

Green Infrastructure Study

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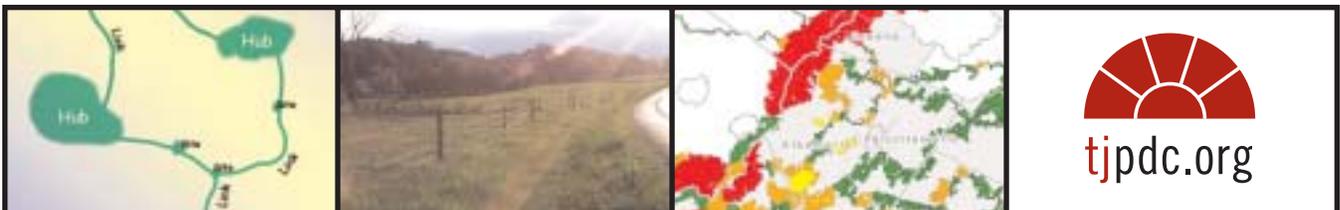


Prepared by the:

Thomas Jefferson Planning District Commission

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Executive Summary

Green infrastructure is an interconnected network of green spaces that conserves natural ecosystem values and functions and provides associated benefits to human populations. Typically, a green infrastructure network consists of large habitat areas, or hubs, linked together by corridors, also known as greenways. The benefits include enhancement of quality of life for residents, economic development and increased property values, maintenance of water quality and quantity, and protection of wildlife habitat. This Green Infrastructure Study is intended to identify an interconnected green infrastructure network for the five county Thomas Jefferson Planning District region and to develop information on implementation measures that can be provided to all jurisdictions for consideration in their planning processes. Particular attention is given to methods for habitat protection, general water quality protection, drinking water protection, water habitat protection, and protection of recreational opportunities.

To help determine ideal locations for green infrastructure, a few geographic features, labeled “cornerstone layers,” were identified from scientific data and prior studies. Habitat layers, derived from Virginia Conservation Lands Needs Assessment (VCLNA) maps, show land cover types deemed especially valuable for wildlife habitat and migration. Steep slopes, land with an incline of 25% or greater, show areas with high susceptibility to erosion. Buffers on major streams protect aquatic habitat and mitigate the impacts of stormwater runoff. Maps of existing trails and greenway systems reveal current cultural resources of value to the community. Finally, lands that are already protected were included as a cornerstone layer. A composite map was generated to form the informational basis of the proposed green infrastructure network.

Staff from the Thomas Jefferson Planning District met with representatives from each of the member jurisdictions to review the proposed maps and make any adjustments to account for parcel boundaries, existing development, and other elements missing from the composite map.

A critical step is incorporating green infrastructure into the local land use process. There are a number of development tools that may be used. Because individual landowners are crucial to the establishment of green infrastructure, parcel maps are needed to identify ownership within the proposed network. Future Land Use Maps reveal the land use aspirations of the community, developed through a comprehensive planning process. Zoning maps help determine the legal restraints currently placed on land in the network. Transportation plans reveal upcoming infrastructure projects which may impact the choice of conservation priorities. Other useful maps include floodplain maps, water and sewer infrastructure maps, agricultural and forestal district maps, the Rivanna watershed land cover map, and a map of areas vulnerable to development created by VCLNA.

Code tools, whether advisory or regulatory, may also help in the implementation phase. Comprehensive Plans are the logical starting point for declaring a community’s goals for green infrastructure, recommendations which may or may not be followed by zoning ordinances. The development review process during a rezoning may open up opportunities for proffers toward green infrastructure. Similarly, a design review board may wish to see elements of green infrastructure in proposals before permitting them in areas under their purview. There are other ordinances, such as riparian buffers and stormwater management requirements, that can serve to build a green infrastructure network.

Other non-regulatory tools are available. Education is important, both for providing land management techniques and grant opportunities to individual land owners and for generating and sustaining political will for continued implementation. Conservation easements can help protect working lands from development. Easements may be donated, purchased outright by the locality, or adopted upon trading development rights to another party for the right to develop more intensively in a designated “receiving area.” This is known as a Transfer of Development Rights policy. Historic districts, scenic byways and rivers, and agricultural and forestal districts are all means for recognizing land of special importance. Site sensitive and low impact development techniques may be encouraged by the locality to preserve as much land as possible while allowing development to proceed. Finally, certain lands may be purchased outright by the locality for use as a public park.

A variety of funding tools from every level of government can be used for green infrastructure. The Virginia Land Conservation Foundation provides resources to localities for open spaces and parks, and the Virginia Recreational Trails Fund does the same for trails or trail facilities. The federal Natural Resources Conservation Service runs a number of programs to assist landowners in managing their water, soil, and other natural resources. At a state level, the Virginia Department of Conservation and Recreation administers a series of incentives to landowners. The Virginia Department of Forestry offers technical assistance and financial incentives for forestal landowners. Other programs include Partners for Fish and Wildlife, Virginia Aquatic Resources Trust Fund, Transportation Enhancement and Safe Routes to School, and various private foundation grants. Local volunteer labor and private donations should not be overlooked.

Evaluation criteria ought to be established to measure the implementation of green infrastructure. Success can be determined through a number of quantitative and qualitative measures: the number of acres protected in high priority areas, reduction of streams on the impaired streams list, mileage of trails available to the public, percentage of forested lands in high priority areas, surveys of public attitudes and preferences, park visitation records, and the economic impact of tourism in the area.

Introduction

What is Green Infrastructure?

Green infrastructure is an interconnected network of green spaces that conserves natural ecosystem values and functions and provides associated benefits to human populations. Green infrastructure recognizes that healthy land and healthy communities depend upon each other. Many aspects of the natural world, from wildlife habitat to rivers and wetlands, thrive when they are part of an interconnected whole. Similarly, human development is enhanced when the natural world is woven throughout our homes and businesses, with recreational opportunities and clean drinking water within easy reach of all citizens. Green infrastructure is a purposeful creation and stewardship of a network of green space throughout the whole region. It is open space with a purpose.

This is a critical time to identify important natural systems and features so they can be properly managed for the future. Development is accelerating throughout the region, offering both a threat to these resources, and an opportunity to protect and enhance them. More and more communities are integrating green infrastructure considerations in their planning processes. This document is intended to be a resource for the localities of the Thomas Jefferson Planning District on this topic.

What does green infrastructure look like? Typically, a green infrastructure network consists of large habitat areas, or hubs, linked together by corridors. Sites, which are smaller areas of some significance, may also be included, and may not be connected.

The challenge of green infrastructure is to balance the need to protect and the need to grow, strategically choosing which lands will remain open and ensuring that proper links are made between these spaces. Instead of reacting to the pressures of development in a haphazard manner, the placement of a community's green infrastructure ought to be deliberate, science-based, and firmly within the public interest. This requires as much foresight as we put into the roads and pipelines needed to build the places we live in.

What are the benefits?

Benefits of green infrastructure include improved water quality and quantity, preservation of biodiversity by providing large habitat areas and corridors for movement between them, provision of areas for recreation, stormwater and flooding control, protection of air quality, enhancement of community appearance, increased property values, and an attraction for tourists

- 1) **Quality of Life.** Children love to play in streams and make trails through the forest. The older generation simply enjoys walking through a serene natural landscape and breathing in the fresh air. This is a basic human desire. Respected biologist E.O. Wilson has explained this as "the connections that human beings subconsciously seek with the rest of life." Additionally, quantitative health benefits have been linked with the preservation of green space. A Columbia University study found that asthma rates

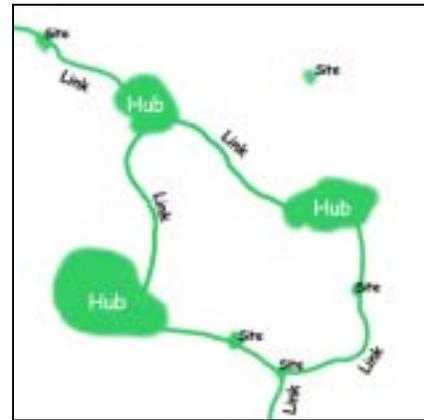


Figure 1. Conceptual drawing of green infrastructure network.

among children in New York aged 4 and 5 decreased by 25% for every 343 trees per square kilometer.ⁱ A study at the Indiana School of Medicine of children aged 3 to 18 found that the more green a neighborhood, the slower the increase in body mass index, lowering the likelihood of obesity.ⁱⁱ Various studies at the University of Illinois have found that greenery in the inner city can lower crime rates, decrease domestic violence, assist residents with coping, and increase a sense of community.ⁱⁱⁱ Further, a University of Sheffield study found that more biologically diverse spaces have higher psychological value.^{iv}

The relationship between what is found on the land and quality of life is well-recognized in the region, as evidenced by the following statements from local comprehensive plans:

- In our vision, Fluvanna County will look like this over the next twenty years: Land use is recognized as directly related to quality of life. Natural resources are protected: rivers are clean and full of life. [Fluvanna County 2009 Comprehensive Plan]
- Louisa County citizens envision a future where residents of Louisa County experience a quality of life which includes maintaining our rural heritage...and working with neighboring localities to protect and preserve our natural resources. [Louisa County 2006 Comprehensive Plan]
- Goal – Recognize that the natural environment is an important facet of our quality of life and efforts should be made to support and enhance that environment. [Nelson County 2002 Comprehensive Plan]
- City Council Guiding Principles: The Charlottesville Community puts a value on trees, parks, greenspace, stream and biodiversity as adding to the appearance and livability of the City. [City of Charlottesville 2007 Comprehensive Plan]
- The maintenance and enhancement of our quality of life, our economic wealth, and the health of our citizens are dependent on our natural environment and the ecological services it provides. Ecological services are ways in which nature meets and fulfills human needs. [Albemarle County Natural Resources and Cultural Assets Component of the Comprehensive Plan, 1999]
- When habitats are intact, they provide not only for the wildlife, but for the residents of Greene as well. The natural beauty contributes not only just a pretty place to live, but also clean water and air. Not to mention a willingness for tourists to visit Greene County and bolster our economy. [Greene County 2003 Comprehensive Plan]

2) **Economic Development.** Economic development is supported by a high quality of life. This was recognized in the TJPDC's 2002 Regional Economic Development plan: "The Economic Development Plan Committee's view of economic development is not primarily based on physical developments, but rather on preserving and supporting the quality of life of our citizens." The plan goes on to say that "Strategies for realizing increased economic activity are not limited to attracting new businesses to the area, but also include supporting existing business and industry, protecting profitable agriculture, and attracting tourists by promoting the region's natural beauty and historical and agricultural heritage."

However, quality of life will in itself attract new businesses. A 1995 survey of MIT graduates who founded their own companies found that when company leaders make a conscious choice about location or expansion, quality of life is ranked first among factors. Second is access to skilled professionals, and as the study goes on to observe, "They locate where such professionals like to live. In

this sense, the quality of life response is really a second vote for access to skilled professionals.”^v A survey of over 1,200 young high-technology workers confirmed that quality of life is what this group seeks, with quality of life coming in only second to salary considerations in evaluating potential jobs. Focus groups conducted as part of the study further revealed that the young workers wanted “easy access to a wide range of outdoor activities and a clean, healthy environment with a commitment to preserving natural resources for enjoyment and recreation.”^{vi}

As the 2002 Regional Economic Development plan noted, attracting tourists is also a viable way of supporting the local economy. A study of the Virginia Creeper Trail in Southwest Virginia estimated that non-local spending related to trail visits during the study period (11/2002-10/2003) generated \$1.6 million in economic impacts and supported close to 30 jobs.^{vii}

Green infrastructure tools and techniques can also be used to protect open space beyond forested habitat areas, such as the rural and historic landscape that helps to give the region its character. Farmland is disappearing at a rapid pace throughout the region – between 2002 and 2007, nearly 12% of the farmland that existed in 2002 was lost (USDA 2007 Census of Agriculture). However, in keeping with national trends, there has been renewed interest in recent years in “eating locally” and an increase in the number of farmers’ markets and other resources that support local agriculture. Similarly, forestland is also quickly disappearing; Virginia Department of Forestry staff estimate that if current trends continue, by 2040, over one million acres of forestland will be lost in the state. Forestry contributes roughly \$27 billion to the Virginia economy, and employs 1 in 33 workers. By spatially locating agricultural and forestal resources and encouraging the use of preservation tools, green infrastructure can help facilitate the stabilization and revitalization of these industries that are important to the heritage of the region.

- 3) **Water Quality and Quantity.** Clean water is a basic need for good health, from individuals to ecosystems. Green infrastructure is one method for mitigating some of the negative impacts of development. Corridors of green space create natural buffers for stormwater runoff, protecting our streams and rivers from building up excess sediment and pollutants. An acre of buffer along a river or stream prevents 21 lbs of nitrogen and 4 lbs of phosphorus from reaching the water each year. A study found that Chesapeake Bay nutrient goals for Maryland could be achieved for \$617,000 using buffers, vs. \$3.7 million using engineering methods.^{viii}

Maintaining areas where water can percolate is vital to providing a consistent water supply. When stormwater soaks into the soil gradually rather than rushing across impervious surfaces (surfaces that cannot be penetrated by water, such as pavement) to the nearest stream, it recharges groundwater and then is naturally released into rivers and streams at a steady pace. This allows both groundwater and surface water users a longer period before water levels drop.

Adequate water is also necessary to support a diverse aquatic community. From a diversity standpoint, a multitude of factors come into play including the magnitude of high flows, their duration and timing, and the change in flows over an annual period, as well as the variability from one year to the next. Understanding this often involves an interdisciplinary approach, taking into account five river

characteristics - hydrology, biology, geomorphology (the shape and materials of the river channel), water quality, and connectivity.^{ix}

4) **Habitat.** Habitat offers several important benefits to human beings, as well as to the animals and plants that call it home.

a) **Biodiversity.** As mentioned under “Quality of Life,” it has been shown that simply being in a more biologically diverse area can have psychological benefit. But additionally, biodiversity provides a pool that people can continue to dip into for resources for crops and medicines. Wild relatives of cultivated crops can provide genes that confer resistance to new threats. Edible plants that are found in the wild but not currently widely cultivated may provide future enrichment for human diets. And medicine relies heavily on natural sources. An analysis of the top 150 prescription drugs in the United States in 1993 found that 57% of them contained active ingredients that had biological origins.^x

Interconnected lands are vital to the preservation of biodiversity. Protecting fragmented and isolated preserves of land for wildlife is not enough to allow a healthy ecosystem to function. For example, Barro Colorado is an island that was created from a mountaintop when the Panama Canal was built. Despite the size of the island – 3700 acres – 65 bird species have gone extinct on it since its creation, with more endangered.^{xi} Ashdown Forest in England, the inspiration for the 100-Acre Wood in Winnie-the-Pooh, is another example. Ashdown Forest is actually a 6178-acre wood. Again despite its size, it has lost 47 plant species since becoming surrounded by development in the 1920s.^{xii} In order to allow species to disperse and migrate as needed and for separate populations to share genetic material to prevent inbreeding, physical connections need to be maintained.

b) **Air Quality.** A study was performed by the TJPDC in 1997 using CITYgreen software (American Forests) and the Gap Analysis land cover that had been recently released by the Virginia Gap Analysis Project (a partnership effort of Virginia Tech and the Virginia Department of Game and Inland Fisheries). The study looked at the services performed by trees in the Rivanna watershed, which occupies about 35% of the planning district. It found that 13,688 tons of ozone, nitrogen dioxide, sulfur dioxide, particulate matter and carbon monoxide are being removed each year by the trees in the watershed. Using per-acre estimates supplied by American Forests, the study calculated that a loss of just 2% of that forest cover could result in an additional \$38 million in costs related to health issues, plant damage, infrastructure damage, etc.^{xiii} Trees also typically decrease air temperature in the summer, which can also improve air quality by reducing ozone formation and the emission of many pollutants.^{xiv}

c) **Carbon Sequestration.** Carbon sequestration, or the removal of carbon from the atmosphere, is seen by many to be an important strategy in combating climate change. Carbon sequestration rates are complex and dependent on many factors, including the species of tree, its age, where it's growing, and the fertility of the soil; studies in the U.S. have found rates varying from 0.9 to 4.6 tons per year/acre.^{xv} According to the U.S. EPA, this equates to the greenhouse gas emissions of somewhere between one half and three cars per year.^{xvi} Virginia Department of Forestry staff estimate that Virginia's forests take up 6.42 million tons of carbon annually, or 14% of emissions in

the state. Maintaining and enhancing the forest cover in the planning district can be one way to offset our region's impacts on global climate.

Process for this Study

This document represents the end of the second phase of a project that began in late 2005. Initial work included development of some map layers by the UVA School of Architecture's PLAC 513 Applied GIS (Geographic Information System) class, and presentations to the Rural Planners Roundtable (in March 2006) and the Thomas Jefferson Planning District Commission (in June 2006). The purpose of the presentations was to get recommendations on the best way to proceed in order to ultimately produce an advisory study for consideration by the localities of the planning district (Albemarle, Fluvanna, Greene, Louisa and Nelson Counties and the City of Charlottesville). The presentation to the Commission included maps produced by the students. The Commission was enthusiastic about the project, but requested that a technical committee be convened in order to produce better, more informed GIS coverages.

The technical committee, which ultimately covered far more than GIS coverages, was convened in August 2006 and met a total of 14 times between then and the end of the second phase of the project in September 2009. The committee's membership remained fluid throughout, but meetings were attended by a mix of local, state, and non-profit staff, as well as some interested citizens. After the introductory meeting in August 2006, meetings usually had specific topics, which included:

- Goals and objectives;
- Review of comprehensive plan goals (a list of complementary goals and objectives found in local comprehensive plans is included in Appendix A);
- Available habitat maps;
- Recreation maps, including trails, parks, and water-based recreation;
- Water resources;
- Determination of the most vital, or cornerstone, layers to map;
- The outline of the study.

The work of the committee was presented back to the Planning District Commission at their May 2009 meeting, where it was endorsed.

Along the way, work was also performed to incorporate the nascent green infrastructure study into concurrent transportation planning efforts; much of this work was performed under a grant the TJPDC received under the Federal Highway Administration's Eco-Logical program. Presentations were made to two committees of the Charlottesville-Albemarle Metropolitan Planning Organization, which approves the long-range transportation plan (UnJAM 2035) for the Charlottesville/Albemarle urban area; green infrastructure was included in the presentation and the workbook at the UnJAM public workshop in May 2008; the green infrastructure elements that had been approved by the technical committee at that point were included in the analysis of urban area transportation projects to determine potential conflicts; and the overlaid map of green infrastructure with transportation projects was presented at a public meeting in March 2009 (and ultimately included in the adopted UnJAM 2035 plan for the urban area). A map of green infrastructure cornerstone layers (developed in June 2009 and including the final cornerstone layers) was also overlaid with the "preferred scenario" of the Greene County Multimodal Plan in order to see where planned land uses might conflict with areas essential to a healthy green infrastructure system. In these ways, application of the green infrastructure plan began in our region before it was even finished.

Goals of the Study

The goals of this study, as developed by the technical committee and endorsed by the Thomas Jefferson Planning District Commission, are:

Overall:

- Develop information on implementation measures that can be provided to all jurisdictions for consideration in their planning processes.

Habitat protection:

- Identify special areas/habitats and develop information on implementation measures that could be used to protect and preserve those habitats.

General water quality protection:

- Set minimum stream buffers (with recommendations for larger buffers and forested buffers).
- Enhance and protect forested areas around streams.
- Protect healthy waters and contain and reverse stream impairment.
- Recommend implementation of standards similar to those used in Chesapeake Bay Act localities for consideration by all jurisdictions in the planning district.

Drinking water protection:

- Ensure that future drinking water supply plans and development plans reflect each other.

Water habitat protection:

- Protect healthy habitats and special habitats through stream restoration and preservation.
- Ensure adequate water is present in channels to support a diverse aquatic biota. This includes flow variability both over the course of a year and from one year to the next.

Recreation protection:

- Provide access to water that's swimmable and fishable.
- Provide access to green space to improve quality of life.

Cornerstone Layers

Although many GIS layers were identified by the technical committee as having value and potential use, the entire set put together becomes a “protect everything, everywhere” scenario which is impractical. The committee opted instead to choose a few layers as essential to a healthy green infrastructure in the region, with other layers presented as a toolbox later in the study. The cornerstone layers, which will be covered in the next section, are:

- Virginia Conservation Lands Needs Assessment Habitat Cores (1st and 2nd priority) and Corridors, the Albemarle Biodiversity Work Group’s Important Sites
- Steep slopes (25%)
- Major streams, recommended to have a 100-ft buffer
- Existing trails and adopted greenway/trail plans
- Lands that already have some level of protection: public lands and lands under permanent conservation easement

Green Infrastructure Cornerstones

The following green infrastructure components are the ones determined by the technical committee as the most important to a green infrastructure network. Their recommendation is advisory only, and in fact, at this writing local review has already resulted in some additions and deletions to the network on a county-by-county basis (covered at the end of this chapter). It is expected that the region's green infrastructure will continue to evolve as existing conditions, available maps and tools, and opportunities and barriers shift. This document does not reflect the end of a process, but rather, the beginning.

Habitat Layers

One of the first topics covered by the technical committee focused on establishing which habitat layers should be included in the presentation and evaluation of the communities' green infrastructure network. This is an area in which considerable work has been done already for the region; the Virginia Department of Conservation and Recreation's Division of Natural Heritage (DCR-DNH), the Nature Conservancy, and Albemarle's Biodiversity Work Group/Natural Heritage Committee (BWG/NHC) have all made efforts to map important areas to preserve for habitat. Additionally, the National Wetlands Inventory has been developed by the U.S. Fish and Wildlife Service, although most maps for the planning district date from the 1980s; the other three mapping efforts have all been within the last decade.

Ultimately, the committee chose to use the Virginia Conservation Lands Needs Assessment (VCLNA) maps developed by DCR-DNH, and the Albemarle BWG/NHC map. The key advantage of the VCLNA maps over the Nature Conservancy's habitat cores map was the appropriateness of scale to the regional issue (100 acres vs. 5,000 acres). The VCLNA's ecological integrity model also considered wetlands in its ranking system.

The VCLNA maps are based on a land cover map (RESAC 2000) derived from Landsat satellite imagery from the year 2000. The habitat cores identified through this process were forested in nature in the planning district. To be considered a habitat core, a patch of habitat had to be at least 100 uninterrupted acres, with a buffer of 100 meters. The cores were then ranked in the ecological integrity model, based on analysis of the following characteristics:

- Total area;
- Depth of interior (fatter cores ranked higher);
- Total length of streams in the core;
- Variety of unmodified wetlands;
- Variability of elevations (because of its impact on the variety of potential habitats);
- Area of essential habitats for the most imperiled species;
- Terrestrial sites of significant biodiversity, based on rarity, quality, and number of species;
- Stream segments containing threatened or endangered species or significant biodiversity;
- Proximity of cores to other cores.

The resulting model ranked the cores 1-5, with 1 being the highest priority. The committee decided to focus on the 1st and 2nd priority cores as a practical measure; using all cores ranked 1-5 resulted in too vast an area to target for protection. (A map showing all five levels of cores is presented in the next section.) Conveniently, following this decision, DCR-DNH mapped potential habitat corridors between the 1st and 2nd level cores statewide. This map was developed using a least-cost path analysis, meaning that the resulting

corridors reflected the product of the shortest distance with the fewest obstacles to travel. The suggested corridors were at least 300 meters wide, in order to provide interior habitat for those species that need it. The corridors were widened where they intersected lower-ranked cores, interior forests, and wetlands. The committee chose to adopt these corridors as the habitat links in the green infrastructure plan as, in general, they provided the needed connectivity between the cores that had already been selected.

Finally, some additional local work has been done on biodiversity in the County of Albemarle. In 2002, a Biodiversity Work Group was initiated to support the Comprehensive Plan goal of “recogniz[ing] the importance of protecting biological diversity in both the Rural Area and the Development Areas for the ecological, aesthetic, and economic benefits to the community.” (In 2005, the Biodiversity Work Group was formalized as the Natural Heritage Committee.) In its 2004 report^{xvii}, the work group identified 38 “Important Sites,” actually comprising 49 distinct mappable areas. These areas were selected by local naturalists as being foremost in their uniqueness, based on their expertise and experience. The sites listed in the 2004 report were mapped by member Tom Olivier and supplied by him to the TJPDC. It was agreed by the committee that the sites, encompassing specific local knowledge in a way that the statewide coverage could not, were a worthwhile addition to the green infrastructure habitat layers. The cornerstone layers map shows the combined habitat layers for the region.

Steep Slopes

The committee selected steep slopes, meaning those slopes with an incline of 25% or greater, as a layer that should be protected by green infrastructure because of those slopes’ tendency toward increased erodibility. This erosion can result in sediment ending up in streams, which in turn can cloud the water, change stream flows, increase flooding, and reduce the habitat available for invertebrates that need pebbly-bottomed streams and support many other animals in the ecosystem. Protecting steep slopes is a significant way to protect both habitat and water quality. The second cornerstone layers map shows slopes of 25% or greater.

Buffers on Major Streams

As discussed in the Introduction, vegetated buffers are valuable for the protection of water quality. They also enhance habitat by reducing stream temperatures and providing organic matter for the bottom of the food chain. One hundred feet on either side of a stream is a commonly-used buffer width; a literature review performed at the University of Georgia found that this was a sufficient width to trap sediment and nutrients and maintain aquatic habitat.^{xviii} The study emphasized, however, that buffers should be used in conjunction with on-site controls for the pollutants in question.

Because of the wealth of small streams in this region, the committee chose larger, third order streams as a feasible recommendation for stream buffering. The streams shown in the third cornerstone layers map are third order or greater. First-order streams are headwater streams, such as those seen arising from a spring or seep. A second-order stream begins when two first-order streams meet. A third-order stream, in turn, is formed when two second-order streams meet.

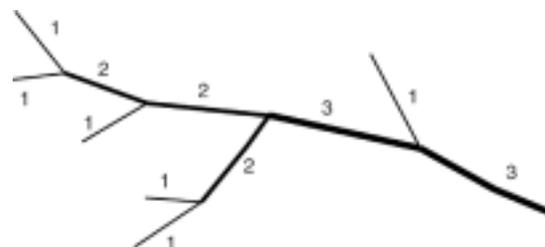


Figure 2. An Army Corps of Engineers diagram depicting stream order.

Existing Trails and Adopted Greenway/Trail Plans

As covered in the Introduction, access to nature is a critical factor in quality of life. Trails and parks are a popular means of providing this access. Depending on the width of vegetation surrounding them and their location, recreation areas may serve as habitat or water quality areas as well. For the purpose of the cornerstone layers, it was decided to include existing trails and plans for trails or greenways that have been adopted by the localities. There are many other proposed trails, but it was felt that those with locality backing were most likely to be constructed. The fourth cornerstone layers map shows the existing and adopted trails and greenways.

Protected Lands

Finally, the committee felt that it was important to show where land already has some level of protection. This includes federal lands, state lands, local parks and lands under conservation easement. The fifth cornerstone layers map shows the protected lands in the region. These protected lands can help to form the backbone of a green infrastructure network.

Composite Map

The sixth cornerstone layers map shows the cornerstone layers together on a single map. This forms the basis for the green infrastructure network for the region. Local reviews resulted in some changes on a locality-by-locality basis, which are reflected in the locality green infrastructure network maps. In Albemarle, the existing stream buffer ordinance is more comprehensive than the buffers proposed in this document, and so the buffers already prescribed by local ordinance are shown.

Green Infrastructure Networks by Locality

Albemarle County and City of Charlottesville

The draft network for Albemarle County and the City of Charlottesville was reviewed by County and City staff. It was agreed to add the Charlottesville parks in green. City staff will check on the status of the Ragged Mountain and Sugar Hollow reservoirs, both of which are City-owned. In Albemarle, the existing and proposed trails were reviewed for accuracy. An additional recommendation was to identify places within the county as locator points. It was agreed that this Study is a “point-in-time” study: An update to the County’s conservation easements will not be made until after completion of this Study and a land cover map of the County is not expected to be completed until Spring, 2010. As Albemarle County updates its Comprehensive Plan, this Study will help inform the Natural Resources Plan.

Fluvanna County

The proposed green infrastructure network was reviewed with Fluvanna County staff and members of the Board of Supervisors. It was suspected that some steep slopes may have been missed in Fluvanna, especially along stream corridors, because of the coarse nature of the elevation coverage used by the TJPDC (30 meter pixels). Fluvanna County staff supplied a more refined elevation coverage. It was also noted that some conservation easements were missing, and these were added. Finally, there were three relatively undeveloped stream corridors for which TJPDC staff were asked to look at the land cover to determine if they could be included. Most areas in these corridors did appear to contain suitable habitat (in many cases, they passed through lower-ranked VCLNA cores) and were added. The green infrastructure network resulting from this review is shown on the Fluvanna County map.

Greene County

In Greene County, the proposed network was reviewed by County staff and a member of the Board of Supervisors before being presented at an open house for the Greene County Comprehensive Plan on June 30, 2009, which also featured displays showing how green infrastructure supports many Comprehensive Plan goals. In the review prior to the open house, it was noted that the VCLNA corridor that ran through Greene actually passed through several subdivisions, rendering it impractical. Several alternate potential corridors were sketched. TJPDC staff then reviewed the Greene County parcel map in conjunction with VCLNA lower-ranked cores and a general forest cover map obtained from the Virginia Department of Forestry (dated 2005) to determine which of the alternate corridors was most suitable, and a corridor in the southern portion of the county was selected. Some core area boundaries were also adjusted as the result of conflicts with existing subdivisions. Staff was also requested to add a corridor along the Rapidan River, which forms the northern border of the county, for drinking water protection purposes. This river is currently the sole public drinking water source for the county.

Louisa County

The Louisa County green infrastructure network was reviewed by planning staff from Louisa County, but no changes were suggested. A close-up of the proposed green infrastructure network for Louisa County is shown on the county's map.

Nelson County

TJPDC staff met with Nelson County planning staff and a member of the Board of Supervisors to review the green infrastructure network for Nelson County. There were a couple of subdivisions that were observed to be within the habitat corridors, and the corridor borders were adjusted to reflect those. The map will also be presented to the Board of Supervisors at their September 8 meeting for further comment.

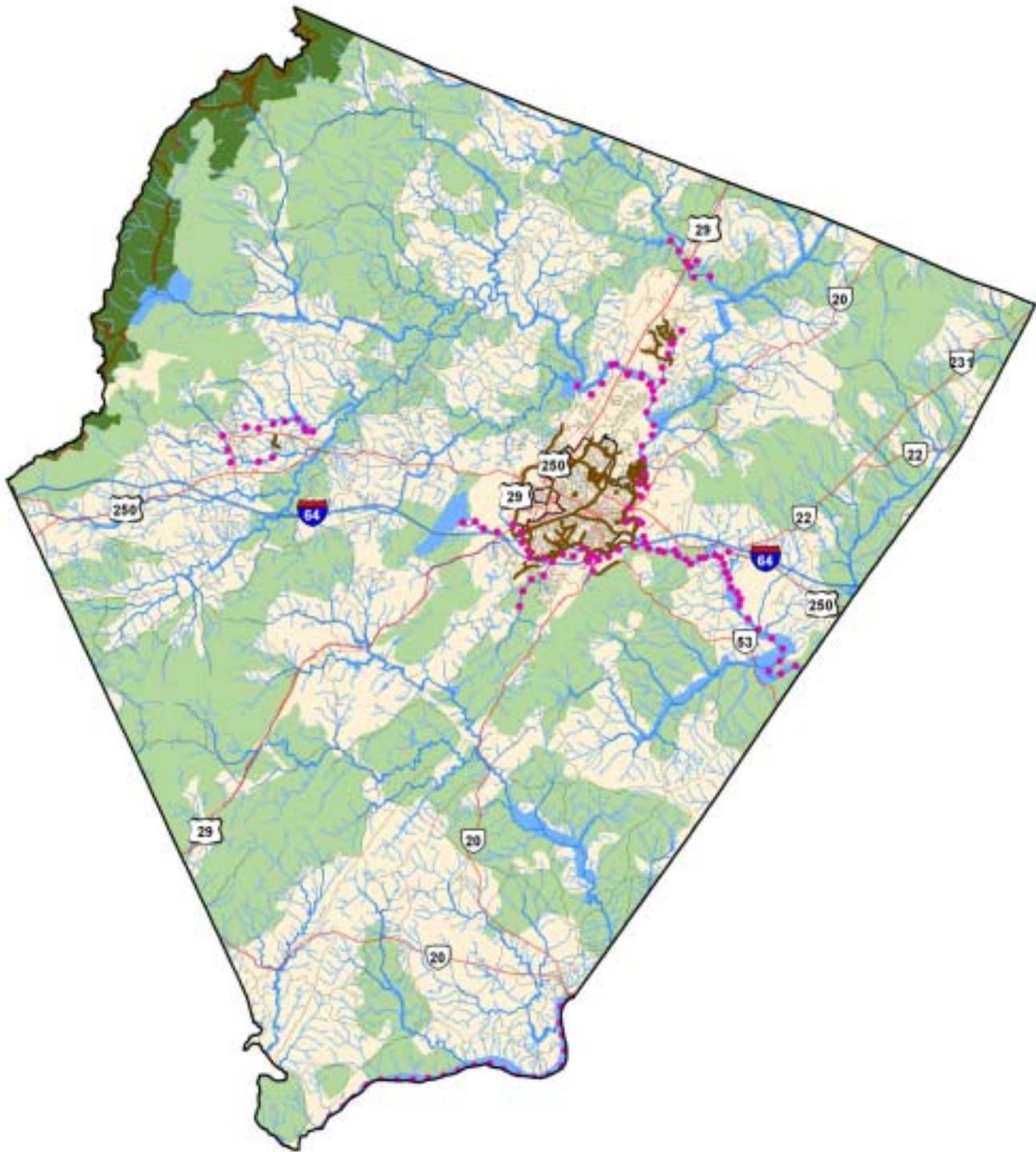
Green Infrastructure Network Map

For each locality, the green infrastructure network resulting after local reviews is shown on a composite map of environmental areas of opportunity. The map reflects some changes from the composite map of the cornerstone layers, but still presents a cohesive system of hubs, corridors, and sites. Maps for each locality included on the following pages include:

- Composite Map of Environmental Areas of Opportunity
- Combined Habitat Layers
- Steep Slopes
- Third Order Stream Buffers
- Trails
- Protected Lands
- Combined Cornerstone Layers



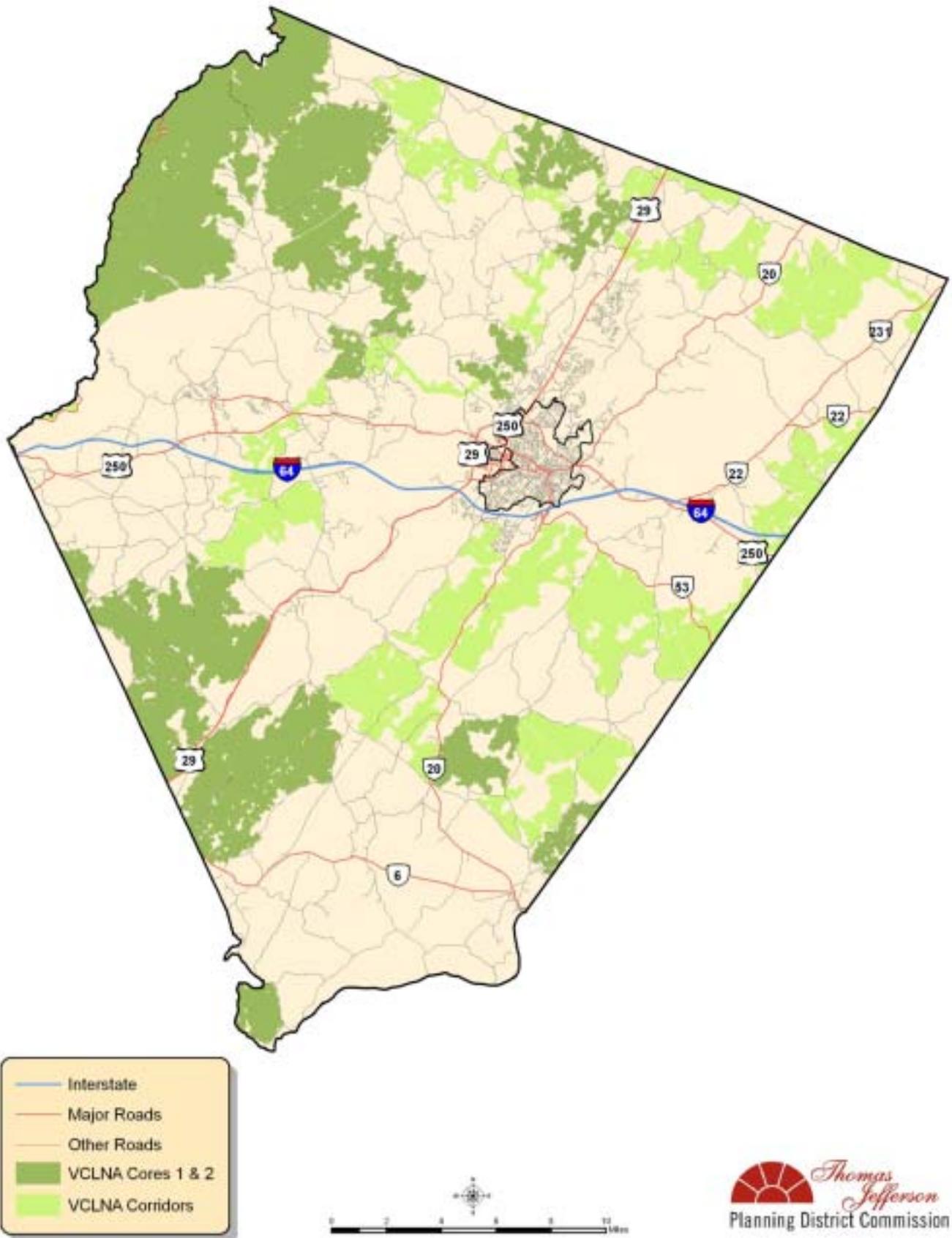
Albemarle County Environmental Areas of Opportunity



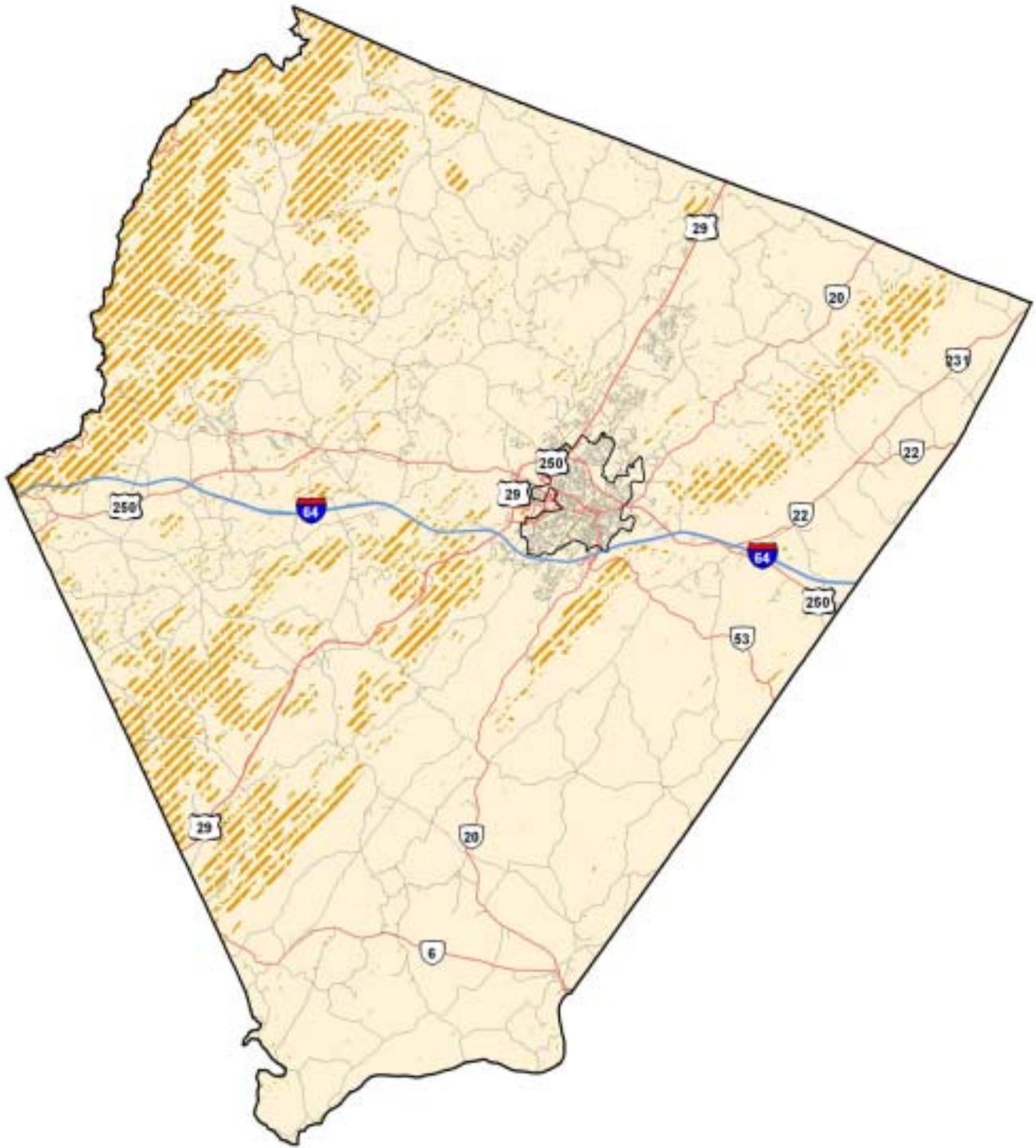
●●●●●	Albemarle Proposed Trails	■	300' or Greater Stream Buffers
—	Existing Trails	■	Water Protection Ordinances
—	Interstate	■	Federal and State Conservation Lands
—	Major Roads	■	Environmental Areas of Opportunity
—	Other Roads		



Albemarle County Combined Habitat Layers



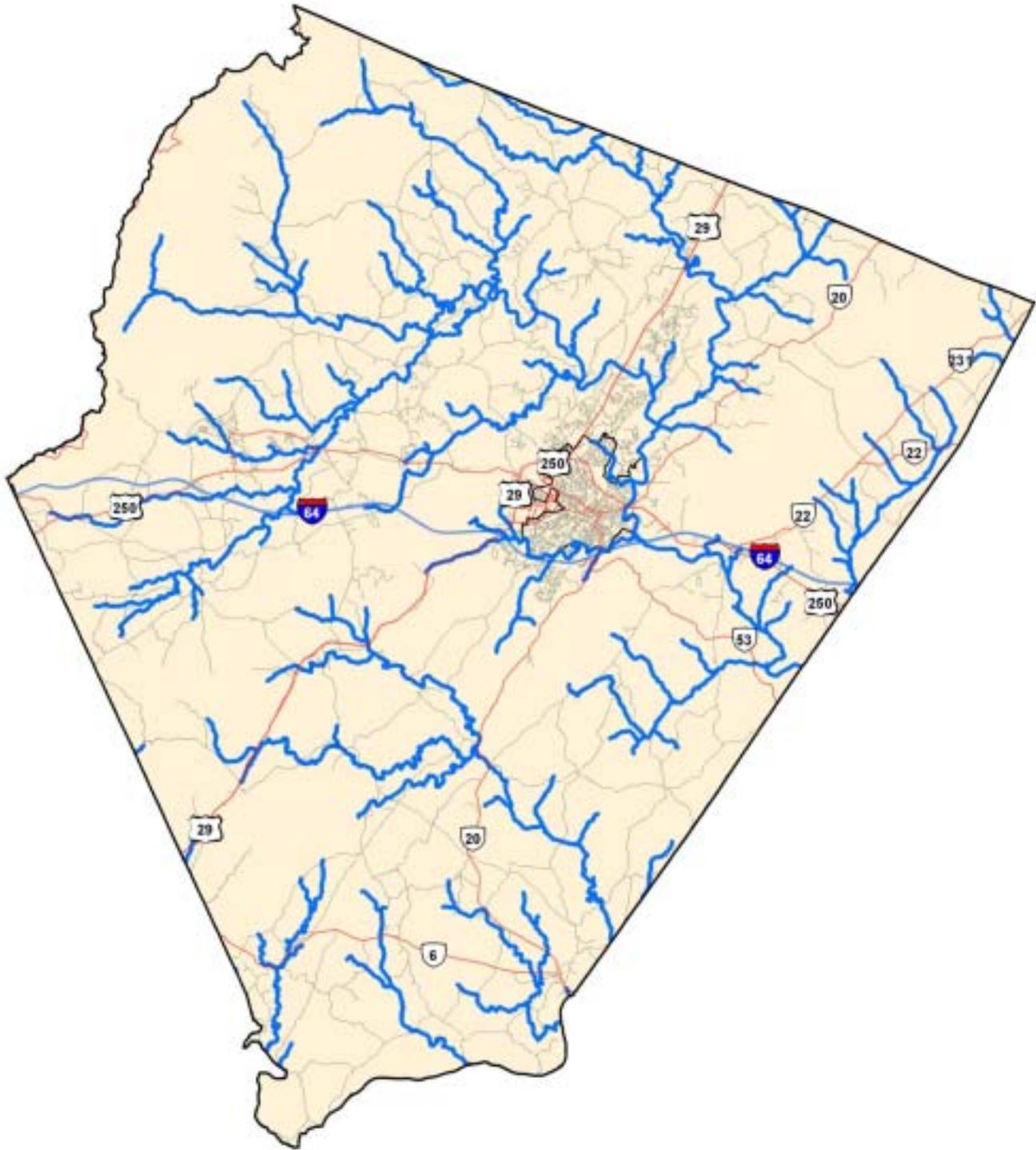
Albemarle County Steep Slopes



- Interstate
- Major Roads
- Other Roads
- ▨ Slopes Greater Than or Equal to 25%



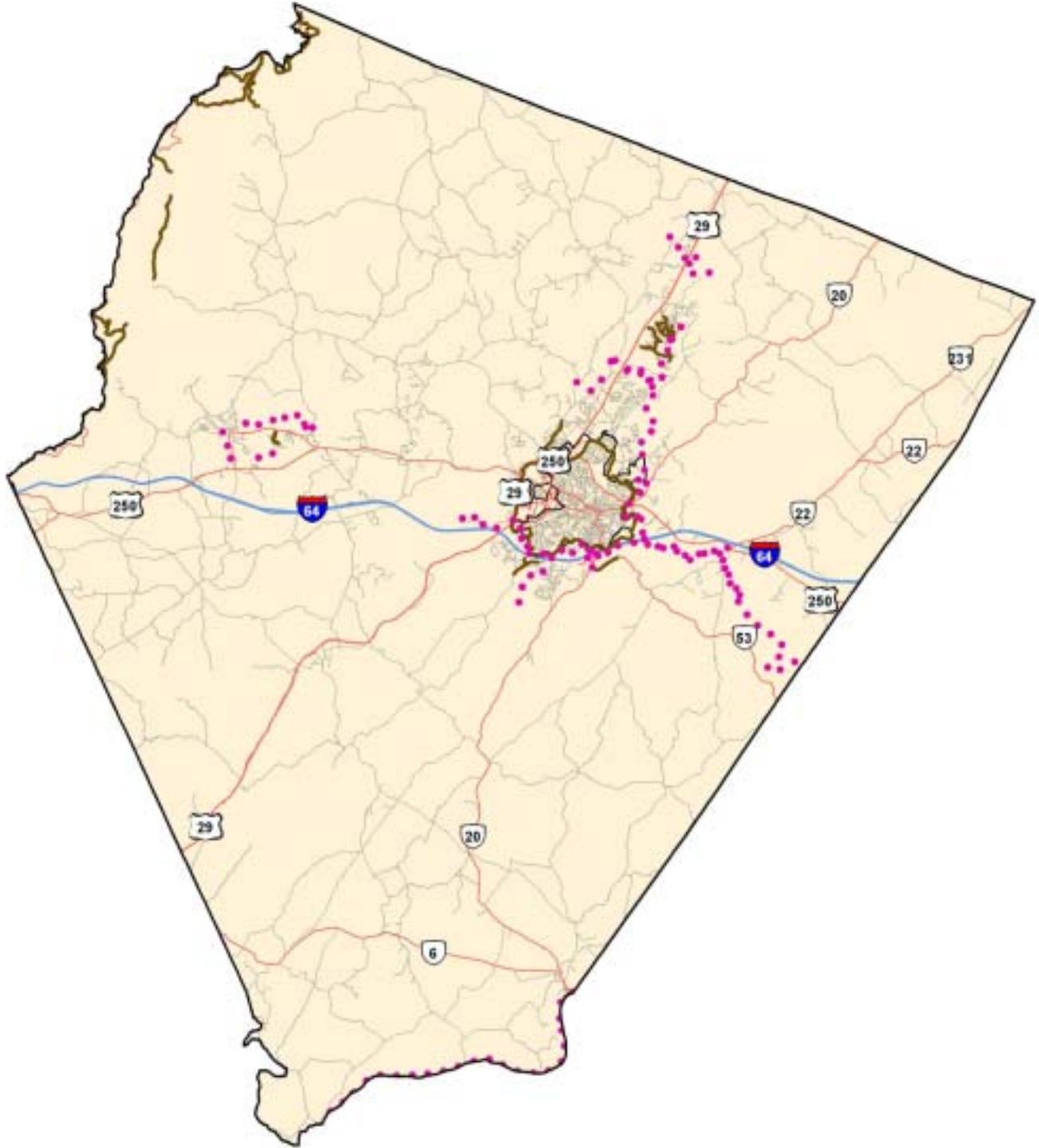
Albemarle County 3rd Order Stream Buffers



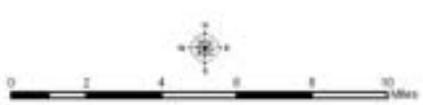
- Interstate
- Major Roads
- Other Roads
- 3rd Order Streams



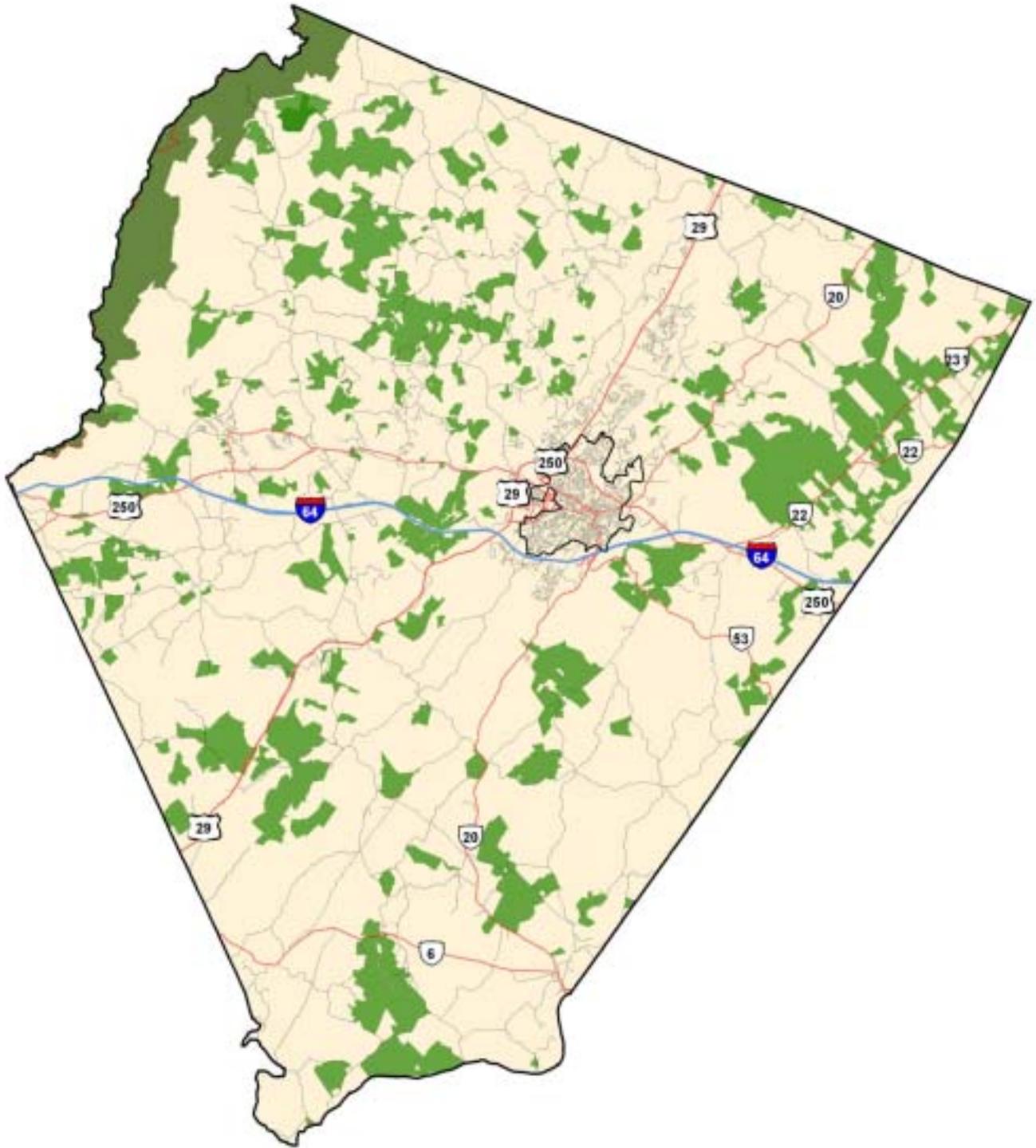
Albemarle County Trails



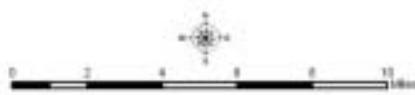
- Alternate Proposed Trails
- Existing Trails
- Interstate
- Major Roads
- Other Roads



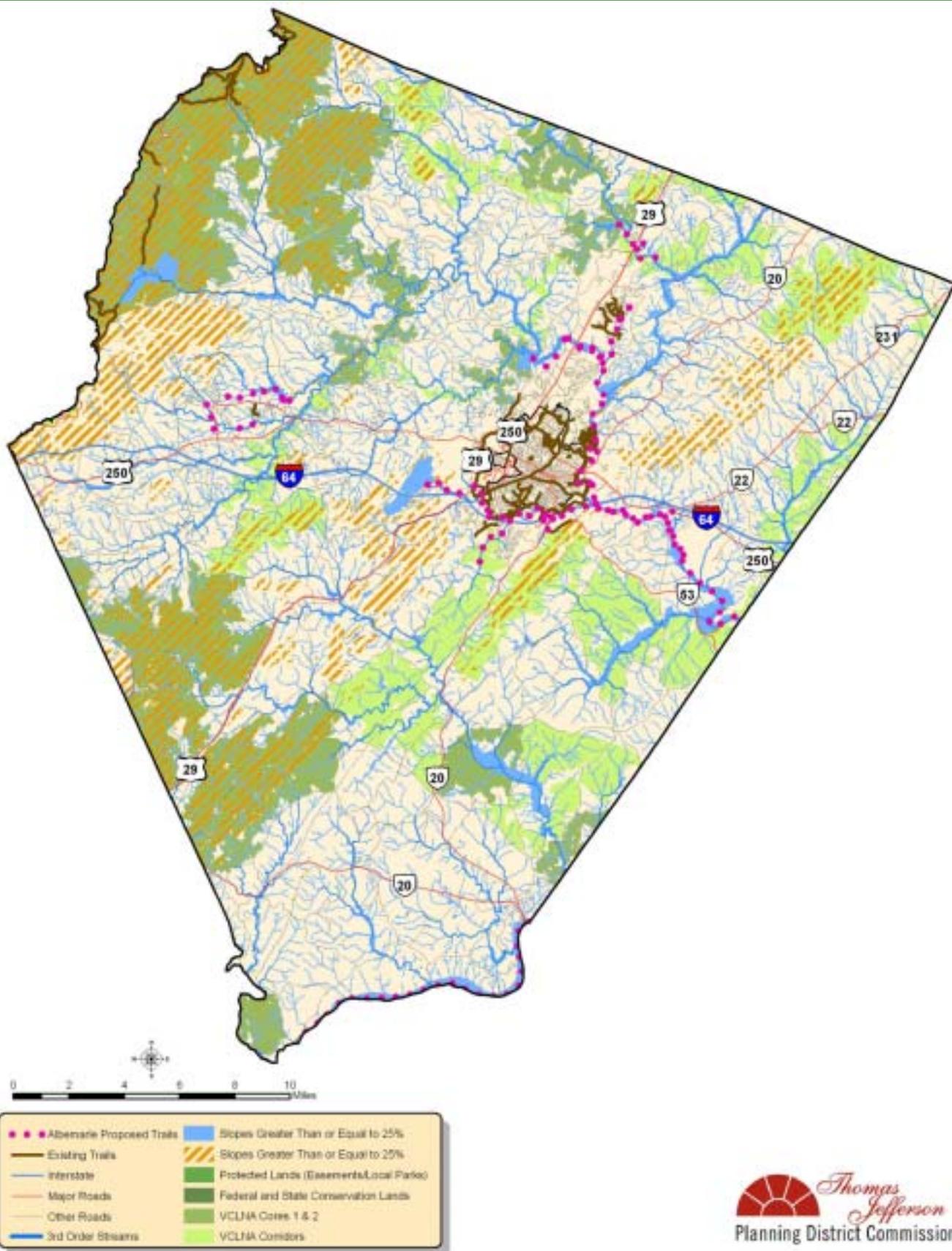
Albemarle County Protected Lands



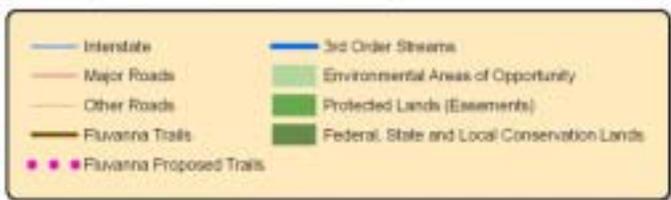
- Interstate
- Major Roads
- Other Roads
- Protected Lands (Easements/Local Parks)
- Federal and State Conservation Lands



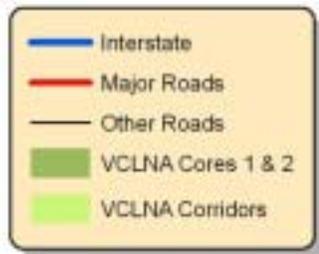
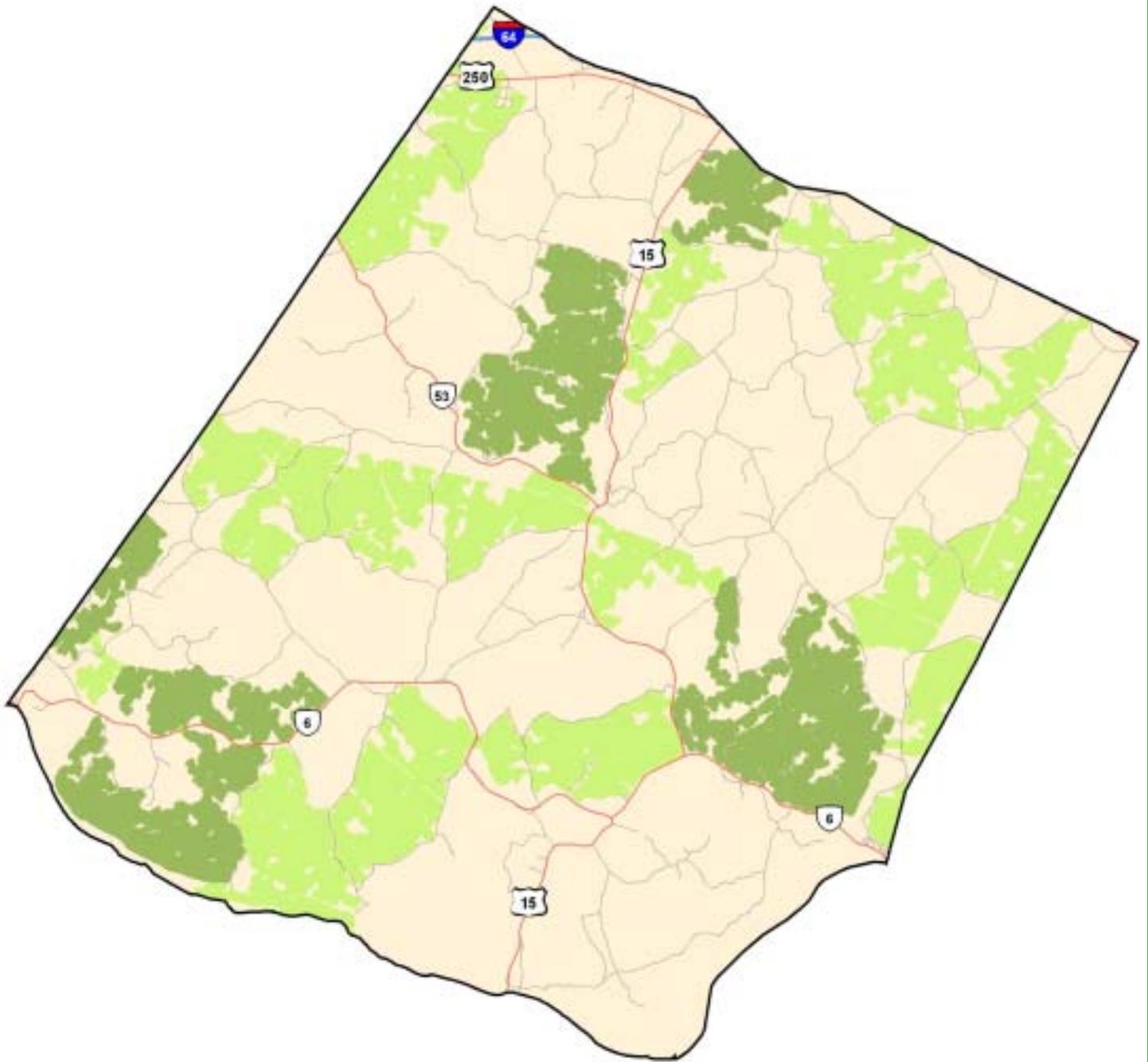
Albemarle County Cornerstone Layers



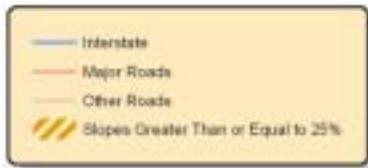
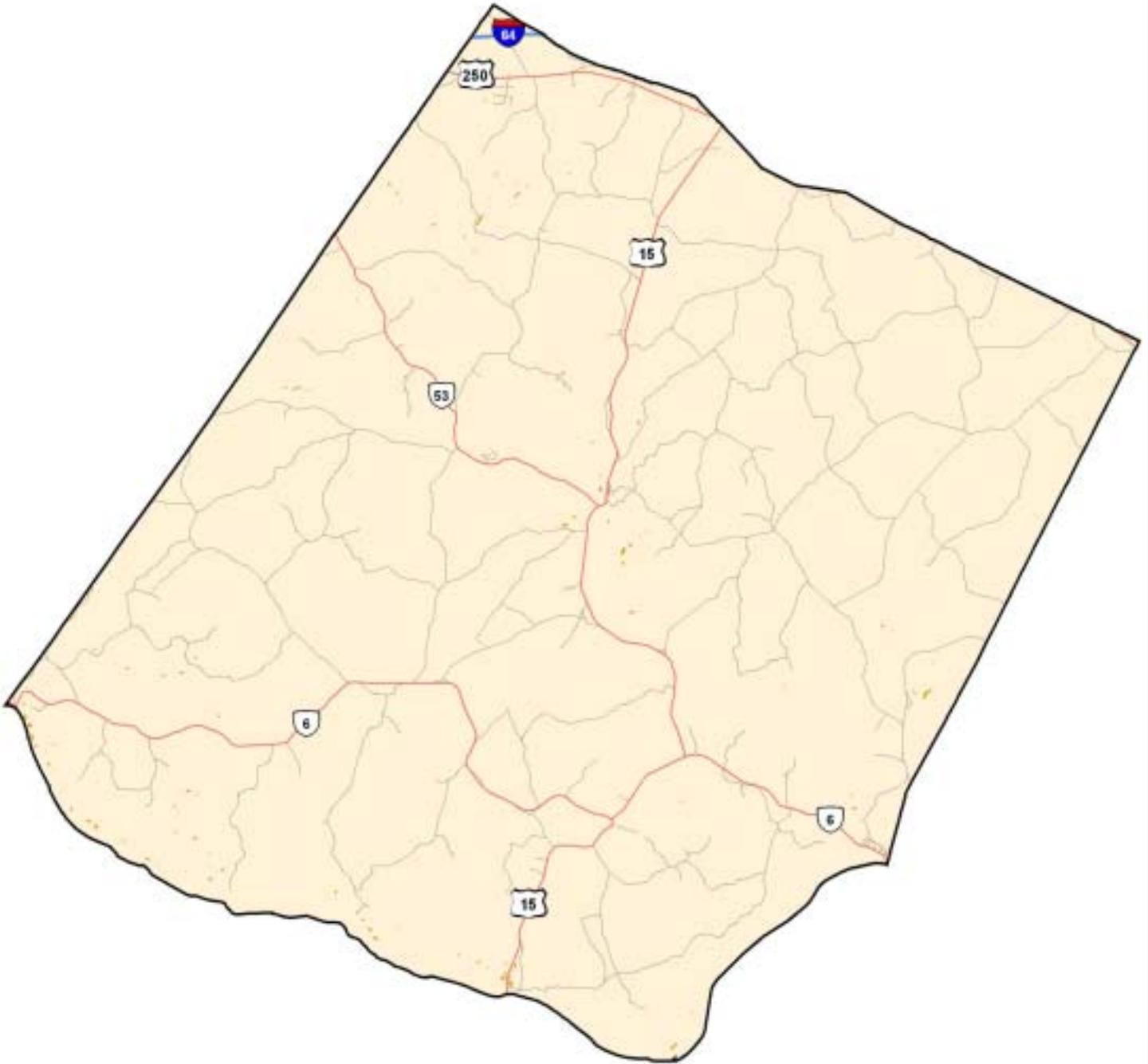
Fluvanna County Environmental Areas of Opportunity



Fluvanna County Combined Habitat Layers



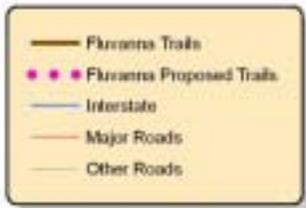
Fluvanna County Steep Slopes



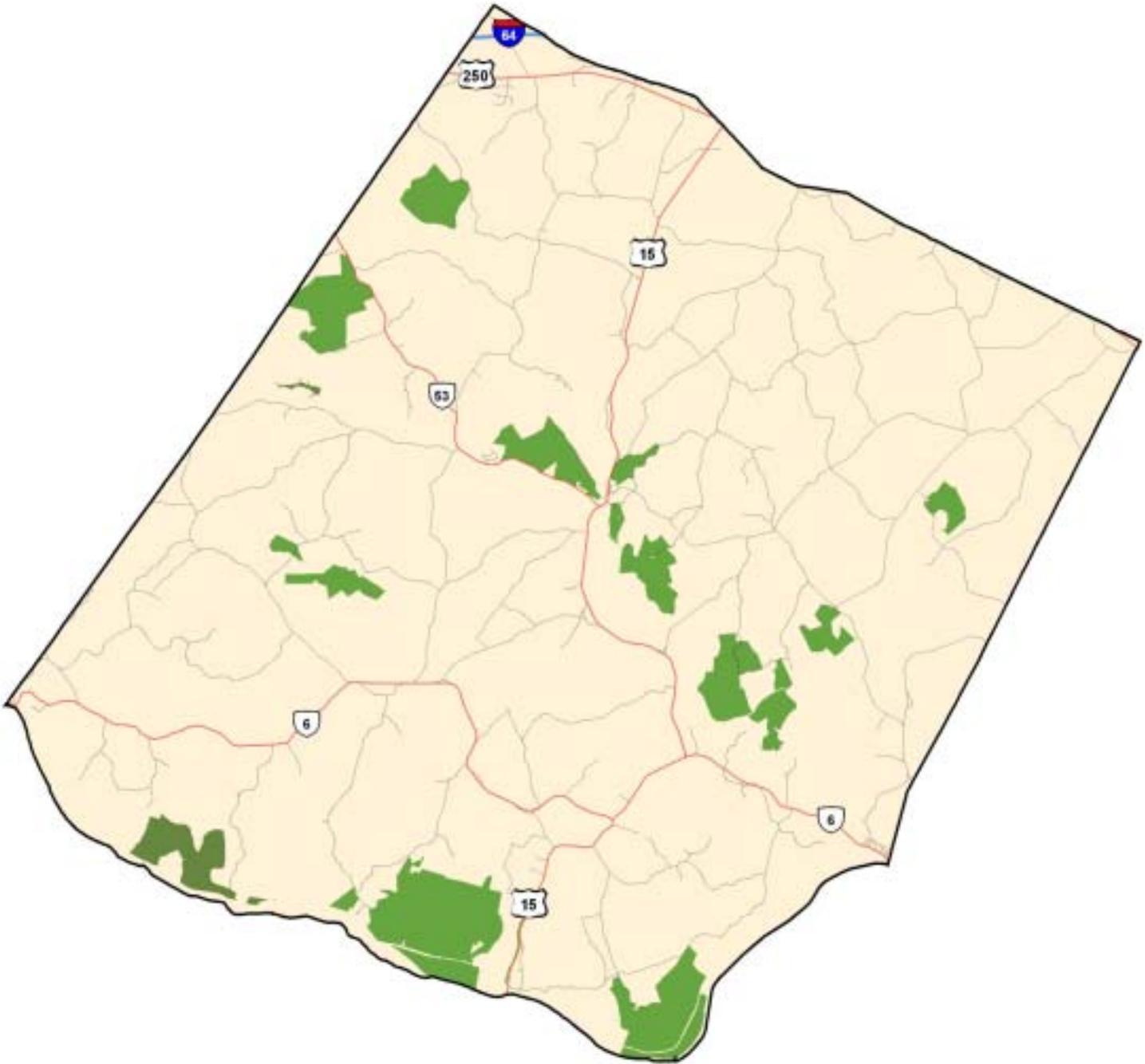
Fluvanna County 3rd Order Stream Buffers



Fluvanna County Trails



Fluvanna County Protected Lands



	Interstate
	Major Roads
	Other Roads
	Protected Lands (Easements/Local Parks)
	Federal and State Conservation Lands



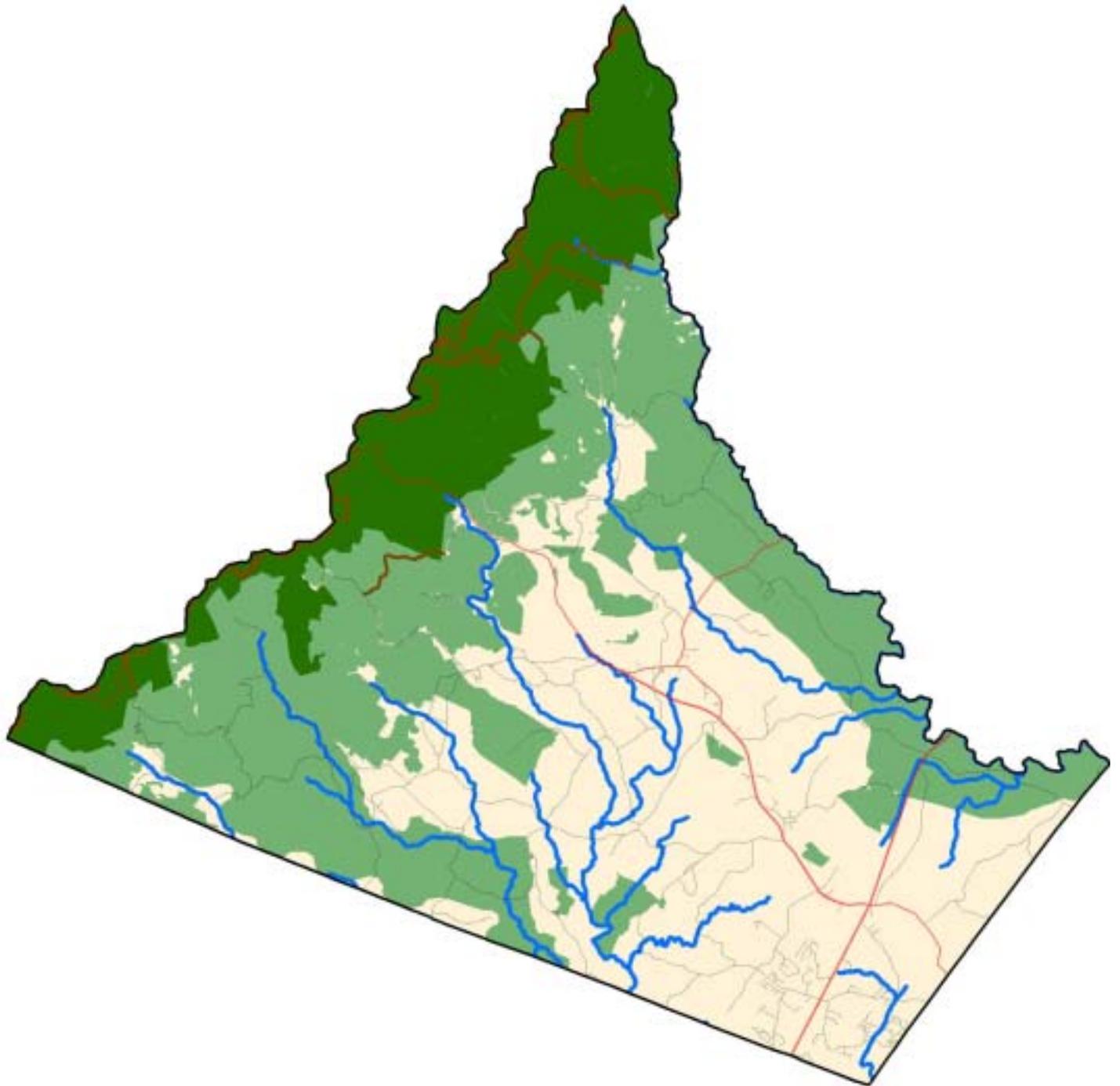
Fluvanna County Cornerstone Layers



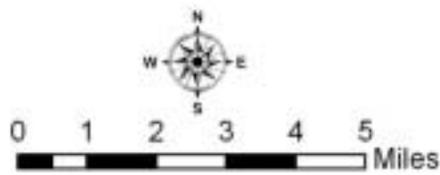
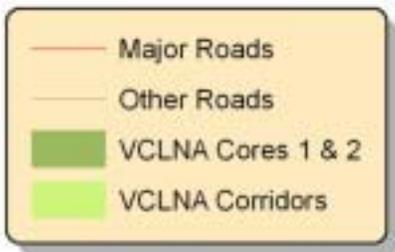
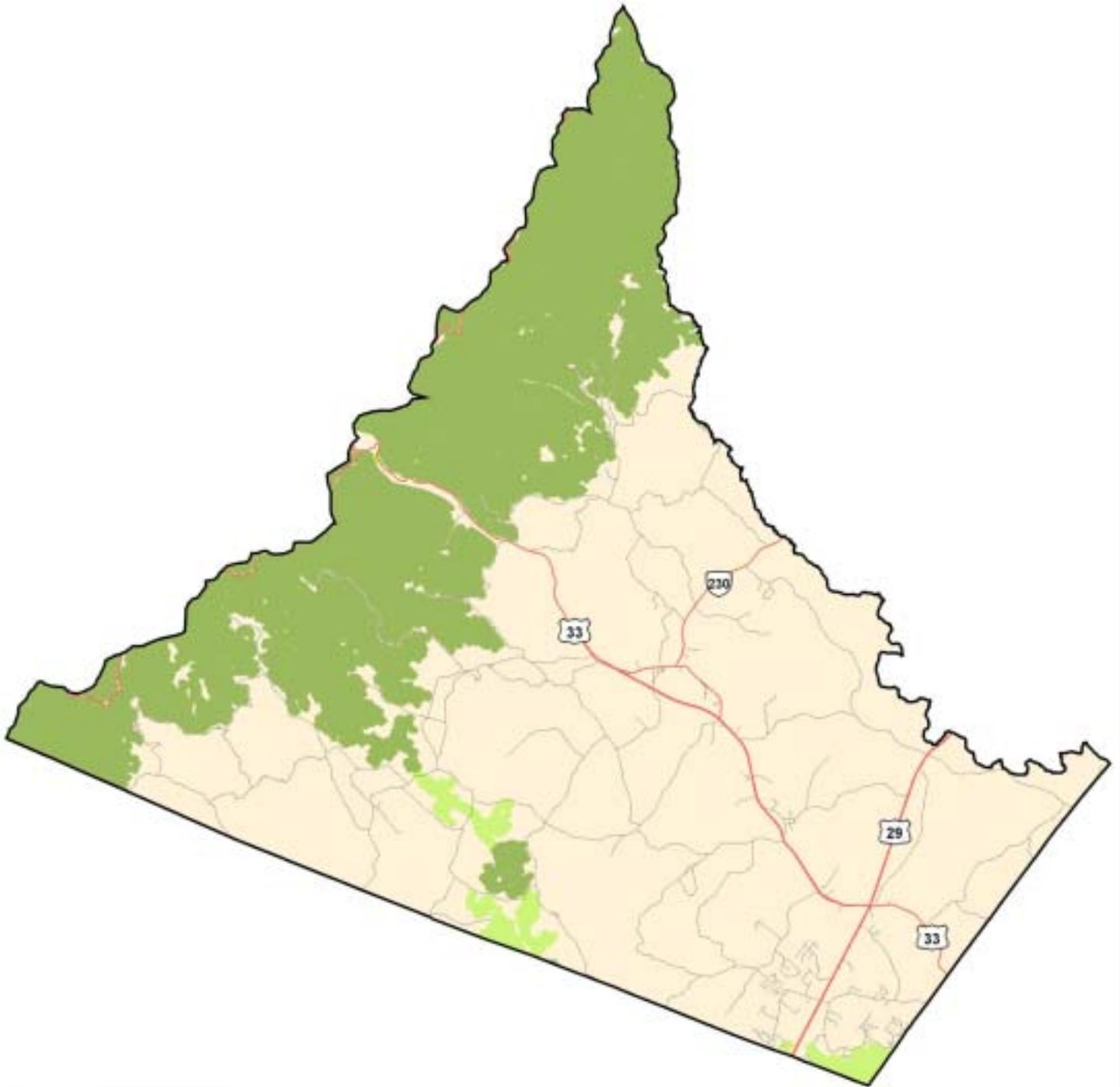
Fluvanna Trails	Water Body
Fluvanna Proposed Trails	Slopes Greater Than or Equal to 20%
3rd Order Streams	Protected Lands (Easements/Local Parks)
Interstate	Federal and State Conservation Lands
Major Roads	VCLNA Cores 1 & 2
Other Roads	VCLNA Corridors



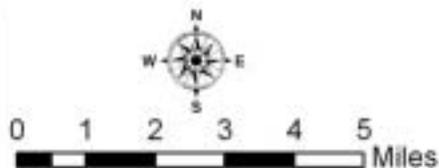
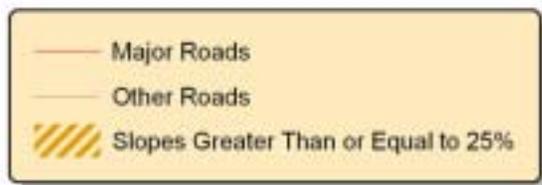
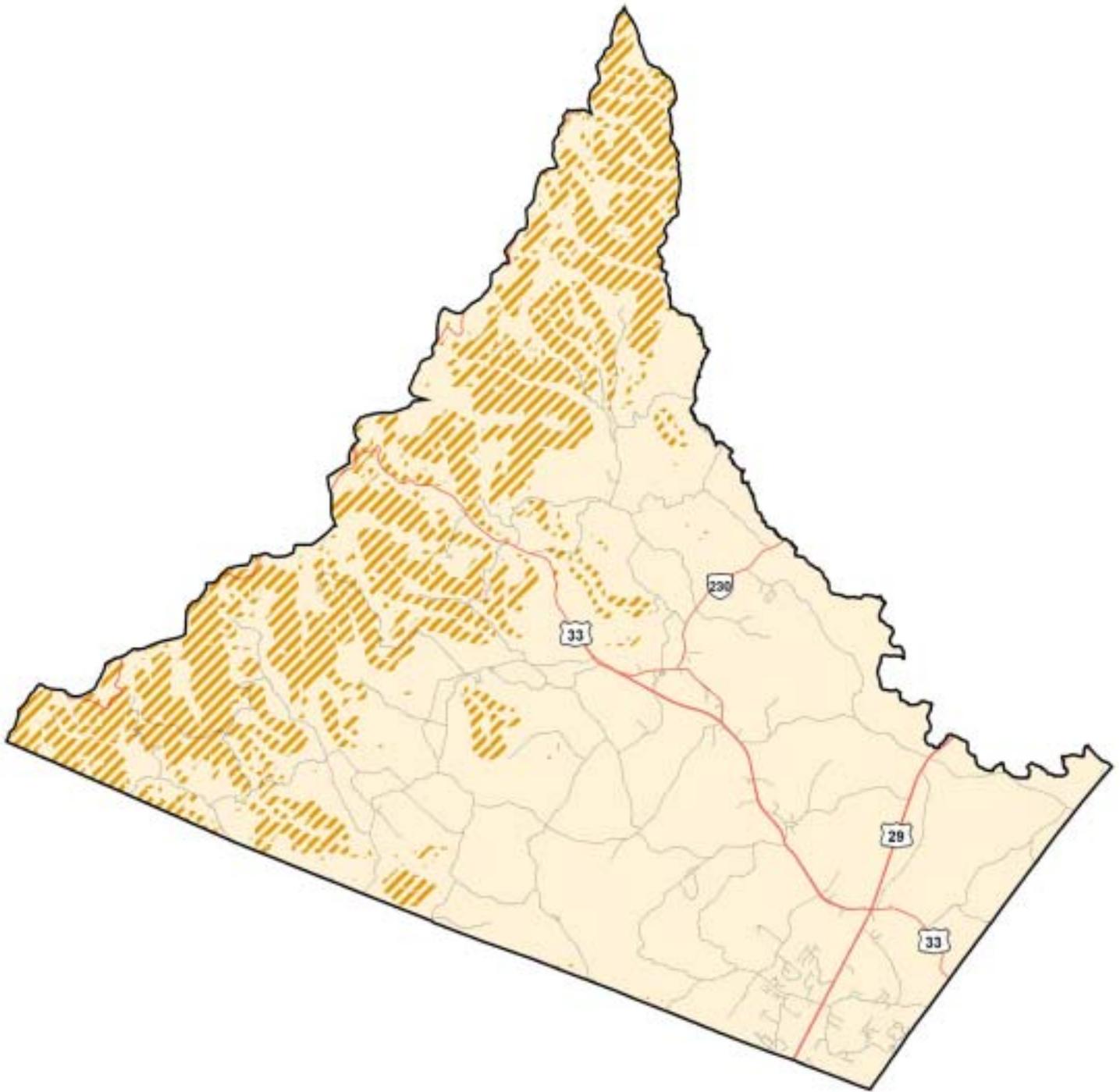
Greene County Environmental Areas of Opportunity



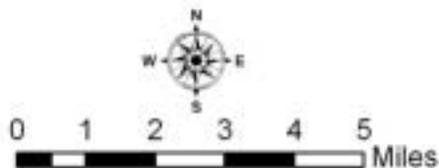
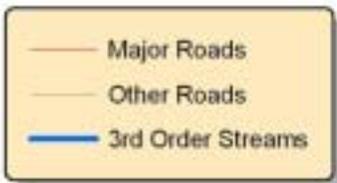
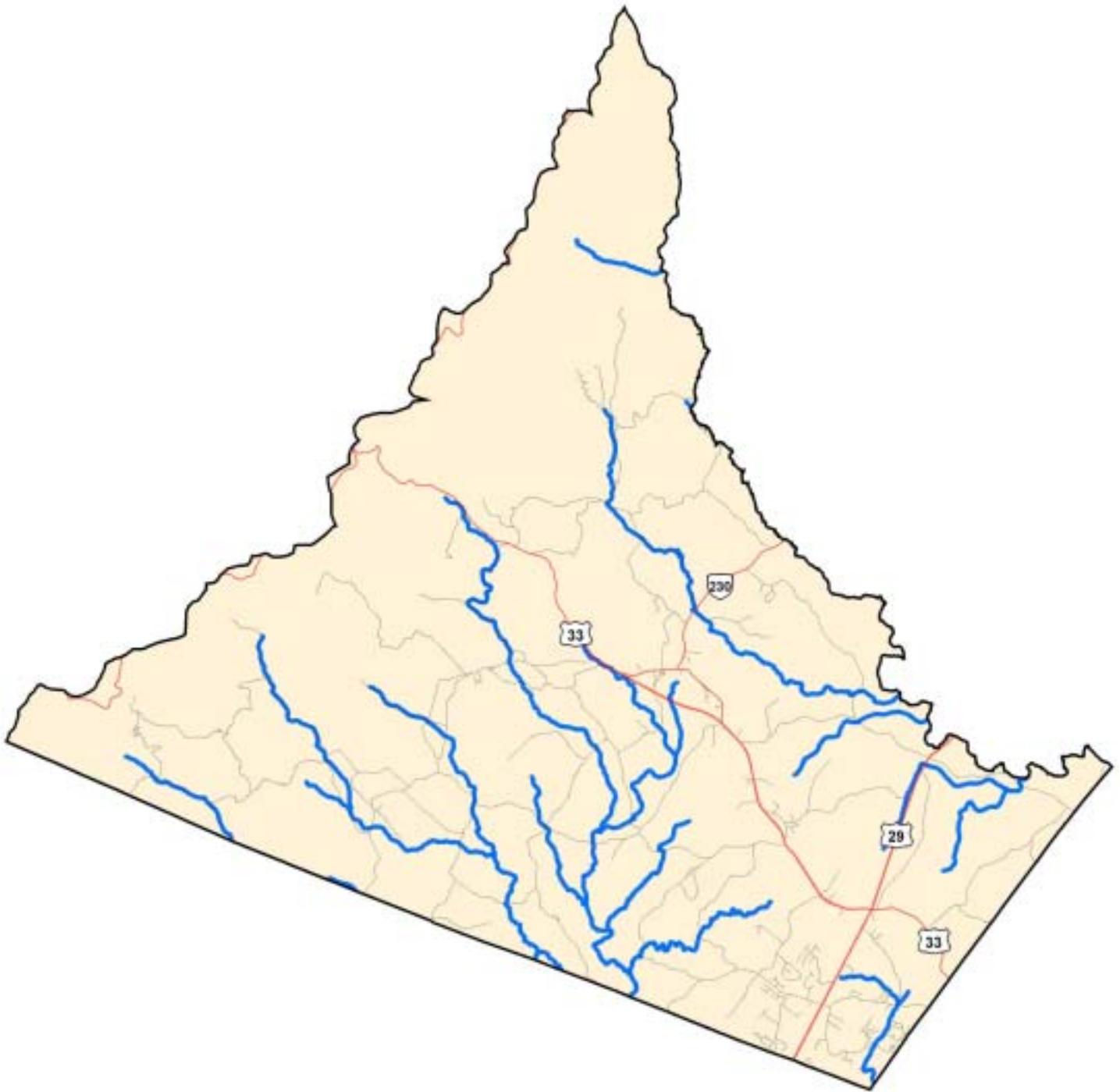
Greene County Combined Habitat Layers



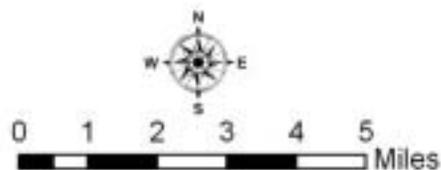
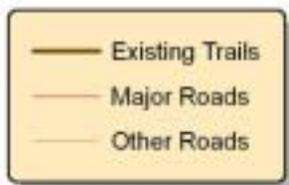
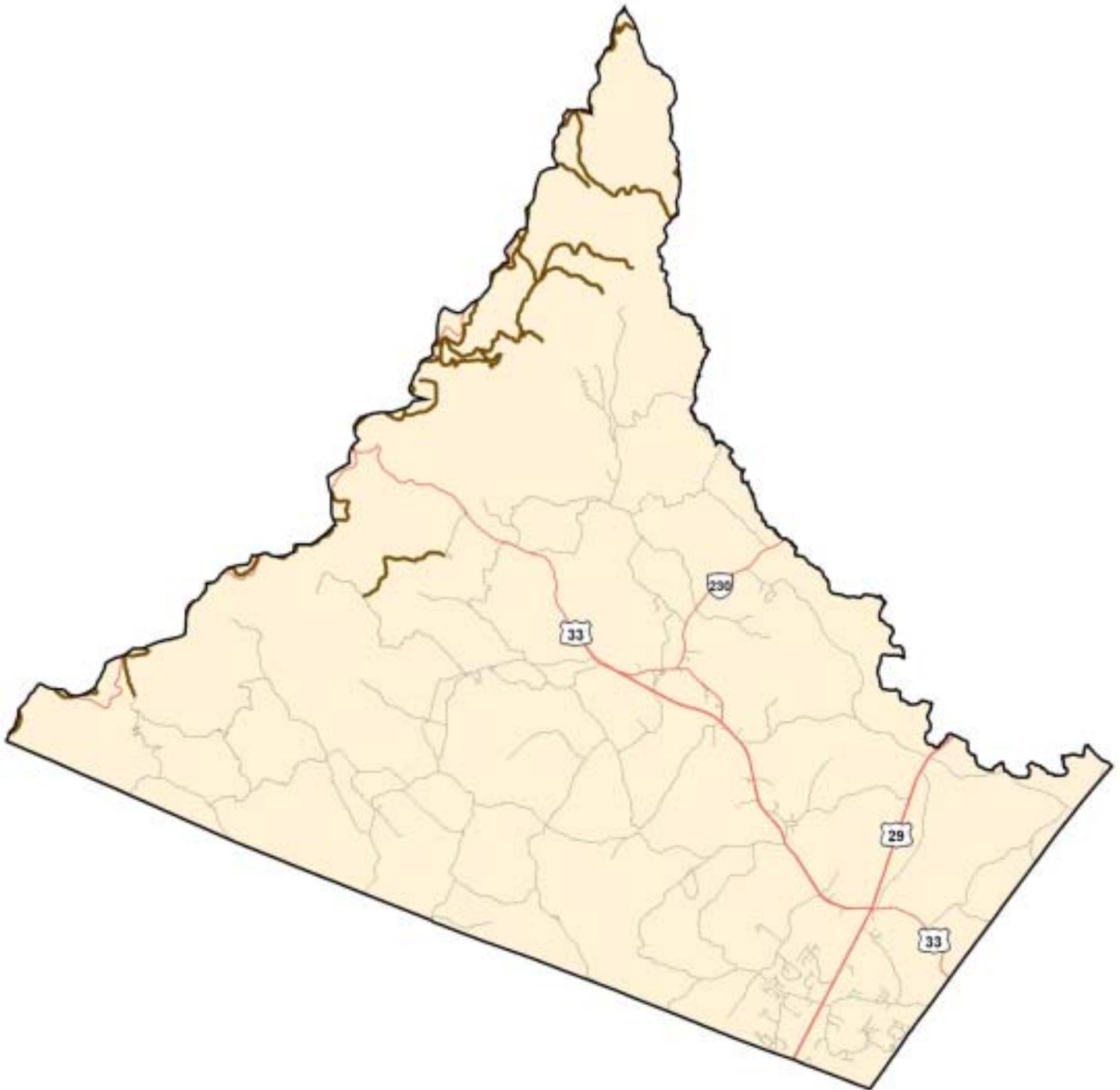
Greene County Steep Slopes



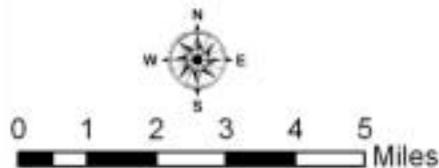
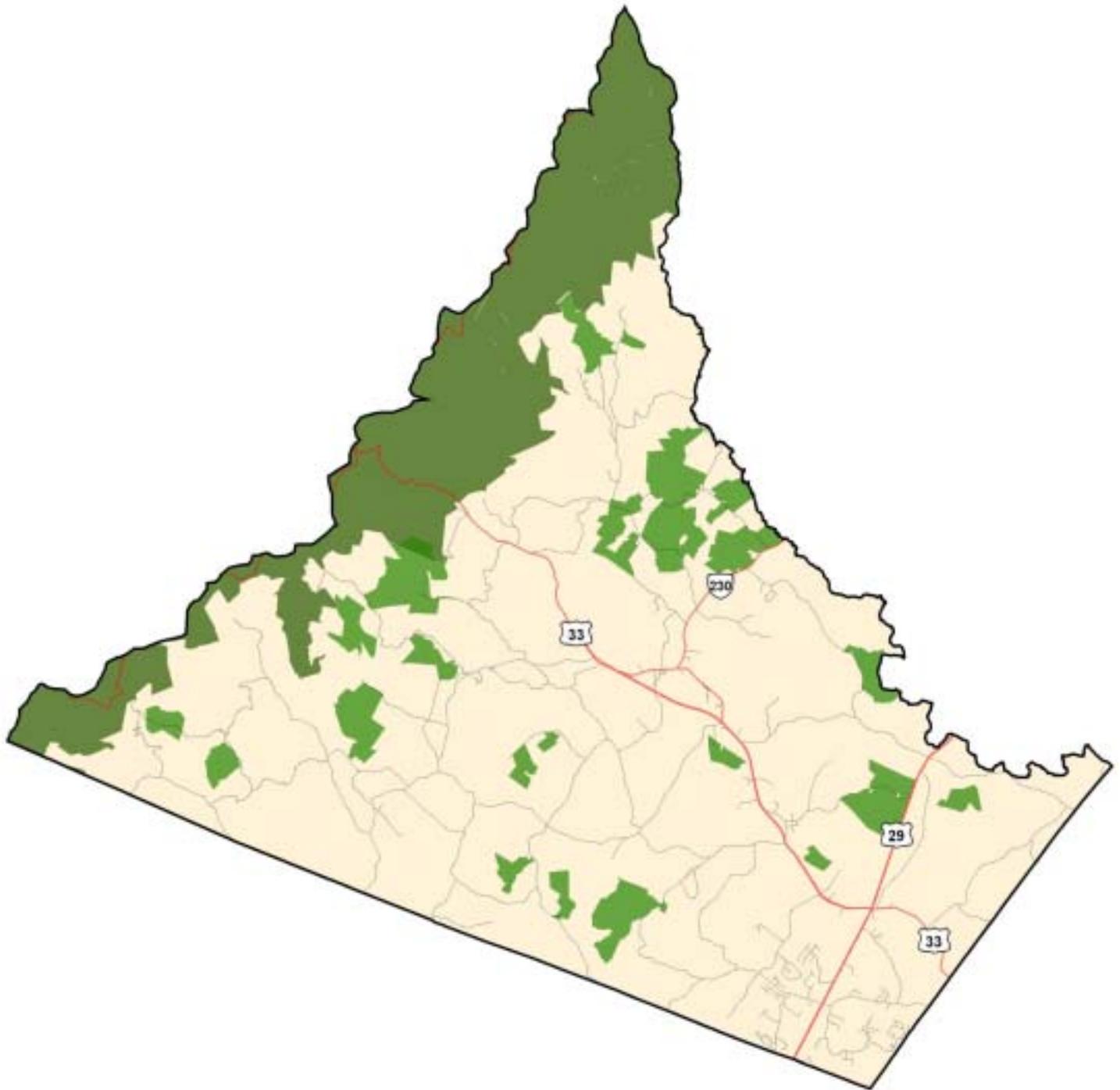
Greene County 3rd Order Stream Buffers



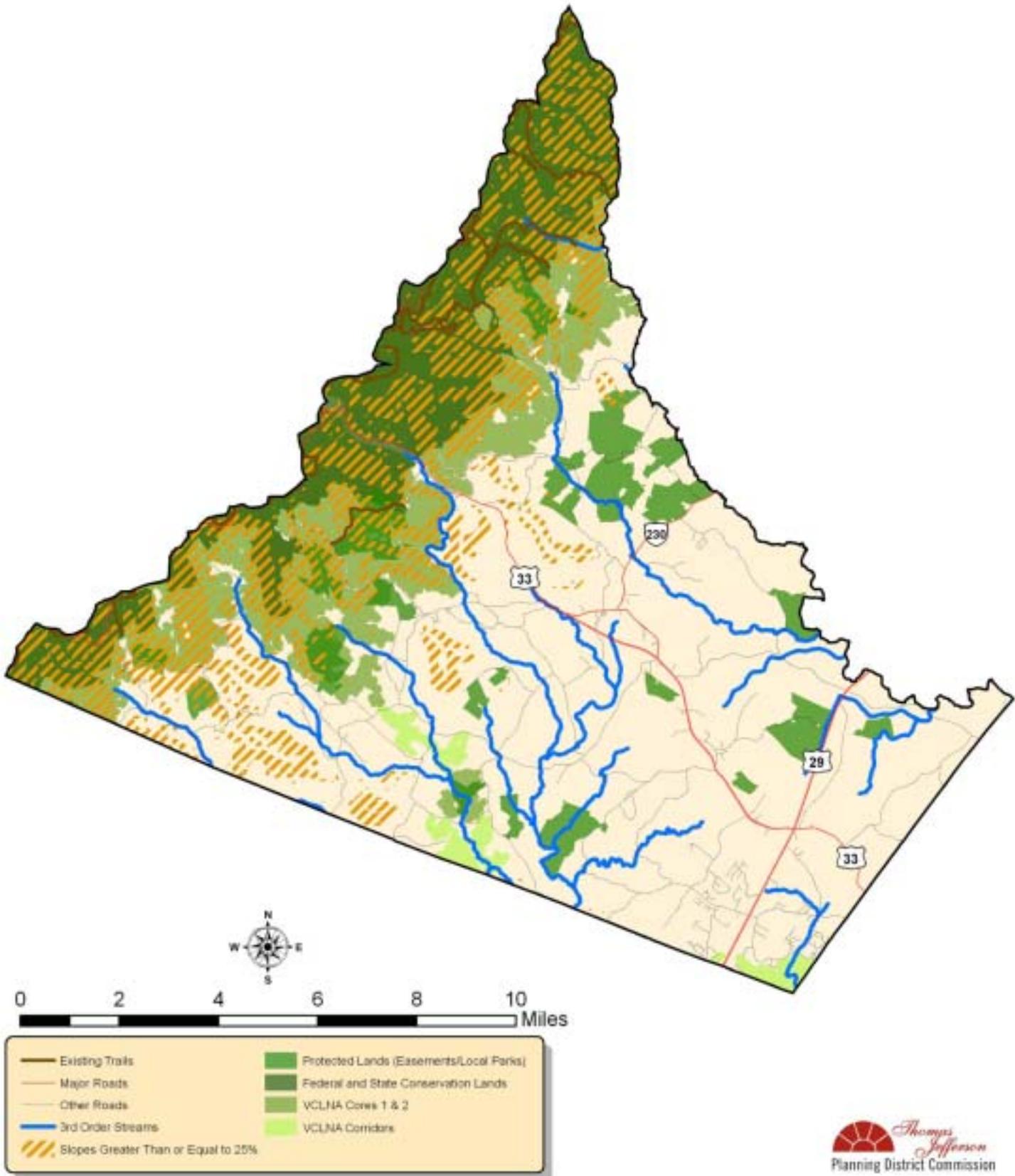
Greene County Trails



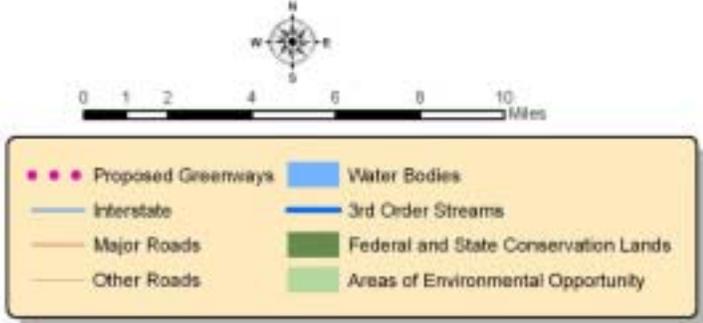
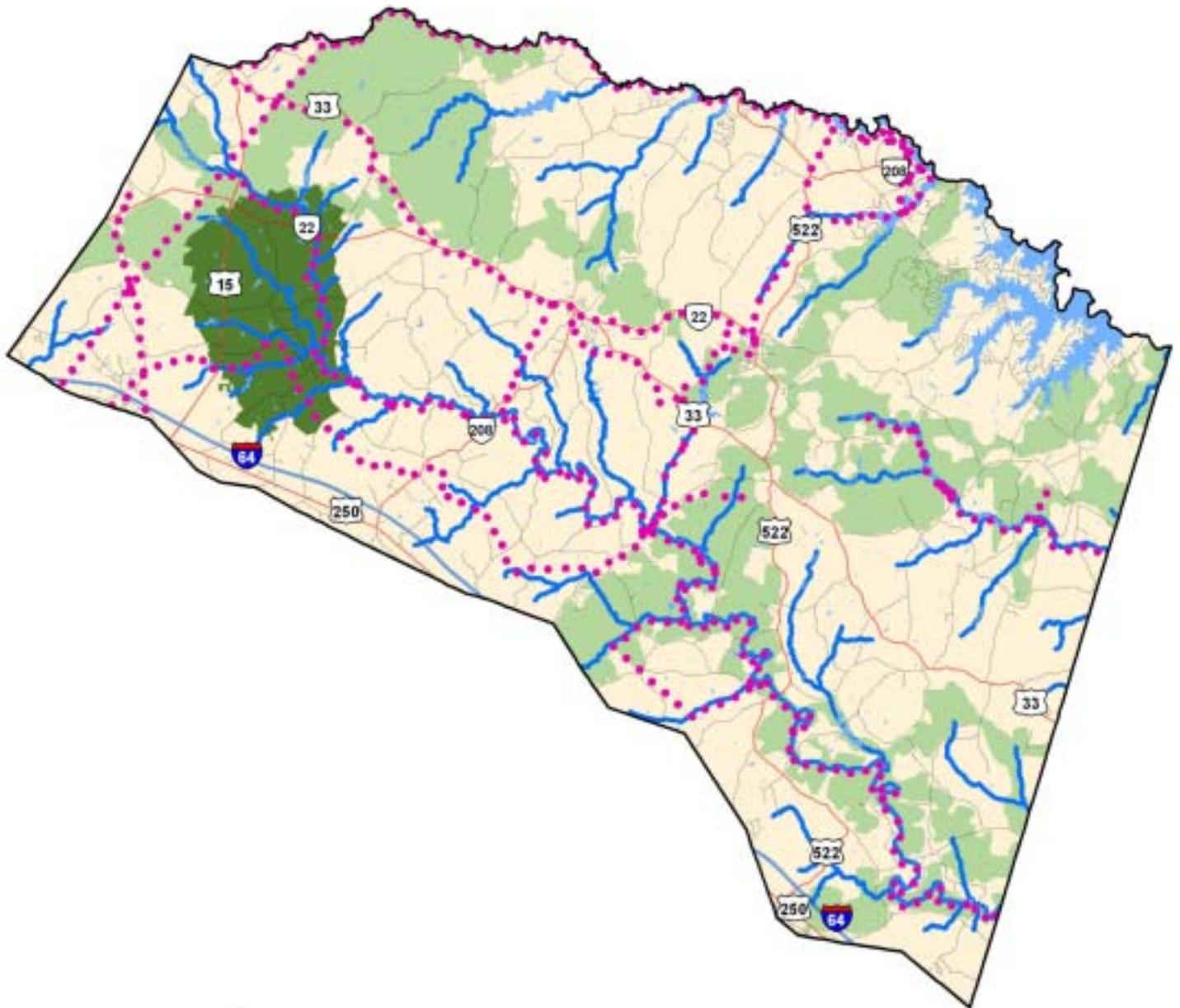
Greene County Protected Lands



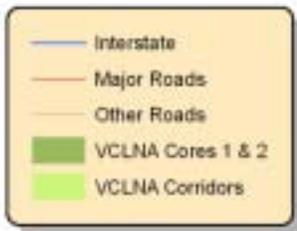
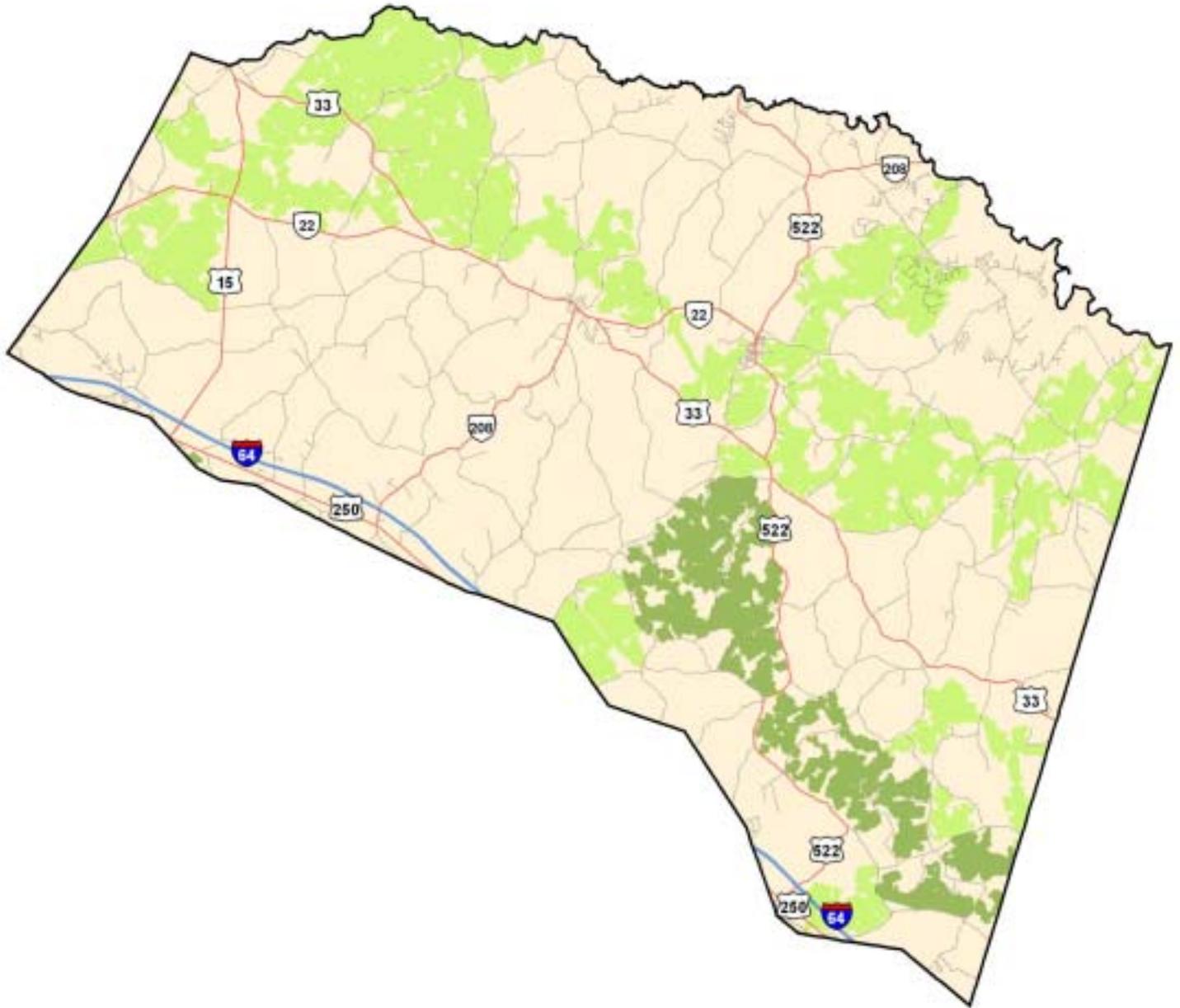
Greene County Cornerstone Layers



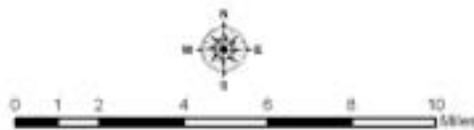
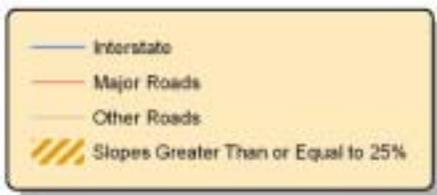
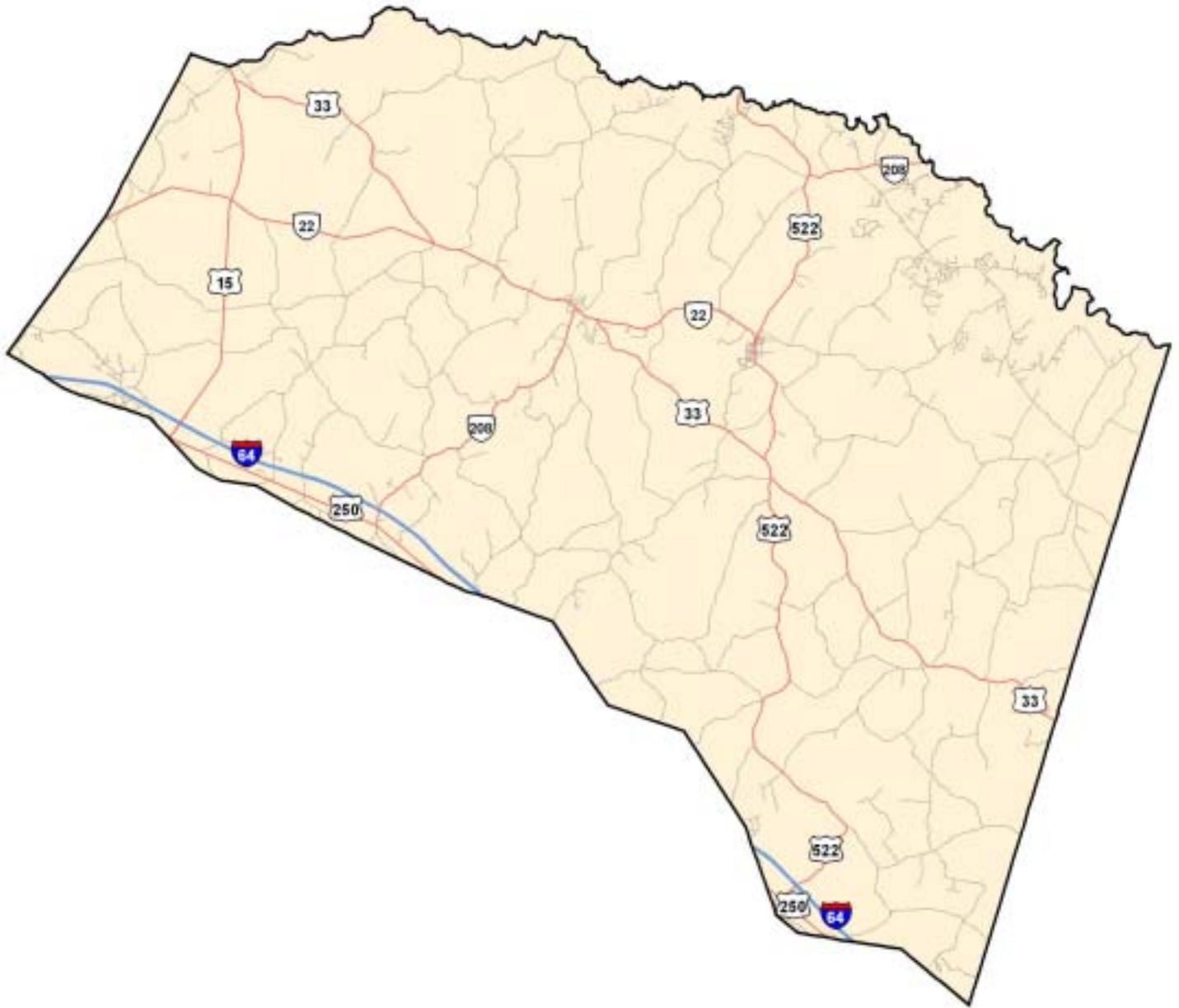
Louisa County Environmental Areas of Opportunity



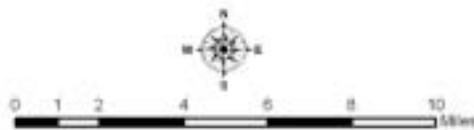
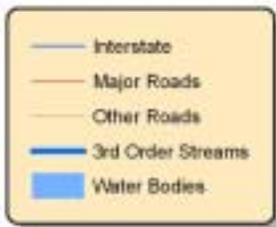
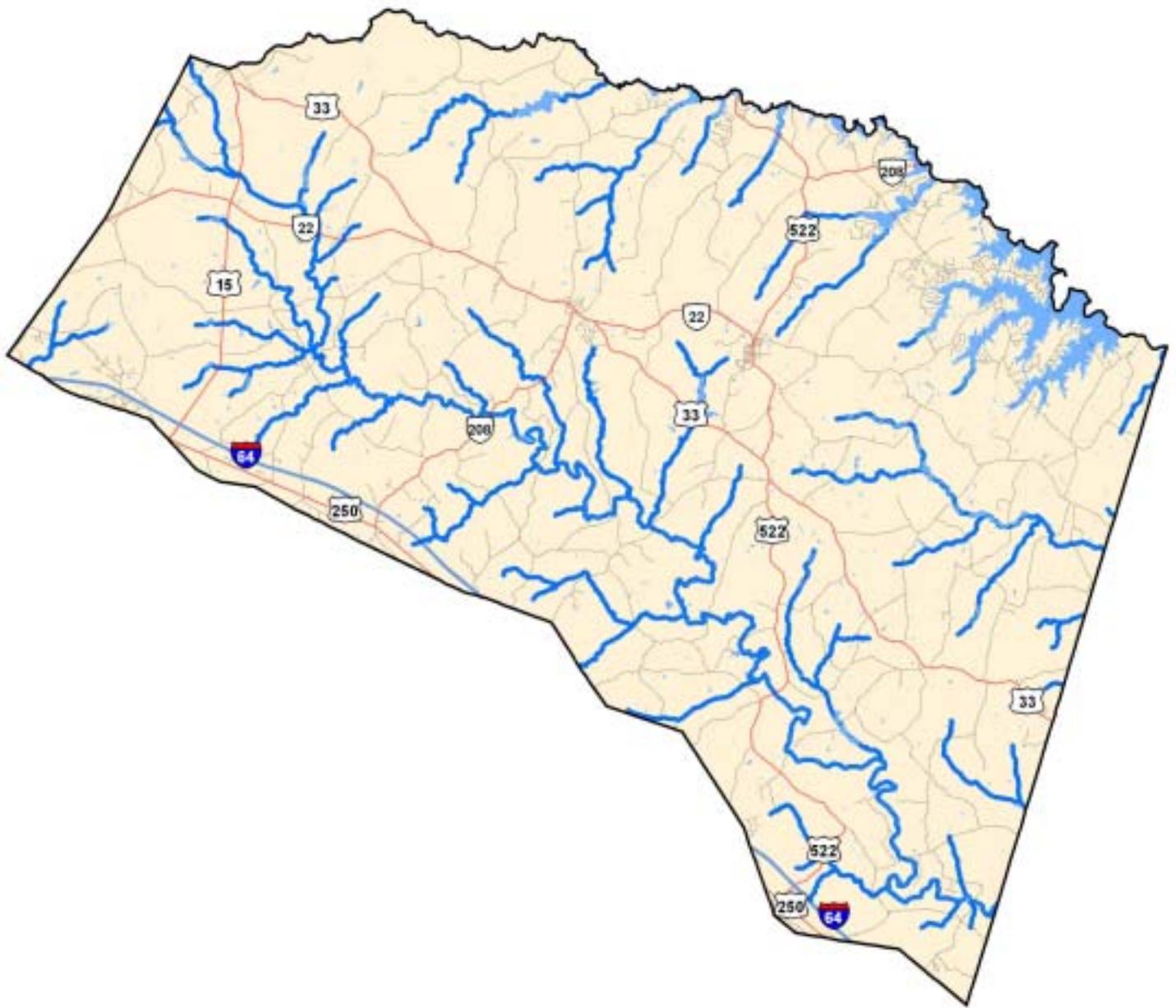
Louisa County Combined Habitat Layers



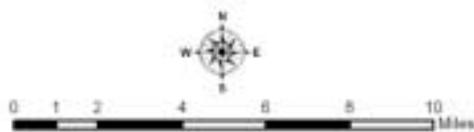
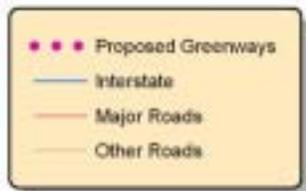
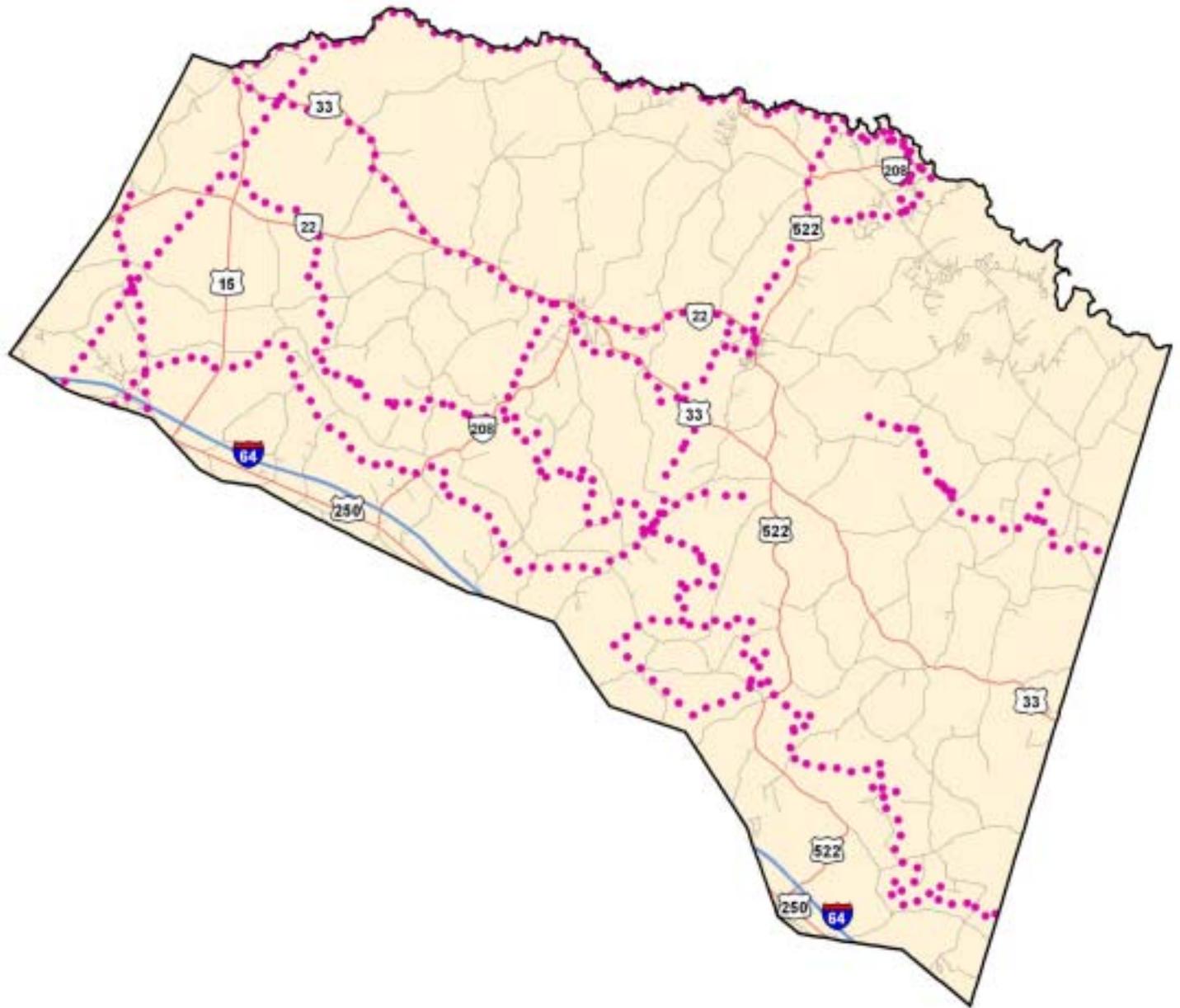
Louisa County Steep Slopes



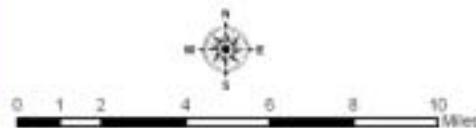
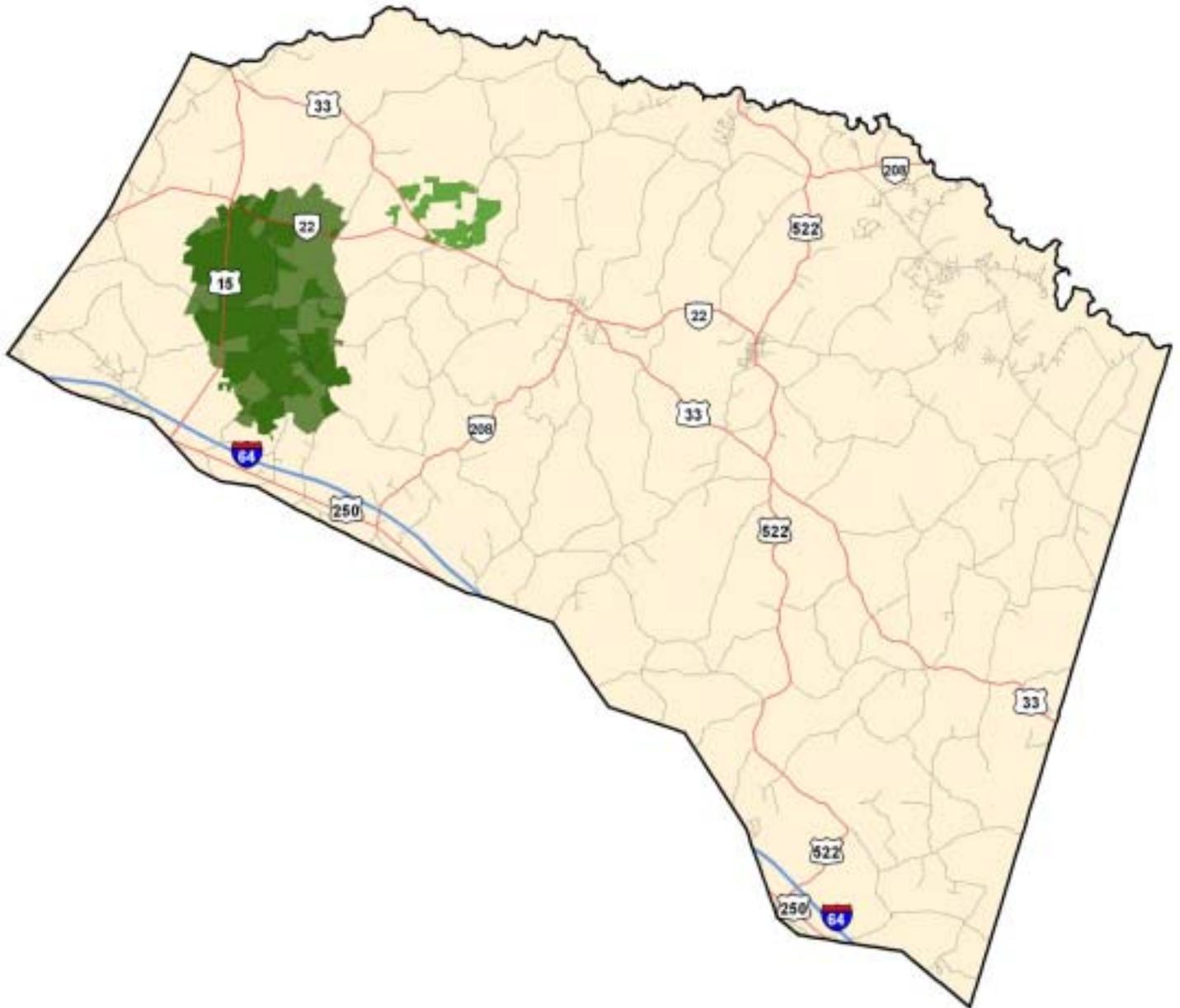
Louisa County 3rd Order Stream Buffers



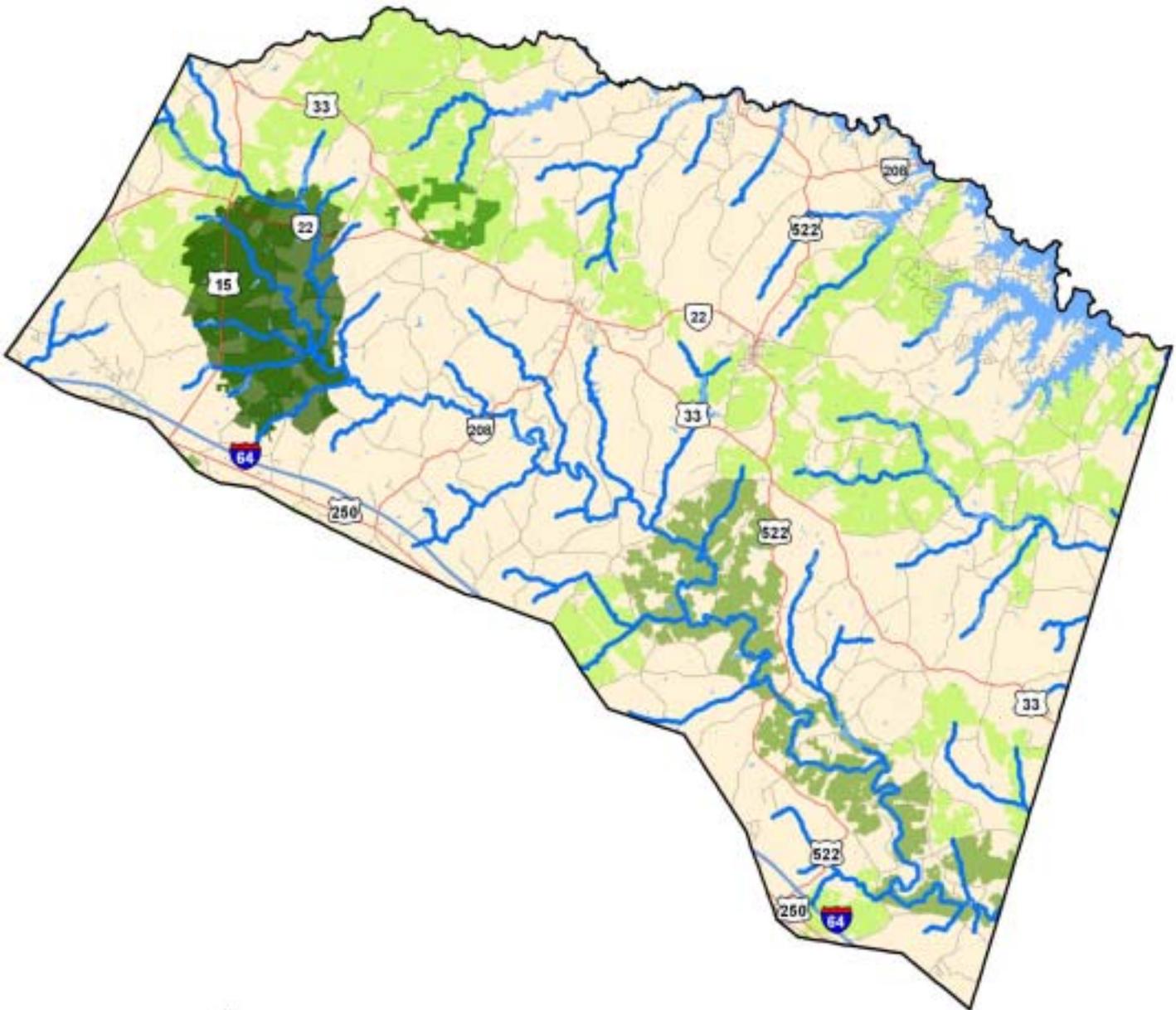
Louisa County Trails



Louisa County Protected Lands



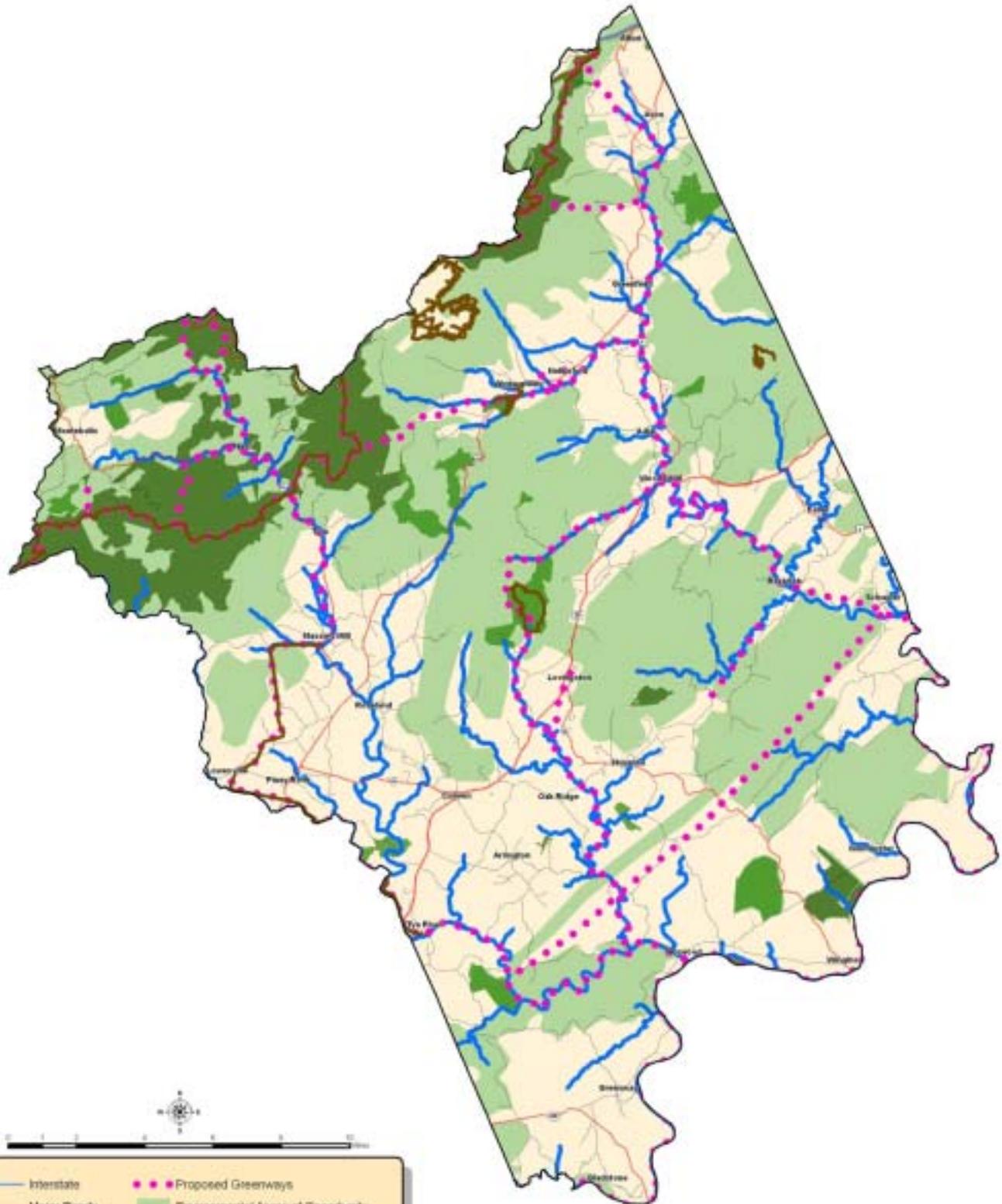
Louisa County Cornerstone Layers



● Proposed Greenways	▨ Slopes Greater Than or Equal to 25%
— Interstate	■ Protected Lands (Easements/Local Parks)
— Major Roads	■ Federal and State Conservation Lands
— Other Roads	■ VCLNA Cores 1 & 2
— 3rd Order Streams	■ VCLNA Corridors
■ Water Bodies	



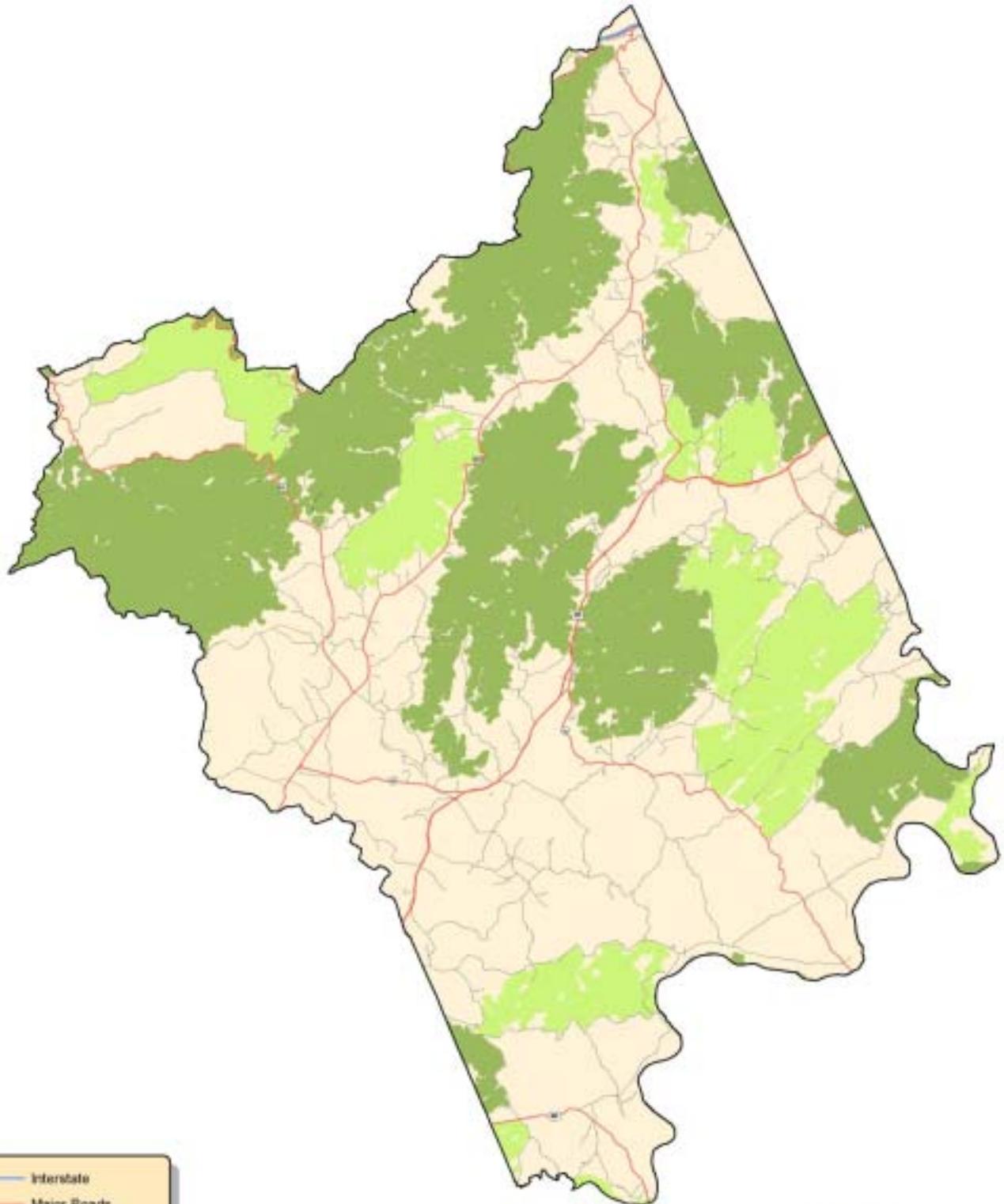
Nelson County Environmental Areas of Opportunity



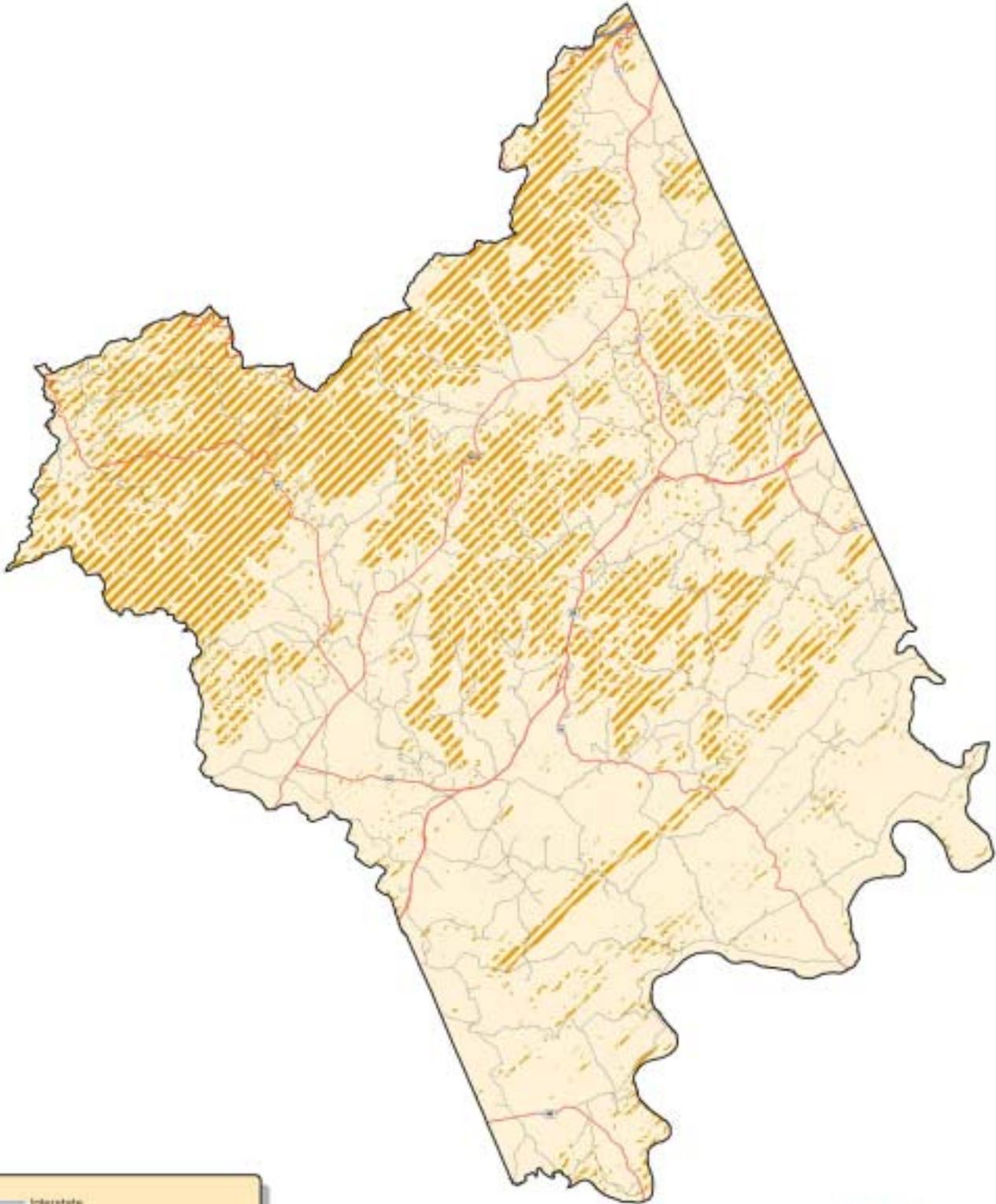
	Interstate		Proposed Greenways
	Major Roads		Environmental Area of Opportunity
	Other Roads		Protected Lands (Easements)
	3rd Order Streams		Federal and State Conservation Lands
	Nelson Trails		



Nelson County Combined Habitat Layers



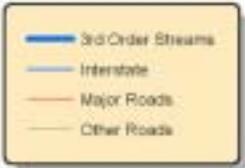
Nelson County Steep Slopes



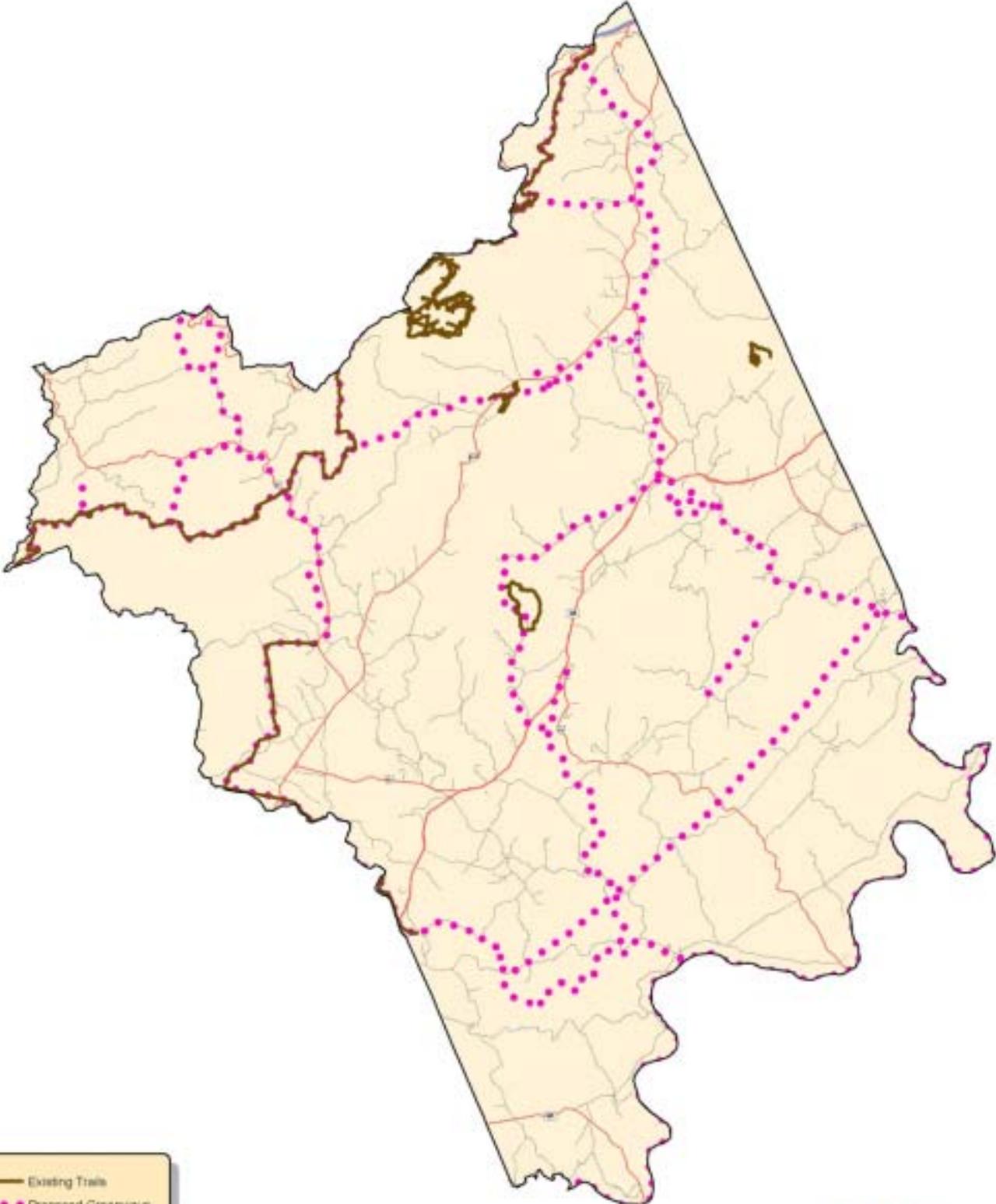
- Interstate
- Major Roads
- Other Roads
- /// Slopes Greater Than or Equal to 25%



Nelson County 3rd Order Stream Buffers



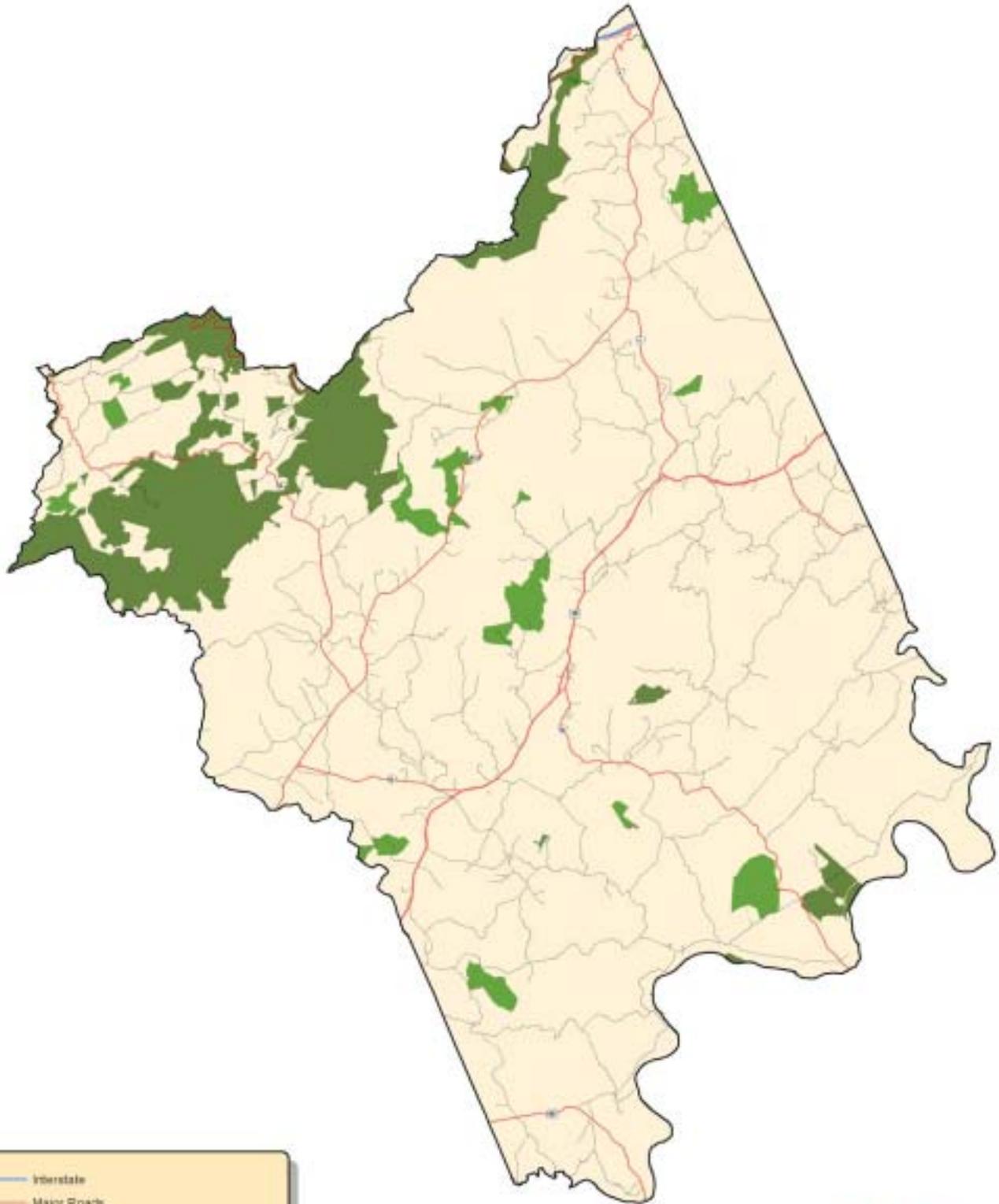
Nelson County Trails



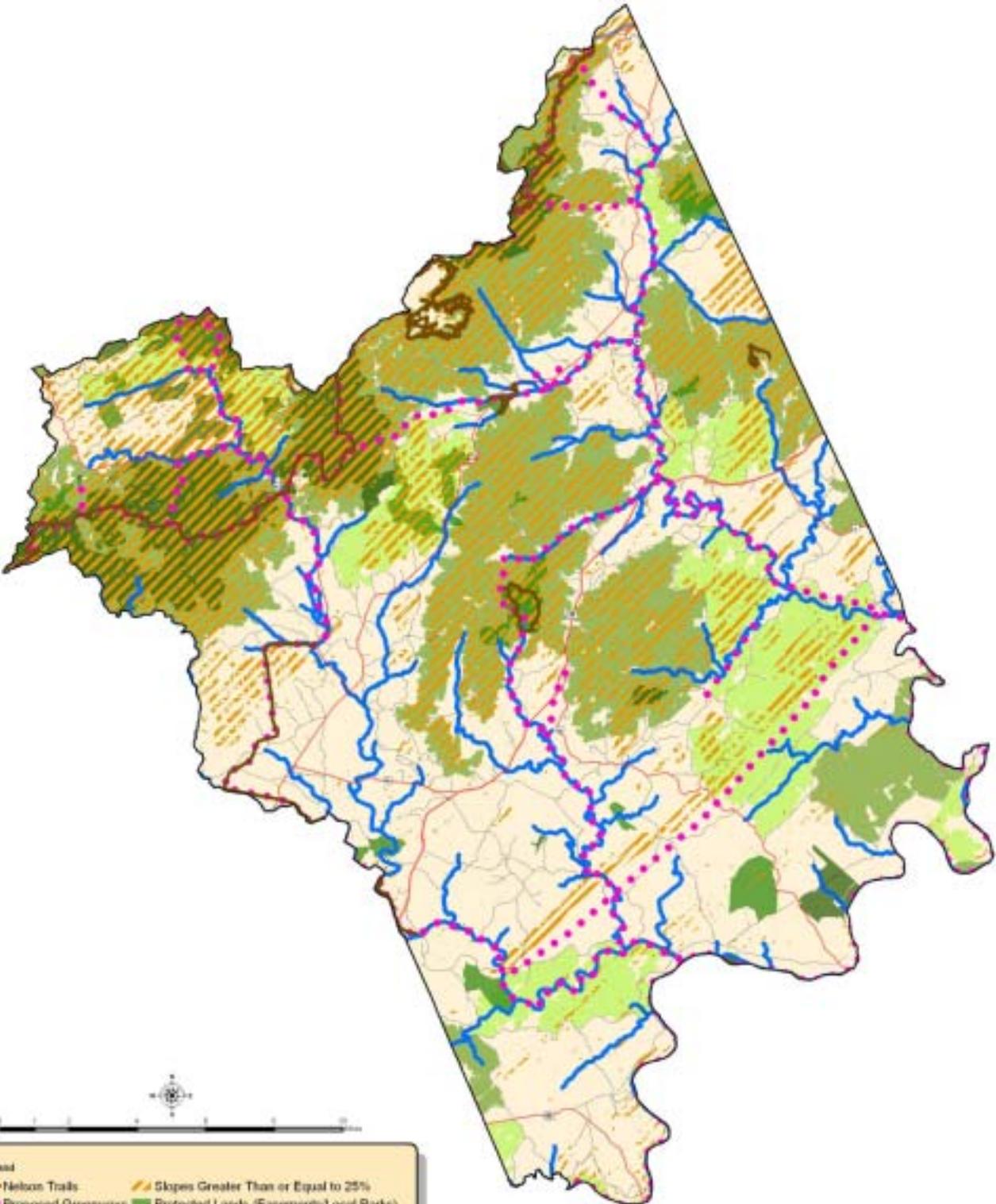
- Existing Trails
- Proposed Greenways
- Interstate
- Major Roads
- Other Roads



Nelson County Protected Lands



Nelson County Cornerstone Layers



Legend

- Nelson Trails
- Proposed Greenways
- Interstate
- Major Roads
- Other Roads
- 3rd Order Streams
- Slopes Greater Than or Equal to 25%
- Protected Lands (Easements/Local Parks)
- Federal and State Conservation Lands
- VCLNA Cores 1 & 2
- VCLNA Corridors



Green Infrastructure Development Tools

This study has identified the important elements of green infrastructure in the Thomas Jefferson Planning District. The implementation of green infrastructure is ultimately the responsibility of local government. Any locality implementing green infrastructure needs to take multiple factors into account. The previous section highlighted many of the environmental and recreational assets that form the foundations of a green infrastructure network, with a focus on a science-based analysis. However, there are also many social and political realities, preexisting conditions, and funding options that must be considered before the network is finalized.

There are tools currently available for this phase of the planning process. A variety of mapping tools help determine the boundaries of property ownership, and government land use controls or transportation plans. Such maps not only reveal the location of existing conditions relevant to green infrastructure, but may help make future projections for growth and land development patterns that can inform the network.

Code tools, whether regulatory or of an advisory nature, play an important role in local implementation by localities once the general outline for green infrastructure has been formulated. A locality should be aware of all options available, at each level of governing authority and citizen oversight. Similarly, a range of outside funding options exists, from government agency programs to grants from non-profit organizations, to help localities implement green infrastructure. Many of the funding sources will be more applicable to certain facets of the network than others.

Other tools, such as public education of the benefits of green infrastructure, should not be overlooked. Ultimately, a strong basis of public support will be necessary for any locality to implement green infrastructure, and well-informed and engaged citizens will be best equipped to oversee the evolution of green infrastructure in their own community. The development and implementation of a local green infrastructure network will require a multidisciplinary approach and a broad-based and creative utilization of all available tools. Finally, green infrastructure should be monitored during the process of implementation to provide feedback for future revisions or additions. In order to effectively monitor, the goals need to be clearly stated in measurable terms from the outset.

Mapping and Predictive Tools

In addition to showing green infrastructure features, maps are available to help determine where green infrastructure is more socially desirable, less costly to implement, more politically feasible, or of greater urgency.

Parcel maps

Parcel maps for any community are available from the local planning department or tax assessor's office. Parcel maps will give a conceptual shape for the preexisting boundaries of ownership, which may inform the content of a realistic green infrastructure plan. Parcels will also give a reasonable indication of where subdivisions or commercial developments currently exist, even if they are more difficult to perceive with aerial photographs. The maps will also help locate landowners of properties under consideration for green infrastructure, which is a crucial piece of information, since most of the available tools are used on a parcel by parcel basis in negotiation with individual landowners.

Parcel maps are also essential for identifying future subdivisions that are already platted. This will help determine the level of risk involved in selecting certain areas of land as components of the plan.

Future Land Use Maps

Most communities have a Future Land Use Map of some type, which sheds light on the vision already adopted for the extent and shape of their own growth. The maps can be used as stand-alone documents, but, in most cases, a land use chapter of the Comprehensive Plan will explain the meaning of terms used on the map and provide much more detail for how the map will be used in the planning process.

It is important for the green infrastructure network to be consistent with other visions for land use accepted by the community. For example, conservation easements and cluster development are useful tools for preserving land in areas set aside for agriculture or low-density residential use, while in areas slated for more density it may be more appropriate to acquire smaller neighborhood parks and greenways with public access. Both are perfectly fine strategies for developing a green infrastructure network, and the future land use map will help determine where each is the more appropriate tool.

Zoning Maps

Communities that choose to adopt land use regulations should use their future land use map to inform a zoning map, which includes legal regulations. The zoning map references land use codes, either codes focusing on allowable uses or on identifiable features of urban form, and applies them to specific areas indicated on the map. A review of the zoning map will help determine the degree to which the introduction of green infrastructure will conform with existing regulations.

There are always measures for altering or even rewriting the zoning code, but it may be more advantageous to work within the current model before considering alterations. However, it's also important to recognize that the green infrastructure plan itself may inform a future zoning map. The existing map, by revealing the restrictions residents have already opted to place upon themselves, can be used to gain a valuable insight into the ideals and goals of a given community.

Transportation Plans

Transportation plans adopted by a local government can offer a number of important insights into a community's vision. First, allocations of future transportation infrastructure will corroborate the land use map and help determine more precisely where future growth may be concentrated. Second, if there are specific roads, paths, or railways set to be constructed in the near future, it will be important to know the exact sites so as to avoid conflicts down the road. Third, there may already be plans for a greenway transportation corridor for cyclists and pedestrians that would serve as a component of green infrastructure in its own right. These elements of the transportation plan can certainly overlap with green infrastructure.

Floodplain Maps

The Federal Emergency Management Agency (FEMA) collects and regularly updates a national database of Flood Insurance Rate Maps (FIRM). For each community, a FIRM will identify areas of special hazard to flooding, as well as areas that have a higher risk premium. These maps could prove helpful for implementing green infrastructure, because they identify areas where development potential is already limited and the water quality impacts of development may be accentuated.

Gray Infrastructure Maps

Gray infrastructure refers to the physical components of the built landscape necessary to provide services to residents. It includes not only the transportation infrastructure, but water and sewer service, the electric grid, broadband networks, communications towers, gas pipelines, and the footprints of structures. Maps of each of these ought to be available from the service providers or the local planning staff.

Water and sewer maps are helpful because they give a further indication of where future growth is likely to occur. They may also reveal areas where green infrastructure may be especially fitting, for example around an existing or planned reservoir or in an area very sensitive for the local drinking water supply.

Power or communications infrastructure, whether overhead or buried, create either challenges or opportunities for green infrastructure. On the one hand, certain species may be either threatened or endangered by their proximity, and they may reduce the aesthetic value of the land for recreational use. On the other hand, lands used for these purposes may already be protected to some degree, making them less costly additions to a green infrastructure network. Buried pipelines are often particularly feasible corridors to preserve, with the one drawback being that they may need to be serviced on occasion. A careful analysis of these maps will help inform the siting of green infrastructure.

Agricultural and Forestal Districts Maps

A map of Agricultural and Forestal Districts will help determine where land is less likely to be developed in the near future, due to voluntary preservation commitments. See the section on “Other Tools” for more on Agricultural and Forestal Districts.

VCLNA Vulnerability Model

The Virginia Conservation Lands Needs Assessment (VCLNA) Vulnerability Model was created by the Virginia Department of Conservation and Recreation (DCR), with other agencies and partners, to map predicted growth in urban and suburban fringes. Various models show the expected changes in different types of development. The models serve as a guide to state and local government, consultants, and developers as to the location of growth patterns, particularly in relation to important environmental resources. They were created with the intention to be a component of a larger green infrastructure plan throughout the state.

Rivanna Watershed Land Cover Map

The Rivanna River Basin Commission and Albemarle, Greene and Fluvanna counties are jointly producing a Land Cover Map for the watershed and region defined by these counties that is based on the 2009 Virginia Base Map Project aerial imagery. This map will be available to the localities in December, 2009, and will classify land cover to 1 to 2 square meter units according to classifications of impervious surfaces (roads, rooftops, driveway, sideways) and land classification (deciduous forest, coniferous forest, open land, bare soil, forest harvest, pine plantations, golf courses, and orchards/vineyards). These maps are expected to be updated on a regular basis and can be used to document current land use conditions as well as changes over time. Though they do not cover the entire TJPDC district, they can be used by many of its localities.

Code Tools

Once the most advantageous and feasible locations for green infrastructure have been identified, there are a variety of tools available for carrying out the plan. Code tools range from the purely advisory, intended to

inform landowners and declare a community's vision, to mandatory regulation on the types and intensities of use allowable on a parcel.

Comprehensive Plans

All members of the Thomas Jefferson Planning District Commission (TJPDC) have a Comprehensive Plan, which is required by the Code of Virginia to be updated every five years. Incorporating green infrastructure into a local Comprehensive Plan is invariably the most important first step toward facilitating its actual creation. The process of writing the Comprehensive Plan allows for public participation, reflection from elected officials, and constructive alterations to the green infrastructure plan in response to feedback. Inclusion in a comprehensive plan also bolsters the public acceptance and legal legitimacy of any land use controls, should the community decide to adopt them in the future.

The Code of Virginia requires several elements in local Comprehensive Plans that dovetail well with green infrastructure. Comprehensive plans must designate areas for the implementation of reasonable ground water protection measures. All communities meeting a certain size or growth threshold are required to create Urban Development Areas, wherein growth is concentrated and organized according to urban design principles. Green infrastructure may help inform the selection of these areas, and likewise areas designated for growth may call for a different type of green infrastructure than would be used in rural areas. Local planners are also required to survey and study a variety of natural features of the area before writing the plan. Of course, many localities choose to exceed the required minimums by including a broad inventory of natural resources and ecosystem services, as well as identifying priorities and potential methods for their preservation or enhancement. Localities in Virginia, both urban and rural, have incorporated green infrastructure plans directly into their Comprehensive Plans, or otherwise used green infrastructure prescriptions to inform a chapter on Environment and Natural Resources.

Zoning Ordinances

Once a locality has drafted a green infrastructure plan and it has been reviewed by the public and ideally incorporated into the locality's Comprehensive Plan, the next step is to determine whether the plan can be actualized through land use codes. Zoning laws can be written to establish parameters that would allow a green infrastructure network to emerge. Zoning regulations themselves cannot simply mandate certain nodes and corridors as fully protected natural areas, but they can restrict the type and intensity of use allowed by landowners in specific areas.

The Code of Virginia lists several valid objectives for zoning that are relevant to green infrastructure:

- Improving the health, safety, convenience and welfare of its citizens.
- Recognizing the need for mineral resources and the needs of agriculture, industry and business in future growth.
- Providing residential areas with healthy surroundings for family life.
- Preserving agricultural and forestal land.
- Assuring that the growth of the community is consonant with the efficient and economical use of public funds.

Rezoning and Proffers

When developers request a Special Use Permit to vary from by-right allowable uses in an area, the planning commission and Board of Supervisors have a certain degree of latitude in determining the benefits to the

community of permitting the requested site plan. Developers may choose to put forth proffers, which are legally-binding commitments from the developer to provide an amenity to the community for the purpose of mitigating the impact of development. It is important to note that proffers are distinct from impact fees, insofar as they are made by developers on a voluntary basis and accepted by a planning commission, as well, on a voluntary basis. Proffers also must be reasonably linked to the nature of the impact from the development in question.

Green infrastructure, because of its proven ability to enhance property values in proximity to the improvements, is an especially viable option for proffers. Developers have often proffered a certain level of open space on the site, an easement for a trail or system of trails on site, bioretention facilities for stormwater management, retention of mature trees, or funds to be used for the acquisition of parkland or greenways. Often site plans will include a combination of proffers. Although proffers are less useful of a tool for the placement of green infrastructure in rural areas where there is less development occurring, they can be the most valuable means of doing so in more urbanized areas.

Design Review Boards

Certain districts, usually with some level of historical significance, can be designated in land use regulations as requiring review by a committee before building, demolishing, or adapting. Historic preservationists, in recent years, have become more aware of the value of preserving the context of historic buildings, beyond just the structures themselves. The Design Review Board may express the wish to see elements of green infrastructure in proposals before permitting them, especially if the preservation of natural resources is inherent to the mission of the board. Like proffers, this tool is typically most effective for more urbanized areas.

Other Land Use Ordinances

Land use ordinances may apply uniformly across the entire locality or state, rather than reference a specific zone. For example, a Water Protection Ordinance may require 100 foot stream buffers on both sides of streams in the rural areas. Development and grading may be restricted within the buffers. These kinds of buffers, known as riparian buffers, not only protect water quality and manage stormwater, but can be essential elements of a green infrastructure network. They make an ideal corridor for wildlife, which are often predisposed to follow water sources.

Localities within the Chesapeake Bay watershed are now required to plan for stormwater management, and the requirements from the Virginia Department of Conservation and Recreation (DCR) may grow in magnitude and scope in the future. Stormwater management offers significant opportunities for overlap with green infrastructure. Open spaces can be an efficient and cost-effective way to collect and filter runoff from impervious surfaces. Stormwater management requirements are often simplest to meet in rural areas, because of the large amounts of space available for filtration. However, innovative approaches are being developed to manage runoff in urban areas as well, through such strategies as green roofs, rain gardens, and vegetative swales. These stormwater management Best Management Practices, many of which are cataloged into a BMP clearinghouse by DCR, can be critical features of green infrastructure implementation.

The State of Virginia must offer enabling legislation for any tools to be used by a locality. Discussion is currently underway at the state level over “Adequate Public Facilities Ordinances”, which would allow

localities to restrict development to public facilities service areas, and impact fees for new development. These and other code tools may become available in the future.

Other Tools

Regulations alone are never sufficient to fully realize a plan. There are other tools available to encourage the voluntary preservation of, or conversion of land into, green infrastructure. This can be achieved through communicating accurate information to the public and inspiring action through a collective community vision, or through providing economic incentives to individual landowners.

Education

Education is not only important for building political support for policy changes, but it also helps orient the community toward collective voluntary action on behalf of the environmental resources surrounding it. Many of the existing tools, such as conservation easements and water quality management practices, are often initiated by individuals. In order to act upon their personal values, citizens need to be made aware of these tools and whatever support they can obtain for making use of them.

Educational campaigns may take several forms. First, a green infrastructure plan itself may help educate the public about its merits, especially if it has gone through an extensive period of public review and media exposure. If the plan is written in an accessible and engaging style and freely made available online and in hard copy, it is more likely to receive wider exposure to the general public.

Second, some localities may choose to conduct marketing campaigns or hold public workshops on the subject of green infrastructure. In cases where the information is targeted to a particular subset of the population, it may be beneficial to directly contact the individuals who would be most interested. Third, the public school system or institutions of higher learning could explain green infrastructure in more detail and walk students through the rationale and process of implementing it. Education should not be overlooked as an important tool, working in conjunction with each of the other tools presented here.

Conservation Easements

Conservation easements are legally enforceable land preservation agreements, usually made in perpetuity, placed on a parcel for the purposes of conservation. Lands can be designated for agricultural or forestal use, recreational use with public access, or solely for the purposes of conservation. The Virginia Outdoors Foundation (VOF) is the primary holder of easements in the area, although non-profit organizations may fill this role as well. Easements can also be written for preservation of historical resources or for trail or multiuse path rights-of-way.

Easements, because of their permanent nature, can create the foundational building blocks of green infrastructure. Because of the tax incentives involved, VOF will often have to be selective in the parcel chosen for protection. They have developed selection criteria that include large chunks of adjunct parcels, areas of particular ecological concern, and areas that are most susceptible to development. A green infrastructure plan can help provide substance and direction to the easement selection criteria and vice versa, ensuring that the state agency and local governments are collaborating with common objectives.

Historic Districts

Historic District designation is often a prerequisite for guidance by a Design Review Board. There are more legal rights for protection afforded to areas that are deemed to be of national or statewide historic

significance. In the Piedmont Virginia area, civil war battlefields are important historic resources that are often required to be maintained in a natural state and are open for recreational use. The Journey through Hallowed Ground is a National Heritage Area, extending from Gettysburg, Pennsylvania to Charlottesville, Virginia. It includes more than 10,000 listings on the National Register of Historic Places. Many of these places can function as green infrastructure hubs.

Scenic Byways and Rivers

The Virginia Department of Transportation (VDOT) maintains an official list of Scenic Byways in Virginia, and the federal National Scenic Byways Program selects routes of national significance. The Blue Ridge Parkway and Skyline Drive are included on the national list, and the state list includes a number of routes throughout the TJPDC. The purpose of the Scenic Byways program is to draw attention to travel routes that offer a unique scenic value and experience, whether natural or historical, in order to encourage tourism and economic development. The designation does not carry any regulatory weight, but may inform local land use controls or sign ordinances.

The Virginia Scenic Rivers Program, operated out of DCR, has a similar mission. Virginia Scenic Rivers Program's intent is to identify, designate and help protect rivers and streams that possess outstanding scenic, recreational, historic and natural characteristics of statewide significance for future generations. In the TJPDC, portions of the Rivanna River, the Moormans River, and the Rockfish River are on the list. Several other waterways are deemed worthy of potential future inclusion.

Scenic Byway and River designations give an extra impetus to green infrastructure plans and reinforce the crucial connection between land preservation and economic development. The use of green infrastructure in conjunction with scenic byways and rivers will help showcase the natural beauty of the region to outsiders and help residents identify with their natural landscape as they travel through it.

Agricultural and Forestal Districts

The Code of Virginia allows localities to adopt specific Agricultural and Forestal Districts within their boundaries, and each member of the TJPDC has opted to do so. These are allocations of land, 200 acres or more per district, voluntarily submitted by landowners to the local governing body. The primary purpose of the districts is to help determine eligibility for land use taxation and protect farmers from nuisance laws that would inhibit standard farming practices.

Once rural areas have been identified for inclusion in the green infrastructure plan, landowners of related parcels could be encouraged to consider adopting this designation. The use of Agricultural and Forestal Districts may be the best option for landowners who are not currently able to commit to the full protection of an easement, yet want to move forward in efforts to voluntarily preserve their land.

Site Sensitive and Low Impact Development

At the individual site level, there are many design strategies that developers can use to draw out the natural features inherent to the landscape. This approach requires a more careful survey of existing conditions and the creation of site-specific plans, but developments that take these steps are often financially successful. A comparative study of real estate values in Concord, Massachusetts found a \$17,100 difference per property between conventional subdivisions and developments that have clustered and protected open space.^{xix}

The related concept of Low-Impact Development is generally used to describe development that incorporates stormwater management techniques to mimic hydrologic activity, yet there is certainly a significant overlap with green infrastructure.

Bundoran Farm, a new subdivision in southern Albemarle County, employed what the architect refers to as preservation development in its site plan. Working farms, protected with conservation easements, are interspersed with other uses. Residential development is limited and carefully placed to preserve the character and use of rural landscapes in perpetuity. There are other examples of site plans, across the spectrum of affordability, that have gone beyond legal land use requirements.

A green infrastructure plan, with a broader scope, could assist developers of individual sites in their efforts to create places where people want to live, work, or shop. Localities may choose to offer incentives to landowners and developers to undertake design strategies that would minimize impact on the environment.

Purchase or Transfer of Development Rights

The State of Virginia allows localities to adopt Purchase of Development Rights (PDR) Programs. A PDR program enables a locality to preserve working lands such as farms and working forest lands, as well as open space and natural areas by restricting future development of the land while permitting landowners to continue to use their land as they had been. Conservation easements are the legal tool used in securing the development rights.

A Transfer of Development Rights (TDR) system follows the same legal apparatus as PDR, but the development rights are instead traded between private landowners on an open market. The local government creates a “sending area,” where development rights are sold from, and a “receiving area,” where the rights can then be purchased and used to develop in some way otherwise prohibited by law. The government also writes the terms and proportions of the trades, and sometimes maintains a public TDR bank to facilitate market activity. The Virginia General Assembly passed enabling legislation for TDR in 2008, but no Virginia localities have yet established a system. However, there are several examples of successful TDR programs currently in use around the country.

These are both powerful tools for implementing green infrastructure in rural areas. PDR programs give the locality more precise control to target conservation efforts, yet the program can also be quite expensive to operate. The State had initially offered some “seed” funding to help create PDR programs, but now localities need to provide all of their own resources. For TDR systems, green infrastructure can help inform the boundaries of sending and receiving areas, yet there is less control over the exact parcels being traded.

Parkland Acquisition

The Virginia Outdoors Plan recommends a minimal amount of land be set aside for local public parks: 4 acres per 1000 citizens for District Parks, 4 acres per 1000 citizens for smaller Community Parks, and 3 acres per 1000 citizens for Neighborhood Parks within walking distance of most residents. Access to parkland creates a number of benefits for people in all walks and stages of life, from providing venues for public gatherings to giving healthy outlets for sports and recreation. Greenways are public parks with a focus on facilitating alternative modes of transportation and recreational travel.

Parks can be important hubs and greenways can be important links in green infrastructure. As areas grow, the locality may consider acquiring more land for parks to meet the needs of their citizens. Although proximity to residents who will use the facility is an important concern in parkland siting, a green infrastructure plan could help inform the precise locations chosen and connect parks into the broader system of preserved lands.

Public Advocacy

While it is incumbent upon government agencies to educate the public of the benefits of green infrastructure, many of the necessary legislative changes are the result of advocacy from organizations and individual citizens. Residents may petition local governments to preserve land around their property, or they may seek to influence policies at the state or federal level designed to aid green infrastructure planning. As with many other aspects of governance, the creation and implementation of a green infrastructure plan can be greatly shaped by an active and engaged citizenry.

Funding Tools

Most green infrastructure networks built around the country are the product of cooperation between local governments, private foundations, citizens' groups, and local businesses. There are means of financial assistance available to help supplement a local initiative. Since green infrastructure crosses through many different disciplines, from traditional conservation to transportation and recreation, it is important to make a broad survey of all assistance available from government agencies and non-profit organizations. The following list contains some of the major opportunities, but it should not be read as an exhaustive record of sources.

Virginia Land Conservation Foundation

The Virginia Land Conservation Foundation is a statewide funding program with a mission that matches the objectives of green infrastructure in rural areas: to conserve open spaces and parks, natural areas, historic areas, and farmland and forest preservation.

In 1999, the General Assembly and the governor established the VLCF to help fund protection of these resources. Funds from the foundation are used to establish permanent conservation easements and to purchase open spaces and parklands, lands of historic or cultural significance, farmlands and forests, and natural areas. State agencies, local governments, public bodies and registered (tax-exempt) nonprofit groups are eligible to receive matching grants from the foundation. The funds are disbursed annually through grants.

Virginia Recreational Trails Fund

The Virginia DCR administers federal FHWA funds set aside specifically for trails or trail facilities. The fund is used for motorized or non-motorized trails, although the largest portion is allocated to multi-use trails. Up to 80% of the costs incurred by a locality for trail construction or maintenance are eligible for reimbursement by Virginia DCR. The primary purpose is to promote recreational trails, but they may also serve a secondary transportation purpose.

Natural Resources Conservation Service Programs

The Natural Resources Conservation Service is a subsidiary of the U.S. Department of Agriculture that helps America's private land owners and managers conserve their soil, water, and other natural resources. They administer dozens of programs including technical assistance for conservation activities, environmental

quality incentives, watershed protection services, easement purchasing programs, and farmer assistance grants. Most of the programs are conducted between individual farmers and the federal government, but a locality may encourage landowners in an area designated for rural green infrastructure to participate.

Virginia Land and Water Conservation Fund

The Land and Water Conservation Fund (LWCF) is available to localities through Virginia DCR for the acquisition and development of public outdoor recreation areas and facilities. The LWCF is a 50% matching grant. Any project receiving assistance must be maintained as an outdoor public area in perpetuity, which fits well with the intentions of green infrastructure.

Virginia Department of Conservation and Recreation and Soil and Water Conservation District Programs for Landowners

Like federal funding programs, the state of Virginia also offers assistance to landowners for conservation efforts through regional Soil and Water Conservation Districts (SWCD). There is a wide array of grant programs available, all of which are fully explained on the DCR website.

Virginia Department of Forestry Programs

The Virginia Department of Forestry (DOF) offers grants and incentives for forest conservation that could be used for planning or implementing green infrastructure in both urban and rural environments. The Urban and Community Forestry Grant Program encourages projects that promote tree planting, the care of trees, the protection and enhancement of urban and community forest ecosystems, and education on tree issues in cities, towns and communities across the nation. Many community forestry plans have been funded through this program.

The Forest Legacy grant provides an incentive based mechanism to protect important fish and wildlife habitat, conserve watershed functions, and maintain recreation opportunities. The program emphasizes protection of forests of regional and national significance, and those that can be effectively protected and managed are emphasized.

Partners for Fish and Wildlife

The Partners for Fish and Wildlife (PFW) program is operated by the U.S Fish and Wildlife Service. The mission of the program is to efficiently achieve voluntary habitat restoration on private lands, through financial and technical assistance, for the benefit of Federal Trust Species, such as migratory birds, interjurisdictional fish (species of fish that are distributed or migrate across political boundaries) and federally listed endangered and threatened species. Since the maintenance of an interconnected habitat for plants and animals is an essential function of green infrastructure, these incentive programs may lead rural landowners toward more active participation in preserving their lands for a local green infrastructure network.

Virginia Aquatic Resources Trust Fund

The Virginia Aquatic Resources Trust Fund is administered in partnership with the United States Army Corps of Engineers Norfolk District (Corps) and The Nature Conservancy in Virginia. The trust fund is paid into by small-scale projects that plan to exceed allowable impact on regulated streams, and the money is applied toward larger-scale conservation projects for streams and wetlands. Funds are allocated to preferred projects within the same watershed where wetland and stream disturbances have occurred.

Transportation Enhancement Program and Safe Routes to School

The Federal Highway Administration (FHWA) runs the Transportation Enhancement Program (TEP), which is intended to encourage alternative transportation projects, such as bicycle and pedestrian facilities, beautification projects, and environmental mitigation. Funds are administered through VDOT as a reimbursement to localities for up to 80% of eligible project costs.

The Safe Routes to School (SRTS) program exists to “enable and encourage children, including those with disabilities, to walk and bicycle to school.” Funding is distributed by VDOT for both a preliminary planning phase and a secondary implementation phase. Projects may be program-based, but most include infrastructure improvements as well. While the central focus of these FHWA programs is transportation, properly designed greenways can be important elements of green infrastructure as well. Furthermore, reducing the need for private automobiles in a community may open up land for green infrastructure that would otherwise be allocated for parking or roadways.

Private Foundation Grants and Corporate Donations

Many non-profit 501(c)(3) organizations can assist in funding certain elements of green infrastructure. Likewise, corporations are often looking for ways to enhance the communities in which they do business. For example, the Kodak American Greenways Program (Eastman Kodak Company, National Geographic Society, and Conservation Fund partnership) provides grants local governments to create or enhance recreational and conservation-oriented greenways in their communities. The list of national and regional organizations is too numerous to list and will vary significantly depending on the locality.

Local Funding

Many localities include funds for acquisition for parks and greenways, either by outright purchase of the land or purchase of easements, in their capital improvement plan. Direct funding is especially pertinent for elements of green infrastructure that are clearly and equitably in the public interest.

Private Donations

An individual landowner may want to take advantage of IRS tax deductions by donating land outright to the locality for the purpose of green infrastructure. This is an important source of open space that should not be overlooked.

Local Volunteer Labor

Sometimes county governments are able to leverage significant local volunteer labor for projects that are of public interest. Working on green infrastructure could be attractive if it is viewed as a fun recreational activity and community celebration in its own right. Volunteer labor may sometimes be counted, depending on the program, toward a local match for assistance funds.

Barriers to Implementation

Poorly Developed Zoning

As described in the “Code Tools” section, land use regulations can be powerful tools for implementing green infrastructure. Conversely, poorly developed zoning laws can actually inhibit the emergence of a green infrastructure network.

Obstructive regulations can take a number of forms. Zoning codes that require only a single specialized use may lead to exaggerated automobile travel patterns, as transportation users must travel between zones in

order to get to/from home, work, and shopping. Higher levels of Vehicle Miles Travelled (VMT) in the locality results in more land needed for roadways and parking, and thus less available for green infrastructure. The same effect can be intensified by zoning laws that require excessively low densities in relation to their location in the urban form.

The Code of Virginia § 15.2-961.1 currently limits an individual locality's ability to regulate forest cover for new and existing developments. The maximum allowable tree canopy requirements range from 10% of the site for commercially-zoned areas to 30% for low-density residential. This state regulation may inhibit the ability localities have to use land use regulations to their fullest potential.

Jurisdictional Boundaries

Features of the natural environment are spatially organized in ways that do not fit neatly within historically-realized political boundaries. At the same time, the jurisdictions circumscribed by these boundaries can be some of the most important actors in devising and carrying out a green infrastructure plan. This creates a dilemma of coordination that is prevalent in many aspects of regional planning. If the scale of a plan is too wide, it risks losing a level of local specificity and identification with the values of a particular community. However, if the scale of the plan is too narrow, the amount of connectivity present in the network may be compromised.

Jurisdictional boundaries and the political allocations of land use control are unlikely to change, but these barriers to implementation can be mitigated in a few ways. First, localities should be encouraged to coordinate their individual plans with adjacent jurisdictions, especially concerning the lands near their borders. Once localized plans have been initiated, it may be helpful to meet and compare maps of high-priority areas along the borders, in order to work toward making the transitions more seamless. Second, sharing information regionally through the TJPDC as plans are being drawn up may help neighboring localities be aware of potential conflicts and opportunities to work together. Third, state agencies could provide a standardized template, especially concerning the scientific evaluation of natural resources. Natural resources assessments in comprehensive plans tend to vary widely from community to community.

Federal Land Management

The Shenandoah National Park, Blue Ridge Parkway and Jefferson National Forest are the significant federal land holdings in the TJPDC. The National Park Service also seeks to achieve a balance between ecological protection and recreational use, only at a scale of national significance. The US Forest Service also manages multiple uses, including forestry, recreation and habitat protection. For a green infrastructure plan to be completely comprehensive, the management of federal land abutting the counties will have to be taken into account.

Measurement of Progress

Green infrastructure plans are inevitably long-range, and the implementation of the plan unfolds in a gradual nature as funding, new sources of scientific data, and political will are made available. To have the continuity necessary for establishing a truly interconnected network, the implementation process needs to outlast the political election cycle and staffing changes within governmental agencies. The plan should be considered a "living document" that evolves as the patterns of development and desires of the community change, so there ought to be mechanisms in place to facilitate the necessary revisions while maintaining the overall goal of establishing green space for ecological and social benefit.

Measuring progress is an essential part of green infrastructure's ongoing implementation. Periodic evaluations will help determine where more attention and resources are needed. They have the potential to keep the plan in the forefront of the public imagination, which is necessary to generate the desire to continue moving forward. Of course, this requires that the goals and objectives be written in such a way that measurements are possible. Establishing clear and objective benchmarks from the outset will give future planners a standard by which to measure progress.

The monitoring stage is just as important as the initiation of a green infrastructure plan. There are a number of factors to consider while tracking the progress of implementation.

Changes in Development Plans

Development plans can come in a variety of scales. The Land Use chapter of Comprehensive Plans will consider growth patterns for an entire jurisdiction. Master Plans will be more focused on a particular area or neighborhood. Finally, Site Plans will be used by developers for individual projects. At every scale, a careful reading of development plans will give a preview of the local patterns of growth or change to be expected in the future.

One way to measure the success of a green infrastructure plan is to determine the extent to which development plans have changed upon the introduction of green infrastructure into the community.

- Are areas of particular ecological or recreational significance explicitly taken into account by the plans?
- Do the plans make efforts to maintain the connectivity of green space with areas outside of their scope?
- Is green infrastructure treated with the same level of concern as more traditional elements of public infrastructure?

The plans may reference green infrastructure by name, but there is no reason to be overly attached to the phrase itself when measuring progress. Likewise, there is no way to establish with certainty that positive changes are caused by the green infrastructure plan itself. However, as long as the essential elements of green infrastructure find greater expression in local plans than they had before, there is evidence that the desired changes are being implemented.

Number of Acres Protected in High Priority Areas

Protected areas may either be protected by easement or under public ownership. The numbers of acres held in easements is readily available at the jurisdictional level from the Virginia Outdoors Foundation or non-profit easement holders on an annual basis. GIS coverages are often available to map the precise locations of the conservation easements. Data on land under public ownership will have to be collected from the agency or jurisdiction involved. This data helps track the progress of land conservation as a whole in the rural areas of the region.

In order to measure more specifically the progress of green infrastructure, the locations of new conservation easements could be overlaid with areas determined to be high-priority in the green infrastructure plan. Public agencies do not always have a high level of control over which parcels become easements, but there are ways to target attention and incentives toward parcels deemed to have a higher

value. An analysis of this overlay would provide a quantified measurement of how well rural land conservation efforts are in sync with the community's vision for its own green spaces.

Reduction of Impaired Streams/Maintenance of Healthy Streams

The Virginia Department of Environmental Quality (DEQ) is required by the EPA to submit regular reports on the health of streams previously placed on an impaired waters list. Public agencies and volunteer groups are engaged in water monitoring throughout the state, providing a significant source of data that could be used to measure the progress of green infrastructure. Just as the delisting of a previously impaired stream would be a measurement of success, the introduction of a stream in the region into the impaired waters list that had previously been evaluated as meeting water quality standards would be a cause for concern.

A majority of the TJPDC lies in the James River basin, although nearly all of Louisa County lies in the York River basin and approximately half of Greene County is in the Rappahannock River basin. Compared to other areas of the state, the Planning District has only a moderate proportion of waters listed as impaired. However, from the perspective of the whole Chesapeake Bay, comparisons across geography are deceptive because the negative water quality effects are more concentrated downstream. Comparisons for an individual stream segment through time are more useful for evaluating progress.

Another way of measuring progress is to consider the number of stream miles or segments that have *maintained* relatively healthy condition. The Rivanna River Basin Commission is working with the Department of Conservation and Recreation and Virginia Commonwealth University to identify healthy streams in the Rivanna basin to add to a Virginia-wide database and assessment tool called *INSTAR*. *INSTAR (Interactive Stream Assessment Resource)* allows users to access and manipulate a database representing over 2,000 stream and river collections statewide. Data represent fish and macroinvertebrate communities, instream habitat, and stream health assessment. The application supports database queries, mapping functions, and online editing capabilities.^{xx} Protection of existing healthy streams is as important as degraded stream restoration because, just as in human health, the ultimate cost of restoration is much greater than the cost of protecting that which is already healthy.

Trail Miles and Usage

The number of miles in an officially-designated trail system is already tabulated by some jurisdictions, and others may want to considering collecting this data through on-the-ground GPS measurements or observing aerial photos. The trails must be publically available, whether within public parks or by easement or agreement with individual property owners, to qualify as an element of the community's green infrastructure.

This is an important indicator, not only for the extent of land conservation taking place, but the degree to which these lands are available for public recreation. Particularly in the urban areas, the use of the land is philosophically essential to green infrastructure. Beyond measuring the physical mileage of trails, it may be possible to estimate their level of usage by the community. While this measurement will necessarily be somewhat subjective, it could indicate whether the green infrastructure is meeting its intended goal of enhancing quality of life. There is also a proven correlation between the usage of natural amenities and the political will to continue preserving them.

Percentage of Forested Areas in High Priority Areas

While the health of a forest can be measured in many different ways, such as the diversity and maturity of trees, the sheer quantity of preserved land for forests provides a simple metric for the progress of this element of green infrastructure. The Virginia Department of Forestry, in conjunction with Virginia Tech, has been using software to analyze aerial photos of tree coverage. A few pilot communities were selected and the method may be extended to other localities in the near future. The analysis can provide estimates of the percentage of tree coverage over a particular area.

Overlaying measurements of either loss of tree coverage or newly planted forests with areas designated as high priority for green infrastructure can serve as a helpful measurement of success.

Change in Land Cover in High Priority Areas

A similar analysis to that of forest cover can be conducted for other types of land cover, such as land used for agriculture. Unlike forestry, other natural land covers will mostly likely have to be evaluated in a negative sense. While it is unlikely that developed land will be converted into farmland, green infrastructure could be measured as successful if it curtails the annual rate of natural land cover loss.

Surveys

Surveys are a perennial tool that can be used to measure success of green infrastructure. They could measure the public awareness and attitude toward the green infrastructure plan itself, although perhaps more importantly surveys could measure the public's perceptions of their own natural surroundings through time.

- Are you able to take advantage of natural recreational opportunities in this community?
- How far is the nearest protected green space from your place of residence?
- Do you believe your community has more or less open space than it did 5 years ago?
- Have you personally implemented any water quality provisions such as rain barrels or rain gardens on your own property?

Some surveys have been used to collect input on the number of different types of green space the public believes are in existence and publically accessible. These results can be used to measure potential future demand for various types of natural areas in the community. The answers to the questions are often compared to more standard demographic characteristics to look for trends in the population. Surveys will inevitably focus on more of the social, rather than ecological, benefits of green infrastructure. Nevertheless, they are an important statistical measurement of success.

Visitation Records

Records of visitation are kept by some public parks. If the park is considered to be an element of the green infrastructure network, these records can provide some insight into whether the network is being used as intended.

Economic Tourism Numbers

The Virginia Tourism Corporation (VTC) estimates the economic impact of travel for each locality in the State. The totals are drawn from a variety of travel related expenses, which include, but are not limited to, tourism spending. While this is may be an indirect measure of the effectiveness of green infrastructure in

the region, it is highly likely that the preservation of an attractive natural environment is at least one significant factor in encouraging tourism.

Heritage tourism, a branch of tourism based on seeking the cultural identity of a place, may be especially encouraged by improvements to the natural environment. Heritage tourists spend a larger amount of money per person, meaning the economic benefits are high relative to the impact of the industry.

ⁱ Tree-Lined Streets “Cut Asthma.” BBC News. 1 May 2008. <http://news.bbc.co.uk/2/hi/health/7374078.stm> [accessed 11 Aug. 2009]

ⁱⁱ *Greener Neighborhoods Mean Slimmer Children*. Washington Post. 14 Nov. 2008. <http://www.washingtonpost.com/wp-dyn/content/article/2008/11/14/AR2008111403128.html> [accessed 11 Aug. 2009]

ⁱⁱⁱ Kuo, Frances E. *Vegetation May Cut Crime in the Inner City; Trees Linked with Less Domestic Violence in the Inner City; Adding Trees Makes Life More Manageable; Where Trees Are Planted, Communities Grow*. University of Illinois at Urbana-Champaign Landscape and Human Health Laboratory. Undated. <http://lhhl.illinois.edu/crime.htm>, <http://lhhl.illinois.edu/violence.htm>, <http://lhhl.illinois.edu/coping.htm>, <http://lhhl.illinois.edu/communities.htm>. [accessed 11 Aug 2009]

^{iv} Dobbs, David. *The Green Space Cure: The Psychological Value of Biodiversity*. Scientific American. 13 Nov. 2007. <http://www.scientificamerican.com/blog/60-second-science/post.cfm?id=the-green-space-cure-the-psychologi> [accessed 11 Aug. 2009]

^v *Insights on High-Tech Companies from the 1995 Survey*. Massachusetts Institute of Technology News Office. Undated. <http://web.mit.edu/newsoffice/founders/Insights.html> [accessed 11 Aug. 2009]

^{vi} Duerkson, Christopher J. and Cara Snyder, *Nature-Friendly Communities* (Washington, D.C.: Island Press, 2005) citing Florida, Richard, *Competing in the Age of Talent: Quality of Place and the New Economy* (Pittsburgh: R.K. Mellon Foundation, 2000).

^{vii} Bowker, J.M., Bergstrom, John, and Joshua Gill. *The Virginia Creeper Trail: An Assessment of User Demographics, Preferences, and Economics*. Virginia Department of Conservation and Recreation. 8 Dec. 2004. http://www.dcr.virginia.gov/recreational_planning/documents/userdems_vct.pdf [accessed 11 Aug. 2009].

^{viii} Lynch, Loretta, and Bob Tjaden. *When a Landowner Adopts a Riparian Buffer – Benefits and Costs*. Maryland Cooperative Extension. 2000. <http://www.riparianbuffers.umd.edu/fact/FS774.html> [accessed 11 Aug. 2009].

^{ix} Annear, Thomas, et al. *Instream Flows for Riverine Resource Stewardship*. Second edition. (Ashland, Ohio: BookMasters, 2004).

^x Grifo, Francesco and Joshua Rosenthal, *Biodiversity and Human Health* (Washington, D.C.: Island Press, 1997).

^{xi} Tallamy, Doug. *Bringing Nature Home* (Portland, Oregon: Timber Press, 2007) citing Robinson, WD. 1999. Long-term changes in the avifauna of Barro Colorado Island, Panama: A tropical forest isolate. *Conservation Biology* 13: 85-97.

^{xii} Tallamy, Doug. *Bringing Nature Home* (Portland, Oregon: Timber Press, 2007) citing Marren, P. 2001. What time hath stole away: Local extinctions in our native flora. *British Wildlife*, June, 305-310.

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- ^{xiii} Thomas Jefferson Planning District Commission. *Assessment of Forest Resources in the Rivanna River Basin*. 1997.
- ^{xiv} Nowak, David. *The Effects of Urban Trees on Air Quality*. USDA Forest Service, Syracuse, NY. (2002) http://www.nrs.fs.fed.us/units/urban/local-resources/downloads/Tree_Air_Qual.pdf [accessed 10 Aug. 2009].
- ^{xv} Stavins, Robert, and Kenneth Richards. *The Cost of U.S. Forest-Based Carbon Sequestration*. Pew Center on Global Climate Change. (January 2005) http://www.pewclimate.org/docUploads/Sequest_Final.pdf [accessed 11 Aug. 2009].
- ^{xvi} *Greenhouse Gas Equivalencies Calculator*. U.S. Environmental Protection Agency. 30 March 2009. <http://www.epa.gov/cleanenergy/energy-resources/calculator.html> [accessed 11 Aug. 2009].
- ^{xvii} Albemarle County Biodiversity Work Group. *Albemarle County Biodiversity: A Report on Its History, Current Conditions, and Threats, with Strategies for Future Protection*. 2004. <http://www.albemarle.org/department.asp?department=planning&relpage=3560> [accessed 27 Aug. 2009]
- ^{xviii} Wenger, Seth. *A Review of the Scientific Literature on Riparian Buffer Width, Extent, and Vegetation*. Office of Public Service & Outreach, Institute of Ecology, University of Georgia. 5 March 1999. http://www.rivercenter.uga.edu/service/tools/buffers/buffer_lit_review.pdf [accessed 26 Aug. 2009].
- ^{xix} Steve Lerner and William Poole, *The Economic Benefits of Parks and Open Space: How Land Conservation Helps Communities Grow Smart and Protect the Bottom Line* (Trust for Public Land, 1999), 13.
- ^{xx} *Welcome to INSTAR*. Virginia Commonwealth University. 12 Nov. 2008. <http://instar.vcu.edu/> [accessed 2 Sept. 2009].