Stewardship Plan for Virginia Tech's Old-Growth Forest near Lane Stadium

by

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Executive Summary

The rare old-growth urban forest near Lane Stadium on the campus of Virginia Tech covers approximately 11.5 acres. It contains over 250 large trees, including dozens of white oak trees that have been estimated by scientists to be over 300 years old (Section 2.3). Research has further shown the old-growth urban forest to have a balanced, uneven-aged structure, which is rare, particularly for forests in urban settings. Evaluations reveal consensus in perspectives among stakeholders in that this forest patch, as the only untouched greenspace left on campus proper, has historical, educational, and research importance. The forest provides significant ecosystem services and is ecologically unique and rare (Sections 1.1, 2.2.1, 2.3, and 2.5). It reflects and contributes to the importance of the region's natural environment as a premium example of a white oak late successional primeval forest community (Section 2.3). The importance of this forest, unofficially known as Stadium Woods (SW), was elevated after the Athletic Practice Facility Site Evaluation Committee (APFSEC) was appointed by Virginia Tech's President Charles Steger and an environmental consulting firm was hired to conduct evaluations on SW to address a 2012 building land use dispute (Sections 1.2 and 2.2).

This Forest Stewardship Plan (FSP) is a thorough compilation of research findings and prioritized recommendations for the protection and posterity of the urban old-growth forest. This FSP includes executive oversight input from a joint venture between Virginia Tech's Vice President of Administration and the College of Natural Resources and Environment's (CNRE). Using the initial findings of the ad hoc APFSEC (Section 2.2), this FSP provides recommendations to sustain SW as a multifunctional, interconnected, and integrated forest that functions as a green infrastructure facility for Virginia Tech and the Town of Blacksburg. This FSP is aimed at minimizing human impacts and maintaining the forest's functionality as a high-quality ecosystem that provides maximum benefits while incurring minimum costs over time (Sections 2.3.6, 2.4, 2.5.4, 2.5.5, 3.2, 3.2.1, 3.3.3, and 3.4.1.).

The intention of the FSP is to help foster an intrinsic appreciation for the forest ecosystem and serve as a guide for the use and management of SW while protecting its ecological health. The FSP recommendations are based upon research strategies that provide a set of actionable objectives for Virginia Tech's operations and management that considers both the prevailing needs of the associated community stakeholders and operational constraints in the application of best management practices (BMP's) and standards of forest and tree stewardship (Sections 1.2, 2.2, and 3). The recommendations of the FSP were formulated to meet the needs of its associated community members and stakeholders and to sustain the quality of the SW ecosystem over time and are summarized as follows:

- Prevent or limit development and activities that degrade the forest and injure its trees.
- Manage risks to ensure human safety.
- Minimize soil and native plant disturbances caused by invasive plant species, human trampling, and/or deer browsing.
- Provide a historic continuity in the species composition reflective of the region by ensuring native species regeneration/planting as revealed by historical ecology.
- Engage partners to develop and maintain social capital and other resources for the stewardship of the forest (Loeb 2011; Mansourian et al. 2005; Steckel et al. 2014) (Sections 3.1, 3.1.1, and 3.5).

Based upon feedback received from two separate SW stakeholder meetings, one consisting of the Town of Blacksburg community group and the other embodying the Virginia Tech community group, the overall majority of stakeholders determined that restoration is the preferred stewardship priority for SW (Section 2.2.1). The Virginia Tech community group also stated that SW provides aesthetics and beauty and is important as a gateway and pedestrian traffic flow area while the Blacksburg community group emphasized that SW is important for future generations (Section 2.2.1). Areas of agreement were also discovered by conducting a strengths, weaknesses, opportunities, and threats (SWOT) analysis as a part of the stakeholder meetings. These meetings and analyses disclosed that:

- SW provides educational value, service learning, and volunteer occasions as strengths and opportunities;
- Concerns exist about the impacts of stadium football pedestrian traffic and current lack of funding and human resources to limit damage and degradation as weaknesses; and
- The football traffic, potential future development, and probable use impacts of the adjacent private land as threats.

A 2012 statistical analysis of SW stakeholders indicated an overwhelming agreement among respondents that SW enhances campus and community life, that it should be protected, and that the public should know that Virginia Tech has an old-growth forest patch located on its campus. Additionally, strong agreement was expressed that a plan should be prepared to address the needs of all the SW stakeholders, even if compromise be required from each of the involved stakeholders. The analysis also indicated that SW has recreational value as a natural forest area, should have trails, and is a part of Virginia Tech's game day experience. Stakeholders indicated that SW is vital for teaching, research, and outreach; has significant historical value; and is important for Corps of Cadets and ROTC training. Additionally, the analysis specified that SW provides ecological values that are very essential to SW stakeholders including storm water mitigation, pollution filtration, carbon sequestration, and biodiversity in the form of native plants and wildlife. The survey also recognized that invasive plant removal is needed. Strong agreement was specified in managing SW for wildlife, tree and forest health, and forest longevity. Very strong agreement was expressed by the survey for managing SW for safety, protecting SW over long timespans, and adopting a use and management plan for the SW old-growth forest fragment (Section 2.2.1).

A commitment to Virginia Tech's principles of community and sustainability in support of collaboration among SW stakeholders will facilitate a balanced approach toward the achievement of the long term-goal of restoration. The utilization of appropriate environmental management techniques will best consider and balance multiple stakeholder interests while protecting the SW ecosystem by considering ecological, community, and management perspectives and, ideally, by incorporating the FSP into the Virginia Tech Long Range Development Plan (Sections 1.3, 2.1, 2.2, 3.1, and 3.2).

SW is a rare high-quality old-growth forest ecosystem that can provide many beneficial functions for the communities of Virginia Tech and the Town of Blacksburg if it is well managed (Sections 2.5, 2.6, and 3.2). SW also is vulnerable to several factors that represent common threats to urban forest fragments across the nation. They include the inherent yet manageable risks that trees pose to property and human safety, human development pressures (parcelization/fragmentation), degradation caused by invasive species, and the ever present shortages of economic resources (Sections 2.3, 2.4, and 2.6). SW must be supported and maintained because it is small and it is located in an urban setting, making it vulnerable to human impacts such as invasive plant species, human trampling, edge effects, and dumping. Budgetary and/or priority constraints associated with the upkeep of the forest represents a noteworthy challenge because nominal budgetary and personnel resources are available for making substantive progress towards the accomplishment of the primary objective of restoration. Therefore, innovative solutions will be required in order to uphold and enhance the SW high-quality ecosystem for the purpose of sustaining its positive functional benefits over time (Sections 2.3.1, 2.3.4, 2.3.6, and 2.6.2).

SW imparts both costs and benefits for community members and stakeholders. The costs associated with SW include the direct expenses of managing and maintaining the forest, indirect liability and damages risks associated with the forest, and opportunity limitations in the form of land use prospects (Sections 2.4, 2.5, and 2.6). The benefits provided by SW include: improvements to water quality, moderation of peak stormwater runoff flow rates, air/water pollution filtration, reduction of urban heat island effect, carbon dioxide sequestration, noise level buffering, economic advantages, improvements to health and well-being, improved social connections, and aesthetics (Section 2.5). SW contributes to the well-being of students, community members, and stakeholders who wish to maintain, enhance, and protect the historical, educational, and environmental functions of SW through the application of the recommendations of the FSP (Sections 2.1, 2.5, and 2.6).

Assessments of natural and man-made features in SW (geology, soils, vegetation, wildlife, ecosystem considerations, safety, security, and ecosystem services) provided detailed information about SW and further informed environmental, social, and management needs and considerations (Section 3). With the overarching goal of restoration in mind, economic, social, and ecological aspects were examined to formulate a set of general goals for SW:

- Effective planning and administration for the forest to deliver:
    - Leadership and accountability for the forest
    - A safe and secure forest
    - A forest with an identity
    - A forest unified with other campus greenspaces
    - Capital investment for the implementation of the stewardship plan

- Engagement with the forest to facilitate:
    - Diverse partners are engaged in stewardship of the forest
    - Educators and researchers are utilizing the forest
    - Service-learning and participatory land care are commonplace
    - The forest is a destination for low-impact recreation and leisure

- Stewardship of the forest to ensure:
    - Soil, leaf litter, and woody debris support ecological function of the forest
    - Forest composition, structure, and health are supported by regeneration of native plants and control of invasive plants and pests
    - Native wildlife is in balance with the forest and cause minimal human conflicts
    - Ecosystem services are sustained by a healthy, functional forest (Section 3.1.2)

Once these goals were created, literature on the science and practice of forestry, urban forestry, and ecology were researched to produce a set of recommendations in conjunction with information from:

- ✓ Stakeholder communications and meetings,
- ✓ Client based communications and meetings,

- ✓ Information from academic research (the application of information to stakeholder interests/concerns),
- ✓ Best management practices from arboriculture and forestry (professional experience and research), and
- ✓ Advice from scientific experts, and natural resource management professionals who have formal training, experience, and credentials (Section 3.1.2)

The FSP recommendations are based on a middle-of-the-road approach that balances the feedbacks and requests of the stakeholders in a way that requires compromises from everyone in the consideration of the widest range of needs possible. It is important to note that the mutually exclusive nature of some stakeholder requests indicates that it is not realistic for the FSP to satisfy all the wishes of every stakeholder group (Sections 1.5, 2.2, and 2.5.5). Although budgetary and personnel limitations exist, the FSP addresses steps that will be necessary to effectively achieve the desired stewardship priority and the primary objective of restoration while acknowledging that the implementation of some recommendations will not be possible until more funding for the SW forest becomes available in the future (Section 2.2). For this reason, it is important to work with community groups who are providing social capital (educational and voluntary services) to help maintain the integrity of the SW ecosystem (Section 2.2). The FSP provides an initial framework of an ongoing process that is intended to evolve over time through an adaptive management approach that will incorporate knowledge and experiences gained through the application of restoration actions and facilitate the needs and values of the associated communities over time while simultaneously allowing for the quick implementation of recommendations (action objectives) as resources become available (Section 1.4).

Restoration of SW, based upon stakeholder interests (Section 2.2.1) and characteristics of the surrounding native Appalachian forests, shall be defined as a mature white oak old-growth forest (non-native and invasive plants are managed and kept in check) that sustains a healthy regeneration of understory layers that grow from a conserved soil structure and supports the above-ground ecosystem (Section 3.2). Ecological restoration is the long-term primary objective for SW and represents the principle consideration for the integration of all the goals and actionable objectives for SW. All management decisions should be weighed according to how well they will meet the stewardship priority (primary objective) as a basis for the decision supporting rationales (Sections 2.6, 3.2, and 3.1.2).

The FSP presents 14 primary recommendations (actionable objectives) that have been designed to effectively achieve the primary long-term stewardship goal of restoration to and sustain the benefits of the woods for current and future generations. The FSP recommendations contain assessments that were determined in conjunction with operations staff on their cost based on technical and financial barriers and are listed as high cost, medium cost, and low cost. The recommendations also contain priority assessments based on stewardship importance and are demarked as high priority, medium priority, or low priority based upon factors such as safety, ecosystem health, community concerns, and availability of resources. The FSP recommendations are listed as follows:

1. Continue to administer the forest restoration planning and management framework and apply green infrastructure planning principles (medium cost, high priority) (Section 3.2).

   a. Strengthen partnerships for the funding and care of SW by brokering facilitated open discussions about interests and values to obtain stakeholder understandings and agreements (high cost, high priority).

2. Establish a positive identity for the woods by providing the campus community with the opportunity to participate in a constructive rebranding of the woods (low cost, high priority) (Section 3.2.1).

3. Identify and manage risks in and around the forest to ensure safety and security (medium cost, high priority) (Section 3.2.2).

   a. Develop and implement a tree risk management plan under the direct supervision of a qualified professional, such as an arborist with the TRAQ credential (high cost, high priority).

      i. Retain the services of a Tree Risk Assessment Qualified (TRAQ) arborist.

      ii. Inspect trees regularly and after severe wind events and storms and before fall and spring football games by a qualified professional.

      iii. Mitigate tree risks in a timely manner when they have been reported or discovered.

      iv. Conduct tree risk inspections and mitigations according to the American National Standards Institute (ANSI) *ANSI A300 (Part 9)* and International Society of Arboriculture (ISA) *Best Management Practices for Tree Risk Assessment.*

   b. Prevent tree damage that may lead to structural defects (low cost, high priority).

   c. Convert dead trees into snags to mitigate risks and create wildlife habitat (medium cost, medium priority).

      i. Drop the tree or branches into the woods (nutrient cycling, reduces human trampling, wildlife habitat) if a tree needs to be cut down or mitigated for safety reasons.

   d. Remove hazardous debris, such as concrete chunks, cinder blocks, and pieces of rebar and pipes sticking up from the ground to increase safety (but retain historically important artifacts) (low cost, medium priority).

   e. Communicate safety awareness to visitors as part of interpretive signage (medium cost, high priority).

f. Plan and implement pedestrian flow controls to enhance security, minimize exposure to potential hazards, and reduce ecological impacts, such as forest floor trampling by humans (high to medium cost, high priority).

    i. Utilize temporary fencing, signage, natural debris materials (deadwood and brush), natural plant material landscapes, and permanent fencing/gates to direct pedestrian traffic.

4. Enhance visitor security (high cost, high priority) (Section 3.2.2).

    a. Establish security enhancements with improved fencing, gates, lighting along paved trails, emergency call boxes, signs and cameras (high to medium cost, high to medium priority).

        i. Install improved fencing along the east Virginia Tech boundary along with gateway areas that facilitate a transition from the Town of Blacksburg to campus.

        ii. Install uniform and aesthetically pleasing lamp posts and lighting along the paved east pathway that match the updated lighting on the west pathway.

        iii. Install security cameras and signs that communicate the area is under surveillance.

    b. Increase personal safety by controlling invasive understory plants and smoothing out mowing edges to provide lines of sight for defensible space and improved security (low to medium cost, high priority).

    c. Install traffic control security gates to provide clearly marked transition zones and to regulate vehicle traffic (medium cost, medium priority).

        i. Prevent any vehicles from driving or parking in SW critical root zones.

5. Unify or connect the forest with other campus green spaces and amenities to increase multifunctionality (high to medium cost, medium to low priority) (Section 3.2.3).

    a. Integrate Stadium Woods into the Virginia Tech master planning process and incorporate the forest into a comprehensive natural land area parkway system involving the use of green corridors (campus trails, walkways, habitat steps, and greenspaces) (low cost, high priority).

    b. Integrate Stadium Woods' paved pathways into the existing recreation trail system (medium cost, medium priority).

    c. Install interpretive signs at strategic locations to educate and inform visitors (medium cost, medium priority).

6. Establish governance for the forest (medium cost, high priority) (Section 3.2.4).

    a. Create a steering committee of stakeholder representatives so Virginia Tech can proactively reduce risks, address needs, and effectively resolve issues. (low cost, high priority).

        i. Use the existing Virginia Tech Arboretum Committee with two additional members, a Town of Blacksburg official and a Virginia Tech student. This new structure also meets the required Tree Campus USA standards for a campus tree advisory committee. If this recommendation is implemented, the Arboretum Committee will need to officially change their membership structure through a formal review and voting process.

    b. Support Virginia Tech protocol of contacting event planning for approval to conduct activities in Stadium Woods so events may be coordinated and establish an appropriate professional to manage the complexities associated with the forest (low cost, high priority).

        i. Establish a governing body and/or responsible professional to manage the complexities associated with the forest.

    c. Utilize a deliberative process to formulate an agreement among stakeholders on the preservation issue (high cost, high priority).

    d. Develop a Virginia Tech Stadium Woods information webpage to further affirm SW's value and to inform and aid in future management (low cost, high priority).

7. Seek alternative and creative funding for the maintenance and restoration of the forest (low cost, high priority) (Section 3.2.5).

8. Continue to encourage and cultivate organizational activities and partnerships to uphold Virginia Tech's covenant and sustain the forest over time (low cost, high priority) (Section 3.3.1).

    a. Endorse Stadium Woods as a destination site to promote Virginia Tech's commitment to sustainability and to enhance economic development (low to medium cost, high priority).

9. Enhance opportunities for teaching and research in the forest (low to medium cost, high priority) (Section 3.2.2).

    a. Create a meeting/class area adjacent to the forest that harmonizes with the landscape (high cost, medium to low priority).

10. Support and enhance both active and passive low-impact recreation (high cost, medium priority) (Section 3.3.3).

    a. Complete the north side loop around the forest so the trail will form a complete track circuit fitness trail and include two exercise stations (medium cost, medium priority).

        i. Support fitness trails to provide running, walking, and exercise trails around the forest and connect to other Virginia Tech fitness trails and the Huckleberry Trail.

        ii. Install exercise stations on the trail around the outside of the forest.

    b. Install a well-designed interpretive nature/recreation trail describing features of historical and biological interest or exterior forest observation spaces to provide passive recreation opportunities along the edge of the forest (high cost, medium priority).

    c. Enhance specific trails with boardwalks and hand rails to protect sensitive areas and facilitate access by people with physical limitations (high cost, low priority).

11. Encourage service-learning activities and participatory land care (low cost, high priority) (Section 3.3.4).

12. Protect soil and maintain water quality (low cost, high priority) (Section 3.4.1).

    a. Practice soil conservation management (low cost, high priority).

        i. Retain litter layers and coarse woody debris on the forest floor to maintain nutrient cycling and ensure long-term soil productivity and health.

        ii. Prevent/reduce any activities that may disrupt the soils that support the forest flora and/or manage to reduce human impacts.

    b. Initiate erosion prevention and mitigation practices on existing trails (medium cost, high priority).

    c. Install ephemeral stream along the emergency access road to allow rain water to flow away from pedestrian traffic, improve water quality, and protect/create habitat (high cost, low priority).

13. Restore, protect, and cultivate natural vegetation to increase health and maintain forest structure (low cost, high priority) (Section 3.4.2).

    b. Reduce mowing to facilitate understory regeneration along the north and east edge of SW to allow natural forest succession to expand the buffer zone (low cost, high priority).

    c. Retain and protect old-growth forest structure by leaving standing snags and fallen woody debris in place wherever feasible (low cost, high priority).

    d. Control invasive plant species throughout the forest (low to medium cost, high priority).

    e. Facilitate regeneration of native plants in canopy gaps and plant native trees in areas impacted by edge effects and human visitors (low cost, high priority).

        i. Manage north and south sections of woods according to specific needs of each section. For instance, the northern section of the woods may require a greater invasive plant species removal effort in conjunction with the reestablishment (by replanting) of the midstory and/or understory layers.

    f. Evaluate existing visitor-created informal trail system by initiating a proactive management approach that provides a balance between visitor access and long-term ecosystem quality (low to medium cost, high priority).

14. Minimize wildlife conflicts and enhance habitat (medium cost, medium priority (Section 3.4.3).

    a. Minimize conflicts and limit populations of nuisance animals (e.g. feral cats) by discouraging their presence (low to medium cost, medium to high priority).

    b. Monitor for deer overabundance to protect native plant biodiversity and forest regeneration by deterring or controlling browse in sensitive areas (low to medium cost, medium to high priority).

    c. Enhance bird habitat by retaining old-growth forest structure and protecting native plant diversity (low cost, high priority).

Successful restoration will require organized leadership, base-line studies, dedicated people, effective community involvement, adequate funding, and coordinated planning to protect, manage, and restore SW. The high degree of complexity associated with the SW ecosystem creates uncertainties in some cases with regard to balancing stakeholder wishes. These issues, however, may be addressed by employing an ongoing learning process of collaborative planning, action, monitoring, and evaluation (Sections 1.4 and 2.2.2). Urban forests generally require lower levels of maintenance than other urban landscapes, yet they still require some amount of ongoing care. This is because urban forest ecosystems are not self-sustaining, due to the human impacts that inevitably occur over time in urban settings (Section 3.5).

The search for innovative approaches in the face of economic and social challenges offers many opportunities for the communities of Virginia Tech and the Town of Blacksburg. The vision of restoration may be accomplished through effective leadership and the social capital of community members working together in partnership with the private sector toward this common goal. These opportunities include the processes of service, learning, teaching, research, and community around an active engagement with SW (Section 3.5). Such an endeavor has the capacity to provide social connections and facilitate a sense of place that produces the combined efforts that encourage volunteer stewardship, opportunities for donations, and mutual learning and understanding to occur (Johnston and Hirons 2014). Performed well, these activities will create synergies to elevate the community spirit by bringing volunteer groups, private endorsements, and public officials together to yield an attractive destination site that serves as a source of community pride and enhances the image of Virginia Tech and the Town of Blacksburg.

Acknowledgments

Although my name is listed on the cover of this document, this Forest Stewardship Plan is truly the reflection and culmination of a collaborative enterprise to which a great many people have offered their contributions. I owe my gratitude to all the persons who have shared their vision, ideas, time, support, dedication, and prayers to the achievement of this endeavor.

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I would like to thank Dr. Michael Sorice, academic committee member, who helped me to discover some of the many complexities and nuances of the human dimensions of natural resource management. This shaped a realization that an almost infinite list of possibilities exists for those who listen well.

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About the Author

Born and raised in Montana, Rodney Walters developed an appreciation for the gifts and beauty of nature. Even as a young child, Rodney exhibited a noticeable love of trees. In his youth, Walters apprenticed for his father in the family tree business where he gained his initial arboriculture skills. Subsequently, Rodney attained higher levels of mastery in arboriculture.

As a young adult, Mr. Walters explored another interest - teaching and mentoring. Walter's progression steered him toward a secondary teaching degree, which he earned in 2001 at Montana State University (MSU). He taught middle school children before progressing to a private boarding school in Montana for inner city students. Later, Rodney served as a Wilderness Senior Field Leader in Montana's backcountry where he worked with at-risk youth to instruct them in teamwork, leadership, and wilderness skills. He encouraged teens to develop higher self-esteem and to develop pride in their accomplishments.

In the fall of 2008, Walters came full circle back to his love of trees when he accepted the Head Arborist Position at MSU where he provided arboriculture and urban forestry services to care for the university's urban forest. There, he served on MSU's Master Landscape Plan committee, the MSU Tree Campus Advisory Committee, and the City of Bozeman Tree Advisory Board. During this time, it became apparent to him that he wanted to pursue a Master's Degree in Urban Forestry.

In the summer of 2014, Walters accepted a position as Masters Candidate in Urban Forest Ecology and Management at Virginia Tech in Blacksburg, VA. His studies and work centered on researching and developing a stewardship plan for an old-growth urban forest remnant located on Virginia Tech's campus. This plan addresses the use and management of the forest's complex ecosystem. Upon completion of his Graduate Degree in Urban Forestry, Rodney accepted a position as the arborist instructor at Clackamas Community College in Oregon City.

Rodney moved with his wife and children to Oregon during the summer of 2016 where his new role will allow him to blend his favorite endeavors: educating and instructing adult students in arboriculture and sharing his love of trees and the wealth of benefits they provide.

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List of Abbreviations

APFSEC……. Athletic Practice Facility Site Evaluation Committee

ANSI……….. American National Standards Institute

BMPs………. best management practices

CNRE………College of Natural Resources and Environment

CRR………... critical root radius

DBH………... diameter at breast height

FREC………. Forest Resources and Environmental Conservation

FSP………….Forest Stewardship Plan

GPS………… Global Positioning System

IPM………… integrated pest management

IPS…………..invasive plant species

ISA………….International Society of Arboriculture

NISC………...National Invasive Species Council

NRV………...New River Valley

PHC…………plant health care

SW…………..“Stadium Woods”

SWOT……… strengths, weaknesses, opportunities, and threats

TRAQ……….Tree Risk Assessment Qualification

UTC…………Urban Tree Canopy

USDA……….United States Department of Agriculture

"When we see land as a community to which we belong,

we may begin to use it with love and respect"

-Aldo Leopold-

1 Forest Stewardship Plan Introduction

1.1 Background and Need for the Forest Stewardship Plan

An exceptionally rare old-growth forest remnant grows atop the Eastern Continental Divide in the New River Valley (NRV) of Virginia. This forest fragment is now evolving in an urban setting as an augmentation to the Lane Stadium area on the Campus of Virginia Tech immediately adjacent to the Town of Blacksburg. Having no official name, this approximately 11.5 acre (Figure 1.1) forest is commonly referred to as "Stadium Woods" (SW). The SW area is an old-growth white oak (*Quercus alba* L.) remnant forest (Copenheaver et al. 2013) that serves as a sample of what the forest ecosystems of the region may have been like before the Europeans settled in the Allegheny Ridge, Drapers Meadow area around 1750. This white oak forest patch contains more than 250 large trees and includes dozens of white oaks that may be over 300 years in age (Figure 1.1) (Biohabitats 2012). SW remains among the historical, agricultural, urban, and suburban development of the surrounding areas and demonstrates the historic rich abundance of the area.

The importance and value of SW have only been recently discovered. In the past, the area was generally neglected and largely ignored. It served as a dumping ground for residual plant and building material, an ecological teaching area for classes, tail-gaiting prior to home football games, bird watching, and a "short cut" to various campus locations. However, the rare

<u>Figure 1.1</u> Location of "Stadium Woods" on the Campus of Virginia Tech showing its proximity to the Town of Blacksburg, numerous large trees, and general boundaries.

old-growth forest characteristics of the stand were revealed following Virginia Tech's 2012 appointment of the Athletic Practice Facility Site Evaluation Committee (APFSEC), to study both the woods and potential building sites of a proposed indoor athletic practice facility. APFSEC was appointed to help resolve the debate that arose from a proposal to construct the new building in SW. Additionally, an independent ecological consulting firm, Biohabitats, was hired to conduct a forest ecological assessment (Seiler 2012) of the area. The prominence of the woods had not been realized by university officials until the debate had reached contentious levels and erupted into petitions, dozens of media reports, and events that were followed by 11 Virginia Tech and Blacksburg community resolutions aimed at preserving SW. Both Biohabitats and APFSEC engaged in analysis and inquiries of the old-growth natural woodland in order to examine the issues that surrounded the proposed building. These reports both made recommendations to Virginia Tech (Biohabitats 2012; Randolph et al. 2012). Virginia Tech officials examined the recommendations and opted to build the new indoor athletics practice facility outside of the north western portion of the woodland area (Figure 1.1). In addition, Virginia Tech officials chose to develop a forest stewardship plan for the SW Environmental Greenway area.

1.2 Intent of the Forest Stewardship Plan

The intention of the Forest Stewardship Plan (FSP) is to help foster an intrinsic appreciation of the forest system by providing a framework in support of the activities occurring in and around them. The plan will further serve as a guide to maintain and improve the ecological health of SW. Several stakeholders currently utilize the SW area for a variety of educational, training, and recreation based activities. Additionally, SW holds value for the surrounding Town of Blacksburg neighbors and visitors to the campus. This plan will provide information to Virginia Tech officials and enable them to make informed decisions concerning activities occurring in and around SW so that its long-term ecological health is not negatively impacted.

The intent of the Forest Stewardship Plan is to provide science-based strategies for stewardship in order to meet the long range needs of Virginia Tech and its associated communities and to maintain the health and increase the intrinsic appreciation for the Stadium Woods old-growth forest patch.

In response to the APFSEC recommendations, Virginia Tech's Vice President for Administration, in collaboration with Virginia Tech's College of Natural Resources and Environment (CNRE) partnered to develop this FSP for SW. A graduate assistantship position was established in order to research and develop the FSP Plan for the university client, Virginia Tech's Office of University Planning. An advisory committee assisted with the plan's development and was composed of Dr. John Seiler, – Forest Biologist, Department of Forest Resources and Environmental Conservation (FREC); Dr. Eric Wiseman, - Urban Forestry and Arboriculture, FREC; Dr. Sarah Karpanty, – Wildlife Biologist, Department of Fish and Wildlife Conservation; and Dr. Michael Sorice, - Natural Resource Management, and Human Dimensions, FREC.

Stewardship may be defined as an active process of engagement with your land (Steckel et al. 2014). The intention is to include and employ research-based methodologies for the care of this valued natural land resource. These researched strategies will provide an actionable roadmap for Virginia Tech's operations and management based on prevailing needs, constraints, and best management practices (BMPs) of forest and tree stewardship.

1.3 Spirit of the Forest Stewardship Plan

The spirit of the FSP will reflect the essence of the Hokie Nation to engage stakeholders, foster an intrinsic appreciation for the value of the old-growth forest, and improve the overall ecological health of the area. These aims are in accordance with Virginia Tech's commitment to sustainability, principles of community, and overall university mission of knowledge creation and dissemination for the improvement of the quality of life (Appendix A). As such, they will appropriately serve as the essence of the FSP. The SW forest offers ample opportunities in each of the above endeavors. By employing a proactive style of stewardship, defined as "an active process of engagement with your land to direct it toward (or keep it at) a desired state" (Steckel et al. 2014), the FSP embodies a thoughtful approach that is attentive to the lifespans of long-lived trees established in an ecosystem that has been continually developing over a period of thousands of years. This may be accomplished by adopting long-term ecological, community, and management perspectives through the consideration and balance of multiple stakeholder interests. Ideally, the FSP will be incorporated into the Virginia Tech Long Range Development Plan for the benefit of the future Virginia Tech community members.

1.4 Goals and Approach of the Forest Stewardship Plan

The overarching aspirations in the development of the FSP are based on the intent established by Virginia Tech Office of University Planning and the process that informed a stewardship priority of restoration during community stakeholder meetings (Appendices B, C, D, E, and F). The FSP will inform the process of moving the SW patch from its existing state to a preferred state: "The ultimate purpose of any stewardship plan is to provide direction for the landowner or manager to take a parcel of land from its current state to the desired state based on the landowner's goals for the parcel" (Steckel et al. 2014). The FSP assesses existing conditions and considers value (Section 2), assigns goals, and provides specific standards-based expert recommendations (Section 3) conveying how SW may be directed toward a more preferred state. The primary goals of the FSP are interrelated:

A. the SW area will be improved by correcting the negative impacts that threaten to disrupt the long-term equilibrium of the ecosystem through a process of restoring the forest to a healthy all native late successional plant community;

B. the value of the area will be increased by improving its quality so it may appeal to and gain support from a wide range of educational and community stakeholders; and

C. the preparation of a well-informed set of maintenance strategies, based on widely accepted scientific findings and best management practices of tree and forest care standards, once implemented, will support objectives A and B.

Urban forest old-growth remnants are so rare, that serious ambiguities exist about practices for their successful management (Loeb 2011). Each old-growth urban forest has unique site-specific factors, distinctive community dynamics, and specific ownership management constraints (Gundersen et al. 2005). Very few scientific comparative studies have been conducted on old-growth urban forests. At the time of Loeb's publication, *Old Growth*

Urban Forests, only 15 comparative scientific studies (5 from the U.S) of old-growth urban forests remnants had been published worldwide in English (Loeb 2011). When natural resource management decisions are characterized by high levels of complexity, uncertainties, and risks, the preferred approach is to employ an ongoing learning process of collaborative planning, action, monitoring, and evaluation known as adaptive management (McFadden et al. 2011; Walters 1986).

Adaptive management involves the identification of stakeholder/partner concerns from the onset of the planning process (Loeb 2011). The FSP is not intended to be prescriptive. Instead, it consists of a series of recommendations covering a span of management scenarios over a range of costs. This will improve flexibility so that, as funding opportunities arise, recommendations may then be quickly implemented. The general stewardship approach will draw upon the cumulative and ever evolving knowledge and techniques of natural resource management experience and science. A mechanism for the iterative monitoring, evaluation, response, and implementation of new information and methodologies will be required in order to facilitate an effective adaptive management approach. This mechanism should entail an iterative process of periodic inventories, collaborative reevaluations, revisions to the stewardship plan, and modifications in the strategic and tactical implementation of methodologies. Knowledge in the fields of ecology is currently expanding at a remarkable rate. It is a certainty that approaches and recommendations will change as practices are informed and revised.

The FSP will employ the widely accepted adaptive management approach, which includes the ongoing process of planning, action, monitoring, and evaluation (Stankey et al. 2005). The U.S. Department of the Interior defines adaptive management as:

> …a decision process that promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. Careful monitoring of these outcomes both advances scientific understanding and helps adjust policies or operations as part of an iterative learning process. Adaptive management also recognizes the importance of natural variability in contributing to ecological resilience and productivity. It is not a 'trial and error' process, but rather emphasizes learning while doing. Adaptive management does not represent an end in itself, but rather a means to more effective decisions and enhanced benefits. Its true measure is in how well it helps meet environmental, social, and economic goals, increases scientific knowledge, and reduces tensions among stakeholders (Williams et al. 2007).

This learning approach allows natural land stewards to design and manage projects better and avoid some of the perils others have encountered (Stankey et al. 2005). *Land for Life - A Handbook on Caring for Natural Lands* weaves an adaptive management methodology into a nine-step process that was developed specifically for the cultivation and implementation of a natural land area stewardship plan (Box 1.1). The first 6 steps serve as a template for the compilation of the FSP. The scope of the FSP is currently limited to the research and development of the plan. Steps 7 - 9 involve the prioritization and implementation of tasks as well as the monitoring and ongoing assemblage/revision of the FSP and/or program. The execution of the FSP will depend upon decisions and actions taken by the university and community stakeholders after the plan has been written and submitted.

Box 1.1 Process for developing and implementing a natural land area stewardship plan (Steckel et al. 2014)

Step 1: Inventory existing natural resources and current stewardship issues.

Step 2: Delineate natural lands from the remainder of the property.

Step 3: Establish stewardship units, delineating areas with similar vegetation and past management

Step 4: Establish the conservation priority for the natural lands.

Step 5: Establish the stewardship goals for the natural lands.

Step 6: Determine appropriate stewardship strategies for each unit.

Step 7: Prioritize and schedule stewardship tasks for each unit.

Step 8: Establish a monitoring program to determine if goals are being met within each stewardship unit.

Step 9: Assemble the Stewardship Plan to record information gathered and decisions made.

Remember that ***because natural systems are continually evolving, land stewardship must similarly evolve over time*** as new stewardship issues are identified, land management knowledge and technology change, and stewardship goals are modified. Therefore, stewardship plans should be revisited on a regular basis (every 3–5 years, or following a significant change, such as new ownership or modification of the conservation priority or stewardship goals) to make sure they are still appropriate in all respects. Steps 6 and 7 should be reviewed and revised as needed on an annual basis (Steckel et al. 2014).

1.5 Limitations of the Forest Stewardship Plan

The FSP is subject to and restricted by certain limitations. The maintenance funding for the SW natural land area is limited. Currently, there is a nominal budget and there are no assigned personnel who may facilitate concentrated maintenance/stewardship efforts for SW. However, Virginia Tech funded a graduate student assistantship with the task of writing this research based FSP. Financial constraints limit the scope of the FSP in areas such as the gathering of new data (must rely upon past data collection efforts) and the details into which the FSP research topics may investigate. The function of the FSP is to assign standards-based recommendations specifically for the immediate SW area. The FSP will not limit recommendations for SW based on financial constraints. Instead, the FSP will provide a range of stewardship practices ranging from inexpensive to expensive that may be implemented if and when funding sources become available in the future.

The FSP will be confined in scope to the SW study area only. As a result, the FSP will not reflect the SW old-growth urban forest as a component of a larger Virginia Tech natural land area management plan/strategy. For example, issues relating to the future condition of the International Peace Garden (adjacent to SW) or other similar Virginia Tech natural land areas will not be addressed.

Since the sole responsibility of managing SW belongs to Virginia Tech, the implementation of the FSP recommendations will be determined by Virginia Tech personnel who are responsible for assigning resources for the care and maintenance of Virginia Tech properties. Due to the realities of financial constraints and the mutually exclusive nature of some stakeholder group interests, it will be impossible to satisfy all the wishes of every single stakeholder group. Ecological conservation efforts represent just one of several interests including economic (management), educational, and recreational pursuits. Therefore, it is unlikely that any one vision driven by a closely focused viewpoint will be happy with all the recommendations (Aldrich et al. 2004). As a result, there may be some groups who perceive the choices to be unfair (McShane and Wells 2004).   A realistic aim of the FSP is a deliberation of the realities involved, followed with actions designed to minimize stakeholder loses, because forest restoration decisions, by necessity, always involve trade-offs (Loeb 2011; Mansourian et al. 2005).   It is desirable to find areas of compromise in order to minimize the losses from which some stakeholder groups may disagree. Efforts should be made to ensure these concessions do not unreasonably fall on any single group (Brown 2005).   The FSP, therefore, will incorporate a general middle-of-the-road approach (compromise) between stakeholder feedbacks.

Given there currently is a nominal budget for SW maintenance, this FSP acknowledges that some recommendations will not be possible until more funding becomes available in the future. This plan provides an initial framework for the establishment of an ongoing process which is intended to evolve through a scientifically based adaptive management approach as knowledge and experience are gained throughout the course of restoration over time. The FSP will best serve as an initial starting point of an ongoing Forest Stewardship Program that is based on an ongoing partnership involving stakeholder representatives who assess the effectiveness of the FSP and makes adjustments accordingly.

2 Assessment of the Forest and Its Human Dimensions

2.1 Forest Assessment Introduction

Effective management of a natural land area engages a triple bottom line approach by assessing the ecological, economic, and community characteristics associated with the resource. This facilitates an enhanced decision-making process that integrates benefits (Gibson 2006) and helps to reduce costs/risks over time. This approach, according to Gibson, will "look for links and seek mutually reinforcing gains on all fronts." This section addresses basic questions for the establishment of the FSP framework. This will serve to inform the FSP process by describing the biophysical characteristics and value. It also establishes the stewardship priority for the SW old-growth urban forest by addressing the stakeholders' desired use and future condition of the woods and relaying the value the stand has to the Virginia Tech and Town of Blacksburg communities. This information apprises the FSP by addressing components of the urban forest sustainability model to determine site-specific information related to the overall shared vision for SW, provides baseline measurements of the vegetation resource, and sets goals for the appropriate management of the resource so a maximum amount of economic, social, and ecological benefits may be realized over time (Clark et al. 1997).

2.2 Social Capital: Stakeholders of the Forest

As the basis of human capital, *Social Capital* (Coleman 1988) is the collective or economic benefits derived from social organization (networks, norms, and social trust) that facilitate coordination and cooperation for mutual benefit (Putnam 1995). A variety of stakeholder groups hold interests in SW. The 2012 debate over the Indoor Athletics Practice Facility site location demonstrated that a variety of concerns exists from the Virginia Tech, Town of Blacksburg, and broader national ecological communities. Some community groups organized social networks to collectively shed light upon their viewpoints, which center around the safekeeping, care, and use of the SW old-growth urban forest.

The 2012 site location dispute lead Virginia Tech's 16th President, Dr. Charles Steger, to request the formation of the ad hoc Athletic Practice Facility Site Evaluation Committee (APFSEC). In May 2012, after four months of meetings and data gathering, APFSEC determined that the issues exemplified more than simply whether or not to build within the woods. The social importance of SW reflected the APFSEC recommendations to "designate SW as a reserve and develop a protection, management, and use plan for the woods." Additionally, since the proposed building site involved a prior greenway designation, APFSEC recommended officials "review procedures for assessing variance with the Master Plan to safeguard against future disagreements of this type" (Randolph et al. 2012).

SW currently has significant budgeting, personnel designation, and priority constraints which greatly limit the extent to which the university is able to apply resources to the management of SW. In light of this reality, community groups have validated their interests by demonstrating a willingness to invest in the SW natural land area. Some groups, such as The Virginia Master Naturalists, College of Natural Resources and Environment, and Big Event participants contribute their expertise and voluntary labor for the improvement of SW. The Virginia Master Naturalists, for example, conduct monthly events to educate community members and engage partners in an ongoing community-based endeavor to remove invasive plants that are occurring in SW by employing environmentally/ecologically sound control methods. These methods include hand pulling invasive plants, such as garlic mustard (*Alliaria petiolata* (Bieb.) Cavara and Grande) and privet (*Ligustrum sinense* Lour.), and cutting back vines, such as English ivy (*Hedera helix* L.), that threaten the canopies of the large old-growth trees.

In an ideal world, Virginia Tech would provide the manpower and financial resources to address the invasive plants occurring in SW; however, budget and personnel constraints currently limit these activities. Therefore, it is important to work with community groups, such as the Master Naturalists, in order to apply the social capital, generously offered by these supporting organizations who provide their volunteer services to help maintain the integrity of the SW ecosystem and who also may be aware of occurrences in and around the woods. This social engagement improves monitoring opportunities with mores eyes in and around the woods who may report potential malefactors. It also communicates a sense of value and purpose that community members associated with the SW area (Crewe 2001; Crowe and Fennelly 2013).

This social capital, in the face of the above-listed constraints, is a tremendous resource for SW. It represents an opportunity for the Virginia Tech and Town of Blacksburg communities to continue to engage in and expand upon constructive partnerships. Such endeavors will help to increase the *deliberative capacity* of groups and allow them to work more successfully together (Dryzek 2010). Such learning opportunities may provide an atmosphere whereby a *mutual-gains approach* (Susskind and Field 1996) may provide openings for *win-win* developments (Thompson 2014) to maximize forest benefits for Virginia Tech, the Town of Blacksburg, and future students and community members.

2.2.1 Forest Value to Stakeholders: Desired Future Use and Condition

In order to determine community values and wishes for SW, a variety of methods were utilized. These approaches included individual stakeholder group introductory interviews, public stakeholder meetings, internet-based feedback, and information from a 2012 survey study (Cross et al. 2012). The individual stakeholder group introductory interviews were held between fall 2015 and early winter 2016. Two stakeholder meetings were held early in 2015 including a Town of Blacksburg community stakeholder meeting (Town of Blacksburg community group) in late January and the Virginia Tech community stakeholder meeting (Virginia Tech Community Group) in early February. Written and web-based feedback was also implemented to gather information from any individual or group who desired to provide input. Finally, results from a previous SW stakeholder survey statistical analysis conducted by a Virginia Tech Environmental

Planning Studio course (Cross et al. 2012) are summarized. This feedback has influenced the development of the FSP recommendations.

Individual Stakeholder Introductory Interviews

Several individual stakeholder introductory interviews were held throughout late fall 2014 and early winter 2015 (Appendix B**)**. These introductory interviews were held to inform stakeholders the FSP writing process was underway and to initiate a stakeholder assessment procedure. The interview meetings also served to gauge various stakeholders' values, desires, preferences, and even their frustrations with the SW management. During the interviews, Town of Blacksburg and Virginia Tech community members provided their perspectives on the history of SW, delivered insights about the values they associated with the woods, and shared what they would like to see happen in the SW natural land area.

A primary function of a stakeholder assessment is to determine if a consensus building effort is feasible. Currently, there is no way to fund a stakeholder assessment and move forward with formal consensus building procedures. This fact, along with confidentiality concerns, led us the decision to not directly utilize the information from the individual stakeholder group meetings in developing FSP objectives (Schenk 2007; Susskind et al. 1999). However, these individual interviews were invaluable in compiling the list of stakeholders who were invited to attend the larger group stakeholder meetings (Appendix B).

Stakeholder Group Meetings

The stakeholder group meetings were held to provide stakeholder groups the opportunity to have their perspectives voiced and heard in a public forum. The purpose of the meetings was not proposed as an agreement procedure; rather, it was to seek stakeholder viewpoints to help inform the FSP process (Figure 2.1). The intent of the meetings was to consult stakeholders for the purpose of obtaining feedback about alternatives and/or decisions in the development of the FSP (International Association for Public Participation 2014). This information influenced and informed the formulation of the FSP stewardship priority, goals, and recommendations (Appendix C).

The format of the stakeholder group meetings included: 1) encouraging stakeholders to discuss their viewpoints in identifying why/if SW is important to maintain as a way to help establish a stewardship priority; 2) appropriate uses (stakeholder goals); and 3) feedback in conducting a strengths, weaknesses, opportunities, and threats (SWOT) analysis for SW (Figure 2.2). In addition to the public comments, stakeholders were encouraged to answer a stakeholder questionnaire worksheet that paralleled the meeting format to make sure everyone, who wanted, had the opportunity to express their viewpoints and further explain: 1) stakeholder values and their chosen stewardship priority; 2) preferred goals; and 3) SWOT considerations (Appendix E).

Twenty-four people signed the attendance sheet at the Town of Blacksburg community group stakeholder meeting with 16 individuals completing the questionnaire worksheet. The Virginia Tech community group stakeholder meeting had 12 people sign the attendance sheet,

Purpose of Stakeholder Group Meetings

- Facilitate discussions with stakeholders to identify the longe range needs of the university and community
- Identify any current and potential activities in and around the Stadium Woods area
- Examine what impacts these activities may have on the overall health of the Stadium Woods ecosystem and if/what measures may be taken to reduce impacts

Figure 2.1 **Purpose of Virginia Tech's "Stadium Woods" stakeholder group meetings**

Stadium Woods Stakeholder Meeting Format

A. ***Establish the Stewardship Priority* -** Identify why the area *is* or *isn't* important to care for and what the stewardship priority should be; consider the social, environmental, and economic value of the forest.

B. ***Identify and discuss forest uses*** - Discuss your group's uses (goals) for the forest: (helps determine objectives).

C. ***Conduct a SWOT analysis*** – Determine what the strengths, weaknesses, opportunities, and threats are for the forest.

Figure 2.2 **Virginia Tech's "Stadium Woods" stakeholder meeting format**

with four questionnaire worksheets completed (Appendices D and F). The statements from both stakeholder meetings were recorded in the meeting minutes and reflect general statements about the woods and comments related to stakeholder feedbacks about a SWOT analysis. Common general statements between the Blacksburg community group and the Virginia Tech community group include comments about the need to control the invasive plants in the woods, the value of the old-growth forest for teaching, education, and research, the recreation potential for SW (jogging, training, meditation, birdwatching, etc.), and the potential of the woodland to serve as a destination for visitors (Appendix D). Areas of agreement between the two stakeholder meetings in the SWOT analysis include:

- educational value, service learning, and volunteer occasions as strengths and opportunities;
- concerns about the impacts of stadium football pedestrian traffic and the current lack of funding and human resources to limit damage and degradation as weaknesses; and
- the football traffic, potential future development, and probable use impacts of the adjacent private land as threats.

Ecosystem services were seen as strengths by the Blacksburg Community group while the Virginia Tech community group stated that a major opportunity existed for the woods if a strong statement by the Virginia Tech upper leadership was made to affirm the importance of the woods (Appendix D).

Community Values and Stewardship Priority for the Forest

Some of the most substantial findings of the stakeholder meetings are associated with stakeholder values and their stated stewardship priority of restoration for SW. Purposeful urban forest planning engages to actualize shared community values for the purpose of providing maximum benefits over time (Miller et al. 2015). Both stakeholder meeting groups stated that SW is the only untouched green space left on campus proper; is historically important; is significant for the educational and research opportunities it provides; is valuable in its provisions of ecosystem services; and is ecologically unique and rare. The Virginia Tech community group also stated that SW provides aesthetics and beauty for Virginia Tech and is important as a gateway and pedestrian traffic flow area while the Blacksburg community group asserted that SW is important for future generations.

Stakeholder meeting inquiries into the desired stewardship priority for the woods was introduced by asking stakeholders about their preferences as to whether they think SW should be preserved, restored, or altered. When asked what the desired use and future condition of the woods should be, 13 out of 16 Blacksburg community group stakeholders selected ***restoration*** as a stewardship priority and 1.5 of 3 Virginia Tech stakeholders chose ***restoration*** as a stewardship priority (Appendix F).

2012 Stadium Woods Stakeholder Survey Statistical Analysis

During the fall of 2012, Dr. John Randolph's Environmental Planning Studio students (UAP 4354) conducted a SW stakeholder survey statistical analysis. This student group solicited input and identified SW stakeholder groups through an online survey of use and value perceptions of the SW area's recreation, environment, history, education, and management. A total of 191 individuals from Virginia Tech and the Town of Blacksburg responded to the survey, 177 of which were verifiable and, therefore, valid. Most of the responses, by far, were derived from Virginia Tech students. Replies were also fielded from recreational users, Virginia Tech alumni, Virginia Tech faculty members, research users, Virginia Master Naturalist, Athletic Department staff and students, wildlife club members, Friends of Stadium Woods members, Corps of Cadets and ROTC members, and a grounds maintenance staff member. The survey's results served as a guide to help assess the perspectives and values for the student group's preliminary recommendations (Cross et al. 2012).

The overall results of the survey indicated an overwhelming agreement that SW enhances campus and community life, that is should be protected, and that the public should know that Virginia Tech has an old-growth forest fragment located on its campus. Additionally, strong agreement was expressed that a plan should be prepared to address the needs of all the SW stakeholders, even if compromise be required from each of the involved stakeholders (Figure 2.3) (Cross et al. 2012). The analysis also indicated that SW has recreational value as a natural forest area, should have trails, and is a part of Virginia Tech's game day experience. Stakeholders indicated that SW is vital for teaching, research, and outreach; has significant

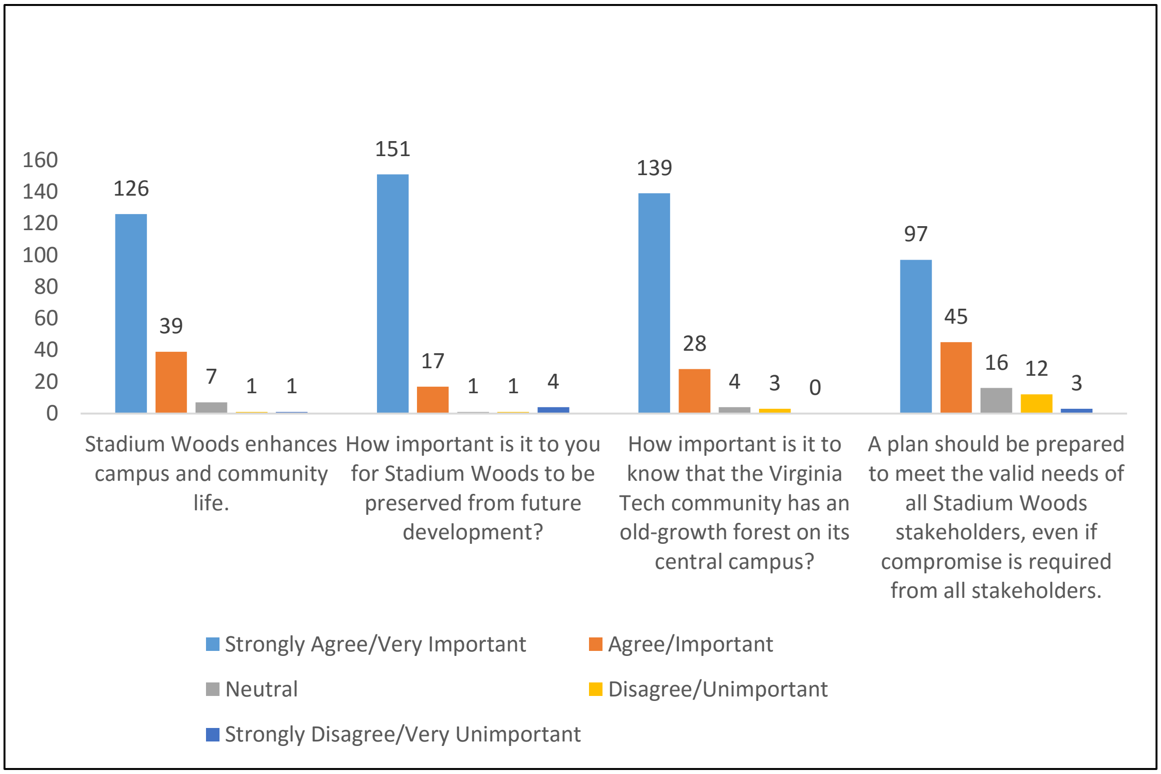


Figure 2.3 Overview of the 2012 Virginia Tech "Stadium Woods" stakeholder survey statistical analysis (Cross et al. 2012)

historical value; and is important for Corps of Cadets and ROTC training. Additionally, the statistical analysis of the survey specified that SW provides ecological values that are very essential to SW stakeholders including storm water mitigation, pollution filtration, carbon sequestration, and biodiversity in the form of native plants and wildlife. The survey also recognized that invasive plant removal is needed. Strong agreement was specified in managing SW for wildlife, tree and forest health, and forest longevity. Very strong agreement was expressed in the survey for managing SW for safety, protecting SW over long timespans, and adopting a use and management plan for the SW old-growth forest fragment (Cross et al. 2012).

Stakeholder Feedback Summary: Informed Development of Stadium Woods Forest Stewardship Plan Recommendations

The 2012 APFSEC recommendations suggest Virginia Tech reserve SW as an important natural land area ecosystem for current and future generations by developing a protection, use, and management plan for the woods (Randolph et al. 2012). These recommendations initiated the development of the FSP. The APFSEC final report identifies SW in what may be described as an *overlay zone,* which is an area identified as environmentally or aesthetically sensitive, because it provides runoff alleviation, groundwater filtration, essential wildlife habitat, and/or aesthetic enhancement qualities (Miller et al. 2015) for Virginia Tech's campus. Since "human engagement in the design and stewardship of urban greenspace is vital to the long-term sustainability of urban ecosystems" (Campbell and Wiesen 2011), the Virginia Tech and Town of Blacksburg communities have been consulted for the purpose of "obtaining public feedback on analysis, alternatives, and/or decisions" (International Association for Public Participation 2016).

Direct public feedback from the 2015 public stakeholder meetings ascribing the communities' values and stewardship priority of **restoration** for SW (Appendix F), in conjunction with the above stakeholder surveys (Figure 2.3) have been used in developing the recommendations in the FSP. The stated community values for SW from the public stakeholder meetings include ecology, education, amenity, public recreation/use, aesthetic, historical, ecosystem services/engineering, and management/care merits (Table 2.1). This public feedback, in conjunction with available technical report data, standards, and BMPs of urban forestry and silviculture, collectively have been used to develop the recommendations in the FSP including the following broad goals: the need to cultivate positive public associations with SW; risk management; amenity multifunctionality and unification; engagement; teaching; research; active and passive recreation; organizational activities/service learning; soil and water quality protection; native vegetation protection and cultivation; and wildlife habitat protection.

Table 2.1 Stated community values from 2015 Virginia Tech and Town of Blacksburg "Stadium Woods" stakeholder meetings (See Appendices D and F for stakeholder values)

Ecological	Biological diversity	Old-growth (rare/unique)	Unique critical habitat	Only untouched area left on campus	Environmentally and ecologically unique
Educational	K-12 education	Higher education	Need for environmental education	Demonstrates university's commitment to the environment	Education and research
Amenity	Proximity to dorms	A place people enjoy	Natural area	Campus location and student traffic through area	Place to escape
Aesthetic	Beauty and aesthetic impact	Focal point for campus	Only true green space left on campus proper	Valuable campus resource	Valuable for its connection to history
Ecosystem Services (Engineering)	Pollution filtration	Stormwater mitigation	Positive health and well-being effects	Urban heat island effect reduction	
Management (Care)	Safety	Gateway area	Maintain for longevity	Space to study nature	
Public Use (Recreation)	Exercise	Walking and jogging	Quiet place for reflection		
Historical	Intergenerational equity	To preserve history	Importance for future generations		

2.2.2 Forest Preservation Issue

Many technical reports have stated that SW should be established as a type of biological reserve and/or given protection status. The following is a list of reports containing the aforementioned suggestions:

- the Virginia Tech presidentially appointed 2012 Athletic Practice Facility Site Evaluation Committee Final Report (Randolph et al. 2012);
- the 2012 Virginia Tech contracted Forest Ecological Assessment (Biohabitats 2012);
- the 2012 Stadium Woods: A dendroecological analysis of an old-growth forest fragment on a university campus (Copenheaver et al. 2013);
- the Virginia Tech, Fall, 2012, UAP 4354 Environmental Planning Studio Course Stadium Woods Preliminary Use and Management Plan (Cross et al. 2012);
- and the 2013 Forest Management Plan: Virginia Tech Stadium Woods senior capstone project (Daig Jr. et al. 2013).

The ad hoc committee appointed by Virginia Tech President Charles Steger in 2012 (APFSEC) to address the practice facility building site controversy specifically states in their number one recommendation:

> The Committee recommends elevating the status of the core of the Woods, designating it as the Stadium Woods Old Growth Reserve or comparable title and protecting it in perpetuity… The Committee also recommends the development of a use and management program to protect and enhance the Woods' ecological value and its beneficial uses by the campus and Town communities… (Randolph et al. 2012).

There are stakeholder groups who continue to advocate for preservation through the establishment of a permanent conservation easement. The issue of preservation was important enough for over ten thousand NRV residents to sign a petition for SW's protection, which ultimately prompted the introduction of a 2014 Virginia State Senate bill to preserve SW. Senate

Bill 92 for the preservation of SW was written and formally presented to the Virginia Legislature by Virginia Senator John Edwards (Legislative Information System 2014). A subcommittee of the Virginia Education and Health Committee subsequently recommended killing Senate Bill 92, which effectively prevented it from being voted on in the Virginia General Assembly.

Although the concept of permanent preservation presents an idealistic vision of a perpetual majestic old-growth forest stand, underlying realities of utilities, maintenance funding, adequate compensatory issues, and day to day management considerations all bring significant questions to bear about the long-term efficacy of a conservation easement. It is possible that, over time, a conservation easement would lead SW to be neglected by organizations who lack the incentives to continually uphold the significant time and expense requirements for maintaining SW at restoration levels. This is because conservation easements continue after ecological and social settings have changed (Merenlender et al. 2004).

The small size and location of the SW forest in an urban environment make it continually vulnerable to the human impacts of invasive plants, visitor trampling, dumping, and other disturbances (Lehvävirta 1999; Loeb 2011). Rather than trying to preserve SW for all time, a better approach may be to uphold levels of restoration as defined by community values through stakeholder engagement in adaptive approaches over time. Adaptive management can provide ways forward when decisions involve uncertainty and high degrees of complexity, such as the case with urban old-growth forests, and may yield better results when there is a shared understanding among a community of stakeholders, especially in defining objectives and management actions (Loeb 2011; McFadden et al. 2011). This provides the latitude necessary for making adjustments over time that continue to uphold community values.

Though not an exhaustive list, other universities containing similar sized stands of old-growth forest, natural land area, and forest stewardship/management plans from universities were sought out as a way to learn from the experiences of other organizations for the compilation of the FSP. This process revealed that small old-growth urban fragments, similar to SW are rare and difficult to find. Only a few examples were identified and each one exists under circumstances (socially, economically, environmentally) that are distinctly different from SW. Yet some useful information arose from the investigation. The most successful university old-growth forests are professionally managed and usually have some financial structure in place to maintain their natural land areas. The old-growth forests and natural land area management plans that appear to be successful tend to embrace community participation, find common goals, and forge partnerships. Managers who embrace positive relationships with community leaders and work with them to increase public engagement, increase awareness and involve community volunteers stand out as exemplary in their efforts. Every university containing a small-old growth forest fragment in this investigation chose not to place their forest in a legal conservation easement including Lakeshore Technical College, Earlham College, and Cornell University, University of Massachusetts Amherst, and Pennsylvania State University (Walters 2015). One natural land management plan from Ithaca College agreed to an "internal conservation easement" as a way to avoid the considerable restrictions, management costs, and transaction fees associated with placing the land into a formal conservation easement (Zadrozny and Brenner 2011).

The question of how to specifically manage SW and ensure the ecosystem quality is maintained for future generations is extremely complex because it depends upon the social contexts and capacities within the relevant communities. A general agreement exists among the SW stakeholders that restoration should be the stewardship priority (Section 2.2.1). However, strong opinions exist regarding how the stewardship priority should be accomplished and how decisions should be made. Furthermore, the care and management of SW does not currently hold primacy with the university, which restricts progress in any meaningful way toward the established stakeholder priority of restoration.

The issue of permanent protection status for SW continues to be an extremely complex and festering concern. Divisions among the stakeholders and associated community members remain. The Virginia Tech president-appointed committee, APFSEC, recommended establishing SW as a reserve to be placed under permanent protection. The issue of how to facilitate a sustainable protection for SW has not yet been satisfactorily resolved among the stakeholders and by all indications, until it is addressed, is not going to go away.

2.3 Natural Capital: Features of the Forest Landscape

2.3.1 Landscape Overview

The approximately 11.5 acres (Appendix G) SW forest is located in southwest Virginia in Montgomery County. It is on the Virginia Tech campus and is roughly rectangular shaped with a north/south axis. It is bounded on the north by the Washington Street tennis courts and on the south by the Southgate Center building. The western border is formed by Lane Stadium and the new Indoor Athletics Practice Facility. The eastern boundary is formed by the perimeter fence of Virginia Tech and the Town of Blacksburg (Figure 2.4).

North and South Sections as Separate Stewardship Units

SW is divided by an emergency access road that separates the northern part from the southern part of the forest (Figure 2.4), which further contributes to edge effects. The southern section has been partially shaded for 50 years by Lane Stadium. This has helped to reduce the amount of invasive plants, reduce the edge effect (Sections 2.3.3 and 2.3.5), and has contributed to a higher ecological health based on the *forest condition score,* an in-house Biohabitats metrics (Biohabitats 2012). Incidentally, the approximately 100-foot-tall new indoor practice facility is likely to contribute to the overall ecosystem health of the north section of the woods by providing late afternoon shade and shelter from west winds in a similar way that Lane Stadium has shaded the south section of the forest.

The north SW section has experienced areas of greater impacts around the immediate vicinity of the rappelling tower where temporary trailer structures were placed as post World War II veteran family housing trailer structures were placed as post World War II veteran family housing (Randolph et al. 2012). In addition, the understory has been periodically cleaned of underbrush and vegetation to facilitate training activities that take place in the general vicinity around a rappelling tower (Biohabitats 2012). These impacts have thinned the overstory trees

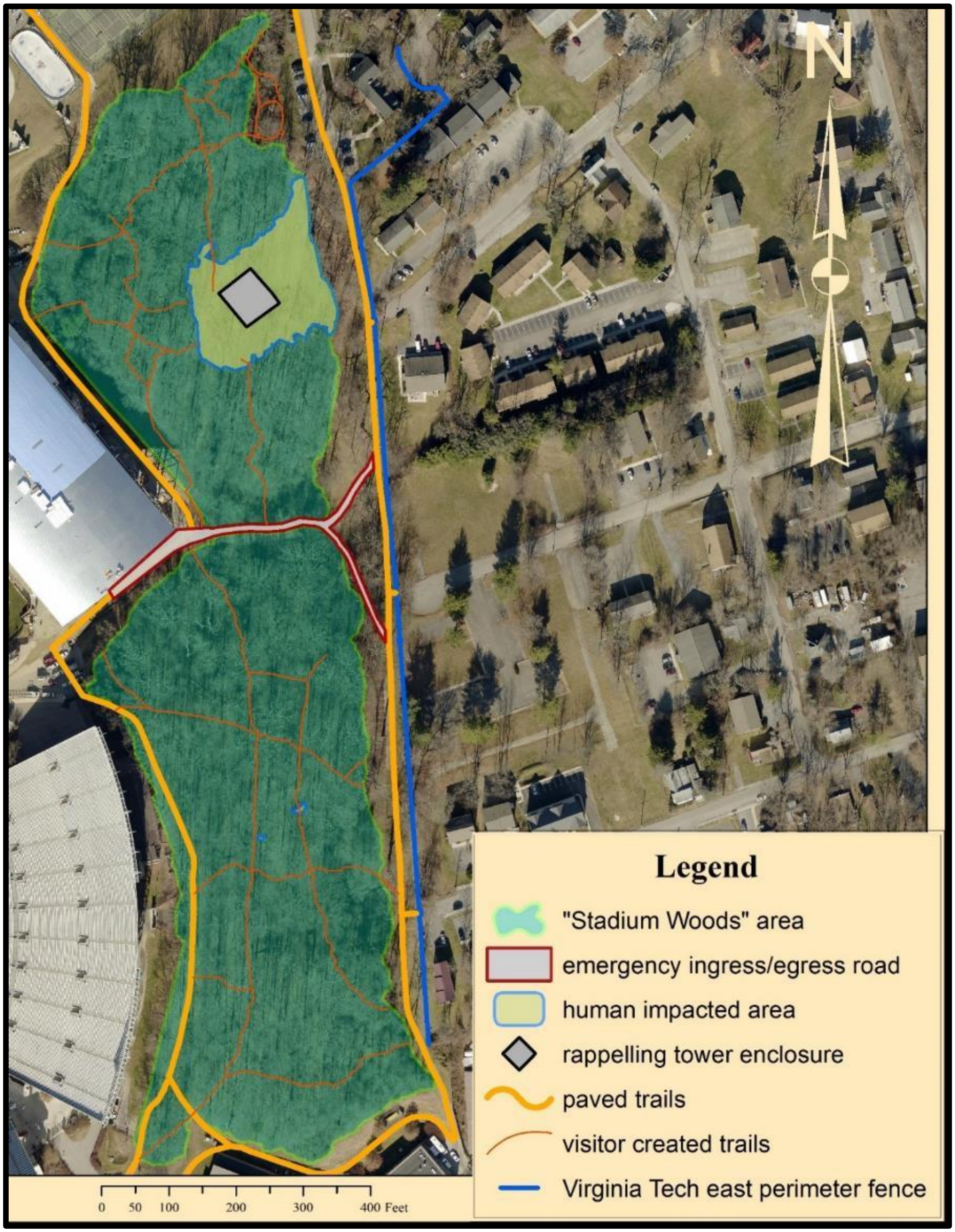


Figure 2.4 **Virginia Tech's "Stadium Woods" depicting emergency ingress/egress road separating the north and south sections into two distinct stewardship units (Biohabitats 2012), human impacted area, rappelling tower enclosure, paved trails, visitor created trails, and Virginia Tech east perimeter fence**

and have prevented regeneration of the understory layers, essential for the health and longevity of the forest. The additional light that reaches the forest floor, due to this missing vegetation, in combination with soil disturbances, have produced a much greater presence of light thriving invasive plant species in some areas of the northern woods (Biohabitats 2012).

Consideration of these differences is important in that they may result in different management practices in order to accomplish the overall stewardship priority of restoration. For instance, the northern section of the woods may require a greater invasive plant species removal effort in conjunction with the reestablishment of the midstory and/or understory layers. In contrast, the south section of the stand may only require the removal of invasive species for ecological restoration. Instead of relying on natural regeneration, the northern woods may involve human planting in order to replace the missing forest layers in and around the impacted areas in order to meet the stewardship priority of restoration.

Man-Made Features and Visitor Impacts

Impacts from human visitation include a network of visitor-created informal paths (social trails), a graveled emergency ingress/egress road that bisects the woods, a rappelling/training tower, and foundation remnants from the post-world War II G. I. housing ("Hurricane Hill"). These features may be considered through the lens of recreation ecology, which provides scientific research, strategies, and methodologies to help managers strike the balance between visitor usage impacts and ecosystem protection for the purpose of maintaining and/or improved quality of life for current and future generations (Leung and Marion 2000; Marion et al. 2011).

Informal Visitor-Created Trails

SW has a network of visitor-created informal trails also commonly called social trails (Figure 2.5). These are defined as visually discernable pathways created or used by visitors that do not fall under a formal trail system (Leung et al. 2011). Trails are a primary resource amenity for access and recreation in natural land areas. Well-designed trails protect natural resources by concentrating visitor traffic on track surfaces (Marion and Leung 2001). Informal visitor-created trails can be a serious concern because they tend to multiply and expand over time. Informal visitor trails can contribute to significantly greater impacts in an area than formally designed trails including widening, muddiness, soil erosion, and tread effects. This is because the visitor created paths were not properly designed, located, built, or maintained for sustainable use (Hockett et al. 2010). Over time, these impacts can promote the loss of tree and shrub cover and encourage soil compositional changes that favor shade-intolerant plant species, including invasive plants (Hammitt et al. 2015).

Emergency Ingress/Egress Road

The emergency ingress/egress road is the graveled road that bisects the south stand of SW from the north stand of SW (Figure 2.4**)**. The purpose of this road is an ingress/egress for emergency vehicles (ambulance, police, or fire) and it is also a significant people mover in the form of pedestrian traffic in the vicinity of Lane Stadium (Mike Mulhare, personal communication, January 13, 2015). The road provides an efficient route for thousands of fans to and from the stadium from the surrounding Town of Blacksburg neighborhoods during Virginia Tech Game day events. The road currently has a stable base that can handle the weight of the emergency vehicles and its crushed stone surface offers adequate durability, however, the road is located on a natural ephemeral stream running between SW and drains significant water when the rainfall is heavy. This can make walking on the road problematic for fans if a game day event is occurring on a rainy day and negatively impacts the water quality of Stroubles Creek. This stormwater runoff carries sediment and other pollutants downstream, which eventually end up in Stroubles Creek and degrades water quality (Figure 2.5). Stroubles Creek is a documented impacted waterway (Parece et al. 2010). A mitigation strategy of keeping rainwater off the roadway could provide better recreation access through SW and reduce ecological impacts.

The road also bisects SW breaking the continuity of the canopy resulting in a proliferation of invasive species along the graveled road (Figure 2.6). This is occurring as a result of the extra sunlight reaching the forest floor through overstory canopy gaps near the road, which allows light thriving invasive species to overrun native plant species (Biohabitats 2012). Hand planting of native tree species along with ongoing efforts to keep these native trees cleared of invasive vines will, over time, help to restore the overstory and improve ecosystem health.

Figure 2.5 **Water running down the emergency ingress/egress access road in Virginia Tech's "Stadium Woods" during heavy rain event (road is built on an ephemeral stream). The new indoor athletic practice facility can be seen in the background, 2/24/2016.**

Figure 2.6 **Invasive plants and vines along the emergency ingress/egress roadway in Virginia Tech "Stadium Woods", 6/24/2015**

Rappelling/Training Tower

The rappelling tower is a fenced training facility located in SW and frequented by law enforcement officials and the Corp of Cadets. The area immediately surrounding the fence has characteristics of an impacted area (Figure 2.4). The impacts include bare ground devoid of organic material (leaves, sticks, decaying matter), areas lacking in forest floor and understory vegetation layers, areas containing high levels of invasive plant species, and a thin overstory layer with canopy gaps. The impacts are a result of a combination of past usage as a temporary housing area (Hurricane Hill) and the relatively high frequencies of foot traffic that currently occur around the tower for training purposes. Occasionally, vehicles are even pulled into the area adjacent to the tower. Vehicles and foot traffic cause soil compaction, unfavorably influences soil hydrology, change soil pH levels, and adversely effects oak tree growth (Craul 1994; Day and Bassuk 1994; DeJong-Hughes et al. 2001; Jordan et al. 2003; Whitecotton et al. 2000). The impacts around the rappelling/training tower resemble characteristics around high use camping areas or high visitor use areas in a national forest.

Post-World War II Housing Remnants

Foundational and sidewalk remnants are present in the northeast corner of SW (Figure 2.8). These housing vestiges serve as testaments to the post-WWII temporary housing units that had been concentrated in the north stand (Figure 2.7). The housing accommodated returning veterans and their families for education programs under the Servicemen's Act of 1944, unofficially known as the G.I Bill. The area was mockingly called "Hurricane Hill" because of

Trailer Camp No. 2, known as Hurricane Hill, in 1949

Sandy and Bill Dawson, 1949 and 2001

Figure 2.7 Temporary housing units that accommodated post-WWII married veterans in the northeastern corner of Virginia Tech's "Stadium Woods". Photos Courtesy of Virginia Tech Magazine, http://www.vtmag.vt.edu/spring02/feature5.html (Young 2002)

Figure 2.8 Sidewalk remains of "Hurricane Hill" community located in Virginia Tech's "Stadium Woods" (Daig Jr. et al. 2013)

the intense wintertime winds that buffeted the hastily constructed housing units. The site once housed 76 trailers that were subsequently removed in the early 1950's (Daig Jr. et al. 2013).

These G.I. housing artifacts embody opportunities for visitor and experiential learning discoveries and engagement with a part of Virginia Tech's history in connection with the north stand of SW. This can be achieved by designing and developing a recreation/visitor trail that utilizes interpretive signage to communicate points of interest within SW. The foundation remnants of Hurricane Hill could be demarcated with signage as points of interests (Daig Jr. et al. 2013). This trail would provide an amenity within SW that integrates touring opportunities (boosting Virginia Tech image as a destination), enhanced K-12 and higher education teaching and learning occasions, and passive recreation. This recreation trail would thus achieve several engagement goals simultaneously.

Impacts on Visitor Safety/Security and Aesthetics

Older non-uniform overhead lighting on street poles along the heavily used east side sidewalk and along the east edge of the woods are not consistent with the well designed, and uniformly-spaced lighting along the west asphalt sidewalk (Lane Stadium west gates). There are also various pieces of concrete (e.g. old picnic table in the south end of SW) and steel debris scattered throughout SW. These features may be considered through the lenses of personal safety and aesthetic amenity of the area, both of which enhance the effectiveness of the other.

2.3.2 Geology and Soils

Geology Description

The SW natural land area embodies a complex ecological system that has been emerging on the approximately 11.5-acre site for eons. SW is located in the Valley and Ridge Physiographic Province (Szary 2015). The soil parent materials are limestone, shale, siltstone, and sandstone.

Soils Description

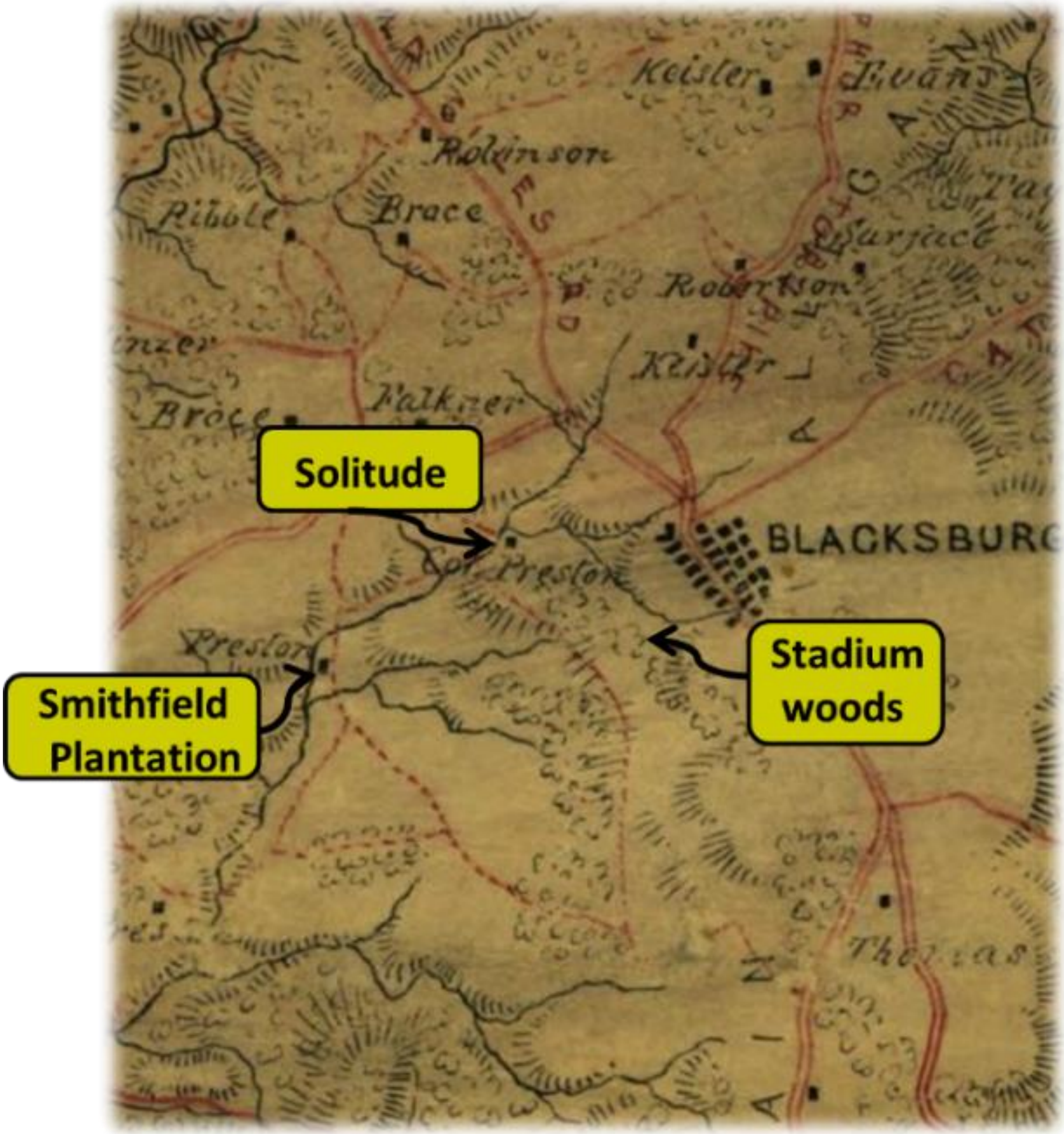
The SW soil may be described as biologically rich, very high in quality and possessing educational significance. Based on the USDA-NRCS National Cooperative Soil Survey, Official Soil Series Description of the SW soils is a Groseclose urban land complex (Appendix H) (USDA 2002). The soil depth to the bedrock can be over 70 inches. The upper 7 inches of the soil consists of loam and is fertile, containing high levels of organic matter. Plant root problems caused by water saturation are generally absent in this soil since it is well drained.

2.3.3 Vegetation Resource

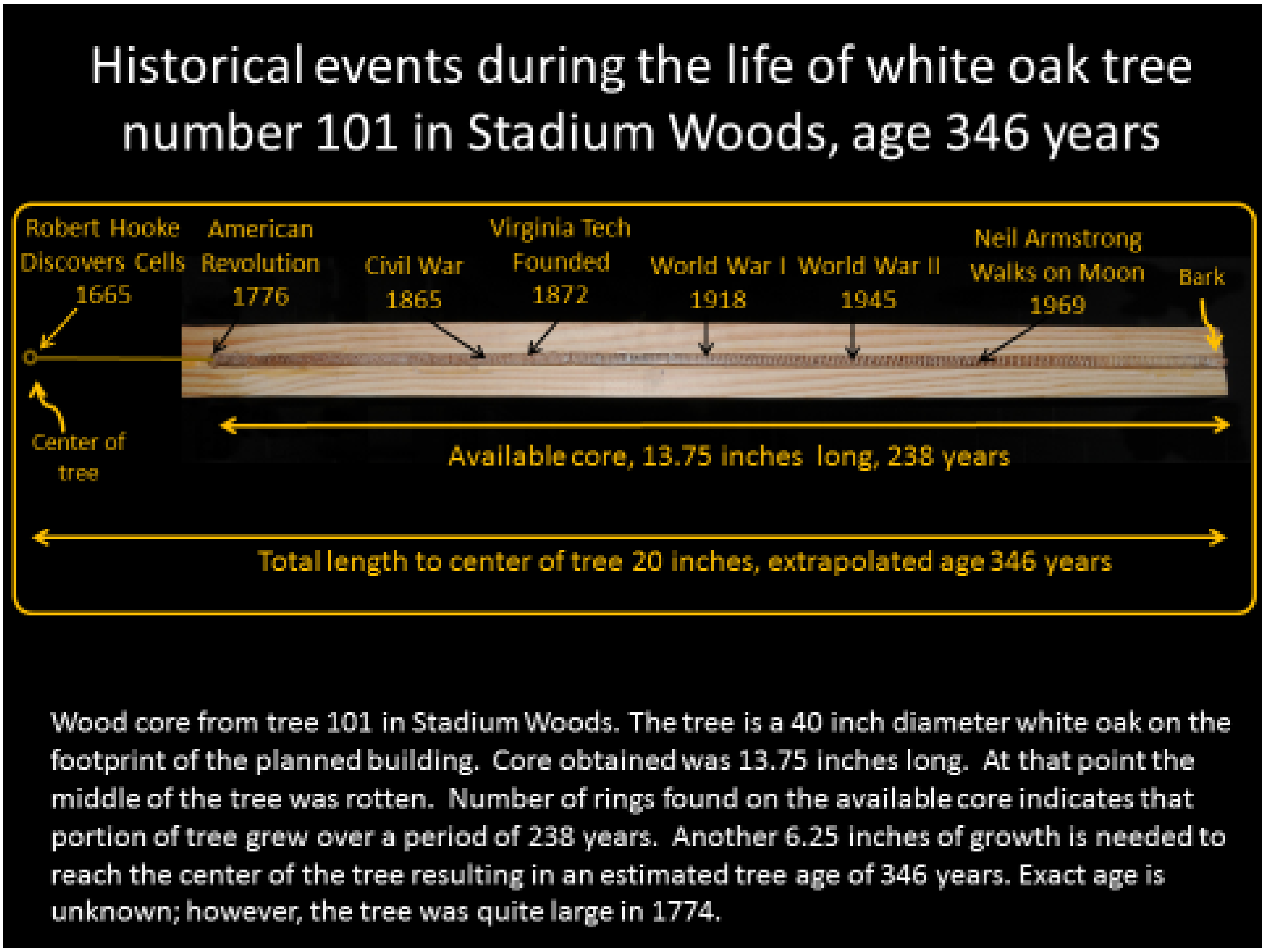
Old-Growth Forest Description

SW contains more than 260 late-successional large white oak and black oak (*Quercus velutina* Lam.) trees over 20 inches in diameter that form a, predominately, closed crown over the entire area (Biohabitats 2012) (Appendix I), including over 50 white oaks that may be over 300 years in age (Biohabitats 2012; Seiler 2012). White oaks are important climax trees for the Appalachian Region (Burns and Honkala 1965; Virginia Tech 2015) and are described as "an outstanding tree among all trees" (Burns and Honkala 1965). They may live more than 600 years, reach heights well over 100 feet, and diameters may exceed 5 feet in diameter. Many of the largest and oldest trees throughout the NRV and greater Appalachian Region are white oak, due to their ability to outlive a majority of other eastern tree species (Seiler 2012; Burns and Honkala 1965). SW appears on historical maps depicting the Town of Blacksburg and Virginia Tech. An 1864 Confederate Civil War reconnaissance map (Figure 2.9) shows SW as part of a forested area, which at the time, may have been part of a much larger stand (Seiler 2012). The exceptional old age of the trees unites the SW site, Virginia Tech, and the Town of Blacksburg historically in time with pre-European peoples, the founding of our Nation, the origins of Virginia Tech and the Town of Blacksburg (Figure 2.10). Old-growth forests are rare in the United States (Hunter Jr. and White 1997). In the southeastern United States, old-growth forests represent less than one-half of one percent of the region's total forests (Gaines et al. 1997). The historical age of the white oak overstory layer is only one of the many factors that make the SW forest unique, and valuable for its stakeholders.

The midstory of SW is composed of mostly black oak, black cherry (*Prunus serotina* Ehrh.), sweet cherry (*Prunus avium* (L.) L.), and red maple (*Acer rubrum* L.) (Biohabitats 2012; Daig Jr. et al. 2013; Seiler 2012). The understory consists of blackhaw (*Viburnum prunifolium* L.), sassafras (*Sassafras albidum (*Nutt.) Nees), serviceberry (*Amelanchier arborea* (Michx. F.)



<u>Figure 2.9</u> Confederate Civil War reconnaissance map shows Virginia Tech's "Stadium Woods" as part of a forested bluff, which at the time, may have been part of a much larger stand (Seiler 2012)



<u>Figure 2.10</u> Historical timeline on white oak core sample taken from tree 101 in Virginia Tech's "Stadium Woods" (Seiler 2012)

Fernald), choke cherry (*Prunus virginiana* L.), blackgum (*Nyssa sylvatica* Marsh.), and flowering dogwood (*Cornus florida* L.*)* (Seiler 2012). The mature forest patch averages more than 170 stems/acre over 4 inches in diameter. The standing green weight biomass of the trees in SW contains between 166.3 - 272.6 tons/acre. This equals between 57.6 - 91.6 tons of carbon/acre in the standing timber alone (Daig Jr. et al. 2013).

Not only does SW contain old trees, but the overall distribution of trees is known as a balanced, all-aged forest, with an overstory, midstory, and understory canopy. This sort of structure is quite rare (Wittwer et al. 2004). This age distribution can be seen by examining the diameter distribution of the forest (Copenheaver et al. 2013). This type of diameter distribution is known by forest managers as an inverse J-shape curve (Leak 1965) and indicates that the forest contains a complete range of tree ages necessary for its self-sustainability. In brief, everything from numerous 1-year-old to relatively few 350-year-old trees exists in the forest. When one of the very big old trees dies, a younger tree is there to take its place in the hole made in the canopy. Ecologists refer to this as canopy gap dynamics (Pickett and White 1985). The robust vegetative species diversity (Daig Jr. et al. 2013) and broad age class distribution are indicative of late-successional or climax vegetation that characterizes old-growth mixed mesophytic forests, (Greenberg et al. 1997; Seiler 2012) and represents contributing factors to the overall health and resiliency of SW.

Tree ring analysis by Copenheaver et al. (2013) of the older white oak trees offers further evidence of its old-growth structure. This study found "asynchronous growth suppression" lasting 34 to 110 years which indicates a "…closed canopy forest with periodic canopy disturbances. These disturbances were not synchronized across the stand and suggest small gap disturbances instead of stand-level disturbances" (Copenheaver et al. 2013). These research findings indicate the large white oak overstory trees are all different in age because they were released from the understory as a result of small canopy gap disturbances caused periodically by fallen or dead overstory trees. This is further evidence indicating that SW is an old growth forest fragment (Copenheaver et al. 2013).

Another positive indicator of the health and resiliency of SW is the relatively high levels of regeneration and the high productivity of the stand (Daig Jr. et al. 2013). With the exception of the impacted areas (Figure 2.5), SW as a whole is generating 8,422 stems/acre of native seedlings and saplings (Daig Jr. et al. 2013). Regeneration densities for mature well-managed forests are typically 5,000 to 12,000 stems/acre (Ward et al. 2013). The regeneration rates occurring in SW are promising in light of the groups of people visiting the woods for educational and training activities, large amounts of people who commute daily through the woods, and the thousands of people who move through the woods during home football events. The informal trails and pathways have most certainly kept impacts limited, allowing regeneration within the forest to take place.

These levels of regeneration and productivity are noteworthy, and uncommon, for an urban old-growth forest remnant. Typically, urban patch understory vegetation is reduced in direct correlation to the percentage of residential area around them (Hamabata 1980). Simply put, they become increasingly degraded due to impacts from high numbers of the urban forest visitors. Copenheaver et al. (2013) analysis notes the positive condition of the forest, "SW contains an unusually high density of large white oak trees growing on a relatively high productivity site" (Copenheaver et al. 2013). The high levels of regeneration, as a significant contributing factor for the vigor and sustainability of the SW forest in conjunction with the high productivity of the stand, indicate the stand is an excellent candidate for restoration stewardship.

Old-Growthness

Several definitional approaches exist for the description of what constitutes an old-growth forest including ecological, stand/tree age, forest dynamics, social/cultural constructs, and economic descriptions. While there are discrepancies of what constitutes an old-growth forest, the merits of SW *old-growthness* (Mosseler et al. 2003) fit well within the parameters of most conceptual frame works that define old-growth forests. SW contains most of the features that describe old-growth forest characteristics (Table 2.2) (Figures 2.11 and 2.12).

A 2001 scientific symposium consisting of old-growth forest experts recognized that a "scientifically meaningful yet policy-relevant definition of *old-growth* presents some basic difficulties" and stated that these types of difficulties (i.e. definition of species) are common in biological sciences and cannot be avoided, stating: "the lack of an all-encompassing, consensual, and uniform definition" should not constrain research or be used as an excuse to avoid the importance of these rich and diverse forest ecosystems" (Mosseler et al. 2003). The symposium identified attributes of *old-growthness* for the purpose of indexing and defining old growth forests (Table 2.2). These features provide a scientifically supported basis for conceptual frameworks that may be used as descriptions of late successional (climax) arboreal ecosystems.

Table 2.2 **Features of late-successional, temperate-zone, old-growth forest types for consideration in developing an index of "old-growthness" and for defining old-growth forests (Mosseler et al. 2003).**

Structural features

- Uneven or multi-aged stand structure, or several identifiable age cohorts
- Average age of dominant species approaching half the maximum longevity for species (approximately 150+ years for most shade-tolerant trees)
- Some old trees at close to their maximum longevity (ages of 300+ years)
- Presence of standing dead and dying trees in various states of decay
- Fallen, coarse woody debris in various states of decay
- Natural regeneration of dominant tree species within canopy gaps or on decaying logs

Compositional features

- Long-lived, shade-tolerant tree species associations (e.g., sugar maple, American beech, yellow birch, red spruce, eastern hemlock, eastern white pine)

Process features

- Characterized by small-scale disturbances creating gaps in forest canopy
- A long natural rotation for catastrophic or stand-replacing disturbance (e.g., a period greater than the maximum longevity of the dominant tree species)
- Minimal evidence of human disturbance
- Final stages of stand development before a relatively steady state is reached

Figure 2.11 Photograph depicting typical structure and composition of "Stadium Woods" during the growing season

Figure 2.12 Photograph depicting typical structure and composition of "Stadium Woods" during the dormant season (photo credit, John Seiler)

In his comparison of social constructs and ecological frameworks, Thomas Spies suggests that social conceptual frameworks of old-growth forests may conjure images of a forest that has grown free of human disturbance and "now is a stand of massive towering trees with jumbles of large tree boles; deep shade pierced by shafts of sunlight; and dense patches of herbs, shrubs, and saplings that perhaps conceal rare species." He describes such forests as "awe-inspiring" and "biologically rich" and asserts that specific definitions have been developed to respond to old-growth management needs that are usually based on attributes of stand structure, composition, and age (Spies 2004). SW meets every one of the attributes of "old-growthness" (Mosseler et al. 2003) and is accurately defined as a white oak old-growth forest remnant located in an urban setting.

The urban location of the SW old-growth forest makes the stand truly exceptional. The accessibility of the stand within the heart of the community "caught between an expanding town and university – and overrun by a civil war – yet inexplicably left uncut is remarkable indeed" (Seiler 2012), because most eastern old-growth forests are only found in rugged terrain that was too difficult for logging (Seiler 2012). Old-growth experts have commented on the rarity and quality of SW old-growth white oaks. Neil Pederson from the tree ring laboratory at Columbia University on 1/25/2012 indicated by mail, "Because many, if not most, white oak forests near human settlements were cut, you might have a truly rare piece of property" as he compared SW to the Murphy Tract in West Virginia. The Murphy Tract has 21 white oaks over 340 years old. SW may have many more trees in excess of 340 years, with over 56 trees over 36 inches in diameter. In a similar 1/25/2012 correspondence, the Director of the Native Tree Society's Live Oaks Project, Lawrence Tucei, noted, "There are many White Oaks in North America in the 50-70-year-old range, but the 200-500-year-old trees are extremely rare" (Seiler 2012).

2.3.4 Wildlife Habitat in the Forest

The foremost conclusions of the Biohabitats site assessment findings are that SW has significant ecological value and contains a wealth of plant species and wildlife diversity, especially birds. The study also determined that the value of SW may be enhanced by the control of invasive plant species. Invasive plant species threaten various native animal species by altering habitat structure, disrupting native plant community compositions, and in some cases, by completely overrunning entire ecosystems (Pimentel et al. 2005). Invasive plant species invasion risks are expanding greatly (Bradley et al. 2010). Populations of animals associated with specific trees and shrubs are being displaced by invasive plant species (US Congress 1993). Safeguarding the native old-growth structure and composition of SW by controlling invasive plants and other ecosystem pressures will maintain animal habitat and diversity and uphold the ecological value of the woods.

Since SW contains large numbers of old trees (59 white oaks over 300 years in age) within an old-growth forest structure, it has a very high value for cavity dwelling wildlife (Biohabitats 2012; Randolph et al. 2012). Mixed mesophytic forests are some of the most biologically diverse ecosystems in temperate regions of the world, supporting rich mammalian, bird, amphibians, and reptile communities that are rare in other forest types (Hinkle et al. 1993).

Native plants in SW such as grape (*Vitis spp.*), cherry (*Prunis spp.*), dogwood (*Cornus spp.*), oak (*Quercus spp.*), pine (*Pinus spp.*), maple (*Acer spp.*), raspberry (*Rubus spp.*) poison ivy (*Toxicodendron radicans*), Virginia creeper (*Parthenocissus quinquefolia*), greenbriar (*Smilax rotundifolia*), and many others are important food sources for wildlife. A habitat limitation for SW includes a lack of a permanent water feature (Biohabitats 2012). The additional complexity of the old-growth structure (woody debris, standing dead trees, pits, mounds) provides additional habitat organizations and further increases wildlife and plant diversity (Gagnon 2016). Leaf litter contributes to the food chain (American Planning Association 2009) and decaying logs, snags, pits, and mounds are used by animals for nesting, denning, prey avoidance, travel, perching, and foraging (Loeb 1999).

The occurrence of standing dead trees in SW is particularly important for wildlife habitat. Snags (standing dead and dying trees) provide crucial habitats that are used by wildlife for a wide variety of behavioral and physiological needs including; excavating, reproducing, grooming, viewing, feeding, escaping predation, nesting, rearing, and more. Large slow decaying standing dead trees over 50 feet tall and greater than 15 inches in diameter are considered to be most valuable for wildlife (Carmichael Jr. and Guynn Jr. 1983; Pokorny et al. 2003). Hollow trunks, excavated cavities, and roosting cracks/slits are made available by snags to provide habitat for a variety of birds, mammals, reptiles, amphibians, and invertebrates (Appendix K) (Burt and Grossenheider 1976; Davis 1983). These animals are essential to the intricate functions of the ecosystem as a whole (Bury et al. 1980; Davis 1983).

Snags are vital foraging and nesting sites for animal species, especially birds (Hunter Jr. 1990). Many bird species are highly dependent upon cavities and dead trees for nesting, roosting, and feeding (Martin and Eadie 1999). The decline of eastern United States primeval forests and forests management practices that eliminate snags have resulted in the decline of bird species that play ecologically important roles in forests, such as insect control and seed dispersal (Scott et al. 1977; Thomas et al. 1975). Population densities of cavity nesting birds are associated with snag densities. Snags are essential for the provision of habitat for many species of primary and secondary cavity nesting birds including chickadees, woodpeckers, flickers, sapsuckers, owls, hawks, ducks, and mergansers (Thomas et al. 1975). Snags need to be retained in SW in the highest densities possible in order to ensure an abundance of habitat opportunities that will continue to support a diversity of birds and other wildlife (Appendix K).

Habitat connectivity, a vital element of landscape structure, is considered to be one of the most important factors for maintaining biological diversity (Taylor et al. 1993). Connectivity is an important consideration for wildlife in SW because SW exists as an isolated forest fragment. The effects of urbanization, such as fragmentation and isolation, changes connectivity patterns of landscapes and can disrupt ecological processes including dispersal and migration (Weber et al. 1999) and has implications in its functionality (food webs, gene flow, pathogen dispersal, yeast networks, etc.) as a node with specific connectivity link patterns within a larger biological network (Cloern 2007; Clucas and Marzluff 2011; Coulon et al. 2004; Rhodes et al. 2006) (Section 2.3.6). Although isolated, SW provides connectivity functionalities as an ecosystem/habitat island and serves as a stepping stone among other patch habitats. SW functions as part of a migration corridor providing a stopping point for migratory birds and other animals, which disperse seeds between Brush, Price, Paris, and Hightop Mountains (Biohabitats 2012) and other forest patches in the NRV. Land animals such as insects, salamanders, turtles, and small mammals could benefit if SW were linked to Huckleberry Trail, which serves as a corridor and connects with other natural habitat patches in the NRV.

Potential Wildlife Concerns

In a few instances, the occurrence of animals in SW could produce problems or concerns. These include cases of wild animals, such as deer, becoming overabundant; domestic animals, such as cats, taking refuge in the woods and becoming feral; and unintended consequences produced by humans feeding animals. Currently, none of these concerns exists in SW. Awareness and monitoring for these potentialities can proactively address situations before they become issues.

In the absence of population control, white-tailed deer (*Odocoileus virginianus*) may become overabundant and cause vegetation damage to forests and in some cases alter entire forest understories and threaten forest ecosystems (Garrott et al. 1993; Rooney 2001). White-tailed deer can be especially harmful to native oak forests (Steckel et al. 2014). This has been especially true in Pennsylvania and other areas in the northeast where the native oak forest have been impacted by deer overabundance for decades (Rawinski and Square 2008). White-tailed deer prefer white oak, and the highest risks of tree species loss may be in forest fragments and islands (Strole and Anderson 1992). White-tailed deer populations have been found to have effects on bird populations with bird populations decreasing as deer population densities increase

(DeCalesta 1994; McShea and Rappole 2000). White-tailed deer have the potential to damage the SW ecosystem and should be monitored and controlled if they are causing damage.

The proximity of SW to residential neighborhoods in the Town of Blacksburg creates probabilities of domestic animals, such a cats (*Felis catus*), escaping into the woods and propagating feral colonies. There have been problems in the past with feral cat colonies occurring in SW. At one time these colonies were bolstered by human feeding of cats in the woods. Cats that are feral can reach populations that exceed the natural carrying capacity of an ecosystem and hyperpredation can occur where predation rates on birds and other animals can become severe (Baker et al. 2005). Feral cats can vector disease to other wildlife and can negatively impact human health (Jessup 2004). Cats have been found to prey on wildlife even when they are well fed by humans (Warner 1985). Cats in urban areas have been found to exhibit high predation rates on birds and small mammals (Baker et al. 2005) and have been found to have negative effects in natural land area ecosystem by producing unsustainable predation rates on some bird populations, especially shrub-breeding species, to produce extinctions that have resulted in cascading effects on food chains (Crooks and Soulé 1999). These negative effects can be particularly severe for habitat island fragments, such as SW (Dickman 1996; Loss et al. 2013; Pimentel et al. 2002).

While benefits of feeding wildlife may exist for tourism and commerce, there are few biological justifications for the feeding of wild animals, and this is particularly true for isolated patches such as SW. The feeding of wild animals can have adverse effects on the health of ecosystems, the animals being fed, and for humans (Orams 2002). Feeding wild animals can alter wildlife ecologies (Robb et al. 2008), create alterations to migration patterns, alter community compositions that favor more aggressive animals, and cause intra and inter-species aggressions (Orams 2002). Feeding of wild animals can alter population levels and behaviors while often failing to improve animal survival rates (Boutin 1990; Gilbert and Krebs 1981; Robb et al. 2008; Sullivan 1990). Feeding can cause animal habituation to humans and create dependency (Orell 1989) and can also create conditions for animal diseases (Fischer et al. 1997), injury, and early death (Orams 2002). The feeding of wildlife can be dangerous for both humans and wildlife because humans can be vulnerable to injury and animals can be at risk as nuisances or by exposure to human or human infrastructures (Orams 2002).

2.3.5 Invasive Plant Species in the Forest

The National Invasive Species Council defines "*invasive species* as *non-native* (alien) to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm or harm to human health" (National Invasive Species Council 2006). The United States Department of Agriculture (USDA) describes invasive plant species (IPS) as having "the ability to thrive and spread aggressively outside its native range" (National Invasive Species Information Center 2015). IPS represent more than an unsightly nuisance to the SW urban forest; they have the capacity to have very real negative ecological impacts:

> Invasive exotic species have been shown to alter, disrupt, and degrade many ecosystem services throughout the eastern United States and across the world. By invading intact forests, riparian zones, or disturbed habitats, they have the ability to alter the environmental and biological conditions around them. Often leading to further invasions" (Devine and Fei 2011).

The SW IPS that have been shown to have negative impacts on regeneration include tree of heaven (*Ailanthus altissima* (Mill.) Swingle), garlic mustard (*Alliaria petiolata* (Bieb.) Cavara and Grande), autumn-olive (*Elaeagnus umbellata* Thumb.), privet (*Ligustrum spp*.), and bush honeysuckle (*Lonicera spp.*). All but privet have also been shown to impact nutrient dynamics (Devine and Fei 2011). IPS pose a direct threat to the very long-term existence of the SW forest:

> Their explosive populations can result in a number of ecosystem disruptions such as habitat loss, reduction in quantity and quality of food sources and nesting sites, altered community succession, changes in fire and hydrologic regimes, altered soil microbiology and decomposition processes, and plant-animal and host-plant relationships. …Left unchecked, these populations (IPS) will eventually create an environment at this site that does not support the type of vision expressed by the campus stakeholders (Biohabitats 2012).

There is little doubt that IPS can disrupt forest regeneration, and reduce the integrity of forests' ecosystem services (Devine and Fei 2011). The reduction of the ecological integrity of the SW forest by IPS "threatens to disrupt the long-term health and viability of the woodland" (Biohabitats 2012). Some of the major IPS affecting the SW patch forest was documented in 2102 (Biohabitats 2012); however, there are additional IPS occurring in the woods (Table 2.3).

In particular locations, the IPS growing in SW represent a threat to the integrity of the forest's long term viability. All IPS that are known to be growing in SW may be found on the Virginia Department of Conservation and Recreation *2015, Invasive Plant Species List* (Appendix J, List A) (Virginia Department of Conservation and Recreation 2015). All but four of the SW IPS are also included on *Severe Threat List* of the Kentucky Exotic Pest Plant Council (Appendix: J, List B) (Kentucky Exotic Pest Plant Council 2013).

Table 2.3 Major invasive plant species occurring in Virginia Tech's "Stadium Woods" modified from (Biohabitats 2012).

Documented in the 2012 *Forest Ecological Assessment* (Biohabitats 2012):

- Asiatic/Oriental Bittersweet (*Celastrus orbiculatus* Thumb.)
- Burning Bush (*Euonymus alatus* (Thunb.) Siebold)
- Bush /Amur Honeysuckle (*Lonicera maackii* (Rupr.) Herder)
- English Ivy (*Hedera helix* L.)
- Japanese Barberry (*Berberis thunbergii* DC.)
- Japanese Honeysuckle (*Lonicera japonica* Thunb.)
- Multiflora Rose (*Rosa multiflora* Thunb.)
- Chinese Privet (*Ligustrum sinense* Lour.)

Also occurring in the woods:

- Autumn Olive (*Elaeagnus umbellata* Thumb.)
- Garlic Mustard (*Alliaria petiolata* (Bieb.) Cavara and Grande)
- Little Leaf Linden (*Tillia cordata* L.)
- Norway Maple (*Acer platanoides* L.)
- Tree of Heaven (*Ailanthus altissima* (Mill.) Swingle)
- Wintercreeper (*Euonymus fortunei* (Turcz.) Hand.-Maz.)

The IPS growing in SW are a significant concern for most SW stakeholders and, left unchecked, could threaten the long-term ecological viability of the SW woodland (Biohabitats 2012). Successful control of the IPS in SW will require ongoing deployments of control methods. This must be balanced in accord with an understanding of the effectiveness, timing, and dose for the application of proven control measures in order to maintain the integrity and viability of the SW ecosystem. In accordance of an adaptive management approach, these efforts will require an ongoing assessment of the how well that balance is being fulfilled (Lloyd 1997; Loeb 2008; Wiseman 2007). *The Virginia Tech 2012 Forest Ecology Assessment* makes very direct recommendations on page 12 of the report:

> Invasive exotics will require a systematic, yet flexible, adaptive management approach. It is critical that an ecosystem-based approach be utilized in suppressing invasive plant activity, as a 'see-and-spray weed-killing mentality is likely to yield poor results and non-target plant mortality. It is also advised that areas of treatment be prioritized and phased as treating the entire site in one application could cause a dramatic negative visual impact (Biohabitats 2012).

The control of IPS in SW represents significant challenges for the woods that are likely to remain for years into the foreseeable future. However, community volunteers (e.g. New River Valley Master Naturalists), undergraduates, and a paid undergraduate worker from the CNRE have demonstrated their commitment to maintaining a healthy ecosystem in SW by selective removal of IPS. These efforts are helping to reduce the impacts of IPS in SW. Additionally, past Virginia Tech Corps of Cadets cleanup efforts removed IPS and debris in the north section of the woods. Since a general or sweeping approach toward the control of the IPS in SW would likely cause harm to the integrity of the ecosystem by damaging or killing native beneficial plants or disrupting the forest's capacity for regeneration (Biohabitats 2012), a pest management approach that utilizes adaptive strategies and considers the benefits and drawbacks over a range of evasive control methods will have a much better chance of yielding satisfactory results.

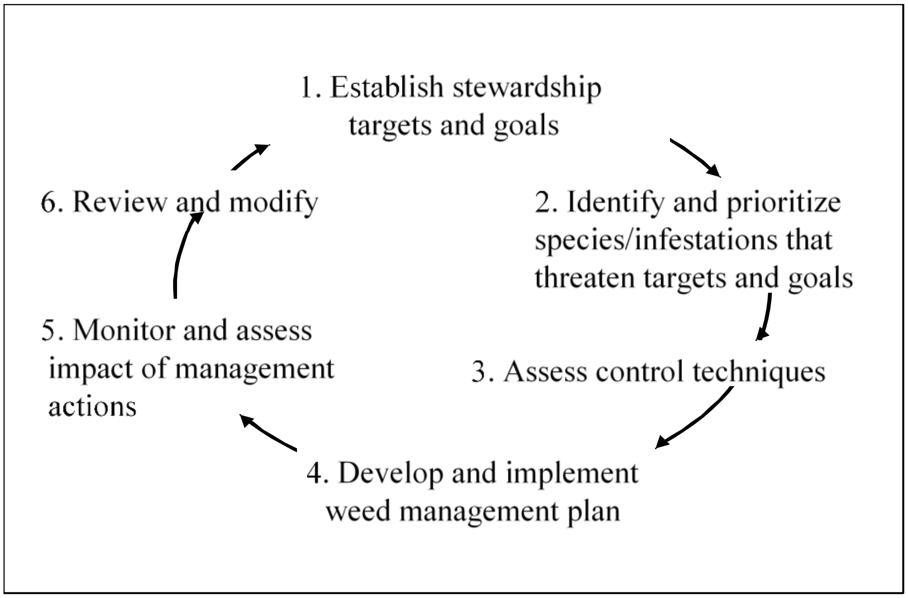
SW is currently exhibiting symptoms of a *distress syndrome* induced by IPS, which may limit the ecological health of SW. IPS may be effecting the SW forest layers by altering soil pH and chemical compositions, changing the characteristics of the forest floor, choking out the understory, and preventing native tree regeneration (Devine and Fei 2011). An effective strategy for the control IPS in SW will assess the problem from an ecological perspective. The ecological health of a forest may be measured by analysis of the corresponding forest layers. Anything that significantly disrupts one or more layers may disrupt the long-term viability of the forest (Section 2.3.3 and 2.3.6). For example, IPS alteration of soil composition may prevent desirable trees from sprouting, thus blocking the development of a vigorous understory and canopy. This may cause eventual forest senescence and increase the IPS populations (Devine and Fei 2011; Levine et al. 2003).

An ecosystem may be considered healthy and free from *distress syndrome* if it is stable and sustainable (Costanza 1992). Since the stewardship priority for SW is restoration and IPS are constant and pervasive threats to old-growth urban forest patches (Loeb 2008), any occurrence of IPS that limits the ability of any SW forest layer to properly function should trigger an *action threshold* (Wiseman 2007) and elicit an *appropriate response process*. **Dealing effectively with the IPS threat may be the single most important activity that will provide a successful outcome for the SW stewardship priority objective of restoration.**

Adaptive strategies are necessary for the successful control of IPS because tactics will need to be modified in IPS removal procedures for years (Loeb et al. 2010; Vidra et al. 2007). The control of IPS in SW will require vigilant efforts over long periods of time, along with the ability to adapt to ongoing sets of surprises and challenges caused by changing dynamics, setbacks, and the persistence of the IPS threat (Tu et al. 2001) (Figure 2.13).

2.3.6 Forest Ecosystem Considerations

The composition of forests systems changes over time until, in the absence of any large disturbance, the ecosystem reaches a state of long-term equilibrium (Litman 2007). Evidence suggests that the SW ecosystem has been living and evolving in a state of long-term equilibrium for hundreds or even thousands of years, as indicated by the old-growth structural composition and asynchronous ages of the late successional white oak dominated overstory (Biohabitats 2012; Copenheaver et al. 2013; Seiler 2012). All forest systems are subject to change and the structure and composition of SW, over time, is vulnerable to undesirable changes (not reflective of stewardship priority of restoration). If no human impacts existed, including invasive plants, invasive diseases, and insects, SW would be self-sustaining long into the future until some natural disruption, such as fire, or weather, etc., changed its composition. However, **the very structure and composition of SW is now inextricably linked to the impacts and/or interventions of humans.**



<u>Figure 2.13</u> Adaptive Weed (invasive plant species) Management Approach (Tu et al. 2001)

Three examples will illuminate this point. Invasive plant species brought as ornamentals to the area are now negatively effecting the woods. Left alone, the invasive plants will alter soil compositions and choke out the native understory layers. These invasive plant processes will stop regeneration in the understory and midstory layers and the long-term viability of the forest will be in jeopardy. Perhaps an invasive insect or disease, such as was the case with the chestnut blight, will destroy an important species within the ecosystem. This event would change the composition of the forest and cause it, over time to reach a new state of equilibrium. A third example reflects how a deer population in the woods could cause the predominantly white oak overstory to become red maple dominant (Steckel et al. 2014). An adaptive management process (Sections 1.4 and 3.2), especially those informed through a combination of management experience and scientific study, will be required over the long-term in order to retain SW as a native white oak old-growth forest patch.

Ecological Assessment of the Forest

The 2012 Biohabitats in-house *Forest Condition Scoring* matrices characterizes the ecological structure, diversity, and overall quality of the woods and offers useful information for SW stewardship related restoration objectives. It also includes valuable insights about the associated SW north and south sections (Section 2.3.1) (Table 2.4) (Biohabitats 2012) provides information about how stewardship efforts may increase the overall condition score of the stand, such as removing invasive species and facilitating eventual improvements in the understory and canopy cover layers. Additionally, the forest condition score highlights areas where stewardship

Table 2.4 Forest condition scoring (FCS) matrix assessment from $1/10^{th}$ acre fixed radius plots inventoried in "Stadium Woods". Negative attributes are scored with negative values with -5 as the worst condition. Positive attributes have positive values with 5 being the most beneficial condition (Biohabitats 2012), modified to correct errors

Evaluation Criterion	Range	North Stand	South Stand	Comments
No of Vegetative Species	1 to 5	3	3	Lower diversity is typical for old-growth (O.G). "SW" diversity is high for an O.G. forest
Successional Serial State	1 to 5	5	5	"SW" fragment is O.G. indicating a late successional (climax) stage
Canopy Cover	1 to 5	5	5	Canopy cover of "SW" greater than 90% and consists of native species. Canopy Closure allows natives to outcompete invasive plants
Understory	1 to 5	3	5	Lack of understory layer in portions of north section diminishes understory layer score in north section
Herbaceous	1 to 5	3	1	North section has more herbaceous plants growing due to the availability of more light. South section has less herbaceous plants due to stadium blocking sunlight to forest floor
Native Regeneration	0 to 5	5	5	Substantial tree regeneration is taking place in "SW"
Significant Trees	1 to 5	5	5	Large O.G. trees provide more ecosystem services, provide more habitat, and improve ecosystem processes in the stand
Forest Interior	0 to 5	0	0	The size of the "SW" fragment disqualifies it from having the existence of a forest interior
Invasive Canopy	-5 to -1	-1	-1	Receives best possible score of -1 due to dominance of native overstory species
Invasive Understory	-5 to -1	-5	-3	Prevalence of invasive species in "SW" reduced forest condition scores
Invasive Herbaceous	-5 to -1	-5	-1	Presence of invasive species in herbaceous layers reduced forest condition scores
Disease/Infestation	0 to 5	5	5	**The patch nature of the "SW" forest is an indication that "SW" is isolated from other natural land areas. This isolation limits the migration of plants and animals to and from the stand and decreases its genetic diversity.**
Proximity to other forests	1 to 5	1	1	
Proximity to wetland	1 to 5	1	1	
Proximity to Rare Threatened or Endangered species	1 to 5	1	1	
Proximity-erosive soil	1 to 5	1	1	
Proximity-hydric soil	1 to 5	1	1	
Proximity-floodplain	1 to 5	1	1	
Score		**29**	**35**	**Total FCS Scoring Range = -3 to 67: The "SW" stand average of 32 ranks in the middle of overall scoring range to indicate moderate ecosystem functionality**

limitations exist, including the small size of the patch, which all but definitionally rejects the existence of a forest interior, and its isolation from other natural land areas. Even with these limitations, the *Forest Ecological Assessment* provides awareness about how the large man-made Virginia Tech structures (Lane Stadium and the Indoor Athletics Practice Facility) located directly to the west side of the woods are mitigating the edge effect and providing a function that mimics interior forest conditions. Also, future opportunities for connection could help to reduce the isolated condition of the woods. For example, if a connection to a corridor, such as the Huckleberry Trail could be made, then some small scale plant and animal migrations could occur. Even with a lack of connection to other natural land areas through corridors, SW "could provide critical linkage between Paris and Hightop Mountain to the east and Brush Mountain to the west" (Biohabitats 2012) for airborne fauna, such as birds, bats, and insects, because few other patches exist that may facilitate the connection (Biohabitats 2012). The 2012 Biohabitats assessment states, "…the abundance of large white oak and black oak trees within the woods as well as the diverse age class structure are the most beneficial factors of this forested area from a habitat and ecosystem function and process perspective."

Forest Fragmentation: Isolation and Edge Effects

Two main characteristics of fragmentation include isolation of forest patches from other similar natural land areas and alterations to the microclimate within the remnant. A study by Dunn and Heneghan (2011) found that native plant species richness declined with smaller isolated patch sizes and isolation of forest stands within urban settings. Another study, however, found no decline in native plant diversity or forest structure in urban forest fragments in the

Sierra Nevada of California, but did record reductions in density and decay stages of snags and fallen logs. It suggested that non-native tree species could decrease and cover could decline in the future as disturbances increased with urban development (Heckmann et al. 2008).

In addition, isolation from other forested areas may affect or segregate the gene flow among animal species that lack the ability to migrate to other natural areas (Clucas and Marzluff 2011) (Section 2.3.4). Patches with less connectivity or greater distances between patches may have lower species variety and be inhabited by organisms that have greater dispersal abilities (Bierwagen 2007). Since SW already exists as an isolated forest patch surrounded by urban development, the only stewardship option is to keep future opportunities for connectivity in mind.

Connectivity is a central objective in the design of green networks (Colding 2011). Connecting an urban forest remnant to a network of other natural land areas allows improved species dispersal and better support of metapopulational dynamics (Opdam et al. 2006). The employment of multiple functions provides added value for the greenspace and provides a wider range of community support. When multiplicity is combined with connectivity and integrated with other urban structures, such as trails, the green infrastructure is elevated to the level of the built infrastructure, thus enhancing benefits for the community and the connected natural land areas.

Fragmented patches are influenced by multiple internal and external factors. The degree by which the stand is influenced, either internally or externally, depends upon factors including size, shape, and position relative to other aspects. The smaller a forest remnant, the more influence external factors of the surrounding environment are likely to have upon the fragment (Saunders et al. 1991). Microclimate alterations and other detrimental consequence of forest fragmentation are often referred to as *edge effects* and include abiotic, direct biological, and indirect biological effects (Murcia 1995).

Edge effects are boundaries or gradients of changes in microclimate, species composition, structure, and flows of energy and nutrients between two distinct biological communities or landscape elements (Bannerman 1998; Murcia 1995). Most edge effects occur within 50 meters of a forest's edge (Matlack 1994; Murcia 1995). Even though almost the entire SW patch technically exists within the edge zone, the woods demonstrate characteristics more comparable to a deep interior region of a forest, especially in the southern woods. This is due, in part, to the shading effect Lane Stadium has on the woods, which helps to moderate the edge effects on the woods by blocking direct sunlight to the canopy floor and reducing wind-related canopy loss on the western side of the woods (Biohabitats 2012; Murcia 1995). The newly constructed Indoor Athletics Practice Facility, in like fashion, will most likely benefit the northern stand over a period of years, by reducing the competitive advantage of sun-loving invasives, reducing solar radiation and wind-related moisture loss, and slowing canopy breakage on edge trees. Edge effect studies in small urban forest fragments have shown that structure (open or closed) and composition (conifer or deciduous) influence configurations of understory vegetation (Godefroid and Koedam 2003; Hamberg et al. 2009). Addressing the edge effects on SW should be a priority.

2.4 Safety, Security, and Risk Management

Urban forests, as a part of the green infrastructure, represent an integral component of a community's physical environment and contribute to an increased quality of life (Pokorny et al. 2003). Urban trees provide an abundance of benefits to urban inhabitants including ecosystem services and wildlife habitat as well as social economic, psychological, medical, and aesthetic advantages. Urban trees also involve ecosystem disservices including maintenance costs and risks (Burden 2008; Gorman 2004; Lohr et al. 2004; Low and Gleeson 2005; Lyytimäki and Sipilä 2009; Roy et al. 2012; Tyrväinen et al. 2005). When properly managed, the benefits of mature urban trees consistently outweigh costs (McPherson 1994) and provide a vigorous return on the investment that is required to sustain the green infrastructure assets (Hauer et al. 2015; Matheny and Clark 2008).

The occurrence of trees causing harm to people is very rare, yet the potential for severe consequences do exist in urban settings, such as SW, that are frequented by people. Strategies and BMPs provide frameworks that allow risks to be both managed at acceptable levels and also to successfully facilitate the many benefits provided by large mature trees (Dunster et al. 2013; Mortimer and Kane 2004; Pokorny et al. 2003). The development of a tree risk management plan (Pokorny et al. 2003) is a sound way to balance tree benefits, costs, and risks while upholding the SW stewardship priority of restoration.

SW contains physical components and facilitates activities that may contribute to higher levels of risks or perceived risks for its visitors. Physical components within SW that express potential risks include the presence of very large trees, woody debris, pits and mounds, spiny or toxic plants, man-made debris (concrete and metal scraps), and areas of restricted visibility. Activities, such as training, classes and labs, as well as other factors, increase tree target exposure durations, including daily commuting and scheduled events, such as home football games, which cause large amounts of people, and sometimes vehicles to move through or near the woods. These factors require a greater awareness of the possible risks within SW and necessitate more diligence in order to maintain safety and mitigate hazard potentials.

2.4.1 Increasing Expectations to Maintain Tree Safety

Universities continue to transition away from the tort liability insularity era, prior to the 1960s, through periods of ever-increasing duty of care requirements. Today's college students and parents expect greater levels of safety on college campuses than ever before. Courts have established that colleges and universities are landowners and have a duty of care to keep their campuses reasonably safe for their "invitees" in areas including property maintenance, housing, and activities where supervision and control are provided (Peters 2006). Furthermore, dangers posed by structurally-deficient trees and tree parts in the United States have been undergoing a legal evolution over the past 40 years that raises the stakes for tree owners where actions or failures to act can now more easily lead to legal liabilities. Moreover, rulings have evolved to require greater levels of responsibility for urban tree owners to maintain safety (Mortimer and Kane 2004). Government agency liabilities vary according to regulations and laws under the jurisdictions in which they serve. Additionally, case outcomes for damages can vary widely and outcomes can be unpredictable (Bloch 2007; Mortimer and Kane 2004). Questions of tort liability and tree risk management involve complex legal considerations and an attorney should always be consulted for decisive interpretations of liability questions (Bloch 2007).

Tree owners have a *duty of care* (Stead 2008) to "take reasonable care to avoid acts or omissions which you can reasonably foresee would be likely to injure your neighbor" (Atkin 1932). *Reasonable care*, according to Dunster et al. (2013) is defined as "the degree of care that a reasonably prudent person should exercise in the same or similar circumstances." This means that tree owners hold some degree of responsibility to ensure a reasonable level of safety for people and property near trees under their care (Dunster et al. 2013) and that obligation is related to what other people in similar circumstances are doing. Professional land managers have been recognized as having expertise in spotting tree hazards. Furthermore, maintaining ignorance of the existence of risks is not a defense against negligence (Anderson and Eaton 1986). Failure to exercise a duty of care, by not responding to a serious tree defect the owner has observed or could have observed, could result in a breach of a tree owner's duty (Mortimer and Kane 2004). This is because the *standard of care* is based upon expectations, in this case of land management professionals, about whether reasonable care has been fulfilled in the exercise of one's duty of care (Dunster et al. 2013). A guiding question one may ask is whether other professionals in similar circumstances are inspecting or hiring someone to inspect their trees.

Specific standards of care most often reflect the contemporary practices of peer group tree owners, organizations, and professionals and are usually articulated in standards and BMPs.

The prevailing standard of care is the bar against which responsible parties will be measured. Standards of care are generally based upon one's qualifications and expertise to assess any foreseeable harm or one's ability to hire the services of a professional who retains said qualifications (Stead 2008). Currently in the United States, the (ISA) Tree Risk Assessment Qualification (TRAQ) for arborists is the prerequisite for professionally delivering the prevailing standard of care. Large organizations, with written procedural guidelines, have more obligations to utilize professionals in the achievement of their standards of care in order to fulfill their obligations and thus perform their duty of care (Stead 2008). Additionally, professional arborists and tree risk assessors can be held to a higher standard for the recognition of hazards because they are considered to be experts (Dunster et al. 2013). *Negligence* results when a duty to prevent harm exists and when a failure to exercise *reasonable care* results in *harm* (Mortimer and Kane 2004). Liability (tort liability) is the legal responsibility for the consequences of harm as a result of negligence (Garner and Black 2004). As long as individuals, organizations, or tree care professionals apply current generally accepted standards of care, by taking reasonable steps in keeping their areas of responsibility safe, then their duty of care has been met (Dunster et al. 2013).

2.4.2 Forested Areas Require Heightened Vigilance

Areas such as SW are considered to be high hazard zones due to their high-risk tree characteristics, such as high density of large diameter, tall old-growth trees (Pokorny et al. 2003). SW contains risks that are common in any natural forest setting. Examples include standing dead trees, large dead tree branches, dead tree tops, trees with poor architecture, decayed trees, root problems, and leaning trees. The existence of an area characterized by higher risk levels warrants higher frequencies of tree risk assessments (2 inspections per year and after severe weather) (Mortimer and Kane 2004). A prevailing practice (standard) in tree risk assessment is risk communication (Dunster 2013).

Tree Law Cases in the USA, Second Edition indicates that visitors have a shared responsibility to exercise reasonable judgement and keep themselves safe by avoiding unsafe situations in and around natural land areas. This has been indicated by previous tree law cases that have ruled that plaintiffs injured by trees may also be negligent if they place themselves or their property under trees they know to be dangerous (Bloch 2007). When land owners and visitors both share responsibility for safety, well-being and security are enhanced.

2.5 Ecosystem Services of the Forest

Ecosystem services underlie all human activities and are widely defined as "the benefits human populations derive, directly or indirectly, from ecosystems (De Groot et al. 2002; Sukhdev et al. 2015) and include "all ecosystem functions and processes from which people benefit in economic terms or relating to their quality of life (Breuste et al. 2013)" (Table 2.5). The restoration of ecosystems is regarded as a key approach for increasing the biodiversity and ecosystem services. Restoration activities that consider narrow sets of ecosystem services may have negative impacts on biodiversity or the provision of other services. Conflicts may arise if restoration efforts become focused on a narrow range of services (Bullock et al. 2011). To minimize the chance of conflicts, a participatory process that addresses the trade-offs that

__Table 2.5__ **Classification of urban ecosystem services** (Alcamo et al. 2003; Niemelä et al. 2011)

- **Provisioning Services** – tangible goods which ecosystems provide directly. This could be fresh water for consumption or production; food for consumption; forest and crop plantations for energy and fiber.
- **Cultural services** – more intangible experiences which are offered or enabled by ecosystems: Landscape, uplands, community forests, and cultural identity.
- **Regulating services** – benefits from ecosystems concerning regulation of natural processes: Wetlands, dunes, and floodplains for flood and flow regulation; vegetative cover for erosion regulation; peat bogs for carbon sequestration, are all examples of the regulation functions, which urban development ignores at its peril.
- **Supporting services** – these underpin the provision of other ecosystem services. Soil formation is essential to other services; wetlands, aquifers, and riparian habitats for water cycling; soil for nutrient cycling.

inevitably exists between economic priorities, social concerns, and ecological considerations need to occur (Bullock et al. 2011; Mansourian et al. 2005). Long-term benefits and socio-cultural values are rarely factored into cost-benefit analysis yet warrant consideration (Farber et al. 2006). A measured utilization of natural resources considers ecosystem quality and will provide multiple services to a broad range of stakeholder interests (Bullock et al. 2011; Mansourian et al. 2005). Although a complete cost-benefit analysis is not taking place for SW, this concept has relevance for the forest. A thoughtful stewardship process will consider and balance the needs of a wide range of stakeholders as well as the high quality of the ecosystem.

2.5.1 Description of the Forest's Ecosystem Services

Towns and cities are dependent upon ecosystems and the services and functions they provide, which improve the conditions of life including health, security, positive social relationships, and human well-being (Gómez-Baggethun and Barton 2013). The SW forest delivers a wealth of ecosystem services for Virginia Tech and the surrounding community (Table 2.6). Some ecosystem services have been measured using an urban tree canopy cover analysis (Appendix L) to estimate pollution and carbon capture values based on the tree canopy coverage area of SW. The tree canopy coverage of SW equals 8% of the total canopy coverage area on the central campus of Virginia Tech (Appendix L). On an annual basis, SW sequesters 59.82 tons of carbon dioxide valued at $2,164.29, captures 164.18 pounds of particulate matter over 2.5 microns worth $512.76, and captures 29.55 pounds of particulate matter under 2.5 microns valued at $1,587.45. In addition, every year, SW removes 36.81 pounds of sulfur dioxide valued

<u>Table 2.6</u> Important urban ecosystem services and underlying ecosystem functions (Gómez-Baggethun and Barton 2013)

Functions and components	Ecosystem service	Examples	Examples of indicators/proxies	References
Energy conversion into edible plants through photosynthesis	Food supply	Vegetables produced by urban allotments and peri-urban areas	Production of food (tons yr^{-1})	Altieri et al. (1999)
Percolation and regulation of runoff and river discharge	Water flow regulation and runoff mitigation	Soil and vegetation percolate water during heavy and/or prolonged precipitation events	Soil infiltration capacity; % sealed relative to permeable surface (ha)	Villarreal and Bengtsson (2005)
Photosynthesis, shading, and evapotranspiration	Urban temperature regulation	Trees and other urban vegetation provide shade, create humidity and block wind	Leaf Area Index; Temperature decrease by tree cover×m^2 of plot trees cover (°C)	Bolund and Hunhammar (1999)
Absorption of sound waves by vegetation and water	Noise reduction	Absorption of sound waves by vegetation barriers, specially thick vegetation	Leaf area (m^2) and distance to roads (m); noise reduction dB(A)/ vegetation unit (m)	Aylor (1972); Ishii (1994); Kragh (1981)
Filtering and fixation of gases and particulate matter	Air purification	Removal and fixation of pollutants by urban vegetation in leaves, stems and roots	O_3, SO_2, NO_2, CO, and PM_{10} µm removal (tons yr^{-1}) multiplied by tree cover (m^2)	Chaparro and Terradas (2009)
Physical barrier and absorption on kinetic energy	Moderation of environmental extremes	Storm, floods, and wave buffering by vegetation barriers; heat absorption during severe heat waves	Cover density of vegetation barriers separating built areas from the sea	Danielsen et al. (2005); Costanza et al. (2006b)
Removal or breakdown of xenic nutrients	Waste treatment	Effluent filtering and nutrient fixation by urban wetlands	P, K, Mg and Ca in $mgkg^{-1}$ compared to given soil/water quality standards	Vauramo and Setälä (2011)
Carbon sequestration and fixation in photosynthesis	Climate regulation	Carbon sequestration and storage by the biomass of urban shrubs and threes	CO_2 sequestration by trees (carbon multiplied by 3.67 to convert to CO_2)	Nowak (1994b); McPherson (1998)
Movement of floral gametes by biota	Pollination and seed dispersal	Urban ecosystem provide habitat for birds, insects, and pollinators	Species diversity and abundance of birds and bumble bees	Andersson et al. (2007)
Ecosystems with recreational and educational values	Recreation and cognitive development	Urban parks provide multiple opportunities for recreation, meditation, and pedagogy	Surface of green public spaces (ha)/inhabitant (or every 1000 inhabitants)	Chiesura (2004)
Habitat provision for animal species	Animal sighting	Urban green space provides habitat for birds and other animals people like watching	Abundance of birds, butterflies and other animals valued for their aesthetic attributes	Blair (1996); Blair and Launer (1997)

at $2.45, 578.46 pounds of ozone worth $748.72, 74.88 pounds of nitrogen dioxide valued at $16.30, and 13.56 pounds of carbon monoxide worth $9.01. The total carbon dioxide and pollution sequestration equal $5,020.98 annually (Appendix L). SW also provides a significant water retention, percolation, and filtration function that provides a significant economic benefit for Virginia Tech (Figure 2.14).

These ecosystem services are but a fraction of the monetary value provided by SW, which includes: *provisioning, cultural, regulating,* and *supporting services* (Table 2.5). Ecosystem services are difficult to quantify, yet still provide significant economic worth. For instance, *Provisioning services* may be included if the SW remnant is recognized as exhibiting educational value that directly delivers income to Virginia Tech employees in the form of jobs (Table 2.5) (Niemelä et al. 2011; Turner et al. 2003).

Nature also holds socio-cultural, historical, or symbolic values that cannot be expressed in monetary terms (Turner et al. 2003). Edward Wilson asserts that humans have a biologically-based intrinsic need to associate with the life and lifelike processes of nature. Steven Kellert postulates there may be a set of nine inherent values attributed to human associations with nature (Kellert and Wilson 1995) (Table 2.7). Natural environments hold moral, spiritual, educational, aesthetic, place-based, and other values for people. These non-monetary values can affect attitudes, and the actions people take regarding ecosystems and the services they provide (Alcamo et al. 2003). Virginia Tech and Town of Blacksburg stakeholders have expressed desires to maintain the ecosystem services that are relevant and valuable to their respective groups (Section 2.2.1).

Figure 2.14 **Virginia Tech Indoor Athletic Training Facility water quality and site area**

Table 2.7 Typology of inherited nature-based human values (Kellert and Wilson 1995)

Term	**Definition**	**Function**
Utilitarian	Practical and material exploitation of nature	Physical sustenance/ security
Naturalistic	Satisfaction from direct experience/contact with nature	Curiosity, outdoor skills, mental/physical development
Ecologic – Scientific	Systematic study of structure, function, and relationship	Knowledge and understanding, Observational skills
Aesthetic	Physical appeal and beauty of nature	Inspiration, harmony, peace, security
Symbolic	Use of nature for metaphorical expression, language, expressive	Communication, mental development
Humanistic	Strong affection, emotional attachment, "love" for nature	Group bonding, sharing cooperation, companionship
Moralistic	Strong affinity, spiritual reverence, ethical concern for nature	Order and meaning in life, kinship and affiliational ties
Dominionistic	Mastery, physical control, dominance of nature	Mechanical skills, physical prowess, ability to subdue
Negativistic	Fear, aversion, alienation from nature	Security, protection, safety

Studies have demonstrated that urban green spaces contribute to ecosystem services such as carbon capture (McPherson and Simpson 1999; Nowak 1994); water runoff and flow regulation (Villarreal and Bengtsson 2005); reduction of the urban heat island effect in the form of mesoclimate and microclimate regulation (Bolund and Hunhammar 1999); pollution removal through air and water filtration (Chaparro and Terradas 2009); buffering and regulation of environmental phenomena such as storms (Costanza et al. 2006; Danielsen et al. 2005; Kerr and Baird 2007); economic savings through energy reduction (Akbari et al. 2001); wastewater treatment and nutrient cycling functions (Sukhdev et al. 2010; Vauramo and Setälä 2011); noise absorption (Aylor 1972; Ishii 1994); wildlife habitat; local foods (Blair and Launer 1997); and engagement opportunities such as recreation and education (Chiesura 2004) (Table 2.6). To some degree, SW provides almost all of the above services. Additionally, studies on the effects that urban forests and trees have on the quality of life for people in cities and towns, are revealing deeper understandings of economic, social, psychological, health, recreation/exercise, and infrastructure functions.

2.5.2 Economic, Social, and Community Benefits

SW, when well cared for, will provide economic benefits to the local economy and sustain a sense of community. New approaches to ecosystem services valuation indicate that the benefits of restoration, if well managed, will outweigh costs (Bullock et al. 2011; Kareiva et al. 2011). The approximately 5-acre old-growth forests at Lakeshore Technical College near Cleveland, Wisconsin consistently attracts visitors who drive 50 miles or more to visit the forest remnant (B. Koeser, personal communication, February 25, 2015). Correspondingly, SW may also be attracting visitors. Research indicates that shoppers will travel greater distances to business districts containing high-quality tree canopies and visit for longer amounts of time while spending up to 12% more money on goods and services (Wolf 2005). In addition to increasing the attraction of Lane Stadium, SW may be directly contributing to the premium real estate values within the surrounding neighborhood. Yard and city street trees can add 3% to 15% to the values of homes in neighborhoods (Wolf 2007). Houses next to natural land areas have values 4% - 20% higher than comparable homes over ½ a mile away from urban green areas (Correll et al. 1978; Crompton 2001; Thorsnes 2002; Tyrväinen and Miettinen 2000; Wachter and Gillen 2006).

Quality spaces containing urban nature, such as SW, are important components in the formation of vital neighborhood spaces, which helps communities to develop social ties through social interaction (Glover 2004; Kim and Kaplan 2004; Kuo et al. 1998; Kweon et al. 1998). Urban green spaces help adults to have a stronger sense of belonging within their community (Kim and Kaplan 2004; Peters et al. 2010). These social ties and sense of belonging helps to produce *the* *glue that holds communities together* (social capital), which in turn help people to form networks and work together to achieve shared goals and mutual benefits, such as monitoring areas to keep them cleaner and safer (Coleman 1988; Doolittle and MacDonald 1978; Putnam 1995; Stone and Hughes 2002). Urban forests help facilitate a sense of community and foster social cohesion (McMillan and Chavis 1986; Peters et al. 2010; Stone and Hughes 2002). This increased social cohesion creates better health and helps communities to reduce crime, thereby increasing public safety (Kawachi et al. 1999; Kennedy et al. 1998; Kuo 2003; Lochner et al. 2003; Lomas 1998; Sampson et al. 2002). Sense of place or *place attachment*, which is an emotional identification with a location or landscape (Eisenhauer et al. 2000; Williams et al. 1992) is influenced by one's sense of community and is a product of culture, history, social dynamics, perceptions, and values associated with a specific location (Bott et al. 2003).

Virginia Tech and Town of Blacksburg community members have demonstrated a social consistency in the interest of safeguarding and restoring SW. Given the right conditions, SW has the capacity to foster a positive sense of community and produce the social capital to help create a sense of belonging and security around the forest remnant for Virginia Tech and the Town of Blacksburg. A positive sense of community among SW would create an endearing sense of place for community members and visitors alike.

2.5.3 Physical and Psychological Health Benefits

Landscapes containing nature, such as SW, contribute to stress reduction, an overall sense of wellness (mental health), cognitive/mental fatigue restoration, which contributes to higher levels of psychological well-being (Berto 2005; Herzog et al. 1997; Irvine et al. 2013; Kaplan 1995; Ulrich et al. 1991). These nature-engendered psychological benefits may increase productivity, quality of life, health, and may extend longevity (Felsten 2009; Herzog et al. 1997; Irvine et al. 2013; Kaplan 1995; Ulrich et al. 1991). Pioneering empirical evidence in environmental psychology indicates that natural landscapes provide restorative qualities for people by producing shifts toward positive emotional states accompanied with affirmatory physiological activity levels (Ulrich et al. 1991). Attentional Restoration Theory, a framework that specifically describes how restorative environments may benefit people, postulates that natural settings are cognitively restorative and facilitate recovery from mental fatigue. Mental fatigue recovery, facilitated by natural environments, helps to mitigate stress and may actually function in stress prevention (Kaplan 1995). A large body of research demonstrates that natural areas are more restorative than built environments lacking in vegetation (Berto 2005; Felsten 2009; Herzog et al. 1997; Irvine et al. 2013; Jiang et al. 2014; Kaplan 1995; Ulrich et al. 1991). Urban forest landscapes offer people opportunities for restoration and higher qualities of life through experiences with nature (Felsten 2009; Irvine et al. 2013; Jiang et al. 2014; Ulrich et al. 1991). Even "unspectacular" unthreading nature produces "a broad shift in feelings toward a more positively toned emotional state, sustained attention or perceptual intake, and positive changes in different bodily systems" (Ulrich 1993). The psychological benefits that SW can provide may be especially useful for Virginia Tech students who are experiencing mental fatigue and stress resulting from the demands of their studies.

Irvine et al. (2013) examined the motivations people gave as reasons for going to urban parks and provided comparisons of the well-being effects individuals receive as a result of their interactions in urban nature. The overall effect was listed as "relaxation" accompanying "positive feelings," and "tranquility." Social connections and elements of spiritual interconnectedness were also described. The urban nature settings within this study were found to provide positive emotions, mental restoration, and physical benefits (Irvine et al. 2013).

SW may provide health maintenance, recreation and active living opportunities for people who take advantage of the close proximity and accessibility of the old-growth urban forest remnant. Exercise in green environments may increase the restorative effects of urban nature (Hansmann et al. 2007) and available outdoor settings for recreation activities may help to increase how often people choose to exercise (Hug et al. 2009). Research repeatedly demonstrates the most favored environments for recreation are those where human influence is low or where nature dominates (Bjerke et al. 2006). SW, therefore, may encourage more people to engage in exercise and activities on campus.

Science continues to show that urban forest landscapes provide restorative benefits, contribute to human well-being, and provide health benefits (Fuller et al. 2007; Mitchell and Popham 2008; Pretty et al. 2007). This demonstrates the importance of urban nature areas, such as SW, and suggests that urban forest benefits extend into the maintenance and recovery of human health. The loss of large amounts of urban trees in Michigan, due to the emerald ash borer infestation, revealed a direct increase in mortality rates due to cardiovascular and lower-respiratory-tract illnesses. Interestingly, these mortality rates increased in areas with higher median incomes (Donovan et al. 2013). Urban trees remove significant amounts of air pollution in cities (carbon monoxide, nitrogen dioxide, ozone, sulfur dioxide, and particulate matter), thereby improving air quality and human health (Nowak et al. 2006). Viewing nature has been shown to help patients experience pain reduction and to recover more quickly when exposed to views of trees (Diette et al. 2003; Park et al. 2002; Ulrich 1984). Access to and use of larger forested parks has been shown to reduce cardiovascular risks and the prevalence of diabetes mellitus (Tamosiunas et al. 2014). Forest walks are more effective at reducing blood glucose levels than walking on a treadmill (Ohtsuka et al. 1998) and produce physiological and psychological benefits (Morita et al. 2007; Tsunetsugu et al. 2010). A review of 240 scientific studies has found reliable evidence supporting the effectiveness of nature-assisted therapy (Annerstedt and Währborg 2011). These findings have implications for the people who may experience health benefits as a result of their engagement with SW and the activities associated with it.

2.5.4 Infrastructure Functions

Natural features offer valuable engineering, architectural, aesthetic, and climate control infrastructure functions (Council of Tree and Landscape Appraisers 2000) and have been described as green infrastructure by urban planners (Pauleit et al. 2011). Green Infrastructure is defined as an interconnected network of green space that conserves natural ecosystem values and functions and provides associated benefits to human populations (Benedict and McMahon 2006). A large portion of SW is currently providing a green infrastructure storm water runoff benefit for the Indoor Athletics Practice Facility as it serves as a large percentage of the site's permeable land area (Figure 2.14). Any deliberation for expansion into this section of the woods would first require the direct expense of building storm water mitigation structures to offset the volume of water mitigation through this part of SW. In addition, SW makes up a large percentage of the total tree canopy coverage area (over 8%) for Virginia Tech's central campus (Appendix L). Tree canopy cover is a vital component for moderating urban heat island effect (Hassan et al. 2005; Moll et al. 1995). SW is currently providing a range of integrated green infrastructure functions for Virginia Tech (Table 2.7 and 2.8) (Appendix M).

2.5.5 Balancing Benefits and Costs to Enhance Community Value

Since all trees involve benefits, costs, and risks, a primary goal of urban forestry is to maximize benefits and to minimize risks over time (Miller et al. 2015). The largest trees contribute the greatest benefits in the form of ecosystem service (Pokorny et al. 2003; Shigo 1992; Southern Center for Urban Forestry Research and Information 2004). Forests with more diversity in their structural attributes contribute to greater biological diversity and produce higher quality habitats. The highest priorities should be placed on green infrastructure that provides the greatest amount of benefits (American Planning Association 2009). The standing dead trees in SW are a part of the forest's dynamic structure and contribute to nutrient cycling and wildlife habitat. Standing dead or structurally weak trees can also pose potential risks. It is important to balance the benefits of both living and standing dead trees while maintaining acceptable levels of safety. Arboricultural and forestry best management practices, such as maintenance, inspection, and mitigation techniques, will provide desired safety levels while innovative habitat management approaches, such as habitat trees, will retain tree benefits. Maintenance and safety enhancements can also mitigate risks. This may be accomplished by improving visibility, monitoring access, directing traffic flows through areas maintained for safety, and improving law enforcement's ability to monitor and ensure public safety in the area (Crowe and Fennelly 2013).

Table 2.8 Green infrastructure functions provided by Virginia Tech's "Stadium Woods"

- Storm water runoff reduction (evaporation, containment on large availability of surface area, and percolation)
- Noise reduction,
- Heat island effect mitigation,
- Air and water pollution filtration and purification,
- Outdoor teaching and research laboratory/facility (soil generation, nutrient cycling, plant and animal habitat ecosystem, etc.)
- Corps of Cadets training facility
- Landscape architectural feature (matches the scale of the stadium and athletics buildings)
- Virginia Tech Athletics game day experience rite of passage

It is essential that any stewardship/management deliberations recognize that different perspectives among stakeholders are to be expected, natural, and common. The reality is that "…tensions between different expectations directed toward urban nature may be partially incompatible" (Lyytimäki et al. 2008). Biodiversity (plant and animal density) is a primary consideration in ecosystem management (Niemelä et al. 2011). Biodiversity is also a key factor in how parks and other urban green areas are valued, yet, preferences for biodiversity differs with age, values, education, and attitudes (Bjerke et al. 2006). Successful stewardship activities should preserve biodiversity while also balancing the needs of a wide range of stakeholder interests. This balance is stated by the ALTERNet Report (A Long-Term Biodiversity, Ecosystem and Awareness Research Network):

> This report is concerned with the relations between lifestyles of urban populations on One hand and protection of biodiversity in urban areas on the other. Urban areas are of importance for the general protection of biodiversity. In the surroundings of cities and within urban sprawls there can be important habitats and valuable corridors for both common and less common species. At the same time a comprehensive, functional and viable green structure is important for urban populations to whom it serves many functions and offers a whole range of benefits. Urban green structure should serve both biodiversity, recreational, educational and other needs. However, uncovered and unsealed space is constantly under pressure for building and infrastructure development in the urban landscape, and the design and usages of urban green structure is a matter of differing interests and expectations. Integrating the green needs of urban lifestyle in the planning process does not come by itself. Nor does finding the synergies between urban lifestyle and urban biodiversity. Careful planning including stakeholder involvement is required (Petersen et al. 2007).

One way to recognize stakeholder perceptions is to facilitate an ongoing monitoring process, such as an interactive blog or website, for the purpose of evaluating viewpoints wherein stakeholders list and rank the importance of benefits and/or costs they associate with the woods. Such an approach can help to tailor local situations to an effective and more impartial distribution of ecosystem benefits (Turner et al. 2003). This would allow managers to assess potential synergies and tensions (Agbenyega et al. 2009) and permit stewards to focus on making progress in mutual areas of interests while bypassing the areas where pressures could limit the achievement of overriding objectives. This may provide opportunities for communication between opposing stakeholder viewpoints and help facilitate understandings among differing perspectives.

In various contexts within its urban setting, SW exhibits functions that may represent both services or disservices to local community members and groups (Gómez-Baggethun and Barton 2013). Urban forests are utilized by many people who are living in close proximity to one another, all with differing interests and perceptions. As such, the ecosystem service of one group or individual may represent a disservice to another individual or group (Escobedo et al. 2011; Lyytimäki et al. 2008; Lyytimäki and Sipilä 2009). Other common disservices may include: blocked views (Lyytimäki et al. 2008); nuisance debris such as leaf litter, fruits, or woody materials; infrastructure wear and tear; animal caused inconvenience or fear; irritation or fear caused by plants or animal characteristics/behaviors; perceptions of cover enabling the occurrence of illicit activities; direct maintenance costs; and poor perceptions affecting reputations as a side effect of less intensely-managed green areas (Lyytimäki and Sipilä 2009). Additionally, urban green spaces can contain toxic plants and animals (Moro et al. 2009); cause health problems from pollen-induced allergies (D'amato 2000); serve as refuges for pathogen carrying animals (Bradley and Altizer 2007); may be viewed as scary and uncomfortable (Bixler and Floyd 1997); and may be perceived as unsafe, especially at night (Jorgensen and Anthopoulou 2007; Koskela and Pain 2000).

Urban ecosystem services, in the form of natural land areas, parks, gardens, and trees, are connected to the conceptual matrix of urban quality of life (Breuste et al. 2013; Kellert 2009; Santos and Martins 2007). Economic calculation methods of city trees and forests all have limitations and most often omit important variables including aesthetics, social (Price 2003), cultural, and quality of life consideration (Box 2011). Current economic valuations of urban nature often miss indirect economic concerns, such as air quality, flood regulation, temperature regulation, etc. (Costanza et al. 2007) and the benefits are not accounted for in the prices established by markets or land-use changes thus causing values to be underestimated in policy, planning, and projects. Meanwhile, the values residents attribute to urban forests go far beyond the clunky bottom line economic assessments that are currently available (Ackerman and Heinzerling 2004).

People may be innately connected to nature (Wilson 1984). Their sense of well-being and even behavior have been proposed to be connected to subconscious evolutionary-based cues within the landscape, such as light, proximity to water, open view sheds, and tree cover (Heerwagen and Hase 2001). As a result, certain landscape compositions may be instinctually more appealing than others, because they historically provided cues on the availability of food, water, and security (Heerwagen and Orians 1993). In general, people innately prefer an open savannah-like landscape of scattered mature trees over a uniform grassy surface (Appleton 1975; Orians 1986; Ribe 1989) with spatially open views (Hawkes 1987; Heerwagen and Orians 1993; Ulrich 1983) under canopy cover (Heerwagen and Orians 1993) within a relatively close proximity to water (Orians 1986; Zube et al. 1983). In short, humans inherently prefer parklike environments with trees over smooth ground surfaces that have limited understory vegetation

(Ulrich 1993). These intrinsic preferences produce a natural tendency for people to seek and create intensively managed, lighted, and biologically barren green open space (Lyytimäki et al. 2008). These spaces are most commonly observed as parks containing large mature trees with mowed grass surfaces. Unfortunately, these types of spaces are lacking in biodiversity. Education may be required to override instinctual preferences toward barren green spaces before support of settings containing high degrees of biodiversity may be achieved. Ulrich asserts that, even then, because of our innate predispositions, well-conceived education programs, may only be able to achieve limited success in fostering widespread recognition of the importance of landscapes that are rich in biodiversity (Ulrich 1993).

These details have relevance for SW because the forest area lacks features, such as openness or water, which may innately produce positive emotional responses for people (Heerwagen and Orians 1993). Instead, SW contains features, such as spaces closed by woody debris and dense understory layers that restrict visual lines of sight. Research shows that these types of environments may cause avoidance or even mild fear in some people (Ulrich 1983). Some stakeholder arguments in favor of removing understory vegetation may be based on these types of innate human preferences. Studies exist, however, that suggest preferences for moderate to dense vegetation exists as well, especially for people in their mid-40s. These preferences are shown to increase with education levels (Bjerke et al. 2006). The scientific community, supported by numerous studies, announces that a great need exists for the vigilant safeguarding of these remaining and increasingly vital areas of rich biodiversity, both within and outside of our urban areas (Niemelä et al. 2011). SW provides a wealth of ecosystem services such as an old-growth forest patch, rich in biodiversity and ecological functionality (Sections 2.3 and 2.5).

At the same time, the woods may be viewed by some people to have detractive qualities. A conscious awareness of these factually authenticated differences will help provide deeper understandings of differing points of view during decision-making procedures involving the future of SW.

2.6 Forest Assessment Summary

2.6.1 What Has Been Learned Here

SW was the center of a 2012 dispute when community members urged the Athletics Department to reconsider building the Athletics Indoor Practice Facility in a portion of the woods. Stakeholders discovered that SW is a rare white oak, old-growth urban forest remnant that delivers a wide range of ecosystem services. It is approximately 11.5 acres in size and located on the campus of Virginia Tech (Figure 1.1) and supports a diverse abundance of vegetation and wildlife in an urban setting. As a result of this discovery, interests and concerns arose about the future of the woods. APFSEC, Virginia Tech's presidentially appointed expert panel, recommended that a protection, use, and management plan be written as means to address the issue. Subsequent meetings with Virginia Tech and Town of Blacksburg stakeholders revealed that SW is valued by community members for its historical significance, recreational opportunities, provision of ecosystem services, and educational importance as a teaching and research area (Section 2.1). The area reflects and contributes to the importance of the region's natural environment as a premium example of a white oak late successional primeval forest community (Section 2.3).

SW provides benefits and costs/risks for community members and stakeholders. The benefits provided by SW include improvements to water quality, moderation of peak stormwater runoff flow rates, air/water pollution filtration, reduction of urban heat island effect, carbon dioxide sequestration, noise level buffering, increased real estate values, improvements to health and well-being, improved social connections, and aesthetics. The costs associated with SW include the direct expenses of managing and maintaining the forest, indirect liability and damages risks associated with the woods, and opportunity limitations in the form of land use prospects (Nowak and Dwyer 2007) (Sections 2.4 and 2.5).

Virginia Tech and Town of Blacksburg community members communicated the values that SW embodies for them as a state-owned natural land area that supports the functions of higher learning and contributes to the well-being of students and community members (Appendices D and F). Desires and concerns were expressed about the fate of SW during stakeholder meetings where feedback was provided to give insights about internal and external factors that may potentially impact the old-growth forest remnant. The stakeholders conveyed their aspirations to maintain, enhance, and protect the historical, recreational, educational, and environmental functions of SW through the application of the forest stewardship plan. A consensus was reached during the group stakeholder meetings expressing that **restoration** is the desired stewardship priority for SW (Section 2.1).

2.6.2 How It Can be Applied to Forest Stewardship

The Virginia Tech and Town of Blacksburg stakeholders have a determined that restoration is the long-term stewardship priority for SW. The stewardship priority establishes the primary goal, which is always to protect and enhance the stewardship priority for the natural land area (Steckel et al. 2014). **Restoration, then, is the primary objective for SW**. All secondary objectives should be weighed according to their ability to uphold the primary objective of restoration. Restoration is a process that will take time, effort, and resources to achieve. SW is a rare high-quality old-growth forest ecosystem that can provide many beneficial functions for the communities of Virginia Tech and the Town of Blacksburg if it is well managed.

As a high-quality old-growth forest ecosystem located in an urban setting on the Virginia Tech campus, SW provides many benefits and opportunities such as education, research, recreation, historic significance, and wildlife habitat. SW also includes several challenges that represent common threats to forests and forest fragments across the nation. They include the inherent yet manageable safety risks that trees pose to property and human safety, human development pressures (parcelization/fragmentation) including human trampling (Loeb 2011), the degradation effects caused by invasive plant species, and pests such as deer or insects (Gagnon 2016), and the ever-present shortages of economic resources.

SW must be supported and substantiated because it is small and in an urban setting, making it vulnerable to human impacts such as invasive plant species, human trampling, edge effects, and dumping (Green Seattle Partnership 2004; Loeb 2011; Steckel et al. 2014; Zipperer

2002). Budgetary constraint represents a noteworthy challenge because nominal budgetary resources are available for the accomplishment of the primary objective of restoration. Therefore, innovative solutions will be required in order to uphold and enhance the SW high-quality ecosystem for the purpose of sustaining its positive functional benefits over time.

The search for innovative approaches in the face of economic and social challenges offers many opportunities for the communities of Virginia Tech and the Town of Blacksburg. The vision of restoration may be accomplished through effective leadership and the social capital of community members working together in partnership with the private sector toward this common goal. These opportunities include the processes of service, learning, teaching, research, and community around an active engagement with SW. Such an endeavor has the capacity to provide social connections and facilitate a sense of place that produces the combined efforts that encourage volunteer maintenance, opportunities for donations, and mutual learning and understanding to occur (Johnston and Hirons 2014). Performed well, these activities will create synergies to elevate the community spirit by bringing volunteer groups, private endorsements, and public officials together to yield an attractive destination site that serves as a source of community pride and enhances the image of Virginia Tech and the Town of Blacksburg.

3 Forest Stewardship Recommendations

3.1 Recommendations Introduction

The SW urban forest has the capacity to provide a wide range of educational, social, recreational, economic, and environmental benefits over time. The Forest Stewardship Plan (FSP) is strategic in nature and reflects suggestions based upon common principles of tree and forest care. Stewardship of an old-growth remnant forest is, by necessity, a long-term endeavor. In recognition of the fact that SW exists within the context of a much wider operational landscape, it is important to note that a number of these recommendations may be constrained by workforce and budgetary realities. Future implementation and specific undertakings of this plan will be determined by the availability of resources and site-specific evaluations and decisions.

This plan is intended to serve as a resource and guide for the implementation of forest stewardship as resources become available. While urban forest remnants generally require lower levels of maintenance than other urban landscapes, they still require some level of ongoing care. Urban forest remnant ecosystems are not self-sustaining, due to human impacts, which inevitably occur over time and require care for the maintenance of their sustainability (Green Seattle Partnership 2004; Loeb 2011; Steckel et al. 2014; Zipperer 2002). When feasible, preventive maintenance is more cost-effective in the long run and greatly enhances visitor safety, forest health, aesthetics, and ecosystem services (Pokorny et al. 2003). Tree and forest care is most efficiently performed under the supervision of a qualified arborist or forester holding the appropriate credentials and licenses for the given tasks.

Of course, as a Virginia Tech facility, SW must serve the useful purposes of supporting community, education, research, and activities for the purpose of helping the university achieve its mission (Appendix A). Balance, therefore, must be achieved in minimizing student and community member visitor impacts and the protection of the rare SW ecosystem. This balance is achievable through applications of sustainable management practices that both sanction access and protection of the SW ecosystem. The following recommendations are based upon prevailing standards and best management practices (BMPs) of arboriculture, urban forestry, silviculture and urban/restoration/recreation ecology. Effective management of SW will allow the enjoyment of its ecosystem services indefinitely into the future.

An integration of protection, enhancement, and/or attenuation (mitigation of negative aspects) will be considered in the formulation of FSP stewardship strategies so a sustainable balance between the health and restoration of the ecosystem and the safe usage/educational options offered by SW may be upheld. The following considerations and features will be addressed to achieve these aims:

- Vegetation management of deciduous forest composition, structure, and health
- Soil – (compaction prevention, erosion control, and invasive plant removal)
- Wildlife habitat (snags, forest layers, connections, and access)

- Hazards (tree defects, snags, lighting, and security)
- Aesthetics (invasive plants, trash, walkways, trails, and traffic control)
- Recreation (value of area, trails, balance visitor access, and minimize impacts)
- Water (erosion, trails, and storm water quality)
- Trails (traffic flow pattern controls, security, compaction, safety, erosion, recreation, and a balance between visitor access and impacts)
- Education (facilitation, timing, and impacts)
- Amenities in or near SW (trails, value of area, education, training, and research)

A well-planned integration of recommendations that considers and addresses relevant characteristics, conditions, functions, uses, and values for SW will help achieve a balance between the maintenance and restoration of the quality of the ecosystem and access for visitors.

The long-term viability of SW may be advanced through the urban forest sustainability model (Clark et al. 1997) by addressing the management/economic, community, and vegetation resources as a whole. Therefore, the FSP will make recommendations on:

- the planning and administration of SW,
- the engagement of people with the forest, and
- environmental considerations within the ecosystem.

The overall aim is to direct the interactions within and upon the system to minimize risk and reduce impacts in an economically feasible manner while simultaneously allowing for a maximum set of benefits for both people and wildlife over time.

Loeb (2011); Steckel et al. (2014); and Mansourian et al. (2005) affirm the soundness of the following actionable goals for sustaining SW:

- **Prevent or limit development.**
- **Manage risks to ensure human safety.**
- **Minimize soil and native plant disturbances caused by invasive plant species, human trampling, and/or deer browsing.**
- **Provide a historic continuity in the species composition reflective of the region by ensuring native species regeneration/planting as revealed by historical ecology.**
- **Engage partners to develop and maintain social capital and other resources for the stewardship of the forest.**

The successful completion of these actions will provide the conditions that are necessary for sustaining the structure, function, and vitality of SW currently and into the future.

3.1.1 Forest Stewardship Goals

The National Urban and Community Forestry Advisory Council, guiding body to the Department of Agriculture, US Forest Service, defines and sets the following vision for urban forestry:

> The art, science, and technology of managing trees, forests, and natural systems in and around cities, suburbs, and towns for the health and well-being of all people… whereby… The Council seeks to establish sustainable urban and community forests, by encouraging communities of all sizes to manage and protect their natural resources, which, if well managed, improves the public's health, well-being, economic vitality, and creates resilient ecosystems for present and future generations (National Urban and Commuity Forestry 2014).

Urban forestry is the management of primarily, but not exclusively, urban trees that involve the actions of balancing society, trees, and economics in an efficient manner to increase the quality of life for communities (Lewis 1991; Phillips and Gangloff 1987). The fundamental goal of urban forestry (a specialized forestry branch) is to maintain forest health while sustaining forest benefits for current and future generations. A key concept of this fundamental goal is sustainability (Thompson et al. 1994). Large mature trees, such as white oak, provide dividends for communities and deliver up to eight times more benefits than small stature trees. The benefits mature trees provide outweigh the costs of their upkeep and efficiently delivers ecosystem services (Southern Center for Urban Forestry Research and Information 2004). Forests, by their nature, require long-term management paradigms to ensure the benefits they afford are sustained over time. The social, political/economic, and biological dimensions (Dwyer et al. 2003) were conjointly considered in the formulation of the FSP goals (Box 3.1).

3.1.2 Arriving at these Goals and Recommendations

The Virginia Tech and Blacksburg communities have established that SW has significant value and should be restored so it may continue to provide benefits for current and future generations (Section 2.2.1 and 2.2.3). Having undergone some levels of degradation common to natural land area forest remnants in urban settings (Loeb 2011), the Virginia Tech and Town of Blacksburg communities have emphasized their hope for restoring the SW urban patch to a white-oak old-growth forest structure and composition that holds exotic and/or invasive vegetation to manageable levels. This is a reflection of the community's desire to safeguard SW through stewardship, which "... is an active process of engagement with your land to direct it toward (or keep it at) a desired state" (Steckel et al. 2014). The recommendations of the APFSEC, the values expressed by Virginia Tech and the Town of Blacksburg communities

Box 3.1 Stewardship goals for Virginia Tech's "Stadium Woods" old-growth urban forest remnant

Restore Stadium Woods so it may continue to provide benefits for current and future Virginia Tech and Town of Blacksburg communities

Provide effective planning and administration for the forest to deliver:

Leadership and accountability for the forest

A safe and secure forest

A forest with an identity

A forest unified with other campus greenspaces

Capital investment for the implementation of the stewardship plan

Engagement with the forest to facilitate:

Diverse partners who are engaged in stewardship of the forest

Educators and researchers who are utilizing the forest

Commonplace service-learning and participatory land care activities

The forest as a destination for low-impact recreation and leisure

Stewardship of the forest to ensure:

Soil, leaf litter, and woody debris support ecological function of the forest

Forest composition, structure, and health are supported by regeneration of native plants and control of invasive plants and pests

Native wildlife is in balance with the forest and causes minimal human conflicts

Ecosystem services are sustained by a healthy, functional forest

(Section 2.2.1, 2.2.2, and 2.2.3), ecological and forest management considerations, and BMPs of Urban Forestry, Urban Ecology, and Silviculture are all factors in the formulation of the FSP goals (Box 3.1). The goals of the FSP, then, are designed to provide a basis for the strategic planning and implementation that will best facilitate the use, restoration, and long-term maintenance of SW.

Ecological restoration is the stated long-term primary objective for SW. The long-term goal of restoration is the principle driver in the integration of all actionable objectives and supporting goals for SW. The formulation of all management decisions and actionable objectives should be weighed according to how well they will help to achieve the primary long-t objective of restoration as a basis for supporting rationales (Section 2.6).

With the overarching goal of restoration in mind, economic, social, and ecological aspects were examined to formulate a set of long-term goals for SW (Box 3.1). Once these goals were produced, the scientifically based experience and expertise of forestry, urban forestry, and ecology were researched in conjunction with information from:

- ✓ Stakeholder communications and meetings
- ✓ Client based communications and meetings
- ✓ Information from academic research (the application of information to stakeholder interests/concerns)
- ✓ Best management practices from arboriculture and forestry(professional experience and research)
- ✓ Advice from scientific experts, and natural resource management professionals who have formal training, experience, and credentials

The FSP recommendations, therefore, apply the knowledge, standards, and BMPs from the above list that have been shown to help to sustain areas, such as SW, in a manner that will allow the old-growth urban forest remnant to continue to provide benefits for the Virginia Tech and Town of Blacksburg communities. This, by necessity, requires that social, political/economic, and biological components of SW be conjointly considered, applied, monitored, and adapted to for optimum implementation of the FSP (Dwyer et al. 2003).

3.2 Planning and Administration of the Forest

- **Continue to administer the forest restoration planning and management framework and apply green infrastructure planning principles**
    - **Strengthen partnerships for the funding and care of the forest by brokering facilitated open discussions about interests and values to obtain stakeholder understandings and agreements**

Green infrastructure planning utilizes a suite of concepts and principles in order to achieve a wide spectrum of benefits for the community (Tables 3.1 and 3.2). Effective planning of SW is the first step in implementing a FSP that provides a multifunctional, interconnected, and integrated old-growth urban forest for Virginia Tech and the Town of Blacksburg that efficiently minimizes/mitigates human impacts and maintains its functionality as a high quality ecosystem that provides maximum benefits with minimum costs over time (Pauleit et al. 2011).

Table 3.1 **Main principles of green infrastructure planning (Pauleit et al. 2011) modified from (Liu 2008)**

Principles	Planning and management of urban green infrastructure needs to:
Multifunctionality	• Consider a broad suite of ecosystem services: abiotic, biotic, and cultural. • Consider combining different functions/uses whenever possible: multiple functions of single greenspace, interconnected green structure, and integrated structures. • Prioritize among functions/uses and set up clear goals through comprehensive analysis and stakeholder involvement. • Conduct monitoring to learn which functions are operating as expected, in a learn-by-doing **a**daptive manner. • Improve awareness of the multifunctions of green infrastructure through communication and public participation/education.
Connectivity	• Consider physical and functional connections between green spaces at different scales and from different perspectives: e.g. recreation, biodiversity, urban climate, stormwater management, etc. • Base green infrastructure planning on thorough analysis of the urban green space resource and its functions.
Integration	• Consider integrating and coordinating urban green infrastructure with other urban (infra) structures in terms of physical and functional relations (e.g. built-up structure, infrastructure, water system). • Create beneficial relationships through communication and negotiation between different professions, administrations, and other actors.
Communicative and social-inclusive process	• Attempt to meet the needs and interests of all stakeholders • Involve stakeholders in decision-making through coordination, cooperation between different professions, sectors and different levels, between public sector and private sector, and public participation.
Long-term strategy	• Adopt the sustainable development concept, considering long-term benefits instead of short-term economic gains. • Consider multiple uses, interactive structures, and balance between different stakeholder's interests, which will help achieve a long-term goal. • Allow adaptation through ongoing learning and discussion between different actors.

Table 3.2 Key abiotic, biotic, and cultural ecosystem services of green urban infrastructure (Pauleit et al. 2011) adapted from (Ahern 2007)

Abiotic	Biotic	Cultural
Surface/groundwater interactions	Habitat for generalists species	Direct experience of natural ecosystems
Soil development process	Habitat or specialists species	Physical recreation
Maintenance of hydrological regime(s)	Species movement (routes, corridors)	Experience/interpretation of cultural history
Accommodation of disturbance regime(s)	Maintenance of disturbance and and successional regime(s)	Provide a sense of solitude and inspiration
Buffering and nutrient cycling	Biomass production	Opportunities for healthy social interactions
Sequestration of carbon and greenhouse gases	Provision of genetic reserves	Stimulus of artistic/abstract expressions
Modification and buffering of climatic extremes	Support of flora/fauna interactions	Environmental education

Planning, management, and adaptive strategies provide the means for success in the achievement of the primary objective of restoration (Poiani et al. 1998). SW is uniquely positioned to uphold and enhance the quality of life for Virginia Tech and Town of Blacksburg residents. The rare old-growth forest structure, within an urbanized setting, provides high levels of ecosystem services, such as bird habitat, fostering human health and well-being, and improving water quality for Stroubles Creek - a designated impaired waterway (Parece et al. 2010).

The quality of the SW ecosystem is unique and, with proper planning, management, and funding, offers the distinctive prospect of serving as a green facility for Virginia Tech. Multiple usages allows more groups to benefit from the woods and considers a wider range of stakeholder interests (Jones and Dudley 2005). *Green infrastructure planning* can help those aims by maximizing the abiotic, biotic, and cultural ecosystem services of urban green infrastructure (Table 3.2). When multiplicity is combined with connectivity and integrated with other urban structures, such as stormwater systems, the green infrastructure is elevated to the level of the built infrastructure. This enhances benefits for the community and the natural land area, which in turn, generates social support and reduces tensions (Pauleit et al. 2011).

The need for comprehensive planning and management is widely recognized in urban forestry (Nowak et al. 2010). The intention of comprehensive planning is to accomplish current and future social, ecologic, and economic well-being for communities (Miller et al. 2015). An important function of urban forestry is to locate and protect rare species and ecosystems, such as SW. Comprehensive urban forestry planning must consider perceived social values and norms that influence land use patterns, the value of the natural resource, and the ecological benefits provided by components of urban nature in the form of ecosystem services. Public interests in urban nature include safety, health, convenience, economy, amenities, human engagement, and increases in the livability of communities. This is because urban trees and vegetation are connected to human health and well-being and improve the quality of life (Miller et al. 2015).

The FSP applies a comprehensive approach in the formulation of SW as a component of the *green infrastructure* of Virginia Tech, the Town of Blacksburg, and the NRV. SW is a rare old-growth forest ecosystem that needs to be safeguarded in order to help Virginia Tech accomplish its mission, currently and into the future (Appendix A). SW holds the capacity to serve as a classroom and laboratory for the dissemination of knowledge for the benefit of our local, regional, national, and world communities. The following framework has been employed in the formulation of the FSP recommendations for the purpose of achieving the long-term stewardship priority and goal of restoration (Box 3.2).

Box 3.2 Framework of restoration planning and management, based on (Vallauri et al. 2005)

Framework of Forest Restoration Planning and Management

Step 1 - Initiate Restoration Plan and Partnerships

- Identify problems/issues
- Stakeholder involvement and participation
- Partnership development (social capital and budget)

Step 2 - Define Stadium Woods Restoration

- All native plant species white oak old-growth
- Eco-regional: Connect to large scale conservation vision

Step 3 - Establish Restoration Strategies and Tactics (include land use scenarios)

- Assessment and decision making
- Recommendations

Step 4 - Implement Restoration

- Set targets
- Identify opportunities
- Measure progress

Step 5 - Adaptive Management

- Monitor and evaluate
- Gather information (research)
- Make adjustments to increase effectiveness
- Share knowledge (Monitor and Evaluate)

Application of the Restoration Planning and Management Framework to Stadium Woods (Box 3.2)

Step 1 - Initiate Restoration Plan and Partnerships

The origin of this FSP can be traced back to the university presidential appointment of APFSEC to resolve the issue surrounding the building site proposal of the Indoor Athletic Training Facility in the environmental greenway area of SW. APFSEC endorsed the development of a protection, management and use plan for SW, thus establishing the basis for the FSP (Randolph et al. 2012). Stakeholders where then identified and consulted during two separate stakeholder meetings for the purpose of obtaining feedback about the values, goals, and insights community members have for the FSP. A general consensus among more than 76% of all the participating stakeholders affirmed that a stewardship priority of restoration is desired because SW is ecologically rare and unique and is important to our communities for providing educational, historic, and ecological benefits (Section 2.2.1).

Goals were examined and selected from a broad field of stakeholders' considerations because employment of multiple functions assembles a wider range of community and stakeholder support and offers more value for urban greenspace (Pauleit et al. 2011). Partnerships for the funding and care of SW, though already underway between Virginia Tech and Town of Blacksburg community groups, may be strengthened through a facilitated brokerage of open discussions about stakeholders' interests and values to obtain stakeholder understandings and agreements (Brown 2005).

Step 2 - Define Restoration

Ecological restoration is defined as an intentional process of assisting and/or accelerating the recovery of a degraded, damaged, or destroyed, ecosystem regarding its health, integrity, and sustainability (Mansourian et al. 2005). Restoration for SW, based upon stakeholder interests (Section 2.2.1) and characteristics of the surrounding native Appalachian forests, shall be defined as an all native plant species mature white oak old-growth forest (invasives are managed and kept in check). SW sustains a healthy regeneration of understory layers that grow from a conserved soil structure and supports the above-ground ecosystem. Although SW is an isolated urban forest fragment, it will ideally consist of a species composition characteristic of the Appalachian Mountain Region. This helps to tie SW to a large-scale, eco-regional, conservation vision (Vallauri et al. 2005) and institutes the value of the SW forest within a greater socio-ecological context, describing it as a part of the larger regional forest community. As a representative sample of a self-generating Appalachian climax community of old-growth trees, SW provides a pinnacle sample that may be revered as an educational laboratory and classroom facility. In this context, SW provides all the associated urban forest benefits to the surrounding natural forest communities. This enhances an educational vision that creates, transfers, applies, and disseminates knowledge through teaching, research, discovery, outreach, and engagement for the benefit of Virginia Tech, the Town of Blacksburg, the Commonwealth of Virginia, the nation, and world community (Appendix A). In this way, SW upholds Virginia Tech's mission.

Step 3 - Establish Restoration Strategies and Tactics

Section 2.2 of the FSP institutes restoration as the primary objective for SW and provides an assessment based on stakeholder comments and a synthesis of technical reports that have been conducted on SW so far to date. Section 3 of this FSP document constitutes the establishment of recommended restoration strategies and methodologies for SW. Standards and BMPs have informed the FSP strategies of tree and forest management for SW. The recommendations are formulated to accommodate a proactive approach that supports sustainability SW.

Step 4 - Implement Restoration

Virginia Tech's Facilities Services in partnership with SW stakeholder groups (e.g. Virginia Tech, its Arboretum Committee, and local members of Virginia Master Naturalists) will undertake the responsibility of carrying out the actions of forest restoration. This management process will consist of setting targets, employing activities, and measuring progress. The implementation of mapping techniques provides an effective means to set targets, identify opportunities, and measure progress in an area of interest. This is typically expressed as a quantitative area or percentage of the total distribution of a biological element (Allnutt 2005). Specific restoration goals for SW determine the types of data and spatial analysis that is required (Allnutt 2005). Biological targets for SW are set by forest conservation principles and will draw on space-based targets that may include variables such as individual tree species, invasive plant species, forest habitat, or ecological process (e.g. soil production, hydrology, bird migrations, etc.).

Step 5 - Adaptive Management

Adaptive management involves periodic monitoring, evaluation, and responses to restoration activities. When better methods are discovered, the stewardship plan should be collaboratively revised to incorporate the improved tactic or strategy (Section 1.4). Information gathering is necessary to facilitate effective adaptive management. Students could be tasked with the collection relevant data for student projects and would be an excellent way to integrate educational and management activities in SW. Baseline measurements have been conducted for the initial assessments and evaluations for the FSP. Yet, these measurements are only useful for forest restoration if they are followed up with periodic sets of data to measure the progress of the applied restoration activities. These measurements include forest health indicators (e.g. forest canopy, understory, sapling/regeneration). Factors which contribute to forest degradation (e.g. invasive species, human trampling, impacted/degraded areas) are essential for evaluating the effectiveness of forest management actions. These measurements should be compared to control areas that have been designed according to research questions/objectives that isolate out factors such as deer, human trampling, invasive plants, etc. These control zones may perhaps be isolated by fencing and signs and kept clear of all invasive plants in order to establish a control group for the dual purpose of conducting scientific research and monitoring the effectiveness of restoration. This information will help to inform adjustments to restoration activities and provide a vehicle by which knowledge may be shared for educational and management purposes alike.

3.2.1 Establish a Positive Identity for the Forest

- **Establish a positive identity for the forest by providing the campus community with the opportunity to participate in a constructive rebranding of the old-growth forest**

The name "Stadium Woods" may have negative connotations due to the 2012 land use question and the preservation issue surrounding the forest. The facilitation of a constructive rebranding of the woods by inviting the campus community to select an appropriate official name may be an important step in the establishment of a sense of permanence for this important natural land area. This official fresh start could be the first step in fostering a positive identity for the old-growth forest.

A positive identity for SW may be developed and sustained by employing design components and maintaining SW as a place where community members and visitors may consistently have positive emotional experiences including enjoyment, pleasure, fulfillment of interests, fascination, and wonder (Beatley 2011; Kellert et al. 2008). This, in turn, will promote SW as a meaningful place and facilitate a sense of place (Eisenhauer et al. 2000; Williams et al. 1992). Aditionally, it may foster *place attachment* among people who have positive emotional experiences associated with the forest (Wolf et al. 2014). General design features that provide positive emotional experiences and elicit a sense of attachment in or near urban nature may include varieties of seating options, comfortable microclimates, water features, food vendors, stewardship options, and activities and features that meet the needs of a wide variety of users and age groups (Ryan 2006; Sustainable SITES 2016).

Some place attachment studies focus on experiences and uses people have with an area. Focus is also placed on the effects the area's physical attributes have upon people. Many forms of area usage foster attachment to a place among a greater range of people. Strategies that promote connections between people and urban natural land areas include:

- Education and communication about the existing features and uses of an area,
- Improving visibility and perceptions of safety,
- Incorporating design features that promote use of the area,
- Providing opportunities for people to adopt urban nature as part of volunteer stewardship programs, and
- Achieving small-scale improvements (Ryan 2006).

Of course, people assign meanings or attachments to natural land areas in other ways as well. Nature develops meaning for people when they associate significance, purpose, symbolic roles, or values with an area (Stedman 2002; Stedman 2003). The significance of a place is also carried through stories among people, which in turn contributes to its value. The value of a place is assigned through an individual's connections to other people, to the place, and to the meaning individuals and groups ascribe to it. If a place leads to a better sense of connectedness to all beings, it can encourage greater self-realization and elicit a sense of awe or sacredness, which in turn may inspire an ethic of care (Beauchamp 2013).

SW is one such place where the interconnections to other times, peoples, ecosystems, and lifeforms may be realized. An ethic of care for SW may elicit a more harmonious relationship between people, the environment, and a sense of the divine. Some may advocate for specific physical features and activities to facilitate festivals and celebrations while others may enjoin a sense of a more harmonious relationship between people and the environment in connection with the divinity of creation (Section 2.5) (Appendices D and E). Both viewpoints have merit. It is up to individuals and the communities alike to decide which form of positive emotional experiences the forest will represent for them.

A tone of respect, protection, and value for the area backed with a high-level charge from a Virginia Tech official to elevate the profile of SW would affirm the university's commitment to the long-term care and protection of the forest. This may provide the assurance that is needed for stakeholder and community groups to move forward together (Appendix D). The woods could then be cooperatively maintained and managed by making the most of the available social capital and focusing efforts on the Big Event, Earth Day, and Sustainability Week. The rebranding campaign could accompany potential donor opportunities that may help to fund additional restoration activities or projects for the woods. In this way, the old-growth urban forest remnant could be maintained and managed as an integrated Virginia Tech green infrastructure facility; it would support education, research, ecosystem services, recreation and leisure, Virginia Tech image/recruitment, and cultural/social/historic heritage. Thus orchestrated, the woods could draw visitors as a destination site (e.g. summer orientation, parent weekends) and continue to provide engineering and landscaping functions for the university while upholding Virginia Tech's commitment to sustainability.

3.2.2 Identify and Manage Risks in and Around the Forest to Ensure Safety and Security

❖ **Develop and implement a tree risk management plan under the direct supervision of a qualified professional**

- Retain the services of a Tree Risk Assessment Qualified arborist
- Inspect trees regularly and after severe wind events and storms (Mortimer and Kane 2004) and before fall and spring football games by a qualified professional.
- Mitigate tree risks in a timely manner when they have been reported or discovered. (Anderson and Eaton 1986; Bloch 2007; Dunster et al. 2013).
- Conduct tree risk inspections and mitigations according to the American National Standards Institute (ANSI) *ANSI A300 (Part 9)* and International Society of Arboriculture (ISA) *Best Management Practices for Tree Risk Assessment*

Develop and Implement a Tree Risk Management Plan

A tree risk management plan involves the application of policies, procedures, and practices that are employed to identify, evaluate, mitigate, monitor, and communicate tree risks (Dunster et al. 2013). The development and implementation of a tree risk management plan or program for SW are recommended for enhanced safety. The goal of a risk management plan is to find the balance among tree benefits, restoration, and costs. The prevailing standard of care is the bar from which responsible parties will be measured (Section 2.4). Currently, in the United States, the prevailing standard of care for tree risk assessment, monitoring, and mitigation is an ISA Tree Risk Assessment Qualified (TRAQ) arborist. Consulting arborists generally hold the TRAQ credential. It is advisable the SW trees be inspected along the paved trails on the south, east, and west sides of SW; along the emergency egress road separating the north and south sections of the woods; near the rappelling tower; and along the larger mulched commuter trails that move east and west through SW. These areas of enhanced safety could provide designated safety routes through and around SW. These designated safety routes will demonstrate the university's provision of its duty of care. An effective tree risk management plan will establish policies and procedures for monitoring, evaluation, documentation, and mitigation of tree risks. Such a plan is best developed and implemented under the direct supervision of a qualified arborist who resides either on staff or retainer for the university (Anderson and Eaton 1986; Dunster et al. 2013; Mortimer and Kane 2004; Pokorny et al. 2003; Schmidlin 2009).

The benefits of a tree risk management plan include: lower frequency and severity of accidents, damage, and injury; fewer expenses for claims and legal fees; longer-lived healthier trees; fewer annual tree removals over time; better visitor experience; and improved community perception of university vigilance. Writing a tree risk management policy initiates the process of defining reasonable care. Regular tree inspections, in combination with resource management evaluations, help organizations to identify and begin to address high-risk trees on a priority basis (Pokorny et al. 2003). Additionally, many factors (e.g. occupancy rates) are involved in the likelihood of a tree failure impacting a target with varying degrees of consequences (Dunster et al. 2013). Very often, perceptions of tree risks are greater than actual risks (Dunster et al. 2013; Mattheck and Breloer 1994; Pokorny et al. 2003). Critical to SW tree risk management is the fact that SW is a unique, semi-natural woodland in an urban setting and not the same as urban trees with many nearby critical targets (e.g. businesses, walkways, cars, homes). Large portions of the SW area have very few to no targets with very low occupancy rates and will require little to no management beyond allowing natural ecological development.

Tree Risk Mitigation Practices

A fundamental tenant of professional tree risk assessment emphasizes the importance of conducting regularly scheduled systematic inspections (Mortimer and Kane 2004). This is particularly critical in higher use areas along paved trails and other infrastructure in and around SW. The presence of trees always involves both benefits and potential risks (Dunster et al. 2013). Three practices exist that will increase public safety and minimize tree liability for tree owners. These procedures include tree inspections (monitoring and assessment), documentation of the inspections, and the use of urban forestry/arboricultural standards and BMPs for tree care and tree hazard mitigation. Owners or controllers of urban property have a duty to take reasonable precautions to safeguard against risks such as inspecting their trees for defects. Owners may increase safety and demonstrate their duty of care by conducting and documenting regularly scheduled examinations of trees that may pose risks to people or property. When a serious tree defect is discovered, tree owners have a duty to remove or mitigate the defect (Anderson and Eaton 1986; Stead 2008).

There are several types of tree mitigation practices that will reduce public risks from tree hazards. Some may involve correcting or removing the tree. However, in many cases, nonlethal options provide comparable levels of safety and retain benefits. These options may include moving the target, closing the area, or converting the tree into a wildlife tree (Dunster et al. 2013; Pokorny et al. 2003).

Prevent Tree Damage by Applying Proactive Tree Maintenance and Preservation BMP's

❖ **Prevent tree damage that may lead to structural defects**

SW offers unique challenges that require a balance between managing the benefits provided by old-growth forest trees and the degree of risks those trees could pose. Arborists have a duty to assess and report tree risks, while tree owners have a duty to have those risks mitigated according to their level of risk tolerance (Pokorny et al. 2003). The ultimate goal is to facilitate public safety while providing healthy, structurally sound, sustainable trees (Pokorny et al. 2003). One example includes the prevention of incidental damage to trees as a result of tree owner construction or maintenance activities. An important question in tree law cases involves whether an action or inaction of a tree owner was ultimately the cause of failure (Anderson and Eaton 1986; Bloch 2007). Damage to tree roots from construction or maintenance activities, such as trenching, vehicle-caused soil compaction, or other tree injuries as a result of such activities, could be shown to be the cause of harm if they lead to tree failure. If a tree failure is proven to be the result of previous owner activities, owner failure to prevent damage (omissions), or owner sanctioned activities, then the owner can be held liable for harm (Anderson and Eaton 1986). The challenge is to perform necessary maintenance and upgrades to utilities without causing unreasonable injuries to trees. This increases the structural integrity of trees and improves safety.

The maintenance of a healthy, safe urban forest is of vital importance in tree and urban forest stewardship. All trees provide both benefits and varying degrees of risk (Dunster et al. 2013; Mattheck and Breloer 1994; Pokorny et al. 2003). A strong case exists for urban forest controllers to develop and implement a comprehensive tree care program as a part of a proactive tree risk management plan:

> An ounce of prevention is worth a pound of cure. Healthy, sound, and sustainable tree populations require expenditures of resources. The paybacks, however, are healthier, longer-lived trees, fewer significant insect and disease problems, and minimized risks from failing trees. A tree risk management program, therefore, should be considered an integral component within a comprehensive, urban forest management program (Pokorny et al. 2003).

In the long term, a comprehensive tree care program is a cost effective way to maximize tree benefits while simultaneously reducing risks and tree maintenance costs (Dunster et al. 2013; Pokorny et al. 2003).

"An ounce of prevention is worth a pound of cure…" (Pokorny et al. 2003)

From a tree risk management perspective, the ideal scenario includes a proactive risk management program based on the framework of a tree care program. The best way to reduce tree risks is to prevent them in the first place through a proactive tree maintenance program that employs American National Standards Institute (ANSI), *ANSI A300, Part 1 through Part 9* for tree care management standards and guidelines and the International Society of Arboriculture (ISA) *Best Management Practices* that provides standards for tree care. These publications provide standards and BMP's for tree planting, pruning, soil management, root management, tree management during construction, integrated pest management, tree risk assessment, safety, and much more. The implementation of standards and practices will increase safety by preventing root and other tree damage during repairs and maintenance of utilities/infrastructure (trenching, equipment compaction, or trunk/branch injuries) by having a qualified tree care professional conduct tree preservation BMPs when work is required within the critical root zone(s) of a tree(s). Tree preservation procedures would ideally be framed as a part of a tree protection strategy under a comprehensive tree care program. This would allow structural tree defects to be prevented or corrected before they become hazardous. This approach recognizes that "…tree risk management is an issue critical to public safety, and similar in importance to other essential public services…" (Pokorny et al. 2003).

Protect Wildlife Habitat and Maintain Safety

- ❖ **Convert dead trees into snags to mitigate risks and create wildlife habitat in areas where needed**

  - If a tree needs to be cut down or mitigated for safety reasons, always drop the tree or branches into the woods (nutrient cycling, reduces human trampling, wildlife habitat)

While all tree defects can lead to structural failures of trees or their parts, SW requires an extended discussion of dead trees and dead tree parts. This is because balance is needed between the ecological benefits of dead wood and snags (known as deadwood biotopes or wildlife trees) and the potential hazards of dead trees and tree parts (Dunster et al. 2013; Mattheck et al. 2015; Mattheck and Breloer 1994; Pokorny et al. 2003). Any dead tree or tree part is considered to be a high risk for failure (Table 3.3) (Mattheck et al. 2015; Pokorny et al. 2003). Page 140 of *Tree*

Table 3.3 Tree defects and risk assessment guidelines (Pokorny et al. 2003)

Defective trees: Risk assessment guidelines		
Tree defects	**Moderate risk of failure**	**High risk of failure**
Decay = Wood that has rotted or is missing. Indicators of advanced decay are rotten wood, fungal fruiting bodies, cavities, holes, open cracks or bulges in the wood.	• Indicators of advanced decay are found on 25% to 40% of the circumference of any stem, branch or root collar. • Shell thickness is >1 and < 2 inches of sound wood for each 6 inches of stem diameter and stem has opening < 30% of stem circumference.	• Indicators of advanced decay are found on 40% of the circumference of any stem, branch or root collar. *Note: In order to verify the extent of decay, you may want to use probes or drills to determine shell thickness.* • Stem has advanced decay and the shell thickness meets the following criteria: • Shell thickness < 1 inch of sound wood for each 6 inches of stem diameter, or, • Stem has an opening 30% of the stem circumference and shell thickness is 2 inches of sound wood for each 6 inches of stem diameter. • Any large branch with decay.
Crack = crack is a separation of the wood; a split through the bark into the wood.	• Stem has a single crack and decay.	• Stem is split in two by a crack. • Stem segment has multiple cracks and decay. • Branch has a crack.
Root problems = inadequate anchoring by the root system, damaged roots or stem girdling roots.	• Roots within the area defined by the Critical Root Radius are 40% damaged, decayed, severed, or dead.	• Leaning tree with recent evidence of root lifting, soil movement or soil mounding. • Roots within the Critical Root Radius are 40% damaged, decayed, severed, or dead. • Girdling roots constrict 40% of the root collar.
Weak branch union = An epicormic branch or a branch union with included bark.	• Branch union has included bark.	• Weak union is also cracked, cankered or decayed. • Large epicormic branch on decaying stem.
Canker = An area where bark and cambium are dead.	• Canker or canker plus decay affect 25% to 40% of the tree's circumference.	• Canker affects 40% of the tree's circumference. • Canker plus decay affect 40% of the tree's circumference.
Poor architecture = growth pattern indicates structural imbalance or weakness in the branch, stem or tree.	• Branch has a sharp bend or twist. • Large, horizontal branch with several vertical branches on it.	• Tree with excessive lean (> 40 degrees). • Leaning tree has a crack in stem. • Leaning tree has canker or decay on the lower stem. • Leaning tree has a horizontal crack on the upper side of the lean and/ or buckling bark and wood on the lower side.
Dead wood = A dead tree or dead branches.		• Any lodged branch. • Any dead tree, tree top or branch.

Law Cases in the USA, Second Edition summary states, "Trees that are dead or in obvious decline require actions to abate the potential hazard posed by failure" (Bloch 2007). However, just because a tree or tree part is at high risk of failure, it does not necessarily pose a hazard. A tree may only be a hazard if it poses a probability of striking a target during failure; large portions of SW have very low occupancy rates that result in a very low likelihood of harm (Dunster et al. 2013; Pokorny et al. 2003). Removing dead trees in their entirety is detrimental to the ecological health of the woods because they are an integral part of old-growth forest structure and they provide habitat for birds, mammals, amphibians, reptiles, and invertebrates (Davis 1983). One way to balance old growth-forest structure (biodiversity) and safety is to convert dead/dying trees into snags, known as wildlife trees (Washington Department of Fish and Wildlife 2011), followed by regularly scheduled safety monitoring of the wildlife trees that have potential targets (Dunster et al. 2013; Mattheck et al. 2015; Pokorny et al. 2003). In urban environments, this balance is often not met because dead and declining trees are usually removed due to ongoing urbanization and safety concerns (Rhodes et al. 2006). Wildlife tree conversions involve the removal of dead branches and tree parts and the retainment of structurally stable standing deadwood as snags for wildlife habitat (Figure 3.1). When properly applied, the method utilizes various corrective measures to reduce the public risk to acceptable levels (Pokorny et al. 2003; Torsello and McLellan 1996). Standing dead trees may be reserved as habitat trees if they are contained within low-use locations and have low proximity to targets (Dunster et al. 2013; Pokorny et al. 2003). "Ideally, such trees would be in areas with no significant targets or only targets with a low occupancy rate…wildlife trees with significant targets should be monitored" (Dunster et al. 2013).

The "Wildlife Habitat/Hazardous Tree Decision Model" operates under two assumptions:

1) **a defective tree exists and various corrective actions can be performed to reduce the public safety risks to an acceptable level, and**
2) **wildlife is using or could potentially use the tree.**

This simple tool poses basic questions to help determine what corrective action(s) could be implemented that will reduce risk to public safety and preserve as much of the tree as possible for wildlife habitation.

If it is not possible to move a target, prune the tree or conduct a partial removal, consider closing the site. This mitigative action can prevent disturbance to wildlife during the most critical (breeding) time. Remember, risk and values must be balanced with common sense when making decisions about hazard trees.

Text prepared by: Mary Torsello and Toni McLellan, USDA Forest Service. Illustration by Julie Martinez

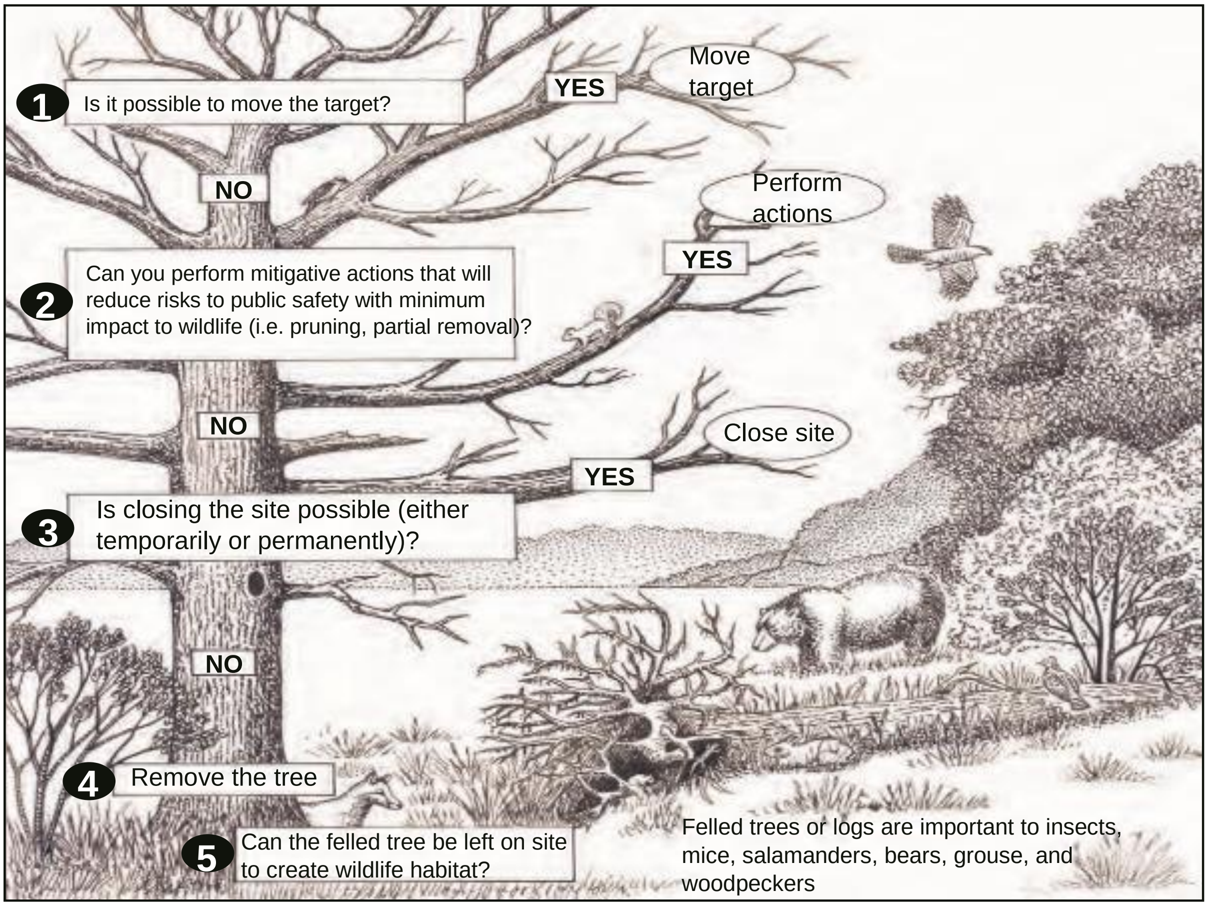


Figure 3.1 "The Wildlife Habitat/Hazardous Tree Decision Model," developed by the U.S. Forest Service, provides a logical approach to deciding whether to convert a defective tree into a wildlife tree (Pokorny et al. 2003)

Corrective management strategies include:

1) **removing targets within striking distance of a wildlife tree,**
2) **performing corrective pruning,**
3) **closing the site, with fencing or signs, to restrict pedestrian traffic within striking distance,**
4) **removing the tree, and**
5) **leaving the felled tree on site" (Pokorny et al. 2003; Torsello and McLellan 1996)**

The conversions of dead trees or dead tree parts into habitat trees is an accepted tree risk mitigation technique (Pokorny et al. 2003). This option, when performed properly and followed up with systematic monitoring, especially where targets may exist, strikes a balance between maintaining safety and preserving critical wildlife habitat. It creates wildlife trees in the forest to achieve equilibrium while maintaining old-growth forest structure (habitat and biodiversity). This option also maintains safety, especially in areas where people are encouraged to frequent, such as around structures, maintained pathways, sidewalks, driveways, parking lots, etc.

Remove Man-Made Debris to Reduce Risks

- **Remove hazardous debris, such as concrete chunks, cinder blocks, and pieces of rebar and pipes sticking up from the ground, to increase visitor safety (but retain historically important artifacts)**

Although the SW natural land area is characterized by complex old-growth forest structures that consist of fallen woody debris, pits, mounds, and other natural barriers, it also includes an assortment of man-made rubble. Some of this debris, such as the "Hurricane Hill" housing remnants has historic value and may be retained (2.3.1). It will be desirable to ensure these historic foundation artifacts are safe for visitors who wish to view them. This could be accomplished with signage or a low fence to designate their presence for public view. There are many other items of debris, including chunks of concrete, old cinder blocks, metal rebar and pipes sticking up from the ground, and other unnatural items which have no positive value for the woods. The above-listed items could provide additional tripping hazards for people who may be unaware of their presence. The removal of all such debris light enough for two men to lift will help to increase safety.

Communicate Safety Awareness and Design Traffic Flow Patterns through Areas that are Maintained for Safety

- **Communicate safety awareness to visitors as part of interpretive signage**

Tree defects that may lead to tree hazards include decayed wood; cracks; root problems; weak branch unions; cankers; poor tree architecture; and dead trees, tops, or branches (Table 3.3) (Dunster et al. 2013; Mattheck et al. 2015; Mattheck and Breloer 1994; Pokorny et al. 2003). Visitors may assume an implied liability for their actions when they decide to visit unmaintained natural land areas, including forest (Anderson and Eaton 1986; Bloch 2007).

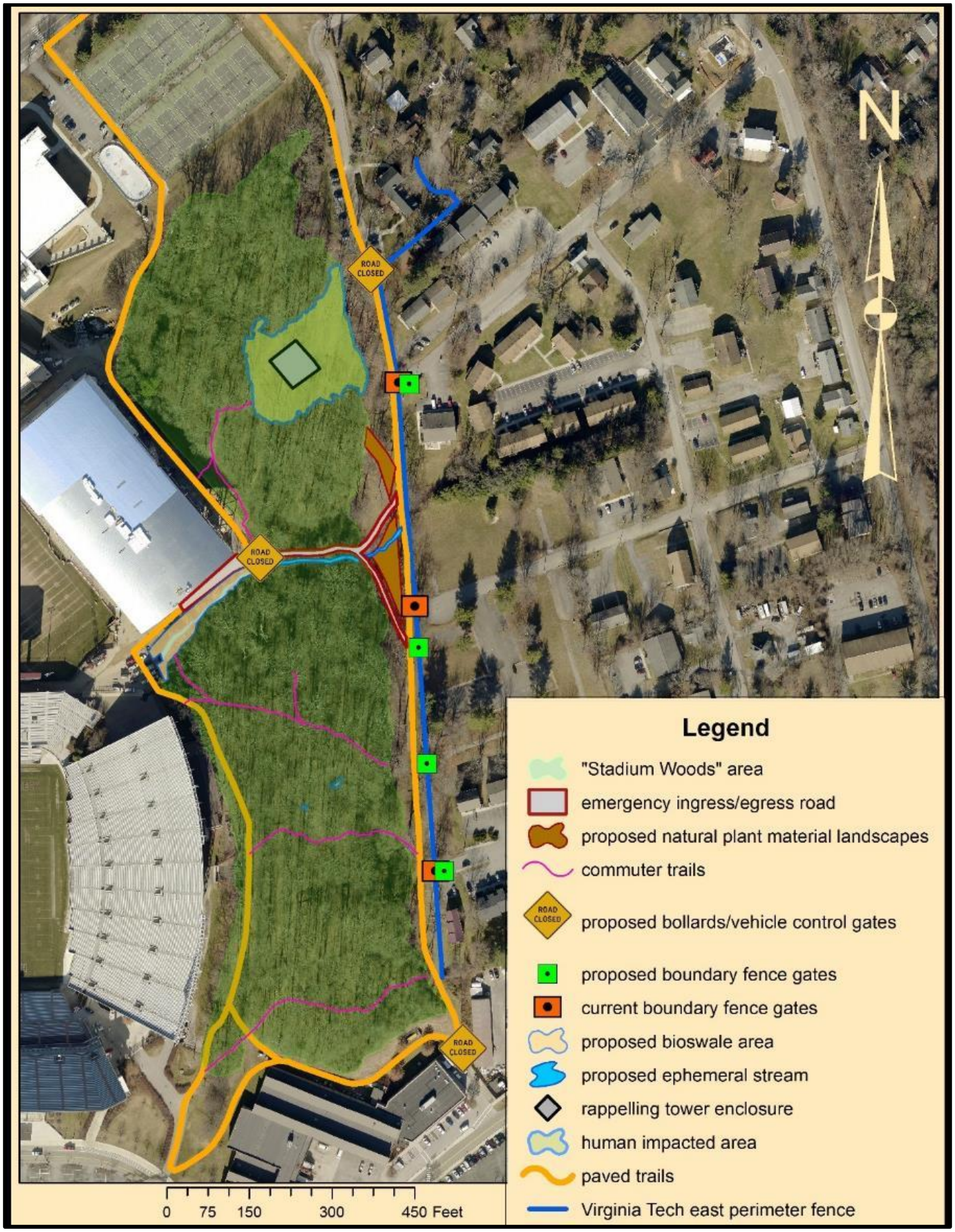
Yet, tree owners also share the responsibility to take reasonable actions to safeguard against risks, especially where people are encouraged to visit (Anderson and Eaton 1986; Bloch 2007; Dunster et al. 2013; Pokorny et al. 2003). There are areas near and in the woods where people are encouraged to visit. These areas include the paved trails along the south, east, and west sides of SW; along the emergency egress road that separates the north and south sections of the woods; near the rappelling tower; and along the larger mulched commuter trails that move east and west through SW. Virginia Tech may demonstrate their duty of care by taking the reasonable actions of providing safety enhancements in and around the SW area, by ensuring a tree risk management plan is employed (described above), and by communicating safety awareness to visitors. Interpretive signage for the area may state: "Please stay safe by using situational awareness and safe behavior, such as avoiding the woods during inclement weather to circumvent slippery trails, falling debris, etc., when traveling through or visiting the woods" (buffer with language and insert as a footnote to a welcoming message).

- **Plan and implement traffic flow control to minimize exposure to potential hazards and reduce ecological impacts, such as forest floor trampling by humans**
  - Utilize temporary fencing, signage, natural debris materials (deadwood and brush), natural plant material landscapes, and permanent fencing/gates to direct pedestrian traffic.

Careful site planning and development of traffic control enhancements, such as strategically placed gates along the university boundary fence and on the paved pathways/roadways, can help to direct pedestrian and vehicular traffic flow patterns in and around SW. Pedestrians can, thus, be encouraged to use routes that are both more easily monitored and have been maintained/enhanced for safety. Many materials and methods may be employed to encourage pedestrians to remain on desired pathways, including the use of temporary fencing (such as is done on other parts of campus during football season), signage, natural debris materials, native plants, naturally landscaped areas, and a university boundary with fence/gate system that directs traffic in desired ways (Appendix P) (Lehvävirta 1999). These strategies will encourage pedestrians toward desired routes through and around SW that have been inspected and monitored for increased safety.

Traffic flow patterns may be encouraged by designing the east Virginia Tech boundary fence with gates installed in places that will encourage pedestrians to utilize the more heavily utilized pathways through the forest, such as the emergency ingress/egress access road (Figure 3.2). Natural plant material landscapes outside SW may be designed to facilitate similar effects (Figure 3.2). Additionally, selected informal trails may be discouraged from use by employing natural obstacles such as deadwood, brush, or small trees planted closely together in a thicket (Lehvävirta, 1999). Man-made materials, such as temporary fencing with signs asking pedestrians to "please respect the restoration/ naturalization efforts" may be ultimately required to prevent informal trail use in some areas (Appendix P).

Four primary informal trails are utilized by pedestrian and bicycle commuters on a daily basis (Figure 3.2). These trails have widened and become hardened with use and contribute to soil compaction and other ecosystem degradation. It may be desirable to discourage the use of one or two of these trails to reduce the occupancy rates of targets below the interior forest trees within SW and reduce environmental impacts.



<u>Figure 3.2</u> Emergency ingress/egress road concept for Virginia Tech's "Stadium Woods", emergency ingress/egress road, proposed natural plant material landscapes, commuter trails, proposed bollards/vehicle control gates, proposed boundary fence gates, current boundary fence gates, proposed bioswale area, and proposed ephemeral stream

Provide Security Enhancements to Increase Security and Value

Enhance Visitor Security

- **Establish security enhancements with improved fencing, gates, lighting along paved trails, emergency call boxes, signs, and cameras**

  - Install improved fencing along the east Virginia Tech boundary along with gateway areas that facilitate a transition from the Town of Blacksburg to campus
  - Install uniform and aesthetically pleasing lamp posts and lighting along the paved east pathway that match the updated lighting on the west pathway
  - Install security cameras and signs that communicate the area is under surveillance

For every 10% increase in tree canopy cover, crime drops by 15% (Gilstad-Hayden et al. 2015), yet the presence of vegetation, especially at night, contributes to perceptions of risks and vulnerabilities (Crewe 2001). Environmental design can enhance security by altering conditions in a way that makes misconduct riskier and potential targets less attractive for wrongdoers. These approaches have been developed to employ design aspects from the human/environmental relationship to produce behavioral effects that improve human security and enhance the quality of life. The methods include the utilization of space design features that integrate physical, social, and security enforcement measures that positively affect human behavior by directing their interactions within environments. Strategies include spatial access control, surveillance, territorial reinforcement, and social engagement to reduce both misconduct and the fear of crime (Table 3.4). These strategies are proven to increase community activity while reducing security problems and have been confirmed to improve property values, business profitability, and productivity (Crowe and Fennelly 2013).

Visitor security in SW will be improved by implementing and integrating security measures that provide improved access control, surveillance, territorial reinforcement, and community engagement (Table 3.4). These strategies can be employed by installing improved fencing, gates, lighting, emergency call boxes, signs, and cameras. Personal safety and sense of security can be increased by controlling invasive understory plants to open lines of sight into SW. This will provide sightlines and facilitate improvements in defensible space to reduce the sense of entrapment and thereby increase the sense of safety (Boomsma and Steg 2012). The installation of traffic control security gates will provide clearly marked transition zones and control vehicle access to SW. Pedestrian traffic flow controls will improve security, minimize exposure to potential hazards, and reduce ecological impacts in the woods (Table 3.4) (Crowe and Fennelly 2013). In these ways, security and ecological functioning of SW may be enhanced to improve the aesthetic functionality of the area.

Provisions, such as lighting along paved trails, emergency call boxes, gates to regulate access, fencing to direct traffic flows, signs to alert visitors about the presence of surveillance, and visible surveillance cameras installed on lamp posts, can assist in increasing security in SW (Table 3.4). Improved fencing and gateway areas will provide access control and territorial reinforcement by providing a clear boarder definition and signaling value and monitoring for the

Table 3.4 Crime Prevention Through Environmental Design (CPED) design strategies, shown to increase security, community activity, and quality of life (Crowe and Fennelly 2013)

CPED Strategies:		
Access Control	• Organized	· Security officers, etc.
	• Mechanical	· Fences, gates, etc.
	• Natural	· Spatial definition (small stone fences, vegetation, pathways, etc.)
Surveillance	• Organized	· Police patrol
	• Mechanical	· Lighting, cameras, audio monitoring
	• Natural	· Lines of sight - Smoother edges (mowing, boarder edges, etc.) - Distance to concealments - Light
Territorial Reinforcement	• Clear Border Definition	· Symbolic barriers (fences, gates, open gateways, signs, lighting standards, benches, exercise equipment, colored pavers, etc.) · Maintenance (signals value and monitoring) · Security monitoring - police - cameras - presence of people (increased use of space - joggers, recreationists, etc.)
	• Clearly Marked Transition Zones	· Entry monuments · Vegetation changes · Defensible space (upkeep - free of graffiti, trash, etc.) - wider pathways - smoother edges with less concealments (mowing)
Social Inclusion	• Community Awareness	· Availability of safety information and crime alerts
	• Community Organization	· Use of space and purpose (involvement of community in purpose)
	• Monitoring by Community	· Community members will keep tabs on space they value

area. Strategically placed entry monuments would enhance this effect (Crowe and Fennelly 2013). An ideal fence design may involve a tall wrought iron fence with Hokie stone-looking pillars. Such a fence gateway system will provide an emblematic barrier that allows movement of animals through the fence for potential increases in connectivity to Huckleberry trail while communicating a high level of aesthetic appeal and care for the area.

Increased lighting and surveillance can improve actual and perceived safety (Boomsma and Steg 2012; Welsh and Farrington 2009). The installation of uniform and aesthetically pleasing lighting along the east paved pathway to match the lighting on the west paved pathway will increase safety, provide territorial reinforcement, and increase surveillance. This may also generate greater use of the area and establish more observers and natural surveillance (Crowe and Fennelly 2013) and make the area more socially safe (Boomsma and Steg 2012). Additional emergency call boxes can reduce the sense of isolation to visitors. The addition of signs alerting potential reprobates to the presence of security cameras will communicate a much greater sense of active surveillance and value for the area and make the SW vicinity more secure (Crowe and Fennelly 2013).

Personal Safety

- **Increase personal safety by controlling understory invasive plants and smoothing out mowing edges along major paved walkways to provide lines of sight for defensible space and improved security**

Perceived and actual security may be enhanced in SW by removing invasive plant species to open lines of sight to increase surveillance and defensible space. A clean, straight mowed line of 20 feet along the eastern pathway between the town and SW will convey attentiveness to aesthetics, reduce concealment opportunities, and increase surveillance. This mowing strip will keep the SW area attractive to recreationists (Table 3.4) (Crowe and Fennelly 2013). This will be particularly important as the grassy area closest to the SW is allowed to naturalize and expand (Section 3.4.2).

The presence of foliage has been shown to lower peoples' fear of crime (Kuo et al. 1998; Kuo and Sullivan 2001b). Yet, dense curtains of foliage, especially in areas that are perceived to be unmaintained/neglected, have been shown to increase perceptions that an area may be unsafe, particularly at night (Crewe 2001; Nasar et al. 1993; Shaffer and Anderson 1985). Areas that contain vegetation have been shown to have actual lower crime rates (Gilstad-Hayden et al. 2015; Kuo and Sullivan 2001a; Kuo and Sullivan 2001b; Lorenzo and Wims 2004). Since fear of crime and actual crime are correlated to spaces where vegetation blocks views, the feeling of safety and actual security may be increased by clearing understory invasive plants that block lines of sight (Braga and Bond 2008; Fisher and Nasar 1992; Michael and Hull 1994; Michael et al. 2001) in a way that maintains/provides defensible space for people (Brower et al. 1983).

Therefore, invasive species should be completely eliminated within 20 feet of the woods and the western paved pathway along the stadium. This increased maintenance in a particularly high traffic area will result in an immediate perception of increased safety. Areas with evidence of higher levels of maintenance experience less crime (Braga and Bond 2008). Indications of higher levels of maintenance include trees, vegetation height control, and the absence of trash and graffiti (Kuo et al. 1998).

Regulation of Vehicle Traffic

- **Install traffic control security gates to regulate vehicle traffic**
  - Prevent any vehicles from driving or parking in SW critical root zones

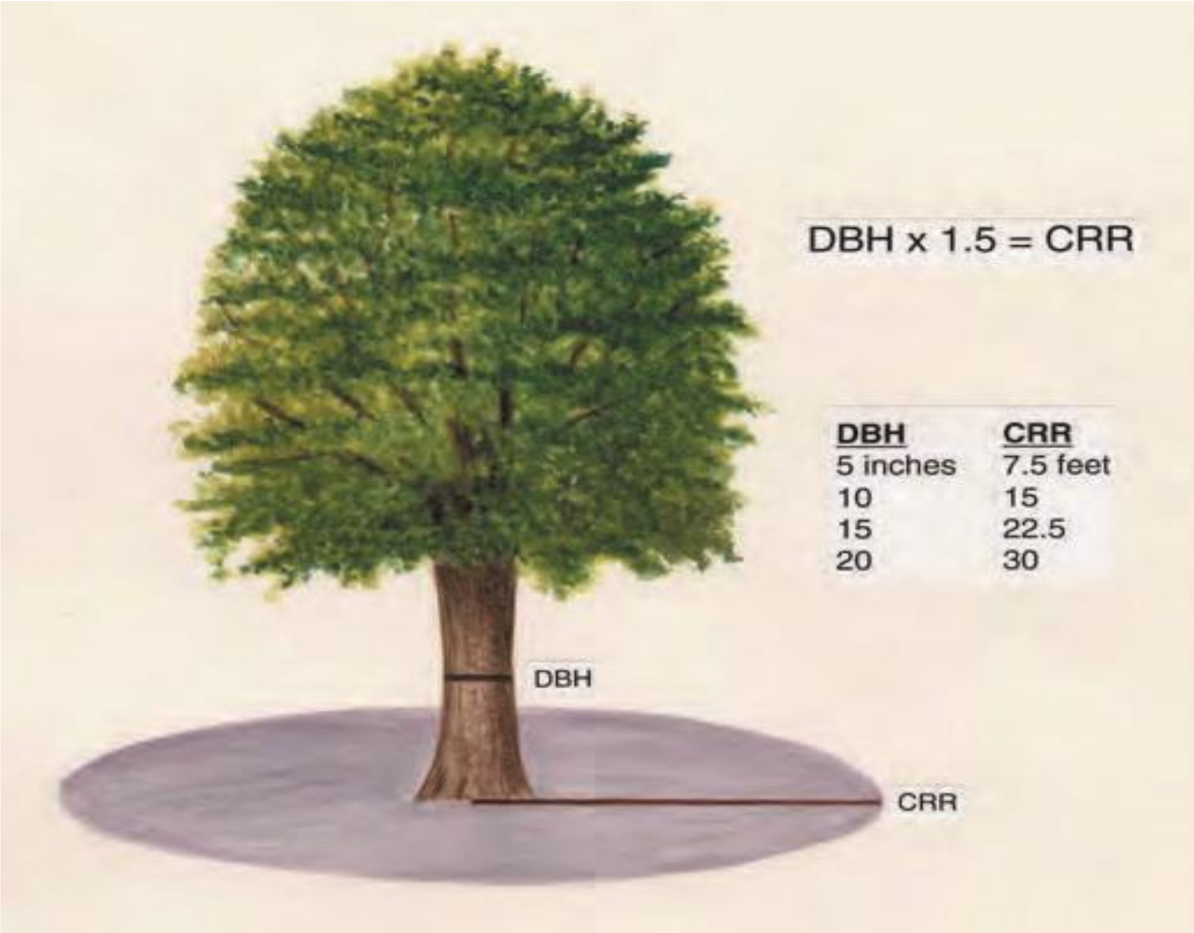
An updated bollard or gate system at strategic locations around SW will continue to support vehicle control in the vicinity. Vehicle traffic is restricted around SW to the east paved pathway and on the emergency ingress/egress road (Figure 3.2) and is limited to specific circumstances during Virginia Tech football game day events. Vehicles are only permitted in the restricted area outside of critical root zones if they have been approved for game day parking or if there is an emergency vehicle conducting official procedures, such as responding to an incident. It is recommended that a bollard or vehicle control gate system be updated and/or strategically located near the end of Clay Street at the far side of the Cranwell Parking lot, on emergency ingress/egress road entryway near the southeast corner of the Indoor Athletic Training Facility, and along the eastern side of the Public Safety Building to continue to limit vehicle access (Figure 3.2).

Automobiles and other heavy equipment are known to cause soil compaction, which is a known causal factor of root damage and necrosis in the root systems of trees. Tree risk and tree preservation standards recommend that all activities that cause root damage, such as vehicle compaction or construction, be avoided within the critical root radius (CRR) (also known as the critical root zone-CRZ) of trees (ANSI 2012; Fite and Smiley 2008; Matheny and Clark 1998; Pokorny et al. 2003) (Figure 3.3). Damage to the CRR (CRZ) can affect the vitality and stability of trees (Figure 3.3) (Fite and Smiley 2008; Pokorny et al. 2003). It is, therefore, recommended that no vehicles or heavy equipment drive or park in the woods to avoid causing damage to tree root systems. This is chiefly true around the rappelling tower where in the past vehicles would drive into the woods to unpack equipment used in training. Groups using the rappelling tower for training should be instructed to use nearby parking areas (e.g. old Cranwell parking lot).

3.2.3 Explore Opportunities to Increase Forest Connectivity

- **Unify or connect the forest with other campus green spaces and amenities to increase multifunctionality and biodiversity**

SW is currently isolated from other campus habitats and to some extent other campus amenities. The application of opportunities for unification with other campus green spaces and amenities will help to increase multifunctionality and biodiversity (Dwyer et al. 2003). Physical connections, such as walkways and informational signage that notifies the public of the available amenities helps to create social and recreational use connections. Additionally, if



"The CRR is used to define the portion of the root system nearest the stem that is critical for stability and vitality of the tree. This area is usually beyond the dripline of the tree. The radius of this circular area is defined as CRR (in feet) = Diameter at Breast Height (DBH) x 1.5 (Pokorny et al. 2003)."

<u>Figure 3.3</u> Illustration showing the critical root radius (CRR) of trees wherein high levels of care should be taken to avoid causing damage such as compaction from vehicles or construction (Pokorny et al. 2003)

sidewalk and/or trail connections have grass, shrubs, or trees, then habitat corridors may be established for subtle plant and animal migrations between natural areas. The integrated addition of these diverse types of connection opportunities will help to increase the multifunctionality of the woods and may even improve the biodiversity of the area (Sections 2.3.4 and 2.3.6).

- **Integrate Stadium Woods into the Virginia Tech master planning process and incorporate the forest into a comprehensive natural land area parkway system involving the use of green corridors (campus trails, walkways, habitat steps, and greenspaces)**

Forest patches or even single trees do not exist as separate entities because they function as part of a larger interconnected living web. SW exists as an isolated forest patch within an urban setting, yet it continues to provide connectivity functions as a step habitat for wildlife (Biohabitats 2012). Because connectivity is a vital component of landscape structure and green network planning, Virginia Tech planning activities should continue to seek opportunities to unify SW with other Virginia Tech recreational and green infrastructure (Sections 2.2.1, 2.3.4 and 2.3.6). The inclusion of SW and other Virginia Tech forests/natural land areas along with campus trees under the umbrella of a larger Virginia Tech comprehensive tree care plan is an ideal scenario that will provide a more effective mechanism for the management of Virginia Tech's urban and rural forests interfaces.

The functionality of SW as an asset that provides a wide range of benefits and services (Section 2.5) may be sustained over time by placing the stewardship priorities and recommendations of the FSP for SW into the comprehensive planning process through Virginia

Tech's Long Range Development Master Plan. This would allow for the integration of SW into a larger Virginia Tech natural land area and landscape plan that both protects ecosystem services and incorporates these areas into an infrastructure system of greenspaces, trails, walkways, and recreational amenities. A statement from a high-level Virginia Tech official recognizing the value of SW as part of Virginia Tech's green infrastructure accompanied with a statement of intent to sustain SW and other green infrastructure on campus as a whole, is an important step for affirming the functional value of SW and other campus greenspaces to the community (American Planning Association 2009). This could be a viable and balanced option to placing SW in a conservation easement.

- **Integrate Stadium Woods' paved pathways into the existing recreation trail system**

The paved pathways that almost encircle SW provide an opportunity to connect to the Virginia Tech's Recreational Sports trail system to create a 5 km track (Chris Wise, personal communication, June 21, 2015). This could be accomplished by completing the paved pathway loop around the outside of the northern end of SW. This would provide an enhanced connection with existing recreation infrastructure and engage visitor usage. Completing the paved pathway around the outside of SW would connect sports, exercise, and recreation running trails to existing Virginia Tech exercise trails and walkways, including Huckleberry Trail. A paved pathway will help to integrate the functional attributes of the SW area (Section 3.3.3).

- **Install interpretive signs at strategic locations to educate and inform visitors**

The provision of low impact learning and recreational amenities, such as entryway signs and interpretive signs that engage visitors about interesting or educational aspects are recommended for SW. A recreation trail containing signage about interesting features and artifacts within the woods could be planned and designed in a way that minimizes impacts. Signs would also be useful to inform visitors. Interpretive signs along trails could provide a self-guided educational tour for visitors. The signs would also be very helpful in communicating expectations to visitors for remaining on the trail in order to minimize ecosystem impacts. Historically significant articles, such as "Hurricane Hill" artifacts along with significant trees could be described. Such features will increase the multifunctionality and value of the forest.

3.2.4 Establish a Process for Administering Oversight for the Forest

Establish governance for the forest

- **Create a steering committee of stakeholder representatives so Virginia Tech can proactively reduce risks, address needs, and effectively resolve issues.**

- Use the existing University Arboretum Committee with two additional members, a Town of Blacksburg official and a Virginia Tech student. This new structure also meets the required Tree Campus USA standards for a campus tree advisory committee (Arbor Day Foundation 2015). If this recommendation is implemented, the Arboretum Committee will need to officially change their membership structure through a formal review and voting process.

A need exists for the ability of a governing body and/or university professional to efficiently adapt to sets of changing dynamics for the purpose of assessing and presiding over the evolving social, economic, and ecosystem subtleties and stewardship care requirements accompanying SW. A steering committee consisting of stakeholder representatives will hold the capacity to address the dynamic and ongoing conditions associated with the complexities of the SW urban ecology (Niemelä et al. 2011; O'Connor et al. 2005). An adaptive management approach facilitated by an openly communicative process will provide the flexibility to make necessary adjustments in a setting of continuously changing considerations (Sections 1.4, 2.2.2, 2.3.5, 2.3.6, and 3.2) (O'Connor et al. 2005).

The existing Virginia Tech Arboretum Committee should be modified to include two additional members, a Town of Blacksburg official and a Virginia Tech student, to more effectively represent stakeholder interests about Virginia Tech's trees. The newly structured committee will meet the required Tree Campus USA standards for a campus tree advisory committee (Arbor Day Foundation 2015) and serve as a steering body that will more effectively address management considerations for SW and other campus trees. The representative stakeholder members will include the following:

- university staff (arborist)
- university administrator
- faculty representative
- student representative
- official town (community) representative
- independent/consultant representative (optional, but useful).

This newly organized Virginia Tech Arboretum Committee will serve as a liaison for the Virginia Tech and Town of Blacksburg stakeholders and citizens for;

- events
- activities
- public relation campaigns
- news articles
- city and community partnerships
- public and alumni requests.

The Arboretum Committee will provide a forum wherein stakeholder partners may convene to educate and inform one another and work toward understanding representative interests and achieve conciliations through agreements.

Additional services of the Arboretum Committee may include participation in locating or suggesting potential funding opportunities (grants, etc.) for SW. This steering committee could also provide added value to the area through designations and certification (Big Trees, Bird Sanctuary, Old-Growth lists, etc.). The Arboretum Committee could also serve as an advisory group to a university professional, such as an arborist.

- ❖ **Support Virginia Tech protocol of contacting event planning for approval to conduct activities in Stadium Woods so events may be coordinated and establish an appropriate professional to manage the complexities associated with the forest.**
- Establish a governing body and/or responsible professional to manage the complexities associated with the forest

Currently, all educational, research, training, exploratory, exercise, recreational, leisurely, community service, social, and cultural activities taking place in SW are unscheduled and undocumented. There are dozens of organized and spontaneous activities taking place in SW, yet Virginia Tech has no records of the timing or frequency of these events. As a result, activities taking place in the woods are not accounted for and impacts of these events are not understood. Activities are an integral part of the development of a *sense of place* and should be encouraged in SW. A *sense of place* can facilitate *place attachment* and qualify a positive value for an area (Relph 1976; Tuan 2013). Long term existence and utilization of benefits, especially those involving shared interests or concerns, such as activities or engagement, contributes to community value and provides a community-based desire to safeguard a valued site (Brown et al. 2003; Manzo and Perkins 2006; Moore and Graefe 1994; Perkins and Long 2002).

As long as the activities are not accounted for, people's actions, values, and needs will be unknown and thus beyond both the perceptions of a governing body and/or responsible professional and their ability to make informed suggestions. A protocol of contacting Virginia Tech's Events Planning Office should be established for groups who are planning activities in SW. Examples of activities include teaching classes, removing invasive plants, performing service-learning cleanup operations, conducting research, etc. An important part of this protocol will be a responsibility for the Events Planning Office to record and track the usage patterns and groups conducting activities within SW. This information could then be consulted to track utilization demands and to inform management decisions that balance amenity benefits with impact reduction.

When conditions are favorable (financial, staffing, etc.), an appropriate expert (campus arborist or urban forest manager) should be established to maintain the daily considerations of SW. A skilled "terrain manager" would retain the skills to successfully oversee public relations, fundraising, planning, events, activities, and maintenance in SW and other areas. A dedicated expert will hold an institutional knowledge of information, history, maintenance needs, and issues associated with the woods and could promote a proactive approach that diminishes tensions, reduces risks, saves money over time, and increases the functional, social, and economic value of the woods.

A qualified arborist or urban forest manager will maximize benefits while minimizing risks by balancing area usage and minimizing ecological impacts. He/she could help coordinate communications, maintenance, and schedule and monitor all activities taking place within the woods through:

- identification and communication of permissible activities,
- education, training, and programmatic scheduling,
- approval or verification of public and alumni activity requests,
- Big Event promotion and coordination, and
- Sustainability Week activity coordination (Earth Week, Arbor Day, Tree Campus USA activities).

A Virginia Tech arborist could network with peers from other Virginia universities and attend training/conferences to stay abreast of the latest developments in urban forest management. This person could hold a Tree Risk Assessment Qualification (TRAQ) and perform and document regularly scheduled tree risk inspections, thus providing proof of Virginia Tech's fulfillment of their duty of care obligations. Tree hazards would then be proactively identified and mitigated. This expert would be a certified pesticide applicator who effectively addresses the invasive plant species and other pest problem while simultaneously conserving the native plants and beneficial insects essential to the ecosystem using Integrated Pest Management (IPM) techniques and BMP's.

An arborist or urban forester could help to engage, educate, and inform community members about their trees and forests and direct community activities, such as volunteer based community service events. This practitioner could answer questions and provide rationales for management activities, thus establishing credibility that the right things are being done according to established standards and would be in the position to direct and perform management and restoration activities in SW including:

- native plant regeneration,
- invasive plant species management,
- trail management, and
- cleanup activities (concrete, utility poles, etc.).

An arborist or urban forester could coordinate the gathering of data for communications, accountability, and adaptive management and would provide monetary benefits by establishing and/or maintaining programs such as Tree Campus USA (grants), and carbon sequestration and natural land area restoration credit programs.

❖ **Utilize a deliberative process to formulate an agreement among stakeholders on the preservation issue**

Based on the assessment provided in this report, the issue of how to facilitate a sustainable protection for SW has not yet been satisfactorily resolved among the stakeholders (Section 2.2.2). Environmentally-based issues are characteristically political (Cortner and Shannon 1993; Landy 1993; Williams and Matheny 1998). The question of how to best protect SW is no exception. Optimal environmental planning processes are informed by the best available scientific information *and* in accordance with the knowledge, values, and preferences of the affected parties (Stern and Dietz 2008). As such, a preferred resolution will ideally be facilitated through a *deliberative* process (Cohen 1989; Dryzek and Niemeyer 2010) that achieves fact-based decisions through inclusion and mutual respect while minimizing defects such as bias, disrespect, and non-inclusion (Mansbridge et al. 2012). These deliberative processes can produce the dialogue necessary for reaching agreements between parties in urban planning processes (Healey 1992). A rational collaborative or communicative approach can produce superior results through the consideration of both scientific facts and community values and by helping parties to achieve mutual understandings through dialogue (Innes and Booher 2010).

For this reason, a deliberative and participatory process (Fung 2006) should be employed among stakeholders for the purpose of determining the best way to provide a sustainable protection for SW while simultaneously upholding (to the degree possible) the interests of all the affected parties. Many deliberative methods and strategies have been developed including:

- Facilitated mediation (Moore 2014; Thayer-Hart 2007);
- Consensus building and mutual-gains approach that expands the interests and priorities of all the stakeholders (Susskind et al. 1999; Thompson 2012; Wu 1996);
- Stakeholder analysis to determine who to involve, what their interests are, and if a consensus process is feasible (Susskind and Thomas-Larmer 1999);
- Multicriteria analysis, surveys, focus groups, consensus building workshops, scenario-building (Jones and Dudley 2005);
- Deliberative polling (Fishkin and Luskin 2005);
- Citizen juries (Crosby and Hottinger 2011);
- Blue ribbon or advisory committees;
- Town hall meetings (Bryan 2010);
- Design charrettes (Lennertz and Lutzenhiser 2003);
- Community organizing (Bobo et al. 2001);
- Joint fact finding (Karl et al. 2007);
- Adaptive management (Williams et al. 2007).

This requires a willingness among all the parties to commit to a process of exploring mutual interests for the purpose of finding solutions that will work for everyone. A facilitated mediation process and/or mutual gains consensus progression should be conducted by a neutral and experienced professional for the purpose of resolving this issue (Jones and Dudley 2005).

❖ Develop a Virginia Tech Stadium Woods information webpage to further affirm value, facilitate activity scheduling, and to inform and aid in future management

The use of digital media provides a means whereby information exchange between administrators, group representatives, community organizations, and individual citizens may be facilitated. It can accommodate policy and decision making by providing participatory feedback from a wide range of groups and individuals, including those who may not be represented by the most outspoken or funded affiliations (Van Dijk 2012). Example include open-source planning and social media as a resource for data gathering and analyses and improved citizen-government dialogue on community topics (Chun et al. 2010).

The establishment of a Virginia Tech SW webpage could be used to capture frequently asked questions with top answers; also a running blog where community members may make comments for the benefit of SW. This type of webpage will facilitate a constructive dialogue that allows a diverse range of people to participate in a conservation about the woods. Such a website will provide insights about the stewardship of SW and clarify stewardship decisions in an ongoing public forum. This website could be used for direct management, such as scheduling events, announcing activities, communicating news, fostering community involvement (including educational activities), and soliciting donations. Cornell University has such a website for their Fischer Old-growth Forest (Cornell University 2016).

3.2.5 Explore Funding Sources for Forest Stewardship

- **Seek alternative and creative funding for the maintenance and restoration of the forest**

Currently, there is no budget for the stewardship and maintenance of the SW urban old-growth forest remnant and the rest of the Virginia Tech urban forest. This remains one of the greatest challenges for effectively addressing the issues necessary for achieving a long-term goal of restoration for the old-growth remnant. Therefore, funding sources should be identified and sought out for the proper maintenance and restoration of the SW old-growth forest remnant. Examples of possible funding sources include:

- endowments,
- alumni donors,
- corporate donors,
- corporate grant foundations,
- USDA Forest Service grants,
- land trusts,
- environmental grant foundations,
- Tree Campus USA grants,
- National Science Foundation grants,
- private donors,
- memorial trees,
- plaques,
- tree naming for fundraising,
- student fees, and
- community fundraising events.

3.3 Engagement with the Forest

Ideally, SW will serve as a green landscape infrastructure/facility with integrated functionalities including community gatherings (service/cultural/social/historical), education, research, engineering, architecture, aesthetics, ecosystem services, recreation, leisure, and image/recruitment. Communication between the community builds trust, fosters collaboration, and creates synergies (Foster-Fishman et al. 2001). Urban forest greenspace areas are important components of the urban landscape and contribute to higher qualities of life in towns and cities. Urban nature fosters well-being and heightens people's ability to function effectively. This understanding is important for engaging people in support of the many benefits provided by these natural areas that, in turn, can, cultivate a sense of social identity and community, which can be "…enormous assets" in the management of urban natural resources (Kaplan et al. 1998). According to Tyrväinen, et al., (2005):

> Nowadays, urban woodland and parks in or in the vicinity of large cities serve as areas for recreation and entertainment, as well as space for biodiversity to compensate for the built parts of the city. It is, therefore, important to emphasize the multifunctional use of trees, green spaces, parks, and woodlands and draw the attention of city dwellers towards the maintenance of biodiversity, of plant succession and the dynamics of low-cost ruderal places (Tyrväinen et al. 2005).

In the case of SW, a tremendous opportunity exists for the engagement of community - higher education partners working together (Community-Campus Partnerships for Health 2007; Kellogg Commission 1999; Reilly 2003) to unlock the potential that SW has for providing a wide range of social benefits and ecosystem services to a broad base range of community members while simultaneously maintaining the quality and health of the old-growth forest remnant.

3.3.1 Encourage Forest Based Activities and Events

- **Continue to encourage and cultivate organizational activities and partnerships to uphold Virginia Tech's covenant and sustain the forest over time**

In order to support and expand upon Virginia Tech's commitment to sustainability, principles of community, and educational mission (Appendix A), there should be a continuation of the development of both activities, and internal and external partnerships involving groups such as Virginia Tech alumni, NRV Master Naturalists, Virginia Tech faculty, Virginia Tech student organizations, and local school groups, and other organizations who provide support for SW. This will facilitate and increase the stewardship and community engagement necessary for producing the social capital to sustain the woods over time (Section 2.2) (Kaplan et al. 1998; Mansourian et al. 2005). Community activities in and around SW can provide funding opportunities, produce alumni contributions, and foster participation in a process that enhances community development, service, and education. This is turn will uphold Virginia Tech's prestige and help to sustain the stewardship of the woods.

- **Endorse Stadium Woods as a destination site to promote Virginia Tech's commitment to sustainability and to enhance economic development**

Urban trees and greenspace enhance the livability and quality of life in towns and cities. This has the effect of attracting highly skilled career minded professionals and visitors

(Montgomery 2013). The enhancement of urban lifestyle and neighborhood amenities, such as natural aesthetics, parks, recreational opportunities, etc., along with the cultural dimensions that support them are known to drive economic development and growth (Clark et al. 2002). "Urban trees and woodlands contribute to an attractive green townscape and thus communicates an image of a positive, nature-oriented city. Indirectly, urban trees and forests can promote tourism and enhance economic development" (Tyrväinen et al. 2005). Observations have shown that old-growth forest remnants on educational campuses attract visitors (Walters 2015). Natural habitats, such as woods, help establish campus identities, stir alumni sentiment, produce a strong sense of community, and create a sense of place. Campus natural land areas, including woodlands, thereby, contribute to the value of a campus by positively influencing fundraising and recruitment and attracting top performing students and faculty (Griffith 1994).

SW should be endorsed as a destination site for the benefit of Virginia Tech and the Town of Blacksburg. Partnerships between community members, local businesses, and civic groups working together to contribute to the promotion of SW would facilitate a positive image for the woods and attract visitors. Signage and/or electronic applications could support self-guided tours in and around SW, Virginia Tech's campus, and the Town of Blacksburg. Guided tours of SW could be provided as part of parent and student recruitment and orientation process, which would help to promote Virginia Tech's image as a green and sustainable university. Welcome signs could accentuate the legendary hospitality of Virginia, and the story of the woods could be an excellent anecdote that communicates the achievements of student service and involvement. SW embodies a rich and visually striking connection to the history and local heritage of Virginia Tech and the surrounding area and has the capacity to provide dividends for the local economy once its value as an intact old-growth forest ecology is recognized and promoted.

3.3.2 Engage Teaching, Learning, and Research

Enhance opportunities for teaching and research in the forest

SW signifies important research prospects for Virginia Tech, along with enhanced educational and training opportunities for its students. Urban old-growth forests remnants are understudied (Clarkson et al. 2007; Dunn and Heneghan 2011; Loeb 2011). As a component of a variant and dynamic urban ecology, SW is a rich subject for academic inquiry and pedagogy:

> These socio-ecological interactions reveal nonlinear subtleties with thresholds, reciprocal feedback loops, time lags resilience, heterogeneity, and surprises. As a result, scientists are stating that it is imperative to move beyond current methods of research to develop a more complete understanding of interdisciplinary research of coupled systems spanning local, regional, national, and global levels (Liu et al. 2007).

Due to its ability to provide interdisciplinary insights into to complex environmentally based questions, SW offers an almost unlimited educational and research opportunities in bio-ecological and socio-ecological systems associated with urban old-growth remnant forests, as well as in forestry, urban forestry, botany, horticulture, soil sciences, biology, entomology, landscape design, urban planning, and many other disciplines.

SW should be sustained as a living green facility and native old-growth forest ecosystem for the purpose of teaching, training, and research to uphold Virginia Tech's educational mission. This may be accomplished by upholding university courses that link relevant subject matter and provide experiential learning in SW with labs, by conducting SW based research, orchestrating service-learning opportunities, making provisions for local community education with public field trips and service learning outings, and enhancing public learning with exploratory and discovery opportunities.

A summer undergraduate intern should be hired each year to conduct research and control invasive plants in SW. This position will provide skilled maintenance and expertise that will be applied to management activities and provide on-the-job training and experience for students who hold the appointment. This intern would be under the supervision of a faculty member in the CNRE and be enrolled in 3 hours of undergraduate research. He or she would be involved in the establishment and re-measurement of permanent plots used to monitor the overarching restoration goal and would work on removal of invasive plants throughout the woods. Each intern would also develop and conduct a research project in SW. This will integrate management activities, research, education, and even help to facilitate SW as a destination site by the availability of the intern to provide tours of the old-growth remnant.

- **Create a meeting/class area adjacent to the forest that harmonizes with the landscape**

The installation of a low impact instructional area located just outside the woods will concentrate students to a designated space and reduce impacts on the woods. At the same time, it will allow the facilitation of training and educational activities. For example, this would be an ideal space for the Corp of Cadets to have prelab instruction prior to deployment for exercises throughout the woods. Other groups could also meet in this location before touring the woods. The meeting area should be located outside of the north eastern corner of SW just south of the International Peace Garden (the location of an old volleyball court). This instructional area should be low impact. Design features, such as Hokie stone seating, could create a small half circle or perhaps a small gazebo or deck could be built as a graduating class donation, similar to those near the Duck Pond. Regardless of the final form, any construction should involve very minimal excavation and it should blend and harmonize with the surrounding landscape.

3.3.3 Recreation and Leisure

Support and enhance both active and passive recreation

Research shows that high percentages populations utilize urban nature for recreation activities. Desired experiences include peace, quiet, and enjoyment of the natural scenery. Recreationists view natural environments as more appealing for leisure activities than built areas and forests are considered to be one of the most attractive types of natural areas. Recreation activities in urban forests include walking, cycling, jogging, picnicking, and berry picking (Tyrväinen et al. 2005). The utilization of forest environments for daily exercise takes place only if such environments are available at nearby locations (de Vries and Goossen 2002; Tyrväinen 2001). Passive recreation such as bird watching, fresh air, getting outside, unstructured relaxation time, meditation, etc., are highly desirable and beneficial recreational activities that have been shown to provide several types of holistic health benefits including stress reduction, recovery from cognitive fatigue, increased sense of social connectedness, a sense of general well-being, and overall wellness (Irvine et al. 2013) (Section 2.5). The enhancement of low-impact recreation and leisure opportunities will help to improve value for a wider range of recreationists and increase the multifunctionality of the SW green infrastructure (Figure 3.4). This may be accomplished by supporting and providing enhancements for multiple levels of activities that may occur in or near the woods.

- **Complete the north side loop around the forest so the trail will form a complete track circuit fitness trail and include two exercise stations**
  - Support fitness trails to provide running, walking, and exercise trails around the forest and connect to other University fitness trails and the Huckleberry Trail
  - Install exercise stations on the trail around the outside of the forest

SW currently has paved pathways that almost completely encircle the forest with the exception of the northern end. The installation of a paved pathway around the northern end of SW would complete a paved loop around the outside of the forest. The paved pathways will then connect with other Virginia Tech and NRV trails (Section 3.2.3) (Figure 3.4). According to Chris Wise, director of Virginia Tech's Recreational Sports, there are not a lot of places on campus for running. A connection of SW paved pathways to Huckleberry Trail would allow people to connect to Virginia Tech's trail system around the lower and upper recreational fields and could create and excellent 5km course up and around the recreational fields and back down closer to the main campus. Chris Wise stated that these types of places really stand out to parents

<u>Figure 3.4</u> Proposed trail loop around north end of "Stadium Woods" with connections to Huckleberry Trail and Virginia Tech's recreational field trails. The formal trail system around "Stadium Woods" would include 2 exercise stations and could implement nature observation spaces for low impact birdwatching and enjoyment of the old-growth trees

and "it is really cool to have activity based opportunities around natural areas on a college campus" (Chris Wise, personal communication, June 21, 2015).

A paved pathway should be installed around the outside of the northern end of SW to complete a formal paved trail loop. This would link a path from central campus to Huckleberry Trail and could be easily tied into the trails around Virginia Tech recreational fields (Figure 3.4). In addition, two exercise stations might be installed on the pathway outside SW to encourage physical fitness activities such as pull-ups, sit-ups, dips, and other exercises.

- **Install a well-designed interpretive nature/recreation trail describing features of historical and biological interests (with interpretive signage)**

A well-designed nature/recreation trail in the interior of the woods presents an opportunity to increase low impact recreation activities that are available in and around SW. A recreation trail could help to facilitate individual and group activities, such as bird watching and plant identification, while confining impacts to the trail (Section 3.4.2). This type of trail could be outfitted with interpretive signage to explain the historical significance of the "Hurricane Hill" housing remnants and would describe old-growth features in the forest along with information about individual trees. This will increase the appeal for touring, education, discovery, and cultural interest while affording low impact recreation (Daig Jr. et al. 2013). Another option would be to install exterior observation spaces in strategic locations along the paved pathways on the outside of SW to provide passive recreation opportunities, such as bird watching, along the edge of the forest. Seating options, such as benches, would provide opportunities for respite, reflection, and cognitive recovery and would help to facilitate psychological well-being (Section 2.5.3).

- **Enhance specific trails with boardwalks and hand rails to protect sensitive areas and facilitate access by people with physical limitations**

Selected trail sections, such as a commuter trail that crosses through the woods, could be enhanced with boardwalks and hand rails to provide accommodations for people who may have physical limitations. This would offer an uncommonly accessible site from which people may experience the grandeur of old-growth forest trees. This would increase the attraction for the area and contribute to its value as a destination site and would keep visitors on a designated pathway to reduce visitor impacts on the woods (Section 3.4.2).

3.3.4 Participatory Forest Stewardship

- **Encourage service-learning activities and participatory land care**

Participation in activities by groups in partnership with Virginia Tech will yield community, monetary, and sustainability benefits. Social Capital produces social ties and a sense of belonging that helps to create *the glue that holds communities together*, which in turn helps people to form networks and work together to achieve goals and mutual benefits, such as monitoring areas to keep them cleaner and safer (Coleman 1988; Doolittle and MacDonald 1978; Putnam 1995; Stone and Hughes 2002).

Appropriate group conservancy should be encouraged in SW. Group involvement and group events inspire social capital. The support of activities and participation may be facilitated by groups such as:

- NRV Virginia Master Naturalists,
- Big Event participants,
- Virginia Tech's Corp of Cadets,
- local Boy Scouts,
- local school groups
- Virginia Tech Arboretum Committee, and
- Virginia Tech Student Groups.

Community stewards and partners may perform a variety of valuable services, including:

- clean up events,
- invasive plant species removal education and control, and
- ecology enhancement (planting trees to boost regeneration in impacted areas such as rappelling tower and along edges, especially the north and east edge).

Social capital currently is and will remain a valuable asset for the control of invasive plant species and other community services that are provided by community members and stakeholders in SW.

3.4 Stewardship of the Forest

Stewardship is defined as "caring for lands and associated resources so that healthy ecosystems can be passed on to future generations" (Dunster and Dunster1996). The stewardship priority of restoration (Section 2.2.1) for SW is defined as assisting and/or accelerating the recovery of SW to an all-natural plant species composition characteristic of a native Appalachian white-oak old-growth forest where invasive plant species are kept in check and a healthy regeneration of native understory layers are sustained from a conserved soil structure that supports the above-ground ecosystem (Section 3.2). The intent is to maintain or reconstruct the historical continuity of native plant species compositions (Loeb 2011) that are found to have been occurring prior to or during the time of European settlement in the NRV. This may be revealed by historical ecology research of the surrounding areas (Loeb 2011). With this in mind, once the American chestnut (*Castanea dentada*) is able to be successfully reintroduced, it is conceivable the SW stakeholders may approve of a gradual shift of the SW species composition back toward a greater focus on the prevalence of the American chestnut.

The ecosystem restoration actions that will facilitate sustainability and restoration in SW include:

- Prevent or limit development and activities that degrade the forest and injure its trees,
- Control invasive plant species,
- Minimize soil and plant disturbances caused by human trampling and deer browsing,
- Fortify impacted areas with tree planting, and
- Control other pests such as deer and insects that may cause unacceptable levels of damage (Steckel et al. 2014).

The ecosystem service functions of SW may be sustained through the protection of the old-growth forest structure wherein biodiversity and habitat are maintained through stewardship and restoration actions. For example, water cleansing and air purification functions of the woods are sustained by protecting canopy cover and the forest floor from disturbance and degradation. This section recommends actions that will provide the conditions necessary for protecting the health and integrity of the SW ecosystem for the purpose of cultivating both human well-being and nature (Mansourian et al. 2005).

3.4.1 Soil Management

Protect soil and maintain water quality

- **Practice Soil Management**
  - Retain litter layers and coarse woody debris on the forest floor to maintain nutrient cycling and ensure long-term soil productivity and health (Harmon et al. 1986).
  - Prevent/reduce any activities that may disrupt the soils that support the forest flora and/or manage to reduce human impacts.

Soil protection conserves forest vegetation which in turn reduces runoff intensity and allows for the infiltration and filtration of sediment. This reduces erosion and maintains water quality and supports the evapotranspiration that mitigates the urban heat island effect (Illgen 2011). All ecosystem services associated with trees and forests are sustained by the soils upon which they stand. An essential balance exists among the soils, soil biota, and the old-growth trees of SW. The SW ecosystem has developed over thousands of years and now exists in a state of relative equilibrium in balance with the environmental factors that lead to its development including; climate, topography, floral communities, fauna, microorganisms, and the soil (Section 2.3). Essentially, the forest layers of SW maintain soil compositions and these soil ecologies provide the conditions that allow for the existence of the historically important old-growth forest plant and animal communities.

Therefore, the ecological integrity of the SW soils should be safeguarded by retaining leaf litter and coarse woody debris, and minimizing human activities that disrupt the soils. Increasing litter or vegetation are the most effective strategies for decreasing erosion (Whisenant 2005a). Coarse woody debris should be kept because it provides essential ecological functions such as providing habitat for organisms, energy flow, nutrient cycling, and sediment trapping (Harmon et al. 1986). Vehicular and foot traffic, and other human activities cause soil compaction, unfavorably influences soil hydrology, changes soil pH levels, and adversely effects oak tree growths (Craul 1994; Day and Bassuk 1994; DeJong-Hughes et al. 2001; Jordan et al. 2003; Whitecotton et al. 2000) (Section 2.3.1). The driving of vehicles or parking in SW should be prevented and visitor access should be limited to designated areas such as approved trails (Sections 3.2.2 and 3.4.2).

- **Initiate erosion prevention and mitigation practices on existing trails and elsewhere if/when needed**

Vegetation preserves soil and maintains water quality, which in turn promotes ecological health (Harmon et al. 1986; Illgen 2011; Whisenant 2005b). Therefore, embankments or other areas (e.g. northwest embankment behind the new practice facility) that show signs of erosion should be stabilized and fortified by planting native forest vegetation to prevent erosion and reduce stormwater runoff volumes. The newly planted vegetation will hold soils in place and prevent humans from disrupting the soils on the steep slopes.

SW has three trail sections that are exhibiting significant erosion (Figure 3.5). These trail sections are located where the trail slope alignment angle runs in parallel with the slope and allows water to channel down the trail and carry away sediments (Section 3.4.2). These three trail sections should be closed and restored by replacing the eroded soils, planting vegetation in densities that discourage humans from entering the area, installing brush (to discourage entrance), and mulch to complete the restoration (Appendix P). In addition, trail assessments should be performed on the informal pathways in SW to assess whether erosion prevention BMP's are needed to reduce current or potential erosion impacts in SW (Section 2.3.4). There are courses offered by Virginia Tech's College of Natural Resources and Environment that can perform trail assessments through student assignments and projects. If the pathway assessments indicate that mitigations are needed, they should be implemented according to standards and practices established by trail science, recreation ecology and/or the US Forest Service wherein trail modifications are performed according to trail assessment recommendations (Hesselbarth et al. 2007; Marion et al. 2011) (Section 3.4.2) (Appendix P). These practices will both help to increase the multifunctionality of SW and minimize ecological impacts.

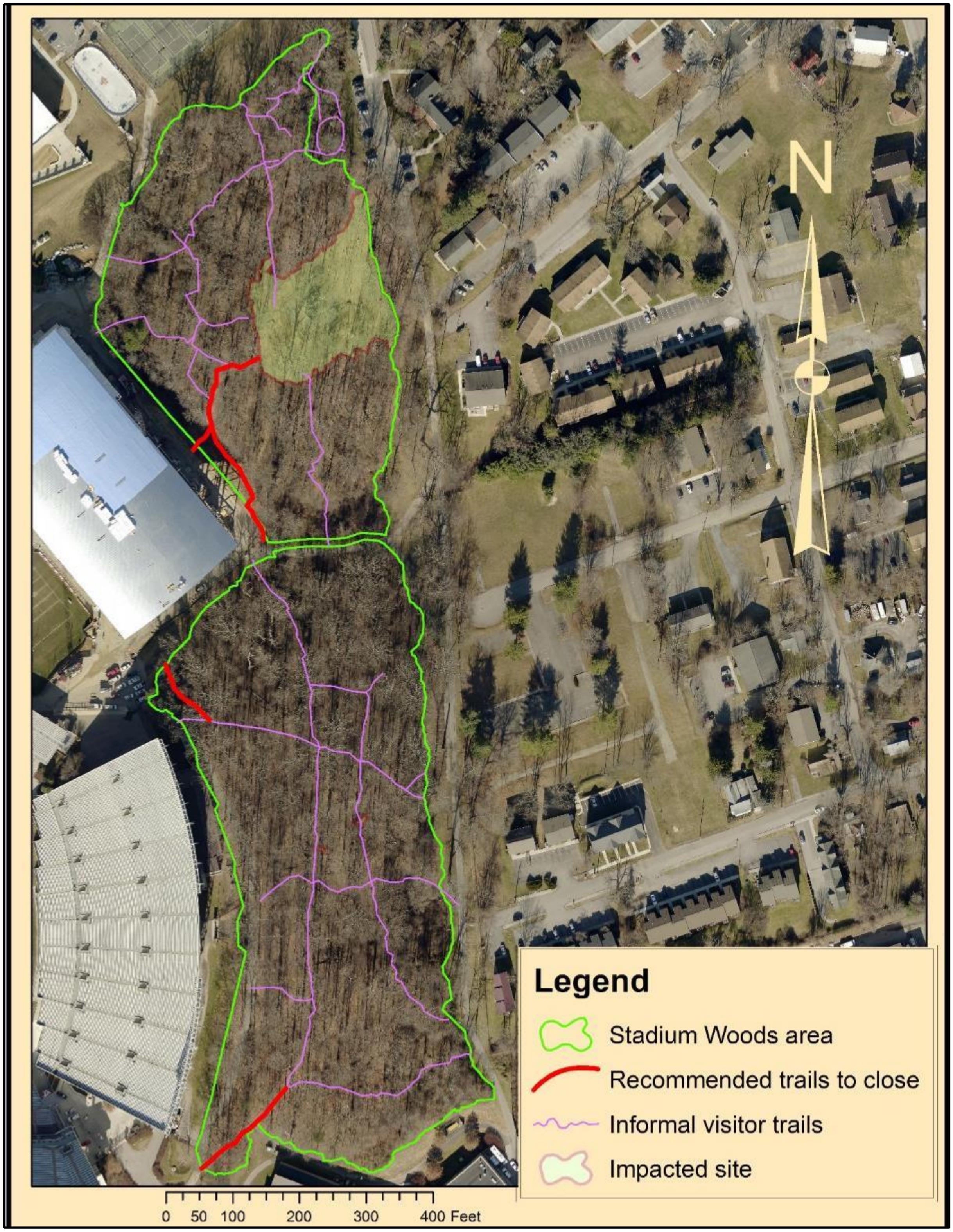


Figure 3.5 **Trails sections in "Stadium Woods" that should be closed because they are exhibiting significant erosion**

- **Install ephemeral stream along emergency access road to allow rain water to flow away from pedestrian traffic, improve water quality, and protect/create habitat**

The existing gravel emergency ingress/egress access road is currently built on an ephemeral stream and becomes flooded during heavy rainfall events. This is detrimental to the water quality of Stroubles Creek, a designated impacted waterway (Section 2.3.1). The running water can also be disruptive to pedestrians who are using the road to traverse the woods (Figure 2.6). The existing gravel emergency access road could be redesigned and modified to provide a dry roadway surface by preventing rainwater from running through the roadway.

Drainage along the emergency ingress/egress access road should be improved. An ephemeral stream bed could be installed along the roadway to provide a natural landscape feature which enhances aesthetics, ecosystem functioning (reducing roadway materials and pollutants washing into watershed), and improves game day pedestrian traffic options by providing pedestrians a safe, dry walkway to the stadium during game day events (Figure 3.2). This improvement would provide a reliable and ecologically sound access to Lane Stadium north and east gates and would reducing the walking that occurs through more environmentally sensitive areas of the woods.

An ecologically enhanced premium version of the ephemeral stream concept would include a bioswale/wetland area planted in the low-lying area of the storm water course. Bioswales are an effective method of utilizing green infrastructure to reduce peak stormwater runoff, capture and process pollutants, and increase water quality (Paul and Meyer 2008). There is an opportunity for native wet/dry shrubs to be planted at the site from approximately the southeast corner of the Athletic Indoor Training Facility to approximately the southwest corner of the same building in the low-lying area before runoff is carried down a stormwater drain (Figure 3.2). A list of native plants that would thrive in this space include red chokeberry (*Aronia artutifolia*), black chokeberry (*Aronia melanocarpa*), silky dogwood *(Cornus amonmum*), red-osier dogwood (*Cornus sericiea*), witch hazel (*Hamamelis virginiana*), common elderberry (*Sambucus canadensis*), pawpa (*Asimina triloba*), hornbeam (*Carpinus caroliniana*), black gum (*Nyssa sylvatica*,), swamp white oak (*Quercus bicolor*), black willow (*Salix nigra*), and American basswood (*Tilia Americana*). Many of these native trees and shrubs are eligible for stormwater credits in Pennsylvania (Acker 2015).

A lower cost option for providing drainage along the emergency roadway is to install a riprap-lined drain ditch to direct rain and runoff off the road and/or upgrading the emergency ingress/egress road to have a crown that causes rainwater to flow off the road instead of running down it. Any project that could impact tree roots should involve a tree protection plan (Section 3.2.2) and the use of specialized tools, such as an air knife or air spade capable of excavating soils for construction projects without destroying structural roots in trees.

3.4.2 Vegetation Management

- **Restore, protect, and cultivate natural vegetation to increase health and maintain forest structure**

One of the most effective actions that will maintain the native tree composition of SW is to encourage the shading that allows native trees to outcompete invasive plant species (Mansourian et al. 2005). This could be accomplished by planting more trees in the lawn around SW, fortifying the forest edge with native trees, planting native trees in impacted areas, such as around the rappelling tower, along the emergency ingress/egress road, and, in some cases, in canopy gaps within SW. According to Virginia Tech's Tom Wieboldt, Curator of Vascular Plants of the Massey Herbarium, "If the desire is to restore the forest as much as possible, or let it recover from past abuses, the best "buffer", in my mind, would be to cut down on all the ambient light getting in from the edge so that the interior is more like a normal forest, i.e. shady" (Tom Wieboldt, personal communication, August 4, 2015).

A dual process of invasive plant species removal and native tree planting along the forest edge, in impacted areas, and in some cases, in canopy gaps within SW where invasive plant species have taken hold should be implemented (Lehvävirta et al. 2002; Loeb 2011; Zipperer 2010). This must be done in conjunction with efforts to reduce human and wildlife impacts that inhibit native tree regeneration within the understory layers of the SW old-growth forest (Leung and Marion 2000; Loeb 2011; Malmivaara-Lämsä et al. 2008; Rossell Jr. et al. 2007). Solutions include reducing human impacts by encouraging people to remain on desired pathways, controlling deer populations, and roping/fencing off selected areas for tree regeneration accompanied with signage that requests cooperation in staying out of the area to help facilitate restoration (Lehvävirta et al. 2004; Rossell Jr. et al. 2007; Wimpey 2011c).

- **Reduce mowing to facilitate understory regeneration along the north and east edge of the forest to allow natural forest succession to expand the buffer zones**

There is a mowed area containing many large, old trees on the eastern side of SW between the town edge and the forest. The soil in this area is compacted due to the mowing and parking activities that have occurred there. A phased-in mowing reduction of this area should be implemented to allow natural succession to expand the edge of the woods. In a relatively short time, soil compaction levels will also improve and a healthy litter layer will develop.

Specifically, in the first year, move the mowed edge 10 to 15 feet from the current edge of the woods. In year three, move the mowing an additional 10 to 15 feet from the new developing edge. Continue this until only a clean, wandering mowed edge of 15 to 20 feet exists between the woods and the current paved pathway. As mowing is reduced, a natural understory will develop (similar to what has occurred between Grove Lane and the south side of The Grove). Invasive species will have to be closely monitored and removed as this new edge develops. The area can also be targeted for tree plantings as part of Earth Day and Arbor Day events. This area would become a “low maintenance space” and would contribute to the Virginia Tech Climate Action Plan. The new clean mowed ribbon along the paved walkway would also indicate an increased level of care in the area, which is a crime deterrent (Braga and Bond 2008; Donovan and Prestemon 2012).

❖ **Retain and protect old-growth forest structure by leaving standing snags and fallen woody debris in place wherever feasible**

It is critical to protect the old-growth forest structure of SW, because it is extremely rare and therefore valuable for scientific study, is also aesthetically pleasing, and provides significant ecosystem benefits, including wildlife habitat. The rarity of the SW old-growth forest structure warrants measures for its use care and protection (Sections 2.2.1, 2.2.2, and 2.2.3). Old-growth forest attributes produce high scenic value. Science shows that uneven-aged old-growth forests over 200 years in age containing trees of large basal trunk areas yield higher long-term aesthetic values (Ribe 1991). SW, as a result of its old-growth forest structure, is high-quality ecosystem that supplies significant benefits and provides wildlife habitat (Sections 2.5 and 2.3.4).

Standing dead snags within SW should be retained because they are especially important for wildlife habitat and ecosystem functionality (Sections 2.3.4 and 3.2.2) (Appendix K). When a big tree dies and a qualified risk assessor has determined the tree must be felled for safety reason, always drop the tree into the woods. This will facilitate nutrient cycling, provide impediments that reduce human trampling, and will provide habitat for wildlife (Sections 3.2.2, 2.5, 3.4.1) (Lehvävirta 1999). If a tree falls into the lawn area outside of the woods, the debris from the fallen tree should be scattered in the woods rather than piled up at the edge of the woods. This is because piles of woody debris can prevent regeneration of native plants in the immediate area under the piles.

Invasive Plant Management

❖ **Control invasive plant species throughout the forest**

A very high priority should be placed on controlling invasive plant species (IPS) in SW at acceptable levels. Effectively dealing with the IPS threat is the single most important activity that will provide a successful outcome for the SW stewardship objective of restoration (Section 2.3.5). Acceptable levels may be determined by planning and adaptive management to balance forest health, safety, aesthetics, and economic and social factors (Section 3.2).

In addition to controlling high invasiveness ranking IPS (Appendix J, List A), an incremental thinning of medium ranking invasive Norway maple trees (*Acer platanoides* L.) (Appendix J) and other non-native trees (e.g. little leaf linden (*Tilia cordata* P. Mill) should be initiated. This will tilt the species composition back toward the defined goal of restoration in SW qualified by an all native species composition. This thinning process may retain the non-native trees as standing dead snags for wildlife habitat by girdling them and allowing them to remain standing (Sections 2.3.4 and 3.2.2) (Appendix K).

Invasive Plant Control Options

Control of the IPS in SW may seem like a daunting task, but much research and work has been done in developing treatments for the control of specific IPS. There is ample literature describing treatment options (Grinstead 2007; Langeland et al. 2011; Nature Conservancy 2001; Tu et al. 2001; Vidra et al. 2007) (Appendix Q). Professional plant health care (PHC) specialists have knowledge of effective control methodologies. Community members such as the Virginia Master Naturalists have IPS control expertise are eager to help. There may be other community resources, such as the ROTC cadets, who may be able to provide excellent help if they are trained well in IPS identification and control methods. Adaptive management will be required for the successful control of IPS because strategies will need to be developed in IPS removal procedures to provide an acceptable mechanism for the implementation of modifications for years (Loeb et al. 2010; Vidra et al. 2007) (Figure 3.5). The control of IPS in SW and elsewhere will require vigilant efforts over long periods of time, along with the ability to adapt to ongoing sets of surprises and challenges caused by changing dynamics, setbacks, and the persistence of the IPS threat.

Comprehensive Approach for Controlling Invasive Plant Species

Since the successful restoration of SW depends upon the successful control of IPS, it is recommended an adaptive management based site weed (IPS) management plan for SW be seriously considered and implemented once funding and/or qualified personnel become available. An IPS management program/plan that employs an IPM approach and utilizes principles of PHC by employing BMPs and standards is an excellent option to effectively address IPS in SW and maintain the health, integrity, and value of the old-growth remnant presently and into the future for Virginia Tech's stakeholders, students, and community members (Nature Conservancy 2001; Tu et al. 2001; Wiseman 2007) (Appendix Q). This option, however, may require a planning process that could take a considerable amount of time to formulate. Additionally, direct funding will also be required to both plan and implement an IPS management plan/program once the planning component has been completed.

An IPS site weed management plan for SW and elsewhere on Virginia Tech's campus may be produced by an outside company (consulting group) who could perform a multistage eradication of IPS in SW to clear the IPS. This company could perform a resweep after two years and then return on call backs when the IPS return and need to be controlled. This approach would produce the most immediate results and would also be the costliest.

The same services could also be performed by an in-house Virginia Tech professional, such as a forester or arborist. In this case, the process could be more control orientated and could be worked into the staff member's annual schedule. A knowledgeable and well-qualified university staff member would/will be an invaluable asset in controlling the IPS problem. A knowledgeable PHC professional dedicated to engaging in the adaptive management process would be a tremendous asset in the management of the SW IPS issue and elsewhere on Virginia Tech's Campus. Such a SW Virginia Tech steward could stay current on the latest research and methodologies for IPS control and would be in a position to coordinate volunteer resources. In addition, they could hold the necessary licensing and application expertise necessary for the effective and efficient control the IPS problem in SW and elsewhere on the Virginia Tech

Campus. Finally, such a qualified professional will have the technical expertise to assemble an IPS site weed management plan and to initiate the action objectives of the plan.

Although eradication as an ideal may reflect an ultimate 'grand prize' and is achievable with the application of enough resources, it is unlikely to be realistic for SW in the short and intermediate terms due to the limited budgetary constraints, manpower resources, and pervasiveness of IPS. Therefore, a control orientated approach of addressing IPS in SW and other campus locations is more realistic. A site weed management plan strategy will, therefore, represent a long-term goal for what is likely to be an ongoing and sustained IPS control effort in SW and elsewhere on the Virginia Tech Campus.

Basic Approach for Controlling Invasive Plant Species

The employment of an adaptive manage strategy, which produces and implements integrated vegetation management tactics (ANSI 2012; Mattrick 2006; Miller 2007; Tu et al. 2001), represents a middle-of-the-road option in its requirements for personnel and resources and may be successful if implemented on an ongoing basis. This approach may be described as a health maintenance model. The focus is ongoing care/treatment of IPS rather than a cure or elimination of the problem. This strategy lends itself to concepts of plant health care PHC, which are endorsed by the International Society of Arboriculture and other organizations.

Vegetation management preferably will involve a Virginia Tech staff member who has the skills, expertise, and licensing requirements to effectively address the IPS issue; however, a trained technician working under the supervision of a licensed applicator may be a lower cost alternative. An undergraduate summer intern position (Section 3.3.2), for example, could provide invasive plant species control, perform plot measurements, and small experiments. He or she could even provide services such as giving tours, etc. A good method in this approach is the employment of stump/stub application of herbicides, such as Garlon™, where stems are cut near the ground and painted with herbicide to kill the roots and prevent resprouting (Mattrick 2006). This method applies an herbicide with translocation properties (movement through plant tissues). Since the herbicide is applied in a highly targeted way using a paint brush it greatly reduces the risk of ecosystem contamination, the killing of non-target plant species, and minimizes the amount herbicide requires. The benefits of the cutting control method are thus maximized by the herbicide application by permanently eliminating the invasive exotic plant in a way that provides minimal soil disturbance. This is a highly selective and effective method of controlling woody IPS in which the timing of this technique is not as critical.

A basic approach should also continue to utilize the current practice of working with the NRV Master Naturalists. These hard working volunteers have been generously providing their qualified volunteer services to remove IPS in SW (Section 2.2). A moderate approach will consider all available strategies and provide enough flexibility to address management objectives which are, by necessity, driven by factors such as prevailing needs, constraints, and the availability of resources.

Low-Cost Approach for Controlling Invasive Plant Species

The use of a low-cost option to control IPS in SW will likely continue to utilize the current practice of accepting help from the NRV Master Naturalists and other volunteer groups who kindly provide their services to control IPS in SW. In this approach, it is important to ensure volunteers are properly trained in specific techniques appropriate for each invasive plant species of concern. Techniques in this low-cost option category for woody IPS removal, suggest the generalized methods of pulling (which if performed improperly, can disrupt the forest floor and encourage more invasives) and cutting with hand tools. When hand cutting is performed, it is best to trim woody IPS back in the spring when root energy reserves are low, because this will greatly reduce resprouting. A no cost no action approach to eschew IPS control in SW is **not** recommended because IPS are a problem in SW that must be addressed.

Native Plant Regeneration and Planting

- **Facilitate regeneration of native plants in canopy gaps and plant native trees in areas impacted by edge effects and human visitors**
    - Manage north and south sections of woods according to specific needs of each section**.** For instance, the northern section of the woods may require a greater invasive plant species removal effort in conjunction with the reestablishment (by replanting) of the midstory and/or understory layers

Regeneration of native plant species may be facilitated both by encouraging natural regeneration to occur and by planting trees in areas that have been impacted by edge effects or human trampling. Natural regeneration of native plant species in SW may be stimulated by protecting healthy areas of the forest and by encouraging people to remain clear of these areas by:

- closing or reroute trails to restore impacts and enable natural regeneration,
- routing pedestrians around less impacted areas of SW,
- planting dense vegetation to discourage human access,
- providing signage and education to encourage people to help protect the SW ecosystem (Appendix P, and by
- building raised paths to allow access while also protecting the ecosystem (Loeb 2011).

Another tactic could involve the systematic, rotational, or as needed closing off forest areas by limiting access with snow fencing and signs to encourage regeneration and provide restoration to the selected areas within SW. In the future, raised pathways in conjunction with fencing may be required to facilitate the dual goal of allowing access and keeping human impact damage at acceptable levels. Adaptive management will be required in order to determine the strategies that maintain ecological health and facilitates human visitors (Loeb 2011) in SW.

Native trees should be planted native trees in canopy gaps overrun by IPS or in impacted areas where mature trees are abnormally thin. This will help to abate edge effects, reduce the occurrence of IPS, and ultimately improve native plant regeneration. A primary benefit of these planting efforts will be to help deter the proliferation of IPS (Sections 2.3.5 and 2.3.6) by shading areas and allowing native plants to outcompete IPS (Mansourian et al. 2005). Assisted regeneration of native plant species is advised for areas of SW that have been impacted to the extent that natural native plant regeneration is being prevented or limited. These areas include the north edge of SW where mature trees are declining as a result of edge effects, along the emergency access road where IPS are effecting native plant regeneration, around the rappelling tower areas effected by human impacts, and other areas along visitor created trails that are effected by human trampling. Vehicular and foot traffic cause soil compaction, unfavorably influences soil hydrology, changes soil pH levels, and adversely effects oak tree growth (Craul 1994; Day and Bassuk 1994; DeJong-Hughes et al. 2001; Jordan et al. 2003; Whitecotton et al. 2000) (Sections 2.3.1, 3.2.2, and 3.4.1). Planting native trees in these areas will help to reestablish the forest understory, midstory, and overstory layers in areas impacted by edge effects, or human activities.

Forest Edge Effects

The small size of SW makes it subject to changes that can impact the vitality of the stand, therefore, addressing edge effects in SW should be a priority (Section 2.3.6). Shade is an important component of forest health and should be maintained in SW by upholding a minimum stand thickness of 100 meters and protecting the continuity of the side canopy (foliage curtain) of the remnant (Matlack 1994). This may be accomplished with native tree plantings that fortify the edges along the east and north side of SW. Edge effects in SW may be reduced by planting native oaks and other native species that support the mid and overstory layers. This will also help to reduce mature tree losses and decline caused by the wind.

Emergency Egress/Ingress Road

Wider harder tracks, such as the emergency ingress/egress road, can cause edge effects and lead to unwanted changes in the forest structure. These unwanted effects may remain for long periods of time and should be viewed as a conservation concern, especially in jeopardized forest ecosystems and in urban areas where trail networks are expanding (Ballantyne et al. 2014; Malcolm and Ray 2000). It is important to rehabilitate forest edges after performing hardening treatments, such as graveling or other actions (Ballantyne and Pickering 2015).

Since invasive plant species are problematic along the SW emergency egress/ingress road, it is recommended the canopy and understory layers be restored along this area. This may be accomplished by planting a variety of native tree species and actively supervising their re-establishment (Ballantyne and Pickering 2015). These restoration efforts will eventually close the canopy gap above the emergency road and provide the additional benefit of making the roadway more aesthetically pleasing (Ribe 1991) and reduce behavior changes in local birds and (Wolf et al. 2013) and other animal species (Noss and Cooperrider 1994).

Rappelling Tower

The impacted area around the rappelling/training tower (Figures 2.4, 3.2, and 3.5) should be managed to reduce or contain visitor impacts using methods similar to the impact reduction techniques around the campgrounds of national parks or forests (Leung and Marion 2000) and include tactics such as concentrating use through design on the impacted area immediately around the rappelling tower by utilizing black locust logs to define the training area, hardening the site, keeping impacts limited, and discouraging use when impact potentials are high (when ground is saturated etc.) (Leung and Marion 2000) (J. Marion, personal communication, March 31, 2015). Natural barriers could also be employed to help limit impacts (Lehvävirta 1999). The impacts around the rappelling tower may not be conducive to a short term or medium term understory restoration, because of continued use and compaction. However, hand planting native trees and cultivating their vitality will increase tree density and canopy cover and improve forest midstory layer structure. Over time, these planted trees may fill in canopy gaps and become part of the SW overstory layer.

Trails

- ❖ **Evaluate existing visitor-created informal trail system by initiating a proactive management approach that provides a balance between visitor access and long-term ecosystem quality**

There should be the immediate closure of the three trail sections that are exhibiting significant erosion (Figure 3.5). In addition, the following procedure should be implemented, as resources allow, for the purpose of developing a more sustainable trail system in SW:

- Evaluate Trails to see if they are sustainably designed (Appendices N, O, and P).
- Relocate as needed to obtain sustainable trail alignments (Appendices N and P).
- Apply trail management actions, like tread drainage or gravel to make the trails more sustainable (Marion and Leung 2004).
- Implement site management and educational actions to encourage people to remain on the trails and reduce human trampling impacts (Appendix P).
- Monitor results of management actions and make adjustments until the desired outcome is achieved.

An assessment of the SW informal trails and other areas/sources of visitor impacts may indicate that much can be accomplished by initiating some simple steps such as: improving communication with visitors, improving maintenance and trail markings, formalizing some informal trails, installing structural elements as barriers against wear (Lehvävirta 1999), and closing unacceptable trails (Appendices O and P). Methodologies designed to minimize visitor impacts may be employed to achieve optimal results. These methodologies, based on research and visitor impact mitigation experience, will help to produce the dual benefits of providing visitor access to SW while simultaneously protecting ecosystem integrity for the enjoyment of future generations.

Visitor-created informal trails are often a concern because these types of unplanned trail networks have not been properly designed, constructed, or maintained for environmental sustainability and impacts, which are often excessive (Hockett et al. 2010). These informal trails also tend to multiply and thereby threaten the integrity of the natural resource, risk visitor safety, and detract from the quality of recreational experiences (Appendix P). Yet, formally designed trails may have negative ecological impacts as well. Wider hardened trails, such as the broader commuter trails, which could be considered for formalization, can cause canopy gaps and lead to changes in the forest structure along a trail (Ballantyne and Pickering 2015). In some cases, it may be better to maintain informal trails if they contain enough sustainable design attributes (Hockett et al. 2010). According to Jeff Marion, it is wise to be skeptical of visitor-created trails, because they are not professionally designed (J. Marion, personal communication, March 31, 2015) (Hesselbarth et al. 2007). It is better to take a long-term perspective when establishing trail systems by investing in performing the work correctly and doing the job right once than to try to force an unsuitable (unsustainable) trail configuration to work (Hesselbarth et al. 2007). The best results will be achieved by developing and implementing a plan that will achieve long-term benefits while sustaining the quality of the ecosystem over time (Olive and Marion 2009).

An adaptive management approach can employ a decision-making framework (many options exists) that allows managers to implement actions, evaluate their success, and, if needed, monitor and implement alternatives as follow-ups until objectives have been successfully accomplished (Appendix P).

SW has a visitor-created informal trail network and a formal trail along Lane Stadium on the west side. These formal and informal trails are used for recreation, education, and pedestrian/bicycle commuting. All these activities can result in damage to the forest, and it is important to minimize these impacts, especially in rare ecosystems and urban areas (Ballantyne et al. 2014). The deterrence of off-trail hiking along with sustainable trail management techniques will help to accomplish these goals (Appendix P).

Due to SW fiscal constraints, two separate but related options are presented. These options are discussed in more detail in Appendix R. They involve planning, maintenance, and monitoring of the trails. The first option involves a more basic, broad practice that can be implemented quickly and cheaply until resources for a second long-term optimal (ideal) methodology can be employed to provide a sustainably designed trail system for SW (Appendix R). The primary difference between the faster lower cost approach and the additional longer-term optimal approach lies, not so much in what is done, but to what extent some of the steps are carried out, especially during the analyses and decision-making processes.

3.4.3 Wildlife and Habitat

A quantitative analysis that assesses the abundance and diversity of wildlife species living in SW would provide valuable information about the SW ecosystem. Yet, so far to date, no substantial scientifically based quantitative assessments have been made about the variety of the fauna living within SW or for any specific animal species that is supported by the woods. Student groups could provide facts about the fauna living in SW by performing wildlife assessments as course projects in the future (Dr. Karpanty, personal communication, January 28, 2016). The use of student projects to collect observation based information on the variety of animal species as well as their population densities will provide the dual benefit of providing hands-on educational opportunities and delivering science-based data for wildlife assessments in SW.

Control of Undesired Animal Populations

- **Minimize wildlife conflicts and enhance habitat**
    - **Minimize conflicts and limit populations of nuisance animals (e.g. feral cats) by discouraging their presence**

The feeding of wildlife has few biological justifications and the effects and consequences of feeding wild and feral (e.g. cats) animals are unpredictable. In many cases, feeding wildlife is known to have harmful effects. Therefore, the feeding of wildlife in SW should be discouraged

(Section 2.3.4). Feeding wildlife creates overpopulations, diseases, and other issues that can create nuisances or disruptions (Orams 2002). Measures to ensure these animals are not fed could be places on signage and communicated by word of mouth during activities at events, such as Virginia Tech's Sustainability Week. If nuisance animals, such as feral cats, are found in SW, they should be trapped and removed (Jessup 2004) (Section 2.3.4).

Protection of Forest Structures that Provide Habitat

- **Monitor for deer overabundance to protect native plant biodiversity and forest regeneration by deterring or controlling browse in sensitive areas**

White-tailed deer can be especially damaging to native plant regeneration within oak dominated forests (Section 2.3.4) (Steckel et al. 2014). Therefore, SW should be monitored for effects of deer browsing. If deer trigger an action threshold response, effective measures should be taken to reduce deer populations below action threshold levels (Garrott et al. 1993). In SW, the most effective method of preventing deer caused ecological damage is to trap and remove the deer (Section 2.3.4). In the future, if deer pressures are difficult to manage, the construction of a fence may be necessary to prevent ecological harm caused by deer (Loeb 2011). An ecosystem management approach toward the assessment and management of deer (Waller and Alverson 1997) monitors indicator plant species, such as lilies (*Maianthemum canadense* and *Trillium grandiflorum*) that indicate a negative response to deer browsing impacts, for the purpose of setting action thresholds (Rooney 2001) (Section 2.3.4).

❖ Enhance bird and wildlife habitat by retaining old-growth forest structure and protecting native plant diversity

Many observations about the variety of birds in SW have been made by local wildlife enthusiasts, such as the NRV Bird Society, the NRV Sierra Club, and others. Recognition of the large numbers of migratory bird species that reside in SW or use the site as stopover points during migrations may be fostered by signage, brochures, or on an informational website.

There should be a focus on habitat protection for the benefit of birds and other wildlife in SW through the sustainment of the old-growth forest structures. Bird and wildlife habitat may be maintained by ensuring forest layers are renewed with native plant regeneration along with the retention of standing dead trees, course woody debris on forest floor, pits and mounds from root plates, layers of decaying matter, and large late-successional trees (Sections 2.3.3, 2.3.4, 2.3.5, 2.3.6, and 2.5). These old-growth forest features produce structural complexities that provide a greater variety of habitat niches for wildlife (Section 2.3.4). Snags in the form of standing dead trees are one of the most important configurations in SW for overstory birds and other wildlife because they provide places where cavity nesters may execute a wide array of behaviors necessary for the completion of their life cycles (Section 2.3.4) (Appendix K). Groundcover layers provide favorable conditions for understory bird species. Keeping feral cat populations suppressed will assure an abundance of bird species will continue to thrive in the sanctuary of SW. The control of IPS is an essential necessity for sustaining the health, vitality, and structural features within SW that in turn provide the environmental conditions that are necessary for wildlife inhabitants (Sections 2.3.4 and 2.3.5).

3.5 Recommendations Summary

The FSP recommendations are designed to facilitate a set of actions that may be undertaken for the purpose achieving the stewardship priority of restoration for the SW old-growth urban forest remnant (Sections 2.2 and 2.6). These actions will sustain SW and its provisioning of ecosystem services while empowering an extension of contexts for education, research, history, recreation, and engagement for the Virginia Tech and the Town of Blacksburg communities. The FSP recommendations are based upon common principles of tree and forest stewardship and serve as a guide for the implementation of restoration activities in SW as resources become available. Successful restoration will require organized leadership, base-line studies, dedicated people, effective community involvement, adequate funding, and coordinated planning to protect, manage, and restore SW (Konijnendijk et al. 2004). Urban forest remnants generally require lower levels of maintenance than other urban landscapes, yet they still require some amount of ongoing care. This is because urban forest remnant ecosystems are not self-sustaining, due to the human impacts that inevitably occur over time in urban settings (Green Seattle Partnership 2004; Loeb 2011; Steckel et al. 2014; Zipperer 2002) (Section 3.3.3.).

Proactive forest stewardship provides opportunities for cost-effective outcomes for visitor safety, forest health, aesthetics, low impact recreation, and ecosystem services (Pokorny et al. 2003). The SW stewardship recommendations, therefore, focus on measures that will increase functional benefits through planning, engagement, and stewardship and are summarized as follows:

- Prevent or limit development and activities that degrade the forest and injure its trees.
- Manage risks to ensure human safety
- Minimize soil and native plant disturbances caused by invasive plant species, human trampling, and/or deer browsing
- Provide a historic continuity in the species composition reflective of the region by ensuring native species regeneration/planting as revealed by historical ecology
- Engage partners to develop and maintain human capital and other resources for the stewardship of the forest (Loeb 2011; Mansourian et al. 2005; Steckel et al. 2014).

Both planning and resources are essential for the effective delivery of forest management actions and by necessity considers social, ecological, and economic dimensions (Grey 1996; Mansourian et al. 2005; Miller et al. 2015). The intent of the FSP recommendations is to prevent issues before they arise in order to save costs and effort over the long term and prevent ecological impacts that are difficult to reverse.

Effective tree and forest management addresses issues before they occur because tree and forest degradation problems become progressively more difficult to solve by the time they become manifested as symptoms. It is, therefore, important to focus on underlying causes of forest degradation, rather than reacting merely to signs of poor ecological health. The implementation of the FSP recommendations, therefore, are designed to support and guide the natural processes of succession by maintaining desired successional growth with the minimal interventions that are necessary to support the health and vitality of the ecosystem (Whisenant 2005b).

A long-term management approach is indispensable for SW because the old-growth urban forest remnant is composed of very long-lived trees and time will be required for partners, stakeholders, and stewards to assemble resources, implement stewardship actions, monitor the results, and assess which tactics are most effective in meeting objectives. The process of determining whether or not SW partners, in general, are getting what they want may only be determined over time through an ongoing adaptive process of monitoring the results of stewardship actions, analyzing their effectiveness in achieving goals, and through revisions of management actions in iterative repetitions until desired outcomes are achieved.

The effective implementation of these stewardship recommendations will generate and sustain the conditions that are essential for protecting the overstory, understory, and sapling layers of the SW old-growth forest remnant. Additionally, communication and education about the significance of the SW old-growth urban forest remnant to current and future community members will provide a social/historical context about the importance of agreements, collaboration, and cooperation among partners for the purpose of learning and working together in the nurturement of the ever awe-inspiring complexities of nature. For it is only through such endeavors that responsiveness and growth may thrive.

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Appendix A

Official University Statements Affirming Virginia Tech's Commitment to Sustainability, Principles of Community, and Educational Mission

Taken from "Presidential Policy Memorandum No. 262", "Virginia Tech Principles of Community", and the "Virginia Tech Mission Statement" (Steger 2013; Virginia Tech 2001; Virginia Tech 2005).

Original University Documentation Affirming Virginia Tech's Commitment to

Sustainability, Community, Service, and Education:

1. On May 9, 2013, Virginia Tech's 15th President, Charles Steger, Ph.D. sent a memorandum to all Virginia Tech employees and students expressing **Virginia Tech's commitment to sustainability**: "Virginia Tech will be a leader in Campus Sustainability."

   Sustainability Vision: Virginia Tech serves as a model community for a sustainable society. Sustainability is an integral part of the fabric of the university as it pursues enhanced economic stability and affordability, diversity and inclusion, environmental stewardship, expansion of knowledge, and education of future leaders.

   Sustainability Mission: The pursuit of sustainability is achieved through Virginia Tech's administration; physical environment and operations; student life and experience; campus culture and behavior; and academic learning, discovery, and engagement." (Steger 2013)

2. **Virginia Tech's Principles of Community** were first endorsed on March 14, 2005, by the Board of Visitors and seven other Virginia Tech entities, and reaffirmed by the university leadership on September 29, 2014. These principles encourage community processes of engagement, inclusion, and mutual respect.

   Virginia Tech Principles of Community affirm "the inherent dignity and value of every person and strive to maintain a climate for work and learning based on mutual respect and understanding; the right of each person to express thoughts and opinions freely; and the value of human diversity. The Virginia Tech Principles of Community reject all forms of prejudice and discrimination (Virginia Tech 2005).

3. **Virginia Tech's Mission statement** asserts the value of service in the creation, transfer, and application of knowledge in order to foster personal growth, advance society, increase societal effectiveness, and improve human quality of life. Virginia Polytechnic Institute and State University (Virginia Tech) is a public land-grant university serving the Commonwealth of Virginia, the nation, and the world community. The discovery and dissemination of new knowledge are central to its mission. Through its focus on teaching and learning, research and discovery, and outreach and engagement, the university creates, conveys, and applies knowledge to expand personal growth and opportunity, advance social and community development, foster economic competitiveness, and improve the quality of life (2001 Mission Statement adapted in 2006, by the Board of Visitors) (Virginia Tech 2001).

Appendix A: References

Steger, C.W. 2013. *Prsidential Policy Memorandum No. 262*. Available online at http://www.policies.vt.edu/policymemos/ppm262.pdf ; last accessed June 9, 2016

Virginia Tech. 2001. *Virginia Tech Mission Statement*. Available online at https://www.president.vt.edu/about-the-office/mission-vision/index.html ; last accessed June 9, 2016

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Appendix B

Stakeholder Group Interview Participants and Interview Questions Asked of Each Stakeholder Group

Stadium Woods Stakeholders: (Interviewed Oct. 2014 – Jan. 2015)

- Operations
- Transportation, Planning, & Sustainability
- Athletics
- Alumni Relations
- Grounds Maintenance
- Corps of Cadets
- Army ROTC
- Recreational Sports
- Landscape Architecture Program
- Architecture & Design
- Parking & Transportation
- Crop & Soil Environmental Science
- Stormwater Compliance
- Water Resources Engineer
- Biological Sciences
- University Police
- Emergency Management
- Town of Blacksburg Parks & Recreation
- Town of Blacksburg Office of Sustainability
- Friends of Stadium Woods
- NRV Sierra Club
- NRV Master Naturalists
- VT Forestry

Questions Posed to Each Stakeholder Group

What is your opinion about finding a name for the woods by means of a campus-wide naming contest?

What do the woods mean to you and our community?

How do you think we may meet your vision for the woods while balancing the interests of others?

What other questions should we be asking?

Who else do you suggest we talk to about Stadium Woods?

What do you envision for the woods in the future?

Appendix C

Public Participation Spectrum

IAP2'S PUBLIC PARTICIPATION SPECTRUM

The IAP2 Federation has developed the Spectrum to help groups define the public's role in any public participation process. The IAP2 Spectrum is quickly becoming an international standard.

INCREASING IMPACT ON THE DECISION →

	INFORM	CONSULT	INVOLVE	COLLABORATE	EMPOWER
PUBLIC PARTICIPATION GOAL	To provide the public with balanced and objective information to assist them in understanding the problem, alternatives, opportunities and/or solutions.	To obtain public feedback on analysis, alternatives and/or decisions.	To work directly with the public throughout the process to ensure that public concerns and aspirations are consistently understood and considered.	To partner with the public in each aspect of the decision including the development of alternatives and the identification of the preferred solution.	To place final decision making in the hands of the public.
PROMISE TO THE PUBLIC	We will keep you informed.	We will keep you informed, listen to and acknowledge concerns and aspirations, and provide feedback on how public input influenced the decision. We will seek your feedback on drafts and proposals.	We will work with you to ensure that your concerns and aspirations are directly reflected in the alternatives developed and provide feedback on how public input influenced the decision.	We will work together with you to formulate solutions and incorporate your advice and recommendations into the decisions to the maximum extent possible.	We will implement what you decide.

(International Association for Public Participation 2014)

Appendix C: Reference

International Association for Public Participation. 2014. *IAP2's Public Partiipation Spectrum*. Available online at https://www.iap2.org.au/resources/public-participation-spectrum ; last accessed June 1, 2016.

Appendix D

Blacksburg Community Group
and
Virginia Tech Community Group

Public Stakeholder Meeting Summary
(Comments and SWOT Analysis)

Community Group Stakeholder Meeting Held at Blacksburg Library 1/21/15

Comments from Public Community Group (taken from meeting minutes) (24 individuals signed the attendance sheet)

Group representation included: (1) Citizen of Town of Blacksburg, (2) Friends of Stadium Woods, (3) Town of Blacksburg Town Council, (4) Virginia Master Naturalists, (5) Virginia Native Plant Society, and (6) Virginia Tech Student Environmental Coalition

Participant A (5)
- Reflection on personal experience with the woods and remarking on the ways that people have used and impacted the woods through the generations
- Woods have survived abuse and now we have a responsibility to respect and protect the woods for future generations

Participant B (1)
- We need to preserve the woods
- Really concerned about the prospect of construction on the adjacent private parcel of high-density housing
- Get the invasive plants out and let nature take its course
- Shouldn't be a "complicated process;" just care for it and let nature take its course

Participant C (6)
- Read a prepared statement about the value of the woods to student education in a variety of courses and disciplines
- Recreation in the woods: jogging, training, meditation and prayer

Participants D & E (1)
- It just makes good sense to have a mature woodland nearby in which teaching and learning can be carried out versus having to bus students off-campus

Participant F (2)
- Believe strongly in restoration, but also want to pursue legal, permanent preservation of the woods (Strong applause to this assertion)

Participant G (2)
- Have a list of recommendations that FSW would like to see addressed in the stewardship plan

Participant H (4)
- Preservation, outreach, and education
- SW provides a unique opportunity in this respect
- A very convenient, strategic location for outreach and education programs
- Some residual invasive plants are actually a "teachable moment" for education
- Would like to have signage on the perimeter paths that interpret what people are seeing in the woods
- Would like to see SW publicized as a destination (brochures, Blacksburg website
- VMN can be a liaison to mobilize volunteer efforts, particularly amongst students
- Much sweat equity in the woods

Participant I (4)
- Read prepared statement about an annual report on restoration service projects carried out in Stadium Woods in 2014

Participant J (1)
- Commented that there should be a public role in the writing of the plan

Participant K (1)
- Commented that there should be greater effort to incorporate how people think and feel about the stewardship of the woods

Participant l (1)
- Asked if there will be an objective outside expert opinion about the stewardship plan

Closure Comments:

Participant C (6)
- Read written statement urging preservation and offering assistance from EC in writing the stewardship plan

Participant M (3)
- Need an advisory committee for Virginia Tech

Blacksburg Community Group Public Stakeholder Meeting and SWOT Analysis

Strengths

- Ecosystem services
- Prime location for learning
- Physical and mental health
- Carbon sequestration
- Stop-over habitat for migrating birds
- Unique and precious
- Watershed protection
- Experiencing nature nearby
- University ownership

Weaknesses

- Parking in the woods by athletics
- Flow-through traffic
- Mowing of forest buffer
- Finding the balance of use values and ecological integrity
- Conflicting proposals for "improvements" that might impact the woods
- Lack of preservation plan
- Contradiction of uses that might be harmful to the woods
- Unplanned paths
- Flow of traffic through the woods following football games

Threats

- University ownership
- Soil compaction
- Invasive plants
- Future construction
- Erosion
- No more impervious surface
- Loving the woods to death; if too many improvements are made, then the impacts will be too heavy and will degrade the woods

Opportunities

- Education
- Demonstrate that people care about nature and put forth effort to conserve it
- Service-learning
- Unique opportunity to experience an old-growth forest
- Observe and study native plants
- Raising awareness about this resources
- Educating youth to influence their parents
- Expanding the forest edge buffer

Comments from Virginia Tech Community Group
(taken from meeting minutes)
(12 Individuals Signed the Attendance Sheet)

Virginia Tech Community Group Stakeholder Meeting Held at Inn at Virginia Tech 2/2/15

Participant A: Views Stadium Woods as a "central park" that has much opportunity for recreation and exploration

- He sees an opportunity to make Stadium Woods a destination for people
- His perspective is that the priority should be somewhere in between restore and alter
- Something that is intriguing is the idea of a path through the woods that would connect with the planned running trails that will encircle the South Gate recreational area

Participant B: Commented that there should be consideration to treating the "north" woods as a separate management unit from the "south" woods due to differences in condition and use

- Finding the balance between use and preservation will be a consideration, particularly when it comes to trail construction, treatment, and upkeep

Participant C: Reiterated the idea of using a dual approach to stewardship in which the north woods (which is the most heavily impacted portion and under some constraints for emergency management

Participant B: "Preservation as defined here is not going to be possible without putting a fence around it and that is not going to be possible given the current traffic pressure on the woods"

- Analogy: think about the Appalachian Trail and how structures are used to direct human behavior and protect the ecological integrity that will be impacted by human traffic
- There is going to be a lot of traffic pressure on the woods in the future when the private land to the east is developed and population density increases
- Traffic pressure is episodic; much of the high volume is associated with game day

Participant D: If we want to be a leader in sustainability, then we need to make a big splash with the woods;

- The stadium is a big deal and Stadium Woods is a big deal; someone needs to be the champion for the woods and be the point person for all matters that revolve around the woods; we need to take care of it; capitalize on it; a way to bring everyone together
- A beautiful backdrop to the athletic facilities
- There has to be a "terrain manager" for every acre of this campus and there has to be accountability for the stewardship plan; without someone accountable for the plan, it will never be implemented; need money

Participant E: Three tiers of implementation

- High level: high cost; creative funding ideas
- Mid level: medium cost
- Low level: these are the low-hanging fruit; extremely low cost or no cost

<u>Participant B</u>:

- Use rappelling tower in August
- Army ROTC: Use it weekly on Tuesdays and is the only adequate space "absolutely pivotal ground"
- Important to capture the data on courses that use the woods and document that use
- A high priority is abating the hazards
- There needs to be a priority of work; first and foremost is to abate hazards created by junk (concrete, rebar, etc.)
- Once these are taken care of, then you can move on to secondary things like creating trail
- There needs to be ownership; the way you get buy-in is to give groups a "stake" in the grounds; if you make recreational trails, then rec sports will take ownership;
- if you make improvements that benefit ROTC, then ROTC will take ownership, etc.
- WE NEED A CAMPUS ARBORIST!!!! THIS PERSON WOULD BE THE POINT OF CONTACT FOR ALL MATTERS OF VEGETATION INCLUDING STADIUM WOODS

<u>Participant D</u>: We need a high-level charge from the university to elevate the profile and focus the effort of "The Big Event," "Earth Day," or "Sustainability Week" onto the woods

1. HIGH LEVEL SUPPORT
2. ESTABLISH RESPONSIBILITY FOR THE WOODS
3. CLEAN UP DEBRIS
4. TRAFFIC PLANNING

- The plan needs to have a phased approach of sequential priority, and the first phase is the need to establish responsibility and accountability

Virginia Tech Community Group Public Stakeholder Meeting and SWOT Analysis

Strengths

(No comments were made regarding strengths)

Weaknesses

- Stadium football traffic
- Funding and human resources to implement plan

Threats

- Future development of the private land on the east side of the woods and the related traffic and disturbance
- Continual trash from game day traffic
- Perceptions of sexual assault risk and the lack of lighting around the woods; need to look at site security holistically (lighting, access, surveillance, etc.); and to incorporate recommendations from police, security, risk, etc., into the plan

Opportunities

- Needs to be a strong statement from the top that the woods are important and will be protected
- Capitalize on the interests and enthusiasm here at VT to recruit volunteer stewards
- Make this the exemplary and precedent-setting plan in the country

Appendix E

Responses from Blacksburg Community Group
and
Virginia Tech Community Group

Public Stakeholder Meetings Questionnaire Worksheet

Stadium Woods Stewardship Plan, Stakeholder Meeting Worksheet

Part A: Establish a Stewardship Priority (Value of the Woods):

- Identify why the Stadium Woods Area is important to care for:

____

____

- Determine the most important stewardship value in the Stewardship Priority Spectrum, (**Preserve**, **Restore**, or A**lter** the current cover type to another cover type):

____

Part B: Identify Goals or Uses Your Group may have for the Woods (Consider Opportunities):

____

____

Part C: Strengths, Weaknesses, Threats, Opportunities; Final Thoughts & Wrap Up:

Strengths: (what benefits do the woods provide?)

____

____

Weaknesses: (What aspects represent a disadvantage or weakness?)

____

____

Threats: (What are some potential risks or issues?)

____

____

Opportunities: (What are some opportunities or favorable circumstances?)

____

____

Appendix F

Blacksburg and Virginia Tech Community Group Public Stakeholder Meeting Questionnaire Worksheet Responses

Blacksburg Community Group Public Stakeholder Meeting Questionnaire Worksheet Responses (16 Worksheets Submitted in Total)

Value

Identify why Stadium Woods is important to take care of:

- Old-Growth rare and unique (4)
- Higher education (2)
- Need for education (unique) (3)
- K-12 education (community) (2)
- Intergenerational equity
- Unique habitat critical to ecosystem
- Biological diversity
- Important for future generations
- Focal point of campus
- Recreation (walking & jogging (2)
- Quiet place for reflection
- To preserve history (2)
- Irreplaceable
- Allow for an uninterrupted natural area
- A place local people may enjoy
- Only untouched area left
- Proximity to dorms
- Exercise
- Place to escape
- Place of inspiration
- Preserve ecosystem services
- Ecosystem services

Stewardship Priority

Preserve	Restore	Alter
2 1 (legally)	7 Remove invasives 1 To natural quality 2 And legally preserve 1 Using BMPs to maintain old-growth characteristics 1 To full potential 1 Ecologically	0
3 Total	**1.5 Total**	**0 Total**

Blacksburg Community Group Public Stakeholder Meeting Questionnaire Worksheets – SWOT Analysis

Strengths

As a Unique Forest

- Valuable to VT & Blacksburg
- Proximity to campus (academia/learning) (2)
- Quiet/peaceful place in urban area (2)
- Habitat (migratory birds (3)
- Unique old-growth (2)
- Native & rare plants
- Not enough protection (2)
- Connection to history & future
- Valuable for education & research opportunities (2)
- Water quality & retention (3)
- Valuable for education (pre, grade, middle, high school)
- Ecosystem services (air, water, temperature reduction (4)
- Biggest trees some may ever see (2)
- Irreplaceable
- Landmark/environment
- Age of trees
- Awe-inspiring

For our Community

- Education (2)
- Service learning
- Health improvements
- Connection to history & future
- Migratory birds, wildlife resource
- History resource
- Solitude
- Biological resource
- Public space
- Inspiration
- Creative space
- Cares about nature easily
- Accessible (opportunity for disabled)
- Great resource continued
- Unifying effort to protect woods

Weak-nesses

For the Woods

- Use values outweigh environmental values (2)
- Continued manpower
- No legal protection
- Too many paths (2)
- Invasive plant species (4)
- Football parking
- Lack of stewardship plan (2)
- Used for dumping (2)
- Underwhelming aesthetics
- No legal protection
- Anything in woods other than reverence & enjoyment
- Football parking

For our Community

- Abuse, lack of respect (parking) (2)
- None (2)
- Not enough protection (2)
- Education (2)
- Lack of parking for field trips
- "Tragedy of the Commons" dynamic
- Poor use
- Trash (community looks bad)

Blacksburg Community Group Public Stakeholder Meeting Questionnaire Worksheets - SWOT Analysis (cont.)

Threats

To The Woods	• Human impacts • Roads • Invasive plants (7) • Development (5) • No legal protection • Pathways (3) • Overuse/misuse (3) • Fence	• Dumping • Parking (compaction) (5) • Compaction (5) • Exercise course • Game Day events • VT is in control • Lack of connection to natural corridors	• Lack of traffic control • Too much lighting or fencing • Man-made structures • Enhancements • Narrow geometry of the woods • Lack of awareness about its true value
From the Woods	• Risks/hazards (3) • Liability issues • None	• People can learn to be safe in woods • Human intervention • Any exercise equipment	
To our Community	• Too complex to manage • None • Could lose nature & place of meaning	• Boardwalks get slimy • Non-permeable surfaces could create problems	
From our Community	• None • Vandalism • Compaction • Litter • Game Day events	• Trampling • Trash • Parking	• Messing with nature has messed things up • Erosion

Blacksburg Community Group Public Stakeholder Meeting Questionnaire Worksheets - SWOT Analysis (cont.)

Opportunities

For the Woods	• Pass on to future (2) • Students (generations) • Fitness trails • To remove invasive plants • Bird nesting area • Create a VT/town advisory committee • Native plant restoration	• To stop football parking • Town volunteers • Destination for visitors • To be nationally recognized as old-growth • Research • Signage	• Education (history & natural resources) • Become native sanctuary site for endangered plants (2) • Walkable place for town, Tech, and visitors • Information brochures w/maps
From the Woods	• Carbon sequestration and storage • Medicinal plants • Research (2)	• Plant reintroduction • Ecological resilience • Examples of time (layers)	
For Our Community	• To walk in old-growth forest • Conservation education • Resilience (social) • Health care • Preservation of evolutionary history (information)	• Experience • Engagement & partnerships (2) • Field trips for school kids • Spiritual • Education	• Appreciation • Place to enjoy • Spirit of community service • Irreplaceable • Destination site (on internet)
From Our Community	• Volunteer management		

Virginia Tech Community Group Public Stakeholder Meeting Questionnaire Worksheet Responses (4 Worksheets Submitted in Total)

Value

Identify why Stadium Woods is important to take care of:

- Only true green space left on campus proper
- Environmentally and ecologically unique
- Beauty and aesthetic impact for the university
- Demonstrates university's commitment to environment
- Connection to history (2)
- Location on campus and student traffic through the area
- A valuable resource for a university campus
- Gateway area
- Education and research

Stewardship Priority

Preserve	Restore	Alter
1	0.5 Combine restore and alter 1 Entire area and acknowledge key areas	0.5
1 Total	**1.5 Total**	**0.5 Total**

Virginia Tech Community Group Public Stakeholder Meeting Questionnaire Worksheets – SWOT Analysis

Strengths

- Preservation of a unique environment (rare)
- Education, research, and collaboration with others in higher education, town of Blacksburg, and New River Valley
- Enjoyment of the university and community
- Play a key role in university's MS-4 permit
- Conveyance to that type of history
- Educational environment for study

Weaknesses

- No present funding for the Woods
- White-collar prioritization
- Little visibility by the university
- Lack of funding for human resources to accomplish goals
- Current maintenance does not provide for maintenance to Stadium Woods to provide a safe condition for increased pedestrian traffic
- Safety & security (need lots LED lighting)

Threats

- Lack of tree care that will remove trees that could fall
- Ongoing encroachment
- Increased use
- Lack of stewardship (presently)
- "Widowmakers," increased use of the area increases risks
- Proposed adjacent community development (impacts)
- Foot traffic due to proximity to student housing in town of Blacksburg right next door

Opportunities

- The student body and community offer free manpower for work
- Student pride in cleanup and restoration
- Recreation
- Challenge courses
- Make Stadium Woods a home run facility for everyone

Proposed Goals

- Maintain the woods for rappelling and training for Corps of Cadets and Army ROTC programs
- Outdoor recreational area for a challenge course (ropes course)
- Trails for walking and jogging to connect outdoor recreation areas to the main campus
- Showcase sustainability
- Need someone to take ownership

Appendix G

Stadium Woods Area

The "Stadium Woods" (SW) area was recorded using a mapping grade Trimble Geo XH combination Global Positioning System (GPS) devise and field computer, with a Hurricane external antennae. This equipment array generally provides sub-meter accuracy, which most often occurs in the 30-50 cm range. Under ideal circumstances, this equipment array may record vector points in the 3-cm accuracy range. These accuracy ranges are considered to be mapping grade and are not reliable for surveys.

The area was delineated as forest if it contained leaf litter and woody debris in combination with understory vegetation. A 1-meter offset to the right was set in the Geo XH GPS/field computer. A point of 1 meter was then measured on a stick, which was used to determine the edge of the woods. This technique allowed the edge of the woods to be gauged while walking with the equipment array without having the external antenna hindered by overhanging branches of understory vegetation. The forest was measured using the GPS/field computer equipment array by walking in a clockwise direction using the stick to maintain a one meter distance from the forest remnant boundary, which is adjusted by the one meter offset setting in the Geo XH GPS/field computer. Mowed grassy areas were not measured as part of the SW forest. The data was collected on the morning of May 26, 2015. Everything was collected in WGS 1984 Coordinate System and post-processed using the Radford Base Station (Blacksburg wasn't working). The files were then re-projected into UTM NAD 1983 Zone 17N Coordinate System.

A blank ArcMap GIS was opened and VATECH15_Delivery.sid 2015 digital orthographic imagery was loaded into the dataframe. The dataframe coordinate system then sets to the coordinate system of the digital orthographic imagery in ArcGIS, which is the NAD_1983_StatePlane_South_FIPS_4502_Feet Coordinate System. The datum is D_North_American_1983 and the projection is Lambert_Conformal_Conic. The SW_Area5_26_15 area polygon shapefile was then loaded into the dataframe. This area polygon shapefile properties lists the coordinate system as GCS_WGS_1984, datum D_WGS_1984. This area polygon layer should project to the NAD_1983_StatePlane_South_FIPS_4502_Feet Coordinate System with the D_North_American_1983 Datum and Lambert Conformal Conic Projection, but there is no way to verify that ArcGIS does this correctly and **inconsistencies may exist.** The area is **12.05 acres** according to the method described above (Figure G-1).

These inconsistencies may distort the shape of the polygon and affect the ArcGIS area calculation. As a result, the ArcGIS area measurements are a calculated approximation of the area size and do not represent a surveyed area calculation. This is a mapping grade measurement used for the purpose of delineating the SW boundary in relationship to other area features, such as trees, roads, etc., for the purpose of establishing where the SW boundary should be demarcated.

In addition, when viewed in the ArcGIS, it was clear that some vector locations were distorted by the Stadium, which interfered with satellite signals to the GPS. A few vector points were clearly out of place, especially near the steel fence between the east side of the stadium and the woods. In this case, the position of the vector points were edited in ArcGIS by using the VATECH15_Delivery.sid 2015 digital orthographic imagery as a reference in a process known as "heads up digitizing".

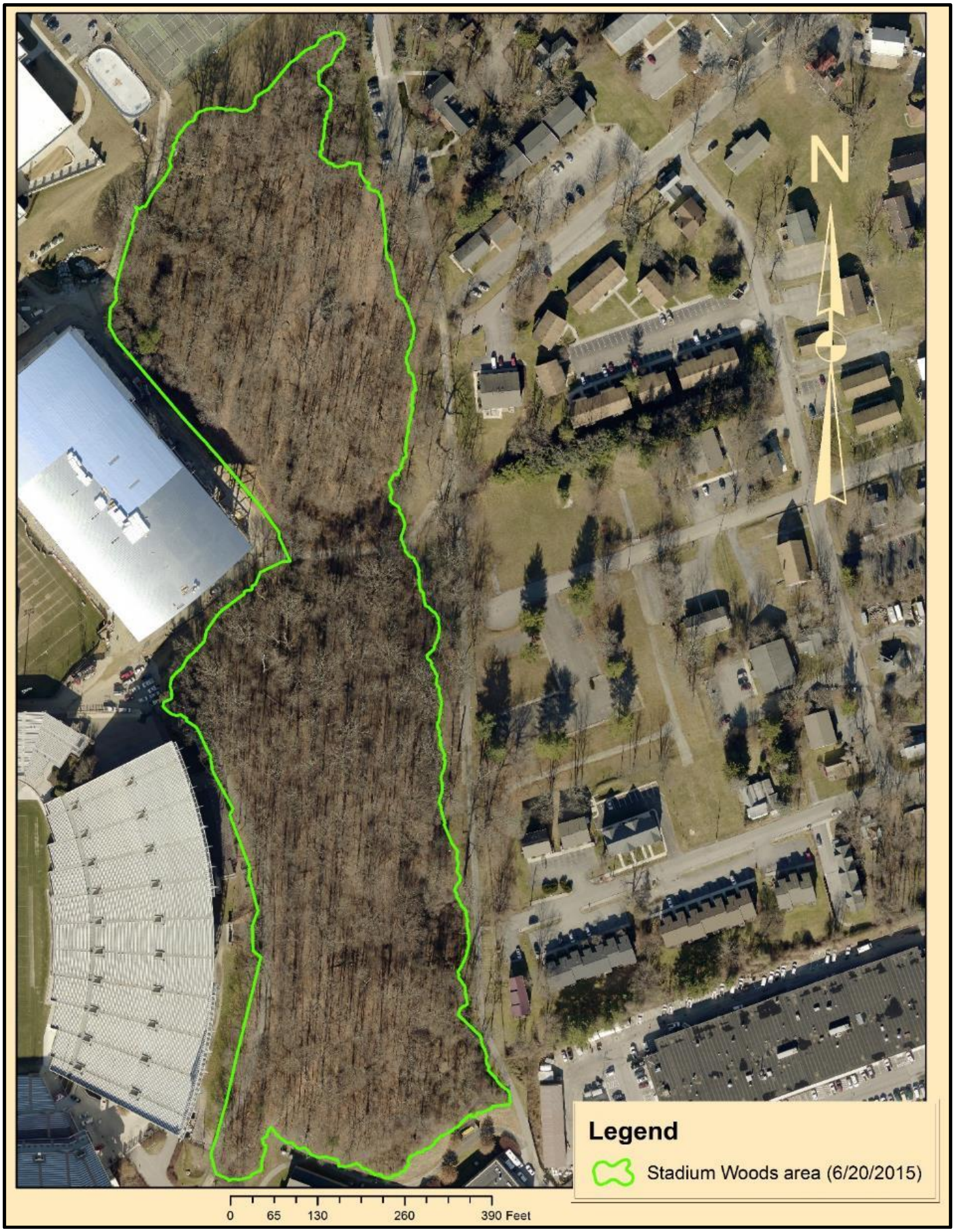


Figure G-1. Virginia Tech's "Stadium Woods" delineated area (12.05 acres) using mapping grade equipment (Geo XH with external Hurricane antenna) capable of sub-meter accuracy and depicted on ArcMap Geographic Information System (GIS)

A true and certified area measurement may be established by a professional surveyor. One such measurement exists; however, the boundary does not line up with the above GPS/GIS delineated area boundary. Our best estimation of the actual area of SW is between 11.3 and 12.2 acres. It is also important to note that the boundary area changes very slightly from year to year according to how the edges are maintained by VT Facility Services Grounds. In addition, boundary allocations may be adjusted once the construction on the indoor practice facility is completed.

Appendix H

Groseclose Soil Survey Data

(USDA 2002)

LOCATION GROSECLOSE VA+TN
Established Series
Rev. DFW-RRD
08/2002

GROSECLOSE SERIES

Soils of the Groseclose series are very deep and well drained with slowly permeable subsoils. They formed in materials weathered from limestone, shale, siltstone, and sandstone. Slopes range from 0 to 75 percent. Mean annual precipitation is about 40 inches, and mean annual temperature is about 54 degrees F.

TAXONOMIC CLASS: Fine, mixed, semiactive, mesic Typic Hapludults

TYPICAL PEDON: Groseclose loam, on a 3 percent convex west (284 degrees) facing slope in a hay field at 2,010 feet elevation. (Colors are for moist soil)

Ap--0 to 7 inches; brown (10YR 5/3) loam; moderate fine granular structure; friable, slightly sticky, slightly plastic; common very fine and fine roots; common fine pores; 2 percent chert gravel; moderately acid; abrupt smooth boundary. (0 to 10 inches thick)

Bt1--7 to 28 inches; yellowish brown (10YR 5/6) clay; moderate very fine and fine subangular blocky structure; friable, sticky, plastic; few very fine and fine roots; common very fine pores; few distinct dark yellowish brown clay films and few black coatings on faces of peds; 2 percent chert gravel; very strongly acid; clear smooth boundary.

Bt2--28 to 40 inches; mottled strong brown (7.5YR 5/8) and yellowish red (5YR 5/8) clay; moderate medium and coarse subangular blocky structure; friable, sticky, plastic; few fine roots; common fine pores; common slickensides; many distinct clay films and few black coatings on faces of peds; 20 percent highly weathered brownish yellow and greenish gray shale and siltstone channers that crush easily to soil material; very strongly acid; clear wavy boundary. (Combined thickness of the Bt horizon is 25 to 55 inches)

C1--40 to 51 inches; mottled strong brown (7.5YR 5/8) and yellowish red (5YR 5/8) clay; massive; friable, sticky, slightly plastic; few very fine roots; few very fine and fine vesicular pores; common slickensides; many prominent clay flows mainly in relic rock joints; 60 percent highly weathered brownish yellow and greenish gray shale and sandstone channers that crush easily to soil materials; 1 percent chert gravel; very strongly acid; clear wavy boundary.

C2--51 to 71 inches; mottled reddish yellow (7.5YR 6/8) and yellowish red (5YR 5/8) clay loam; massive; friable, sticky, slightly plastic; few very fine and fine vesicular pores; common slickensides; many prominent clay flows in relic rock joints; few black coatings on rock fragments; 70 percent highly weathered greenish gray shale and siltstone channers that crush easily to soil materials; very strongly acid.

TYPE LOCATION: Montgomery County, Virginia; about 1000 yards east (93 degrees) of the junction of VA-114 and VA-663 and about 50 yards south of VA-114.

RANGE IN CHARACTERISTICS: Solum thickness ranges from 30 to 60 inches. In some pedons, variegated colors in the solum occur at depths from 20 to 40 inches below the soil surface. Depth to bedrock is more than 60 inches. Rock fragments of chert, siltstone, shale, and sandstone range from 0 to 75 percent in the A horizon and from 0 to 35 percent in the Bt and C horizon. Reaction ranges from extremely acid through strongly acid, unless limed.

The Ap horizon, where present, has hue of 7.5YR or 10YR, value of 3 through 5, and chroma of 3 through 8. It is sandy loam, fine sandy loam, loam, silt loam, clay loam, or silty clay loam in the fine-earth fraction.

The A horizon, where present, has hue of 7.5YR or 10YR, value of 3 or 5, and chroma of 3 through 8. It is sandy loam, fine sandy loam, loam, silt loam, clay loam, or silty clay loam in the fine-earth fraction.

The BA horizon, where present, has hue of 7.5YR or 10YR, value of 4 through 6, and chroma of 4 through 8. It is silt loam, loam, silty clay loam, or clay loam in the fine earth fraction.

The Bt horizon has hue of 2.5YR through 10YR, value of 4 through 6, and chroma of 4 through 8. It is clay, silty clay, silty clay loam, clay loam, or sandy clay loam in the fine-earth fraction.

The C horizon is mottled in shades of red, brown, and yellow. Texture is silty clay loam, silt loam, clay loam, clay, sandy clay loam, or sandy loam in the fine-earth fraction.

COMPETING SERIES: These are the Agnos, Boden, Braddock, Buckhall, Buffstat, Christian, Clifton, Fairfax, Gassville, Goresville, Howell, Littlejoe, Lodi, Monmouth, Muse, Nantahala, Pervina, Quantico, Sequoia, Timberville, Trappist, Unison, Warminster, and Woolwine series in the same family. Agnos, Gassville, and Muse soils have a moderate shrink-swell potential. Boden soils are shallower to bedrock and contain less than 20 percent silt. Braddock soils have dominant hue of 2.5YR or 10YR in the Bt horizon and a moderately permeable subsoil. Buckhall soils have rock fragments of quartz and granite. Buffstat and Littlejoe soils formed in serecite schist and other fine-grained material. Christian and Lodi soils do not have variegated colors from weathered shale and siltstone fragments at a depth of 20 to 40 inches, and in addition have moderate permeability and shrink-swell potential. Clifton soils have flakes of mica throughout the solum. Fairfax, Goresville (T), and Timberville soils have lithological discontinuities in the solum. Howell and Monmouth soils have hue of 2.5Y or 5Y in the lower part of the Bt horizon and in addition, Monmouth soils contain glauconite. Nantahala (T) soils are deep to paralithic contact of metasedimentary rock. Pervina soils have more than 60 inches of rainfall annually and have cool moist winters. Quantico soils have rounded quartz gravel. Sequoia and Trappist soils are less than 40 inches to bedrock. Unison soils contain rounded or subrounded gravel or cobbles of crystalline rocks. Warminster soils formed in Triassic red shale residuum. Woolwine soils are moderately deep to mafic bedrock.

GEOGRAPHIC SETTING: Groseclose soils are on nearly level to very steep convex ridges and sideslopes in the Appalachian Valley. Slope gradients range from 0 to 75 percent. These soils formed in materials weathered from interbedded limestone, shale, siltstone, and sandstone. Mean annual precipitation ranges from 36 to 44 inches and mean annual temperature ranges from 52 to 57 degrees F.

GEOGRAPHICALLY ASSOCIATED SOILS: These are the Poplimento, Litz, Frederick, Vertrees, Timberville, and Ernest soils. Poplimento, Berks Frederick, and Vertrees soils are on landscape positions similar to those of the Groseclose series. Poplimento soils have a higher base saturation. Litz soils have a cambic horizon that contains more than 35 percent rock fragments. Frederick and Vertrees soils have thicker sola. Timberville and Ernest soils are along drainageways and in depressions. Timberville soils have a buried Bt horizon; Ernest soils have a fragipan.

DRAINAGE AND PERMEABILITY: Well drained. Runoff is very slow to very rapid. Permeability is slow.

USE AND VEGETATION: Most areas are used for row crops, hay, or pasture. Corn and small grains are the principal row crops.

DISTRIBUTION AND EXTENT: Virginia, Tennessee, and Kentucky. The series is of moderate extent.

MLRA SOIL SURVEY REGIONAL OFFICE (MO) RESPONSIBLE: Morgantown, West Virginia

SERIES ESTABLISHED: Smyth County, Virginia, 1938.

REMARKS: 1. Highly weathered shale, siltstone, and sandstone fragments that crush easily to soil materials are not considered to be rock fragments. 2. Diagnostic horizons and features recognized in this pedon are:

a. Ochric epipedon - the zone from 0 to 7 inches (Ap horizon).
b. Argillic horizon - the zone from 7 to 40 inches (Bt horizon).

SIR = VA0084, VA0166 (GRAVELLY)
MLRA = 125, 128
REVISED = 4/11/97 RRD

ADDITIONAL DATA: Particle size, chemical, and mineralogy data for the typical pedon (S79VA121-22-(1-6) are available from VPI&SU Soil Survey Laboratory. In addition, particle size (hydrometer), base saturation (Hach), and VPI&SU Soil Testing data are available on 32 additional pedons.

National Cooperative Soil Survey, U.S.A.
https://soilseries.sc.egov.usda.gov/OSD_Docs/G/GROSECLOSE.html

Montgomery County, Virginia

18B – Groseclose-Urban land complex, 2 to 7 percent slopes

Map Unit Setting

National map unit symbol: kc27
Elevation: 1,300 to 3,000 feet
Mean annual precipitation: 30 to 45 inches
Mean annual air temperature: 50 to 57 degrees F
Frost-free period: 117 to 185 days
Farmland classification: Not prime farmland

Map Unit Composition

Groseclose and similar soils: 40 percent
Urban Land: 30 percent
Minor Components: 3 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Groseclose

Setting

Landform: Hills
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Interfluve
Down-slope shape: Convex
Parent material: Limestone, shale, siltstone, and sandstone residuum

Typical Profile

H1 - 0 to 10 inches: loam
H2 - 10 to 28 inches: clay
H3 - 28 to 39 inches: clay
H4 - 39 to 51 inches: clay
H5 - 51 to 79 inches: clay loam

Properties and qualities

Slope: 2 to 7 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Runoff class: High
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Moderate (about 8.7 inches)

Interpretive Groups

Land capability classification (irrigated): None specified

Land capability classification (nonirrigated): 2e

Hydrologic Soil Group: C

Other vegetative classification: Unnamed (G128XB000VA)

Description of Urban Land

Setting

Landform: Hills

Landform position (two-dimensional): Summit

Landform position (three-dimensional): Interfluve

Down-slope shape: Convex

Parent material: Limestone, shale, siltstone, and sandstone residuum

Interpretive groups

Land capability classification (irrigated): None specified

Other vegetative classification: Unnamed (G128XY000VA)

Minor Components

Purdy

Percent of map unit: 3 percent

Landform: Stream terraces, depressions

Landform position (three-dimensional): Tread

Down-slope shape: Linear

Across-slope shape: Linear

Other vegetative classification: Unnamed (G128XY000VA)

Data Source Information

Soil survey Area: Montgomery County, Virginia

Survey Area Data: Version 9, Dec 11, 2013

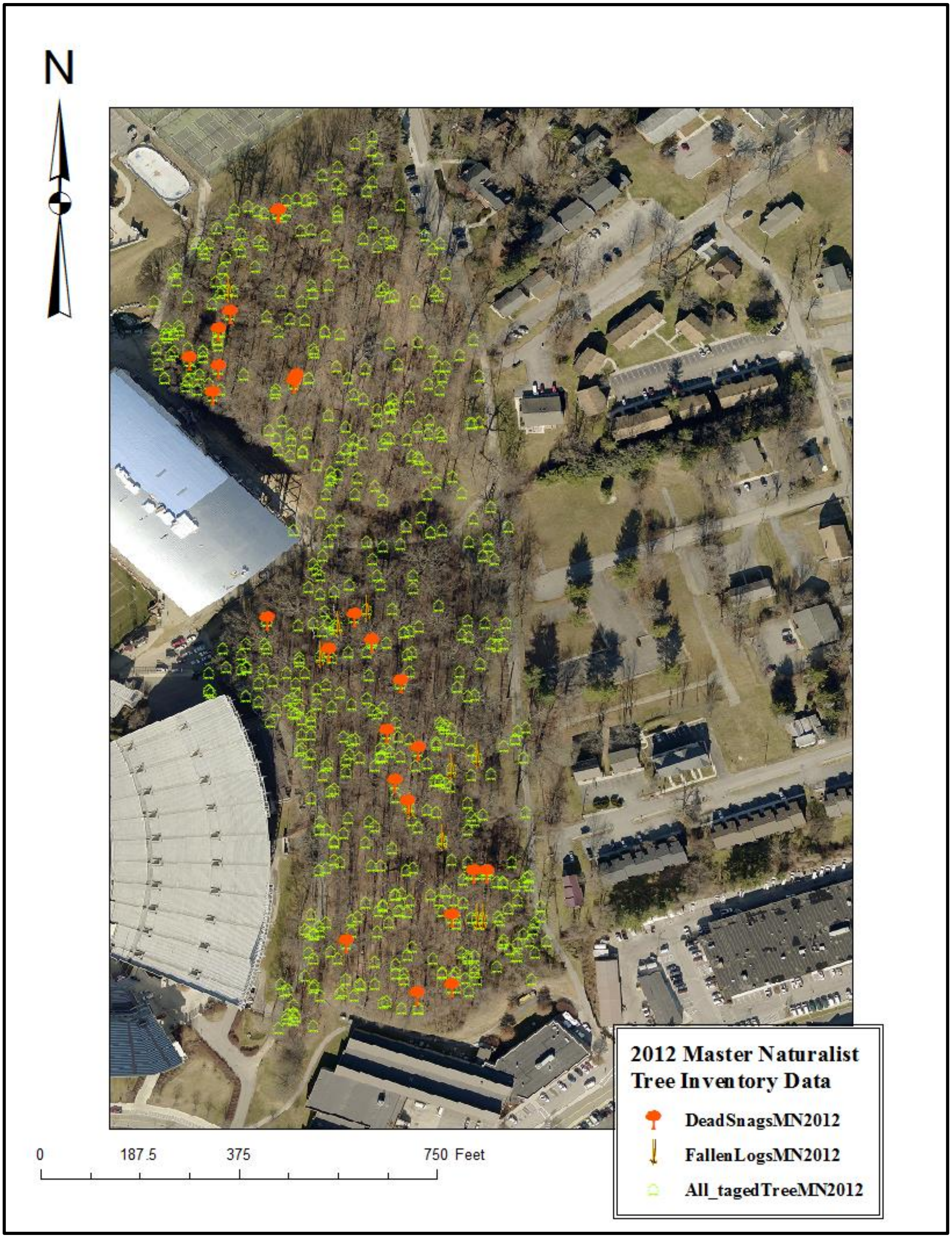
Appendix H: Reference

USDA. 2002. Groseclose Series. Available online at https://soilseries.sc.egov.usda.gov/OSD_Docs/G/GROSECLOSE.html ; last accessed June 3, 2016..

Appendix I

2012 Master Naturalists Tree Inventory Data, Collected with Recreation Grade GPS Displayed in ArcMap GIS

2012 Virginia Master Naturalists Data of Trees over 12” (largest 260 trees and the 54 trees over 36’ DBH)


N
2012 Master Naturalist Tree Inventory Data
DeadSnagsMN2012
FallenLogsMN2012
All_tagedTreeMN2012
0
187.5
375
750 Feet

Appendix J

Stadium Woods Invasive Plant Species and Lists of Invasive Plant Species Relevant to the Appalachian Region: Includes lists of Best Management Practices, Procedures, and Resources for the Control of Invasive Plants

List A: Stadium Woods Invasive Exotic Plant Species (IPS)

Documented on the 2012 *Forest Ecological Assessment*, page 12 (Biohabitats 2012):

- Asiatic/Oriental Bittersweet (*Celastrus orbiculata*)
- Burning Bush (*Euonymus alatus*)
- Bush/Amur Honeysuckle (*Lonicra maackii*)
- English Ivy (*Hedera helix*)
- Japanese Barberry (*Beberis thunbergii*)
- Japanese Honeysuckle (*Lonicera japonica*)
- Multiflora Rose (*Rosa multiflora*)
- Privit (*Ligustrum sinense,* L. vulgare)

Also occurring in the woods:

- Autumn Olive (*Elaeagnus uibellata*)
- Garlic Mustard (*Alliaria petiolata*)
- Norway Maple (*Acer platanoides*)
- Tree of Heaven (*Ailanthus altissima*)
- Winter Creeper (*Euonymus fortune*)

Virginia Invasive Plant Species (IPS) List (Virginia Department of. Conservation and Recreation 2015)


Tree-of-heaven


Phragmites


Wavyleaf Grass

The Virginia Invasive Plant Species List Comprises species that are established - or may become established – in Virginia, cause economic and ecological Harm, and present ongoing management Issues.

The list is for educational purposes only and has no regulatory authority.

To be included on the list, there must be demonstrable evidence that a species poses a threat to Virginia's forests, native grasslands, wetlands or waterways.

The Virginia Department of Conservation and Recreation's Invasive Species Assessment Protocol, approved by the Virginia Invasive Species Working Group, May 2015, was used to conduct a risk Assessment for each listed species. Species were ranked as exhibiting **high**, **medium** or **low** levels of invasiveness based on their threat to natural

Scientific Name	Common Name	Virginia Invasiveness Rank	REGION		
			Mountain	Piedmont	Coastal
Ailanthus altissima	**Tree-of-heaven**	High	•	•	•
Alliaria petiolata	**Garlic Mustard**	High	•	•	•
Alternanthera philoxeroides	**Alligator-weed**	High			•
Ampelopsis brevipedunculata	**Porcelain-berry**	High		•	•
Carex kobomugi	**Japanese Sand Sedge**	High			•
Celastrus orbiculatus	**Oriental Bittersweet**	High	•	•	•
Centaurea stoebe ssp. micranthos	**Spotted Knapweed**	High	•	•	•
Cirsium arvense	**Canada Thistle**	High	•	•	•
Dioscorea polystachya	**Cinnamon Vine**	High	•	•	•
Elaeagnus umbellata	**Autumn Olive**	High	•	•	•
Euonymus alatus	**Winged Euonymus**	High	•	•	
Ficaria verna	**Lesser Celandine**	High		•	•
Hydrilla verticillata	**Hydrilla**	High	•	•	•
Iris pseudacorus	**Yellow Flag**	High	•	•	•
Lespedeza cuneata	**Chinese Lespedeza**	High	•	•	•
Ligustrum sinense	**Chinese Privet**	High	•	•	•
Lonicera japonica	**Japanese Honeysuckle**	High	•	•	•
Lonicera maackii	**Amur Honeysuckle**	High	•	•	•
Lonicera morrowii	**Morrow's Honeysuckle**	High	•	•	
Lythrum salicaria	**Purple Loosestrife**	High	•	•	•
Microstegium vimineum	**Japanese Stiltgrass**	High	•	•	•
Murdannia keisak	**Marsh Dewflower**	High	•	•	•
Myriophyllum aquaticum	**Parrot Feather**	High	•	•	•
Myriophyllum spicatum	**Eurasian Water-milfoil**	High	•	•	•
Persicaria perfoliata	**Mile-a-minute**	High	•	•	•
Phragmites australis ssp. australis	**Common Reed**	High	•	•	•
Pueraria montana var. lobata	**Kudzu**	High	•	•	•
Reynoutria japonica	**Japanese Knotweed**	High	•	•	•
Rosa multiflora	**Multiflora Rose**	High	•	•	•
Rubus phoenicolasius	**Wineberry**	High	•	•	•
Sorghum halepense	**Johnson Grass**	High	•	•	•
Urtica dioica	**European Stinging Nettle**	High	•	•	•
Acer platanoides	**Norway Maple**	Medium	•	•	•
Agrostis capillaris	**Colonial Bent-grass**	Medium	•	•	•
Akebia quinata	**Five-leaf Akebia**	Medium		•	•
Albizia julibrissin	**Mimosa**	Medium	•	•	•
Arthraxon hispidus var. hispidus	**Joint Head Grass**	Medium	•	•	•
Berberis thunbergii	**Japanese Barberry**	Medium	•	•	•
Cirsium vulgare	**Bull Thistle**	Medium	•	•	•
Dipsacus fullonum	**Wild Teasel**	Medium	•	•	•
Egeria densa	**Brazilian Waterweed**	Medium	•	•	•
Euonymus fortunei	**Winter Creeper**	Medium	•	•	•
Glechoma hederacea	**Gill-over-the-ground**	Medium	•	•	•
Hedera helix	**English Ivy**	Medium		•	•

communities and native species.
Invasiveness rank is higher for species that:

- ~ Alter ecosystem process, such as succession, hydrology or fire regime.
- ~ Alter ecosystem process, such as succession, hydrology or fire regime.
- ~ Are capable of invading undisturbed natural communities.
- ~ Cause substantial impacts on rare or vulnerable species or natural communities or high quality examples of more common communities.
- ~ Are found widely distributed and generally abundant where present.
- ~ Disperse readily to new areas.
- ~ Are difficult to control.

Early detection species

The list includes a subcategory of invasive plants that are considered early detection species. These are species not yet established or, if established, are not yet widespread in Virginia but known to be highly invasive in habitats similar to those found here. If discovered in Virginia, these species need to be quickly mapped, photographed and reported to DCR. The management goal for early detection species is eradication, as preventing the establishment and spread of newly arrived species will save valuable natural and economic resources.

INFORMATION

For more information, or to report early detection species, contact Stewardship Biologist Kevin Heffernan with the Virginia Department of Conservation and Recreation at 804-786-9112 or kevin.heffernan@dcr.virginia.gov

Scientific Name	Common Name	Virginia Invasiveness Rank	REGION: Mountain	REGION: Piedmont	REGION: Coastal
Holcus lanatus	**Common Velvet Grass**	Medium	•	•	•
Humulus japonicus	**Japanese Hops**	Medium	•	•	•
Ligustrum obtusifolium var. obtusifolium	**Border Privet**	Medium	•	•	•
Lonicera tatarica	**Tartarian Honeysuckle**	Medium	•	•	•
Lysimachia nummularia	**Moneywort**	Medium	•	•	•
Miscanthus sinensis	**Chinese Silvergrass**	Medium	•	•	•
Najas minor	**Brittle Naiad**	Medium	•	•	•
Paulownia tomentosa	**Royal Paulowina**	Medium	•	•	•
Persicaria longiseta	**Long-bristled Smartweed**	Medium	•	•	•
Phyllostachys aurea	**Golden Bamboo**	Medium	•	•	•
Poa compressa	**Flat-stemmed Bluegrass**	Medium	•	•	•
Poa trivialis	**Rough Bluegrass**	Medium	•	•	•
Pyrus calleryana	**Callery Pear**	Medium	•	•	•
Rhodotypos scandens	**Jetbead**	Medium	•	•	•
Rumex acetosella	**Sheep sorrel**	Medium	•	•	•
Spiraea japonica	**Japanese Spiraea**	Medium	•	•	•
Stellaria media	**Common Chickweed**	Medium	•	•	•
Veronica hederifolia	**Ivy-leaved Speedwell**	Medium	•	•	
Viburnum dilatatum	**Linden arrow-wood**	Medium	•	•	
Wisteria sinensis	**Chinese Wisteria**	Medium		•	
Commelina communis	**Asiatic Dayflower**	Low	•	•	•
Elaeagnus pungens	**Thorny Olive**	Low	•	•	•
Lespedeza bicolor	**Shrubby Bushclover**	Low	•	•	•
Lonicera fragrantissima	**Winter Honeysuckle**	Low	•	•	•
Melia azedarach	**Chinaberry**	Low	•	•	•
Morus alba	**White Mulberry**	Low	•	•	•
Perilla frutescens	**Beefsteak Plant**	Low	•	•	•
Phleum pratense	**Timothy**	Low	•	•	•
Populus alba	**Silver Poplar**	Low	•	•	•
Rumex crispus ssp. crispus	**Curly Dock**	Low	•	•	•
Securigera varia	**Crown-vetch**	Low	•	•	•
Trapa natans	**European Water Chestnut**	Low	•	•	•
Ulmus pumila	**Siberian Elm**	Low	•	•	•
Vinca major	**Greater Periwinkle**	Low		•	•
Vinca minor	**Periwinkle**	Low		•	•
Wisteria floribunda	**Japanese Wisteria**	Low			
EARLY DETECTION SPECIES - not yet widely established in Virginia					
Aldrovanda vesiculosa	**Waterwheel**	High			•
Eichhornia crassipes	**Water Hyacinth**	High			•
Imperata cylindrica	**Cogon Grass**	High			•
Oplismenus hirtellus ssp. Undulatifolius	**Wavyleaf Grass**	High	•	•	
Vitex rotundifolia	**Beach Vitex**	High			•
Heracleum mantegazzianum	**Giant Hogweed**	Medium	•	•	
Ipomoea aquatic	**Water Spinich**	Medium	•	•	
Salvinia molesta	**Giant Salvinia**	Medium	•	•	
Solanum viarum	**Tropical Soda Apple**	Medium		•	•

Photo credits:

Tree-of-heaven, Chuck Bargeron, University of Georgia, Bugwood.org. Phragmites Jim M. Swearingen, USDI National Park Service, Bugwood.org. Wavyleaf grass, Kerrie L. Kyde Maryland Department of Natural Resources, Bugwood.org

Citation:

Heffernan, K., E. Engle, C. Richardson. 2014. Virginia Invasive Plant Species List. Virginia Department of Conservation and Recreation, Division of Natural Heritage. Natural Heritage Technical Document 14-11. Richmond.

List B: Kentucky List of Invasive Plant Species (Kentucky Exotic Pest Plant Council 2013)

1. **Severe Threat:** Exotic plant species which possess characteristics of invasive species and spread easily into native plant communities and displace native vegetation; includes species which are or could become widespread in Kentucky.

Ailanthus altissima	tree-of-heaven
Alliaria petiolata	garlic mustard
Carduus nutans	musk thistle
Celastrus orbiculata	oriental bittersweet
Conium maculatum	poison hemlock
Coronilla varia	crown vetch
Dioscorea oppositifolia	Chinese yam
Elaeagnus umbellata	autumn olive
Euonymus alatus	winged euonymus, burning bush
Euonymus fortunei	winter creeper
Festuca arundinacea (Lolium arundinaceum)	Kentucky 31 fescue
Lespedeza cuneata	sericea lespedeza
Ligustrum sinense, L. vulgare	privet
Lonicera japonica	Japanese honeysuckle
Lonicera maackii, L. morrowi, L. tatarica	amur/bush honeysuckle, Morrow's, tartarian h.s.
Lythrum salicaria	purple loosestrife
Melilotus alba	white sweet clover
Melilotus officinalis	yellow sweet clover
Microstegium vimineum	Japanese grass
Miscanthus sinensis	Chinese silver grass
Paulownia tomentosa	Princess tree
Phragmites australis	common reed
Polygonum cuspidatum	Japanese knotweed
Pyrus calleryana	callery pear
Pueraria lobata	kudzu
Rosa multiflora	multiflora rose
Sorghum halepense	Johnson grass
Stellaria media	Chickweed

2. Significant Threat: Exotic plant species that possess some invasive characteristics, but have less impact on native plant communities; may have the capacity to invade natural communities along disturbance corridors, or to spread from stands in disturbed sites into undisturbed areas, but have fewer characteristics of invasive species than #1 rank.

Akebia quinata	akebia
Albizia julibrissin	mimosa
Arthraxon hispidus	hairy jointgrass
Arctium minus	common burdock
Berberis thunbergii	Japanese barberry
Bromus inermis	smooth bromegrass
Centaurea biebersteinii	spotted knapweed
Chrysanthemum leucanthemum	ox-eye daisy
Cirsium arvense	Canada thistle
Daucus carota	Queen Anne's lace
Dipsacus sylvestris	common teasel
Eleusine indica	goose grass
Glechoma hederacea	ground ivy
Hedera helix	English ivy
Ipomoea hederacea	ivy-leafed morning-glory
Ipomoea purpurea	purple morning-glory
Lespedeza bicolor	bicolor lespedeza
Lespedeza stipulacea (=Kummerowia)	Korean lespedeza
Lespedeza striata (= Kummerowia)	Kobe lespedeza
Mentha piperata	mint
Morus alba	white mulberry
Mosla dianthera	miniature beefsteak
Ornithogalum umbellatum	star-of-Bethlehem
Poa pratensis	bluegrass
Polygonum cespitosum	bunchy knotweed
Polygonum persicaria	lady's thumb
Populus alba	white poplar
Rorrippa nasturtium-aquaticum	water cress
Setaria faberi	giant foxtail
Setaria viridis	green foxtail
Spiraea japonica	Japanese spiraea
Vinca minor	lesser periwinkle

List C: BMPs for Exotic Invasive Plant Species in Forestry and Urban Forestry (USDA 2012)

1. Forestry BMPs for NNIS:

Management Planning

BMP 3.1: Establish a strategy for managing NNIS.
BMP 3.2: Prior to implementing management activities, inventory for and locate NNIS infestations, consistent with the scale and intensity of operations.
BMP 3.3: Consider the need for action based on: (1) the degree of invasiveness; (2) severity of the current infestation; (3) amount of additional habitat or hosts at risk for invasion; (4) potential impacts; and, (5) feasibility of control with available methods and resources.
BMP 3.4: Plan management activities to limit the potential for the introduction and spread of NNIS.
BMP 3.5: Plan for post-activity management of highly damaging NNIS.

Forestry Best Management Practices

BMP 4.1: Provide training in identification of locally known NNIS plants and pests to forest workers.
BMP 4.2: If pre- or post-activity control treatments are planned, ensure that they are applied within the appropriate time window.
BMP 4.3: Consider the likely response of NNIS when prescribing activities that result in soil disturbance or increased sunlight.
During activities:
BMP 4.4: Prior to moving equipment onto and off of an activity area, scrape or brush soil and debris from exterior surfaces, to the extent practical, to minimize the risk of transporting propagules.
BMP 4.5: Take steps to minimize the movement of NNIS plants, insects, and diseases to non- infested areas, during forest stewardship activities.
BMP 4.6: Take reasonable steps to avoid traveling through or working in small, isolated, populations of NNIS during forest activities.
BMP 5.1: To the extent practical, use existing roads, skid trails, and landings to reduce disturbance.
BMP 5.2: Avoid constructing new roads, skid trails, and landings in areas infested with NNIS where possible.

Forest Access

BMP 5.3: Avoid spreading seeds and other propagules from infested to non-infested areas during road maintenance, reconstruction, new construction, and closure.
BMP 5.4: Where site conditions permit, allow natural revegetation of the roads, skid trails, and landings to occur. If seeding or planting is necessary to minimize the threat of highly damaging NNIS from spreading, use native seed or annual, non-invasive cover crops for revegetation.
BMP 5.5: Ensure, to the extent practical, that fill and gravel are free of NNIS and their propagules.

Reforestation and Revegetation

BMP 6.1: Limit the introduction and spread of NNIS during reforestation or revegetation site preparation activities.

BMP 6.2: Revegetate or reforest as quickly as feasible after site disturbance (see also BMP 5.4).

BMP 6.3: When consistent with site conditions and goals, allow natural revegetation of the ground layer to occur. If seeding or planting is necessary to minimize the threat of highly damaging NNIS from spreading, use locally native seed or non-invasive, annual cover crops for revegetation (see also BMP 5.4).

BMP 6.4: Select locally native plant materials that are site appropriate.

BMP 6.5: Plan for post-planting management of NNIS (see also BMP 3.5).

Fish & Wildlife Habitat Management

BMP 7.1: Provide training in identification of locally known NNIS plants and pests to land managers whose objective is wildlife management.

BMP 7.2: Select locally native plants for seed mixes and plant materials used in wildlife habitat projects. (See also Chapter 6: Reforestation and Revegetation.)

BMP 7.3: If NNIS tree or brush removal is planned ensure that it is applied within the appropriate time window such that introduction and spread of NNIS is limited.

BMP 7.4: If desirable (i.e., native) tree or brush removal is planned as part of habitat enhancement, ensure that it is applied within the appropriate time window such that introduction and spread of NNIS is limited.

BMP 7.5: Prior to moving equipment onto and off of a management unit, scrape or brush soil and debris from exterior surfaces, to the extent practical, to minimize the risk of transporting propagules.

BMP 7.6: Take steps to minimize the movement of NNIS plants, insects, and diseases to non- infested areas during habitat maintenance activities.

BMP 7.7: Consider the likely response of NNIS when prescribing activities that result in soil disturbance or increased sunlight.

BMP 7.8: Take steps to minimize the movement of aquatic NNIS, including fish, crustaceans, mollusks, plants, insects, and diseases to non-infested waterways during habitat maintenance and assessment activities.

Fire Management

Pre-fire, Pre-incident Training:

BMP 8.1: Incorporate NNIS awareness, identification, and prevention education into fire training (e.g., fire effects and prescribed fire training).

Prescribed Fire:

BMP 8.2: Avoid placing fire breaks in NNIS infestations.

BMP 8.3: Incorporate invasive species considerations into the planning of prescribed burns. (See also Chapter 3: Management Planning).

BMP 8.4: Avoid spreading NNIS seeds and other propagules from infested to non-infested areas during prescribed fire activities.

BMP 8.5: Following a prescribed burn, rehabilitate soil disturbance related to burn activities, especially bladed or plowed firelines, where NNIS establishment is likely.

Wildfire Suppression:

BMP 8.6: When possible, avoid infestations when constructing fire breaks.

BMP 8.7: Avoid spreading NNIS seeds and other propagules from infested to non-infested areas during firefighting activities.

BMP 8.8: Following a wildfire, rehabilitate soil disturbance related to suppression activities, especially bladed or plowed firelines, where NNIS establishment is likely

Transport of Wood Materials

BMP 9.1: Prior to trucking, implement mitigation strategies to reduce the risk of transporting highly damaging NNIS insect and disease species when present, to the extent practical.

2. Urban Forestry BMP's for NNIS:

Planning

Land Use Planning

BMP 3.1: Know which NNIS affect or could affect your region and property.

BMP 3.2: Assess the extent of NNIS on and near the property by scouting and documenting infestations.

BMP 3.3: Assess current available resources and explore additional resources to prevent the introduction and manage the spread of NNIS.

BMP 3.4: Develop a plan for managing NNIS.

BMP 3.5: Provide training on identification, management, and prevention techniques of known NNIS to employees, contractors, volunteers, elected officials, owners, users, and the public.

Activity Planning

BMP 3.6: When planning for a specific management/maintenance activity, scout for NNIS both within and around the activity area.

BMP 3.7: Plan urban forest management/maintenance activities to limit the introduction and spread of NNIS.

BMP 3.8: Plan to monitor each site following management/maintenance activities; determine necessary treatments based on presence of NNIS.

BMP 3.9: As opportunities arise, interact with and engage researchers to further our understanding of NNIS.

Design

BMP 4.1: Conduct a site assessment prior to site design.

BMP 4.2: Conduct an inventory for NNIS as part of a site assessment.

BMP 4.3: Do not include NNIS in planting designs.

BMP 4.4: Design using plant materials that are site appropriate and less susceptible to highly damaging/detrimental pests and diseases.

BMP 4.5: Design planting conditions that foster the establishment and health of plants.
BMP 4.6: Diversify the planting material within the context of your design.
BMP 4.7: Design with long-term management/maintenance in mind.

Sales

BMP 5.1: Do not purchase, sell or propagate known invasive plant species or their propagules.
BMP 5.2: Do not purchase or sell plant or landscape material you suspect may be infested or infected with invasive pests.
BMP 5.3: When available and appropriate, purchase, sell and propagate species, cultivars and varieties known to be less susceptible to invasive pests as alternatives to more susceptible ones.
BMP 5.4: Plant propagators, wholesalers and retailers should educate themselves and their customers about invasive plants and potential invasive insect and disease issues associated with host plant materials.

Planting & Installation

BMP 6.1: Limit the introduction and spread of NNIS during site preparation activities.
BMP 6.2: Do not plant NNIS.
BMP 6.3: Do not plant material that you suspect may be infested or infected with invasive pests.
BMP 6.4: Select plant materials that are site appropriate, healthy and less susceptible to highly damaging/detrimental pests and diseases.
BMP 6.5: Diversify the planting material within the context of your planting project.
BMP 6.6: Prepare site and plant trees according to current arboriculture industry standards for optimum tree health.
BMP 6.7: Reduce the introduction of pathogens and insects by avoiding unnecessary wounding of trees and other vegetation.
BMP 6.8: Avoid unnecessary soil disturbance.
BMP 6.9: Stabilize disturbed soils in a timely manner to prevent the establishment of NNIS.
BMP 6.10: Use landscape materials that are free of NNIS and their propagules.
BMP 6.11: Monitor sites following planting and installation activities; determine necessary treatments based on presence of NNIS.
BMP 6.12: Prior to relocating equipment, vehicles and trailers, remove soil and debris from exterior surfaces by scraping, brushing, washing or using other methods to minimize the risk of transporting propagules.
BMP 6.13: Remove soil, seeds, vegetative matter and other debris from shoes, clothing and tools prior to leaving an area.

Management/Maintenance

BMP 7.1: Plan management/maintenance activities to limit the introduction and spread of NNIS.
BMP 7.2: When working in an area infested or previously infested with NNIS, utilize monitoring surveys and control records for the property prior to the current work being conducted.
BMP 7.3: Minimize the movement of NNIS to non-infested areas during management/maintenance activities.
BMP 7.4: Reduce the introduction of pathogens and insects by avoiding unnecessary wounding of trees and other vegetation.
BMP 7.5: Perform activities in a way that promotes healthy plants.
BMP 7.6: Use landscape materials that are free of NNIS and their propagules.
BMP 7.7: Avoid unnecessary soil disturbance.
BMP 7.8: Stabilize disturbed soils in a timely manner to prevent the establishment of NNIS.
BMP 7.9: Keep records of activities that could affect NNIS.
BMP 7.10: If possible, monitor recent work sites for NNIS.
BMP 7.11: Prior to relocating equipment, vehicles and trailers, remove soil and debris from exterior surfaces by scraping, brushing, washing or using other methods to minimize the risk of transporting propagules.
BMP 7.12: Remove soil, seeds, vegetative matter and other debris from shoes, clothing and tools prior to leaving an area.
BMP 7.13: Properly treat or dispose of NNIS or materials that may harbor invasive propagules, insects or diseases.
BMP 7.14: If pre- or post-activity NNIS control treatments are planned, ensure they are applied within the appropriate time window and environmental conditions.

Sanitation and Debris Disposal

BMP 8.1: Prior to relocating equipment, vehicles and trailers, remove soil and debris from exterior surfaces by scraping, brushing, washing or using other methods to minimize the risk of transporting propagules.
BMP 8.2: Remove soil, seeds, vegetative matter and other debris from shoes, clothing and tools prior to leaving an area.
BMP 8.3: Minimize the offsite transport of NNIS and materials that may contain NNIS.
BMP 8.4: When necessary to transport NNIS and materials that may contain NNIS off site, cover or otherwise contain those materials.
BMP 8.5: Properly treat or dispose of NNIS or materials that may harbor invasive propagules, insects or diseases.
BMP 8.6: Allow compost piles to heat to appropriate temperatures and times and with proper procedures to reduce the viability of NNIS contained within.
BMP 8.7: Avoid the use of wood chips and compost that may contain invasive propagules.

Monitoring and Research

BMP 9.1: Create an NNIS monitoring plan for properties under your management.
BMP 9.2: Assess the extent of NNIS on and near the property by inventorying, locating and documenting infestations.
BMP 9.3: Monitor sites under your management following management/maintenance activities; determine necessary follow-up based on presence of NNIS.
BMP 9.4: Keep records when inventorying and monitoring.
BMP 9.5: Report new infestations of known NNIS to the appropriate authority.
BMP 9.6: As opportunities arise, interact with and engage researchers to further our understanding of NNIS.

Education

BMP 10.1: Educate yourself about NNIS.
BMP 10.2: Educate employees and volunteers about NNIS.
BMP 10.3: Educate clients, customers and users about NNIS.
BMP 10.4: Educate public officials and other decision makers about NNIS.

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Appendix K

Snags – The Wildlife Tree
(Washington Department of Fish and Wildlife 2011)

Snags – The Wildlife Tree

The Importance of Snags in Your Neighborhood

Racoon family in tree den. A note about raccoons -racoons can become habituated to people; they are aggressive and sometimes dangerous and carry the roundworm *Baylisascaris procyonis* that can infect humans and pets. Do NOT leave pet food and garbage out and never feed raccoons.

Dead Wood Brings New Life

Hard to believe, but trees can actually provide more habitats for wildlife dead than when they are alive. Standing dead and dying trees, called "snags" or "wildlife trees," are important for wildlife in both natural and landscaped settings, occurring as a result of disease, lightning, fire, animal damage, too much shade, drought, root competition, as well as old age.

Birds, small mammals, and other wildlife use snags for nests, nurseries, storage areas, foraging, roosting, and perching. Live trees with snag-like features, such as hollow trunks, excavated cavities, and dead branches can provide similar wildlife value. Snags occurring along streams and shorelines eventually may fall into the water, adding important woody debris to aquatic habitat. Dead branches are often used as perches; snags that lack limbs are often more decayed and, may have more and larger cavities for shelter and nesting. Snags enhance local natural areas by attracting wildlife species that may not otherwise be found there.
All trees of all sizes are potential snags. Unfortunately, many wildlife trees are cut down without much thought to their wildlife value or of the potential management options that can safely prolong the existence of the tree. Wildlife trees offer a one-stop, natural habitat feature. In short, snags "live on" as excellent wildlife trees for all to enjoy!

Wildlife That Use Snags

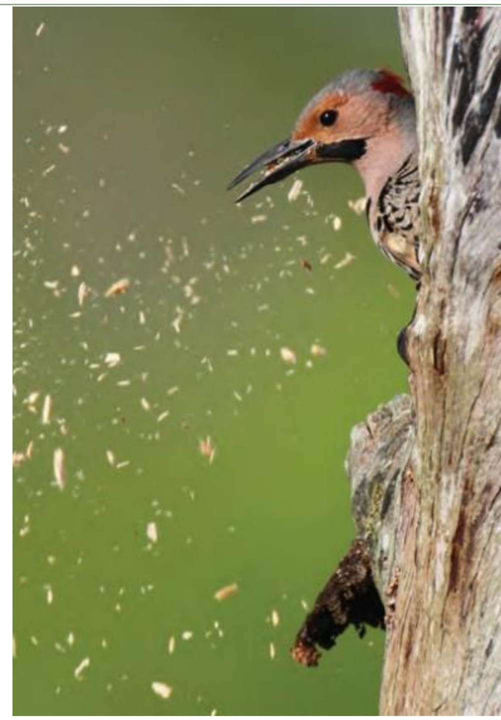
West of the Cascade Mts 39 species of birds and 14 species of mammals depend on tree cavities for their survival. East of the Cascades 39 bird species and 23 mammal species depend on these snags (Pederson, USDA Forest Service). In total, more than 100 species of birds, mammals, reptiles, and amphibians need snags for nesting, roosting, shelter, denning, and feeding (Bottorff, WSU, Snohomish Co. Ext); nearly 45 species alone forage for food in them. Hollow snags and large knot- holes are used by many species of mammals such as squirrels, marten, porcupine, and raccoons. Table 1 shows Washington State bird species that depend on snags.

Tree swallow peering from a nest cavity excavated by a woodpecker.
Photo Credit: Joy Spurr

In winter when snow covers the ground, northern flickers and other commonbackyard wildlife depend heavily on insects and other foods found in snags. Brown creepers, bats, and other small animals will roost behind loose bark and bark slits for winter warmth and shelter. Hollow snags are very valuable in winter as they are used by many species such as squirrels, raccoons, owls, and bear for denning and roosting. This high use of snags by a myriad of species underscores the importance of preserving snags and including them in your landscape

The Woodpecker - Cavity Creator

Woodpeckers such as the northern flicker create new cavities in snags and are thus referred to as "primary cavity nesters. "They have thick-walled skulls supported by powerful neck muscles, and a beveled, chisel-like bill. A woodpecker's strong, grasping feet with sharp, curved nails form a triangular base for support in the verticalposition along with specially adapted tail feathers. The woodpecker's barb-tipped tongue and sticky saliva help it get insects from deep crevices. Unlike other cavity-nesting birds, woodpeckers rarely use nest boxes because they are biologically conditioned to dig their own cavities: the physical motions of cavity excavation stimulate reproduction.



Northern flicker in the process of excavating its nest cavity. Note the wood chips flying.

Young pileated woodpecker emerging from its nest cavity

Woodpeckers excavate several holes each year and rarely nest in the same one in consecutive years, thus creating many cavities for secondary cavity nesters such as bluebirds, tree and violet-green swallows, chickadees, nuthatches, house wrens, wood ducks, squirrels, and owls who cannot excavate cavities themselves.
Secondary cavity nesting wildlife are highly dependent upon the availability of these abandoned nest cavities.

Trees That MakeThe Best Snags

Large conifers such as cedar, fir, larch, and pine, tend to rot more slowly than do deciduous trees such as alder, birch, and cherry. However, large deciduous trees such as cottonwoods, big-leaf maples, and oaks can last many years as snags. Moreover, while alive, they tend to develop cavities in their bulky live and dead branches and trunks

Large snags more than 12 inches in diameter and 15 feet tall offer ideal hunting perches for hawks, eagles, and owls. They function as resting perches for swallows, band-tailed pigeons, mourning doves and other birds; food storage for mice, squirrels, woodpeckers, and jays; and song perches for tanagers and flycatchers. In addition to nesting, woodpeckers use large dead tree trunks as a way to announce their presence during courtship, hammering their bills against the tree's resonating surface. Small snags may be used as song posts by bluebirds, hummingbirds, and other songbirds to attract mates and proclaim nesting territories. Black-capped chickadees nest in small tree snags as little as six feet tall and four inches in diameter.

Tree Species. Snags of both deciduous trees (those that shed leaves in winter) and conifer trees (evergreens) are used by wildlife. The most favored snag species east of the Cascades are: ponderosa pine, western larch, quaking aspen, and paper birch; west of the cascades Douglas fir and western red cedar snags are highly favored and big-

Bald eagles using a large dead tree snag. Bald eagles prefer bulky, tall snags for perching

Hard and Soft Snags

A snag habitat begins to form when a large tree dies and forms a "Hard Snag." As this hard snag decays it gradually becomes a "Soft Snag." A partially or recently dead tree is a hard snag. Hard snags tend to have their bark intact while the heartwood (the non-living inner core) and sapwood (the younger, softer, growing wood between the bark and heartwood) are still firm. These kinds of snags are good for cavity excavating birds. A soft snag has considerable decay in its heart and sapwood. Fungi infiltrate the heartwood and the tree becomes soft or hollow in the center. A soft snag rarely has limbs, and its top may be missing. Over the years, a soft snag gets shorter as weather and animal activity weakens it. Eventually it falls over and continues to provide important food and shelter on the ground.

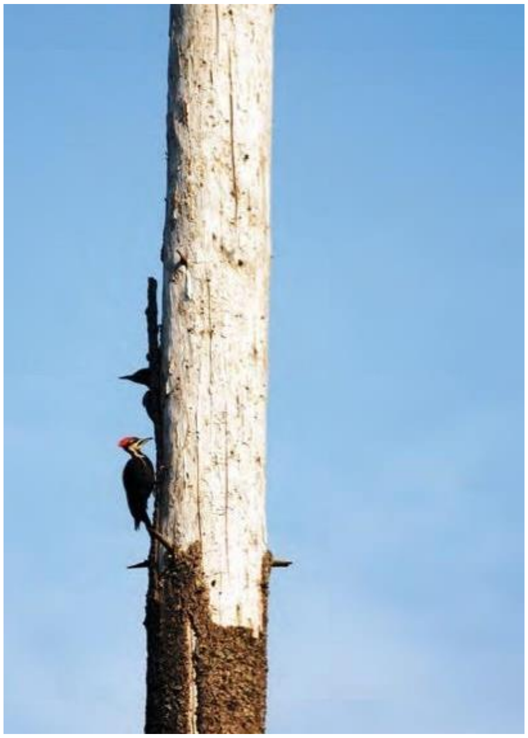
The snag with the abundant nest cavities and foraging evidence is a soft snag that has been used for many years. This photo was taken four years after the flat-top trees were created from live Douglas fir; they have barely started the decay process yet woodpeckers are beginning to work them.

Photo Credit: Patricia Thompson

Red squirrel poking out of a den tree savoring a nut dropped by a passerby. Central Park, New York City.

Photo Credit: Bruce Yolton

urbanhawks.blogs.com/.../2006/01/index.html



Pileated woodpeckers foraging on an old dead snag pulling off the bark to get to the insects underneath. Note the thick bare branch at the top of the tree perfect for bald eagles or other large birds

Photo credit, Patricia Thompson

Dead Tree/Wildlife Condo

You can see where wildlife finds food and shelter if you look carefully at a snag:

- A snag harbors many insects that are food for wildlife. The outer surface of the bark is where birds such as brown creepers, nuthatches, and woodpeckers eat bark beetles, spiders, and ants.
- The inner bark is where woodpeckers eat larvae and pupae of insects. Mammals such as raccoon and black bear may tear into these areas of snags to harvest the protein-rich insects.
- The heartwood is where strong excavators such as the pileated woodpecker prey upon carpenter ants and termites.
- The space between partially detached bark and the tree trunk is where nuthatches, winter wrens, and brown creepers roost or search for food. Pacific tree frogs, several species of bats, and many butterflies also find shelter there.

Live aspen snag"condominium." These trees have many nesting cavities excavated by at least three species of woodpeckers. In the tree on the left, the largest rectangular hole is a pileated woodpecker nest in which the pileateds were seen nesting; the top cavity just under the greenery was excavated and used by northern flickers; smaller nest cavities were excavated by red-naped sapsucker and also used by black-capped chickadee and house wren for nesting. Look for small nest holes in the tree on the right also. *Photo Credit: Patricia Thompson*

leaf maple and cottonwood are also used. Softwood trees such as fir tend to make better food foraging trees, while hardwood trees are sometimes better for nesting cavities. Nevertheless, just about any species of snag tree will be used by wildlife.

Size. Small trees rot rapidly, creating wildlife habitat. Black-capped chickadees nest in snags as small as six feet tall and four inches in diameter. The large conifers such as cedar, fir, larch, and pine, tend to rot more slowly than do deciduous trees such as alder, birch, and cherry. However, large deciduous trees such as cottonwoods, big-leaf maples, and oaks can last many years as snags.
Moreover, while alive, they tend to develop cavities in their bulky and dead branches and trunks.

Decay. The best snags for cavity-nesters are those with hard sapwood (between bark) and decayed heartwood (inner core) making them hard on the outside and soft in the middle. The hard sapwood provides protection from

Cedar snag with top burned out by homeowner adds an interesting and striking feature to this backyard landscape. *Photo Credit: Russell Link*

Photo Credit: Russell Link

predators and insulation against weather, while the softened heartwood allows easy excavation deep into the snag. Many birds avoid very soft snags for nesting because extremely soft wood can be wet or crumbly.

Strong primary excavators, such as the pileated woodpecker and northern flicker, occasionally select living trees with decayed heartwood because they can penetrate through the sound layer of sapwood and excavate the nest cavity in the soft heartwood. Generally, the sapwood remains fairly intact and forms a shell surrounding the decaying heartwood. The excavated interior may remain useable for many years by many species.

A professional arborist creates an alder tree snag giving it a natural-looking jagged top. You must hire a professional to create these tall snags. It is unwise to attempt this yourself.

Snags in Your Landscape

Try to incorporate one or more snags into your landscape keeping old and damaged trees when possible. When clearing, retain trees and tall shrubs near the planned snag to protect it from wind and provide a healthier environment for wildlife. In urban areas, tall snags are best located away from high activity areas, where they won't pose hazard if they fall. Trees that lean away or are downhill from structures and other areas of human activity present little or no risk.

Ways to Tell a Future Snag:

- Sap runs,
- Splits in the trunk,
- Dead main limbs,
- Fungi on the bark.
- Evidence of animal use, such as woodpecker holes.

Also, note any trees you may want to make into a snag including:

- Hazard trees-example, forked top, weak wood, or disease,
- A shade tree in an area where you want sun,
- A tree with roots threatening a drainage or septic system,
- A tree in a group that needs thinning out,
- A tree in an area where there aren't any snags.

Because individual snags may have only one wildlife habitat feature (perch, cavity, etc.), retaining and promoting small clumps of snags throughout a larger property is more likely to provide all of these features. Small dead ornamental and fruit trees can be left in the landscape where they are not a safety hazard because they will be used as perches for preening, resting, foraging, and singing.

Creating Snags from Live Trees

Any snag you provide for wildlife will likely be used. You can even create one from a live tree. Branches or trunk you remove can be added to a brush shelter.

Remember, a tree can provide habitat even when just part of it dies. For instance, if a large conifer has a fork in it, you can girdle one of the forks creating an excellent perch. If the trunk of this tree is large enough in diameter, a future cavity may develop at the perch limb dies. In addition, if the tree is not dying after the side branches and top have been removed; some individual side branches can be girdled to create perches help the tree decline.

Always hire an expert tree service to remove branches and tops of large trees. Make sure that whoever does the work is licensed, bonded, and insured, and understands your intention to make a wildlife tree. Many certified arborists with the International Society of Arboriculture specialize in wildlife tree creation and maintenance.
Check with your local chapter.

There are several methods for creating snags:

- Remove the top third of the tree and half the remaining side-branches.
- Leave the top the way it is and remove a majority of the tree's side-branches.
- Leave the top and sides as they are and girdle the trunk.
- Girdle the branches.

Creating a Cavity in a Live Tree

Gradual Technique

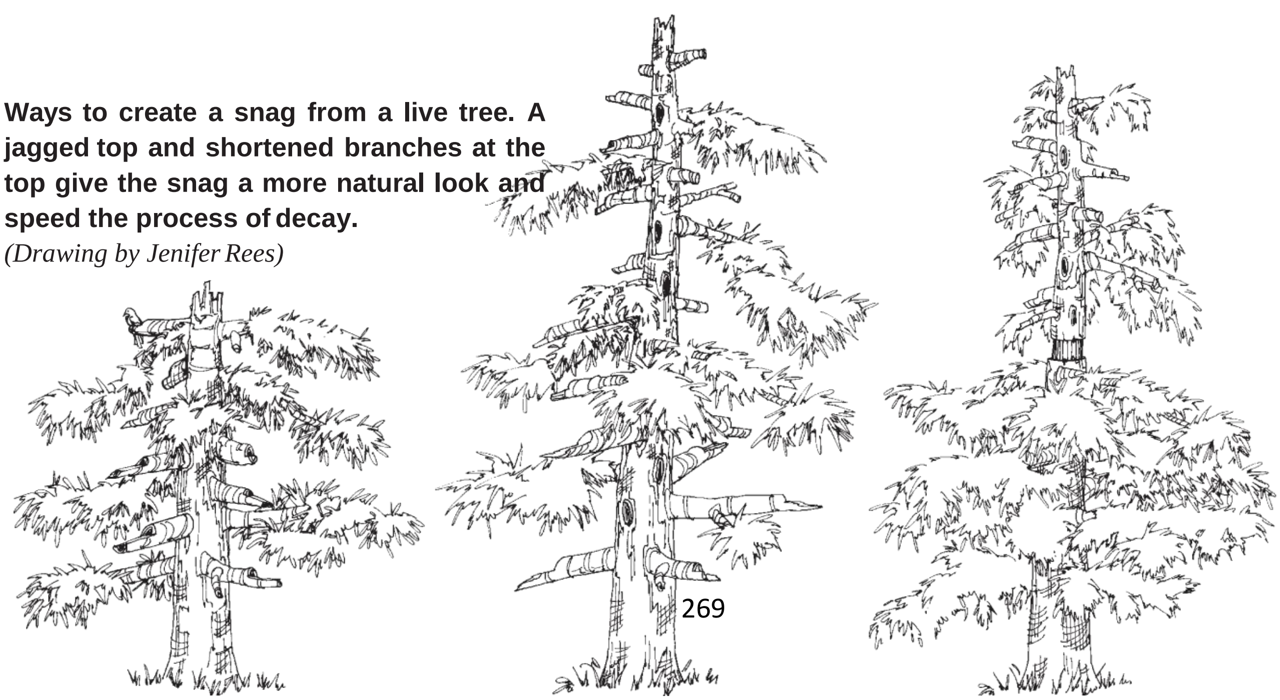
Drill a 1" diameter hole at a ten-degree angle downwards into the heartwood of the tree anywhere water might collect, such as below a crotch of a branch, starting the cavity making process. The illustration shows the drill going up

Remove a large (4" or larger) limb and leave the jagged, broken stub allowing for invasion by bacteria, fungi, and insects. Most diseases attack the dead heartwood and the outer layer can continues its growth around the rotten core; the rest of the tree can continue to grow for many years.

Rapid Technique

Cut a cavity in the trunk using a small chain saw, drill, or chisel. Next, cover the cutout with a piece of wood or sheet metal with the species-appropriate size entry hole drilled into it. Whether this kills a tree depends on the size of the cavity in relation to the size of the tree.

To prevent aggressive, non-native European starlings and house sparrows from nesting in a snag, create or reduce the size of an existing hole to 1 1/8 inches using leather, wood, or metal covers.



Ways to create a snag from a live tree. A jagged top and shortened branches at the top give the snag a more natural look and speed the process of decay.
(Drawing by Jenifer Rees)

Remove the top third of the tree and half the remaining side branches. This method ensures that the tree begins the preferred inside-out decay process, premium sites for cavity-nesting birds. Leave some shortened branches at the top for perches and make the snag look natural by creating a jagged top. A jagged top also provides an avenue for fungi infection and other rot-causing organisms. Water and bird feces will collect and speed decay. Sow bugs, earwigs, and other invertebrates will find their way in and assist in the decay process.

Leave the top intact and remove about 3/4 of the tree's side-branches. Douglas fir, hemlock, and pine respond well to this technique. Western red cedar is a tough conifer to kill in this way, but it makes an excellent snag because it is extremely wind-resistant and long-lasting. Keep branch ends jagged and more susceptible to microorganisms and fungi, and more natural looking.

Leave the top and sides as they are and girdle the trunk. Least preferred method. Girdling creates a dead but intact top, providing a taller snag, but leaves it more susceptible to breaking at the wound site. Girdling tends to cause a tree to rot from the outside in, instead of the preferred inside-out. As a result, by the time the rot has progressed far enough for woodpeckers to excavate a cavity, the tree has become fragile and may easily fall in a windstorm. Furthermore, a cavity in a girdled tree may not be safe because the hole is likely to be shallow, which exposes young to weather and predators.

To girdle a tree, remove a four-inch belt of inner and outer bark around the trunk which stops the movement of water and nutrients. If girdling is done at breast height and the tree falls, this leaves very little remaining snag habitat. Therefore, try to make the girdling cut as high up as possible. Big-leaf maple, aspen, and poplar may send up sprouts, which can be removed or left to grow around the tree as temporary cover. Some tree species, alder for example, are difficult to kill even when properly girdled. A tree girdled in winter may not show signs of decline until well into spring, after it has used its stored energy.

Roosting Slits

Roosting slits for bats and some songbirds, including brown creepers, may be added to created snags that are tall enough and wide enough in diameter to accommodate the cuts. The slits should be at least eight inches deep, one or more inches wide, and angled sharply upward. Bats need to fly up into the slits so the slits should be located in an area free of branches.

The higher up the snag they are, the more likely these roosting slits will be used. Some sun exposure warms these roosts and makes them more attractive in winter.

Brown creeper on a snag with visible roosting slits.

Relocating Snags

It is possible to install a small snag on your property obtained from somewhere else, such as those salvaged from a construction or logging site. Be sure to get permission from the landowner. Snag relocation is difficult, dangerous and usually requires professional help and special equipment. A dead tree is generally much heavier and more fragile than it looks weighing several hundred or even thousands of pounds. If you double the diameter of a cylinder, you quadruple the weight. An old snag, too rotten to support its own weight, is best used as a log.

Relocate the snag to a place it will remain upright and secure. If you are moving it within your property, try to install it as close as possible to its original location minimizing disturbance to wildlife using it. Locate the snag in a wind-protected area near live trees and shrubs.

"Planting" a large snag.

Before setting the snag, cut its base flat so the snag will stand straight. Then do any of the following:

- Place it in a hole approximately one-third the height of the snag and firmly tamp soil, gravel, or pour a concrete footing around it.
- Lower a firm, hollow snag over a metal or wooden post that's been securely placed in the ground.
- Wire the snag to a sturdy post.

Wood duck ducklings plunging from their nest cavity in a tree. This is normal behavior for wood ducks when leaving the nest cavity which can be anywhere between 6 to 15 feet above ground and almost always above water into which they fall.

Photo Credit: Mike Lentz

Hazard Tree and Snag Management

If not managed properly, snags can pose a risk to people and structures. If a dead or dying tree threatens something that can be moved, such as a swing set or patio furniture, consider moving those items before cutting the tree down. An alternative to eliminating the entire tree is to remove only the dangerous section(s). Consulting with a certified arborist with experience in wildlife snags is recommended. These professionals can determine what part of a tree is a hazard and provide management options to reduce or eliminate any risk. Remaining parts can be removed over time. Often, once the unsafe limbs or portions of the trunk have been removed, the tree is safe.

When a tree must be cut down, maximize its habitat value by placing as much of the debris as possible near the area where the tree was removed. In hot, dry areas, move the material into the shade of nearby trees or large shrubs. Bringing branches in contact with the ground will cause them to rot faster. Place a nest box on your site as replacement for cavities lost through tree or limb removal.

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Washington Department of Fish and Wildlife. Backyard Wildlife Sanctuary Program. http://wdfw.wa.gov/wlm/backyard/. Note – in particular, see the link for "Nest Boxes for Birds" section for cavity diameter and related habitat specifics.

Organizations

International Society of Arboriculture, Pacific Northwest Chapter. (503) 874-8263. http://www.pnwisa.org/
Plant Amnesty. (206) 783-9813. http://www.plantamnesty.org/home/index.aspx

Published by the Washington Department of Fish and Wildlife, 2011. 600 Capitol Way North, Olympia, WA 98501. Website: http://www.wa.gov/ Phil Anderson, Director, Washington Department of Fish and Wildlife. Miranda Wecker, Chair, Washington Fish and Wildlife Commission.

King Conservation District

King County

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Appendix L

i-Trees Canopy Report Data
(i-Tree 2016)
and
Urban Tree Canopy (UTC) Analysis
(Virginia Tech 2016)
for
Stadium Woods

A general tree canopy cover analysis was performed utilizing the Virginia UTC mapper (Virginia Tech 2016 and i-Trees canopy (i-Tree 2016) to generate a data set of urban cover types within the defined boundary area (Figure L.1) and an assessment that lists and estimation of the ecosystem services provided by the Stadium Woods old-growth urban forest fragment (Figure L.2).

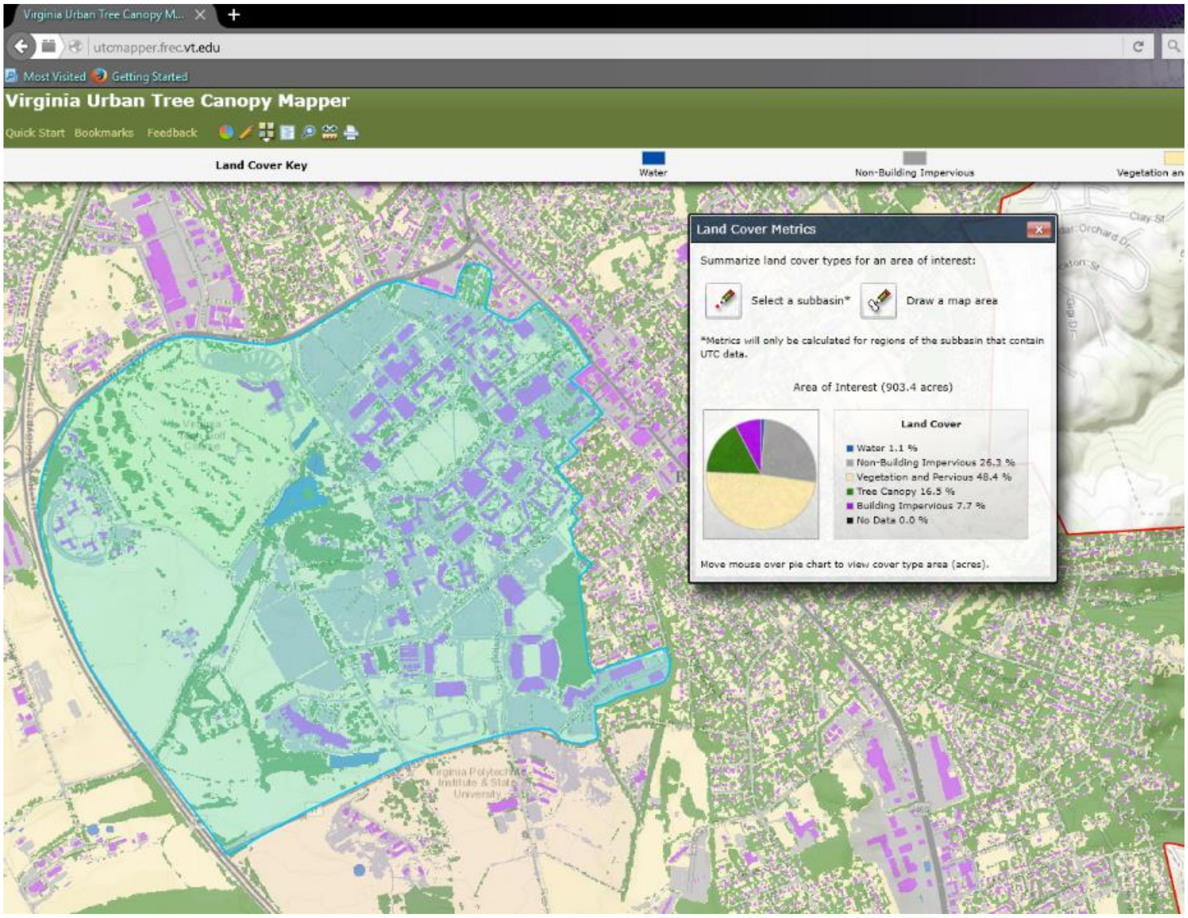
The Virginia UTC Mapper is a web-based GIS based tool that displays land cover classification data for selected areas within municipalities across Virginia. The land cover data is generated from supervised classification of high resolution (1 meter) accuracy imagery collected from the National Agriculture Imagery Program during the summer of 2008. The viewer is an interactive tool that allows viewing, measuring, and reporting of land cover information (VirginiaTech 2016).

The i-Tree Canopy tool provides a statistically valid estimate of land cover types, such as tree cover, from aerial images and estimates values for air pollution reduction and carbon dioxide sequestration as a function of tree canopy coverage. "i-Tree is a state of the art, peer reviewed software suite from the USDA Forest Service the provides urban and community forestry analysis and benefits assessment tools" (i-Tree 2016).

The area of interest (Figure L.1) was assessed to determine the land cover class distinctions between areas of water, non-building impervious areas (parking lots and streets), vegetation and pervious land (lawn), tree canopy cover, and building impervious area (roofs) land cover classes. The actual acreage and percentages were calculated (Table L.1). The area of

Stadium Woods from a GIS based shapefile (Appendix G) was then demarcated on the Virginia UTC mapper showing the tree canopy cover (Figure L.2). Ninety-nine percent of Stadium Woods statistically shows as tree canopy cover. Less than one percent of the Stadium Woods area shows statistically as vegetation and pervious land. This is because there are some canopy gaps in the area around the rappelling tower (Report L.1). Stadium Woods equals 8% of the total tree canopy cover area on the central campus area of Virginia Tech.

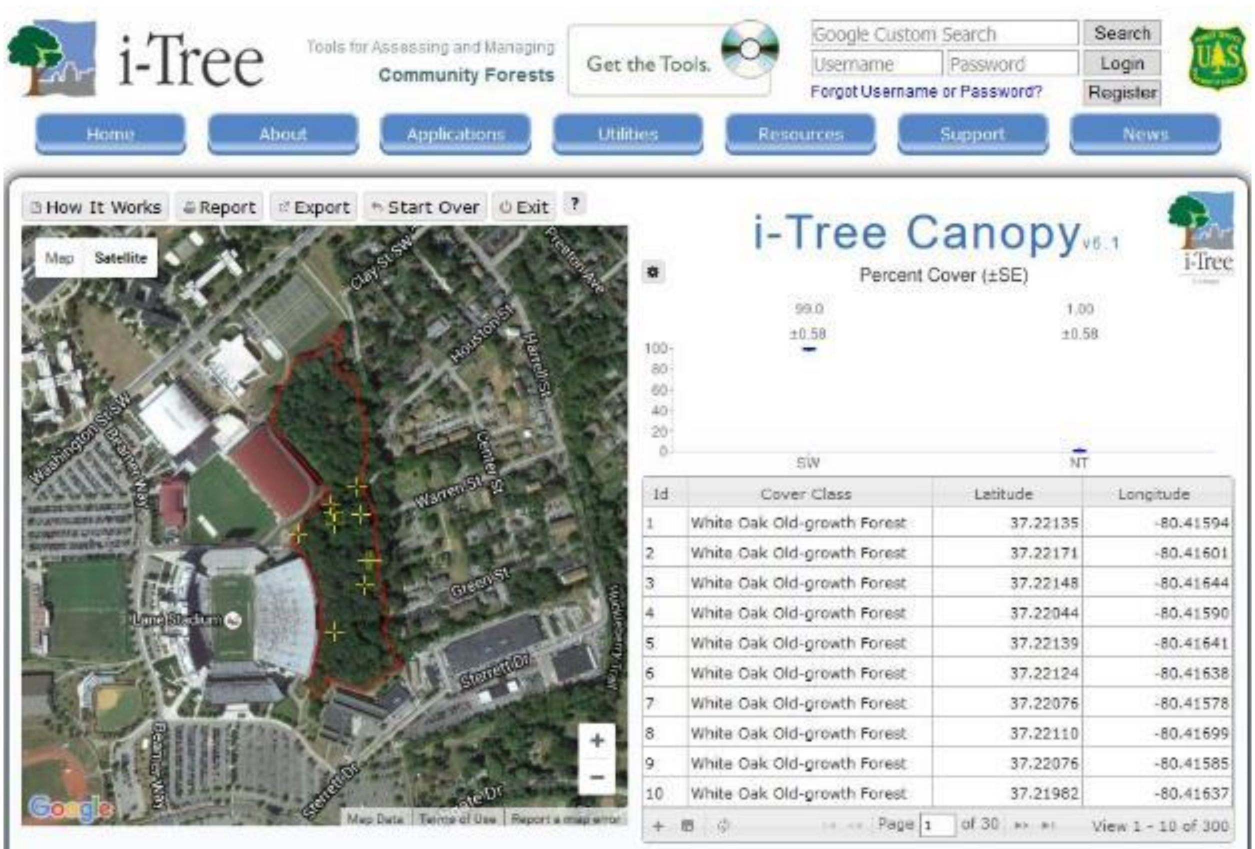
Ecosystem services were measured using an urban tree canopy (UTC) cover analysis (Report L.1) to estimate pollution and carbon capture values based on the tree canopy coverage area of SW. SW sequesters 59.82 tons of carbon dioxide per year valued at $2,164.29, captures 164.18 pounds of particulate matter over 2.5 microns per year valued at $512.76, and captures 29.55 pounds of particulate matter under 2.5 microns annually valued at $1,587.45. In addition, on an annual basis, SW removes 36.81 pounds of sulfur dioxide valued at $2.45, 578.46 pounds of ozone worth $748.72, 74.88 pounds of nitrogen dioxide for a $16.30 benefit, and 13.56 pounds of carbon monoxide valued at $9.01. The total annual carbon dioxide stored in the SW trees is 1,508.16 tons for an overall value of $54, 575.11.



<u>Figure L.1</u>. Area of Urban Tree Canopy (UTC) cover analysis (903.4 acres) delineated by Turner Street, Prices Fork Road, U.S. Highway 460, Southgate Drive, the east Virginia Tech boundary, Washington Street, Kent Street, Otey Street, West Roanoke Street, Draper Road SW, and North Main Street. The graph depicts the total acreage of the analysis area and the percentages of land cover, including water, non-building impervious, vegetation and pervious, tree canopy cover, and building impervious land cover classes.

<u>Table L.1</u>. Central campus of Virginia Tech as demarcated in Figure L.1 percentages of urban land cover types and total acreage of each.

Land Cover Distinction	Acres	Total Land Cover (%)
Water	9.5	1.05
Non-building impervious	237.3	26.27
Vegetation and pervious	437.2	48.40



Tree canopy cover	149.4	16.54
Building impervious	69.9	7.74
Total Land Cover	**903.4**	**100.0**

<u>Figure L.2</u>. Map of area showing first of 30 pages with 10 plots each to calculate statistically based urban tree canopy (UTC) cover analysis performed on Stadium Woods area. 12.05-acre area of analysis is derived from GIS shapefile depicting Stadium Woods area (Appendix G).

<u>Report L.1</u>. i-Tree Canopy UTC assessment and tree benefits report on 12.05 acres (Figure L.2) of Stadium Woods area.

i-Tree

Tools for Assessing and Managing Community Forests

i-Tree Canopy v6.1

Cover Assessment and Tree Benefits Report

Estimated using random sampling statistics on 3/18/16

Cover Class	Description	Abbr.	Points	% Cover
White Oak Old-growth Forest	Tree, non-shrub	SW	296	99.0 ±0.58
Non-Tree	All other surfaces	NT	3	1.00 ±0.58

Tree Benefit Estimates

Abbr.	Benefit Description	Value	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	$9.01	±0.05	13.56 lb	±0.08
NO2	Nitrogen Dioxide removed annually	$16.30	±0.09	74.88 lb	±0.44
O3	Ozone removed annually	$748.72	±4.36	578.46 lb	±3.37
PM2.5	Particulate Matter less than 2.5 microns removed annually	$1,567.45	±9.13	29.55 lb	±0.17
SO2	Sulfur Dioxide removed annually	$2.45	±0.01	36.81 lb	±0.21
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	$512.76	±2.99	164.18 lb	±0.96
CO2seq	Carbon Dioxide sequestered annually in trees	$2,164.29	±12.60	59.82 T	±0.35
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	$54,575.11	±317.74	1,508.16 T	±8.78

I-Tree Canopy Annual Tree Benefit Estimates based on these values in lbs/acre/yr and $/T/yr: CO 1.130 @ $1,333.50 | NO2 6.241 @ $436.94 | O3 48.212 @ $2,597.84 | PM2.5 2.463 @ $106,459.51 | SO2 3.068 @ $133.85 | PM10* 13.683 @ $6,268.44 | CO2seq 9,970.817 @ $36.31 | CO2stor is a total biomass amount of 251,395.359 @ $36.31

Note: Standard errors of removal amounts and benefits were calculated based on standard errors of sampled and classified points.

About i-Tree Canopy

The concept and prototype of this program were developed by David J. Nowak, Jeffery T. Walton and Eric J. Greenfield (USDA Forest Service). The current version of this program was developed and adapted to i-Tree by David Ellingsworth, Mike Binkley, and Scott Maco (The Davey Tree Expert Company).

Limitations of i-Tree Canopy

The accuracy of the analysis depends upon the ability of the user to correctly classify each point into its correct class. As the number of points increase, the precision of the estimate will increase as the standard error of the estimate will decrease. If too few points are classified, the standard error will be too high to have any real certainty of the estimate.

A Cooperative Initiative Between:

www.itreetools.org

Appendix L: References

i-Tree. 2016. *i-Tree Canopy*. Available online at http://www.itreetools.org/canopy/ ; last accessed June 10, 2016.

Virginia Tech. 2016. *Virginia Urban Tree Canopy Mapper*, Department of Forest Resources and Environment. Available online at http://www.utcmapper.frec.vt.edu/ ; last accessed June 10, 2016.

Appendix M

Ecosystem Services

(De Groot, et al. 2002)

Functions, Goods, and Services of Natural and Semi-Natural Ecosystems (De Groot, et al. 2002).

	Functions	Ecosystem Processes and Components	Goods and Services (examples)
	Regulation Functions	***Maintenance of Essential Ecological Processes and Life Support Systems***	
1	Gas regulation	Role of ecosystems in bio-geochemical cycles (e.g. CO_2/O_2 balance, ozone layer, etc.)	1.1 UVb-protection by O_3 (preventing disease) 1.2 Maintenance of (good) air quality 1.3 Influence on climate (see also function 2.
2	Climate regulation	Influence of land cover and biol. mediated processes (e.g. DMS-production) on climate	Maintenance of a favorable climate (temp., precipitation, etc.) for, for example, human habitation, health, cultivation
3	Disturbance prevention	Influence of ecosystem structure on dampening environmental disturbances	3.1 Storm protection (e.g. by coral reefs) 3.2 Flood prevention (e.g. by wetlands and forests)
4	Water regulation	Role of land cover in regulating runoff & river discharge	4.1 Drainage and natural irrigation. 4.2 Medium for transport
5	Water supply	Filtering, retention and storage of fresh water (e.g. in aquifers)	Provision of water for consumptive use (e.g. drinking, irrigation and industrial use)
6	Soil retention	Role of vegetation root matrix and soil biota in soil retention	6.1 Maintenance of arable land. 6.2 Prevention of damage from erosion/siltation
7	Soil formation	Weathering of rock, accumulation of organic matter	7.1 Maintenance of productivity on arable land 7.2 Maintenance of natural productive soils
8	Nutrient regulation	Role of biota in storage and recycling of nutrients (eg. N,P, and S)	Maintenance of healthy soils and productive ecosystems
9	Waste treatment	Role of vegetation & biota in removal or breakdown of xenic nutrients and compounds	9.1 Pollution control/detoxification. 9.2 Filtering of dust particles. 9.3 Abatement of noise pollution
10	Pollination	Role of biota in movement of floral gametes	10.1 Pollination of wild plant species. 10.2 Pollination of crops
11	Biological control	Population control through trophic-dynamic relations	11.1 Control of pests and diseases. 11.2 Reduction of herbivory (crop damage)
	Habitat Functions	***Providing Habitat (Suitable Living Space) for Wild Plant and Animal Species***	Maintenance of biological & genetic diversity (and thus the basis for most other functions)
12	Refugium function	Suitable living space for wild plants and animals	Maintenance of commercially harvested species
13	Nursery function	Suitable reproduction habitat	13.1 Hunting, gathering of fish, game, fruits, etc. 13.2 Small-scale subsistence farming & aquaculture

(De Groot, et al. 2002) (cont.)

	Functions	Ecosystem Processes and Components	Goods and Services (examples)
	Production Functions	***Provision of Natural Resources***	
14	Food	Conversion of solar energy into edible plants and animals	14.1 Building & Manufacturing (e.g. lumber, skins) 14.2 Fuel and energy (e.g. fuel wood, organic matter) 14.3 Fodder and fertilizer (e.g. krill, leaves, litter)
15	Raw materials	Conversion of solar energy into biomass for human construction and other uses	15.1 Improve crop resistance to pathogens & pests 15.2 Other applications (e.g. health care)
16	Genetic resources	Genetic material and evolution in wild plants and animals	16.1 Drugs and pharmaceuticals 16.2 Chemical models & tools 16.3 Test and essay organisms
17	Medicinal resources	Variety in (bio)chemical substances in, and other medicinal uses of, natural biota	
	Information Functions	***Providing Opportunities for Cognitive Development***	
18	Ornamental resources	Variety of biota in natural ecosystems with (potential) ornamental use	Resources for fashion, handicraft, jewelry, pets, worship, decoration, & souvenirs (e.g., furs, feathers, ivory, orchids, butterflies, aquarium fish, shells, etc.
19	Aesthetic information	Attractive landscape features	Enjoyment of scenery (scenic roads, housing, etc.)
20	Recreation	Variety in landscapes with (potential) recreational uses	Travel to natural ecosystems for ecotourism, outdoor sports, etc.
21	Cultural and artistic information	Variety in natural features with cultural and artistic value	Use of nature as motive in books, film, painting, folklore, national symbols, architect, advertising, etc.
22	Spiritual and historic information	Variety in natural features with spiritual and historic value	Use of nature for religious or historic purposes (i.e., heritage value of natural ecosystems and features)
23	Science and education	Variety in nature with scientific and educational value	Use of natural systems for school excursions, etc.; use of nature for scientific research

Appendix M: Reference

De Groot, R.S., M.A. Wilson, and R.M. Boumans. 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics*, 41 (3): 393-408

Appendix N

Formal Trail Monitoring Manual
by J. Marion
as found in (Wimpey 2011a)

Formal Trail Condition Monitoring Manual[1]

(*version 4/25/07*)

This manual describes standardized procedures for conducting an assessment of resource conditions on formal (designated) recreation trails within Great Falls and C&O Parks. The principal objective of these procedures is to document and monitor changes in trail conditions following construction. Their design relies on a sampling approach to characterize trail conditions from measurements taken at transects located every 300 feet along randomly selected trail segments. Distances are measured with a measuring wheel. Measurements are conducted at sample points to document the trail's width, depth, substrate, slope, alignment and other characteristics. These procedures take approximately three minutes to apply at each sample point. Data is summarized through statistical analyses to characterize resource conditions for each trail segment and for the entire trail system. During future assessments it is not necessary to relocate the same sample points for repeat measures. Survey work should be conducted during the middle or end of the primary use season. Subsequent surveys should be conducted at approximately the same time of year.

Materials (Check before leaving for the field)

- This manual on waterproof paper
- Field forms – some on waterproof paper
- Topographic and driving maps
- Clipboard with compartment for forms
- Pencils
- Tape measure in inches (6 ft)
- Metal binder clips (2) to attach tape to stakes
- Line level
- Measuring wheel
- Compass
- Tape measure in tenths of feet (20 ft)
- Tent stakes (3)
- Clinometer

[1] Developed by Dr. Jeff Marion, USDI, U.S. Geological Survey, Patuxent Wildlife Research Center, Virginia Tech Field Station, Dept. of Forestry (0324), Blacksburg, VA 24061 (540/231-6603) Email: jmarion@vt.edu

Point Sampling Procedures

Trail Segments: During the description of amount and type of use (indicators 5 & 6 below), be sure that the use characteristics are relatively uniform over the entire trail segment. Sampled trails may have substantial changes in the type or amount of use over their length. For example, one portion of a trail may allow horse use or a trail may join the study trail, significantly altering use levels. In these instances where substantial changes in the type and/or amount of use occur, the trail should be split in two or more segments and assigned separate names and forms, upon which the differences in use can be described. This practice will facilitate the subsequent characterization of trail use and statistical analyses.

Also collect and record any other information that is known about the trail's history, such as original construction, past uses, type and amount of maintenance, history of use, etc.

General Trail Information

1) **Trail Segment Code:** Record a unique trail segment code (can be added later).
2) **Trail Name:** Record the trail segment name(s) and describe the segment begin and end points.
3) **Surveyors:** Record initials for the names of the rail survey crew.
4) **Date:** Record the date (mm/dd/yr) the trail was surveyed.
5) **Use Level (UL):** Record an estimate of the amount of use the trail receives (high, med., low), relative to other forest trails, from the most knowledgeable staff member. Work with them to quantify use levels on an annual basis (e.g., low use: about 100 users/wk for the 12 wk use season, about 30 users/wk for the 20 wk shoulder season, about 10 users/wk for the 20 wk off-season = about 2000 users/yr).
6) **Use Type (UT):** Record estimates for the types of use the trail receives (including any illegal uses) using percentages that sum to 100%. These should be provided by the most knowledgeable forest staff member. Categories include: Hiking, Horseback, Biking, Other (specify).

Starting/Ending Point: Record a brief description of the starting and ending point of the trail survey. Try to choose identifiable locations like intersections with other trails, roads, or permanent trailhead signs.

Measuring Wheel Procedures: At the trail segment starting point, use a random number table to select a random number from 0 to 300. Record this number on the first row of the form. This will be the first sample point, from which all subsequent sample points will be located in 300 foot intervals. This procedure ensures that all points along the trail segment have an equal opportunity of being selected. Once you get to the first sample point, reset the wheel counter and use it to stop at 300-foot intervals thereafter.

Push the measuring wheel along the middle of the tread so that it does not bounce or skip in rough terrain. Lift the wheel over logs and larger rocks, adding distance manually where necessary to account for horizontal distances. Your objective is to accurately measure the distance of the primary (most heavily used) trail tread. Monitor the wheel counter closely and stop every 300 feet to conduct the sampling point measures. If you go over this distance, you can back the wheel up to the correct distance. If the wheel doesn't allow you to take distance off the counter, then stop immediately and conduct your sampling at that point, recording the actual distance from the wheel, not the missed distance.

If an indicator cannot be assessed, e.g., is Not Applicable, code the data as -9; code missing data as -1.

Rejection of a sample point: Given the survey's objective, there will be rare occasions when you may need to reject a sampling point due to the presence of: (1) bedrock or cobblestone areas that lack defined trail boundaries; and (2) uncharacteristic settings, like tree fall obstructions, trail intersections, roadcrossings, stream-crossings, bridges and other odd uncommon situations. The data collected at sample points should be representative of the 250-foot sections of trail on either side of the sample point. Do not relocate a point to avoid longer or common sections of bog bridging, turnpiking, or other trail tread improvements. Use your judgment but be conservative when deciding to relocate a sample point. The point should be relocated by moving forward along the trail an additional 30 feet; this removes the bias of subjectively selecting a point. If the new point is still problematic, then add another 30 feet, and so on. Record the actual distance of the substituted sample point and then push the wheel to the next sample point using the original 300-foot intervals.

7) **Distance:** In the first column record the measuring wheel distance in feet from the beginning of the trail segment to the sample point.

8) **Trail Type (TT):** Record whether the tread at the sample point was assessed as a direct ascent or side-hill constructed trail (see definitions in #11). Record the letter code in the TT column. **DA** – Direct ascent (fall-line), **SH** – Side-hill trail

9) **Erosion Type (ET):** Record whether soil erosion at the sample point, if present, appears to be recent or historic (see definitions in #11). Record the letter code in the ET column. **RE** = Recent erosion; **HE** = Historic erosion.

10) **Trail Grade (TG):** The two field staff should position themselves on the trail 5 feet either side of the transect. A clinometer is used to determine the grade (% slope) by sighting and aligning the horizontal line inside the clinometer with a spot on the opposite person at the same height as the first person's eyes. Note the percent grade (right-side scale in clinometer viewfinder) and record (indicate units used). Note: if conducted by one person then place clinometer on a clipboard with the window facing you. Orient the clipboard to be parallel to the trail grade and record degrees off the visible scale in the window. After data entry convert to percent slope = [tan (degrees)] x 100.

11) **Landform Grade (LG):** Assess an approximate measure of the prevailing landform slope in the vicinity of the sample point. Follow the one-person procedure described in #7

12) **Trail Slope Alignment Angle (TSA):** Assess the trail's alignment angle to the prevailing land-form in the vicinity of the sample point. Position yourself about 5 feet downhill along the trail from the transect and sight a compass along the trail to a point about 5 feet past the transect; record the compass azimuth (0360, not corrected for declination) on the left side of the column. Next face directly upslope, take and record another compass azimuth – this is the aspect of the local landform. The trail's slope alignment angle ($< 90^0$) is computed by subtracting the smaller from the larger azimuth (done after data entry).

13) **Secondary Treads (ST):** Count the number of trails, regardless of their length, that closely parallel the main tread at the sample point. *Do not count the main tread.*

14) **Tread Width (TW):** From the sample point, extend a line transect in both directions perpendicular to the trail tread. Identify the endpoints of this trail tread transect as the most pronounced outer boundary of visually obvious human disturbance created by trail use (not trail maintenance like vegetation clearing). These boundaries are defined as pronounced trampling-related changes in ground vegetation height (trampled vs. untrampled), cover, composition, or, when vegetation cover is reduced or absent, changes in organic litter (intact vs. pulverized) (see photo illustrations in Figure 1). The objective is to define the trail tread that receives the majority (>95%) of traffic, selecting the most visually obvious outer boundary that can be most consistently identified by you and future trail surveyors. Include any secondary parallel treads within the transect only when they are not differentiated from the main tread by strips of less disturbed (taller) vegetation or organic litter.

Also pay close attention to selecting boundary points that reflect the extent of soil loss representative for this location along the trail. Soil loss measures will be taken from a line stretched between the endpoints you select, so the line should be unobstructed. Organic litter or small rocks that obstruct the line can be removed, but large rock or root obstructions will necessitate moving the line forward along the trail in 1-foot increments until you reach a location where the line is unobstructed. Temporarily place tent stakes at the boundary points and then step back to verify their horizontal and vertical placement as projected along the trail in the vicinity of the sample point. Measure and record the length of the transect (tread width) to the nearest inch (don't record feet and inches).

15) **Maximum Incision, Current Tread (MIC):** Stretch the fiberglass tape tightly between the two tent stake pins that define the tread boundaries – any bowing in the middle will bias your measurements. This transect line should reflect your estimate of the post-construction, pre-use land surface, serving as a datum to measure tread incision caused by soil erosion, displacement and/or compaction. Measure the maximum incision (nearest 1/4 inch: record .25, .5, .75) from the string to the deepest portion of the trail tread. Measure to the surface of the tread's substrate, not the tops of rocks or the surface of mud puddles. Your objective is to record a measure that reflects the maximum amount of soil loss along the transect within the tread boundaries. See Figure 2, noting differences in MIC measures for side-hill vs. non-sidehill trails.

16) **Modal Incision, Current Tread (MOD):** Record what you judge to be the most typical or modal incision measure for the entire transect. This measure will be used to compare against

actual modal incision measures from #16 to evaluate the accuracy of such judgments for use in new rapid assessment tread erosion procedures currently under development.

17) **Cross-Sectional Area (CSA):** The objective of the CSA measure is to estimate soil loss from the tread at the sample point following trail creation. Soil loss may be due to erosion by water or wind, soil displacement from trail users, or compaction. Accurate and precise CSA measures require different procedures based on the type of trail and erosion, some definitions:

Direct-ascent vs. side-hill trails: Trails, regardless of their grade, that more or less directly ascend the slope of the landform are direct-ascent or fall-line trails. Direct-ascent trails involve little or no tread construction work at their creation – generally consisting of removal of organic litter and/or soils. Trails that angle up a slope *and* require a noticeable amount of cut-and-fill digging in mineral soil (generally on landform slopes of greater than about 10%) are termed side-hill trails. The movement of soil is required to create a gently out-sloped bench to serve as a tread. Separate procedures are needed for side-hill trails to avoid including construction-related soil movement in measures of soil loss following construction.

Recent vs. historic erosion: Recreation-related soil loss that is relatively recent is of greater importance to protected land managers and monitoring objectives. Severe erosion from historic, often pre-recreational use activities, is both less important and more difficult to reliably measure. Historic erosion is defined as erosion that occurred more than 10-15 years ago and is most readily judged by the presence of trees and shrubs growing from severely eroded side-slopes.

Measurement Procedure: On the CSA data form, label a new row with the measuring wheel distance for the transect (e.g., D=600 ft). Place the transect stakes as described under the appropriate situation (a-d below). Starting on the left side, record a 0 for the first mark on the line (V_1, at 0 ft), followed by the measurement for the second mark (V_2 at 0.3 ft). The standard interval for these measures is 0.3 ft (3 5/8 in), but for wide trails alternative intervals can be used (e.g., 0.5 ft or 1.0 ft) – if alternative intervals are used *note the interval value* on the CSA form. Take all vertical measures *perpendicular* to the transect line down to the ground surface recording values to the nearest 1/4 in (e.g., .25, .5, .75). Record the values on the data sheet next to their labeled numbers (e.g., V_1, $V_2 \ldots V_n$). Continue measuring each vertical until you reach the far side of the trail and obtain a measure of 0 when the original (non-eroded) ground is reached. ***Note:*** The transect line is not likely to be level, so be cautious in measuring vertical transects that are *perpendicular* to the horizontal transect line. Contact Jeff Marion for a spreadsheet that calculates CSA for this data.

Trail Width	3% Outslope Offset
20	0.6"
30	0.9"
40	1.2"
50	1.5"
60	1.8"
70	2.1"
80	2.4"
90	2.7"
100	3.0"
110	3.3"
120	3.6"
130	3.9"
140	4.2"
150	4.5"

a) Direct-ascent trails, recent erosion: Refer to Figure 2a and follow these procedures. Place two stakes and the transect line to characterize what you judge to be the pre-trail or original land surface. Place the left-hand stake so that the 0 mark on the transect tape will fall on what you believe was the original ground surface but at the edge of any tread incision, if present (see Figure 2a). The tape has been sewn to allow two stake placement options to accomplish this. The transect incision value you record for the 1st mark (V_1) must be 0. Stretch the transect tape tightly between the two stakes – any bowing in the middle will bias your measurements. Insert the other stake just beyond the first transect line mark on the other side of the trail that is on the original ground surface and will be measured as a 0. The transect line should reflect your estimate of the pre-trail land surface, serving as a datum to measure tread incision caused by soil erosion and/or compaction.

Note: For this and all other options (b-d), if the line cannot be configured properly at the sample point due to rocks or obstructing materials that cannot be moved, then move the line forward along the trail in 1-foot increments until you reach a location where the line can be properly configured.

b) Direct-ascent trails with historic erosion: Refer to Figure 2b – if you judge that some of the erosion is historic then follow these procedures. Generally you will find an eroded tread within a larger erosional feature. Place two stakes and stretch the transect line to reflect and allow measurements of the more recent recreation-related erosion (if present) – see guidance in 16a above. If there is no obvious recent erosion tread incision, then position the stakes the same as for your tread width measurement and assess incision between tread boundaries (option not depicted in Figure 2b). The first left-side measure (V_1) must be 0. At the right boundary you must also record a transect with a measure of 0.

c) Side-hill trail: Refer to Figure 2c. The objective of this option is to place the transect stakes and line to simulate the post-construction tread surface, thereby focusing monitoring measuresments on post construction soil loss and/or compaction. When side-hill trails are constructed, soil on the upslope side of the trail is removed and deposited downslope to create a gently out-sloped bench (most agency guidance specify a 5% outslope) for the tread surface (see Figure 3). Outsloped treads drain water across their surface, preventing the buildup of larger quantities of water that become
erosive. However, constructed treads often become incised over time due to soil erosion and/or compaction. The extent of this incision are what these procedures are designed to estimate.

Carefully study the area in the vicinity of the sample point to judge what you believe to be the post-construction tread surface. Pay close attention to the tree roots, rocks or more stable portions of the tread to help you judge the post-construction tread surface. Look in adjacent undisturbed areas to see if roots are exposed naturally or the approximate depth of their burial. Configure the stakes and transect line to approximate what you judge to be the post-construction tread surface. Note that sometimes a berm of soil, organic material and vegetation will form on the downslope side of the trail that is raised slightly above the post-construction tread surface (generally less than 6 inches in height). If present, place the stake and line below the height of the berm as shown in Figure 2c so that it does not influence your measurements. If erosion is severe and/or if the line placement is subjective, use a line level with marks on the bubble glass that allow you to level and then configure the tape as a 3% outslope (a 1 in. drop over 33 in. – see table at right of offset values from level) to standardize the line placement. A 3% outslope is used because actual tread construction may have been somewhat less than 5%, and 3% provides a more conservative estimate of soil loss. It is generally easier and more accurate to place the downslope stake first and configure the line to a 3% outslope to reveal where the uphill stake should be placed. Measure the left-hand stake as transect 1 with a 0 measure and also record a final transect beyond the right-hand stake with a measure of 0.

d) Side-hill trail with historic erosion: Refer to Figure 2d – if you judge that the erosion is historic then follow these procedures. Generally you will find an eroded tread within a larger erosional feature. Place two stakes and stretch the transect line to reflect and allow measurements of the more recent recreation-related erosion (if present). If there is no obvious recent erosion tread incision then position the stakes the same as for your tread width measurement and assess incision between tread boundaries (option not depicted in Figure 2d). The left-hand stake can serve as vertical transect 1; record a 0 for this. At the right boundary you must also record a vertical transect with a measure of 0.

Note: If the line cannot be configured properly at the sample point due to rocks or obstructing materials that cannot be moved, then move the line forward along the trail in one-foot increments until you reach a location where the line can be properly configured.

18-27) **Tread Condition Characteristics:** Along the trail tread width transect, estimate to the nearest 10% (5% where necessary) the aggregate lineal length occupied by any of the mutually exclusive tread surface categories listed below. **Be sure that your estimates sum to 100%**.

S-Soil:	All soil types, including sand and organic soils, excluding organic litter unless it is highly pulverized and occurs in a thin layer or smaller patches over bare soil.
L-Litter:	Surface organic matter, including intact or partially pulverized leaves, needles, or twigs that mostly or entirely cover the tread substrate.
V-Vegetation:	Live vegetative cover, including herbs, grasses, mosses rooted within the tread boundaries. Ignore vegetation hanging in from the sides.
R-Rock:	Naturally-occurring rock (bedrock, boulders, rocks, cobble, or natural gravel). If rock or native gravel is embedded in the tread soil, estimate the percentage of each and record separately.
M-Mud:	Seasonal or permanently wet and muddy soils that show imbedded foot or hoof prints from previous or current use (omit temporary mud created by a very recent rain). The objective is to include only transect segments that are frequently muddy enough to divert trail users around problem.
G-Gravel:	Human-placed (imported) gravel.
RT-Roots:	Exposed tree or shrub roots.
W-Water:	Portions of mud-holes with water or water from intercepted seeps or springs.
WO-Wood:	Human-placed wood (water bars, bog bridging, cribbing).
O-Other:	Specify.

Collect all equipment and move on to the next sample point. **Be sure to assess and record information on the Problem Assessment indicators as you proceed to the next sample point.** These indicators are assessed continuously as pre-defined trail tread problems and when found, surveyors record begin and end distances (from the start of the survey) on the Problem Assessment Form. **Note: After data entry and before analysis, the data for these indicators need to be corrected to add in the 1st randomly selected interval distance so that location data are accurate. In particular, examine any indicators that may begin before and end after the first sample point.**

Problem Assessment Procedures

28) **Informal Trails (IT):** Record the trail distance form the measuring wheel for each informal (visitorcreated) trail that intersects the survey trail segment. This indicator is intended to provide an approximation of the extensiveness of unofficial, visitor-created trails associated with survey trail. Do not count formal trails, roads of any type, extremely faint trails with untrampled vegetation in their treads, trails <10 ft long, or trails that have been effectively blocked off by managers. Informal trails are trails that visitors have created to access features such as streams, scenic attraction sites1, cliffs, vistas, cultural sites, or to cut switchbacks, avoid mud-holes,

rutted treads, steep obstacles, or downed trees, or that simply parallel the main trail. Count both ends of any informal trails ≥10 feet long that loop out and return to or parallel the survey trail. Include any distinct animal or game trails, as these are generally indistinguishable from human trails and their true origin is likely unknown.

29) **Muddy Soil (MS):** Sections of tread (≧ 10 ft)with seasonal or permanently wet and muddy soils that show imbedded foot or hoof prints (≥ ½ inch). Omit temporary muddiness created by a recent rain. This should generally include any longer mud-holes or treads with running water. The objective is to include only tread segments that are frequently wet or muddy enough to divert trail users around the problem, often leading to an expansion of trail width.

30) **Soil Erosion (SE):** Sections of tread (≥ 10 ft) with soil erosion exceeding 5 inches in depth within current tread boundaries. Record SE1 for soil loss 5-10 in., SE2 for 10.1-15 in., and SE3 for 15.1-20 in.

Figure 1. Photographs illustrating different types of boundary determinations. Trail tread boundaries are defined as the most pronounced outer boundary of visually obvious human disturbance created by trail use (not trail maintenance like vegetation clearing). These boundaries are defined as pronounced changes in ground vegetation height (trampled vs. untrampled), cover, composition, or, when vegetation cover is reduced or absent, as pronounced changes in organic litter (intact vs. pulverized). The objective is to define the trail tread that receives the majority (> 80%) of traffic, selecting the most visually obvious boundary that can be most consistently identified by you and future trail surveyors.

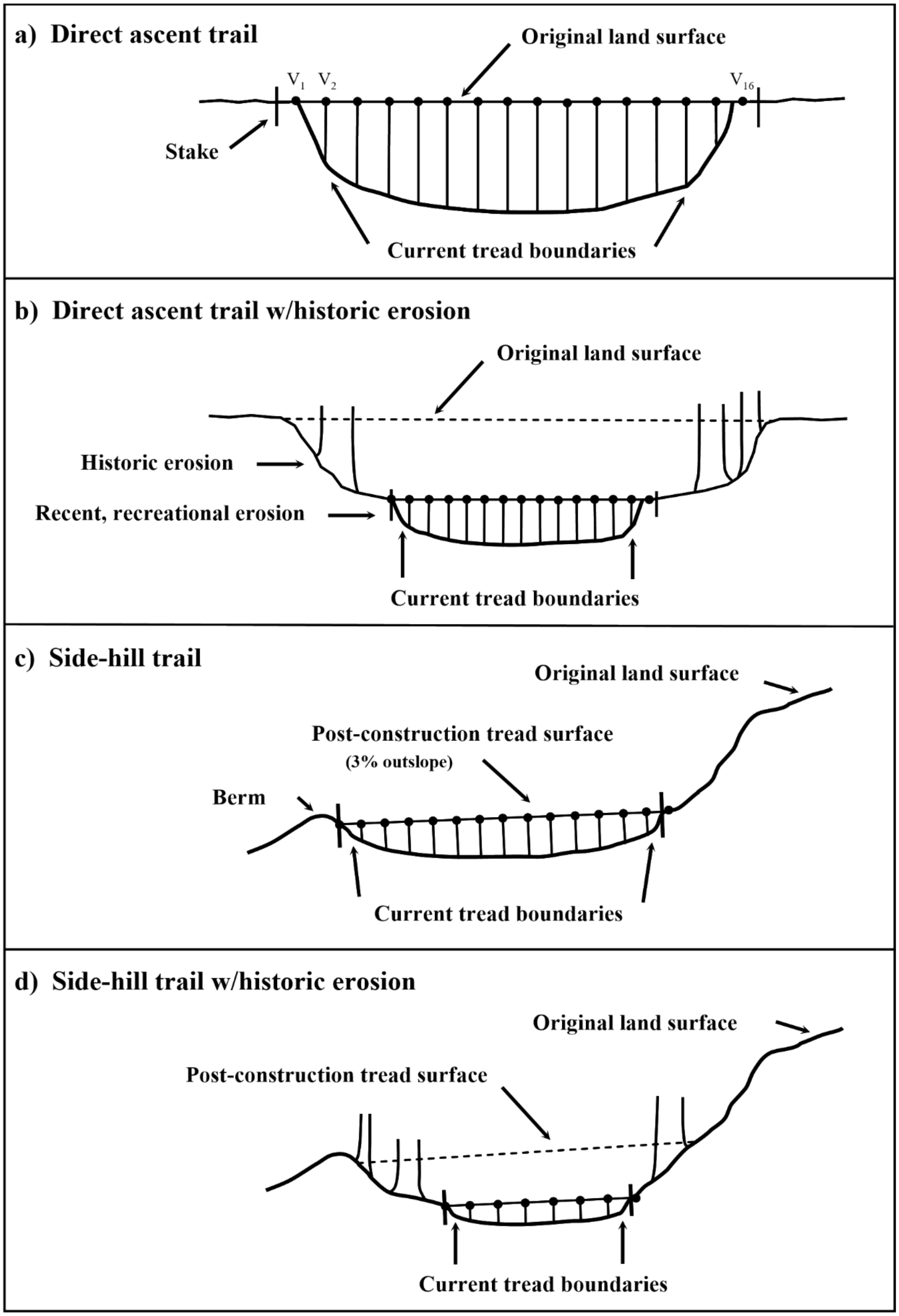


Figure 2. Cross-sectional area (CSA) diagrams illustrating alternative measurement procedures for direct ascent trail alignments (a & b) vs. side-hill trail alignments (c & d) and for relatively recent erosion (a & c) vs. historic erosion (b & d).

Cross-Sectional Area Form

Trail Segment Code ________ **Trail Name** ______________________________

CSA		CSA		CSA	
Transect (in)	**Area**	**Transect (in)**	**Area**	**Transect (in)**	**Area**
D=					
V_1=					

Point Sampling Form

Trail Segment Code ________ Trail Name ____

Surveyors _________________ Date _________ Use Level

Use Type(s): Hiker ______ %, Horse ______ %, Bike ______ %, Other ______ %

Starting Point: **UTM:**

____

Ending Point: ________________________ **UTM:**

Dist	TT	ET	TG	LG	TSA	ST	TW	Tread Substrate Characteristics	MIC	MOD	CSA
					/						
					/						
					/						
					/						
					/						
					/						
					/						
					/						
					/						
					/						
					/						
					/						
								0 10 20 30 40 50 60 70 80 90			

Dist = Wheel Distance **TSA = Alignment (Trail° / Landform°)** **S = Soil** **G = Gravel**
TT = Trail Type (DA, SH) **ST = Secondary Treads** **L = Litter**
RT = Roots
ET = Erosion Type (RE, HE)form) **TW = Tread Width** **V = Vegetation**
W = Water
TG = Trail Grade **MIC = Max. Incision** **R = Rock**
WO = Wood, human-placed **LG = Landform Grade** **CSA (calculated from data)**
M = Mud **O = Other (Specify)**

Problem Assessment Form Cross-Sectional Area Form

Trail Segment Code ________ **Trail Name** ______________________________

Informal Trails	Muddy Soil		Soil Erosion		CSA		CSA		CSA	
Distances	Begin Dist	End Dist	Begin Dist	End Dist	Transect (in)	Area	Transect (in)	Area	Transect (in)	Area
					D=					
					V_1=					

Appendix N: Reference

Wimpey, J.F. 2011a. Formal Trail Monitoring Manual, Appendix 1, In: *Formal and Informal Trail Monitoring Protocols and Baseline Conditions: Great Falls Park and Potomac Gorge*. by Jeff Wimpey, Jeff Marion, and Logan Park. US Geological Survey, Virginia Tech, College of Natural Resources and Environmental Conservation, Blacksburg, VA. 113 p. Available online at https://profile.usgs.gov/myscience/upload_folder/ci2011Jul1215211936429POGO%20Trails%20Study%20Final%20Rpt.pdf ; last accessed June 10, 2016.

Appendix O

Informal Trail Monitoring Manual
by J. Wimpey, J. Marion, and L. Park
as found in (Wimpey 2011b)

Informal Trail Monitoring Manual

Developed by Jeremy Wimpey, Jeff Marion, and Logan Park
Virginia Tech/Dept. of Forestry, Blacksburg, VA
Contact: jmarion@vt.edu, 540-231-6603

Introduction

The creation and proliferation of informal (visitor-created) trails can directly impact sensitive plant communities, rare or endangered flora and fauna, and wildlife habitats. For example, a small patch or population of rare plants may be eliminated by trampling, habitat changes caused by visitor use, or through competition from non-native species introduced by park visitors. Recreationists seeking to access scenic overlooks, water resources, or merely to explore, often trample vegetation sufficiently to create extensive informal trail networks. Such unplanned trail networks generally receive no environmental reviews and resource degradation is often severe due to their lack of professional design, construction, and maintenance. While some degree of visitor impact is unavoidable, excessive trail impacts threaten natural resource values, visitor safety, and the quality of recreational experiences.

Objectives

These protocols are designed to document the number, lineal extent, spatial distribution, area of trampling disturbance, and resource condition of all informal trails within a specified study area. Assessment procedures are efficiently applied through walking surveys that employ sub-meter accuracy Global Positioning System (GPS) units providing field staff a paperless method for collecting trail inventory and resource condition data. When periodically collected over time, these data assist with the monitoring of onsite resource conditions and provide long-term documentation of the existence, location, and condition of informal trails. The data also provide supporting information for management decisions, such as to evaluate which informal trails should be closed or left open, and later to evaluate the success of management efforts to close selected trails, prevent the creation of new trails, or prevent further deterioration of existing trails.

Guidance

This collection protocol should be performed at the end of peak season visitation, i.e., mid-August, when evidence of visitor use is most pronounced and to minimize seasonal variations in trail conditions. Collection should be done at multi-annual intervals (e.g., every three to five years). This schedule assists in locating trails that may emerge or change conditions later in the season. It is important to perform the collection consistently in time across each year to provide management with comparable data.

Materials

- Trimbe GeoXT GPS[1]
    - Loaded with: (1) Informal Trail (IT) Data Dictionary; and (2) formal trail layer

    - Contact Dr. Jeffrey Marion, Virginia Tech, Department of Forestry, jmarion@vt.edu for replacement layers and data dictionaries
  - Stylus
  - Hurricane antenna and connecting lead
  - Trimble backpack and spare external battery
- Tape measure (6-ft auto-retracting)
- Paper maps showing formal trail system
- Pens and notebook

1 – Use the most accurate equipment available. Greater accuracy in data collection translates to more accurate, objective, and efficient GIS editing work.

Methods

Survey staff should be familiar with the study area and its visitor use patterns, particularly where visitors are most likely to depart formal trails and potential off-trail destinations. Scheduling field surveys during times of optimal satellite constellations may be necessary for some areas. Begin work by selecting an area (sub-region of the study area) on the paper map to search. Use features such as trails, roads, and streams, along with prior survey data and personal knowledge, to divide the area into manageable units. Prior data should be used as a guide but not as an authoritative catalog of where informal trails will be found and mapped. To ensure that all informal trails are located, walk all formal trails and search the areas adjacent to each trail for informal trails.

Where possible, do not assess trails created and/or used predominantly by wildlife (e.g., deer). Such trails are generally narrow and go under low-hanging branches that would obstruct human traffic. Be spatially aware and thoroughly search along/near formal trails and features for areas that are likely to draw visitors off the formal trail network (e.g., vistas, water bodies, geographic features of interest, historic structures). In particular, beware of informal trails that depart a formal trail on resistance surfaces (e.g., rock, gravel, bare soil, grass) that may hide the beginning of in informal trail. Some random searching and walking transects across off-trail areas, particularly near any features of interest, are necessary to locate and map all informal trails.

When an informal trail is located, begin an informal trail segment using the IT data dictionary. Use the Condition Class descriptors below to determine and record the appropriate condition class. Do not begin walking the trail segment until the GPS has successfully recorded its first position fix. Walk the trail while collecting the feature until it reaches a junction or changes condition class. Assess and record the segment's average trail width (see below) and then close the segment in the GPS.

Trail width is defined as the most visually obvious outer boundary of trampling-related disturbance that receives the majority (>95%) of traffic. These boundaries are defined by pronounced changes in ground vegetation height (trampled vs. untrampled), cover, composition, or, when vegetation cover is reduced or absent, by disturbance to organic litter (intact vs. pulverized) or lichen. Include any secondary parallel treads within this assessment only when they are not differentiated from the main tread by strips of less disturbed vegetation or organic matter. See Figure 1 for photographs illustrating these trail boundary definitions.

When in areas or times with poor GPS accuracy, stop at trail junctions to record an averaged IT trail junction point. These points will improve the accuracy of GIS data editing.

After thoroughly collecting all informal trails within your sub region, make a notation on you paper map to indicate it has been collected and move on to another sub region.

Decision Rules for Collecting Informal Trail Segments

A condition class change that occurs for less than 2 meters (approximately 6 feet) can be ignored (i.e., collect it as one segment and assign the dominant condition class to the segment). Be careful to try to avoid collecting animal trails. These trails will be narrow and have low-hanging branches/vegetation. Use your judgment and look for signs of human and animal use (footprints, litter, deer browse, etc.).

Condition Class Structure

Class 1: Trail distinguishable; slight loss of vegetation cover and /or minimal disturbance of organic litter.
Class 2: Trail obvious; vegetation cover lost and/or organic litter pulverized in primary use areas.
Class 3: Vegetation cover lost and/or organic litter pulverized within the center of the tread, some bare soil exposed.
Class 4: Nearly complete or total loss of vegetation cover and organic litter within the tread, bare soil widespread.
Class 5: Soil erosion obvious, as indicated by exposed roots and rocks and/or gullying.

Condition class rating descriptions applied to informal trails.

Surveying Tips

- Use the pause and resume (log) capabilities of the GPS to prevent collecting extraneous points at the beginning and end of a segment. Pause the logger when not moving; restart it as you resume movement.
- Working in pairs or using flagging tape and or pin flags will help when the IT network is very dense. Flag sub regions on the ground and work through them individually.
  - ➢ When working a dense network, work small sub-areas and utilize flags and landmarks to delineate them; when collection has been completed within one flagged sub-area, establish an adjacent sub-area and collect it (e.g., 50-100 m long on one side of a formal trail).
- Collect IT anchor points when needed to aid in tying trail junctions to a specific location. Use Trimble's nest feature option.
- Use the formal trail layer and paper maps as a reference.

Data Download and Backup

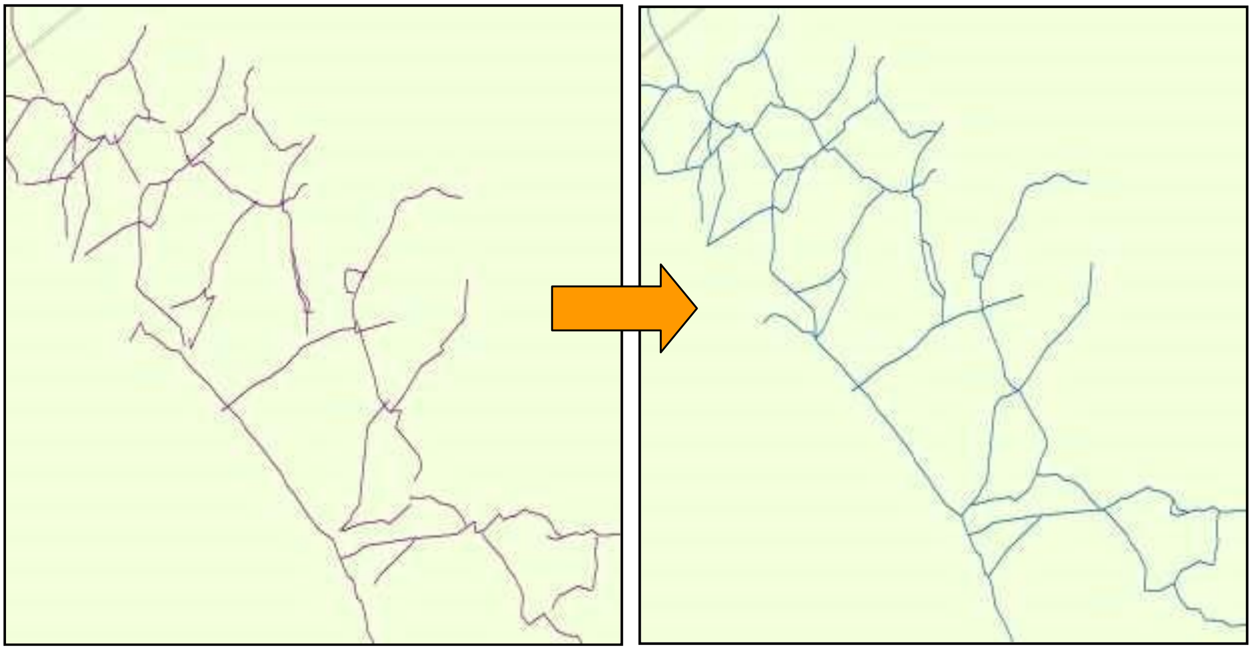
- When finished collecting for the day, close the rover file on the Trimble GPS.
- Connect the GPS to a computer with Pathfinder Office software (work within the preexisting project directory for the current collection).
  Transfer the rover files to the computer.
- If an internet connection is available, download the differential correction files that correspond to all new rover files and differentially correct them.
  - Designate the source base station as the closest available geographically.
  - Review the correction report as well as the corrected files for any errors or processing problems. Open the files in GIS to visually inspect them each day.
  - Ensure that the data were not removed during the correction procedure (e.g., due to missing base station data, high PDOP, etc).
  - Correction files that are not immediately available are generally made available within a week or two.
- Backup all data on a separate HDD and document all necessary metadata.
- Recharge the GPS and external battery.
- Keep a written field notebook record of all fieldwork, including field staff names, search areas, dates/times, and computer filenames.

Editing Data

Data should be post-processed (differentially corrected and converted to GIS appropriate format) using GPS software (e.g., Trimble's Pathfinder Office with conversion to ArcMAP Shapefiles). Merge output files into a single file representing the Informal trail network.

Informal trail data requires editing due to the nature of GPS data collection. GIS staff should edit the data to clean up and improve the accuracy of the informal trail network. Tips for doing this work:

- Use imagery and ancillary GIS datasets to help visualize the local environment.
- Move trail segment endpoints (minimally) to establish connectivity to other informal segments, recreation sites, and formal trails.
  - Use the anchor points layer for establishing junction locations. Use snapping and zoom tools to assist.
- Once the network is close, a clean or build procedure can be used (adjust fuzzy tolerance and dangle length as needed).



Before Editing

After Editing

Figure 1. Trail width is defined as the most visually obvious outer boundary of trampling-related disturbance that receives the majority (>95%) of traffic. These boundaries are defined by pronounced changes in ground vegetation height (trampled vs. untrampled), cover, composition, or, when vegetation cover is reduced or absent, by disturbance to organic litter (intact vs. pulverized) or lichen.

Data Dictionary

Informal Trail:

LineFeature

Label1=Average Width
Condition Class: Menu; Normal, Normal
1 2 3 4 5 Other

Average Width=Numeric, Decimal Places=0
Minimum=1,Maximum=144,DefaultValue=8 Normal, Normal

Segment#:
Numeric, Decimal Places=0
Minimum=0, Maximum=500, Default Value=1, StepValue=1 Normal, Normal

Comment:
Text, Maximum Length=30 Normal, Normal

IT Anchor Point:

Feature

Label1=Number
Label2=Comment

Number=Numeric Decimal Places=0
Minimum=0,Maximum=500, DefaultValue=1, StepValue=1 Normal, Normal

Comment:
Text, Maximum Length=30 Normal, Normal

Appendix O: Reference

Wimpey, J.F. 2011b. Informal Trail Monitoring Manual, Appendix 2. In: *Formal and Informal Trail Monitoring Protocols and Baseline Conditions: Great Falls Park and Potomac Gorge*. by Jeff Wimpey, Jeff Marion, and Logan Park. US Geological Survey, Virginia Tech, College of Natural Resources and Environmental Conservation, Blacksburg, VA. 113 p. Available online at https://profile.usgs.gov/myscience/upload_folder/ci2011Jul1215211936429POGO%20Trails%20Study%20Final%20Rpt.pdf ; last accessed June 10, 2016.

Appendix P

Guidance for Managing Informal Trails
by J. Marion as found in (Wimpey 2011c)

Guidance for Managing Informal Trails

Jeff Marion, USGS Research Scientist
(jmarion@vt.edu, 540-231-6603)

The development, deterioration and proliferation of visitor-created informal trails in protected areas can be a vexing management issue for land managers. Formal trail systems never provide access to all locations required by visitors seeking to engage in a variety of appropriate recreational activities. Traveling off-trail is necessary to engage in activities such as nature study, fishing, or camping. Unfortunately management experience reveals that informal trail systems are frequently poorly designed, including shortest distance routing with steep grades and alignments parallel to the slope. Such routes are rarely sustainable under heavy traffic and subsequent resource degradation is often severe. Vegetation impacts include trampling damage leading to changes in species composition, potential introduction and dispersal of non-native plants, and the loss of vegetation cover. Soil impacts include the pulverization and loss of organic litter, and exposure, compaction, and erosion of soil. Soil deposition in streams, disturbance to wildlife, and damage to historic resources are also possible. Creation of multiple routes to common destinations is another frequent problem, resulting in avoidable impacts such as unnecessary vegetation/soil loss and fragmentation of flora/fauna habitats.

This guidance is provided to assist land managers and volunteer trail maintainer organizations in evaluating informal trail impacts and in selecting the most appropriate and effective management responses.

Adopt a Decision-Making Process

The management of informal trail networks can benefit from application of a planning and decision-making process or framework that includes public dialogue and input. Decisions regarding impact acceptability and the selection of actions needed to prevent recreation-related resource impacts fall into the domain of carrying capacity decision-making. The NPS defines carrying capacity as "the type and level of visitor use that can be accommodated while sustaining the desired resource and visitor experience conditions in the park" (NPS 2006). The NPS applies the Visitor Experience and Resource Protection (VERP) decision-making framework (NPS 1997), while the U.S. Forest Service applies the Limits of Acceptable Change (LAC) framework (Stankey *et al.* 1985).

These formal frameworks direct managers to prescribe objectives for biophysical and social conditions they intend to achieve for specific park zones. Numerical standards of quality are established for each indicator and zone to define the critical boundary line between acceptable and unacceptable conditions, establishing a measurable reference point against which future conditions can be compared through periodic monitoring. These frameworks incorporate an adaptive management decision process, whereby managers can apply actions, evaluate their success, and when needed, apply alternative actions as a follow-up until management objectives are achieved. A simplified framework known as Protected Area Visitor Impact Management (PAVIM) employs an expert panel and problem analysis process (Figure 1) that requires less data (Farrell & Marion 2002). The problem analysis process, which is particularly applicable and useful in informal trail management decision-making, is described below.

Problem Analysis Process

Assemble a team of knowledgeable and experienced individuals with expertise in recreation resources management, visitor management, social science, site and trail management, natural resource management, and interpretation. Visit the site where the impacts or problems are occurring and apply this problem analysis process to guide discussions.

Identify and Evaluate the Problem

The problem analysis begins by developing the group's collective knowledge of the area, amounts and types of recreational uses, and the resource and social problems currently present. Group members most knowledgeable about these topics are asked to share their knowledge with the group. The sharing of differing perspectives, land management agency, trail club, recreation representatives, is encouraged. The significance of the problems and degree to which current conditions are unacceptable are considered when deciding whether management actions are needed. Next, participants with the longest experience in the area are asked to relate the history of the problems or impacts. Previous management actions are described and their effectiveness discussed and evaluated, including why implemented actions were or were not effective.

The core of a good problem analysis is a thorough evaluation of a problem's underlying causes and identification of factors that influence impact severity. For example, substantial off-trail traffic may be the cause for excessive vegetation loss but fragile ground vegetation and poorly marked or maintained formal trails may significantly contribute to the creation of unacceptably extensive or impacted informal trails. The relative influence of three groupings of factors – use-related, environmental, and managerial – should be examined. An improved understanding of these causes and factors is essential to evaluating alternative actions and selecting effective actions.

Identify and Evaluate Strategies and Actions

Step two involves brainstorming by team members to list and then evaluate a diverse array of management strategies and actions. Following list development, study team discussions should focus on careful evaluations of the advantages and disadvantages of each action. A number of important attributes should be considered, including potential effectiveness, management feasibility, costs to visitor freedom and satisfaction, expected visitor compliance, and others as appropriate.

The final step is selecting one or more preferred actions suggested for implementation. Careful consideration of the history of impacts and their management, the desired resource and social conditions for the area, and factors which either cause or influence impacts can help guide more objective and effective decision-making. Management objectives or desired condition statements will suggest the appropriateness of alternative actions relative to the natural, social, and managerial settings of the zone the area is situated within.

Generally, initial actions are feasible, have a low cost to visitors, and are judged to have a good chance at effecting the desired change in conditions. For example, indirect actions such as education or site maintenance should be considered before regulatory or site development actions as they are less obtrusive and do not compromise visitor freedom. More restrictive, expensive, and/or obtrusive actions are generally deferred until justified by the failure of one or more preceding actions. However, severe or unacceptable impacts may warrant bypassing such lighthanded efforts in favor of actions necessary to achieve more effective or immediate results. Alternative actions should be identified for potential implementation in the event that initial actions are ineffective.

For each action, identify likely individuals or organizations responsible for implementing the action and describe the necessary resources they will require. An implementation schedule should also be developed and efforts to obtain funding and staff initiated. At this time it is also useful to consider how a planned action should be monitored for evaluating effectiveness. For example, an accurate GPS survey of informal trail networks with condition class assessments provides a baseline for future comparison and should be conducted prior to implementing corrective actions.

Table 1. Problem analysis for managing resource and social impacts related to visitation.

I. **Identify and Evaluate the Problem**
- ***Describe area and use(s)*** - provide background information about the area, facilities, and visitor use.
- ***Describe problem(s)*** - briefly describe the facility, resource and social impact problems that are occurring.
- ***Problem significance*** - consider if and why the impacts are significant or unacceptable to land managers and protected area visitors
- ***Previous management actions*** - describe the history of the problems and previous actions; discuss the effectiveness of these actions and why they did or didn't work.
- ***Causes and influential factors*** - discuss the underlying causes for the impacts and the role of non-causal but influential factors that may intensify impacts. Consider use-related factors (type and amount of visitor use, visitor behavior and motives, use density), environmental factors (soil and vegetation type, environmental sensitivity, topography), and managerial factors (siting, design, construction, and maintenance of facilities, visitor management).

II. **Identify and Evaluate Strategies and Actions**
- ***List potential strategies and actions*** - create a comprehensive list of appropriate and potentially effective management strategies and actions. Strategies are broad approaches (e.g., modify visitor behavior, manage sites and facilities) and actions are the specific means used to implement a strategy (e.g., educate visitors, relocate campsites).
- ***Evaluate strategies and actions*** - discuss and evaluate the following attributes for each strategy and action: potential effectiveness, management feasibility (cost, staffing, long-term maintenance), advantages/disadvantages (e.g., costs to visitor freedom), expected visitor compliance, etc.

- ***Formulate recommendations*** - through group discussion, develop and write recommendations that reflect the group's consensus views. Describe the recommended action or group of actions to implement first and what might be tried next if these are ineffective.

Problem Definition

For informal trail management decision-making, an inventory of the informal trail network within an area of management concern is particularly useful. If GPS devices and expertise is available, a simple inventory technique is to conduct a walking GPS survey, provided the terrain and forest canopy permit accurate GPS use. GIS software can input, map and analyze the data, providing a visual display of the informal trail network relative to designated trails, roads and other resource features. Computation of the lineal extent of the informal trail network is also possible. If GPS devices cannot be used then an inventory can be made by hand-sketching informal trails onto large-scale maps with lengths assessed by pacing or a measuring wheel.

Where possible, managers may also wish to consider various options for assessing the condition of the informal trails. Many options, ranging from simple condition class evaluations, to trail width and depth measurements, or detailed assessments of soil and vegetation loss are possible. Guidance for assessing trail conditions may be found in the scientific literature (Cole 1983, Leung & Marion 2000, Marion & Leung 2001). Some rapid assessment ―condition class‖ options are included at the end of this document or contact the author for examples of alternative monitoring protocols and manuals. An objective assessment of informal trail conditions can produce quantitative data for indicator variables that can be summarized to characterize current trail conditions, or when replicated, to monitor changes in trail conditions over time. Such data can be used in the previously described formal or informal adaptive management decisionmaking frameworks.

Evaluate Impact Acceptability

The acceptability of informal trail impacts should be evaluated according to park or management zone objectives. Informal trails located in pristine areas where preservation values are paramount are less acceptable than when located in areas that are intensively developed and managed for recreation use. Trails in areas with sensitive cultural and archaeological resources are particularly unacceptable if they threaten such irreplaceable resources.

<u>Environmental Factors</u>

Informal trails located in sensitive or fragile plant/soil types, near rare plants and animals, or in critical wildlife habitats are less acceptable than when located in areas that are resistant to trampling damage and lack rare species. Informal trails that directly ascend steep slopes and/or will easily erode are less acceptable than trails with a side-hill design. Informal trails prone to muddiness and widening are less acceptable, as are trails that may contribute soils to water resources.

<u>Use-Related Factors</u>

Why is a trail in a particular location and what are the visitors trying to access? Which recreation activities are most responsible for creating informal trails? What are the motives responsible for off-trail hiking? Are some impacts avoidable? For example, informal trail impacts related to a poorly marked formal trail or that result from visitors trying to circumvent muddiness or severe erosion are more easily avoided and should be targeted first. It is not uncommon to find several ―duplicative‖ informal trails in close proximity to each other accessing a common destination. Impacts caused by visitors seeking to shortcut a longer, more resistant route are unacceptable, as are impacts caused by visitors who could alternately access their intended destination by staying on resistant durable surfaces (e.g., rocks or gravel) (www.LNT.org). Informal trails resulting from illegal or inappropriate types of uses are less acceptable than if they are caused by permitted uses.

A careful consideration of these and other relevant factors (e.g., visitor safety) can assist managers in making value-laden decisions regarding the acceptability of informal trail impacts. The acceptability of these impacts, in turn, guides decisions about which trails should be left open, rerouted, or closed, and selection of appropriate and effective management interventions.

Selection of Management Strategies

The problem analysis process can assist managers in considering and evaluating a diverse array of potential management strategies and actions. Note that some degree of degradation to natural resources is an inevitable consequence of recreation use, requiring managers to balance recreation provision and resource protection mandates. Roads and formal trails can never provide complete access to the locations visitors wish to see, hence, some degree of informal trail development is inevitable and must be tolerated. The challenge for managers is to evaluate the impacts in light of recreation provision and resource protection objectives, and apply professional judgment to determine which impacts are unacceptable and require management action.

The following section describes four general strategies for managing informal trail impacts: 1) Improve management of formal trails, 2) Ignore or formalize informal trails, 3) Maintain informal trails, and 4) Close and restore unacceptable trails,.

Improve Management of Formal Trails

If formal trail problems are contributing to the development of informal trails, then addressing such problems is generally one of the more effective and efficient options available to managers. Four problems are common. Make sure that formal trails are well-marked in some distinctive fashion so that visitors can clearly distinguish between formal and informal trails – this is often very confusing to most visitors. In rocky areas, paint blazes may be needed on rocks rather than trees because the terrain demands constant attention to the immediate trail tread. ―Overblazing‖ or clearly defined trail borders (e.g., spaced rocks, logs, or scree walls) may be necessary in some tricky areas. Boardwalks, low symbolic fencing, or higher rustic fencing are more effective but more visually obtrusive and costly. The treads of formal trails should be the most attractive location for walking, maintained to be free of muddiness or deeply eroded ruts with exposed roots and rocks. When braided or multiple parallel treads occur managers should define a single intended tread throughout.

Ignore or Formalize Informal Trails

Some informal trails may have reasonably sustainable design attributes and access locations, such as vistas or campsites (hikers), water resources (fishermen), or cliffs (climbers) that are acceptable to land managers. When visitor access to these locations is appropriate, such trails should generally be left open as informal trails or even designated and managed as formal trails. They serve an important resource protection function by concentrating visitor traffic on a narrow tread and protecting adjacent vegetation from trampling damage. Recreation ecology studies have consistently found a curvilinear relationship between the amount of traffic and trampling impacts (Leung and Marion 2000). The majority of trampling impact occurs with relatively low levels of trampling; once a trail is established, further trampling impact is greatly minimized by a concentration strategy that focuses all further traffic to its barren tread. An alternate dispersal strategy is only effective under conditions of very low use and/or when traffic can be confined to durable substrates (e.g., rock, gravel) or vegetation (grasses/sedges).

Sometimes a portion of such informal trails may require a reroute to improve the sustainability of an alignment, such as a very steep section aligned with the fall-line (parallel to the landform slope). An experienced trails professional should conduct a review and provide recommendations for informal trails left open to use. Generally trail alignments should favor side-hill over fall-line alignments, avoid grades over 15%, and favor rocky substrates and non-vegetated or grassy groundcover. As with formal trails, leaving an informal trail with a poor impact-susceptible alignment is rarely a preferred long-term solution. Site development actions, such as graveling or installation of water bars and rock steps, could be applied but these are generally less appropriate on informal trails and would be unnecessary on a well-designed alignment. In most instances, relocation to an improved alignment will be a more cost-effective and sustainable long-term solution, even though pristine terrain is affected.

Due to the relatively poor trail design skills of visitors, it may even be necessary to replace several non-sustainable informal trails with a new well-designed informal or formal trail (with appropriate environmental reviews). An objective evaluation of the aggregate or cumulative impacts, including the total area of trampling disturbance and soil loss, will generally support such a decision. However, this option should only be attempted when managers are relatively certain of their ability to effectively close the pre-existing informal trails.

Maintain Informal Trails

Historically, most park managers have not maintained informal trail networks. However, extending maintenance work to those trails with reasonably sustainable designs left open to use can substantially reduce impacts. For example, managers can piece together a single sustainable route in an area with numerous braided trails and trim obstructing vegetation, subtly enhance tread drainage, or install natural-appearing rockwork on steep slopes. These actions will effectively encourage use and reduce impacts on the sustainable route while reducing use and encouraging natural recovery on alternate informal trail segments. Additional actions, discussed in the following section, can be applied to discourage their continued use.

Close and Restore Unacceptable Trails

Informal trails with poor, non-sustainable design attributes, trails that threaten sensitive resources, or unnecessary trails with duplicative routings should generally be closed and rehabilitated. Managers should recognize that successful trail closures and restoration are rare and require substantial and sustained management effort. The principal reason for low success rates is that while trampling impacts occur rapidly with low levels of use, vegetative and soil recovery occurs very slowly and complete recovery is prevented unless nearly all traffic is removed from treads for several consecutive years. A substantial restoration program involving the addition of soil and plantings of native species, with watering as needed to ensure survival, can hasten natural recovery. However, care must be taken to apply such intensive work only when managers are reasonably certain that effective measures are in place to prevent further trampling of the restoration work.

Selection of Management Actions

An adaptive management program involving education and site management actions is suggested when implementing strategies. Management experience and research have demonstrated that integrating site management and educational actions consistently achieve the highest rates of success. Site management actions are needed to mark and keep visitors on formal trails or to block or hide informal trails; educational actions are needed to inform visitors of the impacts associated with off-trail traffic and what managers would like them to do to protect natural and cultural resources. Visitors frequently misunderstand site management actions that lack signs placed to convey information about impacts of concern and management intent. In the absence of site management actions, visitors may choose to disregard a prompter sign if a well-used informal trail branches off to what looks like an appealing vista.

Educational Actions

An educational component is often critical to communicate a clear rationale for an action – for example, that significant resource impacts can occur in some areas if visitors travel off designated trails. A message with a rationale should be followed by a plea for visitors to remain on formal trails, which need to be clearly designated through site management actions (e.g., blazing, symbolic markers, cairns) to distinguish them from informal trails. Social science research and theory has found that signs with a compelling rationale and clear behavioral plea are more effective than simple "do" and "do not" messages (e.g., "Please Stay on Designated Trails to Preserve Sensitive Vegetation") (Cialdini 1996, Cialdini et al. 2006, Johnson & Swearingen 1992, Marion & Reid 2007, Vande Kamp et al. 1994, Winter 2006). Such literature should be consulted to improve the efficacy of educational messaging.

Some principal goals that educational efforts seek to communicate include: (1) trampling impacts represent a significant threat to resource protection in some areas, (2) off-trail traffic has created informal trails that managers would like to close and restore, (3) remaining on formal trails avoids these impacts, (3) formal trails can be distinguished from informal (visitor-created) trails by distinctive markings, and (4) even small amounts of continued traffic prevent the recovery of informal trails that managers are seeking to close and restore. Unfortunately, as you might expect, this is a lengthy and complex educational message that is challenging to communicate effectively. Research suggests that more complex messages are more effectively communicated personally, rather than on signed or in brochures. Regardless, examples of signs that seek to accomplish these objectives and that have received NPS approval for use are depicted in Figure 1. Note the inclusion of the "no-step" icons that communicate the message with just a glance and are understandable by children and non-English speaking visitors. Generally the larger informative signs are placed in conspicuous locations near trailheads and the more numerous "prompter" signs are placed just beyond junctions with informal trails.

Site Management Actions

A variety of site management actions are available for closing informal trails. Close lightly used trails by actions that naturalize and hide their tread disturbance, particularly along initial visible sections where visitors make the decision to venture down them. Effective actions include

raking organic debris such as leaves onto the tread, along with randomly placed local rocks, gravel, and woody debris designed to naturalize and hide the tread. These actions also lessen soil erosion and speed natural recovery. On trails that have been effectively closed, transplanting plugs of vegetation at the beginning of wet seasons can hasten natural recovery. Revegetation work conducted before successful closure is achieved can be a frustrating waste of time and materials if visitors continue use of the trail and trample the transplanted vegetation.

Figure 1. Examples of informative trailhead sign (left) and trailside prompter signs that can assist management efforts in closing informal trails.

For well-used trails, such work generally cannot fully disguise the disturbed substrates and vegetation so additional measures are necessary for effective closures. Construct a visually obvious border along the main trail, such as a row of rocks or a log, to communicate an implied blockage for those seeking to access the closed trail. Alternately, embed large rocks or place large woody materials or fencing to obstruct access at the entrance to closed trails to fully clarify management intent. Even temporary 2-foot tall post and cord symbolic fences can communicate the importance of closures and effectively deter traffic (Figure 2) (Park et al. 2006). Taller plastic fencing (preferably in green or brown) is also easy to transport and install to discourage traffic on trails that prove more difficult to close. However, fencing is generally perceived as visually obtrusive and inappropriate in more primitive settings.

Placing rocks or woody debris that physically obstructs traffic beyond the beginning of closed trails may be ineffective if visitors are able to circumvent these by walking around them. This can result in new trampling and trails parallel to the closed trail – a significant problem in areas with sensitive or rare vegetation. In such areas it is better for hikers who ignore closures to remain on the closed tread than to create new treads on each side (Johnson et al. 1987). If the trail is in sloping terrain its closure may require the addition of soil to fill ruts and reestablish the original surface contour, and organic litter and vegetation to keep the soil from eroding. Finally, integrating site management work with temporary educational signs may be necessary to obtain a level of compliance that allows vegetative recovery. Also, consider signs to communicate the location of a preferred alternate route when visitors are seeking to reach a particular destination and their only visible access trail is closed.

Figure 2. Low symbolic post and rope fencing (left) and high fencing designed to physically obstruct access (right).

Conclusions

Informal trail management actions should be implemented as part of an ongoing adaptive management program Experimentation will be necessary to refine site management procedures that are appropriate in each management zone or location. Some form of periodic monitoring is critical to program success. A five-year interval could be sufficient for monitoring with quantitative procedures, but annual informal evaluations are needed to effectively guide the application of management actions.

Objective monitoring will be needed if any potentially controversial management actions may be needed (e.g., use restrictions or high fencing). In exceptionally high use areas with sensitive resources there is a good probability that such actions will be necessary. For example, a combination of signs and restoration work may be able to keep 95% of visitors on a designated trail but 5% of 2000 visitors/day is 100 visitors/day, a level of trampling that is sufficient to both create and maintain informal trails. Tall fencing or a regulatory sign that prohibits use of the closed trail and threatens fines may be necessary on trails that are particularly difficult to close. Such situations also indicate a need for further dialogue with trail users to discover their motives and a review of whether the formal trail system should be extended or modified.

Regardless, periodic monitoring provides feedback for gauging the success of management interventions in keeping conditions within acceptable limits. A documented failure of one intervention can be used to justify the use of a more obtrusive or expensive intervention.

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Appendix Q

Integrated Pest Management and Review of US Forest Service (USDA 2012) and Other Resources for Invasive Plant Control Methods with a Viewpoint of Applicability in Managing Invasive Plant Species in SW

By Rodney Walters

Integrated Pest Management

Integrated Pest Management (IPM) encourages a balancing of pest control measures with ecology health while simultaneously considering economic realities. The Food and Agriculture Organization of the United Nations defines IPM as:

> The careful consideration of all available pest control techniques and subsequent integration of appropriate measures the discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce or minimize risks to human health and the environment. IPM emphasize the growth of healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms (Food and Agriculture Organization of the United Nations 2014).

IPM has become perhaps the most widely utilized process for controlling pests in the United States and abroad; it is actively endorsed by the United States Department of Agriculture (USDA), the Environmental Protection Agency, the US Fish and Wildlife Service, the US Army, and broad array other US, state, corporate, and nonprofit organizations. IPM is the accepted approach in the management of forested and other naturalized areas and is utilized in Forestry, Urban Forestry, Recreation, and other fields by applying BMP standards to pest management practices (Wisconsin Forestry.org 2015). In 2007, the International Society of Arboriculture published *Best Management Practices: Integrated Pest Management* to define IPM, BMPs in Arboriculture and Urban Forestry (Wiseman 2007). The *Forestryencyclopedia* states, "IPM was practiced before the concept was defined" (Hain 2011) and offers a Forestry definition of IPM which includes and outline of the most accepted pest management tools which are the bases for BMP's in Forestry, Urban Forestry, Recreation, and other fields:

> IPM in a forest ecosystem is the process of managing a forest with all available tools so that potentially destructive organisms, such as insect and diseases, are maintained at a level that is below economic or damage threshold. These tools are used in conjunction with forest management practices that are designed to meet the overall goals of the forest manager. The tools of IPM include pest thresholds (economic or damage), preventive cultural practices, monitoring, mechanical controls, biological controls, and chemical controls (including the

use of pheromones). As a rule-of thumb, forest management practices that encourage good growth produce pest resistant stands. Typically, pest problems arise in stands that are under stress. Many stress factors, but not all, are caused by poor management practices that can be alleviated" (Hain 2011).

An IPM approach for controlling IPS in SW has the option of drawing from BMPs that are applicable to the control of the specific IPS that are negatively effecting the SW forest remnant.

US Forest Service Non-Native Invasive Species Best Management Practices and Their Applicability for Controlling Invasive Plant Species in Stadium Woods

The United States Department of Agriculture publication *Non-native Invasive Species Best Management Practices, Guidance for the U.S. Forest Service Eastern Region* contains considerable information on Best Management Practices (BMP's) designed specifically for the management of invasive plant species (IPS) (USDA 2012). This 282-page document contains and extensive information about IPS BMPs [described in the document as non-native invasive species (NNIS) for the fields of Forestry, Urban Forestry, Outdoor Recreation Activities, and Transportation and Utility Rights-of-Way practices]. This document contains sections for Forestry and Urban Forestry with BMPs that are most applicable to the management of Stadium Woods. The elements of IPS management in forestry are described by this publication as; *Prevention*, *Early Detection*, *Rapid Response*, *Control*, *Monitoring*, *Restoration*, and Adaptation. These elements are based on the strategic goals of the National Invasive Species Management Plan (The National Invasive Species Council. 2008.

The logic as to which of these IPS management elements from Forestry apply to SW are described as follows: The invasive exotic plant species effecting SW are firmly established in many parts of the stand. As a result, the opportunity for *prevention* by means of *early detection*, and *rapid response* may be lost in the areas that are already infested with IPS. This leaves the options of *control*, *monitoring*, *restoration*, and *adaptation*. Even so, the management elements of *prevention*, *early detection*, and *rapid response* may be employed to prevent, detect, and respond to areas of SW that have not yet been inundated by invasive exotic plant species. The *adaptation* option is not currently a viable option for SW, because the *adaptation* management element would concede that IPS have irreversibly changed the environment and controlling the IPS populations in SW are impossible, which is not the case. SW stewards are not yet ready to surrender the benefits the SW old-growth forest provides for campus and the surrounding community. *Monitoring* activities are functions of *control* and *prevention*. *Restoration* may be too costly at the present time. This leaves SW managers with the option of employing the management element of *control* for the affected areas of the woods in combination with *prevention*, *early detection* and *rapid response* to keep IPS populations away from less affected areas of the SW forest (USDA 2012).

The Urban Forestry IPS management elements are very similar to the forestry IPS management elements except that the *adaptation* element is not offered as an option. Instead, the *adaptation* option is replaced with the element of *Communication and Education* which states:

> We all have a stake in reducing the negative impacts of NNIS (IPS). The prevention and control of NNIS will require modifying behaviors, values, and beliefs and changing the way decisions are made. A successful plan to address NNIS issues will depend on the understanding and acceptance of the magnitude and urgency of the NNIS problem and the actions needed to protect our valuable resources. A wide variety of education, outreach and training programs are needed: to raise awareness of the causes of establishment and consequences of NNIS, to educate people about their management options, to keep them abreast of the most current information and to help motivate them to take action" (USDA 2012).

The consequences of taking no action to address the IPS problem in SW is that its ecosystem services will become degraded, the forest's ability to regenerate will be compromised, and the stand, over time, will lose its value for its stakeholders. Ultimately, without intervention, the stand will deteriorate to the point that it is no longer valued and will suffer either a slow smothering IPS invasion or have its understory layers removed to clean up the IPS mess. With this reality in mind, **ignoring the invasive exotic plant problem is not a feasible option for SW.** SW will be most effectively managed by employing some strategic variation of the management element of *control* (USDA 2012).

IPS control tactics are described in the Forestry and Urban Forestry Best Management Practices sections of the *Non-Native Invasive Species Best Management Practices* publication and are listed as control measures/methods on p.12 and p.189 respectively:

> Employing a combination of prevention and control measures, e.g.: pulling, cutting, targeted pesticide use, biological controls, and native species reintroduction, is an effective way for managers to control NNIS (IPS). This approach is often referred to as integrated pest management (IPM). In the forest context, IPM can be defined as the maintenance of destructive agents (plants, insects, and diseases) at tolerable levels by the planned use of a variety of preventive, suppressive, or regulatory tactics and strategies that are ecologically and economically efficient and socially acceptable" (USDA 2012).
>
> Control methods are measures employed to carry out control strategies. They include manual (pulling and burning); mechanical (cutting and tilling); chemical (targeted pesticide use); biological (use of the fungus *Bacillus thuringiensis* (BT) for insect pests); and cultural methods (planting non-host tree species). Usually no one method is effective at controlling NNIS. To determine the best method or combination of methods to use, one should evaluate the site and the life cycle of the NNIS of concern. When a combination of control methods is used it is referred to as integrated pest management (IPM). In the urban forest context, integrated pest management can be defined as the maintenance of destructive agents (plants, insects and diseases) at tolerable levels by the planned use of a variety of preventive, control or regulatory strategies that are ecologically and economically efficient as well as socially acceptable (USDA 2012).

These control methods may be deployed in SW in any combination which may achieve management objectives and effectively control the introduction, spread, establishment, and adverse ecological effects of IPS while preserving the ecological integrity and health of the stand in a socially acceptable manner.

IPS control methods include *manual*, *mechanical*, *chemical*, *biological*, and *cultural* techniques (USDA 2012). Control methods may be considered treatment tools. The saying 'treatment without diagnosis is malpractice' is as applicable to the treatment of the ecology of a woodland as to the treatment of any other complex living system. With this in mind, each control method must be measured according to its effectiveness in controlling IPS (agent/pathogen) in comparison to the negative effects or complications that treatment may produce. Every control method that may be deployed for the control of IPS contains costs, benefits, and risks. For example, pulling IPS is an excellent control method which yields good results in getting rid of many IPS. However, the pulling of an IPS could leave roots behind which may re-sprout or the root pieces on the ground could re-sprout if they are not all cleaned up. For this reason, repeated hand pulling and/or follow up with herbicide applications will often be necessary (Langeland, et al. 2011). In addition, hand pulling is very time consuming and labor intensive. Laborers and their tools may trample vegetation and disturb soil layers and provide a ripe environment for more IPS to germinate. Cutting is also time consuming and labor intensive and will most often lead to the re-sprouting of the IEPS from stubs and could even encourage more aggressive root growth and further spreading of IEPS in the woodland (Tu, et al. 2001).

Each control method should be carefully analyzed according to a cost/benefit and effectiveness/negative effects comparison matrix which considers the ecology of each forest layer and how well each individual control method may control each specific IPS. Timing of treatment is also crucial in order to maximize the effects of the control method applications or prevent further spread of the IPS. For example, it may be easier to pull up the IPS in the spring when the soil is moist and loose. It is best to treat an IPS during times of the year when their energy reserves are low and the undesirable plants are most vulnerable; or at least, when the risks of spreading further IPS is lower, such as when the risks of spreading seeds or sprouts are low. In effect, a treatment must be prescribed to address each IPS that is affecting SW. This is a sound approach that is embraced by in the IPM and Plant Health Care methodologies. The *Weed Control Methods Handbook: Tools & Techniques for Use in Natural Areas* is an excellent online free resource (including options for uploading or purchasing improved and updated versions of the publication), which offers a thorough documentation of many IPS control methods including manual, mechanical, cultural, biological, and chemical controls. Especially useful in the publication, are its discussions of herbicides which explain chemistry, safety, application methods, properties, behaviors in the environment, and toxicities for 2-4D, Clopyralid, Fluazifop-p-Butyl, Fosamine, Glyphosate, Hexazinone, Imazapic, Imazapyr, Picloram, Sethoxydim, and Triclopyr (Tu, et al. 2001). **A sound knowledge of the available treatment methods will enable greater effectiveness by maximizing benefits, reducing costs, and minimizing risks in the battle to control the IPS problem in SW.**

The implementation of combinations of IPS control methods (known as IPM) will generally maximize benefits and reduce risks while considering costs by:

- Considering available management options,
- Understanding the biology and life cycles of target and not-target species,
- Evaluating ecosystem sensitivity to invasion by introduced organisms,

- Considering the impacts of management on ecosystems,
- Reducing invasive species impacts below and economic/ecological threshold,
- Allowing flexibility to adapt management techniques to changing conditions, and,
- Developing additional managements options
  (University of Florida 2011)

One such control method combination that may prove to be very effective in addressing the IPS problem in SW may be the combination of the cutting method with the chemical control method. Described as *cut stem treatments*, this control method combination makes use of the benefits of cutting and herbicide application while reducing the risks of both. Cut stem treatments first utilizes the mechanical method of cutting to remove the IPS from the understory to open up space for the regeneration of native plants, then it applies an herbicide to the cut stump to kill the roots (Mattrick 2006). An herbicide with translocation properties (movement through plant tissues) applied to a freshly cut stump will kill the plant's root system. The herbicide is applied in a highly targeted way using a paint brush, thus greatly reducing the risk of ecosystem contamination and the killing of non-target species. The benefits of the cutting control method is thus maximized by the herbicide application by permanently eliminating the invasive exotic plant in a way that provides minimal soil disturbance. Risks of herbicide application are reduced using application methods that specifically target individual invasive plant species while avoiding the killing of beneficial plants. The lower application rates also minimize ecosystem contamination in the forest.

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Appendix R

Trail Management Plan Options For "Stadium Woods" (SW)

By Rodney Walters

Basic Trail Management Approach

The following approach is recommended as a way to address the more glaring trail issues in SW until a more involved trail management plan can be created (evaluated, analyzed, planned, designed, implemented, maintained, and monitored):

A plan that considers sustainability and recreation, ideally, should focus on a general collaboration between conservation and recreation stakeholders, especially when centralizing or closing trails. Decisions should be based on trail survey data and could involve experimenting with small trail segments to determine what trail management practices will provide the most benefits (Ballantyne, et al. 2014). The first step should be to prevent, remove, or reroute sections containing the poorest conditions or most intrusive usage (Marion and Leung 2004,Pickering, et al. 2010). Second, in areas where there are dense trail networks, further informal trails should be prevented by educating stakeholders/visitors by talking with them and/or signage along with physical incentives that encourage visitors to remain on desired tracts, such as trail borders (ropes, logs, or rocks), or trail hardening (Ballantyne, et al. 2014). These actions form the basis of our initial recommendation: perform a basic trail evaluation and initiate actions to reduce the most egregiously impacted trail segments.

A preliminary evaluation of the SW visitor created trails has revealed three trail segments that require immediate closure (Figure 3.5). These trail segments have very poor condition class structure ratings (Appendix O), unacceptable high gradients (slope), and exists on angles perpendicular to the landscape contours known as *fall lines* (Wimpey 2011;Wimpey and Marion

2011) resulting in significant erosion during rain events. This is causing environmental impacts as well as aesthetic impacts to some Lane Stadium paved walkways. Two examples of significant erosion occurring in SW may be viewed in the photographs below (Figures R.1 and R.2).

An integration of educational and site management actions will help to ensure the successful closure of the above trail sections. The following methods are derived from Guidance for Managing Informal Trails (Appendix P). Visitors may be educated through a combination of signage and personal communications. Signs may be placed at trail entrances and near trail closure restoration areas to help communicate the need for people to remain on trails and reduce human trampling impacts. Volunteers or uniformed university police could explain the importance of remaining on trails to visitors during game day events. Effective messaging will communicate the following points:

1. Trampling threatens resource protection,
2. Off-trail traffic has created areas/trails that need to be restored/closed,
3. Remaining on trails avoids negative visitor impacts, and
4. Even small amounts of off trail walking prevents closed trails from being restored (Wimpey 2011c)].

The trail sections should be closed off using the following site management actions: Temporary fencing should be put up to block out the site. Educational signs will help explain the restoration of the site and the need for visitors to help recovery actions by staying out of the closed area. Soil should be added to fill the ruts created by the erosion and reestablish the original contour. This will assist native vegetation replanting and serve as a screen to further enhance the site

Figure R.1 **Significant erosion where trail exits the very southern end of "Stadium Woods"**

Figure R.2 **Significant erosion where trail exits the central west side of "Stadium Woods" near the Lane Stadium scoreboard**

restoration. Additionally, a border should be placed along the desired trails to demarcate the tread that visitors should remain on. Large natural woody debris from SW may be placed to hinder access and further communicate the intent for closing the trail section.

There are Virginia Tech courses that are well suited for conducting trail assessments in SW. Social capital, in the form of volunteers, could conduct recommended actions and site management techniques from class project assessments. Details explaining trail analyses, assessment, monitoring, maintenance, and management techniques may be found in the *Formal Trail Condition Monitoring Manual*, *Informal Trail Monitoring Manual,* and *General Guidance for Managing Informal Trails* (Appendices N, O, and P).

Comprehensive Trail Management Approach

A longer-term more sustainable approach will, by necessity, require a more up-front investment in terms of evaluation, analyses, planning, design, construction, monitoring, and maintenance, but will yield far superior results in the form of meeting the goal of achieving long-term recreational and use benefits while sustaining the quality of the ecosystem over time (Olive and Marion 2009). Since this approach will be more effective in reducing human impacts, it will better facilitate the stewardship priority and long term goal of restoration in SW.

When questioned specifically about the trail management in SW, recreation ecologist Jeff Marion suggested the following approach (J. Marion, personal communication, March 31, 2015):

1. Employ a proactive approach by determining
   A. Why the trail system is needed? (How is/will it be used?)
   B. What is wanted? (Recreation and commuter access with low impacts)
2. Decide what to allow and what not (evaluate impact acceptability)
   A. Must be alignment with SW primary objective of restoration as determined by stakeholder consensus and consider social, economic, and environmental factors and consider analyses of relevant indicators.
3. Assess what is there (trail Inventory - evaluate trails to determine if trails have sustainable attributes).
   A. Gather Data (Inventory) according to selected *indicators* (Merigliano 1990; Wimpey 2011).
      1. SW formal trails should be based on professional planning and Design considerations through the Office of University Planning. Formal trail management elements should be considered (Appendix N).
      2. Informal trail segments -condition class structure -indicators along with trail width and grade and alignment attributes (Appendix O).
   B. Perform trail condition evaluation/assessment by comparing indicators to make decisions about management objectives (Appendices N, O, and P).
      1. General recommendations to consider:
         a. Alignment angle should be < 10%.
         b. Contour line trails work best if they follow contours with a variation to the contour of up to a 45degree angle! (Between 45-90 degrees is undesirable).
         c. <10% trail grade is desirable.
         d. >10% grade and on a fall line compounds adverse impacts! (Wimpey 2009).
   C. Recommend usage (communications/signage-specify use).
      1. Nature/recreation trail (showcasing and protecting)
      2. Commuter (limit impacts to designated trails)

4. Decide on actions and implement -Positive and negative aspects to every surface treatment (mulch-has potential for adverse effects, Pavement-not as ecologically desirable due to further fragmentation and barrier for organisms).
    A. Education - Verbal communications and signage to specify usage and why (Widman 2010).

Investment in a long-term proactive approach will establish a trail system that provides minimum impacts over time (J. Marion, personal communication, March 31, 2015) (Leung and Marion 2000; Olive and Marion 2009). Since, the stewardship priority for SW is restoration, this approach will best represent the SW trail system goals of providing recreation and commuter access while simultaneously minimizing human impacts, such as trampling. Trampling impacts include changes in species composition, possible introduction of invasive plant species, loss of vegetation cover, loss of organic litter, soil compaction, and soil (Leung and Marion 2000; Yorks, et al. 1997). These trampling impacts are detrimental to the SW ecosystem. A primary reason that a trail system is needed in SW, is because a sufficiently designed, constructed, and maintained SW trail system will provide the functions of allowing recreation and commuter access while confining impacts to the treads of the pathways (Leung and Marion 2000). SW needs both recreation pathways to accommodate Virginia Tech classes and passive recreationists who are visiting the woods as well as commuter trails that allow them to move efficiently and safely through the woods as they travel back and forth between the Town of Blacksburg and the Virginia Tech Campus.

Decisions regarding the surface treatments of the trails will need to be well thought-out (J. Marion, personal communication, March 31, 2015). A SW trail management plan will describe what may be allowed and what is not acceptable. Some basic considerations include:

- Mulch is a less than desirable trail surface treatment (J. Marion, personal communication, March 31, 2015).

- Pavement is not as ecologically desirable, because it further fragments ecosystems and creates a movement barrier for organisms (Leung and Louie 2008; Leung, et al. 2002) (J. Marion, personal communication, March 31, 2015).

- Angular gravel mixed with native soil (clay-loam and angular gravel ¾" to 1½") is ideal, because it is the most successful trail surface treatment (J. Marion, personal communication, March 31, 2015) (Olive and Marion 2009).

These decisions should be grounded in fact based analyses, the capacity of specific surface treatment to meet the SW primary objective of restoration, and community considerations within an accepted decision making process. A trail network system decision-making process will benefit from stakeholder feedback and discussions (Appendix P). Decision making frameworks can guide planning and operational decisions by offering a defensible process of defining desired future conditions, identifying impact indicators, assessing impact acceptability, conducting problem analyses, and making decisions on management actions (Leung and Marion 2000). The Protected Area Visitor Impact Management (PAVIM) decision-making framework problem analysis process can serve as a guide for informing trail system decisions (Farrell and Marion 2002; Marion and Leung 2004). This decision making framework can help stakeholders, planners, and managers decide objectives, identify and evaluate problems, evaluate and pinpoint strategies and actions, evaluate impact acceptability, and select management strategies (Appendix P). A guiding question in the decision making process will ask whether or not the choices will accomplish the long-term stewardship priority of restoration for SW. Decisions will, by necessity, consider physical, ecological, and social variables as indicators by which to evaluate conditions of human activity so progress toward goals and desired conditions can be assessed (Wimpey 2011). It is important that considerations be given to the fact that there are positive and negative aspects to every surface treatment approach (J. Marion, personal communication, March 31, 2015).

Trails, ideally, need to be evaluated to determine if they have sustainable attributes. The tracks may be assessed according to information gathered from the three types of general trail surveys. These surveys include *trail attribute inventories*, *trail condition assessments*, and *trail prescriptive management assessments* (Marion, et al. 2011). These trail inventories help to record and map physical, ecological, and social *indicators* as a means to track causes and trends of human impacts (Merigliano 1990). This enables comparisons to be made between management objectives and indicator standards so trail inventory information may be collected and analyzed according to the most important data for answering management questions (Wimpey 2011). Any combination of the above trail survey types may be integrated in any way that best meets management objectives.

In general, *trail attribute inventories* can provide highly detailed data sets for formal and informal trail management. *Trail condition assessments* can supply census data from *problem census surveys* for monitoring impact changes on formal and informal trail systems or *condition class surveys* that provide efficient, lower cost, and timely assessments that are very suited for informal trail systems. *Trail prescriptive management assessments* are most suitable for experienced trail professionals who are qualified to make prescriptions of specific trail work needs (Marion, et al. 2011).

Formal trail systems in and around SW should involve professional planning and design through the Office of University Planning and be installed by qualified professionals who are skilled in minimizing tree impacts. These endeavors should consider formal trail management design standards (Hesselbarth, et al. 2007) and monitoring procedures (Wimpey 2011a). In addition, the planning and construction of formal trails should also incorporate a tree preservation plan as a critical part element of the process (Matheny and Clark 1998; Matheny and Clark 2008).

The existing informal SW trails should be viewed critically because unplanned informal trails are generally less sustainable (Wimpey and Marion 2011) and should only be retained if they have been verified to have sustainable attributes. Trails demonstrating sustainable trail characteristics may be retained (Ballantyne and Pickering 2015). This is because established trails greatly minimize impacts by concentrating traffic on barren tread (Marion and Leung 2004). Informal trail segments may be quickly assessed by integrating *condition class* descriptions along with impact indicators such as trail width, trail grade, slope ratio, and trail slope alignment attributes (Appendix O) (Wimpey and Marion 2011; Wimpey 2009).

Trail condition analyses should be evaluated by comparing impact indicators to management objectives in the process of formulating trail management decisions and actions (Appendices N and O). Some basic recommendations or standards of trail science include:

- alignment angle should be < 10%,
- contour line trails work best if they follow contours with a variation to the contour of up to a 45 degree angle! (Between 45-90 degrees is undesirable),

- <10% trail grade is desirable.
- >10% grade and on a fall line compounds adverse impacts!
  (J. Marion, personal communication, March 31, 2015) (Marion and Leung 2004,Wimpey and Marion 2011,Wimpey 2009).

Decisions will depend on trail type/use, traffic intensity, timing of traffic, and ecosystem tolerance (Cole 2004; Pickering 2010). Once the trails have been analyzed, recommendations for their usage should be made. Ideally, usage patterns decisions should be based on the trail's capacity to handle the amount, type, and intensity of traffic along with the existing characteristics of the trail and its associated topography (J. Marion, personal communication, March 31, 2015). Two key factors in trail management are associated with decisions regarding better trail design or trail surface hardening (Ballantyne and Pickering 2015). Decisions that take a long term approach in the design, installation, maintenance, and ongoing monitoring of trails will ultimately yield lower impacts over time with a savings in overall costs (Marion and Leung 2004; Marion, et al. 2011).

Two separate trail types are needed in SW. The first trail type needs to accommodate the thousands of commuters who cross through SW every week during semester sessions. Moreover, the number of people crossing through the woods can reach as high as tens of thousands of people per day during Virginia Tech football game days. Well-designed SW commuter trails will, ideally, accommodate peak traffic on football game days while simultaneously protecting the environment. Environmental degradation is reduced or avoided through applications of good trail design and restricting trail users to designated trails (Marion and Wimpey 2007). A nature/showcase trail is the second trail type needed in SW. This trail should be a well-designed, low impact pathway that allows access through SW for the purpose of showcasing points of interests such as the Hurricane Hill housing remnants (Section 2.3.1), large old trees, and various aspects of the ecosystem (such as the forest interior and various understory zones). The intended usage of these trails may be specified with signage and even through direct personal communications during game day events.

After the trail planning and design choices have been made, installation, maintenance, and ongoing monitoring actions may proceed. Informal trail management primarily focuses on upholding sustainable attributes of existing visitor trails and keeping visitors on existing trails (Appendix P) while formal trail management focuses on trail hardening and/or better trail design (Ballantyne and Pickering 2015). There are many books and resources that provide standards based trail building techniques and solutions. The IMBA's Guide to Building Sweet Singletrack and The Trail Construction and Maintenance Notebook and are two such resources that offer excellent trail building methods (Felton and Internation Mountian Bicycling Association 2004; Hesselbarth, et al. 2007). Experienced trail builders have the skills to construct high quality trails that require less maintenance.

Of course, even the best trails will not provide the desired benefits of reducing human impacts over time unless trail management actions are put in place to support the necessity of preventing people from wandering off the trails. This may be accomplished by integrating a variety of trail management strategies. Formal trails should have more attractive tread surfaces and be well marked so visitors may clearly differentiate between informal and formal trails. Options for the demarcation of sanctioned trails include logs, low symbolic fencing, boardwalks or higher rustic fencing. Informal trails that have sustainable characteristics may be left open or even selected and maintained as formal trails. Portions of informal trails that are unsuitable may be closed and rerouted for long-term feasibility (Appendix P).

It is important to emphasize that trail closures are rare and entail significant and sustained management efforts for successful restoration. This is because soils and vegetation recover very slowly and ecosystem restoration does not occur unless all the traffic is removed for a period of several years. Adding soil and planting native vegetation can be an effective way to naturalize a trail closure and accelerate the recovery process. Such measures should only be taken when managers are committed to the successful resolution of such a restoration process. This may be accomplished through a combination of education and communications (Marion and Reid 2007; Widner Ward and Roggenbuck 2003) along with the application of site management actions (Appendix P) (Lehvävirta 1999; Widman 2010).

Monitoring is an important step that ensures the design, installation, and maintenance steps have been successful. It is an important diagnostic aspect of an adaptive management approach. Monitoring allows responsible parties to see what is working well and to make adjustments in areas that have needs for improvement. This will reduce costs, save resources, and, increase site management strategy effectiveness over time (Mansourian, et al. 2005).

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