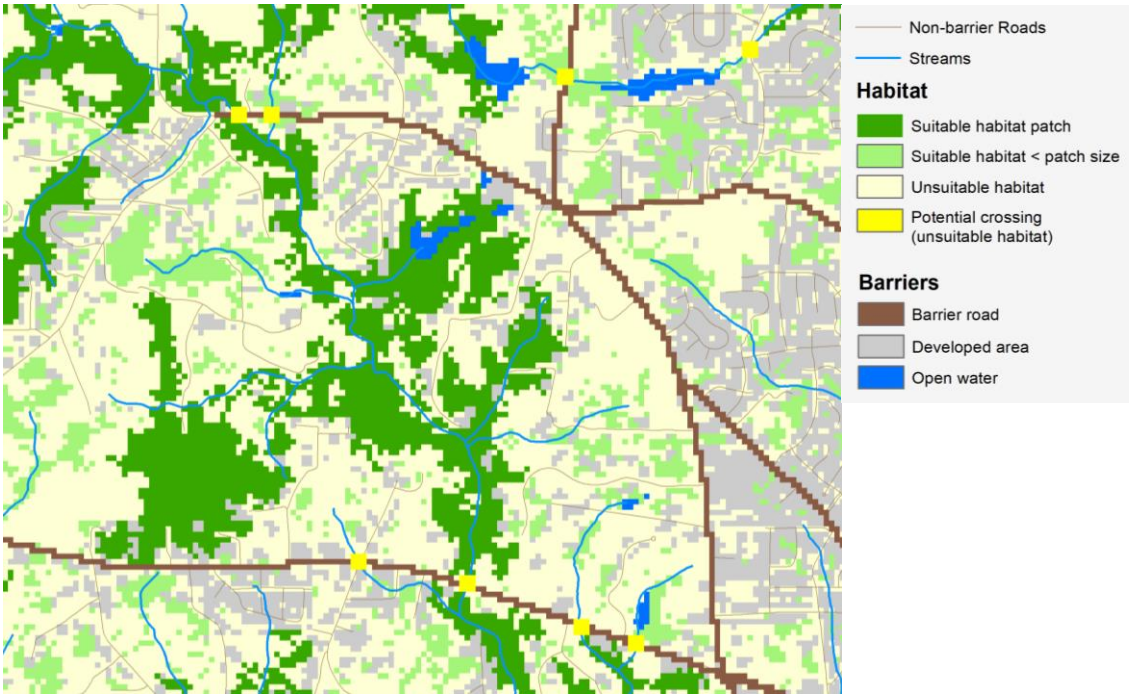

Figure 10. A portion of the cost surface for the Dry-Wet Hardwood and Mixed Forests guild in the project area. Unsuitable habitat areas, including potential crossing locations, are assigned a cost of 1 distance unit. Suitable habitat (non-patch) areas are assigned a cost of 1/3 distance unit, to reflect the lower cost and species' ability to move greater distances through suitable habitat. In the modeling approach for this project, movement proceeds from the edge of one habitat patch to the edge of another patch, such that there is no movement cost associated with the area occupied by habitat patches. Non-barrier roads and streams are shown for context.

Analysis and interpretation

Using a combination of tools and scripts from ArcGIS 10.4 (ESRI 2014), GeoHAT (Fay 2012), Tuttle's custom toolbox for this project (Tuttle unpublished), and NetworkX (Hagberg et al. 2008), a network of habitat patches and least cost corridors was identified for each guild. The relative *connectivity importance value* was then calculated for each corridor segment (*edge*, not to be confused with habitat edge) between two habitat patches. We used the cost-weighted *edge betweenness centrality* (EBC) metric (NetworkX Developers 2019) in NetworkX to represent connectivity importance value for corridor segments. EBC represents the proportion of least cost paths between all patches in the connected network that "travel" through a particular corridor segment, and the value ranges from 0 to 1 (Wade et al. 2015). To assign a connectivity importance value to each patch, the maximum EBC value for all corridor segments connected to the patch was assigned to the patch. In this way, the most important patch-corridor pathways for overall landscape connectivity were mapped.

Species occurrence data for one indicator species in each guild (Figure 11) were used to develop a subnetwork of corridor connections between species occurrences, and the EBC-based connectivity importance values for these *species observation networks* were used to refine the priority habitat network for the project area. Specifically, the maximum connectivity importance value for either the *habitat-only network* or the species observation network was applied for each corridor segment and habitat patch.

Figure 11. Indicator species selected from each of the three habitat types for development of the species observation networks, which were used to refine the priority habitat network for the project area.

The habitat-corridor network for each guild was classified into 4 ranked priority groups based on natural breaks between connectivity importance values (EBC), and the guild networks were combined for viewing in GIS using either a semi-transparent overlay of all three guild networks (as shown in the Results section of this report) or an intersection of the three guild networks as a single layer in which the maximum value across the three guilds was assigned to each patch or corridor segment.

The Technical and Policy Subcommittees reviewed the results of analysis in the context of other relevant GIS layers (such as future land use and zoning districts, existing conservation lands, potential wildlife crossings, etc.) and, based on their knowledge of the project area, tentatively identified priority locations for protection (not reported here), such as corridor pinch points, conflicts with land use and zoning districts, opportunities and gaps in conservation planning areas, and corridor alternatives.

REVIEW OF EXISTING POLICIES, ORDINANCES, AND PROTECTION PRIORITIES

To ensure landscape connectivity within the Eno-New Hope project area and between adjacent watersheds, project results and recommendations will need to be incorporated into local decision-making. In addition, successful landscape connectivity conservation will, by definition, rely on interjurisdictional coordination.

To support these efforts, we synthesized existing policies, ordinances, and protection priorities related to corridor planning and protection within the two watersheds. Governing documents were reviewed for each county and municipal jurisdiction within the project area, including comprehensive plans and unified development ordinances (UDO) as well as separate plans, ordinances, and spatial data layers focused on land use, natural resources, open space, parks and recreation, trails and greenways, water resources, hazard mitigation, and small planning areas. In addition to the New Hope Corridor Open Space Master Plan, several other interjurisdictional plans and agreements were reviewed. Discussion with the Policy Subcommittee and individual interviews with several group members provided additional insight into existing governmental structure and processes related to land conservation and natural resource protection.

The resulting summary of existing policies, ordinances, and conservation priorities related to landscape connectivity provides a resource for interjurisdictional coordination and, along with the corridor analysis results, informs the recommendations provided in this report.

RESULTS

LANDSCAPE HABITAT-CORRIDOR NETWORK

Final corridor analysis results for the three habitat guilds combined reveal a backbone habitat-corridor network running primarily north-south through the project area (Figure 12(a)). Most prominently, results illustrate the high importance of the central New Hope Creek-Jordan Lake corridor in supporting biodiversity and maintaining habitat connectivity across the project area. Also prominent are the Eno River corridor and areas where opportunities exist for protection of corridors across the Eno River-New Hope Creek watershed boundary, which is also a boundary between the Neuse and Cape Fear River basins, respectively.

Results also illustrate how the habitat-corridor network connects NHNAs (which may be considered high-value biodiversity "source nodes") across the project area (Figure 12(b)), and areas where land protection is needed to keep existing conservation lands, the overall network, and neighboring watersheds connected (Figure 12(c)). In the review and interpretation of results, members of the project subcommittees tentatively identified (not shown) protection opportunities, notable gaps, and vulnerable areas in the priority habitat network, including several pinch points along major corridors where urgent protection or restoration action is needed.

The GIS layers encompassing the analysis results will be provided to the project participants, natural resource professionals, and local government planners and decision-makers as a resource for more detailed and ongoing assessment, prioritization, and update of the landscape habitat-corridor network. In particular, further assessment of the results with respect to existing land use layers and conservation planning tools will help shape the integration of these results into an overall landscape conservation strategy for the project area. Care should be taken when using the results to consider the assumptions and limitations of the methods of analysis and the data inputs, particularly the 30 m x 30 m resolution of the base land cover layer, which (for example) cannot effectively identify finer-scale urban vegetation and riparian corridors.

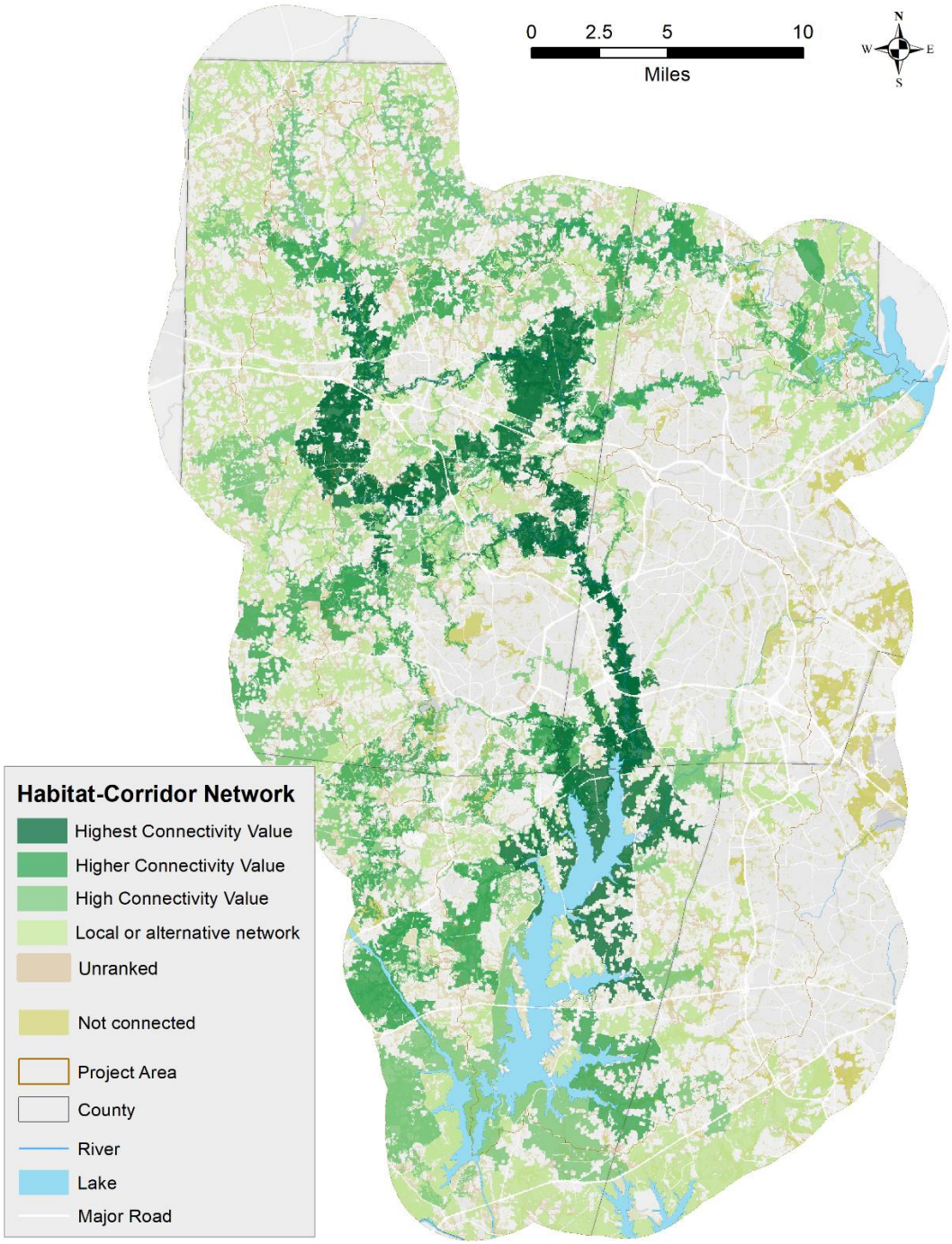

Figure 12(a). *Results of GIS-based corridor analysis for the Eno-New Hope project area, shown here as the priority habitat-corridor network for the three habitat guilds, combined with a semi-transparent overlay. Each guild's network is divided into 4 classes based on natural breaks in the connectivity importance values (EBC). Connectivity importance value for each patch in a guild represents the maximum of the habitat-only and species observation network EBC values. Unranked areas represent suitable habitat smaller than the minimum patch size or corridors with cost distance greater than the guild's cost distance threshold. Disconnected areas represent habitat patches that are not connected to the overall habitat network, either because of intervening barriers or because the lowest cost distance to the overall network is greater than the cost distance threshold for the guild.*

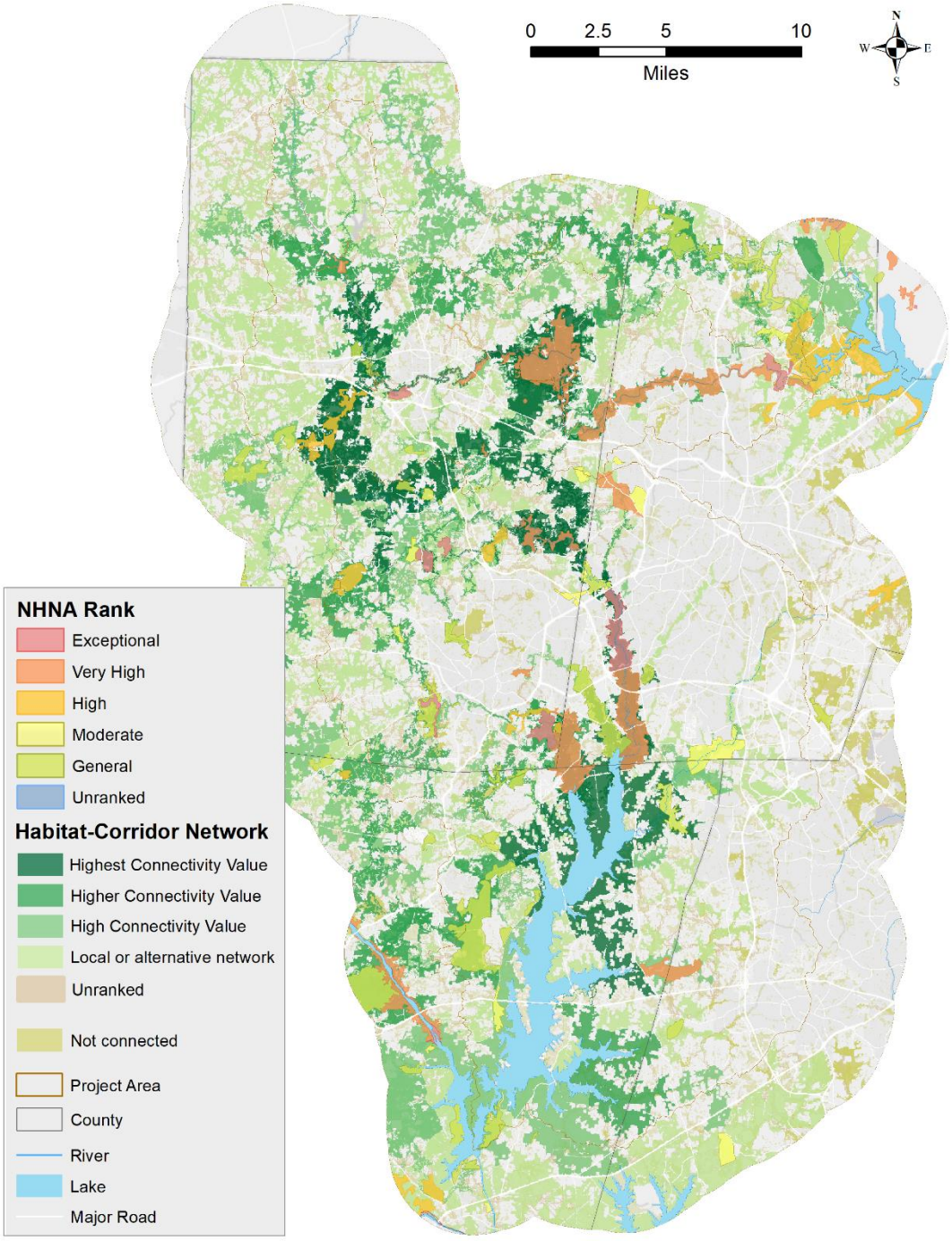

Figure 12(b). *Natural Heritage Natural Areas (NHNAs) (NCNHP 2019c) overlaid on the habitat-corridor network for the project area, depicted as in Figure 12(a).*

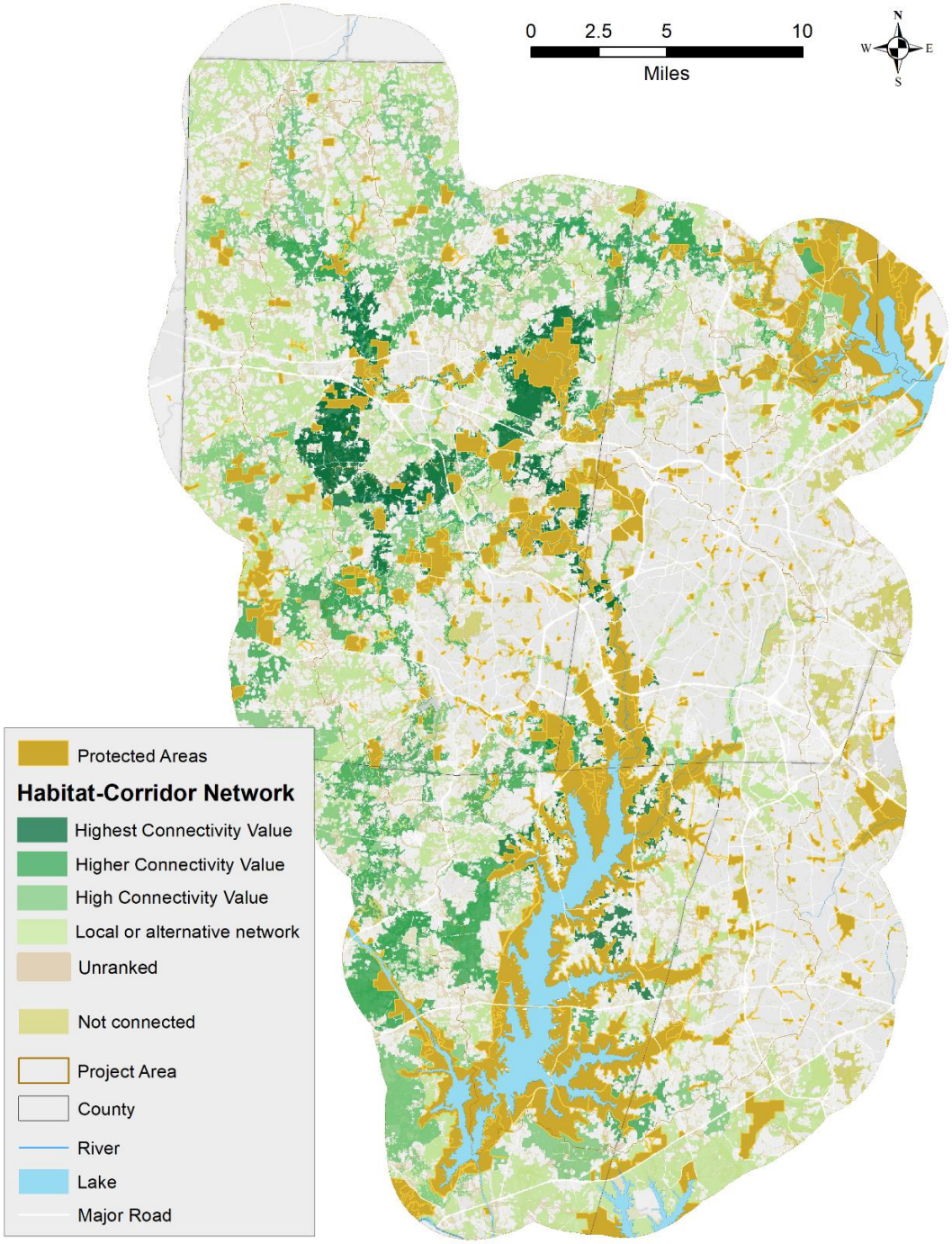

Figure 12(c). *Protected areas (NCNHP 2019b) overlaid on the habitat-corridor network for the project area, depicted as in Figure 12(a).*

EXISTING LAND PROTECTION PRIORITIES

Many jurisdictions have identified or mapped specific land protection priorities in planning documents, which we summarize here by jurisdiction. As expected, many of these priorities overlap with the priority habitat and corridor areas identified in this project (and some priorities from older plans have already been protected). However, it should be noted that not all priorities suggested in these documents have been incorporated into formally adopted plans or ordinances. More detailed comparison of this project's corridor analysis results to existing priorities and other conservation data layers can guide a comprehensive reassessment of land protection priorities that considers landscape-wide habitat connectivity within and between jurisdictions.

CHATHAM-CARY

The **Chatham County Town of Cary Joint Land Use Plan** (2012, last amended 2016) prioritizes a natural buffer along either side of the American Tobacco Trail (ATT) right-of-way (consistent with the Town of Cary's Land Development Ordinance) and, where needed, supplemental plantings to achieve an opaque or semi-opaque buffer. The buffer does not apply to existing development plans.

DURHAM-ORANGE-CHAPEL HILL

Priorities from the **New Hope Corridor Open Space Master Plan** (1991) and County/Town resolutions include (adopted as comprehensive plan amendments by Orange County and the Town of Chapel Hill, and "in concept" by Durham City-County):

- From the resolution: Overland areas between watersheds, the 100-year floodplain of New Hope Creek and Mud Creek, and a 200-foot-wide corridor between Duke Forest and Eno River State Park. Corridor areas are shown in a map attached to the resolution.
- From the master plan: The stream course, 100-year floodplain, 20% slopes adjacent to floodplains, the remaining land between the top of a slope and the nearest road or existing development, the NC 751 Scenic Road, larger tracts of particular historic, educational, or recreational value (open space anchors), and protection of wildlife via mapped wildlife protection areas
- The plan further states, "…strict protection of 20% slopes would result in a patchwork of isolated areas too small to serve as habitat or survive over time. Therefore, it was determined that in keeping with the environmental, recreational, and educational purposes of this Plan, a buffer 200' wide should be preserved adjacent to certain floodplains as indicated in the appropriate components. This buffer includes much of the steep slopes…"
- Specific sites recommended by the plan include:
    - New Hope Creek from NC 54 north and west to Erwin Road in Orange County
    - Dry Creek from New Hope Creek on the north side of Chapel Hill-Durham Boulevard west to Erwin Road and the future Chapel Hill greenway
    - Mud Creek from New Hope Creek north to NC 751
    - Connections between Mud Creek-NC 751 and Eno River State Park along NC 751 and Orange County roads (to the west)
    - Sandy Creek from New Hope Creek on the south side of Chapel Hill-Durham Boulevard northeast across the Boulevard to NC 751

More detailed recommendations for each site are provided in the plan. The plan lists 1,802 acres to be protected (1,699 by acquisition or donation, the rest by conservation easement). Maps in the plan show the areas recommended for protection.

CHATHAM COUNTY

Plan Chatham (2017)

The Conservation Design land use district prioritizes Big Woods NHNA and a connector to the Haw River. The plan also suggests studying the feasibility of establishing a nature preserve on the county-owned land along Terrell's Creek adjacent to Crawford-Dairy Road.

Big Woods Conservation Design Guide (2017)

The design guide includes the following recommendations:

- The county should prepare a map of a proposed connected system of conservation space for the county.
- Chatham County and the Triangle Land Conservancy should partner with interested landowners to permanently protect wildlife hubs and corridors, such as the Big Woods NHNA.
- Where appropriate, consider the use of bottomless culverts, spanning bridges, or other crossing structures to enable the movement of wildlife. This may be especially effective in avoiding impacts to aquatic habitats. Also, consider locating wastewater treatment systems, such as community septic systems or land application areas, outside of key habitat hubs and corridors.
- Identify areas targeted for improved open space, such as greenways, that provide recreational opportunities and alternative transportation options while functioning as wildlife corridors. Such opportunities exist between Bynum, the Big Woods NHNA, and Jordan Lake Game Lands.
- Define the types of resources that should be considered Primary Conservation Areas and Secondary Conservation Areas.
- Recognize opportunities to protect large, intact open space areas so that as development occurs, they continue to extend contiguously across property boundaries to maintain wildlife corridors and connect habitat hub areas.

DURHAM CITY-COUNTY

Durham Comprehensive Plan (2016)

A priority in the comprehensive plan is to restrict uses adjacent to Eno River State Park to those compatible with recreational uses, such as residential uses and public and private recreation and open space.

Durham Urban Open Space Plan (2017)

Priorities include:

- For District 4: Better connectivity between planned trails, riparian corridors, and the ATT.
- For District 5: Develop greenways with linear open space connecting NCCU, Hayti Heritage Center, and Downtown. Foster linear open space connections to Burton Park including stream restoration and tree canopy along the proposed Burton Creek Trail. Preserve and enhance larger tracts of forest in stream valley areas. Create larger corridors to connect Burton Creek and Campus Hills Park. Green connectors could be made to NCCU and Durham Tech that would allow for flexible use of open space.

ORANGE COUNTY

Lands Legacy Program Action Plan 2018-2020

- Action plan objectives include:
    - High-priority Natural Areas (NHNAs) adjacent to existing conservation lands
    - Collaboration with towns for open space acquisition, including trails, greenways, and connecting important open space
- Priority projects include:
    - Upper Eno Preserve – lands adjacent to 7-Mile Creek and trail link to Riverwalk
    - Farmland easements – priority water supply watersheds and riparian buffers
    - Jordan Lake Headwaters Preserve
    - Corridors between New Hope Creek and Eno River
- Acquisition objectives include riparian buffers for the Upper Eno River, Upper New Hope Creek, Bolin Creek, and others

New Hope Corridor Open Space Master Plan: Proposals for Linking Duke Forest and Eno River State Park (1993)

Priorities include:

- To protect a 200-foot wildlife corridor running from Eno River State Park to Duke Forest along Rhodes Creek and parallel to Southern Railway
- A wildlife underpass at the I-85/US-70 interchange

Mountains-to-Sea Trail Route Map (2018)

The Orange County Mountains-to-Sea Trail Route map, adopted in January 2018, shows existing and proposed sections of the trail through Orange County.

Eno Economic Development District Small Area Plan (2008, amended 2009)

Priorities include:

- Wildlife crossing structure(s) upon redesign of I-85/US-70 interchange
- To preserve stream corridors and create public trails between developed areas and Eno River State Park and Duke Forest

Stoney Creek Basin Small Area Plan (1996)

Priorities include:

- Protection of natural terrain features and sensitive ecological areas, especially Duke Forest, wildlife corridors along Stoney Creek, and NHNAs identified in inventories
- The Stoney Creek corridor lies 100 meters (328 feet) on each side of Stoney Creek and connects Duke Forest and the Eno River.

Town of Carrboro

Facilitated Small Area Plan for Carrboro's Northern Study Area (1999)

The Land Use Plan Map for the Northern Study Area proposed potential locations of four new parks (as recommended in the town's Recreation and Parks Master Plan), three of them accessible from the proposed Bolin Creek greenway. In particular, the plan focuses on aiming for more than a small 10-acre park on UNC's Horace Williams Tract, to encompass natural areas within the Bolin Creek floodplain and a remaining hardwood forest stand.

The plan explicitly requires preservation or strict limitation of development in natural areas along the Bolin Creek basin, in the Meadow Flats area, and in other sensitive environmental areas identified in the plan's Environmental Constraints Map.

Conservation Areas in the Upper Bolin Creek Watershed (2005)

The town adopted this map of proposed conservation areas as a guide, stating "Conservation areas shown on the map will be preserved to the extent required by the Town of Carrboro Land Use Ordinance." The proposed conservation areas were mapped according to existing conservation lands and open space as well as conservation areas as defined in the town's Land Use Ordinance.

Recreation and Parks Comprehensive Master Plan Update for the Town of Carrboro (2006)

The recreation and parks action plan suggests a focus on land acquisition for the Bolin Creek and Morgan Creek greenways and designation of portions of these stream corridors as "Natural Areas" or "Nature Preserves".

Town of Chapel Hill

Central West Small Area Plan (2013)

A priority in the plan is to maintain (or reestablish if needed) riparian buffers along streams with sufficient allowance for wildlife corridors.

Chapel Hill 2020 Comprehensive Plan, Future Focus Area 6 (2012)

Priorities include:

- To promote greenways, particularly along and near creeks (Areas 1, 2, 3 on Focus Area map).
- To maximize permanent preservation of open space (Areas 2, 3 on Focus Area map).

WAKE COUNTY

Corridor Acquisition Priorities from the **Wake County Open Space Acquisition Corridors** map (2008) include the Beaver Creek Corridor (acquisition priority) with some "partnership" tracts, and a couple of "partnership" tracts on the tributary north of Beaver Creek

Municipal priorities from the **Wake County Consolidated Open Space Master Plan** (2006) include:

- For **Cary**: The planned open space/greenways map. Cary's goal is 12,000 acres of open space (both public and private).
- For **Apex**: "acquiring 112 acres of active and 70 acres of passive recreation lands", "acquiring up to nine specific Resource Conservation Area tracts", and "…developing the Beaver Creek Greenway and the Lexington Greenway…"

EXISTING POLICIES AND ORDINANCES

Review and synthesis of planning documents, ordinances, and spatial data revealed a set of underlying elements relevant to landscape corridor planning and protection, which can be organized into four general categories: natural resources protection, land use and development, planning and collaboration, and transportation. The results of this review, organized by jurisdiction, are presented as a resource that can be cross-referenced with other jurisdictions, the corridor analysis results, and the recommendations in this report, which can help identify opportunities for ensuring landscape habitat connectivity through specific policies, ordinances, incentives, processes, and collaboration. Official documents should be consulted for additional information. A list of documents reviewed is provided in Appendix D of this report.

CHATHAM-CARY

The *Chatham County Town of Cary Joint Land Use Plan* (2012, amended 2016) envisions that the western Cary/eastern Chatham County area should remain rural and provides for a rural buffer that limits water and sewer services to help achieve this vision. This plan also calls for the creation of parks and greenways in this area.

DURHAM-ORANGE-CHAPEL HILL

The *New Hope Corridor Open Space Master Plan* and its appendices (1991) were reviewed.

Appendix B provides a joint resolution "to Preserve a Corridor of Open Space Connecting New Hope Creek with the Eno River Through Orange and Durham Counties" that was passed by the elected boards of Orange County, Durham City-County, and the Town of Chapel Hill. This resolution states, "Therefore, Be It Resolved that the jurisdictions…support the following: 1. The preservation of a corridor of public open space linking New Hope Creek with the Eno River, including the 100-year floodplain of New Hope and Mud Creeks and a 200' wide corridor connecting the Duke Forest Divisions to the Eno River State Park through Orange and Durham Counties, as shown conceptually on the attached map. 2. Each County and the municipalities within will support and fund the project in a proportionate manner. 3. The Administration of each jurisdiction is directed to prepare more detailed plans for this project, including identifying the exact route, the amount and location of land and easements to be preserved, developing a preservation plan, identifying possible funding sources, and preparing a timetable for completion."

The full plan, which was adopted by Orange County and the Town of Chapel Hill and adopted *in concept* by Durham, contains more detailed recommendations and protection priorities (see the Existing Land Protection Priorities section in this report).

This plan established a multi-jurisdictional advisory committee, the New Hope Creek Corridor Advisory Committee, to help guide conservation efforts by the four jurisdictions and to monitor progress periodically, which has continued to the present day. The presence of this advisory committee since 1991 has provided historical context and continuity that helps the four jurisdictions adhere to the plan's policies and priorities in a changing environment.

ORANGE-CHAPEL HILL-CARRBORO

The *Orange-Chapel Hill-Carrboro Joint Planning Agreement* (1987, last amended 2015) and *Joint Land Use Plan* (1986, last amended 2015) were reviewed.

The *Joint Land Use Plan* indicates that the county's Resource Protection Areas overlay should, in the Joint Planning Areas, "form the basis for a comprehensive parks and open space system which provides

the framework within which other land use categories are to function." The plan reiterates the New Hope Creek Corridor Open Space Areas, which are relevant for the county and Chapel Hill. The *Facilitated Small Area Plan for Carrboro's Northern Study Area* is "specifically incorporated by reference" in the *Joint Land Use Plan* and "...supersedes any provisions of this Plan that are inconsistent with the Small Area Plan with respect to the...Transition Area."

CHATHAM COUNTY

Chatham County's land use and related ordinances as well as the following plans were reviewed: *Plan Chatham* (the Chatham County comprehensive plan) (2017), *Land Use Strategic Plan* (1999), and *Chatham County, North Carolina Agricultural Land Use Plan* (2009).

At the time of this document, Chatham is beginning to revise its ordinances to meet the goals laid out in *Plan Chatham*.

NATURAL RESOURCES PROTECTION

Chatham County has integrated natural resource protection throughout *Plan Chatham*, the comprehensive plan, by including open space protection and landscape connectivity in its conservation goals and as part of its economic, climate resiliency, parks and recreation, transportation, housing, public works/utilities, and community health goals (open space protection is also a goal in Chatham's earlier *Land Use Strategic Plan* and *Agricultural Land Use Plan)*. The county has set a goal to protect an additional 20,000 acres of land by 2040. Within the goal to "conserve natural resources", multiple strategies that aim to protect and connect important natural areas are recommended throughout the plan, including:

- Encourage development design that preserves unique natural features on sites. Examples include wildlife hubs and corridors, mature forest, hedgerows, rare habitats, riparian areas, drainage-ways (above USGS-defined "blue line" streams).
- Encourage development design to preserve forest cover and additional uplands.
- Protect NHNAs, habitat hubs, and wildlife corridors through voluntary reservation, acquisition and partnerships with nonprofits and private entities. Study the establishment of a county-led land acquisition program to assist in local land protection efforts.
- Allow density transfers to protect landscape level green infrastructure (such as greenbelts around towns and planned activity centers).
- Continue to allow administrative approval for conservation subdivisions up to 15 lots and consider allowing administrative approval for conservation subdivisions up to a certain size provided that design criteria are established.
- Allow off-site septic for conservation subdivisions, but discourage for conventional subdivisions
- Website updates and creation of county GIS datasets, including a dataset on wildlife corridors and hubs.
- Develop open space framework plans for areas with high value natural assets. These plans would acknowledge the areas identified as valuable natural resources and describe the integration with public and private development while maintaining the integrity of the resources. Mapped using GIS, these data could inform decisions about open space preservation in conservation design (such as in the plan's Natural Resources Element and the Big Woods Concept Plan in the Big Woods Conservation Design Guide, included as an appendix to *Plan Chatham*).
    - Areas that would be candidate locations for open space framework plans include the Haw River Corridor, Rocky River Corridor, Southeast Jordan Lake, and other areas surrounding NHNAs.

- Support well-designed, decentralized wastewater systems in order to support land use goals and objectives, particularly:
    - …Conservation subdivisions that conserve sensitive natural resources while protecting property rights

LAND USE & DEVELOPMENT

The *Future Land Use and Conservation Map* within *Plan Chatham* shows important natural areas connected to one another through riparian buffers and/or rural lands. Conservation subdivisions with connected natural areas and wildlife corridors are the encouraged residential development pattern in rural and conservation areas identified on the map. Currently, Chatham County has a conservation subdivision option which provides a density bonus for a natural area set-aside of 40% for the protection of the following priority natural features:

- NHNAs and Natural Heritage Element Occurrences
- NC Wildlife Action Plan Upland Systems (≥ 5,000 ft^2 must exist)
- NC Wildlife Action Plan Lowland Systems (≥ 5,000 ft^2 must exist)

At least 50% of the open space must be configured to be contiguous on-site. Applicants must include a fragmentation map that helps the applicant configure the open space to be contiguous with important natural features within 1 mile of the parcel boundaries.

Additionally, Chatham County requires that all developments protect 30-foot, 50-foot, and 100-foot buffers on ephemeral, intermittent, and perennial streams, respectively. When environmental impact assessments are required of developments, they must also identify natural communities, wildlife, and impacts on wildlife.

At the time of this document, Chatham is beginning to revise its ordinances to meet the goals laid out in the comprehensive plan. The plan has provided specific recommendations to improve the incentives for conservation subdivisions. Under Strategy 4.4, the plan recommends "modified submittal requirements for conventional and conservation subdivision design (CSD). Specific amendments to the existing regulations could include the following:

- Modify procedures to simplify the review and approval steps. The process for designing and permitting a residential subdivision that adheres to conservation design standards should be no more arduous or expensive than the process for designing and permitting a conventional residential subdivision.
- Clarify requirements to eliminate vague language and increase predictability.
- Clearly define specific design criteria to be met.
- Ensure standards are measurable.
- Consider allowing administrative approvals.
- Offer incentives to make CSD a more attractive option than conventional subdivision, especially for smaller properties (i.e. <50 acres). Consider the following:
    - Density bonus adjustments (sliding scale based on parcel size)
    - Modifications to street requirements, and/or off-site septic allowances (contingent on soil survey results).
- Further clarify primary and secondary conservation areas and make datasets available to applicants to use as a starting point for identifying primary and secondary conservation areas to be set aside.
- Require conditional use permits for conventional subdivisions in Conservation Areas.

The plan also includes a conservation design guidance document, the *Big Woods Conservation Design Guide*, as an appendix. Using the Big Woods Upland Forest NHNA and adjacent wildlife corridors as an example, the guide outlines how to design conservation subdivisions to ensure priority natural areas are conserved and connected in ways that minimize habitat fragmentation.

PLANNING & COLLABORATION

Plan Chatham recommends that the county "partner with state and local governments and non-profit organizations to increase access to protected lands and unique natural features."

TRANSPORTATION

Chatham County does not address habitat fragmentation in the transportation section of its comprehensive plan, but Policy 7 is to "preserve rural character through appropriately designed transportation infrastructure in areas designated as Rural, Agriculture and Conservation on the Future Land Use and Conservation Map." The plan does recommend that greenways connecting open space be a key piece of the transportation future of the county. Trails and greenways are important components of many community development goals within the plan.

DURHAM CITY-COUNTY

Durham City-County's unified development ordinance and the following plans were reviewed: the *Durham Comprehensive Plan* (2016), *Durham County Open Space Corridor System* plan (1993), *Durham Urban Open Space Plan* (2017), and *New Hope Corridor Open Space Master Plan* (1991).

At the time of this report, Durham is beginning an update of its comprehensive plan and is seeking further information to enhance its environmental protections.

NATURAL RESOURCES PROTECTION

Durham has several policies in the *Durham Comprehensive Plan* that aim to identify and protect natural resources, especially streams, wetlands, and areas identified in the Natural Heritage Inventory or in open space plans for the county. Strategies to protect these resources include:

- Collaboration with partners to acquire lands
- Use of existing documents, plans, and data, such as NCNHP inventory data, to guide priorities
- Restoration of streams and wetlands
- Development of an open space coordination group, "including the Durham Open Space and Trails Commission and various organizations and agencies involved in open space preservation", to improve collaboration in open space preservation. (The Durham Open Space and Trails Commission also provides open space fund-raising support and matching grants program assistance.)

In 1993, the *Durham County Open Space Corridor System* plan set the stage for completion of open space plans for individual "natural area corridors" along major streams in Durham. The plan established policies to support the open space corridor system, including:

- Working with landowners to preserve corridor areas
- Supporting private and public-private efforts
- Cooperating with other public agencies
- Coordinating city and county efforts
- Educating the public on the value of river and stream corridors.

In order to coordinate the *Durham Comprehensive Plan* with open space planning, the city and county formally adopted (in concept) the *New Hope Corridor Open Space Master Plan* (1991) and other open space plans within the city-county (and any future updates of these plans). The *New Hope Corridor Open*

Space Master Plan identifies critical environmental areas, including the stream course, adjacent floodplains, steep slopes (defined as 20% or greater) adjacent to floodplains, larger tracts of particular historic, educational, or recreational value (open space anchors), and the NC 751 Scenic Road (designation and some acquisition), and recommends they be protected through easements or fee-simple acquisition.

LAND USE & DEVELOPMENT

The *Durham Comprehensive Plan* establishes land use and development policies and strategies to protect natural resources, including:

- A development review process that encourages developers to choose conservation subdivisions, infill development, planned developments, cluster developments, and other means to avoid impacting important natural areas, including NHNAs
- Regular update and maintenance of NCNHP data by the planning department
- Restriction of land uses near protected lands to minimize impacts to recreation. In particular, the plan restricts uses adjacent to Eno River State Park to those compatible with recreational uses.
- Protection of undisturbed, naturally vegetated stream buffers and prohibition of most development activities within stream buffers.

The earlier *Durham County Open Space Corridor System* plan established related policies, including:

- Encouraging clustered development away from natural areas
- Requiring inclusion of open space in new developments

Article 8, Environmental Protection of Durham's UDO provides natural resource protections to minimize impacts of developments on the environment, including streams and wetlands, steep slopes, and, through conservation subdivisions, Natural Heritage Inventory sites and defined conservation areas, as follows:

Stream and wetland buffers

Minimally, the UDO requires developments to protect an undisturbed, naturally vegetated, buffer of at least 50 feet on intermittent and perennial streams, including modified natural streams. In watershed protection overlay areas, such as Eno River and Jordan Lake, the buffer for perennial streams is widened to 150 feet in watershed critical areas and 100 feet in watershed protection areas.

While acknowledging the pre-eminence of Federal and State identification and regulation of wetlands, Durham requires at least 25-foot buffers around the perimeter of wetlands 1 acre or greater in size.

Steep slopes

Except in the Patterson Place Compact Neighborhood Tier, the steep slopes ordinance limits grading to no more than 15% of the steep slope area on the tract. Land disturbance solely for the purpose of public right-of-way is exempt from this limit. A residential density credit is provided for the amount of land designated as steep slopes. Steep slopes are defined as areas with a natural grade of 25% or more, an area of 5000 square feet or greater, and located within 200 feet of any floodway fringe or perennial stream or within 100 feet of an intermittent stream.

In the Patterson Place Compact Neighborhood Tier, which is adjacent to and includes portions of the New Hope Creek Corridor designated in the New Hope Corridor Open Space Plan, grading of any portion of steep slopes is prohibited. In addition, "The only allowed disturbance shall be unpaved walking paths and foot trails constructed with minimal disturbance of tree roots and existing vegetation. No tree eight inches dbh [diameter at breast height] or greater shall be removed for the construction of the trail." Steep slopes here are defined as areas with a natural grade of 15% or more, an area of 2500 square feet or greater, and located within 200 feet of any floodway fringe or perennial stream or within 100 feet of an intermittent stream. Development within this tier must conform to adopted plans, including specifically the New Hope Corridor Open Space Plan.

Open space within conservation subdivisions

Developments proposed for areas identified in the Natural Heritage Inventory should use by-right conservation subdivision design to protect significant natural features.

Conservation subdivisions are required to protect 50% of the site as open space. Most of the open space (80%) should consist of features identified as a primary conservation areas. Secondary conservation areas and other open space can be included only after primary conservation areas comprise 80% of required open space.

Primary conservation areas are defined in order of priority as floodplains; riparian buffers; jurisdictional wetlands and their buffers; other water bodies; slopes greater than 25% and at least 5000 square feet in size; mature hardwood forests at least 1 acre in size; wildlife corridors, wildlife habitats, and other important sites.

Secondary conservation areas are defined in order of priority as mature forests at least 12,000 square feet in size; slopes greater than 20% unless identified as a primary conservation area; large, healthy individual trees; and some pedestrian trails. Other conservation areas include, but are not limited to, naturally vegetated areas, or areas re-vegetated to appear naturally vegetated, that are not primary or secondary conservation areas.

PLANNING & COLLABORATION

The *Durham Comprehensive Plan* explicitly recognizes the need for the planning department to prevent habitat fragmentation by "… develop[ing] a plan to interconnect open and green spaces where possible, including many of the larger areas designated for open space in open space plans and large undeveloped large tracts to reduce isolation resulting from fragmentation."

The comprehensive plan directs that:

- "The City Parks and Recreation Department and the County Engineering and Environmental Services Department shall coordinate park development and open space protection programs with the Eno River State Park and the Eno River Association."
- "The City-County Planning Department, City Parks and Recreation Department and the County Engineering and Environmental Services Department shall coordinate Durham's open space plans with other jurisdictions' plans and other regional open space initiatives."
- "The City and County shall continue coordination with the surrounding jurisdictions of Cary, Chapel Hill, Morrisville, Raleigh, Orange County, and Wake County in planning efforts…"
- "Durham City and County shall support State open space efforts, such as the...Mountains to Sea Trail, by coordinating their open space preservation efforts with the State."
- "The County Engineering and Environmental Services Department shall work collaboratively with the Durham Open Space and Trails Commission, local land trusts, the City Department of Parks and Recreation, and other community organizations to increase the amount of open space preserved."

TRANSPORTATION

The comprehensive plan supports the need to work with NCDOT to build wildlife passages under or over roads. The *Durham Urban Open Space Plan* recommends using riparian corridors as greenways to increase connectivity across the urban part of Durham.

ORANGE COUNTY

Orange County's unified development ordinance and the following plans were reviewed: *Orange County Comprehensive Plan 2030* (*Land Use* and *Natural & Cultural Systems* elements) (2008, updated 2012), *A*

Lands Legacy Program for Orange County (2000), *Lands Legacy Program Action Plan 2018-2020*, and *Orange County Parks and Recreation Master Plan 2030* (2014).

NATURAL RESOURCES PROTECTION

The *Orange County Comprehensive Plan 2030* includes natural area resource preservation as one of the Board of County Commissioners' 8 Planning Principles. Specifically, "protection of the County's natural areas, including forests, wildlife habitat, and other important open spaces should be a priority. The County should work with regional and local organizations, the towns, and private landowners to promote and achieve preservation of the County's important natural resources."

The *Natural & Cultural Systems Element* focuses on a systems approach to natural area and natural resource conservation.

- Goal 7 is a balanced and healthy diversity of plant and animal populations.
- Goal 8 is to establish networks of protected natural, cultural, and agricultural lands.
- The Natural Areas, Wildlife Habitat, and Prime Forests component provides "direction and guidance for future land protection efforts in the County." The objective was, at the time, to protect 10% of the county by 2010.

Under Goal 7:

- Objective NA-1 is to "conserve high-priority natural areas and wildlife habitats, including wetlands, rivers and streams, floodplains, steep slopes, prime forests, wildlife corridors, and other critical habitats."
- Objective NA-2 is to "conduct more frequent updates to the County's inventory of natural areas, and include previously unsurveyed areas of the County."
- Objective NA-3 is to "develop a more detailed and consistent methodology for monitoring changes in forest cover throughout the County, and specifically the extent of mature hardwood forest."
- Objective NA-5 is to "prohibit development that would cause adverse impacts on highly significant natural areas and wildlife habitat."
- Objective NA-8 is to "encourage forest management practices on both public and private land that minimize disruption and fragmentation of intact hardwood forests."

Under Goal 8:

- Objective NA-12 is to "establish a system of nature preserves that protect large areas of undeveloped land (including significant natural areas) surrounded by low-density development and working farms and managed forests."
- Objective NA-15 is to "protect land in and around biologically significant areas, and connections between these areas, to allow for the maintenance of native wildlife and plant populations and their functional relationships."

To guide natural area resource preservation, the comprehensive plan includes, as appendices, Lists of Significant Plant and Animal Species in Orange County, Lists of Rare Plant and Animal Species in Orange County, and a Map of Natural Areas and Macrosites.

The *Lands Legacy Program Action Plan 2018-2020* sets and continues the program's land acquisition and protection priorities (see the Existing Land Protection Priorities section in this report for 2018-2020 priorities).

In the *Parks and Recreation Element*:

- Objective PR-1.1 is to "acquire and /or retain public ownership of parks, recreation facilities, open space, and conservation areas that will serve Orange County."

- Objective PR-5.4 is to "encourage development of a system of private open space and conservation areas, including nature preserves, parks, linear parks, and scenic vistas compatible with the character of Orange County."

LAND USE & DEVELOPMENT

In the *Land Use Element*:

- Goal 1 sets the goal of sustainable growth, including environmentally responsible growth.
    - Objective LU-1.1 emphasizes locating higher intensity / high density residential and non-residential development to avoid areas with *protected* natural and cultural resources.
- Goal 2 is to create land uses that are appropriate to on-site environmental conditions and features, and that protect natural resources, cultural resources, and community character.
    - Objective LU-2.2 is to continue to protect valuable resource land such as…natural areas…through the County's Lands Legacy Program, and by directing incompatible development away from these areas through land use and zoning policies and regulations.
- Goal 5 is to keep life, health, and property safe from hazards.
    - Objective LU-5.1 prohibits new development in special flood hazard areas.

Under *Natural & Cultural Systems Element, Goal 8:*

- Objective NA-10 is to "require that all major subdivisions…include within their boundaries open space suitable for low-impact recreation and wildlife habitat."
- Objective NA-13 "promote[s] clustering of residential development and dedication of large areas of undisturbed land for low-impact recreational use by residents and for wildlife habitat. Where feasible, these areas should be contiguous to neighboring tracts of undisturbed land."
- Objective NA-14 is to "encourage developers and neighborhood associations to protect undeveloped community open space through formal conservation agreements."

For the Future Land Use classification map in *Appendix G, Land Use Classification and Overlay Locational Criteria,* land was evaluated to determine the suitability of certain locations to contain various land uses. Areas that are determined to be protected land uses are based on an evaluation of steep slopes, floodplains, rare species, and historic and cultural features. Resource Protection Areas (as an overlay) are "located in areas that contain significant and natural areas and wildlife habitats, including connecting wildlife corridors, as identified by local, state, or federal inventories." The New Hope Corridor Open Space overlay is designated to contain areas of "great diversity, including regionally rare plant species, hardwood trees of size and number uncommon for their location, and important wildlife habitat." All other land use classes are to be purposefully "located away from sites that would, if developed, create a threat to unique or endangered species as identified by the state or federal government."

Under Section 7, General Design Standards of the *Orange County UDO*, the Planning Department is directed to review development proposals to ensure that the land is suitable for the development being proposed. Suitability criteria include potential for flooding, soil drainage, drainage patterns, slope, historic sites, maximum anticipated levels of land disturbance for the project and all proposed individual lots, and unique natural features. Developments proposed for areas identified in Natural Heritage Inventories must include strategies to minimize impacts to the resources, such as clustering lots, conservation easements, etc. Open space is required of developments as well. Under Flexible Developments, 7.12, protected common open space must be set aside at a minimum of 33% and a maximum of 60% of the development site, depending on minimum residential lot size. The open space layout should provide "connectivity and compatibility with both existing development and other types of open spaces." The types of common open space provided in Flexible Developments include Primary Open Space Areas and Secondary Open Space Areas. Primary Open Space areas must be included toward the 33% minimum open space requirement, and Secondary areas can be included only after all Primary areas have been included. Primary Open Space Areas include:

- Wetlands and adjoining land areas identified as part of the NWI map for the county, the county's USDA soil survey, the county natural areas inventory, a required environmental assessment or environmental impact statement, and/or a site analysis by a relevant professional using data from USACE.
- Areas identified in the Orange County "Inventory of Natural Areas and Wildlife Habitats"
- 100-year floodplains and alluvial soils identified as part of the county's flood map and/or soil survey.
- Steep slopes, defined as slopes greater than 25% and identified as part of the county's soil survey or a site analysis by a relevant professional using data from USACE.
- Natural areas and/or wildlife habitats identified as part of the county's natural areas inventory, a required environmental assessment or environmental impact statement, and/or an independent study conducted by a trained botanist and/or biologist.
- Wildlife corridors as identified in the county's comprehensive plan.
- Historic and archaeological sites.

Secondary Open Space Areas can be chosen for access or composition, and compositional criteria include, but are not limited to:

- Woodlands, including lands for production of timber where selective harvesting and wildlife enhancement practices are used.
- Farmland.
- Slopes of 15% to 25%.
- Greenbelt linkages within an approved county greenbelt program.

Orange County ordinances also require 50-foot buffers on perennial and intermittent streams, although in protected and critical watershed areas, the buffer will be wider depending on ground cover and slope steepness, up to 150 feet.

PLANNING & COLLABORATION

The *Land Use Element* of the comprehensive plan emphasizes intergovernmental coordination of land use planning to create a sustainable land use pattern, including courtesy review and continuing an active dialogue with the towns.

The *Natural & Cultural Systems Element* provides many policies to encourage the county to work with partners to achieve its natural resources protection goals:

- The Natural Areas, Wildlife Habitat, and Prime Forests component calls for "a comprehensive natural areas and open space conservation plan" that addresses threats to important natural areas and rare species, connectivity between protected areas, coordination with neighboring counties and conservation partners, and the sustainable management of critical natural resources (Goal 8, Objective NA-11).
- "The goals and objectives are the framework for the County to work with local land trusts, institutions, and private landowners to preserve a natural network of lands in the County and to ensure long-term environmental sustainability of its natural systems."
- Interjurisdictional Coordination: "Natural and cultural resources know no political boundaries. As such, coordination both within Orange County government and with other area jurisdictions is of paramount importance."
- Intragovernmental: "The Commission for the Environment (CFE) is charged to advise the Board of Commissioners on matters affecting the environment, particularly the topical areas of air quality, water resources and natural areas/biological resources, as well as environmental education."

- Intergovernmental: "Coordination of County policies and decisions affecting natural and cultural resources with other jurisdictions in Orange County includes working with the Towns…and the City of Durham, to ensure that the interconnectivity of natural resources is recognized and planned for…The County's Lands Legacy Program strives for close coordination with the other adjoining local governments. Interconnectivity of natural resource lands, whether for wildlife or human uses, is a key component and likely to be an area of emphasis for many years to come."
- "In summary, conservation of the natural and cultural resources within Orange County will require heightened levels of cooperation and collaboration with the other local governments in the County and the region in future years."

TRANSPORTATION

Small area plans prioritize implementation or improvement of wildlife crossing structures at particular locations. Lands Legacy Program staff work with NC DOT to implement these structures when opportunities arise through transportation improvement projects.

Town of Carrboro

The Town of Carrboro's land use ordinance and the following plans were reviewed: *Carrboro Vision 2020: Policies through the Year 2020* (2000), *Facilitated Small Area Plan for Carrboro's Northern Study Area* (1999), and *Recreation and Parks Comprehensive Master Plan Update for the Town of Carrboro* (2006).

At the time of this report, Carrboro is in the process of developing a comprehensive plan to guide achievement of the vision described in *Carrboro Vision 2020*.

NATURAL RESOURCES PROTECTION

The Environmental Protection and Promotion section of *Carrboro Vision 2020* includes several policies that either directly or indirectly support the protection of natural areas and wildlife corridors, including:

- Section 5.2, Water
  - Policy 5.22: "Carrboro should adopt a strategy and set of policies to protect all of our creeks, streams, ponds, and lakes."
- Section 5.3, Open Space, Greenways, and Natural Areas
  - Policy 5.31: "Carrboro should work to preserve open space and greenways through all available means, such as direct purchase, conservation easements, donations, and federal and state grants."
  - Policy 5.32: "The town should map a connected series of greenways that are large enough to serve as wildlife corridors."
- Section 5.6, Farmland Preservation
  - Policy 5.61: "The town should adopt incentives to help limit the conversion of farmland to developed uses that bridge the transition areas. These incentives should be designed to preserve small farms, farm co-ops, and organic farming within new conservation subdivisions and elsewhere."

Recreation and Parks policies in *Carrboro Vision 2020* promote a network of greenways that supports wildlife corridors, including:

- Policy 1.11: "The town should encourage and support the development of greenways and parklands dedicated to public use along streams and easements. There should be a network of connected greenways throughout the town. These greenways should serve as nature trails, biking and walking trails, wildlife corridors. All should protect our natural environment."

- Policy 1.14: "The town should practice and encourage ecologically sound and sustainable maintenance of open space, including parks and greenways."

The *Facilitated Small Area Plan for Carrboro's Northern Study Area* explicitly requires preservation or strict limitation of development in natural areas along the Bolin Creek basin, in the Meadow Flats area, and in other sensitive environmental areas identified in the plan's Environmental Constraints Map.

Goal 2, Objective 2.B. suggests that the town "Investigate and implement various mechanisms for the acquisition of land for the purposes of providing open space, creating trail and bikeway linkages, and preserving environmentally sensitive areas." Similarly, Goal 3, which focuses on "conservation of natural and environmentally sensitive areas, and the protection of environmental quality," includes as an objective the "pursuit of land acquisition or dedication strategies to protect important natural areas."

The action plan for the *Recreation and Parks Comprehensive Master Plan Update for the Town of Carrboro* suggests a focus on land acquisition for the Bolin Creek and Morgan Creek greenways and designation of portions of these stream corridors as "Natural Areas" or "Nature Preserves". The plan outlines greenway guidelines and development criteria that designate environmentally sensitive areas as "no facility development" or "low impact uses/limited development" areas.

LAND USE & DEVELOPMENT

The development-related sections of *Carrboro Vision 2020* include several policies that support the protection of natural areas and natural resources. The Development section states, as a value that should guide development, that "Respect for and protection of the natural environment should be integrated into the town's policies as a high priority in enriching the quality of life." Several Development section policies support protection of natural areas, open space, and buffers, including:

- Section 2.1, Adverse Effects on Public Health and Safety
    - Policy 2.12: "The town should limit development in sensitive areas such as the watershed, wetlands, and other areas the development of which could adversely affect water supplies and habitat. The town's restrictions on development within the University Lake Watershed should be retained and enforced."
- Section 2.2, Preservation of the Natural Environment
    - Policy 2.21: "The town should continue to require the preservation and maintenance of open space when land is developed, to enforce restraints on clear-cutting, and to require adequate buffers."
    - Policy 2.22: "Where development is deemed acceptable, there should be well defined dense development with areas of well preserved open space."
    - Policy 2.23: "The town encourages the planting of native plant species, as well as non-native species that are not invasive. Removal of invasive species is encouraged. The town supports education on this topic and encourages the public to become aware of the list of invasive plant species found in Appendix E-17 of the Town of Carrboro Land Use Ordinance."
- Section 2.4, Carrboro's Character
    - Policy 2.42: "The town should adhere to policies that...retain unspoiled green spaces and other natural areas."

Economic Development, Section 3.1, Nature of Development, states, "In the interest of environmental preservation, new commercial development must minimize negative environmental impact, it must emphasize appropriate buffers, and it must not compromise the integrity of established neighborhoods."

Housing Policy 6.15 supports "...the development of density bonus provisions for projects incorporating environmentally sensitive development and building practices."

In the *Facilitated Small Area Plan for Carrboro's Northern Study Area*, Goal 1 promotes "patterns of growth which minimize negative impacts and maximize positive impacts on the community and the natural environment." Objectives for this goal include requiring clustered residential development and pursuing objectives under the plan's environmental quality goal. Implementation measures for this goal include:

- setting standards for conservation lands and providing density options based on the percentage of land conserved
- requiring "that all primary conservation areas be protected and designated as open space, regardless of the percentage of the development this encumbers, unless the strict provisions required to obtain a variance apply to a particular piece of property"
- providing density incentives and disincentives to encourage conservation subdivisions
- requiring greater detail about natural and cultural features on plans submitted for review
- establishing interactive site plan review procedures that promote early understanding and planning to conserve a site's sensitive natural resources and contribute to "interconnected open space network protection."

Goal 3 focuses on "conservation of natural and environmentally sensitive areas, and the protection of environmental quality." The objectives for this goal include:

- the use of conservation overlay standards to determine site-specific stream buffer widths
- creation of a resource or open space conservation district to prohibit development of natural and environmentally sensitive areas
- pursuit of land acquisition or dedication strategies to protect important natural areas
- mitigation of development impacts to streams and creeks
- identification of primary and secondary conservation areas as defined in the town's land use ordinance

Goal 6, "adequate provision of publicly accessible parks and recreation facilities," focuses on establishing a system of connected greenways, including requiring "...developers of new subdivisions to lay out and construct neighborhood trails through their new developments in such a way that they will connect with and extend the Town's more formal greenway network." This goal also includes the objective of offering a de facto density bonus to obtain more than a 10-acre park from the UNC-owned Horace Williams Tract, to consist of natural areas in the Bolin Creek floodplain and an area of hardwood forest. Implementation measures for this goal include requiring conservation land, open space, and greenways in new subdivisions to interconnect.

Goal 10, "encourage active farmland preservation," describes several strategies that could support the maintenance of corridors that traverse working lands.

The *Carrboro Land Use Ordinance*, Article IX, Zoning Districts and Zoning Map establishes a Conservation District "severely restricting development within and adjacent to certain lakes, ponds, watercourses, streams, creeks, drainage areas, floodplains, wetlands, and other flood-prone areas within the University Lake Watershed." Article IX also establishes a Village Mixed Use District that includes open space protection in two of its 10 required rezoning objectives:

- "The preservation of open space, scenic vistas, agricultural lands and natural resources within the Town of Carrboro and its planning jurisdiction and to minimize the potential for conflict between such areas and other land uses."
- "The creation of a distinct physical settlement surrounded by a protected landscape of generally open land used for agricultural, forest, recreational and environmental protection purposes."

A Village Mixed Use rezoning application for property within the Orange-Carrboro Joint Planning Area "shall be denied if the application is inconsistent with the approved master plan in any substantial way.

...an application for a conditional use permit is inconsistent in a substantial way with a previously approved master plan if the plan of development proposed under the conditional use permit application increases the residential density or commercial floor area permissible on the property or decreases or alters the location of open space areas."

Article XII, Density and Dimensional Regulations provides for "cluster subdivisions" with reduced lot sizes in exchange for setting aside the land "saved" by reduced lot sizes as open space.

Article XIII, Recreational Facilities and Open Space directs that open space should serve several objectives, including:

- preservation of environmentally sensitive lands
- preservation of habitat for wildlife

Residential zoning districts, with a few exceptions, must be developed so that at least 40% of the total area is preserved as permanent open space. Two additional zoning districts must be developed with at least 20% of the total area preserved as open space. Carrboro defines primary and secondary conservation areas that must be identified and prioritized for open space in developments. Where primary open space exceeds 40% of the total area, the development plan should provide for preservation of these additional areas even if on privately owned lots. Residential subdivisions of fewer than 15 dwelling units or consisting solely of multi-family, single-room occupancy units are exempt from the open space requirements. Primary open space includes:

- steep slopes (greater than 25%)
- hardwood areas designated in the Town's GIS
- wetlands as defined pursuant to Section 404 of the Clean Water Act
- floodplains
- water quality buffers on perennial and intermittent streams
- lakes and ponds
- road buffers

Secondary open space includes:

- slopes greater than 15% but not more than 25%
- wooded areas other than hardwood areas designated in the Town's GIS
- vistas along entranceways to the town
- other areas containing unusual natural features (such as major rock formations)
- 60-foot buffers for streams on the Town's adopted Stream Classification Map
- other environmentally, historically, archeologically significant, or unique areas, including water quality buffers on ephemeral streams

Article XVI, Part III requires protection of water quality buffers (with some exempt and allowable activities) in two zones: Zone 1, a streamside zone, should consist of mature forest. Zone 2 is an undisturbed area intended to protect Zone 1; grading and revegetating of Zone 2 are allowed provided that the vegetation of Zone 1 is not compromised. Required total buffer width (split equally between Zones 1 and 2) is 100 feet for perennial streams, ponds, lakes, and reservoirs and 60 feet for intermittent streams and ponds. In the University Lake Watershed, the entire buffer width should consist of Zone 1 buffer. Ephemeral streams and ponds with a contributing drainage area of at least 5 acres require 15-foot Zone 2 buffers (30 feet within the University Lake Watershed).

PLANNING & COLLABORATION

The transportation-related goal of the *Facilitated Small Area Plan for Carrboro's Northern Study Area* includes in its implementation measures two types of coordination: 1) coordination of transportation planning with Chapel Hill and other relevant agencies and 2) promotion of coordination between

developers for the planning of routes. The *Orange-Chapel Hill-Carrboro Joint Planning Agreement* requires the town to coordinate with Orange County and the Town of Chapel Hill in the town's development transition areas and the county's rural buffer zone.

TRANSPORTATION

The Transportation section of *Carrboro Vision 2020* and the transportation-related objectives of the *Facilitated Small Area Plan for Carrboro's Northern Study Area* do not address wildlife habitat, habitat connectivity, or corridors.

Town of Chapel Hill

The Town of Chapel Hill's Land Use Management Ordinance as well as the following plans were reviewed: *Chapel Hill 2020 Comprehensive Plan* (2012), *Chapel Hill Comprehensive Parks Plan* (2013), *Greenways Master Plan* (2013), *Rogers Road: Mapping our Community's Future* (2016), and *Central West: Small Area Plan* (2013).

At the time of this report, the town is in the process of rewriting its Land Use Management Ordinance and refining the Future Land Use Map.

NATURAL RESOURCES PROTECTION

The *Chapel Hill 2020 Comprehensive Plan* has several goals that directly aim to protect wildlife corridors and habitats. Most significantly, Goal NOC.3, to "protect, acquire, and maintain natural/undeveloped open spaces and historic sites in order to protect wildlife corridor, provide recreation and ensure safe pedestrian and bicycle connections. These spaces could include, amongst other things Significant Natural Heritage Areas (SNHA) lands adjacent to and connecting various properties like riparian lands, etc.", directs the Town to implement many actions that the Eno-New Hope Landscape Conservation Project can support, including:

- Create a comprehensive conservation plan that includes a green print map, addressing streams, floodplains, wildlife corridors, natural heritage areas, open space, steep slopes, entranceways and scenic views, tree cover, and farmland
    - Determine priority areas for riparian protection and restoration
    - Work with Orange County to develop an inventory of natural/undeveloped spaces, especially those that serve as wildlife corridors
        - Develop wildlife area map including known endangered species
    - Determine vulnerable habitats and spaces/places for preservation such as Significant Natural Heritage Areas and other areas within the town necessary to maintain and uphold Chapel Hill's distinct balance between people and the natural landscape
- Protect, acquire, and maintain natural/undeveloped spaces for parks, greenways, and community gardens and protect the quality of the community's waterways and air resources
    - Protect the rural buffer established through the Orange County Land Use plan
    - Encourage conservation easements to ensure permanent protection
    - Ensure that the spaces identified in the Green Print Map are protected when development is proposed in surrounding areas

Goals NOC.2 and GPNS.7 also support the protection of wildlife corridors and ecosystems.

Connected parks through natural area greenways (minimum 50-feet wide) are a key piece of parks and recreation development in Chapel Hill, and the *Chapel Hill Comprehensive Parks Plan* aims to continue

to expand this network to meet their recreation and transportation needs. The *Greenways Master Plan* also emphasizes greenways as natural, linear open spaces that provide travel corridors for wildlife.

LAND USE & DEVELOPMENT

Small area plans in areas of priority wildlife corridors call for the protection of natural resources as the areas develop. *Rogers Road: Mapping our Community's Future* guides land use in an area identified by this project as being part of a priority wildlife corridor. This document calls for action that "balances land conservation with density to reduce suburban sprawl, minimizes disruption to the natural landscape, & opens [the] environment to people's use and enjoyment." The *Central West: Small Area Plan* also calls for "respecting the environment, protecting wildlife, enhancing the area's natural features, preserving the area's tree-filled character, and implementing stormwater management standards." It also recommends the "[maintenance or reestablishment] if needed [of] riparian buffers along streams with sufficient allowance for wildlife corridors."

The town's Land Use Management Ordinance also supports the protection of natural resources in areas of new development. In *Article 3, Zoning Districts, Uses, and Dimensional Standards*, the Resource Conservation District (RCD) "retain[s] open spaces and greenways and to protect their environmentally-sensitive character, to preserve urban wildlife and plant life habitats from the intrusions of urbanization," among other goals. The RCD:

- requires 150-foot buffers on perennial streams and 50-foot buffers on intermittent streams
- allows landowners to transfer their development rights to receiving parcels in other districts

Article 5, Design and Development Standards provides regulations that serve to minimize the impact of development on the environment, such as the following:

- *5.3.2. Steep Slopes* minimizes degradation of slopes greater than 15%
- *5.5. Recreation* requires that recreation areas, whether they be for passive or active recreation, must be configured to be adjacent to other recreation areas
- *5.7.5 Significant Tree Stands* protects mature contiguous woodlands to the extent practicable.

PLANNING & COLLABORATION

The *Chapel Hill 2020 Comprehensive Plan*, *Chapel Hill Comprehensive Parks Plan,* and *Greenways Master Plan* all identify the importance of collaborating with partners to meet its environmental protection goals and actions. The *Orange-Chapel Hill-Carrboro Joint Planning Agreement* requires the town to coordinate with Orange County and the Town of Carrboro in the town's development transition areas and the county's rural buffer zone.

TRANSPORTATION

Connected parks through natural area greenways (minimum 50-feet wide) are a key piece of parks and recreation development in Chapel Hill, and the *Chapel Hill Comprehensive Parks Plan* aims to continue to expand this network to meet their recreation and transportation needs.

Town of Hillsborough

The Town of Hillsborough's unified development ordinance and the following plans were reviewed: *Strategic Growth Plan* (2006), *Hillsborough Vision 2030* (2015), *Parks and Recreation Master Plan* (2007, updated 2009 and 2014), *Community Connectivity Plan* (2009, updated 2014 and 2017), *Churton Street Strategic Corridor Plan* (2006), and the *US 70/Cornelius Street Corridor Plan* (2007).

NATURAL RESOURCES PROTECTION

Hillsborough has made natural resources protection a goal in its *Hillsborough Vision 2030* and the *Strategic Growth Plan*. To do this, *Hillsborough Vision 2030* recommends protection of known resources and to document new resources. It explicitly states that local regulations should adequately "identify and protect fragile resources." The *Strategic Growth Plan* calls for the preservation of natural resources by ensuring that "land use patterns should take forms that preserve these key resources including corridors and buffers."

LAND USE & DEVELOPMENT

The *Strategic Growth Plan* identifies the rural buffer as a place where the "extension of public utilities would be avoided, and where rural and environmental preservation are the main objectives." In the town's UDO, Hillsborough provides natural resource protection measures in the "Requirements for Watershed Protection Districts."

- "Natural areas as identified in the Inventory of Natural Areas and Wildlife Habitats of Orange County, NC" are identified as environmentally sensitive areas that should be avoided in the placement of streets, driveways, and buildings.

Under *Article 3, Administrative Procedures, 3.5.5 Conditional Subdivisions*, development standards include:

- The identification and protection of existing "irreplaceable natural features" in the site plan as designated Open Space.
- A minimum of 35% of the land must be set aside for open space

All developments with a required master plan, conditional use permit, or special use permit are required to set aside a minimum of 10% open space to protect significant natural features. Importantly, the ordinance calls for open space to be "arranged for contiguity and connectivity within the development dedicating the open space and to any surrounding dedicated open space for wildlife."

PLANNING & COLLABORATION

Hillsborough Vision 2030 identifies partnerships with local advocacy and nonprofit agencies as a strategy for protecting and identifying natural resources.

TRANSPORTATION

Hillsborough does not address habitat fragmentation in its transportation plans, nor the dual use of greenways as wildlife corridors. However, the *Parks and Recreation Master Plan* does plan to have connected trails within Hillsborough to provide connectivity for pedestrians.

WAKE COUNTY

Wake County's unified development ordinance as well as the following plans were reviewed: *Wake County Transportation Plan* (2003), *Wake County Environmental Stewardship Agenda* (2006, 2011), *Southwest Wake Area Land Use Plan* (2007), *Wake County Land Use Plan* (last amended 2006), *Wake County Consolidated Open Space Master Plan* (2003, 2006), *Wake County Greenway System Plan* (2017), *Wake County Park Facility Master Plan Updates Final Report* (2017), and the *Comprehensive Parks & Recreation Master Plan* (2008).

At the time of this report, the county is in the process of updating its comprehensive plan (PlanWake). In addition, Wake County's Open Space Program staff members are currently interested in updating Wake County's inventory of natural areas with the help of NCNHP.

NATURAL RESOURCES PROTECTION

Wake County has many policies, in multiple plans, to address natural resources protection. In some cases, plans specifically aim to protect wildlife habitats and corridors.

In the *Wake County Land Use Plan*, Goal 5 "encourage[s] the conservation of historical sites, environmentally significant areas, and important natural and cultural resources", and the first objective aims to "identify areas, which provide habitat for significant plant or wildlife species or make a significant contribution to environmental quality" so that they become protected or the landowner is encouraged to "maintain" them.

In the *Southwest Wake Area Land Use Plan*, natural resources protection is prioritized in tiers:

- NHNAs are the highest priority for conservation
- Urban Wildlife Conservation Corridors are a secondary priority for conservation
- Other conservation priorities include the American Tobacco Trail greenway and its noted ability to function as a wildlife corridor if widened to 300 feet

The *Wake County Consolidated Open Space Master Plan 2006*:

- Envisions the county's open spaces to be a "series of natural, interconnected landscapes that will protect vital natural resources" and aims to "Identify key parcels of land and corridors that should be acquired and protected as open space."
- Aims for 30% of the county to be protected as natural areas
- Uses a GIS-based landscape prioritization model verified by expert review. The prioritization approach is currently under review in advance of Wake County's 2019 bond funds. Current prioritization criteria include:
    - water quality
    - drinking water supply watersheds
    - headwater streams
    - properties near impaired streams
    - biodiversity indices
    - connectivity between and proximity to all existing Wake County Open Space preserves
    - parcel size
- Uses county bond initiatives to fund land and easement acquisition by the Open Space program in high-priority areas, following a competitive application process from towns, agencies, and land trusts for specific projects within the county or municipalities.
    - Wake County voters overwhelmingly approved a $120 million parks-greenways-open space protection bond referendum in November 2018 that will be financed over a six-year period (beginning November 2019), from which approximately $20 million is allocated for acquisition and protection of key natural areas/open space lands in the county.

The Open Space program, which implements and administers the master plan, focuses entirely on *natural open space*, which is defined in four categories distinguished by levels and placement of human activity and infrastructure within the natural area.

The *Comprehensive Parks & Recreation Master Plan*:

- Sets a goal for greenways as a place to protect wildlife habitat (also in the *Wake County Greenway System Plan 2017*).

- Considers the protection of lands that "preserve natural resources, wildlife, and help provide clean air and drinking water" as a core service of the county.
- Aims, in Goal 6, to "commit resources to a regional park system connected by trails and greenways."

Protected riparian buffers, which can be used as corridors linking large natural areas, are also identified as an important natural resource to protect in the *Environmental Stewardship Agenda* and the *Southwest Wake Area Land Use Plan*.

LAND USE & DEVELOPMENT

Similarly, in the county's UDO, Wake County provides natural resource protection measures in many places, including in the following zoning classifications:

- Residential Watershed Districts
- RCOD-1 Resource Conservation Overlay District,
- RCOD-2, Resource Conservation Overlay District 2

These zoning classifications are mostly aimed at protecting water resources by requiring riparian buffers on perennial streams of 50 feet and 100 feet depending on the district. In practice, these buffer widths can provide wildlife passage for many species.

Article 5, Lot and Building Standards:

- Allows Cluster and Open Space Development for the protection of 30% of the project as a natural area.
- Provides a 20% density bonus for developments that protect 65% percent open space.
- In all subdivisions, recommends preservation for important wildlife habitats such as "woodlands, steep slopes, rock outcroppings, ponds, streams, rivers, and lakes" in the layout and design phase of subdivision development.

These natural area set-asides, if configured as large, contiguous blocks of wildlife habitat, could create a network of wildlife habitats.

PLANNING & COLLABORATION

The *Comprehensive Parks & Recreation Master Plan* states three times that Wake County will collaborate with partners to achieve its vision for open space protection.

- Collaboration with other local governments and with non-profits is a key strategy in Goal 2 to ensure that the county maintains and enhances its core services, including natural area protection.
- Goal #6 aims to use partners to help identify land to protect and pool resources to gain that protection.
- Goal #7 is "To participate in the planning and collaboration of municipal and regional trail and greenway plans."

TRANSPORTATION

The *Wake County Transportation Plan* recognizes the impact that the transportation network has on wildlife corridors and habitats and aims to develop a transportation network that balances the competing needs of the county.

Town of Apex

The Town of Apex's unified development ordinance and the following plans were reviewed: *Town of Apex Comprehensive Transportation Plan Update* (2011), *2045 Updated Future Land Use Map* (2019), *Town of Apex 2035 Land Use Plan Update | Economic Study and Market Analysis* (2016), and *Peak Plan 2030* (2013).

NATURAL RESOURCES PROTECTION

Apex's *Peak Plan 2030,* the comprehensive plan, recommends encouraging "low impact site development and more ecologically designed and sustainable sites with functional landscapes."

The *Advance Apex: The 2045 Land Use Map Update* memo identifies the western portion of Apex, where buffers around Jordan Lake, floodplains, and other natural lands occur, as low-density rural residential zoning, where there is only 1 dwelling unit per 5 acres.

LAND USE & DEVELOPMENT

Apex's UDO provides specific purposes for its adoption, including the prevention of adverse environmental impacts and the discouragement of sprawl, which will help reduce habitat fragmentation. Tools the UDO provides the community to achieve this include:

- Planned Development Districts: development that encourages protection of natural features and cluster and compact development to the greatest extent possible
- CB Conservation Buffer District: publicly owned natural lands
- Sustainable Development Conditional Zoning District: development that facilitates the restoration and enhancement of the environment and natural resources
- Watershed Protection Overlay Districts: to protect public drinking water supplies in the Swift Creek Watershed and the Jordan Lake Watershed
    - Provides 100-foot and 50-foot buffers on perennial and intermittent streams, respectively. In practice, these buffer widths can provide wildlife passage for many species.

In Article 8 General Development Standards, Resource Conservation standards are applicable to all new development. These standards aim to "to encourage site design techniques that preserve the natural and cultural environment and enhance the developed environment; to control erosion, slippage, and sediment run-off into streams and waterways; to increase slope stability; and to protect wildlife habitat and migration corridors." Resource Conservation Areas (RCAs) in new developments must be located adjacent to other existing RCAs or natural features and be composed of the following priority undisturbed natural areas: riparian or floodplain habitats, forests, steep slopes, significant plant and wildlife habitat, scenic views, rock outcrops, etc. Measures are included to provide alternative RCAs when these natural features do not exist. The size of RCAs is determined by the presence of resources and Town Council.

PLANNING & COLLABORATION

There are no policies to encourage planning and collaboration to protect Apex's natural resources.

TRANSPORTATION

The *Town of Apex Comprehensive Transportation Plan Update* aims to invest in a transportation network that supports the protection of natural resources. Connected parks and greenways are mentioned many times as a way to provide multimodal transportation. The plan aims for greater connectivity of collector streets, while also minimizing impacts to natural resources.

Town of Cary

The Town of Cary's Land Development Ordinance and the following plans were reviewed: the *Cary Community Plan* (2017), *Parks, Recreation and Cultural Resources Master Plan* (2012), and *Parks, Recreation & Cultural Resources Master Plan* (2003).

NATURAL RESOURCES PROTECTION

Cary has three plans that address natural resources protection. In some cases, plans specifically aim to protect wildlife habitats and corridors. In addition, in October 2019 more than three-quarters of voters approved a bond financing referendum that will provide $112 million needed to finance parks-greenways-open space protection projects.

Cary's comprehensive plan, the *Cary Community Plan,* under its Natural Resource Goals aims to:

- "Continue to protect areas that are ecologically important and have a high wildlife habitat value."
- "Work with developers to set aside important open space that provides trail connectivity, wildlife habitat corridors, and water quality protection."

The plan also has a policy statement to:

- "Protect and Restore Open Space and the Natural Environment: Protect and restore environmentally significant areas and either preserve or create green infrastructure throughout the Town and within the built environment."
    - Notably, the intent of this policy is to manage and protect natural communities, reduce forest fragmentation, and provide corridors for wildlife. It specifically aims for "interconnected ecosystems."

The *Parks, Recreation & Cultural Resources Master Plan* (2003) includes goals related to natural resources protection:

- Goal 6 is to protect wetlands, woodlands and other natural areas and wildlife habitats as green infrastructure.
- Goal 7 is to provide facilities that honor and enhance Cary's open space by providing natural areas and preserves, buffers and linkages to the overall open space system.
    - Approximately one-third of lands in new park development should be set aside to be held in their natural condition and should carry a stewardship plan.

Under Chapter 7: Park Recommendations, the plan recommends that:

- "The town [should] evaluate currently owned property and new acquisitions to preferentially set aside Conservation Areas (includes Preserves, Natural Areas, and Greenway Corridors)."

The *Parks, Recreation and Cultural Resources Master Plan* (2012) contains the most comprehensive natural resource protection policies and actions, especially as it relates to reducing habitat fragmentation:

- Under GOAL 1, regarding types of parks in Cary, the goal calls for the protection of "areas that are ecologically important and have a high wildlife habitat value (e.g., riparian corridors, forests, large sections of early successional habitat)." The following actions are recommended:

  "Utilize conservation planning tools to prioritize high value natural resources to acquire for preservation …. Acquisition criteria include:"

    - Broad corridors when possible

    - Connectivity and adjacency to larger natural areas (e.g., Jordan Lake, Lake Crabtree, Umstead State Park, etc.)
    - Connectivity and adjacency to existing parks and greenway corridors
- Under GOAL 2, where Cary specifically addresses greenways, the plan emphasizes the need to provide "wildlife habitat along corridors in design and vegetation."

The implementation of these policies and actions could create a network of wildlife habitats and protected natural resources throughout Cary.

LAND USE & DEVELOPMENT

Cary has policies related to how land is developed in order to protect natural areas.

In the *Parks, Recreation and Cultural Resources Master Plan* (2012) under Goal 1, to have a diverse park system, the town aims to:

- Evaluate zoning within open space priority areas (e.g., land within the National Register Historic District that is zoned as commercial could be rezoned to residential or another designation to reduce property tax burden).
- Continue to work with developers to set aside important open space that provides trail connectivity, wildlife habitat corridors, and water quality protection.

Similarly, in the town's Land Development Ordinance, Cary provides natural resources protection measures in the following zoning classifications:

- RR: Resource/Recreation District
- The Conservation Residential Overlay District, which has the stated goal of "creat[ing] a contiguous network of open spaces by linking the open space areas within the residential development to open space on adjoining land wherever possible."
    - This overlay requires a 50-foot buffer on the American Tobacco Trail and provides a density bonus for larger natural area set-asides.

Under Article 8, Standards for Subdivisions and Uses Requiring Site Plans, "All subdivision development proposals must identify significant natural features on the sketch plan and prioritize them for conservation, including wildlife corridors."

Open space must be configured to be contiguous within and beyond the project area, to the maximum extent feasible.

PLANNING & COLLABORATION

Cary encourages collaboration with other entities in its parks planning. In the *Parks, Recreation & Cultural Resources Master Plan* (2003) within Goal 7, the town plans to "work in partnership with Wake County and adjacent municipalities to identify lands that can provide open space linkages to connect open space systems and to contribute to the overall County Open Space Plan." In the *Parks, Recreation and Cultural Resources Master Plan* (2012), an action under Goal 1 is to pursue partnership opportunities (e.g., grant writing, acquisition, and stewardship activities) with Triangle Land Conservancy, Wake Soil and Water Conservation District, and other conservation organizations.

TRANSPORTATION

The *Cary Community Plan* recognizes the role that greenways play in the transportation network but does not address the impacts that roads have on wildlife corridors and habitats.

RECOMMENDATIONS

To varying degrees, the jurisdictions within the project area have recognized a need to protect connected natural areas and have devised different policies and strategies to address this need. Each jurisdiction can work with its existing policy framework, in coordination with other jurisdictions, agencies, and conservation partners, to use the new information and data described in this report to help protect a connected network of priority wildlife habitat and corridors. The objectives and strategies recommended below are provided to help ensure that protection of the priority wildlife habitat-corridor network identified in this project is incorporated into county, town, and interjurisdictional planning and decision-making processes within the project area.

COMMIT TO LANDSCAPE CONSERVATION

Objective **Ensure that landscape conservation and corridor protection for wildlife habitat connectivity are explicitly supported and funded as a joint priority across jurisdictions.**

The primary strategy recommended for this objective is for the jurisdictions in the project area to pass a joint resolution including, but not limited to, the following elements:

- Establish landscape conservation and landscape corridor protection for wildlife habitat connectivity as an overarching principle, goal, or strategy (see also Plan and Adopt).
    - Develop consensus on shared definitions of landscape conservation, landscape corridor, wildlife habitat, and other terms critical for effective interjurisdictional coordination.
- Acknowledge the necessity of interjurisdictional coordination to achieve protection of a functional landscape habitat-corridor network.
- Commit to enact and fund intra- and interjurisdictional landscape corridor planning, protection, and coordination.
- Acknowledge the importance of following the best available scientific guidelines for landscape conservation and corridor protection, including the implementation of effective wildlife crossing structures, as outlined in NCWRC's Green Growth Toolbox and other comprehensive corridor planning and protection resources.

FOLLOW ESTABLISHED GUIDELINES

Objective **Formally authorize and, if possible, require consultation and use of Green Growth Toolbox guidelines and other authoritative resources for landscape conservation and corridor protection, including best available science on wildlife crossing structures.**

Strategies include, for example:

- Prioritize land conservation efforts in critical habitat areas and corridors (as identified, for example, in this project and verified with ground surveys), around identified pinch points, and in priority corridor areas under high development pressure.

- Communicate with landowners about the importance of their properties for conservation.
- Prioritize land conservation efforts for critical habitat areas and corridors that are adjacent to major roads and highways, to provide the protection needed to incentivize the provision of wildlife underpasses in future transportation improvement projects.
- Assess bridges and culverts in critical wildlife corridors for suitability as crossing structures, and actively work with NCDOT to replace or improve unsuitable bridges and culverts.

PRIORITIZE AND DEFINE

Objective **Ensure that landscape corridor protection priorities are identified, recognized, and incorporated into local land conservation programs and initiatives, including acquisition by open space programs and conservation partners.**

A comprehensive strategy to achieve this objective includes several action items:

- Evaluate corridor maps and priorities identified in this project with respect to existing protection priorities and conservation planning tools.
- Incorporate priorities identified from this project's results into existing protection priorities, strategies, and plans.
- Use the GIS layers from this project to incorporate landscape corridor protection into existing land conservation planning and prioritization approaches.
- Integrate the information from this project into other conservation plans, such as the Jordan Lake One Watershed plan, which may eventually provide an additional funding mechanism for conserving these key properties.
- When needed, verify or update the results from this project with ground surveys.
- Regularly update biological inventory data available for use in land protection and open space planning, including obtaining NCNHP's quarterly updates to NHNAs and Element Occurrences and updated SGCN species status or data from NCWRC.
- Conduct biological and ecological inventory of poorly known areas or areas in need of updated inventory.
- Consider conducting a regional biological and ecological inventory that helps refine the results of this project and promotes interjurisdictional collaboration through shared conservation objectives and priorities.

PLAN AND ADOPT

Objective **Ensure that a clear, explicit path to landscape corridor protection and funding is enabled in existing and new planning documents, with formal adoption by governing bodies to increase the likelihood of implementation and funding.**

Recommended strategies for new, updated, or existing plans include:

- Adopt landscape conservation and landscape corridor protection as an overall planning principle, goal, or strategy in comprehensive plans.
- Adopt or develop a landscape conservation or landscape connectivity plan. Actions to consider include:
    - Adopt this document (or a modified version of it) as a landscape connectivity plan.
    - Adopt and incorporate elements of this plan into existing or updated plans, such as comprehensive, open space, land use, small area, and other plans. Elements to adopt or incorporate can include:
        - Priority landscape corridor maps and GIS layers from this project.
        - Specific landscape corridor protection priorities identified in this project.
        - Specific recommendations provided in this report.
    - Update and expand the New Hope Corridor Open Space Master Plan to include the entire New Hope Creek-Jordan Lake watershed, in collaboration with relevant jurisdictions and conservation partners.
        - Alternative: Fund an updated progress assessment based on the original plan.
        - Prioritize connectivity between New Hope Creek-Jordan Lake and adjacent watersheds, especially the Eno River watershed, and synchronize with existing corridor or watershed plans.
    - Develop an Eno River Watershed Open Space Master Plan, in collaboration with relevant jurisdictions, the Eno River Association, and other conservation partners.
        - Focus on assessment and completion of the Eno River corridor and, where necessary, restoration and mitigation of pinch points.
        - Prioritize connectivity between the Eno River and adjacent watersheds, especially the New Hope Creek-Jordan Lake watershed, and synchronize with existing corridor or watershed plans.

IMPLEMENT AND ADMINISTER

Objective **Ensure that landscape conservation and corridor protection principles and priorities are integral to planning and development.**

Critical steps and strategies for achieving this objective through planning departments include:

For governing bodies and planning department leadership:

- Direct planning staff to develop, if needed, and implement a coordinated set of plans, policies, ordinances, and procedures focused on landscape conservation and corridor protection.

- Incorporate landscape conservation and corridor protection objectives into planning department strategic plans.
- Educate staff on the importance of landscape conservation and corridor protection and the use of conservation planning tools and approaches.
- Fund staff with relevant expertise to serve both county and municipal efforts to achieve landscape corridor protection (see also coordination strategies below).

For integration with existing land use planning and zoning tools, data, and definitions:

- Evaluate corridor maps and priorities identified in this project with respect to existing planning tools, including:
    - Land use and zoning districts or overlays aimed at natural area, natural resource, environmental, or open space protection.
    - Maps of development constraints, whether regulatory, incentivized, or voluntary.
    - Defining criteria for districts, overlays, and constraints.
- Where possible, update districts, overlays, and definitions to better incorporate or synchronize with landscape corridor protection priorities. Examples include:
    - Consider formally adding all or part of the priority corridor areas identified in this project to an existing resource protection overlay, as a separate category defined for corridor protection.
    - Consider revising open space as well as primary and secondary conservation area requirements and definitions to include high-priority corridor areas and, in general, natural open space that is contiguous within and between parcels or development project boundaries.
- Where possible or necessary, create a separate land use or zoning overlay, or protection category within an overlay, to enable landscape corridor protection.

For integration with development standards and decision-making processes:

- Revise development standards and incentives to promote effective landscape corridor protection in development proposals.
    - Consult the Green Growth Toolbox and other references based on best available science for recommended standards and incentives.
- Integrate landscape corridor identification and planning into the development proposal and review process, including in the initial site selection process (or as early as possible).
- Coordinate planning and development review processes with land conservation or open space programs and priorities. Possible strategies to ensure an effective communication and advisory structure include:
    - Designate a staff liaison to land conservation or open space programs to ensure consultation, coordination, and efficiency in pursuing landscape corridor protection objectives.
    - Ensure that conservation data are regularly updated, available, and promoted for use within planning processes.
    - Create a development review advisory committee to provide regular input on development proposals from departments outside planning, including land conservation or open space programs.
    - Empower a citizen/expert advisory board to advise planning staff on landscape conservation and corridor protection considerations.

COORDINATE

Objective **Ensure successful and timely coordination with other jurisdictions, government agencies, conservation partners, and funding entities in pursuing landscape conservation and corridor protection goals.**

Strategies include:

- Convene and empower a landscape conservation advisory commission or working group (such as the Eno-New Hope Landscape Conservation Group) to, for example:
    - Support landscape conservation and corridor protection efforts
    - Establish landscape conservation goals and targets
    - Support fund-raising, pursue joint funding opportunities, or jointly encourage funding entities to support landscape conservation projects
    - Evaluate progress across the project area.
- Work with existing interjurisdictional working groups to communicate and collaborate on landscape corridor protection priorities, including:
    - Work with regional metropolitan planning organizations (MPOs) and NCDOT to integrate wildlife crossing structure priorities into transportation planning and NCDOT projects.
    - Provide a landscape conservation liaison to relevant interjurisdictional working groups.
- Share relevant planning data (especially spatial data layers) and priorities between jurisdictions and agencies, especially for boundary areas, to better incorporate landscape corridor protection priorities into site-specific planning decisions.

LIST OF POTENTIAL CONSERVATION PARTNERS

LOCAL GOVERNMENT

Chatham County	Planning Department Jason Sullivan, Planning Director Parks and Recreation Department
Durham County	Open Space & Real Estate Division Jane Korest, Division Manager Celeste Burns, Open Space & Real Estate Coordinator City-County Planning Department
Orange County	Department of Environment, Agriculture, Parks & Recreation David Stancil, Director Natural & Cultural Resources Division Christian Hirni, Land Conservation Manager Lands Legacy Program Planning and Inspections Orange Water and Sewer Authority, Resource Management & Sustainability
Wake County	Open Space Program Wake County Parks, Recreation and Open Space Chris Snow, Director Deborah Fowler, Open Space Manager Planning, Land Use and Zoning
Town of Apex	Planning Department Parks, Recreation & Cultural Resources
Town of Carrboro	Planning, Zoning and Inspections Recreation and Parks
Town of Cary	Planning and Development Services Parks, Greenways and Environment
Town of Chapel Hill	Planning and Development Services Parks and Recreation
Town of Hillsborough	Planning Department Public Space Division

PRIVATE, NON-PROFIT LAND TRUSTS

Ellerbe Creek Watershed Association	https://www.ellerbecreek.org/ Rickie White, Executive Director
Eno River Association	http://www.enoriver.org/ Kim Livingston, Director of Conservation & Stewardship

NC Botanical Garden Foundation, Inc.	https://ncbg.unc.edu/about/north-carolina-botanical-garden-foundation/ncbgf-land-trust/
Triangle Land Conservancy	https://www.triangleland.org/ Bo Howes, Director of Conservation & Stewardship

PRIVATE EDUCATIONAL INSTITUTIONS

Duke Forest Teaching and Research Laboratory, Duke University	https://dukeforest.duke.edu/ Sara Childs, Director

INTERJURISDICTIONAL PLANNING ORGANIZATIONS AND GROUPS

Capital Area MPO	https://www.campo-nc.us/ Wake County and portions of other counties
Durham-Chapel Hill-Carrboro MPO	http://www.dchcmpo.org/
Raleigh Clean Water Initiative	https://www.triangleland.org/upper-neuse-clean-water-initiative
Triangle J Council of Governments	https://www.tjcog.org/ Jordan Lake One Water Initiative

STATE AGENCIES AND EDUCATIONAL INSTITUTIONS

NC Botanical Garden	http://ncbg.unc.edu/ Johnny Randall, Direction of Conservation
NCDOT State Transportation Improvement Program	https://www.ncdot.gov/initiatives-policies/Transportation/stip/Pages/default.aspx
NC Division of Land and Water Stewardship	https://www.ncdcr.gov/about/nature/division-land-and-water-stewardship Walter Clark, Director NC Clean Water Management Trust Fund https://cwmtf.nc.gov/ NC Natural Heritage Program https://www.ncnhp.org/ Misty Buchanan, Director
NC Division of Parks and Recreation	https://www.ncparks.gov/ Parks Planning Program https://www.ncparks.gov/more-about-us/about-parks-recreation/park-planning Dave Head, Planning Program Manager Land protection/acquisition https://www.ncparks.gov/more-about-us/about-parks-recreation/land-protectionacquisition George Norris, Program Manager for Land Protection
Eno River State Park	https://www.ncparks.gov/eno-river-state-park

NC Wildlife Resources Commission	https://www.ncwildlife.org/ Habitat Conservation Program Green Growth Program & Toolbox https://www.ncwildlife.org/Conserving/Programs/Green-Growth-Toolbox Brooke Massa, Land Conservation Biologist Partners for Green Growth Program & Technical Assistance https://www.ncwildlife.org/Conserving/Programs/Green-Growth-Toolbox/Technical-Assistance Olivia Munzer, Western Piedmont Habitat Conservation Coordinator https://www.ncwildlife.org/Conserving/Programs/Habitat-Conservation-Program Land Protection/Acquisition Brooke Massa, Land Conservation Biologist

FEDERAL AGENCIES

US Army Corps of Engineers – Jordan Lake	https://www.saw.usace.army.mil/Locations/District-Lakes-and-Dams/B-Everett-Jordan/

REGIONAL ORGANIZATIONS AND PROGRAMS

Carolina Wetlands Association	http://carolinawetlands.org/ Rick Savage, President
The Nature Conservancy – NC Chapter	https://www.nature.org/en-us/about-us/where-we-work/united-states/north-carolina/
NatureServe – Southeast Region	http://www.natureserve.org/about-us/contact-us
South Atlantic Landscape Conservation Cooperative	https://www.southatlanticlcc.org/
Southern Conservation Partners	https://www.conservationsouth.org/ Chuck Roe, President
Wildlands Network	https://wildlandsnetwork.org/ Ron Sutherland, Chief Scientist

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Appendix A: List of abbreviations

ATT	American Tobacco Trail
CFE	Orange County Commission for the Environment
CSD	Conservation subdivision design
dbh	diameter at breast height
EBC	Edge betweenness centrality
EEP	Ecosystem Enhancement Program
ELI	Environmental Law Institute
EVT	LANDFIRE Existing Vegetation Type
FEIS	Fire Effects Information System
GeoHAT	Geospatial Habitat Assessment Toolkit
GIS	Geographic information system(s)
LHIG	Landscape/Habitat Indicator Guild
MPO	Metropolitan planning organization
NCCU	North Carolina Central University
NCDOT	North Carolina Department of Transportation
NCNHP	North Carolina Natural Heritage Program
NCWRC	North Carolina Wildlife Resources Commission
NHNA	National Heritage Program Natural Area
NRCS	Natural Resources Conservation Service
NRID	North Carolina State Parks Natural Resources Inventory Database
NWI	National Wetlands Inventory
OWASA	Orange Water and Sewer Authority
RCOD-1	Resource Conservation Overlay District
RCOD-2	Resource Conservation Overlay District 2
SGCN	Species of Greatest Conservation Need
UDO	Unified development ordinance
UNC Chapel Hill	University of North Carolina at Chapel Hill
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
WAP	North Carolina Wildlife Action Plan
WVC	Wildlife-vehicle collision

Appendix B: Glossary

Connectivity (landscape connectivity, landscape permeability): The degree to which the landscape facilitates or impedes movement of organisms or processes (Wade et al. 2015). The extent to which a species or population can move among landscape elements in a mosaic of habitats. This necessitates linkages among individuals, species, communities, and ecosystems at appropriate spatial and temporal scales. Corridors are one means of achieving connectivity. (Hilty et al. 2006) A measure of the ability of organisms, gametes, and propagules to move among separated patches of suitable habitat. Ideally, corridors serve to facilitate connectivity over time and can operate at a range of spatial scales. (Hilty et al. 2019)

Conservation planning: The process that occurs when a group of stakeholders consider the status of an area's natural environment and identify goals and strategies for conserving the area's natural heritage and biological diversity (NCWRC 2013).

Conservation threshold: The minimum level of any characteristic of a species' habitat that is needed in order for local populations to persist over time (NCWRC 2012).

Corridor (landscape, habitat, or wildlife corridor): Avenues along which wide-ranging animals can travel, plants can propagate, genetic interchange can occur, populations can move in response to environmental changes and natural disasters, and threatened species can be replenished from other areas (The Ninth US Circuit Court of Appeals 1997 *in* Walker and Craighead 1997). Any space that facilitates the movement of populations, individuals, gametes or propagules, and plant parts capable of vegetative reproduction in a matter of minutes, hours, or over multiple generations of a species. Corridors may encompass altered or natural areas of vegetation and provide connectivity that allows biota to spread or move among habitat fragments through areas otherwise devoid of preferred habitat. Landscape elements that function as corridors may also serve multiple other purposes, providing aesthetic amenities, ecosystem service values, cultural heritage protection, and recreational opportunities. (Hilty et al. 2019)

Cost surface (resistance surface): A mapped surface representing the degree to which some landscape feature impedes or facilitates some movement process, typically represented as a cell (pixel) value in a grid (raster) within a GIS. Corridors are then modeled in areas with lowest resistance to the movement process considered. The models are relatively easy to apply given existing data, and the approach offers the flexibility to develop models ranging from simple to complex, tailored to the specific conservation needs, and able to be refined as better data become available. A resistance surface is conceptually related to the idea of travel costs from behavioral ecology, and can therefore be designed to integrate ecological concepts important to successful wildlife movement, such as an organism's perceptual range and susceptibility to competition and predation. Resistance-surface connectivity modeling assumes a relationship between surficial proxy measures (such as habitat type or quality) and ease of animal movement. It is important that resistance surfaces be considered hypotheses reflecting a solid consideration of causal biology. (Wade et al. 2015)

Dispersal: Movements that occur within the lifetime of the individual, as, for example, when it leaves its natal site (NCWRC 2015).

Ecological integrity: A system's wholeness, including presence of all appropriate elements and occurrence of all processes at appropriate rates, that is able to maintain itself through time (ELI 2003). The ability of an ecological system to support and maintain a community of organisms that has a species composition, diversity, and functional organization comparable to those of natural habitats within a region. An ecological system has integrity, or a species population is viable, when its dominant ecological characteristics (such as elements of composition, structure, function, and ecological processes) occur within their natural ranges of variation and can withstand and recover from most perturbations imposed by natural environmental dynamics or human disruptions (Parrish et al. 2003).

Ecosystem: An ecosystem is a community of living organisms (plants, animals, and microbes) in conjunction with the nonliving components of their environment (air, water, and mineral soil), interacting as a system. It is a system of environmental conditions, habitats, natural communities, and species that interact (NCWRC 2015).

Ecosystem services: The benefits people obtain, directly or indirectly, from ecosystems. These include *provisioning services* such as food, water, timber, and fiber; *regulating services* that affect climate, floods, disease, wastes, and water quality; *cultural services* that provide recreational, aesthetic, and spiritual benefits; and *supporting services* such as soil formation, photosynthesis, and nutrient cycling. The human species, while buffered against environmental changes by culture and technology, is fundamentally dependent on the flow of ecosystem services. (Millennium Ecosystem Assessment 2005)

Edge effects: The negative influence of habitat or ecosystem edges on interior conditions of the habitat or on associated species. Edge effects can include profound modification of biological and physical conditions. (ELI 2003)

Habitat: The physical features (such as topography, geology, stream flow) and biological characteristics (such as vegetation cover and other species) needed to provide food, shelter, and reproductive needs of animal or plant species (ELI 2003).

Habitat edge: The edge of a habitat adjoining incompatible land. Habitat edge causes "edge effects" whereby species are negatively impacted due to edge conditions, such as a higher number of predators. The width of edge effects differs for different species. (NCWRC 2013) The portion of a habitat patch near its perimeter where environmental conditions are more affected by the surrounding matrix as compared to the patch core (Wade et al. 2015). A boundary between different natural communities, or between a patch and matrix, along which movement of non-living materials, organisms, and information between the two areas may occur (Hilty et al. 2006). Edges can naturally occur or can be the result of human activities, and species responses may differ. (Hilty et al. 2019)

Habitat fragmentation: The breaking up of previously continuous habitat (or ecosystem) into spatially separated and smaller parcels. Habitat fragmentation results from human land use associated with forestry, agriculture, and settlement, but can also be caused by natural disturbances like wildfire, wind, or flooding. Suburban and rural development commonly changes patterns of habitat fragmentation of natural forests, grasslands, wetlands, and coastal areas as a result of adding fences, roads, houses, landscaping, and other development activities. (ELI 2003)

Habitat loss: Reduction in total area of habitat (Wade et al. 2015).

Habitat patch: A relatively homogeneous type of habitat that is spatially separated from other similar habitat and differs from its surroundings (ELI 2003). A discrete area of contiguous habitat, often above a size threshold representing the habitat needs of an organism or species, or the functional needs of a natural community.

Habitat-corridor network: A connected set of discrete habitat patches and corridors between them.

Home range: Area used by an animal in its normal daily activities. Not defended. (NCWRC 2015).

Indicator guild: A group of species that show similar patterns of response to specific types of environmental change (Hall 2008).

Indicator species: A species that is closely associated with a particular habitat type, and whose presence indicates quality habitat (NCWRC 2012).

Invasive species: Any species that does not occur naturally in North Carolina and poses serious threats to native ecosystems, due to the species' propensity to spread rapidly and out-compete native species (adapted from NCWRC 2013).

Landscape: For the scale of this project, a large heterogeneous land area (for example, multiple square miles or several thousand hectares) consisting of a cluster of interacting ecosystems repeated in similar form (such as a watershed) (ELI 2003).

Landscape conservation: An approach that brings people together across geographies, sectors, and cultures to collaborate on conserving our important landscapes and the myriad ecological, cultural, and economic benefits they provide (Network for Landscape Conservation, http://landscapeconservation.org/about/what-is-landscape-conservation/)

Landscape/Habitat Indicator Guild: A group of species that have similar habitat and movement needs, respond in similar ways to landscape fragmentation, and collectively serve as indicators of landscape habitat integrity (Hall 2008).

Landscape habitat integrity: Defined by Hall (2008) as simply the inverse of the degree of landscape fragmentation.

Least cost corridor: A corridor representing areas of lowest movement cost between two discrete endpoints (habitat patches), determined by a threshold of total movement cost above the cost of the least cost path.

Least cost path (shortest path): In cost distance analysis (or shortest path modeling), the single path with the lowest total sum between two endpoints (habitat patches). In raster-based GIS analysis, the least cost path is only a single pixel wide, which is unlikely to represent the exact path taken by an organism. (Wade et al. 2015)

Matrix: A component of the landscape, often altered from its original state by human land use, which may vary in attributes from human-dominated to natural, and in which corridors and habitat patches are embedded (Hilty et al. 2019).

Metapopulation: A network of semi-isolated populations with some level of regular or intermittent migration and gene flow among them, in which individual populations may be extinct but then be recolonized from other subpopulations (ELI 2003).

Movement barrier: A physical object or environmental condition that obstructs or prohibits animal movement from one part of the landscape to another.

Natural community: A distinct and recurring assemblage of populations of plants, animals, bacteria, and fungi naturally associated with each other and their physical environment (Schafale 2012).

Natural Heritage Element Occurrence (NHEO): Occurrences of rare plants and animals, exemplary or unique natural communities, and important animal groupings, as tracked and documented by NCNHP. Collectively, these plants, animals, natural communities, and animal assemblages are referred to as "elements of natural diversity" or simply as "elements." Maps of NHEOs are maintained and distributed by NCNHP and are updated quarterly (NCWRC 2013).

Natural Heritage Natural Area (NHNA): Terrestrial or aquatic sites that are of special biodiversity significance as defined by NCNHP. A site's conservation priority rating or significance may be due to the presence of rare species, rare or high-quality natural communities or other important ecological features. Maps of NHNAs are updated quarterly. (NCNHP 2019d, NCWRC 2013)

Non-native species: Any species that has been introduced (either intentionally or accidentally) to an area outside its natural past or present distribution. This includes any part (gametes, seeds, eggs, or propagules) of such species that might survive and subsequently reproduce. Nonnative species can be invasive, injurious, or beneficial where they occur. (NCWRC 2015)

Resilience: The ability to retain essential processes in the face of disturbances or expected shifts in ambient conditions; ecosystem resilience provides the ability to support native diversity (NCWRC 2015).

Separation distance for suitable habitat: Distance of intervening suitable habitat not known to be occupied that is great enough to effectively separate occurrences by limiting movement or dispersal of individuals between them (NatureServe 2019a).

Separation distance for unsuitable habitat: Distance of intervening unsuitable habitat that is great enough to effectively separate occurrences by restricting movement or dispersal of individuals between them (NatureServe 2019b).

Species of Greatest Conservation Need (SGCN): In North Carolina, SGCN have been defined as species that are currently rare or have been designated as at-risk of extinction; those for which we have knowledge deficiencies; and those that have not received adequate conservation attention in the past. In addition to these species for which there is high conservation concern, SGCN may also include those species for which we are unable to determine true status in the state and are therefore a priority for research due to these knowledge gaps. (NCWRC 2015)

Succession: The process of replacement of one community with another, typically after disturbance (adapted from NCWRC 2015).

Suitable habitat: Habitat capable of supporting reproduction or used regularly for feeding or other essential life history functions; a habitat in which you would expect to find the species (assuming appropriate season and conditions) (NatureServe 2019a). Habitat that meets the survival and reproductive needs of a species, allowing for a stable or growing population over time (ELI 2003).

Unsuitable habitat: In most cases, unsuitable habitat is habitat through which individuals may move, but that does not support reproduction or long-term survival (NatureServe 2019b).

Wetland: An area of land with soil that is either permanently or temporarily saturated with water (NCWRC 2012).

Appendix C: List of Landscape/Habitat Indicator Guilds in the project area

Terrestrial (or semi-terrestrial) wildlife indicator species known to occur in the Eno River and New Hope Creek watersheds, grouped according to Hall's Landscape/Habitat Indicator Guilds (LHIG) (Hall 2008, 2009). The three LHIG habitat types selected for corridor analysis include General Wet-Mesic Hardwood Forests, Dry-Wet Hardwood and Mixed Forests, and Sparsely Settled Mixed Habitats. The three focal species selected for additional *species occurrence network* analysis are marked with an asterisk.

MORE TEXT HERE.

Habitat Guild	Taxonomic Group	Common Name	Scientific Name
General Wet-Mesic Hardwood Forests	Amphibian	Four-toed Salamander*	*Hemidactylium scutatum*
	Bird	Acadian Flycatcher	*Empidonax virescens*
	Bird	Kentucky Warbler	*Geothlypis formosa*
	Dragonfly or Damselfly	Coppery Emerald	*Somatochlora georgiana*
Dry-Wet Hardwood and Mixed Forests	Amphibian	Marbled Salamander	*Ambystoma opacum*
	Amphibian	Mole Salamander	*Ambystoma talpoideum*
	Amphibian	Spotted Salamander	*Ambystoma maculatum*
	Bird	Eastern Whip-poor-will	*Antrostomus vociferus*
	Bird	Yellow-throated Warbler	*Setophaga dominica*
	Moth	Straw Besma	*Besma endropiaria*
	Reptile	Eastern Box Turtle*	*Terrapene carolina carolina*
Sparsely Settled Mixed Habitats	Mammal	Bobcat*	*Lynx rufus*
	Mammal	Long-tailed Weasel	*Mustela frenata*
	Reptile	Timber Rattlesnake	*Crotalus horridus*
General Hydric Forests	Bird	Prothonotary Warbler	*Protonotaria citrea*
General Wet Hardwood Forests	Bird	Louisiana Waterthrush	*Parkesia motacilla*
	Bird	Rusty Blackbird	*Euphagus carolinus*
	Moth	Broadly Pectinate Hypomecis Moth	*Hypomecis longipectinaria*
Cool Mesic Slopes	Amphibian	Eastern Red-backed Salamander	*Plethodon cinereus*
Cool Heath Bluffs	Butterfly	Brown Elfin	*Callophrys augustinus*
General Mesic Hardwood Forests	Reptile	Smooth Earthsnake	*Virginia valeriae*
Rich Wet-Dry Hardwood Forests	Moth	Franck's Sphinx	*Sphinx franckii*
Piedmont Monadnock Forests	Moth	A Geometrid Moth	*Lytrosis permagnaria*
Dry-Xeric Mixed Forests, Woodlands, and Barrens	Bird	Chuck-will's-widow	*Antrostomus carolinensis*
	Butterfly	Confused Cloudywing	*Thorybes confusis*
	Butterfly	Northern Oak Hairstreak	*Satyrium favonius ontario*
	Reptile	Scarlet Kingsnake	*Lampropeltis triangulum elapsoides*
General Semi-Natural Pine Forests and Woodlands	Bird	Brown-headed Nuthatch	*Sitta pusilla*
Wet-Mesic Forest-Field Ecotones and Groves	Bird	American Woodcock	*Scolopax minor*

Habitat Guild	Taxonomic Group	Common Name	Scientific Name
Dry-Wet Forest-Field Ecotones and Groves	Bird	Red-headed Woodpecker	*Melanerpes erythrocephalus*
Mix of open and forested habitats	Reptile	Mole Kingsnake	*Lampropeltis calligaster*
Reservoirs	Bird	Bald Eagle	*Haliaeetus leucocephalus*
Beaver Ponds and Successional Wetlands	Bird	Hooded Merganser	*Lophodytes cucullatus*
	Reptile	Eastern Ribbonsnake	*Thamnophis sauritus*
Canebrakes	Bird	Swainson's Warbler	*Limnothlypis swainsonii*
Inland Freshwater Marshes	Bird	King Rail	*Rallus elegans*
	Bird	Least Bittern	*Ixobrychus exilis*
	Moth	Louisiana Owlet Moth	*Macrochilo louisiana*
Semi-Natural Grasslands	Bird	American Kestrel	*Falco sparverius*
	Bird	Barn Owl	*Tyto alba*
	Bird	Grasshopper Sparrow	*Ammodramus savannarum*
	Bird	Loggerhead Shrike	*Lanius ludovicianus*
Successional Fields	Bird	Northern Bobwhite	*Colinus virginianus*
	Bird	Prairie Warbler	*Setophaga discolor*
	Butterfly	Monarch	*Danaus plexippus*
Urban Areas	Bird	Chimney Swift	*Chaetura pelagica*
	Bird	Common Nighthawk	*Chordeiles minor*
Habitat guild not yet determined	Amphibian	Cope's Gray Treefrog	*Hyla chrysoscelis*
	Amphibian	Gray Treefrog	*Hyla versicolor*
	Bird	Gadwall	*Anas strepera*
	Dragonfly or Damselfly	Blackwater Clubtail	*Gomphus dilatatus*
	Dragonfly or Damselfly	Septima's Clubtail	*Gomphus septima*
	Dragonfly or Damselfly	Spine-crowned Clubtail	*Gomphus abbreviatus*
	Dragonfly or Damselfly	Splendid Clubtail	*Gomphus lineatifrons*
	Mammal	Tricolored Bat	*Perimyotis subflavus*
	Reptile	Queen Snake	*Regina septemvittata*
	Sawfly, Wasp, Bee, Ant	American Bumblebee	*Bombus pensylvanicus*

Appendix D: List of planning documents and ordinances reviewed

Additional planning documents not listed below were reviewed for this project. However, only those documents with protection priorities, policies, or ordinances most relevant to the project objectives are included in the results.

Jurisdiction	Document	Year	Last amended/ updated
Interjurisdictional	Chatham County Town of Cary Joint Land Use Plan	2012	2016
	New Hope Corridor Open Space Master Plan	1991	
	Orange-Chapel Hill-Carrboro Joint Planning Agreement	1987	2015
	Orange-Chapel Hill-Carrboro Joint Land Use Plan	1986	2015
Chatham County	Land use and related ordinances as of July 2019		
	Plan Chatham (the Chatham County comprehensive plan)	2017	
	Land Use Strategic Plan	1999	
	Chatham County, NC Agricultural Land Use Plan	2009	
	A Comprehensive Conservation Plan for Chatham County, NC	2011	
Durham City-County	Unified development ordinance as of December 2019		
	Durham Comprehensive Plan	2016	
	Durham County Open Space Corridor System plan	1993	
	Durham Urban Open Space Plan	2017	
Orange County	Unified development ordinance as of July 2019		
	Orange County Comprehensive Plan 2030 (Land Use and Natural & Cultural Systems elements)	2008	2012
	A Lands Legacy Program for Orange County	2000	
	Lands Legacy Program Action Plan 2018-2020	2018	
	Orange County Parks and Recreation Master Plan 2030	2014	
	New Hope Corridor Open Space Master Plan: Proposals for Linking Duke Forest and Eno River State Park	1993	
	Mountains-to-Sea Trail Route Map	2018	
	Eno Economic Development District Small Area Plan	2008	2009
	Stoney Creek Basin Small Area Plan	1996	
Town of Carrboro	Land use ordinance as of November 2019		
	Carrboro Vision 2020: Policies through the Year 2020	2000	
	Facilitated Small Area Plan for Carrboro's Northern Study Area	1999	
	Recreation and Parks Comprehensive Master Plan Update for the Town of Carrboro	2006	
	Conservation Areas in the Upper Bolin Creek Watershed	2005	
	Recreation and Parks Comprehensive Master Plan Update for the Town of Carrboro	2006	
Town of Chapel Hill	Land use management ordinance as of July 2019		
	Chapel Hill 2020 Comprehensive Plan	2012	
	Chapel Hill Comprehensive Parks Plan	2013	
	Greenways Master Plan	2013	
	Rogers Road: Mapping our Community's Future	2016	
	Central West Small Area Plan	2013	
Town of Hillsborough	Unified development ordinance as of July 2019		
	Strategic Growth Plan	2006	
	Hillsborough Vision 2030	2015	
	Parks and Recreation Master Plan	2007	2009, 2014
	Community Connectivity Plan	2009	2014, 2017
	Churton Street Strategic Corridor Plan	2006	

Jurisdiction	Document	Year	Last amended/ updated
	US 70/Cornelius Street Corridor Plan	2007	
Wake County	Unified development ordinance as of July 2019		
	Wake County Transportation Plan	2003	
	Wake County Environmental Stewardship Agenda	2006	2011
	Southwest Wake Area Land Use Plan	2007	
	Wake County Land Use Plan		2006
	Wake County Consolidated Open Space Master Plan	2003	2006
	Wake County Open Space Acquisition Corridors map	2008	
	Wake County Greenway System Plan	2017	
	Wake County Park Facility Master Plan Updates Final Report	2017	
	Comprehensive Parks & Recreation Master Plan	2008	
Town of Apex	Unified development ordinance as of July 2019		
	Town of Apex Comprehensive Transportation Plan Update	2011	
	2045 Updated Future Land Use Map	2019	
	Town of Apex 2035 Land Use Plan Update | Economic Study and Market Analysis	2016	
	Peak Plan 2030 (the Town of Apex comprehensive plan)	2013	
Town of Cary	Land development ordinance as of July 2019		
	Cary Community Plan (Town of Cary comprehensive plan)	2017	
	Parks, Recreation and Cultural Resources Master Plan	2012	
	Parks, Recreation & Cultural Resources Master Plan	2003	

Appendix E: List of resources for landscape connectivity planning

NORTH CAROLINA LANDSCAPE CONSERVATION PLANNING GUIDES, DATA, AND ASSISTANCE

Ernest, M and R Sutherland. 2017. Prioritizing wildlife road crossings in North Carolina. Wildlands Network, Durham, NC. Available from https://wildlandsnetwork.org/wp-content/uploads/2017/01/Prioritizing-wildlife-road-crossings-in-North-Carolina-2017-1.pdf.

NCNHP data. Current data available from https://www.ncnhp.org/data.

NCNHP information requests and site review requests. https://www.ncnhp.org/data/request-information.

NCWRC. 2012. Conservation recommendations for priority terrestrial wildlife species and habitats in North Carolina. NCWRC, Raleigh, NC. Available from https://www.ncwildlife.org/LinkClick.aspx?fileticket=gpdoxjaXTew%3d&tabid=1719&portalid=0&mid=4866

NCWRC. 2013. Green Growth Toolbox: wildlife and natural resource stewardship in planning. Green Growth Toolbox handbook second edition. NCWRC, Raleigh, NC. Available from https://www.ncwildlife.org/Conserving/Programs/Green-Growth-Toolbox/Download-Handbook

NCWRC Green Growth Toolbox workshops, data, technical assistance, and site assessment. https://www.ncwildlife.org/conserving/programs/Green-Growth-Toolbox.

NCWRC. 2015. North Carolina wildlife action plan. NCWRC, Raleigh, NC. Available from http://www.ncwildlife.org/plan.aspx.

Wildlands Network. 2019. Eastern Wildway. https://wildlandsnetwork.org/wildways/eastern/.

CORRIDOR ECOLOGY AND CONSERVATION

Conservation Corridor: Connecting Science to Conservation. Available from https://conservationcorridor.org/. "Our mission is to bridge the science and practice of conservation corridors."

Hilty, JA, ATH Keeley, WZ Lidicker, Jr, AM Merenlender, editors. 2019. Corridor ecology: linking landscapes for biodiversity conservation and climate adaptation. Second edition. Island Press, Washington, DC.

Hilty, JA, WZ Lidicker, Jr, AM Merenlender. 2006. Corridor ecology: the science and practice of linking landscapes for biodiversity conservation. Island Press, Washington, DC.

LANDSCAPE CONSERVATION AND CONNECTIVITY PLANNING

Ament, R, R Callahan, M McClure, M Reuling, and G Tabor. 2014. Wildlife connectivity fundamentals for conservation action. Center for Large Landscape Conservation, Bozeman, MT. Available from https://largelandscapes.org/resources/.

Beier, P, D Majka, S Newell, E Garding. 2008. Best management practices for wildlife corridors. Northern Arizona University, AZ. Available from http://corridordesign.org/dl/docs/corridordesign.org_BMPs_for_Corridors.pdf.

Bentrup, G. 2008. Conservation buffers: design guidelines for buffers, corridors, and greenways. General Technical Report SRS-109. US Department of Agriculture, Forest Service, Southern Research Station, Asheville, NC. Available from https://www.fs.usda.gov/nac/buffers/index.html.

Environmental Law Institute (ELI). 2003. Conservation thresholds for land use planners. The Environmental Law Institute, Washington, DC.

Landscape Conservation Cooperative Network. 2019. Conservation issue: landscape conservation design. Available from https://lccnetwork.org/issue/landscape-conservation-planning-and-design.

NatureServe/Landscope America. 2019. Connecting landscapes: a practitioner's resource for assessing and planning for habitat connectivity. Available from http://www.landscope.org/focus/connectivity/.

NRCS. 2004. Part 613: Conservation corridor planning at the landscape level--managing for wildlife habitat. National Biology Handbook Subpart B--Conservation Planning. US Department of Agriculture, Natural Resources Conservation Service, Washington DC.

CONNECTIVITY MODELING

Conservation Corridor: Corridor Toolbox. https://conservationcorridor.org/corridor-toolbox/.

NatureServe/Landscope America. 2019. Connecting landscapes: a practitioner's resource for assessing and planning for habitat connectivity. Available from http://www.landscope.org/focus/connectivity/.

Wade, AA, KS McKelvey, and MK Schwartz. 2015. Resistance-surface-based wildlife conservation connectivity modeling: summary of efforts in the United States and guide for practitioners. General Technical Report RMRS-GTR-333. US Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

LANDSCAPE CONSERVATION AND CONNECTIVITY PLANS FROM OTHER STATES

Chisholm, M, A Bates, D Vriend, and D Cooper. 2010. Wildlife passage engineering design guidelines. Report prepared by Stantec Consulting Ltd. for the City of Edmonton, Office of Natural Areas. Available from https://www.edmonton.ca/city_government/documents/WPEDG_FINAL_Aug_2010.pdf.

Conservation Corridor: Connectivity Plans Library. https://conservationcorridor.org/connectivity-plans-library/.

New Jersey Division of Fish and Wildlife. 2019. Connecting habitats across New Jersey guidance document version 1.0. New Jersey Department of Environmental Protection, State of New Jersey. Available from https://www.njfishandwildlife.com/ensp/chanj.htm.

Shilling, F, P Cramer, L Farrell, and C Reining. 2012. Vermont transportation and habitat connectivity guidance document. Report prepared for the Vermont Agency of Transportation. Available from http://stayingconnectedinitiative.org/assets/vtrans_transport_habitat_connectivity_guidance_final_dec2012.pdf

Washington Department of Fish and Wildlife. 2009. Landscape planning for Washington's wildlife: managing for biodiversity in developing areas. Olympia, WA. Available from https://wdfw.wa.gov/sites/default/files/publications/00023/wdfw00023.pdf.

TRANSPORTATION PLANNING FOR WILDLIFE

Clevenger, AP, and MP Huijser. 2011. Wildlife crossing structure handbook. Design and evaluation in North America. Publication No. FHWA-CFL/TD-11-003. US Department of Transportation, Federal Highway Administration, Central Federal Lands Highway Division, Lakewood, CO.

Defenders of Wildlife. 2007. Getting up to speed: a conservationist's guide to wildlife and highways. Defenders of Wildlife, Washington, DC. Available from https://defenders.org/sites/default/files/publications/getting_up_to_speed.pdf.

Huijser, MP, P McGowen, AP Clevenger, and R Ament. 2008. Best practices manual: wildlife-vehicle collision reduction study. Report to US Congress. Federal Highway Administration, McLean, Virginia, USA. Available from http://www.fhwa.dot.gov/environment/hconnect/wvc/index.htm.

National Research Council. 2005. Assessing and managing the ecological impacts of paved roads. The National Academies Press, Washington, DC. Available from https://doi.org/10.17226/11535.

Southeast Aquatic Resources Partnership. Resources for culvert assessment. https://southeastaquatics.net/ and https://southeastaquatics.net/sarps-programs/southeast-aquatic-connectivity-assessment-program-seacap/culvert-assessments/sarp-culvert-assessment-manual.

Van der Ree, R, DJ Smith, and C Grilo, editors. 2015. Handbook of road ecology. John Wiley & Sons, Ltd, West Sussex, UK.

For more information on this project including how to support these efforts, please visit:

ncbg.unc.edu/eno-new-hope-plan