US 301 Waldorf Area Transportation Project
Natural Resources Work Group

Environmental Stewardship Methodologies and Results

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Prepared by

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TABLE OF CONTENTS

Executive Summary

I. Introduction

II. Coordination with SHA

III. Focus Group Sessions

IV. Literature Review

V. Natural Resource Identification and Assessment

1. Green Infrastructure Conceptual Approach
2. Assessment of Forest Resources
3. Assessment of Wetland Resources
4. Assessment of Stream Resources
5. Assessment of Natural Heritage Resources
6. Green Infrastructure Network Identification

VI. Natural Resource Prioritization

1. Green Infrastructure Network Prioritization
2. Conservation Site Selection
3. Restoration Site Selection
4. Forest Conservation Value
5. Reforestation Values and Cost
6. Invasive Species Control
7. Stream and Riparian Corridor Conservation and Restoration
8. Wetland Conservation and Restoration
9. Natural Heritage Prioritization
10. Natural Heritage Stewardship Recommendations
11. Conservation Site Assessment
12. Restoration Site Assessment

VII. Environmental Stewardship Project Selection

VIII. References

IX. Acknowledgements

X. Appendices

EXECUTIVE SUMMARY

In partnership with the State Highway Administration (SHA) of the Maryland Department of Transportation, The Conservation Fund (TCF), the Maryland Department of Natural Resources (DNR), and the U.S. Fish and Wildlife Service (FWS) – Chesapeake Bay Field Office utilized an Environmental Stewardship (ES) approach for the identification and evaluation of natural resource protection opportunities for the US 301 Transportation Improvements Project in Waldorf, Maryland. This team of TCF, DNR, and FWS, known as the Natural Resources Work Group (NRWG), created a decision framework for identifying an optimal portfolio of ES natural resource actions for each build Alternative Retained for Detailed Study (ARDS). ES actions are provided above and beyond, voluntarily, not in-lieu of, required compensatory mitigation and seek to maximize the enhancement, protection, and improvement of natural, community, and cultural resources. On a parallel track, the Community Resource Working Group (CRWG) identified potential community and cultural projects independently from NRWG, although it was intended that projects from both work groups be pooled at the end.

The NRWG was officially convened by SHA on November 6, 2006, followed by a kick-off meeting with the project Interagency Work Group (IAWG) on May 9th, 2007. Focus groups meetings on ES needs were held in the summer of 2007, with most resource assessments completed in the same year. Green infrastructure network design and field validation of modeling results took place in 2008, with training of SHA staff in green infrastructure planning occurring in the fall of 2008. NRWG completed the conservation and restoration protocols and field site evaluations in 2009, with a final report submitted to SHA in December 2009.

ES needs are environmental and cultural resources identified as significant from public involvement processes and science-based resource assessments. ES opportunities are specific projects that implement the protection or enhancement of these resources. To evaluate ES natural resource needs and opportunities, the NRWG utilized a green infrastructure approach to identify conservation and restoration priorities and align those to ES needs and opportunities. Green Infrastructure is defined as strategically planned and managed networks of natural lands, working landscapes, and other open spaces that conserve ecosystem functions and provide associated benefits to human populations (Benedict and McMahon, 2006). Green infrastructure provides a framework that can be used to guide future land development and land conservation decisions to accommodate population growth and protect and preserve community assets and natural resources. The green infrastructure network design and its associated resource assessments are being used to evaluate and rank potential ES opportunities based on their benefits and costs. Draft ES packages will be developed that will provide a comprehensive collection of improvement projects that meet the natural and community/cultural needs of the US 301 Transportation Improvements Project in the Waldorf Study Area. Conceptual designs will be completed and impacts to other resources will be calculated and included in the Final Environmental Impact Statement (FEIS)/Final Section 4(f) Evaluation.

SHA demonstrated its commitment to resource preservation and enhancement by including ES as a component of the US 301 Transportation Improvements Project Purpose and Need Statement. With the Final ES package, natural, community, and cultural conservation and restoration projects will help fulfill natural environmental resource and community/cultural needs in the US 301 Waldorf Study Area. This report focuses on the ES natural resource opportunities identified by the NRWG, and is written so that this approach can be replicated in other counties and states. Details are in the Appendices.

I. INTRODUCTION

The Maryland Department of Transportation, State Highway Administration (SHA) is committed to adopting, for the US 301 Transportation Improvements Project in Waldorf, Maryland, a broader proactive philosophy toward protecting and enhancing the environment, which goes beyond the conventional compensatory requirements of federal and state environmental statutes. Environmental stewardship (ES) is an approach that seeks to maximize the enhancement, protection, and improvement of natural, community, and cultural resources while working collaboratively with all appropriate permitting agencies and community stakeholders. ES represents an opportunity to improve the present environmental conditions by leaving them in better shape than existed prior to the implementation of the project. It is a non-regulatory program, meaning that it is not associated with compensatory mitigation required to offset direct impacts to resources affected by the project. Environmental stewardship actions are provided above and beyond, not in lieu of, required regulatory mitigation. SHA has shown this commitment by including ES as a component of the US 301 Transportation Improvements Project Purpose and Need Statement. With the final ES package, natural, community, and cultural restoration and enhancement projects will help fulfill natural environmental resource and community/cultural needs in the US 301 Waldorf Study Area.

The type, quantity and location of ES measures are determined on a project-specific basis after the identification of priority stewardship needs within the study area through consultation with project partners and a variety of public stakeholders. SHA asked the Maryland Department of Natural Resources (DNR), The Conservation Fund (TCF), and the U.S. Fish and Wildlife Service (FWS) – Chesapeake Bay Field Office to complete an identification and evaluation of natural resources as part of an environmental stewardship (ES) opportunities study for the US 301 Transportation Improvements Project in Waldorf, Maryland. SHA is currently assessing a number of alternatives which aim to provide a long-term improvement to congested highway conditions in the Waldorf area. Alternatives under consideration include upgrades of the existing US 301 roadway and roadways on new alignments both east and west of the Waldorf area. The southern project limit includes the intersection of US 301 with Washington Avenue and Turkey Hill Road immediately north of the town of LaPlata. The northern limit includes the US 301/MD 5 interchange area, including the intersection of US 301 and MD 381.

SHA envisions a balanced approach between natural resource and community resource opportunities to aid in addressing and executing priority environmental and community stewardship actions for the Waldorf area. The execution of actions to take advantage of environmental enhancement, protection and improvement opportunities will be assessed in terms of the balanced priorities of the community, resource agencies and the resources available to implement those actions. For this project, the Environmental Stewardship Team is being led by SHA with assistance from two technical work groups: the Natural Resource Work Group (NRWG) and the Community Resource Work Group (CRWG). These work groups have functioned independently but are coordinating at key milestones or decision points. Each of the work groups has worked with the project Interagency Work Group (IAWG) to provide an opportunity for federal, state, and local agency input and guidance into the stewardship process. This report focuses on the work of the NRWG.

The NRWG was tasked with providing an objective and scientifically defensible identification and evaluation of natural resource stewardship opportunities. The resulting list of stewardship needs and opportunities provided by the NRWG will be utilized by the Interagency Work Group (IAWG) to recommend priority stewardship projects to SHA. Specific tasks were outlined for each agency (TCF, DNR, and FWS) in separate Scopes of Work. The objectives of the environmental stewardship study were to:

- promote the project goals of environmental stewardship to further the enhancement, protection and improvement of natural, community and cultural resources,
- consider the multiple resource issues of agency partners and stakeholders in an objective, scientifically defensible manner,

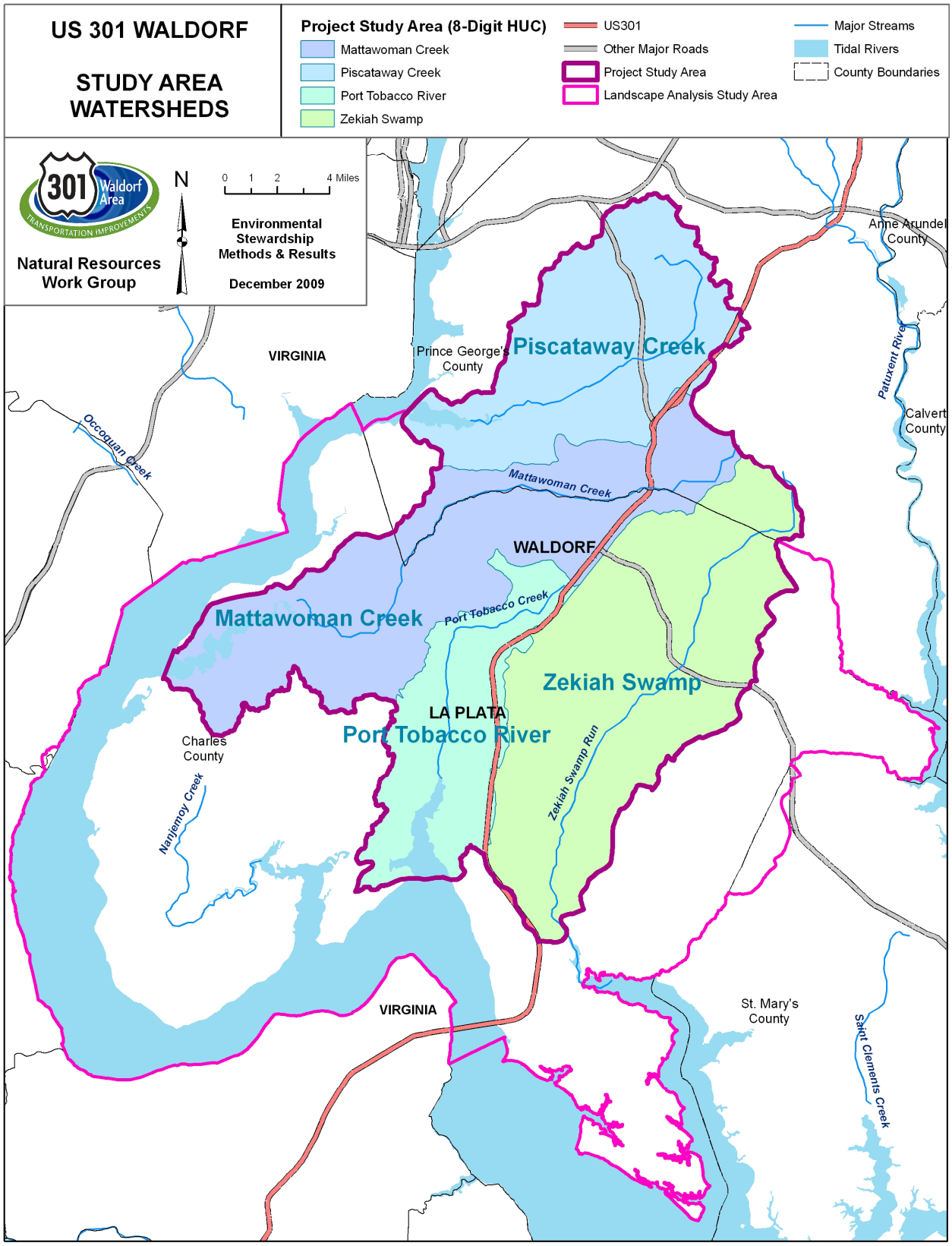
- incorporate principles of ecosystem management as outlined by the Federal Highway Administration (FHWA's) "Eco-Logical" and "Green Highways" approach for infrastructure development,
- incorporate aspects of Maryland's Green Infrastructure Assessment for identifying stewardship opportunities,
- establish protocols for identifying and evaluating natural resource stewardship needs and opportunities for the US 301 Transportation Improvements Project that can also be employed by SHA for future transportation projects,
- demonstrate and ensure that stewardship decisions are backed by scientifically justifiable, credible and authoritative resource assessments and evaluations, and
- develop a baseline and set of performance measures which may be used to gauge the effectiveness of the long-term performance of environmental stewardship efforts.

The US 301 Waldorf Area Transportation Improvements project has a defined limit of study for compliance with the National Environmental Policy Act (NEPA). For both stewardship and compensatory mitigation projects, this included the four potentially impacted watersheds of Mattawoman Creek, Port Tobacco River, Piscataway Creek, and Zekiah Swamp. While ES projects were constrained within these watersheds, NRWG delineated a green infrastructure network in a broader area: within the entirety of Charles County and the southern watersheds of Prince George's County.

Using the NRWG's approach, ES packages can be developed for each build Alternative Retained for Detailed Study (ARDS). These ES packages are designed to address existing environmental needs, offset negative environmental impacts unrelated to the US 301 Waldorf project, and provide improvements to the surrounding natural environment. The ES packages provide environmental improvements independent of regulatory requirements for mitigating any direct impacts of the US 301 Project and reflect the types of affected resources specific to that alternative.

After much discussion and analysis of local natural, community, and cultural needs and coordination with local, state, and federal resource agencies, community groups, and the general public, an approach to ES was developed that will provide a comprehensive package of improvement projects or measures that meet these natural and community/cultural needs. Specific products of the NRWG include the following:

- A summary of focus group feedback on ES needs.
- A literature review of resource assessments and peer reviewed studies on green infrastructure within the project study area.
- Resource assessments of forests, wetlands, streams, and natural heritage sites.
- A green infrastructure assessment with associated GIS data layers that includes the study area watersheds and the rest of Charles County.
- Conservation and restoration protocols for field site evaluation and ranking.
- An optimization decision support tool and preliminary portfolio of potential projects to rank ES opportunities based on costs and benefits.
- A comprehensive ES framework that can be applied to other SHA projects with an Environmental Stewardship component.



Map 1. US 301 project area: four watersheds potentially impacted by highway construction.

II. COORDINATION WITH SHA

SHA Coordination on Project Design

On October 17, 2006, TCF, DNR, and FWS participated in an initial scoping meeting with SHA to obtain an overview of their proposed ES approach that maximizes environmental benefits and goes above and beyond compensatory mitigation. The outcome of the meeting was the formation of the Natural Resources Work Group (NRWG), with TCF, DNR, and FWS structured as an inter-disciplinary, collaborative team to address ES needs and opportunities for the project.

On November 6, 2006, TCF, DNR, and FWS participated in a kick-off NRWG workshop with SHA to discuss and confirm the overall objectives of the ES process and the expectations of SHA. The workshop addressed the overall ES conceptual process, the roles and responsibilities of the participants (both at the agency and individual level), and the schedule for identifying and evaluating ES opportunities in light of the overall schedule for project development. The NRWG team members subsequently developed a detailed scope of work with roles, responsibilities, tasks, and deliverables in response to an RFP document describing SHA's proposed approach.

The defining characteristics of the NRWG's proposed work plan, which distinguish this effort from previous ES efforts by SHA, are: (1) the focus on a green infrastructure approach to identify natural resource ES needs and opportunities, and (2) development of an optimal portfolio of ES actions that maximizes environmental benefits given specific project costs. The desired outcome of the green infrastructure approach and optimization methodology was to facilitate the ability of SHA and the IAWG to formulate an ES final package that provided the most environmental benefits under a given budget.

IAWG Review and Concurrence

On May 9th, 2007 the NRWG participated in a kick-off meeting with the IAWG that introduced the project team and provided an overview of the NRWG project work plan. The NRWG received general concurrence from the IAWG on the project approach and provided some initial comments related to an initial step in the effort – the identification of natural resource stewardship needs within the US 301 project study area. Following this kick-off meeting, the NRWG periodically made presentations to the IAWG to provide a progress report and obtain concurrence on the environmental stewardship approach and key methodology.

On February 13th, 2008, the NRWG presented the proposed Green Infrastructure network design methodology and participated in a question and answer session. The IAWG approved this methodology but requested a review of the forthcoming ranking parameters and weights. IAWG further reviewed the ranking scheme and overall approach on May 14th, 2008 and July 9th, 2008. TCF trained SHA staff on green infrastructure planning in Fall 2008. TCF presented the conservation and restoration protocols and the Optimization Decision Support Tool (ODST) to the IAWG on December 10th, 2008.

III. FOCUS GROUP SESSIONS

Following IAWG concurrence on the general approach to identifying ES needs, a series of four focus group interviews with key stakeholders were convened in July 2007 to obtain input on natural resource stewardship needs. Based on IAWG input and additional follow -up with key agencies and organizations, an invitation list was compiled for each of the four focus group sessions listed below:

- July 10th, 2007 – Prince George's County Representatives, Upper Marlboro
- July 18th, 2007 – US 301 Interagency Representatives, Baltimore
- July 19th, 2007 – Charles County Representatives, La Plata
- July 19th, 2007 – NGOs / Make-up session, Waldorf

A total of 64 individuals participated in the four focus group sessions, which were facilitated by The Conservation Fund. Each focus group session followed the same agenda. Participants were asked to provide specific feedback that was compiled by the NRWG.

The first item covered on the agenda was the identification of recommended environmental stewardship activities and priority natural resources. Participants first engaged in a facilitated discussion (recorded on flip charts) on the types of environmental stewardship activities most needed in the project area as well as the priority natural resources in the project area. The intent of this discussion was to receive qualitative comments that would provide additional information to the NRWG on the quantitative rankings of these resources/activities which followed the discussion.

The second item on the agenda was a review of data sources and identification of additional documents and resources. Participants were asked to review a list of data sources and to offer recommendations for additional sources or types of data that might be helpful to the NRWG. Numerous sources were recommended for consideration as a part of the process.

The final item on the agenda was the identification of needs and proposal of specific projects, whereby participants had the opportunity to recommend actual specific projects and/or needs for consideration and evaluation by the NRWG. Participants were asked to provide information on the need for the specific project, including a brief description of the activity type, the resource, and any pertinent studies. Participants were then able to place a dot (assigned by a unique identifier corresponding to the information provided by each participant) onto a map of the project area. Upon conclusion of this activity, participants were thanked for their input and the sessions were adjourned. Appendix A-1 contains a summary of methods for each agenda item.

For the identification of recommended environmental stewardship activities and priority natural resources, each participant was provided a form and asked to allocate 100 points among four categories of stewardship activities and 100 points among eight categories of natural resources. The aggregated results are as follows in Tables 1 and 2, with conservation/preservation activities and forests (closely followed by streams and wetlands) ranking the highest.

Table 1. Environmental stewardship preferences of focus group attendees.

Environmental Stewardship Activities	**Percent of allocated points**
Conservation / Preservation	60%
Restoration / Creation	18%
Management Actions	11%
Recreation / Public Access to Open Space	11%

Table 2. Natural resource preferences of focus group attendees.

Priority Natural Resources	**Percent of allocated points**
Forests	22%
Streams and Aquatic Resources	19%
Wetlands	17%
Marine Fisheries	10%
Species Habitat	11%
Passive Recreation Areas	5%
Historic/Archeological	6%
Agriculture	9%

For the identification of needs and proposal of specific projects, participants identified a total of 328 site-specific project ideas. Participants placed dots onto a map of the project area; see Appendix A-2 for detailed results. The allocation of suggested projects closely resembled the overall stewardship and natural resource preferences. Mirroring the results in Table 1, participants suggested mostly conservation/preservation activities on the dot map (Table 3). Suggested activities most often included streams and aquatic resources, followed by forests and wetlands (Table 4).

Table 3. Stewardship activities recommended as projects by focus group attendees.

Environmental Stewardship Activities	**Percent of proposed projects**
Conservation / Preservation	62%
Restoration / Creation	23%
Management Actions	10%
Recreation / Public Access to Open Space	5%

Table 4. Resource types targeted for potential projects by focus group attendees.

Priority Natural Resources	**Percent of proposed projects**
Streams and Aquatic Resources	25%
Forests	20%
Wetlands	18%
Marine Fisheries	13%
Species Habitat	14%
Passive Recreation Areas	4%
Historic/Archeological	3%
Agriculture	4%

Summaries of the focus group sessions follow.

Prince George's County Session

The first session was held on Tuesday, July 10, 2007 from 1:00 to 5:00 pm at the Show Place Arena and Prince George's Equestrian Center in Upper Marlboro, MD. Invitations to this session were targeted to Prince George's County elected officials and staff. Eight people attended this session, representing two county council members, as well as several county departments.

Of significance to this group was that, although they supported environmental stewardship activities, they did not support any of the bypass alternatives, and did not want their participation in the focus group meetings to be misconstrued. Sample comments from this session included a strong emphasis on preserving/protecting the county's "rural tier" and the Mattawoman Creek and Zekiah Swamp watersheds. Participants were also concerned about how stewardship activities would be funded, as well as how to address soil erosion and septic system capacity. In addition, they were interested in how this effort could enhance the county's existing Purchase of Development Rights (PDR) program, and recommended numerous data sources for the project. Lastly, they stressed the importance of agriculture and recommended that an eighth category be added to the natural resources form. This category was added and used throughout the remaining 3 focus group sessions. Participants identified 37 specific needs/projects using the dot allocation process, many of which were broad in scope (rather than 'site-specific'). Overall, this group offered many specific projects and comments for the NRWG's consideration.

Interagency Work Group (IAWG) Session

The second session was on held on Wednesday, July 18, 2007 from 11:00 am to 2:30 pm at the Maryland State Highway Administration Headquarters in Baltimore, MD. Invitations to this session were sent to Interagency Work Group members, as well as other federal and state agency representatives with an interest in the project area. Twenty-three (23) people attended this session.

A prevailing sentiment from this group was that the process of identifying stewardship needs and opportunities should be based primarily on science, and less on political or public interests. Participants also felt that it was critical to espouse a 'watershed approach' to stewardship, not focusing on needs/projects as isolated elements. In that same vein, they emphasized the need to protect buffers and upland areas as well as the streams and wetlands. Participants prioritized natural resources ahead of public access and recreation. They also noted that a strategic framework for disparate conservation efforts (statewide) was needed, given limited available funding. The group identified 85 specific needs or projects.

Charles County Session

The third session was on held on Thursday, July 19, 2007 from 1:00 to 5:00 pm at the Charles County Department of Social Services in LaPlata, MD. Invitations to this session were targeted to Charles County elected officials and staff. Five people attended this session, including one county commissioner and various county departments.

The Charles County group, although small, was very well prepared (having met as a group prior to the session). They emphasized the need to encourage concentration / clustering of development (focusing on four current 'Activity Centers'), while limiting 'greenfield' development, as well as the need for new and improved stormwater retrofits, alongside watershed restoration. They highlighted the need for increased buffer requirements between development and stream boundaries (an "effective" vs. "arbitrary" margin of protection). Proposed tools to accomplish these goals included easements, a Purchase of Development Rights (PDR) program, and incentives for protection/restoration, as well as regulatory controls. They provided access to numerous GIS data resources to contribute to the process. The group identified 29 specific need/projects in Charles County, ranging from developing a 'green ring' around the county's urban centers, to stormwater retrofits. Charles County representatives voiced their support for the 301 bypass option.

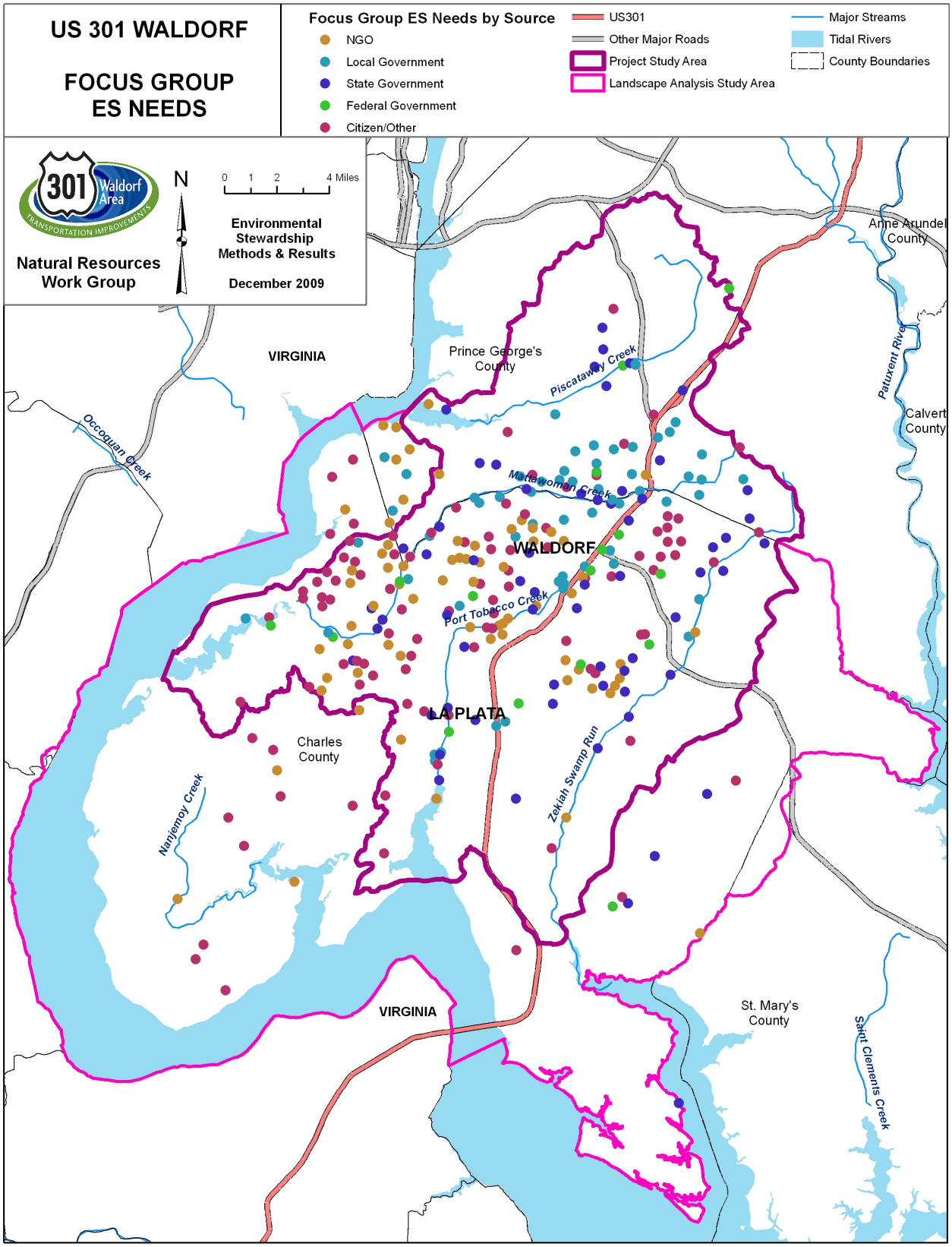
Public Interest Session

The fourth (and final) session was on held on Thursday, July 19, 2007 from 5:30 to 9:00 pm at the Thomas Stone High School in Waldorf, MD. Invitations to this session were targeted to non-governmental organizations (NGO) with interests in the project area. People unable to attend other sessions were also invited to attend this session. Twenty-eight (28) people attended this session, representing various NGO's.

The primary sentiment of the group was strong opposition to *any* of the 301 bypass alternatives (especially the western alternative), and resentment and mistrust toward the SHA. The group was weary of SHA selecting the western bypass alternative, as that alternative, in their opinion, would open up a pristine and ecologically sensitive wetland area to intense development pressures. Once the group had an opportunity to offer a few comments about the project, they were reminded that the focus groups were not a venue to discuss the specifics of the project, and remained on track throughout the rest of the session. Protection, preservation, and restoration of natural resources (more than cultural resources/uses) were the prevailing emphasis of this group. Agriculture and recreation (especially fishing) were also indicated as important, but second to the protection of the natural resources. Mattawoman Creek, in particular, was stressed as the most important resource to protect. This group identified 177 specific needs/projects.

Needs Summary

Map 2 shows the locations of environmental stewardship projects recommended by participants in the four focus groups. Appendix A-2 contains a tabular summary of all stewardship needs identified on the map. For each dot on the map, the type of need and a brief description were recorded. Each dot was further classified based on the type of natural resource and the type of environmental stewardship activity. Each dot could fall into more than one natural resource type and/or activity.



Map 2. Locations of environmental projects suggested by participants in the four focus groups.

IV. LITERATURE REVIEW

Following the May 2007 kick-off meeting, the NRWG, led by The Conservation Fund, began compiling a list of pertinent studies to be reviewed. The July 2007 focus group sessions identified additional documents to be reviewed prior to the identification and evaluation of natural resource stewardship opportunities.

Documentation reviewed prior to conducting field investigations included the Watershed Restoration Action Strategy (WRAS) report for the Port Tobacco Watershed in Charles County (Charles Co., 2006); the Stream Corridor Assessment Survey reports produced by the Maryland Department of the Environment (MDE) for the Port Tobacco Watershed (MDE, 2006), the US Naval Surface Warfare Center Indian Head Division in Charles County produced by Maryland Department of Natural Resources (DNR, 2006), and Andrews Air Force Base in Prince Georges County (DNR, 2000), Charles Co. Watershed Restoration Studies for National Pollutant Discharge Elimination System (NPDES) permits (Charles County 2003, 2004, 2007), Charles County Zoning Field Inspection reports, and the Waldorf sub-area plan (ERM, date unknown).

Interviews were also conducted with a variety of government managers, planners and non-governmental organizations (NGOs). The list of organizations consulted included the Charles County Department of Planning & Growth Management (PGM), Port Tobacco River Conservancy (PTRC), The Nature Conservancy (TNC), US Fish & Wildlife Service (FWS), Charles County Soil Conservation District (CH SCD), Prince George's County Soil Conservation District (PG SCD), U.S. Natural Resources Conservation Service (NRCS), Maryland National Capital Park & Planning Commission (MNCPPC), and Maryland DNR Freshwater Fisheries, Watershed Services, Fish Passage, Natural Heritage programs, and managers at the Mattawoman Natural Environmental Area (NEA) & Wildlife Management Area (WMA). NRWG also reviewed available Geographical Information Systems (GIS) data layers from NRCS, DNR, FWS, and the planning departments of Charles and Prince George's counties.

TCF completed an extensive literature review, which can be found in Appendix B. Literature sources were organized into eight categories, roughly corresponding to the ES Natural Resources classification used for the focus group sessions: (1) Forests, (2) Streams, (3) Groundwater, (4) Wetlands, (5) Marine Fisheries, (6) Rare Species / Natural Heritage, (7) Recreation, and (8) Adopted Plans. Within each category, TCF summarized literature by county and watershed. Highlights from the literature review follow.

<u>Forests</u>

Originally mostly forested (Besley, 1916), the study area was largely cleared for agriculture, especially tobacco, beginning in the 17th century (Redman/Johnston Associates, 2003; CCHPAC, 2004; LCI, 2007b). Many farms were abandoned between 1900 and 1970 and forest regrew, but urban sprawl began around 1950 and has subsequently been accelerating (Redman/Johnston Associates, 2003; CCHPAC, 2004; LCI, 2007a; LCI, 2007b). In Charles County and elsewhere in southern Maryland, soil erosion from poor practices was a problem from colonial times up until the 1940's (Redman/Johnston Associates, 2003; LCI, 2007b). Many farms were rendered unusable for generations (Gibb, 2008). Most existing forest in the area dates from before the 1950's, although probably all of it is secondary growth (LCI, 2007a). This is consistent with aerial photos that show a significant area of forest in 1938, although much of it appears young then. Some areas with high water tables or steep slopes, such Zekiah Swamp, have been forested since before the Civil War (Tri-County Council, 1985; Redman/Johnston Associates, 2003; LCI, 2007a).

Prince George's County is already mostly suburban, and development continues at a rapid pace (MGC, 2000). If current trends of forest loss continue, woodland coverage will drop from 138,451 ac in 2000 to 126,501 ac in 2025, below county goals (M-NCPPC, 2005a). Charles County also faces significant forest losses. Forest in Charles County with the highest ecological value and the highest development risk are largely along Mattawoman Creek or the western portion of the Zekiah Swamp watershed, although development may be scattered throughout the county (Woods Hole Research Center, 2007). Much of the Mattawoman Creek watershed is within Charles County's Development District (USACE, 2003). According to a study by USACE

(2003), over 10,000 acres of forest, over 2,000 acres of croplands, and almost all existing pasture in the Mattawoman watershed are expected to be converted to suburbs between 2000 and 2020.

Housing developments along Mattawoman Creek.

Most forested wetland sites in Zekiah Swamp surveyed in 1995 showed signs of past logging activity (NHP, 1996). Most of the high quality forested wetlands are in the southern part of the swamp, which is difficult to access and further from development (NHP, 1996). Other high quality forests were found within Cedarville State Forest and in the central part of the swamp where deep water deters access (NHP, 1996). Brentland Woods, in the Port Tobacco watershed, is a large contiguous tract of forest that provides excellent habitat for forest interior birds (FIDS) and other wildlife (McCarthy et al., 1988). Many large, old trees remain (McCarthy et al., 1988).

Wolf Den Branch floodplain forest in Cedarville State Forest.

The Nanjemoy Peninsula is "one of the most ecologically and culturally significant landscapes remaining in Maryland" (BLM, 2004). It contains remarkably large blocks of relatively unbroken forest, mostly hardwoods, that extends eastward into the Nanjemoy Creek watershed. All forest is secondary growth following abandonment of agriculture; some forest stands may contain trees over 100 years old though. Mast-producing trees (e.g., oaks and hickories) and fruit-producing understory vegetation are common, which benefits wildlife. This extensive forest cover provides habitat for rare species and area-sensitive wildlife, and is relatively resilient to natural disturbances like fire and tornados. The most mature sections of forest show little evidence of encroachment by invasive species or other signs of artificial disturbance. Forests of similar age and quality are rare in southern Maryland; and of these, the Nanjemoy forest is by far the largest (BLM, 2004).

Extensive hardwood forest (with some pine plantations) in the Nanjemoy Creek watershed and Potomac River bend.

Streams

The clearing of forests and poor agricultural practices caused severe soil erosion in southern Maryland. Sediment deposits within the town of Port Tobacco are a foot or more deep (Gibb, 2008). Aggradation in streams and rivers was significant enough to impair navigation and cause the closure of ports on Mattawoman Creek, Port Tobacco River, the Patuxent River, and elsewhere (LCI, 2007b; Gibb, 2008). Historic land use changes, hydraulic alterations like ditching and damming, and the extirpation and subsequent reintroduction of beavers, may have influenced stream geomorphology considerably.

A study of watersheds in Charles County found that conversion of forests to development increases the discharges of water, nitrogen, phosphorus, and organic carbon, while conversion of forests to cropland increases the discharges of nitrate (Jordan et al., 2000). If growth continues at its present rate, imperviousness in the Mattawoman Creek watershed will double from around 7% in 2000 to 13% in 2020, and reach 24% at build-out (when 80% of development that current zoning allows is reached). Numerous studies have shown significant declines in stream condition when imperviousness exceeds 10% (e.g., Baltimore County, 2005; McGinty et al., 2005; Allen and Weber, 2007). Forest, especially in the riparian zone, is the most beneficial land use for maintaining stable hydrology, good water quality, and diverse stream biota (e.g., Roth et al., 1999; Jones et al., 2001; Allen and Weber, 2007; Weber, 2007b).

According to Kazyak and Brindley (2005), Zekiah Swamp and Nanjemoy Creek had the highest concentration of sites with good Index of Biotic Integrity (IBI) scores. Five of the top six stream sites in Charles County were in the Zekiah Swamp watershed (Kazyak and Brindley, 2005). Zekiah Swamp is the highest ranking watershed in the state for freshwater stream and riverine biodiversity, based on species rarity, biological integrity, and migratory fish density (Kazyak et al., 2005). Zekiah Swamp is a stronghold watershed (necessary

for species survival in the state) for five fish species of greatest conservation need (GCN): bluespotted sunfish, flier, ironcolor shiner, least brook lamprey, and warmouth (Kazyak et al., 2005).

Piscataway Creek rates higher than other Prince George's streams in IBI assessments (Kazyak and Brindley, 2005; M-NCPPC, 2005a), and is a stronghold watershed for American brook lamprey and comely shiner (Kazyak et al., 2005). However, 72% of Maryland Biological Stream Survey (MBSS) sites scored in the Poor range for either the fish or benthic macroinvertebrate IBI, indicating that degradation is relatively widespread in the watershed (Stranko et al., 2002). The most prevalent impacts were erosion, poor physical habitat, and relatively low dissolved oxygen levels, all likely resulting from high levels of urbanization (Stranko et al., 2002).

Mattawoman Creek is a stronghold watershed for warmouth (*Lepomis gulosus*), a species of sunfish (Kazyak et al., 2005). MBSS sampling found fish and benthic communities rating fair to poor in the headwater areas (MDE, 2006b). These ratings improved downstream towards the Potomac (MDE, 2006b). The worse conditions in the headwaters are probably a result of increased development there (MDE, 2006b). On average, nutrient concentrations are low, but occasionally exceed standards (MDE, 2004; MDE, 2006b; Saffer et al., 2006). MDE established loading caps for nitrogen and phosphorus (MDE, 2004). The USACE (2003) recommends protection of the stream valley from development to maintain hydrology and water quality, as well as implementing low impact designs in the watershed and examining existing development for stormwater retrofits.

Mattawoman Creek.

MDE also established nutrient loading caps for Port Tobacco River (MDE, 1998). Recent sampling recorded good water quality in most of the watershed (Kilian et al., 2006; Primrose, 2006). Fish IBI scores were generally Fair to Poor throughout the watershed. Benthic IBI scores were mixed, with Good scores along the main stem and some of the lower tributaries, and Poor scores in the more developed areas (Kilian et al., 2006). Port Tobacco is a stronghold watershed for fliers (*Centrarchus macropterus*), a small sunfish (Kazyak et al., 2005). Stream Corridor Assessment surveys identified 218 potential environmental problem sites in the watershed, including 5 fish blockages at road crossings (MDE, 2006c). An estimated 32% of stream miles had eroded banks, 21% had inadequate buffers, and <1% were channelized (MDE, 2006c).

Groundwater

Aquifers are the primary source of water in the Waldorf area (Wilson and Fleck, 1990). Water levels in the Waldorf aquifer system declined by up to 95 feet between 1962 and 1985, the result of increasing withdrawals from 0.15 mgd to 2.7 mgd. Groundwater models showed that withdrawals from this system should not exceed 6.6 mgd to avoid reaching 80% of total available drawdown.

Wetlands

MDE (2006b) recommended seven factors to prioritize wetland preservation, giving preference to wetlands of special state concern, Ecologically Significant Areas, areas within or near the Green Infrastructure, areas of high development risk, surface water reservoir watersheds, Rural Legacy Areas, and designated scenic rivers and their tributaries. MDE (2006b) also recommended factors to prioritize wetland restoration, giving preference to farmed wetlands, non-wetland hydric soils, poorly drained soils, riparian areas, areas at the head of tide or adjacent to headwater streams, areas along scenic rivers and tributaries, agricultural land or urban areas, areas with an approved Total Maximum Daily Load (TMDL) for nutrients or sediments, areas within or near the Green Infrastructure, and outside Priority Funding Areas. Prime farmland was excluded or ranked lower. Existing wetlands were excluded, but candidates for enhancement.

MDE (2006b) ranked Zekiah Swamp, Gilbert Swamp, and Nanjemoy Creek, as well as portions of the Port Tobacco floodplain and other areas, as the highest priority for wetland preservation in Charles County. MDE (2006b) identified numerous wetland restoration opportunities, with many of the high priority sites in the Mattawoman Creek, Port Tobacco, Zekiah Swamp, and Gilbert Run watersheds. Mattawoman Creek watershed has two State-designated Wetlands of Special State Concern (WSSC) and four potential WSSCs. WSSCs have also been identified in the Port Tobacco River and Piscataway Creek watersheds.

Zekiah Swamp.

In 1974, Zekiah Swamp was described by the Smithsonian Institution and Maryland DNR as "the largest natural hardwood swamp in Maryland and one of the most important remaining ecological areas on the East Coast" (Tri-County Council, 1985). The Zekiah was designated an area of Critical State Concern by the Maryland Dept. of State Planning in 1981, and a priority wetland under the 1986 Emergency Wetlands Resources Act, and a Wetland of Special State Concern in 1990 (DNR, 1994). Zekiah Swamp is also a Natural Heritage Area, and part of a State Scenic River (the Wicomico River) (M-NCPPC, 2005a).

Ebony Jewelwing damselfly in Zekiah Swamp.

Marine Fisheries

Anadromous fish (yellow perch, white perch, alewife, and blueback herring) have historically been found in Piscataway Creek, Mattawoman Creek, Allens Fresh Run (the tidal portion of Zekiah Swamp), and Port Tobacco River (O'Dell et al., 1975). Long (2000) reported that Mattawoman Creek "is an exceptional anadromous fish spawning and nursery ground that presently exhibits one of the highest densities of anadromous juveniles and the healthiest trophic fish assemblages in the Chesapeake system." Carmicheal et al. (1992), in a study of eight tidal Chesapeake tributaries, reported that anadromous juveniles in Mattawoman Creek were 40 times more abundant per unit effort than the other seven combined. This was the only tributary where shad were collected, or where substantial numbers of alewife, blueback herring, and white perch were collected. The mean number of species captured per year was also greatest here, and the Mattawoman had the most balanced trophic structure (Carmicheal et al., 1992).

The high number of anadromous fish in Mattawoman Creek could be attributed to its low salinity (freshwater is found at the mouth), or (at the time of the study) the large amount of forest and low level of urbanization in the watershed. DNR found a clear relationship between bottom fish richness, dissolved oxygen, and land use (Carmicheal et al., 1992). Carmicheal et al. (1992) wrote that Mattawoman Creek "represents as near to ideal conditions as can be found in the northern Chesapeake Bay, perhaps unattainable in the other systems, and should be protected from overdevelopment."

Alewife (*Alosa pseudoharengus*).

Rare Species / Natural Heritage

McCarthy et al. (1988; 1989) list a number of rare species and community sites. Magnolia Bogs are a globally imperiled (G1) habitat endemic to the mid-Atlantic (NatureServe). The Mattawoman Creek watershed has two, both severely threatened. Maryland DNR considered protection of Zekiah Swamp's high quality natural communities "a top priority" (NHP, 1996). A 1995 survey found 18 ecologically significant sites, which are described and mapped in NHP (1996).

Pitcher plants in a Cedarville State Forest bog.

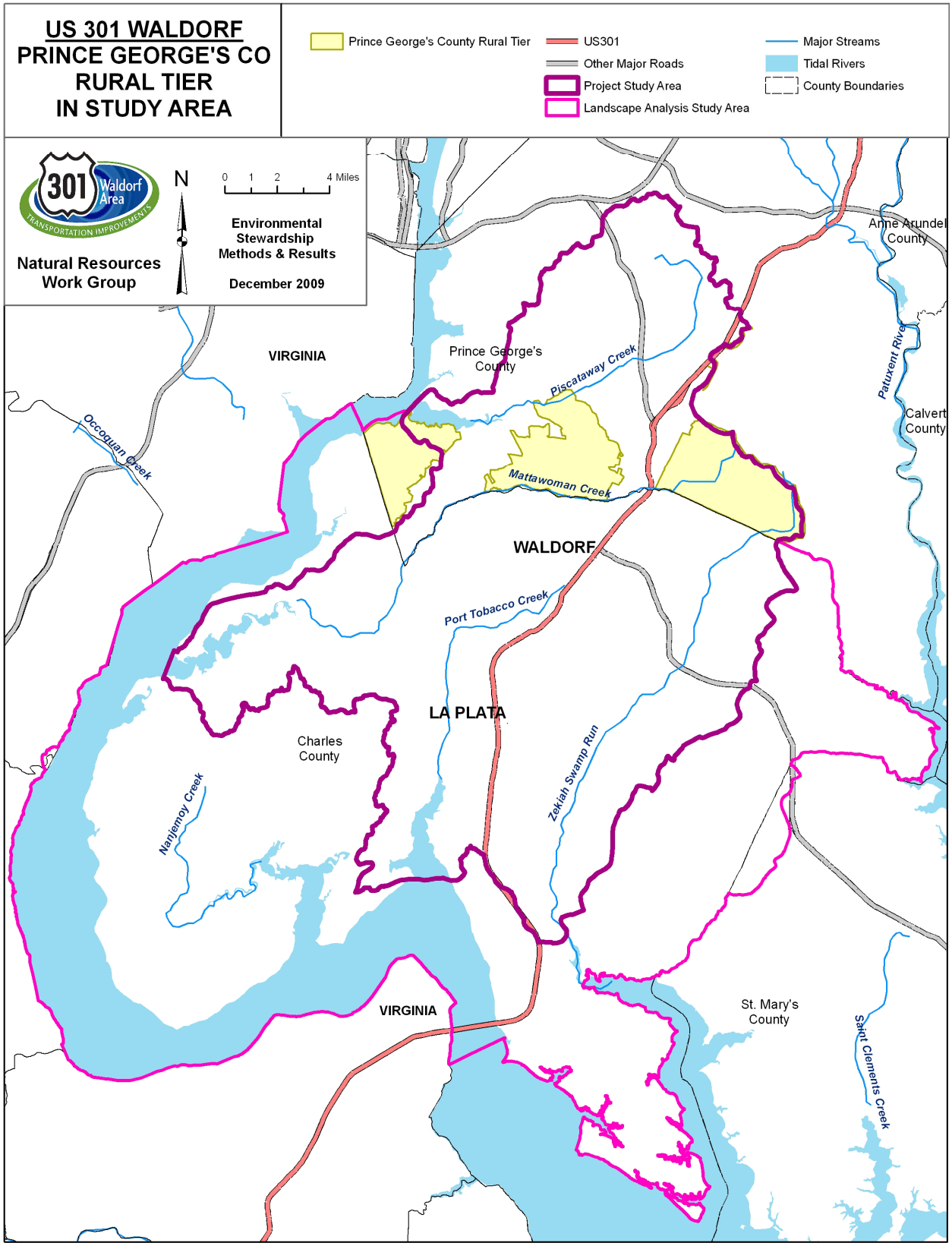
Recreation

Charles County contains abundant natural resources, including forests, natural shorelines, and one of the densest populations of nesting Bald Eagles in the lower 48 states (Fermata, 2000). The county's proximity to Washington DC makes it a potentially attractive market for outdoor tourism such as birding or hiking, the two fastest growing outdoor recreation activities in the nation (Fermata, 2000). Bass tournaments, especially in Mattawoman Creek, bring Charles County millions of dollars each year (Reardon, 2007). Fermata (2000) recommends marketing strategies to increase tourism, as well as buying land to conserve biodiversity and open space, especially in the Douglas Point/Mallows Bay area.

Adopted Plans

In Prince George's County, most of the US 301 project area falls within the county's Rural Tier, which was created "to balance agricultural pursuits and preservation of remaining environmentally sensitive features to maintain a rural character in the southeastern most area of the county" (M-NCPPC, 2005) (See Map 3). Prince George's County has an adopted Green Infrastructure Plan from 2005 that covers approximately 168,000 acres of the county and has a goal "to preserve, enhance, and/or restore an interconnected network of county-wide significant environmental features that retains ecological functions; maintains or improves water quality and habitat; and supports the desired development pattern of the General Plan (M-NCPPC, 2005)." Specific objectives relevant to the US 301 project include limiting loss of woodland cover within the green infrastructure network and strategically targeting all off-site forest mitigation acreage into the green infrastructure network and/or adjacent to streams outside of the green infrastructure network. Fifty percent of the forest mitigation acreage should be targeted to improving water quality by establishing, enhancing, and/or restoring riparian forest buffers.

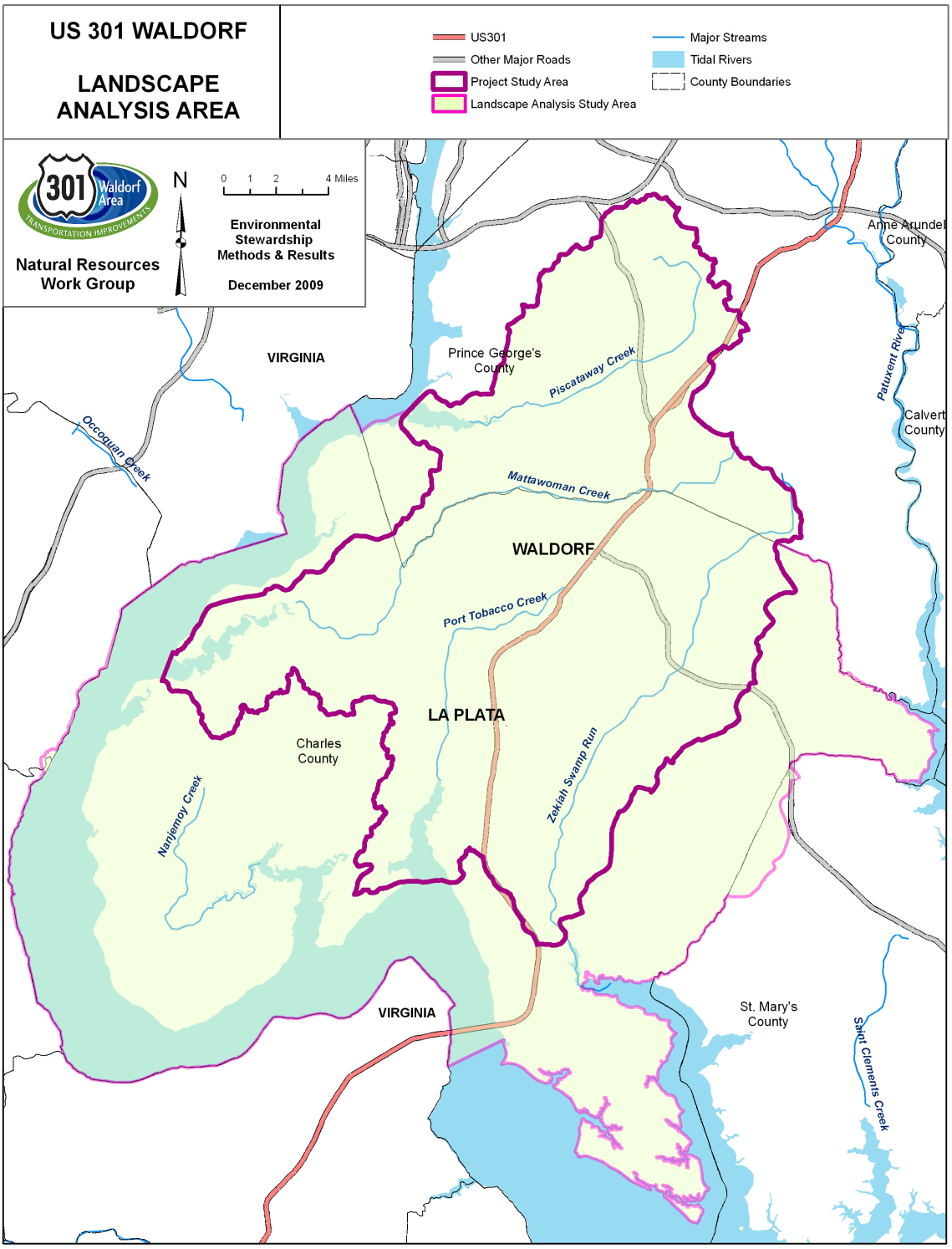
Charles County's 1997 Comprehensive Plan noted a number of ecological greenways, including Mattawoman Creek and Zekiah Swamp (MGC, 2000). Charles County has a goal of protecting 50% of the county's land area, or about 147,000 acres (ERM, 2006). Primary protection targets include the unprotected portion of the Mattawoman Creek valley as identified in the Mattawoman Creek Watershed Management Plan and unprotected portions of the Green Infrastructure as identified by the state assessment. However, the US 301 corridor, which runs through the Waldorf Sub-Area planning area, is Charles County's and Southern Maryland's major retail, business, and employment corridor (CCDPGM, 2004). The Sub-Area's population is projected to increase to almost 90,000 people by 2020 (CCDPGM, 2004).



Map 3. Prince George's County "rural tier" in the landscape analysis area.

V. NATURAL RESOURCE IDENTIFICATION AND ASSESSMENT

The NRWG next assessed the existing natural resource conditions. Stream and wetland analyses were primarily focused on the four focus watersheds, but other analyses focused on the broader study area (Map 4).



Map 4. US 301 landscape analysis area (Charles County and part of Prince George's County) and project area (watersheds potentially impacted by highway construction).

1. Green Infrastructure Conceptual Approach

A key element of the NRWG strategy to identify ES needs is the use of a green infrastructure approach to identify conservation, restoration, and best management practice priorities within the US 301 Study Area. The Natural Resource Work Group delineated and ranked a green infrastructure network for the US 301 Study Area and the overlapping watersheds included within the US 301 project.

Green Infrastructure is defined as strategically planned and managed networks of natural lands, working landscapes, and other open spaces that conserve ecosystem functions and provide associated benefits to human populations (Benedict and McMahon, 2006). Green infrastructure provides a systematic and strategic approach to land conservation, encouraging land use planning and practices that are beneficial to nature and people. The planning and management of a green infrastructure network can guide the creation of an open space system that supports multiple objectives.

According to Webster's New World Dictionary, infrastructure is defined as "the substructure or underlying foundation, especially the basic installations and facilities on which the continuance and growth of a community or state depends". When we think of infrastructure, we typically think of built (or gray) infrastructure such as roads, electric power lines and water systems, as well as social infrastructure such as schools, hospitals and libraries. However, the concept of green infrastructure elevates air, land, and water to an equal footing with built infrastructure, and recognizes that open space is not merely "nice to have", but is a "must have." Protecting and restoring our natural life-support system is a necessity, not an amenity. What gives the term green infrastructure its staying power is its ability to invoke images of planned networks of green spaces that benefit wildlife and people, link urban settings to rural ones and, like other infrastructure, form an integral part of government programs and budgets.

The basic building blocks of the green infrastructure network are core areas, hubs and corridors, as depicted in Figure 1. Core areas contain well-functioning natural ecosystems, and provide high-quality habitat for native plants and animals. These are the nucleus of the ecological network. Hubs are slightly fragmented aggregations of core areas, plus contiguous natural cover. Hubs are intended to be large enough to support populations of native species, and serve as sources for emigration into the surrounding landscape, as well as providing other ecosystem services like clean water, flood control, carbon sequestration, and recreation opportunities. Corridors link core areas together, allowing wildlife movement and seed and pollen transfer between them, and thereby promoting genetic exchange. Each type of core area is associated with a type of corridor or linkage depending on the movement abilities and landscape preferences of organisms living in that type of core area. For example, river otters live in riparian forest along perennial water, and prefer to travel in waterways with adjacent tree cover. Other wetlands and forest are generally better than open areas as linkages for otters. For most animals, urban areas and major roads (except under bridges) act as barriers to movement. Steep slopes (e.g., ravine sides) may be avoided by some species like turtles.

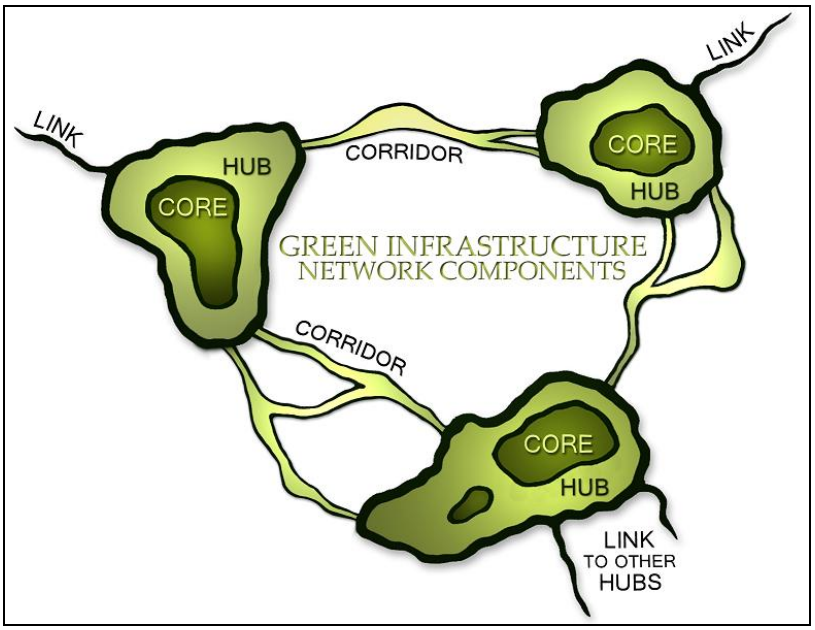


Figure 1. Conceptual green infrastructure diagram.

A fourth element – sites – includes other important natural features that may not be incorporated into the hub and corridor network. Although these features may not be in a large enough block of natural land to constitute a hub, they may still provide valuable ecosystem services or habitat for imperiled plants or animals. An array of human-oriented land uses can complement the green infrastructure network by providing a compatible use buffer between sensitive habitats and more developed landscapes. Such land uses as working farms and forests, recreational trails, scenic vistas, and historic/cultural sites also provide important benefits to human populations. Although even yard and street trees provide some benefits, like shading and air purification, the state's most important natural lands are those that are large and intact enough to provide a full suite of environmental functions.

Green infrastructure network identification follows principles of landscape ecology and conservation biology, such as these guidelines from Noss (1992) and Benedict and McMahon (2006) for maintaining native biodiversity and ecosystem processes:

- A GI network should contain, in a system of protected areas, the best remaining examples of all native ecosystem types.
- The network should maintain viable populations of all native species in natural patterns of abundance and distribution.
- The network is designed to maintain ecological and evolutionary processes, such as disturbance regimes, hydrological processes, nutrient cycles, and biotic interactions.
- A conservation network should contain the best remaining examples of the full suite of native biodiversity.
- Large blocks of habitat, containing large populations of a species, are superior to small blocks of habitat containing small populations.
- Habitat in contiguous blocks is better than fragmented habitat.
- To maintain connectivity, useable habitat, and gene flow, blocks closer together are better than blocks further apart.
- Interconnected blocks of habitat are better than isolated blocks, and corridors or linkages function better when habitat within them resembles that preferred by target species.
- Habitat blocks with compatible buffers like silviculture or agriculture are preferable to abrupt boundaries with development.
- Accommodate human activities compatible with goals of resource protection.

The first step in developing a GI network is to identify species and natural communities occurring in the study area, and then identify their habitat preferences and requirements, home range sizes, dispersal abilities, suitable landscape features for dispersal, barriers to dispersal (e.g., highways or development), and the species role in ecosystem function. Simultaneously, data are acquired that depict the locations and characteristics of landscape features like land cover, streams, roads, topography, etc. Spatial data are processed using Geographic Information Systems (GIS) to identify core areas, hubs, and corridors in the study area. Efforts are made to ensure that the input data and model outputs represent the real world as closely as possible, and data limitations are noted.

"Umbrella" and "keystone" species native to the area are used to determine size, connectivity, and other thresholds in the GI network design. Umbrella species are a species or group of species whose habitat needs overlap those of other animals and plants. Keystone species are those with an important role in ecosystem function, such as pollinators and top carnivores. Habitat preferences of umbrella and keystone species help identify core areas and hubs. Connectivity requirements of less vagile (i.e. mobile) species (e.g., amphibians and small mammals) are used to model corridors.

In the US 301 Project, the forest umbrella species were forest interior breeding birds (FIDS), which require large forest areas to breed successfully and maintain viable populations. The habitat needs of FIDS overlap those of many other plant and animal species including large mammals, many wildflower species, wood frogs, and wild turkeys. When sufficient habitat is protected to sustain a diversity of forest birds, important components and microhabitats of the forest will be encompassed and be protected (Jones et al. 2000). Wetland umbrella species were separated by the type of wetland system, and included Louisiana waterthrush, Prothonotary warbler, Least bittern, amphibians, and turtles. Fish and mussels were the aquatic umbrella species. Corridor umbrella species included reptiles, amphibians, fish, and mammals, depending on the type of linkage.

The types of landscapes and ecosystems incorporated into a GI network depend on the region's topography, climate, geology, historic and current species composition, present configuration, and other factors. The US 301 study area was divided into the following core ecosystem types, based on broad differences in function: forests, wetlands, and aquatic systems. There was some overlap between the three; for example, riparian forested wetlands can fall under all three categories. Forests are the dominant terrestrial ecosystem in the study area; 95% of Maryland was historically covered in forest (Besley, 1916; Powell and Kingsley, 1980). We hoped to include grassland systems as well, but lacked data that could accurately identify them. We also considered other landscape types in the GI analyses for their buffering and connectivity properties. For example, agricultural land is less a barrier to wildlife movement than developed land.

For the US 301 Project, core areas include:

- Core forest, based on habitat requirements of forest interior breeding birds, are blocks of forest containing at least 100 ha (250 ac) of mature interior (>100 m/328 ft from the edge) deciduous or mixed forest.
- Core wetlands, based on habitat requirements of several species of birds, amphibians, and reptiles, are unimpaired wetlands with adjacent forest or water.
- Core aquatic areas are naturally functioning streams with continuous riparian vegetation that are not impounded by human structures like dams. The Potomac River itself was not explicitly part of our analysis, since its watershed is much bigger than the study area.
- Other core areas include significant habitat not falling within the forest, wetland, or aquatic categories. Some habitats, like grassland, could not be accurately identified using available GIS data, but DNR delineated those containing rare species.

As part of the green infrastructure network design for the US 301 Project, the NRWG reevaluated the Maryland Green Infrastructure Assessment parameters (Weber, 2003) to develop a comprehensive framework for assessing natural resource ES needs. The NRWG reassessed target species and their associated habitat; identified, defined, and incorporated additional or revised parameters; and developed revised ecological weighting factors. Parameters considered terrestrial, aquatic, and wetland resources and ecological values of particular sensitivity in the US 301 study area. A detailed methodology for the green infrastructure update can be found in Appendix C.

2. Assessment of Forest Resources

Collection of forest plot data

The Fund collected forest plot data at 62 sites throughout the landscape study area in fall 2007, and used this to identify and calibrate parameters modeling high-quality forest. Sites were randomly selected, with approximately half falling within high quality forest interior bird habitat (polygons delineated by Maryland DNR in 2003, based on 1990's GIS data), and half outside. 43 of these plots were in Charles County, and the other 19 were in Prince George's County. All plots were at least 100 m (328 ft) from non-forest, and contained fairly uniform conditions (e.g., canopy height and successional stage).

At each plot, we recorded topographic, hydrologic, disturbance, and invasive species information within a 50 m (164 ft) radius from the center point. Within 11.3 m (37 ft) of the center point, we recorded the height and percent cover of each stratum. We measured height to the top of a representative tree in the canopy layer and each subcanopy layer using a Haga altimeter. We recorded the species and diameter at breast height (dbh) of all canopy trees, separated tree and shrub species in the subcanopy and shrub strata into dominant and non-dominant categories, and noted the presence of snags, downed logs, tree cavities, and pit and mound structure. We also collected information less pertinent to this study, such as sapling and seedling compositions and densities, ground layer composition, litter and humus depth, and soil characteristics. When possible, we collected site history and management information from land owners or renters. Appendix G contains a sample data sheet. The community rating combines variables related to disturbance, hydrology, maturity, structure, composition, diversity, successional trajectory, and habitat quality, and was calibrated using plot data from throughout Maryland and relationships with forest bird richness on the eastern shore (see description in Weber et al., 2006).

Forest plot results

Most sampled sites (47 of 62) contained deciduous forest. Seven sites contained coniferous forest, and eight were mixed. Over half the stands (34) were 40-80 years old, with 15 older than 80 years, and 13 younger than 40 years. Nineteen stands contained early successional forest, 25 were mid-successional, and 18 were late successional. Mature forest tended to be dominated by oaks (*Quercus spp.*), beech (*Fagus grandifolia*), tulip poplar (*Liriodendron tulipifera*) (which is long-lived despite being a fast-growing pioneer), and hickories (*Carya spp.*), depending on soil drainage, pH, logging history, and other factors. However, mature floodplain forest was often dominated by red maple (*Acer rubrum*), sycamore (*Platanus occidentalis*), and other hydrophytic species. Crown top height varied between 13 - 41 m (mean 27 m), and mean canopy tree diameter varied between 11.7 – 74.6 cm (mean 36.1 cm). Over half the plots (52%) contained visible disturbances. Overall scores varied between 102 and 518 (mean 327), corresponding to 15 Excellent sites, 23 Good, 22 Fair, and 2 Poor.

Mature oak forest near Piscataway National Park in Prince George's County.

Young deciduous forest southeast of Waldorf

Exotic species

58% of plots in the US 301 landscape study area contained exotic plants. The average exotic plant coverage was 15%, with several sites blanketed by them. Japanese honeysuckle (*Lonicera japonica*) was by far the most common exotic plant in our plots. Exotic plants were not commonly seen above ground level.

We compared the following variables to invasive plant prevalence: canopy height; canopy mean tree diameter; forest type; stand age; forest successional stage; presence of logging roads or trails; percent of site with visible signs of recent logging; mean distance to the nearest forest edge; mean distance to the nearest road; and mean distance to the nearest developed area. Results are summarized below:

- Later successional forest stands had less exotic plant cover than earlier successional stands ($p<0.01$, $F=5.31$, $df=61$). Mean exotic plant cover was: late 3%, mid 12%, early 31%. Possibly, invasive species arrived when sites were disturbed. Late successional stands (dominated by oaks, hickories, or beech) may not have afforded these opportunities for invasion. The most prevalent invasive plant, Japanese honeysuckle, is shade-tolerant, so shade is probably not a factor. Many late-successional stands had been disturbed by gypsy moths, ice, wind, or selective logging, but the forest floor was not as disturbed as happens from clear cutting or if the site recently recovered from agricultural use.
- All plots with trails (n=8) had exotic species (Chi-square, $p=0.01$).
- Plots with <5% exotic species cover were likely to be >400m from the forest edge or >1 km from developed land. No plots >400m from the edge contained >5% exotic species cover, although the sample size was small (5 plots >400m from edge, $p=0.08$). Only one of 11 sites >1 km from developed land contained >5% exotic species cover (Chi-square, $p<0.05$).
- Other variables were not predictive.

Canopy height

Field data showed a significant relationship between canopy height and forest community condition, and suggested a threshold >24m to identify mature, high-quality forest. Results included:

- Canopy tree diameter was strongly related to canopy height ($R^2 = 0.61$, $p<0.001$).
- Forest community score was significantly related to canopy height ($R^2 = 0.34$, $p<0.001$).
- Plots with a canopy >21m tall had significantly greater scores (averaging 361) than plots with shorter canopies (scores averaging 260) ($F=27.6$, $p<0.001$, $df=61$).
- Plots with a canopy >24m tall had significantly greater scores (averaging 366) than plots with shorter canopies (scores averaging 269) ($F=27.3$, $p<0.0001$, $df=61$).
- Forest communities rating Excellent or Good had higher canopy heights than those rating Fair or Poor. All Excellent stands were >24m, and 80% were >26m. All Good stands were ≥21m, and 85% were ≥23m. Fair stands varied from 13-35m, with a median of 21m. Poor stands were at most 24m tall, with a median <20m.
- Mature forest stands had taller canopies (95% >24m, and 80% ≥30m) than intermediate-aged stands (95% >21m, and 80% ≥23m). Both were taller than young stands, which were generally <20m (95% <24m, and 75% ≤20m).
- Looking at broadleaf forest (n=47), canopy height was not very helpful at identifying successional stage. Most notably, tulip poplars (*Liriodendron tulipifera*) are common early successional trees that grow quickly and very tall (often >30m). Tulip poplars are long-lived, though, and can persist in mid- and late-successional forest.

The Fund contracted the James W. Sewall Company to calculate canopy height from LiDAR data throughout Charles County, and calibrated this using plot data (see Weber and Boss, 2009). Canopy height was derived from LiDAR first return and bare earth points as the maximum height per 6-meter grid cell. We averaged LiDAR-derived canopy heights within the radius of our field plots (averaging 11 cells per plot), and compared these numbers to field-measured crown top heights. We selected the best fitting curve to adjust LiDAR-derived canopy height.

Comparing to the maximum LiDAR height, crown top height measured in the field was usually greater than LiDAR-derived height, especially for shorter trees. A logistic regression (Field Height = 42.195 / (1+ 4.768 * EXP(-0.09178 * LiDAR Height))) was the best-fitting curve (R^2 = 0.72). A LiDAR canopy height threshold >20m identified 97% of plots with field-measured heights >24m (i.e., 3% false negatives), and 78% of plots with LiDAR >20m had field heights >24m (i.e., 22% false positives) (Chi-Square, p= 0.000015, n=49). All false positives had canopy heights 21-24m. The average field height for plots with LiDAR >20m was 29.7m; with LiDAR ≤20m, it was 19.3m ($p < 0.000001$, F=38.19, df=48).

Canopy height and forest age

The Fund compared forest plot data to LiDAR canopy height data processed in Charles County, historic (1938) aerial photos digitized in Prince George's County, and other data such as land cover, slope, stream proximity, wetlands, and floodplains. Canopy height was a strong predictor of forest age, and predictive power was improved by including other variables. These comparisons allowed us to construct a spatial model classifying forest in the study area into three age categories: <30 years old, 30-70 years old, and >70 years old (see Weber and Boss, 2009).

Because we did not have permission to drill cores in trees, we estimated forest stand age using canopy tree composition, spacing, and size, historic photos where available, and signs of past disturbance. Canopy tree diameters were compared to data for the same species and similar growing conditions, collected from sites with known ages. Young forest (<40-50 years) on abandoned farmland was usually dominated by closely spaced early successional trees, with almost no subcanopy under deciduous canopies, or a canopy still dominated by pines (*Pinus* spp.). Young forest dominated by oaks or other non-pioneer species was usually the result of severe gypsy moth damage, logging, or other acute disturbances. We estimated forest age since agricultural abandonment, clearcutting, or total canopy loss to gypsy moth caterpillars. We discounted partial canopy loss to selective harvesting, pests, storms, or other factors.

We first compared the estimated age of each forest plot to its field-measured, LiDAR, and corrected LiDAR canopy height. The correlation between age and crown top height (measured in the field) was 0.81 (R^2 = 0.66, $p<0.001$). Forest at least 80 years old was generally >28m tall ($p<0.001$, F=56.4, df=61). Corrected LiDAR canopy height was likewise a strong predictor of forest age (Figure 2; R^2 = 0.67, $p<0.001$).

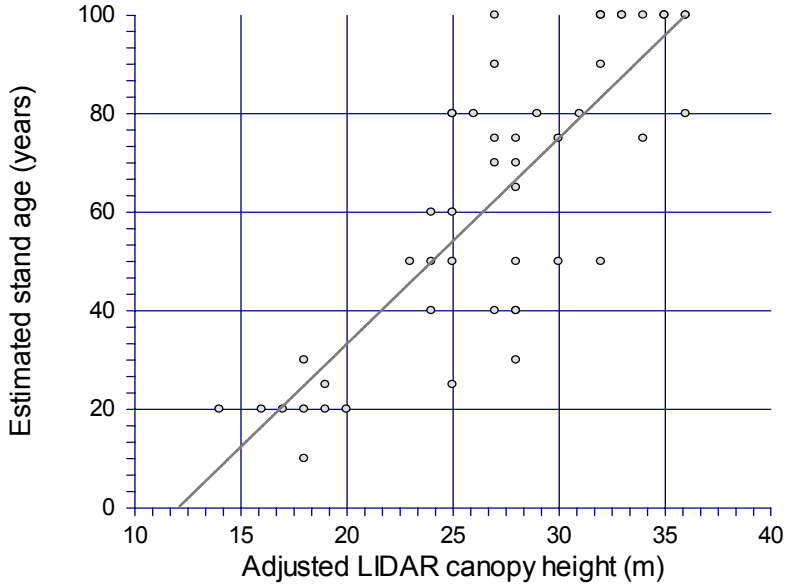


Figure 2. Estimated forest stand age vs. canopy height from LiDAR data calibrated using field measurements.

Using the field and corrected LiDAR regressions as a guide, we grouped LiDAR data into the following brackets: <22m (Short), 22-28m (Medium), and >28m (Tall). A Tukey-Kramer Multiple-Comparison Test significantly discriminated ($p<0.05$, $df=46$) between all groups (See Table 5).

Table 5. Estimated stand age vs. canopy height.

Height bracket	Number of Plots	Estimated age (years)			
		Mean	Std.	Min.	Max.
Short	9	20	6	10	30
Medium	22	60	4	25	100
Tall	18	>88	4	50	>100

The Tall height bracket generally corresponded to forest >70 years old, the Medium bracket to forest 30-70 years old, and the Short bracket to forest <30 years old. LiDAR alone seemed to underestimate the area of forest >70 years old in Charles County. Logging, pests (especially gypsy moths), and storms have had great effects on county forests. Nevertheless, about a third of plots in the 30-70 year height bracket were >70 years old.

Forest age relationships with multiple variables

To improve discrimination between age classes, we considered additional variables besides canopy height:

- Land cover class (deciduous/coniferous)
- Wetland (yes/no)
- In 100 year floodplain (yes/no)
- Percent slope (averaged within plot)
- Slope-weighted stream distance (averaged within plot)

Coniferous forest was likely to be young (<40 years). Given the history of land use in Charles County and examining 1938 aerial photographs, we hypothesized that forest in stream valleys or on steep slopes was likely to be older than forest on terrain easier to farm or not subject to best management restrictions. The slope-weighted stream distance was the distance from 1:24K National Hydrography Dataset flowlines with each cell multiplied by the percent slope, using the cost distance function in ArcGIS. The cost distance function assigns each raster cell the accumulative cost to the closest source cell; here, the cost was the slope and the source was the nearest stream, so stream valley slopes would have greater values than valley floors. We thereby hoped to incorporate stream valley topography better than a fixed-distance approach. The mean cost distance value within 100 year floodplains was 34 (std. dev. 93). Ninety percent of cells within 100 year floodplains had a value <94, and 95% less than 165. Using NCSS statistical software for Microsoft Windows (Hintze, 2007), we tested all remotely sensed variables against estimated age, and examined correlations between these variables.

Univariate tests found land cover to be significant, but the low number of wetland and floodplain plots hampered the other categorical analyses. Wetlands were not a significant variable, but there were only 4 plots within wetlands. Plots within 100 year floodplains were older on average, but sample size was small (3 floodplain plots), and the difference was not significant. Remotely sensed land cover was significant: deciduous forest was older on average (67 years) than coniferous forest (26 years) ($p < 0.001$, $df = 61$). Similarly, using field data, and omitting mixed forest, hardwood forest was older on average (71 years) than pine forest (21 years) ($p < 0.0001$, $df = 59$). The mean for mixed forest was 50 years ($n=2$). Plots with a LiDAR-derived slope >6% were older on average than plots with gentler slopes, but this difference was not significant. We did not find a significant univariate relationship between forest age and slope-weighted distance to streams.

Natural forest community data collected by TCF and DNR in 2007 (n=123) showed a relationship between forest maturity and slope, but not between maturity and inundation or soil drainage (Tables 6-8). Forest on slopes >16% was more likely to be mature than forest on slopes <16% (Chi-square, $p<0.01$).

Table 6. Natural community maturity vs. site slope.

Mean slope	Mature communities	Intermediate or young communities	% Mature
0-3%	25	30	45
3-8%	18	10	64
8-16%	12	12	50
>16%	14	2	88

Table 7. Natural community maturity vs. site inundation.

Inundation	Mature communities	Intermediate or young communities	% Mature
Never	52	42	55
Infrequently	16	8	67
Regularly	0	2	0
Always submerged	1	2	50

Table 8. Natural community maturity vs. site soil drainage.

Soil drainage class	Mature communities	Intermediate or young communities	% Mature
Well drained	32	21	60
Moderately well drained	15	20	43
Somewhat poorly drained	8	5	62
Poorly drained	12	6	67

Stepwise regression against age retained corrected LiDAR canopy height as the most significant variable (R^2 = 0.67), with slope-weighted stream distance as the only other explanatory variable (increasing R^2 to 0.71). Discriminant analysis also retained canopy height and slope-weighted stream distance. Again, canopy height was the more important variable.

We then used a classification tree model (CART) programmed for Microsoft Excel, splitting forest age into 3 groups suggested by the canopy height results: young (≤30 years), intermediate (30-70 years), and mature (>70 years). Classification trees are predictive models which split variable values to match observations as closely as possible. To prevent overfitting of the data by an overly specific or complex model, we stopped splitting nodes if they were at least 95% "pure" or had been split six times, and pruned the number of splits (branches). We adjusted the algorithm to remove biases against categorical variables. Then we randomly selected 20% of the data as a test set, re-partitioned the data 20 times (dividing into different random training and test sets), and selected the model that most accurately classified the data (Figure 3; Table 9).

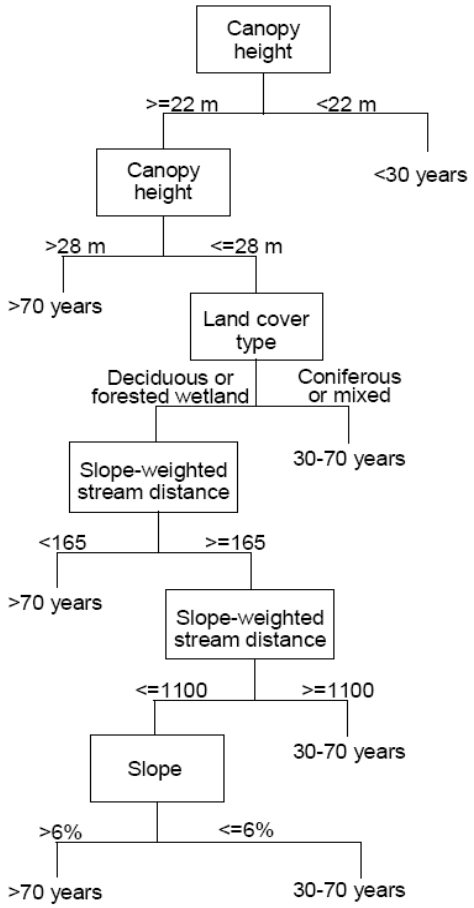


Figure 3. Classification tree model predicting forest age classes in Charles County.

Table 9. CART model classification fit to training and test data.

Training data

Observed forest age (years)	**Predicted forest age (years)**			
	>70	30-70	≤30	TOTAL
>70	15	0	0	15
30-70	2	11	0	13
≤30	1	1	7	9
TOTAL	18	12	7	37

Test data

Observed forest age (years)	**Predicted forest age (years)**			
	>70	30-70	≤30	TOTAL
>70	8	0	0	8
30-70	0	2	0	2
≤30	0	0	2	2
TOTAL	8	2	2	12

Aerial photos and forest age

Where LiDAR data was missing, we used woodland in 1938 and 2005 aerial photos digitized by Prince George's County. Examining 1938 aerial photos, areas digitized by the county as 1938 woodland varied from old fields to mature forest, with the majority appearing to be young to intermediate in age at the time. Areas that were forested in both 1938 and 2005 were assumed to be at least 70-80 years old.

Comparing these areas to plot data, deciduous forest identified in both 1938 and 2005 photos was likely to be at least intermediate in age, and possibly mature, and almost certainly mid to late successional. Of the four sites not identified as woodland in 1938, 3 were identified as young in the field, and one as intermediate in age. All four of these sites were dominated by early successional trees. Of the 12 sites identified as woodland in 1938, 4 were mature, 6 were intermediate aged, and 2 were young. Of the young forests, one was a pine stand that was probably cleared in the interim, and the other had lost its canopy trees to gypsy moths and/or other disturbances. All mid to late successional forest was identified in 1938 photos. Forest identified in 1938 photos was significantly less likely to be young than forest not identified in 1938 photos (Chi-square, $p<0.05$, $n=16$). Although the sample size was too small to detect significance, all mature forest plots were identified as forest in 1938.

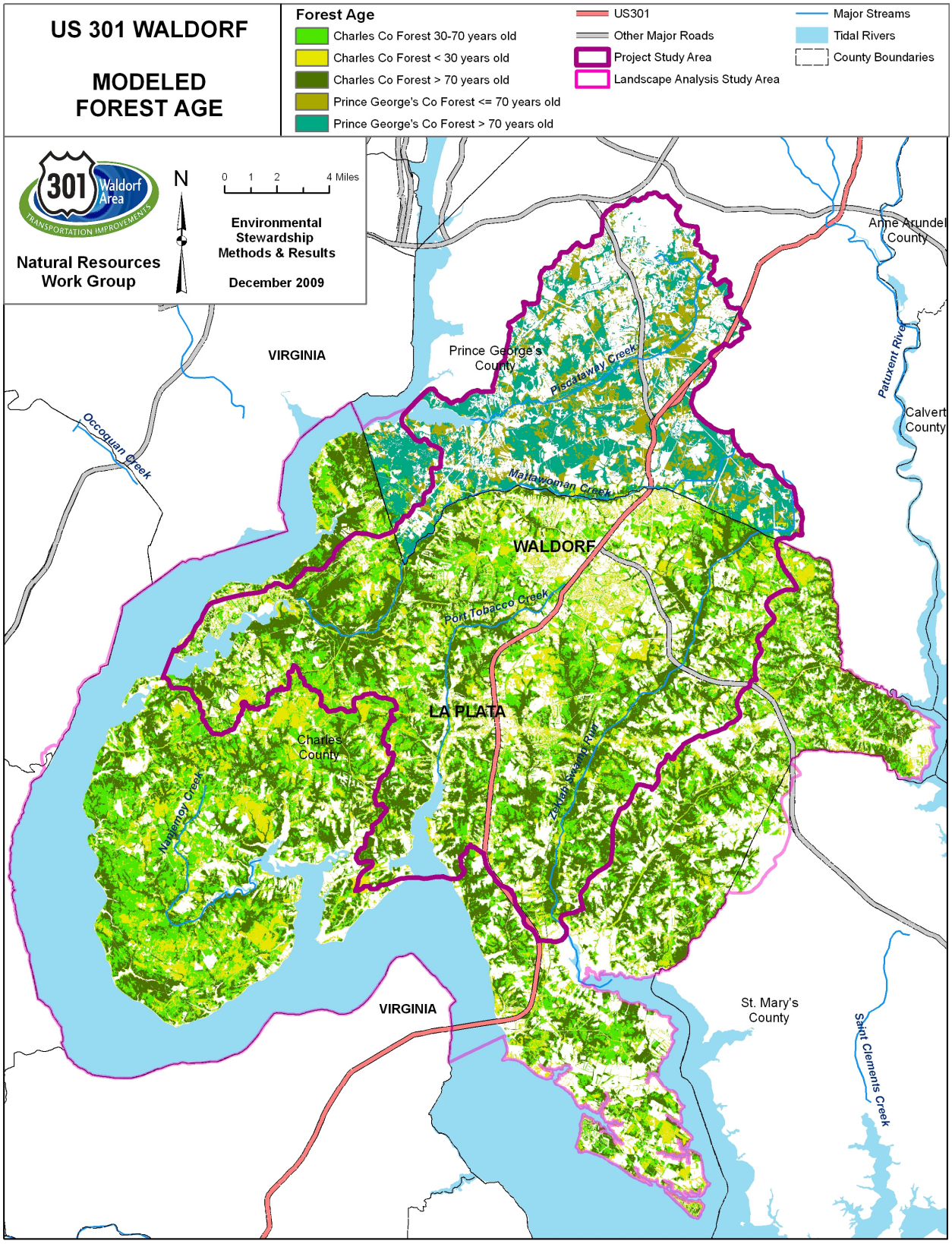
There were 6,412 acres (2595 ha) of overlap between LiDAR coverage and digitized 1938 photos. In this area, 73% of forest with a canopy height ≥25 m (82 ft) was also woodland in 1938. Conversely, 69% of woodland in both 1938 and 2005 had a canopy height ≥25 m. The latter error was decreased by excluding pines (e.g., loblolly plantations which could have been cut in the interim). 75% of non-pine forest with a canopy height ≥25 m was also woodland in 1938, and 72% of non-pine woodland in both 1938 and 2005 had a canopy height ≥25 m.

Spatial forest age model

We applied a focal filter to canopy height, slope-weighted stream distance, and slope. This calculated a mean value within a 12 m (39 ft) radius circle (roughly corresponding to our field plot size) for each 6 m cell. We then applied the decision rules from the classification tree to identify young, intermediate, and mature forest in the area with LiDAR data (Charles County plus some overlap). Because it was unrealistically grainy in places, the mature class was smoothed using a focal majority (recording the class that appeared most often within 12 m of each cell location), and then areas <0.4 ha (1 ac) were omitted. No smoothing was subsequently required for younger forest.

In Prince George's county, we relied on digitized aerial photos. Forest appearing in both 1938 and 2005 photos was assumed to be more than 70 years old. Where LiDAR data was available, we subtracted recent clear-cuts and young regrowth (canopy height <22 m (72 ft)). We also manually digitized and subtracted other obvious clear-cuts from 2007 aerial photos. It was not practical to do this comprehensively for the entire study area, and only a cursory attempt was made. We also overlaid NLCD data, and assumed (based on our field surveys) that areas classified as coniferous (pine) were intermediate or young in age.

Finally, we merged the results from LiDAR and aerial photos. We grouped Charles County forest into three classes: <30 years old, 30-70 years old, and >70 years old. Areas dominated by seedlings or young saplings (<5 m (16 ft) tall) were considered old field or scrub-shrub stages rather than forest. Not counting seedling or young sapling stages (<5 m tall), model output showed 35% of forest in Charles County >70 years old, 37% between 30-70 years, and 28% <30 years. Mature forest tended to occur in stream valleys, although this was not always the case. Prince George's forest, except where LiDAR was available, was grouped into two classes: ≤70 years old and >70 years old. Map 5 shows model output for the study area.



Map 5. Modeled forest age in the US 301 landscape analysis area.

We validated the model by comparing output to independent data collected by DNR in forest communities. These sites were classified as probably >70 years old if they were denoted "mature" by the surveyor, or if they had a tall canopy (>28 m (92 ft)) dominated by oaks or beech. Descriptive notes and canopy presence of Virginia pine (*Pinus virginiana*) were also considered. All but one of the additions was in bottomland hardwood forest along Mattawoman Creek or lower tributaries. The surveyor had described all but one of 13 alluvial forest plots in Mattawoman NEA or Myrtle Grove WMA as "young", but based on their tree composition and height, some of these plots were probably >70 years old. The survey did not discriminate between young and intermediate aged forest, but few of the sites were within young (<30 years old) forest.

We buffered the DNR data points 12 m (roughly corresponding to TCF's plot size) and calculated the majority modeled forest age class within each buffer (Table 10). DNR's observations, although not evenly distributed throughout the study area, agreed with the model in identifying relatively mature forest (Chi-square, $p<0.05$). 90% of observed mature forest was modeled as such. However, 64% of observed younger forest was also modeled as mature forest (Table 10).

Table 10. Comparison of forest maturity from DNR surveys to forest age model.

Identified as mature in field?	**Identified as mature by model?**		
	no	yes	Total
no	8	14	22
yes	4	35	39
TOTAL	12	49	61

A better test of the model would randomly select new sites throughout the study area, stratified by relative modeled age class abundance, and age indicator canopy trees using increment borers.

3. Assessment of Wetland Resources

Methods Summary

The DNR Riparian and Wetland Restoration Services group (RWRS) was responsible for providing the best available wetland data, which included a GIS wetland layer scored to reflect habitat and water quality benefits through a Level I landscape analysis performed by the Virginia Institute of Marine Science (VIMS). In addition, RWRS was responsible for field verification of the wetland data. Field staff assessed 30 sites for wetland condition using four Rapid Assessment Methods (RAMs): Delaware Rapid Assessment Protocol (DERAP), Ohio Rapid Assessment Method (ORAM), Pennsylvania State University Stressor Checklist (Penn State), and Montana Department of Environmental Quality Wetland Rapid Assessment Form (MT DEQ). Descriptions of the four methods are included below, and datasheets for each method are included in Appendix F.

The DERAP was developed to assess the ambient condition of nontidal wetlands (flats, depressions, and riverine) on the Maryland and Delaware Outer Coastal Plain. The method uses the hydrogeomorphic (HGM) wetland classification, and is applicable to restored and created wetlands in addition to natural wetlands. An important component of the method is the Qualitative Condition Rating (QCR). The QCR is a modification of the Tiered Aquatic Life Use Model and ranks disturbance levels from 1 to 6, with a score of 1 signifying a site with minimal disturbance. The model uses best professional judgment to rate changes in biotic structure and hydrogeomorphic function (See Appendix F-1). The DERAP method is divided into three stressor categories: Habitat/Plant Community, Hydrology, and Buffer. Within the three categories are lists of stressors that carry varying weights. The stressor weights are tallied to calculate a final condition score, which can then be categorized into stressor buckets (good, fair, and poor). Final scores are HGM subclass dependent (James, 2007).

Similar to the DERAP, the Ohio method was designed to assess the ambient condition of nontidal wetlands. The ORAM can also be used for regulatory purposes. While the HGM wetland classification system is used for ORAM, the final scores are not HGM subclass dependent. The Ohio method uses narrative descriptions to characterize the wetland's size, buffer, hydrology, habitat, and vegetative structure. The assessors choose the narrative description that best captures the wetland's characteristics. Each description carries a score: scores are subtotaled by category and then totaled for a final score between 0 and 100. Scoring can be recalibrated for specific ecological regions (James, 2007).

Both a landscape (Level 1) and a rapid field (Level 2) assessment are included in the Penn State Method. The landscape assessment focuses on the percent forest cover in a 1 km (0.6 mi) buffer around the wetland. The rapid field assessment characterizes the buffer type (natural forest, shrub/sapling, herbaceous, other) and width, followed by a long list of stressors categorized under hydrology, water quality, and vegetation. Percent forest cover and number of stressor categories factor into the final wetland score. These scores rank the level of impairment, ranging from 0 to 100, with lower scores signifying minimal impairment and higher scores signifying greater impairment (James, 2007). This scoring is opposite to the other three RAM's used for this study.

The Montana DEQ method was developed to assess all freshwater wetland types for regulatory decision making, land use planning, and monitoring ambient wetland condition. Included in the method is a ranking that assesses the restorability and wetland condition trend toward natural restoration. Both the HGM and Cowardin (NWI) wetland classification systems are used to describe the wetland. Similar categories are used to assess the wetland, including hydrogeomorphology, vegetation, water quality, and buffer condition. Also included in the method is an additional category for assessing the condition of riparian systems. Lists of RTE and invasive species are specific to Montana, but may be adapted for other regions. Final scores are calculated for each category, and from these scores a Wetland Impact and Overall Score are calculated. The Overall Score allows the assessors to categorize the wetland into four condition buckets: Excellent, Good, Fair, and Poor. The method also includes a list of stressors that the assessors rank from highest to lowest impact (James, 2007).

Wetland in Mattawoman Creek floodplain.

Summary of Findings

Of the 30 sites visited, 27 were still wetlands. Sampling occurred during October 2007 and May 2008. The October 2007 sampling was at the end of the growing season and during an intense drought, therefore, many sites had no water present. We sampled eight additional sites in May 2008. From the sample of 27 wetlands (12 potential Green Infrastructure core sites and 15 non-core sites), the ORAM scores correlated best with the DERAP QCR ($r^2 = 0.64$). DNR intended to develop a rapid wetland assessment method specific to the study area by combining the strongest metrics from the four RAM's tested. However, this would require a much larger sample size, stratified by HGM subclass and perhaps by watershed. Therefore, DNR suggested that the ORAM be used to assess wetland condition in the study area and that the ORAM scores be used to validate the GI model. In the future, it will be necessary to add metrics for tidal wetlands to ORAM. The restorability and wetland trend metrics from the Montana method are also useful tools for documenting whether restoration is required, and then to determine the amount of effort and resources required.

4. Assessment of Stream Resources

Methods Summary

The stream conditions characterization for the four watersheds in the study area involved three main steps: 1) collection of readily available GIS data; 2) stream stability field reconnaissance assessment; and 3) GIS and field data analysis. The GIS data gathered related to those factors that have the most potential to influence stream stability. The data that were selected included existing land use/land cover, aerial photography, topography, soils, and percent impervious surfaces.

The stream stability reconnaissance assessment involved the development of a standardized assessment form (See Appendix E) and assessment of streams within representative watershed conditions. The standardized form was a rapid assessment of stream stability based on observations and minimal measurements. The form contained fluvial geomorphic stream condition and stream habitat condition assessment parameters. Fluvial geomorphic stream assessment parameters included: Rosgen stream type, stream stability evolution, channel dimensions and pattern, width/depth ratio, entrenchment, incision, bank height, depositional features, bed and bank materials, flow regime, vertical and lateral stability, sediment supply and amount, debris jams, and utility crossings. The stream habitat assessment parameters included: bed features, quality of bed features, water conditions, fish blockage, flow velocity and depth variability, flood plain width, and dominant riparian vegetation species and age. Approximately 1,000 to 1,500 feet (300-450 m) of stream was walked for each stream reach assessed. A rating of stable, unstable, or recovery was assigned to each stream reach. A rating of "stable" was assigned to streams that were stable or had minimal localized lateral erosion. A rating of "unstable" was assigned to streams that had system wide active lateral or vertical instability problems. A rating of "recovery" was assigned to streams that were rebuilding stable channel dimension, pattern, and profile.

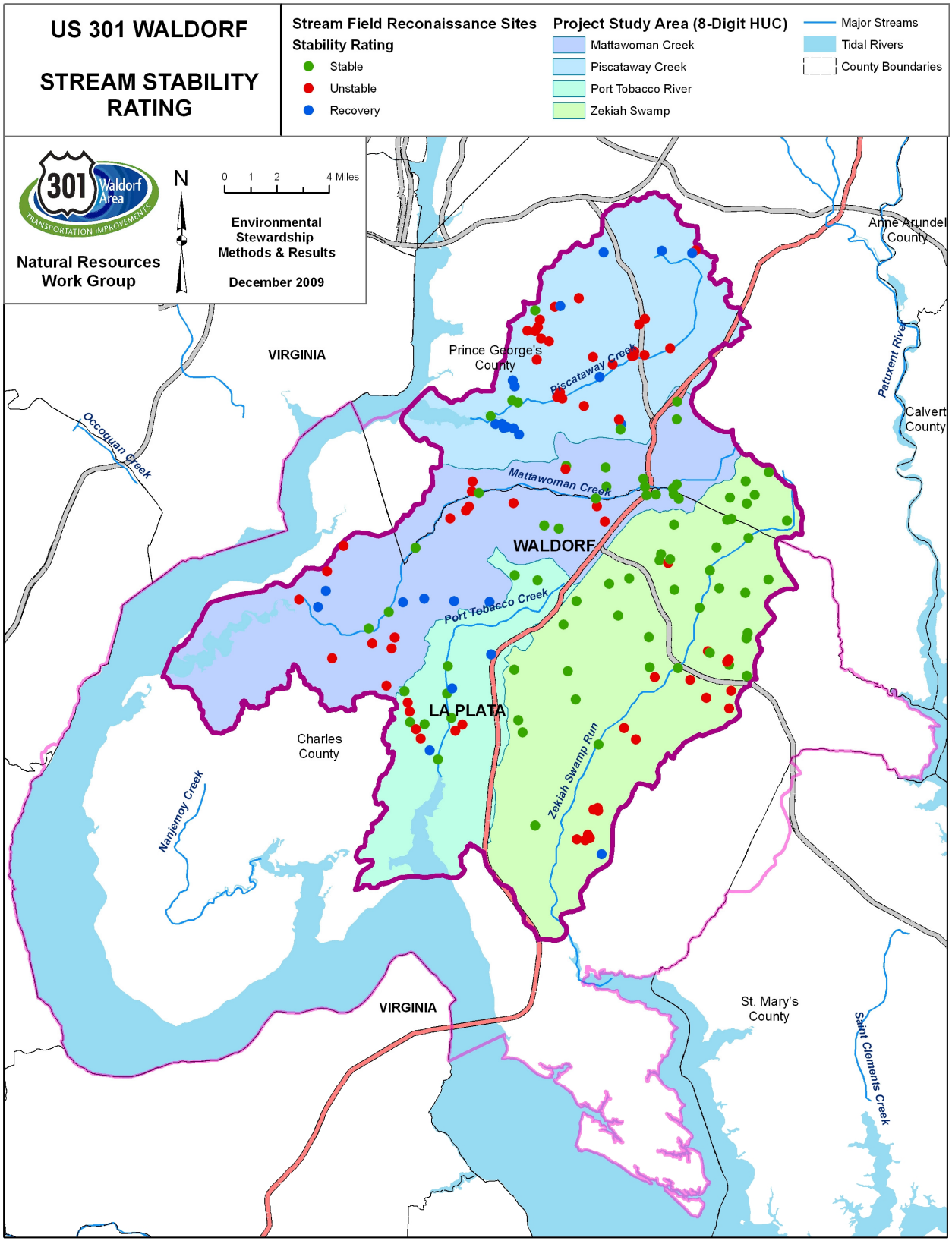
Stable stream in Cedarville State Forest

Representative watersheds were selected based on size, land use/land cover, percent impervious surfaces, and location within the project area. The objective was to assess a variety of watershed conditions throughout the entire project area. Within each representative watershed, select stream reaches were assessed throughout the watershed in order to characterize the entire stream system and to develop a potential relationship between watershed characteristics and stream stability. An understanding of this relationship would increase the accuracy of predicting the stream stability of the remaining stream systems within the project area not assessed as part of the reconnaissance surveys.

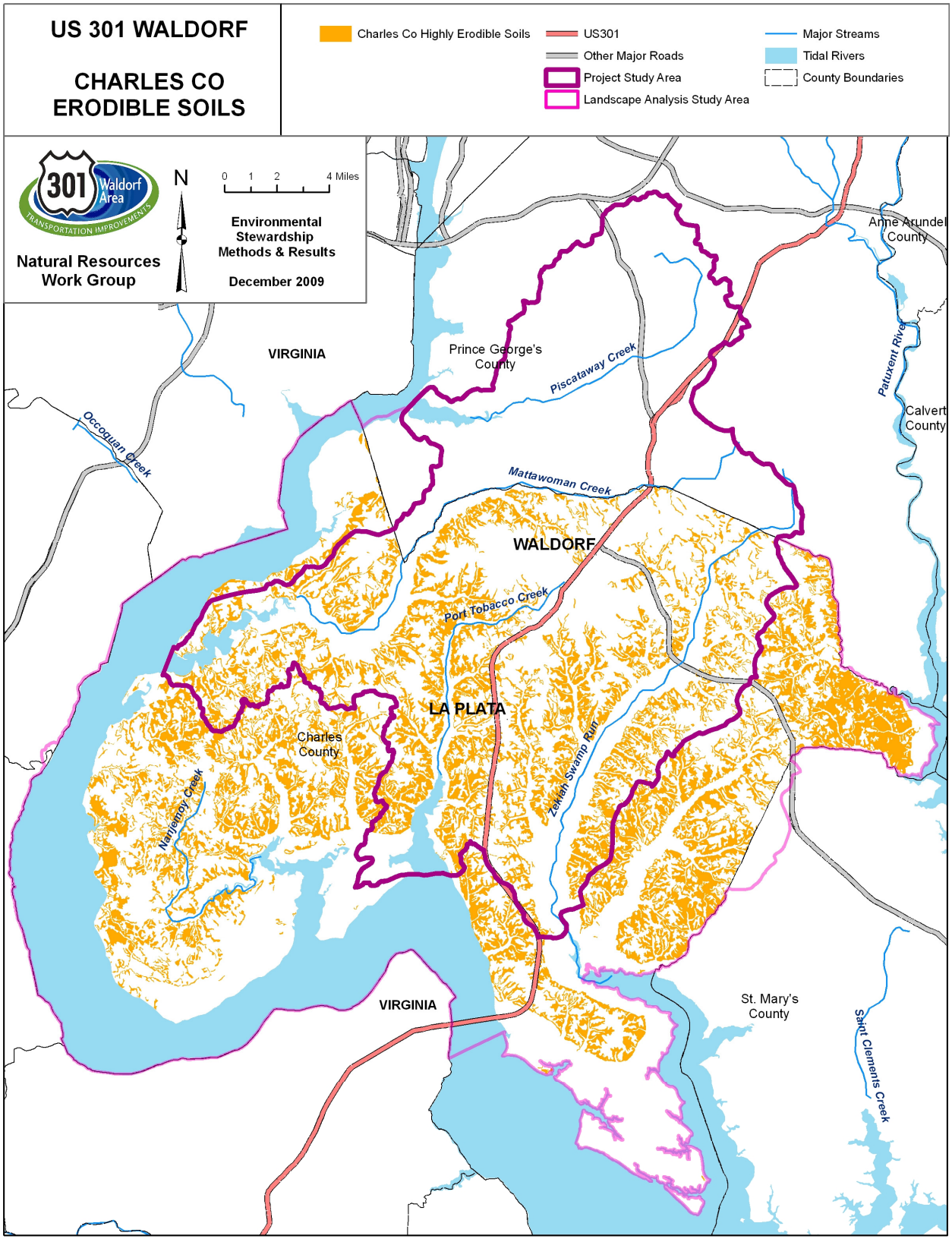
Unstable tributary to Tinkers Creek, undergoing severe erosion.

Once the stream stability field reconnaissance assessment was completed, we compared the field and GIS data. The stream stability field data were entered into GIS as a layer that showed the location and stability rating of each stream reach assessed (Map 6). GIS data layers included highly erodible soils, forest age, topography, and percent impervious surfaces. Soil data were only available for Charles County. A majority of the highly erodible soils (Map 7) were in areas with steep topography. Therefore, we assumed that the steep slopes in Prince Georges County also had highly erodible soils. Stream slopes were calculated from topography (Map 8). The forest age classification was developed as part of this study, and was described earlier. Impervious surfaces were derived from building, road, and parking lot locations provided by the counties (Map 9).

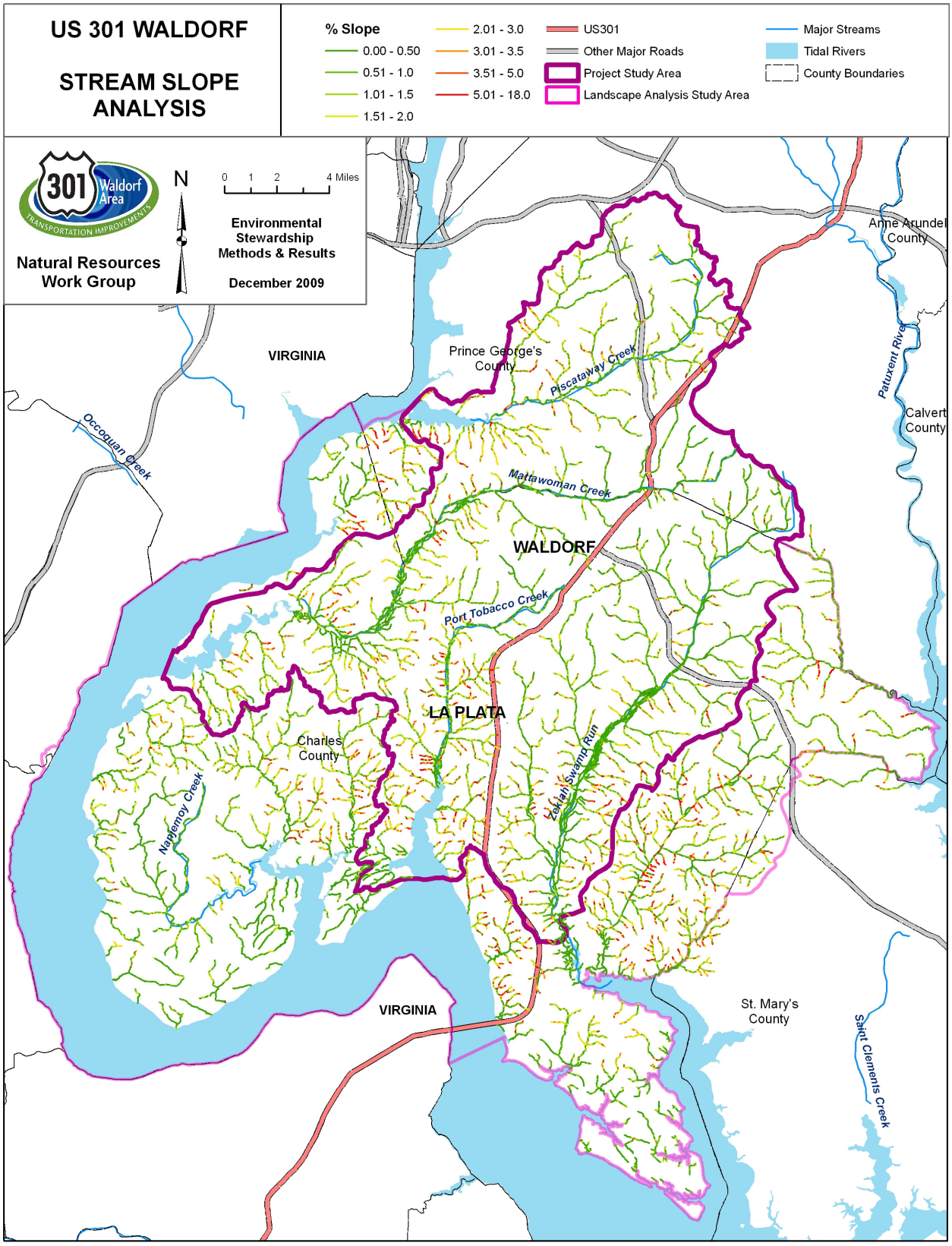
TCF compared the stream stability field ratings to corresponding site and watershed characteristics, and assessed what combination of these variables best predicted stream stability in the 301 study area (see Appendix E). Site characteristics included channel slope and riparian cover, and presence of grade controls, beaver dams, or signs of past channelization (if noted by FWS). We identified and analyzed drainages using the program GISHydro. Imperviousness, forest cover, and forest age were also calculated within 12-digit (approximately 3rd order stream) and 8-digit (4th to 5th order stream) watersheds. We conducted statistical analyses in NCSS and a classification tree application written for Microsoft Excel.



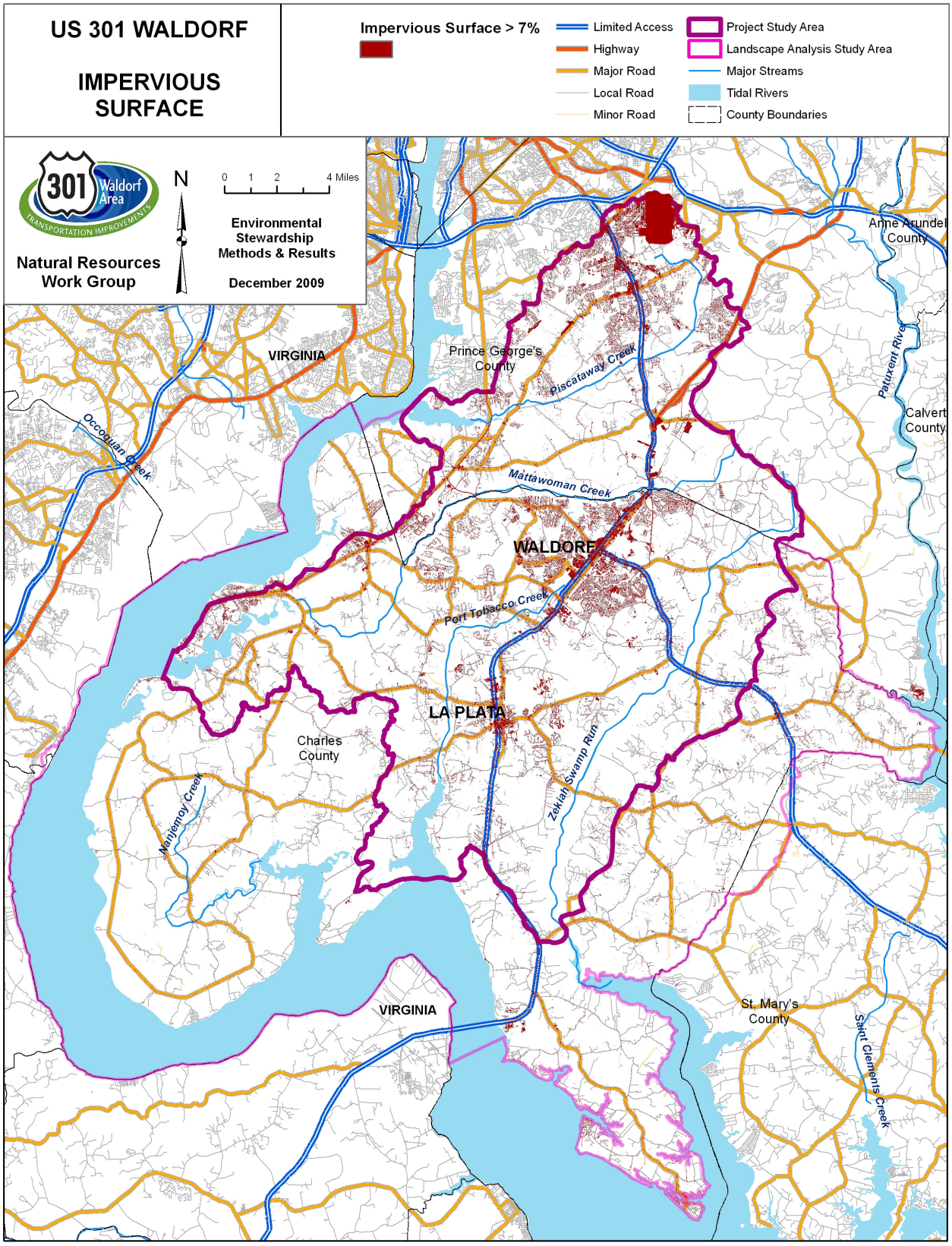
Map 6. Stream stability ratings in the US 301 project watersheds.



Map 7. Highly erodible soils in Charles County, MD.



Map 8. Stream slopes in the US 301 landscape study area.



Map 9. Impervious surfaces in the US 301 landscape study area.

Summary of Findings

A total of 163 stream reaches, totaling approximately 40 miles (64 km) of stream length, were assessed as part of the stream field data reconnaissance survey (See Table 11). Forty sites were assessed in the Mattawoman watershed, 46 in the Piscataway watershed, 18 in the Port Tobacco watershed, and 59 in the Zekiah Swamp watershed. Table 11 shows the number of sites per stability rating by watershed. The Zekiah Swamp watershed had the most stable stream sites and the Piscataway watershed had the most unstable and recovery stream sites.

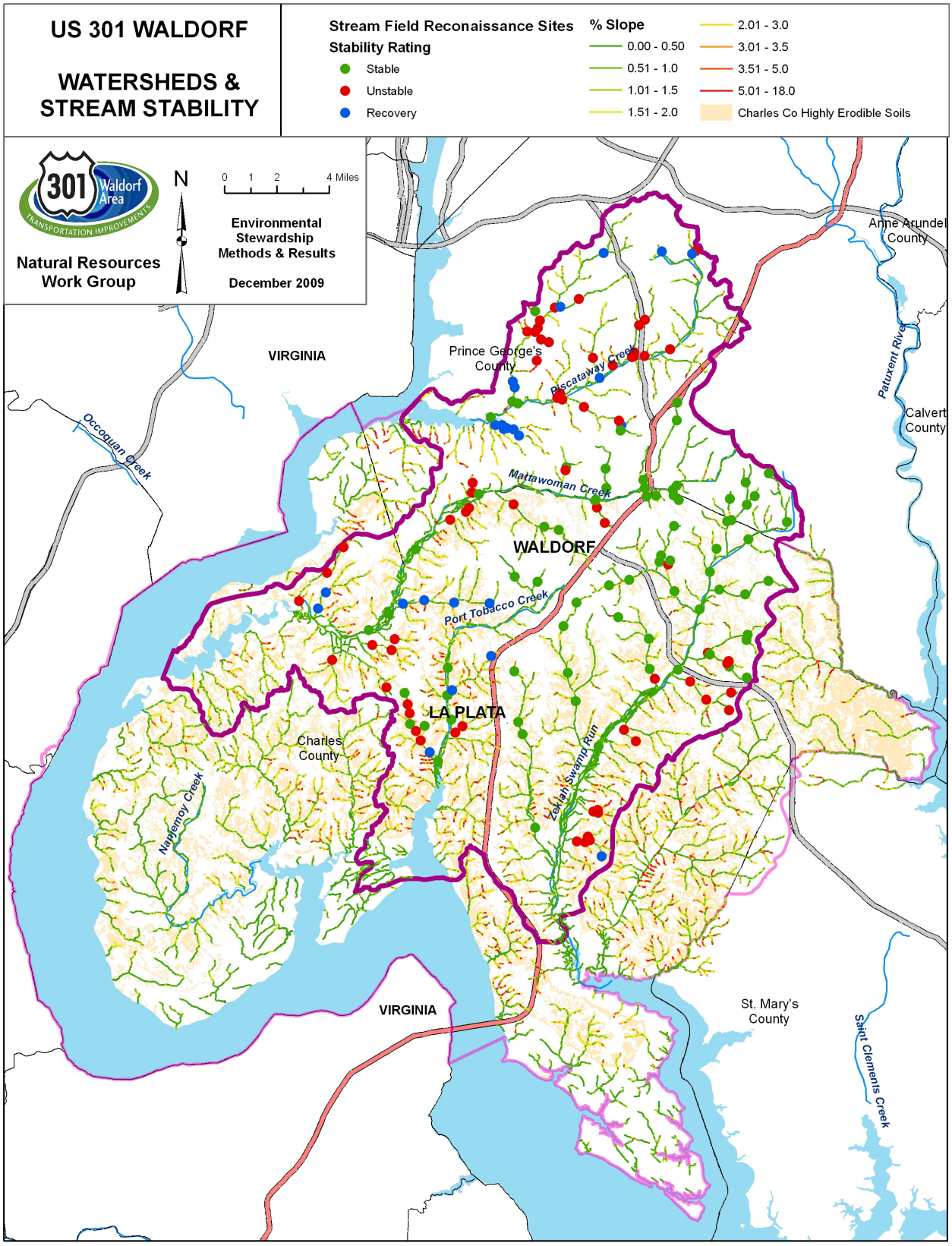
Table 11. Stream field reconnaissance data summary.

		Stability Rating (% of sites in watershed)		
Watershed	**Number of sites**	**Stable Sites**	**Unstable Sites**	**Recovery Sites**
Mattawoman	40	50%	35%	15%
Piscataway	46	15%	59%	26%
Port Tobacco	18	50%	33%	17%
Zekiah Swamp	59	68%	31%	2%
All watersheds	**163**	**47%**	**40%**	**13%**

The comparison of watershed characteristics to the stream stability ratings revealed a general relationship and could assist in the development of criteria to predict stream stability for the remaining stream reaches within the project study area (See Map 10). Streams assessed with shallow slopes (1.5 to 2.0 percent or less) in non-erodible soils that were well connected to adjacent flood plains and primarily forested with mature forests (greater than 70 years old) were typically rated as stable streams. Stream assessed with steep slopes (approximately 1.5 to 2.0 percent or greater) generally located in highly erodible soils with forest stand ages less than 70 years old were typically rated as unstable streams. Also, if a drainage area had an impervious surfaces percent greater than 15 percent, regardless of stream slope or soil erodibility, the stream reach was typically rated as unstable. The best illustration of this relationship is in Zekiah Swamp. The southeastern portion of the watershed consists primarily of steep sloped streams in highly erodible soils and a majority of the stream reaches assessed received an unstable rating. Moving up the watershed to the north-eastern portion of the watershed, the streams become shallow sloped with less highly erodible soils and the majority of the stream reaches assessed received a stability rating of stable.

Stream sites with grade controls (beaver dams, roads, or other structures impounding water downstream) were usually stable (Chi-square, $p<0.01$). Prior channelization did not seem to have an effect on stream stability by itself. Stream sites were more likely to be stable if they had a larger drainage area, had a lower channel slope in their drainage, had a lower land slope in their drainage, had less urban area in their drainage, had less imperviousness in their drainage, had more forest in their drainage, had less imperviousness in their 8-digit watershed, and had more forest in their 8-digit watershed (ANOVAs, $df=132$, $p<0.05$). Stream stability was not significantly related to channel slope or riparian forest at the reach scale, or imperviousness or forest cover at the 12-digit watershed scale.

Logistic regressions reported that drainage land slope was the most significant variable predicting stream stability, correctly classifying 84% of stable streams and 74% of unstable streams. Other significant variables included drainage area, imperviousness in the 8-digit watershed, and mean channel slope in the drainage. When these three variables were added, the logistic equation correctly classified 94% of stable streams and 81% of unstable streams. Adding further variables did not increase predictive power appreciably. Recovering streams could not be predicted by logistic models with available data. Drainage land slope, imperviousness in the 8-digit watershed, drainage area, and drainage percent forest correctly classified 93% of stable streams, 76% of unstable streams, but only 30% of recovering streams.



Map 10. Stream stability field rating, calculated stream slope, and impervious surfaces.

Discriminant analysis also reported that drainage land slope was the most significant variable. Adding additional variables (imperviousness in the 8-digit watershed, drainage area, drainage percent forest, imperviousness in the 12-digit watershed, the presence of grade controls, and forest percent in the 8-digit watershed) increased predictive accuracy. A classification tree used mean channel slope in the drainage, drainage area, drainage imperviousness, the presence of grade controls, and percent mature forest (>70 years old) in the 12-digit watershed. Although this tree was complex, it classified both training and validation data fairly accurately.

We condensed the classification tree and other analyses to the following:

- If downstream beaver dams or other grade controls impounded or retarded stream flow, the channel was probably stable.
- Streams with a mean drainage channel slope <0.34% were usually stable.
- All but two stable stream reaches had a mean drainage channel slope <1.1%. Streams with >1% mean drainage channel slope were usually unstable.
- Streams in the Piscataway Creek watershed, which is 12percent impervious, were usually unstable, unless their mean drainage channel slope was <0.34%. Some of the destabilized streams were recovering, including all those with a drainage area <3% impervious or in tributaries with >40% forest >70 years old.
- Streams in 8-digit watersheds <10% impervious, drainages with 0.34-1.0% mean channel slope, and 12-digit watersheds >40% forest >70 years old, were stable.
- Streams in 8-digit watersheds <10% impervious, drainages with 0.34-1.0% mean channel slope, and drainage areas >3.6 mi^2, were usually stable.
- Streams in 8-digit watersheds <10% impervious, drainages with 0.34-1.0% mean channel slope, drainage areas <3.6 mi^2, and 12-digit watersheds <40% forest >70 years old, were difficult to predict, but were stable if drainage imperviousness was <1.75%.
- In general, it was difficult to predict unstable vs. recovering streams.

There are exclusion areas to the stream stability criteria as a result of past and current landscape changes caused by anthropogenic and natural activities. For example, the headwaters of Jordan Swamp (a tributary to Zekiah Swamp), where it flows through St. Charles, is geomorphically stable even though the drainage area has far greater than 15% impervious surface. This is because the stream was significantly over-sized and large, in-line storm water management ponds were constructed to, most likely, manage flood flows. Now this section of stream reach has a low stream energy that is not capable of eroding stream banks or down cutting. Similarly, Piney Branch (a tributary to Zekiah Swamp), downstream of La Plata Road (Rte. 488), is highly incised and has widespread lateral erosion problems even though the stream slope is less than 1.0% and the watershed is primarily forested. This is because the channel was straightened and deepened in the past to reduce, most likely, potential flooding problems for the road crossing.

We applied the stream stability rating criteria to the remaining stream reaches not assessed within the project area. The Zekiah Swamp watershed had the most stable reaches because the majority of the streams are shallow sloped and the watershed was primarily rural and forested. The Mattawoman watershed had the next most stable streams, and consisted of an equal mix of shallow and steep sloped streams, with slightly more development than the Zekiah Swamp watershed, but still less than 15% impervious surfaces. However, tributaries to the Mattawoman with high impervious surfaces are typically unstable. The mainstem of the Port Tobacco watershed is primarily stable because it is shallow sloped, but a majority of its tributaries are unstable because of steep sloped streams in highly erodible soils even though the watershed has less than 15% impervious surfaces. The Piscataway watershed had the most unstable stream reaches. This was primarily because of the high percent of impervious surface within the watershed.

5. Assessment of Natural Heritage Resources

Introduction

The Maryland Department of Natural Resources' Natural Heritage Program (NHP) is the lead State agency responsible for the conservation of the State's nongame wildlife, including mammals, birds, reptiles, amphibians, and invertebrates, as well as the rare, threatened, and endangered (RTE) plants and animals native to Maryland. NHP also provides for the conservation of the State's biodiversity by identifying the remaining habitats and natural communities that are required for successfully maintaining sustainable populations of declining, significant, and rare species. Once identified, the location of these areas and the information summarizing the significance of these areas are provided to land planners, land managers, and other decision-makers via information products that are useful for the types of decisions being made.

Since 1980, staff of DNR's Natural Heritage Program (NHP) have compiled data from numerous sources and conducted field surveys for significant natural habitats and the unique, unusual, and rare species found within these habitats. With the ultimate goal of conserving Maryland's native biological diversity, NHP focuses primarily on the rarest species as indicators of areas worthy of conservation efforts, including acquisition, easements, restoration, proper stewardship activities, and compatible land use zoning. Currently about 1,000 plants and animals are considered rare, threatened, or endangered in Maryland, and their status and population locations are being actively tracked by NHP. Complete lists of Maryland's rare, threatened and endangered (RTE) species, as well as the explanation of the global and state rank and status codes used by DNR, can be found online at www.dnr.state.md.us/wildlife.

Extant populations of these 1,000 species are grouped into habitat units called Ecologically Significant Areas (ESAs). The ESAs of Maryland were developed by NHP to depict the habitat areas and their minimal buffers that need to be conserved and properly managed in order to sustain most of the State's rarest species and natural communities. Certain rare species, primarily the bald eagle and Delmarva fox squirrel, specifically have not been included in the ESA GIS polygon layer because specific regulatory conservation measures are in place to ensure their existence in the state.

In 2005, DNR developed a Wildlife Diversity Conservation Plan. This plan identifies 502 animal species considered of Greatest Conservation Need (GCN) in Maryland. About 300 of these were already considered rare by NHP and were being actively tracked and monitored, but the remaining 200 are more common species that are believed to have declining populations. NHP now also includes these GCN species and the 35 Key Wildlife Habitats that contain them in its conservation activities. By focusing survey and conservation efforts on habitats and native vegetation communities, rather than on single rare species, entire suites of representative and common species, as well as declining and rare species found within these natural communities, will be afforded greater levels of protection.

Conservation of large forests with intact core areas is especially important for a group of species known as Forest Interior Dwelling Species (FIDS). However, conservation for the widest array of plant and animal species must take place at a more refined habitat scale. For example, adding 500 acres of bottomland forest onto an existing public land unit containing mostly bottomland forest may not increase overall biodiversity conservation as much as adding 500 acres of a different type of forest, such as an upland, dry Oak – Hickory forest. Different forest types contain habitat for different suites of plants and wildlife. In addition, grassland, shrub, and early successional forest provide habitat for many bird species with declining populations (Sauer et al., 2008). Finally, many significant and rare habitats are small in size.

The Natural Communities of Maryland have been classified by DNR through a taxonomic hierarchy, similar to the classification of species. The hierarchy includes four levels: System, Subsystem, Ecological Community Group, and Association (or Community Type); for example:

System: Terrestrial System;
Subsystem: Dry Forests and Woodlands;
Ecological Community Group (or ECG): Chestnut Oak Forests;
Association: *Quercus prinus – Quercus rubra / Hamamelis virginiana* Forest.

The most detailed level, Associations, are those found within the National Vegetation Classification Standard (NVCS), developed by NatureServe and adopted by USGS and the Federal Geographic Data Committee (FGDC). A summary of DNR's current classification, considered the First Approximation, is included in Appendix D-1. This classification and the conservation ranks associated with the various ECGs and Associations are still considered a working draft, and some adjustments to classes and ranks will likely occur over time as additional natural community data are gathered and analyzed.

For this project, natural community data, survey protocols, and rankings were developed at the Ecological Community Group (ECG) level. This level of the classification is recommended because it provides more useful and pertinent information than simply wet forest versus dry forest, for example, yet it does not get over-involved in such detail (i.e., the Association level) that the amount of data collection required for analysis and spatial attribution is too cumbersome.

The field survey protocols used by the Natural Heritage Program have evolved over the past 28 years, primarily to take advantage of improvements in technology, as well as advancements in natural community classification. Current protocols for rare species surveys are compiled in this document in a much more detailed format than previously available, and the natural community survey protocols for rapid assessments have been newly developed over the past few years.

Field Survey Protocols

This section describes NHP protocols for conducting field surveys to gather data on rare, threatened and endangered (RTE) species, as well as on natural communities at the Ecological Community Group (ECG) level. Although NHP maintains a GIS of known occurrences of both of these resource types, additional information is frequently required. NHP data for a given area might be considered old and in need of current data to assess the existence and condition of a previously known population or habitat/natural community. More frequently, NHP has likely never conducted surveys or known of others conducting surveys within a given study area, and new fieldwork is required to assess the presence and condition of RTE species and ECGs potentially occurring in the study area. The following protocols are recommended to be compatible with standard protocols in use by DNR for RTE species and natural community surveys. Detailed methodologies for surveying and prioritizing both RTE species and ECGs are provided in Appendix D-2 and D-4.

1. Compile and Summarize Existing Information

Before beginning any field survey, important baseline information must be obtained. Basic mapping information of the defined study area, such as current aerial photography or satellite imagery, USGS 7.5 minute topographic quadrangle maps, wetlands maps, soils/geology maps, and property tax maps were gathered. For efficiency and accuracy, it is recommended that a digital version of these maps be obtained and used within a Geographic Information System (GIS), such as ESRI's ArcGIS or MicroImages' TNTmips software programs. Within a GIS, a desktop analysis of various landform features (e.g., slope, aspect, elevation, soils, geology) should be conducted, as determined by the features that best identify the habitats used by RTE species or that best define an ECG. Also, data on the specific natural resources being inventoried were compiled, reviewed, analyzed, and prioritized given all the pertinent variables and criteria for the project, as described below.

1.1 Rare, Threatened, and Endangered Species Data

DNR's Natural Heritage Program (NHP) maintains the State's GIS, called Biotics, that houses the information required for the conservation and management of the terrestrial and aquatic species considered

rare, threatened, or endangered within Maryland. To adequately prepare for this project, not only were the data currently contained within Biotics reviewed, but the manual data in the backlog being prepared for entry into Biotics also were reviewed. These latter records, as they were located, were prioritized for entry into Biotics so they could more easily be included in the data analysis portion of the project.

Because of the extremely limited time allowed for field surveys during this project, NHP staff focused only on revisiting precisely-located (mappable to a few seconds of latitude/longitude) RTE species records within the exact watersheds of this project, including Piscataway Creek, Mattawoman Creek, Zekiah Swamp, and Port Tobacco River. Usually, imprecisely located records are also included during RTE surveys because they can provide a broader view of the range of species and habitats potentially encountered within the project area. These records are very important to consider when conducting surveys in new areas, or de novo surveys. However, these records are not spatially explicit and usually are more historical in nature, so they are more likely to be extirpated than more recent records. For a short project such as this Environmental Stewardship Study, these records are insufficient for direct conservation and management purposes. All precisely located records falling at least partially within the project area underwent a review. Appendix D-3 contains a list of the RTE species determined to occur within the study area as of the end of 2006.

1.2 Natural Community Plots

Over the past 10-15 years, NHP has gathered both qualitative and quantitative data on the natural communities located within areas and habitats of interest. Primarily these include areas with RTE species, but they have also included areas studied as reference wetlands for assessments funded by the U.S. Environmental Protection Agency. These plots have been identified not only to their natural community type (Association), but also to their more generalized Ecological Community Group (ECG) type. NHP reviewed its natural community data to determine which areas may need additional field verification for various reasons, including: to determine the extents of the natural community/ECG; to determine whether areas still exist in the same condition; to determine the natural community/ECG types within extensively forested areas; or to document changes in condition. Appendix D-5 contains a list of the Ecological Community Groups that were known to occur or believed to potentially occur in the study area as of the end of 2006, prior to any additional fieldwork conducted as part of this project.

1.3 Species of Greatest Conservation Need & Key Wildlife Habitat Data

In 2005, DNR completed its Wildlife Diversity Conservation Plan (WDCP). This Plan is available on the DNR website at http://www.dnr.state.md.us/wildlife/divplan_wdcp.asp. The WDCP lists 502 species as of Greatest Conservation Need (GCN) in Maryland and places them within the context of 35 Key Wildlife Habitats throughout the State. These data were reviewed in the context of the project study area to determine whether any significant or critical needs for field verification, perhaps in conjunction with either the RTE species or natural community fieldwork, were needed for these species and habitats. Appendix D-4 contains a list of GCN species occurring in the Upper Coastal Plain physiographic region, within which this study area is located, according to the data contained within the WDCP.

2. Categorize existing Ecologically Significant Areas

The Ecologically Significant Areas (ESAs) of Maryland were developed by the Natural Heritage Program to depict the habitat areas and their minimal buffers that need to be conserved and properly managed in order to sustain most of the State's rarest species and natural communities. Certain rare species, primarily the bald eagle and Delmarva fox squirrel, specifically have not been included in the ESA GIS polygon layer because specific regulatory conservation measures are in place to ensure their existence in the State.

To identify the existing ESAs, the statewide ESA layer was clipped to the study area and further categorized as to the primary generalized habitats of forest, wetland, aquatic, or "other" habitat that were contained within each ESA. This information was provided to The Conservation Fund (TCF) for their use in the GIS analysis phase of the project. Appendix D-5 contains a list of the 49 Ecologically Significant Areas within the study area as of the end of 2006, prior to any fieldwork conducted as part of this project.

3. Prioritize RTE /GCN Field Verification Needs

NHP's field verification needs for RTE and select species of Greatest Conservation Need were prioritized, based on the following criteria:

1. Age of the record: Any record that is 10 years or older is probably in need of more recent field evaluations to determine if the species is still present and to update the information regarding habitat quality, threats, and management needs for its habitat.

2. Uniqueness of the occurrence: Any record that represents the only known occurrence within Maryland is in need of field verification unless the record is only 5 years old or less. If the record is missing essential information regarding habitat quality, threats and management needs for its habitat, regardless of the age of the record, then field verification may be warranted.

3. Rarity of the species: Field verification priorities were evaluated with regard to the global and state conservation or rarity status of each species. For example, species that are ranked as G1S1 were given much higher priority than species ranked as G5S2 or G5SU.

4. Legal status of the species: Field verification priorities were evaluated with the legal status of the species in mind. For example, species State-listed as Endangered were given higher priority than species listed as Threatened, or In Need of Conservation. Non-listed species were provided the lowest priority, all other criteria being equal.

5. Regional significance for the species: A species may be provided higher priority if this area represents a stronghold for it within the State. For example, it may be generally considered a low priority because of its rarity within the state, but if a large majority of the Maryland occurrences for the species are within the study area, it may be given a higher priority for field verification.

6. Property ownership: Private lands may be prioritized over lands in public ownership unless there is some indication that management issues need to be addressed on public lands and that the type of management required is such that a restoration project under this type of administrative or financial framework would be valuable. For this project, NHP staff determined that lands owned by the Department of Defense (e.g., Andrews Air Force Base) or by other federal agencies, such as the National Park Service (e.g., Piscataway National Park), would not be included in the field surveys.

7. Presence within the Green Infrastructure: A species may be provided higher priority if it occurs within a hub or corridor within the current Green Infrastructure. Since forested and wetland areas within the Green Infrastructure are frequently targeted for conservation and management activities, a better understanding of the natural communities, habitats, and species within hubs and corridors is important for effective conservation actions.

8. Concentrations of Species/Natural Communities: Areas were given high priority if they contained or were highly likely to contain habitats that supported multiple higher-priority species or high quality natural communities within the same vicinity.

Other factors that were considered to prioritize field surveys include the presence of Natural Heritage Areas, the presence of occurrences within regulated areas such as Wetlands of Special State Concern and the Chesapeake Bay Critical Area, and the proximity of the record to existing public lands. The amount of time within the schedule of the project that is allotted to do field verification work was also a major constraint on priorities.

4. Prioritize ECG/KWH Field Data Collection Needs

Because NHP had a limited amount of data regarding vegetation communities within the study area, most NHP fieldwork for this project occurred in relation to terrestrial Natural Community/Ecological Community Group (ECG) data collection. Since DNR's Ecosystem Analysis Center conducted fieldwork for wetland assessments, NHP focused its limited time on terrestrial ECG types. After determining which ECG types were most likely to occur within the study area, based on knowledge of their general distribution within the State, the ESAs and Green Infrastructure hubs were prioritized for rapid assessment to determine ECG type and habitat quality. NHP's field data collection needs for ECGs were prioritized based on the following criteria:

1. Uniqueness of the occurrence: Any record that represents the only known occurrence within Maryland is in need of field verification unless the record is only 5 years old or less. If the record is missing essential information regarding habitat quality, threats and management needs for its habitat, regardless of the age of the record, then field verification may be warranted.

2. Rarity of the ECG: Field verification priorities will be evaluated with the global and state conservation or rarity status of the ECG or component natural communities in mind.

3. Regional significance of the ECG: A natural community may be provided higher priority if the study area represents a stronghold for it within the State. For example, it may be generally considered a low priority because of its rarity within the state, but if a majority of the occurrences for the ECG are within the study area, it may be given a higher priority for field verification.

4. Local significance for the ECG: A natural community may be provided higher priority if it is considered a disjunct occurrence or outlier from its primary distribution within the State or region.

5. Property ownership: Private lands may be prioritized over lands in public ownership unless there is some indication that management issues need to be addressed on public lands and that the type of management required is such that a restoration project under this type of administrative or financial framework would be valuable.

6. Presence within the Green Infrastructure: ECGs were considered a higher priority if they occurred within a higher-ranking hub of the current Green Infrastructure. A separate GIS analysis was conducted to determine which hubs should be considered higher priorities for surveys (see Appendix D-6 for details).

Other factors that weighed in to determine field verification priorities included the presence of characteristic abiotic factors such as geology, soil types, and topography, as well as the proximity of the area to existing public lands. The amount of time within the schedule of the project that NHP staff were allotted to do field data collection work was also a major constraint on NHP priorities. Areas were prioritized that provided the greatest number of verification opportunities.

5. Landowner Contact

Once the areas for RTE and ECG surveys were determined and prioritized, the tax database associated with the PropertyView GIS layer was researched to locate the landowner's name and contact information. This information was provided to DNR's Ecosystem Analysis Center for compilation into a larger DNR landowner contact spreadsheet. This spreadsheet was provided to SHA, and that agency mailed out permission letters for property access in the fall of 2007. Follow-up phone calls were frequently conducted to ensure permission was secured and to provide the landowner with a more specific timeframe for access.

6. Conducting Field Surveys

Perhaps the single most important factor in conducting field surveys is to ensure that the surveyor is experienced and qualified to conduct surveys for the resources in question. Frequently multiple surveyors are needed to survey for NHP resources. A competent and experienced botanist may be able to conduct both the RTE plant surveys and the natural community surveys, but may not be qualified to conduct the animal surveys. Even among animals, it may difficult to locate a qualified surveyor able to conduct the various types of survey methods required for the various animal groups. For example, a FIDS survey would require someone experienced with bird songs and calls; however, a fish survey frequently requires the use of electroshock equipment. Every animal group requires different techniques and sometimes even specialized techniques for certain species within an animal group.

A qualified surveyor must also be aware of and implement the most appropriate survey methods for conducting surveys. Standard protocols, used and approved by the most appropriate Unit within DNR, should always be required. For example, DNR has developed standard methodology for conducting FIDS surveys. Frequently, a surveyor must return to a given area multiple times to increase the probability of detection, primarily for animals. RTE plants must be surveyed during the time period when the rare species is readily identifiable (for all but a few species, this is during their specific flowering/fruiting period), and the entire area of potential habitat must be checked; transects or other methods that sample only a portion of the habitat are not sufficient.

Finally, standard data collection and reporting forms should be required. NHP has separate standard field survey forms for RTE plants and animals, as provided in Appendix D-7, with instructions for filling out the forms detailed in Appendix D-9). The standard natural community observation form is also provided in Appendix D-8), with the instruction manual explained in Appendix D-10. An alternate and more generalized standard form for collecting site-based data regarding management concerns, site description, general threat description, and other textual information has been used by NHP in the past, but was not used for this project.

After preliminary review of the data and surveys needed for this project, an experienced vegetation ecologist was hired to determine final fieldwork priorities and to complete the surveys for RTE plants and for ECGs.

6.1 RTE Plant surveys

Based on records within NHP's Biotics GIS, 52 RTE plant species (listed in Appendix D-11) were known to occur within the study area at 140 separate locations. The most rare species were New Jersey Rush, *Juncus caesariensis*, (G2 S1, Endangered) and Long's Bittercress, *Cardamine longii*, (G3 S1, Endangered).

Fieldwork for RTE plants occurred from the end of July to October for late flowering species, and again in early spring from mid-May to June for a few of the spring-blooming species. Although field efforts were mostly focused on gathering natural community observation data, via a new rapid assessment field form, RTE plant data were collected wherever their locations overlapped in the areas surveyed. Of the 52 RTE species known to occur in the project area, only a few were targeted due to time of season, location, and other factors mentioned above. These were then compiled and sorted based on proximity to targeted forested community sites. Because of time and the amount of work needed in order to complete this project, sites that existed on public land were surveyed first while landowner permission was sought for private property via the SHA's property owner notification letter. Permission for selected private property sites was finally obtained in October 2007. Prior to visiting selected sites, the field ecologist reviewed site details including topography, hydrology, geologic formations, subsequent soil types and any other pertinent details. Important information regarding known RTE plant occurrences, such as diagnostic characteristics and habitat distribution were also reviewed. Once all pre-field information was obtained and read, the field ecologist then selected the best route through the area for survey. The trail, line or transect was decided on based on several factors such as access point, existing trail system, diversity of potential community types, targeted community types, known RTE locations and available time. This predetermined route was then hiked and observations were recorded,

paying close attention in areas favorable for targeted RTE plant species. In some instances, routes were adjusted based on landscape conditions, natural communities present, or the presence of habitats favorable for RTE species. The subsequent RTE data were collected via a handheld device into a specially created electronic RTE data field form. These data were then downloaded into an Access database for final edits. After the data were reviewed and edited, a point shapefile and rare plant field form document format was then created, exported and submitted to the Conservation Technology Program, Maryland Natural Heritage Program to be processed into Biotics.

6.2 RTE/GCN Animal surveys

Fifteen RTE animal species (listed in Appendix D-2) were recorded within the study area. Among the 15 species are 10 freshwater fishes, 3 freshwater mussels, a butterfly, and a bird. Because the majority of these species locations were based on fairly recent data and because of the limited time and funding for this project, NHP determined that additional surveys would not be conducted for any RTE animal species.

DNR's Wildlife Diversity Conservation Plan (WDCP) lists a total of 280 animal species of Greatest Conservation Need, both vertebrates and invertebrates, as occurring or likely to occur during some portion of their life cycle (e.g., birds migrating through the area) in the Upper Coastal Plain physiographic region. Of these 280 species (listed in Appendix D-4), about half (141 species) are already rare enough (ranked as S1 or S2) to be included on the list of species that NHP currently tracks and actively promotes their conservation. An additional 70 resident or breeding GCN animals are ranked as S3 (44 species) or S3S4 (26 species) and are passively tracked as "watchlist" species by NHP. The breeding locations and habitats of these species are not specifically included in NHP's central GIS at this time, but records are maintained in hardcopy files for future use should further analysis prove they have become more rare and the need to provide active conservation actions becomes imperative.

Of the remaining 25%, or 69 GCN species, many are considered Forest Interior Dwelling Species (FIDS) and are found in a number of the Green Infrastructure hubs located within this study area. About 25 species, or 36% of the remainder, are considered shrubland and grassland species. These species were not considered priorities for this project, for various reasons. Finally, a review of species distributions in relation to this study area did not reveal any GCN species for which this area was particularly important or represented a significant portion of their range within Maryland. For these reasons and others related to the time and scope of this project, NHP determined that surveys would not be conducted for any GCN animal species.

6.3 Natural Community surveys

At least 27 Ecological Community Groups (listed in Appendix D-3) were known or suspected to occur within the 4 watersheds that comprise the study area. Within this study area, over 400 hundred sites were targeted for having potentially high quality forested areas. These potential sites were targeted due to a number of factors including GI score, proximity to ESAs, forest patch size, aerially observable landscape conditions, potential community types and proximity to known RTE occurrences. These sites were then prioritized according to size, potential quality, accessibility, and by priority community types or RTE plant species. Again, because of time and the amount of work needed in order to complete this project, sites that existed on public land were surveyed first while landowner permission was sought for private property via the SHA's property owner notification letter. Permission for selected private property sites was finally obtained in October 2007. Prior to visiting selected sites, the field ecologist reviewed site details, including topography, hydrology, geologic formations, subsequent soil types and any other pertinent details. Once all pre-field information was obtained and read, the field ecologist then selected the best route through the area for survey. The trail, line or transect was decided on based on several factors such as access point, existing trail system, diversity of potential community types, targeted community types, known RTE locations and available time. This predetermined route was then hiked and observations were recorded, paying close attention especially for areas favorable for targeted forested community types. In some instances, routes were adjusted based on landscape conditions, natural communities present, or habitats favorable for RTE species. The subsequent natural community data were collected via a handheld device into a specially created

electronic natural community observation data field form. These data were then downloaded into the Natural Community Observation database in MS Access for final edits. After the data were reviewed and edited, a point shapefile and natural community observation data report format was created, and the forms were exported into a word document for inclusion into this report.

For this project, a revised rapid assessment ECG form was developed to include a number of attributes needed to evaluate the quality of a given area, primarily focusing on three factors: size, condition, and landscape context. Attributes that focus on condition include both the age/stage of the ECG and the types and intensity of disturbances impacting it. Examples of disturbances include the presence of invasive species, trash or hazardous materials, excessive erosion, and excessive deer browse.

The revised rapid assessment ECG form, also called the Natural Community Observation Form (as provided in Appendix D-8), has been extensively documented and developed into a digital form for use in Trimble Juno data collection GPS/GIS handheld device. The electronic field form requires a Pendragon Forms v5.1 license, which is an MS Access-based program that allows the user to create custom field forms for a hand-held units and simultaneously creates an Access database that later houses the data. Also, installation of ArcPad enables the user to quickly develop shapefile locations for ECG observations while in the field. The manual developed to accompany the revised Natural Community Observation Form is found in Appendix D-10.

Once the community data were reviewed and edited, they were then converted into a format that could be utilized in PCORD, a multivariate ecological data analysis program (Version 5; McCune and Mefford 1999). This program was the primary tool used to help verify ECG observations made in the field. The two main ordination techniques that were used to help identify the community groups were TWINSPAN and NMDS. Two Way Indicator Species Analysis, or TWINSPAN is a hierarchical divisive classification model that clusters sites based on the species heterogeneity; while Non-metric Multidimensional Scaling is an ordination tool that can be used to identify the relationships of recognized vegetation types to one another and the environmental gradients along which they are distributed. Because of the large number of zeros typical of presence/absence datasets, Beals smoothing was used to alleviate the truncation that occurs. Beals smoothing is a method of data transformation to remove excessive zeros by replacing zero values with degrees of absence of a species in a community data matrix. By reducing the number of zero occurrences in a dataset, it enhances the ability to see and interpret patterns and improves the detection of compositional gradients. The analysis was run and the field observations were compared with the results. As expected, the results of the analysis closely supported the observations made in the field with only minor adjustments needed.

Finally, after the community groups were identified they were mapped in ArcView 9.2 as a polygon shapefile and attributed to its corresponding observation point data. In order to reach this final step, several layers of data needed to be added to the ArcView project. This additional data included soil data, geology, NWI, latest aerial photography (NAIP 2007), DOQQ and topographic maps. In some instances, particularly Prince George's County, certain soil maps needed to be scanned, digitized and geo-referenced. Next, the community observation points were imported into ArcView and converted into a shapefile. The different layers were then scrutinized thoroughly in order to see landscape patterns and the subtle landscape changes that help indicate potential community transitions. Boundaries lines were then drawn to indicate these transitions. Once this ECG layer was complete, it was then scored.

Field Survey Results

Field surveys were conducted from July through November, 2007 and again in the spring of 2008. Thirty-eight field visits were conducted, including 30 in 2007 and 8 in the spring of 2008.

1. RTE Plant Results

Eight areas were visited containing previously known RTE plant locations; 22 new specific locations were discovered for the seven plant species listed in Table 12, in addition to four watchlist plants (*Bartonia*

paniculata, Carex louisianica, Eleocharis tortilis, and Rhododendron arborescens). The seven RTE plants were found at three different Ecologically Significant Areas (ESA's): Mattawoman Creek, Chapman's Forest, and County Line Trail Seep.The ESA conservation boundaries for these were updated, as necessary, to reflect the habitat and habitat buffer needs for the new populations.

Table 12. RTE plants located during 2007-2008 field surveys.

Scientific Name	Common Name	GRank	SRank	State Status
Cyperus refractus	Reflexed Cyperus	G5	S2	
Cyperus retrofractus	Rough Cyperus	G5	S2	
Ilex decidua	Deciduous Holly	G5	S2	
Ludwigia decurrens	Primrose Willow	G5	S2S3	
Melica mutica	Narrow Melicgrass	G5	S1	Threatened
Parnassia asarifolia	Kidneyleaf Grass-of-parnassus	G4	S1	Endangered
Paspalum fluitans	Floating Paspalum	G5	S1	Endangered

Within the timeframe of this project, although not a part of this project, new locations for two additional RTE plants were located by outside sources and reported to NHP staff. These species were the state endangered Swollen Bladderwort (*Utricularia inflata*), ranked as G5 S1, and Primrose Willow (*Ludwigia decurrens*), ranked as G5 S2S3. These were located outside of existing ESA's so new conservation boundaries for the habitats of these species were developed.

2. RTE/GCN Animal Results

No surveys for RTE or GCN animals were conducted as part of this project. However, the results of surveys conducted by others were reported to NHP. Seven species of odonates (dragonflies and damselflies) were reported from this study area at 10 separate locations. A list of these species is provided in Table 13, below.

Table 13. RTE/GCN animals located 2007-2008 by outside sources.

Scientific Name	Common Name	GRank	SRank	State Status
Cordulegaster erronea	Tiger Spiketail	G4	S2	
Cordulegaster obliqua	Arrowhead Spiketail	G4	S2	
Erythrodiplax minuscula	Little Blue Dragonlet	G5	S1	
Gomphus rogersi	Sable Clubtail	G4	S1	Endangered
Libellula flavida	Yellow-sided Skimmer	G5	S2	
Nehalennia gracilis	Sphagnum Sprite	G5	S2	
Tachopteryx thoreyi	Gray Petaltail	G4	S2	

3. Natural Community Results

During the 2007 and 2008 field seasons, a total of 89 natural community observation records were collected by the Natural Heritage field vegetation ecologist. At these 89 locations were 6 Ecological Community Groups, listed in Table 14. Several additional ECGs were observed and noted, though data were not obtained in those particular cases due to time constraints, the location being slightly outside of the project area, or a lack of permission to access private property. These additional community groups include Coastal Plain Seepage Bog/Fen, Basic Mesic Forests, and Altered Dry-Mesic Forest and Woodlands.

Only one rare to uncommon community type, a Coastal Plain – Piedmont Acidic Seepage Swamp (S3), was documented; four plots were located in this community type. In addition, four high quality, but common (S4 – S5) ECGs were surveyed. These areas were targeted for surveys because they were identified as potential high quality areas from GIS analyses. The S4 - S5 ECGs included Mesic Mixed Hardwood Forest (31 of 37 plots were good to excellent), Coastal Plain – Piedmont Bottomland Forest (20 of 22 plots were good to excellent), Coastal Plain Oak – Beech Forest (12 of 13 plots were good to excellent), and Basic Mixed

Hardwood Forest (1 plot was excellent quality). Eight plots were taken from altered habitats, including two that were directly caused by beaver activity.

Table 14. Summary of Ecological Community Groups involved in this project and the polygon shapefile data.

Ecological Community Group	# of Polygons	Total Acres	Total Hectares
Surveyed			
Coastal Plain – Piedmont Acidic Seepage Swamps (S3)	17	13.0	5.3
Coastal Plain – Piedmont Bottomland Forests (S4)	58	10003.7	4048.3
Coastal Plain Oak – Beech Forests (S4)	53	2706.3	1095.2
Coastal Plain Semipermanent Impoundments (S5)	15	176.2	71.3
Mesic Mixed Hardwood Forests (S4)	61	8450.6	3419.9
Reported, but not Surveyed			
Coastal Plain Seepage Bog/Fen (S1)	3	11.2	4.5
Basic Mesic Forests (S4)	0	0	0

Once identified, NHP created shapefiles of ECGs. These polygons included the distribution of the ECGs within the area of the observation point and extended, where possible, within the same ecological system while staying within the US 301 Environmental Stewardship Study area.

Ecologically Significant Areas

Forty-seven Ecologically Significant Areas (ESAs) were located entirely or substantially within the study area. These ESAs are listed in order of their priority scores. The Chapman's Forest and Mattawoman Creek ESA's were updated as a direct result of this project. Chapman's Forest was reduced to now include only the area outside the Mattawoman Creek drainage, although it is immediately adjacent to the Mattawoman. Areas formerly within Chapman's Forest that were within the Mattawoman Creek drainage are now considered part of the Mattawoman Creek ESA. A new ESA was created, called Mattawoman Creek Macrosite. Natural Heritage methodology allows for the nesting of "standard sites" within larger areas of the same ecological system or with similar ecological functions and requirements. These larger areas, or "macrosites," usually encompass and join multiple standard sites. For areas containing aquatic or wetland species, macrosites are frequently defined by drainage systems or sometimes by entire watersheds. Mattawoman Creek Macrosite currently contains and links 6 standard sites: Araby Bog, Bryans Road Bog, Clifton Mitigation Wetland, Mattawoman Creek, Mattawoman Creek – Accokeek, and Sun Valley Wetlands. By contrast, the Zekiah Swamp Macrosite, which had already been created prior to this project, contains 18 standard sites.

During the timeframe for this project, additional sources provided data to NHP resulting in 4 additional new ESAs being added and several more that were slightly modified. The newly added ESAs are Devils Nest, Little Kerrick Tributary, Sun Valley Wetlands, and Upper Mattawoman Creek. Also, it was determined that 4 ESAs overlap the study area by only a slight, insignificant amount (less than 6 acres). These are no longer considered part of the project. Currently, a total of 47 ESAs are located entirely or substantially within the study area. These ESAs are listed in order of their priority scores in Table 15. The digital GIS data (named ESA_CH-301ESS_final.shp) was transferred to The Conservation Fund for inclusion within the larger GIS analysis for this project. A description of the ESAs that are being recommended by NHP for conservation, restoration, or management action are included in Appendix D-12.

Table 15. Ecologically Significant Areas within the Study Area as of July, 2008.

ESA Name	ESA Score	Size (ac)	Size (ha)
Zekiah Swamp Macrosite	4030	16664	6744
Piney Branch Bog	1055	107	43
Mattawoman Creek Macrosite	780	17900	7244

ESA Name	ESA Score	Size (ac)	Size (ha)
Brandywine Receiving Station Site	485	1178	477
Stetham Park Wetlands and Barrens	470	111	45
Mattawoman Creek	460	6315	2556
South Brice Roadside Bogs	300	17	7
Allen's Fresh	250	402	163
Piney Branch	230	775	314
Bel Alton Runs	200	141	57
Piscataway Park Site	195	95	38
Mockley Swamp	190	59	24
Bryantown Swamp	165	244	99
East Piscataway Marsh	165	122	49
Araby Bog	115	184	74
North Clark Run	110	18	7
Andrews Air Force Base Site 1	100	12	5
Andrews Air Force Base Site 3	100	13	5
County Line Trail Seep	95	109	44
Piscataway Creek – Cheltenham	95	1333	539
Bryans Road Bog	90	20	8
Little Kerrick Tributary	90	36	15
Peartree Hill Swamp	90	339	137
Fort Ravine	85	49	20
Brentland Woods	75	494	200
Cedarville Bog	75	33	13
Mount Vernon Ravine	75	189	77
Rum Point	75	244	99
Dentsville Bridge Swamp	70	263	107
Clifton Mitigation Wetland	50	68	28
Hoghole Run	50	253	102
Merry Mount Woods	50	7	3
Port Tobacco Run	50	174	71
Ross Branch	50	182	73
St. Charles Roadside	50	223	90
Sun Valley Wetlands	50	76	31
Devils Nest	45	563	228
Ellenwood Woods	45	7	3
Hawkins Gate Powerline	45	24	10
Thomas Stone Woods	45	211	85
Zekiah Swamp - Booth Wetlands	45	28	11
Fox Run	25	149	60
Jordan Swamp	25	604	245
Piscataway Creek - Tinkers Creek	25	425	172
Upper Mattawoman Wetlands	25	107	43
Cat Pond	5	98	40
Mattawoman Creek – Accokeek	5	6	3

6. Green Infrastructure Network Identification

The Green Infrastructure network identification is described below. Details are in Appendix C. As mentioned earlier, the basic building blocks of the green infrastructure network are core areas, hubs and corridors. Core areas contain fully functional natural ecosystems, and provide high-quality habitat for native plants and animals. These are the nucleus of the ecological network. Hubs are slightly fragmented aggregations of core areas, plus contiguous natural cover. Hubs are intended to be large enough to support populations of native species, and serve as sources for emigration into the surrounding landscape, as well as providing other ecosystem services like clean water, flood control, carbon sequestration, and recreation opportunities. Corridors link core areas together, allowing wildlife movement and seed and pollen transfer between them, and thereby promoting genetic exchange. Each type of core area is associated with a type of corridor or linkage depending on the movement abilities and landscape preferences of organisms living in that type of core area.

Using the Maryland Wildlife Diversity Conservation Plan (NHP, 2005) and modeled distributions from the Mid-Atlantic Gap Analysis, we identified species and natural communities occurring in the study area. From a variety of sources[1] we then identified these species' habitat preferences and requirements, home range sizes, dispersal abilities, suitable landscape features for dispersal, barriers to dispersal (e.g., highways or development), and roles in ecosystem functions. Umbrella and keystone species native to the area were used to determine size, connectivity, and other thresholds in the GI network design. Umbrella species are a species or group of species whose habitat needs overlap those of other animals and plants. Keystone species are those with an important role in ecosystem function, such as pollinators (e.g., butterflies and wild bees), seed dispersers (many birds and mammals), hydraulic engineers (beavers), and top carnivores (e.g., bobcats, river otters).

Habitat preferences of umbrella and keystone species helped parameterize core areas and hubs. We categorized native habitats into the following types: mature forest, riparian forest, forested wetlands, wetland-forest complexes, marsh, streams, old fields, scrub-shrub, early successional forest, pine forest, and potential turtle nesting areas. Connectivity requirements of less vagile (i.e. mobile) species (e.g., amphibians and small mammals) were used to model corridors.

We acquired data[2] that depicted the locations and characteristics of landscape features like land cover, streams, roads, topography, etc. Spatial data were processed using Geographic Information Systems (GIS), primarily in ArcGIS. Statistical analyses were conducted in NCSS. We made efforts to ensure that the input data and model outputs represented the real world as closely as possible, and noted data limitations (see Appendix C).

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[1] Bushman and Therres (1988), Robbins et al. (1989), Herkert et al. (1993), Tesky (1993), Burke and Gibbons (1995), Bay (1996), Hodges and Krementz (1996), Robbins (1996), Jones et al. (2000), Blackbird-Millington Corridor Conservation Area Plan, Hess (2000), Pennsylvania GAP Analysis Project (2000), Johnson and Igl (2001), Dechant et al. (2003), Rubino and Hess (2003), Mason et al. (2003), Bayne (2004), Roswell (2004), NHP (2005), Opler et al. (2006), Crawford and Semlitsch (2007), and NatureServe (2007).

[2] Sources: Maryland State Highway Administration (SHA), Maryland Dept. of Natural Resources (DNR), Charles County, and Prince George's County.

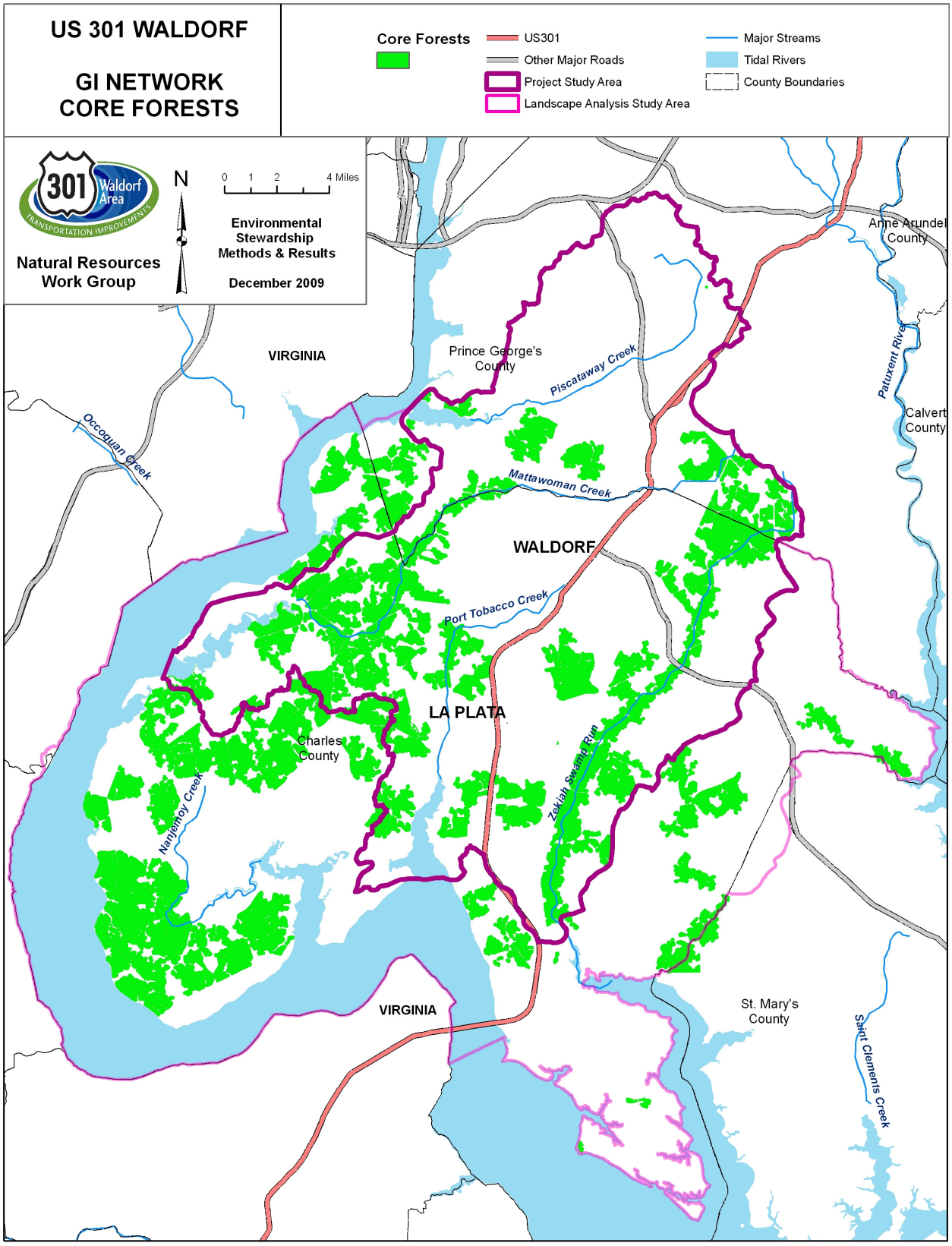
Core forest

Forest umbrella species were forest interior breeding birds (FIDS), which require large forest areas to breed successfully and maintain viable populations. The habitat needs of FIDS overlap those of many other plant and animal species including large mammals, many wildflower species, wood frogs, and wild turkeys. When sufficient habitat is protected to sustain a diversity of forest birds, additional important components and microhabitats of the forest should be encompassed and protected (Jones et al. 2000). A forest block with 100 ha (250 ac) of mature interior (>100m/328 ft from edges) deciduous or mixed forest would provide minimum habitat for 15 of the 18 FIDS found in the study area (Bushman and Therres, 1988). A bigger block than this is better. Robbins et al. (1989), Herkert et al. (1993), and Roswell (2004) also support a 100 ha (250 ac) minimum forest area.

We identified forest from LiDAR data in Charles County (identifying canopy height >5 m (16 ft) and subtracting impervious surfaces like buildings), and tree canopy data in Prince George's County that had been digitized from aerial photos. Forest patches were defined as areas of continuous tree canopy, with non-forest, roads, utility corridors, etc. separating one patch from another. Core forest areas were forest patches that contained 100 ha (250 ac) of mature interior (>100 m/328 ft from edges) deciduous or mixed forest, were at least 400 m (1300 ft) deep in spots, and had at least 50% forest cover within 2 km (1.2 mi) of the centroid. According to plot data we collected in the study area, mature forest was either identified as woodland in both 1938 and 2005 aerial photos in Prince George's Co., or had a LiDAR-calculated canopy height >24 m (79 ft). We also added Ecologically Significant Areas for forest-dependent species.

Comparing to field data, 80% of forest plots scoring "Excellent" were within core forest. Excellent and Good sites were found more often in core forest, and Fair and Poor sites were more often outside (Chi-square, $p<0.05$). Map 11 shows the locations of core forest in the landscape study area.

Undisturbed mature deciduous forest near Douglas Point in Charles County.



Map 11. Core forest areas in the US 301 landscape analysis area.

Core wetlands

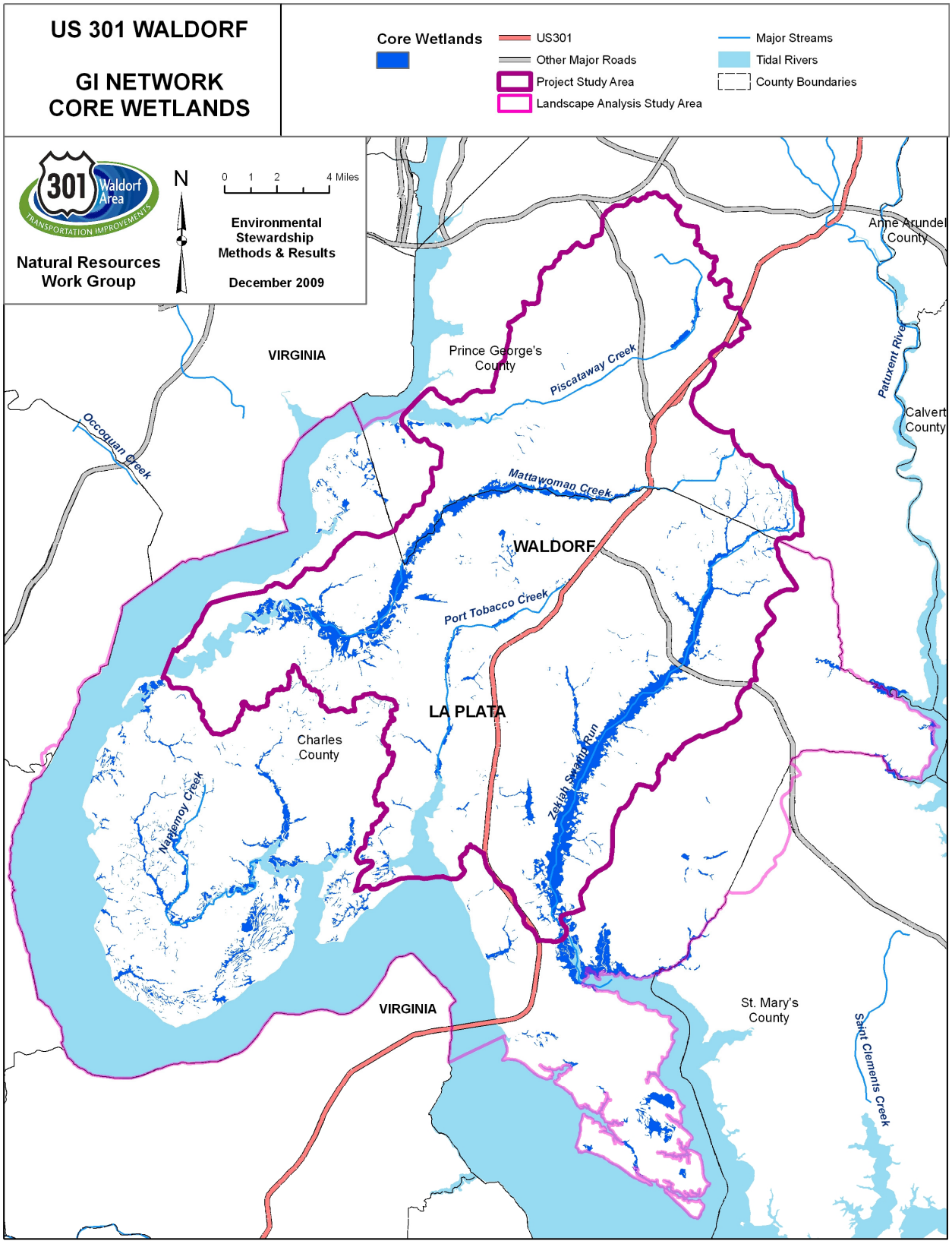
Core wetlands were defined as relatively unimpaired wetlands that met the habitat needs of wetland-dependent species. Wetlands had been delineated by DNR from aerial photos. We removed wetlands that had been modified hydrologically by ditching, draining, excavation, filling, or impoundment, unless impounded by beavers. Based on comparisons to stream incisement and macroinvertebrate data, wetlands also had to contain at least 40% natural cover and <10% imperviousness in their upstream catchment. Finally, wetlands need at least a 30 m (100 ft) buffer of natural vegetation to remove sediments, phosphorous, nitrogen, and other pollutants (North Carolina State University, 1998). We therefore removed areas <30 m (100 ft) from development, mines, agriculture, roads, or railroads (except for bridges).

We classified unmodified wetlands into four habitat types: riparian forest, forested wetlands, wetland-forest complexes, and marsh. Although there was overlap in many cases, these corresponded to different umbrella species and size thresholds (See Table 16). We also added Ecologically Significant Areas for wetland-dependent species.

Table 16. Core wetland umbrella species and associated habitat.

Wetland system	**Umbrella species**	**Minimum requirements**
Riparian forest	Louisiana waterthrush, wood turtle	Riparian deciduous forest along natural perennial streams, at least 300 m (984 ft) wide, and at least 100 ha (250 ac) of interior forest (>100m from edge) (Bushman and Therres 1988, Mason et al. 2003).
Forested wetlands	Prothonotary warbler	At least 100 ha (250 ac) of mature swamp or floodplain forest with standing water and >30 m (100 ft) from forest edge (Bushman and Therres 1988, Robbins 1996, Weber et al. 2006).
Wetland-forest complexes	Amphibians and turtles	Unimpacted and unpolluted wetlands (at least seasonally flooded) and vernal pools with at least 215 m (705 ft) of surrounding forest (Semlitsch and Jensen 2001, NatureServe 2007); we used a 95% threshold, with roads given stronger avoidance.
Marsh	Least bittern	Unimpaired marsh (either tidal or non-tidal) at least 5 contiguous ha (12 ac), with at least a 30 m (100 ft) buffer of natural vegetation or water (Robbins 1996, NatureServe 2007). Furthermore, marsh bird community integrity has been shown to decline significantly when development within 500 m and 1000 m of the marsh exceeds 14% and 25%, respectively (DeLuca et al. 2004).

Comparing to field data collected in 2007-08, core wetlands tended to be in better condition than non-core wetlands. DNR wetland Qualitative Condition Rating (QCR) ratings, which range from 1 (best condition) to 6 (worst) were better in core wetlands (average 2.4) than non-core wetlands (average 3.3) ($p<0.05$, $F=4.51$, $df=26$). The only poorly rated core wetland was a restoration site dominated by invasive species. Ohio Rapid Assessment Methodology (ORAM) scores, which ranged from 89 (best sampled site) to 44 (worst sampled site) were better in core wetlands (average 67) than non-core wetlands (average 57) ($p<0.05$, $F=5.16$, $df=26$). Map 12 shows the locations of core wetlands in the landscape study area.



Map 12. Core wetlands in the US 301 landscape analysis area.

Core aquatic areas

Core aquatic areas were unimpaired streams providing suitable habitat for fish, mussels, and benthic macroinvertebrates, plus associated floodplains and riparian cover. To identify these areas, we first compared MBSS biological data at randomly selected sample sites to conditions in their upstream catchment. Streams with Good benthic IBI scores (≥4.0) were usually found in catchments with >40% forest and wetland and <15% imperviousness (Chi-square, $p<0.005$, $n=99$). Fish IBI scores were related to in-stream velocity/depth diversity and maximum stream depth (stepwise regression, $r^2 = 0.32$). Benthic IBI scores were related to catchment percent imperviousness, in-stream velocity/depth diversity, and catchment percent riparian forest and wetland cover (stepwise regression, $r^2 = 0.39$).

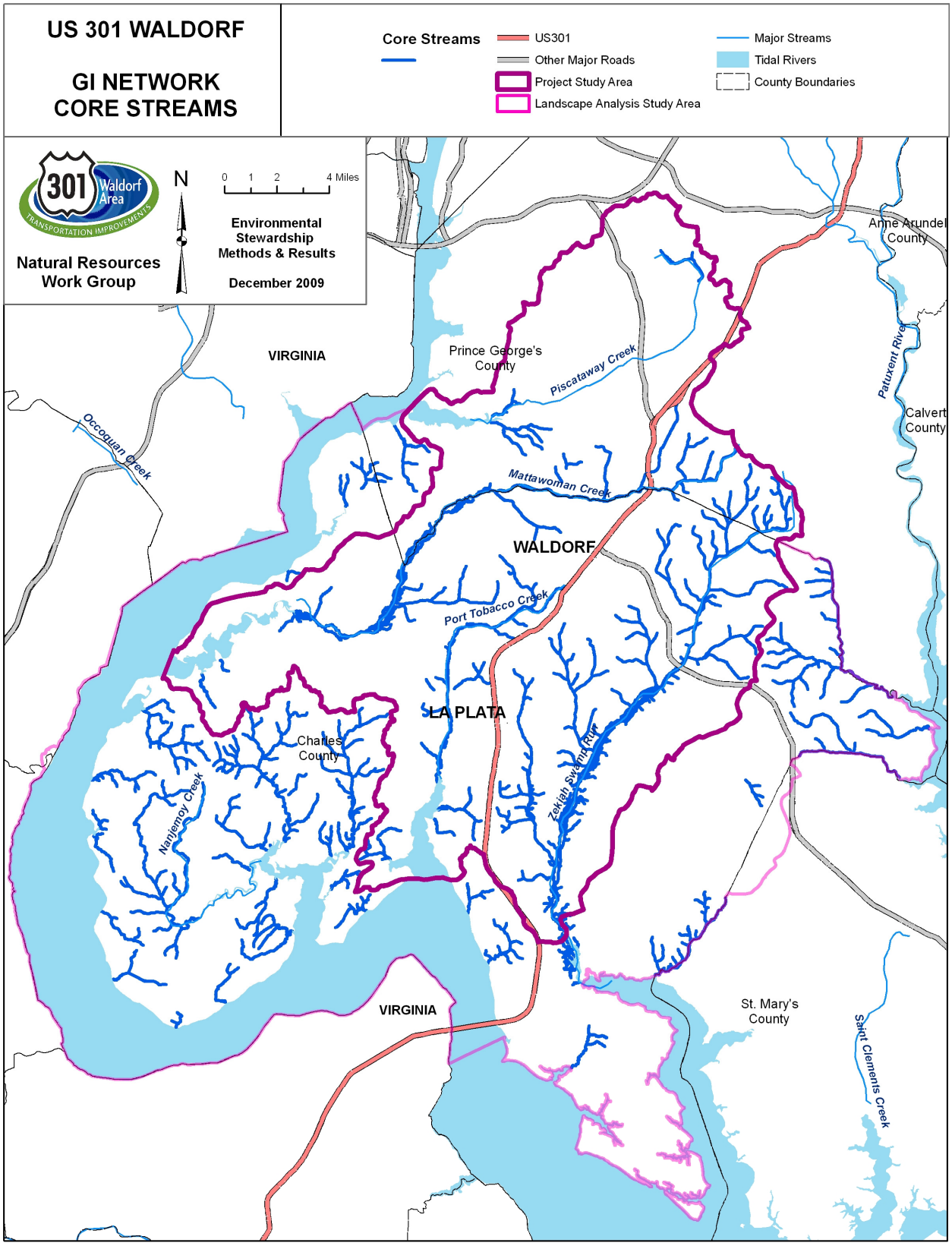
Next, we extrapolated these thresholds to all watersheds (DNR 12-digit) in the study area, to identify "core watersheds" (less likely to have impaired streams; or more likely to have high-quality streams). 65 of 69 DNR 12-digit watersheds (all except those draining Andrews Air Force Base and one draining Waldorf) met the 40%/15% thresholds. We then removed MBSS catchments with benthic IBI scores < 2 in all sites in that catchment. There were 6 such catchments out of 99. Finally, we added MBSS stronghold and sentinel watersheds, and catchments with high-quality stream sites. The above watersheds (meeting land cover thresholds, important for biodiversity, reference standard, and/or with exemplary biological communities) covered 97% of land in the study area.

Core Streams

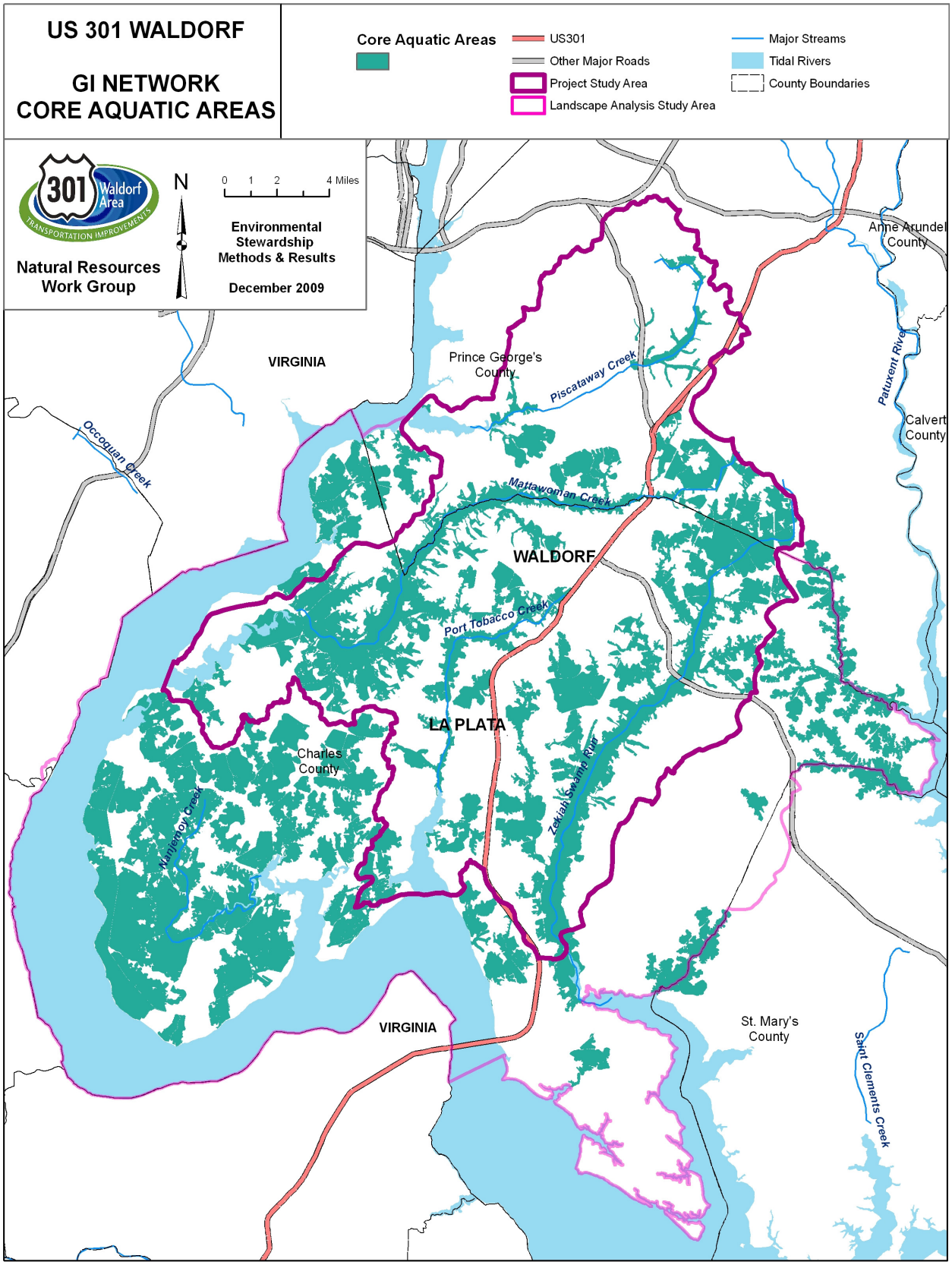
We defined "core streams" as natural streams within core watersheds. Because core watersheds covered virtually the entire study area, this was not a useful starting point. Instead, we relied mostly on geomorphic survey data collected by U.S. Fish & Wildlife Service, along with biological and habitat data. Core streams had to meet the following criteria:

- The stream should be stable, or recovering from past instability. Past erosion should be mostly healed over. Ongoing severe erosion degrades aquatic habitat and can smother mussels; and entrenchment separates the stream from its floodplain.
- Fish and benthic IBI's both ranking Fair to Good. These could rank slightly lower if the stream is stable and contains high-quality habitat, or was influenced by conditions like natural tannins or beaver impoundment.
- If anadromous fish eggs or larvae were recently recorded in the stream, it would be considered a core stream even if IBI scores are low and the stream has erosion problems. However, we did not have any stream reaches where this was the case.
- The stream should be unchannelized, and provide good fish, mussel, and/or benthic invertebrate habitat.
- The stream should contain forest or wetland buffers, preferably at least 30 m (100 ft) on each side to trap sediments and remove pollutants.
- The stream should be perennial (except for extreme drought events), run at least 1.5 km (1 mi) without dams, other blockages, or inadequate buffers, and include a second or higher order stream. Isolated first order streams generally provide limited habitat for fish. According to their fish blockage database, DNR Fisheries considered streams with lengths less than around 1.5 km (1 mi) to be too small to justify opening fish blockages.

Where no survey data existed, modeling and extrapolation (e.g., considering soil erodibility, slope, neighboring conditions, etc.) were used. Once core streams were identified (Map 13), we added adjacent natural cover. We also added streams and adjacent natural cover identified as Ecologically Significant Areas for aquatic-dependent species. Map 14 shows the locations of core aquatic areas in the study area.



Map 13. Core streams in the US 301 landscape analysis area.



Map 14. Core aquatic areas in the US 301 landscape analysis area.

Other core habitat

We added areas with natural cover identified as Ecologically Significant Areas for species not forest, wetland, or aquatic dependent. There were 7 such areas, covering a total of 503 ha (1243 ac). We also added other ESAs that fell outside core forest, wetland, or aquatic areas. There were 7 areas, all <5 ha (12 ac).

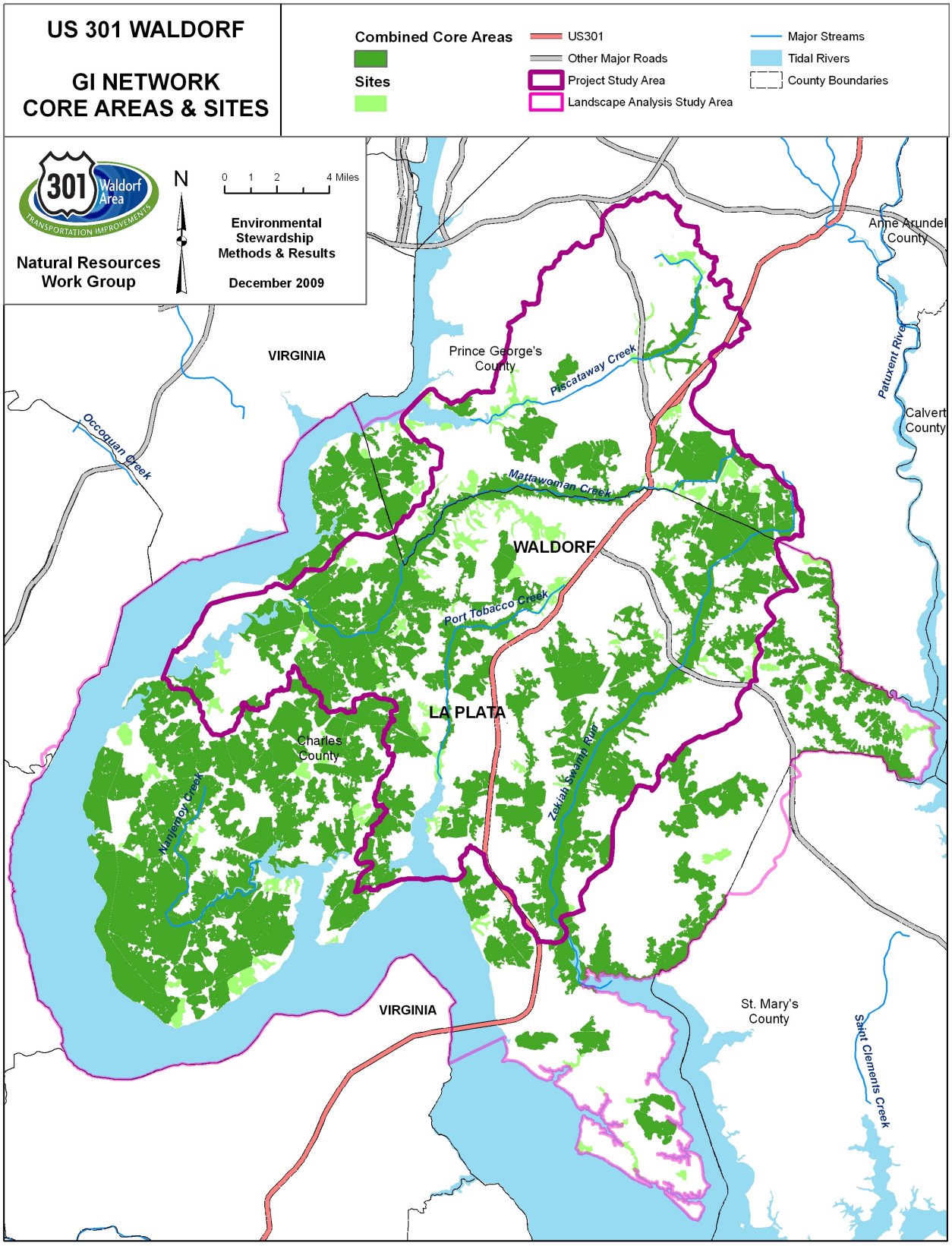
We hoped to identify potential nesting areas for snapping turtles, painted turtles, spotted turtles, redbelly turtles, and box turtles. These would be open areas with sandy or loamy soil and within 100 m (328 ft) of wetlands or open water, but not subject to frequent disturbance. Unfortunately, GIS model output was not useful. Comparing to aerial photos, land use data was inaccurate. Most identified open areas were farmed. Similarly, we were unable to identify meadow or old field habitat for grassland birds, since available land cover or land use data[3] were unable to discriminate between grasslands and agriculture.

Because there was significant overlap, we combined core forest, wetland, aquatic, and other areas described above. If the combined areas were at least 100 contiguous hectares (250 ac), they were termed "core areas" in the green infrastructure network. If they were <100 ha (250 ac), they were termed "sites" (see Map 15).

Other habitat, which was incorporated into hubs (see next section), included early successional forest and mature pine forest. Prairie warblers were the umbrella species for early successional forest, requiring blocks at least 1 ha with a canopy height <20 m (66 ft). Pine warblers were the umbrella species for pine forest, requiring 30 ha (74 ac) or greater blocks of pine trees at least 40 years old.

Unmowed pasture in Charles County.

[3] NLCD, GAP, or MDP land use



Map 15. Core areas and sites in the US 301 landscape analysis area.

Hubs

Hubs were aggregations of core areas, other habitat, and other natural land, divided by major roads or gaps >100 m (328 ft), and at least 100 ha (250 ac) in size. Hub keystone and umbrella species, and their associated habitat are listed in Table 17. Hubs were intended to be large enough to support populations of native species, and serve as sources for emigration into the surrounding landscape. Not all core areas, other habitat, or other ecological features fell within hubs, if they were isolated and below the size threshold. However, this does not mean such areas are unimportant. Map 16 shows the locations of hubs in the study area.

Table 17. Hub keystone and umbrella species and associated habitat (mostly from NatureServe, 2007).

Landscape feature	**Species**	**Ecosystem role**	**Habitat**
Forest hubs with nearby fields	Bobcat	Top carnivore (ecosystem regulation)	Primarily large tracts of non-flooded forest, including edges.
Hubs - riparian	River otter	Top aquatic carnivore (ecosystem regulation)	Open water (e.g., perennial streams, ponds) with riparian forest
Hubs - riparian	Beaver	Creates wetlands	Riparian forest (2nd - 4th order streams or ponds)
Forest hubs with nearby fields	Wild turkey	Seed dispersal (other animals also do this)	Mature forest with clearings or fields nearby
Forest hubs with nearby fields	Barn owl	Carnivore (ecosystem regulation)	Need large grassland or wet meadow areas for foraging and nest in tree cavities (which also could occur in wetlands).
Forest hubs with nearby fields	Great horned owl	Top carnivore (ecosystem regulation)	Medium to large blocks of forest with large trees and nearby fields

Corridors

Corridors are linear features linking core areas together, to allow animal and plant propagule movement between them, in the hope of creating viable and persistent metapopulations. Each type of core area was associated with a type of corridor or linkage depending on the movement abilities and landscape preferences of organisms living in that type of core area (Table 18). We assessed the landscape between core areas for its linkage potential, identifying conduits and barriers to wildlife and seed movement. The search radius defines the distance between core areas or suitable habitat for analysis purposes. Because of landscape and computational considerations, the maximum search radius was 10 km (6 mi), although some wide-ranging species can travel further than this in search of suitable habitat.

Eastern box turtle, a corridor focal species for this project.

Table 18. Habitat-specific linkage types used to identify potential corridors (mostly from NatureServe, 2007).

Type of core area	Connectivity target species	Best linkages	Search radius (km)
Forests	Bobcat, gray fox, wild turkey, flying squirrel, woodland vole, Northern short-tailed shrew, five-lined skink	Forest cover with interior habitat	10
Meadows	Meadow butterflies	Old fields, pasture, or powerline corridors	10
Riparian forest and wetlands	River otter, mink, beaver, wood turtle, semi-aquatic snakes, salamanders, frogs, crayfish	Wide riparian forest and wetlands preferred. Other wetlands and forest are generally better than open areas.	5
Forested wetlands or wetlands in forest	Salamanders, frogs, Eastern box turtle	Moist woods with vernal pools, wetlands, and unpolluted streams	5
Marsh	Muskrat, marsh rice rat, meadow jumping mouse	Marsh, waterways	3
Streams	Fish and mussels	Unblocked perennial streams with unpolluted water	10

For all target species, urban areas and major roads (except under bridges) were considered barriers (NatureServe, 2007). Steep slopes (e.g., ravine sides) may be avoided by some species like turtles. Linkages should pass through hubs and protected land where possible; hubs because they represent larger, more intact natural areas, and protected land to ease corridor implementation and reflect potentially compatible management. Meadows were dropped since core grasslands could not be accurately identified using available GIS data. Riparian forest and wetlands, forested wetlands, and marsh were combined since linkages were generally along waterways and bottomlands.

We used least cost path analyses to identify optimal linkages between core forests, core wetlands, and core aquatic areas (See Appendix C for details). Corridors included all natural land along these pathways, out to the nearest road or development (see Map 16). Ideally, corridors should be at least 200 m (650 ft) wide, based on interior forest bird requirements (Hodges and Krementz, 1996; Jones et al., 2000) and a study by Vidra (2004) that showed that corridors >200 m wide generally had <10% exotic invasive plants. A width of 300 m (984 ft) is preferable (Bond, 2003; Mason et al., 2003).

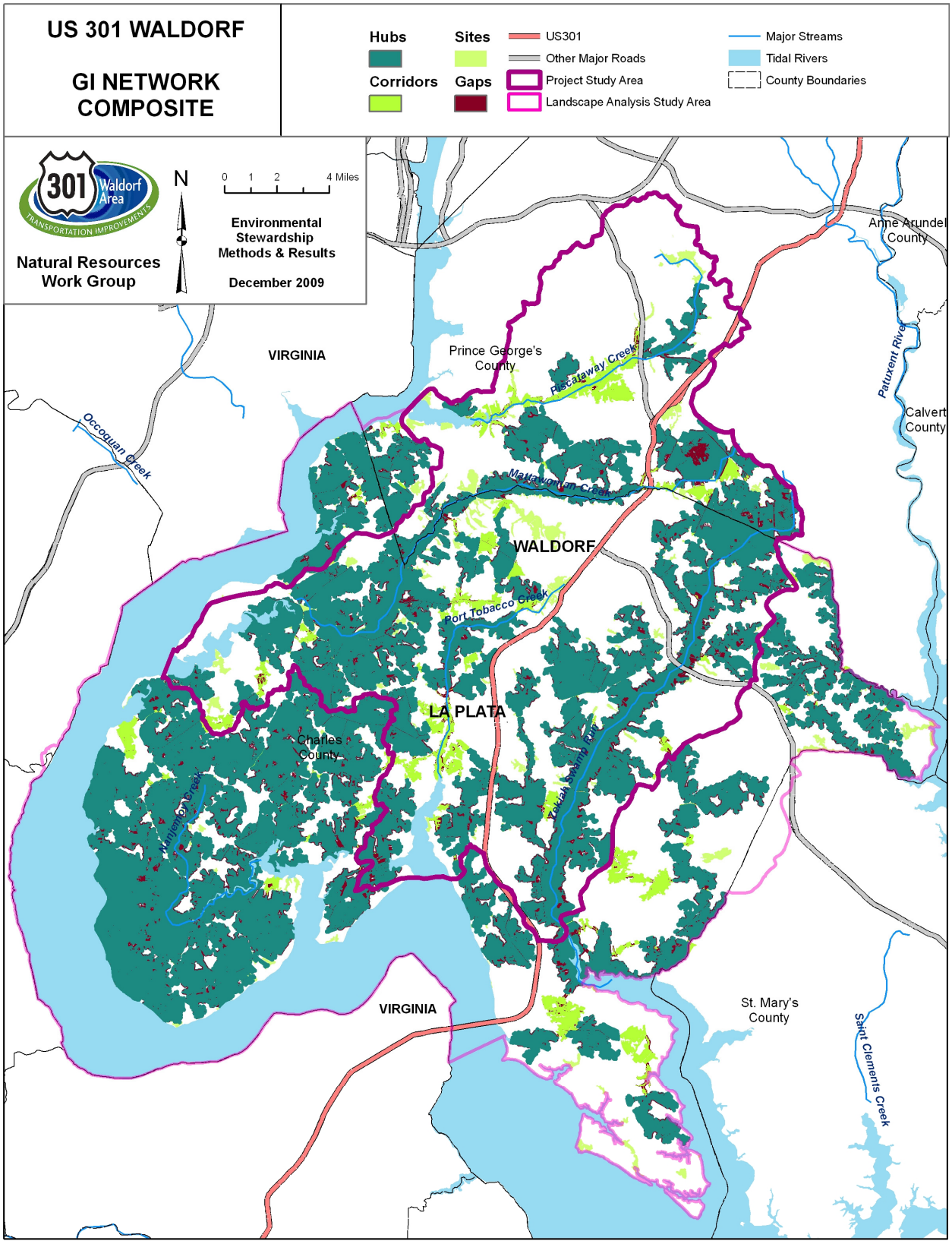
Buffers

We next identified a potential buffer of low-intensity land use around core areas, hubs and corridors. This compatible use buffer was defined as existing undeveloped land (natural, silviculture, agriculture, etc.) within 1 km (0.6 mi) or out to the nearest road or railroad. This could be used to help guide agricultural preservation activities. From an ecological perspective, preserving agriculture could protect the green infrastructure from high-intensity disturbances associated with urban development. From an economic perspective, it could protect a disappearing agriculture base from urban sprawl. And from an aesthetic perspective, a protected agricultural buffer area could maintain large swaths of rural landscape.

Green Infrastructure Restoration Needs

"Gaps" are areas within the GI that do not currently have natural vegetation, such as agricultural, barren, or lawn areas. Revegetation of these areas with natural land cover would strengthen the integrity of hubs and corridors, decrease negative edge effects, ease wildlife movement, and decrease opportunities for invasive plants. Forest, wetland and stream restoration within the network would benefit the network as a whole, and the restoration project would be more likely to succeed over the long term. For example, wetland restoration within a GI hub, especially near existing core wetlands, could benefit from nearby sources of native species and a more natural hydrology. Restoration projects in urban or agricultural areas, although they may provide benefits like stormwater retention and flood attenuation, often become dominated by exotic species and may be subject to hydrologic impairments and influxes of pollutants. Similarly, stream restoration in a hub, especially where the watershed is mostly forested, may benefit from a more stable base flow and storm flow, and may be linked to more diverse populations of fish and benthic organisms.

We identified gaps within hubs and corridors that could be restored to natural cover (Map 16). Impervious surfaces and roads were excluded. We identified corridor breaks and stream buffer gaps (within 30 m/100 ft of a stream in the GI) as high priorities. Internal gaps (entirely within a hub or corridor) were deemed higher priorities than gaps on the periphery of the network. We also identified unbuffered stream reaches outside the GI, but upstream of aquatic core areas.



Map 16. Hubs, corridors, and gaps in the US 301 landscape analysis area.

VI. NATURAL RESOURCE PRIORITIZATION

1. Green Infrastructure Network Prioritization

Core Area Ranking

We calculated a number of parameters for each core area and site, and calibrated their values to numbers between 0 and 1 (see Appendix C for details). We examined these variables with correlation analyses, principle components analysis, cluster analyses, and other tests of data structure and variable significance. We found that the following variables contributed to differences between core areas:

- Size of hub the core area is within (not in a hub = 0)
- Area of Ecologically Significant Areas (ESAs)
- Area of mature interior forest (>100 m/328 ft from edge)
- Area of minimally impacted wetlands
- Length of core streams
- Maximum depth (distance to nearest edge of core area)
- Mean distance to nearest major road
- Mean distance to nearest development
- Proximity index (sum of neighboring core sizes divided by the square of the distance)
- Relative connectivity potential (function of proximity to other core areas and intervening land use, habitat quality, roads, hydrology, etc.).

Combining the above variables, the Douglas Point area and Zekiah Swamp ranked the highest (Map 17). The top two core areas (which only differed in score by 1%) were middle Zekiah Swamp (between Rt. 5 and Rt. 6) and the western Nanjemoy watershed near Douglas Point.

Hub Ranking

We also calculated, calibrated, and examined a number of parameters for each hub. We found that the following variables contributed to differences between hubs:

- Area of Ecologically Significant Areas (ESAs)
- Area of mature interior forest
- Area of minimally impacted wetlands
- Length of core streams
- Maximum depth (distance to nearest edge of hub)
- Mean distance to nearest major road
- Mean distance to nearest development
- Proximity index (sum of neighboring hub sizes divided by the square of the distance)
- Relative connectivity potential (function of proximity to other hubs and intervening land use, habitat quality, roads, hydrology, etc.).

Because they explained more of the variation between hubs, we gave ESA area and mature interior forest area twice the weighting of other variables. Combining hub variables, the Douglas Point/Potomac bend area and Zekiah Swamp/Cedarville State Forest ranked the highest (Map 18).

Corridor Ranking

We ranked corridors (Map 19) using the following parameters:

- Average rank of linked hubs.
- Number of hubs linked.
- Major road crossings without bridges.

Watershed Variables

- Anadromous fish spawning habitat use (8-digit watershed level), using rankings by DNR Fisheries Service (See Table 19)
- Percent of streams in 8-digit watershed that are core streams
- Stronghold watersheds (12-digit watershed level; generally corresponding to third-order streams).
- Mean combined (fish + benthic) IBI score (12-digit watershed level)

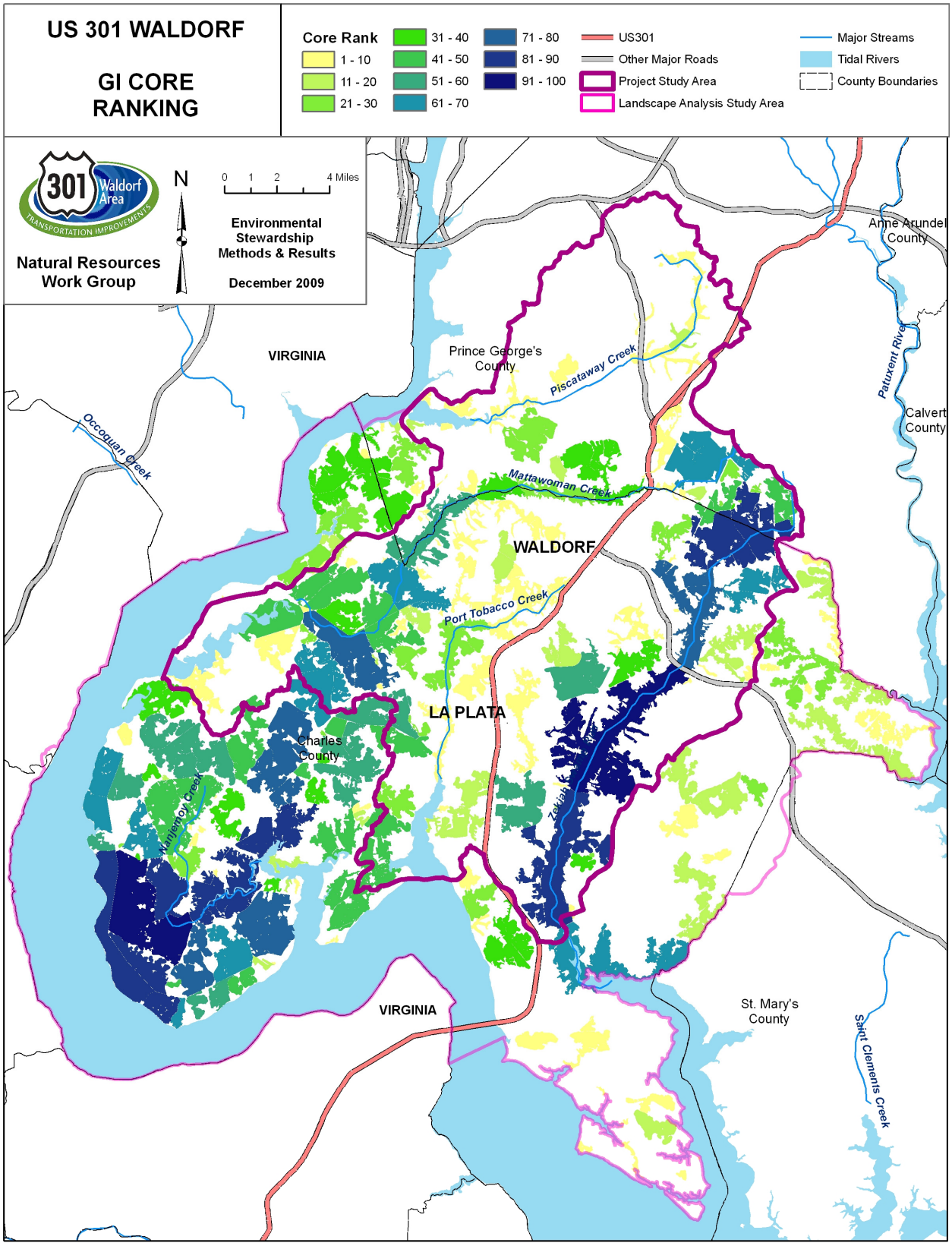
Table 19. US 301 study area watersheds, ranked by anadromous fish use.

	Yellow perch rank	White perch rank	Herring rank	Rank Stream length used	Sum of these Ranks	RANK Score (5 = highest)
Mattawoman	5	5	5	5	20	5
Nanjemoy	5	5	5	3	18	4
Port Tobacco	5	5	5	2	17	3
Zekiah	5	5	5	1	16	2
Piscataway	1	5	5	4	15	1
All other watersheds						1

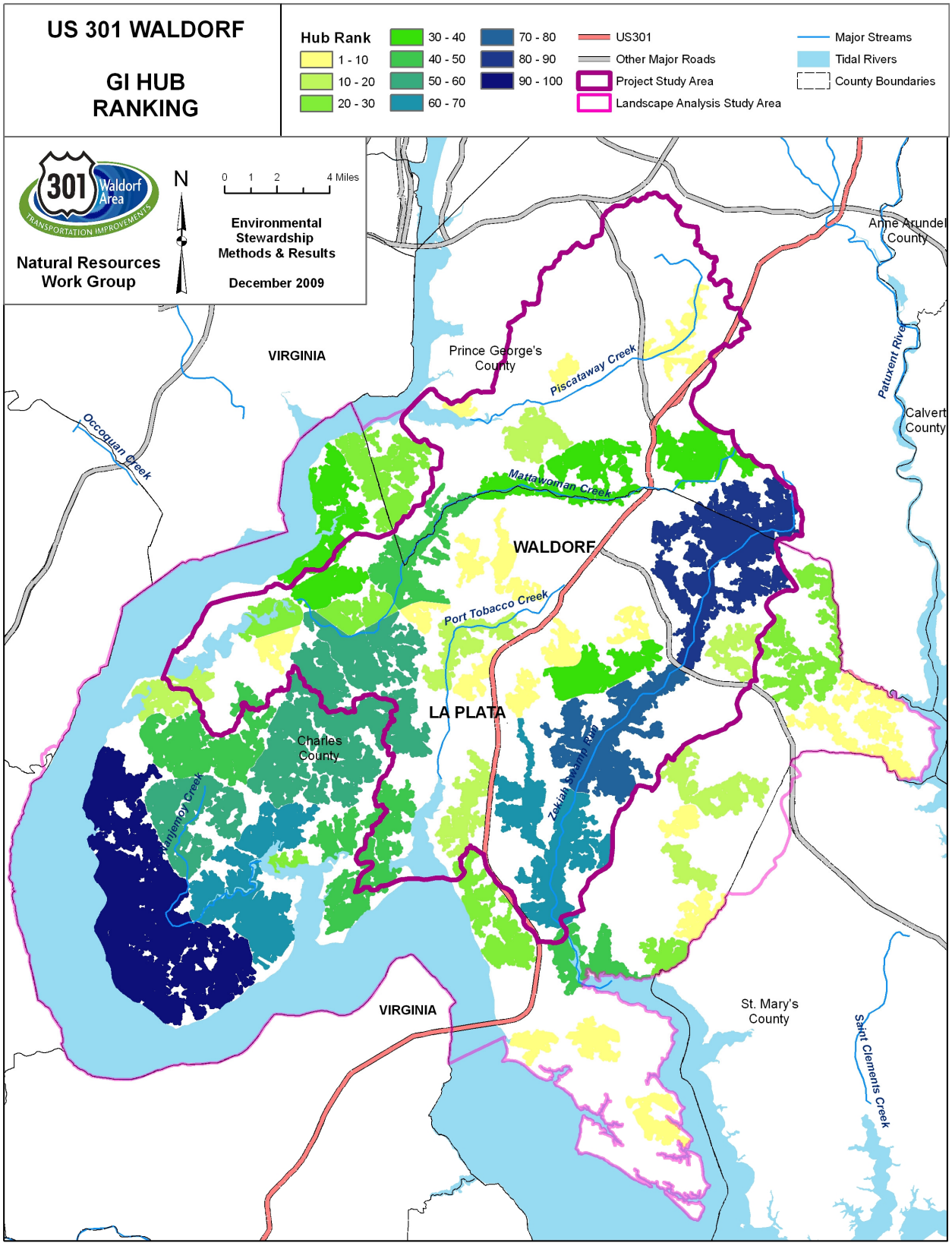
Local Scale Variables

We also assessed ecological resources for each 36 m^2 grid cell in the study area. This allowed for finer scale site ranking according to habitat quality, ecosystem condition, and human disturbance. All parameters were calibrated to equal-area distributions between 0 and 100. The fine-scale parameters included:

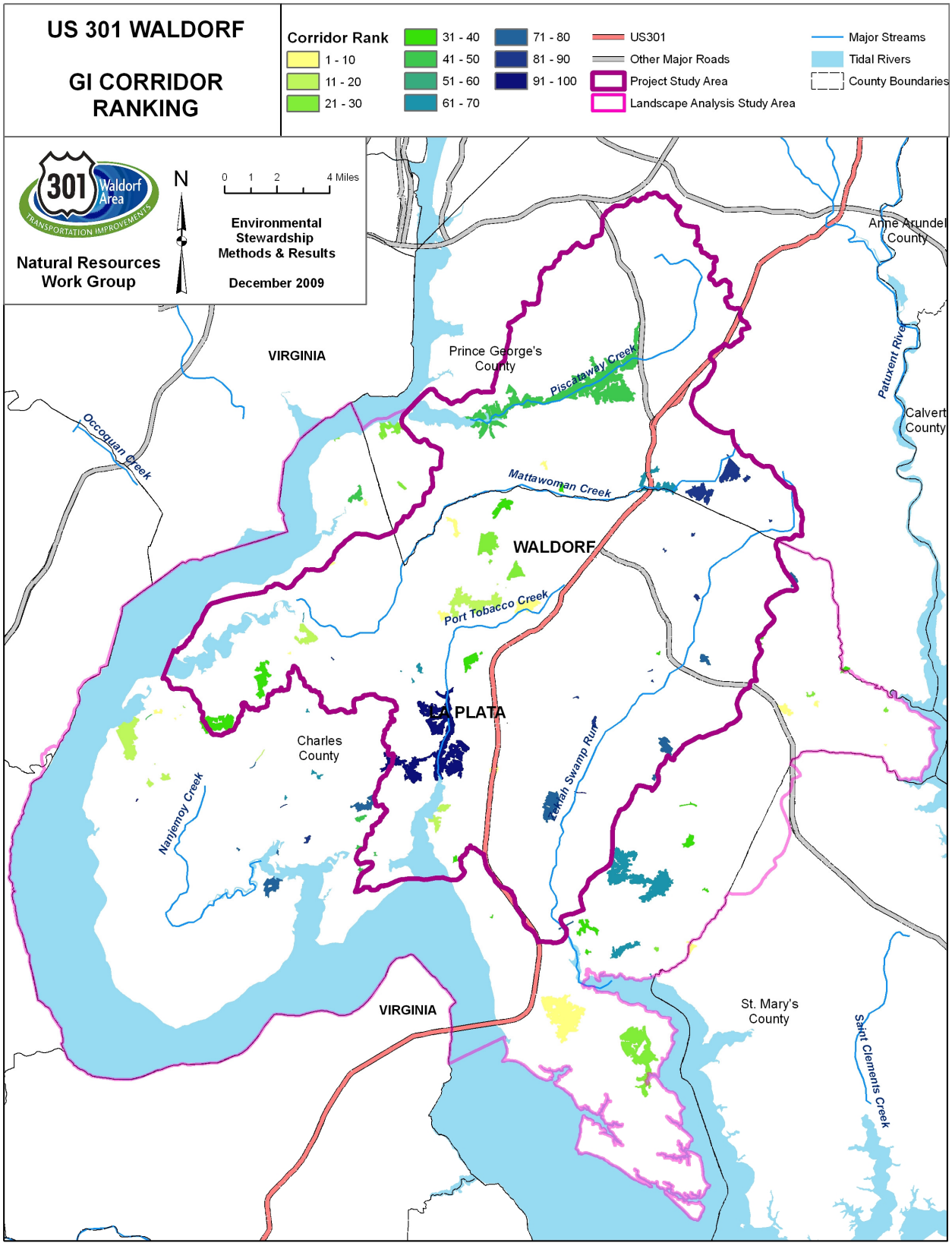
- Ecologically Significant Area (ESA) rank
- Ecological Community Group (ECG) rank
- Forest maturity
- Wetland condition and proximity
- Hydrologic proximity to core streams
- Proximity to water, including streams, other open water, and wetlands flooded at least seasonally
- Distance to edge of forest, wetland, or water
- Distance to development



Map 17. Core area and site ranks in the US 301 landscape analysis area.



Map 18. Hub ranks in the US 301 landscape analysis area.



Map 19. Corridor ranks in the US 301 landscape analysis area.

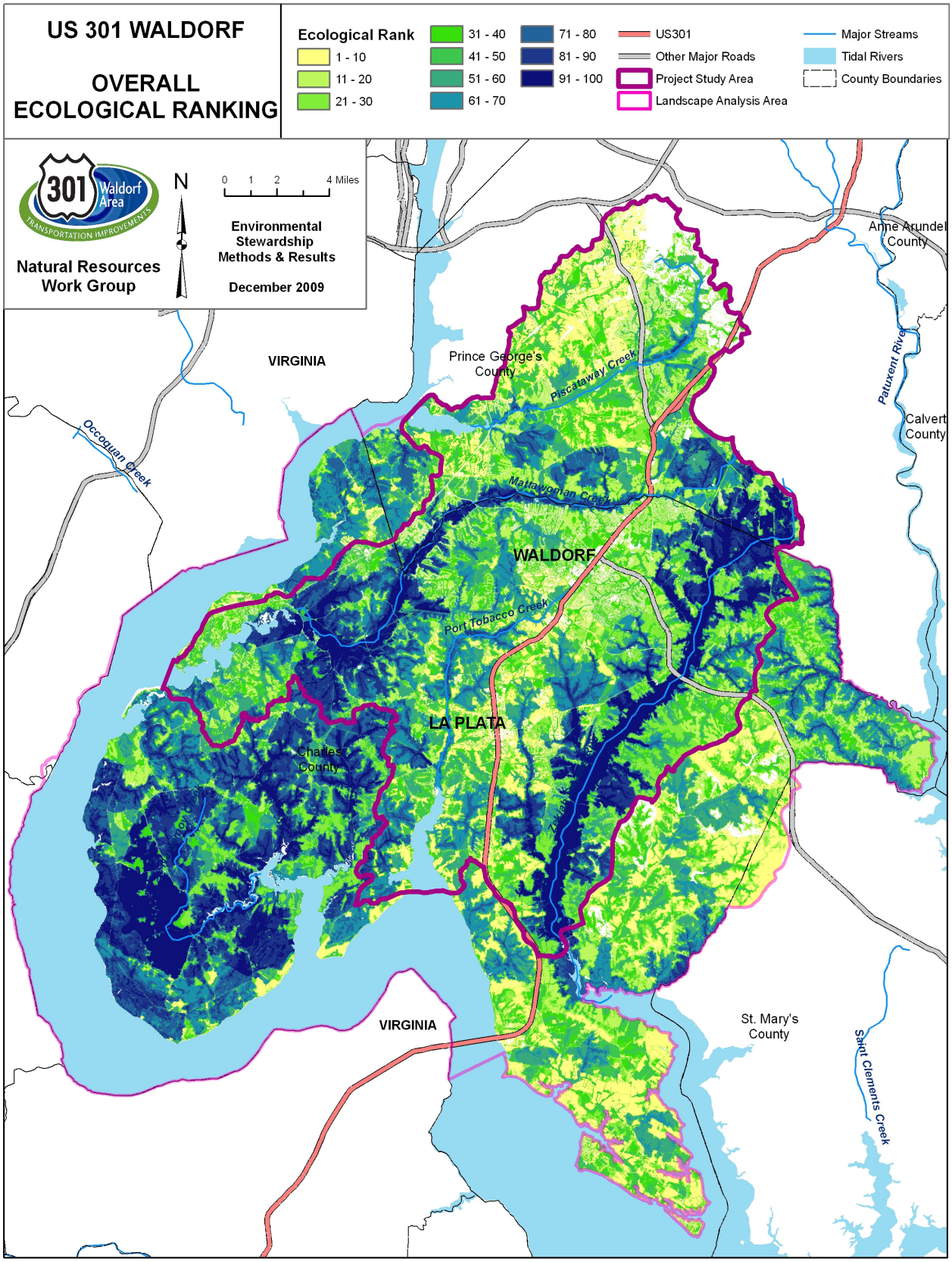
Overall Ecological Ranking

The conservation score for ecological significance was an overlay of data at all of the scales listed above. Watershed data was at two scales (DNR 8-digit and 12-digit; roughly equivalent to 3rd order and 4th order streams), and terrestrial data was at two scales (hub/corridor and core area), not counting data at the individual grid cell scale. Corridors do not overlap hubs; therefore scores at these scales are not spatially additive. We compared the ratings of natural community sites assessed in 2007 (n=82) to core rank, hub rank, percent core streams in the watershed, and all local (grid cell) variables. Variables were averaged within 12 m (39 ft) of the plot center point. Of local variables, distance to development was not significant in any analyses, and this metric was ecologically similar to distance to edge. Therefore, we dropped distance to development from the combined score. No other variables were dropped because field sampling was limited to vegetation, mostly in areas where rare species might occur. Forest age was a consistent predictor of community condition, and was given a high weight in the combined score. Wetland condition and proximity, water proximity, distance to edge, core stream proximity, and hub rank were also related to community ratings. ESA presence and rank were correlated with variables at greater spatial scales. ECG rank was, surprisingly, not related to community score. In addition, ECG boundaries were delineated for only a small fraction of the study area, limiting the usefulness of this variable. Table 20 lists the parameters and their weights used to derive an overall ecological score for each grid cell in the landscape. Variables were weighted equally unless there was evidence to suggest otherwise. Scores were transformed to an equal-area distribution between 0 (lowest in study area) and 100 (highest). We compared these weights to alternative variable weightings (See Appendix C), using natural community and forest plot data. The combination in Table 20 was the best predictor of both natural community condition and forest condition. Map 20 shows output from this model.

Wood frog (*Rana sylvatica*), which requires intact forest containing vernal pools.

Table 20. Parameters and weights for ecological score tabulation.

Scale	Variable	Scale weight	Variable weight within scale	Total weight
Core area/Site	Hub area	20.0	0.100	2.0
	ESA area		0.100	2.0
	Area of mature interior forest		0.100	2.0
	Area of unimpacted wetlands		0.100	2.0
	Length of core streams		0.100	2.0
	Maximum depth of core or site		0.100	2.0
	Distance to major roads		0.100	2.0
	Distance to development		0.100	2.0
	Proximity index		0.100	2.0
	Connectivity index		0.100	2.0
Hub	ESA area	20.0	0.182	3.6
	Area of mature interior forest		0.182	3.6
	Area of unimpacted wetlands		0.091	1.8
	Length of core streams		0.091	1.8
	Maximum depth of hub		0.091	1.8
	Distance to major roads		0.091	1.8
	Distance to development		0.091	1.8
	Proximity index		0.091	1.8
	Connectivity index		0.091	1.8
Corridor	Average rank of linked hubs	11.4	0.333	3.8
	Number of hubs linked		0.333	3.8
	Major road crossings without bridges		0.333	3.8
8-digit watershed	Anadromous fish spawning habitat use	10.0	0.500	5.0
	Percent core streams in watershed		0.500	5.0
12-digit watershed	Stronghold watershed (Tier 1/Tier	10.0	0.500	5.0
	Mean combined IBI score		0.500	5.0
Grid cell (36 m^2)	ESA presence and rank	40.0	0.071	2.9
	Ecological Community Group rank		0.071	2.9
	Forest maturity		0.286	11.4
	Wetland condition and proximity		0.143	5.7
	Proximity to core streams		0.143	5.7
	Proximity to water		0.143	5.7
	Distance to edge of forest, wetland, or water		0.143	5.7
TOTAL		**100.0**		**100.0**



Map 20. Overall ecological ranking in US 301 landscape analysis area, derived by combining the weighted variables in Table 20.

Finally, we calibrated the ecological score within different subsets of the study area, using an equal-area distribution. These subsets included:

- The entire study landscape
- Charles County
- US 301 ES project boundary (Piscataway Creek, Mattawoman Creek, Zekiah Swamp, and Port Tobacco River watersheds)
- Unprotected mature core forest in the US 301 ES project area
- Unprotected core wetlands in the project area
- Unprotected ESAs in the project area
- Unprotected core stream floodplains in the project area

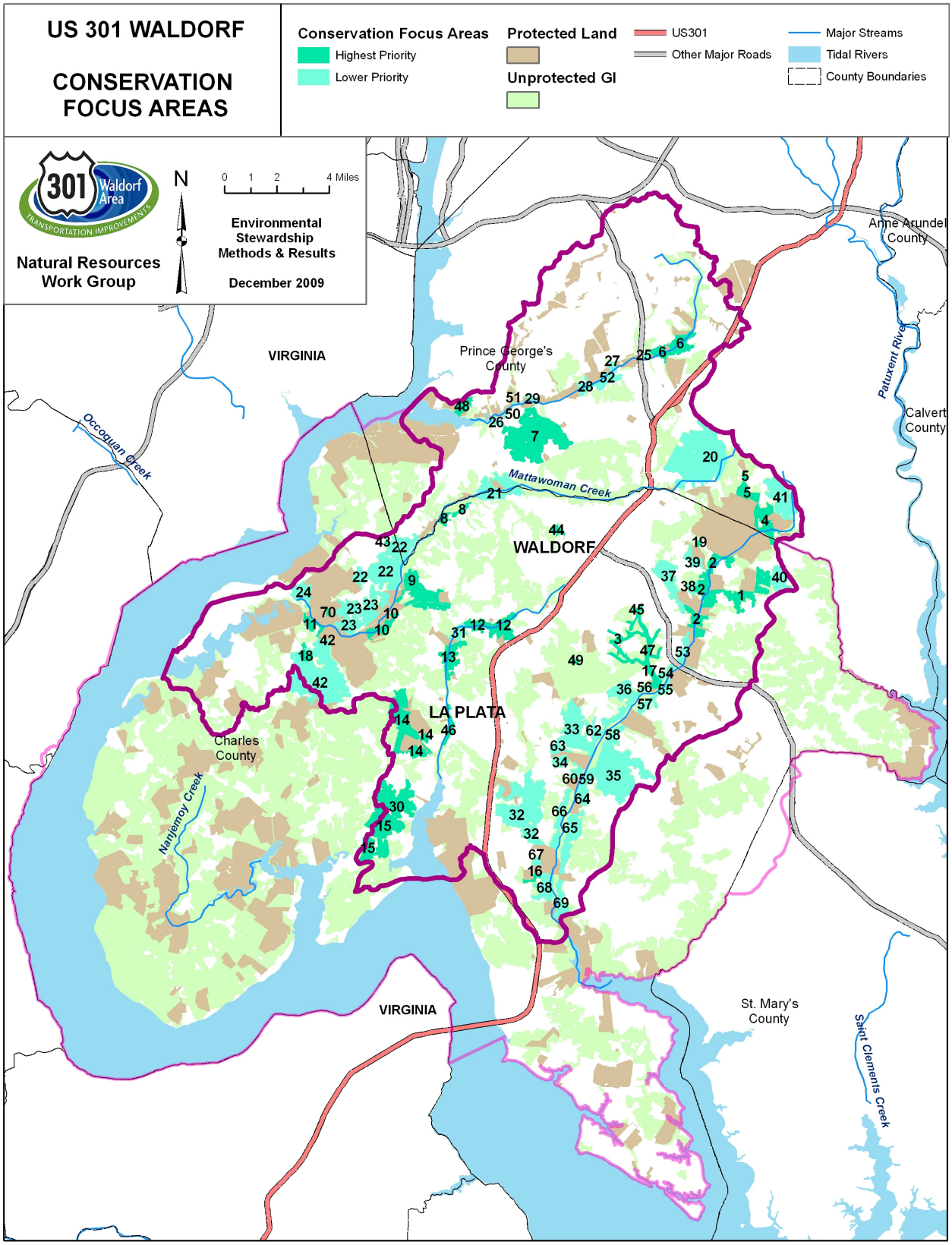
Within the entire study area and Charles County, the Potomac bend/Nanjemoy watershed area and Zekiah Swamp/Cedarville State Forest area ranked the highest. Within the US 301 ES project boundary, Zekiah Swamp ranked the highest overall and for focusing protection of forests, wetlands, streams, and biodiversity.

2. Conservation Site Selection

In 2008, NRWG identified two tiers of conservation priorities based on the highest-ranking Green Infrastructure within each project watershed: Piscataway Creek, Mattawoman Creek, Port Tobacco River, and Zekiah Swamp. The top tier of conservation priorities contained top ranking unprotected forests, wetlands, Ecologically Significant Areas, and/or streams, and were reasonably possible to develop. In most cases, the top tier priorities were also adjacent to existing protected lands, and contained large properties (i.e., were not subdivided). The second tier of conservation priorities connected top tier areas or protected land, or were large blocks of natural land with a high ecological ranking (See Map 21 and Table 21). Conservation focus areas totaled 13,083 acres (3988 ha).

Conservation involves fee simple or easement acquisition of properties from willing landowners. There were hundreds of individual properties within the conservation focus areas. We identified parcels in the focus areas that were at least 20 acres (6 ha) in size, digitized their boundaries, and for each parcel, calculated the area of green infrastructure, mean ecological score, and proximity to existing protected land. Concurrently, SHA mailed letters to these landowners, seeking permission for NRWG to conduct field assessments.

Active beaver lodge at Devil's Nest Run, one of NRWG's conservation priority areas.



Map 21. Locations of US 301 conservation focus areas. The numbers on the focus areas correspond to the "Site ID" in Table 21.

Table 21. Description of US 301 conservation focus areas.

Site ID	Site name	Tier	Area (ha)	Mean ecological score
7	Forested Piscataway Creek tributary catchments	1	803	67.6
15	Goose Creek, northern watershed	1	477	75.9
14	Hoghole Run watershed	1	434	73.1
2	Zekiah Swamp south of Cedarville State Forest	1	397	92.6
9	Old Woman Creek near Mattawoman Creek	1	366	83.2
30	Henson Landing area	1	343	68.8
47	Piney Branch	1	314	80.7
12	Port Tobacco Creek/Pages Swamp	1	256	71.5
1	Devil's Nest	1	256	87.0
6	Piscataway Creek	1	213	64.7
4	Tibutary to Zekiah Swamp Run north of Cedarville State Forest	1	189	90.4
13	Port Tobacco Creek	1	174	71.9
5	Wolf Den Branch north of Cedarville SF	1	106	87.9
10	Mattawoman Creek	1	103	88.6
48	Mount Vernon Ravine	1	77	62.7
46	Port Tobacco Run	1	71	68.5
11	Mattawoman Creek near WWTP	1	68	92.4
8	Mattawoman Creek	1	67	77.1
3	Piney Branch Bog	1	52	61.1
18	Araby Bog	1	50	83.6
45	Stetham Park Wetlands and Barrens	1	45	64.9
44	Sun Valley Wetlands	1	31	59.3
16	Ross Branch (Zekiah Swamp tributary)	1	28	90.6
49	Little Kerrick tributary	1	15	66.9
17	Piney Branch	1	12	88.7
19	Zekiah tributary linking portions of Cedarville State Forest	1	11	93.8
43	Bryans Road Bog	1	8	61.9
20	Mattawoman headwaters hub	2	985	73.7
42	Mattawoman Creek hub	2	944	83.3
32	Zekiah Swamp area with high ecological score	2	743	79.8
35	Zekiah Swamp area with high ecological score	2	723	86.8
22	Mattawoman tributaries	2	618	77.6
23	Mattawoman tributaries	2	462	75.0
33	Zekiah Swamp area with high ecological score	2	406	82.0
21	Mattawoman Creek	2	296	78.7
41	Zekiah Swamp area with high ecological score	2	290	85.3
65	Zekiah Swamp area with high ecological score	2	239	93.2
37	Zekiah Swamp area with high ecological score	2	231	86.5
36	Zekiah Swamp area with high ecological score	2	191	90.4
68	Zekiah Swamp area with high ecological score	2	164	88.8
66	Zekiah Swamp area with high ecological score	2	139	93.4
40	Zekiah Swamp area with high ecological score	2	137	82.3
24	Mattawoman Creek south of Chapman Forest	2	122	82.6

Site ID	Site name	Tier	Area (ha)	Mean ecological score
62	Zekiah Swamp area with high ecological score	2	120	90.0
69	Zekiah Swamp area with high ecological score	2	116	92.4
59	Zekiah Swamp area with high ecological score	2	97	94.4
52	Piscataway Creek	2	94	49.5
53	Zekiah Swamp area with high ecological score	2	93	88.6
39	Zekiah Swamp area with high ecological score	2	79	79.5
58	Zekiah Swamp area with high ecological score	2	76	94.1
31	Port Tobacco Creek connection	2	72	71.3
28	Piscataway Creek	2	71	49.3
57	Zekiah Swamp area with high ecological score	2	69	93.6
34	Zekiah Swamp area with high ecological score	2	62	86.3
54	Zekiah Swamp area with high ecological score	2	62	95.6
64	Zekiah Swamp area with high ecological score	2	54	96.0
55	Zekiah Swamp area with high ecological score	2	47	95.7
63	Zekiah Swamp area with high ecological score	2	46	86.7
60	Zekiah Swamp area with high ecological score	2	44	95.9
38	Zekiah Swamp area with high ecological score	2	43	87.9
27	Piscataway Creek	2	29	51.4
26	Confluence with Piscataway Creek	2	26	61.8
29	Piscataway Creek	2	26	65.8
67	Zekiah Swamp area with high ecological score	2	26	89.3
25	Piscataway Creek	2	25	68.3
56	Zekiah Swamp area with high ecological score	2	15	95.5
70	Mattawoman protected land inholding	2	13	84.4
51	Piscataway Creek	2	12	69.7
50	Piscataway Creek	2	10	68.2

3. Restoration Site Selection

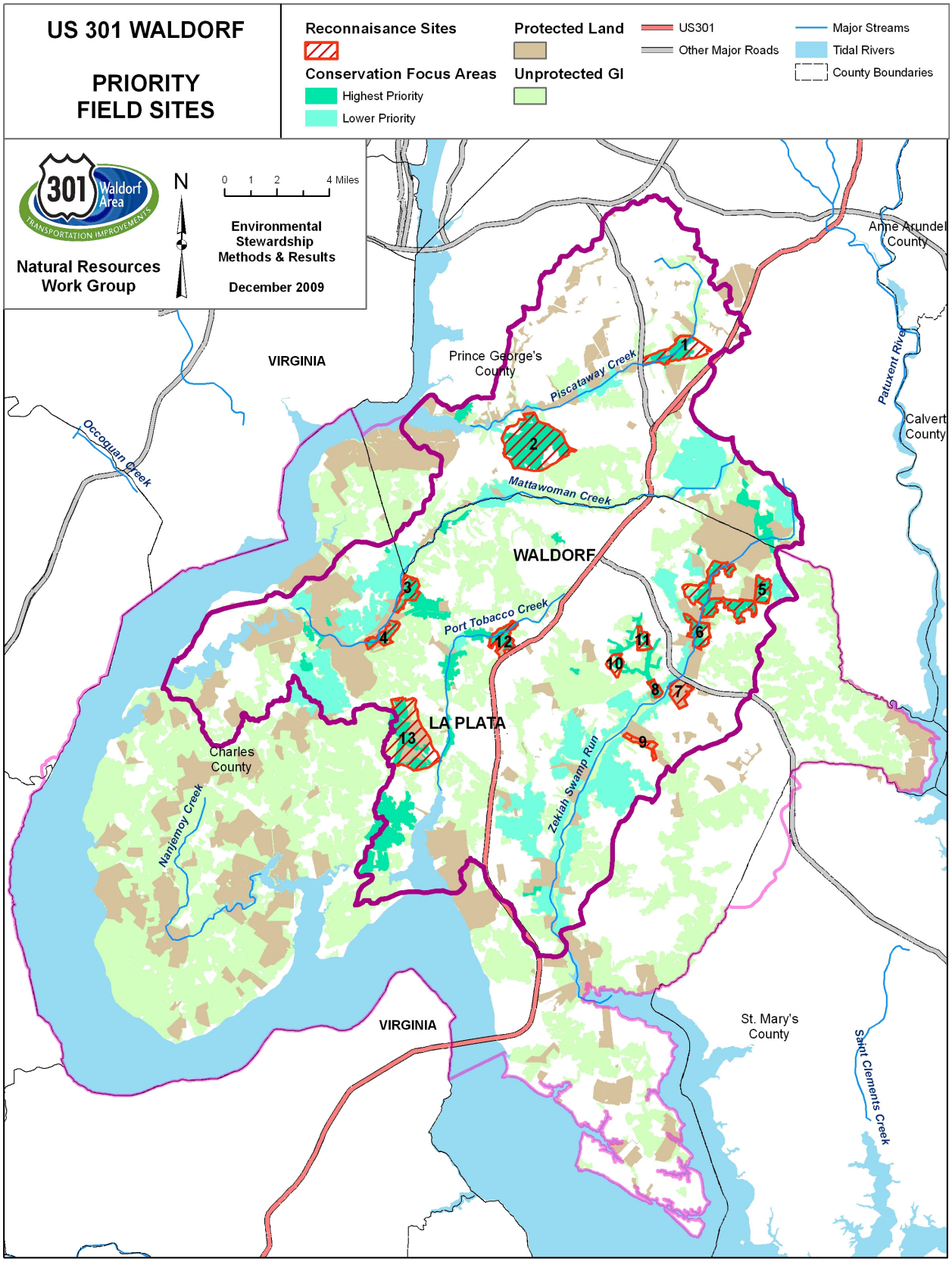
Restoration includes a wide variety of activities to improve ecological functions, such as reforestation, wetland creation or restoration, stream restoration or stabilization, invasive species removal, stormwater management, construction of fish passages, ditch removal, road underpasses, and abandoned road or railroad removal. To maximize ecological benefits, NRWG decided to focus restoration efforts in the conservation focus areas and currently protected high-ranking Green Infrastructure. Further, state and federal permitters generally require that restoration projects be conducted on land protected with easements that will retain the site in a natural condition (e.g., conservation easements, park land). This reinforced the link between restoration and conservation priorities.

In June 2009, NRWG narrowed down the 13,000 ac (5261 ha) of conservation focus areas and a long list of restoration needs, identifying 13 sites to perform field reconnaissance for conservation and restoration efforts (Map 22; Table 22). NRWG selected at least one site per 8-digit watershed; four of the total were prioritized for conservation only, two for restoration only, and seven for both conservation and restoration.

Table 22. Description of US 301 priority conservation and restoration sites for field reconnaissance.

Site ID	Activity
1	Stream and wetland restoration and conservation easements
2	Conservation and restoration of forest and streams
3	Conservation; assess streams and wetlands
4	Conservation; assess streams and wetlands
5	Conservation of forest, wetlands, streams, and rare species habitat
6	Conservation of forest, wetlands, streams, and rare species habitat
7	Stream restoration on protected land (lower priority than other sites)
8	Conservation and stream/wetland restoration
9	Stream restoration on protected land (lower priority than other sites)
10	Possible 301 bypass site - expand on NEPA field assessment?
11	Possible 301 bypass site - expand on NEPA field assessment?
12	Possible 301 bypass site - expand on NEPA field assessment?
13	Hoghole Run comprehensive watershed conservation and restoration

Unnamed tributary to Piscataway Creek, a potential stream and wetland restoration site.



Map 22. Locations of 13 priority conservation and restoration sites. The numbers on the sites correspond to the "Site ID" in Table 22.

4. Forest Conservation Value

To develop the core forest model, the Fund collected quantitative data in fixed-radius, randomly selected plots, allowing a reasonably fair comparison of conditions and variable relationships throughout the study area. However, this methodology may be unsuitable for rapid assessment of conservation opportunities, such as walking a property and estimating its ecological value. To assess properties on the ground, the Fund decided to build on existing DNR protocols (described in Weber, 2003). "Tier 4" of the DNR parcel ranking system involves sampling the different natural communities (plus noting human-maintained areas like row crops) on a given property, scoring them, and combining these community scores according to their relative area.

For this approach to be feasible, the forest assessment had to be greatly streamlined, since each fixed-radius plot takes about an hour to complete. The rapid assessment (Appendix H) takes less than half that time. Species diversity metrics were removed since they can't be measured consistently without setting up a plot. Further, ground cover varies seasonally.

The Fund tested this methodology at Rosaryville State Park, Kerrick Swamp, Devil's Nest, and Mill Dam Run (the latter three while assisting RTE surveys). Data collected at Rosaryville was compared to a series of aerial photos (1938, 1965, 1993, 1998, 2000, and 2005) to test the relationship between site history and current condition (See Table 23). Except for some unimproved trails, the forest had not been disturbed since agricultural abandonment.

Northern portion of what is now Rosaryville State Park in 1938.

Table 23. Comparison of site history and forest community condition in Rosaryville State Park, MD.

Community description	**History**	**Rating from data collected**
Mature mesic hardwood forest in stream valleys east of powerline: >100 years old, dominated by large *Liriodendron tulipifera* and *Fagus grandifolia* trees in valleys, except in wetlands or recent stream alluvium (see next community). *F. grandifolia* was common in all age classes. Large *Quercus rubra* and *Carya* spp. were common on valley slopes and small stands of *Q. alba* occurred on drier ridges. *Lindera benzoin* was the most common shrub. No signs of disturbance, but *Lonicera japonica* was scattered throughout. *Podophyllum peltatum* dominated the ground cover, which was highly diverse, with numerous species. Forest interior birds heard throughout.	The stream valleys have been forested at least 100 years, containing sizeable trees in 1938.	Excellent (measurements taken at 3 sites)
Mid-successional Coastal Plain bottomland forest in stream valleys east of powerline: >80 years old, dominated by *Liriodendron tulipifera, Liquidambar styraciflua, Acer rubrum* and. *Platanus occidentalis*. Trees were large in most areas except at a site where beaver dams or other sources may have impounded the stream decades ago. Species diversity was high. Invasive species were common on the forest floor, but no other signs of disturbance. (Note: Sand deposits at meanders of the main stem of Charles Branch were dominated by young *Platanus occidentalis* and *Acer rubrum*. These stands were small, and not sampled).	Forested at least 100 years, containing sizeable trees in 1938.	Good (measurements taken at 2 sites)
Early successional mesic hardwood forest ~45 years old. Canopy dominated by even-aged monoculture of *Liriodendron tulipifera* with 40-48 cm dbh. There was almost no subcanopy, but a thick shrub layer of *Lindera benzoin* and a thick ground layer dominated by *Toxicodendron radicans* and other vines. *Lonicera japonica* and *Hedera helix* were common on the forest floor, but no other signs of disturbance.	Farm field in 1938, old field in 1965, and closely spaced trees in 1993.	Fair
Early successional Coastal Plain bottomland forest ~40 years old. Canopy dominated by 25-35 cm dbh *Liriodendron tulipifera, Liquidambar styraciflua,* and *Quercus palustris*. Invasive species dominated the forest floor, but no other signs of disturbance.	Farm field in 1938, old field in 1965, and trees in 1993.	Fair
Early successional mesic hardwood forest: 30-40 years old. Canopy dominated by 20-40 cm dbh *Liriodendron tulipifera, Betula nigra,* and *Liquidambar styraciflua.* Invasive species dominated the forest floor, but no other signs of disturbance.	Farm field in 1965, but trees in 1993.	Fair
Early successional mesic hardwood forest: 10-12 years old. Canopy dominated by pole-sized (10-20cm dbh) *Liriodendron tulipifera* and *Liquidambar styraciflua. Lonicera japonica* and *Celastrus orbiculatus* were scattered throughout, but there were no other signs of disturbance.	Farm field in 1993, old field in 1998, and young trees in 2000.	Poor (but bordering Fair)
Grass field, mowed at least annually.	Field in 2005.	N/A

Mature mesic hardwood forest >100 years old, dominated by large *Liriodendron tulipifera*, *Fagus grandifolia, Quercus rubra* and *Carya spp.* trees.

Early successional mesic hardwood forest around 45 years old. Canopy dominated by even-aged monoculture of *Liriodendron tulipifera* with 40-48 cm dbh.

Early successional mesic hardwood forest, around 10-12 years old. Canopy dominated by pole-sized (10-20 cm dbh) *Liriodendron tulipifera* and *Liquidambar styraciflua.*

5. Reforestation Values and Cost

In 2008, The Conservation Fund developed a reforestation assessment protocol (Appendix I) to assess fields, lawns, and barren areas for reforestation benefits and costs. This protocol was tested in the field and modified accordingly. Potential reforestation sites are first assessed in the office, noting whether it is a gap in the Green Infrastructure, the ecological rank of this Green Infrastructure element (core, hub, or corridor), the position of this gap (corridor break, interior gap, etc.), and whether the site is adjacent to a stream, rare species habitat, or other important natural area.

Next, staff visit the site in the field, first verifying the office landscape assessment, then noting potential to improve water quality, reduce erosion, and provide wildlife habitat. Staff also categorize and score the restoration difficulty, physical accessibility to the site, and potential negative impacts of the restoration (loss of grassland habitat, productive agriculture, etc.). Potential reforestation cost depends on the use of shelters to protect against herbivory (recommended), the use of sludge or compost application (may be needed for mine reclamation), and contouring.

6. Invasive Species Control

The Conservation Fund, working with DNR's Invasive Plant Specialist, Kerrie Kyde, also developed and tested a field protocol for prioritizing invasive species control (Appendix J). Potential restoration sites are first assessed in the office, noting whether the area is in the Green Infrastructure, and the ecological rank of this Green Infrastructure element (core, hub, or corridor).

Next, staff visit the site in the field, first verifying the office landscape assessment, then categorizing and scoring threats to rare species or natural communities, the aggressiveness of the invasive species, the difficulty of eradication, physical accessibility to the site, potential negative impacts of vegetation clearing or chemical use, and the likelihood that control measures will succeed. Restoration costs per acre depend on the invasive species in question, the extent of infestation, physical accessibility, and the planting of replacement native species.

7. Stream and Riparian Corridor Conservation and Restoration

The U.S. Fish and Wildlife Service (FWS) developed a rapid stream and riparian corridor conservation and restoration protocol to rank potential stream and riparian corridor stewardship projects. While FWS developed the protocol specifically to meet the objectives of the U.S. 301 Environmental Stewardship Study, the assessment parameters are based on well-established and proven assessment methods. FWS field-tested this protocol and modified it accordingly.

The stream protocol contains both office and field components (Appendix K). The office component requires use of a physiographic hydrologic regional curve to determine bankfull channel width, depth, and cross section area based on the drainage area of the proposed project area. This information is required for the field assessment portion of the protocol since several of the assessment parameters evaluate bankfull channel conditions. Additionally, Rosgen valley type and watershed percent impervious surface are determined in the office.

The field component of the protocol contains four sections: stream stability assessment; restoration potential solution, cost, and feasibility; existing riparian/instream habitat assessment; and proposed riparian/instream habitat assessment. The stream stability assessment section consists of four parts: lateral stability, vertical stability, stability trend, and stream classification. The parameters of the lateral stability assessment include width/depth ratio, dominant Bank Erosion Hazardous Index and Near Bank Stress (BEHI/NBS), confinement, lateral stability extent, and cause description of lateral instability. The parameters of the vertical stability assessment include streambed aggradation condition, streambed degradation condition, confinement,

vertical stability extent, and cause description of vertical instability. The parameters of the stability trend include stream stability evolution, stream sensitivity, and recovery potential. The stream classification uses the Rosgen Stream Classification system.

The parameters of the restoration potential solution, cost, and feasibility include restoration potential solution, construction access, constraints, potential success/risk, and restoration potential description. FWS based potential restoration costs on restoration complexity. Costs per linear foot were derived from actual recent stream restoration projects within the Baltimore/Washington metropolitan area.

The existing and proposed riparian/instream habitat assessments include similar parameters, to allow comparison between the existing site condition and the proposed site condition, which is based on the potential restoration solution. The parameters of the riparian/instream habitat assessment include instream cover, epifaunal substrate, velocity/depth regimes, shading, water appearance, nutrient enrichment, riparian vegetation, riparian zone, and sediment supply potential.

FWS based the scoring format of the conservation and restoration protocol on EPA's Rapid Bioassessment protocol. Each assessment parameter has four potential ratings or categories, and each of these ratings has an associated numerical score (see example in Table 24). The overall score for each of the four sections (stream stability; restoration potential solution, cost, and feasibility; existing riparian/instream habitat; and proposed riparian/instream habitat) is the sum of the parameter scores for that section.

Table 24. Conservation and Restoration Protocol Assessment Parameter Scoring Example

Stream Stability Parameter	**Category**			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
Lateral Stability				
1. Width/Depth Ratio (Rosgen 1996)	Ratio of < 1.2	Ratio of 1.2 - 1.4	Ratio of 1.4 - 1.6	Ratio of > 1.6
SCORE _____	10 9	8 7 6	5 4 3	2 1

Since the assessment protocol has four separate sections, a variety of scoring combinations can be created for ranking purposes. Each of the assessment section scores can be used individually. The stream stability and existing riparian/instream habitat scores can be added together to create an overall existing conditions characterization score. The stream restoration potential solution, cost and feasibility and proposed riparian/instream habitat scores can be added together to create an over all potential restoration score. And an overall project score can be created by subtracting the characterization score from the restoration score. The reason for subtracting instead of adding the two scores is to account for the potential increase in habitat benefits. For example, consider two potential restoration projects with the same potential restoration score, but one project has a lower existing conditions score. If the scores were added together, the project with the higher existing conditions score would rank higher than the other project even though the other project would have a greater increase of habitat benefits.

8. Wetland Conservation and Restoration

The Riparian and Wetland Restoration Services group (RWRS) at DNR developed assessment protocols for office and field evaluation of wetland stewardship opportunities, both for conservation and restoration. The office analysis incorporates GIS datasets such as soils, wetlands, land use, aerial photography, and streams and rivers. From this data, the assessors can determine the wetland size, identify hydric soils, measure the distance to the nearest hydrology source, determine the proximity to other wetlands in the area, and record

the wetland classification. Property data allow the assessors to identify land ownership (public or private) and the names and addresses of landowners.

After completing the office analysis, the assessors conduct a rapid field analysis. The field assessment (Appendices F and L) verifies the data collected in the office, records general site characteristics such as observed stressors, and estimates the techniques and resources required for restoration. Restoration techniques may include ditch plugs, invasive species management, excavation, grading, planting, or stream restoration to restore wetland hydrology.

Based on 2007-8 sampling results, initial wetland condition is assessed with the Ohio Rapid Assessment Method (ORAM; Appendix F) and the Qualitative Condition Ranking. Wetlands with high scores and minimal impacts should be high conservation priorities. To rank restoration potential, field assessors categorize the amount of restoration required, the type and effort required, physical accessibility, potential impacts to vegetation and other habitat features while doing construction, the potential for restoration success (complex designs are riskier), and the potential to increase wetland area, buffer width and quality, hydrology and water quality, habitat and microtopography, and native plant cover and diversity. Monitoring the site pre- and post-restoration ideally will show improvements in the buffer, hydrology, habitat alteration and development, and plant community category scores of the ORAM, and an increase in the total score over time. RWRS also developed categories of restoration costs, based on experience with previous projects.

The Conservation Fund tested the wetland field protocols in 2009, and found them easy to use, although further work is needed to make the different resource assessments more compatible.

9. Natural Heritage Prioritization

Scoring Ecologically Significant Areas

NHP's current scoring methodology for Ecologically Significant Areas focuses entirely on the rarity of the species within the ESA; the data for ECGs are scored separately for now, as discussed in Section 9 of this report. A scoring matrix for rare species was developed by NHP in the late 1990's, in conjunction with Virginia Natural Heritage Program, and more recently modified with input from DNR's Maryland Biological Stream Survey. Table 25, below, depicts the current version of the species scoring matrix. To apply the matrix, species with "range ranks" (i.e., a rank that spans multiple categories, such as S1S2 or S1S3) must be rounded up or rounded according to standard NatureServe protocols. For example, an S1S2 species is scored as an S1 species, and an S1S3 species is scored as an S2 species. Subspecific taxa with a "T" rank are rounded by substituting "G" for "T". For example, Chermock's Mulberry Wing butterfly is ranked as G4T1 and is scored as if it were a G1 taxon.

Table 25. Scoring matrix for determining RTE species scores.

	G1	**G2**	**G3**	**G4**	**G5**	**G?**	**GH**	**GX**
S1	500	300	200	70	50	75		
S2		250	150	45	25	50		
S3			110	10	5	3		
S4				3	1	1		
S5					1	1		
S?	350	120	90	60	20	25		
SU	350	120	90	60	20	25		
SH	75	60	45	30	10	20	10	
SX	0	0	0	0	0	0	0	0

Once the score for each species is determined, the scores for all species known to occur within the ESA, as determined by the data contained within the Biotics GIS, are added together. This tally provides the final ESA score. However, it should be noted that scores for ESAs are dynamic and will change as new species locations are added to Biotics or as the ranks for the species are periodically reviewed and revised.

NHP staff has long debated whether to add an additional weight/score to each species' occurrence within an ESA to account for the viability or quality of the occurrences. In theory, higher quality or more viable populations should be afforded greater conservation opportunities than poorer quality examples. However, NatureServe protocols for evaluating and ranking the quality or viability of each occurrence of a species, or even for groups of species, has been in flux for at least 25 years. Species viability assessments are extremely difficult, time consuming, and data intensive. According to a 2008 NatureServe summary of the dilemma surrounding the viability determination of rare species occurrences, "[e]ven if [population] abundance could be determined in a meaningful, repeatable way, we would still lack a secure scientific basis for specifying precisely defined, objective occurrence viability criteria. Conservation biologists have had enormous difficulty in determining or agreeing on quantitative population viability criteria for various taxonomic groups. And long-term population trends from the real world frequently are at odds with theoretical considerations." Until NHP can find sufficient funding to review and update existing occurrence quality ranks in accordance with current NatureServe guidelines, which currently use generic, subjective criteria, the concept of species occurrence quality will not be incorporated into our ranking structure.

Scoring Ecological Community Groups

For this project, NHP staff developed a new scoring methodology for separate polygons of Ecological Community Groups. Because it is new, it should be considered a first iteration that will be modified for future uses and needs.

Ecological Community Groups were scored based on five factors, or metrics: Rarity (or SRank), Area, Stage, Disturbance, and Landscape Context. The scores for each metric were added for a combined total score. Both the Stage and Disturbance metrics were calculated using the field data collected during the rapid assessments and documented on the Natural Community Observation form. Therefore, it is highly recommended that at least one rapid assessment point be collected for each polygon being evaluated for priority. A description of each metric follows:

- The metric "SRank" is a scoring of relative rarity of the communities within the state of Maryland, with S1 being the rarest and S5 being the most common communities: S1=500, S2=250, S3=100, S4=50, and S5=25. This scale is consistent with that developed for scoring species and ESA's, as described in Section 8 of this report.

- The Area of each ECG polygon was derived using ArcGIS v. 9.2 Xtools. Once the area was calculated, natural breaks was used to cluster the areas into 4 classes for scoring. The largest class was scored 50, the next largest class 10, next largest 5, and the smallest class group was scored 0. This metric was calculated only within each ECG. Therefore, the largest polygon of a small-patch community, such as a seepage wetland, received a higher score relative to other examples of that same seepage wetland type..

- The Stage metric relates to the age and optimal state of the ECG. Since NHP only conducted rapid assessment on forests, the following scores were assigned: climax or old growth=500, near old growth=250, mature=50, intermediate=10, and young=0. These age classes may not be appropriate for all general types of communities, such as emergent wetlands or grasslands.

- The Disturbance metric was additive based on the matrix below with less disturbance equating to a higher score and better site condition or quality. The matrix reflects the disturbance relations both within

each type and also among the types. A "0" column in the degree of disturbance equals no disturbance of that type. The values are represented by the following matrix:

Disturbance Type	Degree of Disturbance			
	0	1	2	3
Trash	1	0.75	0.50	0.25
Exotic/Browsing/Insect	2	0.50	0.33	0.17
Logging/Erosion/Trails/ Clearing/Hydro Alt.	3	0.25	0.17	0.09

- Once the disturbances were totaled for each ECG polygon, the totals were classified using natural breaks into 4 group classes: best condition=50, next best=25, next=10, and the most disturbed group=0.

- The final metric, Landscape Context, was calculated by first defining the landscape context as representing the amount of undeveloped land within a five kilometer radius around each ECG polygon. ECG polygons were buffered by 5000 meters. We selected and exported the following classes from the DNR 2002 land use land cover to represent a "developed land" layer: 11, 12, 13, 14, 15, 16, 17, 18, and 80. The buffered ECG polygon layer was intersected with the developed layer. Percentage of the buffered polygon that was developed was calculated in Excel. Landscape buffers with 0-10% of the buffer developed were scored 50, 10-25% = 25, 25-50%=10 and greater than 50%=0.

The digital data were then included within the larger GIS analysis for this project. Although it is tempting to use these ECG scores to compare all polygons of all ECG types, this practice might be somewhat misleading. High quality examples of all ECG types need to be conserved, and this scoring system favors rare vegetative communities over common ones. While the rarest communities frequently have the greatest urgency for conservation, high quality common communities also need conservation action when considering the desire to "keep common species common." Therefore, when reviewing this data, it would be perhaps more useful to compare the scores of polygons within the same ECG, rather than across ECG types, particularly since some polygons are missing. Disturbance and Stage data compounds the difficulty of simply adding the data to GIS models for analyses. Polygons with incomplete information will either need to be reviewed manually by staff ecologists, or will need to have a revised scoring system to compare these separately. As this protocol is applied in future projects, it is highly recommended that natural community observation data be collected for all polygons that will be included in prioritization or ranking analyses.

Scoring Rare Species Locations in the Field

Appendix M contains a form to be used when field surveys discover one or more species currently included on DNR's lists of either "Rare, Threatened and Endangered Animals of Maryland" or "Rare, Threatened and Endangered Plants of Maryland" (available online at http://www.dnr.state.md.us/wildlife/espaa.asp). Not only do the NHP standard data collection forms (NHP Rare Plant Survey Form and NHP Rare Animal Survey Form) need to be completed and submitted to NHP (contact Lynn Davidson, NHP's Conservation Technology Manager, at ldavidson@dnr.state.md.us), but the boundary for the conservation of the habitat for those species (the Ecologically Significant Area boundary) needs to be either newly created for new, disjunct sites or updated if it is near or adjacent to an existing boundary. Please coordinate with NHP (specifically with Lynn Davidson) regarding this process.

In the event that a boundary is created or updated, a score will be calculated based on the species present. To begin, a score for each species (not each location or occurrence of each species) is calculated using the matrix in Appendix M. After each species is scored, the sum of the scores for all the rare species at a given Ecologically Significant Area is equal to the score for that area.

Scoring Rare Natural Communities in the Field

In addition to rare species, rare or high quality common natural communities or Ecological Community Groups might be discovered during field surveys of a given area. A current version of the Maryland Natural Community Classification can be obtained from DNR's Natural Heritage Program (contact Lynn Davidson). Not only does the NHP standard data collection form (Appendix D-8: Natural Community Observation Form) need to be completed and submitted to Lynn Davidson, but the boundary of the natural community needs to be either newly digitized, or updated if it is near or adjacent to an existing boundary.

The conservation value of Ecological Community Groups should be scored based on five factors or metrics (Appendix M): Rarity (or S Rank), Size, Stage, Disturbance, and Landscape Context. The scores for each metric are then summed. Both the Stage and Disturbance metrics are calculated using the field data collected during the rapid assessments and documented on the Natural Community Observation form. Therefore, it is highly recommended that at least one rapid assessment point be collected for each polygon being evaluated for priority.

10. Natural Heritage Stewardship Recommendations

The most effective stewardship opportunities for rare species conservation usually involve direct protection of the ESA via fee simple acquisition or conservation easements because rare species are frequently indicators of high quality habitats or unique habitats very susceptible to man-made disturbances. Also, their habitats might require very specific disturbance regimes, such as prescribed burns, to ensure maintenance of the rare species populations. However, many ESAs are also in need of more general stewardship actions in the form of invasive species control. Once an area becomes severely degraded, large-scale restoration actions may still be insufficient to restore the habitat such that it is suitable for recolonization by most rare species.

The Natural Heritage Program developed some specific recommendations for environmental stewardship opportunities based on its targeted surveys during this project, as well as data collected during previous surveys of this study area. Appendix D-12 describes 6 of the 47 Ecologically Significant Areas that NHP recommends for conservation, restoration, or management actions within the US 301 Environmental Stewardship Study project area. These 6 ESAs are Piney Branch Bog, Devils Nest, Mattawoman Creek – Myrtle Grove, Mattawoman Creek – Chapman's Forest, Thomas Stone – Hoghole Run, and Zekiah Swamp. Each ESA Summary includes the following sections:

- Summary of Ecological Significance
- State Rare, Threatened, and Endangered Species Present
- Other Values and Significance
- Threats and Management Needs
- Conservation Recommendations
- Detailed Site Description

The first section highlights the ecological value of the area, primarily from the perspective of rare or declining flora and fauna or significant natural communities. The second section is a table that lists the known rare and state listed species that have been documented from the area. Additional information of a more general nature related to wildlife present or habitat values is provided in the third section. The section on Threats and Management Needs usually highlights specific problems or concerns of a more immediate nature to within the ESA. Larger or long-term threats, such as global warming or air pollution, are frequently not included even though they might also be negatively influencing these areas. The Conservation Recommendations section outlines some of the highest priority actions that are needed for maintaining and improving these significant areas. However, this report includes only a few of the many conservation actions that could be undertaken at these ESAs. Finally, the last section provides an in-depth look at the habitats, ecological community groups, and often the natural community associations found within each ESA.

Although the ESAs selected for detailed analysis and conservation action recommendations in this report are among the highest priorities for NHP, only a very few have been included. Many of the remaining 41 ESAs are also high priorities for protecting the habitats of rare, threatened, and endangered species in this area. If all 47 ESAs were under consideration, a potentially overwhelming number of conservation opportunities would be available to conserve the rare species habitats and significant natural communities within the 301 Environmental Stewardship Study area.

Restoration

Restoration costs usually will be rolled into the costs for wetland or stream restoration projects. Projects involving the management of invasive plant species will vary by the extent of the area to be controlled and the type of control measures required, for example: (1) herbicide application for control of Japanese stiltgrass (*Microstegium vimineum*) and garlic mustard (*Alliaria petiolata*) may be estimated at $160/acre[4] for a total cost estimated at $800/yr for five years (to control for new growth from the seed bank); and (2) manual removal of dense areas of English ivy (*Hedera helix*), and wineberry (*Rubus phoenicolasius*) may be estimated at $1500/acre[5], for a total cost of $4500 over 3 years.

Monitoring

Monitoring protocols for evaluating the long-term success of stewardship actions generally involve repeated visits to an area over an extended number of years and conducting a set protocol specifically designed for the most effective species-specific surveys. Possible protocols could range from a very time-consuming, highly-detailed collection of all pertinent life history data of each individual within an RTE species population, to just determining annual population size, to determining only presence/absence of the species every few years, or, as a bare minimum, simply determining that the known habitat still exists in roughly the same condition (e.g., no spread of invasive species or extensive defoliation by exploding deer populations). A number of factors will need to be evaluated before determining the appropriate monitoring intensity, including the number and rarity status of the species present, as well as the available staff and budget.

11. Conservation Site Assessment

In this section, we demonstrate the methodology for assessing a property within a focus area for its conservation values. We also discuss restoration options. Landowner information has been omitted.

Step 1: Desktop (GIS) Assessment

The first step is to identify key natural resources on the property in ArcGIS, and calculate the parcel size, area of Green Infrastructure hubs and/or corridors, mean ecological score, core area rank, hub rank, corridor rank, distance to existing protected land, and other metrics. Maryland Property View contains parcel ownership, assessed value, and other information. We calculated the quantitative metrics for all digitized properties at once, rather than having to perform the same calculations dozens or hundreds of times. We also examined the property using current aerial photographs (2007 NAIP), LiDAR, and other data. For this property, GIS data showed:

- Total property size: 20 ac (8 ha).
- Within top priority Conservation Focus Area (Zekiah Swamp). Contains top unprotected core forest, stream, wetland, and ESA.
- Adjacent to Cedarville State Forest and partly within Zekiah Swamp.
- Almost entirely forested except for house and access road.
- Area in Green Infrastructure (within a hub): 18 ac (most of property)
- Core rank: 85/100

[4] Amount used by NRCS in wildlife habitat incentives program plans (WHIP) with federally authorized funding.
[5] Also from WHIP

- Hub rank: 82/100
- Mean ecological score: 91/100
- Forest: Mature bottomland forest
- Wetland: PFO1A along east side of property. Note: from topography, likely that wetland exceeds DNR polygon boundaries.
- Stream: Stable (projected) tributary to Zekiah Swamp Run.

Step 2: Contact landowner

The next step is to contact the landowner. SHA policy was to wait 30 days after letters were mailed, and unless the landowner explicitly stated otherwise, assume access permission. We strongly recommend that staff try to obtain landowner phone numbers, and follow letters with calls: explaining the purpose of the visit, requesting permission to collect data, arranging a mutually convenient time to visit, and asking about potential hazards like hunters, dogs, or livestock. If phone numbers cannot be obtained, staff should knock on the door (if a house is on-site) before proceeding further. If a landowner is unwilling or hesitant to grant access, thank them for their time, and move to the next property on the list.

In this case, the landowners had given written permission to visit their property, and provided contact phone numbers. When we called, they confirmed permission to access the property, and also mentioned that 10 acres of the property were in a conservation easement with Charles County, which we did not know.

Step 3: Map the property and identify sample sites

Before collecting field data, staff should delineate natural communities in the area of interest based on aerial photos, topography, wetland layers, etc., aggregating into a manageable number of distinct areas (preferably <10, with each community comprising >5% of the property or of special interest). If the property contains many spatially distinct but structurally and functionally similar communities, identify which are likely to be similar, and plan to sample the largest or most representative of each type.

We compared the digitized property boundaries to 2007 NAIP aerial photos, LiDAR DEM, LiDAR canopy height, modeled forest age, core streams, NHD streams, DNR wetlands, overall ecological score, conservation focus area boundaries, Ecological Community Groups, Ecologically Significant Areas, and Green Infrastructure hub, corridor, and gap boundaries. We used this data to digitize potential ecological community boundaries: in this case, upland forest, forested wetland, a small meadow, and a house site and driveway. The DNR wetland boundary did not match the LiDAR topography, so we used the latter to estimate wetland extent.

We loaded these potential community boundaries, an aerial photo, and other layers onto a Trimble Juno SB GPS with ArcPad 8.0. We had to reproject data layers to UTM Zone 18N to match the photo projection.

Step 4: Visit the property and collect data

Following preparation in the office, visit the property. Staff should attempt to collect all field data in a single visit. Using the appropriate forest, natural community, wetland, stream, and/or rare species assessment protocols, assess each community that covers >5% of the property or is otherwise significant. Samples should be taken in homogeneous, representative areas, in or near the center of the community. If community boundaries differ from those mapped in the office, revise these in the field (marking on the paper map and/or GPS), and adjust field sampling as needed. Streams should be assessed by reach (a relatively homogenous section of a stream having a sequence of repeating structural characteristics). For example, stream branches would be considered separately, and discontinuities like beaver dams, other impoundments, or major slope changes would serve as reach separators. Staff should also estimate the threat of development the property faces if fee or easement acquisition is not pursued.

Although this is uncommon, the landowner gave a tour of their property, which was not only the parcel NRWG digitized (Lot 43: Fig. 1; green boundaries), but Lot 48, Parcel C, and Parcel A (magenta boundaries). The landowner told us that Parcel C was under a conservation easement with the county, as was part of Lot 43. We asked about the site history, which is helpful when interpreting current conditions. The landowner thought it had been logged before they bought the property (around 15 years prior), but other than around the house, they had been keeping it in a natural state.

We collected data from two upland forest communities (using the upland forest plotless assessment), an old field (using the same assessment), and a wetland (using the Ohio Rapid Assessment Methodology (Mack, 2001), the Delaware Rapid Assessment Protocol (Jacobs, 2007), and a wetland restoration assessment designed for this project by MD DNR). These assessment methodologies are described earlier in this document. We excluded the house, yard, parking area, and driveway from the conservation and restoration assessments. There was no stream on the parcel, only drainage ditches of varying ages, which lowered the water table, speeded overland flow, and favored less hydrophytic vegetation. No stumps remained in the parcel, but old logging roads, skidder tracks, and tree sizes and composition suggested selective logging perhaps 40 years ago. Wetland extent was somewhat greater than our initial boundary, which was determined using the LiDAR DEM; and was much greater than the DNR wetland extent. We recorded the wetland boundary location with the GPS and extrapolated using the LiDAR DEM when back in the office. A detailed field survey could delineate a more precise wetland boundary, but this was unnecessary for approximating community boundaries. Examining the historic floodplain source, Zekiah Swamp Run, we found it to have been channelized. The channel was no longer being maintained, and banks did not appear too high to prevent overflow. A few photos from this visit follow Figure 4.

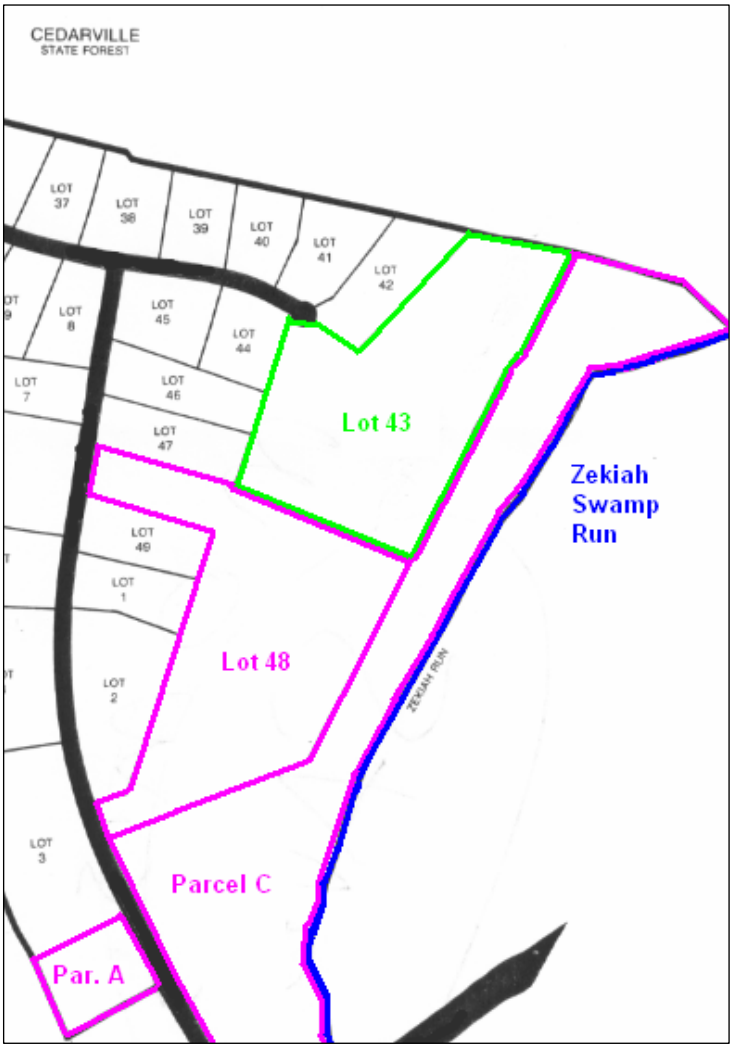


Figure 4. Parcels owned by landowner visited in this pilot assessment. The parcel we collected data for has green boundaries; other parcels owned by the same landowner have magenta boundaries, and part of Zekiah Swamp Run is shown in blue. Besides Lot 43, we also reconnoitered Parcel C, Lot 48, and the adjacent Cedarville State Forest.

Mid-successional mesic upland forest dominated by *Liriodendron tulipifera, Quercus spp.,* and *Pinus virginiana.*

Wetland in the Zekiah Swamp Run floodplain, impacted by historic ditching and logging.

One of several historic ditches on the property, this one carrying water from nearby slopes.

Zekiah Swamp Run, which was channelized, but no longer maintained as such.

Step 5: Assess conservation potential of the property

Scores on data sheets can be added back in the office. Community boundaries should be revised as needed, the area of each community calculated, and a score associated with each. The overall property field score is the area-weighted sum of the community scores. We have provided an Excel spreadsheet to help calculate property ecological scores.

Figure 5 shows the revised community boundaries for the example parcel. Table 26 shows its ecological scores combined to produce an overall field score. This parcel did not have scores for streams, rare species, or rare communities. We used the forest worksheet to assess the old field, which was dominated by young tree saplings. Table 27 shows the field score combined with the GIS scores. This data is added to the pool of properties analyzed by the benefit-cost optimizer.

Weber (2003) contains other examples of property conservation assessments, currently online at:

- http://dnrweb.dnr.state.md.us/download/bays/gia_appg.pdf
- http://dnrweb.dnr.state.md.us/download/bays/gia_apph.pdf
- http://dnrweb.dnr.state.md.us/download/bays/gia_appi.pdf
- http://dnrweb.dnr.state.md.us/download/bays/gia_appj.pdf
- http://dnrweb.dnr.state.md.us/download/bays/gia_appk.pdf

Step 6: Assess potential restoration opportunities

Restoration worksheets should be filled out along with conservation worksheets for each delineated ecological community. These worksheets rate each potential project according to their ecological benefits, restoration ease, potential access and environmental constraints, risk of restoration failure, and estimated cost.

We filled out invasive species worksheets for the upland communities, and the wetland restoration potential worksheet for the floodplain portion of the property. We did not think it was worth trying to remove invasive species (primarily *Lonicera japonica*): while common, they were not dominant, and would probably recolonize the site from neighboring house lots and trails. However, we did recommend restoration of natural hydrology, especially plugging the drainage ditches or slowing their flow with log vanes and diverting water onto the wetland. This project scored 43 out of 50 possible points, with a potential cost estimated around $4000-$6000/acre. Restoring a natural morphology to Zekiah Swamp Run was another option, but this would be much more difficult and expensive.

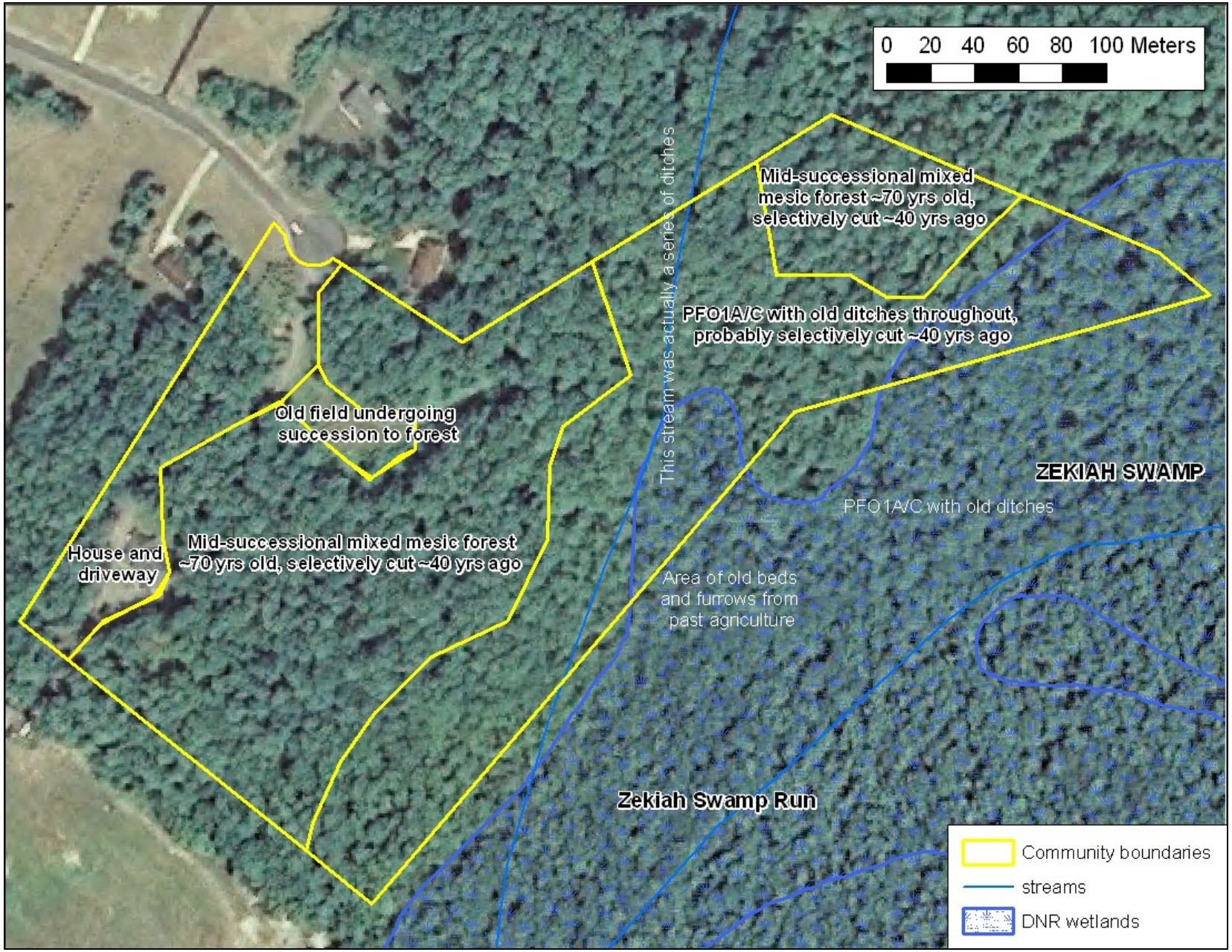


Figure 5. Ecological community boundaries and descriptions in the example parcel. We also examined areas outside this parcel, but owned by the same family or state-owned.

Table 26. Overall field scoring for the example parcel.

UPLAND COMMUNITIES (forest and non-forest)

Sample point ID	Community type	Community score	Community score as fraction of reference score	Community area (ac)	Area fraction	Area fraction * Score	Description and comments
1	upland forest	269	0.688	7.72	0.8025	0.5521	Mid-successional mixed mesic forest, ~70 yrs old, selectively cut ~40 yrs ago
2	upland forest	328	0.839	1.55	0.1611	0.1352	Mid-successional mixed mesic forest, ~70 yrs old, selectively cut ~40 yrs ago
4	upland old field	148	0.379	0.35	0.0364	0.0138	Old field undergoing succession to forest
UPLAND TOTAL				9.62	1.0000	0.7010	

WETLAND COMMUNITIES (incl. ponds and lakes)

If wetland community is small (e.g., <5% of parcel) and embedded in a larger forest community, assess the forest and indicate wetland presence on the data sheet

Sample point ID	Wetland type	Wetland score	Wetland score as fraction of reference score	Wetland area (ac)	Area fraction	Area fraction * Score	Description and comments
3	PFO1A/C	66	0.825	7.51	1.0000	0.8250	PFO1A/C with old ditches throughout, probably selectively cut ~40 yrs ago
WETLAND TOTAL				7.51	1.0000	0.8250	

STREAMS

Sample reach ID	Existing stream stability score	Existing stream habitat score	Stability score as fraction of reference score	Habitat score as fraction of reference score	Length (ft)	Length fraction	Length fraction * stability score	Length fraction * habitat score	Description and comments
			0.000	0.000	0.001	1.000	0.000	0.000	only ditches in parcel
STREAM TOTAL					0.001	1.000	0.000	0.000	

RARE, THREATENED OR ENDANGERED SPECIES PRESENT

EO ID	Species name	G Rank	S Rank	RTE score	EO score as fraction of reference	Description and comments
					0.000	no RTE spp found
RTE TOTAL					0.000	

ECOLOGICAL COMMUNITY GROUPS

Sample point ID	ECG name	Natural community score	Natural comm. score as fraction of reference	Nat. comm. area (ac)	Area fraction	Area fraction * Score	Description and comments
			0.000	0.001	1.000	0.000	no rare communities found
ECG TOTAL			0.000	0.001	1.000	0.000	

Ecosystem types and calibration info

Community type	Max. score	Reference score	Weight
Forest	565	391	1.0
Wetland	100	80	1.0
Stream (stability)	90	81	0.5
Stream (habitat)	90	81	0.5
Rare species (RTE score)	500	45	0.5
Rare communities (ECG score)	1150	300	0.5

Property totals

Category	Subtotal
Forest	0.701
Wetland	0.825
Stream (stability)	0.000
Stream (habitat)	0.000
Rare species (RTE score)	0.000
Rare communities (ECG score)	0.000
OVERALL FIELD SCORE	1.526

Table 27. Overall assessment of the example parcel.

Site ID	****	Tax PIN	*****
Property owner	*****		
On-site manager	*****		
Address	*****		
Phone	*****		

CONSERVATION FACTORS	VALUE	UNITS	METHOD
Total property size	20	acres	Calculate in GIS
Area of Green Infrastructure hubs and/or corridors on the property	18	acres	GIS: tabulate area
GI core/site area rank (0=not in core/site area)	85	0-100	GIS: zonal maximum
GI hub rank (0=not in hub)	82	0-100	GIS: zonal maximum
GI corridor rank (0=not in corridor)	0	0-100	GIS: zonal maximum
Mean landscape ecological score	91	0-100	GIS: zonal mean
Field score	1.53	0-4	from field worksheet
Proximity to existing protected land	10	0-20	Calculate or visual in GIS
Is this property permanently protected from development?	partly	yes/no	talked to landowner - part of lot (wetland) under conservation easement
Is this property permanently protected from mining?	no	yes/no	unclear what terms of easement are
Estimated fee simple acquisition cost	684400	$	From Property View. Note: easement best option
Estimated easement acquisition cost	?	$	
Estimated risk of development within 20 years	15	0-20	already house on lot

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12. Restoration Site Assessment

Site assessment for restoration should be done concurrently with conservation assessment, unless on land that is already protected. As described for conservation site assessments, the first step is to examine areas with current aerial photos and available GIS data. Next, staff should contact the landowner(s) and request permission to visit the site. On site, staff should follow restoration protocols as described in earlier sections, rate each project according to its ecological benefits, and estimate costs of the project (including monitoring).

Invasive Japanese stiltgrass (*Microstegium vimineum*) in Charles County.

VII. ENVIRONMENTAL STEWARDSHIP PROJECT SELECTION

What is Optimization?

Selection of environmental stewardship projects requires both sound science and sound economics. Yet, the most common technique for selection conservation and restoration projects to implement often focuses solely on the likely benefits of a project without considering the cost of these projects. This 'rank-based' approach, also referred to as 'benefit targeting', ranks potential projects from highest to lowest based on their benefits. The implementing organization then seeks to select the top-ranked projects until the available budget is exhausted. This can result in highly inefficient investments since it may ignore potential selections that offer high quality at a significantly lower cost to implement with the rank-based approach. A project's cost is explicitly factored into the decision process only to determine whether enough money remains in the budget.

Mathematical optimization is the branch of computational science that seeks to answer the question "What is best?" for problems in which the quality of any answer can be expressed as a numerical value (Kaiser and Messer, 2010). Such problems arise in all areas of business, physical, chemical and biological sciences, engineering, architecture, economics, and management. A mathematical optimization model (OM) consists of an objective function and a set of constraints in the form of a system of equations or inequalities. OMs are used extensively in almost all areas of decision-making, such as engineering design and financial portfolio selection. In particular, OM has proven to be a useful tool in selecting conservation projects that yield greater benefits for a given cost—or, to put it another way, optimization maximizes aggregate benefits to achieve the desired conservation objectives (Allen et al., 2006; Messer, 2006; Amundsen et al., 2010; Messer and Allen, 2010).

The OM uses the principals of binary linear programming and adapts them into a user-friendly tool built into Microsoft Excel spreadsheets to help identify the portfolio (or set) of cost-effective projects that maximizes aggregate benefits. The OM uses data about the benefits of potential projects, the relative priority weights that the organization would like to assign these benefit measures, and economic data about the projects' costs and overall budget constraints. The optimization model evaluates each of the possible sets of available projects and selects the set that maximizes the *aggregate* benefits given a specified budget. The OM can help distinguish between high-cost "Cadillac" projects—which can rapidly deplete available funds while making relatively small contributions to overall goals—and "best buy" projects—which are still of high quality and when combined, provide significantly greater aggregate benefits.

Measuring the Benefits of Optimization

Dr. Kent Messer began working on the application of optimization to conservation projects as a Ph.D. student at Cornell University. His research quantified the potential benefits of using the OM for an ongoing land acquisition project in the Catoctin Mountains in central Maryland (the location of the Camp David presidential retreat). The results of this research found that compared to rank-based models, optimization could obtain conservation benefits worth an additional $3.1 to $3.9 million (Messer, 2006). An explanation for these dramatic results is that optimization avoids "budget sponge" parcels that often dry out the budget prematurely. Instead the OM assesses the ecological and economic value of all land parcels and selects "good buys" that offer excellent benefits given their cost. The money saved can then be used to acquire more high quality acres. Most importantly, the OM achieved the highest efficiencies in the lowest budget scenarios, like those most common in conservation efforts.

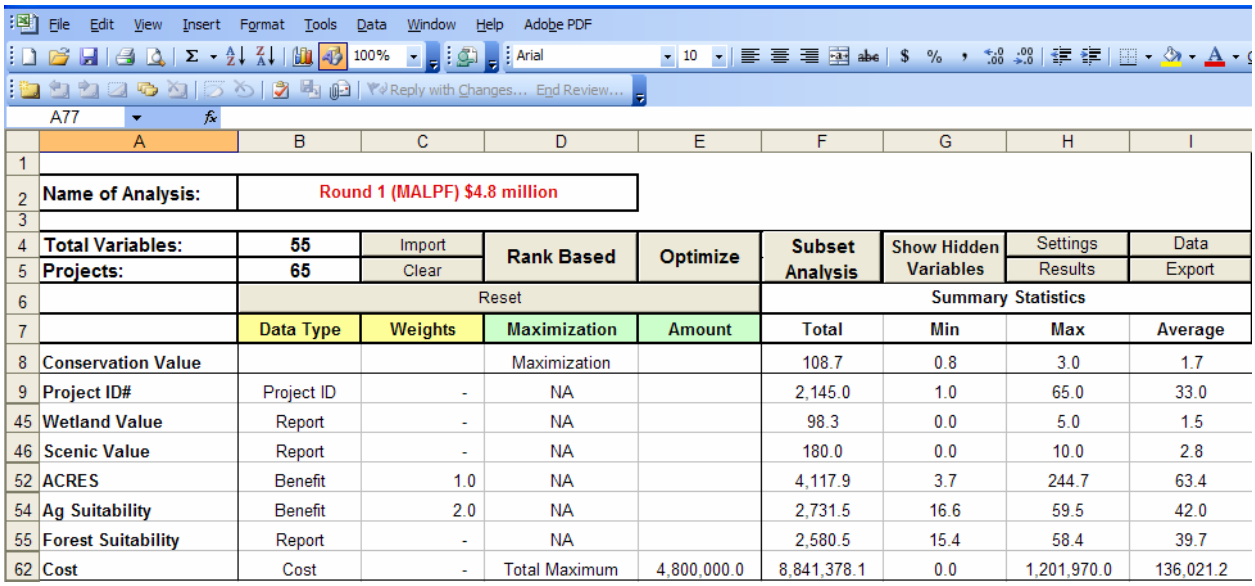
Optimization has been applied recently to several working landscape conservation projects in Delaware and Maryland. As described in Messer and Allen (2010), optimization was used in a historic analysis of the Delaware Agricultural Land Protection Foundation (DALPF). The results of this study suggest that while DALPF programs of a competitive auction structure that selected projects solely based on landowner discount did yield aggregate results that were improvements over a simple rank-based approach, optimization could have used the same $93 million spent over the last decade to protect an *additional 12,000 acres* at the

same cost. The benefits of optimization in this context were estimated to be $25 million. Optimization was also applied to evaluate how it could help achieve the *Livable Delaware* project's goal of permanently protecting "half of Delaware's remaining agricultural lands" by 2024. The results of this research suggest that optimization would enable the State to save an estimated $32 million compared to a rank-based approach (Allen et al., 2006).

As documented in Amundsen et al. (2010), Baltimore County, Maryland, used the optimization technique of cost effective analysis to select agricultural easement projects during their 2007-2009 application rounds. In total over those three years, optimization has helped the County protect an additional 680 acres of high-quality agricultural land at a cost savings of approximately $5.4 million. These estimates suggest that the return on investment during these three years is more than 60 to 1. In other words for every one dollar that Baltimore County spent to adopt optimization, it has returned more than 60 dollars in conservation benefits.

Overview of the Optimization Decision Support Tool

An Optimization Decision Support Tool (ODST) has been developed for the US 301 Project to create a user friendly workflow for SHA and the IAWG to help select environmental stewardship projects. The ODST provides functionality within a Microsoft Excel spreadsheet to perform two forms of optimization analysis (binary linear programming and cost effective analysis) as well as the traditional rank-based analysis for project selection. See Figure 6 for a view of the user interface in Excel.



	A	B	C	D	E	F	G	H	I
1									
2	**Name of Analysis:**	Round 1 (MALPF) $4.8 million							
3									
4	**Total Variables:**	**55**	Import	**Rank Based**	**Optimize**	**Subset Analysis**	**Show Hidden Variables**	Settings	Data
5	**Projects:**	**65**	Clear					Results	Export
6		Reset				**Summary Statistics**			
7		**Data Type**	**Weights**	**Maximization**	**Amount**	**Total**	**Min**	**Max**	**Average**
8	**Conservation Value**			Maximization		108.7	0.8	3.0	1.7
9	**Project ID#**	Project ID	-	NA		2,145.0	1.0	65.0	33.0
45	**Wetland Value**	Report	-	NA		98.3	0.0	5.0	1.5
46	**Scenic Value**	Report	-	NA		180.0	0.0	10.0	2.8
52	**ACRES**	Benefit	1.0	NA		4,117.9	3.7	244.7	63.4
54	**Ag Suitability**	Benefit	2.0	NA		2,731.5	16.6	59.5	42.0
55	**Forest Suitability**	Report	-	NA		2,580.5	15.4	58.4	39.7
62	**Cost**	Cost	-	Total Maximum	4,800,000.0	8,841,378.1	0.0	1,201,970.0	136,021.2

Figure 6. Optimization Decision Support Tool user interface example.

Binary linear programming considers the selection of projects a 'yes' or 'no' binary choice and then uses the Branch and Bound algorithm developed in the field of Operations Research to solve for the set of projects that maximize the total conservation benefits given user-defined constraints. A key advantage to binary linear programming is that it *guarantees* that it will identify an optimal solution to the problem (assuming a solution exists). The structure of binary linear programming is very flexible and can accommodate a wide range of constraints. This analysis requires the Excel add-in program Risk Premium Solver.

Cost effectiveness analysis is a technique used to evaluate alternative treatments where the benefits are measured in non-monetary units while the costs can be measured in monetary units. In these cases, selection is determined by calculated summing the weighted, normalized benefit measures (the Conservation Value) and dividing it by a project's costs. This approach then uses this benefit/cost ratio by selecting the projects with the highest ratios until the budget is exhausted. A key advantage of cost effectiveness analysis is that it

tends to be easier to explain this selection process than the binary linear programming method. However, this approach does not guarantee optimality. This lack of optimality can arise due to an inability to effectively use the entire budget set – this problem can be especially acute in low-budget scenarios where the individual project costs are high. Additionally, in situations where there are multiple constraints, such as staff constraints in addition to budget constraints, cost effective analysis can also be inefficient (Messer 2006).

Rank-based analysis is also an available function since users of the ODST may be interested in seeing how the traditional methods of project selection differ from the results from the optimization analysis, which also facilitates documenting the cost savings or added benefits of the optimization approach in project selection at a given budget.

Please see Appendix N for the OSDT Reference Guide that provides further details on the functionality of the tools. Appendix O includes the ODST Excel files with preliminary ES projects used to derive the sample results.

Using the ODST for Environmental Stewardship Project Selection

As outlined in Section VI of this report, conservation and restoration sites will be assessed for their environmental benefits using field-based and GIS-derived technical protocols to assign a relative numerical value of each project's benefits. Tables 26 and 27 in the previous section provide a summary for how these benefit scores are calculated. In addition, costs will be estimated for implementing the potential environmental stewardship project, which may include real estate acquisition expenses, physical restoration costs, and ongoing monitoring and management costs associated. These are compiled for each project. Each environmental stewardship project will have a unique identifier, one or more benefit scores, and a cost estimate that will be assembled in an Excel spreadsheet used by the ODST to perform the three types of available analysis. The ODST user can then run various scenarios that select a portfolio of projects that maximizes aggregate benefits based on a defined budget and other potential constraints. The options for creating different scenarios are outlined in the ODST Reference Guide in Appendix N.

Once a sufficient number of environmental stewardship projects have been evaluated for their costs and benefits, SHA and the US 301 IAWG can utilize the ODST to develop a set of project portfolios based on each build Alternative Retained for Detailed Study (ARDS). ODST users can adjust the portfolio selections based on the likely impacts of different alignments and can generate a list of projects scheduled to be implemented in the Final Environmental Impact Statement (FEIS)/Final Section 4(f) Evaluation.

Sample Results

Within the top tier conservation areas, the optimization tool identified portfolios of environmental stewardship projects at different budget levels that maximized the ecological benefits at each given cost. Because a state budget shortfall placed the final phase of the US 301 Project on hold, we did not visit enough sites to develop a full suite of potential conservation and restoration projects. However, Table 28 shows sample results for unprotected properties greater than 20 acres in size within top tier focus areas, and containing adjusted land assessment data provided by MD PropertyView. For these scenarios, we assumed that environmental stewardship would be implementation through fee simple acquisition for a preservation outcome. Had these been restoration projects, the estimated costs the restoration activities would have been used instead of the land assessment values.

We utilized green infrastructure area, mean ecological score, and proximity to protected land as benefit factors to derive an aggregate conservation value, but we did not have field data from the technical protocols for all properties. We normalized the three metrics in this example to values between 0 and 1 (see Messer, 2006), and summed them to derive an overall "conservation value" metric. We ran two scenarios, one for a budget of $15 million, with a maximum of 30 projects (to represent potential limitations of implementation capacity); and the other for a budget of $15 million that would allow selection of an unlimited number of

projects (to benchmark the value of optimization versus rank-based selection without constraints beyond funding).

The OM outperformed rank-based selection for the $15 million budget and a maximum of 30 transactions. The optimized selection contained 15% more green infrastructure area, with a 1% higher overall conservation value. On top of that, there was nearly $3.5 million left in the budget using optimization, indicating that implementation capacity rather than budget was the limiting factor, and that even more land could have been protected given a higher transaction capacity. To confirm this, our next scenario did not constrain the number of projects that could be selected for the $15 million budget. Under this scenario, optimization using binary linear programming far exceeded the rank-based selection. For the same budget of $15 million, 30% more green infrastructure areas was protected that had 213% more aggregate conservation value, partially the result of being able to select more projects but also the result of avoiding some highly ranked "budget sponges" that were selected by the rank-based method.

Table 28. Sample comparison of optimization and rank-based selection of projects for fee simple purchase with a budget of $15 million.

Maximum Allowable Acquisitions	Selection method	Number of projects selected	Total Cost	Area of GI Network selected (acres)	Aggregate conservation value (normalized)
30	Rank-based	30	$14,650,170	4,596	41,848
30	Optimized	30	$11,502,541	5,291	42,410
unlimited	Rank-based	31	$14,997,362	5,403	43,624
unlimited	Optimized	117	$14,985,997	7,044	136,354

This proof of concept illustrates the likely value of optimization as an environmental stewardship project selection tool. We hope that SHA and the IAWG will have an opportunity to use the approaches outlined in this report to identify opportunities for the US 301 Project and will consider use this approach for future transportation improvement projects where environmental stewardship project portfolios need to be developed. The entire NWRG approach (i.e. focus groups, resource assessments, green infrastructure network design, technical protocols, and optimization) is intended to be replicable and can be utilized as a holistic approach for integrating green and gray infrastructure planning throughout Maryland.

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X. APPENDICES

Appendix A. Focus Group Meetings

1. Focus Group Meeting Methods
2. Focus Group Meeting Results

Appendix B. Natural Resources Literature Review

Appendix C. Green Infrastructure Network Design Methodology

1. GI Network GIS Data Layers
2. Detailed Green Infrastructure Methodology

Appendix D. Natural Heritage Program Materials

1. Maryland's Natural Community Classification Summary
2. RTE Species within the Study Area as of 2006
3. Natural Communities within the Study Area as of 2006
4. GCN Species within the Study Area as of 2006
5. Ecologically Significant Areas within the Study Area as of 2006
6. GIS Analysis of Green Infrastructure Hubs for ECG Surveys
7. NHP Standard Data Collection Forms
8. Community Observation Form
9. Rare Plant and Animal Survey Form Instructions
10. Natural Community Observation Form Manual
11. Ecologically Significant Areas within the Study Area as of 2008
12. Recommended ESA Actions

Appendix E. Stream Assessment Field Form and Statistical Analyses

Appendix F. Wetlands Field Assessment Forms

1. Delaware Rapid Assessment Protocol (DERAP
2. Ohio Rapid Assessment Method (ORAM)
3. Pennsylvania State University Stressor Checklist (Penn State)
4. Montana Department of Environmental Quality Wetland Rapid Assessment Form (MT DEQ)

Appendix G. Forest Plot Data Sheet

Appendix H. Forest Plotless Protocol

1. Forest Plotless Data Sheet
2. Forest Plotless Instructions

Appendix I. Reforestation Data Sheet

Appendix J. **Invasive Species Data Sheet**

Appendix K. **Stream Ranking Assessment Method**

Appendix L. **Wetland Restoration Potential Assessment**

Appendix M. **Natural Heritage Resource Assessment – Numerical Rating Calculation Sheet**

Appendix N. **Optimization Decision Support Tool Reference Guide**

Appendix O. **ODST Files**