Technical Report of a Natural Resources Assessment:

Harpers Ferry National Historical Park

By

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A major paper submitted to the faculty of Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Master of Natural Resources

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April 24, 2010
Falls Church, Virginia

Keywords: Harper's Ferry National Historical Park, natural resources, assessment, State of the Parks

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Abstract

This paper is the technical report of a natural resources assessment of Harpers Ferry National Historical Park (HAFE or Park) conducted in the summer of 2007 on behalf of the National Parks Conservation Association (NPCA), in conjunction with the Center of the State of the Parks. It was written to support the development of the NPCA's 2009 document, *Harper's Ferry National Historical Park: A Resource Assessment.* This paper reports on the results of the investigation of HAFE's natural resources, as well as the Park's documentation of its natural resources. It describes the Park's biogeographical and physical setting; its regional and historical context; unique Park resources and designations; scientific efforts conducted at the Park; and the natural resources management of the Park. In addition, this paper discusses measures of ecosystem and biotic health and indicators of environmental quality within the Park. The author highlights certain natural resources that are in especial danger or are of extraordinary value. The author also comments on the state of the natural resources at HAFE and makes recommendations regarding the effective management and prioritization of the Park's natural resources. Please note that a separate investigation was conducted to investigate the Park's cultural resources and those resources are not discussed in this paper.

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I. Introduction

By the mid 19th century, the small town of Harpers Ferry, West Virginia, had evolved from a rural hamlet into a thriving industrial center. Water power was abundant, natural resources were plentiful, and transportation lines radiated out along the Shenandoah and Potomac Rivers, north and west across the Baltimore & Ohio (B&O) Railway, and south to Washington, D.C., by way of the Chesapeake & Ohio (C&O) Canal. The town's strategic location set the stage for John Brown's famous slave uprising in 1859, in which he led a raid on the Federal Armory. Harpers Ferry was the site of a famous 1862 battle during the Civil War, and was hotly contested during the remainder of the War, changing hands no less than eight times. The historical significance of the area during the Industrial Era and the Civil War resulted in the town and its surrounding environs being designated first as a National Historical Monument on 30 June 1944, and later redesignated on 29 May 1963 as a National Historical Park.

The National Park Service (NPS) manages Harpers Ferry National Historical Park (HAFE) and is charged with protecting the cultural and natural resources found within the Park to commemorate the historic events that transpired in Harpers Ferry and to provide a venue for preserving relics of archaeological and historical significance (NPS 2007a). HAFE has grown in piecemeal fashion, as the Park expanded its acreage through land purchases, private and public land donation, and exchange of federal lands. When the 1944 Congressional enactment (58 Statutes 645) created Harpers Ferry National Monument, the lands allocated to the Park were not to exceed 1,500 acres. The Act of 14 July 1960 (74 Statutes 520) authorized the acquisition of 30 more acres, including areas and structures of historical significance such as Storer College, the John Brown Fort Site, and the Federal Armory site. In 1963, the State of Maryland donated 763 acres that included several important Civil War action sites. On 24 October 1974, the signing of Public Law (PL) 93-466 adjusted the Park boundaries to increase the allotted acreage to 2,000 acres. The Act of 3 January 1980 (PL 96-199), an amendment to the National Parks and Recreation Act of 1978, expanded Park boundaries again, by authorizing the acquisition of the Short Hill tracts of land in Virginia, an increase of 2,475 acres. The Act of 3 January 1989 (PL 101-109) increased the Park acreage to 2,505 acres by allowing for the donation of the Nash and Murphy's Farm (NPS 2000). Finally, PL 108-307, approved 24 September 2004, authorized the expansion of the Park to its present size by increasing the authorized acreage from 2,505 to 3,745, an increase of 1140 acres (NPS 2007a). The Park currently spans 3,646 acres and management continues to explore avenues for expansion (Hebb 2007g, pers. comm.).

II. Park and Resources Context

A. Biogeographic and Physical Setting

i. Park Location, Size/Area

HAFE lies at the confluence of the Shenandoah and Potomac Rivers and at the conjunction of Maryland, Virginia, and West Virginia (Figure 1). It surrounds the historic town of Harpers Ferry, West Virginia, and occupies a spot at the foothills of the Blue Ridge Mountain section of the Appalachian Mountain Range. Consequently, the Park is located within the Blue Ridge Mountain and on the edge of the Valley and Ridge physiographic provinces (Thornberrry-Ehrlich 2005). When it was created as a National Historical Monument in 1944, the Park consisted of less than 1,500 acres. Today, HAFE comprises approximately 3,646 acres of woody forests, mountainous hillslopes, historic town lands, open and agricultural fields, wetlands, and riparian areas (NPS 2007a).

Figure 1. Aerial photo of HAFE (NPS 2007d)

HAFE is made up of a series of individually acquired land parcels (Figure 2). Table 1 describes the nine land parcels incorporated into the Park before 2000. Excerpted from the Harpers Ferry National Historical Park 2000 Resources Management Plan (NPS 2000):

Table 1. Land parcel descriptions

1. Historic Town and environs
This relatively small part of the Park receives most of the Park's visitors. It consists of 20+ historic structures that are used as interpretive facilities, Park offices, or that are currently vacant. This area is located at the confluence of the Shenandoah and Potomac Rivers and is located within the 100-year floodplain. An extensive restoration program began in the late 1970s and concluded in the mid-1990s. A railroad trestle dating to the early 1800s runs through this area. Land adjacent to the historic buildings in this area was used as the primary parking area for visitors. With the development of the Visitor Center and parking facilities on Cavalier Heights and the implementation of a shuttle system in 1989, parking lots were removed and the site restored to its historic use.
2. Federal Armory site and Potomac River frontage
This floodplain site lies adjacent to the Historic Town along the Potomac River and is probably the most significant historic site within the boundaries of the Park. It is the original site of the Federal Armory and Canal which operated from the late 1700s to the Civil War. Much of the original Armory site was covered with fill in the late 1800s for the development of railroad facilities, but the foundations of the Armory buildings still exist

under the fill. A 1500-foot retaining wall along the Potomac River is the most prominent, visible historic structure on the site.
3. Virginius Island
This floodplain area was the center of private industry during the early and mid-1800s. This island, containing about 13 acres, is on the north side of the Shenandoah River, a short distance west of the Historic Town. It was extensively developed with canals to provide water power in the early 1800s. In 1859, Virginius had an iron foundry, machine shop, cotton mill, flour mill, sawmill, and carriage manufacturing shop all privately operated. Most of the ruins of these early businesses are still evident, but natural processes have been permitted to reclaim much of the area. An active railroad passes through the Island.
4. Camp Hill
Camp Hill is located west of the Historic Town and consists of the following: the wooded slope containing a portion of the Appalachian Trail and the historic Jefferson Rock; several historic buildings constructed for the Federal Armory and used adaptively for Park administrative purposes; several historic structures built for the Federal Armory and Storer College which are adaptively used by the Harpers Ferry Center; modern structures constructed for the Harpers Ferry Center and the Mather Training Center constructed in the 1960s; and the Park's maintenance facilities. All of the above government facilities and historic structures are intermingled in the community of Harpers Ferry and are above the floodplain.
5. Bolivar Heights and Elk Run
Bolivar Heights and Elk Run are located approximately one mile west of the Historic Town and consist of the following: a south-facing, fenced, open field containing an interpretive trail and small parking lot; an adjoining mowed field which abuts residential development in Bolivar, WV; and a west-facing, wooded slope containing Civil War trenches. This site is noted for its Civil War activity - 12,500 Union troops surrendered to Confederate General Stonewall Jackson in September 1862. This area also contains the Civil War Trust property acquired in 1998.
6. Cavalier Heights
This area contains the Visitor Center and entrance facilities, and a wooded slope and lowland. It consists of the following: Visitor Center, large parking lot, bus maintenance facilities; remnants of a historic canal which provided water to the industrial complex on Virginius Island and which has filled-in to become an 8-acre wetland; and a wooded, steep slope and shoreline south of the wetland.
7. Loudoun Heights
Loudoun Heights is located south of the Shenandoah River from the Historic Town and consists of approximately 500 acres of steep, wooded land. This area is bordered by the Shenandoah and Potomac Rivers, Appalachian Trail and Keyes Ferry and Blue Ridge Acres residential developments. It is bisected by Chestnut Hill Road, which provides access to the residential developments and connects to Route 9. The site is also bisected by a 34.5 kilivolt powerline right-of-way maintained by the Allegheny Power Company. The site consists of hiking trails, scenic overlooks, the Appalachian Trail, and numerous Civil War archeological sites.
8. Maryland Heights
Maryland Heights is located north of the Potomac River and borders the small town of Sandy Hook. It consists of 790 acres of steep, wooded slopes, rock outcroppings, several streams, historic fortifications, scenic overlooks and several miles of hiking trails.
9. Short Hill
Short Hill is located in Loudoun County, Virginia, and consists of 370 acres of steep

wooded slopes, shoreline along the Potomac River, several poorly defined trails and historic ruins. This land was acquired in 1981 for scenic protection of the view through the Harpers Ferry Gap from Jefferson Rock.

The most recent expansions include Murphy Farm on Bolivar Heights; the northern extension of Schoolhouse Ridge ("Jackson's Left Flank"), which is made up of former Fish and Wildlife Service property along Millville Road, Perry Orchard, and the Civil War Preservation Trust property west of Bakerton Road; Ott Farm; the Werner property; Appalachian Trail lands; and several other parcels of agricultural lands. The 99-acre Murphy Farm was the site of important events in the 1862 battle and housed the John Brown Fort from 1895-1909 during one of its many moves (Moyer et al. 2004; NPS 2003b).

Many of the Park's land parcels are geographically fragmented by private and public land and structures (Figure 2). The Park is further segmented by a variety of disparate natural and anthropogenic features. The Shenandoah and Potomac Rivers carve out several of the Park's land parcels. United States Route 340, a major east-west corridor, passes through the Park, as do several other roads and highways. The incorporated towns of Harpers Ferry, population approximately 310 (Harpers Ferry Town Web site 2007) and Bolivar, population approximately 1,100 (Bolivar Town Web site 2007), are located between the lower town and the Bolivar Heights section of the Park. Approximately two miles of the Historic Appalachian National Scenic Trail (ANST) cuts through Park boundaries and the CSX Corporation Railroad (formerly the Baltimore and Ohio [B&O] Railroad) continues to operate a track that runs through the lower town section of the Park (Figure 3).

While several miles of the Potomac and Shenandoah Rivers cut through HAFE, the rivers are not within HAFE boundaries and the NPS does not have authority over these waterways. The NPS also has no authority over the railroad, roads, and highways that intersect the Park, nor does it have sole authority over the portion of the ANST that runs through the Park. In addition, the Park shares a border with the C&O Canal National Historical Park. The NPS at HAFE is challenged to work closely with a number of private, local, state, and federal government entities to manage Park resources in a manner that fulfills its original charge.

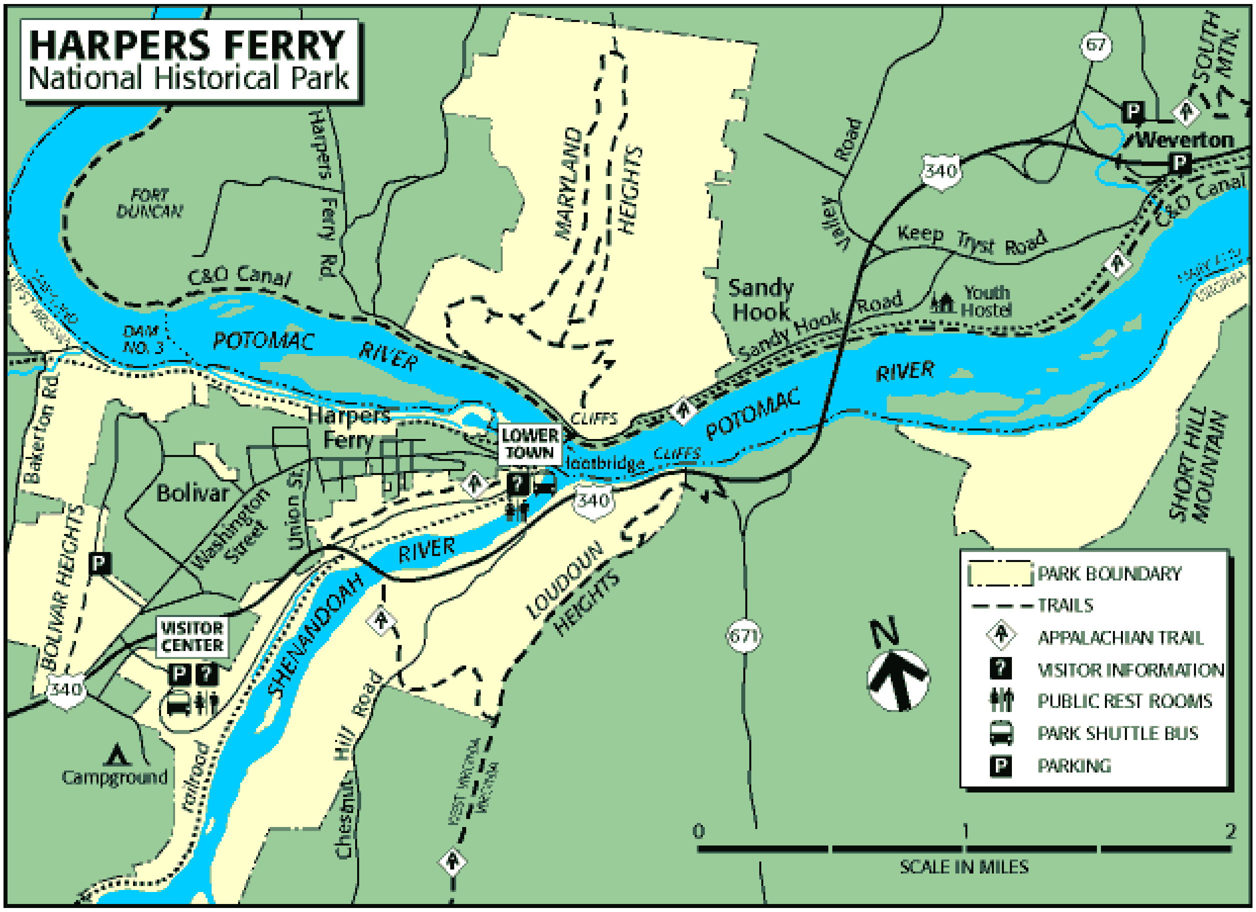
Today, HAFE receives more than 0.5 million visits each year, with most of the visits occurring during the warmer months. Visitors come to enjoy the Park's natural resources and 50-plus contemporary buildings, 15 miles of trails and paths, and over 150 historic structures. Some of these historic artifacts include prehistoric and historic archeological sites, buildings, monuments, fence lines, cemeteries, roads, farm fields and forests present during the mid nineteenth century (Hebb 2002). The Park also maintains 13 hiking trails that cover approximately 18 miles of terrain through the different sections of the Park. Visitors who drive to HAFE mainly park their vehicles in the lot at the Visitor Center; they reach the lower Historic Town via six shuttle buses operated by the Park or on foot on hiking trails. There is little parking availability in the Historic Town, as the roads narrow and floodplain space is at a premium. The NPS shuttle service runs regularly between the Historic Town and the Visitor Center and occasionally provides shuttle services for tours at Murphy's Farm, Bolivar Heights, and Camp Hill (NPS 2007c).

Other NPS operations that are located within in the Park and that occupy Park buildings include the Harpers Ferry Center, the Mathis Training Center, the headquarters of the ANST, the NPS Museum Services Divisions, and the NPS Potomac Heritage Trail Office (Hebb 2002). There is one permitted wastewater discharge site on HAFE grounds that is subject to the West Virginia National Pollutant Discharge Elimination System General Permit For Vehicle Washing Establishments #WV0078743. The site is the vehicle washing facility located in the corner of one of the parking lots at the main visitor center, where Park staff occasionally wash down the shuttle buses. The permit does not contain discharge limits, but does have best management practices and monitoring requirements for conventional pollutants (NPS 2007i, WVDEP 2007).

Figure 2. Current map of HAFE outlining the variegated land parcels (NPS 2007f)

Aerial Photo Date: April 1980

Figure 3. Older (pre-2004 expansion) HAFE map showing anthropogenic structures (NPS 2007d)



ii. Climatic Regime

HAFE occupies a transitional zone between the more maritime climate of the Atlantic Slope and the drier areas of the Allegheny Mountains (Pauley et al. 2005). This somewhat sheltered position is only occasionally affected by Atlantic coastal storms and the area is prone to a precipitation deficit and periods of drought. Prolonged periods of drought have been known to occur, and summers are often characterized by dry spells that are punctuated by extreme weather events such as thunderstorms and hail storms. The area averages 35-40 thunderstorms per year, mostly during the summer months (Hatfield and Warner 1973).

The area's climate varies widely across the seasons. The annual average temperature in the region is 53 degrees Fahrenheit, but the summers are warm, humid, and stormy, with temperatures occasionally exceeding 100 degrees and averaging 82 degrees.

Though winter temperatures have been documented to drop down to 0 degrees, the season is generally more moderate, with an average seasonal temperature of 32 degrees and alternating between freezing (i.e., cold and storming) and thawing (i.e., fair and warming) weather. Fall and spring temperatures average in the mid-50s (NPS 2007a; NPS 2007c).

Cloud cover in the Park is thickest during the winter and clearest during the summer (Hatfield and Warner 1973). The annual precipitation averages 39.5 inches, with approximately equal parts falling during the spring, summer, and fall, and slightly less falling during the winter. Average winter snowfall varies widely, but typically ranges from 20-25 inches. The relative humidity for the Park is high, with an annual average of 70 percent. During the spring season, the average humidity hovers around 67 percent; during the fall, the relative humidity averages around 71 percent. At HAFE, the wind typically blows N-NW and annual wind speed averages 9 miles per hour (mph). Thunderstorms have been known to generate wind bursts peaking at 77 mph (NPS 2007a).

During the summer and winter months, the region is subject to intense storms that can bring significant amounts of precipitation. A large precipitation event at the Park can trigger catastrophic occurrences such as rockslides and/or mudslides and flooding. The Potomac and Shenandoah have incised steep cliffs in the topography surrounding the rivers' confluence, creating ideal conditions (i.e., unstable steeps and confined river channels) for weather-related disasters.

iii. Geology and Land Forms

HAFE is located in the Blue Ridge province of the Appalachian Mountain Range. Most of the rock formations in the area are igneous (i.e., molten origin) or metamorphic (i.e., altered by high temperature and/or pressure); the region's formations are predominantly made up of quartzite, phyllite, and limestone (Kenworthy and Santucci 2004). The geological formations of the area exhibit the folded, fractured, and steeply dipping rock beds characteristic of continental mountain-building activities. These land features strongly influenced human development of the area, requiring the construction of canals, bridges, and tunnels. The rock types and formations also allowed for the development of numerous local slate quarries (Thornberrry-Ehrlich 2005). These formations, however, were not conducive for retaining paleontological resources. The rock types (i.e., created under high temperature and pressure conditions) are not known for preserving fossils and consequently, no formal paleontological inventories have been undertaken for HAFE (Kenworthy and Santucci 2004).

The Park also borders the Valley and Ridge geological province, which is characterized by resistant sandstone ridges and erodable carbonate valleys. As such, the region exhibits karst topography. The portion of HAFE west of the Blue Ridge Mountains contains over 700 acres of karst topography featuring caves, sinkholes, and springs (PMIS - Karst). The area has several known cave systems and the Park has one significant cave, John Brown's Cave, which is a narrow, lateral limestone cave that runs approximately 4,000 feet and opens along the CSX Railroad bed (Thornberrry-Ehrlich 2005; Hebb 2007a). Park management is working on acquiring land that contains a series of caves known as Harpers Ferry Caverns (Hebb 2007b, pers. comm.).

The most recent soil surveys for Jefferson County, WV, Washington County, MD, and Loudon County, VA, date from 1973, 2001, and 1960, respectively. The USDA Natural Resources Conservation Service is in the process of updating the Jefferson County soil survey. Soil information specific to HAFE, however, is generally unavailable.

The common soil associations in the Park and their typical uses are described in Table 2.

Table 2. Soil associations at HAFE (NPS 2007c, Perles 2007, Hatfield and Warner 1973)

Soil Association	Location at HAFE	Description	Notes
Berks-Weikert	Historic Town; throughout Park	Shaly silty loams	Conducive to erosion; forestland
Benevola-Frankstown-Braddock	Potomac River northwest of Historic Town to Bloomery Road; Jackson's Right Flank	Clay, shaly silt loam, and gravelly loam, respectively; rounded	Underlain by limestone and dolomite rocks; quarried as blast furnace

		gravelly rocks near the surface	flux; limited agricultural uses
Braddock-Landes-Ashton	Along the Shenandoah River	Landes series is a fine sandy loam	Landes series is subject to flooding; suitable for agriculture and pastureland
Dekalb-Laidig	Foothills below the Blue Ridge Mountains; from Virginia state line to the Poromac River north of Bolivar Heights	Well-drained, containing stones throughout; steep slopes	Slopes restrict land use; forestland
Edgemont-Laidig-Steep rock land	Foothills, side, and crest of the Blue Ridge Mountains	Shaly silt loan underlain by shattered shale and fine-grained sandstone	Steep slopes and rock outcroppings; forestland
Duffield-Franktsown-Huntington alluvium	Jackson's Right Flank; most agricultural flatlands in Park	Huntington – silt loam local alluvium; silty limestone and interbedded limey shales	Suitable for dairy, general, orchards, and residential development; forestland

The topographic relief in the Park varies to extremes. While the Park is largely made up of gently graded forested slopes and rolling fields, it also contains steep cliffs and broad floodplains. The highest elevation in the Park occurs on Maryland Heights (1,448 feet) and the lowest point, which also represents the lowest elevation in the state of West Virginia, occurs at the confluence of the Shenandoah and Potomac Rivers (235 feet) (NPS 2000; Hatfield and Warner 1973). The combined flow of these rivers has carved the Harpers Ferry Water Gap as it exits the Blue Ridge Mountains. The gap varies in width and in spots, it is considered to be an extreme example of its kind. It exposes resistant rock cliffs along Blue Ridge-Elk Ridge to the west and Short Hill-South Mountain to the east (Thornberrry-Ehrlich 2005). These cliffs, many of them over-steepened by human activity (e.g., mining and construction), represent a significant risk for slope failure independent of or in conjunction with extreme weather.

Kite (1997) observed that:

> *West Virginia presents some of the most severe slope failure problems in the country and…Harpers Ferry National Historical Park represents some of the most severe slope-stability hazards in eastern West Virginia*.

Several geological monitoring studies have identified a variety of slope failure formations in the Park, including rock falls, rock topples, rock slides, debris slides, debris slumps and creep. Mass wasting events from the stronger rock units (e.g., quartzite cliffs) are potential hazards. Similarly, less-resistant rock units (e.g., shales and mudstones) present major concerns for landslide events. In addition, non-rock land formations, such as thick soils or unconsolidated river deposits, are vulnerable to failure when exposed on a slope, particularly during extreme weather events. A heavy rainstorm, common in the eastern climate, can quickly saturate rock and soil, potentially causing a slump, mudslide, or mudflow. These earth-moving events have the potential to cause serious damage to valley slopes, many of which lack stabilizing vegetation due to anthropogenic activities (Thornberrry-Ehrlich 2005).

Slope failures can result from natural erosion of high-relief features, but the slope failure risks in this area are exacerbated by anthropogenic activities; inappropriate land use and slope manipulation (construction and development in the path of natural processes) have significantly increase the likelihood of slope failure events. Geological monitoring studies agree that the three primary hazard areas of concern are found: (a) in the lower town where slopes were over-steepened in the 19th century to make way for construction of buildings; (b) along Route 32 (Chestnut Hill Road) where the slope has been over-steepened to widen the road; and (c) the entire face of Maryland Heights, where slope failures have been the most prevalent (NPS 2000; Cloues 2000; Gilliam et al. 2002; Kite 1997). All slope failures, most especially the cliff sections of the Historic Town that have been mined to clear space for construction and visitor trails winding through high-relief viewsheds, present a risk of property damage and could lead to human injuries or fatalities (NPS 2000).

In particular, Jefferson's Rock has been recognized as a locale with a high potential for a rock fall. In 1783, Thomas Jefferson visited a rock outcropping in Harpers Ferry, high above the confluence of the Shenandoah and Potomac Rivers, and observed that the view was "stupendous and worth a voyage across the Atlantic" (Campbell 1996). This outcropping, later designated as Jefferson Rock, is one of the Park's most recognized and visited natural historic resources (Gilliam et al. 2002). Due to rock formation and fracture patterns, specific stone blocks in this outcropping have an extremely high potential for failure. Experts have recommended that the outcrop be continuously monitored (Gilliam et al. 2002).

As is the case for many of the other historical Parks, one of the goals in managing HAFE is to maintain the landscapes as they were at the time of the specific events that led to the creation of the Park. As preservation and restoration efforts include both natural and cultural resources, this goal is continuously threatened by the natural processes of erosion and weathering. The geology of Harpers Ferry has strongly influenced the development of the town and its surrounding areas. Cliff slopes were cleared for residential and commercial construction and mined for building materials; many of the buildings in the historic town and the former Armory were built from local materials (NPS 2000). Continuous geologic processes of weathering, erosion, deposition, and land movement, combined with extreme slope failure events, present serious challenges to the preservation of the historic landscape as a "snapshot in time" (Thornberrry-Ehrlich 2005).

iv. Hydrologic Overview

The Shenandoah and Potomac Rivers flow through HAFE, but NPS does not have authority over these segments. The Shenandoah, which drains 7,873 square kilometers, flows into the Potomac River at Harpers Ferry Water Gap. The Park contains 2 miles of the Potomac River's West Virginia shoreline and approximately 3 miles of both shores of the Shenandoah River (Hebb 1988). The Park also contains many first- and second-order streams, springs, springbrooks, and seeps, which are characteristic of a highly erodable karst landscape. Segments of two tributary streams, Elks Run and Piney Run, terminate at the Potomac River within the Park. Flowing Springs Run flows through the West Virginia portion of the Park and terminates in the Shenandoah River outside of Park borders (See Figure 4). Many of the smallest waterbodies run intermittently and only exist during the wetter months (Lamp et al. 2004).

In addition, there are approximately 100 acres of wetland areas within the Park boundaries. Most of the wetlands are located along the floodplains of the Shenandoah River, west of the town of Harpers Ferry. The C&O Canal, which operated in the area from 1828 to 1924, is no longer maintained and natural siltation has slowly created marshy wetland (Bates 2000). The Shenandoah Canal, which was constructed to provide water power to Virginius Island industries, and the Armory Canal along the Potomac River, are now slow-flowing freshwater bodies (NPS 2000). Virginius "Island" is not a single natural island, but three original islands that were later connected with fill. It is located in the floodplain found just downstream of the river bend above the Highway 340 bridge and just above the confluence of the Shenandoah and Potomac Rivers (Craig 1990). Virginius Island was extensively developed with canals that are being slowly reclaimed as wetland habitats by natural processes. Flowing Springs Run feeds an intermittent wetland system on Jackson's Right Flank in the southwestern portion of the Park. While the stream flows steadily year-round, this marshy area is sensitive to drought and beaver dam-building activities upstream and oscillates between wet and dry characteristics each season (Lamp et al. 2004).

The effects of upstream structures on the hydrology of the waterways at Harpers Ferry have not been well documented, either in the past or in the present, and remain unknown. The Potomac and Shenandoah Rivers upstream of Harpers Ferry have been and continue to be affected by human structures. While there are no active dams or canals in the immediate vicinity of Harpers Ferry in the present day, area waterways were heavily modified in the 19th century. The C&O Canal Company built several of its locks in the Canal in and around the Park. Dam 3, known as the Armory Dam, U.S. Potomac Dam, or Armory Potomac Dam, was built at mile 62.27 along the C&O Canal towpath in the Park (Gray 2005). The dam was first built between 1799 and 1800, rebuilt in 1828, and extended in 1832–33 to accommodate the C&O Canal. Its intake provided water first for the Armory Canal, then for more than forty miles of the C&O Canal, and also the Patowmack Company's Long Canal (Gray 2005). In 1859, the U.S. government began work on the New Armory Dam just below Dam 3 at mile 62.20 on the C&O Canal towpath. The work "stopped with the outbreak of Civil War, and, with the destruction of the Harpers Ferry Armory in 1861, the government's involvement in manufacturing at Harpers Ferry came to an end and work on the new dam never resumed" (Gray 2005).

In the historic town section of HAFE, most precipitation drains into culverts and ditches, some of which are classified as historic structures. In turn, these culverts eventually drain into natural waterways. The condition of structures and the outflow from the culverts are not monitored and have little documentation (Thornberrry-Ehrlich 2005).

While many of the HAFE's smaller waterbodies have been identified, the Park does not have a complete inventory of its wetland and water resources. The Park is covered by the United States Geological Survey (USGS) National Wetland Inventory, but a more in-depth field inventory of the Park's wetlands is ongoing and scheduled to be completed in the near future. Obtaining digital coverage for existing data on springs, brooks, and intermittent streams, and mapping new spring locations could be useful for better tracking of all water resources in the Park (Thornberrry-Ehrlich 2005).

The major hydrological concern at HAFE is flooding from the rivers, because rising waters have high potential for impacting the cultural and geological resources located along the floodplains of the Park. Many of the historic structures and visitor trails are built on the floodplain and are extremely sensitive to flood damage. Flooding can also have significant impacts on flora and fauna populations in flood-zone habitats. The potential for flooding at Virginius Island is especially high, as the Island's location makes it vulnerable to flooding from both the Shenandoah and Potomac Rivers (Craig and Reed 1990; Doheny and Fisher 2000; Fuertsch 1992). Flooding at Virginius Island is particularly damaging for the Park, as it contains the remains of a number of historic structures and many of the Park's interpretive exhibits.

The topography of the Park contributes both to the risk and the impact of flooding. Heavy precipitation runs rapidly down steep slopes and is not slowed by much stabilizing vegetation. Once waterways begin to overflow, their incised channels do not have room for water to spread; consequently area floods tend to be very deep. Analysis by the USGS of flood frequency and magnitude has found that floods reaching heights of 20 feet or more can be expected to occur at Harpers Ferry every five years (Doheny and Fisher 2000). The flood record at Harpers Ferry is extensive, stretching back over

Figure 4. Regional map of water resources in HAFE vicinity (NPS 1997)

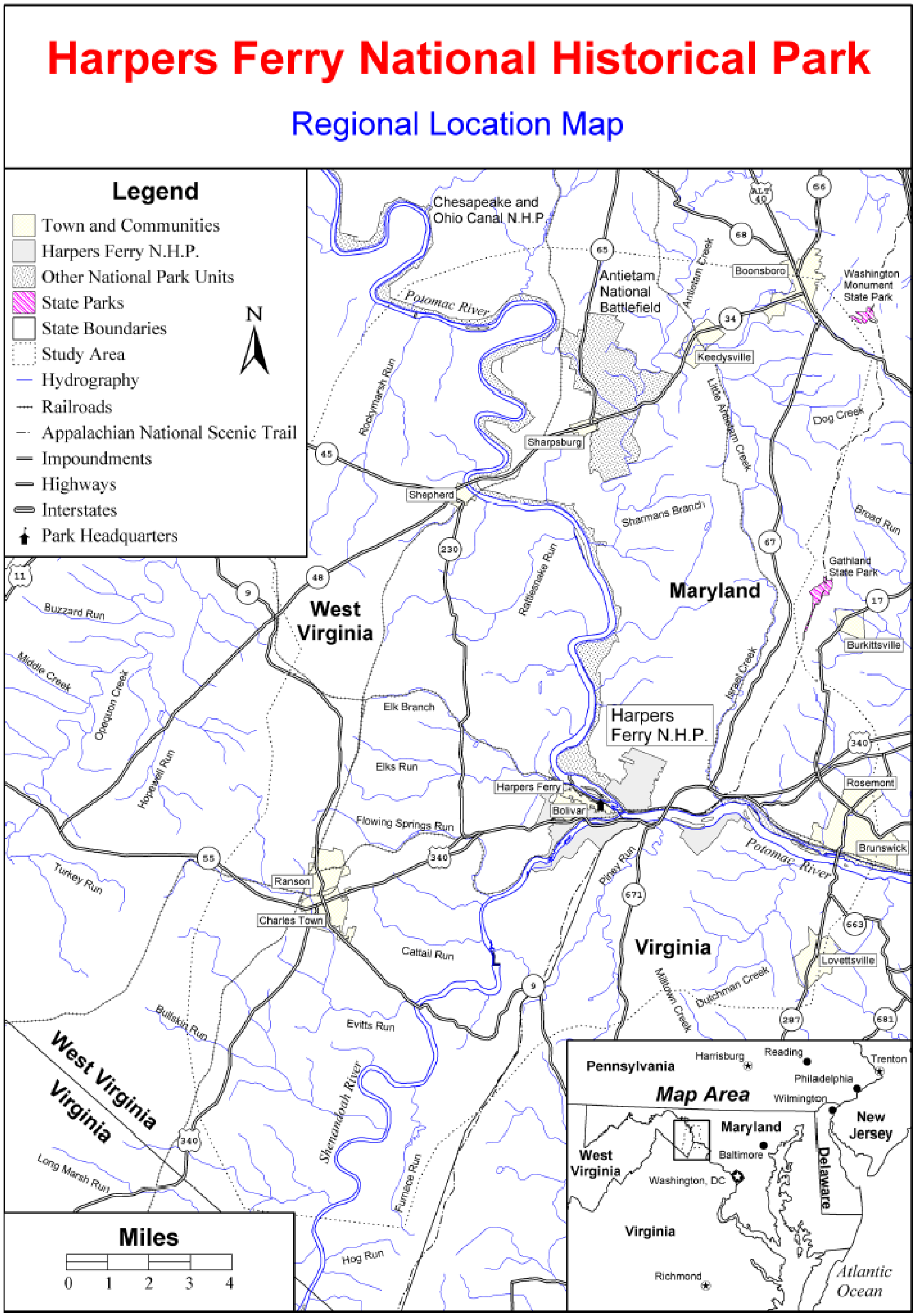


Table 3. Historical flood chronology for Harpers Ferry, West Virginia, from 1748 to 1896 (Fuertsch 1992)

Date of flood	Year of flood	Dominant River
Unknown	1748	Both
Unknown	1753	Shenandoah
Unknown	1771	Both
Unknown	1810	Both
Unknown	1823	Potomac
Unknown	1832	Potomac
Unknown	1840	Potomac
April	1843	Both
September 14	1843	Both
September 21	1843	Both
November 5	1846	Shenandoah
October	1847	Potomac
November	1847	Shenandoah
April 18	1852	Both
September 20	1859	Both
November 8	1860	Both
April	1861	Both
August 19	1861	Unknown
September 29	1861	Shenandoah
March 9-10	1862	Unknown
April 9	1862	Unknown
April 13-14	1862	Unknown
April 22-23	1862	Unknown
June 2-5	1862	Unknown
February 9	1863	Unknown
March 10	1863	Unknown
April 16-17	1863	Unknown
May 6-8	1863	Potomac
December 19-20	1863	Potomac
May 15-21	1864	Potomac
February 27-March 4	1865	Potomac
March 17-18	1865	Both
May 12-13	1865	Potomac
May 21-24	1865	Potomac
September 30	1870	Shenandoah
November	1877	Unknown
Unknown	1885	Unknown
Unknown	1886	Unknown
Unknown	1887	Unknown
Unknown	1889	Both
Unknown	1891	Unknown
Unknown	1893	Unknown

250 years. Historical flood information derived from historic, paleobotanic, and paleostage indicators covers the period from 1748-1896 (Table 3), when systematic flood information began to be recorded (Fuertsch 1992).

Botanical, physical, and anthropogenic evidence demonstrate that flooding also took place at Harpers Ferry during the years of 1896, 1942, 1949, and 1955 (Fuertsch 1992). USGS streamflow-gaging stations have been operating on both the Shenandoah and Potomac rivers for many years at locations just upstream and downstream of their confluence. The USGS maintains more recent data on some of the more significant flooding events that have taken place at Harpers Ferry (Table 4).

Table 4. Data on twelve of the largest floods at Harpers Ferry, West Virginia (Doheny and Fisher 2000)

Date of flood	Peak gage height at Harpers Ferry (ft)	Estimated peak discharge at Harpers Ferry (ft^3/s)	Approximate recurrence interval (years)
March 19, 1936	36.5	467,000	125
October 16, 1942	33.8	407,000	75
November 6, 1985	29.8	326,000	35-
September 8, 1996	29.8	326,000	35-
June 23, 1972	29.7	319,500	30
January 20, 1996	29.2	305,000	25
April 27, 1937	29.0	302,000	25
May 13, 1924	27.6	270,000	20-
August 20, 1955	23.9	209,000	10-
October 29, 1937	21.5	178,500	6+
March 21, 1975	21.5	178,500	6+
October 10, 1976	21.5	178,500	6+

Key: (+) = slightly greater than; (-) = slightly less than

In addition to flooding concerns, water resources are threatened by contamination and overuse in the urban and agricultural settings both within parklands and in the upstream drainage. The most severe threats to Park hydrology are presented by existing and future development in the rapidly growing region (Thornberrry-Ehrlich 2005).

v. Ecological and Habitat Classifications

HAFE falls mainly in the Blue Ridge ecoregion, but also borders on the Ridge and Valley and Northern Piedmont ecoregions. The Blue Ridge ecoregion is characterized primarily by forested highlands, intermixed with agriculture and small parcels of developed land (Taylor et al. 2006). These characteristics describe approximately 80-90 percent of parklands. In addition, the Park contains low, rounded hills, irregular plains, and open valleys typical of the Northern Piedmont and the more rugged and mountainous terrain of the Valley and Ridge ecoregions (Friesen and Stier 2006; Auch 2006).

Approximately 90 percent of the Park is covered by an upland, mixed-hardwood, deciduous forest (Vanderhorst 2000; NPS 2007a). The major forest types include chestnut-scarlet-black oak, oak-maple/beech, tulip tree, and sycamore-green ash. "The two differential dominant tree species of the upland forest communities are tulip tree (*Liriodendron tulipifera),* which dominates moist lower slopes, ravines and benches, and chestnut oak (*Quercus prinus*), which dominates dryer positions and aspects" (Vanderhorst 2000; Bartgis and Ludwig 1996). The chestnut oak communities differentiate along a moisture gradient; dryer areas are characterized by understory short shrub species in the blueberry family (*Ericaceae* family), while more mesic (moist) areas are typified by red oak (*Quercus rubra*) and sweet birch (*Betula lenta*) in the canopy and several characteristic shrub and herbaceous species in the understory (Vanderhorst 2000). Other, less extensive, oak-hickory-dominated forest communities that include white ash (*Fraxinus americanus*) and scrub pine (*Pinus virginiana*) cover the areas of thin soil overlying bedrock (Vanderhorst 2000). These rocky, steep, north-facing slopes support the Park's richest assemblage of montane species, which are rarely found below 2,500 feet in West Virginia. Canada hemlock (*Tsuga canadensis*) is an important species for maintaining these relatively cool, mountainous forested microclimates. The understory is populated by silvery sedge (*Caren argyrantha*), red elderberry (*Sambucus pubens*), flowering raspberry (*Rubus odoratus)*, and lettuce saxifrage (*Saxifraga micranthidifolia*).

The areas of lower elevation, along the present and former floodplain, contain wetland vegetation and water-seeking trees. The most diverse floodplain forests are found on the nearshore islands (e.g., Virginius Island). These areas are forested by box elder

(*Acer negundo*), sycamore (*Platanus occidentalis*), northern red oak (*Quercus borealis*), Shumard's oak (*Quercus shumardii*), green ash (*Fraxinus pensylvanica*), river birch (*Betula nigra*), and silver maple *(Acer saccharhinum)*. The understory of the floodplain forests often contains a well-developed shrub layer of paw-paw (*Asimina triloba)*, spicebush (*Lindera benzoin*), ironwood (*Carpinus caroliniana*), and bladdernut (*Staphylea trifoliate*), in addition to well-developed herbaceous layers consisting primarily of spring ephemeral plants. The riparian areas contain wetland species that can tolerate seasonally dry habitats, such as halberd-leaf mallow fog-fruit (*Phyla lanceolata*), tickseeds (*Bidens*), wingstern (*Verbesina alternifolia*), smartweeds (*Polygonum*), and variable grasses, as well as muddy-shore habitat species including swamp loosestrife (*Decodon verticillatus*), water willow (*Justica americana*), honeyvine (*Cynanchum laeve*), wild senna (*Cassia hebecarpa*), grapes (*Vitis*), and dogbane (*Apocynum medium*) (Bartgis and Ludwig 1996).

While the Park is highly fragmented, with parklands segmented in disparate parcels and with many natural and man-made barriers between each area, nearly all of these forest types are located in each parcel of the Park (Bates 2000). The majority of tree stands in the Park do not exceed 100 years of age, due to previous anthropogenic uses in the area. The composition of the forest does not necessarily indicate successional maturity (Fuertsch 1992). The forest is considered to be mostly healthy, though elms, butternuts, dogwood, and hemlocks are species of concern due to disease or infestation (primarily gypsy moths). In addition, a number of non-native and invasive plant species have been found within Park boundaries.

The remaining areas of the Park include wetland and riparian zones, cultivated and uncultivated agricultural lands, rocky cliffs, lentic and lotic waterbodies, and suburban lands. The wetland and floodplains habitats host some of the richest and most diverse populations of flora and fauna in the Park. Plant inventories, which make up the majority of taxanomic inventories completed at the Park, have found a variety of trees and shrubs, grasses and sedges, ferns, and wildflowers. Other inventories have found stream vertebrate and invertebrate communities to be mostly healthy and representative of the species expected to be present. Currently the Park is estimated to host approximately 14 amphibian, 18 reptile, 36 mammal, 30 spider, 43 fish, 174 bird, and 276 insect species (NPS 2007c). HAFE continues to survey plant and animal species found in the Park.

B. Regional and Historical Context

i. Land Use History

The history of Native American settlement in the Harpers Ferry area is not well-documented, but archaeological evidence demonstrates that Native Americans inhabited the region at least on a seasonal basis for centuries prior to European settlement. The first European–American to colonize the area was Peter Stephens, who began operating the Shenandoah Ferry in 1733. Fourteen years later, Robert Harper took over the ferry operation and founded the town of Harpers Ferry (Moyer et al. 2004; Jefferson County Planning Commission 2004). With the support of George Washington, the United States government built the Federal Armory in the town in 1799. With abundant natural resources such as water power, stone, and timber (both for building and for charcoal), the town had developed into a busy industrial center easily accessible by rivers, rail, and canals within a century of its founding (Moyer et al. 2004).

The town thrived until the Civil War. As an industrial center and transportation hub, Harpers Ferry was a strategic locale greatly prized by the opposing armies. The area changed hands eight times and the occupation and fighting severely depressed the town’s economy. Before the war, human activities in the region (e.g., logging, construction, and clearing fields for agriculture) had significantly altered the landscape. During the industrial boom, dense development accompanied by gradual deforestation led to increasing runoff rates, sedimentation, and flood discharges. These changes in the hydrological regime accelerated geomorphological processes that altered the region’s stream and river channels (Fuertsch 1992). During the war, the area’s forests were almost entirely denuded to sustain the military. In addition, much of the town’s infrastructure - buildings, factories, and bridges - was destroyed. After the war, rebuilding efforts were hampered by frequent floods of increasing magnitude. These floods, in particular, those of 1870, 1889, and 1936, were particularly devastating to the town's industrial base on Virginius Island and the area was unable to regain its former prominence (Fuertsch 1992).

The Post-industrial era was a time of environmental recovery throughout West Virginia, particularly in the Shenandoah River basin. Historical and aerial photos taken in Harpers Ferry throughout the 19th and 20th centuries show the gradual re-vegetation and reforestation of the region (Fuertsch 1992). A channel survey conducted in 1943 confirmed that the area's vegetation had stabilized by 1940. The channel was surveyed again in more recent years during the building of US Route 340; comparison between the two surveys showed that the Shenandoah River channel has remained consistent from 1943 up though the present (Fuertsch 1992).

HAFE was created as a National Monument in 1944. Since then, the Park has been expanding its boundaries, seeking to better protect the cultural and natural resources of the area. The Park's major push for expansion generally stems from concern about impacts from lands adjacent to the Park's borders. The resource management objective at HAFE, as recorded in the Park's statement for management, is to protect the aesthetic values of the Park by ensuring that development in and around it is compatible with the historic and natural scene (Hebb 1988). In recent years, Park management has become increasingly concerned about neighboring construction development that could impact HAFE's boundary habitats and scenic viewsheds (e.g., expanding roads, tall buildings, cell phone towers). Responding to increasing pressure from Park management, local government, and grassroots organizations, Congress authorized a special boundary study of HAFE in 1988. This study identified 1,700 acres of adjacent lands deemed as necessary to acquire in order to preserve the integrity of the existing Park; these conclusions provided the impetus for the Park expansions in 1989 and 2004 (Moyer et al. 2004).

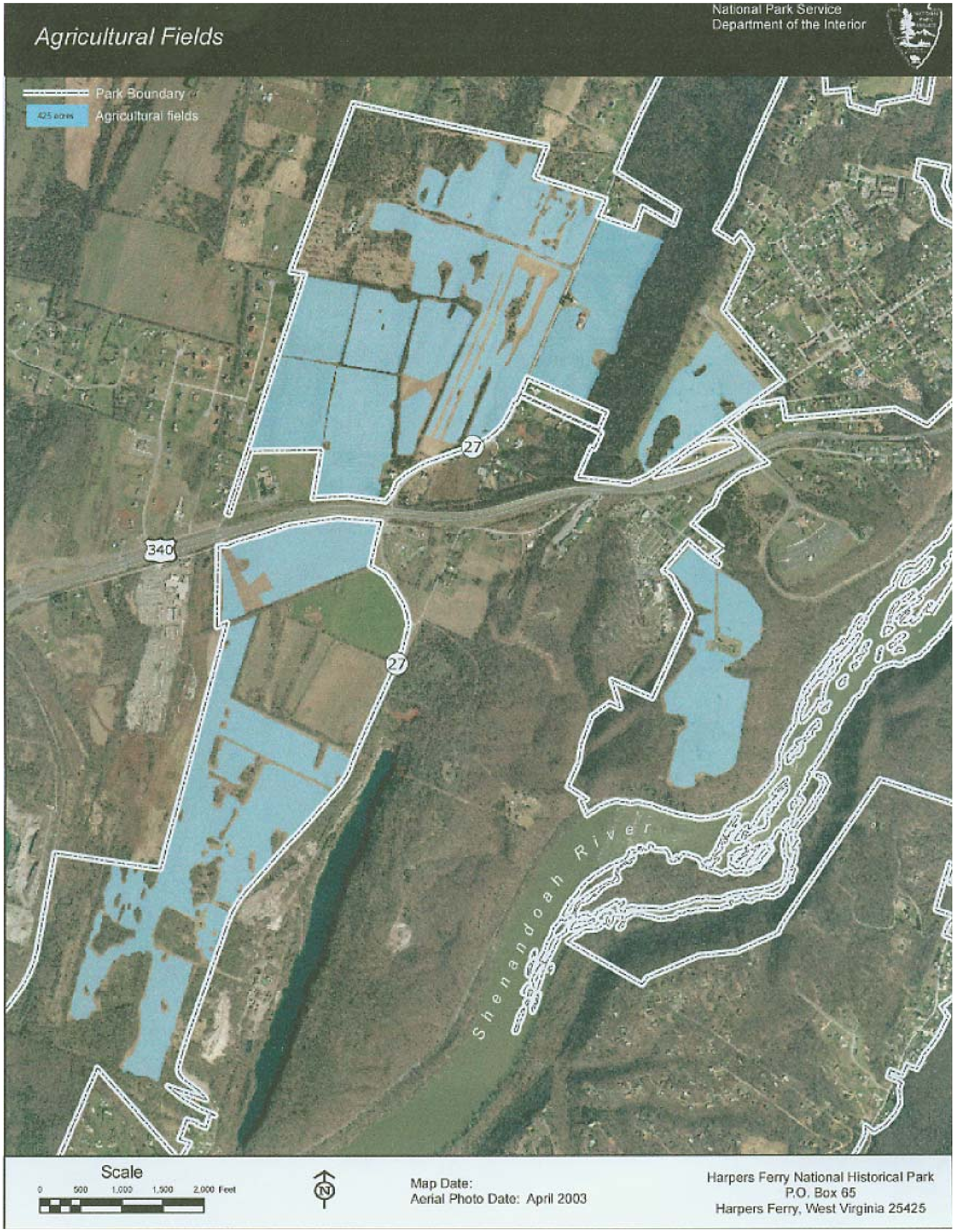
In keeping with its charge to preserve the history embodied in the Park's land and structures, HAFE also manages its open spaces to represent historically accurate uses.

In its last few expansions, the Park gained a number of land parcels suitable for agriculture. Though the continuity of historical land use is not documented, these parcels are thought to have been in agricultural uses since the Civil War (Hebb 2007h, pers. comm.). Approximately 425 acres of this land are leased to local farmers through a special permitting process that began in 1999 (Figure 5). The farmers, currently 4 farmers planting in 6 fields, apply to the NPS to plant and harvest crops of their choice (e.g., hay), which the NPS must then approve. In turn, they pay a small fee and agree to abide by a set of conditions and to trade work in kind, generally by providing mowing services at the NPS' request. In this way, the NPS gains access to a fleet of tractors to mow their open fields - several of the battle sites are maintained as open space, e.g., Bolivar Heights - and historical uses are maintained (NPS 2007b; NPS 2000). Though logging was a historical land use, no modern-day logging takes place at the Park (Hebb, 2007i, pers. comm.).

ii. Adjacent Land Use

The town of Harpers Ferry and the bulk of parklands are located in Jefferson County, West Virginia. Private residential and commercial lands, public, and even federally managed public lands are interspersed between disparate Park parcels. The Appalachian National Scenic Trail and the C&O National Historic Park (CHOH) bisect the Park. A Department of Homeland Security Training Facility lies adjacent to the Park. In addition, HAFE manages public lands surrounding the Park through cooperative agreement with the ANST and the U.S. Fish and Wildlife Service (USFWS). There are 51 parcels of nonfederal (i.e., both public and private) land in HAFE, which encompass a variety of land uses (Hebb 2007j, pers. comm.). Adjacent land use is a high-priority concern for HAFE.

Figure 5. Agricultural fields at HAFE (NPS 2007g)



HAFE is affected by land use decisions of all three of its host counties; Jefferson County, WV; Loudon County, VA; and Washington County, MD. While the area surrounding the Park is mostly rural, the region's population has been steadily growing. Radiating urbanization pressure from Baltimore, MD and Washington, D.C., and continuing development in nearby suburban centers such as Frederick, MD, Leesburg, VA, and the Dulles, VA area are expected to spur population growth in the Harpers Ferry area, as Jefferson County becomes a more attractive residential option within a reasonable commute of these locations (Jefferson County Planning Commission 2004). The Park has continually worked to incorporate or negotiate land use with adjacent lands to prevent encroachment by development. Local zoning ordinances do not provide buffers for development, except for 1000 feet along the riverfronts (Hebb 2007d, pers. comm.). The most serious threats of boundary development include the disruption of scenic views, dissonance with the historic landscape, increased traffic congestion and noise pollution, and destruction and/or fragmentation of habitat.

Before it was acquired by the Park in 2002, the Murphy Farm was an area of contention between developers and conservationists. In 1999, developers sought to build housing units and a sewage treatment plant on the historic battle site. Strenuous objection from the local public and from several conservation and historical preservation groups defeated the petition. The Trust for Public Land purchased the property in October 2002 and donated the 99-acre parcel to HAFE in December 2002 (ACHP 2007). This case illustrates the difficulties in reconciling the County's aims for promoting growth in the area while retaining the natural and cultural heritage that makes it unique. Competing interests converge on properties bordering HAFE, forcing Park management to wrestle with the preservation of the 19th century landscape and development of lands that are technically available.

The most current encroachment threat to the Park is an ongoing plan to develop the Old Standard Quarry, a 410-acre land parcel that sits in a "thumb" of private land that is virtually surrounded by HAFE land and adjacent to the Schoolhouse Ridge viewshed (see Figure 6).

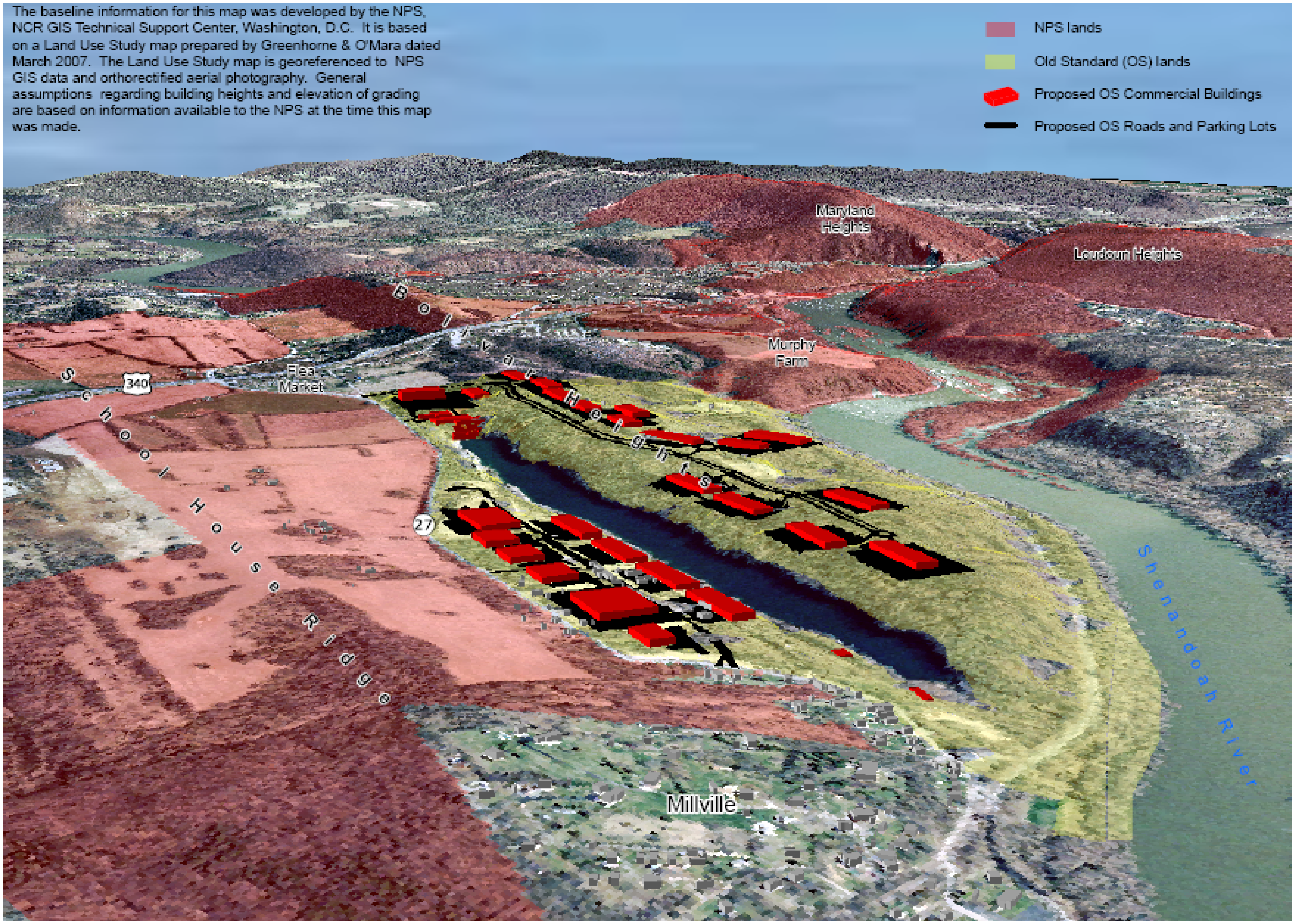
The Old Standard Quarry was an active limestone quarry throughout much of the 19th and 20th centuries, but has not been operational in more than 30 years (Henry 2007a). Developers intended to build 2 million square feet of commercial space including a hotel and conference center, residential housing units, office buildings, and recreation areas. In preparation for the anticipated construction, the developers bulldozed a 45-foot wide, 2,000-foot-long trench on the property to lay water and sewer lines in August 2006. The developers did not seek the permission of the NPS or local zoning commission to do so and the action prompted protest from NPS officials, historic preservation organizations, and the public (Repanshek 2007). As of September 2007, neither the Department of the Interior nor the Justice Department has taken action against the developers for this illegal excavation (Wheeler 2007). The Civil War Preservation Trust, an organization that conducts an annual inventory of endangered Civil War battlefields, designated HAFE as one of the top 10 most endangered battle sites in March 2007, based on the military significance of the location and urgency of this threat (CWPT 2007).

In order to begin construction, the developers petitioned the City of Charles Town to rezone the 640 acres of the property from residential and rural to commercial uses. When that April 2007 petition was denied, the developers petitioned Jefferson County to rezone a 410-acre portion of the land. Their petition was predicated on the parcel being incorrectly zoned as rural and residential, that zoning being incompatible with the commercial mining operation previously occupying the land (Henry 2007a). HAFE management became concerned about the impacts on the Schoolhouse Ridge scenic views, increases in traffic congestion, noise, and light pollution, and the fundamental change of landscape character that a multistory, mixed-use commercial campus would bring to the area. In response to the developers' rezoning petition, Park officials wrote a rebuttal letter on 5 June 2007, to the Jefferson County Planning Commission, marking how the developmental effects of the proposed construction conflicted with the stated goals of the 2004 Jefferson County Comprehensive Plan (Campbell 2007). Park staff, conservation and historical preservation organizations, and local stakeholders met with

County officials to express opposition to the project. On 17 July 2007, the County Board narrowly voted 3-2 against rezoning the Old Standard parcel (Henry 2007b). While preservationists hailed the decision as a victory, the developers claimed their denied petition was only a temporary setback (Henry 2007b) and Park management developed a proposition to expand the Park's borders once again and incorporate all the lands under debate. On 23 August 2007, Park representatives briefed Jefferson County officials on this proposal, which met with mixed reactions. The Jefferson County Planning Commission tabled the issue until 20 September 2007 (McMillion 2007).

Even absent the pressures from new development, the existing land uses of the lands immediately bounding and traversing the disparate areas of HAFE have a significant impact on Park lands. Parcels of the Park are bordered by and contain roads and trails, railroad tracks, bridges, and canals; all of these structures require operation and maintenance regimes that, since there are no setback regulations in the effect, have a least some impact on the surrounding ecosystem. A number of road problems have been identified in the vicinity of HAFE that are likely to be addressed in upcoming county development. The West Virginia Department of Highways (WVDOH) traffic counts have shown that vehicle traffic and congestion around HAFE has been steadily increasing in recent years. Jefferson County has proposed a number of projects to improve traffic flow along U.S. Route 340, the busiest highway used to access both the Park and the rest of the County. The proposed plan to widen the road by the Harpers Ferry Water Gap poses the greatest threat to parklands (Jefferson County Planning Commission 2004). Neighboring residential, commercial, agricultural, and recreational uses also potentially threaten the integrity of the preserved landscape and the ecosystems.

Figure 6. Map of proposed Old Standard LLC Quarry development (NPS 2007e)



HAFE does benefit from the land management practices of some of its adjacent neighbors. The Chesapeake and Ohio Canal National Historical Park (CHOH) is located just north of HAFE, across the Potomac River. CHOH protects 200 miles of the Maryland shoreline of the Potomac River, including the section that passes below Maryland Heights through HAFE. The protection afforded the Appalachian National Scenic Trail (ANST) provides additional protection for HAFE lands on Loudon Heights in Virginia and South Mountain in Maryland that contain sections of the trail. In addition, the State of Virginia owns and manages 3,000 feet of shoreline of the Potomac River by Harpers Ferry. The level of protection created from the combination of these boundaries has helped to preserve an important historic landscape (Hebb 1988).

C. Unique Park Resources and Designations

i. Aesthetic Resources

The Park has numerous valuable aesthetic resources that include natural and culturally significant viewsheds, including the views from Jefferson Rock, Maryland, and Loudon Heights. The historic views in and around the lower Historic Town and natural views along Virginius Island and the rivers are equally scenic. Protection for these viewsheds is becoming increasingly important as adjacent lands continue to develop (Hebb 2002).

Visitors access scenic areas through a series of trails that wind throughout the Park. Some trails feature a specific natural resource (e.g., Jefferson Rock Trail) or cultural resource (e.g., Lower Town Trail) sites, but most trails contain a variety of scenic habitats, historic structures, and interpretive exhibits (NPS 2007c). For example, the Murphy's Farm trail guide contains a number of historical sites of interest, but also includes two viewing stations with some of the Park's best views of the Shenandoah River. Guided visitor tours focus on historical interpretation of the Park's resources, but ranger presentations generally incorporate some discussion of how the Park's natural resources have influenced the history of the area. For example, tours of the historical ruins along the Potoma Wayside floodplain and on Virginius Island could not be complete without mentioning how the rivers helped to both create, by providing water power and transportation, and destroy, through near-continuous flooding, the industrial center (Wong 2007; NPS 2007c).

The Park has acquired many parcels of land for the purpose of protecting its scenic views (Hebb 1988). Threats from adjacent land use and from private and public land uses within the Park, however, continue to threaten viewshed resources. Projects that could visually impair the landscape around HAFE include “the potential expansion of U.S. Route 340 through the Water Gap, and potential improvements of U.S. Route 32, commercial and high-density residential development adjacent to the Park, and potential siting of communications towers along the skyline around the Park” (NPS 2000).

Jefferson County has acknowledged the importance of protecting its scenic vistas. The topic has been the subject of vigorous public comment during commercial development processes. The County’s 1994 Comprehensive Plan stated that scenic vistas should be protected through the purchase of easements. Even without an easement in place, area courts have voided the issuance of a building permit for a telecommunications tower based on non-conformance with the Comprehensive Plan’s stated viewshed protection goals. The Comprehensive Plan also recommends promotion of development that does not impinge on the area’s “night sky” (i.e., control of light pollution). The County continues to prioritize the identification and protection of scenic views in its 2004 Comprehensive Plan (Jefferson County Planning Commission 2004).

Natural threats also pose significant concerns for aesthetic resources. Large portions of the oak-dominated forest have been periodically defoliated by gypsy moth infestations. Park management continues to work with the NPS’s Integrated Pest Management (IPM) team and the United States Forest Service (USFS) to monitor and protect HAFE’s tree canopy (NPS 2007a; Pauley et al. 2005). The erosion processes that created the high cliffs and stunning vistas over the Potomac and Shenandoah Rivers at Maryland and Loudon Heights also pose a threat to visitors’ enjoyment of these scenic views. While mass wasting does not specifically affect the views from or of these points, rock falls and other slope failure events along the trails leading to scenic observation sites potentially endanger visitors, particularly following extreme weather events (Thornberrry-Ehrlich 2005).

ii. Unique Features

HAFE contains a number of distinguishing historical features. Some of the Park's historical sites are nationally famous and cited in history textbooks. The physical remnants of John Brown's raid on the Federal Armory may be considered as priceless artifacts of American history. John Brown's Fort, the only Federal Armory building to survive the Civil War, was moved across the country four times before it was returned to a site close to its original location in the lower Historic Town. Virginius Island was one of the most significant early industrial centers in the United States. Open fields are maintained and preserved artifacts are displayed to commemorate an almost continuously occupied Civil War battle site. The Park preserves these sites as a snapshot-in-time of a commercially bustling and strategically significant industrial center.

Harpers Ferry Water Gap is a hydrologically significant natural feature. The confluence of two large river systems created a stunning geological feature and the view of the Water Gap from Jefferson's Rock is historically important.

While the Park does not contain any federally listed threatened or engendered species, it does host a number of rare or threatened state-listed heritage species. The flora of the Park have been extensively surveyed and many species of concern (i.e., globally or locally rare or threatened) have been documented (see Tables 10 and 11). The Park contains a number of rare plant species and rare plant habitats, including limestone red-cedar glades and low-elevation montane habitats.

iii. Special Designations

The majority of property within the Park is listed on the National Register of Historic Places. The Register was created under the National Historic Preservation Act of 1966 in order to coordinate and support public and private efforts to identify, evaluate, and protect the United States' historic and archeological resources. HAFE properties that are not listed on the Register are eligible to be listed; they receive the same protection as listed properties. One hundred forty-seven structures or features have been placed on the List of Classified Structures. There are several types of cultural resources in the Park that relate to the Civil War: cultural landscapes, archeological resources, monuments, buildings, earthworks and roads. Park management considers all HAFE lands to be zoned as cultural (NPS 2007a). In addition, the conjunction of nationally significant properties in this area, HAFE, CHOH, and the ANST, has created a historically and culturally significant landscape that could be considered worthy of listing in the National Register of Historic Places as a rural historic district (Hebb 1988).

D. Park Science and Resource Management

i. Management Plans

Park management is in the process of developing a General Management Plan (GMP). This document has been in draft form for several years, undergone several public comment periods, and is in its final stages of approval. This GMP is intended to set the direction of Park development and provide guidelines for Park management for the next 15-20 years. As such, the planning process for this document considered how management of the Park could be changed to better serve its original charge of preserving natural and cultural resources to commemorate historical events at or near Harpers Ferry (NPS 2003a). It is the first GMP to be developed for HAFE and the first Park-wide management plan since the 1980 Development Plan. The GMP is expected to consolidate the management concepts articulated in the 2000 Natural Resource Management Plan and the 2000 Cultural Resource Management Plan. Prior to the update in 2000, the Park's plans had addressed natural and cultural resource components in one document. The reunion in the upcoming GMP of these development concepts is expected to be indicative of a more holistic management view of the Park's resources. In a major departure from previous management practices that considered all HAFE lands to be zoned as cultural, for plan development purposes, the GMP planning team rezoned the Park into seven distinct management zones (Table 5):

Table 5. Management zones proposed in draft GMP (NPS 2004)

Zone	Description
Scenic/ natural preservation	The primary purpose of this zone is to protect and preserve natural and cultural resources and maintain the scenic viewsheds as seen from key locations within the Park. Appropriate forms of recreation such as hiking, fishing, and nature watching would continue to be allowed. Opportunities for solitude and natural soundscapes would be prevalent. This zone would be applied in the outlying portions of the Park such as Short Hill and Loudoun Heights.
Cultural landscape	The primary purpose of this zone is to present the historic appearance of certain areas that are important to the history of Harpers Ferry. Natural resources may be modified to provide historic landscapes or views, or to prevent damage to cultural resources. Visitors would find a quiet, contemplative atmosphere with interpretation of the major features and their history. This zone would be applied primarily to areas containing historic farms and battlefields such as Bolivar Heights.
Historic structure	This zone would appear to be a living 19th century community. Visitors would be able to find information and interpretation of the many aspects of Harpers Ferry inside and outside the restored historic buildings. Opportunities to view special demonstrations or exhibits would be available. Access to this zone would be by Park transportation. This zone would be applied to the Lower Town portion of the Park.
Archaeological preservation	The primary purpose of this zone is to protect and preserve cultural resources while allowing visitor access. Vegetation would be allowed to grow naturally unless cultural resources are threatened. Visitors would explore this zone primarily on their own with some interpretive signs provided along the trails. This zone would be applied to areas that are rich in archeological sites but largely undeveloped such as Virginius Island.
Visitor portal	This zone encompasses the main entry points for visitors to the Park. It would contain most of the visitor orientation and transportation-related facilities. Visitors would find public restrooms and drinking water and get information from Park staff. All visitors would be encouraged to begin their visit here so that they may learn what is available and the best way to see the Park.
Adaptive use	In this zone, management prescriptions would call for using historic structures for modern uses. For example, an historic house could be restored to its original appearance on the outside while the interior could be used for Park offices. Visitors in this zone would engage in mostly self-guided exploration of building exteriors. Interpretive signs would be provided along the pathways. This zone would be applied to areas like the Storer College campus.
Facility management	The Park's maintenance facilities, equipment and supplies would be located in this zone, away from sensitive natural and cultural resources and separated from visitor use areas. This zone would not be for public use.

Each of the zones represents distinct goals for resource conditions and/or visitor experience. These zones allow for the development of management prescriptions that are tailored more closely to the preservation of the specific resources in that portion of the Park. The GMP is expected to be finalized and released in late 2007 (NPS 2003a; NPS 2004).

The stated purpose of the HAFE Land Protection Plan (LPP; Hebb 1988) is “to identify methods of assuring the protection of the natural, historic, scenic, cultural, recreational, or other significant resources, and to provide for adequate visitor use.” It was developed in response to the 1982 policy statement issued by the United States Department of the Interior requiring NPS parks to identify and pursue lands within and around their borders that influence the achievement of the park management goals. The LPP describes the 1988 contemporary state of Park lands, including the federally owned parcels and the non federally owned parcels, rights of way, road, other government, and private ownership. It also outlines the Park’s reasoning and strategy for acquiring additional land. Since 1988, a number of the land parcels targeted in the plan have been acquired and the Park has grown by more than 1,300 acres; therefore, the LPP is considered to be outdated.

For the 2000 update of the Park management plans, the cultural and natural resource components were separated into two management plans, a Cultural Resources Management Plan (CRMP) and a Natural Resources Management Plan (NRMP). The NRMP documents the Park's resources and describes a management, monitoring and research program for natural resources. It is designed to provide Park management with guidelines for protecting, preserving, and managing the nark’s natural resources in a manner upholding the Park’s original charge.

The natural resources management program at HAFE is administered under the Park’s Office of the Superintendent. The program is staffed with two full-time positions, the natural resources manager and the natural resources management specialist. These individuals are responsible for developing and implementing the natural resources program and have additional responsibilities with the land management program. In addition, the program shares the time of a geographic information system (GIS) specialist with the ANST (NPS 2000).

Program staff administer and perform a number of management activities, including "coordination of the environmental compliance program, exotic species control, monitoring and protection of rare plant populations, [administering the] agricultural lease program, maintenance and operation of automatic monitoring sensors, writing proposals for resource surveys and inventories, development of GIS thematic layers, pesticide use monitoring and reporting, and assistance with external threats such as wireless telecommunications issues and state and federal highway issues" (NPS 2000). In addition, work with the land management program account for approximately 50 percent of staff time. Those activities include "maintenance of lands records ([e.g.,] plats, deeds, title evidence, appraisal reports, closing documents and information pertaining to adjacent lands), maintenance of databases containing information on over 300 adjacent landowners, maintenance of over 40 miles of boundary, coordination of boundary surveys, identification and documentation of encroachments, development and maintenance of information pertaining to acquisition of land, Level I contaminant surveys, [managing] adjacent landowners issues, development of maps, [tracking] tax information and other information for federal state and local officials, development of proposals for economic studies involving land acquisitions, development of legislative support data, and preparation of the Park's Land Protection Plan" (NPS 2000).

The NRMP identifies a series of natural resource issues and concerns. These management needs have provided the basis for research and project planning since the NRMP was implemented. Key issues are summarized in Table 6.

Table 6. Natural resource issues identified in 2000 NRMP (NPS 2000)

Natural resource management needs and issues of concern
Monitoring and protection of rare plant populations
Lack of basic data on rare animal populations
Lack of basic data on the distribution and abundance of invasive plants
Lack of basic data on white-tailed deer

Lack of data to determine community health
Monitoring of streams and wetlands
Lack of basic data on the effects of flooding in the outlying areas of the Park
Lack of basic data on the identification, distribution and abundance of native and exotic vegetation on historic structures
Monitoring geological resources

The Park does not have an integrated pest management (IMP) plan. Gypsy moths are the primary pest of concern in this area. The Park conducts ongoing monitoring in conjunction with the USFS, using aerial and egg mass surveys. When the density of the gypsy moth population, which is projected from the egg mass surveys, indicates the likelihood of moderate to heavy defoliation, the Park performs an environmental assessment (EA) of its suppression options. These EAs describe the relative benefits of various suppression methods and determines the most effective course of action with the least environmental impact. The Park's last EA of the gypsy moth suppression program was conducted in 2002.

HAFE management recently released an updated Fire Management Plan (July 2007). The plan describes how HAFE's fire management policy upholds NPS general management policies and HAFE's enabling charge. This document details the fire management objective, the operation programs required to achieve those objectives, and the research and monitoring required to effectively manage fire in a park that is predominantly covered in a hardwood forest. The plan restates the Park's current policy of fire suppression. Current NPS policy does not allow for natural (wildfire) or man-made burns – none are planned at HAFE (NPS 2007a).

In addition to developing its own management plans, Park management policies must work in conjunction with the management goals of the areas over which the Park holds joint authority (e.g., ANST) and the lands along Park borders. Policies developed by Jefferson, Washington, and Loudon Counties, the National Capital Region Network (NCRN) of the NPS Inventory and Monitoring (I&M) program, the state environmental protection divisions in West Virginia, Virginia, and Maryland, the USFWS, and USFS, special interest organizations (e.g., Friends of Harpers Ferry, the Harpers Ferry

Conservancy, and other preservation groups) and local government are taken into consideration during the development of HAFE's management policies.

ii. Research and Monitoring

Many studies have been conducted at HAFE to provide baseline information on the biota present in the Park; additional projects have investigated water quality, geological conditions, and land development. Table 7 summarizes the status of the natural resource inventories completed at the Park through 2000. The fair through poor designations in Table 7 refer to a variety of factors, including completeness of the survey performed, number of surveys conducted, the quality of the researchers performing the survey (i.e., research scientist as compared with public volunteer), and how recently the studies were conducted.

Vegetative resources at the Park have been extensively studied, as nearly 90 percent of the Park's acreage is forested. The Park's flora inventories are the most complete of all the natural resource studies. Most of the upland habitat of the Park has been surveyed at least once and researchers have compiled detailed lists of the plants present. While most of the surveys do not include the information required to determine the health of the Park's vegetative communities, surveys that have been conducted more than once provide some indicators of the vegetative communities' composition over time. Studies at HAFE involving flora that were conducted after 2000 include: *Flora Inventory and Community Classification and Delineation of a Rare Limestone Glade Habitat in Harpers Ferry National Historic Park* (2007), the *Exotic Plant Management Team Annual Reports* from 2002-2006, *A sedge, grass and rush inventory of seven parks in Maryland* (2006), and *Plant Communities of Harper's Ferry National Historical Park: Analysis, Characterization, and Mapping* (2000). Each year, the USFS performs aerial surveys of the Park to assess defoliation threats. In this way, significant changes to the canopy are monitored.

Table 7. HAFE resource inventories through 2000 (NPS 2000)

STATUS OF RESOURCE INVENTORIES

Resource Inventory Elements	Comments	Poor	Fair	Good
Scientific Collections	Herbarium specimens collected as part of a 1987 Exotic Plant Survey. Also, specimens collected by independent researcher who had collected largely between 1982 and 1984. The collections contain over 300 voucher specimen.		✓	
Aerial photography	A collection of b/w, color and CIR aerial photograph. Complete park coverage limited to 1989 and 1999. For other years, partial coverage includes: 1976 (b/w), 1979 (b/w), 1980 (color), 1983 (CIR, summer), 1984 (CIR, winter), 1985 (b/w), 1988 (IR), 1990 (IR).		✓	
Automated Resource Bibliography	Completed in 1996 as part of the NPS Inventory and Monitoring Bibliography project. Procite database containing 156 entries.			✓
Vascular Plant List	*Checklist of the Vascular Flora of Harpers Ferry National Historical Park*, The Nature Conservancy,1998. Compiled from lists dating to 1965.			✓
Vertebrate Animal List	*Checklist: Arthropods-Birds-Mammals-Plants-Reptiles-Trees*, HAFE, 1965. *Short Hill Mt. Raptor Banding Report*, Roger Jones, 1992 and 1993.		✓	
Invertebrate Animal List	*Checklist: Arthropods-Birds-Mammals-Plants-Reptiles-Trees*, HAFE, 1965.	✓		
T&E Species List	*Rare Plant Survey*, Maryland Natural Heritage Program, 1994. *Rare Plant Survey*, The Nature Conservancy, 1997-98.			✓
Vascular Plant Surveys	*Exotic Plant Survey*, North American Resources Management, 1987. *Plant Community Classification*, The Nature Conservancy, 1999. *Checklist of the Vascular Plants For of Harpers Ferry National Historical Park*, Garrie Rouse, 1998 (included field surveys to document new occurrences and to confirm prior occurrences).		✓	
Vertebrate Animal Surveys	*Short Hill Mt. Raptor Banding Report*, Roger Jones, 1992 and 1993.	✓		
Invertebrate Animal Surveys		✓		
T&E Species Surveys	*Rare Plant Survey*, Maryland Natural Heritage Program, 1994. *Rare Plant Survey*, The Nature Conservancy, 1997-98.			✓
Vascular Plants Distribution/Abundance	*Butternut Survey*, The Nature Conservancy, 1999. *Hemlock Woolly*	✓		

	Adelgid Survey, HAFE, 1994. *Rare Plant Survey*, Maryland Natural Heritage Program, 1994. *Rare Plant Survey*, The Nature Conservancy, 1997-98.			
Vertebrate Animal Distribution/Abundance	*Short Hill Mt. Raptor Banding Report*, Roger Jones, 1992 and 1993.	✓		
Invertebrate Animal Distribution/Abundance		✓		
T/E Species, Distribution/Abundance	*Rare Plant Survey*, Maryland natural Heritage, 1994. *Rare Plant Survey*, The Nature Conservancy, 1997-98. Includes abundance and distribution information.			✓
Digital Vegetation Associations	*Photo Interpretation of Vegetative Cover Types*, VPI, 1993. *Plant Community Classification*, The Nature Conservancy, 1997-99.			✓
Soils Maps (SCS Order 3 surveys)	Soil Conservation Service Soil Surveys: *Loudoun County, Virginia*, Series 1951, No. 8; Soil; *Washington County, MD*, Series 1959, No. 17; *Jefferson County, West Virginia*, issued 1973.		✓	
Digital Geology Maps	Surficial and bedrock digital data developed by the USGS, 1998.			✓
Digital Cartographic Data	Developed in 1991-92 for the park's GIS. (elevation data and digital line data consisting of hydrography, political boundaries, park boundaries, project boundary, transportation and major utilities). Digital USGS 7.5 minute quadrangles, Land Info, 1996).			✓
Water Quality	*Baseline Water Quality Data Inventory and Analysis Report*, 1997. *Paleohydrologic Investigation in the Vicinity of HAFE*, Susan Fuertsch, 1992.		✓	
Water Chemistry		✓		
Air Quality		✓		
Weather	Automated weather station which collects standard weather data hourly. Installed in 1990. Prior to 1990, weather data was collected manually beginning in 1983.			✓

When compared with the vegetative studies, fewer fauna studies have been conducted, though a number of projects inventorying vertebrate and invertebrates have been conducted in recent years. These studies document the presence of and draw some conclusions about the abundance of the populations of Peregrine Falcons (2001-2005), butterflies and skippers (2002-2003), dragonflies and damselflies (2005), bats (2005), aquatic insects (2004), fish (2003), small mammals (2003), white-tailed deer, (2002-2005), birds (2004), and amphibians and reptiles (2003) at the Park.

There have also been a number of reports on the abiotic resources at HAFE released in recent years. A structural rock slope stability evaluation of Jefferson Rock was performed in 2002 (Gilliam et al. 2002). Non-NPS agencies continue to monitor water quality at stations near the Park. The *Paleontological Resource Inventory and Monitoring Report for the Northern Capital Region* was completed in 2004. In addition, the NPS has begun issuing regional air quality reports. A report that included brief mention of the HAFE region was released in 2005 (NPS 2005a).

NPS's I&M program at the Center for Urban Ecology (CUE) in Washington, D.C. monitors the National Capital Region Network of national parks for "vital signs" of environmental health. HAFE is part of the NCRN of parks, which consists of 11 national parks in the District of Columbia, Virginia, Maryland, and West Virginia. There are 21 vital signs identified in the NCRN for monitoring long-term ecosystem health (Table 8).

Table 8. Vital signs for NCRN (NPS 2005b, updated 2007 by Christine Wong)

Vital Sign Group	Vital Sign	Monitoring protocol	Status at HAFE
Air and climate	Ozone	Ozone	●
	Wet deposition	Wet Nitrogen and Sulfur Deposition	●
	Visibility and particulate matter	Visibility and particulate matter	●
	Mercury deposition	Mercury deposition	●
	Weather	Weather and climate	●
Geology and soils	Shoreline features	Landscape dynamics and landcover change	--
	Physical Habitat Index	NCRN Biological Stream Survey	+
Water	Surface water dynamics	Surface water dynamics	+
	Water chemistry	Water chemistry and water nutrients	+
	Nutrient dynamics	Water chemistry and water nutrients	+
	Aquatic macroinvertebrates	NCRN Biological Stream Survey	+
Biological integrity	Invasive/Exotic Plants	Plants Invasive and exotic species	●
	Forest Insect pests	Insect pests	+
	Forest vegetation	Forest vegetation	●
	Fishes	NCRN Biological Stream Survey	+
	Amphibians diversity	Amphibian species diversity	+
	Landbirds	Landbirds	+
	White-tailed Deer	White-tailed deer	+
	T&E species and communities	Rare, threatened, and endangered species	--
Landscapes	Land cover/Land use	Landscape dynamics and landcover change	+

	Landscape condition	Landscape dynamics and landcover change	+

Key: ● = monitored by NPS or other agency
+ = CUE developing protocols
-- = does not apply to this park

Some of these vital signs are monitored on a regional basis; others are measured within individual parks. The air and climate quality and the invasive/exotic plants vital signs are regionally monitored and several years worth of data have been collected. There are no air-monitoring stations at HAFE. Reports, which so far include national reports on air quality and exotic plant management, are typically released on an annual basis. CUE has recently begun working on vegetation classification and mapping in all of the NCRN parks. Data from these monitoring activities are not yet published. As seen in Table 8, the CUE has plans in place to begin monitoring a number of ecosystem measures in the HAFE region.

Though much of the research activity at HAFE in recent years has been performed by Park or NPS researchers, the Park is the site for academic research from a number of nearby institutions (Table 9).

Table 9. Ongoing and proposed research at HAFE (NPS Research Permit and Reporting System 2007)

Project	Researcher/ Institutions
Karst survey	NPS and outside contractors
Wetlands inventory	University of Maryland
Jefferson County Soil Survey update (soil core sampling)	USDA
Forest vegetation classification and monitoring	NPS CUE
Cicadidae keratin chemistry as a biomonitor of environmental setting and contamination from past land use	USGS
Exotic pest and invasive species detection	NPS CUE
Antrolana lira and associated stygobitic invertebrates inventory	William Orndorff
Pilot study to test and develop rare, threatened, and endangered species monitoring protocols	NPS CUE
Air quality monitoring	NPS CUE
Wild mushroom survey	NPS CUE
Long-term water chemistry monitoring	NPS CUE
Long-term water level and stream monitoring	NPS CUE

Fern survey	NPS and outside contractors

The natural resource management staff at the Park wishes to continue inventory and analysis of its natural resources. They identified a number of weak areas in the 2000 NRMP, which are summarized in Table 6. Future research will likely prioritize those deficiencies.

iii. Education and Outreach

While some of the exhibits at HAFE feature its natural resources, the focus of public education and outreach at the Park is in keeping with its original charge and primarily based on its archaeological and historical resources. The interpretive exhibits and guided tours tend to highlight the Park's efforts to preserve the historically significant 19th-century landscape. Most rangers are historians and their talks focus on historical events. They are, however, trained to incorporate discussion of the how the environment at HAFE influenced those historical events. The Education Coordinator at HAFE estimated that approximately 15 percent of the time spent on historical tours is used to discuss the natural environment. In addition, one of the guided tours focuses on the geological resources at the Park (Bragaw 2007, pers. comm.). In recent years, Park management has begun to put greater emphasis on the Park's natural resources; specifically, on the natural resources in conjunction with their impact on historical or cultural resources and particularly in its education and outreach programs targeted at children (Bragaw 2007, pers. comm.).

For the past 5 years, the education and outreach staff at the Park have been working with Bridging the Watershed (BTW), an outreach program of the Alice Ferguson Foundation, in partnership with the NPS and area schools, whose purpose is to "provide personally meaningful, educational experiences that connect students to their place in the natural and cultural world," to modify their student curriculum. This program description is taken from the BTW Web site (http://www.bridgingthewatershed.org/):

> *BTW was developed in 1998 through a grant from the National Park Foundation as a model education program in the District of Columbia metropolitan area for an underserved population in national parks: high school students. It is the hope of BTW partners that this*

model, already spreading throughout the Potomac watershed, will be replicated in other national parks to serve high school students in any watershed. Using national parks as living laboratories to support national, state, and local science and math education standards, students increase awareness and understanding of the Potomac watershed. This education and heightened awareness will hopefully lead them to become future stewards of national parks and the environment.

BTW creates lesson modules to guide field experiences in national parks. The overarching goal of the lessons is to help students understand the environmental issues that threaten the health of the Potomac Watershed. In conjunction with HAFE staff, BTW developed its first site-specific module, featuring the influence of water power at Harpers Ferry. The module was written to show how, “the physical and historical geography of the Harpers Ferry area demonstrates how landscapes shape human history and how human endeavors profoundly affect natural landscapes—a powerful reminder that the actions of today determine the opportunities of tomorrow” (BTW 2007). The module contains 5 parts: 1) Introduction to Water Power, 2) Lesson 1: Pre-Industrial Water Power in Europe; 3) Lesson 2: Catherine’s Cotton Factory 4) Lesson 3: Human Impact on River Environments Pre-Field Study: Before You Visit the Park; and 5) Lesson 4: Contemporary River Use Conflicts. Separate lesson plans are available for students, teachers, and rangers. In addition to this HAFE-specific module, Park staff have also presented other lesson modules at HAFE, including Water Canaries, a lesson in assessing benthic macroinvertebrates, Watershed Watchdogs, a unit on assessing water quality, and Alien Invaders, a lesson on assessing exotic invasive species.

The Park sponsors one training institute each year to train area teachers on the BTW lesson modules. Each year, approximately 20 teachers attend this training and there are currently over 100 area teachers trained. Recently, the Park obtained a grant that allowed the sponsorship of three training sessions in the past year for rangers to be trained on the BTW modules. One day in the fall and one day in the spring are set aside exclusively for the outreach and education program to present these natural-resource-based learning programs. These lesson modules may also be presented at others times of the year, at teachers’ request (Bragaw 2007, pers. comm.).

The Park has also worked with another organization, Environmental Concern, Inc. (EC), to develop natural-resource-based education for children. EC is "a public non-profit corporation dedicated to wetland education, restoration, and research" (EC 2007). The program's Schoolyard Wetland Habitats program helps education organizations build and maintain demonstration wetland habitats. EC worked with HAFE staff to create a wetland area at the Nash Farm Environmental Education Center. The project involved building an approximately 3,600-square foot wetland area at Nash Farm "to provide an outdoor classroom as well as the water quality improvement, stormwater retention, and habitat benefits that wetlands inherently provide" (EC 2007). Area students assisted in planting the vegetation at the new wetland, which took place on 12 October 2005. Nash Farm continues to be maintained as a mid-20th century farmscape and houses an NPS environmental education and interpretation center with an outdoor laboratory (NPS 2004).

Park staff has been making efforts to learn more about educating children in natural settings. Two staff members attended the 12 September 2006 conference on *Children and Nature: A National Dialogue for the Health and Well-Being of Our Children.* The Park's Education Coordinator stated that Park management is interested in exploring opportunities to connect children with the outdoors through interactions with the natural resources at the Park. The Park has proposed to build a landscape playground, which would allow children to interact with the natural environmental in a controlled space (Bragaw 2007, pers. comm.).

In addition to the formal education and outreach programs, the public occasionally has opportunities to participate in biotic counts at the Park. These informal surveys provide additional data on Park biotic resources and highlight public interest in the Park's natural resources. Prior to the Park's formal bird inventory completed in 2004, natural resource staff relied on interested public volunteers to participate in bird surveys. Individuals and groups of birders who frequent the Park have been known to send in lists of species sighted. In addition, the Audubon Naturalist Society sponsored public butterfly and wildflower counts in 2003 and 2004.

III. Assessment Criteria

A. Ecosystem Measures and Biotic Health

i. Ecosystem Extent and Function

a. Cover and Habitat Characterization

Parklands are maintained to retain as much as possible of the 19th- and early 20th-century landscape. During the early 20th century, the forest and understory vegetation rebounded from their denuding prior to and during the Civil War. Almost the entire Park is covered by some form of vegetation, excepting the cliffs and rock outcroppings and anthropogenic structures. Current natural resource management practices support a fully vegetated landscape, including forested hillslopes, wetland plants in overgrown abandoned canal channels, riparian overgrowth in floodplains and along waterways, and maintenance of open spaces. Natural open spaces, such as meadows, glades, and clearings, are allowed to develop without Park intervention, excepting trail maintenance and treatment for invasive species. Anthropogenic open spaces, such as agricultural fields, residential areas, and battle sites representative of the 19th century landscape, are maintained through continuance of historical land uses and mowing of the battle sites to retain their historical appearance. Some of the present-day land uses of Park and adjacent lands (e.g., agriculture, residential living, light commercial industry, roads and railways) impact the biotic edge communities.

The vegetative cover of the Park is dominated, up to 90 percent coverage of the Park's acreage, by upland Eastern Deciduous Forest (NPS 2007a). This land cover type is so pervasive, resulting in incremental environmental gradients, that it is difficult to discern discrete plant species assemblages (Vanderhorst 2000). In addition, the forest at HAFE is mostly second- or third-growth forest, the trees in the area having been logged extensively to clear open space for agriculture, to provide timber construction materials, and for charcoaling purposes to support industry. As a result, most of the forest is less than 200 years old and none of the plant communities in the Park represent "climax" succession (Vanderhorst 2000). There is no record of when logging ended at the Park, and there is no modern-day logging within Park boundaries.

Because forests cover so much of the Park, forest losses are the most noticeable form of habitat loss. While certain tree species are subject to species-specific infestation or disease (e.g., hemlock, butternut, and elm), the most significant threat to the tree canopy is defoliation by periodic gypsy moth infestation. Repeated gypsy moth outbreaks can lead to the loss of oak species and other trees and could change the composition of the forest and its undestory vegetation (Hebb 2002). Loss of forest canopy increases insolation that dries the forest floor, leading to increased soil temperatures that, as one result, reduce numbers of salamander species (Pauley et al. 2005). Gypsy moths, an exotic invasive species, prefer oak-type forest habitats. They were first noticed in Jefferson County, WV, in 1975 and have been monitored at HAFE since 1981. The USFS and/or Park staff conduct egg mass surveys in all susceptible areas of the Park each fall as the primary monitoring tool to determine population density and the basis for management action. Surveys were not conducted from 1996-1999 because of a gypsy moth population decline cause by the fungus *Entomophaga maimaiga*. In addition, the USFS began conducting annual aerial surveys of the Park to quantify gypsy moth defoliation in 1983 (Hebb 2002).

Gypsy moth defoliation at HAFE first occurred in 1983 with seven acres of light defoliation on Maryland Heights. Significant defoliation was detected at the Park as follows: 1988 (15 acres), 1992 (262 acres), 1993 (7 acres), 2000 (200 acres), and 2001 (180 acres). The Park implemented management activities (aerial treatment with Gypchek®) to suppress gypsy moth populations in 1984, 1987, 1988, 1989, 1993, 2001, and 2002 (Hebb 2002). There has not been a need for gypsy moth suppression activities at HAFE since 2002.

In addition to gypsy moths, defoliation has been caused by native looper and canker caterpillars (NPS 2000). Hemlock trees in the Park have been devastated by the woolly adelgid (*Adelges tsugae*) and are likely to be locally extirpated in the near future (NPS 1994; Bartgis and Ludwig 1996). The forest community understory and herbaceous layers are dominated in many areas of the Park by exotic invasive species, especially in the floodplain of the Potomac and Shenandoah rivers (Bartgis and Ludwig 1996; Pauley et al. 2005) (further discussed under Total species).

The remaining areas of the Park include approximately 100 acres of wetland, riparian zones along the Potomac and Shenandoah Rivers and smaller streams of undetermined acreage, cultivated and uncultivated open spaces and approximately 425 acres of agricultural lands, rocky cliffs, and commercially and residentially developed lands. The Park does not have authority over its rivers and the characteristics of the Park's waterbodies have not yet been fully documented. While the wetland and floodplains habitats are known to host some of the richest and most diverse populations of flora and fauna in the Park, detailed inventories of these areas are still in development and little information is available.

b. Fragmentation

The Park has a history of mixed land use. Anthropogenic structures, including buildings, roads, railroads, and bridges are interspersed among parklands. Abandoned road cuts, waterways, and structures give evidence of historic disturbances within land parcels. In addition, HAFE lands lie adjacent to or surrounding non-Park lands. These adjacent land parcels host a number of land uses, some of which are not compatible with Park management goals and impact the biotic communities in bordering HAFE lands.

Many of the Park's land parcels are geographically fragmented. As shown in Figure 2, parklands are interspersed with private and public land and structures. The Park is further segmented by a variety of disparate natural and anthropogenic features, including the Shenandoah and Potomac Rivers, roads and highways, the incorporated towns of Harpers Ferry and Bolivar, the ANST, and the CSX Corporation Railroad. All of these features disrupt patch connectivity, contribute to species isolation, and present dispersal and recolonization barriers to terrestrial species. Some of the present-day land uses of Park and adjacent lands (e.g., recreational trails, agricultural and residential mowing, use of roads and railways) infringe on edge biotic communities because no setbacks were required when these features were added to the landscape.

This juxtaposition of anthropogenic and biotic uses creates marginal habitat in these areas. It also creates edge environments that promote establishment and expansion of alien plants (Bartgis and Ludwig 1996).

Some of the plant and animal populations – particularly small amphibians and rare plants - are highly affected by the extreme fragmentation of the Park's land. Rare plants are isolated by the patchy distribution of favorable growing conditions and many of the rare plant communities in the Park exist only in sporadic or singular patches (Bartgis and Ludwig 1996; Fleming 1999). The restrictions of geography and man-made structures and land uses may prevent these communities from spreading. Growth of plant communities may also be inhibited by invasive plant species (further discussed under Total Species). Amphibians often migrate during breeding season to breeding areas and during this time, large numbers of amphibians can be killed on roads and highways. Road kill mortality is a major concern for spotted salamanders and turtles species that have been observed to cross the roads towards breeding areas. "Turtles are long-lived with relatively low fecundity and attrition could lead to declines in populations" (Pauley et al. 2005). Habitat fragmentation also creates barriers for population migration and gene flow. For the many small amphibian species that cannot or will not cross roads, these barriers can create islands of genetically isolated populations (Pauley et al. 2005). Road kill mortality can be mitigated by limiting traffic in known amphibian crossing areas at night during breeding season; habitat fragmentation and species isolation, however, are more difficult to ameliorate.

There are no current dispersal barriers in the Park's waterways. Historical structures, such as locks, dams, and canals, have not been in use since well before the creation of the Park and are in varying states of disrepair and decay.

c. Community Structure and Function

The Park contains numerous ecosystem niches; some are healthy and intact and others are less so. Many of the biotic species expected in this ecoregion are present, in addition to populations of rare species. The forest, grasslands, wetlands, and aquatic habitats have been found to be reasonably diverse (further discussion under Species

Composition and Condition). Some species expected to be found in this region that have not been sighted at the Park can be explained by the lack of completeness in the biotic surveys, rather than by assuming habitat degradation and/or species extirpation.

The vegetated cover of the Park has rebounded strongly from the denuding land uses of the 19th and early 20th centuries. Second- or third-growth forest stands have grown steadily for the past 100 years and most areas of the Park exhibit a well-developed canopy and understory. Monocultures on adjacent agricultural lands, predominantly hayfields that require continuous mowing, are clearly delineated from uncultivated lands and the edge infringement between land uses here is small or nonexistent. The defoliation that affects habitat cover of some forest fauna species, particularly the oak-type trees that are the preferred habitat of gypsy moths, is monitored and managed by Park and USFS staff. The gypsy moth population has been controlled such that suppression activities have not been required since 2002. Isolated tree species of concern due to infestation or disease include hemlock, butternut, elm, and dogwood. Of these, the loss of the once-abundant hemlock trees from woolly adelgid infestation has the most significant implications for local vegetative community health. This loss is especially significant because the hemlock is an important species for maintaining the mountainous, forested microclimates that support locally rare montane understory vegetation and their extirpation would greatly affect these patches.

The first-order streams in the Park are important to the community structure of the riverine-based systems. The small headwater streams are the source of organic matter and drifting organisms (e.g., algae and invertebrates) that colonize downstream habitats and serve as the base of the food chain. Headwater streams are also important habitat for migrating organisms, such as spawning fishes and adult insects (Lamp et al. 2004). Habitat and food sources for macroinvertebrates, amphibians, and small mammals are also strongly influenced by the presence of terrestrially derived leaf and wood materials, as well as in-stream plant materials. These materials have been found to be plentiful in and around various types of waterbodies throughout the Park (Lamp et al. 2004). Floodplain and wetland habitats are periodically impacted by flooding; however, biotic populations in this area are typically transient species that can adjust to changing hydrological regimes. The loss of several types of rare plant colonies due to flooding has been documented (further discussed under Total Species).

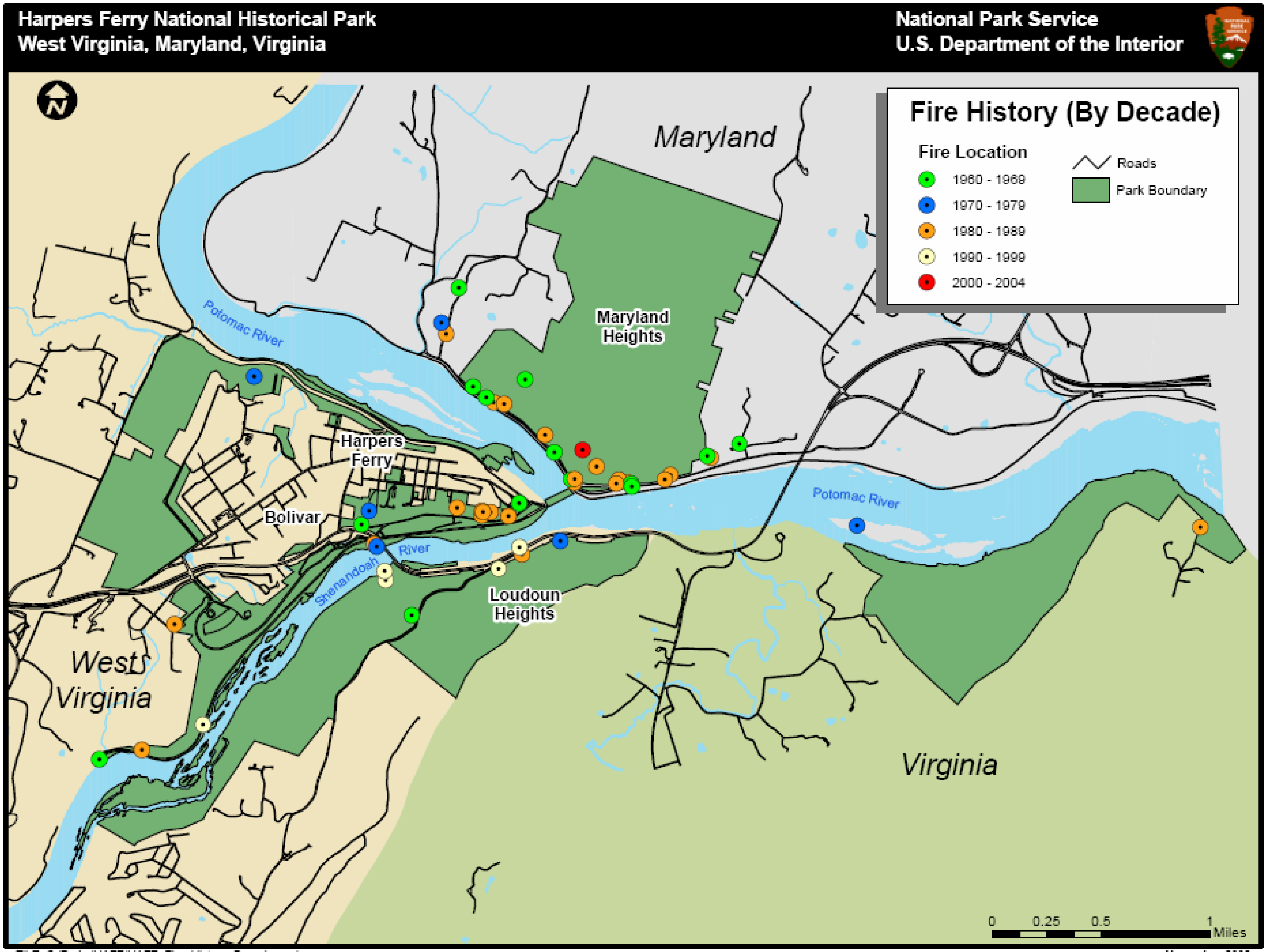
The most serious threats to community structure and function are boundary encroachment by development and community edge impact by adjacent land uses. The Park manages these threats by working with neighboring entities to coordinate desired land uses as much as possible and through an ongoing program of adjacent land acquisition.

d. Disturbance Regimes

The most serious historical disturbance to the natural resources in this area was complete deforestation during the Civil War. Since then, the vegetation has rebounded and most of the Park has reforested. The Park's regime of mixed land uses and fragmented parceling, however, ensures that parklands will never be returned to a pristine state. Instead, the Park fulfills its charge to preserve the historical character of the area by maintaining historical land uses.

The Park has experienced periodic natural disturbances such as drought, fire, and flooding. Droughts are not ecosystem drivers in this climate. There is no historical evidence that modern HAFE ecosystems have been significantly influenced by fire. The forests have had ample opportunity to rebound from charcoaling operations that took place from the late 18ths through mid-19th century. The threat of fire is not a major management concern in this area except in periods of extreme drought. The records that exist for 52 fires from 1960 through 2003 indicate that most fires took place on the forested slopes of Maryland and Loudoun Heights and were fully suppressed (Figure 7). Wildfires are not of significant concern, as most of the fires that have been documented in the past century have been caused by human carelessness or arson. During the 20th century, the current Park management policy towards natural and wildfire has been suppression. The Park's 2007 Fire Management Plan continues the fire suppression policy and states that there are no plans to use prescribed burns (NPS 2007a).

Figure 7. Map of fire events at HAFE (NPS 2007h)



Floods, however, have a long documented history at HAFE and have affected both the human and natural development of the area. While heavy flooding does not appear to threaten the biotic populations in the Park (i.e., though some colonies have been destroyed, many of the rare plant populations are adapted to the constantly changing riparian habitat (Fleming 1999)), flooding has increased erosion along the river channels, particularly at Virginius Island. The steep slopes near the confluence of the Shenandoah and Potomac rivers are deeply incised and flow over bedrock. Increased erosion in these areas has implications for additional slope instability. The flooding history at HAFE has also significantly affected residential and commercial development in the area, with each large flood destroying the man-made structures in the floodplain.

The most serious threat to HAFE today is development. With natural ecosystems interspersed with human uses and lying adjacent to incompatible land uses, further development is an ongoing concern. In addition, some of the historical and current uses within the Park, such as oversteepening cliffs resulting in increasing likelihood of slope failure, are actually deleterious for maintaining those uses (previously discussed under Geology and Land Forms). Park management is continually trying to incorporate adjacent and/or nearby lands, especially those parcels of historical or ecological significance. Park management also works with adjacent and nearby stakeholders to promote land use and development that preserves the integrity of the Park's historical landscape.

The deer population at HAFE has been overabundant. Deer surveys conducted between 2000-2004 indicate that deer overpopulation is a problem at most Northern Capital Region parks. Overabundance of deer, which is defined as a density of 40 or more deer per square mile, results in over-browsing of native vegetation that leads to proliferation of exotic species and opening or removal of the understory. Changes in the understory can decrease moisture levels by increasing airflow on the forest floor; in addition, deer can trample ephemeral pools and create trails that can lead to erosion (Pauley et al. 2005). The deer population at HAFE has decreased slightly over the past

5 years, though the trend is as yet statistically insignificant, and hovers just below a mean deer density of 40 deer per square mile (Bates 2005). Deer are often killed on the roads within the Park, though they are generally unaffected by the railroad. Poachers are known to hunt deer, but poaching is not considered to be a significant problem at the Park (Hebb 2007c, pers. comm.).

Other land use threats to HAFE's natural resources are related to regular Park use and the maintenance of anthropogenic structures in and around the Park. Ordinary use and ongoing maintenance of roads, railroad, trails, and waterways impact fragile ecosystems. Visitors at the Park also impact the natural resources. Recreational use of trails threatens rare plant populations both by trampling and by providing a mechanism for exotic and invasive plant dispersal. In particular, the rare and sensitive plant populations in wetlands and riparian areas are subject to trampling by visitors using water resources (e.g., fishermen and swimmers). The influx of invasive species has been extensively aided by human activities in edge environments (e.g., the railroad, canals, trails, and roads) that promote the establishment and expansion of alien plants (Bartgis and Ludwig 1996). Other threats to the vegetation include vista clearing by Park neighbors, taking of plants, wildfires caused by illegal campfires, debris burning by adjacent landowners, and arson (NPS 2000). (Note: other than this mention in the HAFE NRMP, no additional information about plant poaching was found.) The NPS recently installed a bat gate, a structure that allows bats to pass through but bars the entry of larger entities, at John Brown Cave in order to seal off the cave from the non-NPS-sponsored human exploration that threatened to damage the cave (Hebb 2007a, pers. comm.).

While the implications of climate change have not been explored for HAFE, several impacts might be inferred. Warming temperatures will extend the habitat of more southerly species, which will likely include a number invasive species. Infestations of new invasive species such as the emerald ash borer (*Agrilus planipennis*) represent a serious threat to Park vegetation (Swearingen 2007, pers. comm.). In addition, a number of the smaller, first-order streams at HAFE are intermittent waterbodies that only flow when the water table is high (Lamp et al. 2004). Increasing shifts in temperature may cause more frequent occurrence of drought that would dry out these streams and destroy habitat for a number of plant and animal species.

ii. Species Composition and Condition

a. Total Species

No federally listed endangered or threatened species are known to occur in HAFE. Plant inventories, however, have identified 26 state-listed endangered, threatened, or potentially threatened plant species within Park boundaries (Table 10). The diversity of plants at HAFE is higher than expected, with a number of patches of locally or globally rare plants.

Table 10. Rare plants found in HAFE as of 1998 (Fleming 1999)

Location	Common name	Rarity
West Virginia portion	Virginia nailwort (*Paronychia virginica*)	Globally rare
	Torrey's mountain-mint (*Pycnanthemum torrel*)	Globally rare
	Wooly lipfern (*Cheilanthes tomentosa)*	State rare
	Awned cyperus (*Cyperus inflexus*)	State rare
	Swamp loosestrife (*Decodon verticillatus*)	State rare
	Halberd-leaved mallow (*Phyla lanceolata*)	State rare
	Arrow arum (*Peltandra virginica*)	State rare
	Shumard's oak (*Quercus shumardii*)	State rare
	Rock skullcap (*Scutellaria saxatilis*)	State rare
	Starry false Solomon's seal (*Smilacina stellata*)	State rare
	Blue false indigo (*Baptisia australis*)	State watch list
Maryland portion	Short's rockcress (*Arabis shortii*)	State rare
	Lobed spleenwort (*Asplenium pinnatifidum*)	State rare
	Crested iris (*Iris cristata*)	State rare
	Ellisia (*Ellisia*)	State watch list
	Spring avens (*Geum vernum*)	State watch list
	Downy alumroot (*Heuchera pubescens*)	State watch list
	Spring forget-me-not (*Myosotis verna*)	State watch list
Virginia portion	Short's rockcress (*Arabis shortii*)	State rare
	Short's aster (*Aster shortii*)	State rare
	White trout-lily (*Erythronium albidum*)	State rare
	Sweet-scented Indian-plantain (*Cacalia suaveolens*)	State rare
	Blue wild-indigo (*Baptisia australis*)	State watch list
	Carey's sedge (*Carex careyana*)	State watch list
	Silk dogwood (*Cornus amomum*)	State watch list
	Harbringer-of-spring (*Erigenia bulbosa*)	State watch list
	Starry false Solomon's-seal (*Smilacina stellata*)	State watch list
	Large-fruited sanicle (*Sanicula trifoliate*)	State watch list

Rare plant surveys were conducted during the 1994-1995 and 1998-1999 field seasons at HAFE. These surveys identified 85 rare plant populations at the Park, including the 26 state-listed species in Table 10. Many of the rare species are exotic plants that inhabit the Park's shorelines. A plant community survey in 2007 found an additional 9 West Virginia state-listed species of concern (Table 10). In addition, a quality assurance (QA) study conducted in 1998 reviewed all of the previous plant investigations at the Park. The QA study determined that inventories had identified a total of 561 vascular plant species at HAFE (Rouse 1998). All of these surveys focused on reporting species incidence and estimating marginal plant populations. They also pinpointed major threats to the rare plant populations. Plant lists current as of 1998 are found in Appendix A.

A survey conducted in 2006 documented the flora in a rare limestone red-cedar glade habitat and found many species of rare plants. Investigators observed a total of 190 plant species, including 172 vascular plant and three nonvascular plant species representing 55 plant families. An additional 15 species were documented during previous surveys of the site. Many of the plants observed are state-listed or globally rare plants, some of which are thought to be restricted to limestone cedar-glade habitats (Perles 2007). Nine West Virginia state-listed species of special concern were observed in the limestone red-cedar glades (Table 11).

Table 11. West Virginia plant species of concern found on Jackson's Right Flank (Perles 2007)

Species	State rarity status
Lesser snakeroot (*Ageratina aromatica var. aromatica*)	Endangered
Sideoats grama (*Bouteloua certipendula*)	Vulnerable
Downy milkpea (*Galactia volubilis*)	Endangered
Grooved flax (*Linum solcatum*)	Endangered
Limestone adder's tongue (*Ophioglossum engelmannii*)	Endangered
Shumard's oak (*Quercus shumardii*)	Endangered
Lanceleaf buckthorn (*Rhamnus lanceolata ssp. Lanceolata*)	Endangered
Fringe-leaf wild petunia (*Reullia humilis*)	Endangered
Broad-lead ironweed (*Vernonia glauca*)	Endangered

The limestone red-cedar glades are small, consisting of two parcels of less than an acre in size, and four areas, one approximately 6.5 acres in size and three that are less than an acre each, that have the potential to be restored as this type of habitat. The existing glades are considered to be of fair to poor quality based on size, condition, and context (Perles 2007). Though these glades are small and not of optimal quality, they have conservation value because they: "a) are examples of a global- and state-rare vegetation community, b) provide habitat for rare plant species, c) occur at a lower elevation than any other limestone red-cedar glades in the state, and d) are the only limestone red-cedar glades in the state known to occur on Tomstowm Dolomite" (Perles 2007). These communities are considered globally rare because many of the examples of this habitat are threatened or have been destroyed by mining and quarrying activities. These habitats are also threatened because limestone red-cedar glades are highly susceptible to woody plant invasions, primarily by eastern red-cedar (*Juniperus virginiana)*. Without periodic disturbance such as forest fire or human management, woody species will colonize open areas and glades will undergo natural succession to hardwood forest. The investigator recommended that the Park's primary management goal for maintaining these limestone red-cedar glades should be to "reduce woody plant cover and to prevent encroachment by woody species so that sun-loving glade plants can thrive. It is likely that without management, many of the rare species in this habitat will be lost as the woody plants continue to encroach and eliminate the open habitat" (Perles 2007). The invasive species of concern at this site include the tree of heaven (*Ailanthus altissima*), invasive shrubs, Asian bittersweet (*Celastrus orbiculata*), white mulberry (*Morus alba*), garlic mustard *(Alliaria petiolata*), and other herbaceous invasive species. Other threats include deer browse and human recreational use (Perles 2007).

A plant list compiled in 1965 by Park staff listed 124 exotic plant species at HAFE. A survey during the 1987 field season confirmed 132 naturalized exotic species found in HAFE (NARM 1987). As of November 2002, the NPS I&M field team identified 207 exotic plant species at the Park. The NPS I&M team continues to monitor exotic plants in the National Capital Region parks. A list of exotic plants at HAFE is found in Appendix B.

Aggressive invasive plants are among the most serious threats to rare and sensitive plant populations, particularly in edge communities (i.e., along railroads, canals, trails, and highways) favorable to the introduction and colonization of the exotic plants. Rare plant populations in these areas are constantly disturbed and are pressured by encroaching invasive plants. Lobed spleenwort (*Asplenium pinnatifidum*) and crested iris (*Iris cristata*), rare plants in Maryland, share habitat with Japanese honeysuckle (*Lonicera japonica*) and Japanese grass (*Microstegium vimeneum*). A variety of exotic weeds, including the bluegrass *Poa compressa*, the cheatgrass *Bromus tectorum,* spotted knapweed *(Centaurea maculosa)*, soapwort *(Saponaria officinalis),* white sweetclover *(Melilotus alba),* mullien *(verbascum thlapsus),* and chickweed *(Stellaria media)*, dominate the open woodland landscape (Bartgis and Ludwig 1996). Short's rockcress (*Arabis shortii*) competes with abundant garlic mustard and ivy-leaved speedwell (*Veronica hederaefolia)* weeds along the upland slopes. Two colonies of Short's rockcress and one colony of snowy campion (*Silene nivea*) were actually destroyed by poison ivy and these other weeds.

Exotic plants flourish along the Park's floodplains, as flooding disturbs native populations and promotes distribution of plant seeds. The Blue Falls portion of the Park, which supports populations of the globally rare Virginia nailwort (*Paronychia virginica*), blue false indigo *(Baptisia australis),* and Torrey's mountain-mint *(Pycnanthemum torrel),* represents one of the most significant rare plants sites in eastern West Virginia (Bartgis and Ludwig 1996). The plants in this area, along with the starry false Solomon's-seal (*Smilacina stellata*)*,* are seriously threatened by grape-hyacinth (*Muscari botyroides*), dame's-rocket *(Hesperia matronalis),* and grassy weeds*.*

In addition to competition from invasive plants, rare plants are also threatened by flooding and human activities. Floodplain plants may be disturbed or destroyed by heavy flooding and/or trampling by fishermen and other water recreationists. Snowy campion colonies were highly disturbed by the heavy flooding in 1996 and may have disappeared entirely from the Park. One colony of rock skullcap was destroyed by trail maintenance work along the Appalachian Trail (Fleming 1999).

A 2006 study examined the sedge, grass and rush (graminoid) populations at the Park. At HAFE, 88 taxa were found during the 2005-2006 field seasons. These taxa were estimated to represent 73%-88% of all graminoids in the Park. The Park was surveyed in conjunction with six other National Capital Region parks and HAFE demonstrated the lowest graminoid species richness. The survey at HAFE was estimated to be the least complete survey of the group (Engelhardt 2006). The graminoids found at HAFE are listed in Appendix C.

A 2002-2004 survey for dragonflies and damselflies (odonates) at HAFE found 51 species of odonates in distinctly different areas of the Park (Jackson's Right Flank, Short Hill, Shenandoah River, Maryland Heights, and the Potomac River). Surveyors also found Asian clams, an invasive exotic species, along the Shenandoah and Potomac Rivers. The report concluded that the "NPS units along the Potomac River corridor may possess the highest level of diversity for odonates of all the National Parks in the United States" (Orr 2005). Of the four National Capital Region parks surveyed for this study, however, HAFE exhibited significantly fewer species of odonates than the other parks. Of the species identified, 10 were on the Maryland state heritage species lists. A list of odonates found at HAFE, including identification of threatened, endangered, and rare species, is found in Appendix D.

An assessment of aquatic insects in nine HAFE streams conducted from May 2002 through April 2004 compared indicators of aquatic health and water quality. A number of the streams were found to be relatively pristine, with a high number of pollution-sensitive aquatic invertebrate taxa (Lamp et al. 2004). By this measure, other streams were found to be less pristine, as invertebrate diversity decreased as indicators of water quality degradation increased (Lamp et al. 2004). The environmentally sensitive invertebrate taxa found at these sites are listed in Appendix E.

During 2002-2003, an inventory was conducted at the Park to document the Park's butterfly and skipper species. The survey found 74 species, including nine species on state Heritage lists. The investigators also concluded, based on habitat analyses, that an additional 20 species were likely to be found, for a Park total of 94 species (Durkin 2003). The list of butterflies and skippers sighted at the Park is found in Appendix F.

A bat survey, conducted during the summer of 2003, netted three species of bats and caught echolocation calls of three additional species. HAFE was surveyed along with ten other National Capital Region parks. In comparison with those parks, HAFE demonstrated a comparable species diversity and evenness. Investigators speculated that the cliffs at the Park might provide roosting areas for rare eastern small-footed bats (Gates and Johnson 2005). A list of the bat species identified at the Park is found in Appendix G.

During spring 2002 through fall 2004, a reptile and amphibian (herpetological) survey was conducted at eight parks in the Northern Capital Region. The most species were found at HAFE, with 18 species of amphibians and 15 species of reptiles including 5 species of frogs, 2 species of toads, 11 species of salamanders, 2 species of lizards, 8 species of snakes, and 5 species of turtles. Investigators found 1 state-listed (West Virginia) species of concern, the wood turtle (*Clemmys insculpta*) (Pauley et al. 2005). The list of reptiles and amphibians, in addition to a list of species potentially inhabiting the area, is found at Appendix H.

A small mammal survey conducted between 2000-2002, including both winter and summer sampling, found 16 species of small mammals at HAFE. HAFE was surveyed along with seven other National Capital Region parks. The number of species captured at the Park during survey with respect to the size of the Park sampled was the highest of all the parks (McShea and O'Brien 2003). The small mammal species sighted in the Park, in addition to the potential mammal species found in the area, are listed in Appendix I.

Avian surveys were conducted at the Park between February 2001 and November 2002. From 64 surveys, 114 species were documented, with nine species confirmed as breeders in the Park. Of the resident species (breeders and winter residents) expected to occur in the Park, 75.6% have been documented; 31 expected residents and 51 expected migrants were not documented. HAFE was surveyed in conjunction with five other National Capital Region parks. In comparison with those parks, HAFE exhibited moderate species richness. A list of the avian species sighted in the Park is found in Appendix J.

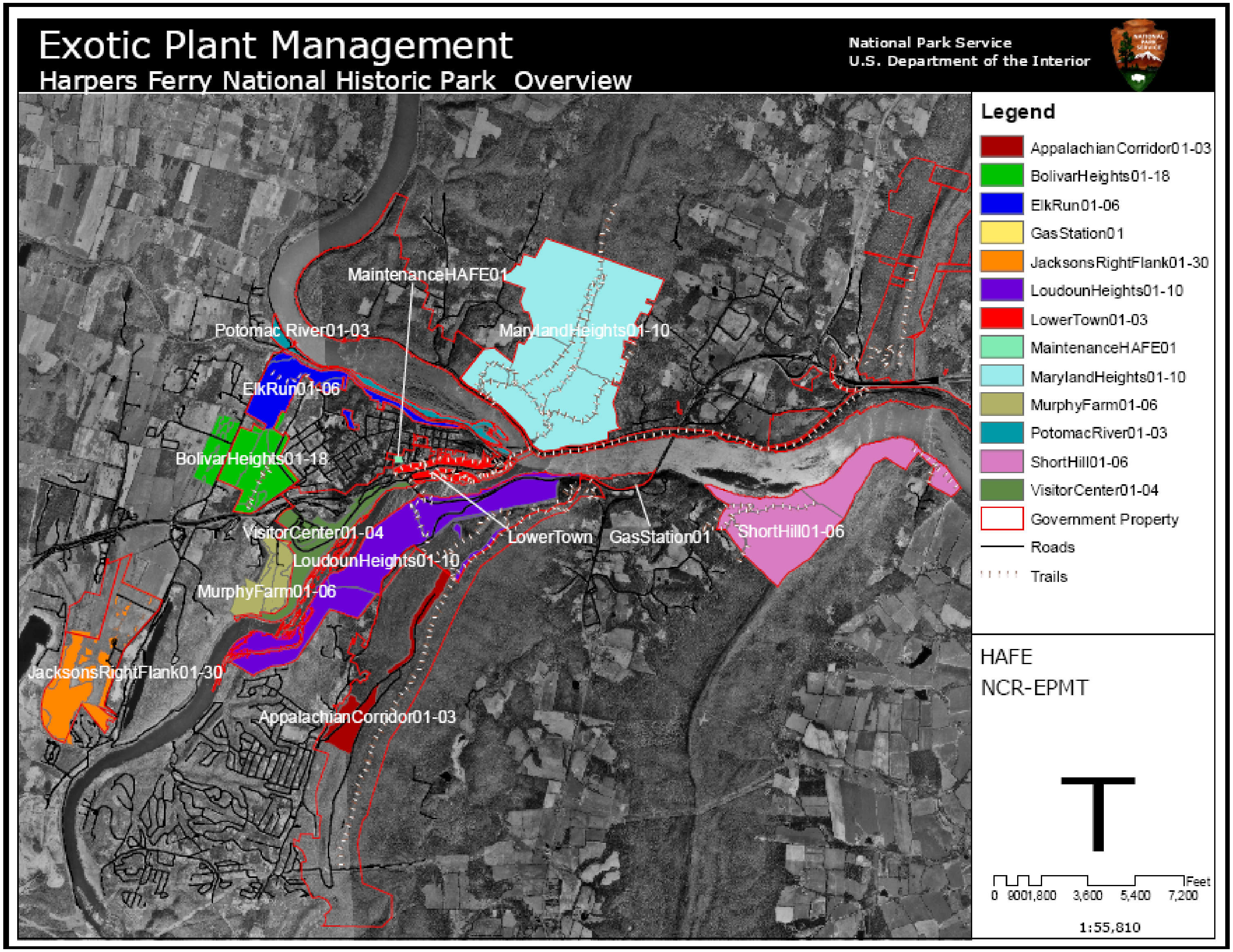
Previous surveys of freshwater fishes in Virginia documented the occurrence of 40 species of fishes in streams surrounding the Park (Jenkins and Burkhead 1994). A fish inventory taken during 2003-2004 collected 35 species from three streams (Elks Run, Flowing Springs Branch, and Piney Run) within the Park. Three of the species expected were fishes that primarily occur in larger streams and rivers and all are expected to occur in both the Potomac and Shenandoah rivers, which were not surveyed in this study. Based on habitat analyses, two additional species that were not captured, the creek chub (*Semotilus atromaculatus*) and Potomac sculpin (*Cottus girardi*), are likely to occur in the Park. One of the species collected, the pearl dace (*Margariscus margarita*), has special conservation status. The index of biotic integrity (IBI) scores for the fish assemblages at the HAFE collection sites all rated in the "Poor" category. These scores reflect a number of fish assemblage attributes, including the presence of pollution-tolerant species, and introduced species. Current studies are investigating the stressors that reduce biological integrity of water bodies in the National Capital Region (Raesly et al. 2004). The fishes collected at HAFE are listed in Appendix K.

b. Native Species

The surveys mentioned in the above section have provided a baseline for a number of plant and animal species at the Park. These inventories, many of which were the first of their kind performed at HAFE, cannot trace species composition or population change over time. Some investigators, however, have made comparisons with historical records of species occurrence and drawn conclusions about community health.

The rare plant populations at HAFE have been surveyed twice, each time for several field seasons, during the 1990s. Detailed information on historical plant species populations does not exist; earlier studies recorded the species observed, but little or no information on the size or locations of each community of plants. Investigators, however, were able to detect population changes from the sparse data gathered during the two recent surveys. Many sensitive rare plant communities, some of which are considered threatened at the state level, are threatened by invasive weeds that compete for habitat and resources. The threat of invasive plants is so pervasive at HAFE that the NCRN exotic plant management team (EPMT) began vegetation monitoring in 2002, which continues annually through the present day. THE NCRN EPMT inventories exotic plant species at HAFE for several weeks each year. Over the years, the inventories have identified 23,429.28 species acres of exotic plant-infested areas at the Park (Salmons 2007, pers. comm.). For occurrences of multiple species of exotic plants in the same area, each species' coverage area is identified and counted separately; therefore the total area of species acres is many times the total acreage of the Park. This monitoring effort focuses on inventorying the location and abundance of the exotic species present in the Park and identifying which areas need to be treated to control infestations. The Park's policy is to only address immediate infestation needs; there is no general policy of eradication (Hebb 2007f, pers. comm.). The NCRN-EPMT has been treating and re-treating 13 units at the Park for a variety of exotic species that encroach upon native and rare plant species (see Appendix L for additional information on treatment units and target species). The treatments are chemical or physical, rather than biological controls, and are not intended to protect specific native plant species (Hebb 2007f, pers. comm.). Each year, the NCRN-EPMT takes a focused approach to exotic plant management. In 2006, the team targeted high-priority areas across the NCRN parks for re-treatment to ensure that the invasive plant populations are controlled (NPS 2006). Park management works with the NCRN-EPMT to identify and implement exotic plant management needs.

Figure 8. Exotic plant management units at HAFE – overview map (NPS 2007j)



Several plant species are of such particular concern at HAFE that the Park has conducted surveys to determine the health of those species populations. The results of the studies, which were conducted for eastern hemlock and butternut, showed that 92% of the hemlock trees surveyed were infested with hemlock woolly adelgid and 75% of the butternut trees surveyed were infested with the *Sirococcus clavigignenti-juglandacaerum* fungus (NPS 2000). Park management has also marked American elms and native eastern dogwood as tree species of concern. The elms have been historically subject to Dutch elm disease and have mostly disappeared from the Park. Native eastern dogwoods have not been monitored, so the status of the community is unknown but the trees are suspected to be affected by Dogwood Anthracnose, a common disease in flowering dogwoods (NPS 2000). Concern about tree cover loss from gypsy moth defoliation has been addressed in this report in section Cover and Habitat Characterization.

The hemlock woolly adelgid is an exotic insect that prefers to inhabit eastern (or Canada) hemlock trees. It damages hemlock trees by sucking the sap out of growing stems, causing the trees to prematurely drop their needles. This inhibits new growth and makes trees more susceptible to drought, disease, and other insect infestations. The hemlock population at HAFE is very small. The Park is predominantly forested with deciduous hardwood trees, with conifers comprising less than 1% of the forested cover. Of the conifers, Virginia pine (*Pinus virginiana*) is the most abundant, followed by Northern red cedar (*Thuja occidentalis*), and then Eastern hemlock (NPS 1994). Park staff had been aware of the presence of the hemlock woolly adelgid in the area for some time. By the time the 1994 survey (NPS 1994) was conducted, the insect was found to be well-entrenched in the Park's hemlock community. The survey evaluated 100 trees in nine stands on Loudon Heights and Short Hill Mountain, with 92% showing signs of hemlock woolly adelgid infestation. Most of these trees exhibited light to moderate levels of infestation, with approximately 54% of the trees showing light to moderate decline. Two stands on Short Hill Mountain exhibited a severe decline in tree vigor, with 15% of the trees classified as dead from natural causes. This baseline study did not provide enough information to determine whether the hemlock woolly adelgid infestations, either independently or in conjunction with other stressors, caused the decline in the health of the hemlock population. The insect remains a prime suspect and Park management plans to continue monitoring its presence in the area.

Sirococcus clavigignenti-juglandacearum is a perennial fungus of unknown origin that causes spreading branch and stem cankers that eventually girdle infected trees. Much of the butternut population throughout West Virginia is subject to this disease (Tracy et al. 1999). At HAFE, Tracy et al. (1999) found that most of the Park's trees are in varying stages of the disease. Tree canopies were thin and the canopy cover ranged from 0-100%, with the average cover at 73.5%. The affected trees also lacked the lateral spreading branches typical of a healthy butternut. Butternut is currently considered a "species at risk" on the list of the Endangered and Threatened Plants under the Endangered Species Act (ESA). The West Virginia Natural Heritage Program has listed the butternut as very rare species vulnerable to extinction since 1997 (Tracy et al. 1999).

The odonate study, though the first comprehensive survey of dragonflies and damselflies in the Park, noted the lack of species historically present in the Potomac River watershed. Though the Potomac River corridor is considered to possess some of the highest diversity of odonates in the United States, some of the species considered endemic to the area were not found at HAFE during the study. HAFE also contained significantly fewer species of odonates than the other three parks surveyed for the study (Orr 2005). Odonate species are threatened by environmental degradation, including habitat destruction and contamination. Upstream pollution and encroaching development compromise the riparian and wetland habitat (e.g., small streams and seeps) that odonates require to thrive. Odonates serve as an excellent indicator species, because they are extremely sensitive to changes in the aquatic environment. Degradation and/or loss of aquatic systems may be reflected in the odonate species composition more quickly than can be monitored for most other plant or animal groups (Orr 2005). While this baseline survey is a good beginning step for developing an indicator of system health, continued monitoring of the odonate population is required for determining future changes within the aquatic environment. The study at HAFE was investigating how controlling mosquitoes to prevent the potential spread of West Nile Virus would impact the odonate community. Orr (2005) concluded that some insecticides for controlling virus-bearing mosquitoes could harm odonate populations and made recommendations for Park management to consider other insect populations when selecting insecticide regimes. Odonates are first trophic level insect predators for many aquatic ecosystems and are considered to be keystone fauna in the mid-Atlantic Region (Orr 2005). Because they provide biological information that can be used for management of freshwater ecosystems, it would be useful to continue monitoring the presence and function of odonates in the Park.

The varied habitats at HAFE host one of the most diverse populations of butterflies and skippers in the Maryland-Virginia-West Virginia area. The 2002-2003 survey found 74 species, including 9 species on state Heritage lists, and identified another 20 species that are likely contained within the Park. When compared to informal butterfly and skipper surveys done throughout the 1970s and 1980s, the Park's current populations appear to be mostly healthy and intact. One species, however, the West Virginia White (*Pieris virginiensis),* was found to be greatly diminished (Durkin 2003). This once-common butterfly is in serious decline throughout the region and is Heritage-listed in Maryland and Virginia. Its decreasing population is attributed both to the rapid spread of the exotic invasive garlic mustard plant and habitat-destroying development (Durkin 2003). The butterfly is hosted by the toothwort plants (*Dentaria spp.),* which are being out-competed by the garlic mustard weeds. Robust colonies of West Virginia White were found on Maryland Heights and Loudon Heights during the 1970s; during the more recent survey, only two individuals were observed (Durkin 2003). The decline of this particular butterfly illustrates the fragility of the Park's current diversity. Invasive plants and encroaching development are serious threats for the Park's butterfly and skipper communities. The recent surveyors recommended that garlic mustard in the West Virginia White's historical habitats be aggressively controlled and that recognized habitat areas be preserved from the effects of commercial development in the region to the greatest extent possible (Durkin 2003).

Peregrine Falcons (*Falco peregrinus*) have historically nested in the Short Hill Mountain area. There are records of breeding pairs being shot down and nestlings being removed by falconers throughout the 1940s (Gabler 1983). The last Peregrine Falcon nest at HAFE was reported in 1952. The Peregrine Falcon was declared endangered under ESA in 1970. In 1984, the status of one of the peregrine subspecies was changed from endangered to threatened and it was taken off the list entirely in 1994. By 1999, all the other Peregrine Falcon subspecies had been taken off the endangered species list. The Peregrine Falcon, however, is still a state-listed endangered species in Virginia and Maryland and is considered to be a rare species in West Virginia (Scott 2005). The Park initiated a Peregrine Falcon restoration project in 2001, with the goal of having a nesting pair return to the Park. The Maryland Heights Peregrine Falcon Restoration Site, which located along the upper western portion of the Maryland Heights cliffs, is closed to the public during the early summer when young birds are present (NPS 2003b). The latest season for reintroducing fledgling falcons at HAFE was summer 2005. Birds were released each summer between 2001 and 2005.

As of the last reintroduction effort, 29 Peregrine Falcons have been released, six of which were fitted with satellite transmitters (Scott 2005). HAFE is a partner in the FalconTrak project, the largest tracking and research project ever undertaken on wild Peregrine Falcons in the United States. The project uses the tracking information gleaned from the satellite transmitters to study the migratory and nesting patterns of the released birds (Dominion 2001). Thus far, none of the reintroduced birds have returned to HAFE to nest. Project staff hope that falcons released at HAFE will imprint on the Maryland Heights cliffs and return as a breeding adult (NPS 2007c). While Park staff is interested in continuing the program, lack of funds has prevented additional falcon reintroduction efforts in 2006 and 2007. Park staff hopes that sufficient resources (i.e., funds and personnel time) are available to resume the program in the near future (Hebb 2007k, pers. comm.).

As mentioned previously in this report, the deer population at HAFE has been overabundant to the extent that the deer significantly impact other flora and fauna. In this area, deer have no natural predators and overpopulation is a serious issue. Several years (2000-2004) of fall and winter deer counts indicate that the deer population at HAFE has been slightly decreasing. Though the trend is as yet statistically insignificant, the current deer population hovers just below a mean deer density of 40 deer per square mile, the point below which the deer population is no longer considered overabundant (Bates 2005).

iii. Biotic Impacts and Stressors

a. Animals and Insects

Though baseline surveys are useful for identifying the species present at the Park, the species inventories provide little information about community health and population change. The animal and insect populations surveyed at HAFE are stressed by a number of biotic, environmental, and anthropogenic factors. The effects of most of these stressors have not been quantified and would require long-term monitoring of the affected populations. General stressors, however, have been identified and the qualitative effects on the animal and insect populations can be observed or inferred.

Changes to the forest canopy can affect wildlife communities. Forested areas with full or partial canopy and downed woody debris are important habitats for many species, in particular, some species of amphibians and reptiles. Wood and leaf materials serve as important food sources and habitat for aquatic macroinvertebrates (Lamp et al. 2004). Openings in the forest canopy, such as caused by gypsy moth defoliation or clearing for agriculture and development, allows increased sunlight that dries the forest floor. This leads to increased soil temperatures that reduce numbers of animals that depend on the habitat (e.g., some salamander species) (Pauley et al. 2005) and promotes understory plant growth. Openings in the tree canopy that reduce the presence of in-stream plant materials can harm aquatic macroinvertebrate populations.

Many animal and insect species are sensitive to the environmental quality of their habitat. The fish survey indicated that the overall fish IBI at the Park was 1.29 and the

IBI scores of fish assemblages at quantitative sites are rated as “poor” (Raesley et al. 2004, Hilderbrand et al. 2005). These scores are indicative of a stressed population. The IBI score reflects the presence of a number of pollution-tolerant species and introduced species, indicating that the stream characteristics and water quality do not favor pollution-sensitive species. A similar trend was noticed in the study of aquatic invertebrates. The more pristine streams with higher water quality in less disturbed areas of the Park contained greater overall faunal diversity and a variety of pollution-intolerant invertebrate species. The more degraded streams, with higher concentrations of pollutant chemicals and overabundant nutrients, were less diverse and supported more pollution-tolerant species (Lamp et al. 2004). The aquatic invertebrates study (Lamp et al. 2004) also found that the diversity of stream communities correlated inversely with the concentration of aluminum found in the streams. While the biological effects of aluminum are not precisely known, the observed trend indicates that the presence of aluminum is detrimental to the aquatic invertebrate population. The same study found high levels of chloride in many of the Park’s streams, which has also been associated with reduced diversity and abundance aquatic invertebrates (Lamp et al. 2004). Other insects are also sensitive to environmental toxins. The investigators in both the odonates and butterfly surveys noted that pesticides and chemical pollutants, both those used within the Park and those entering the Park from further up in the watershed, could be harmful to the insect populations. They suggested that environmental quality indicators be closely monitored, especially with regards for management of rare and Heritage-listed species.

As discussed earlier in the report (under Disturbance Regimes), implications of climate change on fauna at HAFE have not been studied in depth but can be inferred. Warming temperatures will extend the habitat of more southerly species, making it possible for new animal and insect species to encroach on native species. In addition, increasing temperatures may cause more frequent occurrence of drought that would permanently dry out the intermittently flowing first-order streams that provide habitat for a number of animal species.

Concerns about exotic and invasive species with regards to HAFE fauna center primarily on competition for native plant species that provide habitat for sensitive insect populations (e.g., garlic mustard encroaching on toothwort plants, the habitat for the rare West Virginia White butterfly). In the faunal inventories, no mention is made of exotic or invasive species that threaten animal populations, though the presence of Asian Clams has been noted in the Park. The animal inventories did not note incidence of disease in the populations surveyed. The most likely natural disaster at HAFE is flooding, which has minimal impact on animal species

Noise from passing trains, vehicles, or recreationists has been a part of this environment for over 170 years. The areas designated for mixed human and natural use are already highly disturbed and continuing historical uses should not adversely affect the wildlife in the area (Hebb et al. 2001). Area management officials are aware, however, that new or increased noise pollution could have an undesired impact on area wildlife and even human quality of life. Accordingly, the Jefferson County Comprehensive Plan makes recommendations to minimize existing noise pollution and to control new development and the resulting increased traffic congestion that adds to noise pollution. The County's Plan also recommends promotion of development that minimizes light pollution (Jefferson County Planning Commission 2004). Park management works with area officials to stop or minimize the noise and light pollution impacts of development on lands adjacent to and nearby the Park, the most recent example being the proposed development of the Old Standard Quarry (discussed under Adjacent Land Use).

Most anthropogenic land uses are not beneficial for wildlife. Though the resident fauna seems to have adapted to the current habitat restrictions, Park management is sensitive to the threat posed to wildlife habitats by encroaching adjacent development. Some land uses, however, are beneficial and create additional habitat for biota. Much of the wetland areas in the Park are revegetated remnants of man-made structures. The most significant wetland in the Park, an 8-acre patch along Shoreline Drive, is an abandoned man-made lake (Lake Quigley) that was produced by impounding the water of the

Shenandoah River (NPS 2000). Another significant wetland area grew out of the abandoned Shenandoah Canal. These areas provide important habitat for a variety of wildlife, particularly reptiles and amphibians. These areas create additional habitats for the Park's herpetological communities. These habitats, however, are fragmented and bounded by roads subject to vehicular traffic and can create a population sink that may kill more migrating animals on roads than the potential new breeding areas can produce (Pauley et al. 2005). In addition, these fragmented populations will eventually take on an "island biogeography," with particularly limited genetic diversity (Pauley et al. 2005).

Surveyors were concerned about Park management practices that could affect certain insect populations. Orr (2005) noted that spraying to kill West Nile Virus potentially bearing mosquitoes could affect odonate populations, depending on the insecticide regime used. The report recommended that the lifecycle and habits of the odonate state-listed species of concern be considered in the selection of pesticides and the locations for treatment. The report also noted that use of general insect adulticides could lower the abundance of aquatic insects that comprise a large portion of the food base for first-level predators. Durkin (2003) made similar recommendations about the prohibition or selective use of pesticides that could impact the butterfly and moth populations at the Park.

Wildlife is also affected by the human recreationists using the Park. Recreationists trample on habitat and leave behind unbiodegradable litter. Humans may remove amphibians and reptiles from their natural habitats; this is a particular problem with turtles, which are often taken to be pets (Pauley et al., 2005). Human impact necessitated the installation of a bat gate at John Brown Cave to protect that resident bat population and the cave ecosystem from visitors. Deer poaching is known to occur but is not considered to be a particular problem at the Park (Hebb 2007c, pers comm.).

Though these other anthropogenic stressors are significant, particularly to specific biotic communities, the most prominent threat to animal and insects at HAFE is encroaching development. Preservation of habitat and air, water, and soil quality is of paramount importance when considering management strategies for Park fauna.

b. Plants

Though the plant inventories have indicated the presence of many different plant assemblages at the Park, the surveys are not conducted often enough to establish population changes or measure the effects of community stressors. General biotic, environmental, and anthropogenic stressors on the plant population, however, can be observed or inferred.

Changes to the forest canopy can significantly affect the composition of plant communities. Forested areas with full or partial canopy favor shade-tolerant species and woody plants. Open areas support herbaceous shrubs and shade-intolerant species. Openings in the forest canopy, such as caused by gypsy moth defoliation, wildfire, or clearing for agriculture and development, interrupt the natural succession towards hardwood forest and may alter the conditions of the habitat enough that new plant assemblages may colonize the area. For rare plant assemblages, such as those found in the limestone red-cedar glades, man-made disturbances in the forest canopy are recommended as a management tool for maintaining habitat for these species. For maintaining the integrity of the forest canopy, disturbance-controlling management techniques such as gypsy moth suppression and carefully planned adjacent development are required.

Floods are not thought to have a long-term effect on floodplain plant communities. The floodplain plant communities are among the most diverse population in the Park and contain many of HAFE’s rare plants. These species seem to be adapted to periodic flooding - though flooding disturbs the plant communities, the loss is not necessarily permanent. Plants lost in one flooding incident may reappear at a later time in another area, as flooding is one mechanism of seed dispersal. The plants that occur in the floodplain, to some extent, are selected to live in that environment (Fleming 1999).

Some anthropogenic land uses, including agriculture, residential and commercial uses, historical structures, and clearings for roads and trails favor the growth of shade-intolerant plant species. These same uses, however, particularly the transportation uses, provide a vector for dispersing exotic and invasive plant species. In addition, plants may be susceptible to harm from vehicle pollution. Recreational users trample plants, which is especially harmful for those marginal populations growing along roads and trails.

As discussed earlier in the report (under Native Species), several diseases and infestations are known or thought to be affecting the Park's populations of hemlock, butternut, elm, and dogwood trees. The hemlock and butternut trees have been surveyed for at least one field season and the forested canopy is monitored annually to measure gypsy moth defoliation. Excepting these species of concern, certain threatened populations of plants, and periodic defoliation, the vegetation on Park lands seems healthy, having fully rebounded from the deforestation in the previous century.

As addressed earlier in this report (under Total Species), competition from exotic and invasive species presents one of the greatest threats to rare plant species at HAFE. A number of rare plants are in direct competition with encroaching species that require human intervention to maintain the threatened species.

As discussed earlier in the report (under Disturbance Regimes), implications of climate change on flora at HAFE have not been studied but can be inferred. Warming temperatures will extend the habitat of more southerly species, making it possible for new plant species to encroach on native species. In addition, it would be possible for new diseases and pest insects to infest plants at the Park. NCRN staff expect that the emerald ash borer, an exotic beetle that feeds on ash trees, will be able to enter the Park if overall temperatures continue to rise (Swearingen 2007, pers. comm.). Rising temperatures may also decrease the flow in small, intermittently flowing streams destroying habitat for a number of plant species.

Though these other anthropogenic stressors are significant, particularly to specific biotic communities, the most prominent threat to plant communities at HAFE is encroaching development. Preservation of habitat and air, water, and soil quality is of paramount importance when considering management strategies for Park flora.

B. Environmental Quality

i. Air Quality

There is no air quality monitoring at HAFE. Weather information, including daily maximum and minimum temperature, precipitation amount and duration, relative humidity, 10-minute wind speed averages and direction, and hourly fuel moisture readings were recorded by Park staff at the Park's fire weather station until 1998. Until the early 1990s, these records were handwritten and kept in hardcopy form only. The more recent data was kept electronically and uploaded in the Forest Service Weather Information Management System (WIMS) database. The Park used weather data from WIMS or the National Weather Service, which directly uploaded data from weather station #461201 in the Park, until the early 2000s, when the equipment was removed from the Park. The Park no longer operates a fire weather station, so fire management personnel rely on the regional fire management officer for fire weather data from other NPS fire weather stations in the area (Hebb 2007l, pers. comm.). Long term trends in HAFE weather and climate are discussed earlier in this report under Climatic Regime.

The NPS NCRN does not monitor air quality near HAFE. The closest stations collecting air quality data are Shenandoah National Park, approximately 70 miles away to the southwest, and limited monitoring (visibility only) in Washington, D.C., approximately 70 miles away to the southeast. NPS air monitoring indicates that the general region has fair to medium air quality in most of the general indicators, but these data are not localized enough to be of much use for interpreting air quality at the Park (NPS 2005a). The closest air quality monitoring station to the Park is administered by the West Virginia Department of Environmental Protection (WVDEP) at Martinsburg, WV, which is approximately 15 miles away from HAFE. Data from this station indicate moderate to good (borderline between the two designations) ozone quality during 2000-2005

(WVDEP 2005). At the Martinsburg station, the concentrations of ozone for the years 2001-2005 have been just over, or below the National Ambient Air Quality Standard (NAAQS) of 0.85 ppm since 2001. These data are reported as 4th highest daily maximum 8-hour concentrations of ozone averaged over 3 years (i.e., each measurement is reported as the average of three consecutive years).

HAFE is located in the Eastern Panhandle (i.e., Berkeley and Jefferson counties) of West Virginia, which was identified as a potential air quality non-attainment area for 8-hour ozone. This designation was deferred because the area voluntarily entered a program to expedite actions for addressing its ozone problems (WVDEP 2005). The program, called an Early Action Compact, requires areas to identify and implement control strategies earlier than would otherwise be required under the Clean Air Act and subsequent amendments. Department of Air Quality planning staff members in the WVDEP have been assisting local officials in Berkeley and Jefferson counties to meet the program requirements on schedule (WVDEP 2005).

The U.S. Environmental Protection Agency (EPA) maintains two separate ambient air quality standards for particulate matter (PM). One standard addresses PM particles that are coarse but equal to or less than 10 micrometers in diameter (known as PM10). The other standard addresses levels of fine particulate matter (known as PM2.5), which contains particles equal to or less than 2.5 micrometers in diameter. Both short-term (i.e., a day) and long-term (i.e., a year) exposure to PM are associated with adverse health effects (WVDEP 2005). At the Martinsburg station, the PM10 annual averages averaged over 3 years at Martinsburg taken between 2000 and 2004 have all been below the NAAQS of 50 $\mu g/m^3$. The PM10 24-hour, 3-year maximum values taken between 2000 and 2004 have all been below the NAAQS 150 $\mu g/m^3$. The PM2.5 annual averages taken between 2000 and 2005, reported as averages over 3 years, have all been slightly above the NAAQS of 15 $\mu g/m^3$. The PM2.5 measurements taken in 24-hour increments, averaged over 3 years for the years between 2000 and 2005 have all been below the NAAQS of 65 $\mu g/m^3$. All of these data indicate that the PM measurements at Martinsburg are below the NAAQS (WVDEP 2005). Therefore, particulates are not of particular concern in the general vicinity of HAFE at the present time.

The U.S. EPA, National Oceanic and Atmospheric Administration, NPS, tribal, state, and local agencies contribute to the AIRNow Web site (http://www.airnow.gov/), which provides the public with national air quality information. On this site EPA calculates the Air Quality Index (AQI) for five major air pollutants regulated by the Clean Air Act: ground-level ozone, PM, carbon monoxide, sulfur dioxide, and nitrogen dioxide. For each of these pollutants, EPA has established NAAQs to protect public health. An “unhealthy for sensitive populations” designation is assigned when any of these pollutants surpasses the NAAQS for that pollutant, reaching “code red” status on the AQI. For different sensitive populations (i.e., heart disease, asthma and lung disease), there are different sets of pollutants of concern. The reports for Loudon, VA, Washington, MD, and Berkeley, WV (the county neighboring Jefferson County to the northwest, the closest monitoring station in WV) counties from 2000 to 2006 show that the AQI measured fewer than 5 unhealthy days per year for heart-disease-sensitive populations (AIRNow 2007). These results demonstrate that PM pollution and carbon monoxide concentrations did not breach the NAAQSs for these pollutants more than a few days per year. The reports from those same areas with consideration for asthma or other lung disease populations, however, showed that the AQI measured a greater number of unhealthy days per year. The results demonstrate that ozone, PM pollution, and sulfur dioxide breached NAAQSs for fewer than 5 days per year since 2003. The measurements in 2000 through 2002, however, revealed a larger number of unhealthy days, up to 23 unhealthy days (in Loudon County, VA) in 2002 (AIRNow 2007). These data indicate that general air quality in recent years in the vicinity of HAFE has been mostly high. The higher numbers of unhealthy days in the early 2000s, however, demonstrate that the area is susceptible to air pollution that may harm sensitive human populations.

Exhaust from motor vehicles emits carbon monoxide, lead, ozone, and nitrogen oxides (WVDEP 2005). Park and local management entities are aware that development, with its attendant increase in vehicular traffic, has implications for lowering air quality. Recent area development plans have included traffic studies to examine the potential impact of the proposed development, and officials consider whether development projects are likely to significantly increase local traffic when making zoning decisions. In the recent controversy over the Old Standard Quarry development, vehicular traffic impact studies were a major point of contention. The opponents of the development plan contended that the increase in vehicular traffic was severely underestimated by the developer's traffic impact study (Smart Mobility 2007).

Information was not available on the presence of chlorinated oxides, chlorinated nitrates, hydrofluorocarbons, fuel hydrocarbons, hydrocarbons, and volatile organic chemical air pollutants at HAFE.

ii. Water Quality

Though the Shenandoah and Potomac Rivers run through HAFE, the waterbodies do not lie within the boundaries of the Park. Park boundaries do, however, encompass a number of seeps and springs, as well as segments of three tributary streams to the Potomac and Shenandoah Rivers; Piney's Run, Elk Run, and Flowing Springs Run. All of these waters ultimately drain to the Chesapeake Bay. Elk Run is classified as an outstanding natural resource water in West Virginia. West Virginia anti-degradation standards require that outstanding natural resource waters shall be "maintained and protected and improved where necessary" (Norris and Cattani 2005). In addition, Piney Run, the Potomac River, and the Shenandoah River are all classified as impaired waters in West Virginia (Norris and Cattani 2005). The Shenandoah River is additionally classified by Virginia as impaired water (Jefferson County Planning Commission 2004). EPA authorizes the states to issue total maximum daily loads (TMDLs) for impaired waters. These limits represent the calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards and an allocation of that amount to the pollutant's sources. Piney Run has a TMDL for fecal coliforms and the Potomac and Shenandoah Rivers both have TMDLs for polychlorinated biphenyls (PCBs) and nutrients. While the source of the contaminants in Piney Run is not known, the pollutants of concern in the Potomac and Shenandoah Rivers are thought to enter the watershed through runoff.

The characteristics of these waters impact the Park's natural resources. The water quality in these waterbodies is measured at a number of gaging stations in and around the Park maintained by the USGS and other state and federal agencies (Figure 9). HAFE staff does not monitor water quality. The NPS's 1997 *Baseline Water Quality Data Inventory and Analysis* report for HAFE surveyed all the data gathered in and around the Park at these monitoring stations from 1933 until 1996 (Table 12). These data were mined from six of EPA's national databases: (1) Storage and Retrieval (STORET) water quality database management system; (2) River Reach File (RF3); (3) Industrial Facilities Discharge (IFD); (4) Drinking Water Supplies (DRINKS); (5) Water Gages (GAGES); and (6) Water Impoundments (DAMS). These data and analyses indicated that the area's surface waters are "generally of good quality with some impacts from human activities" (NPS 1997). Point sources that have been identified in the local watershed include private residencies served by individual septic systems, runoff from a large junkyard adjacent to the Park, a sewage treatment plant within the Park's boundary, and package treatment plants discharging to streams that flow through the Park. Non-point sources of pollution include runoff from highway and railroad corridors, upstream mine drainage, atmospheric deposition, agricultural runoff, recreational use, and stormwater runoff from adjacent communities. In addition, area flooding can create problems with water pollution at HAFE; during periods of flooding, floodwater can inundate and overflow the Harpers Ferry town wastewater collection system, part of which is located in the Park.

These data were screened against published EPA water quality criteria and instantaneous concentration values selected by the NPS Water Resources Division (WRD) to identify potential water quality problems. The results of this screening process found 21 groups of parameters that exceeded screening criteria at least once. Dissolved oxygen, pH, chlorine, cyanide, antimony, cadmium, chromium, copper, lead, selenium, silver, and zinc exceeded their respective EPA criteria for the protection of freshwater aquatic life. Fluoride, nitrate, nitrite, nitrite plus nitrate, antimony, beryllium, cadmium, chromium, lead, and nickel exceeded their respective EPA drinking water criteria. Bacteria concentrations (total coliform and fecal coliform) and turbidity exceeded the WRD screening limits for freshwater bathing and aquatic life, respectively. These data had an average pH of about 8.1 and an average acid neutralizing (or alkalinity) capacity of approximately 936 μeq/l (NPS 1997).

The most significant exceedances of EPA drinking water and freshwater aquatic life criteria, as well as NPS WRD-selected indicator criteria, were for total and fecal coliforms. Total coliform counts exceeded the NPS WRD bathing water criterion, 100 colony forming units (CFU)/most probable number (MPN)/100 ml, in more than 50% of 762 observations. Fecal coliform count exceeded the NPS WRD bathing water criterion, 200/MPN/100 ml for fecal coliforms, in more than 34% of 1,086 observations. Anthropogenic pollution such as runoff from agricultural lands and sewer or sewage treatment plant overflows that commonly occur during storm events is the most likely sources of this high rate of exceedance. These exceedances are of significant concern to Park management because of the access that the Park provides to the rivers for recreation. Most of the other contaminants of concern were generally observed to be below threshold criteria.

While the 1997 water chemistry analysis of the Park's waters indicated that most waterbodies were generally in good condition, more recent studies reveal that almost all waterbodies sampled in the Park exhibit some level of degradation (Lamp et al. 2004, Hilderbrand et al. 2005). The contaminants of concern, coliforms, metals, nutrients, and chloride, found in the waters all indicate human sources of pollution. Chloride levels were high in many upland streams, likely introduced through road salt applications and other human activities. Aluminum concentrations, possibly derived from industrial pollution, were also higher than expected in several of the streams (Lamp et al. 2004). Both these contaminants are associated with decreased biological productivity. The nitrogen and phosphorus levels for all the waterbodies sampled were elevated above

Figure 9. Water quality monitoring locations at HAFE (NPS 1997)

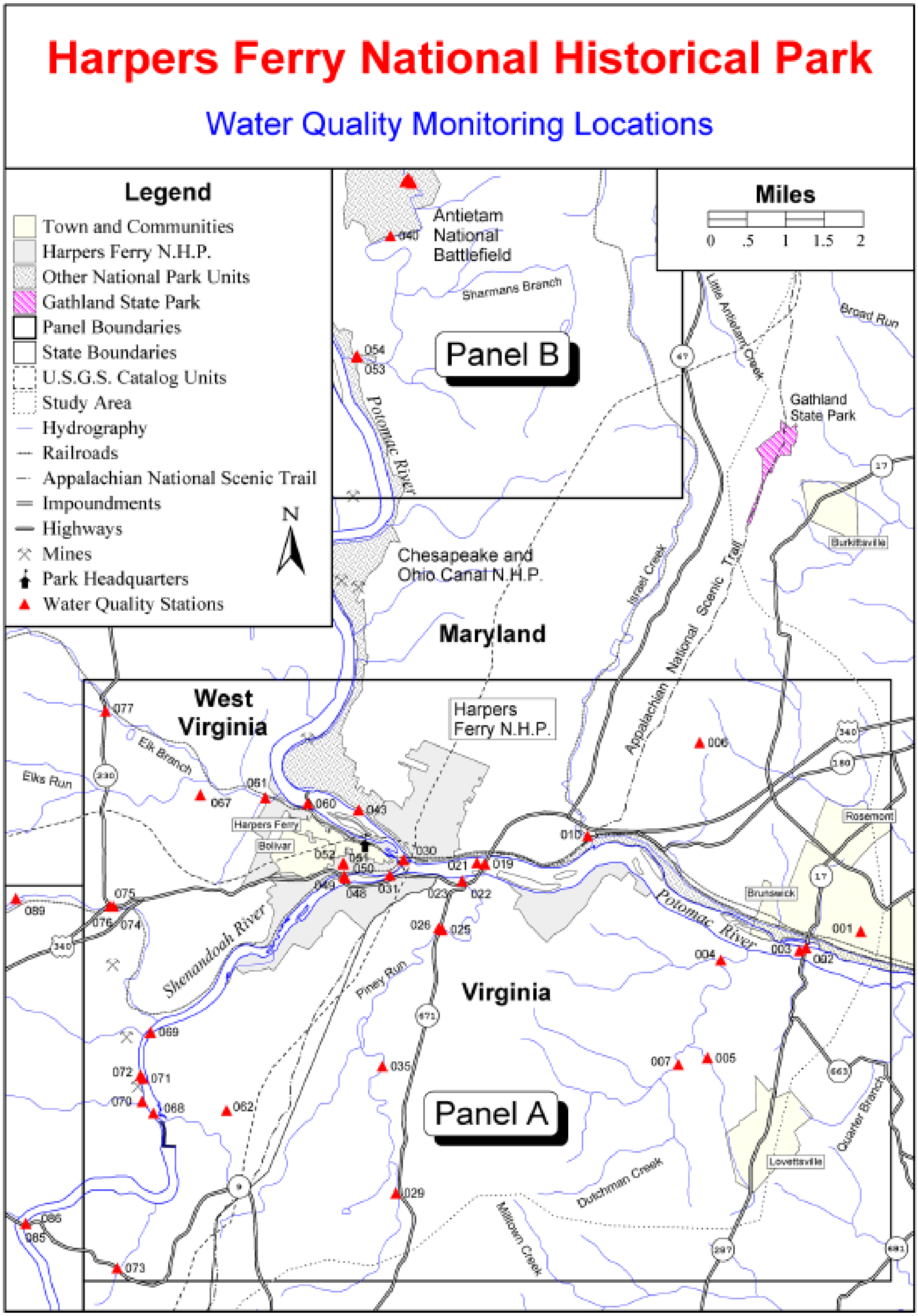


Table 12. Water quality data in HAFE vicinity (NPS 1997)

Parameter	Period of measure	# of measurements	# of monitoring stations	# of observations	# of exceedances	% of exceedances (per observations)	Criterion of measure
Dissolved oxygen	1946-1996	1,732	78	1,613	7	0.4	≤ 4 mg/L; EPA – aquatic life
pH	1945-1996	2,947	87	2,826	122	4.3	6.5-9.0 pH units; EPA – aquatic life
Turbidity	1954-1996	1,281	32	1,243	58	4.7	50 turbidity units; WRD criterion
Total coliform	1966-1995	878	17	762	409	53.7	100 CFU/MPN/100 ml; WRD bathing water criterion
Fecal coliform	1946-1996	1,201	35	1,086	376	34.6	200 CFU/MPN/100 ml; WRD bathing water criterion
$Nitrate_1$	1933-1996	1,051	47	941	5	0.5	10 mg/L for N; 44 mg/L for NO_3; EPA – drinking water
$Nitrite_2$	1970-1996	732	37	622	3	0.5	1.0 mg/L; EPA – drinking water
Nitrite plus nitrate	1969-1996	1,075	58	1,039	2	0.2	10 mg/L; EPA – drinking water
$Chlorine_3$	1976-1978	5	1	5	3	60.0	0.019 mg/L; EPA – acute aquatic life
$Cyanide_4$	1930-1984	93	5	93	1	1.1	0.022 mg/L; EPA – acute aquatic life
Fluoride	1957-1995	718	23	718	3	0.4	4.0 mg/L; EPA – drinking water
$Antimony_4$	1979-1995	30	3	30	14	46.7	6.0 µg/L; EPA – drinking water
$Beryllium_{4,5}$	1982-1995	78	6	78	1	1.3	4.0 µg/L; EPA – drinking water
$Cadmium_{4,5,6}$	1968-1996	537	34	511	17	3.3	3.9 µg/L; EPA acute aquatic life
$Chromium_{4,5,6,7}$	1968-1996	657	31	657	2	0.3	16 µg/L; EPA acute aquatic life
$Copper_{4,5,6}$	1959-1996	365	32	364	13	3.6	18 µg/L; EPA acute aquatic life
$Lead_{4,5,6}$	1967-1996	578	31	578	82	14.2	15 µg/L; EPA – drinking water
$Nickel_{4,5,6}$	1973-1996	239	29	293	1	0.3	100 µg/L; EPA – drinking water
$Selenium_{4,5,6}$	1975-1995	244	19	244	1	0.4	20 µg/L; EPA acute aquatic life
$Silver_{4,5,6}$	1968-1995	327	18	313	11	3.5	4.1 µg/L; EPA acute aquatic life
$Zinc_{4,5,6}$	1959-1996	380	35	380	22	5.8	120 µg/L; EPA acute aquatic life

1 = dissolved and total N and as NO_3
2 = dissolved and total as N and dissolved as NO_2
3 = total residual
4 = total
5 = dissolved
6 = suspended
7 = hexavalent

pristine levels, though the N:P ratio suggested that algae growth was inhibited. While the concentration of phosphorus did not indicate impairment, the nitrate levels at Flowing Springs Run were significantly elevated (Hilderbrand et al. 2005). In addition, both the Shenandoah and Potomac Rivers (including the segments flowing through HAFE) are known to contain high concentrations of nutrients. No impairment was found for pH, specific conductance, dissolved organic carbon, or sulfate at any of the sites sampled in the Park (Hilderbrand et al. 2005).

The fish IBI for Flowing Springs Run was measured at 1.29 in 2004, indicating “very poor” conditions. This score reflects a stressed environment and/or population and is lower than the typical Highland stream score of 2.0 (Hildebrand et al. 2005). This low score, however, was somewhat ameliorated by the benthic IBI score of 3, which indicated the low end of “fair” conditions. A low score on one index does not necessarily reflect an impaired condition. In general, the higher of the two scores are used to evaluate the condition of the sampling site (Hilderbrand et al. 2005). The score can be reflective of prior degradation, current conditions, or an early indicator of stressors and ongoing degradation. Therefore, these scores are most useful for evaluating the condition of a site when used in the context of long-term monitoring. The fish IBI for Elks Run, Flowing Springs Run, and Piney Run in 2003 and 2004 also indicated “poor” conditions.

In general, the lowland waters in the HAFE area are hard, containing significant concentrations of calcium and magnesium (NPS 2007c). These naturally occurring elements are commonly found in waters that flow through limestone and dolomite rocks. Waters flowing through limestone are naturally buffered against acidic conditions, as the dissolved limestone forms calcium and carbonate ions. Alkalinity, the buffering capacity of water, is a function of the concentration of carbonate ions. Therefore, acid rain is not a significant concern at HAFE for the waters flowing in carbonate rocks. The highland streams flowing though quartzite and phyillite rocks, however, lack that buffering capacity and may be more subject to acidification. Acidification in these streams is significant because some toxins, such as aluminum, are much more soluble at nonneutral pH levels, which allows increasing concentrations to be available for biological uptake (Lamp et al. 2004).

Currently, there is no monitoring of the water quality in any of the Park's wetland areas. These waterbodies are among the habitats most sensitive to environmental degradation, and characterization of the flow into and within these areas is extremely important for gauging the health of the ecosystem. In particular, monitoring is needed for the three streams that flow into the 8-acre wetland along Shoreline Drive. "These streams flow through private lands that contain a large car junkyard, adjacent residential and commercial developments served by individual septic systems, and stormwater runoff from the adjacent towns" (NPS 2000).

As discussed in Research and Monitoring, the NCRN has plans for long-term water quality monitoring at HAFE. The protocols for formal surface water dynamics, water chemistry, nutrient dynamics, and aquatic macroinvertebrates monitoring are still in development. In the meantime, NCRN continues to perform periodic (monthly to quarterly) sampling at Flowing Springs Run in the Park for air temperature, acid neutralizing capacity, dissolved oxygen, flow, nitrate, nitrogen ammonia, pH, phosphorus, specific conductance, salinity, water depth, water temperature, and stream wetted width. Data are kept in EPA's STORET database and recent data (since the 1997 report) have not been analyzed or published.

iii. Soils and Sediments

The soil horizons on much of Park lands were disrupted during the deforestation in the 19th and early 20th centuries (Fuertsch 1992). Soil formation in the Park has also been disrupted by agriculture and anthropogenic development (e.g., building and road construction). The organic matter in the soils is poorly developed and slowly reforming (Hebb 2007e, pers. comm.).

There have been few documented soil sampling efforts and no formal soil mapping efforts at the Park. Park management sampled the soil in several of the agricultural fields in the late 1990s; the samples indicated that fertility in the fields is suitable for hayland production (NPS 2000). Soil pH taken from Jackson's Right Flank during 2005 vegetation plot sampling ranged from 7.0 to 7.5 (Perles 2007). Most of the Park's efforts in regards to soil documentation had been focused on developing GIS layers for soils mapping. Much general soils information is available in digital format and Park staff is in the process of developing digital soils maps for HAFE.

In some areas of the Park, soils are especially subject to erosion. The highland forested steeps are well-vegetated and not particularly conducive to erosion. The steep, rocky areas of the Park that have been denuded and developed, however, are subject to rock weathering and erosion that can lead to slope failure (see Geology and Land Forms for additional discussion of slope failure.). In addition, the lowland areas near the rivers are easily erodable, particularly during periods of flooding. The area of the Park most susceptible to flood-induced erosion is Virginius Island and the channels along the Shenandoah River. Virginius Island as a whole is relatively stable and able to withstand even large floods; large-scale channel scour has not occurred in the area in the past 50-100 years. Small-scale sedimentation changes are ongoing and localized erosion and deposition takes place during every flooding event (Fuertsch 1992).

IV. Natural Resource Highlights

The Park has a number of scenic vistas, including views from the previously mentioned Jefferson Rock, the cliffs on Maryland and Loudon Heights, and both natural and cultural views around the lower Historic Town and along Virginius Island. The Park has invested enormous time and effort to preserve these viewsheds from disruption as adjacent lands continue to be developed. In addition, the Park is part of a culturally and naturally significant landscape. The conjunction of HAFE, the CHOH, and the ANST has created a rural historic district that some consider to be worthy of listing in the National Register of Historic Places.

HAFE partners with USGS on river issues such as historic dams and flooding. Because of the geological resources present, local universities use the Park as a geology laboratory. In addition, the US Fish and Wildlife Service National Conservation Training

Center uses HAFE as a model in classes it runs on how natural resource management is conducted in national parks.

The biotic surveys completed in the Park are all baseline surveys that have only been able to identify a certain percentage of all taxa living in the Park. The inventories are not able to provide information on population dynamics. State-listed rare or threatened species found in the Park include the wood turtle, the West Virginia White (butterfly), a variety of odonate species, and the Peregrine Falcon. Several of these inventories identified species, including rare or threatened species, that were not found at the time of the survey, but deemed likely to inhabit the Park (see Appendices D, F, H, and I). In recent years, the Park has participated in an innovative Peregrine Falcon reintroduction and tracking program with William and Mary, US Fish and Wildlife Service, Maryland Department of Resources, and Dominion Power. Thus far, 29 birds have been released, and Park staff hope that falcons released at HAFE will imprint on the Maryland Heights cliffs and return as breeding adults.

V. Conclusions and Recommendations

In general, the natural resources at HAFE are in fair to good condition, especially considering the resources designated towards their maintenance. The Park is charged with protecting cultural and natural resources found within the Park to commemorate the historic events that transpired in Harpers Ferry and provide a venue for preserving relics of archaeological and historical significance. Consequently, a large portion of the Park's resources are devoted to maintaining its cultural and historical resources. For example, out of approximately 100 Park staff, 50 of whom are devoted to Park maintenance, only two full-time equivalent positions are devoted to managing the Park's natural resources. The natural resource staff is also involved with Park's land management program and faces continually increasing responsibilities. The development of required documentation alone, such as for updating land and resources management plans, environmental assessments for new projects, and overseeing research efforts in the Park, constitutes a significant staff burden.

The most significant threat to the Park's natural resources is development of adjacent and nearby lands. The area around Harpers Ferry is rapidly developing and encroaching incompatible land uses pose the greatest threat to the Park both at the present time and in the future. The Park's main strategy for ameliorating the effects of adjacent land development, land acquisition and conservation easements, consumes a large portion of the time and funding set aside for the natural resource program.   Park management spends a considerable amount of effort working with adjacent stakeholders to develop compatible land uses, but pressure from developers and other competing interests represent ongoing threats.

The 2000 NRMP identified a number of high-priority natural resource issues and concerns (see Table 6). These management needs have provided the basis for research and project planning since the NRMP was implemented. Many of these needs are related to the development or enhancement of baseline information on the Park's biotic (i.e., rare and threatened species, information on community health, threats from invasive species) and abiotic (i.e., inventory and monitoring of water, soil, and geologic resources) resources. In addition, staff is working to create digital repositories of natural resource information. This effort includes the scanning and storage of older document and populating GIS databases with Park characteristics.

The NPS CUE is conducting ongoing research and monitoring efforts at HAFE and a number of other NCRN parks. Much of the research involving long-term monitoring, such as air and water quality monitoring, is expected to be conducted by the CUE. CUE researchers are also working on a number of basic resource inventories, including vegetation and karst topography surveys. In addition, University of Maryland researchers are in the process of conducting a wetland areas survey of the Park.

Several geological resource surveys have been conducted at the Park. Natural erosion processes, coupled with HAFE's extreme topographic relief, combine to present a significant geological resource management concern. There is a high risk for slope failure in several portions of the Park. Monitoring of these areas for movement, in addition to steeply sloped areas, particularly in conjunction with rainfall information, is important for tracking slope failure potential. In addition, erosion and culvert management are related that have thus far received little management attention. An inventory of the Parks' culverts, including the impacts of culvert outflows as well as the condition of the culverts themselves, is needed.

Flooding is a major concern at HAFE, because rising waters have high potential for impacting the cultural and geological resources located along the floodplains of the Park. Flooding also saturates the substrate and has implications for increasing the risks for slope failure. The Park lacks basic data on the effects of flooding in the outlying areas of the Park. Tracking such information will aid Park management in assessing and managing the threat of flooding.

The rare plant populations at HAFE are among the Park's most significant natural resources. Several researchers have recommended monitoring of the rare plants, particularly the state-listed species of concern and those colonies threatened by invasive species. Some of the rare plant species represent the only recorded local populations of those plants.   Fleming (1999) recommended that the Short Hill portion of the Park, which contains a number of rare plant species, be given "some kind of special protection such as 'Wildland' or 'Nature Preserve' to ensure that no type of development or restoration occurs at this site."

The Park has very little information on its water resources. While the Potomac and Shenandoah Rivers lie outside the Park boundaries, information on these waterbodies (i.e., general characteristics, water quality data, flow, water height and flood records) is available from outside sources such as the USGS and the WVDEP. The smaller streams, seeps, culverts, ditches, and still waterbodies and wetlands within the Park, however, have received very little documentation. Detailed inventories of the Park's aquatic resources, both natural and man-made, are needed.

The Park has very little information on its soil resources. The soil surveys for Jefferson, Washington, and Loudon counties constitute the majority of the Park's soil data and the

Jefferson and Loudon soil surveys are decades out of date. In addition, these surveys are not specific to HAFE. Detailed surveys of Park-specific soil resources are needed.

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Appendix A: Vascular plants at HAFE

List taken from HAFE species database (NPS 2007k).

Latin	Common	Status	Nativity
Chaerophyllum procumbens	spreading chervil	Probably	Native
Cryptotaenia canadensis	Canadian honewort, honewort	Present	Native
Daucus carota	bird's nest, Queen Anne's lace, wild carrot	Probably	Non-Native
Daucus carota	bird's nest, Queen Anne's lace, wild carrot	Probably	Non-Native
Osmorhiza longistylis	aniseroot, longstyle sweetroot	Present	Native
Pastinaca sativa	wild parship, wild parsnip	Probably	Non-Native
Torilis japonica	erect hedgeparsley	Probably	Non-Native
Aralia nudicaulis	wild sarsaparilla	Present	Native
Hedera helix	English ivy	Present	Non-Native
Asarum canadense	Canadian wild ginger, Canadian wildginger	Present	Native
Achillea millefolium	bloodwort, carpenter's weed, common yarrow	Probably	Non-Native
Ambrosia artemisiifolia	annual ragweed, common ragweed, low ragweed	Present	Native
Antennaria plantaginifolia	plantainleaf pussytoes, woman's tobacco	Present	Native
Anthemis arvensis	corn chamomile, mayweed, scentless chamomile	Probably	Non-Native
Arctium minus	bardane, beggar's button, burdock	Probably	Non-Native
Arctium minus	bardane, beggar's button, burdock	Probably	Non-Native
Artemisia annua	annual wormwood, sweet sagewort	Present	Non-Native
Artemisia annua	annual wormwood, sweet sagewort	Present	Non-Native
Aster divaricatus		Present	Native
Aster pilosus	white heath aster, white oldfield aster	Probably	Native
Aster simplex		Probably	Native
Bidens polylepis		Probably	Native
Bidens vulgata	big devils beggartick, tall beggarticks, western sticktight	Probably	Native
Carduus acanthoides	plumeless thistle, spiny plumeless thistle	Probably	Native
Carduus crispus	curled thistle, curly plumeless thistle	Probably	Non-Native
Centaurea cyanus	bachelor's button, cornflower, garden cornflower	Probably	Non-Native
Chrysanthemum leucanthemum	ox-eye daisy, oxeye daisy	Probably	Non-Native
Cirsium vulgare	bull thistle, common thistle, spear thistle	Probably	Non-Native
Erigeron annuus	annual fleabane, eastern daisy fleabane	Present	Native
Erigeron philadelphicus	Philadelphia daisy, Philadelphia fleabane	Present	Native
Galinsoga parviflora	gallant soldier, gallant-soldier, gallantsoldier	Probably	Non-Native
Heterotheca mariana		Probably	Native
Polymnia canadensis	rayless leafcup, whiteflower leafcup	Present	Native

Polymnia uvedalia		Present	Native
Solidago caesia	wreath goldenrod	Present	Native
Solidago canadensis	Canadian goldenrod, common goldenrod	Probably	Native
Solidago erecta		Probably	Native
Solidago nemoralis	dyersweed goldenrod, gray goldenrod	Present	Native
Solidago ulmifolia	elmleaf goldenrod	Present	Native
Taraxacum officinale	blowball, common dandelion, dandelion, faceclock	Present	Non-Native
Verbesina alternifolia	wingstem	Present	Native
Xanthium strumarium	cocklebur, cockleburr, common cocklebur	Present	Non-Native
Lobelia inflata	Indian tobacco, Indian-tobacco	Probably	Native
Lobelia siphilitica	great blue lobelia	Probably	Native
Triodanis perfoliata	clasping bellwort, clasping Venus' looking-glass	Present	Native
Arabis laevigata	smooth rock-cress, smooth rockcress	Present	Native
Barbarea vulgaris	garden yellow rocket, garden yellow-rocket	Probably	Non-Native
Brassica rapa	birdsrape mustard, field mustard, rape, wild mustard	Probably	Non-Native
Capsella bursa-pastoris	shepardspurse, shepherd's purse, shepherd's-purse	Probably	Non-Native
Cardamine arenicola		Probably	Native
Cardamine parviflora	sand bittercress, smallflowered bittercress	Probably	Native
Dentaria heterophylla		Probably	Native
Erucastrum gallicum	common dog-mustard, common dogmustard	Present	Native
Hesperis matronalis	dame rocket, dame's rocket, dames rocket	Present	Native
Lunaria annua	annual honesty	Probably	Non-Native
Thlaspi perfoliatum	claspleaf pennycress	Probably	Non-Native
Amaranthus spinosus	pigweed species, spiny amaranth, spiny amaranthus	Probably	Non-Native
Amaranthus spinosus	pigweed species, spiny amaranth, spiny amaranthus	Probably	Non-Native
Cerastium nutans	common chickweed, longstem chickweed	Present	Native
Dianthus armeria	Deptford pink, Deptford's pink	Present	Non-Native
Dianthus barbatus	sweetwilliam	Probably	Non-Native
Saponaria officinalis	bouncing bet, bouncing-bett, bouncingbet	Present	Non-Native
Silene dichotoma	dichotoma silene, forked catchfly	Probably	Non-Native
Silene noctiflora	night-flowering catchfly, nightflowering silene	Probably	Non-Native
Stellaria pubera	star chickweed	Present	Native
Chenopodium album	common lambsquarters, lambsquarters	Probably	Non-Native
Phytolacca americana	American pokeweed, common pokeweed	Present	Native
Commelina communis	Asiatic dayflower, common dayflower	Probably	Non-Native
Tradescantia virginiana	Virginia spiderwort	Present	Native
Nyssa sylvatica	black gum, black tupelo, blackgum	Present	Native
Cyperus erythrorhizos	red-root flat sedge, redroot flatsedge, redroot nutgrass	Present	Native

Agrostis tenuis		Present	Native
Hystrix patula		Present	Native
Setaria glauca	pigeongrass, wild millet, yellow bristlegrass, yellow foxtail	Present	Non-Native
Lonicera japonica	Chinese honeysuckle, Japanese honeysuckle	Present	Non-Native
Lonicera tatarica	bush honeysuckle, Tartarian honeysuckle	Probably	Non-Native
Lonicera tatarica	bush honeysuckle, Tartarian honeysuckle	Probably	Non-Native
Sambucus canadensis	american elder	Present	Native
Viburnum acerifolium	mapleleaf viburnum	Present	Native
Viburnum prunifolium	blackhaw	Present	Native
Dipsacus sylvestris	common teasel, Fuller's teasel	Probably	Non-Native
Equisetum hyemale	horsetail, scouring horsetail, scouringrush	Present	Native
Euphorbia maculata		Present	Native
Euphorbia preslii		Present	Native
Phyllanthus caroliniensis	Carolina leaf-flower, Carolina leaflower	Probably	Native
Coronilla varia	crownvetch, purple crown-vetch	Probably	Non-Native
Medicago lupulina	black medic, black medic clover	Probably	Native
Medicago sativa	alfalfa	Probably	Non-Native
Melilotus alba	white sweetclover	Present	Non-Native
Melilotus officinalis	yellow sweet-clover, yellow sweetclover	Present	Non-Native
Trifolium pratense	red clover	Present	Non-Native
Trifolium repens	Dutch clover, ladino clover, white clover	Present	Non-Native
Vicia angustifolia	garden vetch	Probably	Non-Native
Vicia tetrasperma	lentil vetch, sparrow vetch	Probably	Native
Betula lenta	sweet birch	Present	Native
Quercus macrocarpa	bur oak	Present	Native
Quercus marilandica	blackjack oak	Probably	Native
Quercus muehlenbergii	chinkapin oak	Present	Native
Quercus prinus	chestnut oak	Present	Native
Quercus rubra	northern red oak	Present	Native
Vinca minor	common periwinkle, lesser periwinkle, myrtle	Present	Non-Native
Asclepias purpurascens	purple milkweed	Probably	Native
Matelea carolinensis	maroon Carolina milkvine	Probably	Native
Impatiens capensis	jewelweed, spotted touch-me-not	Present	Native
Impatiens pallida	pale snapweed, pale touch-me-not	Present	Native
Erodium cicutarium	alfilaree, alfilaria, cutleaf filaree	Present	Native
Geranium maculatum	spotted crane's-bill, spotted geranium, wild crane's-bill	Present	Native
Hamamelis virginiana	American witchhazel, witch-hazel, witchhazel	Present	Native
Carya glabra	pignut hickory	Present	Native
Lithospermum arvense	corn gromwell, puccoon	Probably	Non-Native
Mertensia virginica	Virginia bluebells	Present	Native
Glechoma hederacea	creeping charlie, gill-over-the-ground, ground ivy	Present	Non-Native
Lamium amplexicaule	common henbit, giraffehead, henbit, henbit deadnettle	Probably	Non-Native

Lamium purpureum	purple deadnettle, red deadnettle	Probably	Non-Native
Mentha X verticillata var. peduncularis		Probably	Non-Native
Nepeta cataria	catmint, catnip, catwort, field balm	Present	Non-Native
Perilla frutescens	beefsteak, beefsteak mint, beefsteakplant, Purple mint	Probably	Non-Native
Perilla frutescens	beefsteak, beefsteak mint, beefsteakplant, Purple mint	Probably	Non-Native
Salvia lyrata	lyreleaf sage	Probably	Native
Lindera benzoin	northern spicebush, spicebush	Present	Native
Sassafras albidum	sassafras	Present	Native
Dioscorea quaternata	fourleaf yam	Present	Native
Dioscorea villosa	wild yam	Probably	Native
Allium tricoccum	ramp, small white leek, wild leek	Present	Native
Allium vineale	wild garlic	Present	Native
Asparagus officinalis	asparagus, garden asparagus, garden-asparagus	Probably	Non-Native
Muscari botryoides	common grape hyacinth	Present	Non-Native
Polygonatum biflorum	king Solomon's seal, King Solomon's-seal	Present	Native
Smilacina racemosa		Present	Native
Smilax glauca	cat greenbrier	Present	Native
Asimina triloba	pawpaw	Present	Native
Althaea rosea		Probably	Non-Native
Malva neglecta	buttonweed, cheeseplant, common mallow, dwarf mallow,	Probably	Non-Native
Sida spinosa	prickly fanpetals, prickly sida	Probably	Non-Native
Lythrum salicaria	purple loosestrife	Probably	Non-Native
Corallorrhiza maculata	spotted coralroot, summer coralroot	Present	Native
Corydalis flavula	pale corydalis, yellow fumewort	Present	Native
Dicentra canadensis	squirrel corn	Probably	Native
Dicentra cucullaria	Dutchman's-breeches	Probably	Native
Chelidonium majus	celandine	Present	Non-Native
Juniperus virginiana	eastern red-cedar, eastern redcedar, red cedar juniper	Present	Native
Saururus cernuus	lizard's tail, lizards tail	Present	Native
Plantago lanceolata	buckhorn plantain, English plantain, lanceleaf	Probably	Non-Native
Plantago rugelii	black-seed plantain, blackseed plantain, Rugel's plantain	Present	Native
Polygonum cespitosum	oriental ladysthumb	Present	Non-Native
Polygonum cilinode	fringed black bindweed	Probably	Native
Polygonum convolvulus	black bindweed, climbing buckwheat, climbing knotweed	Probably	Non-Native
Polygonum scandens	climbing false buckwheat, climbing knotweed	Probably	Native
Asplenium platyneuron	ebony spleenwort	Present	Native
Dryopteris marginalis	marginal woodfern, woodfern	Present	Native
Woodsia obtusa	blunt-lobe woodsia, bluntlobe cliff fern	Present	Native
Polypodium virginianum	rock polypody	Present	Native

Pellaea atropurpurea	purple cliffbrake, purple-stem cliff-brake	Present	Native
Lysimachia ciliata	fringed loosestrife, fringed yellow-loosestrife	Present	Native
Lysimachia nummularia	creeping jenny, moneywort	Present	Non-Native
Lysimachia vulgaris	garden loosestrife, garden yellow loosestrife	Probably	Non-Native
Podophyllum peltatum	may apple, mayapple	Present	Native
Menispermum canadense	Canadian moonseed, common moonseed	Present	Native
Aquilegia canadensis	American columbine, Colorado columbine, red columbine	Probably	Native
Clematis virginiana	devil's darning needles, devil's-darning-needles	Probably	Native
Ranunculus abortivus	early woodbuttercup, kidney-leaf buttercup	Probably	Native
Ranunculus recurvatus	blisterwort, littleleaf buttercup	Present	Native
Elaeagnus umbellata	autumn olive, oleaster	Present	Non-Native
Rhamnus frangula	columnar buckthorn, European alder	Probably	Non-Native
Amelanchier arborea	allegheny serviceberry, apple shadbush	Present	Native
Duchesnea indica	India mockstrawberry, Indian strawberry	Present	Non-Native
Duchesnea indica	India mockstrawberry, Indian strawberry	Present	Non-Native
Geum canadense	white avens	Present	Native
Geum canadense	white avens	Present	Native
Geum virginianum	cream avens	Probably	Native
Potentilla canadensis	dwarf cinquefoil	Present	Native
Prunus cerasus	sour cherry	Probably	Non-Native
Prunus persica	peach	Probably	Non-Native
Prunus virginiana	chokecherry, chokecherry	Present	Native
Rosa canina	dog rose	Probably	Non-Native
Rosa multiflora	multiflora rose	Present	Non-Native
Rosa multiflora	multiflora rose	Present	Non-Native
Rubus phoenicolasius	Japanese wineberry, wine raspberry, wineberry	Present	Non-Native
Heuchera americana	alumroot, American alumroot	Present	Native
Heuchera americana var. brevipetala		Probably	Native
Saxifraga virginiensis	early saxifrage	Present	Native
Galium aparine	bedstraw, catchweed bedstraw, cleavers	Present	Native
Galium triflorum	fragrant bedstraw, sweet bedstraw, sweetscented bedstraw	Present	Native
Houstonia longifolia	long-leaf summer bluet, longleaf bluet, longleaf summer bluet	Present	Native
Acer negundo	ashleaf maple, box elder, boxelder, boxelder maple	Present	Native
Rhus glabra	smooth sumac	Probably	Native
Ptelea trifoliata	common hoptree, hoptree	Probably	Native
Ailanthus altissima	ailanthus, copal tree, tree of heaven, tree-of-heaven	Present	Non-Native
Staphylea trifolia	American bladdernut, american bladdernut	Present	Native

Justicia americana	American water-willow, common water-willow, spike justica	Present	Native
Campsis radicans	common trumpetcreeper, cow-itch, trumpet creeper	Probably	Non-Native
Fraxinus pennsylvanica var. subintegerrima		Present	Native
Ligustrum obtusifolium	border privet	Probably	Non-Native
Ligustrum ovalifolium	california privet	Probably	Non-Native
Ligustrum vulgare	European privet, wild privet	Present	Non-Native
Cymbalaria muralis	Kenilworth ivy	Probably	Non-Native
Linaria genistifolia	broomleaf toadflax	Probably	Non-Native
Linaria vulgaris	butter and eggs, butterandeggs, flaxweed	Probably	Non-Native
Linaria vulgaris	butter and eggs, butterandeggs, flaxweed	Probably	Non-Native
Penstemon hirsutus	hairy beardtongue	Probably	Native
Verbascum blattaria	moth mullein, white moth mullein	Probably	Non-Native
Verbascum phoeniceum	purple mullein	Present	Non-Native
Verbascum thapsus	big taper, common mullein, flannel mullein, flannel plant	Present	Non-Native
Veronica persica	bird-eye speedwell, birdeye speedwell, birdseye speedwell	Probably	Non-Native
Ipomoea hederacea	entireleaf morningglory, ivy-leaf mornin-glory	Probably	Non-Native
Ipomoea hederacea	entireleaf morningglory, ivy-leaf mornin-glory	Probably	Non-Native
Ipomoea lacunosa	pitted morningglory, white morninglory, whitestar	Probably	Native
Cuscuta gronovii	scaldweed	Present	Native
Cuscuta pentagona	bush-clover dodder, field dodder, fiveangled dodder	Present	Native
Hydrophyllum canadense	blunt-leaf waterleaf, bluntleaf waterleaf	Present	Native
Hydrophyllum virginianum	Shawnee salad, Shawnee-salad	Present	Native
Phacelia dubia	smallflower phacelia	Probably	Native
Datura stramonium	Jamestown weed, jimsonweed, mad apple, moonflower	Present in Park	Non-Native
Physalis subglabrata	husk tomato, longleaf groundcherry, smooth groundcherry	Probably	Native
Solanum carolinense	apple of Sodom, bull nettle, Carolina horsenettle	Probably	Native
Hypericum perforatum	common St Johnswort, common St. John's wort	Probably	Non-Native
Humulus japonicus	Japanese hop	Present	Non-Native
Morus alba	mulberry, white mulberry	Present	Non-Native
Morus alba	mulberry, white mulberry	Present	Non-Native
Morus rubra	red mulberry	Present	Native
Celtis occidentalis	common hackberry, hackberry, western hackberry	Present	Native
Ulmus americana	american elm	Present	Native
Ulmus rubra	slippery elm	Present	Native

Urtica dioica	California nettle, slender nettle, stinging nettle, tall nettle	Present	Non-Native
Sicyos angulatus	blueeyedgrass, bur cucumber, burcucumber	Present	Native

Appendix B: Exotic Plants at HAFE

List taken from HAFE species database (NPS 2007k).

Harpers Ferry Vascular Plants November 2002
EXOTCS
Wetland (O, FW) and Upland (F, U)

Park	Family	Scientific Name	Habit	Exotic/ Natualized	0=Valid Name
HAFE	Euphorbiaceae	Chamaesyce nutans	F	E	0
HAFE	Molluginaceae	Mollugo verticillata	F	E/N	0
HAFE	Primulaceae	Lysimachia vulgaris	F	E	0
HAFE	Taxaceae	Taxus cuspidata	F	E	0
HAFE	Ulmaceae	Ulmus pumila	F	E	0
HAFE	Caprifoliaceae	Lonicera japonica	F-	E	0
HAFE	Araliaceae	Hedera helix	FU	E	0
HAFE	Asteraceae	Tragopogon porrifolius	FU	E	0
HAFE	Asteraceae	Tragopogon pratensis	FU	E	0
HAFE	Brassicaceae	Alliaria petiolata	FU	E	0
HAFE	Brassicaceae	Barbarea verna	FU	E	0
HAFE	Brassicaceae	Barbarea vulgaris	FU	E	0
HAFE	Brassicaceae	Hesperis matronalis	FU	E	0
HAFE	Caprifoliaceae	Lonicera tatarica	FU	E	0
HAFE	Commelinaceae	Commelina communis	FU	E	0
HAFE	Fabaceae	Wisteria sinensis	FU	E	0
HAFE	Lamiaceae	Glechoma hederacea	FU	E	0
HAFE	Liliaceae	Asparagus officinalis	FU	E	0
HAFE	Malvaceae	Hibiscus syriacus	FU	E	0
HAFE	Moraceae	Morus alba	FU	E	0
HAFE	Polygonaceae	Rumex obtusifolius	FU	E/N	0
HAFE	Rosaceae	Duchesnea indica	FU	E	0
HAFE	Scrophulariaceae	Linaria vulgaris	FU	E	0
HAFE	Scrophulariaceae	Penstemon laevigatus	FU	E/N	0
HAFE	Scrophulariaceae	Veronicastrum virginicum	FU	E	0
HAFE	Solanaceae	Solanum dulcamara	FU	E/N	0
HAFE	Solanaceae	Solanum dulcamara var. dulcamara	FU	E/N	0
HAFE	Urticaceae	Urtica dioica	FU	E/N	0
HAFE	Urticaceae	Urtica dioica ssp. gracilis	FU	E/N	0
HAFE	Urticaceae	Urtica urens	FU	E	0
HAFE	**Asteraceae**	**Hasteola suaveolens**	**FW**	**E**	**0**
HAFE	**Dipsacaceae**	**Dipsacus fullonum**	**FW**	**E**	**0**
HAFE	**Dipsacaceae**	**Dipsacus fullonum ssp. sylvestris**	**FW**	**E**	**0**
HAFE	**Dipsacaceae**	**Dipsacus sylvestris**	**FW**	**E**	**0**
HAFE	**Lamiaceae**	**Mentha aquatica**	**FW**	**E**	**0**
HAFE	**Lamiaceae**	**Mentha X verticillata**	**FW**	**E**	**0**
HAFE	**Lamiaceae**	**Mentha X verticillata var. peduncularis**	**FW**	**E**	**0**
HAFE	**Onagraceae**	**Circaea quadrisulcata**	**FW**	**E**	**0**
HAFE	**Onagraceae**	**Circaea quadrisulcata var. canadensis**	**FW**	**E**	**0**
HAFE	**Papaveraceae**	**Chelidonium majus**	**FW**	**E**	**0**
HAFE	**Papaveraceae**	**Chelidonium majus var. majus**	**FW**	**E**	**0**
HAFE	**Polygonaceae**	**Polygonum caespitosum**	**FW**	**E/N**	**0**
HAFE	**Primulaceae**	**Lysimachia nummularia**	**FW**	**E/N**	**0**
HAFE	**Tamaricaceae**	**Tamarix chinensis**	**FW**	**E**	**0**
HAFE	**Lamiaceae**	**Mentha X piperita**	**FW+**	**E**	**0**
HAFE	**Lythraceae**	**Lythrum salicaria**	**FW+**	**E**	**0**
HAFE	**Brassicaceae**	**Rorippa nasturtium-aquaticum**	**O**	**E/N**	**0**
HAFE	**Scrophulariaceae**	**Veronica anagallis-aquatica**	**O**	**E**	**0**

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EXOTCS
Wetland (O, FW) and Upland (F, U)

Park	Family	Scientific Name	Habit	Exotic/ Natualized	0=Valid Name
HAFE	Aceraceae	Acer palmatum var. atropurpurea	U	E	0
HAFE	Aceraceae	Acer platanoides	U	E	0
HAFE	Aceraceae	Acer pseudoplatanus	U	E	0
HAFE	Apiaceae	Daucus carota	U	E	0
HAFE	Apiaceae	Torilis arvensis	U	E	0
HAFE	Apiaceae	Torilis japonica	U	E	0
HAFE	Apocynaceae	Vinca major	U	E	0
HAFE	Apocynaceae	Vinca minor	U	E	0
HAFE	Asteraceae	Anthemis arvensis	U	E/N	0
HAFE	Asteraceae	Arctium minus	U	E/N	0
HAFE	Asteraceae	Artemisia annua	U	E/N	0
HAFE	Asteraceae	Carduus acanthoides	U	E	0
HAFE	Asteraceae	Carduus crispus	U	E	0
HAFE	Asteraceae	Centaurea biebersteinii	U	E	0
HAFE	Asteraceae	Centaurea cyanus	U	E	0
HAFE	Asteraceae	Centaurea scabiosa	U	E	0
HAFE	Asteraceae	Chondrilla juncea	U	E	0
HAFE	Asteraceae	Cichorium intybus	U	E	0
HAFE	Asteraceae	Cirsium vulgare	U	E	0
HAFE	Asteraceae	Galinsoga quadriradiata	U	E/N	0
HAFE	Asteraceae	Lactuca serriola	U	E/N	0
HAFE	Asteraceae	Leucanthemum vulgare	U	E/N	0
HAFE	Asteraceae	Taraxacum officinale	U	E	0
HAFE	Asteraceae	Taraxacum officinale ssp. officinale	U	E	0
HAFE	Asteraceae	Tussilago farfara	U	E	0
HAFE	Berberidaceae	Berberis thunbergii	U	E	0
HAFE	Boraginaceae	Buglossoides arvensis	U	E	0
HAFE	Boraginaceae	Echium vulgare	U	E	0
HAFE	Brassicaceae	Brassica napus	U	E	0
HAFE	Brassicaceae	Brassica nigra	U	E	0
HAFE	Brassicaceae	Brassica rapa	U	E	0
HAFE	Brassicaceae	Capsella bursa-pastoris	U	E	0
HAFE	Brassicaceae	Erucastrum gallicum	U	E	0
HAFE	Brassicaceae	Lepidium campestre	U	E	0
HAFE	Brassicaceae	Lunaria annua	U	E	0
HAFE	Campanulaceae	Campanula rapunculoides	U	E	0
HAFE	Cannabaceae	Humulus japonicus	U	E	0
HAFE	Caryophyllaceae	Agrostemma githago	U	E	0
HAFE	Caryophyllaceae	Dianthus armeria	U	E	0
HAFE	Caryophyllaceae	Dianthus barbatus	U	E	0
HAFE	Caryophyllaceae	Dianthus plumarius	U	E	0
HAFE	Caryophyllaceae	Saponaria officinalis	U	E/N	0
HAFE	Caryophyllaceae	Silene dichotoma	U	E	0
HAFE	Caryophyllaceae	Silene latifolia	U	E	0
HAFE	Caryophyllaceae	Silene latifolia ssp. alba	U	E	0
HAFE	Caryophyllaceae	Silene noctiflora	U	E	0
HAFE	Caryophyllaceae	Silene vulgaris	U	E	0

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EXOTCS
Wetland (O, FW) and Upland (F, U)

Park	Family	Scientific Name	Habit	Exotic/ Natualized	0=Valid Name
HAFE	Caryophyllaceae	Stellaria media	U	E/N	0
HAFE	Celastraceae	Celastrus scandens	U	E	0
HAFE	Chenopodiaceae	Chenopodium album	U	E	0
HAFE	Chenopodiaceae	Chenopodium ambrosioides	U	E/N	0
HAFE	Chenopodiaceae	Chenopodium ambrosioides var. ambrosioides	U	E/N	0
HAFE	Chenopodiaceae	Chenopodium botrys	U	E	0
HAFE	Clusiaceae	Hypericum perforatum	U	E	0
HAFE	Convolvulaceae	Convolvulus arvensis	U	E	0
HAFE	Convolvulaceae	Ipomoea purpurea	U	E/N	0
HAFE	Crassulaceae	Sedum acre	U	E	0
HAFE	Cupressaceae	Chamaecyparis pisifera	U	E	0
HAFE	Cupressaceae	Juniperus chinensis	U	E	0
HAFE	Cupressaceae	Juniperus chinensis var. pfitzeriana	U	E	0
HAFE	Elaeagnaceae	Elaeagnus umbellata	U	E	0
HAFE	Elaeagnaceae	Elaeagnus umbellata var. parvifolia	U	E	0
HAFE	Euphorbiaceae	Euphorbia cyparissias	U	E	0
HAFE	Fabaceae	Albizia julibrissin	U	E	0
HAFE	Fabaceae	Coronilla varia	U	E	0
HAFE	Fabaceae	Medicago lupulina	U	E	0
HAFE	Fabaceae	Medicago sativa	U	E	0
HAFE	Fabaceae	Melilotus alba	U	E	0
HAFE	Fabaceae	Melilotus officinalis	U	E	0
HAFE	Fabaceae	Pueraria montana	U	E	0
HAFE	Fabaceae	Pueraria montana var. lobata	U	E	0
HAFE	Fabaceae	Robinia pseudoacacia	U	E	0
HAFE	Fabaceae	Trifolium arvense	U	E	0
HAFE	Fabaceae	Trifolium aureum	U	E	0
HAFE	Fabaceae	Trifolium campestre	U	E	0
HAFE	Fabaceae	Trifolium hybridum	U	E	0
HAFE	Fabaceae	Trifolium pratense	U	E	0
HAFE	Fabaceae	Trifolium repens	U	E	0
HAFE	Fabaceae	Vicia angustifolia	U	E	0
HAFE	Fabaceae	Vicia sativa	U	E	0
HAFE	Fabaceae	Vicia sativa ssp. nigra	U	E	0
HAFE	Fabaceae	Vicia tetrasperma	U	E	0
HAFE	Fagaceae	Castanea sativa	U	E	0
HAFE	Fagaceae	Fagus sylvatica	U	E	0
HAFE	Geraniaceae	Erodium cicutarium	U	E/N	0
HAFE	Geraniaceae	Erodium cicutarium ssp. cicutarium	U	E/N	0
HAFE	Geraniaceae	Geranium molle	U	E/N	0
HAFE	Ginkgoaceae	Ginkgo biloba	U	E	0
HAFE	Hippocastanaceae	Aesculus hippocastanum	U	E	0
HAFE	Hydrangeaceae	Philadelphus coronarius	U	E	0
HAFE	Juglandaceae	Juglans regia	U	E	0
HAFE	Lamiaceae	Lamium amplexicaule	U	E	0
HAFE	Lamiaceae	Lamium purpureum	U	E	0
HAFE	Lamiaceae	Leonurus cardiaca	U	E	0
HAFE	Lamiaceae	Leonurus cardiaca ssp. cardiaca	U	E	0
HAFE	Lamiaceae	Nepeta cataria	U	E/N	0

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Wetland (O, FW) and Upland (F, U)

Park	Family	Scientific Name	Habit	Exotic/ Natualized	0=Valid Name
HAFE	Lamiaceae	Perilla frutescens	U	E	0
HAFE	Liliaceae	Allium vineale	U	E	0
HAFE	Liliaceae	Allium vineale ssp. vineale	U	E	0
HAFE	Liliaceae	Hemerocallis fulva	U	E	0
HAFE	Liliaceae	Lilium lancifolium	U	E	0
HAFE	Liliaceae	Muscari botryoides	U	E	0
HAFE	Liliaceae	Ornithogalum umbellatum	U	E	0
HAFE	Lythraceae	Lagerstroemia indica	U	E	0
HAFE	Malvaceae	Abutilon theophrasti	U	E	0
HAFE	Malvaceae	Alcea rosea	U	E	0
HAFE	Malvaceae	Hibiscus trionum	U	E	0
HAFE	Malvaceae	Malva neglecta	U	E	0
HAFE	Malvaceae	Malva sylvestris	U	E	0
HAFE	Moraceae	Broussonetia papyrifera	U	E	0
HAFE	Moraceae	Maclura pomifera	U	E	0
HAFE	Oleaceae	Ligustrum obtusifolium	U	E	0
HAFE	Oleaceae	Ligustrum ovalifolium	U	E	0
HAFE	Oleaceae	Ligustrum vulgare	U	E	0
HAFE	Oleaceae	Syringa vulgaris	U	E	0
HAFE	Pinaceae	Picea abies	U	E	0
HAFE	Pinaceae	Picea pungens	U	E	0
HAFE	Poaceae	Agrostis capillaris	U	E	0
HAFE	Poaceae	Cynodon dactylon	U	E	0
HAFE	Poaceae	Setaria glauca	U	E/N	0
HAFE	Polygonaceae	Polygonum convolvulus	U	E	0
HAFE	Polygonaceae	Polygonum persicaria	U	E/N	0
HAFE	Polygonaceae	Rumex acetosella	U	E/N	0
HAFE	Polygonaceae	Rumex crispus	U	E/N	0
HAFE	Ranunculaceae	Ranunculus acris	U	E/N	0
HAFE	Ranunculaceae	Ranunculus acris var. acris	U	E/N	0
HAFE	Rosaceae	Agrimonia eupatoria	U	E	0
HAFE	Rosaceae	Malus baccata	U	E	0
HAFE	Rosaceae	Malus pumila	U	E	0
HAFE	Rosaceae	Malus sylvestris	U	E	0
HAFE	Rosaceae	Potentilla recta	U	E	0
HAFE	Rosaceae	Prunus avium	U	E	0
HAFE	Rosaceae	Prunus cerasifera	U	E	0
HAFE	Rosaceae	Prunus cerasus	U	E	0
HAFE	Rosaceae	Prunus domestica	U	E	0
HAFE	Rosaceae	Prunus persica	U	E	0
HAFE	Rosaceae	Prunus subhirtella	U	E	0
HAFE	Rosaceae	Prunus subhirtella var. pendula	U	E	0
HAFE	Rosaceae	Pyrus communis	U	E	0
HAFE	Rosaceae	Rhodotypos scandens	U	E	0
HAFE	Rosaceae	Rosa canina	U	E	0
HAFE	Rosaceae	Rubus phoenicolasius	U	E	0
HAFE	Rutaceae	Poncirus trifoliata	U	E	0
HAFE	Salicaceae	Populus alba	U	E	0
HAFE	Salicaceae	Populus nigra	U	E	0
HAFE	Salicaceae	Populus nigra var. italica	U	E	0

Harpers Ferry Vascular Plants November 2002
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Wetland (O, FW) and Upland (F, U)

Park	Family	Scientific Name	Habit	Exotic/ Natualized	0=Valid Name
HAFE	Sapindaceae	Koelreuteria paniculata	U	E	0
HAFE	Scrophulariaceae	Cymbalaria muralis	U	E	0
HAFE	Scrophulariaceae	Linaria genistifolia	U	E	0
HAFE	Scrophulariaceae	Paulownia tomentosa	U	E	0
HAFE	Scrophulariaceae	Verbascum albiflorum	U	E	0
HAFE	Scrophulariaceae	Verbascum blattaria	U	E	0
HAFE	Scrophulariaceae	Verbascum phoeniceum	U	E/N	0
HAFE	Scrophulariaceae	Verbascum thapsus	U	E	0
HAFE	Scrophulariaceae	Veronica arvensis	U	E	0
HAFE	Smilacaceae	Smilax rotundifolia	U	E	0
HAFE	Solanaceae	Datura stramonium	U	E	0
HAFE	Taxodiaceae	Cryptomeria japonica	U	E	0
HAFE	Tiliaceae	Tilia X vulgaris	U	E	0

Appendix C: Graminoid species at HAFE

Species list taken from Engelhardt's 2006 report, "A sedge, grass and rush inventory of seven parks in Maryland."

Agrostis stolonifera
Andropogon gerardii
Andropogon virginicus
Anthoxanthum odoratum
Arrhenatherum elatius
Brachyelytrum erectum
Bromus commutatus
Bromus inermis
Bromus japonicus
Bromus pubescens
Bromus sterilis
Carex aggregata
Carex albicans var. albicans
Carex amphibola
Carex blanda
Carex cephalophora
Carex communis
Carex digitalis
Carex emoryi
Carex festucacea
Carex frankii
Carex granularis
Carex grisea
Carex jamesii
Carex laevivaginata
Carex laxiflora
Carex lurida
Carex muehlenbergii
Carex pensylvanica
Carex platyphylla
Carex rosea
Carex stipata var. stipata
Carex swanii
Carex virescens
Carex vulpinoidea
Carex willdenowii
Cyperus squarrosus
Cyperus strigosus
Dactylis glomerata
Danthonia spicata
Dichanthelium boscii
Dichanthelium clandestinum
Dichanthelium depauperatum
Dichanthelium dichotomum
Dichanthelium laxiflorum
Dichanthelium villosissimum
Echinochloa crus-galli
Eleocharis erythropoda
Elymus hystrix
Elymus repens
Elymus villosus
Elymus virginicus
Eragrostis capillaris
Eragrostis frankii
Festuca rubra
Festuca subverticillata
Juncus acuminatus
Juncus effusus
Juncus tenuis
Juncus torreyi
Leersia oryzoides
Leersia virginica
Lolium arundinaceum
Lolium perenne
Luzula multiflora
Microstegium vimineum
Muhlenbergia schreberi
Muhlenbergia tenuiflora
Panicum dichotomiflorum
Panicum rigidulum
Phleum pratense
Poa annua
Poa compressa
Poa pratensis
Poa sylvestris
Poa trivialis
Schoenoplectus americanus
Schoenoplectus pungens
Scirpus georgianus
Secale cereale
Setaria faberi
Setaria parviflora
Sorghastrum nutans
Sphenopholis intermedia
Sphenopholis obtusata
Tridens flavus
Triticum aestivum
Vulpia octoflora

Appendix D: Dragonflies and damselflies at HAFE

This list contains the data points (# of individuals) found within HAFE by specific location in Orr's 2005 report, "Dragonflies and damselflies, significant non-target insects likely to be affected by West Nile Virus management in the National Capital Parks." The "Other Sites" column contains the data points found outside of the four locations specifically targeted during the survey but within the boundaries of HAFE.

COMMON NAME	STATE RANK	JACKSON'S RIGHT FLANK (Jefferson Co. WV) # DATA POINTS	SHORT HILL (Loudoun Co. VA) # DATA POINTS	MARYLAND HEIGHTS (Washington Co, MD) # DATA POINTS	SHENANDOAH RIVER (Jefferson Co. WV) # DATA POINTS	OTHER SITES (Various Locations) # DATA POINTS	TOTAL SPECIES # DATA POINTS
DARNERS							
Spatterdock Darner	S1(MD),	0	0	1	0	0	**1**
Shadow Darner		0	0	2	3	0	**5**
Common Green		7	0	0	6	4	**17**
Springtime Darner		0	0	0	0	2	**2**
Swamp Darner		0	4	1	0	0	**5**
CLUBTAILS							
Black-shouldered		0	12	0	71	44	**127**
Eastern Ringtail	S2(MD)	0	2	0	1	1	**4**
Spine-crowned	SH(MD),	0	0	0	0	1	**1**
Lancet Clubtail		6	0	0	0	0	**6**
Midland Clubtail	S2(MD),	0	0	0	0	1	**1**
Ashy Clubtail		115	0	0	0	0	**115**
Cobra Clubtail	S3(MD)	0	10	0	0	3	**13**
Dragonhunter		0	2	0	1	0	**3**
Arrow Clubtail		0	8	1	30	22	**61**
CRUISERS							
Stream Cruiser		1	0	0	0	0	**1**
Swift River Cruiser		0	5	0	4	4	**13**
Royal River Cruiser	S3(MD)	0	0	0	1	0	**1**
EMERALDS							
Common Baskettail		23	1	0	33	0	**57**
Prince Baskettail		0	8	0	26	1	**35**
Umber	S3(MD),	0	17	0	0	4	**21**
SKIMMERS							
Calico Pennant		232	0	0	0	0	**232**
Halloween Pennant		0	0	0	9	0	**9**
Common Pondhawk		87	0	0	352	612	**1051**
Bar-winged Skimmer	S3(MD)	0	0	1	0	0	**1**
Slaty Skimmer		0	0	0	2	8	**10**
Widow Skimmer		18	0	2	37	0	**57**
Common Whitetail		145	7	15	86	51	**304**
Twelve-spotted		11	0	0	5	0	**16**
Great Blue Skimmer		0	3	0	0	2	**5**
Blue Dasher		42	0	3	400	1	**446**
Wandering Glider		2	0	0	1	0	**3**
Spot-winged Glider		3	0	0	5	12	**20**
Eastern Amberwing		0	0	0	46	0	**46**
Cherry-faced	S2(MD)	3	0	0	0	0	**3**
Black Saddlebags		0	0	0	24	1	**25**
JEWELWINGS							
Ebony Jewelwing		2242	4	0	8	73	**2327**
American Rubyspot		0	8	0	13768	43	**13819**
SPREADWINGS							
Southern Spreadwing		0	0	1	0	0	**1**
Slender Spreadwing		3	0	0	1	0	**4**
POND DAMSELS							
Blue-fronted Dancer		4	104	0	783	4050	**4941**
Violet Dancer		89	0	0	1	0	**90**
Powdered Dancer		0	2100	22	7292	8499	**17913**
Blue-ringed Dancer	S3(MD)	0	0	0	3106	0	**3106**
Blue-tipped Dancer		3	0	0	1	0	**4**

COMMON NAME	STATE RANK	JACKSON'S RIGHT FLANK (Jefferson Co. WV) # DATA POINTS	SHORT HILL (Loudoun Co. VA) # DATA POINTS	MARYLAND HEIGHTS (Washington Co, MD) # DATA POINTS	SHENANDOAH RIVER (Jefferson Co. WV) # DATA POINTS	OTHER SITES (Various Locations) # DATA POINTS	TOTAL SPECIES # DATA POINTS
Dusky Dancer		0	32	0	195	108	**335**
Double-striped Bluet		1	0	0	0	0	**1**
Familiar Bluet		8	0	0	534	42	**584**
Stream Bluet		0	10	0	4476	602	**5088**
Skimming Bluet		0	0	0	12	0	**12**
Fragile Forktail		133	0	5	436	0	**574**
Eastern Forktail		4	0	0	43	1	**48**
TOTAL BY		**3182**	**2337**	**54**	**31799**	**14192**	**51564**

Appendix E: Environmentally-sensitive aquatic invertebrate taxa in springbrooks at HAFE

This list contains the taxa from the environmentally- sensitive orders, Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) found in stream sites from Lamp's 2004 report, "Aquatic insects of Harpers Ferry National Historical Park: Assessing environmental associations and ecological vulnerability." Specimens that were too small to identify or missing key parks are marked by, "---".

Site	Order	Family	Genus	Number
DAM	Plecoptera	---	---	4
	Trichoptera	Rhyacophilidae	*Rhyacophila*	4
ELK	Ephemeroptera	Ameletidae	*Ameletus*	1
		Baetidae	*Baetis complex*	3
		Ephemerellidae	*Ephemerella*	43
		Heptageniidae	*Stenonema*	18
			Cinygmula	2
			Stenacron	2
	Plecoptera	Nemouridae	*Amphinemura*	98
	Trichoptera	Hydropsychidae	*Hydropsyche*	8
			Cheumatopsyche	18
			Macrostemum	2
		Limnephilidae	*Pycnopsyche*	1
		Philopotamidae	*Chimarra*	6
			Dolophilodes	1
		Rhyacophilidae	*Rhyacophila*	1
JRF	Ephemeroptera	Baetidae	*Centroptilum*	10
	Trichoptera	Leptoceridae	*Mystacides*	2
		Limnephilidae	*Pycnopsyche*	4
MHP	Ephemeroptera	Ameletidae	*Ameletus*	15
		Ephemerellidae	---	1
		Leptophlebiidae	*Paraleptophlebia*	1
	Plecoptera	Nemouridae	*Amphinemura*	6
			Ostrocera	14
	Trichoptera	Limnophilidae	*Limnephilus*	1
		Rhyacophilidae	*Rhyacophila*	28
PNR	Ephemeroptera	Ameletidae	*Ameletus*	2
		Baetidae	*Baetis complex*	3
		Caenidae	*Caenis*	3
		Ephemerellidae	*Ephemerella*	1
			Eurylophella	1
		Heptageniidae	*Stenonema*	13
		Isonychiidae	*Isonychia*	3
		Leptophlebiidae	---	1
	Plecoptera	Capniidae	*Allocapnia*	120
		Nemouridae	*Amphinemura*	6
			Prostoia	5
		Perlidae	*Acroneuria*	11
			Perlesta	1
		Taeniopterygidae	*Strophopteryx*	8
			Taeniopteryx	4
	Trichoptera	Hydropsychidae	*Cheumatopsyche*	23

		Philopotamidae	*Chimarra*	1
			Dolophilodes	4
		Rhyacophilidae	*Rhyacophila*	1
		Uenoidae	*Neophylax*	1
SHD	Plecoptera	Nemouridae	*Amphinemura*	36
	Trichoptera	Limnephilidae	*Ironoquia*	1
		Rhyacophilidae	*Rhyacophila*	4
SHH	Ephemeroptera	Ephemerellidae	*Eurylophella*	1
		Heptageniidae	*Stenonema*	5
		Leptophlebiidae	*Paraleptophlebia*	24
	Plecoptera	Capniidae	---	5
		Leuctridae	*Zealeuctra*	7
		Nemouridae	*Amphinemura*	33
			Nemoura	1
	Trichoptera	Hydropsychidae	*Cheumatopsyche*	2
			Diplectrona	2
			Hydropsyche	8
		Leptoceridae	---	1
		Limnephilidae	*Chyranda*	4
			Pycnopsyche	3
		Philopotamidae	*Chimarra*	1
SPH	Ephemeroptera	Ephemerellidae	*Drunella*	1
	Plecoptera	Capniidae	*Allocapnia*	3
		Nemouridae	*Amphinemura*	12
	Trichoptera	Hydropsychidae	*Cheumatopsyche*	1
		Limnephilidae	*Pycnopsyche*	41
		Philopotamidae	*Dolophilodes*	13
SPM	Ephemeroptera	Ameletidae	*Ameletus*	39
		Ephemerellidae	---	2
		Leptophlebiidae	*Paraleptophlebia*	63
	Plecoptera	Capniidae	*Allocapnia*	123
		Nemouridae	*Amphinemura*	298
		Perlodidae	*Clioperla*	5
			Isoperla	29
	Trichoptera	Philopotamidae	*Dolophilodes*	6

DAM = Dam 3 Stream
ELK = Elks Run
JRF = Jackson's Right Flank, Flowing Springs Run
MHP = Maryland Heights – Potomac Stream
PNR = Piney Run
SHD = Shoreline Drive Stream
SHH = Short Hill Stream
SPH = Spring House Stream
SPM = Short Hill – Peachers Mill

Appendix F: Butterflies and Skippers at HAFE

Species list taken from Durkin's 2003 report, "Initial survey of the butterflies and skippers of Harpers Ferry National Historical Park: 2002-2003."

Area Key:

1. Bolivar Heights
2. Schoolhouse Ridge
3. Jackson's Right Flank
4. Cavalier Heights
5. Virginius Is./Shenandoah shore
6. Loudoun Heights
7. Maryland Heights

Key to species occurrence levels (OL)

expressed as the number of individuals likely to be seenpn on one during a peak flying period

A - Abundant (30 or more during normal flight period)

C - Common (3-20 individuals)

U - Uncommon (0-3 individuals)

R - Rare, rarely seen

Un - Undetermined

	English name	Latin name	Areas 1	2	3	4	5	6	7	Dates observed	Typically found	Host plant	OL
	Swallowtails	***Papilioninae***											
1	Pipevine Swallowtail	*Battus philenor*	x	x	x	x	x		x	*2002: 4/15, 5/4,7/26, 8/3,21 2003:4/27; 5/15, 6/7; 8/19*	throughout	Virginia snakeroot	C
2	Zebra Swallowtail	*Eurytides marcellus*	x	x	x	x	x	x	x	*2002: 4/15,5/15, 7/3,10,26, 8/3,21 2003: 4/16, 27; 5/8, 15; 6/7; 7/5, 25, 12, 25; 8/19*	throughout	pawpaw	A
3	Black Swallowtail	*Papilio polyxenes*	x	x	x	x	x		x	*2002: 4/15,; 7/10; 8/3, 21; 9/ 9 2003: 4/15, 27; 6/7, 16; 7/1, 12, 25; 8/19; 9/17*	throughout	Queen Anne's lace	A
4	Spicebush Swallowtail	*Papilio troilus*	x	x	x	x	x	x	x	*2002: 4/15, 5/4, 15; 6/11; 7/10, 26; 8/21, 9/9 2003: 5/15; 6/16; 7/12, 25; 8/19*	wooded edges	spicebush, sassafras	C
5	Eastern Tiger Swallowtail	*Papilio glaucus*	x	x	x	x	x	x	x	*2002: 4/15; 5/4; 6/11; 7/10; 8/3, 21; 9/9 2003: 4/27; 5/15; 6/7, 16; 7/1, 5, 12, 25, 8/19*	throughout	tulip popler, wild cherry	A
6	Appalachian Tiger Swallowtail	*Pterourus appalachiensis*	x							*2003: 4/14 2003: 4/15*	summits	undetermined	Un
7	Giant Swallowtail	*Papilio cresphontes*					x			*2002: 8/3**	river corridor	pricky ash	R
	Whites	***Pierinae***											
8	West Virginia White	*Pieris virginiensis*							x	*2002: 5/4 2003: 4/25**	wooded slopes	toothworts	R
9	Cabbage White	*Pieris rapae*	x	x	x	x	x	x	x	*2002: 4/15; 5/4,15,; 7/3,10,26; 8/3, 21; 9/9 2003: 4/15, 16, 27; 5/8; 6/7, 16; 7/1, 12, 25 , 8/19; 9/17*	throughout	crucifers (mustards)	A
10	Falcate Orangetip	*Anthrocharis midea*	x							*2002: 4/15 2003: 4/15*	open woods	rock cresses	C
	Sulphurs	***Coliadinae***											
11	Clouded Suphur	*Colias philodice*	x	x	x	x	x		x	*2002: 5/4,15; 6/11; 8/3, 21; 9/6 2003: 4/27; 6/7; 7/12,25; 8/19*	open areas	clovers	A
12	Orange Sulphur	*Colias eurytheme*	x	x	x	x	x		x	*2002: 4/15; 5/4,15, 6/11; 7/3,10,26; 8/21; 9/9 2003: 7/1, 25 , 8/19; 9/17*	open areas	clovers, vetches	A
13	Cloudless Sulphurr	*Phoebis sennae eubule*			x	x				*2002: 8/21 2003: 8/19*	open areas	sennas	R
14	Little Yellow	*Eurema lisa*			x					*2002: 10/2**	hillsides	sennas	R
15	Sleepy Orange	*Eurema nicippe*			x					*2002: 7/12 **	river/stream corridors	sennas	R
	Hairstreaks	***Theclinae***											
16	Banded Hairstreak	*Satyrium calanus*		x			x			*2003: 7/1,12*	sunlit openings	oaks	U
17	Juniper Hairstreak	*Callophrys gryneus*				x				*2003: 7/25; 8/19*	red cedar canopy	red cedar	C
18	Henry's Elfin	*Callophrys henrici*							x	*2003: 4/16*	brushy barrens	redbud	C
19	Gray Hairstreak	*Strymon melinus*			x		x			*2002: 7/26 2003: 7/12*	fields, roadsides	tick trefoils, vetches, clovers	C
	Blues	***Polyommatinae***											
20	Eastern-tailed Blue	*Everes comyntas*	x	x	x	x	x		x	*2002: 6/11; 7/10,26; 8/3, 21; 9/9 2003: 7/12, 27; 9/1*	open areas	tick trefoils, clovers	C
21	Spring Azure	*Celastrina ladon*	x				x	x	x	*2002: 4/15, 16; 5/4 2003: 4/15, 16;, 27; 5/8, 15; 6/7*	openings	dogwood, wild cherry	C
22	Summer Azure	*Celastrina ladon neglecta*		x	x	x	x		x	*2002: 6/11; 7/26; 9/9 2003: 6/7, 16; 7/12, 25 , 8/19*	wooded openings	viburnum, wingstem	C
23	Appalachian Azure	*Celastrina neglectamajor*	x				x		x	*2002: 4/15, 5/23* 2003: 6/3**	puddles, openings	black cohosh	U
24	Silvery Blue	*Glaucopsyche lygdamus*						x		*2002: 4/15*	puddles, openings	wood vetch	R

(continued)

	English name	Latin name	Areas 1	2	3	4	5	6	7	Dates observed	Typically Found	Host plant	OL
	Brush-foots	***Nymphalidae***											
25	American Snout	*Libytheana carinenta*		x						*2003: 7/12, 25*	muddy areas	hackberry	U
26	Variegated Fritillary	*Euptoieta claudia*	x	x	x				x	*2002: 6/11, 7//26, 8/3, 21, 9/3, 9 2003: 6/7; 8/19*	open areas	violets	U
27	Great-Spangled Fritillary	*Speyeria cybele*	x	x	x	x	x		x	*2002: 6/11, 7/3, 10, 26, 8/3 2003: 6/16, 7/1, 12, 25, 8/19*	open areas	violets	A
28	Meadow Fritillary	*Boloria bellona*	x	x	x		x		x	*2002: 4/15;7/3, 10, 26, 8/3, 21, 9/9 2003: 4/27; 6/16; 7/1,12, 25, 8/19*	fields	violets	A
29	Silvery Checkerspot	*Chlosyne nycteis*		x					x	*2002: 7/26; 8/3 2003: 6/7*	fields	wingstem, wild sunflower	A
30	Pearl Crescent	*Phyciodes tharos*	x	x	x	x	x	x	x	*2002: 5/4,15; 7/3, 10, 26, 8/3, 21, 9/3, 9 2003: 5/15; 7/12, 25, 8/19, 9/17*	open areas	asters	U
31	Question Mark	*Polygonia interrogationis*		x	x	x		x	x	*2002: 5/15; 7/10, 26 2003: 4/15,16; 5/15; 7/25*	wooded edges	nettles, elm, hackberry	C
32	Eastern Comma	*Polygonia comma*		x	x					*2002: 4/15 2003: 6/16*	wooded edges	nettles, elm, hops	C
33	Mourning Cloak	*Nymphalis antiopa*	x							*2002: 4/15 2003: 4/27*	wooded edges	willow, elm, cottonwood	C
34	American Lady	*Vanessa virginiensis*		x				x	x	*2003: 4/27; 5/8; 7/12, 25*	open areas	everlasting, pussytoes	C
35	Painted Lady	*Vanessa cardui*		x	x					*2003: 7/12*	open areas	thistles, mallows	C
36	Red Admiral	*Vanessa atalanta*		x	x	x	x		x	*2002 5/4; 7/10, 26 2003: 4/27, 5/15; 6/7; 7/1,12; 9/17*	open areas	nettles	C
37	Common Buckeye	*Junonia coenia*		x		x		x		*2002: 7/26, 8/3, 21, 9/ 9 2003: 9/17*	open areas	plantain, foxglove	C
38	Red-spotted Purple	*Limenitis arthemis astyanax*			x		x			*2002: 7/26*	wooded edges	wild cherry, poplar, aspen	C
39	Viceroy	*Lemenitis archippus*			x	x				*2002: 6/11; 7/10; 9/9*	near water	willows, poplars	U
40	Hackberry Emperor	*Asterocampa celtis*	x	x	x		x	x		*2002: 7/26; 8/21 2003: 7/1, 5, 12; 8/19*	wooded edges	hackberry	C
41	Tawny Emperor	*Asterocampa clyton*	x	x	x		x		x	*2002: 6/11; 8/3 2003: 7/25; 8/19*	wooded edges	hackberry	C
	Satyrs	***Satyrinae***											
42	Northern Pearly Eye	*Enodia anthedon*							x	*2003: 7/25*	wooded areas	bottlebrush grass	U
43	Little Wood Satyr	*Megisto cymela*			x					*2002: 6/11*	wooded edges	orchard grass	C
44	Common Wood Nymph	*Cercyonis pegala*	x	x						*2003: 6/16*	wooded edges	purpletop, other grases	C
	Milkweed Butterflies	***Danaeinae***											
45	Monarch	*Danaus plexippus*	x	x	x	x			x	*2002: 7/10, 26; 8/ 21 2003: 6/16, 7/1, 12, 25, 8/19, 9/17*	meadows, openings	milkweeds	C
	Open-winged Skippers	***Pyrginae***											
46	Silver-spotted Skipper	*Epargyreus clarus*	x	x	x	x	x	x	x	*2002: 5/4, 6/11, 7/3, 10, 26, 8/3, 21, 9/9 2003: 4/27; 5/15; 6/7,16, 7/1, 5, 12, 25, 8/19*	wooded openings	locusts, tick trefoils	A
47	Northern Cloudywing	*Thorybes pylades*		x						*2002: 7/26*	dry fields	tick trefoils, bush clover	U
48	Hayhurst's Scallopwing**	*Staphylus hayhurstii*			x			x		*2002: 6/11 2003: 5/15***	wooded areas	lamb's quarters	C
49	Dreamy Duskywing	*Erynnis icelus*				x	x	x	x	*2003: 5/15; 6/7*	dry fields	willows, poplars, aspens	C
50	Sleepy Duskywing	*Erynnis brizo*						x		*2003: 4/27*	edges, trails	black oak, scrub oak, other oaks	C
51	Juvenal's Duskywing	*Erynnis juvenalis*							x	*2003: 4/27*	mud puddles	red oaks, white oaks	C
52	Horace's Duskywing	*Erynnis horatius*	x		x	x	x			*2002: 6/11; 7/10; 8/21 2003: 6/16; 9/17*	wooded areas	red oaks, white oaks	C
53	Wild Indigo Duskywing	*Erynnis baptisiae*	x	x	x	x	x			*2002: 7/10, 26; 8/21 2003: 7/12; 8/19*	open areas	wild indigo, crown vetch	C
54	Comn. Checkered Skipper	*Pyrgus communis*			x		x			*2002: 7/26; 8/3, 21*	weedy fields	mallows	U
55	Common Sootywing	*Pholisora catullus*		x						*2002: 7/3, 10*	fields	lamb's quarters	U
	Grass Skippers	***Hesperiinae***											
56	Swarthy Skipper	*Nastra lherminier*		x						*2002: 7/26*	dry fields	little bluestem	U
57	Clouded Skipper	*Lerema accius*			x					*2002: 8/21*	bushy wet meadows	silver plumegrass	U
58	Least Skipper	*Ancyloxypha numitor*			x			x		*2002: 5/23 , 9/9*	grassy stream edges	bluegrass, rice cutgrass	C
59	European Skipper	*Thymelicus lineola*		x		x				*2002: 7/10; 8/21*	tall grass	timothy grass	C
60	Fiery Skipper	*Hylephila phyleus*	x		x					*2002: 7/25; 8/21*	marshy areas	crab grass, Berumuda grass	U
61	Indian Skipper	*Heperia sassacus*					x			*2002: 5/23**	rocky hillsides, openings	panic grasses	U

(continued)

	English name	Latin name	Areas 1	2	3	4	5	6	7	Dates observed	Typically Found	Host plant	OL
62	Peck's Skipper	*Polites peckius*	x	x			x			*2002: 7/10,26 ; 8/3, 21; 9/8*	wet meadows	rice cutgrass	U
63	Tawny-edge Skipper	*Polites themistocles*	x	x						*2002: 7/26; 9/9*	wet meadows	panic grasses	U
64	Crossline Skipper	*Polites origenes*	x		x					*2002: 8/21, 9/9*	wet meadows	purpletop grass	U
65	Northern Broken-Dash	*Wallengrenia egeremet*		x						*2002: 7/10*	weedy fields	panic grass	U
66	Little Glassywing	*Pompeius verna*		x	x		x			*2002: 7/26; 8/21 2003 7/12, 7/25*	wet meadows, edges	purpletop grass	U
67	Sachem	*Atalopedes campestris*	x	x	x		x		x	*2002: 7/10, 7/26; 8/21*	open areas throughout	crab grass, Bermuda grass	A
68	Delaware Skipper	*Anatrytone logan*		x	x					*2002: 7/1, 7/10*	marshes near dry fields	big bluestem, switchgrass	R
69	Hobomok Skipper	*Poanes hobomok*					x		x	*2002: 5/2*, 23* 2003: 6/3**	sunlit openings	panic grasses	U
70	Zabulon Skipper	*Poanes zabulon*		x					x	*2002: 5/4; 7/20,26*	edges, trails	purpletop grass, love grass	U
71	Dun Skipper	*Euphyes vestris*		x	x					*2002: 7/3, 19; 9/9*	marsh edges	sedges, grasses	C
72	Pepper and Salt Skipper	*Amblyscirtes hegon*							x	*2003 5/8*	grassy clearings	Indian grass, other grasses	R
73	Comn. Roadside Skipper	*Amblyscirtes vialis*			x				x	*2002: 7/26 2003: 5/15*	grassy clearings	bluegrass, wild oats, bentgrass	R
74	Ocola Skipper	*Panoquina ocola*					x			*2003: 9/14**	river corridors	grasses	R

* Richard Orr observation

** Dick Smith observation

Appendix G: Bats found at HAFE

Species list taken from Gates and Johnson's 2005 report, "Bat inventories of the National Capital Region Parks."

Bats captured:
Big Brown bat
Eastern Red bat
Northern Myotis

Bats detected acoustically:
Eastern Red bat
Hoary bat
Little Brown bats
Eastern Pipistrelles

Appendix H: Amphibians and Reptiles at HAFE

Checklist of the amphibians and reptiles observed at HAFE in Pauley et al.'s 2005 survey, "Final report: Reptile and amphibian inventories in eight parks in the National Capital Region."

Scientific Name	Common Name
FROGS	
Bufo a. americanus	Eastern American Toad
Bufo fowleri	Fowler's Toad
Pseudacris c. crucifer	Northern Spring Peeper
Rana catesbeiana	American Bullfrog
Rana c. melanota	Northern Green Frog
Rana palustris	Pickerel Frog
Rana sylvatica	Wood Frog
SALAMANDERS	
Ambystoma jeffersonianum	Jefferson Salamander
Ambystoma maculatum	Spotted Salamander
Desmognathus fuscus	Northern Dusky Salamander
Desmognathus monticola	Seal Salamander
Eurycea bislineata	Northern Two-lined Salamander
Eurycea l. longicauda	Long-tailed Salamander
Gyrinophilus p. porphyriticus	Northern Spring Salamander
Notophthalmus v. viridescens	Red-spotted Newt, Red Eft
Plethodon cinereus	Eastern Red-backed Salamander
Plethodon hoffmani	Valley and Ridge Salamander
Pseudotriton r. ruber	Northern Red Salamander
TURTLES	
Chelydra s. serpentina	Eastern Snapping Turtle
Chrysemys p. picta	Eastern Painted Turtle
Glyptemys insculpta	Wood Turtle
Pseudemys rubriventris	Northern Red-bellied Cooter
Sternotherus odoratus	Stinkpot
Terrapene c. carolina	Eastern Box Turtle
LIZARDS	
Eumeces fasciatus	Common Five-lined
Eumeces laticeps	Broad-headed Skink
Sceloporus undulatus	Eastern Fence-Lizard
SNAKES	
Agkistrodon c. mokasen	Northern Copperhead
Carphophis a. amoenus	Eastern Wormsnake
Diadophis p. edwardsii	Northern Ring-necked Snake
Elaphe o. obsoleta	Black Ratsnake
Heterodon platirhinos	Eastern Hog-nosed Snake
Lampropeltis t. triangulum	Eastern Milksnake
Nerodia s. sipedon	Common Watersnake
Opheodrys a. aestivus	Northern Rough Greensnake

Thamnophis s. sirtalis Eastern Gartersnake

Appendix I: Small mammals found and expected to be found at HAFE

Lists of small mammals found and expected to be found at HAFE taken from McShea and O'Brien's 2003 inventory, "Small mammal survey of National Capital Region Parks - Final report."

Species found at the park:

Scientific name	Common name
Blarina brevicauda	Northern short-tailed shrew
Cryptotis parva	Least shrew
Sorex fumeus	Smoky shrew
Sorex longirostris	Southeastern shrew
Glaucomys volans	Southern flying squirrel
Clethrionomys gapperi	Red-backed vole
Microtus pinetorum	Pine vole
Mus musculus	House mouse
Peromyscus leucopus	White-footed mouse
Sciurus carolinensis	Eastern gray squirrel
Tamias striatus	Eastern chipmunk
Neotoma magister	Eastern woodrat
Procyon lotor	Raccoon
Vulpes vulpes	Red fox
Odocoileus virginianus	White-tailed deer

Species expected to be found at the park:

Species	Abundance
Sorex cinereus	LA
Sorex fumeus	LA
Sorex longirostris	LA
Microsorex hoyi	R
Blarina brevicauda	C
Crytotis parva	R
Scalopus aquaticus	LA
Condylura cristata	A
Tamias striatus	LA
Sciurus carolinensis	C
Sciurus niger	LA
Tamiasciurus hudsonicus	R
Glaucomys volans	LA
Oryzomys palustris	A
Reithrodontomys humulis	A
Peromyscus maniculatus	R
Peormyscus leucopus	C
Neotoma magister	R
Clethrionomys gapperi	R
Microtus pennsylvanicus	LA
Microtus pinetorum	LA
Synaptomys cooperi	A
Rattus rattus	A
Rattus norvegicus	R
Mus musculus	LA
Zapus hudsonicus	LA

C- common; LA- locally abundant ; R – rare; A – absent

Appendix J: Avian species found and expected at HAFE

Species list taken from Sinclair et al.'s 2004 inventory, "Avian inventory at six National Capital Region national parks: Final report."

List of observed species at HAFE:
Key: common (CO), probable (PR), possible (PO)

Species	CO	PR	PO
Double-crested Cormorant			
Great Blue Heron			
Great Egret			
Green Heron			
Black Vulture			
Turkey Vulture			
Canada Goose	x		
Wood Duck	x		
American Black Duck			
Mallard			
Canvasback			
Bufflehead			
Common Merganser			
Osprey			
Bald Eagle			
Sharp-shinned Hawk			
Cooper's Hawk			
Red-shouldered Hawk			
Broad-winged Hawk			
Red-tailed Hawk			
Peregrine Falcon			
Wild Turkey			
Northern Bobwhite			
Killdeer			
Spotted Sandpiper			x
Laughing Gull			
Ring-billed Gull			
Herring Gull			
Rock Dove			
Mourning Dove			
Yellow-billed Cuckoo			
Chimney Swift			
Ruby-throated Hummingbird			
Belted Kingfisher			
Red-bellied Woodpecker	x	x	
Yellow-bellied Sapsucker			
Downy Woodpecker		x	
Hairy Woodpecker			
Northern Flicker			
Pileated Woodpecker			
Eastern Wood-Pewee	x	x	
Acadian Flycatcher			

Species	CO	PR	PO
Eastern Phoebe			
Great Crested Flycatcher		x	
Eastern Kingbird			
White-eyed Vireo			
Yellow-throated Vireo			
Blue-headed Vireo			
Warbling Vireo		x	
Red-eyed Vireo		x	
Blue Jay			
American Crow			
Fish Crow			
Common Raven			
Purple Martin			
Tree Swallow			
Northern Rough-winged Swallow	x		
Barn Swallow			
Carolina Chickadee			
Black-capped Chickadee			
Tufted Titmouse		x	
Red-breasted Nuthatch			
White-breasted Nuthatch			
Brown Creeper			
Carolina Wren		x	
House Wren			x
Winter Wren			
Golden-crowned Kinglet			
Ruby-crowned Kinglet			
Blue-gray Gnatcatcher			
Eastern Bluebird		x	
Hermit Thrush			
Wood Thrush	x	x	
American Robin			
Gray Catbird			
Northern Mockingbird			
Brown Thrasher		x	
European Starling			
Cedar Waxwing			
Northern Parula			
Yellow Warbler			
Black-throated Blue Warbler			
Yellow-rumped Warbler			
Black-throated Green Warbler			
Blackburnian Warbler			
Yellow-throated Warbler			
Prairie Warbler			x
Black-and-white Warbler			
American Redstart			
Prothonotary Warbler			
Worm-eating Warbler		x	
Ovenbird			
Louisiana Waterthrush		x	

Species	CO	PR	PO
Scarlet Tanager		x	x
Eastern Towhee			
Chipping Sparrow			
Field Sparrow			x
Savannah Sparrow			
Grasshopper Sparrow		x	
Song Sparrow		x	
White-throated Sparrow			
Dark-eyed Junco			
Northern Cardinal		x	
Rose-breasted Grosbeak			
Indigo Bunting	x	x	
Red-winged Blackbird			
Common Grackle	x		
Brown-headed Cowbird			
Orchard Oriole			
Baltimore Oriole		x	x
Purple Finch			
House Finch			
American Goldfinch			
House Sparrow	x		

List of resident (R) and migrant (M) bird species expected to occur, but not observed, at HAFE:

Common Name	Expected Occurrence
Pied-billed Grebe	M
Little Blue Heron	M
Green-winged Teal	M
Northern Pintail	M
Blue-winged Teal	M
Northern Shoveler	M
Gadwall	M
American Wigeon	M
Redhead	M
Ring-necked Duck	M
Lesser Scaup	R
Hooded Merganser	M
Red-breasted Merganser	M
Ruddy Duck	M
Northern Harrier	R
Rough-legged Hawk	R
American Kestrel	R
Merlin	M
Ring-necked Pheasant	R
Ruffed Grouse	R
American Coot	M
Solitary Sandpiper	M
Upland Sandpiper	M
Common Snipe	M
American Woodcock*	R
Bonaparte's Gull	M

Common Name	Expected Occurrence
Black-billed Cuckoo	R
Barn Owl	R
Eastern Screech-Owl	R
Great Horned Owl	R
Barred Owl	R
Short-eared Owl	R
Common Nighthawk	R
Whip-poor-will*	R
Red-headed Woodpecker	R
Yellow-bellied Flycatcher	M
Alder Flycatcher	M
Willow Flycatcher	R
Least Flycatcher	M
Horned Lark	R
Bank Swallow	M
Cliff Swallow	R
Veery*	M
Gray-cheeked Thrush	M
Swainson's Thrush	M
American Pipit	M
Loggerhead Shrike*	R
Philadelphia Vireo	M
Blue-winged Warbler	M
Golden-winged Warbler*	M
Tennessee Warbler	M
Orange-crowned Warbler	M
Nashville Warbler	M
Chestnut-sided Warbler	M
Magnolia Warbler	M
Cape May Warbler	M
Palm Warbler	M
Bay-breasted Warbler	M
Blackpoll Warbler	M
Cerulean Warbler*	R
Northern Waterthrush	M
Kentucky Warbler*	R
Connecticut Warbler	M
Mourning Warbler	M
Common Yellowthroat	R
Hooded Warbler*	R
Wilson’s Warbler	M
Canada Warbler	M
Yellow-breasted Chat	R
Blue Grosbeak	R
Dickcissel	R
American Tree Sparrow	R
Vesper Sparrow	R
Fox Sparrow	M
Lincoln’s Sparrow	M
Swamp Sparrow	M
White-crowned Sparrow	R

Common Name	Expected Occurrence
Bobolink	M
Eastern Meadowlark	R
Rusty Blackbird	M
Pine Siskin	M
Evening Grosbeak	M

* indicates species of concern

Appendix K: Fishes at HAFE

Species list taken from Raesly et al.'s 2004 survey, "Final report: Inventory and biological monitoring of fishes in national parks of the National Capital Region."

Fish species observed at HAFE:
Anguilla rostrata
Campostoma anomalum
Clinostomus funduloides
Cyprinella spiloptera
Cyprinus carpio
Luxilus cornutus
Margariscus margarita
Nocomis micropogon
Notemigonus crysoleucas
Notropis buccatus
Pimephales notatus
Rhinichthys atratulus
Rhinichthys cateractae
Semotilus corporalis
Catostomus commersoni
Hypentelium nigricans
Moxostoma erythrurum
Ameiurus natalis
Ameiurus nebulosus
Noturus insignis
Gambusia holbrooki
Ambloplites rupestris
Lepomis auritus
Lepomis cyanellus
Lepomis gibbosus
Lepomis macrochirus
Lepomis megalotis
Micropterus dolomieu
Micropterus salmoides
Pomoxis annularis
Pomoxis nigromaculatus
Etheostoma blennioides
Etheostoma caeruleum
Etheostoma flabellare
Etheostoma olmstedi

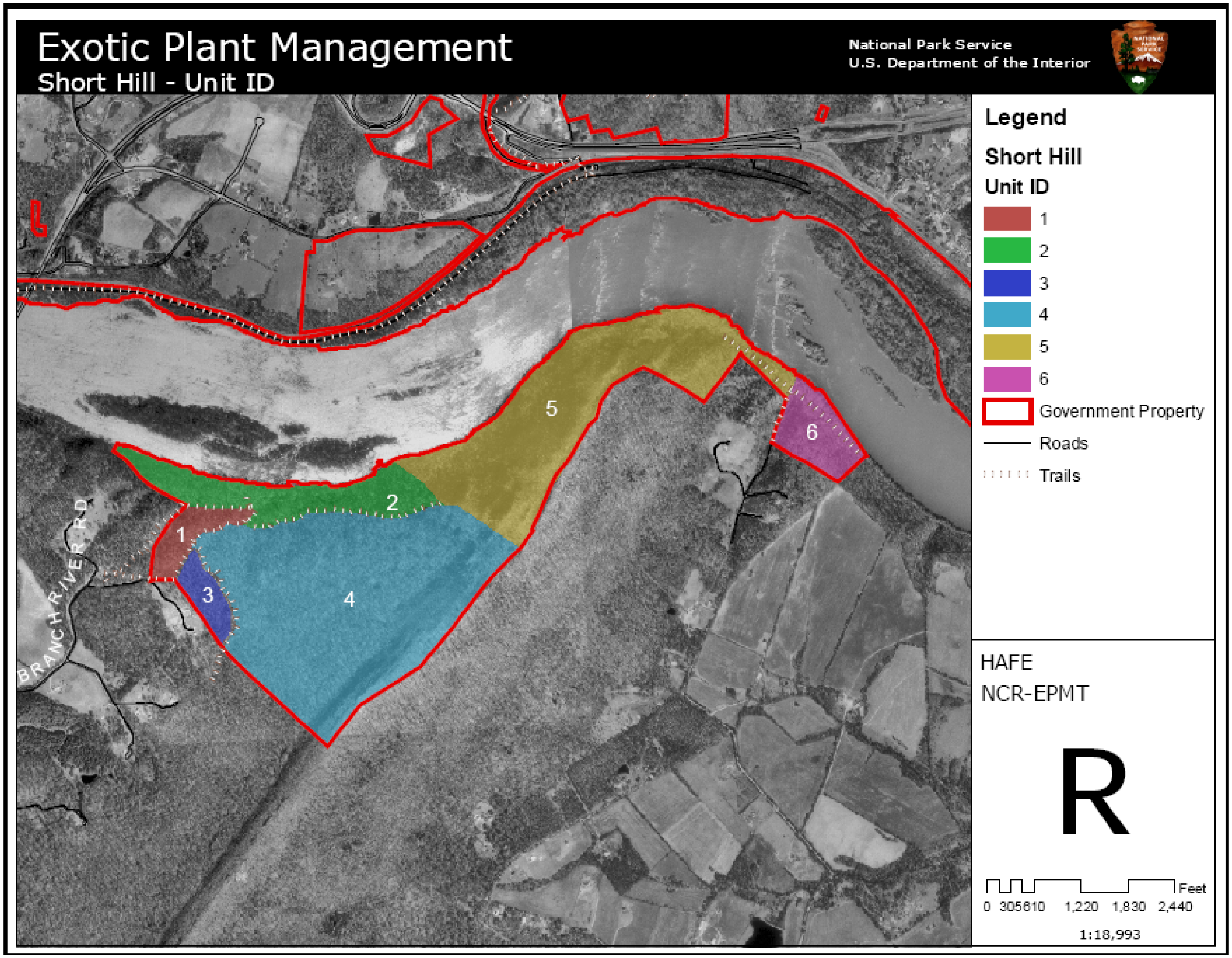
Appendix L: Exotic Plant Management at HAFE

Area coverage of exotic plant inventories at HAFE from 1 October 2000 through 31 August 2007 (NPS 2007j).

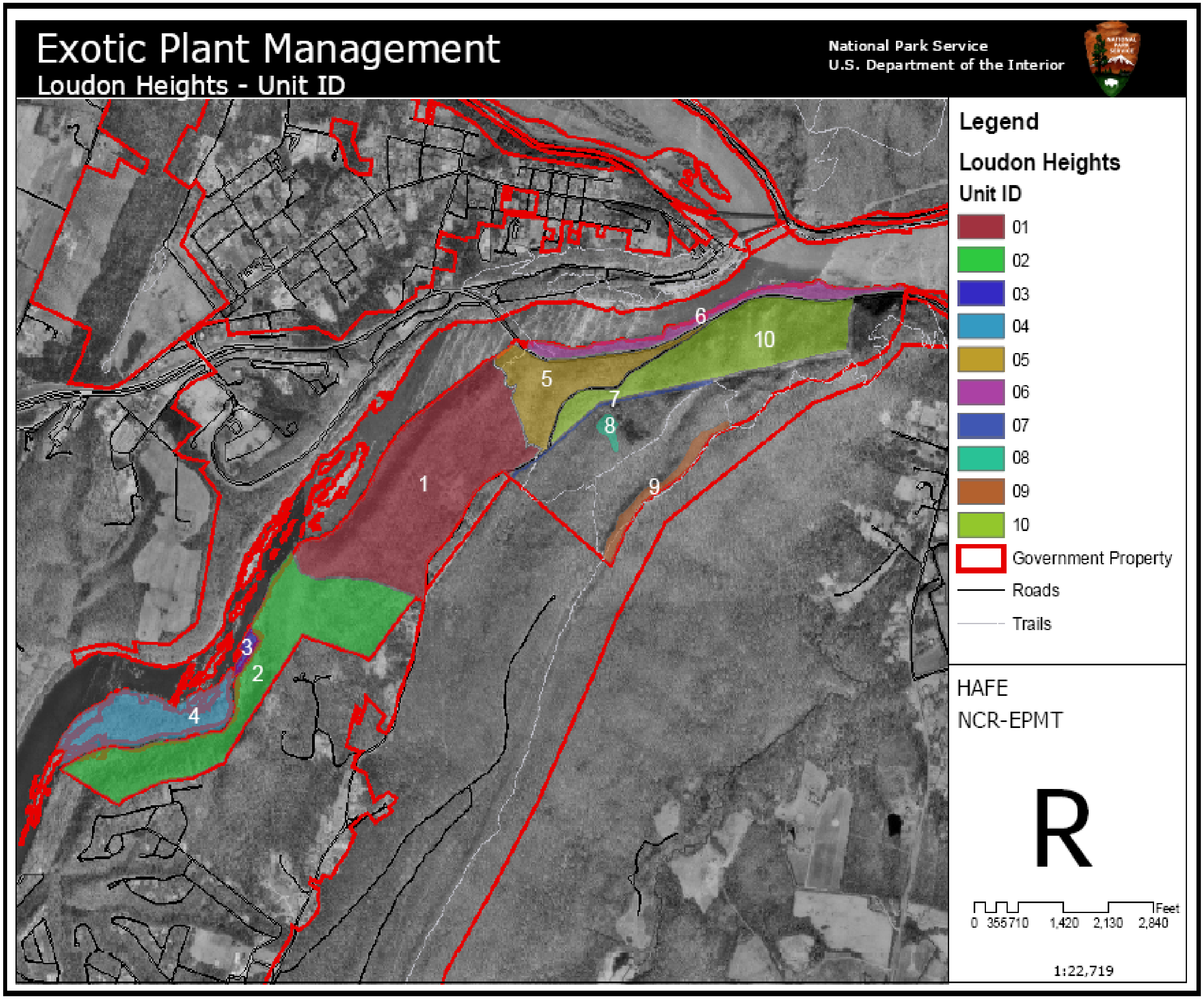
Species	Area coverage
Unknown	161.85
Acer platanoides	340.84
Aegopodium podagraria	9.48
Ailanthus altissima	2,043.12
Albizia julibrissin	33.93
Alliaria petiolata	2,215.28
Arctium minus	116.19
Artemisia annua	30.69
Berberis thunbergii	1,288.30
Broussonetia papyrifera	85.87
Buxus microphylla	4.90
Carduus nutans	6.88
Celastrus orbiculatus	513.49
Chrysanthemum leucanthemum	83.08
Cichorium intybus	194.36
Cirsium	16.40
Cirsium arvense	268.57
Cirsium vulgare	98.32
Clematis terniflora	2.63
Conium maculatum	10.10
Coronilla varia	119.49
Datura stramonium	101.52
Daucus carota	164.26
Dipsacus sylvestris	262.59
Duchesnea indica	225.82
Elaeagnus umbellata	201.33
Euonymus alata	83.01
Euonymus fortunei	40.29
Forsythia viridissima	17.88
Glechoma hederacea	441.71
Gleditsia triacanthos	47.60
Hedera helix	455.35
Hemerocallis fulva	40.29
Ipomoea hederacea	203.57
Lamium amplexicaule	47.97
Lathyrus leucanthus var. laetivirens	40.29

Lespedeza	2.60
Ligustrum	98.16
Ligustrum obtusifolium	324.75
Ligustrum vulgare	407.67
Linaria vulgaris	75.74
Lonicera	450.75
Lonicera japonica	1,997.25
Lonicera morrowii	6.88
Maclura pomifera	44.64
Mahonia bealei	9.48
Melandrium album	24.30
Microstegium vimineum	1,234.62
Narcissus pseudonarcissus	26.44
Paulownia tomentosa	1,390.68
Perilla frutescens	1,052.31
Phragmites australis	13.76
Phyllostachys	6.06
Polygonum perfoliatum	147.98
Pueraria lobata	42.83
Rosa multiflora	1,997.74
Rubus phoenicolasius	2,158.04
Rumex crispus	42.28
Setaria geniculata	123.18
Setaria glauca	231.47
Silene vulgaris	9.96
Sorghum halepense	18.13
Taraxacum officinale	50.63
Verbascum thapsus	934.76
Vicia minutiflora	77.98
Vinca minor	213.51
Wisteria floribunda	128.30
Wisteria sinensis	23.36
Xanthium strumarium	19.95
Yucca glauca	26.04
Total Acres Inventoried in HAFE	23,429.48

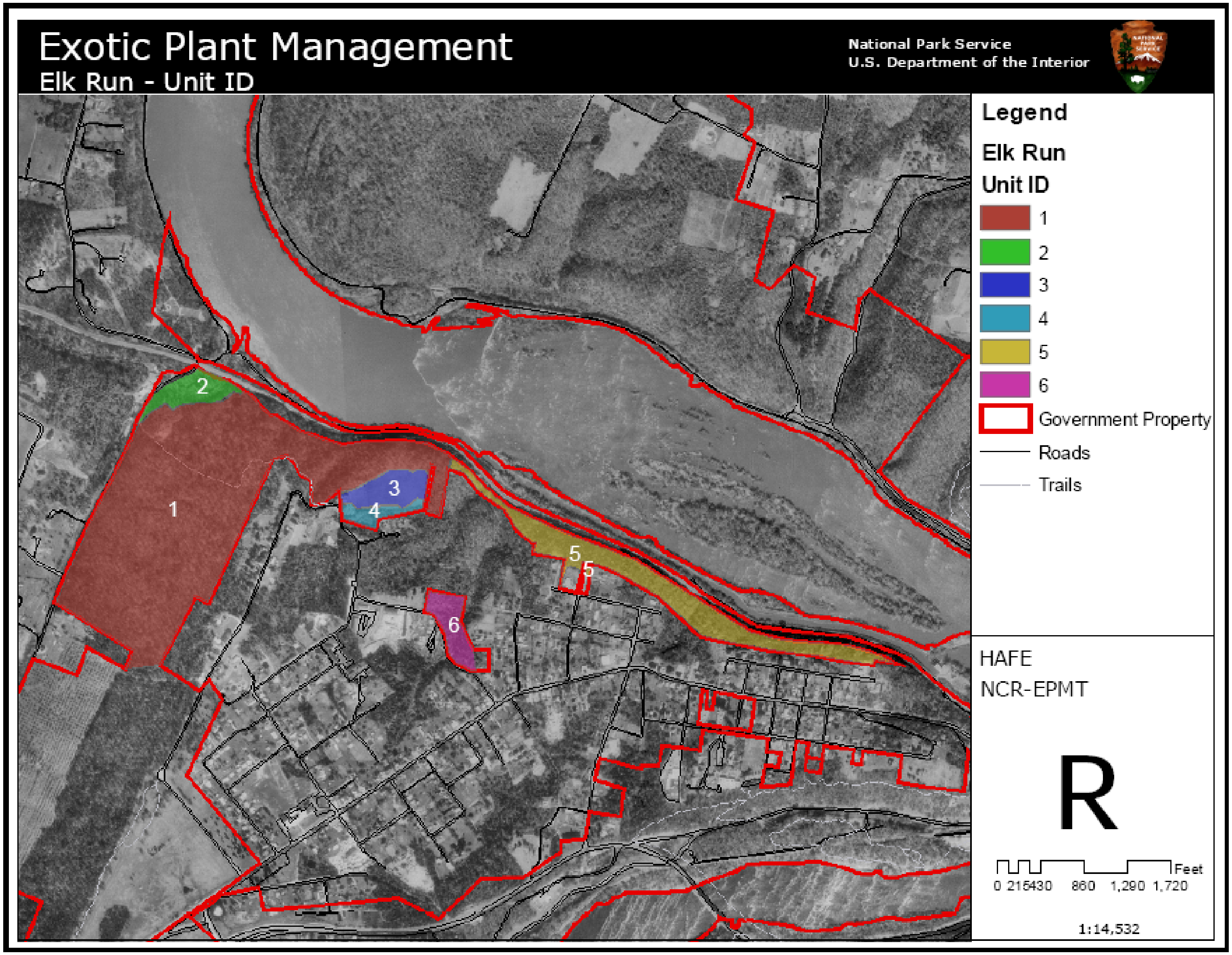
Exotic plant management units at Short Hill (NPS 2007j)



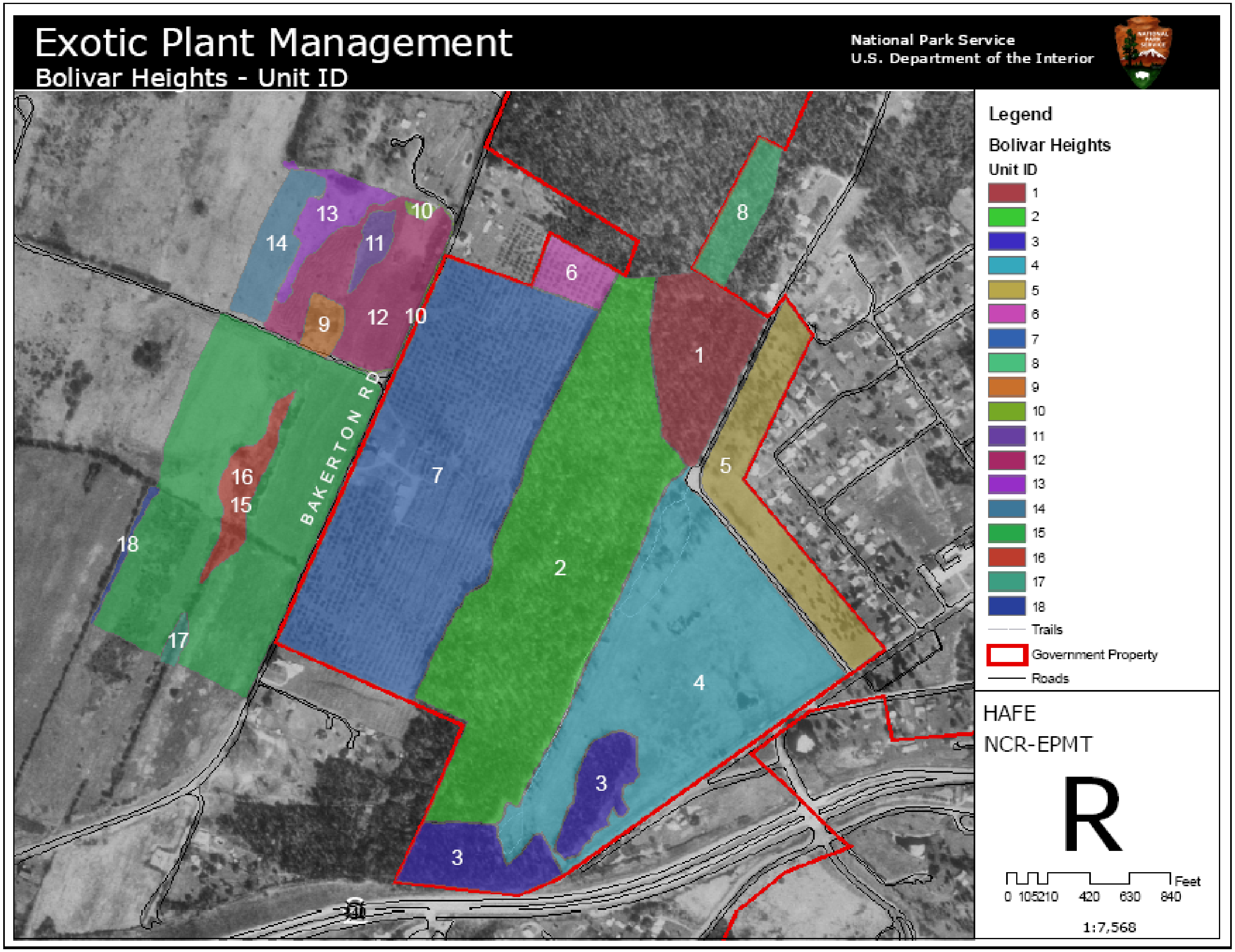
Exotic plant management units at Loudon Heights (NPS 2007j)



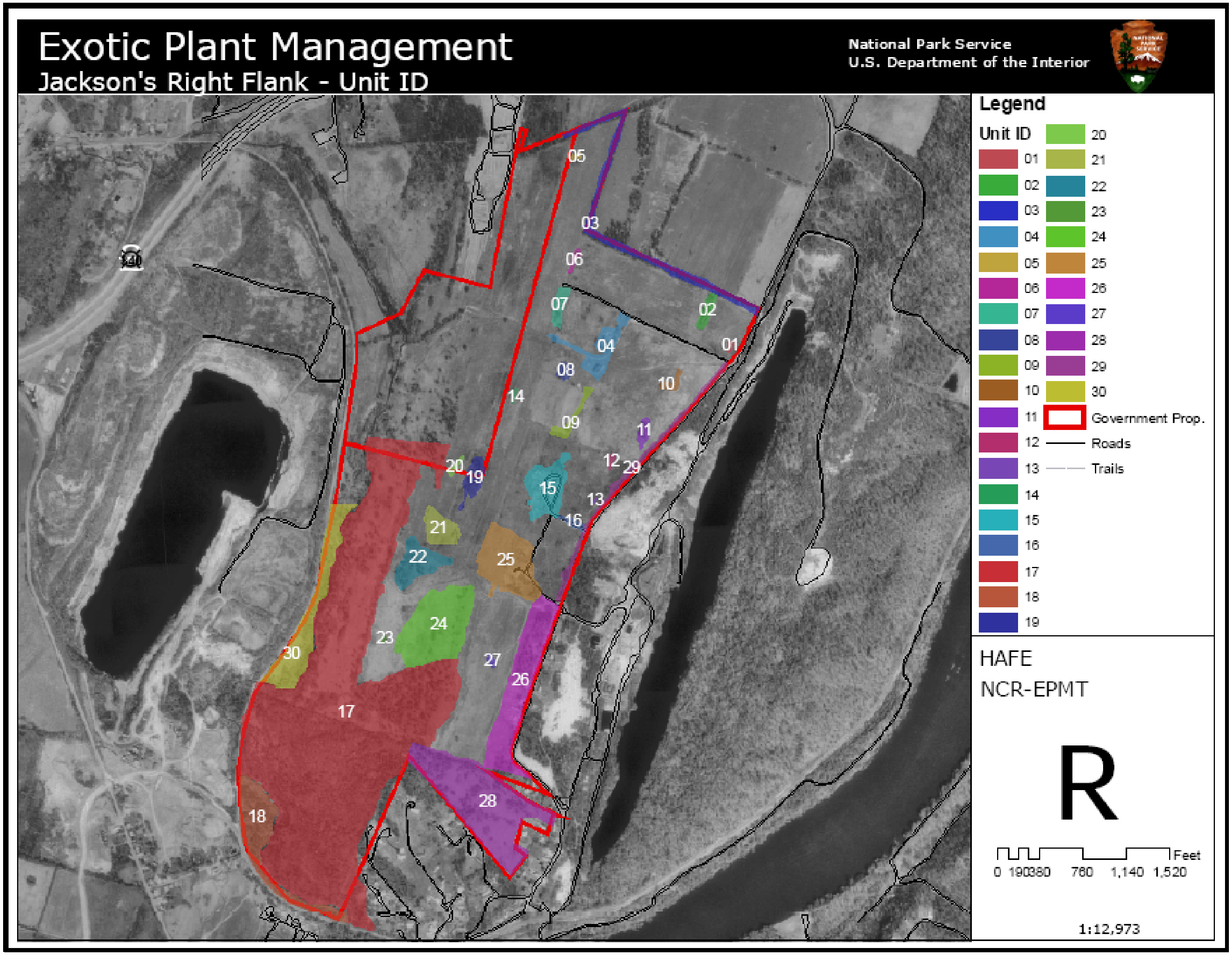
Exotic plant management units at Elk Run (NPS 2007j)



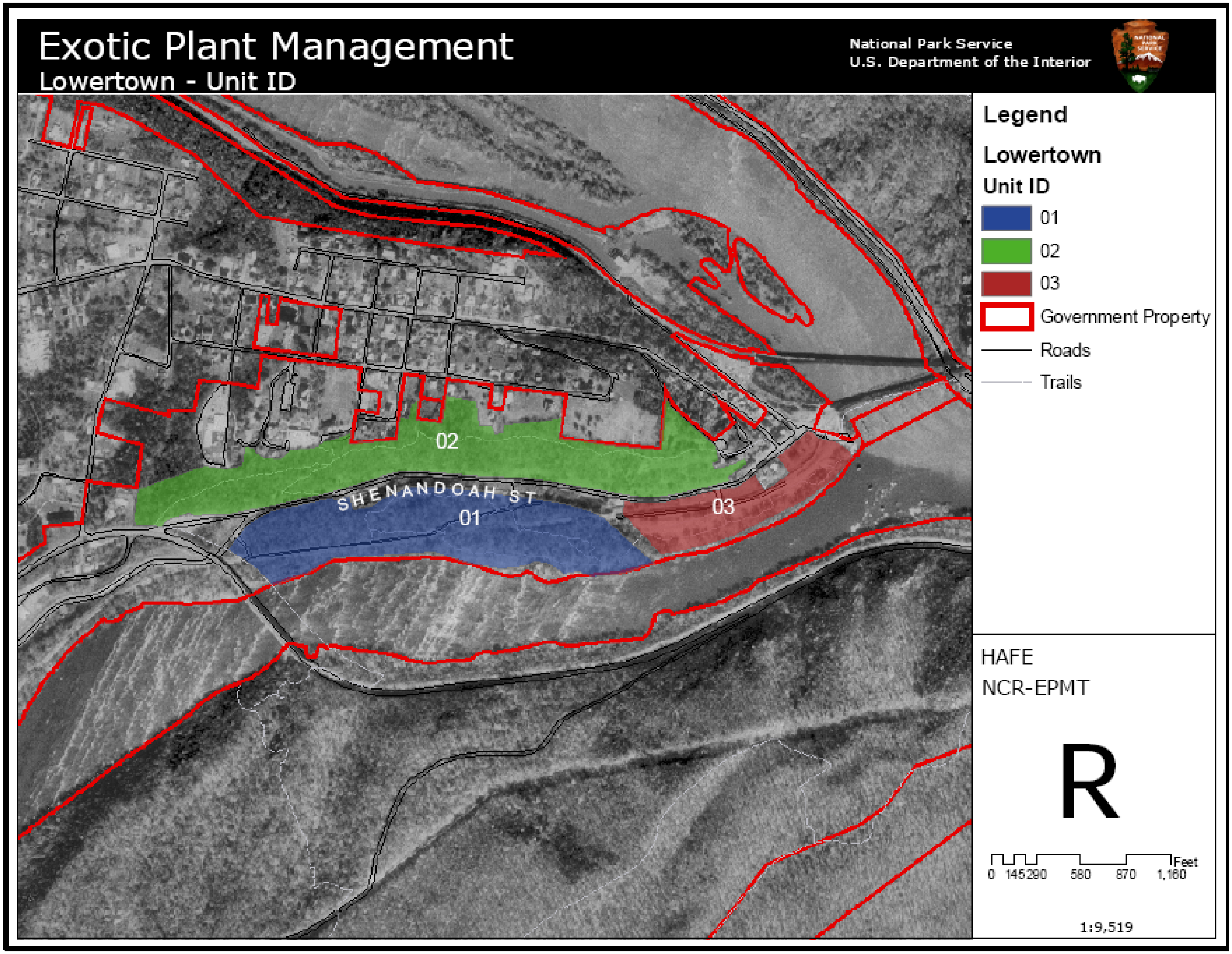
Exotic plant management units at Bolivar Heights (NPS 2007j)



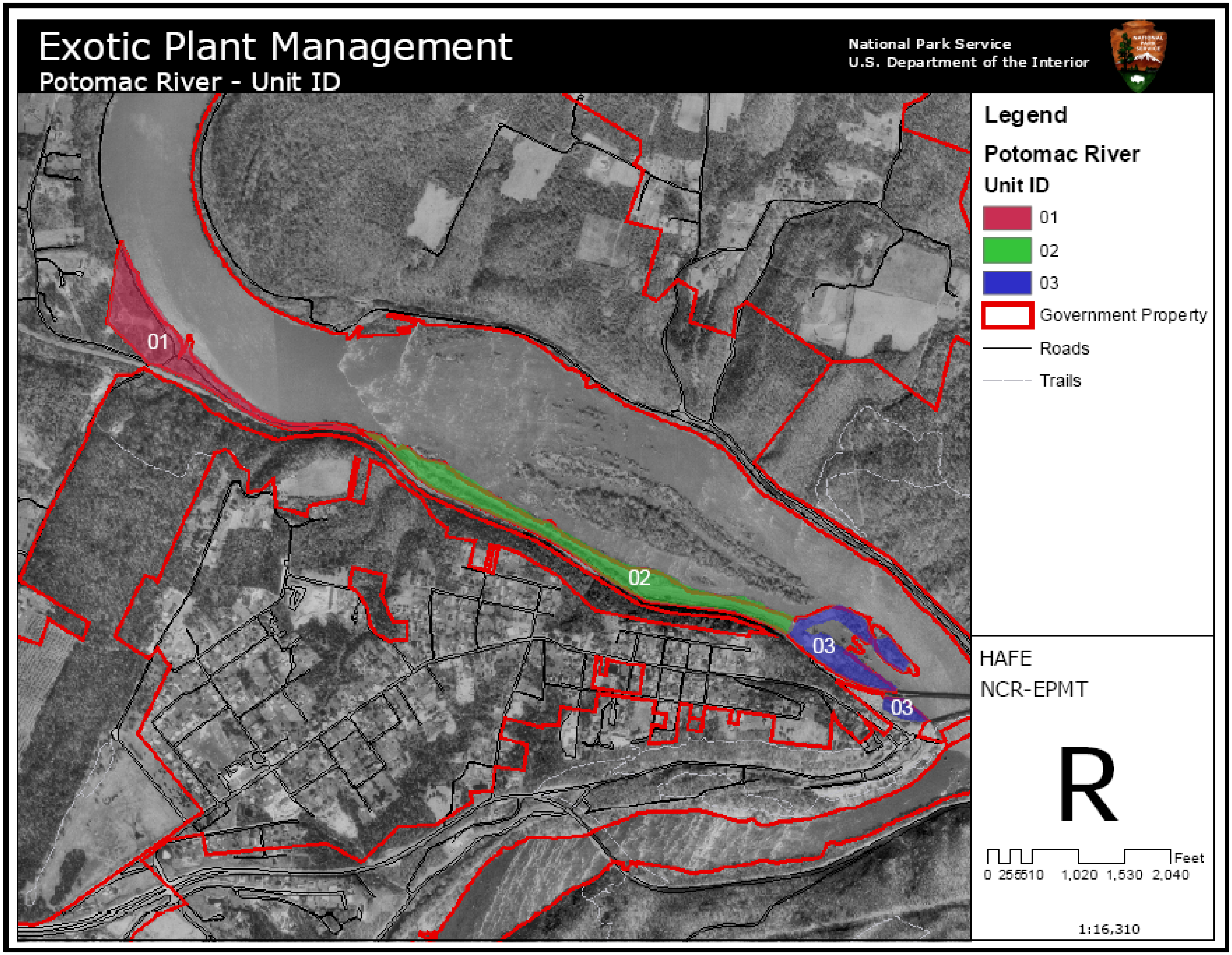
Exotic plant management units at Jackson's Right Flank (NPS 2007j)



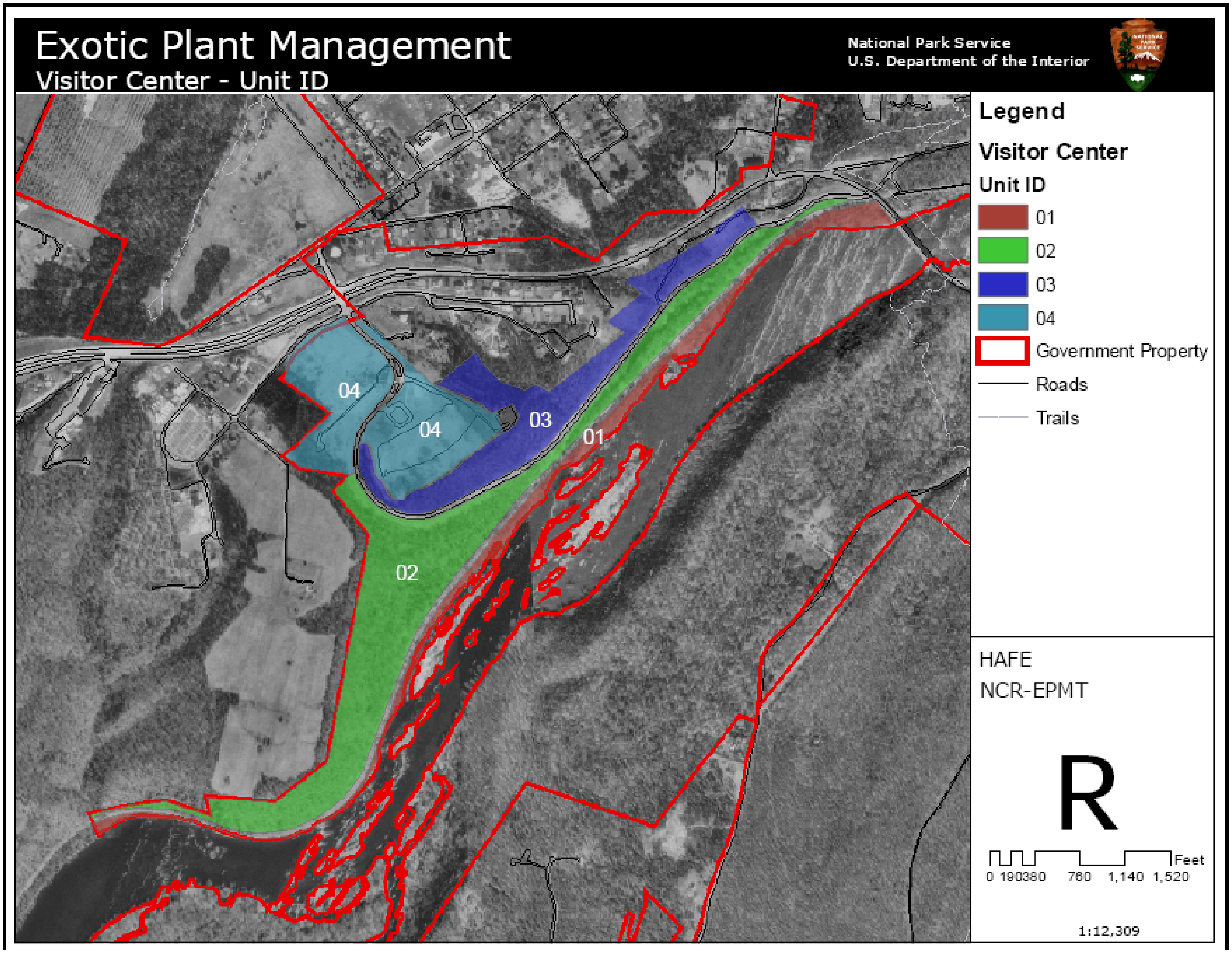
Exotic plant management units in Lower Historic Town (NPS 2007j)



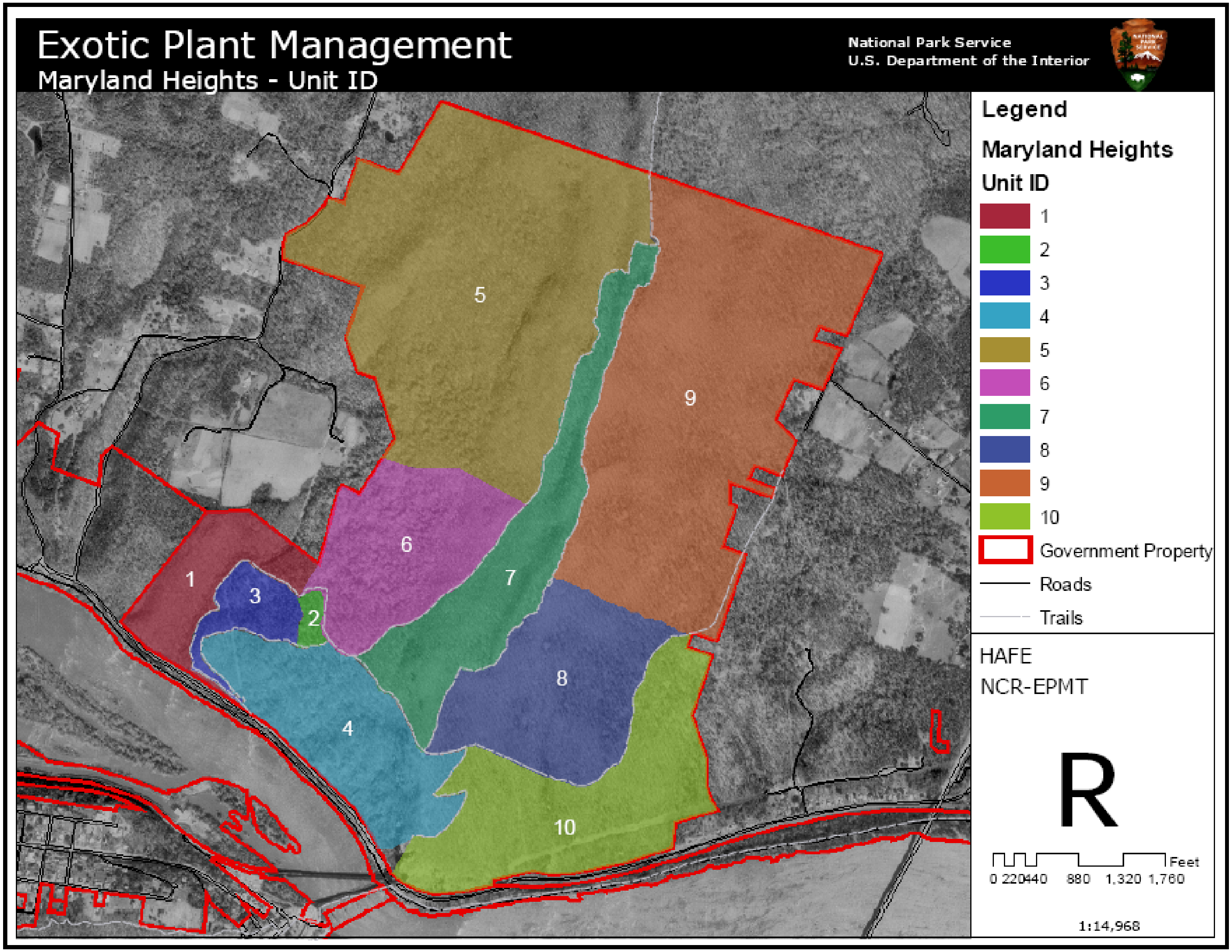
Exotic plant management units at the Potomac River (NPS 2007j)



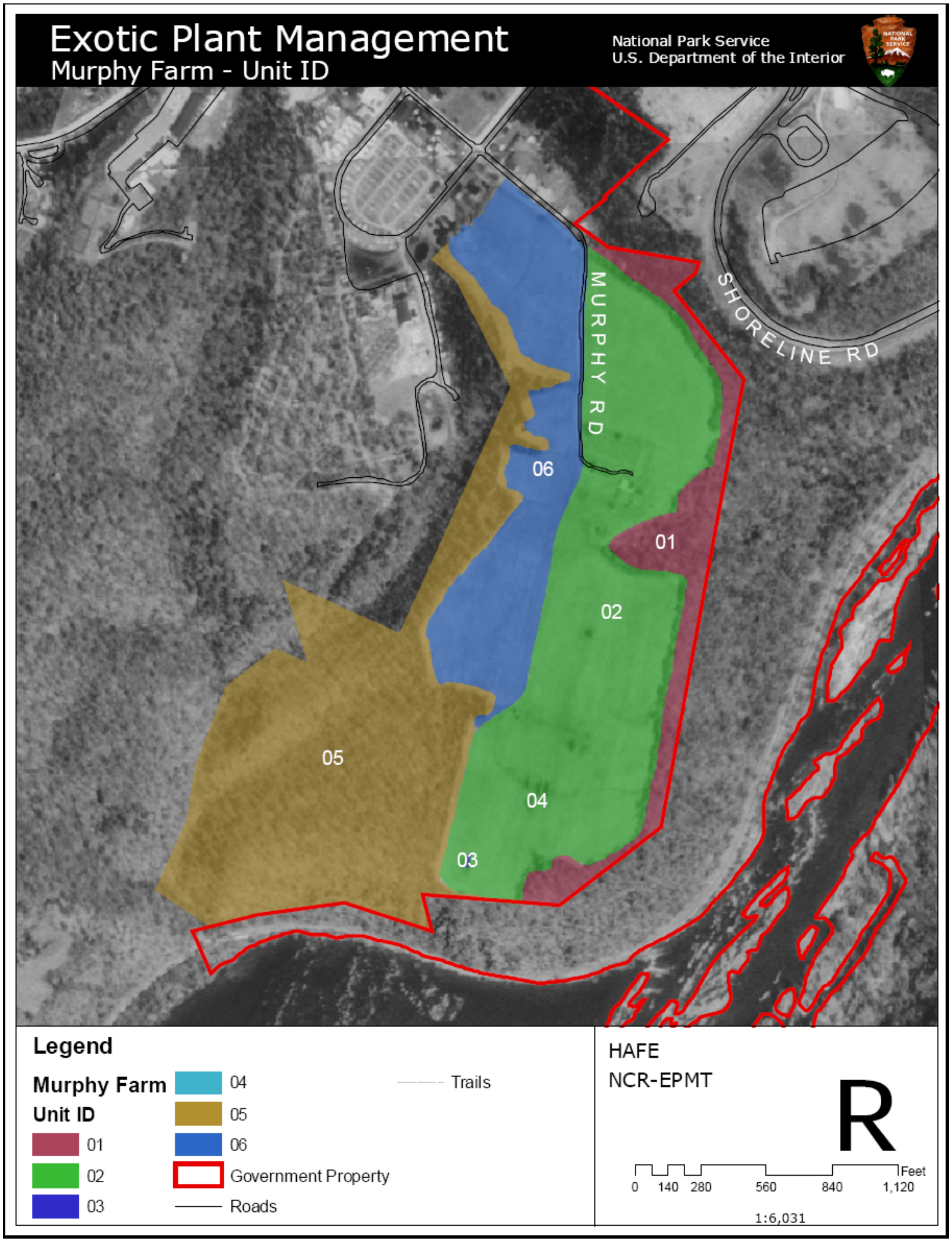
Exotic plant management units at the Visitor Center (NPS 2007j)



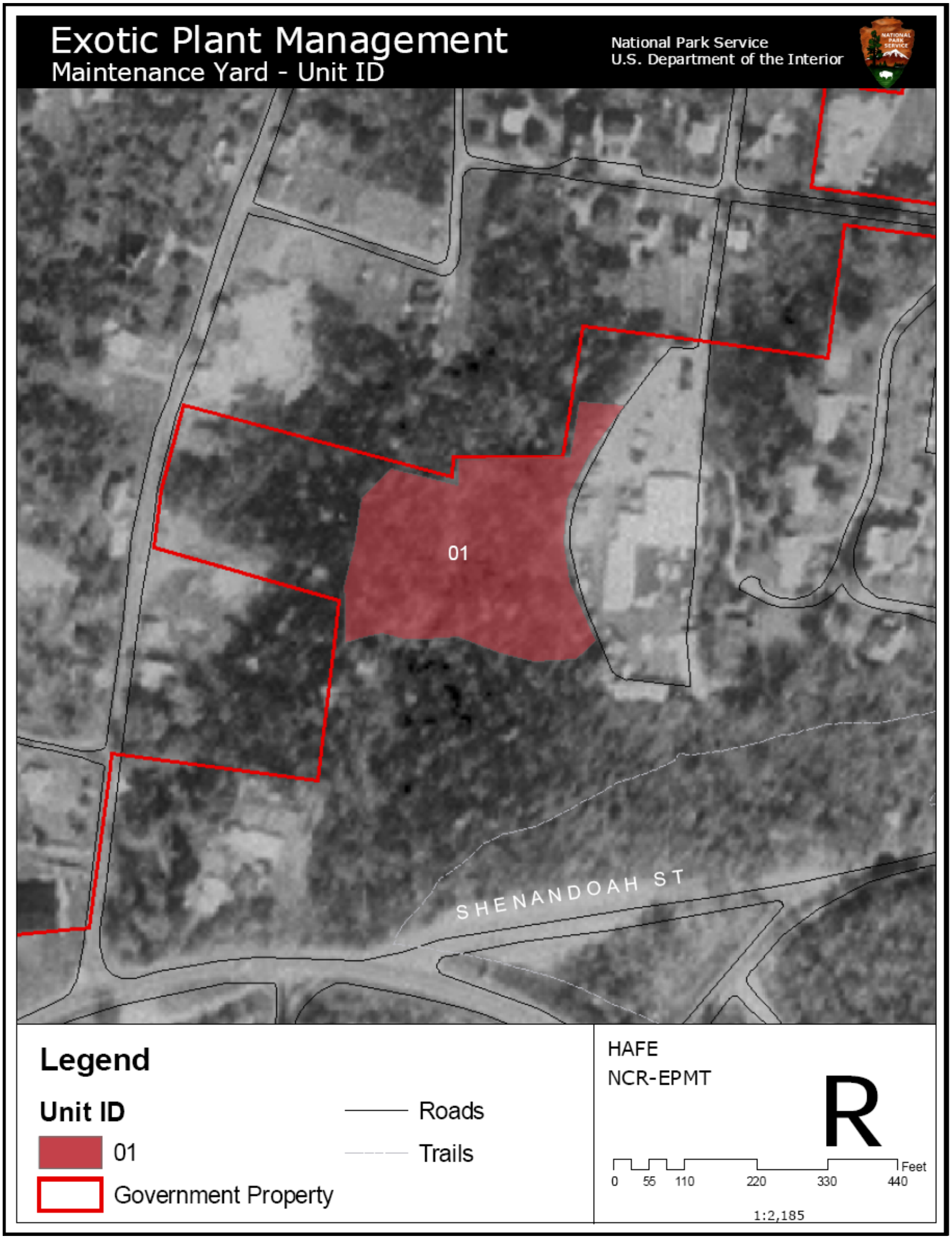
Exotic plant management units at Maryland Heights (NPS 2007j)



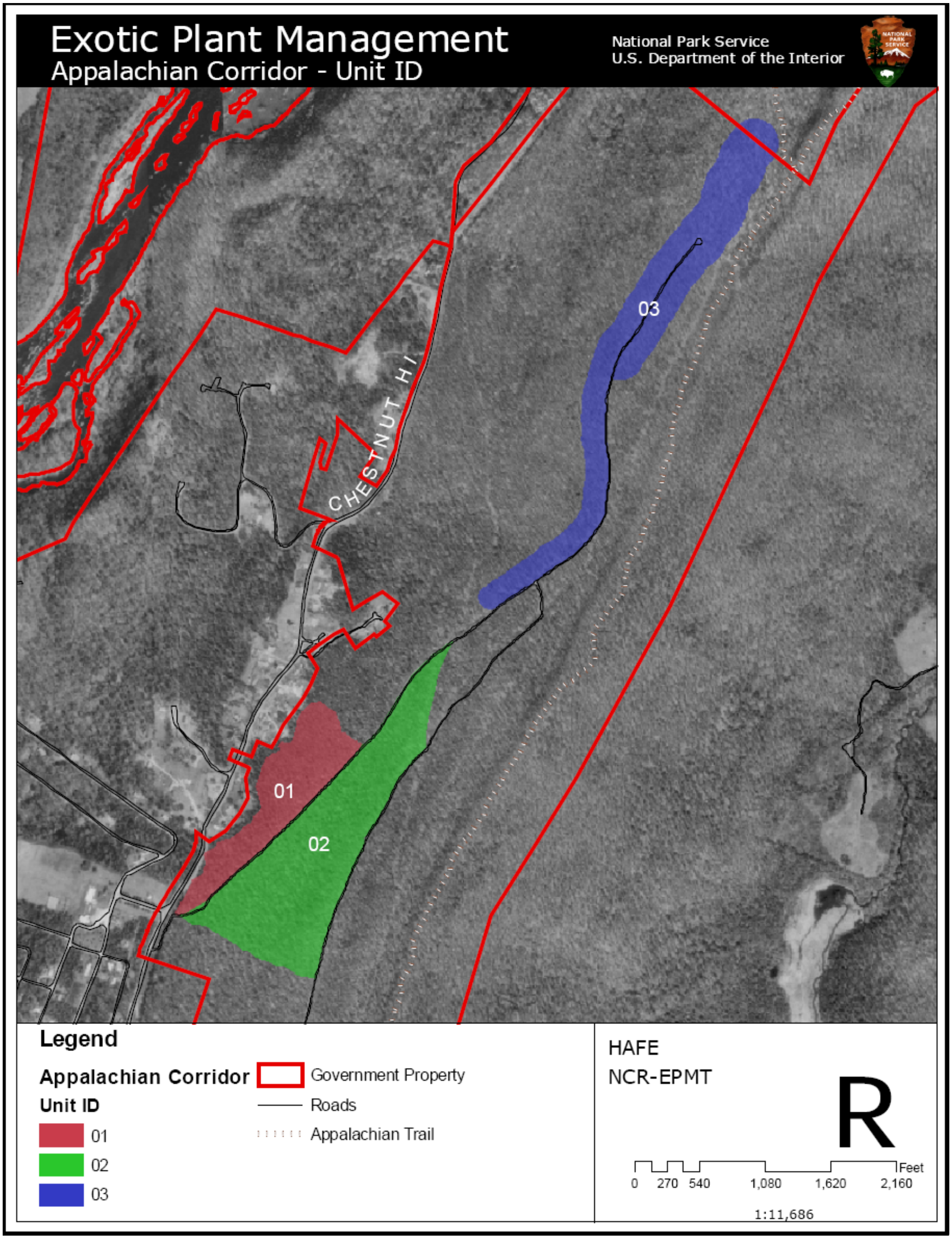
Exotic plant management units at Murphy Farm (NPS 2007j)



Exotic plant management units at the maintenance yard (NPS 2007j)



Exotic plant management units at the Appalachian Corridor (NPS 2007j)



Exotic plant management units at the gas station (NPS 2007j)

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EDUCATION

M.N.R., Natural Resources, Virginia Polytechnic Institute and State University, expected in Spring 2010
M.S., Earth Science, Dartmouth College, 2002

- Thesis title: "Investigating New Hampshire orchards as a possible source of arsenic contamination"

B.S., Geology, Washington and Lee University, 2000

- Magna cum laude, Honors Thesis in Geology

B.A., Music, Washington and Lee University, 2000

- Magna cum laude, Honors Thesis in Music

WORK EXPERIENCE

2004-present Environmental Scientist III, Tetra Tech, Inc., Fairfax, VA

- Inspector – Conducts solo and leads team regulatory inspections and audits (over 75 unique inspections to date) to assist the state of California and US EPA Regions 2, 4, 5, and 9 in improving wastewater management practices, including file and program document reviews, staff interviews, industrial facility site visits, and inspection summary reports.
- Trainer – Conducts on-the-job pretreatment program training for US EPA, state, local, and internal company staff; presents training modules at the annual National Pretreatment Meeting.
- Regulatory support – Government contractor working on drinking water and wastewater projects for US EPA; familiar with federal regulations, especially the Clean Water Act (CWA). Working on projects (regulatory development and technical support) involving the Pretreatment Program, Cooling Water Intake Structures §316(b) Rule, the National Pollutant Discharge Elimination System (NPDES) Permit Program, the Clean Water Act Awards Program, and the Water Security, Source Water Protection, and Concentrated Animal Feeding Operations Programs.
- Researcher and program implementation support – Collects information and develops technical materials (e.g., white papers, guidance manuals, memoranda, fact sheets, outreach materials); organizes stakeholder interfaces and conducts interviews for data collection; prepares, formats, and manages databases; conducts data analysis.
- Web support – Supports the design, modification, and deployment of the US EPA Pretreatment Program's Quickplace Web site and US EPA's Source Water Protection Web site; collects information for the Web sites, writes content, and performs database and site maintenance.

2002-2004 Senior Analyst, The Cadmus Group, Inc., Arlington, VA

- Government Contractor – Worked on projects involving the Federal and State drinking water quality standards and experience in voluntary government programs (e.g., ENERGY STAR marketing and media analysis, Indoor Air Quality-Tools for Schools Program).
- Researcher – Conducted literature, web-based, and archival research, used in the development (design, layout, technical content and drafting) of guidance and technical documents, presentations, case studies, reports, briefs, and multi-media materials for government clients.
- Conference planning – Provided logistical, organizational, and administrative support for conference/workshop planning (4 conferences, up to 450 attendees).

PUBLICATIONS

Wong, Christine (primary researcher). *Harpers Ferry National Historical Park: A Resource Assessment*. National Parks Conservation Association. February 2009.

Carl E. Renshaw, Benjamin C. Bostick, Xiahong Feng, Christine K. Wong, Elizabeth S. Winston, Roxanne Karimi, Carol L. Folt, and Celia Y. Chen. Impact of Land Disturbance on the Fate of Arsenical Pesticides. *Journal of Environmental Quality* 2006 35: 61-67.

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