National Park Service
U.S. Department of the Interior

Morristown National Historical Park
New Jersey

Morristown National Historical Park

Vegetation and White-tailed Deer Management Plan
Environmental Assessment/Assessment of Effect

July 2017

Cover Photo by:VHB

United States Department of the Interior
National Park Service
Morristown National Historical Park

Vegetation and White-tailed Deer Management Plan
Environmental Assessment/Assessment of Effect

July 2017

The National Park Service is preparing this Vegetation and Deer Management Plan/Environmental Assessment/Assessment of Effect (the plan) for Morristown National Historical Park (the park). The park is managed to preserve and protect resources associated with the 1777, 1779, and 1780 winter encampments of General George Washington's Continental Army during the American Revolutionary War. Park goals are to protect, preserve, and maintain significant cultural landscapes and to consider ecological values when protecting park resources (NPS 2003). A part of achieving this goal has been to manage park vegetation to maintain a historic pattern of field and forest. Action is needed to protect the forested landscape because invasive plants and deer browsing have inhibited the establishment of native hardwood understory regeneration, which is needed to replace canopy trees lost to natural mortality.

This document was prepared to satisfy the requirements of the National Environmental Policy Act (NEPA) and Section 106 of the National Historic Preservation Act (NHPA). This plan evaluates the impacts of a no-action alternative (alternative A) and an action alternative (alternative B). The no-action alternative would include the continuation of current management, which involves actions to prevent the spread of invasive plant species into forested areas currently unoccupied by invasive species but would not include any deer population control. The action alternative would include forest management through invasive plant species management, forest canopy management, and seed or seedling plantings. Deer browsing would be controlled through direct reduction of the white-tailed deer population as needed. The alternatives would result in both beneficial and adverse impacts on forest vegetation, white-tailed deer population, and the cultural landscape. These impacts would be associated with forest management techniques to control invasive plant species and actions to control deer browsing. The action alternative would result in no adverse effect on historic properties.

Note to Reviewers and Respondents:
If you wish to comment on this plan, you may mail comments within 30 days of release of this document to the name and address below or you may post them electronically at http://parkplanning.nps.gov/morr. Before including your address, phone number, e-mail address, or other personal identifying information in your comment, you should be aware that your entire comment, including your personal identifying information, may be made publicly available at any time. While you can ask us in your comment to withhold your personal identifying information from public review, we cannot guarantee that we would be able to do so.

Superintendent
Morristown National Historical Park
30 Washington Place
Morristown, NJ 07960

This page intentionally left blank.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

CFR	Code of Federal Regulations
CWD	Chronic Wasting Disease
dbh	diameter at breast height
FGDC	Federal Geographic Data Committee
GPS	global positioning system
IPM	Integrated Pest Management
National Register	National Register of Historic Places
NEPA	National Environmental Policy Act
NETN	Northeast Temperate Network
NHPA	National Historic Preservation Act
NJDFW	New Jersey Division of Fish and Wildlife
NPS	National Park Service
the park	Morristown National Historical Park
PEPC	[National Park Service] Planning, Environment and Public Comment
USDA	US Department of Agriculture
USNVC	United States National Vegetation Classification

This page intentionally left blank.

1

PURPOSE AND NEED

INTRODUCTION

The National Park Service is preparing this Vegetation and White-tailed Deer Management Plan/Environmental Assessment/Assessment of Effect (the plan) for Morristown National Historical Park (the park). The park is managed to preserve and protect resources associated with the 1777, 1779, and 1780 winter encampments of General George Washington's Continental Army during the American Revolutionary War. Park goals are to protect, preserve, and maintain significant cultural landscapes and to consider ecological values when protecting park resources, as defined in the park's general management plan (NPS 2003). A part of achieving this goal has been to manage park vegetation to maintain a historic pattern of field and forest.

This plan was prepared in accordance with the National Environmental Policy Act of 1969 (NEPA) and its implementing regulations (40 CFR 1500-1508); the Department of the Interior NEPA regulations (43 CFR Part 46); NPS Director's Order #12: *Conservation Planning, Environmental Impact Analysis, and Decision-making* (NPS 2011b); and the accompanying NPS NEPA Handbook (NPS 2015). In addition, the National Park Service is integrating the NEPA compliance process with that for Section 106 of the National Historic Preservation Act of 1966 (NHPA), and using the NEPA documentation and coordination processes for Section 106 compliance pursuant to 36 CFR 800.8(c); therefore, this plan also serves as an assessment of effect to historic properties under Section 106.

The National Park Service began this planning process with the intention of preparing an environmental impact statement. However, as planning progressed, the team identified no significant impacts on park resources from implementation of any alternatives discussed in this plan. Therefore, the National Park Service determined that an environmental assessment was appropriate for meeting NEPA requirements.

PURPOSE, NEED, AND GOALS

PURPOSE AND NEED

The purpose of this plan is to provide a framework for managing vegetation and the browsing intensity of white-tailed deer (*Odocoileus virginianus)* to promote a naturally regenerating hardwood forest with mixed-aged classes of trees that reflect the historic and naturally diverse character of the park.

This plan is needed because the National Park Service aims to protect the park's landscape in a cultural as well as ecological context; an important part of this landscape is a naturally regenerating mixed-hardwood forest that reflects historic character, natural diversity, and natural processes. Currently, that naturally regenerating and sustainable mixed-hardwood forested landscape is threatened due to a lack of regeneration. Native hardwood regeneration has been unsuccessful at the park due to two factors, which are described in further detail in "Chapter 3: Affected Environment":

- as they expand, invasive herbs, shrubs, and vines are outcompeting native species and depressing or eliminating native tree seedling regeneration rates over much of the forest. Note: for the purposes of this document, the term invasive species will refer to invasive plant species.
- historically high levels of white-tailed deer browsing on understory woody growth has contributed to lower tree seedling regeneration rates. The understory is considered that portion of the forest floor containing herbaceous plants, tree seedlings, and shrubs.

Natural hardwood forests rely on regeneration (germination from seeds and sprouting from stumps) originating from large mature trees, referred to as the overstory canopy, to provide seedlings and saplings that will one day replace aging and dying canopy trees. This natural process is reliant upon having sufficient seedling/sapling numbers available. As seedlings and sprouts age, they reach a stage called "advanced regeneration," in which stems in the young sapling stage are somewhat suppressed by the shade of the overstory, but are able to secure enough sunlight to develop and store carbohydrates in the roots. Once sunlight becomes available from an opening created in the canopy, advanced regeneration, with its stored energy, is ready and available to exert rapid height growth to occupy the space in the opening (Healy 1997).

Over time, the absence of forest regeneration will result in either (1) the replacement of forest stands with species that do not reflect the forest's historic character or natural diversity, or (2) the disappearance of mixed hardwoods altogether (Healy 1997). Consequently, action is needed to meet the park's general management plan direction of maintaining a naturally regenerating and sustainable forested landscape. This plan proposes immediate action to address these issues, as well as monitoring and potential future actions to address continued adverse impacts, as appropriate.

GOALS

The NPS interdisciplinary planning team considered input from the public and the project's science advisory team (a team of agency scientists and consultants) to refine the goals for native forest regeneration at the park and to develop primary and secondary goals. Primary goals must be met to a large degree for an alternative to be considered reasonable and carried forward in the plan. Secondary goals help in further articulating the goals for the plan.

The plan's primary goals (including targets when applicable) to promote conditions for the native hardwood forest to naturally regenerate are to:

- Minimize the establishment of new populations of invasive species that could threaten hardwood forests.
- Increase mixed-aged classes of hardwood trees. Stocking guides for similar Northeastern hardwood forests indicate that it will take between 1,000 and 1,500 seedlings per acre to create a "moderately dense" hardwood forest (NPS 2012b). If this target is met while controlling deer browsing and allowing sunlight to reach the forest floor, the 1,000 to 1,500 seedlings per acre would grow to between 550 and 900 sapling-size trees (between 4- and 5-inch diameter at breast height[dbh]) (Leak et al. 1969).
- Reduce existing invasive species to minimize competition for hardwood regeneration.

- Maintain deer density at a level where browsing does not interfere with forest regeneration. The maximum number of deer that an ecosystem similar to the park can tolerate while still maintaining regeneration of native hardwood species is estimated at 20 to 25 deer per square mile (Tilghman 1989).
- Maintain forested components of the park's cultural landscape.

The plan's secondary goals are to:

- Promote conditions that improve the variety and vigor of the native understory herbaceous and shrub layer cover.
- Maximize regional efficiency (e.g., by including other agencies, adjacent landowners, neighbors, etc.) in creating conditions that promote a naturally regenerating and sustainable forest.
- Adaptively manage forest vegetation and deer browsing based on results of monitoring and understanding of the relationships between deer browsing, invasive species, and forest regeneration, including potential deer health factors such as chronic wasting disease (CWD).
- Help visitors and the public understand the park's vegetation and white-tailed deer management strategies.

PROJECT AREA AND AREA OF POTENTIAL EFFECT

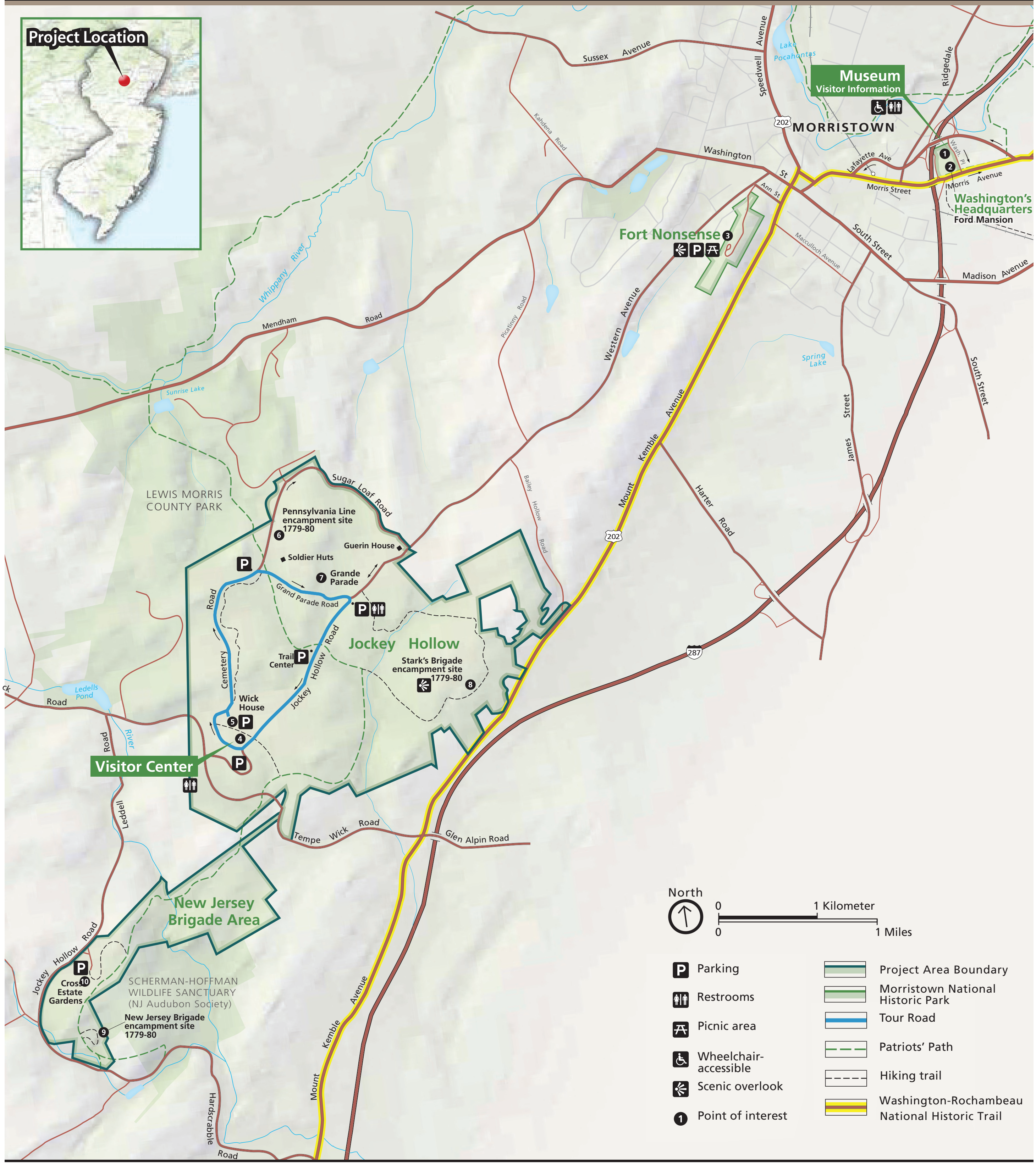
The park is located in northern New Jersey, less than 30 miles west of Newark. The park spans two counties (Morris and Somerset Counties) and five communities (Morris Township, Morristown, the Borough of Bernardsville, Harding Township, and Mendham Township). Nearby population centers include Madison, Basking Ridge, Bernards Township, and Mendham Borough. See figure 1 for a map of the project vicinity.

The park includes four separate units: Washington's Headquarters, Fort Nonsense, Jockey Hollow, and New Jersey Brigade. The project area for this plan is defined within the boundaries of the Jockey Hollow and New Jersey Brigade units:

- Jockey Hollow (1,339 acres), approximately 3 miles southwest of Fort Nonsense, is the site of the "log-house city" constructed by approximately 10,000 troops during the winter of 1779–80.
- New Jersey Brigade (approximately 321 acres), approximately 1 mile southwest of the main encampment area at Jockey Hollow, preserves the site of the encampment of 1,000 troops from the New Jersey Brigade in 1779–80.

See figure 2 for a map of the project area.

An area of potential effect on historic properties is also defined for this project, based on NHPA Section 106 regulations (36 CFR 800). The area of potential effect is defined as the geographic area in which an undertaking may directly or indirectly cause alterations in the character or use of historic properties if such properties exist. For this plan, the area of potential effect is defined with the same boundaries as the project area described above and shown on figure 2.

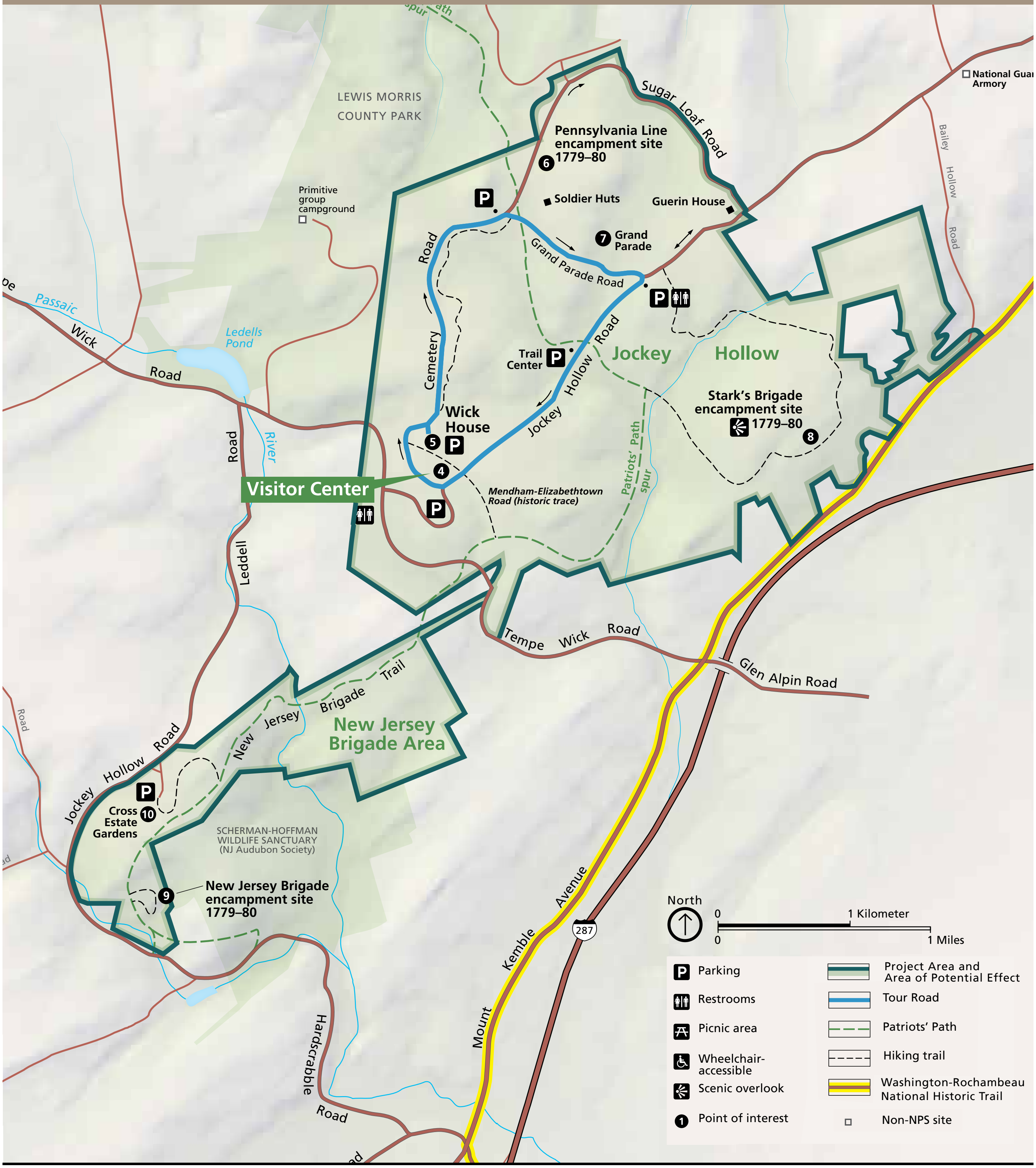


Vegetation and White-tailed Deer Management Plan
Environmental Assessment/Assessment of Effect

FIGURE 1
Project Vicinity Map

National Park Service
US Department of the Interior

Morristown National Historical Park
New Jersey



Vegetation and White-tailed Deer Management Plan
Environmental Assessment/Assessment of Effect

FIGURE 2
Project Area and Area of Potential Effect

HISTORY AND DESCRIPTION OF MORRISTOWN NATIONAL HISTORICAL PARK

On March 4, 1933, President Herbert Hoover signed the bill establishing the park as the first national historical park in the national park system. Subsequently, land donations from the Town of Morristown (Fort Nonsense), Lloyd Smith (1,000 acres in Jockey Hollow), the Washington Association of New Jersey (Washington's Headquarters), and Charles McAlpin (owner of the former Kemble property, 124 acres), as well as additions of the Stark Brigade site in 1937, the New Jersey Brigade unit in 1969, and other small boundary adjustments brought the park to its current size of approximately 1,705 acres.

The landscape history of the project area and vicinity helps to shape the project purpose and need. The townships surrounding the park were first settled in the 1730s; while farms and associated development are known to have been part of the area landscape, it is assumed that more extensive clearing did not take place until the arrival of Washington's Army in 1779. Before European settlers arrived, Indian tribes occupied the area and likely used fire to clear areas for agricultural use (NPS 2003). Historical documents suggest an oak-dominated forest was present upon the army's arrival, and the troops cleared large oaks to build shelters and use for firewood. After the Revolutionary War period, the land was converted to agricultural use where suitable; lands not suitable for farming returned to forest. After the Civil War, the region experienced an agricultural decline; by the early 20th century, younger forests began to replace open fields. Original forested areas in the park continued to be used for timber and charcoal until the 1920s. Areas held in fields until the late 19th and early 20th centuries became occupied by fast-growing, shade intolerant tree species such as tulip poplar (*Liriodendron tulipifera*) and white ash (*Fraxinus americana*), and are referred to in this document as the successional forests. The older stands of trees on the park with a higher component of oaks (*Quercus* spp.) and hickories (*Carya* spp.) are referred to as mature forests. After official establishment of the park, the land was left undisturbed to become the maturing stands of hardwoods present today.

ISSUES AND IMPACT TOPICS

Issues are "problems, concerns, conflicts, obstacles, or benefits that would result" if either the no-action alternative or the proposed action are implemented (NPS 2015). Impact topics are resources of concern that could be affected, either beneficially or adversely, by implementing any of the proposed alternatives.

ISSUES AND IMPACT TOPICS RETAINED FOR FURTHER ANALYSIS

The following issues and impact topics were retained for detailed analysis in this plan.

The lack of forest regeneration due to deer browsing and invasive species encroachment could result in changes to the appearance of the managed cultural landscape. The appearance of the cultural landscape of the Jockey Hollow and New Jersey Brigade units could be changed because native tree species of the character-defining dense forest show little or no regeneration. The heavy browsing of deer on native species and the steady spread of invasive species that outcompete native species could result in a less dense forest or a forest consisting of different plant species than what historically existed within the cultural landscape. Over decades, trees lost to natural mortality would not be replaced by natural regeneration. The proposed action would be designed to maintain the forested components of the project area, which could result in protection of the cultural landscape over time. Temporary noise and visual disruptions within the cultural landscape would likely occur during implementation of the action alternative. Therefore, potential impacts of the alternatives will be analyzed in detail under the impact topic of "Cultural Landscape." Additionally, a determination of effect on historic properties under NHPA Section 106 is in an assessment of effect in chapter 4.

Native species within the mixed hardwood forest are showing little to no regeneration. The mixed hardwood forest is currently threatened because native tree species show little or no regeneration. In particular, those portions of the forest with components of oak and hickory may see shifts in species competition to more shade-tolerant species. If no action is taken, the natural diversity of the hardwood forests could be lost as trees die from natural causes. This loss of diversity could result in a loss of acorn- and nut-producing trees (mast-producing trees), which white-tailed deer currently use as food sources. If forest diversity shifts from mast-producing trees to shade-tolerant trees, food sources may be altered that could impact the white-tailed deer population. To achieve a regenerating hardwood forest with mixed-aged classes of trees that reflect the historic and naturally diverse character of the park, several elements of the proposed action would impact vegetation within the park. For example, the proposed action of non-native invasive species control may have impacts on native vegetation by eliminating competition for soil, water, and light resources needed for growth. Impacts to vegetation may also occur from the action of midstory canopy removal to promote more sunlight reaching the forest floor and promoting hardwood regeneration. The midstory canopy consists of shade-tolerant trees that grow underneath the dominant overstory tree canopy. Deer population control is another action that may be taken to reduce the browsing intensity and to promote native forest regeneration and herbaceous growth in the understory. Therefore, potential impacts of the alternatives will be analyzed in detail under the impact topics of "Forest Vegetation" and "White-Tailed Deer Population."

Direct reduction actions could change movement and behavior patterns of the white-tailed deer population. Proposed actions within this plan include lethal removal of deer by sharpshooting to achieve and maintain a target density of 20 to 25 deer per square mile necessary to support successful forest regeneration. While the plan was being prepared, an external factor (disease) reduced the deer population in the park, resulting in a current density below the target specified in the plan. No lethal removals are needed at present; however, in the event that deer density rebounds in the future, the preferred alternative still includes sharpshooting as a management tool to maintain deer density at levels that support successful forest regeneration. Therefore, this plan could result in an overall reduction of the white-tailed deer population if lethal removal is implemented in the future. Additionally, the proposed actions may result in changes to the movement and behavior of the deer population. Direct reduction actions could cause deer to avoid certain areas in the park, resulting in higher competition for areas that were not targeted, as well as increased movement across the park boundary. Therefore, potential impacts of the alternatives will be analyzed in detail under the impact topic of "White-tailed Deer Population."

ISSUES AND IMPACT TOPICS CONSIDERED BUT DISMISSED FROM FURTHER ANALYSIS

The following issues and impact topics were initially considered but then dismissed from further analysis for the reasons given.

Archeological Resources

The proposed action is not expected to have an impact on archeological resources when the mitigation measures described below are implemented.

Morristown National Historical Park is rich in archeological resources. While many of these resources date to the encampment period of the late 18th century, numerous sites dating to other historic periods are also present. Less is known about earlier prehistoric or Native American resources, but recent testing has revealed the presence of such sites in the Grand Parade area of Jockey Hollow, and environmental indicators of such deposits are common. Morristown has been subject to archeological investigation since the 1930s. While most of the archeological work conducted through the 1970s focused on evidence of encampment-related resources, some more recent work has examined sites dating to other periods. Most recently, in the summer of 2017, several gun emplacements and a series of soldiers huts were identified in the Fort Hill area of Jockey Hollow. While a number of archeological projects have been completed, only a small area of the park has been systematically surveyed, and many sites remain undiscovered.

Actions implemented as part of this plan would largely consist of the removal of vegetation and the planting of seedlings. These, and staging of the management activities, would have the potential to disturb unknown and/or not relocated archeological resources if conducted in advance of systematic archeological survey. The initial mitigation measure for archeological resources in areas to be treated by the plan would consist of an evaluation of each area for the presence of such resources. Evaluation would consist of examination and analysis of geographical and historical variables using geographical information systems (GIS) and field reconnaissance. Areas determined to be not sensitive would be excluded from further protective measures. Sensitive areas would be subject to systematic archeological survey.

Systematic archeological survey consisting of further surface reconnaissance and limited testing would enable project proponents to delineate and protect archeological deposits and features during management actions. Development of an Unanticipated Discovery Plan to mitigate impacts to resources discovered during management activities would further protect important archeological sites. Locating and delineating, and subsequently avoiding, archeological sites would serve as a mitigation measure protecting these resources. Actions proposed by the plan would not result in impacts. Therefore, the impact topic of archeological resources was dismissed from further analysis.

Special Status Species and Other Wildlife and Wildlife Habitat

Three federally threatened or endangered species that may be found in or around the study area have been identified: the Indiana bat (*Myotis sodalist*), the northern long-eared bat (*Myotis septentrionalis*), and the bog turtle (*Clemmys Glypemys*). Changes to vegetation within the project area could result in changes to the habitat quality for these species, or disturbance to individuals.

The range of the northern long-eared bat includes all of the northeast and mid-Atlantic sections of the country where bats may occupy forested habitats for summer roosting and pup rearing. Surveys conducted in 2002 and 2010 detected the northern long-eared bat in the park. Similarly, the park is reported to be within the buffer area for Indiana bat maternity colonies and within the species' summer migratory range. The goal of this plan is to manage for a sustainable, reproducing forest. This goal will ensure that forest habitat is available for both listed bat species. Certain actions, such as invasive species control in the forest understory (herbicide treatments and mechanical treatments), management of existing gaps, and deer population control to manage the intensity of deer browsing, would not be detrimental to listed bat habitat requirements for roosting and feeding because those actions would not involve the removal of trees that could be used by the roosting bats. In addition, the park would implement a site-specific bat acoustic and mist netting survey to determine if any listed bats occupy an area before an action is taken that could impact the species.

Because the Indiana bat and northern long-eared bat leave their hibernacula in the spring season to occupy forested roosting sites and rear pups during the summer months, tree removal actions proposed in the plan were carefully considered because tree removal would cause a minimal impact to these protected bat species. Tree removal could impact roosting maternity populations and equipment noise could temporarily disturb roosting bats. To mitigate any impact to these bat species, the National Park Service would abide by all aspects of the recent 4(d) rule for the northern-long eared bat cited in 50 CFR Part 17, which would also serve to protect the Indiana bat. This means that the park would not purposefully capture or harm individual bats, no actions would be performed within 0.5 mile of a known hibernacula (there are no hibernacula located on park property), and any mechanical tree removal actions would be performed during the non-roosting season of September 15 to April 15.

Bog turtles prefer habitats consisting of open-canopy, herbaceous wetlands and bogs (USFWS 2001). There are no known wetland areas of the park that contain suitable habitat for this species, and no animals have been documented as occurring in the park. Actions proposed by alternatives such as invasive species control, deer density control, and forest canopy manipulations would not involve this habitat type, and therefore would not have any effect on bog turtles.

The National Park Service is continuing informal consultation with the US Fish and Wildlife Service (USFWS) in accordance with the Endangered Species Act of 1973, as amended (87 Stat. 884, as amended; 16 USC 1531 et seq.). The National Park Service will continue to consult with the US Fish and Wildlife Service as appropriate to obtain the most current information on the Indiana bat, northern long-eared bat, and the bog turtle, and to determine if any new species would require analysis. If the park determines that actions are required during the bat roosting season that could impact the species, consultation with the US Fish and Wildlife Service would ensue to establish a protocol for performing bat surveys to determine absence/presence of listed bats. Due to this consultation process and proposed mitigation measures to protect listed bats, special status species have been dismissed from detailed analysis in this plan.

The project area provides habitat for a variety of wildlife species. Changes to vegetation, particularly in the understory and midstory, could result in changes in the quality of existing habitat for wildlife such as small mammals and birds. Actions proposed in this document are not expected to impact population levels of existing wildlife. Tree removal undertaken to promote more sunlight to reach the forest floor and invasive species control measures may temporarily impact individual animals by altering vegetation that provides nesting and cover habitat. However, recovery of habitats is expected, and populations would resume use of those habitats. Maintaining target white-tailed deer concentrations would benefit other small mammal wildlife species that are dependent on mast food sources, such as acorns, by reducing competition for food sources (McShea 2000). In addition, the reduction in deer numbers will also benefit the growth of herbs, shrubs, and saplings that provide understory habitat for nesting songbirds (Tymkiw 2013) and other herbivores such as mice and rabbits. While animals other than deer would not be targeted by lethal reduction efforts, they could be temporarily disturbed by the sound of a firearm, which could result in momentary flight reactions. Such impacts due to direct reduction actions, however, would occur only a few days of the year, and sufficient habitat is available in the remainder of the park for animals to move from the disturbance. Therefore, the impact topic of other wildlife, and wildlife habitat was dismissed from further analysis.

Soils

Invasive plant species currently act as ground cover in areas of the park and removing species in these areas could result in a loss of soil through ground disturbance and erosion. However, the alternatives presented in this plan do not include the uprooting of trees with heavy mechanical equipment that would result in large volumes of soil disturbances. Techniques to remove large trees would include herbicide injections at the trunk and/or felling trees with chain saws and leaving the trees on the ground to decay. Mechanical actions include components such as the bush-hogging of stems above the ground surface, the hand removal of shrubs/saplings, and/or the installation of new plantings. Uprooting of shrubs/saplings using hand tools would involve minimal soil disturbances (2 to 3 square feet of area and soil depths generally less than 1 foot) specific to each individual stem. Such actions, either individually per tree or collectively, are not anticipated to promote the erodibility of soils, greatly alter soil chemistry, or change soil physical properties because they are not disturbing large volumes of soils. Actions related to invasive plant management and deer browsing management are not expected to impact soils because those actions will generally be above the ground surface. Therefore, the impact topic of soils was dismissed from further analysis.

Water Quality

Elements of the proposed action such as the use of herbicides to manage invasive species could affect water quality within the park. The loss of a stabilizing understory due to deer browsing or invasive plant removal could also affect water quality or quantity within the park. Mitigation measures would be implemented to minimize potential impacts from invasive plant treatments, including prohibiting direct herbicide spray treatments in wetlands and implementing buffer protections for wetlands to prevent herbicide drift into wetlands and water bodies. All pesticide use would be guided by the National Park Service’s Pesticide Use Proposal System (PUPS). Use of herbicides would likely not require any additional treatment techniques such as bush hogging or soil disturbances. Thus, though the stems would die, they would still be in place acting as temporary stabilizing features until the stems/roots decay and new vegetation emerges. The tree canopy would remain and help stabilize treatment areas from excess pollutants reaching surface waters. The overstory trees provide leaf-fall and dead sticks/logs on the ground to help slow down runoff on steep slopes, and tree roots help to enhance soil structure for rain absorption, as well as prevent soil erosion. The actions proposed in the action alternative would result in minimal or no changes to water quality. Therefore, the impact topic of water quality was dismissed from further analysis.

Wetlands

Five small areas of freshwater, forested/shrub wetlands are scattered throughout the park. A 0.58-acre Montane Basic Seepage Swamp classified as rare or uncommon (G3) by NatureServe also exists within the park (NPS 2008). Elements of the proposed action such as the use of herbicides to manage invasive species could affect wetlands if undertaken in their vicinity. However, no actions in this plan would result in the dredging or filling of wetlands or the uprooting of trees causing disturbances in wetlands. Actions in this plan would be undertaken primarily within upland forested areas. The plan calls for the installation of new plants, which could occur within wetlands. However, no herbicide spray treatments would occur within wetlands given the sensitive nature of the ecosystems, as described under “Water Quality” above. Thus, the actions proposed under the alternatives would result in no substantial changes to wetlands. Therefore, the impact topic of wetlands was dismissed from further analysis.

Floodplains

Portions of the project area are located within a 100-year flood zone (areas with a 1% probability of flooding each year) associated with the Indian Grove Brook and Passaic River (FEMA 2007). These areas extend approximately 25 to 250 feet from the main channel, depending on elevation and slope. Changes in vegetation and ground cover within the floodplain could result in changes to the floodplain functions and values. However, the plan does not propose the construction of facilities within floodplains or alterations to topography within floodplains that could affect floodplain storage and functions. While vegetation-related actions may occur within a flood zone, such actions would not include heavy machinery that could disturb floodplain soils or disrupt the current stability of the floodplains. Consideration of floodplain values would be incorporated into the strategies for potential removal of vegetation so that sufficient ground cover and vegetation remain to maintain adequate floodplain values. Annual actions such as understory herbicide treatments, midstory shade removal, or select overstory canopy tree removal within small areas of floodplains are not expected to affect overall floodplain functions, and would work towards improving the sustainability of the forested floodplains. In addition, deer are an ever-present, ecological component of floodplains in the park, and managing deer numbers is not expected to result in changes in existing floodplain functions. Therefore, the impact topic of floodplains was dismissed from further analysis.

Public Health and Safety

This plan includes the potential removal of deer via sharpshooting to control deer numbers if needed in the future. The use of firearms in a public area could raise concerns over the safety of park visitors and employees. However, deer reduction activities would be conducted in a manner that would avoid and minimize risk to the safety of park visitors and employees. Mitigation measures would include the use of professionals trained in the use of firearms, developing a plan specifically designed with safety in mind, and ensuring visitors do not enter areas being targeted for lethal reduction. Visitor access would be limited as necessary during deer reductions, and NPS personnel would patrol public areas to ensure compliance with park closures and public safety measures. Compliant with New Jersey state law, sharpshooting would not occur within 450 feet of any building or school playground, even if unoccupied (NJDFW 2016c). Because these mitigation measures would be in place, no impacts to public health and safety are expected. Therefore, the impact topic of public safety was dismissed from further analysis.

Indian Trust Resources and Sacred Sites

The Department of the Interior requires its bureaus to explicitly consider effects of its actions on Indian Trust resources in environmental documents (NPS 2015). The federal Indian Trust responsibility is a legally enforceable obligation on the part of the United States to protect tribal lands, assets, resources, and treaty rights, and it represents a duty to carry out the mandates of federal laws with respect to Native American tribes. No known Indian Trust resources are located in the project area, and the lands comprising the park are not held in trust by the secretary of the interior for the benefit of Indians due to their status as Indians. Therefore, the issue of Indian Trust resources was dismissed from further analysis.

Environmental Justice

The Department of the Interior requires its bureaus to specifically discuss and evaluate the impacts of their actions on minority and low-income populations and communities, as well as the equity of the distribution of the benefits and risk of the decision (NPS 2015). Environmental justice was considered but dismissed from further analysis for the following reasons:

- The park staff and planning team solicited public participation as part of the planning process and gave equal consideration to all input from persons regardless of age, race, income status, or other socioeconomic or demographic factors.
- Implementation of the proposed action would not result in any identifiable adverse human health effects. Therefore, there would be no direct or indirect adverse impacts on any minority or low-income population.
- The impacts associated with implementation of the proposed action would not disproportionately affect any minority or low-income population or community.
- Implementation of the proposed action would not result in any identified impacts that would be specific to any minority or low-income community.

2

ALTERNATIVES

INTRODUCTION

This chapter describes actions that would take place under each alternative being considered by the National Park Service. They include the no-action alternative, which would continue current management of the park's forest vegetation, and the proposed action/NPS preferred alternative. Monitoring and evaluation of restoration would guide potential future management actions and are described in the alternatives. This chapter also includes alternative management concepts that were considered but dismissed from further analysis and the rationale for their dismissal.

ALTERNATIVE A: NO ACTION

Under the no-action alternative, the National Park Service would continue to implement current management actions, policies, research, and monitoring efforts related to invasive plant management, deer browsing impacts, and chronic wasting disease.

FOREST MANAGEMENT

Under alternative A, the National Park Service would continue existing forest management practices. Presently, NPS staff practices passive forest management to maintain the cultural landscape and aesthetics of the park setting. Trees are generally allowed to grow and die under the influences of natural processes. However, programs such as fire suppression are instituted as needed to protect the forests from catastrophic events, and individual trees may be removed when they threaten property improvements or human harm.

The National Park Service recognizes the influence of invasive species as a deterrent to the natural development of the park's forests (Ehrenfeld and Dibeler 1987; Ehrenfeld 1999; Russell 2001; Shaw and Patterson 2006). To limit the spread of invasive species, the National Park Service currently removes new occurrences of invasive plants from the borders between invaded and noninvaded areas using small-scale herbicide applications. These treatments are guided by the National Park Service's PUPS process and coordination with the regional integrated pest management (IPM) coordinator. Prescribed fire has not been used by the National Park Service to treat invasive species at the park. The National Park Service prioritizes treatment of certain invasive species—such as Japanese barberry (*Berberis thunbergii*), stiltgrass (*Microstegium vimineum*), Siebold viburnum (*Viburnum sieboldii*), Oriental photinia (*Photinia villosa*), black swallowwort (*Cynanchum louiseae*), and porcelainberry (*Ampelopsis brevipedunculata*)—that threaten the ecological integrity of the park or its cultural landscape. The National Park Service has used herbicides on invasive species cited above, as well as hand-tools such as weed wrenches, where removal of invasive saplings and shrubs is needed. The National Park Service uses the most effective and least harmful methods, based on guidance from the NPS Northeast Region exotic plant management coordinator to manage invasive species; however, removal efforts are intermittent and depend on staff and funding availability. The results of these treatment efforts are tracked and analyzed to refine subsequent control measures of invasive species.

The park is also part of an early detection program for invasive and nonnative plants conducted by the Northeast Temperate Network (NETN), an inventory and monitoring division of the National Park Service. This program monitors target or "watch" invasive species that are not already commonly established but have the potential to cause major ecological or economic problems if they become established. These include some of the species named above. Natural resource staff conduct field sampling and map areas occupied by invasive species, invasive-free areas, and landscape features in conjunction with the NETN program.

DEER MANAGEMENT

The National Park Service currently does not actively manage the size or density of the deer population, nor does it fence off areas of the park to control the impacts of deer browsing as a management tool (several small fenced areas are established for research purposes). The extent of deer management at the park has been to respond to specific incidences of injured deer. Deer seriously injured by a vehicle may be euthanized if it is the only humane alternative, or park staff may contact local animal control for assistance with handling an injured deer. If deer are euthanized, they are moved off the roadway into the forest, covered with brush, and left to decompose.

Chronic Wasting Disease Management

Although chronic wasting disease has not been detected in the park or in the state to date, if it is determined to be present within 60 miles, park staff would follow NPS guidelines and actions (NPS 2002a) and coordinate with the state of New Jersey as appropriate; the state's guidance can be found in the New Jersey Chronic Wasting Disease Response Plan (NJDFW 2013). The monitoring of prevalence and distribution in neighboring states and in New Jersey should chronic wasting disease be detected is an important tool the plan prescribes to achieve this goal. This alternative contains actions to promote early detection of chronic wasting disease and to facilitate cooperation and data sharing with NJ Division of Fish and Wildlife. The following actions, which are derived from the NPS Director's memorandum on chronic wasting disease (NPS 2002a), are consistent with the NJDFW plan:

- If chronic wasting disease is found within 60 miles of Morristown National Historical Park, NPS staff would engage in opportunistic and targeted surveillance to assist with CWD detection within the area. Opportunistic surveillance includes testing samples from deer found dead (e.g., hit by car, died from disease, predator kill, lethal culling) to detect chronic wasting disease. Targeted surveillance involves culling individuals that show clinical signs of chronic wasting disease (e.g., emaciation, drooling and lethargy, lingering by water sources for extended periods, isolating themselves from other deer) and testing them for chronic wasting disease. Testing would be pursued until sufficient samples have been collected to be 99% certain of detecting the disease if it is present at 1% prevalence, and CWD surveillance for disease detection would occur at 3- to 5-year intervals, as funding allows.

- If chronic wasting disease is found within 5 miles of the park or the park lies within a NJDFW disease management zone, NPS staff would coordinate and cooperate with New Jersey Division of Fish and Wildlife, to the extent possible, to determine the prevalence and distribution of chronic wasting disease in the area.
- NPS staff would coordinate closely with New Jersey Division of Fish and Wildlife to share CWD data. Samples collected through park CWD surveillance activities would contribute to overall state CWD surveillance data.
- An adaptive management approach similar to that outlined in the NJDFW 2013 Chronic Wasting Disease Response Plan would be used to evaluate, modify, and respond appropriately to CWD threats and concerns as a greater understanding of CWD ecology progresses.
- Prior to meat donation, NPS staff would consult with the NPS Office of Public Health. Donation practices would be consistent with the NPS guidance, "Elk and deer meat from areas affected by chronic wasting disease: A guide to donation for human consumption" (NPS 2006a).

MONITORING, EDUCATION, AND COOPERATION

Though the National Park Service is not currently managing the forest canopy or deer browsing, 25 fenced exclosures (totaling 13 acres) were installed as research studies to monitor the effectiveness of deer browsing prevention and other vegetation management treatments. In addition, the NPS NETN program has established 28 plots in the park, 14 of which are sampled every other year for a variety of factors including regeneration, ratio of seedlings to saplings, herbaceous growth, and soil factors such as soil pH and chemistry. The National Park Service also annually conducts spotlight counts to monitor trends in the deer population over time and determine deer density.

The park currently has ranger-led interpretive programming in the summer and park staff conducts occasional informative talks on invasive species. The National Park Service anticipates adding interpretive materials to further educate visitors on vegetation management actions. NPS staff post signs when public areas have been treated with herbicides as required by New Jersey state law.

The National Park Service holds meetings or consults as appropriate with neighboring agencies and/or landowners when there is concern about hazard trees or invasive plants on park property or boundary issues, or to inform park neighbors of planning efforts. For instance, neighbors were contacted to complete a survey as part of the Deer, People & Parks, and Perspectives of Residents in Communities Near Morristown National Historic Park program in 2007 (Siemer et al. 2007).

ALTERNATIVE B: PROPOSED ACTION/ NPS PREFERRED ALTERNATIVE

Under alternative B, the National Park Service would implement actions to promote reestablishment of a mixed-age hardwood forest through forest management, which includes invasive plant management and possibly canopy thinning and planting seeds or seedlings. Reestablishment of mixed-age hardwood forest would also be promoted through deer management. Invasive plant management includes the following treatment methods: chemical herbicide application, removal by hand or power tools, and removal by heavy equipment. Canopy thinning includes the following treatment methods: removal of midstory shade or select overstory trees by hand or power tools and heavy equipment. These treatment methods are described in more detail below. Prescribed fire may be used during future treatments to remove invasive plant species or for canopy thinning, but would be subject to separate site-specific compliance and is not included in this plan. The park would implement forest management actions first in existing naturally occurring forest gaps (and future gaps that may naturally form), then in successional and mixed forests, and last within mature forests. Deer management includes sharpshooting as needed to maintain deer density levels that support successful forest regeneration and the implementation of management actions to promote early detection of chronic wasting disease and facilitate cooperation and data sharing with NJ Division of Fish and Wildlife. All actions would be accompanied by the implementation of research and monitoring protocols, education and public outreach, and cooperation and coordination with neighboring landowners.

FOREST MANAGEMENT

Under alternative B, NPS staff would implement one or more forest management actions in a given forest stand or treatment area each year; this may vary depending on funding and staff availability. Generally, forest treatment areas would include forest openings and/or a contiguous stand of trees or other vegetation where tree and plant species, invasive plant issues, soil, and existing understory vegetation are similar and the area is not intersected by roads or trails (i.e., using roads and trails as treatment area boundaries). These treatment areas would generally occur within:

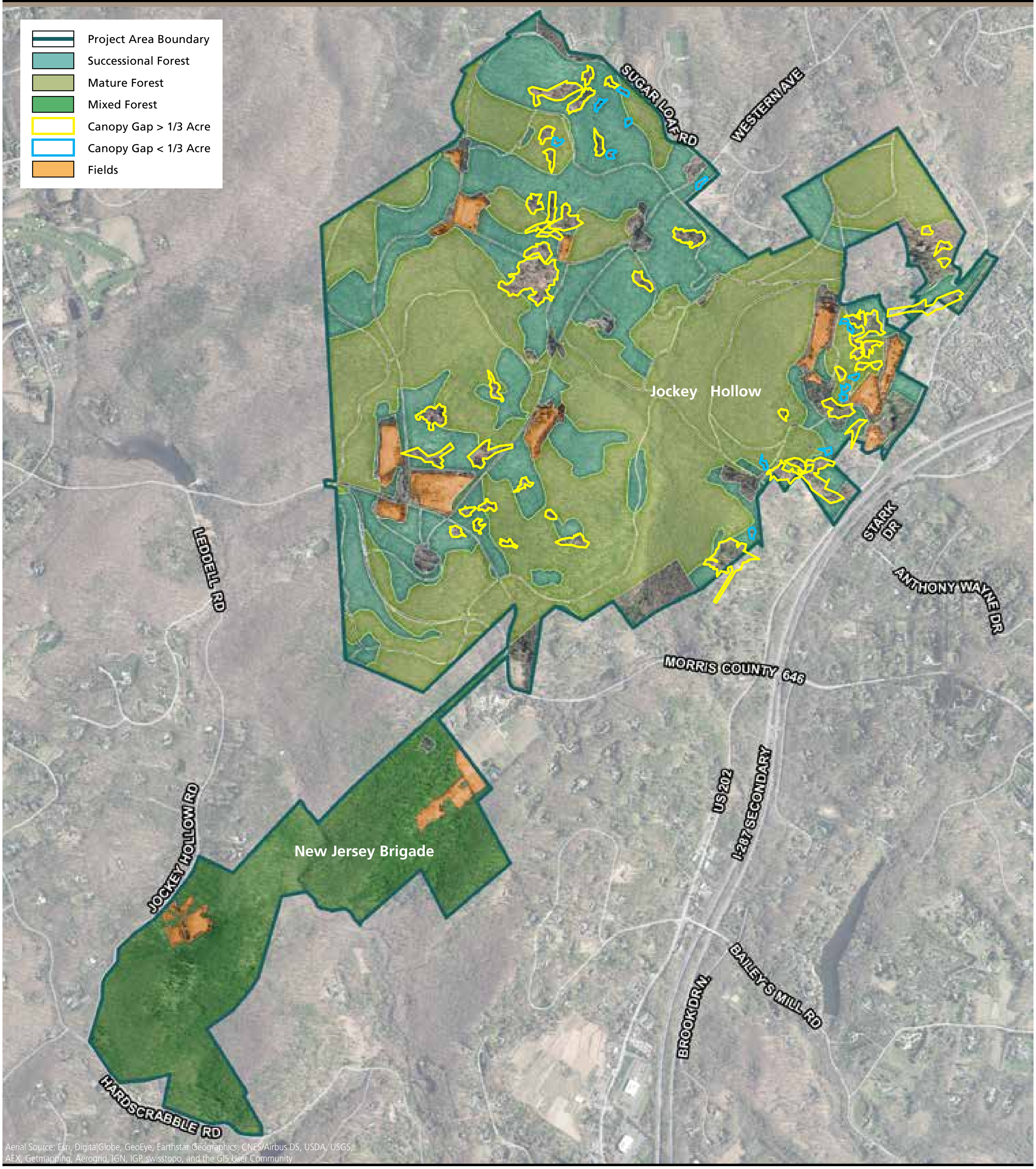
- existing forest gaps (naturally occurring dead or blown-down timber that occurs within both mature and successional forests)
- successional forest at the Jockey Hollow unit and mixed forests at the New Jersey Brigade unit
- mature forest (characterized by older-age classes of trees with a higher component of oaks)

The types of forest that would be treated are described below in order of priority. As is described in the following sections, the first priority for the National Park Service would be the treatment of the existing 65 acres of naturally occurring gaps (and future gaps that may form) to promote mixed-age hardwood forest regeneration. Treatment areas within successional forests (416 acres) and mixed forests (290 acres) would be a second priority, followed by treatment areas within mature forests (667 acres). Specific combinations, durations, and intensities of treatment methods for each treatment area would be developed during plan implementation based on site conditions, lessons learned from the effectiveness of prior treatments, and ongoing forest monitoring results. To ensure that project goals are achieved, the extent, duration, and intensity of treatments may be adjusted based on the outcome of monitoring. Project goals indicate that between 1,000 and 1,500 seedlings may be needed per acre to create the desired "moderately dense" hardwood forest. All treatment area prescriptions would be designed to achieve project goals and follow required mitigation measures.

Management of Naturally Occurring Forest Gaps. Given the combination of numerous naturally occurring forest gaps in the Jockey Hollow and New Jersey Brigade units of the park, implementation of the forest management aspects of the plan would initially focus on the 65 acres of existing gaps within the park (see figure 3). These gaps, ranging in size between 0.2 acres and approximately 7 acres within both mature and successional forests, were created primarily by wind throw of canopy trees during Hurricane Sandy; some have become heavily infested with invasive plants. Since treatments would not be necessary to control shade, these areas present an opportunity to promote mixed-aged forest regeneration with invasive species control. Therefore, these areas would be prioritized and treated first.

National Park Service
US Department of the Interior

Morristown National Historical Park
New Jersey



Source: Natural Resources & Science GIS - 20130311 - jf

Vegetation and White-tailed Deer Management Plan
Environmental Assessment/Assessment of Effect

North

0 2,000 Meters
0 2,000 Feet

FIGURE 3
Forest Type and Canopy Gap Location

To promote regeneration within existing gaps, several treatment methods would be available for use. Invasive plant management methods include chemical, mechanical, and manual methods. When appropriate, restoration techniques such as reseeding, replanting, and bucking (i.e., using a chainsaw to cut into smaller sizes) dead and down trees would be used. These methods and techniques are described in greater detail below.

Management of Successional, Mixed, and Mature Forests. As treatment methods result in progress towards forest regeneration in the forest gap openings, the National Park Service would begin managing mature and successional forest outside of existing naturally occurring gaps by controlling invasive plant species and selective removal of midstory, shade-tolerant trees (such as beech [*Fagus grandifolia*]) to allow additional sunlight to reach the forest floor for hardwood seedling/sapling establishment. The successional forests at Jockey Hollow unit and the mixed hardwoods covering the New Jersey Brigade unit would be targeted first because they are more heavily infested with invasive species and have a higher risk of loss compared to the mature forests. The size of treatment areas and combination of treatment techniques would vary depending on the density of invasive plants inside the area, availability of existing seed sources, and condition of native hardwoods. The project area contains approximately 1,373 acres of forest, as shown on figure 3 above.

Management actions used in the existing successional, mixed hardwood, and mature forest would include invasive plant management to reduce competition with seedlings, saplings, and native understory herbaceous and shrub layer cover and to promote the establishment of advanced hardwood regeneration. The treatment method and size of the treatment area would be determined based on professional judgement using experience gained from monitoring results from previous invasive species treatments, and would range from approximately 5 to 40 acres of invasive plant management annually.

The proposed action would allow the selective thinning of midstory, shade-tolerant trees to meet native forest regeneration goals. Stems would be removed primarily by chemical (herbicide injection) or mechanical (chainsaw) means above ground level. This alternative would also allow select thinning of black locust trees (*Robinia pseudoacacia*), which grow at various locations in the park; black locust is an invasive plant species that spreads aggressively in localized areas via root suckers, forming monocultures (USFS 1965). Black locust trees may be thinned if the goal is to remove black locust or American beech, or if invasive plant species management and deer browsing management alone were not providing forest regeneration progress.

The National Park Service would monitor regeneration of trees in response to vegetation and deer control treatments in comparison with the project goals, outlined in chapter 1. If the results show low success relative to regeneration targets, NPS staff may choose to augment natural regeneration by planting seeds or seedlings of native tree species to reach regeneration goals.

Extent, Rates, and Combination of Treatment. The exact area receiving treatments within an existing gap or in a forest would vary in size depending on the density of invasive plants inside the area, existing seed sources, and the condition of native hardwoods. Sometimes a treatment area would be very small—for example, in a small existing gap where the density of invasive species is high and requires intensive effort to manage.

As described in the adaptive management cycle section of this chapter, park staff would evaluate the effectiveness of treatment actions and the need for retreatment measures. For example, based on lessons learned from initial treatments, subsequent treatment areas may be adjusted to be larger or smaller if, through monitoring, NPS staff identifies an optimally sized treatment area for meeting regeneration targets.

Because of the high probability that treated areas may be reinfested with invasive species, periodic retreatments may be required. This means NPS staff would assume progressively heavier landscape management responsibilities each year as new areas are treated and older treatment areas are monitored and retreated (e.g., retreatment of treatment area 1 would be required while NPS staff are carrying out initial treatment of treatment area 2; retreatment of both treatment area 1 and 2 may be required as NPS staff are carrying out initial treatment of treatment area 3 until regeneration shows progress towards regeneration monitoring goals, etc.). The additional effort required for subsequent monitoring and treatment of previously treated areas would place incrementally greater demand on park staff time. Therefore, the rate at which treatments would be accomplished would be dependent on staff availability and funding, within the approximate range of 5 to 40 acres treated per year.

Invasive Plant Management Treatment Methods

Invasive plant management would follow the park's updated Integrated Pest Management (IPM) approach as required by NPS policy and guidelines (NPS 2006b). Treatment methods to control undesirable vegetation may include chemical herbicide application, removal by hand or power tools, or removal by heavy equipment. The defining features of the IPM approach include: a coordinated effort combining knowledge of species biology, the environment, and available technology to reduce damage; treatment on a case-by-case basis; treatment of existing invasive plants using available and feasible treatment methods; and a framework to evaluate and treat future outbreaks. The IPM approach is described in greater detail in section 4.0 of the "Morristown Invasive Plant Management Plan" in appendix A. The Morristown Invasive Plant Management Plan contains further explanation of the invasive plant management actions discussed in the environmental assessment.

Because of the extent and complexity of invasive species infestation at the park and the dynamic nature of the park's forest ecology, park managers require a comprehensive suite of tools with which to combat invasive plant growth and encourage propagation of native hardwood species within the existing gaps and forests. The specific methods for the control and eradication of invasive species and undesirable native species would include any or all the techniques described below, and would be chosen using the IPM process described in section 4.0 of the "Morristown Invasive Plant Management Plan" in appendix A.

The following describes methods that could be used for invasive plant management actions under alternative B.

Chemical Herbicide Application. Removal of invasive plants would, in many areas, be accomplished by applying chemical herbicides in accordance with their labeled use. The specific herbicide chosen would be based on its proven effectiveness in previous NPS applications, particularly against the park's high-priority species, such as Siebold's viburnum, Oriental photinia, black swallowwort, and porcelainberry. Herbicides currently approved for use at Morristown include Garlon 4 Ultra Herbicide and Accord XRT II herbicide. Application methods include portable sprayers, motorized spray tanks, and hand-wicking. Described in greater detail in in section 4.4.3 of the "Morristown Invasive Plant Management Plan" in appendix A, chemical herbicide application methods available to the park under the action alternative include:

- Foliar spraying. Foliar spray applications involve spraying green foliage with pesticide. Foliar applications are made with a low-pressure backpack sprayer, motorized spray tank, or similar hand-operated pump sprayer.
- Cut surface. Cut and injection applications involve cut-stump methods, girdling, hack and squirt, and stem injection. Herbicide applications would be made with backpack sprayers or spray bottles.
- Basal bark. Basal bark applications involve applying pesticide to the bark of uncut stems near ground level with a backpack sprayer.
- Individual plant treatment. Individual plant treatments could also be applied with the use of glove applications, hand wicking, and swiping.

Removal by Hand or Power Tools. In sensitive areas containing archeological resources or areas removed from roads and not accessible by heavy equipment, removal of invasive species may be completed by manual hand-pulling or hand-cutting or mechanical power tools such as mowers, weed whips, chain saws, and trimmers. Hand pulling is most effective for pulling shallow-rooted species and is conducted by removing as much of the root as possible while minimizing soil disturbance. Manual pulling of deep-rooted species may require repeated treatment to effectively deplete the root system. Portions of roots could break off, remain in the soil, and regenerate. Pulling tools would be a treatment option for removing individual plants that are deep-rooted. Pulling tools (e.g., weed wrenches™) could be used to control small infestations, such as when an invasive plant is first identified in an area. These tools grip the weed stem and remove the root by providing leverage. Pulling tools are most effective on firm ground rather than soft, sandy, or muddy substrates.

Hand cutting tools would be a treatment option for removing the aboveground portions of annual or biennial plants. Use of hand tools such as trowels, shovels, and pulaskis are simple forms of mechanical treatments. These tools could be used to remove a larger portion of the root system or to sever the plant’s taproot below the point where nutrients are stored.

Power tools, such as mowers, could be used to treat small to large infestations. Mowers work best in large, relatively flat treatment areas that do not include sensitive environmental resources. Weed whips and brush blades could be used at small sites, selectively around sensitive vegetation or sites that are inaccessible or are too rocky or too forested to be mowed. Power tools (such as weed whips, brush blades, chainsaws, tractors, or utility terrain vehicle [UTV] -pulled mowers) remove aboveground biomass, reduce seed production, and reduce plant growth. Power tools do not remove belowground biomass, which is sometime desired. Power tools are useful for controlling annual plants before they set seed. Power tools could also be used along with other treatments, such as chemicals, to treat perennial invasive plants.

Removal by Heavy Equipment. In a limited number of areas of dense invasive plant infestation where archeological resources would not be affected and there is direct road access to the treatment area, heavy equipment such bush hogs, tree masticators, mulching machines, skid loaders with forestry cutter attachments, and tub grinders could be used to remove dense stands of large trees such as black locust. These methods are described in greater detail in section 4.3.2 of the “Morristown Invasive Plant Management Plan” in appendix A.

Removal, Disposal, Mulching, and/or Burning of Slash, Mulch, and Other Vegetative Debris. It is estimated that treatments of invasive species, downed trees, or breaking down deadfall within gaps could result in 12 to 50 cubic yards of biomass waste per acre, depending upon the density of invasive plant stands and the amount of deadfall. Biomass generated would include slash (coarse and fine woody debris generated from cutting) as well as mulch (shredded woody debris). In most cases, vegetative debris could be left in place to decompose. In rare cases when large quantities of woody biomass would cover the ground to the extent that native plants and hardwood regeneration are unable to germinate and grow, the removal of this biomass would be critical to successful regeneration of a native hardwood forest environment. Where burning is not practicable to reduce biomass, removal by hand (e.g., raking aside, dragging aside, or hauling out) may be required. Removal by heavy equipment, using equipment described in the above section, is likely to be used only in areas near roads or trails and in areas with no archeological resource concerns. In all cases, care would be taken by park staff to ensure moving or removing vegetative debris would not further spread seeds of invasive species.

Canopy Thinning Treatment Methods

Actions to reduce the level of shade in the park's forests may include conducting selective removal of the overstory canopy trees and the removal of shade-tolerant trees in the midstory. These actions would open dense forest stands to allow sunlight to the forest floor, which is needed for successful establishment of seedlings and advanced regeneration. Selective cutting techniques include using hand tools or power tools such as a chainsaw. In most cases, felled trees would be bucked into smaller sections and left in place to decompose. Herbicides may also be used via tree injection. Injected trees would be left on the stump to form snags for wildlife benefit unless a dead tree poses a threat to park infrastructure or could possibly fall and injure park staff or visitors. In rare cases, depending on the volume of vegetative debris, requirements for seedling regeneration, and if archeological resource sensitivity is low, NPS staff may need to use heavy equipment to remove the debris or downed tree.

The National Park Service considers the existing forest overstory canopy an important component of the park's historic character. Therefore, removal of mature, overstory trees would be considered only after other invasive plant and deer browsing management techniques did not show progress in meeting forest regeneration goals. If overstory canopy tree removal is implemented, preference would be given to retaining oaks and hickories, in accordance with the park's biodiversity goals and to protect future habitat trees (Shaw and Patterson 2006).

If forest openings are created using selective cutting, repeated treatments of invasive species may be required to prevent reestablishment of invasive plants in these openings. The methods used to treat invasive species are described above.

The following describes treatment methods that could be used for midstory shade and overstory canopy thinning actions under alternative B.

Removal by Hand or Power Tools. Where a light-on-the-land approach is required or in areas not accessible by already established roads, only hand tools or power tools such as chainsaws would be used to cut, pile, or remove vegetation.

Removal by Heavy Equipment. Grinders, brush hogs, rotary axes, chippers, and other forestry equipment-would be used to break down and remove vegetative debris. Use of heavy equipment for thinning and debris removal would only be used in areas near roads or trails and in areas with no archeological resource concerns.

Planting Seeds or Seedlings Treatment Methods

If natural seed production from seed trees is not adequate, it would be necessary in some cases to plant native tree seedlings to accelerate hardwood restoration and to prevent encroachment and reintroduction of invasive species. In general, site conditions would expect to be highly variable between locations considered for tree planting. Existing tree canopy, the amount of sunlight reaching the forest floor, competition from other plants, and the size of the trees to be planted (Dickmann and Lantagne 1997) would factor into the number of seedlings to plant. Since larger seedlings have higher success of reaching the forest canopy (Dickmann and Lantagne 1997), the park may consider planting larger seedlings at a wide spacing (15 to 25 feet, or 70 to 194 trees per acre) compared to a tighter spacing typically recommended for more intensive uses such as timber production. If there are reproductive trees surrounding a forest gap, the density of planted seedlings could be reduced with the expectation that natural regeneration would augment plantings. NPS staff would monitor natural seedling recruitment levels every 5 years to determine the number of additional seedlings to plant for each site.

In this alternative, prevention of deer browsing on newly planted seedlings/saplings within treated forest gaps, as well as within the openings created by selective cutting, would also be required. This may require screens or plastic tubes to protect individual stems from deer browsing until they are tall enough (about 60 inches high) to withstand browsing.

Forest Management Best Practices

The following best management practices would be applied to avoid or minimize potential adverse impacts from implementation of forest management actions:

- The park would schedule all mechanical tree removal activities during the winter hibernation period when bats are not in the area, leaving understory vegetation treatments such as herbicide treatments to be performed during the growing season. The National Park Service would consult with the US Fish and Wildlife Service before actions are implemented, to ensure compliance with the Endangered Species Act.
- Buffers and timing restrictions would be applied as necessary to minimize disturbance of sensitive and special status species present in or near treatment areas.
- Wetlands would be avoided by all mechanical treatments.
- Direct herbicide spray treatments would be prohibited in wetlands, and buffer protections would be implemented to prevent herbicide drift into wetlands and water bodies.
- Contractor employees would be instructed on the cultural sensitivity of the general environment and their activities would be monitored by NPS staff. Corridors for activities requiring heavy machinery and vehicle movement would be established and defined on the ground. Employees would be instructed to avoid conducting these activities beyond the established zone.
- The minimum size equipment needed to complete the actions laid out in the alternatives would be used. Minimum impact treatment measures should be used in all cases where treatment area is archeologically sensitive.
- Contractor employees would be instructed on the archeological sensitivity of the general environment and their activities would be monitored by NPS staff. Corridors for vehicle movement and staging would be established and defined on the ground, and would avoid areas of known archeological sensitivity.

- § NPS archeological monitors would be empowered to redirect management work in the event archeological resources are discovered. Alternate work areas could be established in advance to avoid loss of time.
- § Known and significant archeological resources should be identified through systematic archeological survey, and subsequently avoided. Identification of resources at the survey level will save the expense and time involved with mitigation, and will allow management actions to run more smoothly.
- § An Unanticipated Discovery Plan would be developed to mitigate potential adverse impacts in the unlikely event that archeological resources are encountered during the actions proposed. If previously unknown archeological resources were discovered, all work in the immediate vicinity of the discovery would be halted until the resources could be identified and documented and, if significant resources could not be preserved in situ, an appropriate mitigation strategy (e.g., the excavation, recordation, and mapping of cultural remains prior to disturbance, to ensure that important archeological data that otherwise would be lost is recovered and documented) would be developed in consultation with the state historic preservation office and, as appropriate, associated American Indian tribes.
- § A Memorandum of Understanding would be developed with the New Jersey State Historic Preservation Officer and associated Tribes to plan actions to be taken in the event of unanticipated discovery or the need for mitigation.
- § Standard noise abatement measures would be used during implementation of the alternatives. These measures could include the following elements: a schedule that minimizes impacts on visitor experience, the use of the best available noise control techniques wherever feasible, the use of hydraulically or electrically powered tools when feasible, and location of temporary noise sources as far from sensitive uses as possible.
- § Public use areas would be signed to warn the public of project traffic or other potential hazards. Where public safety cannot be reasonably ensured, some areas may be temporarily closed to public use, which may last up to a day at a time.

DEER MANAGEMENT

While deer density levels are currently below the park's target range and no removal actions are needed at this time, alternative B would include sharpshooting as a management tool if densities were to rebound. Sharpshooting would be used to maintain deer density levels that support successful forest regeneration (approximately 20 to 25 deer per square mile) (Tilghman 1989; Horsley et al. 2003). Forest regeneration success would be monitored; target deer population densities could be adjusted lower based on measured forest regeneration rates. This adjusted target density would not be lower than 10 deer per square mile. The park would continue to implement current management actions and policies to promote early detection of chronic wasting disease and facilitate cooperation and data sharing with NJ Division of Fish and Wildlife.

Management of Deer Browsing

Deer browsing management would include the removal of deer via sharpshooting to control deer numbers if needed. Sharpshooting would involve the use of firearms by qualified federal employees, contractors, or skilled volunteers to remove deer within the park in designated areas. All sharpshooters would be held to rigorous skill and safety standards. Methods, removal numbers, and sex preferences are described below.

Sharpshooting Methods. The National Park Service would manage sharpshooting; teams of qualified federal employees and authorized agents would be involved. Authorized agents serving as team members could include skilled volunteers, other agency and tribal personnel, and contractors. NPS staff would directly supervise teams in the field during any deer reduction activities, including directing team members on which deer to shoot. All other activities, such as setting up bait stations, locating deer, and preparing carcasses for disposition or donation would also be coordinated with park staff. In addition, before assisting with sharpshooting actions, all team members would need to complete training and meet a number of predetermined requirements, including a demonstrated level of firearm proficiency and experience with direct removal techniques and carcass processing.

In most locations, high-power, small-caliber rifles would be used. Nonlead ammunition would be used in this case to meet NPS policy (NPS 2009b). Use of nonlead ammunition would serve to preserve the opportunity to donate the meat or to leave it in the field for scavenging wildlife without risking dissemination of lead into the food chain. Every effort would be made to ensure humane treatment of individual deer.

Sharpshooting would primarily occur at night (between dusk and dawn) during late fall and winter months when deer are more visible and there are fewer visitors at the park. Park staff would notify state wildlife enforcement officers prior to sharpshooting events. Spotlights would be used during night operations. In some restricted areas, sharpshooting may take place during the day, if needed. In this case, the areas would be closed to park visitors. In both cases, sharpshooters would be located in elevated positions (e.g., tree stands) or in clearly marked, high-clearance government vehicles traveling on trails and/or roads within the park. The public would be notified of any park closures and deer management activities in advance via media releases and alerts posted to the park's website and social media venues. In addition, printed notifications posted at visitor contact areas, park bulletin boards, and public billboards located within adjacent communities would be used as necessary. Visitor access would be limited as necessary during sharpshooting, and NPS personnel would patrol public areas to ensure compliance with park closures and public safety measures. Consistent with New Jersey state law, sharpshooting would not occur within 450 feet of any building or school playground (NJDFW 2016c). During sharpshooting activities, noise-suppression devices and night vision equipment would be used to reduce disturbance to the public. Activities would be conducted in compliance with all federal firearm laws administered by the Bureau of Alcohol, Tobacco, Firearms, and Explosives.

Temporary bait stations could be used to attract deer to safe removal locations. The stations would be placed in park-approved locations, away from public-use areas, to maximize the efficiency and safety of the sharpshooting program. During their deer study at the park, Salmon and Underwood (2007) found that around 10 pounds of bait per station was adequate to attract deer to stations. If more than one bait station were simultaneously used to attract deer, these stations would be adequately separated for safety reasons.

Training. On-site training would include park orientation and required safety measures to protect visitors, NPS employees, and volunteers. Volunteers may also assist in other activities, such as transporting and processing carcasses, maintaining bait stations, and implementing park closures. Volunteer training would be provided by NPS staff to support volunteer involvement.

Carcass Removal. The carcasses from deer killed via sharpshooting would be transported by NPS staff and/or contractors, first to a central location for temporary storage during sharpshooting activities, then off-site for processing; more than one processing facility may be used. Meat may be taken directly from the meat processing facility to a local food bank or food pantry.

Number of Deer Removed. Although not prescriptive or intended to be a strict guide for implementation, assumptions are necessary for the analysis in this plan regarding the number of deer that may be removed. All numbers are approximate and would depend on how the deer population responds to actions taken by the park; therefore, adaptive management approaches would be key to a successful program. These approaches are described in greater detail in the adaptive management cycle section of this chapter.

It is important to note that several factors could influence the actual numbers of deer removed and, therefore, the corresponding frequency/intensity of management actions and the number of years to reach the density range. These factors could include the deer density in the park, reproduction and mortality rates, and removal numbers in any given year. For example, if actual deer density is higher than what is assumed in this plan, the National Park Service may need to increase the number of deer removed, the number of management actions implemented, and/or the time needed to reach the desired population density. If reproduction rates are higher and mortality lower than estimated, the population growth would be greater and more deer may need to be removed, potentially increasing the number of management actions needed and time needed to reach the desired population density.

Park staff would determine the number of deer to be removed based on the most recent deer population survey and the initial deer density goal of approximately 20 to 25 deer per square mile, as well as the experience of other deer population reduction programs, technical feasibility, and success of forest regeneration in later years of plan implementation. The park estimates that current deer density is 17 deer per square mile, based on estimates completed in fall 2016; this corresponds to a parkwide population estimate of approximately 44 deer. No sharpshooting activities would be implemented while the deer population is below the target density. However, if deer populations rebound to exceed this target density, sharpshooting would be implemented to reduce the population accordingly.

Maintaining an acceptable population density would depend on the results of ongoing vegetation monitoring and the associated adaptive management approach (described in the adaptive management section in this chapter), as well as the size and recruitment rate of the deer population. In urban deer populations, mortality rates are generally very low (approximately 10%). In the park, the recruitment rate (e.g., the proportion of the fawn population that survives to one year of age) appears to be about 40% (Christie and Sayre 1989). Assuming through the adaptive management approach the National Park Service continues to target densities on the lower end of the population goal of 20 to 25 deer per square mile and recruitment rates remain about 40%, it is estimated that if deer densities were to rebound above target levels, 20 to 30 deer may need to be removed per year through sharpshooting to maintain these target densities.

Chronic Wasting Disease Management

The park would continue to implement current management actions and policies related to chronic wasting disease as described under alternative A.

Deer Management Best Practices

The following best management practices would be applied to avoid or minimize potential adverse impacts from implementation of deer management actions.

- Sharpshooting would not take place within 450 feet of a building or school playground, even if not occupied.

- § Sharpshooting would be undertaken by qualified individuals trained in the use of firearms. A sharpshooting plan would be developed to ensure safety protocols are followed.
- § The National Park Service would make public notifications prior to sharpshooting activities to remove deer. In addition, sections of the park would be closed to the public during sharpshooting activities for public safety. NPS personnel would patrol public areas to ensure compliance with park closures and public safety measures.

MONITORING, EDUCATION, AND COOPERATION

The National Park Service would continue to monitor the 25 fenced exclosures and 28 NETN plots as noted under alternative A. In addition, the National Park Service would increase monitoring of baseline conditions and responses for the invasive species, deer browsing, and canopy factors through visual inspections of treatment areas and increased spotlight counts of deer. This data would be a key component in determining whether park goals are met and if any management actions through the implementation of the plan need to be adjusted.

Alternative B would add to and build on current interpretive and educational efforts. Likely additions include programming specific to deer and vegetation management, use of bulletin boards, and use of website alerts to disseminate information to the public about NPS management actions at the park and what to expect. In addition, notifications of public meetings, newsletters, and other materials would be made available to update and inform the public on vegetation and/or deer management actions.

Under alternative B, the actions described under the no-action alternative would continue. In addition, notifications of public meetings, newsletters, and other materials would be made available to update and inform the public on vegetation and/or deer management actions.

ADAPTIVE MANAGEMENT CYCLE

Adaptive management is defined in the scientific literature as a systematic approach for improving resource management by learning from management outcomes (Sexton et al. 1999). This is a result of the experimental nature of adaptive management. Since outcomes are to varying degrees unknown, input from several different sources likely will yield better results and facilitate adaptation to unforeseen circumstances and outcomes.

Successful management of natural systems is a challenging and complex undertaking. Managing vegetation in the park means managing and monitoring several natural systems in conjunction with one another—hardwood forests; invasive species; and the deer population. Not only will there be many unknowns for each system, but the way they interact and the best way to adjust management actions to achieve a given goal is difficult to predict. This means it may be unclear which factor—deer browsing, management of invasive species, scarcity of direct sunlight or other unknown elements—is predominant if vegetation (e.g., hardwood regeneration, mixed-age, invasive species control) targets are not being met. Only through examination of different combinations of effort and treatment can park managers understand how to create a self-sustaining hardwood forest (516 DM 1.3 D [7]).

Alternative B in this plan incorporates an adaptive management cycle in meeting the goals described in chapter 1. An adaptive approach is based on monitoring of certain variables where the outcome is potentially different than predicted. This means NPS staff would conduct a treatment or combination of treatments, monitor key factors to assess results, and use the information to determine whether actions need to be modified (Murray and Marmorek 2004). The actions would not be outside of those described in this plan, but the timing or intensity may change.

FOREST MANAGEMENT

The purpose of the vegetation management program is to assess the forest treatments and mitigation of environmental impacts. Existing research and monitoring efforts, including the use of existing and new research plots (as described in the no action alternative), would continue. Stand characteristics, such as overstory density, regeneration density, and invasive species, would be monitored before and after treatments to determine if project goals were achieved, to measure the effectiveness of vegetation treatment efforts, and improve future vegetation treatment methods used in the park. If vegetation treatment efforts are unsuccessful, then retreating the area or applying different combinations of treatments would be considered.

DEER MANAGEMENT

Existing research and monitoring efforts described in the no action alternative would continue. As a part of assessing effectiveness of actions in meeting stated goals, NPS staff would compile information on the number of seedlings and saplings growing under patch openings and within a stand, as well as the extent of native understory species growth and regeneration and other factors that were causing deer densities to exceed park goals. The park would also evaluate the effectiveness of sharpshooting to maintain target density or adjust the number of deer that need to be removed.

ADAPTIVE MANAGEMENT CYCLE OR PROCESS

Under alternative B, the NPS management approach would be implemented according to the following five steps:

1. Gather data on existing conditions. A description of existing conditions would serve as an important baseline for comparisons when actions in the selected alternative are implemented. The National Park Service has current information on: (1) the number of existing forest gaps and their size across the entire forest at Jockey Hollow and New Jersey Brigade units; (2) the data collected in ongoing monitoring of 28 plots that includes observed changes in density of invasive species and hardwood seedling regeneration; (3) approximate deer densities inside the park; and (4) results of necropsies of deer that have been killed by natural causes, collisions with cars, etc. Additional data on the demographics of the deer population would be collected as practicable. Additional information on deer populations would be gathered before population control efforts are conducted.
2. Apply the management actions. NPS staff would determine the order in which it believes is best to apply these actions. In alternative B, NPS staff could begin treatment within existing forest gaps; the following year, it could begin monitoring for successful regeneration and the regrowth of invasive species in its first stand. The application of management actions would depend on the assessment of specific conditions on the ground and the selection of the tool or tools best suited for those conditions.
3. Monitor the effectiveness of each management action. Effectiveness is measured by movement toward goals and targets stated in chapter 1 of this plan. As an example, the National Park Service has goals for both the number of surviving seedlings across the stand (1,000 to 1,500 per acre) and the number of saplings (550 to 900 per acre) (NPS 2012b; Leak

et al. 1969). Currently, although hardwoods are regenerating, they are not growing past their initial sprouting stage, which is likely a result of deer browsing or because they are being crowded by invasive plants. Monitoring of growth within the treatment areas in alternative B would be important. The data gathered through these efforts would determine whether seedlings are surviving and deer browsing goals are met. Although deer browsing is related to the size of the population, it is possible that allowing the herd size to increase to something higher than target levels could still result in successful survival of seedlings. The opposite is also a possibility—e.g., even reaching desired deer population densities may not result in dense enough hardwood seedling survival (eventually an average of 550 to 900 saplings).

4. Increase intensity of management if needed. If monitoring shows hardwood regeneration or growth is not occurring as desired, NPS staff would need to adjust the intensity of deer browsing management and population control, forest thinning, and management of invasive species to meet this goal. For example, if seedling numbers are high but sapling numbers are low, NPS staff may reduce the deer population size in alternative B because this very likely indicates browsing is continuing to stop regeneration from occurring. If seedling and sapling numbers are reaching target levels under treatment areas but not in the remaining portion of the stand, it is likely that shade is the culprit, and additional thinning may be needed to increase hardwood regeneration. If deer numbers are low but regeneration is not taking place under gaps or in shaded areas, a more aggressive removal of invasive species or lack of seed source may be the issue.
5. Reduce intensity of management if needed. If the management action is effective and the forest is regenerating above target levels, lowering the intensity of the action would be considered. For example, if the deer population has been maintained at 20 per square mile (the lower end of the initial density target) and hardwood seedlings are regenerating at 2,000 per acre and successfully growing into saplings at 1,800 per acre, it may be that the National Park Service can allow deer densities to increase.

ALTERNATIVE ELEMENTS CONSIDERED BUT DISMISSED

Options suggested from several sources (including public scoping) were evaluated by the National Park Service but were dismissed from further analysis. The alternative elements and the rationale for dismissing them are discussed in the following sections.

PUBLIC HUNTING

During public scoping, some commenters advocated the use of hunting in the park to manage the deer. Public hunting is not currently authorized within the park and, therefore, the activity would be inconsistent with existing laws, policies, and regulations for the park. As a result, hunting was dismissed from further consideration.

LARGE-SCALE FENCING, INCLUDING FENCING THE ENTIRE PARK

The National Park Service considered fencing the entire park or large areas of the park to control deer browsing. The park has approximately 1,370 acres of forested land, which would require several miles (estimated at 13 miles) of deer-proof fencing. Because deer are an important part of the forest ecosystem, it would be contrary to the plan's stated need and goal to remove and exclude them from the park.

This option also presents several technical and economic challenges. Fencing would alter deer established home ranges and movements as well as movement patterns of other wildlife (Owen and Owen 1980; Clevenger et al. 2001), and the installation and indefinite maintenance of a tall fence around a large block of land would be expensive and consume staff time not needed under other alternatives. Because the park is already forested and subject to high winds, damage to fences by blown-down trees would be a persistent maintenance issue (NPS 2012a). As a fence increases in length, monitoring and maintenance become increasingly more difficult, time consuming, and costly. The cost of materials for a high-tensile fence, such as those used successfully in Pennsylvania, averages about $1.18/foot and $30/acre/year to maintain. This translates to $80,000 for materials to install the fence and $42,000 in materials to maintain it each year. Labor costs would be additional. A three-dimensional fence is similar in cost at about $1.20/foot (Bender n.d.).

Large fenced areas smaller than the entire park (such as an 80- to 100-acre stand or even the entire Jockey Hollow Unit) were considered. However, the park was established and is managed to reflect an 18th century landscape pattern of field, forest, orchard, and clearings that was present during the encampment of the Continental Army under General George Washington. Much of the park boundary is visible, and a fence around it or around large blocks of forest would result in a substantial alteration of the very landscape this plan is trying to protect and preserve.

For these reasons, large-scale fencing was dismissed as unreasonable because it would result in too great of an environmental impact and would be unreasonably expensive when compared to the other alternative elements.

REINTRODUCING OR INCREASING PREDATORS

Predators that could influence the park's deer population size include wolves (*Canis lupus*) and cougars (*Puma concolor*), although both species are extirpated from New Jersey. Coyotes (*Canis latrans*) do feed on newborn white-tailed deer, as to a lesser extent do black bears (*Ursus americanus*). A 2004 inventory of mammals at the park found coyotes and black bears have been observed in the park (USGS 2007).

Wolves and cougars both require very large territories to survive (wolves have home ranges of about 30 square miles when deer are the primary prey, for example). Reintroducing wolves and cougars into a park of 2.6 square miles surrounded by suburban development would be infeasible because suitable habitat of the needed size is not available. Black bears feed on deer fawns on an opportunistic basis and would, therefore, not be effective control on deer numbers.

Coyotes are generalist feeders (Pennsylvania Game Commission 2017), meaning that animals search for any easy meal of meat (live prey/carrion) or fruits/berries. Relationships between coyotes and deer have long been an area of research focus. Research indicates that fawns are most vulnerable to coyote predation during the spring/summer months. Adult coyotes can take an ailing adult deer during the winter. Healthy adult deer are rarely taken by an adult coyote (Ogle 1971). Far fewer fawns are taken if alternate prey (rabbits, for example) is available.

The coyote population has steadily grown in the northeastern states. In New Jersey, coyotes have been documented in all 21 counties (NJDFW 2016b) with a 2006 statewide population estimated at around 3,000 animals (McBride 2006). No density numbers for coyotes in the park have been developed, but park staff estimate that between 1 and 5 coyotes per square mile occupy habitat in the park based on general density in New Jersey provided by the NJ Division of Fish & Wildlife (NJDFW

2016b). For coyotes to make a noticeable impact on the deer population at the park, the numbers of predators would need to be increased and the impact of each would need to be substantial. For this reason, adding sufficient numbers of coyote as a deer density reduction or maintenance strategy was considered infeasible.

LIVE TRANSFER (TRANSLOCATION)

Capturing live deer to transfer to an alternate private or public location is technically possible, but biologists have concerns of the potential for the spread of chronic wasting disease. This would involve killing or capturing and testing a large portion of the population for chronic wasting disease, which is required by NPS policy. This would require a capture facility and holding individual wild deer until test results were available. A receiving site for translocated live deer within the state of New Jersey would also be needed.

Currently NPS policies require park units to perform testing on enough deer to determine with 99% accuracy that chronic wasting disease is not present at higher than a 1% level before translocating deer (NPS 2002a). This is true even if no chronic wasting disease has been found in an ungulate population, but testing of deer on park lands to date has been inadequate to satisfy a 99% confidence interval. To ensure to within a 1% confidence interval that the herd does not have chronic wasting disease, most of the approximately 44 deer within the park's boundaries would need to be tested. Because high densities of white-tailed deer are common in the state, it is unlikely that a receiving site would be available. Translocation across state lines is not allowed because of the risk of spreading chronic wasting disease. Captured deer are at risk of myopathy and injury during handling. In addition, translocated deer could result in the death of more than 50% of the deer during the first year after release (Jones and Witham 1990). In one study, only 15% of the relocated deer survived one year after relocation (O'Bryan and McCullough 1985). Likewise, injury is possible to biologists from thrashing deer during handling.

Translocation was dismissed as a reasonable alternative because of concerns discussed above relating to policy, feasibility, and high mortality.

ALTERNATE LETHAL REMOVAL TECHNIQUES

Deer removal by capturing, tranquilizing, and euthanizing the deer using veterinarian-approved, humane methods would require more skills, time, and labor than sharpshooting, and, therefore, is estimated to be more expensive. Deer under drop nets would need to be tranquilized before they are euthanized because the net itself would cause stress and live deer would thrash and be difficult to handle. In addition, potassium chloride, if used to euthanize deer, requires anesthesia first by law. Carcasses would need to be disposed of in a landfill or burned because meat would not be suitable for human consumption. Because these options offer no benefits beyond sharpshooting, would be more expensive, and are considered less humane than sharpshooting because of handling and stress to live deer, they were dismissed from further analysis as technically infeasible.

CONTRACEPTIVES

Fertility control by contraceptives was considered as an alternative for deer population management. Previous studies, including a 2007 study, "Exploring the Feasibility of White-tailed Deer Fertility Control Programs," conducted within the park found that the use of contraceptives may be an effective method of controlling white-tailed deer populations (Salmon and Underwood 2007). However, administration of contraceptives for this plan was dismissed because no contraceptive agent is available that meets NPS criteria for use in free-ranging deer populations (Powers and Moresco 2015). While contraceptives have been analyzed and even incorporated into selected actions for past NPS deer management plans, they have not actually been used in NPS units that recently completed plans because no acceptable agent has materialized. In addition, development of an agent that meets NPS criteria does not appear to be imminent. Thus, because the use of contraceptives is not technically feasible at this time, and any future use is speculative, this is not considered a reasonable alternative. Therefore, the use of contraceptives was dismissed from further consideration.

SURGICAL STERILIZATION

Surgical sterilization of females is an effective method of controlling reproduction and has been used extensively in domestic animal medicine. However, implementation requires capture, general anesthesia, and surgery conducted by a veterinarian, which is generally considered labor intensive and costly (Boulanger et al. 2012) and calls into question the sustainability of sterilization as a wildlife management tool, except under very limited circumstances. Boulanger and others (2012) note that surgical sterilization is a costly but effective technique for reducing suburban deer herds if 80% or more of the female deer in a population are sterilized and that proportion is maintained over time.

Overall success using surgical sterilization was greatest for closed populations (habitats where animals cannot arrive or leave). Only in rare circumstances is physical sterilization reversible. As these techniques are currently still in the experimental stages, however, the ecological impacts of permanent sterilization in a mostly closed deer population are unknown. In addition, the potential negative side effects—such as limiting the ability of natural selection pressures to act on the population, consequences of altering reproductive and social behaviors, and altering demographic structure of the population—are not fully understood and require further investigation before implementing this as a management technique. This option would involve administering a tranquilizing agent to female deer via dart by qualified personnel. Once the tranquilizing agent has taken effect, surgery in the field would be performed by a qualified veterinarian to remove or disconnect select reproductive organs, affecting permanent infertility. Overall, this option would require a substantial amount of time per deer.

Depending on the method of sterilization, this procedure may have behavioral effects on both male and female deer. If gonads are removed, then the source of important reproductive hormones would be removed. This is likely to change deer social interactions. If gonads are not removed, females would continue to ovulate and show behavioral signs of estrus, potentially extending the breeding season.

There is a general understanding in white-tailed deer biology that managing the female component of the population is more important than managing the male component. Based on the polygamous breeding behavior of white-tailed deer, treating males with reproductive control (in this case, surgical sterilization) would be ineffective when the goal is population management (Warren 2000; Garrott and Siniff 1992).

The potential use of surgical sterilization in combination with other deer population management actions was also reviewed. Discussion focused on the following:

- potential number of deer that would require treatment
- the length of time required to achieve the deer density goal if implemented in combination with direct reduction

- mortality of treated females
- available research on population level effects particularly for large, free-ranging deer populations
- baseline data on park deer required to fully develop a combined alternative involving surgical sterilization
- potential implications of using a nonreversible management action

Based on these reasons, surgical reproductive control was dismissed as a management option. Surgical reproductive control was also dismissed as an element of a combined alternative because there is little available research on population level effects. Therefore, the use of an irreversible management action based on population parameters that could potentially change greatly in the future was dismissed.

LARGE-SCALE HAZING

The use of hazing as an alternative to keep deer away from regenerating hardwood areas was dismissed because it would involve the continual harassment of wildlife, which would be costly, potentially ineffective unless it occurred routinely, and could result in deer leaving the park and adversely affecting adjacent landowners. Therefore, this alternative was dismissed as technically infeasible.

CREATION OF LARGE CLEAR CUTS

The National Park Service considered the use of large (up to 20 acres) clear cuts to recreate the types of landscape disturbance that are known to have given rise to the current forest composition (Shaw and Patterson 2006). Creating gaps of this size would require intensive and sustained management of invasive species that would be beyond the NPS staff's capacity to manage. Gaps of this size would also likely require increasing the intensity of deer management actions due to the substantial increase in available forage that would grow in the clear cut. In addition, large clear cuts would result in immediate changes to the dense forest which contributes to the historic appearance of the cultural landscape. These changes would limit the park's ability to protect the important cultural landscape of the park. This alternative was therefore dismissed as technically infeasible.

3

AFFECTED ENVIRONMENT

INTRODUCTION

This chapter describes the existing conditions of the impact topics retained for analysis in chapter 1. These resources include forest vegetation, white-tailed deer population, and the cultural landscape. The information provided in this chapter will be used as context for comparing the potential impacts of each alternative, which are presented in "Chapter 4: Environmental Consequences."

FOREST VEGETATION

The National Park Service conducted a study of the various vegetation cover types at the Jockey Hollow unit of the park in 1977 (Ehrenfeld 1977). Based on this study, plant community types at Jockey Hollow are described broadly as Successional Broadleaf Forest, Mature Broadleaf Forest, Conifers, and Open Areas. These forest types are described below. The successional forest and mature forest labels remain informally used today and are the terms used for the purposes of this environmental assessment. Figure 3 shows the distribution of forest types within the Jockey Hollow unit; table 1 below summarizes the area of each forest type in Jockey Hollow from the Ehrenfeld study.

In the 1977 study, the term successional forest was given to those forests dominated by hardwoods that overtook abandoned fields around the late 1800s and early 1900s. The general composition lacks oak and hickory as major constituents and is composed primarily of tulip poplar, white ash, black locust, and black birch (*Betula lenta*) in the canopy with dense understories of mainly spicebush (*Lindera benzoin*), blackhaw (*Viburnum prunifolium*), and dogwood (*Cornus florida*). Where shrubs are absent, these stands contain a dominance of snakeroot (*Eupatorium rugosum*), blackberries (*Rubus* spp.), and dense vines of wild grape (*Vitis* spp.). Ehrenfeld (1977) further segregated the successional forests into mixed successional, white ash-black locust, white ash-tulip tree, pure hardwood stands (a mix of seven different species), and a single stand of Tree-of-heaven (*Ailanthus altissima).* Today, the understory is dominated by invasive species, described in further detail in this section below.

Mature forests are defined as those stands in the Jockey Hollow unit containing a common component of mature individuals over 100 years of age and including a dominant or principal element of oak (Ehrenfeld 1977). Stand origins generally date to the mid- to late-1800s, and are associated with either farm abandonment after the peak timeline of agricultural use or existing second growth wooded areas that were commonly a source of trees for fuel and left to regenerate. These stands existed when the park was established. Ehrenfeld (1977) categorized eight types of the mature forests, with non-oak associates used to distinguish differences between types. Mature Broadleaf Forests were recognized as having a dominance of various oaks (*Quercus rubra, Q. alba, Q. prinus, Q. velutina*) with subordinate canopy species of tulip poplar, black birch, white ash, and beech. Common understory shrubs included maple leaf viburnum (*Viburnum acerifolium*), witch hazel (*Hamamelis virginiana*), spicebush, blackhaw, and Blue Ridge blueberry (*Vaccinium vacillans*).

TABLE 1. SUMMARY OF FOREST TYPES AT JOCKEY HOLLOW

Major Type	Dominant Constituents	Area (ha)	Percent Coverage
Successional Broadleaf Forest	Mixed Successional	67.8	13.7
Successional Broadleaf Forest	White Ash – Black Locust	37.6	7.6
Successional Broadleaf Forest	White Ash – Tulip Poplar	29.5	5.9
Successional Broadleaf Forest	Tulip Poplar	31.8	6.3
Successional Broadleaf Forest	White Ash	3.8	0.8
Successional Broadleaf Forest	Black Locust	3.5	0.7
Successional Broadleaf Forest	Red Maple	6.1	1.2
Successional Broadleaf Forest	Sassafras	2.3	0.5
Successional Broadleaf Forest	Black Walnut	2.2	0.5
Successional Broadleaf Forest	Black Birch	1.1	0.2
Successional Broadleaf Forest	Tree-of-heaven	0.6	0.1
Successional Broadleaf Forest	**Total**	**186.3**	**37.5**
Mature Broadleaf Forest	Mixed Oak – Black Birch	67.0	13.5
Mature Broadleaf Forest	Mixed Oak – Tulip Poplar	90.4	18.2
Mature Broadleaf Forest	Mixed Oak - Beech	23.6	4.8
Mature Broadleaf Forest	Mixed Oak	27.9	5.6
Mature Broadleaf Forest	Mixed Hardwood	39.5	8.0
Mature Broadleaf Forest	Chestnut Oak	14.8	3.0
Mature Broadleaf Forest	Mixed Hemlock – Hardwood	0.9	0.2
Mature Broadleaf Forest	Stream Thicket	11.7	2.4
Mature Broadleaf Forest	**Total**	**275.8**	**55.7**
Coniferous Forest	White Spruce/Red Pine	3.1	0.6
Open Areas	n/a	30.8	6.2
Jockey Hollow Total	n/a	**495.8**	**100.0**

Source: Ehrenfeld 1977

Ehrenfeld and Dibeler (1987) performed a similar forest stand analysis at the New Jersey Brigade unit and found the successional forest type to be the most common form. Variants of the successional forest type were identified based on the dominant canopy species and the composition of the understory. The tulip poplar–mixed hardwood forest with a variable understory was the most common forest variant at the New Jersey Brigade unit. Dominant canopy species in this type included tulip poplar, black birch, beech, red maple (*Acer rubrum*), white ash, and chestnut oak. Understory species included maple leaf viburnum, spicebush, *Eupatorium* spp., lowbush blueberry (*Vaccinium augustifolium*), and brambles of *Rubus* and *Rosa* associated with disturbed areas. Strong variations were noted in the understory between those forests the authors classify as typical understory species and other stands dominated by brambles and vines with little or no canopy tree reproduction. In addition, Ehrenfeld and Dibeler (1987) recognized that historical dominants of oak, chestnut, and hickory were missing and being replaced over time by tulip poplar, black birch, beech, white ash, and maple.

In a 2008 report, the National Park Service identified 14 vegetation associations parkwide (Sneddon et al. 2008) using the US National Vegetation Classification (USNVC) system established by the Federal Geographic Data Committee (FGDC 2008). Minor variations occurred between the Northern Piedmont Mesic Oak–Beech Forest Association (which also contained a component of tulip tree), and the Successional Tulip Tree Forest Association. These were difficult to separate by distinct boundaries. Sneddon et al. grouped these two associations together for classification and mapping purposes, which comprises the largest vegetation association in the park covering 568.26 hectares (Sneddon et al. 2008). Table 2 below provides a summary of the association types and respective land area of each association found in the park. Just as Wohl (1994), Ehrenfeld (1999), and Russell (2001) had documented, Sneddon et al. (2008) also noted dramatic changes in the understory vegetation when comparing their plot data with Ehrenfeld's survey from 1977.

TABLE 2. VEGETATION ASSOCIATIONS FOUND AT MORRISTOWN NATIONAL HISTORICAL PARK. AREA REPORTED IN HECTARES.

Association Type	USNVC or Land Use Code	Size (ha)
Smartweed-Cutgrass Wetland	CEGL004290	0.13
Northeastern Old Field	CEGL006107	36.35
Dry-Mesic Chestnut Oak – Red Oak Forest	CEGL006057	25.00
Tulip poplar – Beech – Maple Forest	CEGL006296	11.64
Northeastern Dry Oak – Hickory Forest	CEGL006336	7.90
Southern New England Red Maple Seepage Swamp	CEGL006406	2.79
Hemlock – Red Oak – Mixed Hardwood Forest	CEGL006566	0.98
Skunk Cabbage – Orange Jewelweed Seep	CEGL006567	0.24
Northeastern Modified Successional Forest	CEGL006599	10.02
Northern Piedmont Mesic Oak – Beech Forest	CEGL006921	16.30
Northern Piedmont Mesic Oak – Beech Forest and Successional Tulip poplar Forest	CEGL006921/CEGL007221	568.26
Black Locust Successional Forest	CEGL007279	11.75
Montane Basic Seepage Swamp	CEGL008416	0.58
Orchards and Plantations	UO	11.20
Pond/Reservoir	UP	0.15
Commercial and Services	US	1.28
Transportation, Communications and Utilities	UU	4.04
Park Total	n/a	710.61

Source: Sneddon et al. 2008

The natural establishment of advanced regeneration in the park has stopped for all forest species except American beech, a shade-tolerant species often avoided by deer. A 2001 park study concluded that although almost all tree species in the forest produce seeds that germinate, seedling survival beyond 2 to 3 years is rare (Russell 2001). In a follow-up study evaluating tree seedling plots over a 5- to 6-year span, all oak seedlings had died—most after their first year—and any seedlings that survived remained very small (less than 3 cm tall) (Russell 2002). This lack of regeneration means the forest primarily consists of mature trees and lacks sufficient new stem growth to replace the older trees as they naturally die. In addition to the lack of tree regeneration, native understory shrubs that once thrived in the park, such as spicebush, are now almost completely absent (Russell 2002).

A closed hardwood canopy results in a heavily shaded understory. A review of forest monitoring data from 1995–2001 revealed that the canopy cover in forests within the park is often over 90% (Russell 2002). In this study, Russell found that hardwood seedlings, including shade-tolerant birch and maple, grew very slowly under the closed canopy at the park—no more than a few centimeters during the 7-year period. In addition to shade caused by overstory canopy trees, many stands often had heavy mid-canopy and ground shade due to dense cover of invasive species, which is discussed below (Russel 2002).

Invasive plant species have been increasing in the park since the 1970s. In the 1970s, while their presence was noted (Ehrenfeld 1977), invasive plants were believed to be unsuccessful at outcompeting native vegetation. In Ehrenfeld's 1977 report, Tree-of-Heaven, Japanese honeysuckle (*Lonicera japonica*), Chinese privet (*Ligustrum sinense*), Japanese barberry, and black locust were identified as the most common species encountered, most notably in disturbed areas. Stiltgrass was not itemized as a common plant and is presumed to be absent from the park at that time.

Over time, scientists found that because of aggressive reproductive and growth tendencies, invasive understory plant species began to spread across the park, outcompeting hardwood seedlings and native understory plants (Ehrenfeld and Dibeler 1987; Christie and Sayer 1989; Ehrenfeld 1999; Russell 2001; Russell 2002). Instances of these species increased by the 1980s and 1990s, particularly Japanese barberry and stiltgrass, which were observed to be the most frequently occurring understory vegetation in the park at the time (Dibeler and Ehrenfeld 1990; Ehrenfeld 1999). Field surveys conducted in 1993 and 1995 (Ehrenfeld 1999) found notable increases in understory shrub density between the two sample periods, but species richness dramatically declined as invasive species began to outcompete native plants.


Successional forest dominated by an understory of Japanese barberry

In 1994, Wohl mapped the density and extent of Japanese barberry in the Jockey Hollow and New Jersey Brigade units. The results indicated higher stem densities within successional forest stands compared to mature oak stands, a conclusion also reached by Ehrenfeld (1999) (Wohl 1994). The highest densities of barberry stems per hectare (more than 431 per hectare) were found in the northeast end of the New Jersey Brigade unit, while lower densities occurred on hillside slopes associated with Mt. Kemble, Sugar Loaf Hill, and Fort Hill in the Jockey Hollow unit. Another study of vegetation in the Jockey Hollow unit sampled 13 plots and found fewer trees per plot in 2001 compared to 1995 (Russell 2002). Dogwood, ash, red maple, and black birch experienced the highest mortality, most of which occurred in the smaller diameter classes. However, beech was more common in the sapling stage on a wider scale due to its shade tolerance; spicebush was gone from all plots except one; and virtually no saplings were sampled in plots highly invaded by invasive species. Additional studies in the late-1990s and early-2000s showed growth of invasive species continued but stabilized (Ehrenfeld 1999; Russell 2002). However, when established forest monitoring plots were surveyed in 2003–2004, Japanese barberry was found in all plots sampled, both in plots originally invaded and formerly uninvaded. This survey also revealed new invasive species such as wineberry (*Rubus phoenicolasius*) and European bittercress (*Cardamine impatiens*) in several plots (Shaw and Patterson 2004).

Today, the National Park Service has identified a total of 131 species of nonnative plants throughout all vegetative community types in the park. Of this total, 67 species are known to occupy forested habitat types, forest edges, or forest openings. Those nonnatives considered to be invasive total 37 species, many of which currently inhabit forested habitats in the park or have the potential to inhabit the forest communities (table 3). The two most prominent nonnative invasive inhabitants at the park are stiltgrass and Japanese barberry.

TABLE 3. NONNATIVE PLANT SPECIES CONSIDERED INVASIVE OR POTENTIALLY INVASIVE AND WITH THE POTENTIAL TO IMPACT FOREST COMMUNITIES AT MORRISTOWN NATIONAL HISTORICAL PARK

Scientific Name	Common Name	Form	Duration	Listed as invasive by New Jersey
Acer palmatum	Japanese maple	Tree	Perennial	
Acer platanoides	Norway Maple	Tree	Perennial	X
Ailanthus altissima	Tree of Heaven	Tree	Perennial	X
Aralia elata	Japanese angelica tree	Tree	Perennial	
Paulownia tomentosa	Empress (Princess) Tree	Tree	Perennial	X
Robinia pseudoacacia	Black Locust	Tree	Perennial	X
Styrax obasia	Fragrant Snowbell	Tree	Perennial	
Berberis thunbergii	Japanese barberry	Shrub	Perennial	X
Elaeagnus umbellata	Autumn olive	Shrub	Perennial	X
Euonymus alatus	Winged euonymous, burning bush	Shrub	Perennial	X
Ligustrum vulgare	Japanese Privet	Shrub	Perennial	X
Lonicera tatarica	Tartarian honeysuckle	Shrub	Perennial	X
Photinia villosa	Oriental photinia	Shrub	Perennial	X
Rhamnus cathartica	Common buckthorn	Shrub	Perennial	X
Rhodotypos scandens	Black Jetbead	Shrub	Perennial	X
Rosa multiflora	Multiflora rose	Shrub	Perennial	X
Rubus phoenicolasius	Wineberry	Shrub	Perennial	X
Spiraea japonica	Japanese spiraea	Shrub	Perennial	
Viburnum sieboldii	Siebold's virburnum	Shrub	Perennial	X
Viburnum dilatatum	Linden viburnum	Shrub	Perennial	X
Actinidia arguta	Hardy kiwi	Vine	Perennial	
Akebia quinata	Five-leaf akebia, Chocolate vine	Vine	Perennial	X
Ampelopsis brevipedunculata	Porcelainberry	Vine	Perennial	X

Note: Determination of whether a nonnative plant is invasive or potentially invasive was based on available literature and best professional judgment of park staff and the NPS Northeast Exotic Plant Management Team and review of available literature. Determination of whether or not a plant is listed as invasive by New Jersey was based on NJDEQ Policy Directive 2004-02.

TABLE 3. NONNATIVE PLANT SPECIES CONSIDERED INVASIVE OR POTENTIALLY INVASIVE AND WITH THE POTENTIAL TO IMPACT FOREST COMMUNITIES AT MORRISTOWN NATIONAL HISTORICAL PARK (CONT.)

Scientific Name	Common Name	Form	Duration	Listed as invasive by New Jersey
Celastrus orbiculatus	Oriental bittersweet	Vine	Perennial	X
Cynanchum louiseae (nigrum)	Black swallowwort	Vine	Perennial	X
Lonicera japonica	Japanese honeysuckle	Vine	Perennial	X
Parthenocissus tricuspidata	Boston ivy	Vine	Perennial	
Persicaria perfoliatum	Mile-A-Minute Weed	Vine	Perennial	X
Wisteria sinensis	Chinese wisteria	Vine	Perennial	X
Alliaria petiolata	Garlic mustard	Herb	Annual	X
Cardamine impatiens	Narrowleaf bittercress	Herb	Annual, Biennial	X
Coronilla varia	Crown vetch	Herb	Perennial	X
Microstegium vimineum	Japanese stiltgrass	Herb	Annual	X
Polygonum caespitosum	Oriental ladythumb	Herb	Annual	
Polygonum cuspidatum	Japanese knotweed	Herb	Perennial	X
Ranunculus ficaria	Lesser celandine	Herb	Perennial	X
Vinca minor	Common periwinkle	Herb	Perennial	X

Heavy deer browsing has limited the regeneration of native hardwoods and contributed to an herbaceous and woody understory lacking native species in the forest today. Selective browsing by deer of palatable plant species has resulted in the dominance of unpalatable ones, including both native and nonnative species. Christie and Sayre (1989) concluded that an overall increase in diversity of less palatable herbaceous species accompanied by a decrease in diversity of woody species is strong evidence of browsing pressure adversely affecting forest regeneration, structure, and compositional diversity. They also concluded that although successional forests (younger, fast-growing forests) were used by deer year-round, mature forest stands (older forests) were used by deer only in winter; this indicated that successional forests (as well as streamside thickets) were some of the most preferred habitats by deer. An examination of tree seedlings found that, although 1994 was a year of excellent production of oak seedlings, all oak seedlings in sample plots from 1994 had died by 2001, most within their first year and primarily due to deer browsing (Russell 2001). Garlic mustard (*Alliaria petiolata*) had increased in spatial extent to become the second most common invasive herbaceous plant behind stiltgrass. These findings and those from other scientists (Ehrenfeld 1999, Wohl 1994) led to the conclusion that deer herbivory and the spread of invasive species were severely

Mature forest at Jockey Hollow with little to no understory limiting the ability of forests in the park to adequately provide the regeneration necessary to ensure sustainability of the forest ecosystem over time (Russell 2001).

Park monitoring data show inadequate tree regeneration to restock the future forest, and severe selective deer browsing. Out of all plots sampled, only one had adequate tree regeneration, and this plot was located in a deer exclosure. The park had the highest deer browsing evidence on deer-preferred and non-preferred species out of all network parks. The park also has a high occurrence rate of invasive species, with Japanese barberry being present in 24 of 28 sampled plots and an average of over five indicator invasive species per plot. Indicator invasive species are those that are capable of suppressing forest succession, or that dominate under a shaded canopy. The most extreme impacts from deer herbivory and invasive species occur in successional forest stands where most of the plant cover in the understory is invasive species (NPS 2014).

EFFECTS OF HURRICANE SANDY

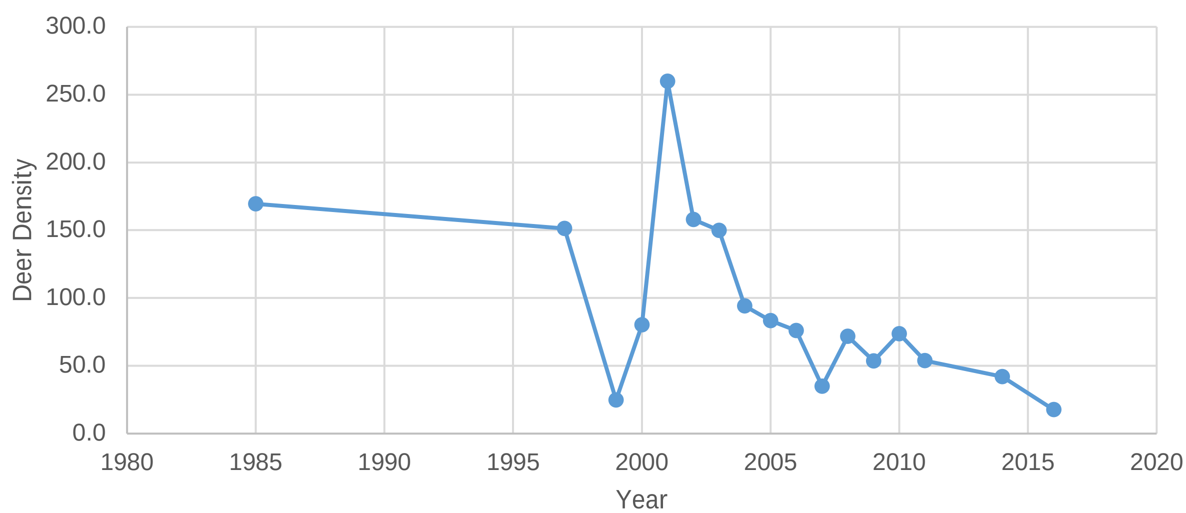
In October 2012, high winds from Hurricane Sandy uprooted trees in the park. In many parts of mature and successional forests in the park, only partial canopy openings were created, while in other parts of the park complete canopy openings were created by wind bursts that caused trees to become uprooted; some of the canopy openings are several acres in size. The most notable tree damage occurred on southeast-facing slopes of Mt. Kemble, Fort Hill, and Sugar Loaf Hill, which received the brunt of the hurricane’s winds. Park managers have performed field surveys to identify gap locations, sizes, and shapes, using global positioning system (GPS) mapping technology to better understand the extent and dynamics of these newly created canopy openings. Figure 3 depicts the result of this mapping effort. Approximately 65 acres of new canopy gaps were formed, which comprises approximately 4% of the total forested area prior to the storm making landfall.

WHITE-TAILED DEER POPULATION

Deer populations in the park have fluctuated over time. In the 1930s, a white-tailed deer sighting in the park was a rare event. In 1977, the deer population was anecdotally reported to be in balance with the available resources in the park, based on the appearance of healthy deer, no browse line, and abundant understory shrub and tree reproduction (Ehrenfeld 1977). By 1988, however, the white-tailed deer population grew substantially in the Jockey Hollow unit, prompting the park to conduct a study of the deer population and deer movements. This study by Christie and Sayre (1989) found an estimated 163 deer per square mile at the Jockey Hollow unit. The park and surrounding open areas were found to have acted as a de facto sanctuary for the deer from continuing residential and commercial development in the area. In addition, deer survival and growth of the population were closely linked with acorn production and the amount of open habitat for grazing (Christie and Sayre 1989). Christie and Sayre (1989) noted that by the time the survey was conducted, starvation was occurring among first-year fawns, productivity was low, and changes in vegetation composition, structure, and species richness indicated overbrowsing. Another survey of vegetation by Ehrenfeld showed nearly 100% of native species understory stems were browsed and forests were devoid of native understory tree or shrub regeneration (Ehrenfeld 1999).

For varying reasons, the deer population in the park has declined since the mid-1990s. In 1996, population density was estimated at 156 deer per square mile in Jockey Hollow (Salmon and Underwood 2007). The population density dropped to 79 deer per square mile in 1997, and to 60 deer per square mile by 1998 (Salmon and Underwood 2007). Due to a newly implemented public hunting program on the neighboring Lewis Morris County Park, deer density dropped to around 25 deer per square mile in 1999. Despite the drop, damage had been done to park vegetation; a 2003 vegetation survey noted severe browsing had nearly eliminated native and nonnative palatable species up to a height of approximately 7 feet in some areas of the forest (Shaw and Patterson 2006). According to NPS estimates, recent deer densities are as follows: in fall 2014, the population was 42 deer per square mile; by fall 2015 the population had dropped to 27 deer per square mile, and in fall 2016, the population was 17 deer per square mile. See figure 4 below for a graph of the change in deer density since 1985. The exact reason for the recent decline in deer density in the park is not known, but biologists speculate it could be a combination of multiple factors including disease (Berheim et al. 2016) and poor physical condition due to an ever-present decline of palatable food resources as invasive species dominate the forest landscape. As this brief history shows, factors influencing deer densities are variable, including disease, external hunting pressure, and availability of native palatable food sources.

Figure 4. White-tailed Deer Density Estimates at Morristown National Historical Park (Deer Per Square Mile)



Sources: Christie and Sayre 1989; NPS 2003; NPS 2017

Christie and Sayre (1989) examined deer movements in the park by using radio telemetry on 14 deer in order to monitor seasonal activities in 1985 and 1986. The results of this study, similar to other studies cited by Christie and Sayre (Progulske and Baskett 1958, Marchington and Jeter 1966, Marshall and Whittington 1968, and Tierson et al. 1985), found that deer residing in the park generally exhibited an affinity for established home ranges. Home ranges were found to range in size between 84 to 275 ha (207 to 680 acres), with an average home range size of 167 ha (412 acres). When analyzing deer movements during various seasons of the year, home range comparisions between seasons showed considerable overlap.

CULTURAL LANDSCAPE

The park's general management plan identifies the Jockey Hollow and New Jersey Brigade units as one cultural landscape (NPS 2003), although separate cultural landscape inventories have been completed for each unit (NPS 2009a, 2011a). The cultural landscape of the Jockey Hollow and New

Jersey Brigade units encompasses approximately 1,660 acres that were utilized by the Continental Army between 1777 and 1782. The park is composed primarily of rounded hills separated by narrow valleys and brooks. Nine brigades made camps here during the Revolutionary War, and the cultural landscape reflects elements that are reminiscent of that encampment period as well as 20th century efforts to interpret the site for a modern audience.

Two periods of significance are associated with the cultural landscape, as identified by the cultural landscape inventories for the two units (NPS 2009a, 2011a). The first period of significance is the Encampment Period, which is associated with the wintertime encampments of the Continental Army, especially the winters of 1777 and 1779–1780. The cultural landscape inventory for the Jockey Hollow unit identifies 1777–1782 as the primary years of significance (NPS 2009a). The second period of significance is associated with the Commemorative Period, when efforts were conducted to memorialize the Revolutionary War and events that took place in the park. This period of significance is defined as 1873–1942.

The natural features of the area were particularly advantageous for the Continental Army. The relatively high elevation of the site provided a defensive advantage from which to monitor enemy troop movement, while the water sources and dense woodland supported the thousands of troops that were camped during the winters of the war. Today, both Jockey Hollow and the New Jersey Brigade units are dominated by woodlands, which isolate several park elements from one another and provide a buffer between the park units and surrounding suburban development. These large swaths of naturally occurring growth are interspersed with much smaller designed landscapes, consisting of open fields, orchards, gardens, and pastures associated with Continental Army operations and farmsteads located within the park.

Orchard at Wick Farm within Jockey Hollow

The current forest growth would not have been recognizable during the war when the encampment stripped virtually all woodland for lumber, which was used as firewood and in the construction of huts and common facilities. Instead, the spatial organization is more representative of the pre-war Colonial Period, when only portions of the natural woodland were cleared for use as agricultural fields, namely in relatively flat areas. The current extent and composition of the woodlands is most representative of the early 20th century period when the park was established and developed by the National Park Service and the Civilian Conservation Corps. After the decline of farming in the late 19th century, local fields were abandoned and were reclaimed by successional forest. NPS management practices in the 20th century, such as the policy of passive forest management, have resulted in a mixture of forest growth that developed after the Revolutionary War period and younger successional growth that succeeded the abandoned agricultural fields.

Overall, there is a moderate level of integrity in the cultural landscape for the Encampment Period. Although the vegetation has changed since the Encampment Period and the character of the forest has changed, many features of the Encampment Period exist today. These features include historic roads, encampment remains, streams, spatial organization, and strategic views to the east (NPS 2003).

In addition, the cultural landscape report notes that in the wooded areas of the New Jersey Brigade unit, the lack of understory enhances Encampment Period views from the site of the brigade's camp downhill to the road and Indian Grave Brook (NPS 2004).

For the Commemoration Period, there is a high level of integrity, particularly in the Jockey Hollow unit. Overall, the dense forest continues to represent its overall condition and appearance during the commemoration of the Revolutionary War in the 20th century (NPS 2003). Some aspects of the cultural landscape have been diminished through manmade and ecological change. Modern residential suburban development now surrounds the park and diminishes the historic setting of the landscape. In addition, the steady spread of invasive species, coupled with heavy deer browsing has somewhat changed the forest character. As discussed under the impact topic of "Forest Vegetation" above, native forest regeneration has slowed and invasive species are outcompeting native species.

The cultural landscape is not managed to fully recreate the encampment scene because it would require removal of approximately 600 acres of hardwood trees to mimic those needed by Washington's army for huts and fuel. According to the park's general management plan, there is a lack of comprehensive knowledge of precisely which areas were cut and to what degree for the encampment. Similarly, the National Park Service decided that re-creating the ecological conditions that were present before the army arrived would be virtually impossible because there are no records of the type, abundance, and distribution of tree and understory species in the park in the 18th century (NPS 2003). Instead, the National Park Service protects and manages the landscape with its broader cultural and ecological contexts (NPS 2003). An important piece of this landscape in both its cultural and ecological context is a naturally regenerating mixed hardwood forest that reflects historic character, natural diversity, and natural processes. This critical element of the landscape is currently threatened by a lack of native hardwood regeneration and encroachment of invasive species.

4

ENVIRONMENTAL CONSEQUENCES

INTRODUCTION

This “Environmental Consequences” chapter analyzes both beneficial and adverse impacts that would result from implementing any of the alternatives considered in this plan.

GENERAL METHODOLOGY FOR ANALYZING IMPACTS

In accordance with the Council on Environmental Quality regulations, direct and indirect impacts are described under each impact topic (40 CFR 1502.16), and the impacts are discussed in terms of context and intensity (40 CFR 1508.27). Where appropriate, mitigating measures for adverse impacts are also described and incorporated into the evaluation of impacts. The specific methods used to analyze impacts for each resource may vary; therefore, these methodologies are described under each impact topic. For all impact topics, the geographic study area is generally defined as the project area, as shown on figure 1.

CUMULATIVE IMPACT ANALYSIS METHODOLOGY

Cumulative impacts are defined as “the impact on the environment which results from the incremental impact of the action when added to other past, present, or reasonably foreseeable future actions regardless of what agency (federal or nonfederal) or person undertakes such other actions” (40 CFR 1508.7). Cumulative impacts are analyzed by adding the impacts of other actions to those of the alternatives described in this environmental assessment/assessment of effect. The following describes the past, present, and reasonably foreseeable actions that contribute to the cumulative impacts on park resources that would be affected by the alternatives.

Past, Present, and Reasonably Foreseeable Actions

The following action was determined to be a potential contributor to the cumulative impacts on the affected resources in conjunction with the potential impacts of the alternatives presented in this document.

Deer Hunting at Lewis Morris County Park. Lewis Morris County Park is located adjacent to Morristown National Historical Park to the northeast, and is administered by the Morris County Park Commission. The Morris County Park Commission white-tailed deer management program includes annual bow and firearms hunting seasons throughout its various county parks, including Lewis Morris County Park. The program is administered in order to manage the overabundance of white-tailed deer, which pose threats to the biodiversity of native flora and fauna within the various Morris County parks (Morris County Park Commission 2016). According to the 2015–2016 deer management program end-of-year report, a total of 56 deer were harvested from Lewis Morris County Park during the 2014–2015 season, and a total of 25 deer were harvested in the 2015–2016 (Morris County Park Commission 2016). The 2016–2017 hunting season was held at Lewis Morris County Park on various days from late November 2016 through early February 2017. Continuation of this annual deer management program for the foreseeable future is anticipated.

IMPACTS ON FOREST VEGETATION

METHODOLOGY

The National Park Service has implemented numerous studies across decades to examine vegetative conditions of the park, particularly in relation to changing deer densities as described in chapter 3. The results of these studies, a review of the literature, best professional judgment by NPS staff and outside experts, and noted observations by biologists working at the park were used to analyze impacts to vegetation for each alternative. Early studies prior to the spread of invasive species and the spike in deer density assisted scientists in understanding forest stand conditions and natural processes in a relative balanced-state condition. In addition, deer-vegetation relationship studies at the park and elsewhere helped with predicting outcomes and changes that would result from proposed actions.

IMPACTS OF ALTERNATIVE A: NO ACTION

Impact Analysis

Although park managers would continue their limited efforts to control the spread of invasive species under alternative A, it is likely that invasive species would continue to be present and spread throughout the forest understory. The existing presence of invasive species in the successional forests of Jockey Hollow Unit and the mixed hardwood forest of the New Jersey Brigade Unit would continue to dominate the understory. This alternative would result in invasive plants inhibiting native species establishment and growth, resulting in a permanent alteration of plant composition. In addition, this alternative would allow the invasive species to outcompete natural forest regeneration, thereby causing a slow decline in forest structure as canopy trees die and are not replaced. The mature forests of the Jockey Hollow unit, where invasive species are less present, would be under constant threat of invading nonnative plants that could ultimately result in heavily infested ground cover similar to the successional forests.

Under this alternative, the existing forest gaps would be left as-is; fallen stems would remain on the forest floor to decompose; and vegetation establishment would be left to natural processes influenced by the presence of invasive species. With the extensive propagule pressure (reproductive structures such as seeds and spores) from existing invasive plants within and surrounding gaps and no deer browsing control, these open areas would experience the growth and rapid spread of invasive species in response to the forest disturbances (Eschtruth and Battles 2009; Cheplick 2010). The spread of invasive species would continue to diminish the ability for forest regeneration to occur due to the invasive species outcompeting the native species for required resources. Thus, the lack of hardwood regeneration would persist under alternative A.

Under alternative A, no plan would be in place to reverse the trend of invasive plants occupying much of the park or for supplemental planting of native tree seedlings, which would result in invasive species continually outcompeting native species for resources. The National Park Service's current management of invasive plants in the park is generally limited to preventing the spread of invasive plants along the perimeter of existing infestations and treating small isolated populations as outbreaks are detected. The intensity of the treatments is typically influenced by the availability of labor and funds. Alternative A would continue the existing invasive species management methods and continue with NETN vegetation monitoring. Invasive species management actions would continue to vary depending on the target species and methods chosen for any particular control effort. Consequently, impacts to forest vegetation by control of invasive species under this alternative would vary. Control efforts such as manual and chemical removal techniques would likely be contained within small areas, reducing vegetative competition in the understory that would promote regeneration of hardwoods. Chemical treatments along the perimeter of invasive species populations would keep invasive plants from spreading into non-invaded areas of mature forests. However, adverse impacts to native vegetation, although small in the number of individual plants, would be possible from the accidental spraying of native plants in the vicinity of invasive species being treated. Measures would be taken to avoid this accidental spraying to the extent practicable by training personnel to identify targeted plants.

No midstory or overstory canopy removal would be proposed under alternative A; this would allow shade-tolerant tree species to dominate the midstory under the overstory canopy cover and continue to inhibit the recovery of native herbs, forbs, shrubs, and forest regeneration. This would result in continued suppression of forest regeneration and deterioration of the forest, as canopy trees are not replaced when they die, particularly without mechanisms to control the deer population to abate browsing impacts. The park would likely experience heavy declines and potential extirpation of certain native forest plants from deer browsing similar to the decline of spicebush during a time of high deer numbers as documented by Russell (2002), and conditions would be in place to allow the unpalatable invasive species to dominate the understory. Under alternative A, natural forest habitat conditions would continue to be dominated by invasive species, and forest regeneration would not occur.

Because no means to control the white-tailed deer population are proposed under alternative A, deer browsing would likely continue to be a contributor to the overall poor health of the forests in the park because white-tailed deer prefer to browse on native plants over invasive species (Christie and Sayre 1989; Russell 2002). Although the current deer density is below the maximum target range at 17 deer per square mile, deer density has fluctuated greatly over recent decades and the future trend in deer density is unclear. Without means to control deer numbers when needed, invasive species would continue their competitive advantage over native species, resulting in the continued occupation of invasive species throughout much of the successional and mixed forest types and the potential spread of invasive species into the mature forests currently unoccupied by invasive plants. This continued occupation of invasive species, in turn, would cause a decline in native forest vegetation—as invasive species spread and suppress native understory plants and hardwood regeneration, a lack of seedlings/saplings would be available to replace naturally dying canopy trees.

The 25 existing exclosure fences would remain for experimental purposes at the park under this alternative, which would continue to protect some vegetation from deer browsing. The resulting data obtained during the studies would improve the NPS staff's knowledge of deer browsing pressure and interrelationships between competing native and nonnative understory vegetation exposed to various experimental treatments absent of deer browsing. The experimental outcomes from these exclosure studies would assist NPS staff with future decisions benefiting invasive species control, native species recovery, forest regeneration and advanced regeneration development. No new fences would be erected under this alternative, and deer would continue to access all other areas of the park.

Cumulative Impact Analysis

The annual deer hunting seasons at the adjacent Lewis Morris County Park have resulted and may continue to result in a reduction in the number of deer browsing on forest vegetation, resulting in beneficial impacts to native vegetation. Because the hunt reduces the number of deer in the area, the number of deer available to browse on vegetation in the park is reduced. While there are no data available to accurately know how many of these deer harvested in the county park also ranged onto the Jockey Hollow and New Jersey Brigade units, it is assumed that some individual deer harvested during the hunt may have also browsed in the park. However, the number of deer that exerted pressure on the project area and then were removed during the Lewis Morris County Park harvest is likely to be low and relatively inconsequential.

The adverse impacts of alternative A would contribute to the continued deer browsing impacts on forest vegetation in the park. When considered with the actions identified above, alternative A would greatly contribute to the adverse impacts on forest vegetation and the other actions would not contribute a noticeable benefit to offset the adverse impacts. As a result, the overall cumulative impact would be adverse due to the continued lack of forest regeneration.

IMPACTS OF ALTERNATIVE B: PROPOSED ACTION

Impact Analysis

The control of invasive species is a critical element in reversing the declining forest at the park, particularly in the successional forests of Jockey Hollow and the mixed hardwood stands at the New Jersey Brigade unit. The treatment of invasive species would promote the establishment of native herbs, forbs, shrubs, and tree seedlings/saplings. As invasive species are reduced through these treatments, there would be less competition for resources (light, moisture, nutrients) for native species, and those native species would have the opportunity to regenerate. Over time, the application of treatments to control invasive species within the successional and mixed hardwood stands would likely reduce propagule pressure to mature stands where invasive species are not as prevalent. The use of mechanical or chemical treatments to control invasive plants may temporarily impact those native plants remaining in the forests. Impacts may include incidental mortality or the introduction of stress or injury to plants due to non-targeted chemical treatment. In conjunction with other actions, this invasive species management would create favorable forest conditions in the park over several decades by reaching the target goal of 550 to 900 sapling-size trees per acre and creating a regenerating mixed-age hardwood forest.

This alternative would include, as part of adaptive management, the manual planting of tree seedlings/saplings within the forest and existing gaps if, through monitoring, it is discovered that natural hardwood regeneration continues to be suppressed. The location and number of tree plantings would vary based on localized conditions and available funding. Plantings would be protected from deer using tubes, and competing vegetation would be removed surrounding each planting. This action may be needed to "jump-start" the recovery of a regenerating forest. This action would help create favorable forest regeneration conditions in the park by providing an artificial source of stems available to replace dying trees in the overstory canopy, thus continuing to regenerate the forest landscape.

If the above-discussed actions do not promote advanced regeneration, midstory shade removal actions may be undertaken. To address the existing condition of a heavily-shaded understory and the resulting lack of ground-level vegetation habitat, understory shade-tolerant trees would be selectively removed as needed in up to 100 acres of forest each year, dependent upon available funding. Up to 1,000 acres of understory shade trees could be treated in the first 10 years of plan implementation. The removal of understory shade would mimic natural disturbances and would allow more sunlight to reach the forest floor, promoting seedling establishment of overstory canopy tree species. This action, in combination with other actions such as invasive species control, would also promote the establishment of preferred native herbs, forbs, and shrubs (Ruffner and Groninger 2002). Vegetation biomass is expected to increase substantially in the lower layers of the forests within treatment areas that would be favorable to the establishment of a mixed age forest with overstory canopy, midstory, and understory native vegetation. This action would create favorable conditions for forest seedlings and saplings to become established, which would help create mixed age of the forests in the park over the next several decades.

Once gap management, invasive plant control, and midstory shade removal are implemented, the forests in the park would be expected to experience a direct response in the increase of native plants species and forest regeneration. As this occurs, the abundance of palatable food sources for deer would increase, thereby increasing the overall deer habitat quality and deer physical condition. These factors could cause the declining deer population trend to reverse. To keep deer density under control in the event of another population spike, alternative B would include treatments to maintain the deer population size at the target density of 20 to 25 deer per square mile; this would limit deer browsing of native vegetation species to a rate that should allow forest regeneration to occur (Tilghman 1989 and Stout 1999). Reduced deer browsing would allow for increased seedling/sapling numbers, which would ensure stem replacements in the canopy over time.

The 25 existing exclosure fences would remain for experimental purposes at the park under this alternative. Impacts to forest vegetation from exclosure fencing actions under alternative B would be the same as described under alternative A.

Cumulative Impact Analysis

The annual deer hunting seasons at the adjacent Lewis Morris County Park have resulted and may continue to result in a reduction in the number of deer browsing on forest vegetation. These impacts are described under alternative A.

The beneficial impacts of alternative B would contribute to the reduction in deer browsing on forest vegetation, which would promote forest regeneration. When considered with the actions identified above, alternative B would greatly contribute to the beneficial impacts on forest vegetation to which the other actions would slightly contribute. As a result, the overall cumulative impact would be beneficial due to the reduced deer browse and improved forest regeneration.

CONCLUSION

The continuation of current management under alternative A would result in adverse impacts on forest vegetation at the park, which is an important feature associated with the winter encampments of the Continental Army that the park was established to preserve (NPS 2003). Taking no action would continue the trend of a lack of advanced regeneration in the forests, which would eventually result in a loss of forest health and density. Although steps for early detection of invasive species outbreaks would continue, actions would be minimal to keep invasive species from spreading into non-invaded areas and to eradicate newly introduced invasive plants before they spread. In addition, should another spike in the deer density occur, such as the spike that occurred during the 1980s and 1990s, the condition of native forest vegetation would remain in peril as the deer would heavily browse on more palatable native species, leaving invasive species behind to multiply. The park contains robust natural resources of considerable diversity including within the mature forest stands (NPS 2003). Therefore, the loss of the density or diversity of the forest as a park resource would be counter to the park's general management plan goal to preserve park resources (NPS 2003) and would limit the ecological integrity of the park's native vegetation.

By comparison, alternative B would make available many tools for NPS staff to manage forest vegetation and deer browsing, which would result in the beneficial impact of promoting forest regeneration and allowing the National Park Service to preserve the important forest feature associated with the winter encampments. These treatments, including invasive plant management techniques, would occur at different rates and times inside and outside naturally occurring gaps, with gap treatments taking place first. The mature forest stands in the Jockey Hollow and New Jersey Brigade units were identified as high-quality, robust natural resources in the park's general management plan (NPS 2003). Treatments available under alternative B would promote forest regeneration and a mixed-aged forest, thus improving and preserving the ecological integrity provided by native forest vegetation in the park. This alternative would help the National Park Service achieve its goal of preserving park resources, as laid out in the park's general management plan (NPS 2003). The management actions under alternative B would work in combination to promote forest regeneration, thereby providing more beneficial impacts on forest vegetation in the project area than alternative A. Alternative B would best allow the National Park Service to preserve the important dense forest landscape and maintain the ecological integrity of native park vegetation.

IMPACTS ON WHITE-TAILED DEER POPULATION

METHODOLOGY

The evaluation of impacts on the white-tailed deer population was based primarily on a qualitative assessment of how expected changes to park vegetation (because of increased or decreased browsing pressure) would affect deer habitat and how these changes would affect the deer population itself. The evaluation also considered potential impacts to the deer population directly associated with implementation of the alternatives (e.g., change in daily movements to avoid sharpshooting).

Data on demographic factors such as sex ratio, age structure, and abundance are often collected by natural resource managers and used in modeling wildlife population dynamics. The dynamics of a population are determined by demographic factors and elements such as productivity, survival, harvest rate/mortality rate, and rate of population growth. These, in turn, are directly influenced by deer condition and indirectly by habitat quality (e.g., quality and quantity of available forage). Lastly, deer behavior and risk of disease occurrence and amplification are influenced by all the above.

Available information on the deer population (demographics, condition, population dynamics, behavior, and disease) was compiled and used as a basis for assessing potential changes in the deer population, as noted above.

IMPACTS OF ALTERNATIVE A: NO ACTION

Impact Analysis

Alternative A would continue the existing invasive species management methods and continue with NETN monitoring of invasive species, as discussed under the forest vegetation impact analysis above. Invasive species management actions would continue to vary depending on the target species and methods chosen for any particular control effort. Consequently, impacts on white-tailed deer by control of invasive species under this alternative would vary. Manual efforts such as hand-pulling or the use of a weed wrench of individual stems would likely be contained within small areas, causing only minimal habitat alterations. For chemical treatments, adverse impacts on individual deer are possible due to the ingestion of herbicides if consumed by deer within days after foliage applications. However, the use of chemical herbicides to control invasive plants would include only those herbicides known to have very low toxicity to animals.

Under alternative A, no plan would be in place to fully reverse the trend of invasive plants occupying much of the park and overtaking native vegetation that contributes to the overall habitat quality for deer. As described under the forest vegetation impact analysis above, invasive plants would remain a permanent fixture of the ecosystems at the park under alternative A, and the continual spread of invasive plants—and thus the loss of quality deer habitat—would likely continue. With the growing presence of invasive plants, fewer native plants would be available for browsing by deer, and the quality of browse for deer would deteriorate.

Under alternative A, no plan would be in place that would control the size of the deer population. Although the deer population density is currently lower than the target of 20 to 25 deer per square mile, there is potential for the population density to spike as it did in the 1980s and 1990s, given the complexity of factors affecting deer population dynamics such as mortality rates and recruitment, which are in turn affected by weather, food supply, and disease. At higher deer density levels, competition for habitat resources would increase, putting added stresses on the already-impacted forest understories. The park is dominated by invasive species in the understory across much of the forests as a result, in part, of deer browsing more palatable native plants. Without population control measures in place, overbrowsing from higher deer numbers could occur in the future, causing fewer food supplies for deer within the forests of the park. This would result in adverse impacts on the overall physical condition of individual deer and the deer population.

Under alternative A, white-tailed deer movement and behavior patterns would be unchanged because no new actions would be implemented that would cause deer to change home ranges and movement patterns within the park.

Cumulative Impact Analysis

The annual deer hunting seasons at the adjacent Lewis Morris County Park have resulted and may continue to result in some reduction of park deer numbers by removing deer that may range on both properties. Annual Morris County data shows that the total number of deer harvested each year at the county park varies widely, primarily due to weather conditions during the few days of the permitted hunt affecting hunter turnout and hunter success (Morris County Park Commission 2016). There are no data available to accurately know how many of these harvested deer also ranged onto the project area, but the percentage of deer using the project area and being subsequently harvested in Lewis Morris County Park is likely to be low. Nevertheless, the harvesting of deer at the county park to some degree helps to control deer numbers in the local region, thereby limiting the potential adverse impacts to the deer population from overpopulation.

The adverse impacts of alternative A would contribute to the possibility that deer numbers could spike in the project area resulting in too many deer competing for limited food resources, higher levels of starvation, and overall lower condition. When considered with the actions identified above, a spike in the deer population under alternative A would noticeably contribute to the adverse impacts on the white-tailed deer population, while the other actions would minimally offset impacts by slightly reducing deer numbers. As a result, the overall cumulative impact on the white-tailed deer population would be adverse due to the potential for an increase in deer population density and a continued reduction in adequate habitat.

IMPACTS OF ALTERNATIVE B: PROPOSED ACTION

Impact Analysis

Under this alternative, herbicide applications, removal of invasive plants by hand or with power tools would be used to control invasive species within the successional forests of Jockey Hollow, the mixed hardwood forests in the New Jersey Brigade unit, and existing forest gaps, as described under the forest vegetation impact analysis. Under these actions, deer could ingest herbicide-treated plants; however, the herbicides used to control invasive plants would include only those known to have very low toxicity to animals. Additionally, the use of some tools (such as chainsaws) would likely cause loud noises that could disturb deer. These treatments could cause temporary displacement for some individuals, as deer would likely avoid certain areas of the park while those actions are taking place. Because deer are tightly attracted to their home range, they would be expected to return to the project area after implementation actions are completed.

Over the long term, treatments of invasive species would provide a beneficial impact to deer. Removal of invasive species that dominate much of the forest understory would create favorable conditions for establishment of native plants and tree seedlings. Within an estimated timeline of approximately 8 to 12 years after treatments, habitat conditions for deer would be expected to improve, including increased numbers of native plants available for foraging and increased oak and hickory regeneration, enabling sustainability of the mast-producing species that are important for deer survival in harsh winters. Treated forest gaps, with the added sunlight received, would likely demonstrate extensive forest regeneration, creating dense stands of native vegetation interspersed across the park within a landscape of open forests and fields. These treated sites would be beneficial to deer by providing important sources of cover during extreme adverse weather conditions. Overall, the control of invasive species would result in improved habitat for white-tailed deer through increased food production, cover, and sustainability of the forests at the park.

Alternative B could include the direct reduction of the deer herd in the park if the population increases above the target density in the future. The number of deer to be impacted (i.e., removed) could be as high as 20 or 30 deer per year if a spike in the number of deer is ever determined to exceed the target range of 20 to 25 deer per square mile. In addition, changes in deer behavior are possible as a result of direct reduction of the deer population. These changes could occur due to human disturbance from NPS staff and/or contractors travelling to and from bait sites, occupying shooting areas, and discharging firearms (Williams, DeNicola, and Ortega 2008), and may result in variations in normal movement patterns of the deer population as deer seek to avoid sharpshooters. This could result in deer temporarily moving out of the project area and into adjacent lands and populated areas of varying habitat quality. However, direct reduction actions, if needed, are expected to only take place during a few weeks each year and limited to relatively small areas at any one time. Because deer are tightly attracted to their home range, they would be expected to return to the project area after implementation actions are completed (Underwood 2005; Porter et al 2004). Direct reduction actions would also provide beneficial impacts on the deer population by reducing deer browsing of native species, which would increase native understory density and species richness. This would increase the quality of the deer habitat in the project area, which may improve the health of the deer herd.

In conjunction with invasive species control and decreased deer browse, canopy thinning treatment methods implemented as necessary would improve forest regeneration. As discussed under the forest vegetation impact analysis, more sun reaching the forest floor would greatly enhance the environmental conditions for the establishment of native tree seedlings, herbs, forbs, and shrubs, which are palatable to deer. The increase in sunlight reaching the forest floor from the removal of midstory shade trees would help to stimulate plant growth and establishment where plants are otherwise shaded out. Stands targeted for midstory shade removal would therefore experience improvements in palatable plants available for deer forage that improve the health of the deer population.

Cumulative Impact Analysis

The annual deer hunting seasons at the adjacent Lewis Morris County Park have resulted and may continue to result in some reduction of park deer numbers by removing deer that may range on both properties. These impacts are described under alternative A.

The beneficial impacts of alternative B would contribute to the overall health of the deer herd over the next decades by improving habitat. The adverse impacts would temporarily result in changes to behavior of individual deer. When considered with the actions identified above, alternative B would noticeably contribute to the beneficial impacts on the white-tailed deer population to which other actions slightly contribute. As a result, the overall cumulative impact on the white-tailed deer population would be beneficial due to an improved deer habitat through removal of invasive species and promotion of native plant establishment and growth.

CONCLUSION

Under alternative A, the quality of deer habitat would be diminished due to a continued deteriorating forest condition, as invasive plants continue to spread into unoccupied areas, occupied areas choke out native species, and regeneration of native mast trees is prohibited. Alternative A would limit the National Park Service’s ability to achieve the park’s general management plan goal of resource protection because there would be no measures in place to control the deer population in the likely event of a future spike in density. Without population control measures, deer numbers could spike to high numbers and future overbrowsing could occur, causing fewer food supplies for deer in the park, resulting in adverse impacts on the overall physical condition of individual deer and the deer population. The loss of quality white-tailed deer habitat would be inconsistent with NPS *Management Policies 2006*, which instructs the National Park Service to protect the natural integrity of natural resources (NPS 2006c).

Alternative B would result in increased beneficial and reduced adverse impacts to the deer population over alternative A. Alternative B would introduce actions that are intended to reverse the trend of invasive species spread and inadequate regeneration of mast trees. Alternative B would promote better deer habitat than alternative A through the reestablishment of native plants palatable for deer browsing, particularly mast trees. The park's general management plan identifies the robust natural resources within the park as having considerable diversity. Actions under alternative B would improve the health of the deer herd and maintain their population within the park at a density that would promote ecological diversity and integrity of the park's native vegetation. This would be consistent with both the park's general management plan goals and NPS *Management Policies 2006* general principles for managing biological resources (NPS 2003; NPS 2006c). Invasive species would be controlled, forest regeneration would become established in the understory, and the goal of obtaining a regenerating mixed hardwood forest would be achieved. This mixed hardwood forest would offer an improved habitat for white-tailed deer. Although implementation of the actions under alternative B would result in some adverse impacts on individual deer such as noise disturbances due to the use of power tools, these impacts would be temporary and would not result in impacts on the deer population as a whole. Alternative B would allow to the National Park Service to protect the diverse natural resources within the park, including a healthy population of the native white-tailed deer.

IMPACTS ON THE CULTURAL LANDSCAPE

METHODOLOGY

Potential impacts on the cultural landscape are analyzed in terms of changes to character-defining features of the resources, based on the Director's Order #28: *Cultural Resource Management Guidelines* definition of a cultural landscape. Director's Order #28 defines a cultural landscape as "a reflection of human adaption and use of natural resources and is often expressed in the way land is organized and divided, patterns of settlement, land use, systems of circulation, and the types of structures that are built. The character of a cultural landscape is defined both by physical materials, such as roads, buildings, walls, and vegetation, and by use reflecting cultural values and traditions" (NPS 2002b). These features contribute to the property's integrity, which is composed of location, design, setting, materials, workmanship, feeling, and/or association.

The current conditions of the cultural landscape, as presented in chapter 3, were compared with the alternatives described in chapter 2 to determine the impacts on the cultural landscape. This section assesses impacts under the National Environmental Policy Act. An NHPA Section 106 assessment of effect on historic properties is presented in a separate section at the end of this chapter.

IMPACTS OF ALTERNATIVE A: NO ACTION

Impact Analysis

Under the no-action alternative, the cultural landscape would continue to be at risk of degradation due to deer browsing, invasive species encroachment, and closed canopies that when combined, would continue to inhibit forest regeneration, as discussed under the topic of “Forest Vegetation” above. The lack of forest regeneration would eventually lead to a reduction in the density of the forest areas, which would reduce the ability of the cultural landscape to remain reminiscent of the pre-Revolutionary War woodlots encountered by the Continental Army when they arrived in the area and of the Commemorative Period landscape that was managed in the decades after the park was established. Additionally, the dense woodlots screen from view the surrounding modern residential developments and roads from the historic area. Increasing the visibility of those modern developments by reducing forest density would detract from the authenticity and character of the cultural landscape’s setting.

Deer browsing would continue to result in a reduction of understory vegetation and hardwood seedlings, which is detrimental to forest regeneration, as discussed under the impact topic of “Forest Vegetation” above. Although the deer population density has been declining in recent years, as discussed in chapter 3, the population size has historically fluctuated due to varying factors. If the population of white-tailed deer increases in population density due to a lack of population control under alternative A, there could be an increase in deer browsing, which would result in an increased loss of historic appearance and character. Although the continuation of deer browsing would result in the loss of native understory, the lack of understory would continue to preserve partial views through the forest of the New Jersey Brigade unit downhill towards Indian Grave Brook, which were important views during the Encampment Period, as described in the park’s cultural landscape report (NPS 2004). However, the eventual loss of forest density due to the lack of native understory would result in a greater loss of historic character and appearance than would be preserved through these partial views.

Under the no-action alternative, the continuation of the current management measures to limit encroachment of invasive species into the cultural landscape would result in a somewhat preserved historic appearance. However, as discussed under the impact topic of “Forest Vegetation,” because the current invasive species management measures are not adequate, it is likely that invasive species would continue to be present and spread throughout the cultural landscape. This would result in a continued loss of historic appearance and character due to the presence of invasive species and the loss of native species that contribute to the cultural landscape.

Cumulative Impact Analysis

During scoping, the team considered other NPS and non-NPS projects to determine other actions that have or would have the potential to affect the cultural landscapes within the scope of this project. The team did not identify any past, present, or reasonably foreseeable actions by the National Park Service or other parties that would result in cumulative impacts on the cultural landscape. Therefore, there are no cumulative impacts on the cultural landscapes associated with alternative A.

IMPACTS OF ALTERNATIVE B: PROPOSED ACTION

Impact Analysis

Under alternative B, the actions undertaken to reduce deer browsing, reduce growth of invasive species, and reduce the canopy cover to improve hardwood forest regeneration would preserve and improve the cultural landscape. These actions would improve regeneration of the mature and successional forests within the project area, which would preserve the vegetation and dense forest that contribute to the historic appearance and preserve the landscape that Washington's Continental Army would have encountered when first arriving in the area and the landscape that the National Park Service managed during the Commemorative Period. Though the Continental Army eventually cleared much of the hardwood forests during their encampment, those native hardwood trees were crucial to the soldiers' survival, and therefore, impact the cultural landscape's ability to visually convey the historic importance of the pre-Encampment Period landscape to today's visitors. Additionally, the preservation and improvement of forest density would maintain the visual screening and noise dampening of the surrounding modern suburban developments and roadways, contributing to the preservation of the cultural landscape's appearance, feeling, and setting. Alternative B would result in a denser understory, which would obstruct the existing partial views from the New Jersey Brigade unit downhill that were important during the Encampment Period, resulting in a slight diminishment of the landscape. However, an obstruction of these views would not diminish the overall integrity of the cultural landscape because the understory would support a dense forest that would reflect the periods of significance, particularly the Commemorative Period. A reduction in invasive species growth would result in a reduction of plants that detract from the historic appearance of the landscape and enable the growth of native vegetation that contributes to the historic appearance and significance and of the cultural landscape.

Implementation of actions under alternative B would result in adverse impacts on the cultural landscape that last the duration of implementation of some actions. The use of power tools for removal of invasive species and the implementation of sharpshooting would create noise disturbances that detract from the periods of significance. However, these impacts would be limited to the duration of the actions. The duration of use of power tools would vary based on the number of plants to be removed as determined through annual monitoring and surveying. The first year of removal would likely require up to a few weeks of removal actions with power tools. Subsequent years may only require maintenance removal, which would require fewer days of noise disturbance within the landscape. Skilled sharpshooters would be able to conduct sharpshooting actions with as few shots as possible, which would minimize noise within the landscape. Therefore, even if sharpshooting activities take place over the course of several days, the noise disturbances impacting the landscape would only occur for a brief moment when a shot occurs. The duration of the noise disturbances from sharpshooting would vary by year, depending on the number of deer identified for removal. Because the current deer population is lower than the target density, no impacts due to sharpshooting would occur the first year. However, if future surveys indicate the population has increased and sharpshooting is required, noise disturbances over several days would occur. After the initial reduction, subsequent years may require fewer deer to be removed and, therefore, the duration of sharpshooting activities—and related noise disturbances—would be shorter. Noise abatement measures would be implemented, as outlined under "Forest Management Best Practices" in chapter 2, to reduce the intensity of these noise disturbances during implementation.

Cumulative Impact Analysis

During scoping, the team considered other NPS and non-NPS projects to determine other actions that have or would have the potential to affect the cultural landscapes within the scope of this project. The team did not identify any past, present, or reasonably foreseeable actions by the National Park Service or other parties that would result in cumulative impacts on the cultural landscape. Therefore, there are no cumulative impacts on the cultural landscapes associated with alternative B.

CONCLUSION

The continuation of current management under the no-action alternative would not result in new impacts, but would allow the overall trend of degradation of the cultural landscape to persist. This would limit the National Park Service's ability to ensure cultural resources are preserved, protected, and receive appropriate treatments and maintenance, as promoted in NPS *Management Policies 2006* (NPS 2006c). While the National Park Service would continue ongoing forest management actions, including removal of invasive species as time and funding allows, the impacts of the lack of hardwood regeneration in the park's forests caused by deer browsing and the continued spread of invasive species would result in a diminished quality of the cultural landscape as native canopy trees are not replaced via natural processes. Additionally, because current actions to remove and prevent invasive species encroachment are not adequate and there are no mechanisms to control heavy deer browse, invasive species that do not contribute to the character of the cultural landscape would continue to outcompete native species that do contribute. Over a period of decades, a gradual change in the forest composition from native to nonnative invasive species is expected to occur. Therefore, over time, the no-action alternative would result in a less dense forest that does not reflect the landscape first encountered by Washington's Continental Army or the landscape that existed during the Commemorative Period.

Alternative B would result in increased beneficial and reduced adverse impacts over alternative A. The forest setting is a very important feature of the cultural landscape of the park. Actions under alternative B would promote tree seedling germination, reduce invasive species competition, and control deer browse that would improve forest regeneration necessary to replace canopy trees lost to natural mortality. These actions would preserve and improve the dense forest that contributes to the historic appearance and character of the cultural landscape. The density of the forest would be maintained with native species, which would continue to visually screen the surrounding modern development from the cultural landscape, resulting in beneficial impacts. Although some adverse impacts would occur due to use of hand tools and equipment during invasive species removal and potential sharpshooting activities, noise abatement measures would be in place to minimize the noise disturbance during implementation. Overall, alternative B would improve and preserve the integrity of the cultural landscape. This would allow the National Park Service to follow the NPS cultural resource management program described in NPS *Management Policies 2006* and ensure cultural resources are protected and made available for public enjoyment and understanding, as well as to continue the park's establishing purpose to preserve the lands and features associated with the winter encampments of the Continental Army (NPS 2006c and 2003).

Neither alternative A nor alternative B would result in impacts on other character-defining features of the cultural landscape, including the circulation patterns, topography, geology, and small-scale features. Therefore, the cultural landscape would maintain its overall integrity and ability to reflect the periods of significance for the park under both alternatives. Both the Jockey Hollow and the New Jersey Brigade units would continue to be eligible for listing in the National Register as contributing resources to the park.

NATIONAL HISTORIC PRESERVATION ACT SECTION 106 ASSESSMENT OF EFFECT

The analyses of effects on historic properties that are presented in this section respond to the requirements of Section 106 of the National Historic Preservation Act, in accordance with the regulations implementing Section 106 (36 CFR 800, Protection of Historic Properties). The effects of alternative A (no action) and alternative B (proposed undertaking) are summarized below. The analysis of effects on historic properties was based on a review of previous studies, consideration of the proposed strategies, and other information provided by the National Park Service.

AREA OF POTENTIAL EFFECT

For this assessment of effect, the geographic study area is generally defined as the area of potential effect, as described in chapter 1 and shown on figure 2.

IDENTIFICATION OF HISTORIC PROPERTIES

Historic properties within the area of potential effect include the cultural landscape of Jockey Hollow and the New Jersey Brigade unit, which also contains the component landscapes of the Wick House and the Cross Estate, and known archeological resources. With the exception of the Cross Estate, these historic properties are all listed on the National Register as part of the historic district listing for Morristown National Historical Park (NRIS number 66000053), which is listed under Criterion A, for its association with the American Revolutionary War (NPS 1980). The Cross Estate was determined eligible for listing on the National Register under Criterion C for its landscape design (NPS 2011a).

The cultural landscape of Jockey Hollow and the New Jersey Brigade unit is described in detail in chapter 3. Also within this landscape are the component landscapes of the Wick House in Jockey Hollow and the Cross Estate in the New Jersey Brigade unit, briefly described below. The historic landscapes and settings of these properties are considered as part of the greater cultural landscape detailed in chapter 3.

The Wick House is located within Jockey Hollow and was built circa 1750 by Henry Wick on his farm property. The Cape Cod—style house was built on a hill surrounded by a heavily wooded area, farm fields, and orchards. During the Revolutionary War, the house was the headquarters of Major General Arthur St. Clair in the winter of 1779–1780. During that winter, two Continental Army brigades of the Pennsylvania line encamped on portions of the Wick farm (NPS 1980, 2009a). Today, the Wick House property is generally surrounded by successional forest and is addressed as part of the greater cultural landscape described in chapter 3.

The Cross Estate encompasses 162 acres in the New Jersey Brigade unit. It is located on a hilly landscape surrounded by mostly wooded terrain. The site is eligible for listing in the National Register for its landscape design and is significant at the local level. The estate was originally built in 1903, but underwent major renovations throughout the 1930s through early 1970s. The National Park Service acquired the property in 1975 as part of the park (NPS 2011a). Formal gardens, meadows, and lawns were maintained throughout the estate's history. Today, much of the Cross Estate property is covered by mixed hardwood forest (NPS 2011a) and is addressed as part of the greater cultural landscape described in chapter 3.

Archeological resources are known to occur throughout the area of potential effect, and the archeological record is well known due to previous archeological studies and surveys. These resources are generally important for their association with the Continental Army encampments during the Revolutionary War. Additionally, these resources have the potential to provide important information about the Revolutionary War era, including social and economic differentiation in American society, and regional and social variation in material culture (NPS 1980).

ALTERNATIVE A: NO ACTION

Under the no-action alternative, the continuation of current management would result in no adverse effect on historic properties. The no-action alternative would result in changes to the cultural landscape over the next several years and decades, including the potential for a thinning of the dense forest and understory as discussed under the "Impacts on Forest Vegetation" section above. However, the National Park Service would continue to implement existing forest management actions including monitoring programs, herbicide treatments, pulling of invasive plants, and public education and outreach. These actions would mitigate the potential for adverse effects on the cultural landscape. Although the forest would become less dense over time, the cultural landscape is not currently managed to reflect a specific period, but rather allowed to reflect ecological changes in vegetation over time, as discussed in chapter 3. Therefore, a reduction in forest density would not necessarily diminish the historic integrity of the cultural landscape. Additionally, the circulation patterns, small-scale features, topography, and geology that contribute to the cultural landscape would not be affected under the no-action alternative. The historic structures of the Wick House and the Cross Estate properties would not be affected under the proposed undertaking, and their landscapes are addressed as part of the Jockey Hollow and New Jersey Brigade unit cultural landscape. No other historic structures, objects, or archeological resources would be affected under the proposed undertaking. The Jockey Hollow unit, the New Jersey Brigade unit, the Wick House, the Cross Estate, and known archeological resources would continue to be eligible for listing in the National Register as contributing resources to Morristown National Historical Park. Therefore, implementation of the no-action alternative would result in no adverse effect on historic properties.

ALTERNATIVE B: PROPOSED UNDERTAKING

The implementation of the proposed undertaking would result in no adverse effect on historic properties. Actions implemented under the proposed undertaking to reduce deer browse, reduce growth of invasive species, and reduce canopy cover to improve hardwood forest regeneration would preserve and improve the cultural landscape, particularly the dense forested areas. These actions would improve regeneration of the mature and successional forests within the area of potential effect, which would preserve the vegetation and dense forest that contribute to the historic appearance and preserve the landscape that Washington's Continental Army would have encountered when first arriving in the area. Though the Continental Army eventually cleared much of the hardwood forests during their encampment, those native hardwood trees were crucial to the soldiers' survival, and contribute to the cultural landscape's ability to visually convey the historic importance of the pre-encampment landscape to today's visitors. Additionally, the preservation and improvement of the forest density would maintain the visual screening and noise dampening of the surrounding modern suburban developments and roadways, which would contribute to the preservation of the cultural landscape's historic setting and feeling. A reduction in invasive species growth would remove plants that detract from the historic appearance of the landscape and assist in the growth of vegetation that contributes to the historic integrity of the cultural landscape. Although some noise disturbance would occur due to the use of hand tools and equipment, noise abatement measures would be in place to minimize the noise disturbance during implementation, as outlined in chapter 2. These disturbances are expected to be minimal and temporary, and, therefore, would not result in an adverse effect on historic properties.

The circulation patterns, small-scale features, topography, and geology that contribute to the integrity of the cultural landscape would not be affected under the proposed undertaking. The historic structures of the Wick House and the Cross Estate properties would not be affected under the proposed undertaking, and their landscapes are addressed as part of the Jockey Hollow and New Jersey Brigade unit cultural landscape in the paragraph above. No other historic structures or objects would be affected under the proposed undertaking. Effects on archeological resources would be avoided by measures outlined in chapter 2. The cultural landscape would maintain its overall integrity and ability to reflect the periods of significance for the park under the proposed undertaking. The Jockey Hollow unit, the New Jersey Brigade unit, the Wick House, the Cross Estate, and known archeological resources would continue to be eligible for listing in the National Register as contributing resources to Morristown National Historical Park. Therefore, implementation of the proposed undertaking would result in no adverse effect on historic properties.

5

CONSULTATION AND COORDINATION

AGENCIES AND TRIBES CONSULTED

Agency and tribal consultation began early in the NEPA process and is ongoing to ensure that all relevant agencies are informed of any NPS planning actions. The National Park Service will continue to consult with relevant agencies and tribes, as appropriate, as the project continues. The National Park Service consulted with or is consulting with the following agencies and tribes:

- US Fish and Wildlife Service
- New Jersey Natural Heritage Program
- New Jersey State Historic Preservation Office
- Delaware Tribe Historic Preservation Office
- Delaware Nation Cultural Preservation Director
- Stockbridge-Munsee Community Tribal Historic Preservation Office

PUBLIC REVIEW

This plan will be on formal public and agency review for 30 days and has been distributed to a variety of interested individuals, agencies, and organizations. It also is available on the internet at http://parkplanning.nps.gov/morr, and hard copies are available at the park's headquarters.

SCIENCE ADVISORY TEAM MEMBERS

The following individuals participated as members of the science advisory team:

- Bob Masson, Biologist, NPS Morristown National Historical Park
- Sheila Colwell, Senior Natural Resources Program Manager, NPS Northeast Regional Office
- Dan Niosi, Environmental Protection Specialist, NPS Environmental Quality Division
- Kirsten Leong, Wildlife Biologist, NPS Biological Resource Management Division
- Ryan Monello, Wildlife Biologist, NPS Biological Resource Management Division
- Jenny Powers, CSU Wildlife Veterinarian, NPS Biological Resource Management Division
- Kate Miller, Plant Ecologist, NPS Northeast Temperate Network
- Brian Mitchell, Program Manager, NPS Northeast Temperate Network
- Eliot Foulds, Historic Landscape Architect, NPS
- Betsy Lyman, Liaison of the Northeast Exotic Plant Management Team, NPS
- Chuck Cutter, Silviculturalist, US Forest Service
- Brian Underwood, Research Wildlife Biologist, US Geological Survey
- Susan Predl, Wildlife Biologist, NJ Division of Fish and Wildlife
- Tim Davis, Senior Environmental Scientist, VHB
- Heidi West, Science Team Coordinator, TQ NEPA

PREPARERS AND CONTRIBUTORS

The following contractor team members served as preparers of or contributors to this document:

- Margaret Beavers, Environmental Scientist, VHB
- Tim Davis, Senior Environmental Scientist, VHB
- Doug DeBerry, Senior Environmental Scientist, VHB
- Erin Leatherbee, Preservation Planner, VHB
- Tracy Littell, Environmental Planner and former Project Manager, VHB
- Jennifer Morrissey, Senior Environmental Planner and Project Manager, VHB
- Mariah Murphy, former Environmental Scientist, VHB
- Kimberly Threlfall, Senior Environmental Planner, VHB
- Rita Walsh, Senior Preservation Planner, VHB
- Tricia Wingard, former Project Manager, VHB
- Heidi West, NEPA Planner, TQ NEPA

The following NPS interdisciplinary team members served as contributors to this document:

- Richard Aldridge, former Chief Ranger, Morristown National Historical Park
- Anne DeGraaf, Management Assistant, Morristown National Historical Park
- Jill Hawk, former Superintendent, Morristown National Historical Park
- Bob Masson, Biologist, Morristown National Historical Park
- Justin Monetti, former Chief of Interpretation, Morristown National Historical Park
- Thomas Ross, Superintendent, Morristown National Historical Park
- Sheila Colwell, Senior Natural Resources Project Manager, NPS Northeast Regional Office
- Carmen Chapin, Chief of Natural Resource Stewardship, NPS Northeast Regional Office
- Mary Foley, Chief Scientist Emeritus, NPS Northeast Regional Office
- Jennifer McConaghie, Resource Planning and Compliance Chief, NPS Northeast Regional Office

- Missy Morrison, former Resource Planning Specialist, NPS Northeast Regional Office
- Morgan Elmer, Project Manager, NPS Denver Service Center
- Tom Thomas, former Project Manager, NPS Denver Service Center
- Ann Van Huizen, former Project Manager, NPS Denver Service Center
- Dan Niosi, Environmental Protection Specialist, NPS Environmental Quality Division
- Kirsten Leong, former Wildlife Biologist, NPS Biological Resource Management Division
- Jenny Powers, CSU Wildlife Veterinarian, NPS Biological Resource Management Division

This page intentionally left blank.

REFERENCES

Bender
n.d. "Reducing deer damage to forest crops," Upper Peninsula Tree Improvement Center, Michigan State University.

Berheim, E. H., D. M. Wells, and J. A. Jenks
2016 "Interim Reports 2015 and 2016: An Evaluation of Techniques and Tools to Monitor and Model the Deer Population at Great Swamp National Wildlife Refuge." South Dakota State University, Brookings, SD.

Bormann, B. T., D. C. Lee, A. R. Kiester, D. E. Busch, J. R. Martin, and R. W. Haynes
2006 "Adaptive Management and Regional Monitoring." Chapter 10 in: R.W. Haynes, B.T. Bormann, and J.R. Martin (eds.). *Northwest Forest Plan—the First Ten Years (1994-2003): Synthesis of Monitoring and Research Results*. PNW GTR 651, USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

Boulanger, J. R., P. D. Curtis, E. G. Cooch, and A. J. DeNicola
2012 "Sterilization as an alternative deer control technique: a review." *Human-Wildlife Interactions* 6(2): 273-282.

Buckland, S. T., D. R. Anderson, K. P. Burnham, and J. L. Laake
1993 *Distance Sampling: Estimating Abundance of Biological Populations.* Chapman and Hall, London.

Centers for Disease Control and Prevention, Department of Health and Human Services (CDC)
2012 "Lyme Disease Prevention and Control." Accessed July 20, 2012. http://www.cdc.gov/lyme/.

Cheplick, G. P.
2010 "Limits to local spatial spread in a highly invasive annual grass (*Microstegium vimineum*)." Biological Invasions 12:1759-1771.

Christie, R. C. and M. W. Sayre
1989 "White-Tailed Deer Management Study, Morristown National Historical Park." Prepared for the U.S. Department of the Interior, National Park Service, Office of Scientific Studies.

Clevenger A. P., B. Chruszcz, and K. E. Gunson
2001 "Highway mitigation fencing reduces wildlife-vehicle collisions." *Wildlife Society Bulletin* 29: 646-653.

DeNicola, A. J., S. J. Weber, C. A. Bridges, and J. L. Stokes
1997b "Nontraditional techniques for management of overabundant deer populations." *Wildlife Society Bulletin* 25: 496-499.

Dibeler, B. J. and J. G. Ehrenfeld
1990 "Vegetation and Land-Use History of the New Jersey Brigade Area of Morristown National Historical Park, New Jersey, Since 1700". *New Jersey Academy of Science* 35(2): 1-11.

Dickmann, D, and D. Lantagne

1997 "Planting oaks for timber and other uses." North C entral Regional Extension Publication No. 605. Michigan State University. 12pp.

Ehrenfeld, J. G.

1977 "Vegetation of Morristown National Historic Park: ecological analysis and management alternatives final report." Center for Coastal and Environmental Studies, Rutgers University, New Brunswick, NJ.

1980 "Understory response to canopy gaps of varying size in a mature oak forest." *Bulletin of the Torrey Botanical* 107(1): 29-41.

1982 "The History of the Vegetation and the Land of Morristown National Historical Park, New Jersey, Since 1700." *New Jersey Academy of Science* 27(1): 1-19.

1999 "Distribution and dynamics of two exotic species, *Berberis thubergii* and *Microstegium vimineum* in Morristown National Historic Park." Dept. Ecology, Evolution, and Natural Resources, Rutgers University, New Brunswick, NJ.

Ehrenfeld, J. G. and B. J. Dibeler

1987 "Vegetation of the New Jersey Brigade Area of Morristown National Historic Park Final Report." Center for Coastal and Environmental Studies, Rutgers University, New Brunswick, NJ.

Eschtruth, A. K. and J. J. Battles

2009 "Assessing the relative importance of disturbance, herbivory, diversity, and propagule pressure in exotic plant invasion." Ecological Monographs 79(2):265-280.

Feldhamer, G. A., J. E. Gates, D. M. Harman, A. J. Loranger, and K. R. Dixon

1986 "Effects of interstate highway fencing on white-tailed deer activity." *Journal of Wildlife Management* 50: 497-505.

Federal Emergency Management Agency (FEMA)

2007 Flood Insurance Rate Map Summerset County, New Jersey. Panel 56 of 301, Map Number 34035C0056E.

Federal Geographic Data Committee (FGDC)

2008 "Vegetation Classification Standard, Version 2." Washington, DC. Accessed February 10, 2017. http://www.fgdc.gov/standards/projects/FGDC-standards-projects/vegetation/NVCS_V2_FINAL_2008-02.pdf

Flory, S. L. and J. Lewis

2009 "Nonchemical methods for managing Japanese stiltgrass (*Microstegium vimineum*)." Invasive Plant Science and Management 2:301-308.

Garrott, R. A. and D. B. Siniff

1992 "Limitations of male-oriented contraception for controlling feral horse populations." *Journal of Wildlife Management* 56(3): 456-464.

Gates, A. S.

1999 "The impact of intensive deer browse and invasive alien plants on breeding bird communities at Morristown National Historic Park." MS thesis, Rutgers University.

Handel, S. N.

1996 "Checklist of flowers and ferns, Jockey Hollow, Morristown National Historic Park, Morristown, New Jersey." Rutgers University Department of Biological Sciences, Piscataway, NJ.

Healy, W.
1997 "Influence of deer on structure and composition of oak forests in Central Massachusetts." In *The Science of Overabundance; Deer Ecology and Population Management*. Smithsonian Institution, 249–266. Washington, DC.

Horsley, S.B., S.L. Stout, and D.S. deCalesta
2003 "White-tailed Deer Impact on the Vegetation Dynamics of a Northern Hardwood Forest." *Ecological Applications* 13(1): 98-118.

Jones, J. M. and J. H. Witham
1990 "Post-translocation survival and movements of metropolitan white-tailed deer." *Wildlife Society Bulletin* 18(4): 434-441.

Kilpatrick, H. J., A. M. Labonte, and K. C. Stafford, III
2014 "The relationship between deer density, tick abundance, and human cases of Lyme disease in a residential community." *Journal of Medical Entomology* 51(4): 777-784.

Leak, W. B., D. S. Solomon, and S. M. Filip
1969 "A silvicultural guide for northern hardwoods in the northeast." U.S. Department of Agriculture, Forest Service Research Paper NE-143. Northeastern Forest Experiment Station, Upper Darby, PA.

Loftis, L. D.
2004 "Upland oak regeneration and management." In *Upland Oak Ecology Symposium: History, Current Conditions, and Sustainability*. *General Technical Report SRS-73*, edited by Spetich, M. A., 163-167. Asheville, NC: US Department of Agriculture, Forest Service, Southern Research Station.

Marquis, D. A., R. L. Ernst, and S. L. Stout
1992 "Prescribing silvicultural treatments in hardwood stands of the Alleghenies (Revised)." US Department of Agriculture Forest Service General Technical Report NE-96. Northern Forest Experiment Station.

McBride, T.
2006 "Coyote management: an integrated approach." New Jersey Fish & Wildlife Digest 20(1):20-21.

McShea, W. J
2000 "The Influence of Acorn Crops on Annual Variation in Rodent and Bird Populations." *Ecology* 81: 228-38.

Miller, G. W., J. N. Kochenderfer, and K. W. Gottschhalk
2004 "Effect of pre-harvest shade control and fencing on northern red oak seedling development in the central Appalachians." *In Upland Oak Ecology Symposium: History, Current Conditions, and Sustainability*. *General Technical Report SRS-73* edited by Spetich, M. A., 182-189. Asheville, NC: US Department of Agriculture, Forest Service, Southern Research Station.

Morris County Park Commission
2016 "Morris County Park Commission 2015/16 White-tailed Deer Management Program." Prepared by Kelli Kovacevic, Superintendent of Natural Resources Management, Morris County Park Commission.

Mulholland, Mitchell, Timothy Binzen, Christine Arato, Dennis Bertland, Christopher L. Donta, Sharon Swihard, Jan Whitaker, and Margaret Kelly

2001 "Integrated Cultural Resource Report, Morristown National Historical Park" Draft. Amherst, Massachusetts.

Murray, C., and D. Marmorek

2004 "Adaptive Management: A Spoonful of Rigour Helps the Uncertainty Go Down." Presented at the 16th International Annual Meeting of the Society for Ecological Restoration, Victoria, British Columbia, Canada, August 23–27, 2004.

National Park Service (NPS)

1980 National Register of Historic Places Inventory–Nomination Form for Morristown National Historical Park.

2002a "Director's CWD Guidance Memorandum." July 26.

2002b Director's Order #28: *Cultural Resource Management Guidelines*. NPS Office of Policy.

2003 *Morristown National Historical Park Final General Management Plan and Environmental Impact Statement*.

2004 Cultural Landscape Report for Morristown National Historical Park. Draft.

2006a "Elk and Deer Meat from Areas Affected by Chronic Wasting Disease: A guide to Donation for Human Consumption."

2006b "Integrated Pest Management Plan." Morristown National Historical Park.

2006c *Management Policies 2006*. National Park Service, Washington, DC. http://www.nps.gov/policy/MPandCC.pdf.

2008 Vegetation Classification and Mapping of Morristown National Historical Park, New Jersey. Technical Report NPS/NER/NRTR—2008/116. Northeast Region, Philadelphia, PA.

2009a Cultural Landscapes Inventory for Jockey Hollow, Morristown National Historical Park. 1999. Condition Reassessment 2009.

2009b *Get the Lead Out! An Initiative to Address Lead Reduction in National Park Service Natural Resource Activities*.

2011a Cultural Landscapes Inventory for Cross Estate, Morristown National Historical Park. 1998. Condition reassessment 2011.

2011b Director's Order #12: *Conservation Planning, Environmental Impact Analysis, and Decision-making*. NPS Office of Policy.

2012a E-mail from Robert Masson, Biologist, Morristown National Historical Park to Consultant Heidi West, regarding the effect of high winds on forest trees and mammal survey in the park.

2012b "Final Morristown National Historical Park Vegetation and Deer Management Plan/Environmental Impact Statement Science Team Report." On file at park headquarters.

2012c "A National Park Service Manager's Reference Notebook to Understanding Chronic Wasting Disease."

2014 "Forest Health Monitoring Update for Morristown National Historical Park."

2015 *NEPA Handbook*. September 2015.

2017 Morristown National Historical Park Deer Density Estimates 2004-2017. NPS unpublished data.

New Jersey Division of Fish and Wildlife (NJDFW)

2013 Chronic Wasting Disease Response Plan 2013.

2016a Chronic Wasting Disease FAQs, February 2016. Accessed February 8, 2017. http://www.state.nj.us/dep/fgw/pdf/cwdqanda.pdf

2016b "Coyotes in New Jersey." Updated April 6, 2016. Accessed February 7, 2017. http://www.state.nj.us/dep/fgw/coyote_info.htm.

2016c *New Jersey Hunting & Trapping Digest*. August 2016.

O'Bryan, M. K. and D. R. Mccullough

1985 "Survival of black-tailed deer following relocation in California." *Journal of Wildlife Management* 49(1): 115-119.

Ogle, T. F.

1971 "Predator-prey relationships between coyotes and white-tailed deer." *Northwest Science* 45: 213-218.

Owen, M. and D. Owen

1980 "The fences of death." *African Wildlife* 34: 25-27.

Pennsylvania Game Commission

2017 "Eastern Coyote" Accessed February 7, 2017. www.pgc.pa.gov/Education/WildlifeNotesIndex/Documents/coyote.pdf.

Pierce, A. R., G. P. Parker, and K. Rabenold

2006 "Forest succession in an oak-hickory dominated stand during a 40-year period at the Ross Biological Reserve, Indiana." *Natural Areas Journal* 26(4): 351-359.

Porter, W. F., H. B. Underwood, and J. L. Woodard

2004 "Movement behavior, dispersal, and the potential for localized management of deer in a suburban environment." *Journal of Wildlife Management* 68(2): 247-256.

Powers, Jenny and Anneke Moresco

2015 "Review of Ungulate Fertility Control in the National Park Service: Outcomes and Recommendations from an Internal Workshop – February 2012. Natural Resource Report NPS/NRSS/NRR—2015/1038." Fort Collins, CO.

Ruffner, C. M. and J. W. Groninger

2002 "Oak ecosystem restoration and maintenance in southern Illinois." In (M. A. Spetich, ed.) *Upland Oak Ecology Symposium: History, Current Conditions, and Sustainability*. Fayetteville, AR.

Russell, E. W. B.

1995 "Recommendation for Land Management, Jockey Hollow Area, Morristown National Historical Park." Prepared for the Department of the Interior, National Park Service, New England System Support Office.

2001 “The forests of Morristown National Historic Park and their future considerations.” Report to National Park Service, Morristown National Historic Park.

2002 “Changes in the forests of the Jockey Hollow Unit of Morristown National Historic Park Over the Last 5-15 Years.” National Park Service Technical Report NPS/BSO-RNR/NRTR/2002-9.

Salmon, P. A., and H. B. Underwood
2007 “Exploring the Feasibility of White-tailed Deer Fertility Control Programs”. National Park Service Technical Report NPS/NER/NRTR-2007/087.

Sexton, W. T., A. Malk, R. C. Szaro, and N. Johnson
1999 “Values, Social Dimensions, Economic Dimensions, Information Tools” In *Ecological Stewardship: A Common Reference for Ecosystem Management*, Volume 3. Oxford, UK: Elsevier Science.

Shaw, S. and W. A. Patterson III
2006 “Strategies for Managing the Forest at Morristown National Historical Park.” Technical Report NPS/NER/NRTR--2006/040. National Park Service. Boston, MA.

Siemer, W. F., K. M. Leong, D. J. Decker, and K. K. Smith
2007 “Deer, People, and Parks: Perspectives of Residents in Communities Near Morristown National Historical Park.” Human Dimensions Research Unit (HDRU Series Publication 07-10). Department of Natural Resources, Cornell University, Ithaca, NY. December.

Sneddon, L., R. E. Zaremba, E. Largay, G. Podniesinski, S. Perles, and J. Thompson
2008 “Vegetation Classification and Mapping of Morristown National Historical Park, New Jersey.” Technical Report NPS/NER/NRTR—2008/116. National Park Service. Philadelphia, PA.

Stafford, K. C.
2007 *Tick Management Handbook: An integrated guide for homeowners, pest control operators, and public health officials for the prevention of tick-associated disease.* Revised Edition. The Connecticut Agricultural Experiment Station. The Connecticut General Assembly.

Stout, S. L.
1999 “A conflict between forest renewal and white-tailed deer: a silviculturist’s perspective on values.” In *Proceedings, Conference on The Impact of Deer on the Biodiversity and Economy of the State of Pennsylvania September 24-25, 1999*, 27–39. Harrisburg, PA: The Audubon Society.

Tilghman, N. G.
1989 “Impacts of white-tailed deer on forest regeneration in northwestern Pennsylvania.” *Journal of Wildlife Management* 53(3): 524-532.

Trimble, G. R., Jr.
1973 “The regeneration of central Appalachian hardwoods with emphasis on the effects of site quality and harvesting practices. Resource Paper NE-282.” Upper Darby, PA: US Department of Agriculture, Forest Service, Northeastern Forest Experiment Station.

Tymkiw, E. L., J. L. Bowman, and W. G. Shriver
2013 “The effect of white-tailed deer density on breeding songbirds in Delaware.” *Wildlife Society Bulletin* 37(4): 714-724.

Underwood, H. B.
2005 *White-tailed Deer Ecology and Management on Fire Island National Seashore (Fire Island National Seashore Synthesis Paper).* Technical Report NPS/NER/NRTR-2005-022, Boston, MA.

United States Fish and Wildlife Service (USFWS)
2001 *Bog Turtle (Clemmys muhlenbergii) Northern Population Recovery Plan*. US Fish and Wildlife Service, Hadley, MA

United States Forest Service (USFS)
1965 *Silvics of Forest Trees of the United States.* Agricultural Handbook No. 271. US Department of Agricultural, Forest Service.

United States Geological Survey (USGS)
2007 *An Inventory of Terrestrial Mammals at National Parks in the Northeast Temperate Network and Sagamore Hill National Historic Site. Scientific Investigations Report 2007–5245.* Reston, Virginia.

Van Lear, D
2004 "Upland oak ecology and management." *Upland Oak Ecology Symposium: History, Current Conditions, and Sustainability. General Technical Report SRS-73* edited by Spetich, M. A., 65–71. US Department of Agriculture, Forest Service.

Vercauteren, K. C., T. R. Vandeelen, M. J. Lavelle, and W. H. Hall
2010 "Assessment of abilities of white-tailed deer to jump fences." *Journal of Wildlife Management* 74(6): 1378-1381.

Warren, R. J.
2000 "Overview of fertility control in urban deer management." In *Proceedings of the 2000 Annual Conference of the Society of Theriogenology*, 237–246. Society for Theriogenology, Nashville, TN.

Williams, S. C., A. J. DeNicola, and I. M. Ortega
2008 "Behavioral Responses of White-tailed Deer Subjected to Lethal Management." *Canadian Journal of Zoology* 86: 1358-1366.

Wohl, N.
1994 "Density and Distribution of Japanese Barberry (*Berberis Thunbergii*), an Exotic Shrub Species Naturalized in the Morristown National Historical Park, Morris County, New Jersey." Pennsylvania Cooperative Fish and Wildlife Research Unit, Merkle Laboratory. The Pennsylvania State University, University Park, PA.

This page intentionally left blank.

APPENDIX A

MORRISTOWN INVASIVE PLANT MANAGEMENT PLAN

This page intentionally left blank.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS

CFR	Code of Federal Regulations
DO	Director's Order
DOI	Department of the Interior
EDRR	early detection and rapid response
EPMT	Exotic Plant Management Team
IPMP	Invasive Plant Management Plan
ISED	invasive species early detection
NETN	Northeast Temperate Inventory and Monitoring Network
NISC	National Invasive Species Council
NISMP	National Invasive Species Management Plan
NPS	National Park Service
OSHA	Occupational Health and Safety Administration
the park	Morristown National Historical Park
P.L.	Public Law
RM	Reference Manual
USC	United States Congress
USDA	US Department of Agriculture

This page intentionally left blank.

MORRISTOWN NATIONAL HISTORICAL PARK
INVASIVE PLANT MANAGEMENT PLAN

1.0 INTRODUCTION

One of the largest threats to native plant communities at Morristown National Historical Park (the park) is the spread of nonnative, invasive plant species. Nonnative or exotic species are defined as species that have been introduced either deliberately or accidentally through human activities and are "likely to cause economic or environmental harm or harm to human health" (Executive Order 13112). Having been introduced into an environment in which they did not evolve, these organisms are capable of establishing self-sustaining populations and have no natural enemies to limit reproduction and spread (MacDonald et al. 1989). Invasive species exhibit early rapid and prolific growth and are able to out-compete native vegetation for space, light, water, and nutrients. Once introduced, management is necessary because invasive species are one of the leading threats to biodiversity and the ecological integrity of ecosystems worldwide (Mooney et al. 2005).

Within the United States, invasive exotic plant infestations cover approximately 100 million acres of land and are spreading at a rate of between 8 and 20 percent per year (BLM 1998). Currently over 1.4 million acres of National Park Service (NPS) lands are infested (NPS 2016) and in the fiscal year 2015, the NPS spent $18.27 million on invasive species management (NPS 2016). In New Jersey, 974 plant species, or about 30 percent of the State's flora, are nonnative with 72 species of nonnative plants also considered to be invasive. It is estimated that nearly 50 new plant species have been introduced to the state over just the last 25 years and that invasive plant species probably cover hundreds of thousands of acres in the state (NJISC 2009). Some invasive species not only alter ecosystem processes and reduce native biodiversity but also may transport disease, interfere with crop production, or cause illnesses in animals and humans. These species affect both aquatic and terrestrial habitats. For these reasons, invasive species are of statewide, national, and global concern (NISC 2016).

A total of 136 nonnative plant species have been identified across all vegetation communities at the park (see "Appendix A-1: Morristown National Historical Park NonNative Plant List"). Over 50% of these species inhabit forests within the park, the forest edge, or have the potential to rapidly invade forest openings created naturally (e.g., windfall) or for vegetation management purposes (e.g., promoting growth of oak species). Approximately 30% of nonnative plant species are also considered invasive with the potential to impact forest plant communities at the park, listed later in this document. Some species have been present at the park for several decades and have increased their distribution and density across the park landscape. For example, Japanese barberry (*Berberis thunbergii*) was present only in small isolated patches at the park in the 1970's and Japanese stiltgrass (*Microstegium vimineum*) was first detected in the park in 1989. A 1995 survey of park vegetation reported these species present in 45% and 55% of sample plots, respectively (Ehrenfeld 1999). A resurvey of these same plots in 2001 reported that Japanese Barberry had not spread, but the density of stems within its existing range had increased substantially (Russell 2002). Other species are new arrivals to the park such as mile-a-minute weed (*Polygonum perfoliatum*) which was detected in the park in August 2013. Recent monitoring by the Northeast Temperate Inventory and Monitoring Network (NETN) has determined that invasive plant cover is increasing for primary species such as Japanese barberry, which are increasing at a rate of 10-20% per cycle (every four years) in some plots (NPS 2017). Due to the ability of these highly invasive plant species to colonize and spread rapidly, they are considered a primary threat to native plant communities, particularly within forest canopy gaps, at the park. In accordance with NPS Management Policies (2006), the Morristown National Historical Park Invasive Plant Management Plan (IPMP) is being developed based on the determination that management of invasive plants is necessary as a critical element of an overall approach to forest vegetation management and to achieving the objectives of the Morristown National Historical Park Vegetation and White-tailed Deer Management Plan Environmental Assessment/Assessment of Effect (EA/AoE).

1.1 INVASIVE PLANT TREATMENT PLAN OBJECTIVES

The introduction and spread of invasive species is a dynamic process. The abundance and distribution of existing invasive species in the park may change, and new species may arrive despite the best efforts of the park. The following are goals and objectives for this plan; however, as a result, the species-specific management objectives may evolve over time.

Goal 1 — Prevention and Early Detection: Protect ecosystems from the impacts of invasive plants through an integrated and comprehensive approach, emphasizing the prevention of spread of invasive plants, early detection, and treatment of newly established populations.

Objectives for Goal 1:

- Incorporate preventive and follow-up measures to actions with the potential to bring new seed or reproductive material into the park (e.g., ground-disturbing construction, importation of roadside maintenance materials).
- Conduct surveys for new populations of invasive plants, and respond quickly to eradicate incipient populations before control treatments become difficult and costly.
- Minimize conditions that favor invasive plant introduction, establishment, and spread.
- Incorporate best management practice prevention measures associated with park operations to reduce the risk of new infestations of invasive plants.

Goal 2 — Prioritization and Control: Remove invasive plant populations that pose the greatest threat to park resources.

Objectives for Goal 2:

- Identify invasive species for control that pose the greatest threat to park resources and that are the most feasible to control.
- Establish and maintain feasible objectives for invasive plants.
- Use integrated pest management tools to find the most effective and appropriate tool, or combination of tools, to eradicate or reduce the impact of invasive plants.
- Minimize secondary impacts from control efforts.
- Reduce the impact of invasive plants on sites of cultural, scenic, and high ecological value, including historic viewsheds.

Goal 3 — Outreach and Education: Educate, inform, consult, and collaborate with park employees, concessioners, visitors, park partners, private property holders, and gateway communities to address invasive plant issues.

Objectives for Goal 3:

- Expand collaborative efforts among park neighbors, park partners, gateway communities, and the public to share methods of preventing and controlling the spread of invasive plants.
- Ensure that interested parties are well informed about the timing and locations of upcoming invasive plant control treatments.
- Educate and inform park visitors on invasive plant issues.
- Provide stewardship opportunities for the public.

Goal 4 — Monitoring and Research: Ensure that the invasive plant program is regularly monitored and improved, environmentally safe, and supported by science and research.

Objectives for Goal 4:

- Monitor and evaluate the effectiveness of control techniques and adapt them based on results.
- Document the abundance and distribution of invasive plants in the park.
- Detect changes in nonnative species distribution, abundance, and rate of spread.
- Identify vectors of spread to determine ways of preventing new species and populations from becoming established in the park.
- Promote research in the park upon which to base future management decisions.

Goal 5 — Ecological Restoration: Restore ecosystems and key ecological processes that have been impacted by invasive species to meet desired future conditions.

Objectives for Goal 5:

- Integrate ecological restoration practices in invasive plant control treatments to guard against infestations.

2.0 SUMMARY OF EXISTING INFORMATION ON INVASIVE PLANT SPECIES AT THE PARK

2.1 CHANGES IN FOREST VEGETATION OVER TIME: 1977-2001

Research related to the species composition and relative abundance of park forests was initiated by Rutgers University in 1977 (Ehrenfeld 1977). Historical data from earlier vegetation descriptions, witness trees, land-use records, and historical accounts were used to describe the current woody vegetation of the Jockey Hollow section of the park, evaluate the successional trends and ecological processes evident in the vegetation, describe the pre-settlement vegetation and land-use history of the area and provide recommendations for management. Ehrenfeld (1977) generally categorized wooded areas as “mature” and “successional” forest.

A total of 92 woody plant species were identified including 24 (26% overall) nonnative species. Successional forests were present on lands previously disturbed by past land management practices such as clearing for crops and pasture. Past land use and level of disturbance is likely directly related to the difference in level of infestation by nonnative plants between mature and successional forest areas of the park today (Ehrenfeld 1977, Kourtev et al. 1998, Russell 2002).

Management issues identified in 1977 included the growth of vines within successional forests, impacts associated with white-tailed deer, forest pests (e.g., gypsy moth) and disease, and the presence of nonnative plant species. Tree of heaven (*Ailanthus altissima*) and honeysuckle (*Lonicera* spp.) were reported as the most aggressive nonnative species. Privet (*Ligustrum* spp.) and Japanese barberry (*Berberis thunbergii*) were reported to have “disseminated throughout the woods” but they were noted to be not “sufficiently aggressive to outcompete the native vegetation.” Deer, while noted as abundant, were not considered to be a significant management problem at this time.

In 1993 and 1995, the same researcher returned to the park to evaluate changes in plant communities within “mature” and “successional” forests. The goals of this study were to (1) document the extent of exotic species occurrence throughout these two park areas, (2) determine whether the occurrence of exotic species was correlated with features of the forest structure or physical environment, (3) determine the patterns of spread of the two most important exotics, Japanese barberry and Japanese stilt grass, and (4) set up a system of permanent plots to monitor forest health into the future.

A total of 366 sample points were established along 49 transects throughout Jockey Hollow and the New Jersey Brigade area of the park for the purpose of documenting species composition (trees, shrubs, and herbaceous plants), including the presence of nonnative plants, and to determine the pattern of spread of two highly invasive species, Japanese barberry and Japanese stiltgrass (Ehrenfeld 1999). In 1993, Japanese barberry and Japanese stiltgrass were documented at 45% and 55% of sample points, respectively. Although Japanese barberry exhibited a preference for east- and southeast facing slopes, Japanese stiltgrass exhibited no environmental preference.

In 1995, small but significant increases in the populations of both species were documented. Although nonnative plant species were not described as interfering with natural processes such as forest regeneration at this time the level of deer browse on tree seedlings was described as “severe” and management recommendations included both control of deer browse and nonnative plants (Ehrenfeld 1999).

In 2001, Russell (2002) re-sampled a subset of vegetation plots established by earlier researchers in order to document changes in vegetation over time in forest areas where Japanese barberry and Japanese stiltgrass were present compared to areas where these species were absent (or sparse). Plots where these invasive plant species were present were reported as “almost completely lacking in regeneration of canopy species” (p. 9). Over time (1995-2001) the number of tree stems per plot in invaded sites decreased from 12.0 to 9.7 stems per plot compared to a minor decrease in uninvaded plots from 13.9 to 13.3 stems per plot (Russell 2002). The overall conclusion was that areas where Japanese barberry and Japanese stiltgrass were abundant were in danger of losing their forest canopy as canopy tree species died and were unable to be replaced. The synergistic connection between the herbaceous/ground layer and the forest overstory was referred to by Gilliam (2007) as “linkage”, a process-level phenomenon that has been observed in many eastern US forests. In some cases, researchers have noted that in addition to competitive interactions such as shading and nutrient requisition, invasive species in the herbaceous layer of a forest can change the soil chemistry and thus affect the ability for overstory trees to regenerate in otherwise suitable localized sites (i.e., gap-phase replacement, Muscolo et al. 2014).

A vegetation map for the park was completed in 2008. Fourteen associations were described, with eleven of these representing forested plant communities. Plant associations where invasive species such as Japanese barberry, multiflora rose, winged burning bush, oriental bittersweet, Japanese honeysuckle, Japanese stiltgrass, and garlic mustard were described as present to locally abundant in the shrub and herb layers included:

- Northern Piedmont Mesic Oak – Beech Forest
- Successional Tuliptree Forest
- Tuliptree – Beech – Maple Forest
- Northeastern Modified Successional Forest
- Northeastern Dry Oak-Hickory Forest
- Black Locust Successional Forest
- Southern New England Red Maple Seepage Swamp
- Smartweed – Cutgrass Wetland

During the field validation phase of the vegetation map, 48 nonnative plant species were documented. Seven nonnative plant species were also identified as invasive including Japanese barberry (*Berberis thunbergii*), garlic mustard (*Alliaria petiolata*), Japanese honeysuckle (*Lonicera japonica*), Amur honeysuckle (*Lonicera maackii*), oriental bittersweet (*Celastrus orbiculatus*), Japanese stiltgrass (*Microstegium vimineum*), and multiflora rose (*Rosa multiflora*).

2.2 NONNATIVE, INVASIVE PLANT LIST FOR THE PARK

In 2013, an overall list of nonnative plants present at the park was assembled through review of existing data and knowledge and experience of park staff and members of the NPS Northeast Exotic Plant Management Team. A total of 136 nonnative plant species was identified across all vegetation communities (see appendix A-1). Over 50% of these species inhabit forests within the park, the forest edge, or have the potential to colonize forest openings created naturally (e.g., windfall) or for vegetation management purposes (e.g., promoting growth of oak species).

Not all nonnative plant species are considered invasive and not all pose the same risk to native plant and animal communities. To narrow the focus of mapping and prioritizing the many nonnative plant species at the park, only those species considered to be invasive or potentially invasive (e.g., in forest canopy gaps) were considered in development of an invasive plant species management strategy at the park. A total of 37 nonnative plant species were considered invasive with the potential to impact forest plant communities at the park (table A-1). Determination of level of invasiveness was based on best professional judgment and site specific experience of park staff and members of the NPS Northeast Exotic Plant Management team and on available literature. Primary sources of technical information included the USDA Plants Database (available at http://plants.usda.gov/java/), the Center for Invasive Species and Ecosystem Health (available at http://www.invasive.org/), the Plant Conservation Alliance (available at www.nps.gov/plants/index.htm), and the New Jersey Invasive Plant Council (available at http://www.nj.gov/dep/njisc/).

Although nonnative plants that are also considered non-invasive were not considered in priority setting they do co-exist with invasive plant species and should be treated in the course of treating prioritized invasive plants.

TABLE A-1. NONNATIVE PLANT SPECIES CONSIDERED INVASIVE OR POTENTIALLY INVASIVE AND WITH THE POTENTIAL TO IMPACT FORESTED PLANT COMMUNITIES AT MORRISTOWN NATIONAL HISTORICAL PARK

Scientific Name	Common Name	Form	Duration	Listed as invasive by New Jersey
Ailanthus altissima	Tree of Heaven	Tree	Perennial	X
Actinidia arguta	Hardy kiwi	Vine	Perennial	
Robinia pseudoacacia	Black Locust	Tree	Perennial	X
Berberis thunbergii	Japanese barberry	Shrub	Perennial	X
Euonymus alatus	Winged euonymous, burning bush	Shrub	Perennial	X
Ligustrum vulgare	Japanese Privet	Shrub	Perennial	X
Photinia villosa	Oriental photinia	Shrub	Perennial	X
Rosa multiflora	Multiflora rose	Shrub	Perennial	X
Rubus phoenicolasius	Wineberry	Shrub	Perennial	X
Viburnum sieboldii	Siebold's virburnum	Shrub	Perennial	X
Celastrus orbiculatus	Oriental bittersweet	Vine	Perennial	X
Cynanchum louiseae (nigrum)	Black swallowwort	Vine	Perennial	X
Lonicera japonica	Japanese honeysuckle	Vine	Perennial	X
Persicaria perfoliatum	Mile-A-Minute Weed	Vine	Perennial	X
Wisteria sinensis	Chinese wisteria	Vine	Perennial	X
Alliaria petiolata	Garlic mustard	Herb	Annual	X
Cardamine impatiens	Narrowleaf bittercress	Herb	Annual, Biennial	X
Microstegium vimineum	Japanese stiltgrass	Herb	Annual	X
Polygonum caespitosum	Oriental ladythumb	Herb	Annual	
Ranunculus ficaria	Lesser celandine	Herb	Perennial	X
Acer palmatum	Japanese maple	Tree	Perennial	
Acer platanoides	Norway Maple	Tree	Perennial	X
Aralia elata	Japanese angelica tree	Tree	Perennial	
Paulownia tomentosa	Empress (Princess) Tree	Tree	Perennial	X
Styrax obasia	Fragrant Snowbell	Tree	Perennial	

Note: Determination of whether a nonnative plant was invasive or potentially invasive was based on available literature and best professional judgment of park staff and the NPS Northeast Exotic Plant Management Team and review of available literature. Determination of whether or not a plant is listed as invasive by New Jersey was based on NJDEQ Policy Directive 2004-02.

TABLE A-1. NONNATIVE PLANT SPECIES CONSIDERED INVASIVE OR POTENTIALLY INVASIVE AND WITH THE POTENTIAL TO IMPACT FORESTED PLANT COMMUNITIES AT MORRISTOWN NATIONAL HISTORICAL PARK (CONT.)

Scientific Name	*Common Name*	*Form*	*Duration*	*Listed as invasive by New Jersey*
Elaeagnus umbellata	Autumn olive	Shrub	Perennial	X
Rhodotypos scandens	Black Jetbead	Shrub	Perennial	X
Viburnum dilatatum	Linden viburnum	Shrub	Perennial	X
Akebia quinata	Five-leaf akebia, Chocolate vine	Vine	Perennial	X
Ampelopsis brevipedunculata	Porcelainberry	Vine	Perennial	X
Coronilla varia	Crown vetch	Herb	Perennial	X
Vinca minor	Common periwinkle	Herb	Perennial	X
Lonicera tatarica	Tartarian honeysuckle	Shrub	Perennial	X
Rhamnus cathartica	Common buck thorn	Shrub	Perennial	X
Spiraea japonica	Japanese spiraea	Shrub	Perennial	
Parthenocissus tricuspidata	Boston ivy	Vine	Perennial	
Polygonum cuspidatum	Japanese knotweed	Herb	Perennial	X

2.3 INVASIVE PLANT SPECIES ABUNDANCE AND MAPPING

In order to provide a visual overview of the extent and abundance of each invasive plant species, the park was divided into seven management zones based on anthropogenic/manmade boundaries including roads, trails and the park boundary (figure A-1). Units include the NJ Brigade, Tea Hill, Sugarloaf Hill, Inner Tour Road, Fort Hill, Mount Kemble, and the Warren property. Within each zone, each invasive plant species was determined to be present or not and, if present, assigned an abundance category (high, moderate, low, absent) by park staff and the NPS Northeast Exotic Plant Management Team based on available park data, professional judgment, and familiarity with on-the-ground conditions. Abundance categories were assigned uniformly across the management zones and therefore should be considered a maximum estimate. Those species that were both widely distributed across zones and most abundant (moderate to high abundance across the majority of zones) were garlic mustard, narrow leaf bittercress, Japanese stiltgrass, Japanese barberry, multiflora rose, and oriental bittersweet. Maps of the distribution and abundance of high occurrence of invasive plant species at the park are provided in "Appendix A-2: Nonnative Plant Species Mapping."

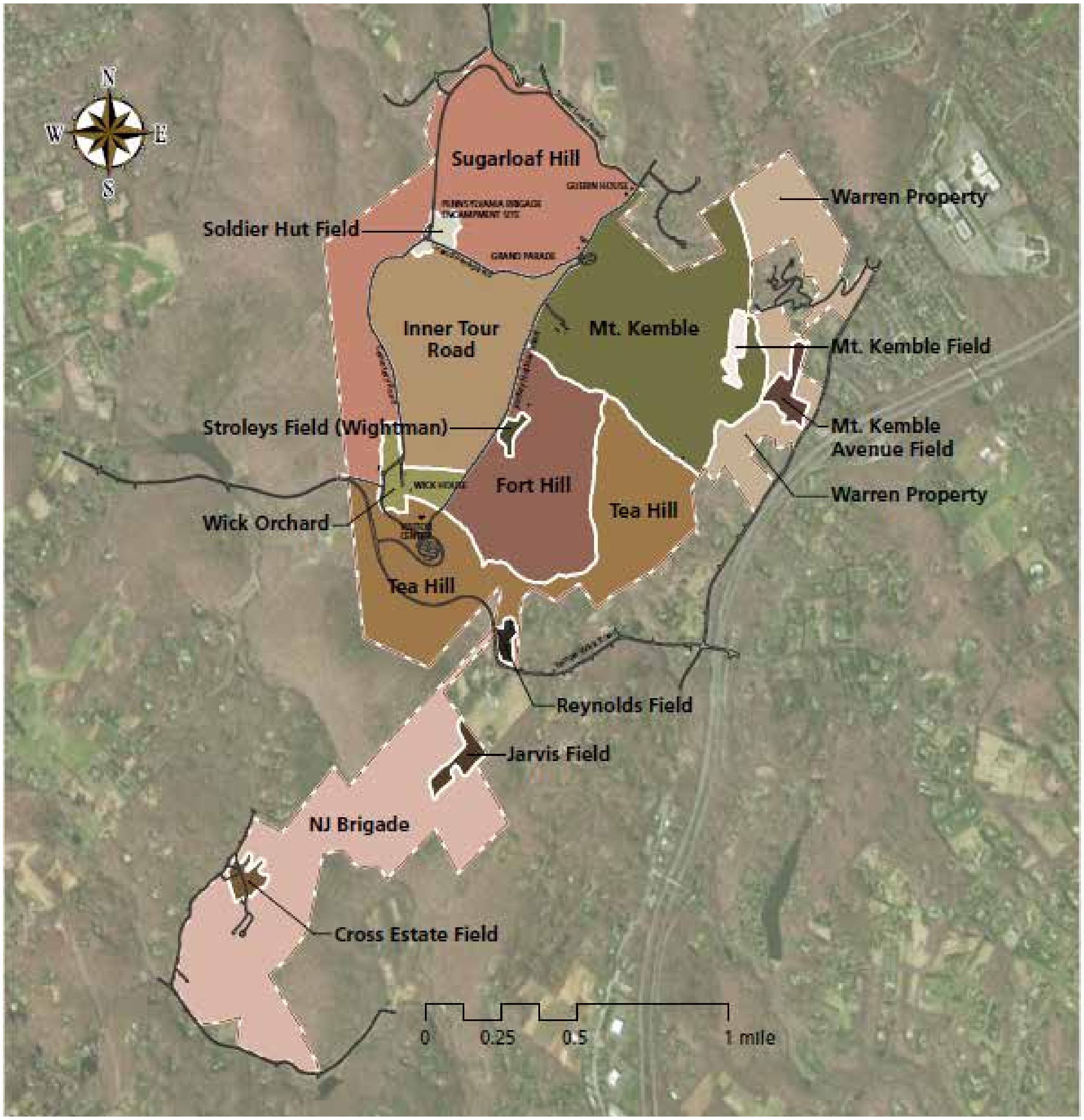


FIGURE A-1. MANAGEMENT ZONES (BASED ON ROADS, TRAILS, AND PARK BOUNDARY) USED TO MAP THE LOCATION AND ABUNDANCE OF NONNATIVE PLANT SPECIES AT MORRISTOWN NATIONAL HISTORICAL PARK

2.4 INVASIVE PLANT SPECIES PRIORITIZATION

The list of invasive plant species for the park was prioritized using methods outlined in the *Handbook for Ranking Exotic Plants for Management and Control* by Hiebert and Stubbendieck (1993). This method assesses each species according to its environmental threat potential and its current control/eradication potential. Initial steps in the prioritization process were to (1) develop a list of existing nonnative plants and (2) determine the location, extent, and abundance of nonnative plants (See Sections 2.2 and 2.3 above). This information was used to assess the current level of impact, the species' invasiveness, and abundance within the park. A comprehensive search of the literature for information on the ecology, biology, and control methods for each exotic species also contributed to the determination of species invasiveness as well as the feasibility of control or management (e.g., Swearingen et al. 2010). All information was then entered into the "Exotic Species Ranking System Data Form" and scores assigned. For each species, total score for level of impact was plotted against the feasibility of control on a four-quadrant grid to allow comparison based on these two primary factors (figure A-2). It should be noted that Heibert and Stubbendieck (1993) clearly state that the purpose of the system is to separate the more innocuous species from the disruptive species and that the actual numeric values have little meaning or value. Highest treatment priority is invasive species that pose a significant environmental threat but which are more easily controlled. The second priority includes species that pose a significant threat but are harder to control or manage (table A-2). The third priority for treatment is those species that pose a lesser threat and have a higher control potential, while species that pose a lesser threat to the environment combined with a lesser control potential are considered the lowest priority for treatment. As new nonnative plants are introduced to the park or significant changes occur in the extent or abundance of existing species, this ranking should be repeated.

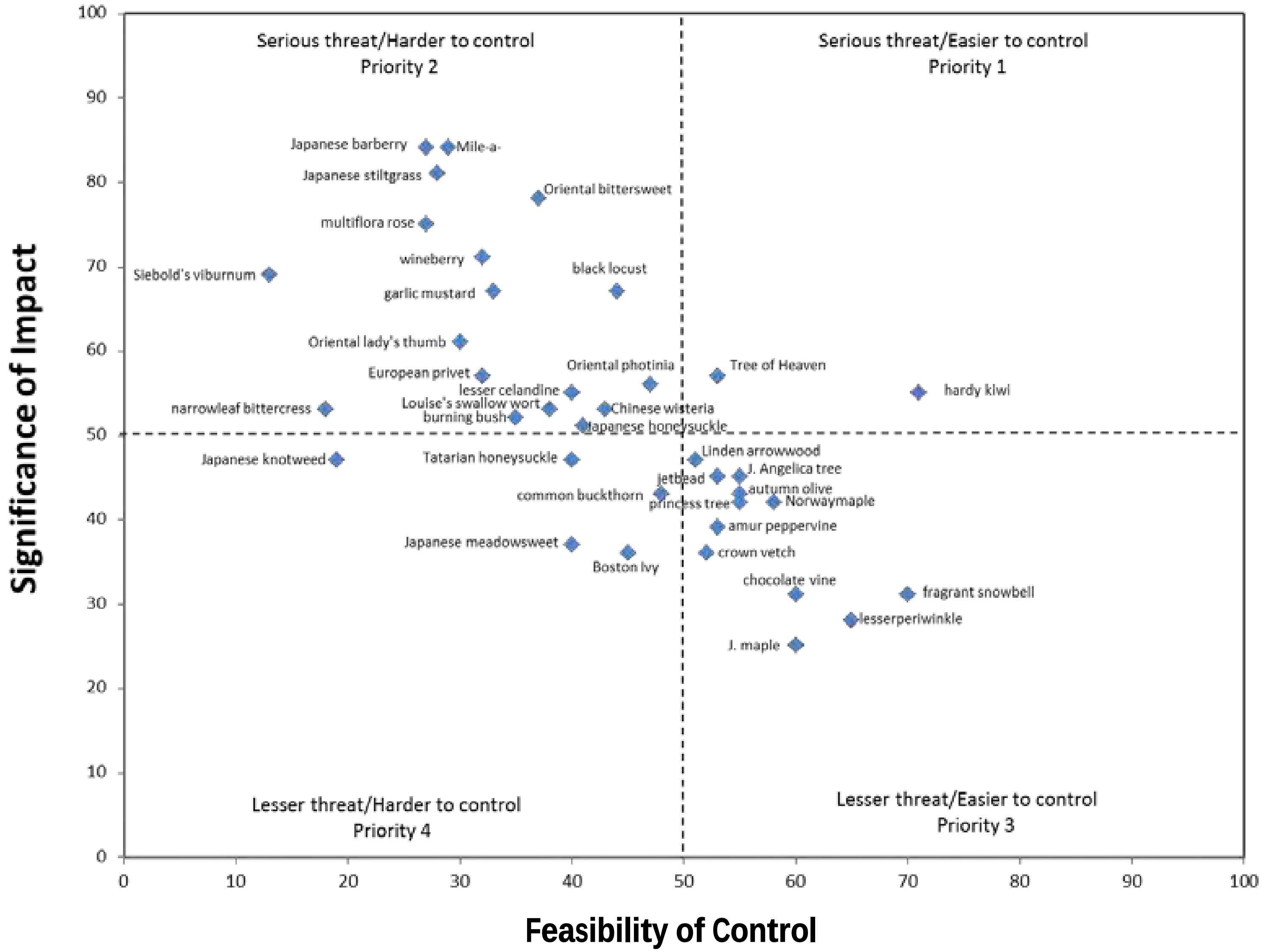


FIGURE A-2. PRIORITIZATION OF INVASIVE PLANT SPECIES AT THE PARK BASED ON ECOLOGICAL THREAT POTENTIAL AND SUCCESSFUL CONTROL POTENTIAL (BASED ON RANKING SYSTEM DEVELOPED BY HIEBERT AND STUBBENDIECK 1993)

TABLE A-2. LISTING INVASIVE PLANT SPECIES BY TREATMENT PRIORITY AT MORRISTOWN NATIONAL HISTORICAL PARK (BASED ON RANKING SYSTEM DEVELOPED BY HIEBERT AND STUBBENDIECK 1993)

Common Name	*Scientific Name*	*Treatment Priority*
hardy kiwi	*Actinidia arguta*	1
tree of heaven	*Ailanthus altissima*	1
oriental photinia	*Photinia villosa*	2
burning bush	*Euonymus alatus*	2
European privet	*Ligustrum vulgare*	2
black locust	*Robinia pseudoacacia*	2
wineberry	*Rubus phoenicolasius*	2
oriental bittersweet	*Celastrus orbiculatus*	2
multiflora rose	*Rosa multiflora*	2
Siebold's viburnum	*Viburnum sieboldi*	2
Japanese barberry	*Berberis thunbergii*	2
Japanese stiltgrass	*Microstegium vimineum*	2
garlic mustard	*Alliaria petiolata*	2
narrowleaf bittercress	*Cardamine impatiens*	2
lesser celandine	*Ranunculus ficaria*	2
Japanese honeysuckle	*Lonicera japonica*	2
Chinese wisteria	*Wisteria sinensis*	2
Louise's swallow wort	*Cynanchum louiseae*	2
mile-a-minute weed	*Persicaria perfoliata*	2
oriental lady's thumb	*Polygonum caespitosum*	2
linden arrowwood	*Viburnum dilatatum*	3
Japanese angelica tree	*Aralia elata*	3
jetbead	*Rhodotypos scandens*	3
autumn olive	*Elaeagnus umbellata*	3
Norway maple	*Acer platanoides*	3
princess tree	*Paulownia tomentosa*	3
amur peppervine	*Ampelopsis brevipedunculata*	3
chocolate vine	*Akebia quinata*	3
fragrant snowbell	*Styrax obasia*	3
Japanese maple	*Acer palmatum*	3
lesser periwinkle	*Vinca minor*	3
crown vetch	*Coronilla varia*	3
common buckthorn	*Rhamnus cathartica*	4
Tatarian honeysuckle	*Lonicera tatarica*	4
Japanese meadowsweet	*Spiraea japonica*	4
Boston ivy	*Parthenocissus tricuspidata*	4
Japanese knotweed	*Polygonum cuspidatum*	4

2.5 PARK INVASIVE PLANT MANAGEMENT ACTIONS

Efforts to inventory, monitor and manage nonnative, invasive plant species at the park began in the late 1990s. Current efforts have expanded from park staff and volunteers to include the Northeast Exotic Plant Management Team and the Northeast Temperate Network Inventory and Monitoring Program. Activities have included identification and mapping, mechanical and chemical control, early detection, and limited monitoring.

Invasive plant control has targeted species that are present in high abundance, represent an emerging threat or are on an early detection species list, impact historic landscapes, or pose a threat to rare plant communities. Implementation of this program has been based on the availability of park staff, volunteers and partners, and funding. Typically, removal projects have been conducted within discrete units with a project start and end point. More recently the park has implemented a strategy to treat some species on a cyclical basis.

Control of established invasive plants has been consistently implemented in historic (e.g., Soldier Huts and Wick Farm) or naturally significant areas (e.g. wetlands) and along the edges of invasions (e.g. forest edges). A combination of mechanical and chemical methods has been applied including cut stump with the application of Roundup or Garlon 3A, foliar application of herbicides, and use of a weed wrench for smaller plants. Generally, the location of control efforts are mapped with a GPS unit and coordinates are sent annually to the NPS Northeast Temperate Monitoring Network. Major invasive plant removal projects over the last 20 years are described below:

- An ambitious volunteer project was conducted to remove oriental bittersweet in 1999-2000 along four miles of park roads and 27 miles of trails. Most bittersweet vines were cut with a chain saw and no herbicides were used. Morristown National Historical Park and the Scherman-Hoffman Audubon Sanctuary also completed a joint oriental bittersweet control project in the early 2000's. Control using the same methods was conducted in the New Jersey Brigade Unit and in the adjacent Audubon property.
- In summer of 2002, all barberry stems were removed from a 90m x 90m plot by hand in preparation for the construction of a 2 acre exclosure. No herbicides were used. In 2007, as part of an encroachment settlement, 7.5 acres of Japanese barberry was removed between the Jockey Hollow Visitor Center and Wick Farm. The barberry was pulled by hand and removed off site. Park staff and volunteers have continued to remove invasive plants from this exclosure on an annual schedule including Japanese barberry, oriental photinia, oriental bittersweet, and multiflora rose. In 2008, A Rutgers University professor discovered the Barberry geometer (*Caryphista meadii),* a native moth species that consumes barberry leaves near the two acre exclosure. Barberry was monitored near the 2 acre exclosure and it was determined that there was only light defoliation that had resulted from the moth.
- In May of 2010, a contractor treated approximately 20 forested acres of Japanese barberry and multiflora rose (*Rosa multiflora*) within the Jockey Hollow Unit. Treatment consisted of a foliar application of a 2% solution of Garlon 3A mixed with water and a surfactant. A follow up treatment was completed on August 26, 2010. However, within three years after the treatment, the Japanese barberry and multiflora rose resprouted in the area and today are at pre-treatment density levels.

- In 2010, the park received assistance from New Jersey Invasive Species Strike Team interns. Focus of control efforts was emerging woody invasives such as Siebolds viburnum, oriental photinia (*Photinia villosa*) and Linden viburnum (*Viburnum dilatatum)*. Method of control was basal bark applications of Garlon 4 Ultra.
- A local garden club assisted the park with controlling Japanese barberry around a wet area that has been classified as a Montane Basic Seepage Swamp. The area was classified during development of the park's vegetation map. The swamp has been designated as G3 (rare or uncommon) by NatureServe and supports a high plant species diversity.
- Relatively recent invasions are treated as soon after initial documentation as possible and these species include Japanese knotweed (*Fallopia japonica)*, mile-a-minute weed (*Persicaria perfoliata*), oriental photinia (*Photinia villosa*), chocolate vine (*Akebia quinata)*, Japanese aralia (*Japanese aralia)*, porcelainberry (*Ampelopsis brevipedunculata*), and black swallowwort (*Vincetoxicum nigrum)*. Generally, these represent small populations that are treated using a foliar herbicide application (Accord XRT II, Garlon 3A, Garlon 4 Ultra). Kiwi vine (*Actinia arguta)* is manually cut at 1-2 locations.
- In 2015, Chinese bush-clover (*Lespedeza cuneata*) spread along park roads and trails, but has been effectively controlled by Garlon 4 Ultra.
- The State of New Jersey Department of Environmental Protection released a species of weevil (*Rhinoncomimus latipes)* that consumes only mile-a-minute weed, which has been effective in reducing density levels and stopping the spread of the mile-a-minute weed (NJDA 2014).
- In 2017, initial trials appear to indicate that pendimethalin at a rate of four quarts per acre is an effective control for Japanese stiltgrass.
- Prior efforts to control black swallowwort have been unsuccessful; in 2017, Escort XP and Garlon 3A will be used in an attempt to control the species.

2.5.1 Role of the Northeast Exotic Plant Management Team

The National Park Service currently has 17 Exotic Plant Management Teams (EPMTs) that assist parks in the management and control of invasive plant species. Within that capacity, they may be involved in activities including cooperation and collaboration, inventory and monitoring, prevention, treatment and control, and restoration. Teams vary in their structure and composition. However, all teams use or fund highly trained personnel to control invasive plants with the most efficient and effective methods available. Their efforts are focused on priority invasive plant populations that have been identified by the parks they serve. Each team serves multiple national parks and the Northeast EPMT serves 25 parks including the park. However, not all national park units are served by an EPMT. Information on EPMTs and the Northeast EPMT can be found at: http://www.nature.nps.gov/biology/invasivespecies/EPMT_teams.cfm

The Northeast EPMT initiated actions to control nonnative invasive plants at the park in 2004. Between 2004 and 2011, the EPMT has spent 3 days conducting inventory and monitoring activities at the park. A total of 18 days have been spent in the field implementing both mechanical and chemical control methods to spot treat (initial or retreat) 16 invasive plant species (table A-3). In total the area treated using all methods was approximately 10 acres over 8 years. Other EPMT activities conducted routinely are data management and reporting. Although limited time is spent in the field at the park, Northeast EPMT staff also are available to provide advice and guidance and the team contributed significantly to the development of this document.

TABLE A-3. SUMMARY OF NONNATIVE SPECIES TREATED AND TYPE OF TREATMENT CONDUCTED BY THE NORTHEAST EXOTIC PLANT MANAGEMENT TEAM AT MORRISTOWN NATIONAL HISTORICAL PARK BETWEEN 2004 AND 2016

Scientific Name	Type of Action	Treatment	Herbicide Product Name	EPA Registration No.	Chemical Common Name
Actinidia arguta	Mechanical	Cut (only)	n/a	n/a	n/a
Actinidia arguta	Chemical	Foliar-Ground-Spot	Accord Concentrate, Garlon 3A	62719-324, 62719-37	glyphosate IPA, triclopyr amine
Akebia quinata	Chemical	Foliar-Ground-Spot	Garlon 3A	62719-37	triclopyr amine
Ampelopsis brevipedunculata	Chemical	Foliar-Ground-Spot	Garlon 3A	62719-37	triclopyr amine
Aralia elata	Chemical	Foliar-Ground-Spot	Garlon 3A	62719-37	triclopyr amine
Berberis thunbergii	Chemical	Foliar-Ground-Spot	Accord Concentrate, Garlon 3A	62719-324, 62719-37	glyphosate IPA, triclopyr amine
Berberis thunbergii	Chemical	Foliar-Ground-Spot	Garlon 3A	62719-37	triclopyr amine
Celastrus orbiculatus	Chemical	Foliar-Ground-Spot	Garlon 3A	62719-37	triclopyr amine
Cynanchum nigrum	Chemical	Foliar-Ground-Spot	Garlon 3A	62719-37	triclopyr amine
Elaeagnus umbellate	Chemical	Foliar-Ground-Spot	Garlon 3A	62719-37	triclopyr amine
Euonymus alata	n/a	Inventory only	n/a	n/a	n/a
Lonicera japonica	Chemical	Foliar-Ground-Spot	Garlon 3A	62719-37	triclopyr amine
Microstegium vimineum	Chemical	Foliar-Ground-Broadcast	Pendulum AquaCap	241-416	pendimethalin
Microstegium vimineum	Chemical	Foliar-Ground-Broadcast	Plateau	241-365	imazapic
Microstegium vimineum	Chemical	Foliar-Ground-Broadcast	Journey	241-417	imazapic & glyphosate IPA
Photinia villosa	Chemical	Cut/Stump	Garlon 3A	62719-37	triclopyr amine
Photinia villosa	Mechanical	Pull/Dig	n/a	n/a	n/a
Polygonum cuspidatum	Chemical	Foliar-Ground-Spot	Accord Concentrate	62719-324	glyphosate IPA
Polygonum cuspidatum	Chemical	Foliar-Ground-Spot	Accord XRT II	62719-556	glyphosate
Rosa multiflora	Chemical	Foliar-Ground-Spot	Garlon 3A	62719-37	triclopyr amine
Styrax sp	Chemical	Basal Bark	Garlon 4 Ultra Specialty Herbicide	62719-527	triclopyr ester
Styrax sp	Chemical	Foliar-Ground-Spot	Garlon 3A	62719-37	triclopyr amine
Styrax sp	Chemical	Hack (w/herbicide)	Garlon 4 Ultra Specialty Herbicide	62719-527	triclopyr ester
Viburnum dilatatum	Mechanical	Pull/Dig	n/a	n/a	n/a
Viburnum sieboldii	Mechanical	Pull/Dig	n/a	n/a	n/a
Viburnum sieboldii	Chemical	Cut/Stump	Garlon 4	62719-40	triclopyr ester
Viburnum sieboldii	Chemical	Foliar-Ground-Spot	Garlon 3A	62719-37	triclopyr amine
Viburnum sieboldii	Chemical	Cut/Stump	Glypro	62719-324	glyphosate IPA

Source: EMPT APCAM database, extracted 10/18/2013

Notes: For the herbicide product name, where two different products have been mixed together for a chemical application both chemicals are indicated in the same box.

Journey herbicide is a premix of both glyphosate IPA and imazapic and, therefore, both chemical common names are provided.

TABLE A-3. SUMMARY OF NONNATIVE SPECIES TREATED AND TYPE OF TREATMENT CONDUCTED BY THE NORTHEAST EXOTIC PLANT MANAGEMENT TEAM AT MORRISTOWN NATIONAL HISTORICAL PARK BETWEEN 2004 AND 2016 (CONT.)

Scientific Name	Type of Action	Treatment	Herbicide Product Name	EPA Registration No.	Chemical Common Name
Viburnum sieboldii	Chemical	Foliar-Ground-Spot	Glypro	62719-324	glyphosate IPA
Viburnum sieboldii	Chemical	Cut/Stump	Transline	62719-259	clopyralid
Viburnum sieboldii	Chemical	Foliar-Ground-Spot	Glypro, Transline	62719-324, 62719-259	glyphosate IPA, clopyralid
Viburnum sieboldii	Chemical	Foliar-Ground-Spot	Accord Concentrate, Garlon 3A	62719-324, 62719-37	glyphosate IPA, triclopyr amine
Wisteria sinensis	Chemical	Foliar-Ground-Spot	Garlon 4 Ultra Specialty Herbicide	62719-527	triclopyr ester
Wisteria sinensis	Chemical	Foliar-Ground-Spot	Garlon 3A	62719-37	triclopyr amine

2.5.2 Role of I&M and Invasive Species Early Detection

In 2010, the Northeast Temperate Inventory and Monitoring Network (NETN) developed and implemented an invasive species early detection (ISED) program in 12 parks including Morristown. The ISED program was designed to facilitate detection of priority pests and exotic plants at early stages of establishment while the costs of eradication are still low and the chances of successful eradication are high. The stated objectives of the ISED program are to:

- Develop and maintain a list of target "watch" species that occur in localized areas of parks, are extremely rare, or are not currently present within a park, but have the potential to cause major ecological or economic problems if they were to become established;
- Detect incipient populations (i.e., small or localized) and new introductions of these target nonnative species before they become established in areas of high and moderate management significance;
- Develop, maintain, and distribute appropriate target species identification information for all NETN field crews, cooperators, resource managers and volunteers;
- Develop and maintain an early detection tracking system;
- Target limited management resources toward highest priority risks when there is the highest probability of successful treatment or eradication.

The major components of the ISED program include: 1) a target list of early detection species for each park; 2) laminated field guides for each park containing the target list and identification cards for each target species; 3) a reporting plan to ensure park managers and NETN staff are informed quickly of detections; and 4) data management and annual reporting of early detection and invasive species data. ISED target lists are reviewed periodically by NETN staff and species are removed when repeated detections indicate that a species is more established than previously thought and species are added based on detection of species with a high invasive potential near park boundaries. The current list of nonnative invasive plants on the park early detection species list is provided in table A-4 below.

Starting in 2013, NETN field crews recorded ISED sightings into the smartphone application “What’s Invasive,” and parks were encouraged to do the same. This application includes updated target lists for the park and automatically stores important data associated with the detection including GPS location, photographs, and extent of population. This information can later be downloaded as an excel spreadsheet from the website.

TABLE A-4. INVASIVE PLANT SPECIES EARLY DETECTION TARGET LIST FOR MORRISTOWN NATIONAL HISTORICAL PARK DEVELOPED BY THE NORTHEAST TEMPERATE NETWORK

Scientific Name	*Common Name*	*Park Status*
Akebia quinata	chocolate vine	X
Ampelopsis brevipedunculata	porcelainberry	X
Aralia elata	Japanese aralia	X
Cynanchum spp.	swallow-worts	X
Dioscorea oppositifolia	Chinese yam	X
Lonicera maackii	amur honeysuckle	XX
Oplismenus hirtellus ssp. undulatifolius	wavyleaf basketgrass	X
Parthenocissus tricuspidata	Boston ivy	X
Photinia villosa	oriental photinia	--
Polygonum perfoliatum	mile-a-minute	X
Pueraria montana var. lobata	kudzu	X
Ranunculus ficaria	lesser celandine	X
Rhodotypos scandens	black jetbead	X
Styrax japonicas	Japanese snowberry	XX
Viburnum dilataum	linden arrowwood	X
Viburnum sieboldii	Siebold’s viburnum	--
Wisteria floribunda/ W. sinensis	Japanese/Chinese wisteria	--

“X” indicates a species remaining on the list
“--" indicates a species removed from the list
“XX” indicates a species added to the list for 2013

3.0 RELATIONSHIP TO WHITE-TAILED DEER AND CLIMATE CHANGE

White-tailed deer enhance the ability of invasive, nonnative plants to establish and spread through selective browsing and removal of competing native plant species. Many nonnative plants are unpalatable to local herbivores or resistant to local pathogens (Keane and Crawley 2002; Latham et al. 2005). Species that are known to be unpalatable to deer include garlic mustard (*Alliaria petiolata*), Japanese barberry (*Berberis thunbergii*), Japanese honeysuckle (*Lonicera japonica*), Japanese stilt grass (*Microstegium vimineum*), and tree-of-heaven (Swearingen and Bargeron 2016). The invasiveness of unpalatable, nonnative plant species is exacerbated when they are avoided by deer in favor of more palatable native species (Anderson, Dhillion, and Kelley 1996; Williams 1996; Ward 2000). As native species in the forest understory disappear and food becomes scarce, deer become less selective but still avoid invasive species (Latham et al. 2005).

As described in earlier sections of this plan, the dense cover of nonnative species at the park such as Japanese barberry and Japanese stiltgrass, may prevent the establishment and growth of other plants even after release from heavy browsing (e.g., tree and shrub seedlings) (Horsley and Marquis 1983; Stromayer and Warren 1997; Waller and Alverson 1997). Bourg (2008) suggested that deer management, in the absence of invasive plant removal, may be insufficient to promote restoration of the native plant community.

Changes that are predicted to occur with changing climate near the park are likely to exacerbate issues related to the introduction and spread of nonnative plant species, including an increase in carbon dioxide, warmer temperatures (particularly in winter) and an increase in precipitation. These changes will have consequences for invasive, nonnative plants such as the introduction of new invaders and more rapid spread of existing species (Moran and Alexander 2014). For example, kudzu (*Pueraria lobata*) is a highly aggressive, nonnative plant that currently infests over 2.5 million acres in the southeastern United States. The presence of kudzu is limited in the northeast by winter low temperatures. As winter temperatures increase with climate change and this environmental constraint is removed, kudzu is expected to be able to colonize and become established in new locations, becoming a new invader to Northeastern states and possibly to the park.

Characteristics that some nonnative plants already possess will also allow them to adapt to a changing environment better than native species. Characteristics such as increased growth rates in response to increasing CO_2 and tolerance of a wider range of environmental conditions compared to native plants will promote colonization, establishment, and spread of species that already exist at the park such as mile-a-minute weed and oriental bittersweet.

4.0 PROPOSED INVASIVE PLANT MANAGEMENT ACTIVITIES

The scope of actions described in this IPMP describes long-term management of invasive plants that will:

- Comply with NPS policies and applicable laws and regulations;
- Encompass both existing and planned activities;
- Integrate with the Vegetation and White-tailed Deer Management Plan EA/AoE for the park;
- Address and integrate the activities in the park that contribute to prevention, early detection and rapid response, containment or control of existing populations of invasive plant species, and promote communication and collaboration with others; and
- Provide a flexible decision-making framework to facilitate future management of newly discovered nonnative, invasive plants and treatment options.

The strategy and actions described will allow the park to move from a program that lacks clear direction and is implemented on a spot treatment basis to a more comprehensive invasive plant strategy that will promote management at a park wide scale (and beyond) that is targeted toward high priority invasive plants and park environments, facilitates the most efficient use of park resources, and provides the highest probability of success.

Treatment methods will include mechanical and chemical techniques. Biological controls for control of invasive plant species are not included in this plan because they are species-specific with the primary biological control already present in the park.

Invasive plant management will be conducted using an Integrated Pest Management (IPM) approach as required by NPS policy and guidelines. IPM is a decision-making process that supports the NPS mission by coordinating knowledge of nonnative species biology, the environment, and available technology to prevent unacceptable levels of pest damage. This process helps the resource manager determine whether the treatment is necessary and appropriate, where the treatment should be administered, when treatment should be applied, and what strategies should be used for immediate and long-term results. IPM is done on a case-by-case basis, so that treatment strategies are tailored to local conditions. The IPM approach proposes treating existing species with available and feasible treatment methods. However, additional, potentially unidentified species are likely to invade in the future and new, effective control techniques. Thus, the process includes a framework for evaluating, decision-making, and implementing actions to control the impact of those species. The actions described in this plan are incorporated into the proposed action of the Vegetation and White-tailed Deer Management Plan EA/AoE:

- Regulatory Measures
- Prevention
- Early Detection and Rapid Response
- Treatment Methods
- Communication and Collaboration

4.1 PREVENTION

As described in the National Invasive Species Council *Management Plan 2016–2018* (NISC 2016) and New Jersey Strategic Management Plan for Invasive Species (NJISC 2009), prevention is considered the first line of defense. Once a nonnative, invasive species becomes established a sustained and significant effort may be required to control it, therefore preventing the introduction of new invasive species is considered the most environmentally and economically sound approach and should be a high priority. It is also considered a cultural treatment method. Prevention primarily involves identifying and avoiding the most common methods of nonnative invasive plant introduction and adopting best management practices to reduce the probability of introduction and spread.

The park would apply a series of prevention techniques and best management practices designed to prevent invasion and permanent establishment of invasive plants during the course of daily or routine activities and operations. General objectives of the best management practices and mitigation measures include:

- Incorporating nonnative invasive plant prevention and control into park planning;
- Avoiding introduction of nonnative invasive seeds, or removing sources that would introduce weed seed and propagules, to prevent new infestations and additional spread of existing species;
- Avoiding the creation of environmental conditions that promote nonnative invasive plant germination and establishment;
- Re-establishing vegetation to prevent conditions that promote establishment of nonnative invasive plants when project disturbances create bare ground;

- Setting work standards that prevent nonnative invasive plant spread; and
- Improving the effectiveness of prevention practices through increased awareness and education.

Examples of preventative measures that will be implemented at the park include:

- Adoption of the NETN standard operating procedure for limiting exotic species transport, including as a standard permit condition for researchers working in the park.
- Equipment used for invasive plant management and routine maintenance (e.g., roadside mowers) will be power washed and/or vacuumed after each use and prior to moving from one area of the park to another.
- Travel through the park either via vehicle, on foot, bike, etc. would occur only along authorized roads and trails whenever possible.
- Contractors and cooperators (e.g. power company) will be educated about the threats of invasive species, and how infestations can be prevented (e.g., cleaning vehicles, equipment, boots, etc.) Where appropriate, preventative measures will be included in contracts and agreements with outside entities.
- Use of native seed, local if available, purchased or collected for forest restoration/revegetation.
- Use of native plant species for use in ornamental landscaping unless otherwise required as an element of the cultural landscape.
- Reseeding or revegetation of disturbed areas following construction or other ground disturbing events. Disturbed sites will be closely monitored for five years after project completion to ensure that colonizing invasive plants are rapidly found and addressed.
- Educational and/or interpretive materials will be developed and provided to the public at key locations in the park that define nonnative, invasive plant species, provide examples of high priority species, describe actions the park is taking to address the introduction and spread, and provide information on how the public can help.
- Outreach and training will be provided across divisions in the park (administration, interpretation, law enforcement, facilities) to increase awareness and describe actions each division can take to contribute to invasive plant prevention and management.

4.2 EARLY DETECTION AND RAPID RESPONSE (EDRR)

While prevention is a high priority, of equal importance is actively watching for new invaders and acting quickly to remove them before they can establish and spread. Early detection and rapid response describes a program that detects early and eradicates or contains invasive species just beginning to establish in the park. It may also be used to describe efforts to prevent the spread of widespread invasive species into new areas. On-going monitoring of park landscapes is critical and this is the foundation of an EDRR program. Technical aspects of a successful program include: 1) reporting suspected new species to the park resource manager or appropriate entity; 2) identification and vouchering (as appropriate) of submitted specimens; 3) documentation of the location of new records in a spatially-referenced database; 4) assessment of potential impacts of the new introduction; and 5) rapid response to eradicate any new introductions that are deemed potentially invasive (NJISC 2009). A well-developed EDRR program has the potential to save the park a great deal of time and money. When management of an invasive species does not begin until the plant is readily visible in the landscape, has had several years to establish, develop a seed bank, and expand into adjacent areas, the potential for eradication decreases.

The park would continue to conduct invasive species early detection through the NETN as described in Section 2.5. Additionally, the following actions would be taken:

- Use of the NETN Invasive Plant Early Detection Protocol would be expanded to include the Northeast EPMT, park staff from other divisions that travel through the park on a regular basis, and volunteers as appropriate.
- Laminated early detection species cards would be provided to staff from other divisions and training would be provided on the protocol and species identification.
- The focus of EDRR at the park will be on those species identified on the NETN invasive species early detection list and those species categorized as Priority 1 or 2 invasive species (see Section 2.4) but not widely distributed across the park and with a low occurrence.
- Implementation would target high risk invasion pathways including along roads, trails, around parking areas, along power lines, and other high visitor use areas within the park. Other sites may be added based on specific projects such as those resulting in ground disturbance.
- The park would adopt use of the NETN smartphone application “What’s Invasive” to record early detection species. This application includes updated target lists for the park and automatically stores important data associated with the detection including GPS location, photographs, and extent of population that will facilitate rapid response actions.
- Promote increased coordination between the NETN and New Jersey Strike Team to ensure the invasive species early detection list developed by the NETN is as comprehensive as possible and updated appropriately and to facilitate the accurate and timely reporting and use of information by both partners.
- Promote increased coordination between the NETN and Northeast EPMT to: (1) provide identification of potential invaders either via the NETN smartphone application or physically (e.g., voucher specimen or site visit); (2) assess the potential impacts of the new introduction; and (3) include the Northeast EPMT in the reporting chain for new potential introductions. The Northeast EPMT will take the lead on assessing the potential impacts of new introductions using methods described by Hiebert and Stubbendieck (1993) to determine level of invasiveness/significance of impact for an individual nonnative species. Technical information on species biology may be contributed by specialists with the NETN as necessary. Inclusion of the Northeast EPMT in the reporting chain will facilitate rapid response as well as contribute information that can be used to update invasive species early detection lists for other parks they serve.
- NETN vegetation monitoring crews will be instructed to remove nonnative invasive plants on the invasive species early detection list within long-term vegetation monitoring plots based on the assumption that there will be only a few individuals that can easily be hand pulled with negligible disturbance (e.g., small tree and shrub seedlings).

The realities of globalization, reduced budgets, and limited staff and staff time lead to the assumption that nonnative invasive plants will likely continue to emerge in the park. Fortunately, not all nonnative plants become invasive and invasive species often undergo a lag period between introduction and subsequent colonization of new areas. Treatment methods used to implement rapid response as well as containment and reducing the spread of species that become established will be manual/mechanical, chemical, or a combination of both.

4.3 TREATMENT METHODS

Decisions on appropriate treatment method will be made using an IPM approach. IPM is a decision-making process that supports the NPS mission by coordinating knowledge of nonnative species biology, the environment, and available technology to prevent unacceptable levels of pest damage. This process helps the resource manager determine whether the treatment is necessary and appropriate, where the treatment should be administered, when treatment should be applied, and what strategies should be used for immediate and long-term results. IPM is done on a case-by-case basis, so that treatment strategies are tailored to local conditions.

Containing and reducing the spread of invasive plants on the early detection list and established invasive plant populations will be implemented to minimize their harmful impacts and promote achievement of the goals of the Vegetation and White-tailed Deer Management Plan EA/AoE. Control of established populations will focus on the highest priority sites and species across the park. Prioritization of sites across the park will be based on the best professional judgment of park staff with high priority given to protecting the most critical natural and cultural resources in an ecological context. For example, at the park, vegetation characterized as Montane Basic Seepage Swamp and ranked by NatureServe as globally rare or uncommon (G3) (NPS 2008) or mature forests characterized as less disturbed, with higher diversity and fewer invasive plant species compared to successional forests, may be high priority areas for treatment. As described above in Section 2.4, invasive plant species at the park have been prioritized based on level of invasiveness and ability to successfully control. Consistent with NPS *Management Policies 2006*, “higher priority will be given to managing invasive species that have, or potentially could have, a substantial impact on park resources, and that can reasonably be expected to be successfully controlled. Lower priority will be given to invasive species that have almost no impact on park resources or that probably cannot be successfully controlled” (NPS 2006). Treatment actions will include cultural, manual/mechanical, and chemical (herbicide) methods, as described below. Actions to control established populations of invasive plants will be conducted in partnership with the Northeast EPMT, and others (e.g., Student Conservation Association, AmeriCorps) where possible and appropriate.

4.3.1 Cultural Treatments

Cultural treatments are practices that promote the growth of desirable plants and reduce the opportunities for invasive plants to grow. Examples include irrigation and seeding of native plant species. Cultural treatment methods involve manipulating treatment areas to present invasive plants with effective native competitors. Examples of cultural treatments that could be implemented at the park include:

- Prevention (described in Section 4.1)
- Reseeding/Planting and Restoration

Reseeding/Planting and Restoration

Invasive species can severely alter the resiliency of native plant and animal communities and thus, their ability to recover post-treatment or post-disturbance. Restoration treatments are an integral part of control and management efforts to help guard against future re-infestations, the creation of "disturbed" areas that are quickly colonized by other nonnative plants, and to achieve long-term forest vegetation management goals described in the Vegetation and White-tailed Deer Management Plan EA/AoE. Restoration techniques may range from complex engineering endeavors involving correction of hydrology to simple tree seedling planting events conducted by volunteers. Restoration actions associated with control of invasive plant species described in the IPMP are limited to small scale actions associated with a specific treatment (e.g., manual/mechanical, chemical). Larger scale forest restoration is considered within the context of the Vegetation and White-tailed Deer Management Plan EA/AoE; actions outside of the EA/AoE would require a separate NEPA process.

Reseeding could be used to encourage the re-establishment of native plants and to prevent the establishment of invasive plants post manual/mechanical or chemical treatment. As part of restoring native plant communities, the park could reseed areas that do not have adequate seed banks to recover naturally, or in areas where native species can be used to out-compete invasive species. For this treatment option, parks would require that materials used for reseeding, planting and restoration be non-invasive, preferably native species, of the same genetic provenance (genotype) of the plants from a similar habitat in adjacent or local areas to maintain the integrity of park flora (NPS 2006). Overseeding (i.e., seeding on top of established vegetation) could be used in areas where park staff anticipates planted species to outcompete existing invasive species.

4.3.2 Manual/Mechanical Treatments

Manual treatments can be used in any area throughout the park and are most effective on shallow-rooted species. Manual pulling of deep-rooted species would not be implemented at the park due to the potential impacts on archeological and other cultural resources. In rare instances where this may be the only available method, the action would be preceded by an evaluation of applicable laws and policies under NEPA, including Section 106 of the National Historic Preservation Act of 1966. Hand pulling is conducted by removing as much of the root as possible while minimizing soil disturbance. However, it should be noted that disturbance of the soil can stimulate the seed germination of both native and nonnative species.

Mechanical treatments involve physical damage to or removal of part or all of the plant. Types of mechanical treatment include using hand cutting tools, pulling tools, power tools, or heavy equipment. Hand cutting tools are a treatment option for removing the aboveground portions of annual or biennial plants (Miller 2003). Use of hand tools, such as trowels, shovels, and pulaskis are simple forms of mechanical treatments. These tools can be used to remove a larger portion of the root system or to sever the plant's taproot below the point where nutrients are stored. Efforts would be made to collect and dispose of viable seeds from plants that are cut, or to cut plants when seeds are not viable. Pulling tools are a treatment option for removing individual plants that are deep-rooted and would be preceded by a site-specific NEPA evaluation. Pulling tools (e.g., weed wrenches™) could be used to control small infestations, such as when an invasive plant is first identified in an area. These tools grip the weed stem and remove the root by providing leverage. Pulling tools are most effective on firm ground rather than soft, sandy, or muddy substrates.

Power tools, such as mowers, are used to treat small to large infestations. Mowers work best in large, relatively flat treatment areas that do not include sensitive environmental resources. Weed whips and brush blades can be used at small sites, selectively around sensitive vegetation or sites that are inaccessible or are too rocky or too forested to be mowed. Power tools (such as weed whips, brush blades, chainsaws, tractors, or utility terrain vehicle-pulled mowers) remove aboveground biomass, reduce seed production, and reduce plant growth. Power tools do not remove biomass, which is sometime desired. Power tools are useful for controlling annual plants before they set seed. Power tools can also be used along with other treatments, such as chemicals, to treat perennial invasive plants.

Heavy equipment (such as bulldozers, tilling equipment, hydro-axe or heavy loaders, etc.) can be used to treat dense invasive plant infestations with greater control and efficiency. Heavy equipment would only be used in areas of dense invasive plant infestations, such as invasive tree infestations and conifer plantations, and where there are no natural or cultural resources that could be impacted by this equipment. The use of heavy equipment could trigger the need for additional, site-specific analysis under NEPA. Depending on the outcome of site-specific NEPA analyses, the park could decide to implement the use of heavy tools or determine that such activities would result in substantial impacts and therefore, preclude their use.

Mechanical methods are highly selective for individual plants and would generally be employed in concert with other treatments, such as the use of herbicides. For example, manual or mechanical treatments may be followed by application of pesticides to treat cut stumps, re-sprouts and new seedlings. Hand weeding by itself is typically ineffective in controlling large infestations of invasive plant species. Both manual and mechanical treatments could be used to treat individual plants or specific treatment areas.

Best management practices would be followed to ensure that the overall effectiveness of manual/ mechanical treatment is maximized and the potential for impacts is minimized. All contractors would also comply with these practices. These general best management practices include the following:

- A NPS job hazard analysis would be updated annually and provided to all individuals involved in manual/mechanical treatments.
- Treatment methods would be employed during the appropriate stage of the plant's life cycle (phenology) to increase effectiveness.
- Hand-pulling would be used at times of year when the root of the plant is most likely to be pulled intact (not broken at the crown, allowing it to resprout) from the soil.
- Compliance with Section 106 of the National Historic Preservation Act of 1966 will be ensured prior to initiation of any activities with the potential to cause surface/soil disturbance (e.g., use of a weed wrench).

4.3.3 Chemical Treatments

Non-selective herbicides can be effective for treating pure stands of a single invasive plant species in areas where desirable plants are scarce or absent. Herbicides can also be used to treat small patches of invasive plants where hand pulling or cutting is not feasible.

Using chemical treatments consists of applying herbicides, as prescribed by their labels and using a variety of application methods. Examples of application methods include portable sprayers, utility terrain vehicles equipped with sprayers, and hand-wicking. Recent technology has produced several specialty pesticides that are very selective in control of certain weed species at low application rates. These low application rates greatly reduce non-target plant effects and have resulted in successful control efforts in mixed plant communities.

Parks must obtain approval from either the Regional or National IPM Coordinator before using an herbicide or other pesticide. The combination of an active ingredient with compatible inert ingredients is referred to as a formulation. Pesticides are formulated for a number of different reasons including that a pesticide's active ingredient in a relatively pure form is rarely suitable for field application. An active ingredient usually must be formulated in a manner that increases pesticide effectiveness in the field, improves safety features, and enhances handling qualities.

A pesticide's formulation gives the product its specific characteristics. The unique formulation allows a pesticide to be used to treat specific species or to treat species under specified environmental conditions. Some of the pesticides described in this IPMP, for example, are formulated specifically for wetland use.

Pesticides have three names: trade name, common name, and chemical name (formula). For example:

- Roundup® (trade name);
- Glyphosate (common name, also the active ingredient); and
- N-(phosphonomethyl) glycine (chemical name)

A summary of pesticides available for the park to use to date under this plan is provided in table A-5 below. However, should additional herbicides appropriate for the park be approved by the EPA within the lifespan of this plan, those treatments would also be available for use by the park.

TABLE A-5. APPROVED CHEMICALS TO TREAT EXOTIC, INVASIVE PLANTS ON NPS-MANAGED PROPERTIES

Brand Name	Type	Active Ingredient	EPA Reg. No.	Notes
Element 3A/ Garlon 3A	Herbicides	Triethylamine salt of Triclopyr	62719-37	As a post emergent for hop and arum and as a pre-emergent. Has been used as a control for Japanese angelica tree, fiveleaf akebia, black swallowwort, snowbell.
Escort XP	Herbicides	Metsulfuron methyl	352-439	n/a
Milestone	Herbicides	Triisopropanolammonium salt of Aminopyralid	62719-519	n/a
Garlon 4 Ultra	Herbicides	Butoxyethyl ester of Triclopyr	62719-527	n/a
Polaris	Herbicides	Isopropylamine salt of Imazapyr	228-534	Only for phragmites
Sethoxydim E Pro	Herbicides	Sethoxydim	79676-4	Grass-specific
Rodeo	Herbicides	Isopropylamine salt of glyphosate	62719-324	n/a
Accord XRT II	Herbicide	Glyphosate	62719-556	For Japanese knotweed

Source: NPS

TABLE A-5. APPROVED CHEMICALS TO TREAT EXOTIC, INVASIVE PLANTS ON NPS-MANAGED PROPERTIES (CONT.)

Brand Name	Type	Active Ingredient	EPA Reg. No.	Notes
Pendulum AquaCap	Herbicide	Pendimethalin	241-416	For Japanese stiltgrass control
Indicator XL	Indicators	n/a	Exempt	n/a
Basoil Blue	Indicators	n/a	Exempt	For oil applications
Phase	Adjuvants	n/a	Exempt	New penetrant to use on Arum and potentially other species
Kinetic	Adjuvants	n/a	Exempt	n/a
Ammonium sulfate	Adjuvants	Ammonium salts	Exempt	n/a
JLB Oil	Carriers	vegetable oil	Exempt	n/a
Hygrade I	Carriers	n/a	Exempt	For oil applications

Herbicides could be applied a number of different ways, as follows:

- Foliar spray applications involve spraying green foliage with pesticide. Pesticides used for foliar application are mixed at low concentrations (typically 0.25–5 percent by volume) and are typically mixed with water, though a surfactant / adjuvant may be added to increase absorption by species with waxy leaves. An adjuvant is a substance added to a pesticide to aid its action, but has no pesticide action by itself. Some pesticides require the addition of an adjuvant to work effectively. Surfactants are adjuvants that are used in conjunction with pesticides to increase absorption. A surfactant is a surface active ingredient that lowers surface tension of the solvent in which it is dissolved or the tension between two immiscible liquids. Safety procedures, the Safety Data Sheets and the product labels must be available on site for all pesticides, surfactants and adjuvants used under the IPMP.
- Foliar applications are made with a low pressure (20–50 psi) backpack sprayer at rates of one gallon or less per minute. Foliar treatments are applied after full leaf expansion in the spring and before leaf senescence in the fall. Pesticide treatments are dried, for example, for at least one hour at an air temperature above 60°F to ensure adequate absorption and translocation. However, the drying time and temperature varies with the chemical and formulation. In areas that receive significant public use, it is often necessary to close off the treatment area until the pesticide has completely dried. Pesticides used at the park are typically applied with a backpack, motorized spray tank, or similar hand-operated pump sprayer equipped with a flat spray tip or adjustable cone nozzle. Spray is applied to the leaves and stems of target plants using a consistent back and forth motion to promote complete and consistent coverage. Pesticides would be applied so that they thoroughly cover foliage, but not to the point of run-off.
- Cut surface applications include cut stump methods, hack and squirt, and frill (girdle). Higher concentrations of pesticide (10–50 percent by volume—mixed with either water or penetrating oil) are usually used in cut stump applications. The main advantages to these methods are: (1) they are very economical, (2) there is minimal probability of non-target damage through drift or overspray, (3) minimal application time, and (4) they can be used in the winter with appropriate pesticide as long as snow depth does not impede proper application to root collar. Backpack sprayers or spray bottles are also effective for all of these methods. There are four types of cut stump methods that could be implemented under the IPMP:

- Cut Stump Method: Horizontally cut stems at or near ground level; all cuts should be level, smooth, and free of debris. Pesticide is applied immediately to the cambial area (i.e., the lateral meristem, including the vascular cambium and cork cambium) of the stump and root collar.
- Girdling Method: Bark is removed from the entire circumference of the trunk of a woody plant with pesticide applied to the exposed area, resulting in the death of wood tissues beyond the damage. This method allows for the removal of an individual tree within an ecologically protected community.
- Hack and Squirt Method: Using an axe or similar cutting tool, uniformly spaced cuts are made around the base of the stem. The cuts should angle downward, be less than 2.5 cm (1 inch) apart, and extend into the sapwood. Apply pesticide to each cut to the point of overflow.

Basal bark applications involve applying pesticide to the bark of uncut stems near ground level. Ground level is usually avoided to avoid collateral problems with roots of other plants growing in and around the target species. Basal bark applications are usually mixed at higher concentrations (10-50 percent by volume) and mixed with vegetable or petroleum based oil. This method is used on species that sprout prolifically if the stem is cut (such as Tree of Heaven or black locust). A variant of this method is injecting stems/trunks with a small dose of pesticide. Devices such as the EZ-Ject® Lance as well as other products are used to implement this method. Basal bark treatments are effective for controlling woody vines, shrubs, and trees. Treatments can be made any time of year, including the winter months, except when snow or water prevents spraying the basal parts of the stem. Proper plant identification is crucial during the dormant season due to the absence of foliage. Pesticide is applied with a backpack sprayer using low pressure (e.g., 20-40 psi) with a straight stream or flat fan tip. To control vegetation with a basal stem diameter of less than 7.6 cm (3.0 in) the park would typically apply specified pesticide-oil mixture on one side of the basal stem to a height of approximately 15.25 cm (6 in) from the base. Pesticide is applied to the point of run-off; within an hour mixture should almost encircle the stem. For stems greater than 7.6 cm (3.0 in) basal diameter or with thick bark, treat both sides of the stem to a basal height of 30.5 cm (12 in) to 61 cm (24 in).

Individual plant treatments can also be applied with the use of glove applications, hand wicking, and swiping. Glove applications involve the selective application of pesticides to targeted plants. This is achieved by first applying pesticide to an absorbent glove covering an impermeable glove that protects the applicator’s hand from contact with the pesticide. The pesticide is then transferred to the targeted plant by contacting it with the saturated glove. Hand wicking is well suited for applications on spot patches of invasive species. Swiping is typically done with an apparatus consisting of a fabric wrapped bar that has been treated with pesticide. The bar is held between two individuals or mounted on equipment and passed over the target species. The bar can be raised to selectively treat different species to minimize contact with shorter stature non-target species.

A non-toxic marking dye, which aids in detecting areas already treated, is typically mixed with the chemical in all application methods described above.

Use of pesticides would be considered only after manual/mechanical or cultural treatment methods have been ruled out. Under some circumstances, pesticides may be the only feasible option for managing an invasive plant. Pesticides and formulation selected for treatment would be known to be effective on the target invasive plant and known to have a minimal effect on the environment. To minimize potential environmental effects, pesticides and their respective formulations would be selected based on the presence of non-target plants (including sensitive, threatened and endangered, and traditional use plants), soil texture, depth and distance to water, and environmental conditions.

Only those pesticides that have been registered by the EPA, and permitted for use by the state of New Jersey would be used at the park. When considering the use of a chemical treatment, the park resource manager would confirm that its use is necessary and that all other treatment options are either not acceptable or not feasible. The resource manager would also confirm that use of the selected pesticide is appropriate for the site and that it has the potential to be effective on the target species. Similarly, to determine the potential for surface water contamination, the resource manager would consider the potential effects of any selected pesticide based on its distance to streams, rivers, or other water bodies; soil types where application is proposed; and the leaching potential of the selected pesticide. Taking these extra steps would help to ensure that the most appropriate and cost-effective pesticide is selected. These considerations would be evaluated in cooperation with the Northeast EPMT and the NPS Regional IPM Coordinator.

Pesticides are classified according to their mode of action, which is determined by the active ingredients. For example, 2,4-D, Aqua-Kleen®, Barrage®, Esteron® brand 99, and Weedone®, whose active ingredient is 2,4-D, are plant growth regulators that stimulate nucleic acid and protein synthesis and affect enzyme activity, respiration, and cell division causing plant cells to divide and grow uncontrollably. The pesticide 2,4-D is absorbed by plant leaves, stems, and roots and moves throughout the plant, and is accumulated in growing tips. In another example, Accord Concentrate, Accord XRT II, Journey, Glypro, and Roundup, whose active ingredient is glyphosate, are absorbed through plant leaves and soft stem tissue and move both up and down within the plant. Glyphosate acts by preventing the plant from producing an essential amino acid. This reduces the production of protein in the plant and inhibits plant growth.

Pesticides containing active ingredients that are not listed on table A-5 may also be used under the park IPMP if they meet all conditions outlined in this document and are approved by the Regional or National IPM Coordinator. Each pesticide varies in terms of its chemical and biological behavior in the environment, and those behaviors are typically disclosed on the product’s label and/or manufacturer’s website. However, for informational purposes in this plan, factors that affect pesticide behavior in the environment include pesticide properties, soil characteristics, and climatic conditions. Factors that influence the behavior of pesticides in the environment are summarized below. This summary is based on information provided by Tu, Hurd, and Randall (2001) in The Nature Conservancy’s Weed Control Methods Handbook:

- Acid or base strength — refers to whether a pesticide has basic, acidic, or non-ionizable properties. This factor determines the ability of a pesticide to exist in soil water or be retained onto soil solids. In general, pesticides whose pH is close to the pH of soil are strongly retained and are not subject to runoff, erosion, and/or leaching. In contrast, pesticides whose pH is not close to that of the soil are less strongly retained and are subject to runoff, erosion, and/or leaching. These pesticides are also more available for plant uptake than those pesticides that are strongly retained onto soil solids.
- Water solubility — refers to how readily a pesticide dissolves in water and determines the extent to which a pesticide is in the solution (water) phase or the solid phase. How readily a pesticide

dissolves determines the tendency for pesticides to move or transfer from water to air, soil, and organisms. A pesticide that is water soluble generally does not have long-term residual effects.

- Volatility — refers to the tendency of a pesticide molecule to become a vapor. Volatility is critical for predicting the tendency of pesticides to move from the site of application to air, water, soil, and plants/organisms. Pesticides with high vapor pressures are likely to escape from the soil or foliage and volatilize in the atmosphere.
- Soil retention/Leachability — is an index of the binding capacity of the pesticide molecule to soil organic matter and clay. In general, pesticides with high soil retention are strongly bound to soil and are not subject to leaching. Those not exhibiting high soil retention are not strongly bound and are subject to leaching. Leaching is the movement of pesticides, carried by water, downward through permeable soils.
- Soil persistence — refers the longevity of a pesticide molecule, typically expressed in terms of a half-life, as determined under normal conditions in the region where the pesticide would be used.

These factors influence the environmental fate and effects of a pesticide, including its residual soil activity, persistence, volatilization, water solubility, and potential for leaching into ground water.

Once a pesticide has been selected, the park resource manager would submit a pesticide use proposal using the internet-based Pesticide Use Proposal system. In general, the Regional IPM Coordinator would be responsible for reviewing and approving proposed pesticide uses. However, review and approval from the National IPM Coordinator would be required for pesticide uses that involve: aquatic applications or situations in which the applied pesticide could reasonably be expected to enter waters or wetlands; pesticide uses that may affect rare, threatened, or endangered species or associated critical habitat; pesticide use on 400 or more contiguous acres; and/or use of a restricted-use pesticide as defined by the EPA. Currently no restricted use pesticides are being considered for use in the park.

Best management practices would be followed to ensure that the overall effectiveness of pesticides is maximized and the potential for impacts is minimized. All contractors would also comply with these practices and NPS policy when applying pesticides. These general best management practices include the following:

- A NPS job hazard analysis would be updated annually and provided to all individuals involved in the application of pesticides.
- Pesticides would be applied at the appropriate time based on the pesticide’s mode of action. Poor timing of application can reduce the effectiveness of pesticides and can increase the impact on non-target plants.
- Pesticides would be applied according to application rates specified on the product label.
- Reduced application rates of pesticides would be used wherever possible. Reduced application rates are often more effective than higher application rates because translocation is not curtailed prematurely prior to loss of physiologic function. Higher rates may burn off leaves and reduce translocation.
- Pesticides would be applied as near to the target plant as possible.
- Pesticide application would account for meteorological factors such as wind speed, wind direction, inversions, humidity, and precipitation in relation to the presence of sensitive resources

near the treatment area and direction provided on labels. Pesticides would only be applied when meteorological conditions at the treatment site allow for complete and even coverage, which would prevent drifting of spray and allow sufficient drying time before precipitation events.

- Pesticide application would be timed and applied to minimize impact onto non-target sensitive resources and reduce the risk of human exposure including to applicator and the general public.
- Pesticides would be applied using coarse sprays to minimize the potential for drift. Combinations of pressure and nozzle type that would result in fine particles (mist) would be avoided. Thickeners, if the product label permits, may be added.
- In areas where there is the potential to affect surface water or ground water resources, pesticide pH and soil pH would be considered to select the pesticide with the lowest leaching potential.
- Highly water-soluble, terrestrial pesticides would not be used in areas where there is potential to affect surface water or ground water resources.
- Pesticides with high volatility would not be used to treat areas located adjacent to sensitive areas because of the potential for unwanted movement of pesticides to these areas, or the use of volatile pesticides would be timed during seasons of cool weather to minimize volatilization.
- Pesticides with high soil retention would be used in areas where there is potential to affect surface water or ground water resources.
- Pesticides with longer persistence would be applied at lower concentrations and with less frequency to limit the potential for accumulation of pesticides in soils.
- Safety protocols for storing, mixing, transporting, handling spills, and disposing of unused pesticides and containers would be followed at all times.
- Equipment would be maintained and calibrated prior to each application of pesticides. During all applications, droplet size would be controlled to decrease the risk of pesticide drift to nontarget species outside the immediate treatment area. Droplet size is controlled by the nozzle, psi, and adjuvants.
- Safety Data Sheets would be kept in a central location and updated regularly.

4.4 COLLABORATION AND COMMUNICATION

Communication, coordination, and collaboration is an essential element of an invasive plant management strategy for the park. Collaboration would be an on-going process that would build consensus with interested parties, including adjacent landowners, decision-makers, technical experts, and the general public. Several types of collaboration would be conducted including collaboration between the following:

- divisions in the park and other NPS programs
- the park and the public
- the park and neighboring private landowners
- the park and neighboring state land managers
- the park and exotic plant management experts
- the park and the New Jersey Strike Team and other entities involved in exotic plant management

The park would significantly increase information sharing related to invasive plant management across divisions in the park. Specifications for invasive plant management and best management practices to be included in contracts would be provided to the Administration Division. Best management practices related to the activities of other divisions such as Facilities would be provided and discussed at a park all employees meeting. Use of the NETN Invasive Plant Early Detection Protocol would be expanded to include park staff from other divisions that travel through the park on a regular basis and the Northeast EPMT. Laminated early detection species cards would be provided to park staff and training on the protocol and species identification would be conducted by the NETN.

The park would also promote increased collaboration and coordination between the NETN and Northeast EPMT to: (1) provide accurate identification of potential invaders either via the NETN smartphone application or physically (e.g., voucher specimen or site visit); (2) assess the potential impact of new introductions; and (3) include the Northeast EPMT in the reporting chain for new potential introductions. The Northeast EPMT would take the lead on assessing the potential impacts of new introductions using methods described by Hiebert and Stubbendieck (1993) to determine level of invasiveness/significance of impact for an individual nonnative species. Technical information on species biology may be contributed by experts with the NETN as necessary. Inclusion of the Northeast EPMT in the reporting chain would facilitate rapid response as well as contribute information that could be used to update invasive species early detection lists for other parks they serve.

The park would collaborate with the general public to disseminate consistent information about current and proposed exotic plant management activities and increase awareness of issues associated with nonnative invasive plants. As warranted, the park would conduct periodic public meetings regarding planned management activities and issues. These meetings would also provide a forum for the public to express concerns.

The park would collaborate with neighboring landowners to exchange information on the importance of and methods for managing exotic plants, and where possible, to seek mutual cooperation and coordination on agreed-upon activities for managing existing exotics, and identifying/responding to invasive species that are new to the area. Collaboration would include providing information related to importance of planting non-invasive plant species on private lands adjacent to the park. Collaboration with neighboring land managers, universities, other agencies and associated stakeholders would also be an opportunity for individuals to share and learn from their exotic plant management successes and challenges.

On-going collaboration with exotic plant management experts both within and outside the NPS would also be conducted on a regular basis. Experts would include, but will not be limited to, the Northeast EPMT, NETN, academia, other state and federal agencies' staff, and private individuals. This level of collaboration is needed to help NPS resource managers keep informed on the latest exotic plant management technologies and strategies and the potential for additional species to invade the park.

Other collaborative opportunities may include the following:

- Participating in and conducting seminars or workshops on invasive plant management
- Cooperating with other agencies to develop and disseminate educational materials (publications, posters, videos, and internet) to the public, interested organizations, and agency employees
- Working with non-profit organizations, such as local conservation districts and youth conservation corps.

4.5 TREATMENT EFFECTIVENESS MONITORING

Monitoring is the repeated collection and analysis of information to evaluate progress and effectiveness in meeting resource management and invasive plant treatment objectives (Elzinga et al. 1998) and is an essential part of an invasive plant management strategy. Monitoring programs can range from simple data collection efforts, such as taking photo points, to more complex plot and transect data collection. All are ongoing processes that provide useful information on which control techniques are working and which ones are not. Without monitoring, there is no way to determine whether control efforts are contributing to fulfillment of desired management objectives, nor is it possible to implement an IPM approach. Invasive plant treatment objectives for this plan are listed in section 1.1 above.

In addition to the limited monitoring conducted by the Northeast EPMT, the park would conduct additional monitoring as needed to determine the effectiveness of applied invasive plant treatments. The monitoring program will likely differ depending on the species in question and location in the park as well as whether any restoration actions were taken. At a minimum, monitoring would be used to answer the following questions:

- Were treatment objectives met (eradication, containment, or other)?
- What was the plant’s response to the treatment method?
- Is the treatment cost-effective?
- Are there variables in the treatment (season, timing of treatment, etc.) that are not being measured or that would impact the treatment?

While results may not be immediate or the cause of the results may be difficult to distinguish, monitoring is important to justify funding proposals or treatment programs to stakeholders; influence decision-making; and determine the effectiveness of the treatments and select the best treatment methods. If monitoring is not measuring the right attributes or if results are mixed, it may not be immediately useful. As a result, the park will consult with staff of the Northeast EPMT and NETN to develop appropriate monitoring protocols or to take advantage of existing monitoring protocols that are quick and easy to do; repeatable (with low observer bias); require little expertise to accomplish; are effective (responding quickly to an increase or decrease in plants); and are adaptable to different environments.

At a minimum, monitoring efforts would record the site location, existing species present, the target invasive plant species and treatment method, the effect of the treatment, and the results. At a minimum, the treatment effect would be measured by recording density and/or percent cover of invasive plant species as well as desirable native species. The appropriate number of sampling points or plots will be used to capture change with a degree of certainty/accuracy. Record keeping and reporting the use of pesticides would be completed in compliance with NPS guidelines.

5.0 LITERATURE CITED

Anderson, Roger C., Shivcharn S. Dhillion, and Timothy M. Kelley

1996 "Aspects of the Ecology of an Invasive Plant, Garlic Mustard (*Alliaria petiolata*) in Central Illinois." *Restoration Ecology,* 4(2): 181-191.

Bourg, N. A.

2008 "Interactive Effects of White-tailed Deer and Invasive Plants on Temperate Deciduous Forest Native Plant Communities." 93rd Ecological Society of America Annual Meeting. August 3-8, 2008, Milwaukee, WI.

Ehrenfeld, J. G.

1977 "Vegetation of Morristown National Historic Park: ecological analysis and management alternatives final report." Center for Coastal and Environmental Studies, Rutgers University, New Brunswick, NJ.

1999 "Distribution and dynamics of two exotic species, *Berberis thubergii* and *Microstegium vimineum* in Morristown National Historic Park." Dept. Ecology, Evolution, and Natural Resources, Rutgers University, New Brunswick, NJ.

Elzinga, Caryl L., D. W. Salzer, and J. W. Willoughby

1998 "Measuring and monitoring plant populations." BLM Technical Reference 1730-1. BLM/RS/ST-98/005+1730. Bureau of Land Management, National Business Office, Denver, CO.

Gilliam, F. S.

2007 "The ecological significance of the herbaceous layer in temperate forest ecosystems." *Bioscience*, 57(10): 845-858.

Hiebert, Ronald D. and James Stubbendieck

1993 *Handbook for Ranking Exotic Plants for Management Control*. Natural Resources Report NPS/NRMWRO/NRR-93-08. July 1998. National Park Service, Natural Resources Publication Office, Denver, CO.

Horsley, S. B and D. A. Marquis

1983 "Interference by Deer and Weeds with Allegheny Hardwood Reproduction." *Canadian Journal of Forest Research*, 13: 61-9.

Keane, R. M. and M. J. Crawley

2002 "Exotic Plant Invasions and the Enemy Release Hypothesis." *Trends in Ecology and Evolution* 17: 164-70.

Kourtev, P. S., J. G. Ehrenfeld, and W. Z. Huang

1998 "Effects of Exotic Plant Species on Soil Properties in Hardwood Forests of New Jersey." *Water, Air, and Soil Pollution* 105: 493-501.

Latham, R. E., J. Beyea, M. Benner, C. A. Dunn, M. A. Fajvan, R. R. Freed, M. Grund, S. B. Horsley, A. F. Rhoads, and B. P. Shissler

2005 *Managing White-tailed Deer in Forest Habitat from an Ecosystem Perspective: Pennsylvania Case Study*. Report by the Deer Management Forum for Audubon Pennsylvania and Pennsylvania Habitat Alliance, Harrisburg.

Miller, J. H.

2003 *Nonnative Invasive Plants of Southern Forests: A Field Guide for Identification and Control*. Revised. Gen. Tech. Rep. SRS-62. Asheville, NC: US Department of Agriculture, Forest Service, Southern Research Station.

MacDonald, I. A. W., L. L. Loope, M. B. Usher, and O. Harmann

1989 "Wildlife conservation and the invasion of nature reserves by exotic species: a global perspective." In Drake, J., F. diCastri, R. Groves, F. Kruger, H. A. Mooney, M. Rejmanek, and M. Williamson (eds.). *Biological Invasions: A Global Perspective*. Wiley and Sons.

Mooney, H. A.

2005 Invasive Alien Species: The Nature of the Problem. In *Invasive Alien Species: A New Synthesis*. Mooney, H. A., R. N. Mack, J. A. McNeely, L. E. Neville, P. J. Schei, and J. K. Waage (eds.). Island Press, Washington.

Moran, E. V. and Alexander, J. M.

2014 "Evolutionary responses to global change: lessons from invasive species." *Ecology Letters*, 17(5): 637-649.

Muscolo, A., Bagnato, S., Sidari, M., and Mercurio, R.

2014 "A review of the roles of forest canopy gaps." *Journal of Forestry Research*, 25(4): 725-736.

National Park Service (NPS)

2003 *Morristown National Historical Park Final General Management Plan and Environmental Impact Statement*.

2004 Natural Resource Management Reference Manual #77. Updated February 5, 2004. Available at https://www.nature.nps.gov/rm77/. Accessed June 29, 2017.

2006 *Management Policies 2006*. National Park Service, Washington, DC. http://www.nps.gov/policy/MPandCC.pdf.

2008 Vegetation Classification and Mapping of Morristown National Historical Park, New Jersey. Technical Report NPS/NER/NRTR—2008/116. Northeast Region, Philadelphia, PA.

2010 "2010 Guidance on Integrated Pest Management Procedures: Park, Superintendent, Region, and WASO IPM Responsibilities." Available at www.nps.gov/training/tel/Guides/ipm_responsibilities_08102010.doc.

2016 "Invasive Plant Management in the National Park Service." Presented at the California Invasive Plan Council Symposium, Yosemite National Park, Fish Camp, CA, November 2-5, 2016. Available at http://cal-ipc.org/symposia/archive/pdf/2016/1_Hogan.pdf. Accessed June 29, 2017.

2017 Forest Data Summaries for Morristown National Historical Park: 2007–2017. Northeast Temperate Monitoring Network.

National Invasive Species Council (NISC)
2016 *Management Plan 2016–2018*. Washington, DC.

New Jersey Department of Agriculture (NJDA)
2014 *Rhinoncomimus latipes* (Coleoptera: Curculionindae) as a Biological Control Agent for Mile-a-minute, *Periscria perfoliata* in New Jersey. Annual Report 2014. Phillip Alampi Beneficial Insect Laboratory, Division of Plant Industry.

New Jersey Department of Environmental Protection (NJDEP)
2004 Policy Directive 2004-02: Invasive Nonindigenous Plant Species. Trenton, NJ. October 2004. Available at http://www.nj.gov/dep/commissioner/policy/pdir2004-02.htm. Accessed June 29, 2017.

New Jersey Invasive Species Council (NJISC)
2009 *New Jersey Strategic Management Plan for Invasive Species*. Trenton, NJ.

Pommerening, A. and Murphy, S.T.
2004 "A review of the history, definitions and methods of continuous cover forestry with special attention to afforestation and restocking." *Forestry*, 77(1): 27-44.

Russell
2002 "Changes in the forests of the Jockey Hollow Unit of Morristown National Historic Park Over the Last 5-15 Years." National Park Service Technical Report NPS/BSO-RNR/NRTR/2002-9.

Stromayer, K. A. K. and R. J. Warren
1997 "Are Overabundant Deer Herds in the Eastern United States Creating Alternative Stable States in Forest Plant Communities?" *Wildlife Society Bulletin* 25: 227-34.

Swearingen, J., B. Slattery, K. Reshetiloff, and S. Zwicker
2010 *Plant Invaders of Mid-Atlantic Natural Areas*, 4th ed. National Park Service and US Fish and Wildlife Service. Washington, DC.

Swearingen, J. and C. Bargeron
2016 Invasive Plant Atlas of the United States. University of Georgia Center for Invasive Species and Ecosystem Health. Available at http://www.invasiveplantatlas.org/. Accessed June 29, 2017.

Tu, M., C. Hurd, and J. M. Randall
2001 Weed Control Methods Handbook, The Nature Conservancy. Version: April 2001.

Bureau of Land Management
1998 "Pulling Together: National Strategy for Invasive Plant Management." Denver, CO.

Waller, D. M. and W. S. Alverson
1997 "The White-tailed Deer: A Keystone Herbivore." *Wildlife Society Bulletin* 25(2): 217-26.

Ward, J. S.
2000 *Limiting Deer Browse Damage to Landscape Plants.* Connecticut Agricultural Experiment Station Bulletin 968, New Haven.

Williams, C. E.
1996 "Alien Plant Invasions and Forest Ecosystem Integrity: A Review." Pp. 169-85 in S. K. Majumdar, E. W. Miller, and F. J. Brenner (eds.), *Forests—A Global Perspective*. Easton: Pennsylvania Academy of Sciences.

This page intentionally left blank.

APPENDIX A-1:
MORRISTOWN NATIONAL HISTORICAL PARK
NONNATIVE PLANT LIST

This page intentionally left blank.

Morristown National Historical Park Nonnative Plant List - 7/13

TREES (18 species)

Acer platanoides – Norway maple
Ailanthus altissima – Tree of heaven
Gingko biloba – Gingko
Pawlonia tomentosa – Princess tree
Morus alba – White mulberry
Styrax grandifolia – Big-leaf snowbell
Ulmus procera – English elm
Robinia pseudoacacia – Black locust
Abies balsmea – Balsam fir
Picea glauca – White spruce
Pinus resinosa – Red pine
Thuja occidentalis – Northern white cedar
Castanea mollisima – Chinese chestnut
Aesculus hippocastanum – Horse chestnut
Broussonetia papyrifera – Paper mulberry
Prunus avium – Sweet cherry
Prunus persica – Peach
Pyrus communis – Pear

SMALL TREES (13 species)

Acer palmatum – Japanese maple
Aesculus pavi – Red buckeye
Aralia elata – Japanese angelica tree
Cornus kousa – Korean dogwood
Elaegnus umbellata – Autumn olive
Photinia villosa – Oriental photinia
Photinia spp. – Photinia
Rhamnus cathartica – Common buck thorn
Styrax obassia – Styrax
Viburnum plicatum tomentosum – Viburnum
Viburnum rhytidophyllum – Leather leaf viburnum
Viburnum setigerum – Viburnum
Viburnum sieboldii – Siebolds viburnum

SHRUBS (13 species)

Berberis thunbergii – Japanese barberry
Euonymous elatus – Winged euonymous
Ligustrum vulgare – Japanese privet
Lonicera japonica – Japanese honeysuckle
Lonicera tartarica – Tartarian honeysuckle
Lonicera villosa – Mountain fly honeysuckle
Philadelphus coronaries – Mock orange
Poncirus trifoliata – Hardy orange
Rosa multiflora – Multiflora rose
Rhodotypos scandens – Black jetbead
Rubus phoenicolasius – Wineberry
Spiraea japonica – Japanese spiraea
Viburnum dilatatum – Linden viburnum

VINES (7 species)

Actinidia arguta – Hardy kiwi
Akebia quinata – Fiveleaf akebia
Ampelopsis brevipedunculata – Porcelainberry
Celastrus orbiculatus – Oriental bittersweet
Cynanchum nigrum – Black swallowwort
Wisteria sinensis – Chinese wisteria
Parthenocissus tricuspidata – Boston Ivy

HERBS (85 species)

Abutilon theophrasti – Velvet leaf
Achillea millefolium – Common yarrow
Ajuga reptans – Bugleweed
Alliaria petiolata – Garlic mustard
Allium vineale – Wild garlic
Artemisia vulgaris – Mugwort
Asparagus officinalis – Garden asparagus
Barbarea vulgaris – Garden yellow rocket
Brassica kabler – Charlock
Brassica nigra – Black mustard
Carduus nutans – Musk thistle
Centaurea maculosa – Spotted knapweed
Centaurea nigra – Black knapweed

Cerasteum vulgatum – Common mouse chickweed
Cardimine impatiens – Narrowleaf bittercress
*Chelidonium maju*s – Greater celandine
Chrysantheum leucanthenum – Ox-eye daisy
Cichorium intybus – Chickory
Circium arvense – Canada thistle
Cirsium vulgare – Canada bull thistle
Commelia communis – Asiatic Dayflower
Convolvulus arvensis – Field Bindweed
Coronoilla varia – Crown vetch
Datura stramonium – Jimson weed
Daucus carota – Queen anne's lace
Dianthus ameria – Deptford pink
Epipactus helleborine – Broadleaf helliborine
Euphorbia esula – Leafy spurge
Euphorbia spp. – Spurge
Galinsoga ciliate – Peruvian daisy
Galium mollugo – Wild madder
Galium verum – Yellow bedstraw
Glechoma hederacea – Creeping charlie
Hesperis matronalis – Dame's rocket
Hieracium pretense – Yellow hawkweed
Hieracum spp. – Hawkweed
Hypericum perfolatum – Common saint john's-wort
Lathyrus latifolius – Everlasting pea
Linaria vulgaris – Butter-and-eggs
Lespedeza cuneata – Chinese Bushclover
Lysimachia nummularia – Moneywort
Lychnis alba – White campion
Malva moschata – Musk mallow
Melilotus alba – White sweet clover
Microstegium vimineum – Japanese stiltgrass
Myosotis scorpiodes – True forget-me-not
Nasturtium officinale – Watercress
Nepeta cataria – Catnip
Origanum vulgare – Wild marjoram
Ornithogalum umbellatum – Star-of-Bethlehem
Phragmites australis – Pragmites
Plantago lanceolata – English Plantain
Plantago major – Common plantain
Polygonum cuspidatum – Japanese knotweed
Polygonum caespitosum – Oriental ladythumb

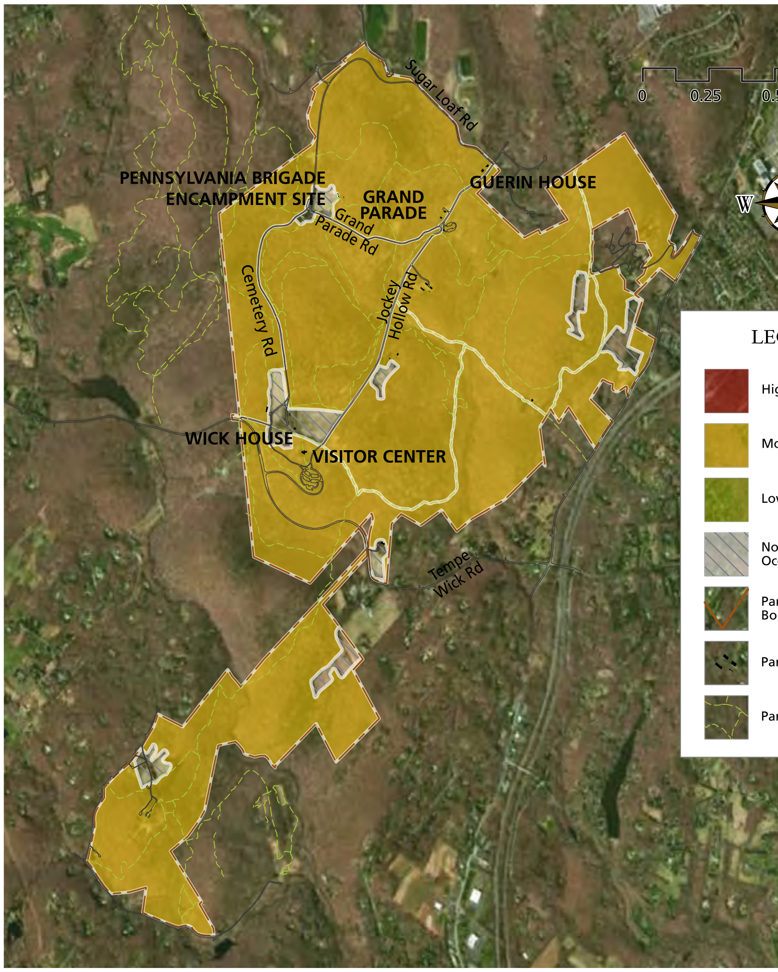
Polygonum persicaria – Spotted ladythumb
Potentilla recta – Rough fruited cinquefoil
Trifolium pratense – Red clover
Ranunculus acris – Tall buttercup
Ranunculus bulbosus – Bulbous buttercup
Ranunculus ficaria – Lesser celandine
Ranunculsu repens – Creeping buttercup
Rorippa sylvestris – Creeping yellow cress
Rumex acetosella – Sheep sorrel
Rumex crispus – Curled dock
Silene cucbalus – Bladder campion
Silene latifolia – White campion
Triflorium agrarium – Hop clover
Trifolium dubium – Least hop clover
Trifolium hybridum – Swedish clover
Trifolium procumbens – Low hop clover
Urtica dioica – Stinging nettle
Verbascum blatteria – Moth mullein
Sisymbrium officinale – Common hedge mustard
Solanum nigrum – Deadly nightshade
Taraxacum officinale – Common dandelion
Thymus serpyllum – Wild thyme
Tragopogon pratensis – Meadow salsify
Verbascum thaspus – Mullein
Veronica arvensis – Corn speedwell
Veronica chamaedrys – Birds-eye speedwell
Vicia cracca – Tufted vetch
Vicia sativa – Common vetch
Vicia tetrasperma – Slender vetch
Vinca minor – Common periwinkle

TOTAL NUMBER OF INVASIVE PLANT SPECIES – 136

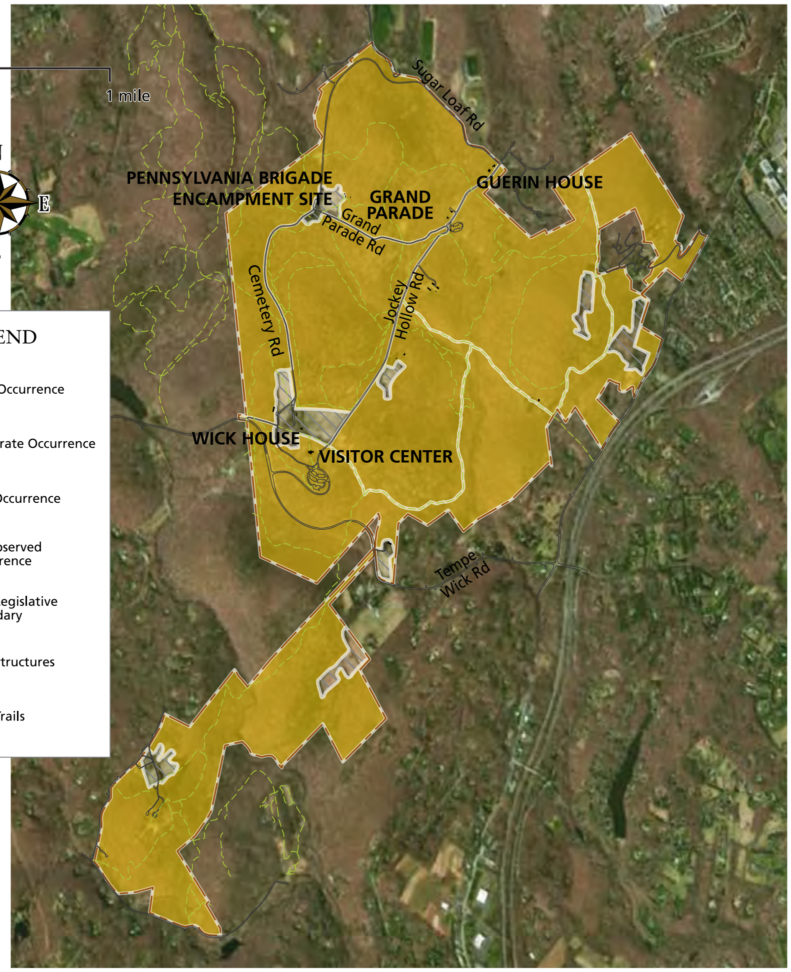
APPENDIX A-2:
NONNATIVE PLANT SPECIES MAPPING

This page intentionally left blank.

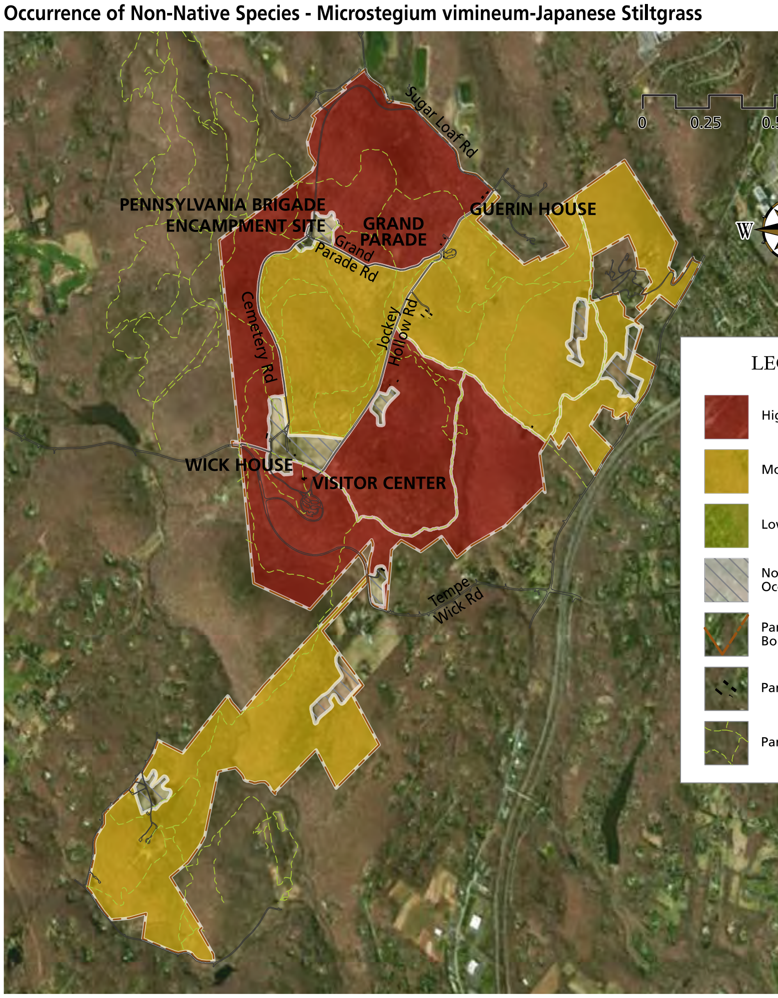
Occurrence of Non-Native Species - Alliaria petiolata-Garlic Mustard



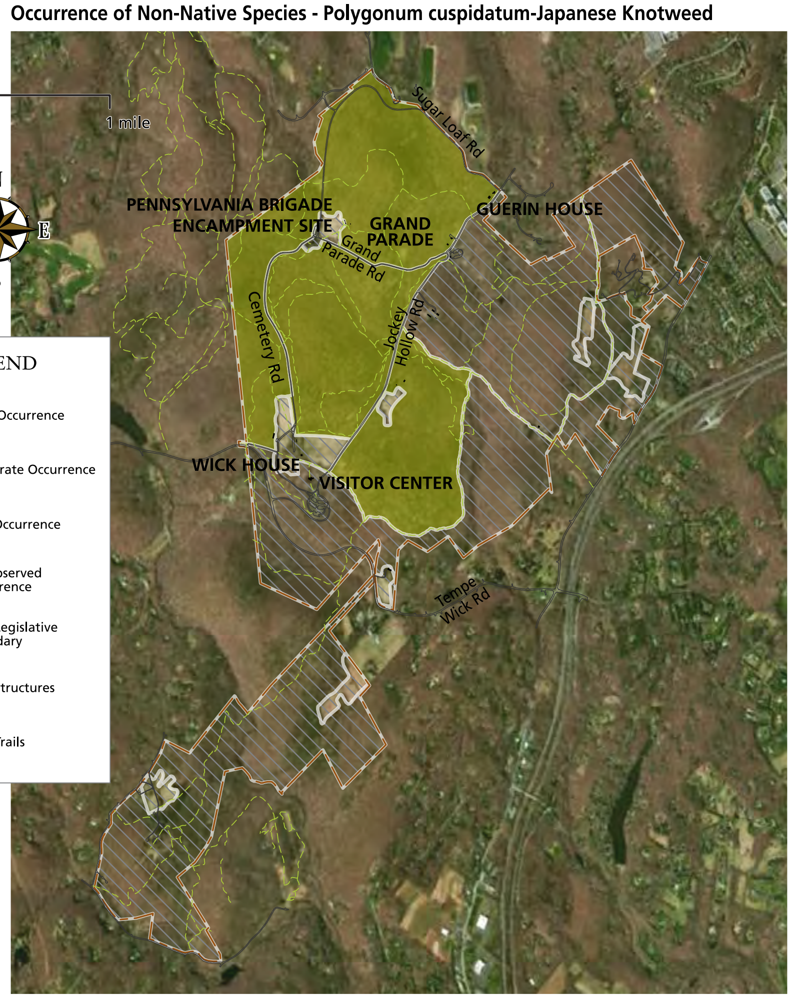
Occurrence of Non-Native Species - Cardimine impatiens-Narrowleaf Bittercress



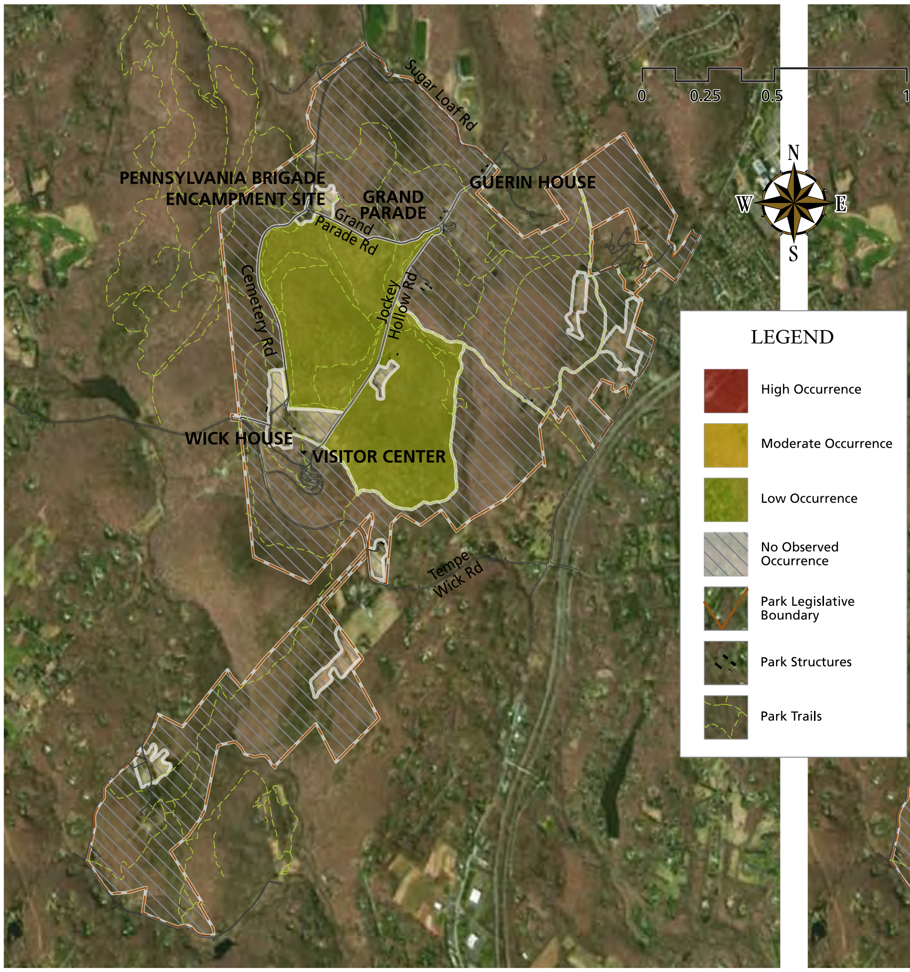
Occurrence of Non-Native Species - Microstegium vimineum-Japanese Stiltgrass



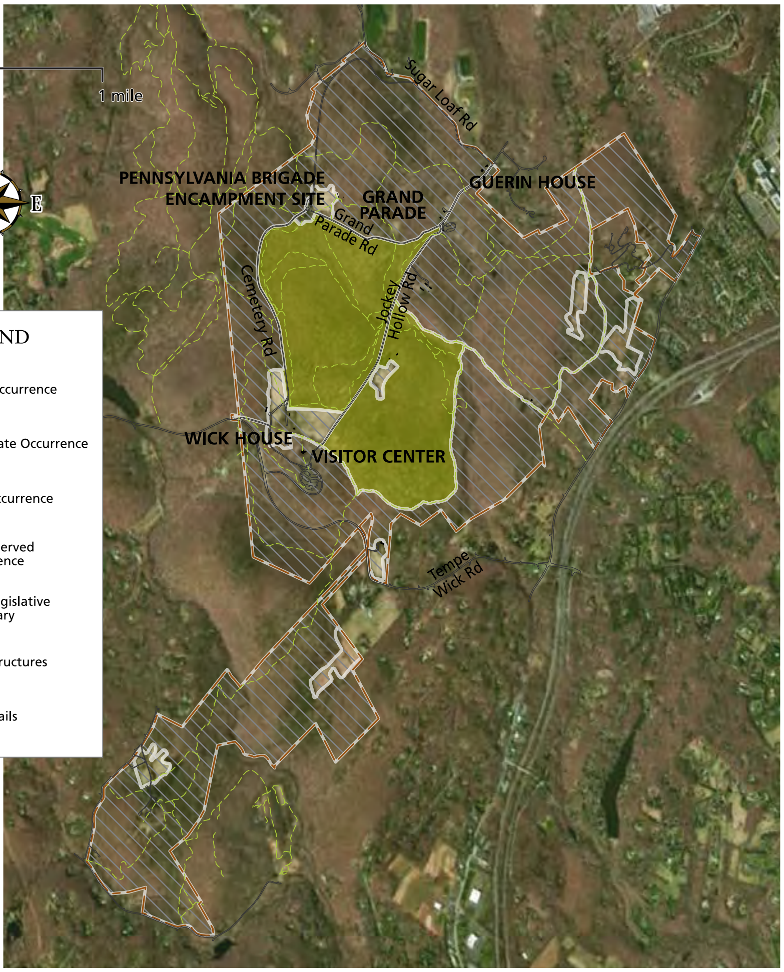
Occurrence of Non-Native Species - Polygonum cuspidatum-Japanese Knotweed



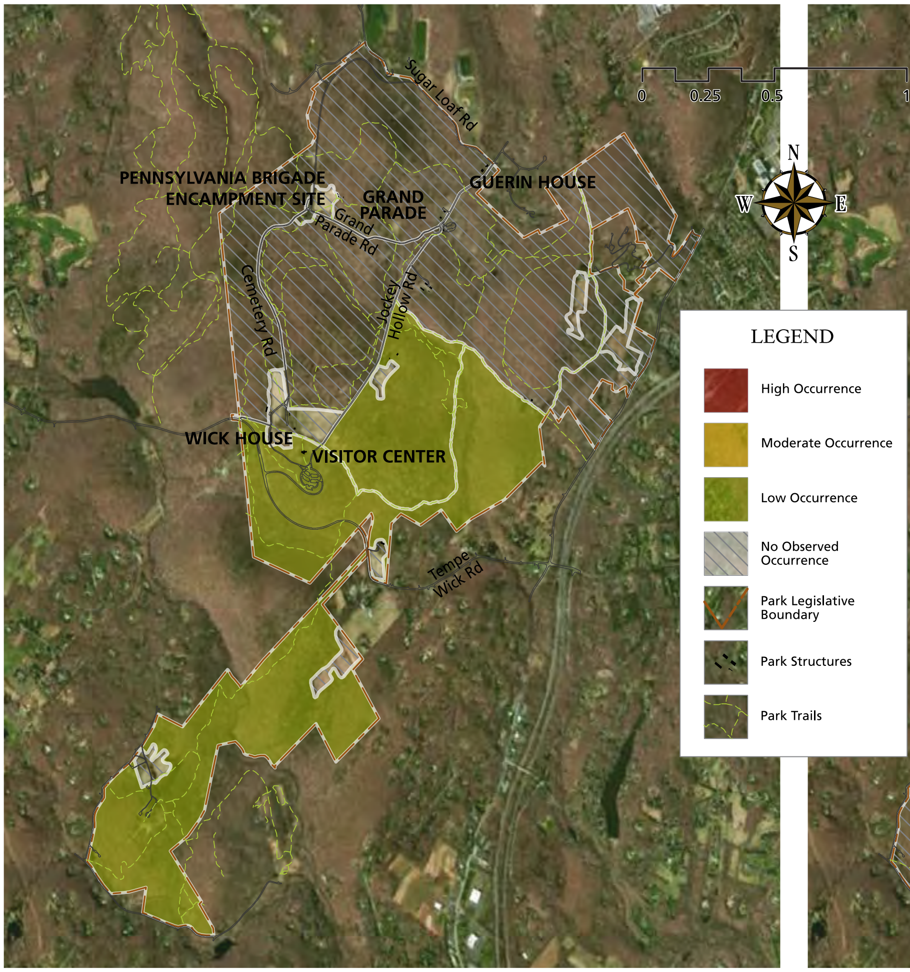
Occurrence of Non-Native Species - Polygonum caespitosum-Oriental Ladythumb



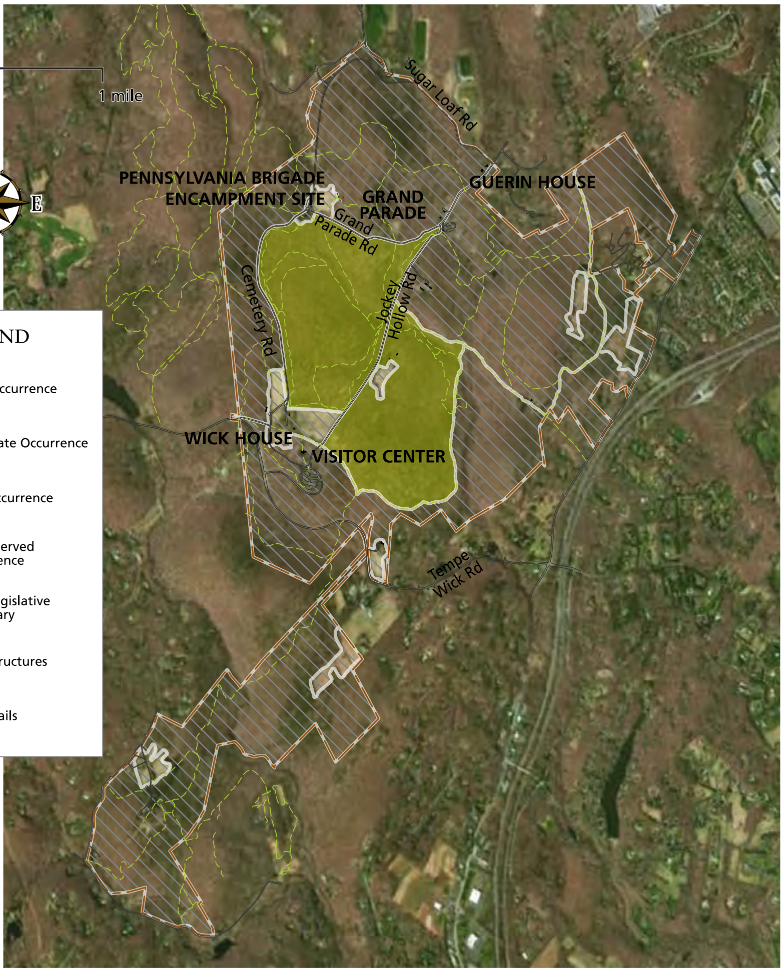
Occurrence of Non-Native Species - Polygonum persicaria-Spotted Ladythumb



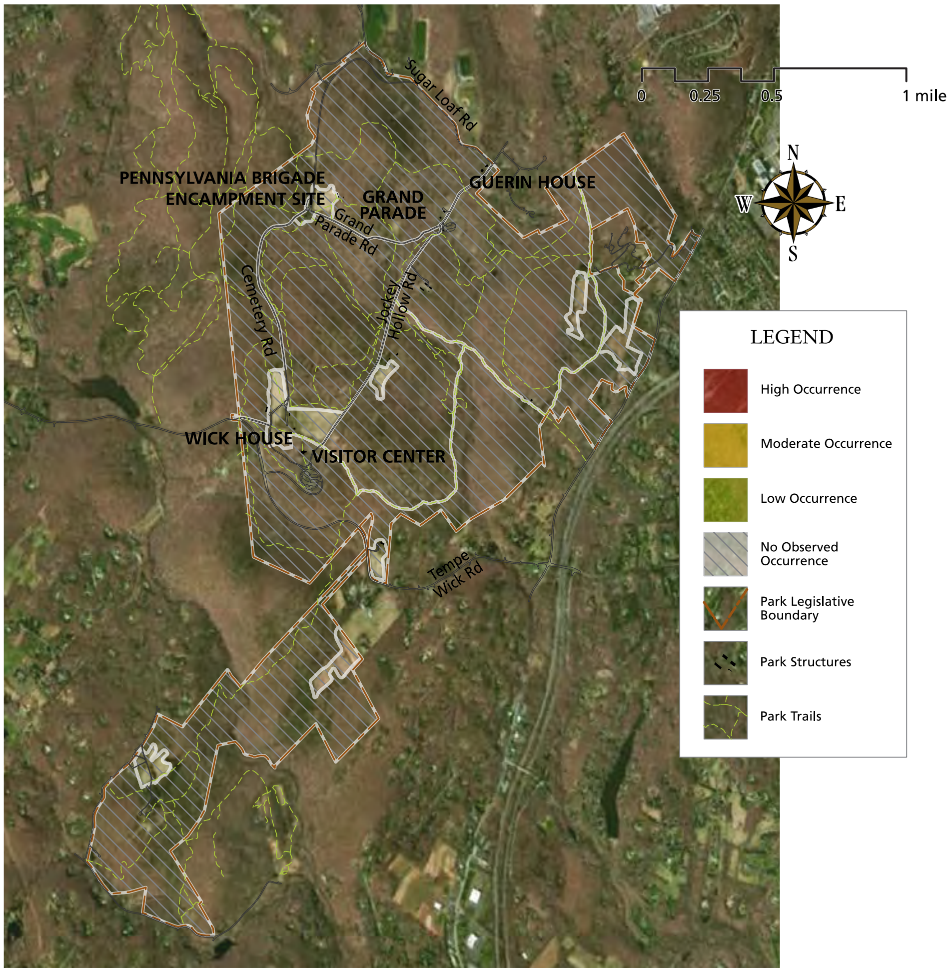
Occurrence of Non-Native Species - Ranunculus ficaria-Lesser Celandine



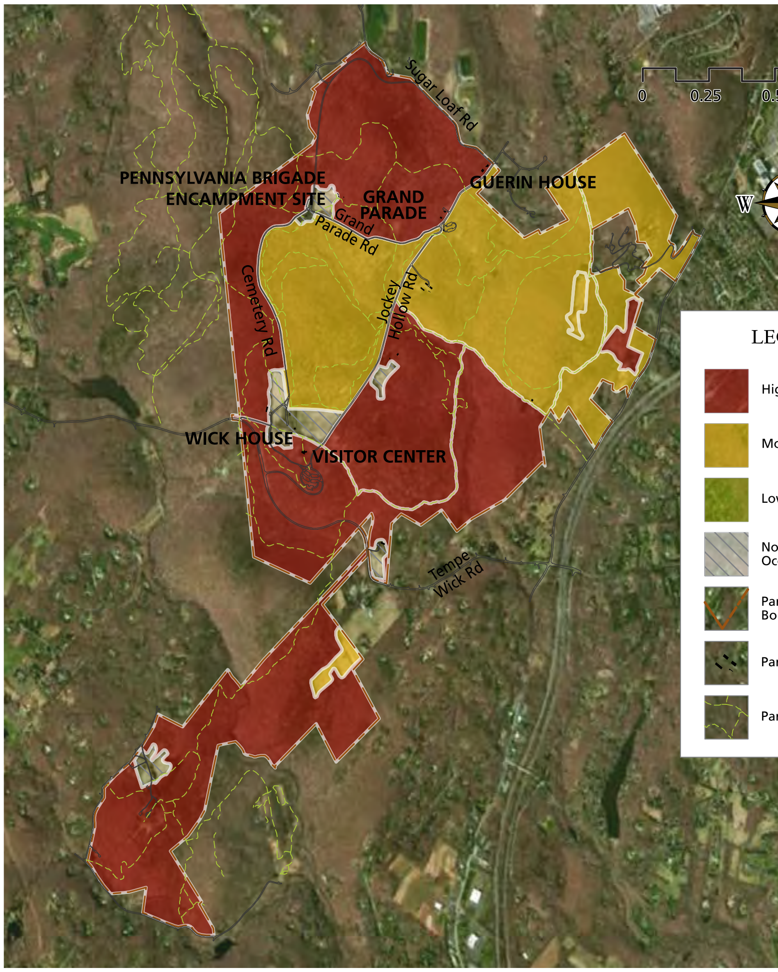
Occurrence of Non-Native Species - Verbascum thaspus-Mullein



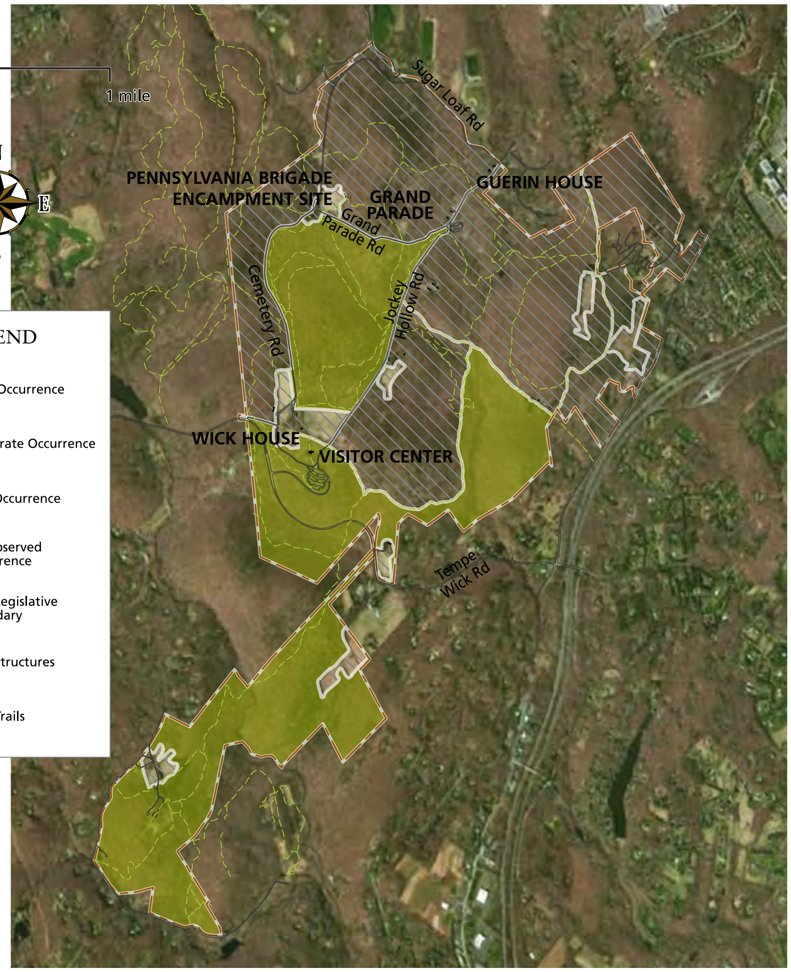
Occurrence of Non-Native Species - (NO DATA) Lysimachia nummularia-Moneywort



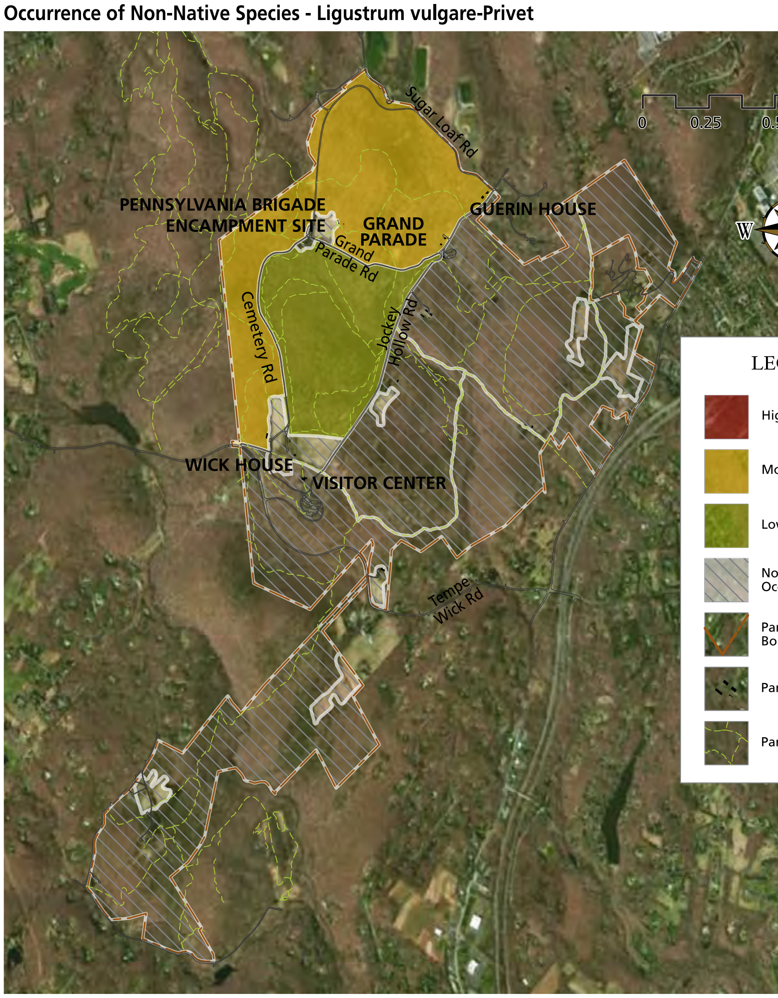
Occurrence of Non-Native Species - Berberis thunbergii-Japanese Barberry



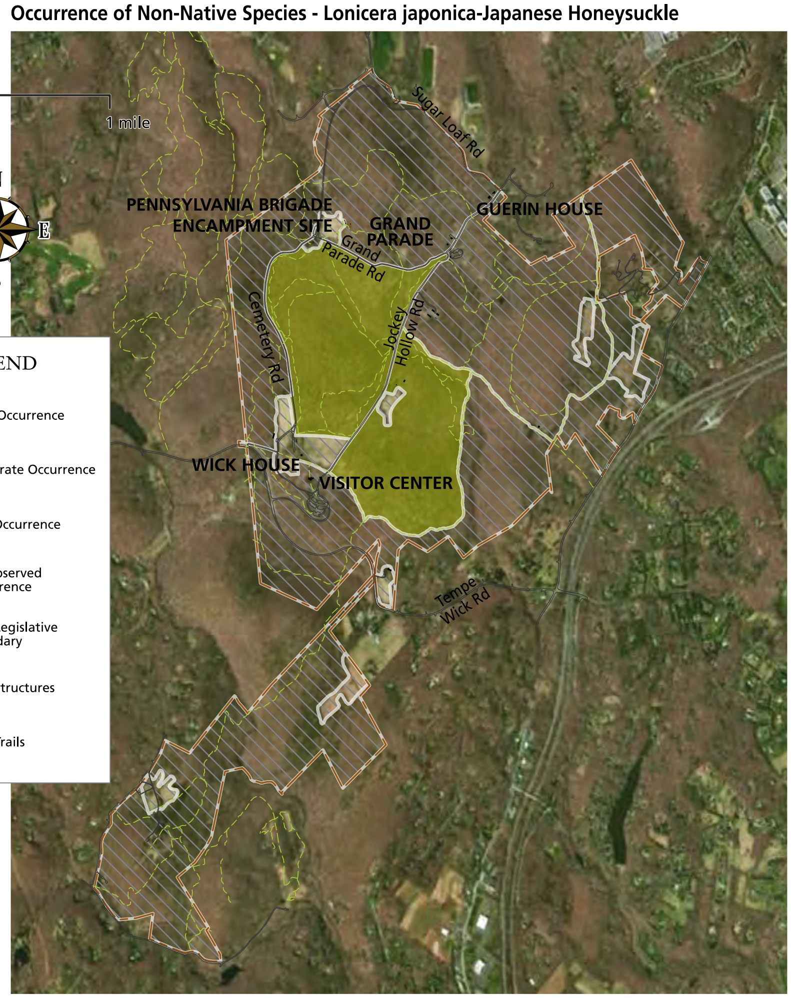
Occurrence of Non-Native Species - Euonymous elatus-Winged Euonymous



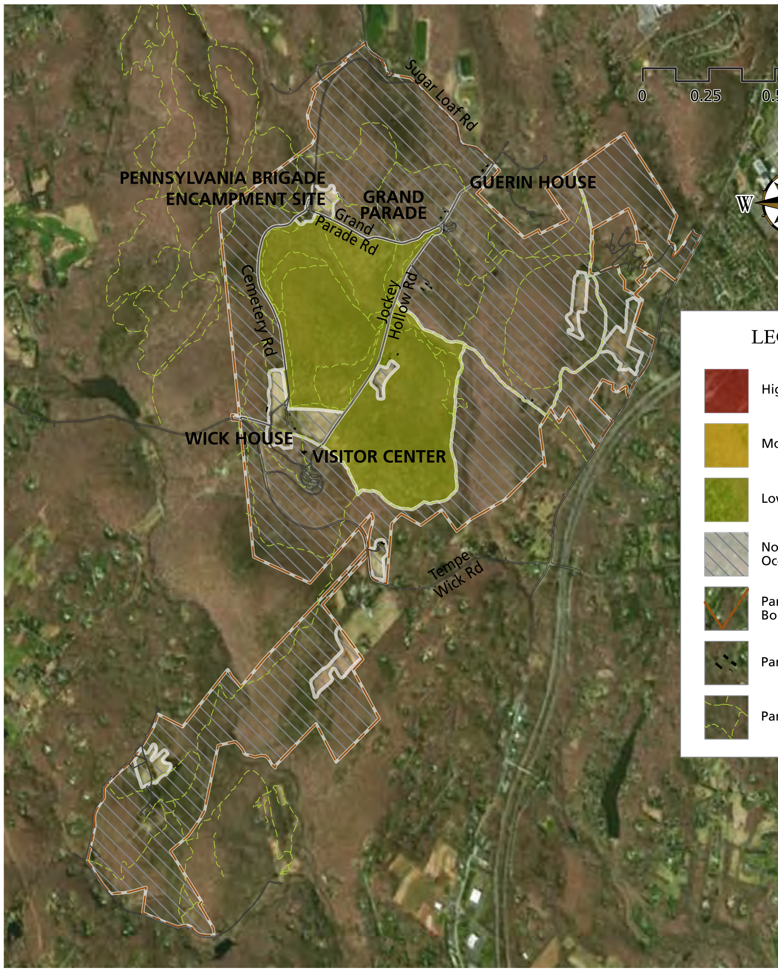
Occurrence of Non-Native Species - Ligustrum vulgare-Privet



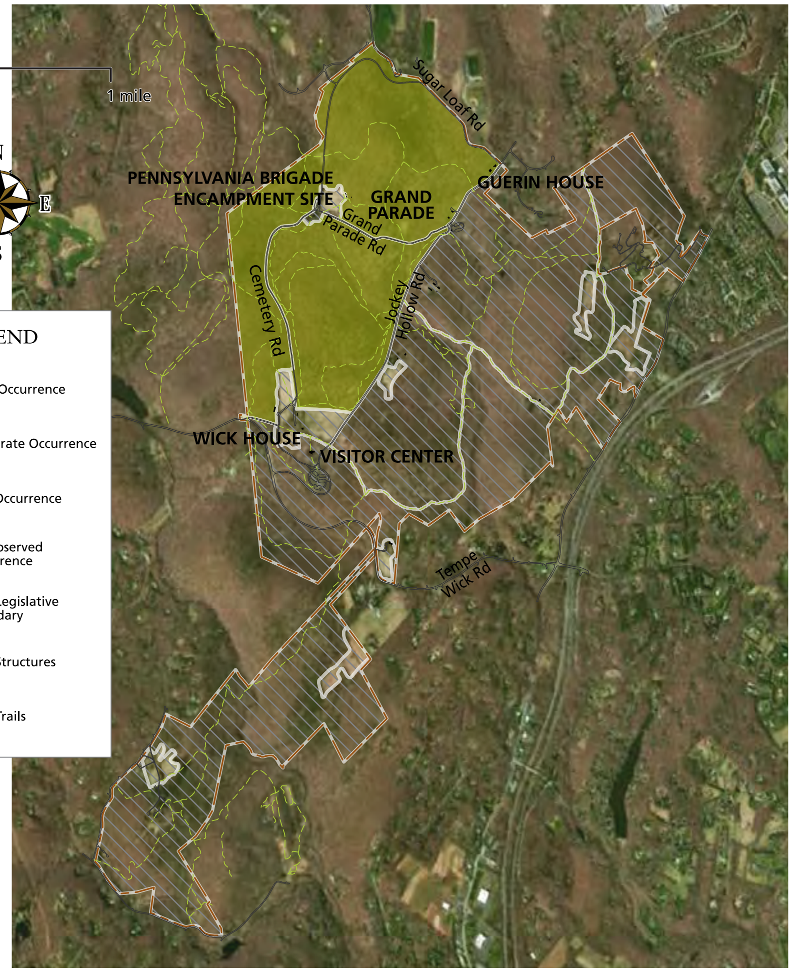
Occurrence of Non-Native Species - Lonicera japonica-Japanese Honeysuckle



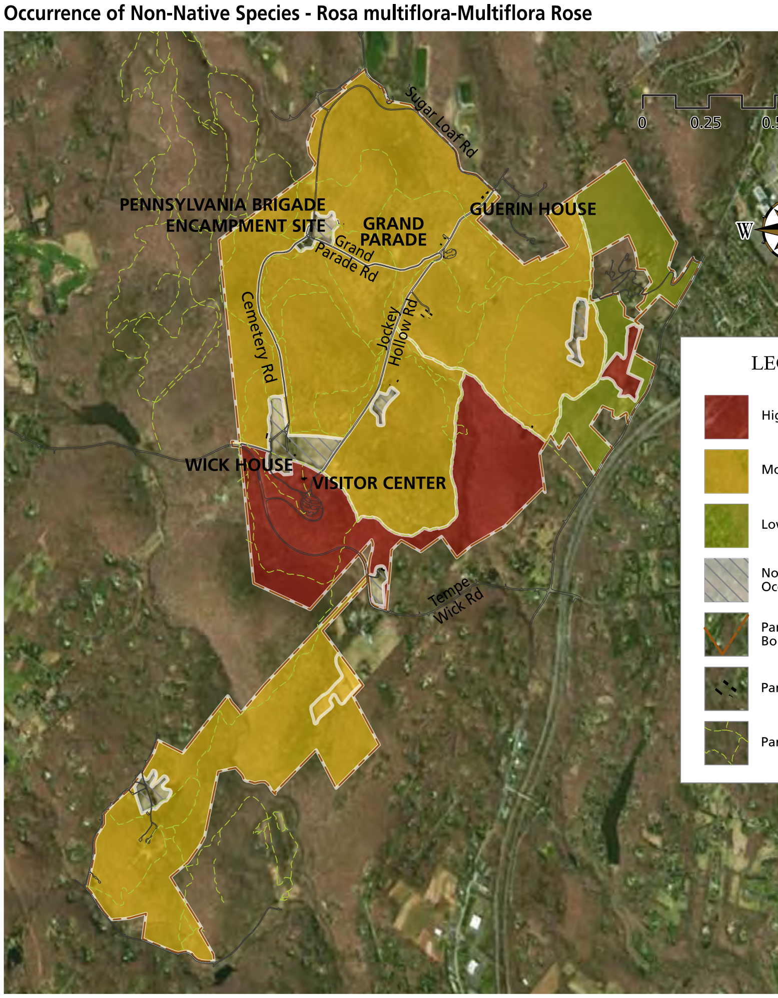
Occurrence of Non-Native Species - Lonicera tartarica-Tartarian Honeysuckle



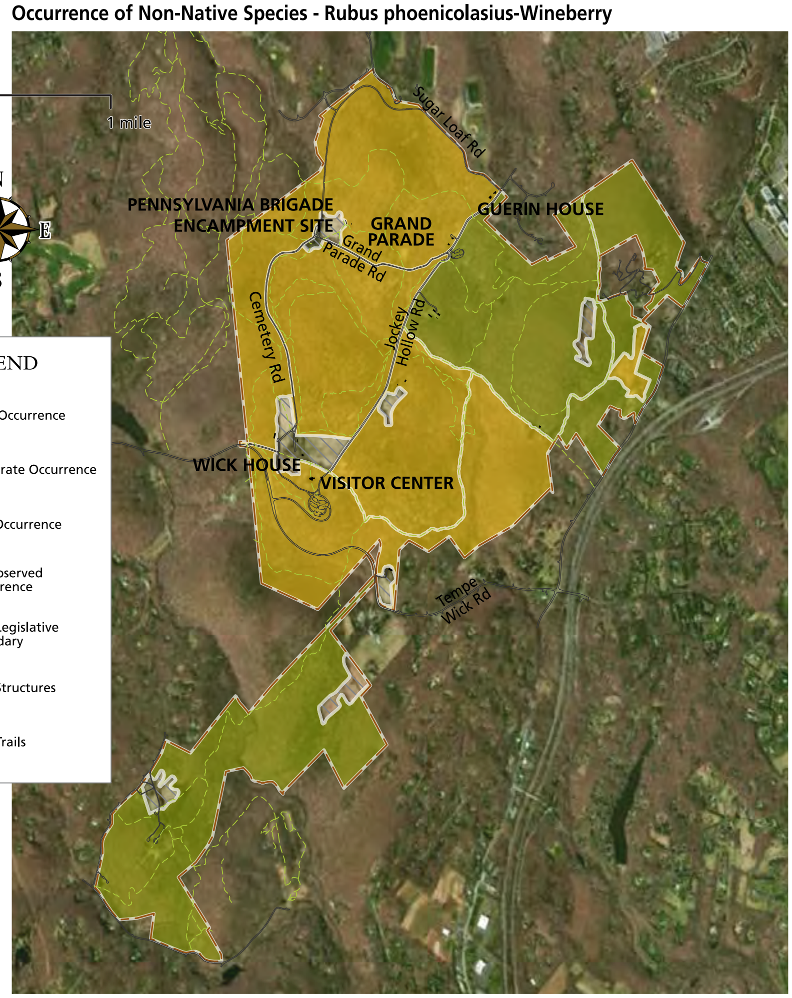
Occurrence of Non-Native Species - Rhodotypos scandens-Black Jetbead



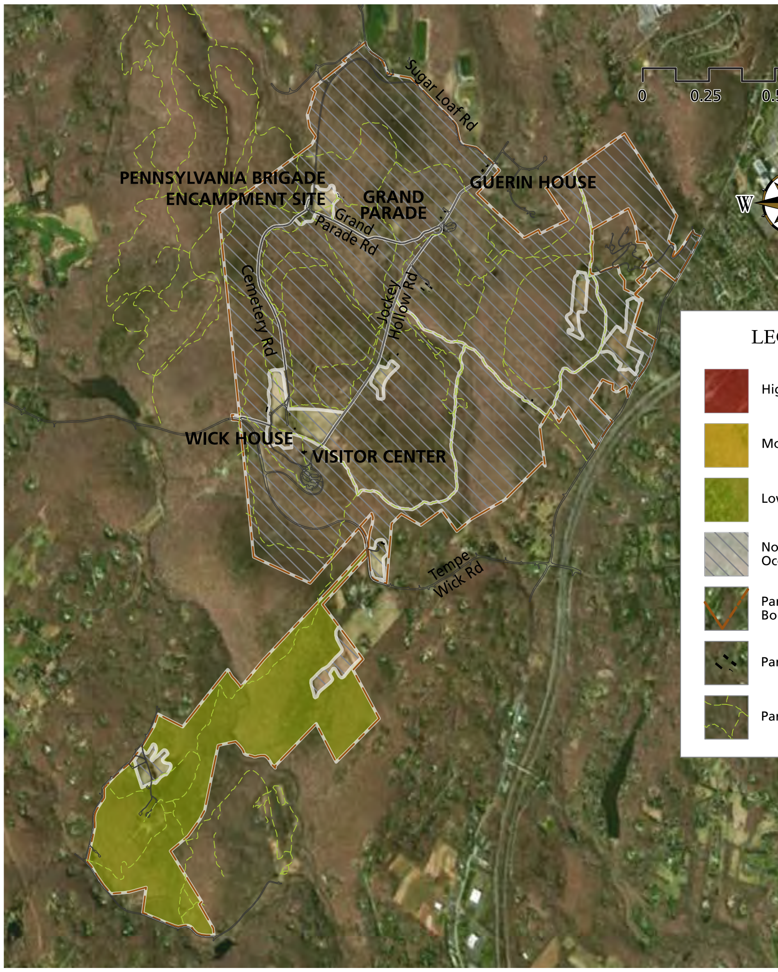
Occurrence of Non-Native Species - Rosa multiflora-Multiflora Rose



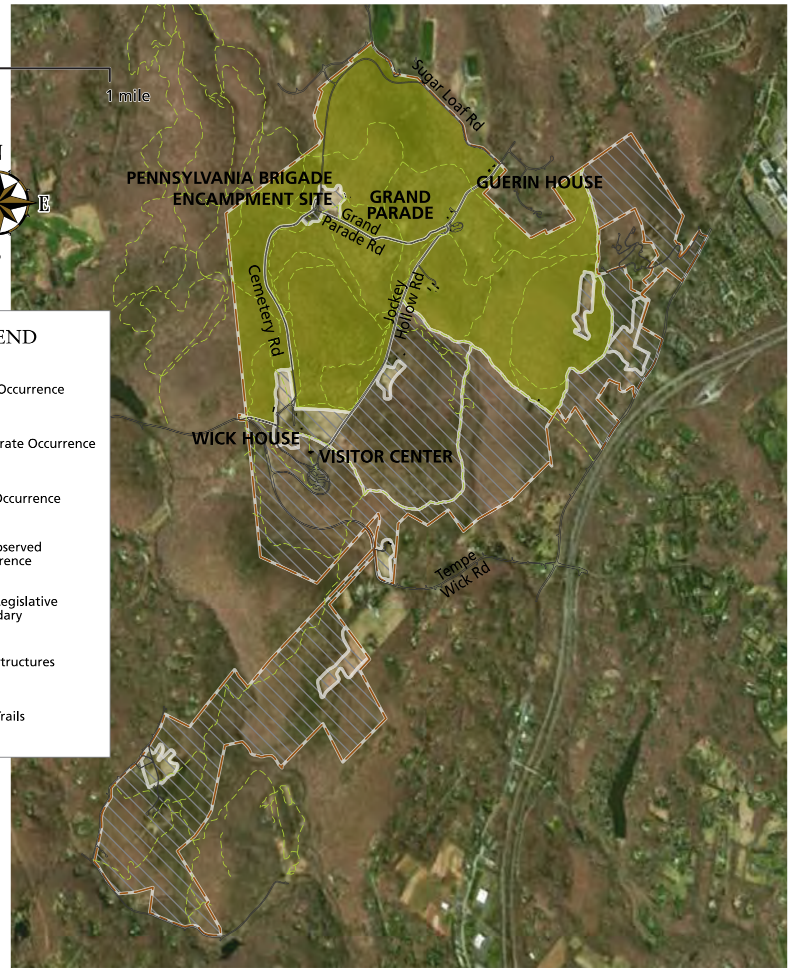
Occurrence of Non-Native Species - Rubus phoenicolasius-Wineberry



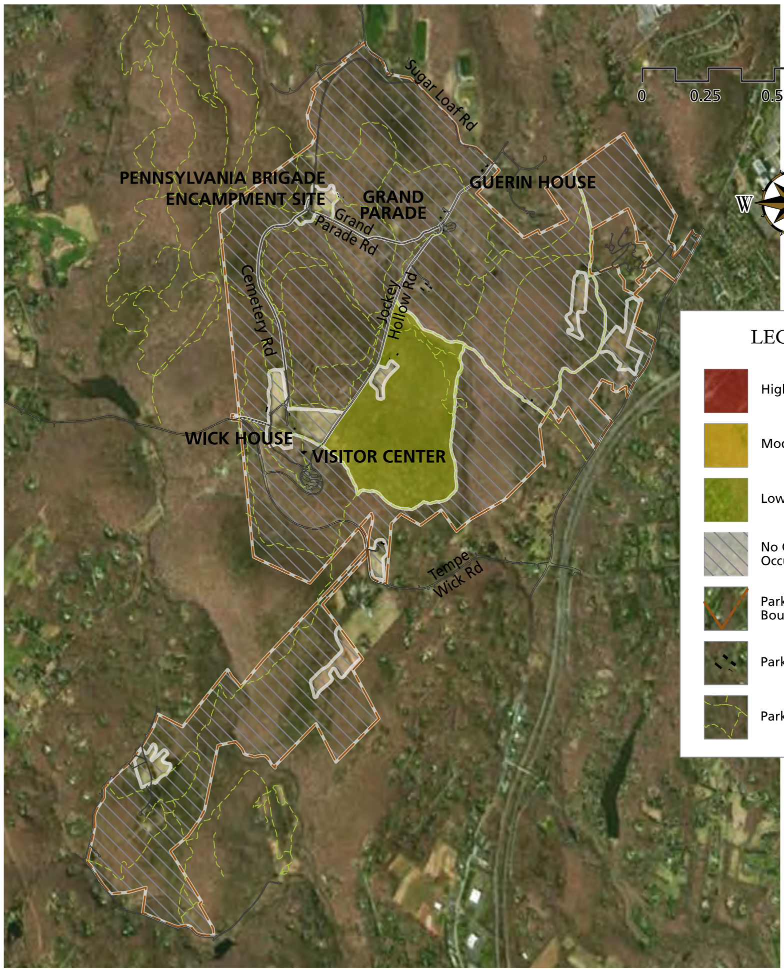
Occurrence of Non-Native Species - Spiraea japonica-Japanese Spiraea



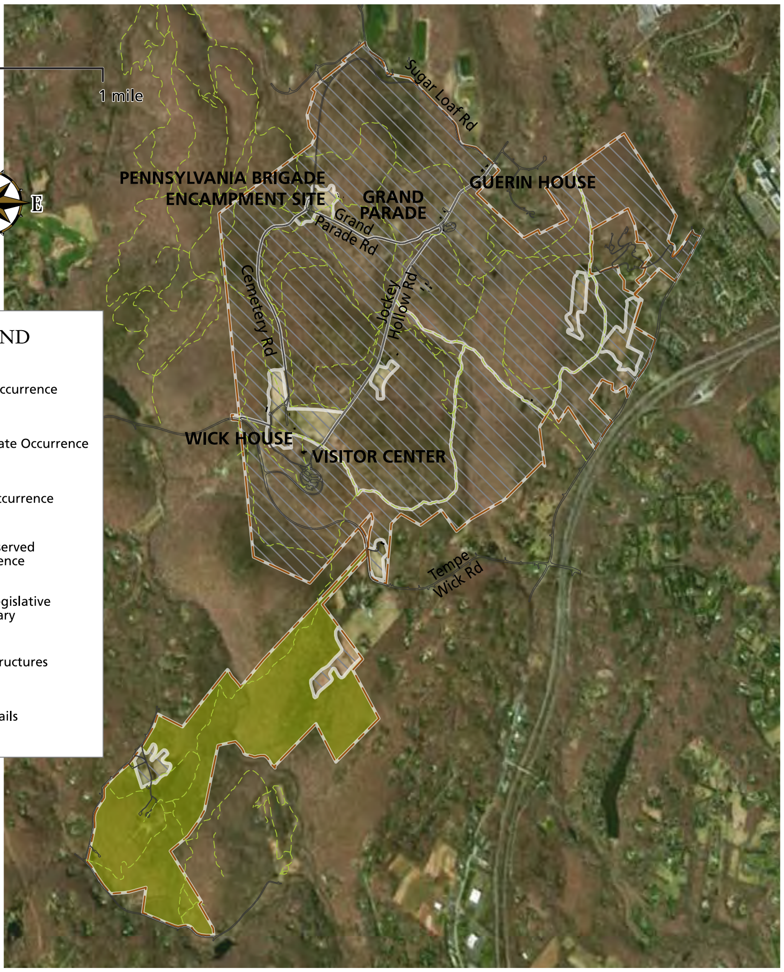
Occurrence of Non-Native Species - Viburnum dilatatum-Linden Viburnum



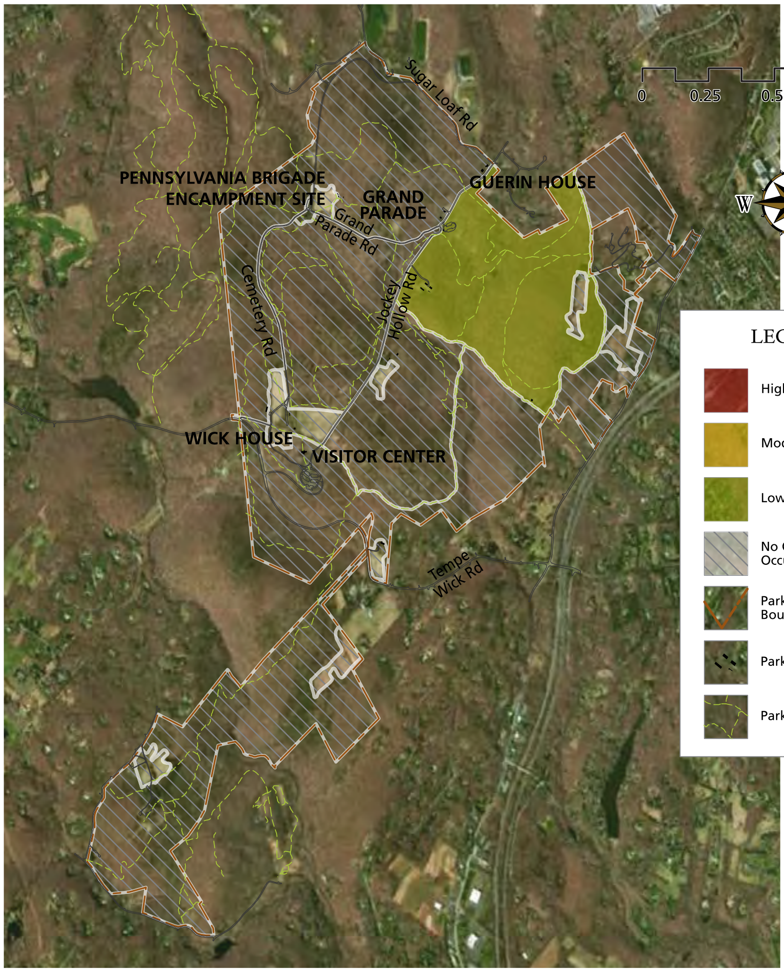
Occurrence of Non-Native Species - Acer palmatum-Japanese Maple



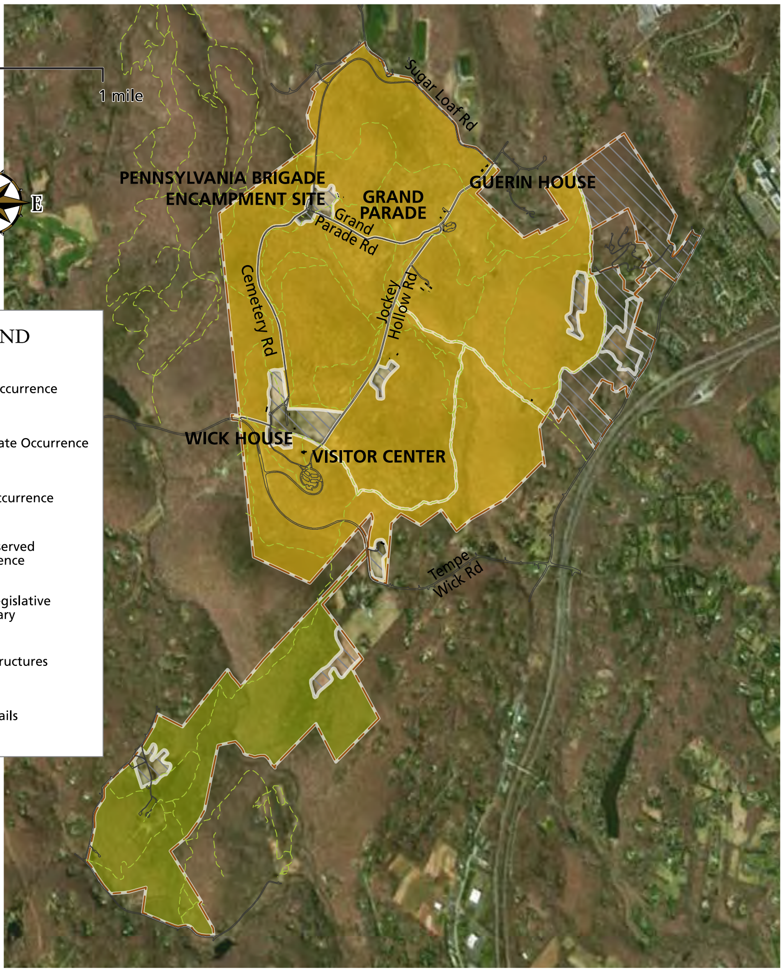
Occurrence of Non-Native Species - Aralia elata-Japanese Angelica Tree



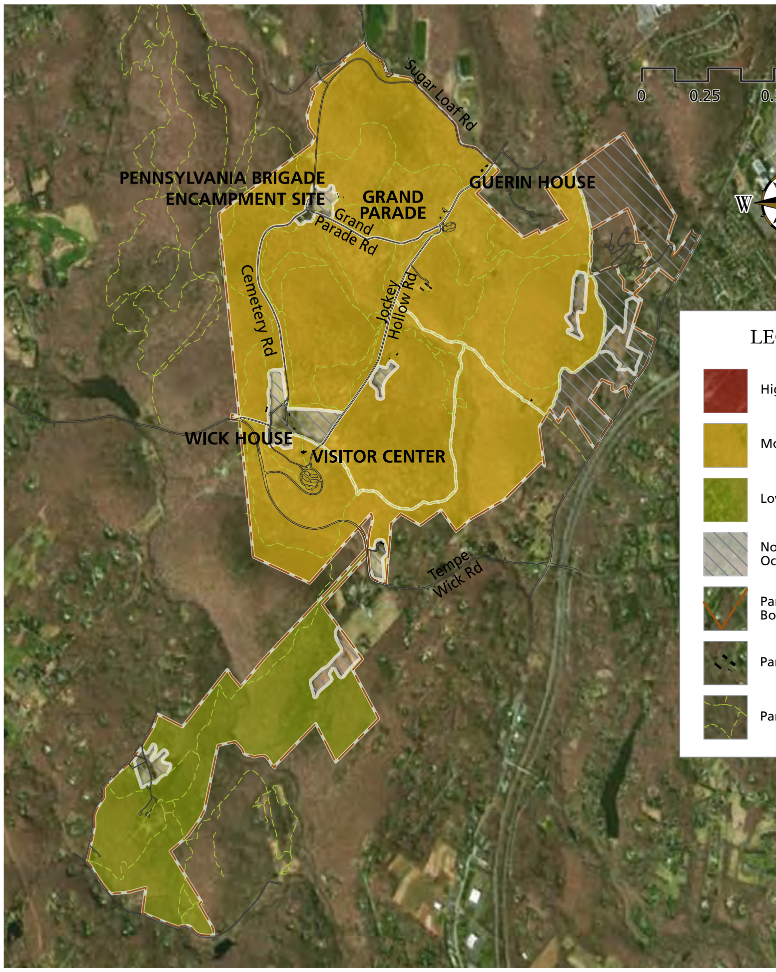
Occurrence of Non-Native Species - Elaegnus umbellata-Autumn Olive



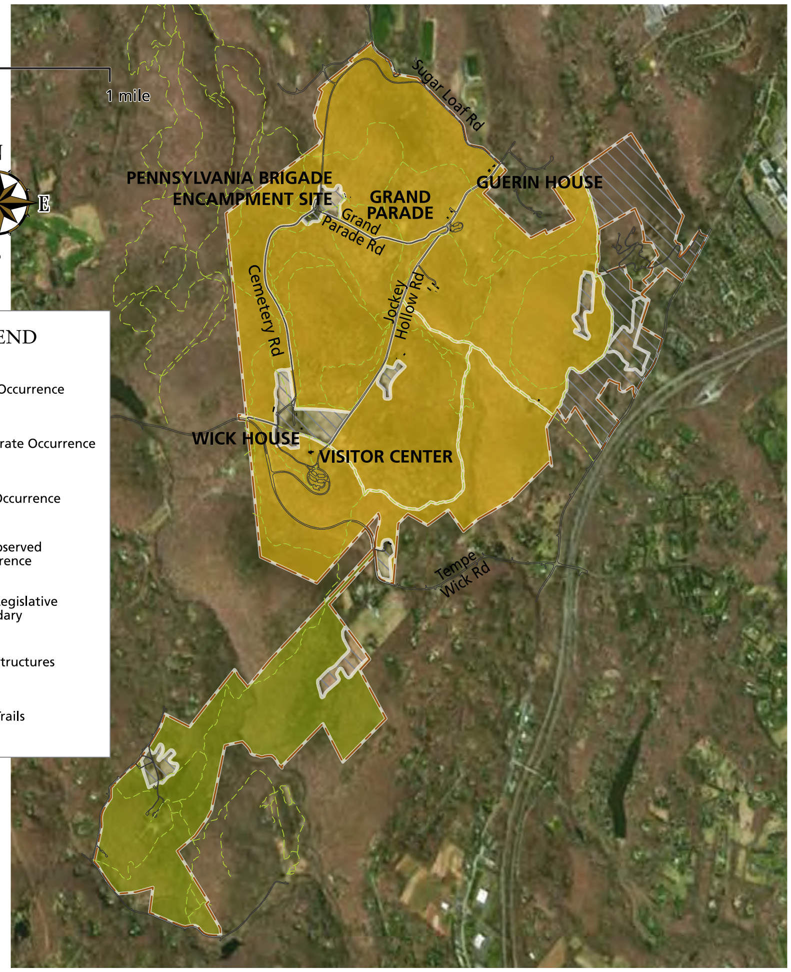
Occurrence of Non-Native Species - Photinia spp.-Photinia



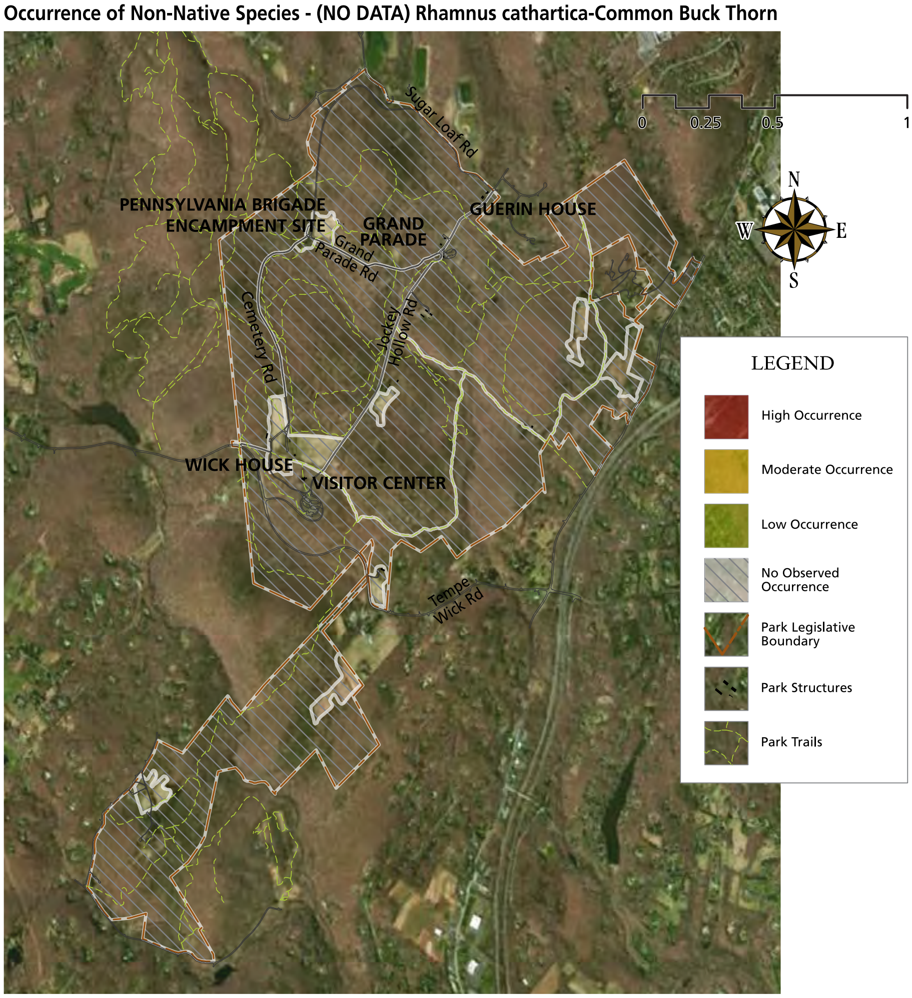
Occurrence of Non-Native Species - Photinia villosa-Oriental Photinia



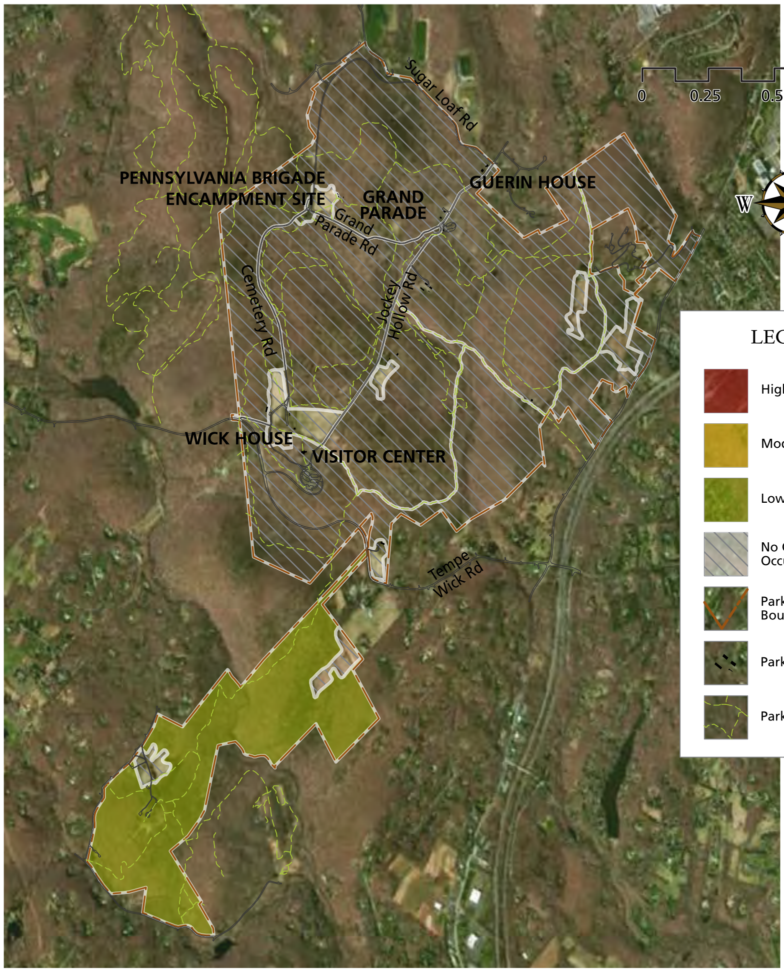
Occurrence of Non-Native Species - Viburnum sieboldii-Siebolds Viburnum



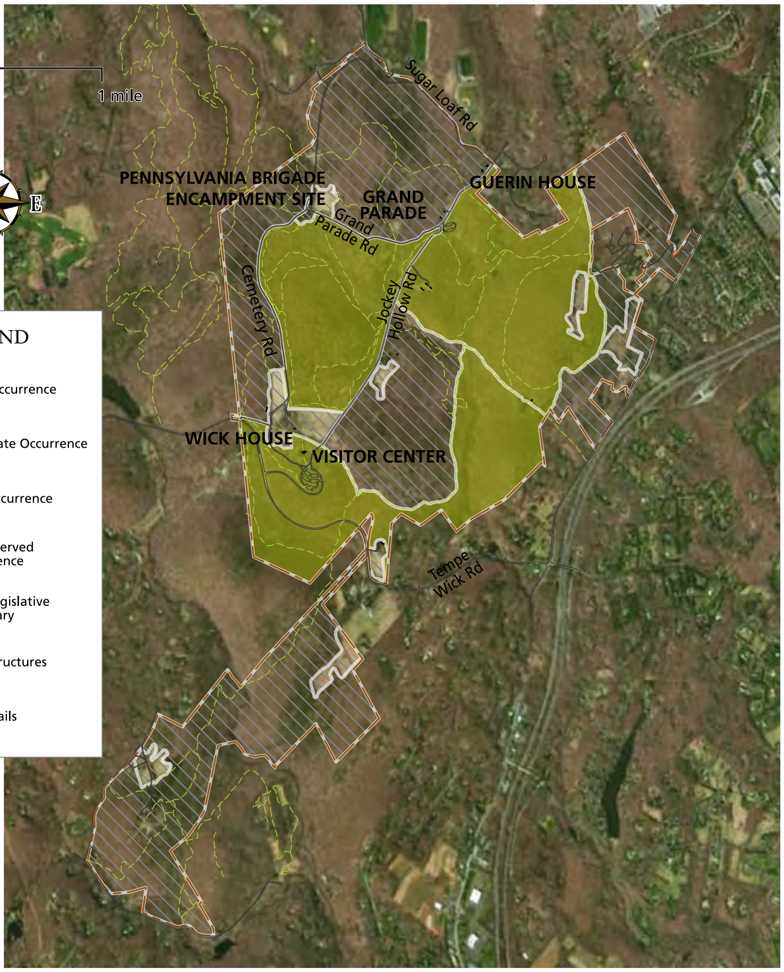
Occurrence of Non-Native Species - (NO DATA) Rhamnus cathartica-Common Buck Thorn



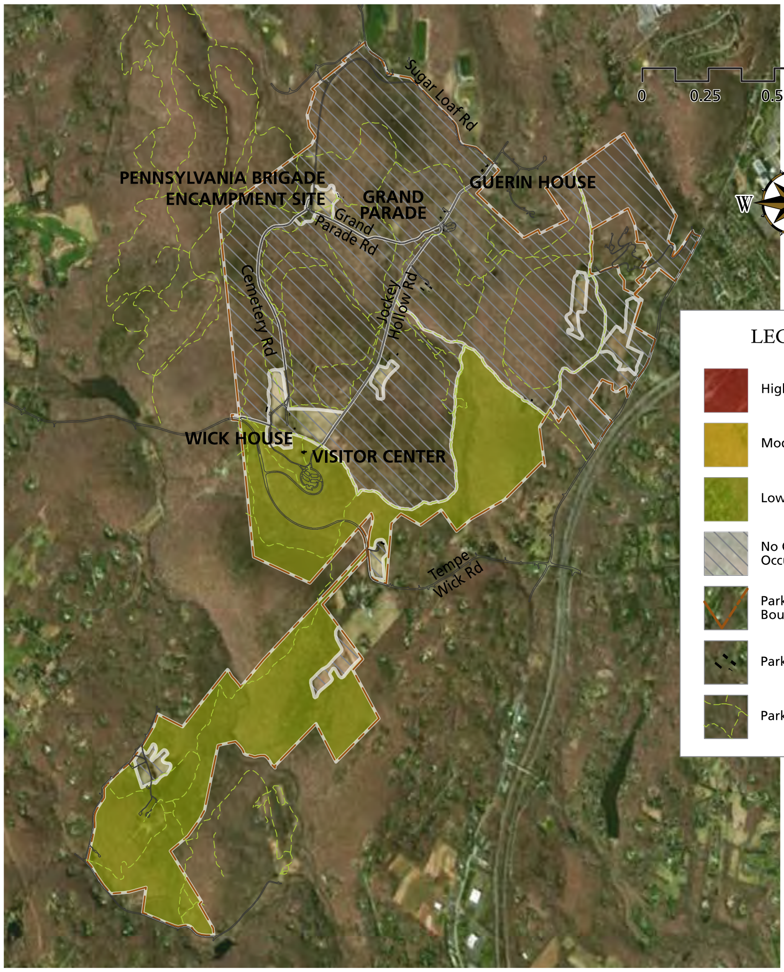
Occurrence of Non-Native Species - Acer platanoides-Norway Maple



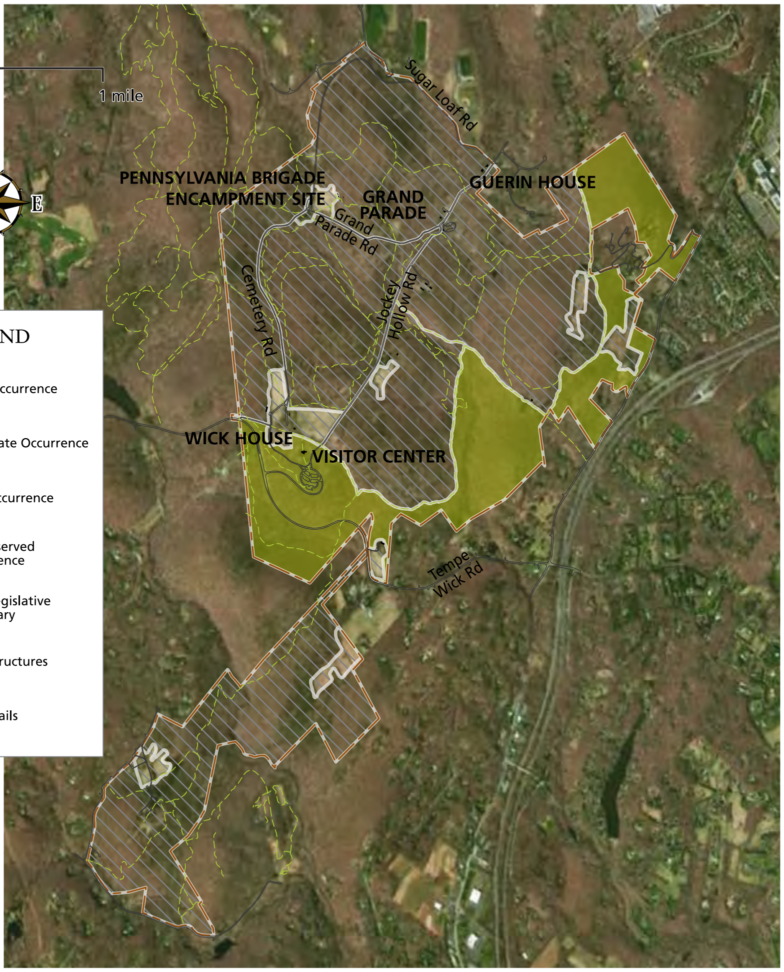
Occurrence of Non-Native Species - Ailanthus altissima-Tree of Heaven



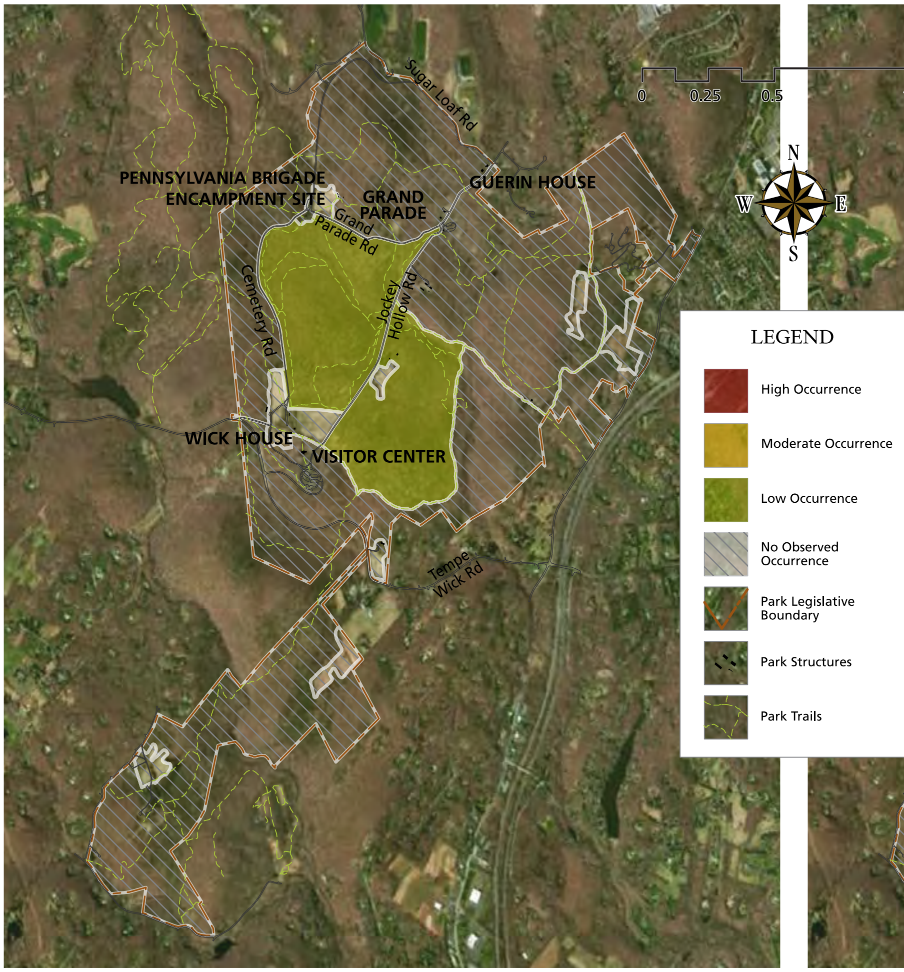
Occurrence of Non-Native Species - Pawlonia tomentosa-Empress Tree



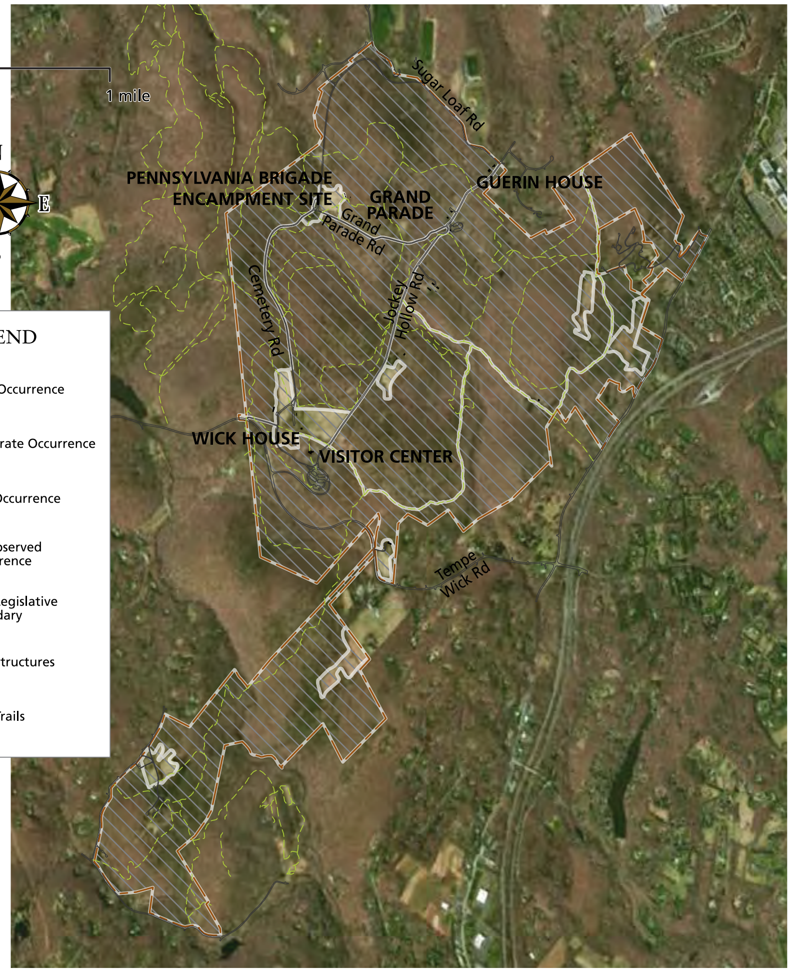
Occurrence of Non-Native Species - Styrax grandifolia-Big-leaf Snowbell



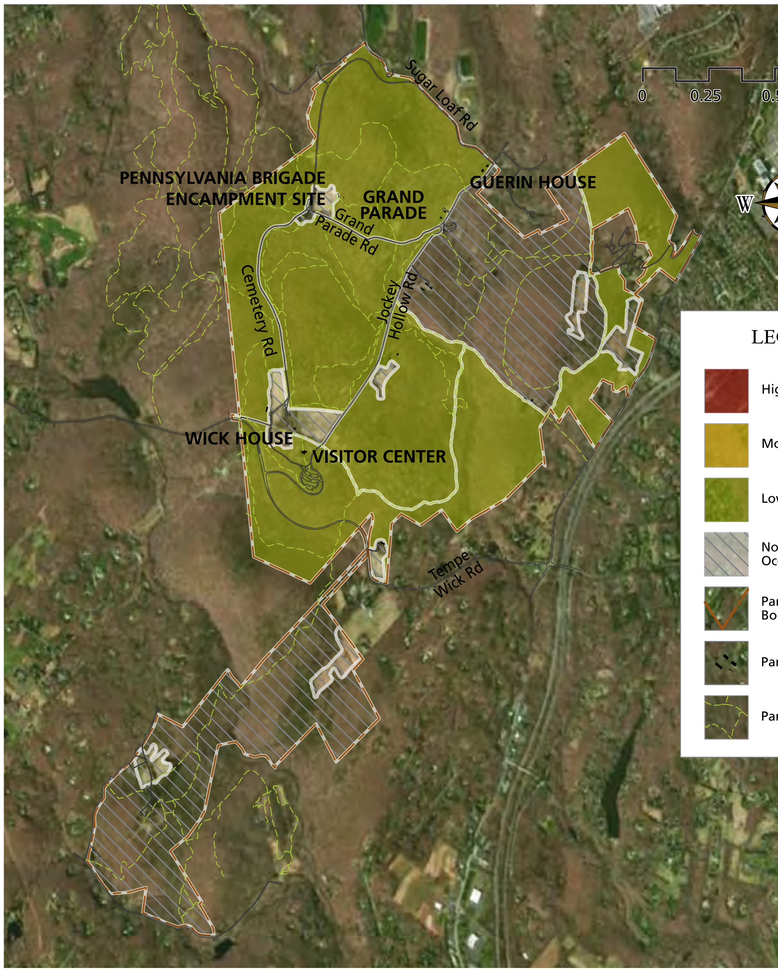
Occurrence of Non-Native Species - Ulmus procera-English Elm



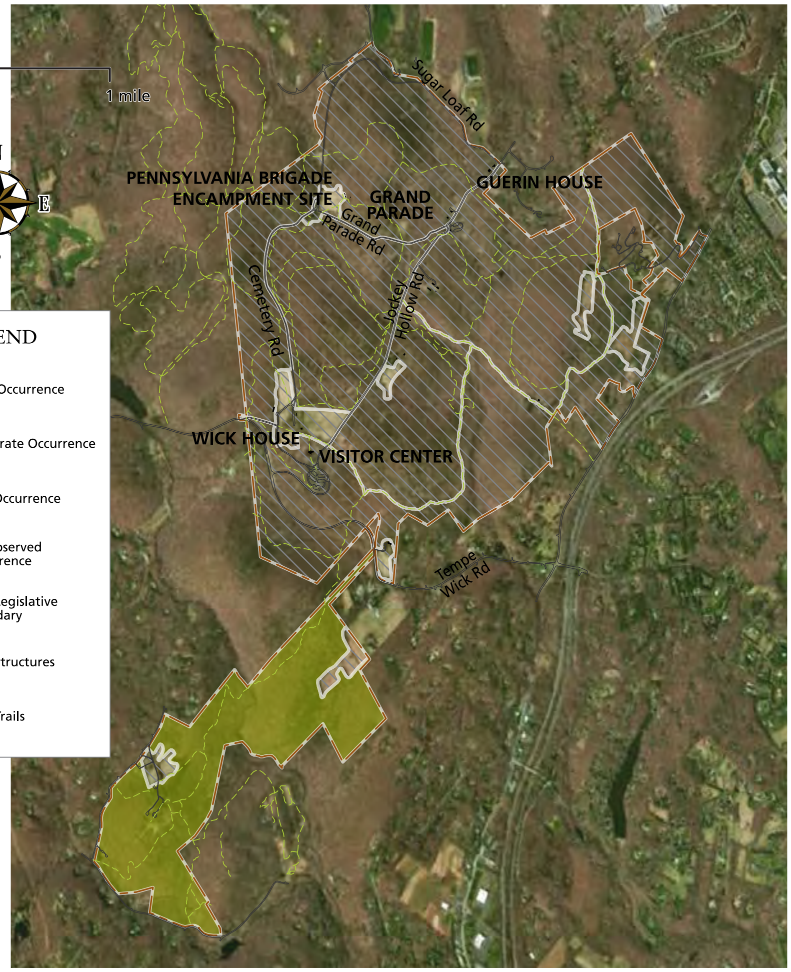
Occurrence of Non-Native Species - (NO DATA) Morus alba-White Mulberry



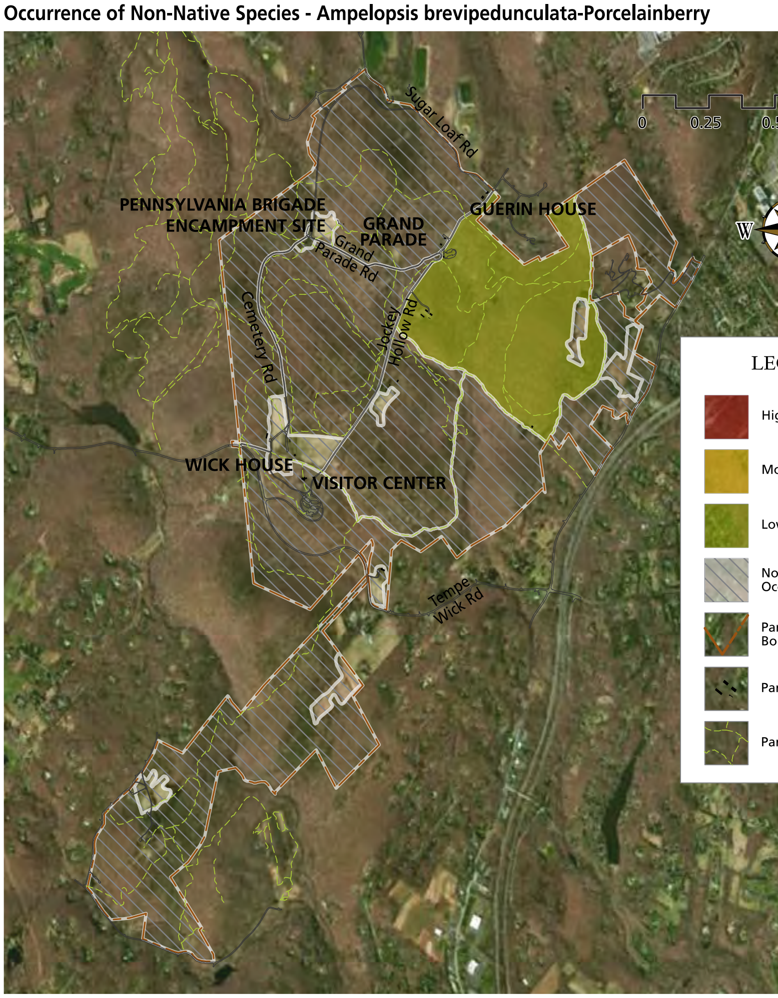
Occurrence of Non-Native Species - Actinidia arguta-Hardy Kiwi



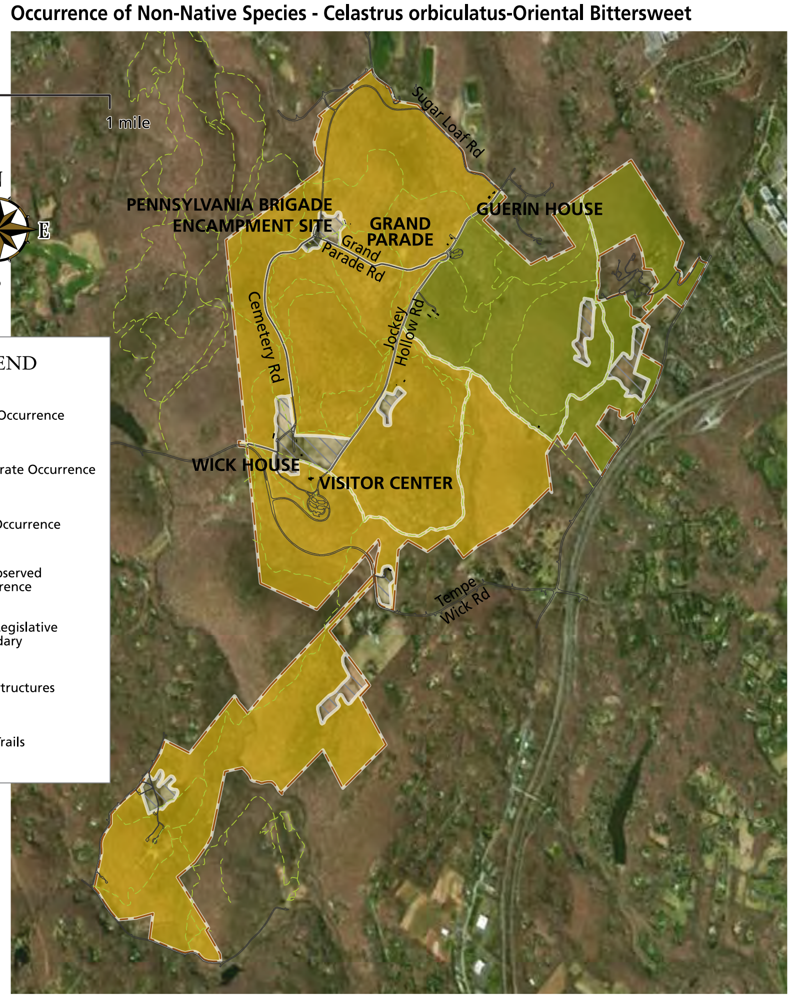
Occurrence of Non-Native Species - Akebia quinata-Fiveleaf Akebia



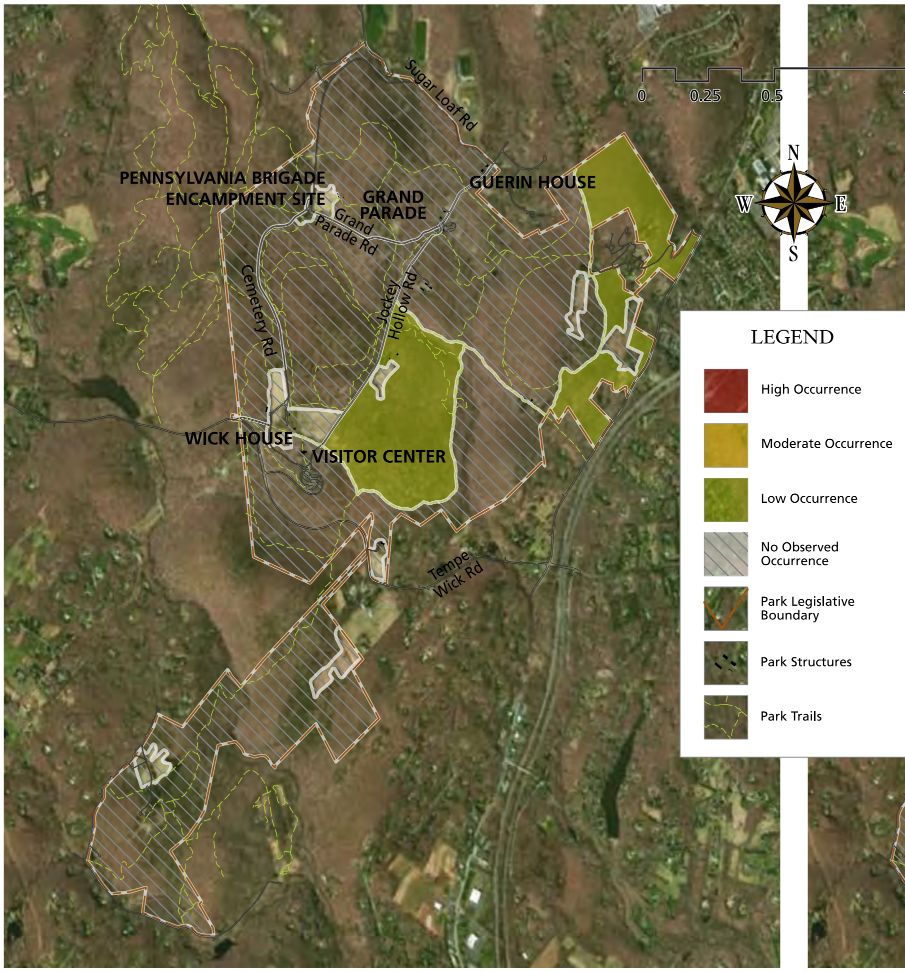
Occurrence of Non-Native Species - Ampelopsis brevipedunculata-Porcelainberry



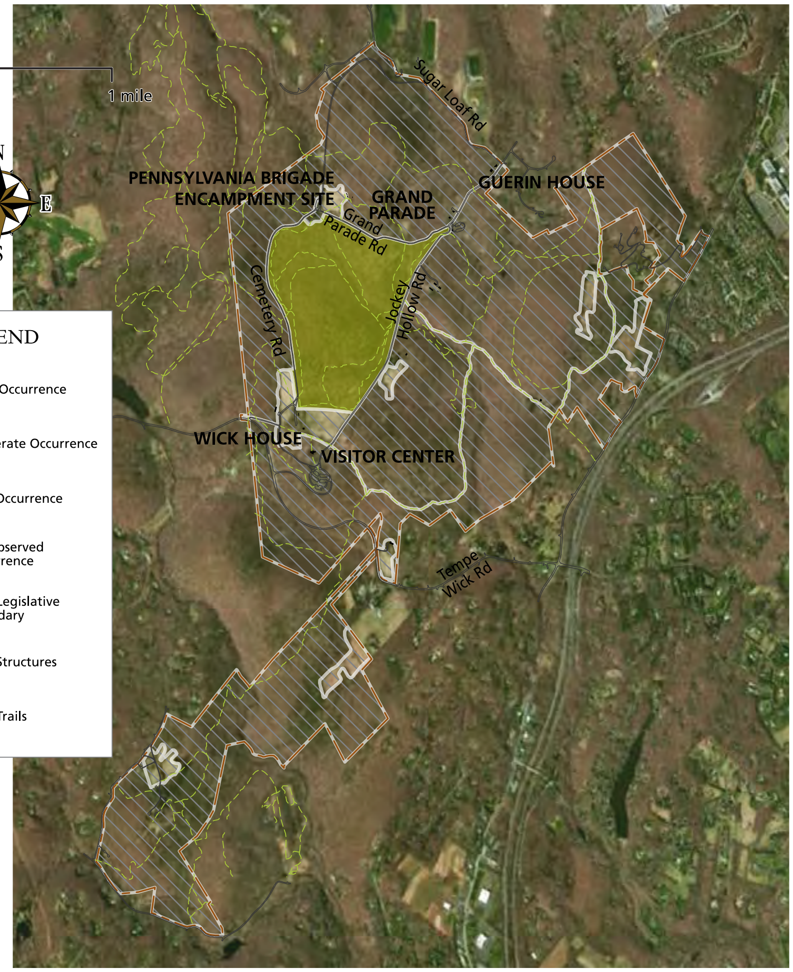
Occurrence of Non-Native Species - Celastrus orbiculatus-Oriental Bittersweet



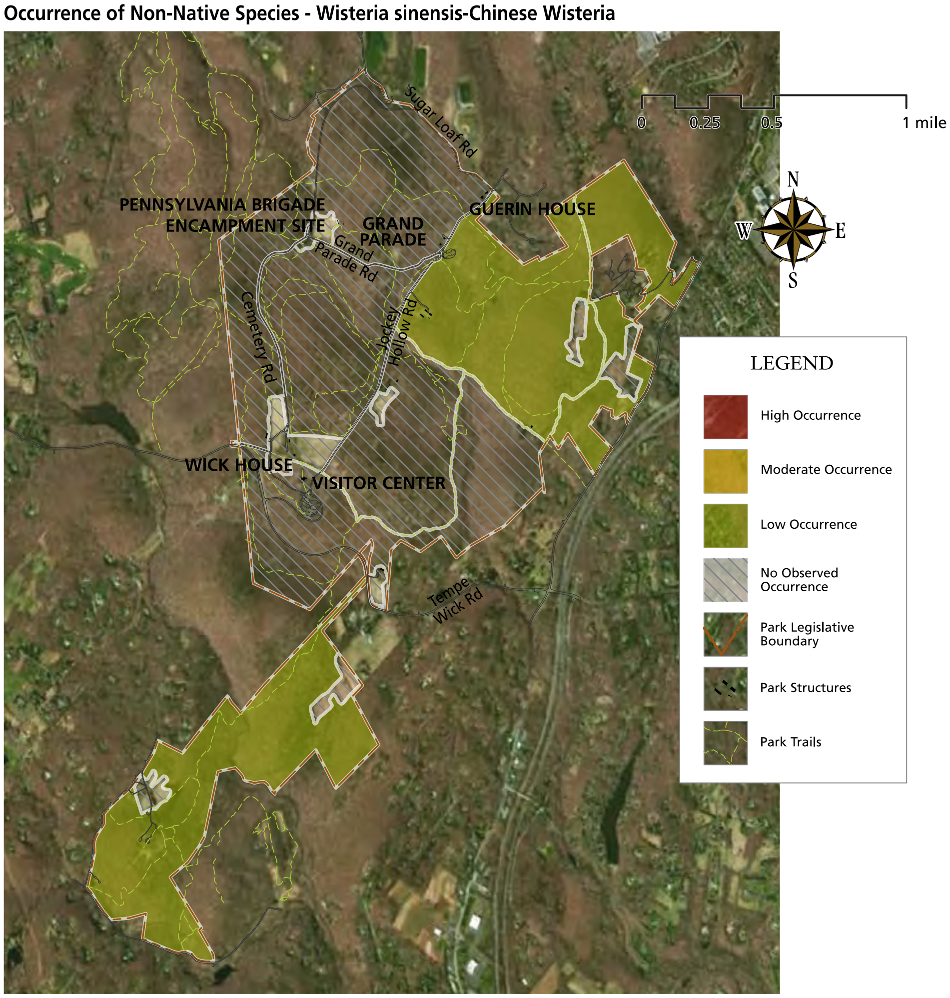
Occurrence of Non-Native Species - Cynanchum nigrum-Black Swallowwort



Occurrence of Non-Native Species - Parthenocissus tricuspidata-Boston Ivy



Occurrence of Non-Native Species - Wisteria sinensis-Chinese Wisteria



As the nation's principal conservation agency, the Department of the Interior has responsibilities for most of our nationally owned public lands and natural resources. This includes fostering wise use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historic places, and providing for the enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people. The department also promotes the goals of the Take Pride in America campaign by encouraging stewardship and citizen responsibility for American Indian reservation communities and for people who live in island territories under US administration.

NPS/MORR/July 2017