National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Natural Resource Condition Assessment for Abraham Lincoln Birthplace National Historical Park, Kentucky

Natural Resource Report NPS/CUPN/NRR—2011/445

ON THE COVER
Surrounding Knobs of the Knob Creek Unit and the Memorial Building at the Birthplace Unit of ABLI
Photographs by: Sean Taylor Hutchison

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Acronyms

ABLI	Abraham Lincoln Birthplace National Historical Park
ATN	Attainment
CASTNet	Clean Air Status and Trends Network
CBC	Christmas Bird Count
CEC	Commission for Environmental Cooperation
CFR	Code of Federal Regulations
CFU	Colony Forming Unit
CRMS	Center for Remote Sensing and Mapping Science
CUPN	Cumberland-Piedmont Network
DO	Dissolved Oxygen
dv	Deciview
EEA	Essential Ecological Attribute
FEMA	Federal Emergency Management Agency
FMP	Fire Management Plan
GIS	Geographic Information System
GMP	General Management Plan
I&M	Inventory and Monitoring
IMPROVE	Interagency Monitoring of PROtected Visual Environments
KCKC	Knob Creek Water Quality Sampling Site
KLCD	Kentucky Land Cover Dataset
KYDAQ	Kentucky Division of Air Quality
KYDGI	Kentucky Division of Geographic Information
KYDOW	Kentucky Division of Water
MDN	Mercury Deposition Network
MRLC	Multi-Resolution Land Characteristics
NA	Not Assessed
NAAQS	National Ambient Air Quality Standards
NADP/NTN	National Atmospheric Deposition Program/National Trends Network
NAV	No Reference Condition
NBKC	North Branch Knob Creek Water Quality Sampling Site
NLCD	National Land Cover Database (2001) or Dataset (1992)
NPS	National Park Service
NOAA	National Oceanic Atmospheric Administration
NRCA	Natural Resource Condition Assessment
NVCS	National Vegetation Classification Standard
NWI	National Wetlands Inventory
ppb	parts per billion
PM	Particulate Matter
QL	Quantifiable Limit
RSS	Resource Stewardship Strategy
SEEPMT	Southeast Exotic Plant Management Team
SpC	Specific Conductance
SSTS	Sinking Spring Water Quality Sampling Site
STORET	STOrage and RETrieval

SU	Standard Unit
TBD	To Be Determined
TDS	Total Dissolved Solids
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geologic Survey
VIEWS	Visibility Information Exchange Web System
VSMP	Vital Signs Monitoring Program

Publisher's Note: Some or all of the work done for this project preceded the revised guidance issued for this project series in 2009/2010. See Prologue (p. xv) for more information.

Executive Summary

This Natural Resource Condition Assessment (NRCA) of Abraham Lincoln Birthplace National Historical Park (ABLI) brings together existing scientific data and other information in order to determine the current condition of a selected suite of abiotic and biotic natural resources present within park boundaries. The purpose of this assessment is to provide National Park Service (NPS) scientists and managers with a complete and ready reference on the current state of knowledge about these natural resources with a special emphasis on graphical displays and spatial representations using a Geographic Information System and related databases.

ABLI is located in LaRue County, Kentucky and is a memorial to our 16th president. The park comprises two distinct units, the Birthplace Unit and the Knob Creek Unit located about eight miles to the northeast. Though of obvious historical and cultural significance, ABLI also possesses a range of important natural resources which were identified for this study in consultation with NPS scientists, park personnel and external experts.

The assessment framework used herein was developed by grouping the selected natural resources with their related attributes and indicators into several hierarchical levels which were adapted from approaches in the *NPS Ecological Monitoring Framework* (NPS 2005) and the Essential Ecological Attribute (EEA) categories from the United States Environmental Protection Agency – Science Advisory Board (USEPA SAB 2002). 'Indicators' are the subset of physical, chemical, and biological elements that were selected to represent the overall health or condition of a natural resource or natural system. For some indicators in this study, a suitable data record had already been established through an ongoing Inventory and Monitoring (I&M) Program of the NPS Cumberland Piedmont Network (CUPN). Some indicators also may have had a record of legacy data and some, though deemed important, had a scant history of previous study. Therefore, another significant aspect of this NRCA is to identify gaps in data and current knowledge both temporally and spatially.

In order to determine the current condition status of the study indicators, the data on each were compared against certain reference values such as existing legal and regulatory standards, any management-specified objectives, and expert opinions on the topic as appropriate. Reference values, which can be qualitative or quantitative by their nature, generally represent the desirable resource condition. Our comparison of natural resource data to the appropriate reference conditions utilized a three-color, 'stoplight' approach.

Following is the condition summary for the major abiotic and biotic natural resource categories considered in this assessment:

Abiotic Natural Resources

Water Quality

Overall Condition: Acceptable

The assessment of water quality involved analyzing data for six indicators: dissolved oxygen, pH, specific conductance, nitrate, temperature, and *E. coli*. All parameters (excepting *E. coli*) have been in 100% attainment of their established reference conditions since the water quality monitoring protocols were implemented at ABLI in 2004. During this period, *E. coli* has been in 100% attainment at the north branch of Knob Creek but only reached 90% and 83% attainment levels at the Knob Creek and Sinking Spring sampling sites respectively. Initial data from an ongoing study of aquatic insects also indicates the overall good health of the water resources.

Air Quality

Overall Condition: Of Significant Concern

In this category only one indicator received a rating of 'Acceptable' - particulate matter less than 2.5 micrometers ($PM_{2.5}$). All other parameters including ozone, total deposition, and visibility, received 'Of Significant Concern' ratings due to insufficient attainment of established reference conditions. All the air quality indicators show marginal trends toward improvement.

Land Cover

Overall Condition: Acceptable

Between 1991 and 2001 only a very small percentage (<1%) of the land within the park units had been converted from 'natural' to 'human modified' areas. During that same period only about seven acres within a 1,000 meter buffer zone around and adjacent to the Birthplace Unit transitioned from forest either to agriculture or urban and zero acres were transitioned from 'natural' to 'human modified' around the Knob Creek Unit.

Biotic Natural Resources

Vegetation

Overall Condition: Acceptable

This condition rating was based primarily on the conclusions of a recent multi-year study (Jones and Pyne 2008) that documented more than 90% of the plant species expected to occur at ABLI. Less than 4% of those were invasive species considered to be potential threats to ecological integrity at the park. ABLI also contains vegetation communities that are considered rare at the state, national, and global levels. A data gap exists pertaining to the spatial extent, severity, and management priorities concerning invasive species.

Birds

Overall Condition: Acceptable

Avian populations will likely always be small at the Birthplace Unit due to its small size, bisecting highway, and visitor use. No management actions are recommended provided the current condition is the desired condition. A recent study (Monroe 2005) documented 85% of the expected avian species.

Herpetofauna

Overall Condition: Caution

A recent study (MacGregor 2007) found only 60% of the expected herpetofauna species leading to several recommendations to help maintain or enrich their diversity. The Birthplace Unit was especially lacking in species diversity.

Mammals

Overall Condition: Acceptable

Author comments from a recent survey (Gumbert *et al.* 2006) led to this condition statement even though the goal of documenting 90% of expected species was not met. Many of the expected species not found during this survey are rare or cryptic and may yet be sighted in subsequent studies.

The finding of a single Gray Bat (*Myotis grisescens*), a federally endangered species, has potential management implications. Further studies about the how the Gray Bat uses the park units (feeding, roosting, etc.) are needed before explicit management actions concerning bats can be recommended.

Fish

Overall Condition: Acceptable

There is a lack of data on fish at the Birthplace Unit primarily due to the limited surface flow in a karstified environment, however, a study of fish conducted at Knob Creek had findings that were considered by expert opinion to be excellent when compared to the Kentucky Index of Biotic Integrity.

Threats, Stressors and Disturbances

In this category, the ones deemed to be potentially important concerns at ABLI include aspects of air quality (ozone, wet and dry deposition), visibility, aspects of water quality (*E. coli*), land cover change, fires, extreme disturbance events such as floods and storms, invasive/exotic plants and animals, infestation, disease, and trauma, and visitor use.

The threats, stressors and disturbances that were evaluated in this study include:

Fires: Acceptable
Subsurface Geologic Process: Caution
Severe Weather: Caution
Invasive Species: Caution
Ozone: Caution
Wet and dry deposition: Of Significant Concern
Visibility: Of Significant Concern
E. coli: Caution
Land Cover change: Acceptable
Infestation, Disease, and Trauma: TBD
Visitor Impacts: TBD

Acknowledgments

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Meetings with ABLI personnel Sandy Brue, Chief of Interpretation, and Keith Pruitt, Superintendent, were very useful in framing the park perspective and setting meaningful goals for the assessment.

Discussions with Jeff Albright, NRCA Program Coordinator, and his technical guidance were helpful in developing the assessment framework and keeping us on track in the early stages of the project.

We also thank colleagues from Western Kentucky University who contributed their skills and support in various ways: Marilyn Anderson and the ARTP Staff, Dr. David Keeling, Head, Department of Geography and Geology, Dr. John All, Kevin Cary, and Wendy DeCroix.

Prologue

Publisher's Note: This was one of several projects used to demonstrate a variety of study approaches and reporting products for a new series of natural resource condition assessments in national park units. Projects such as this one, undertaken during initial development phases for the new series, contributed to revised project standards and guidelines issued in 2009 and 2010 (applicable to projects started in 2009 or later years). Some or all of the work done for this project preceded those revisions. Consequently, aspects of this project's study approach and some report format and/or content details may not be consistent with the revised guidance, and may differ in comparison to what is found in more recently published reports from this series.

Publisher's Note: Some or all of the work done for this project preceded the revised guidance issued for this project series in 2009/2010. See Prologue (p. xv) for more information.

Chapter 1 NRCA Background Information

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national park units, hereafter "parks". For these condition analyses they also report on trends (as possible), critical data gaps, and general level of confidence for study findings. The resources and indicators emphasized in the project work depend on a park's resource setting, status of resource stewardship planning and science in identifying high-priority indicators for that park, and availability of data and expertise to assess current conditions for the things identified on a list of potential study resources and indicators.

NRCAs represent a relatively new approach to assessing and reporting on park resource conditions. They are meant to complement, not replace, traditional issue and threat-based resource assessments. As distinguishing characteristics, all NRCAs:

NRCAs Strive to Provide…

Credible condition reporting for a subset of important park natural resources and indicators

Useful condition summaries by broader resource categories or topics, and by park areas

- are multi-disciplinary in scope[1]
- employ hierarchical indicator frameworks[2]
- identify or develop logical reference conditions/values to compare current condition data against[3,4]
- emphasize spatial evaluation of conditions and GIS (map) products[5]
- summarize key findings by park areas[6]
- follow national NRCA guidelines and standards for study design and reporting products

[1] However, the breadth of natural resources and number/type of indicators evaluated will vary by park

[2] Frameworks help guide a multi-disciplinary selection of indicators and subsequent "roll up" and reporting of data for measures ⇨ conditions for indicators ⇨ condition summaries by broader topics and park areas

[3] NRCAs must consider ecologically-based reference conditions, must also consider applicable legal and regulatory standards, and can consider other management-specified condition objectives or targets; each study indicator can be evaluated against one or more types of logical reference conditions

[4] Reference values can be expressed in qualitative to quantitative terms, as a single value or range of values; they represent desirable resource conditions or, alternatively, condition states that we wish to avoid or that require a follow-on response (e.g., ecological thresholds or management "triggers")

[5] As possible and appropriate, NRCAs describe condition gradients or differences across the park for important natural resources and study indicators through a set of GIS coverages and map products

[6] In addition to reporting on indicator-level conditions, investigators are asked to take a bigger picture (more holistic) view and summarize overall findings and provide suggestions to managers on a area-by-area basis: 1) by park ecosystem/habitat types or watersheds, and 2) for other park areas as requested

Although current condition reporting relative to logical forms of reference conditions and values is the primary objective, NRCAs also report on trends for any study indicators where the underlying data and methods support it. Resource condition influences are also addressed. This can include past activities or conditions that provide a helpful context for understanding current park resource conditions. It also includes present-day condition influences (threats and stressors) that are best interpreted at park, watershed, or landscape scales, though NRCAs do not judge or report on condition status per se for land areas and natural resources beyond the park's boundaries. Intensive cause and effect analyses of threats and stressors or development of detailed treatment options is outside the project scope.

Credibility for study findings derives from the data, methods, and reference values used in the project work—are they appropriate for the stated purpose and adequately documented? For each study indicator where current condition or trend is reported it is important to identify critical data gaps and describe level of confidence in at least qualitative terms. Involvement of park staff and National Park Service (NPS) subject matter experts at critical points during the project timeline is also important: 1) to assist selection of study indicators; 2) to recommend study data sets, methods, and reference conditions and values to use; and 3) to help provide a multi-disciplinary review of draft study findings and products.

NRCAs provide a useful complement to more rigorous NPS science support programs such as the NPS Inventory and Monitoring Program. For example, NRCAs can provide current condition estimates and help establish reference conditions or baseline values for some of a park's "vital signs" monitoring indicators. They can also bring in relevant non-NPS data to help evaluate current conditions for those same vital signs. In some cases, NPS inventory data sets are also incorporated into NRCA analyses and reporting products.

In-depth analysis of climate change effects on park natural resources is outside the project scope. However, existing condition analyses and data sets developed by a NRCA will be useful for subsequent park-level climate change studies and planning efforts.

Important NRCA Success Factors …

Obtaining good input from park and other NPS subjective matter experts at critical points in the project timeline

Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures ⇨ indicators ⇨ broader resource topics and park areas)

Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for indicator-level condition findings

NRCAs do not establish management targets for study indicators. Decisions about management targets must be made through sanctioned park planning and management processes. NRCAs do provide science-based information that will help park managers with an ongoing, longer term effort to describe and quantify their park's desired resource conditions and management targets. In the

near term, NRCA findings assist strategic park resource planning[7] and help parks report to government accountability measures[8].

Due to their modest funding, relatively quick timeframe for completion and reliance on existing data and information, NRCAs are not intended to be exhaustive. Study methods typically involve an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or indicator, reflecting differences in our present data and knowledge bases across these varied study components.

NRCAs can yield new insights about current park resource conditions but in many cases their greatest value may be the development of useful documentation regarding known or suspected resource conditions within parks. Reporting products can help park managers as they think about near-term workload priorities, frame data and study needs for important park resources, and communicate messages about current park resource conditions to various audiences. A successful NRCA delivers science-based information that is credible and has practical uses for a variety of park decision making, planning, and partnership activities.

Over the next several years, the NPS plans to fund a NRCA project for each of the ~270 parks served by the NPS Inventory and Monitoring Program. Additional NRCA Program information is posted at: http://www.nature.nps.gov/water/NRCondition_Assessment_Program/Index.cfm

NRCA Reporting Products…

Provide a credible snapshot-in-time evaluation for a subset of important park natural resources and indicators, to help park managers:

Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations
(near-term operational planning and management)

Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values
(longer-term strategic planning)

Communicate succinct messages regarding current resource conditions to government program managers, to Congress, and to the general public
("resource condition status" reporting)

[7] NRCAs are an especially useful lead-in to working on a park Resource Stewardship Strategy (RSS) but study scope can be tailored to also work well as a post-RSS project

[8] While accountability reporting measures are subject to change, the spatial and reference-based condition data provided by NRCAs will be useful for most forms of "resource condition status" reporting as may be required by the NPS, the Department of the Interior, or the Office of Management and Budget

Chapter 2 Park Description

Abraham Lincoln Birthplace National Historical Park (ABLI) is a memorial to the birthplace and boyhood home of the 16th president of the United States (Blythe *et al.* 2001). The park is comprised of two units separated by approximately eight miles. The Birthplace Unit features a large memorial building and information resources that attract approximately 200,000 visitors per year. The Knob Creek Unit, sometimes known as the Boyhood Home Unit, is a more rural setting. The Birthplace Unit and the Knob Creek Unit measure approximately 113 and 228 acres respectively.

2.1 Setting

ABLI is located in LaRue County in the central Kentucky region. According to the 2000 census, LaRue County had a population of 13,373 ranking it 82nd among the 120 counties in Kentucky. According to the Kentucky State Data Center the population of LaRue County is expected to grow to 14,563 by the year 2020 (KSDC 2009). The Birthplace Unit is located approximately three miles south of Hodgenville, Kentucky along Highway 31E. The Knob Creek Unit is located eight miles northeast of the Birthplace Unit also along Highway 31E (Figure 1).

2.1.1 Geography

Two distinct physiographic regions define the geography of ABLI. The Birthplace Unit is located within the Pennyroyal Plateau, which is characterized by sinkhole plains, caves, and other karst features. The Knob Creek Unit is located a short distance past the eastern boundary of the Pennyroyal Plateau in the Outer Bluegrass region, just beyond the Muldraugh Escarpment which divides the two. This area is characterized by steep slopes and gullies and is often referred to as the Knobs region of Kentucky.

The United States Environmental Protection Agency (USEPA) uses the concept of ecoregions as an alternative to traditional geographic divisions. The incorporation of ecology-based elements into regionalization is seen as essential to addressing negative anthropogenic influences on sensitive ecosystems (Commission for Environmental Cooperation (CEC) 1997). Ecoregions are defined areas of similar physiography, climate, biology, and human activities that sometimes conform to, but are not necessarily restricted by, traditional geographic boundaries. Ecoregions are classified by increasing levels of detail. Level I ecoregions are the broadest classification and Level IV ecoregions are the smallest level of geographic distinction.

ABLI lies within the Eastern Temperate Forest Level I ecoregion which is characterized by a moderately humid climate and relatively dense and diverse forests (CEC 1997). Within the Eastern Temperate Forest lies an approximately 950,000 km^2 area called the Southeastern Plains which is the Level II ecoregion for ABLI. This ecoregion is characterized by irregular plains and low hills with oak, hickory, loblolly and shortleaf pine dominating the tree species (CEC 2008). The Interior Plateau is the Level III ecoregion of ABLI that extends northward from southern Alabama through middle Tennessee into central Kentucky and into parts of southern Indiana and Ohio. This area is described as having distinct geology compared to neighboring regions to the west and lower elevations than the Appalachian region to the east, with primarily oak-hickory forests and diverse fish fauna (USEPA 2010). The same geographic boundary (the Muldraugh Escarpment) that separates the ABLI park units into different physiographic regions also divides

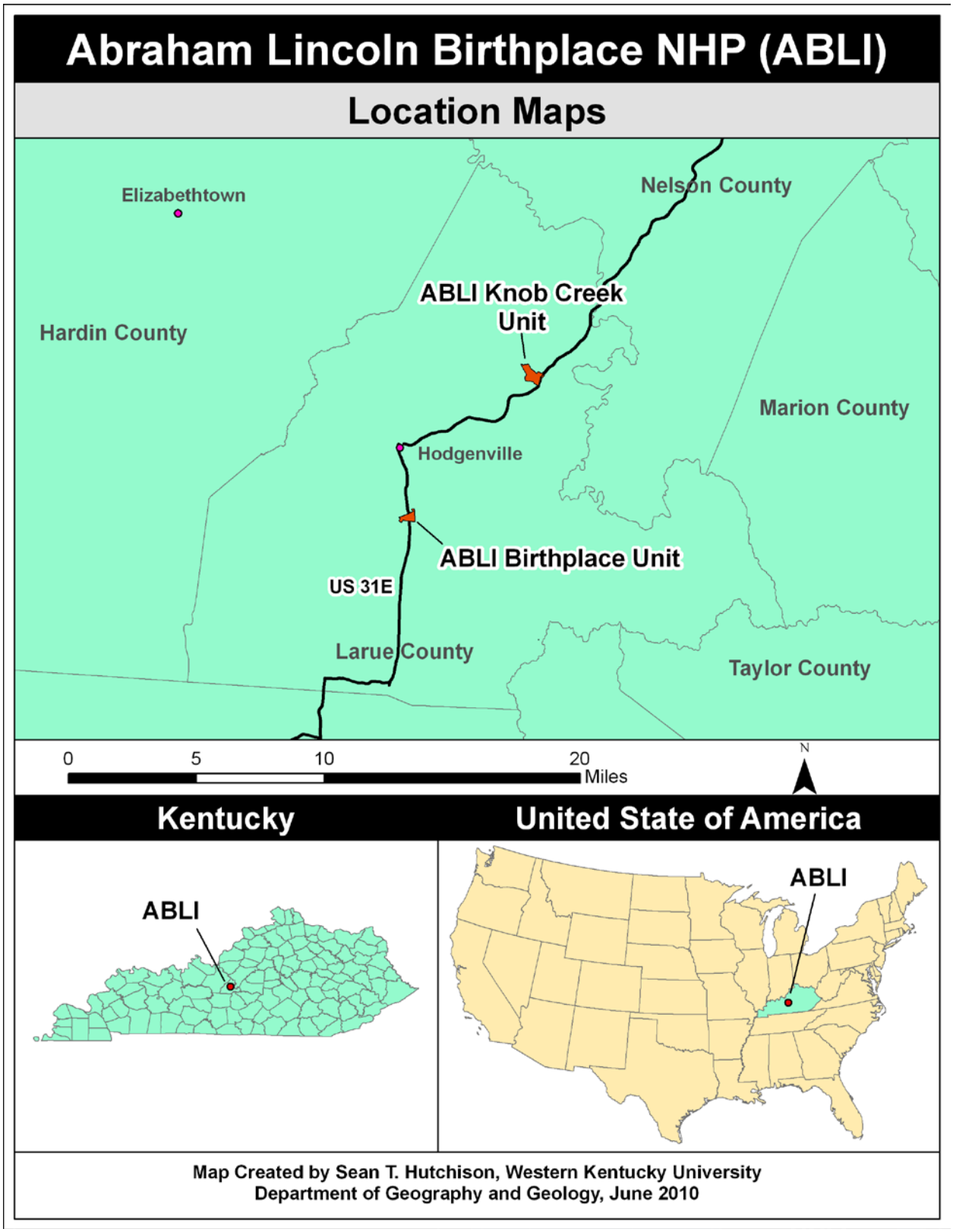

Figure 1. General location map for ABLI.

the units into different Level IV ecoregions which are described by Woods *et al.* (2002). The Birthplace Unit lies within the Mitchell Plain Level IV ecoregion which is called the Pennyroyal Plateau or, informally, the 'sinkhole plain' in Kentucky. This region is underlain by limestones of the Mississippian Period which contain well developed karst features, has potentially degraded water quality due to human activity and possible natural occurrences of bluestem prairie and oak-hickory forests that compete with extensive crop and pasture land. The Knob Creek Unit of ABLI lies within the Knobs-Norman Upland Level IV ecoregion which can be underlain by Silurian through Mississippian age sedimentary rocks and characterized by rounded hills with a range of geologic, topographic, and ecological diversity, and numerous perennial upland streams. Figure 2 is a map highlighting the Level IV ecoregions of ABLI as they occur within the larger, Interior Plateau Level III ecoregion and their location within Kentucky.

2.1.2 Geology

The geologic setting is important because it has a strong influence on the development of the landscape and in turn the biotic inhabitants. Human activities in particular are strongly influenced by the geologic resources available within the local area. There is no doubt that the presence of abundant water at Sinking Spring was an attractive, if not essential, attribute considered by Thomas Lincoln when he purchased his farm in 1808 at what we now know as the Birthplace Unit. Later, when the family relocated to Knob Creek, the fertile soils of the floodplain there certainly held the promise of future prosperity.

Both ABLI park units are located within the Hodgenville 7.5 minute geologic quadrangle map (GQ-749, Moore 1968; Johnson 2005) and their bedrock geology is illustrated in Figure 3. The formations displayed on the maps belong to the Mississippian Period and, in stratigraphic (ascending) order, are known as the Borden Formation, Harrodsburg Limestone, Salem Limestone, and St. Louis Limestone. In some places Quaternary alluvium overlies the Mississippian bedrock as unconsolidated deposits of mixed sediments mainly associated with streams and their floodplains.

The following descriptive information for the geologic units in Figure 3 is derived primarily from the Geologic Resources Inventory report for ABLI (Thornberry-Ehrlich 2010).

The Birthplace Unit is underlain in its entirety by the St. Louis Limestone which is one of two principal formations (the other being the Ste. Genevieve Limestone, not present on the map) that comprise the Pennyroyal Plateau or 'sinkhole plain' in this region of Kentucky. The lithology is primarily limestone, dolostone, and limy shale with silty, carbonaceous, siliceous, and cherty zones present. The relatively pure limestone layers of the St. Louis Limestone were once quarried locally.

The St. Louis Limestone forms the rolling landscape at the Birthplace Unit and is prone to karst development supporting a vast network of sinkholes, underground streams and caves in the area. Figure 4 illustrates the abundance of closed depressions and sinkholes that characterize the surface of the Birthplace Unit. These represent active or potential inputs to the karst system and they require planning and management relative to the potential karst hazards described below.

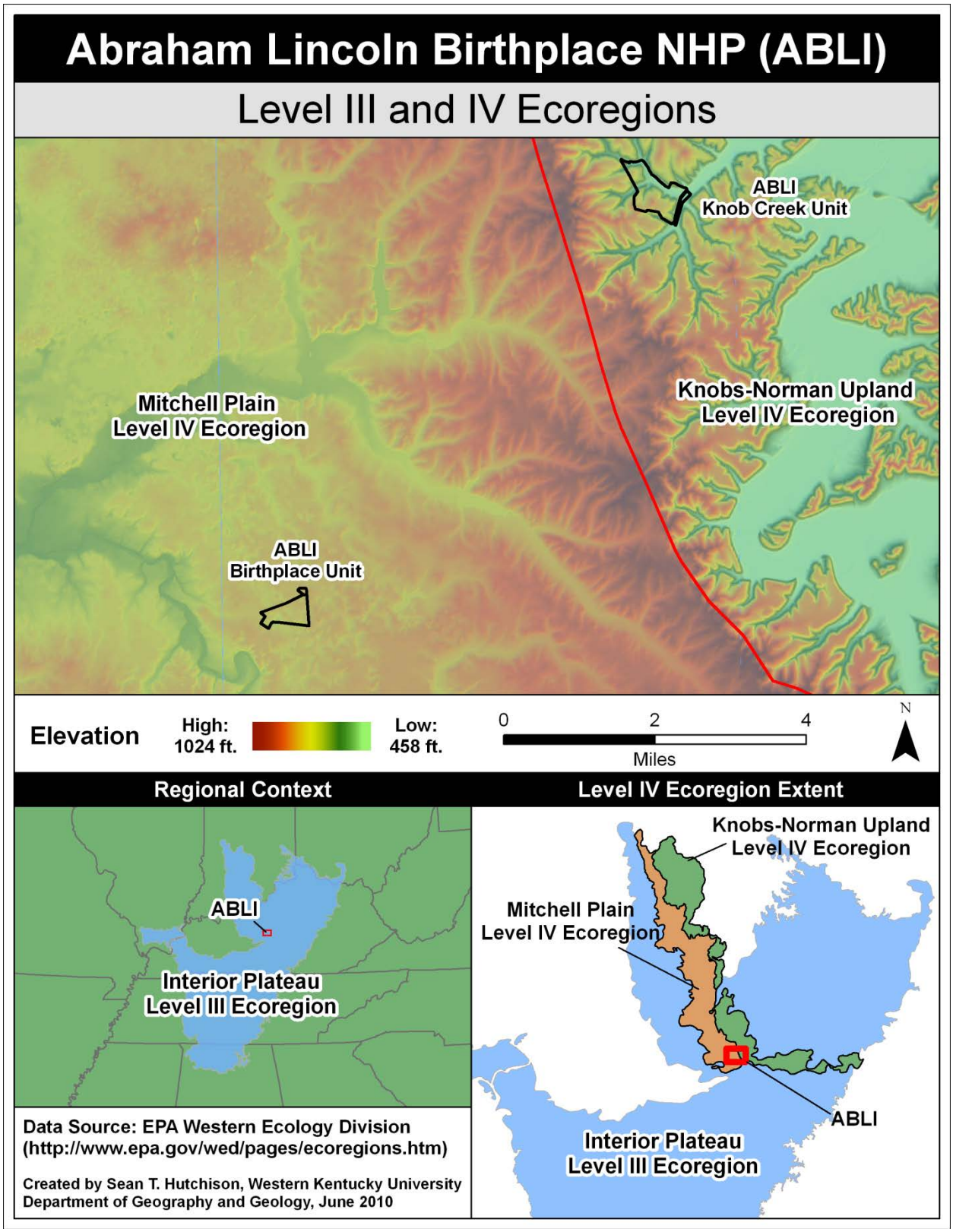

Figure 2. Level III and IV ecoregions for ABLI.

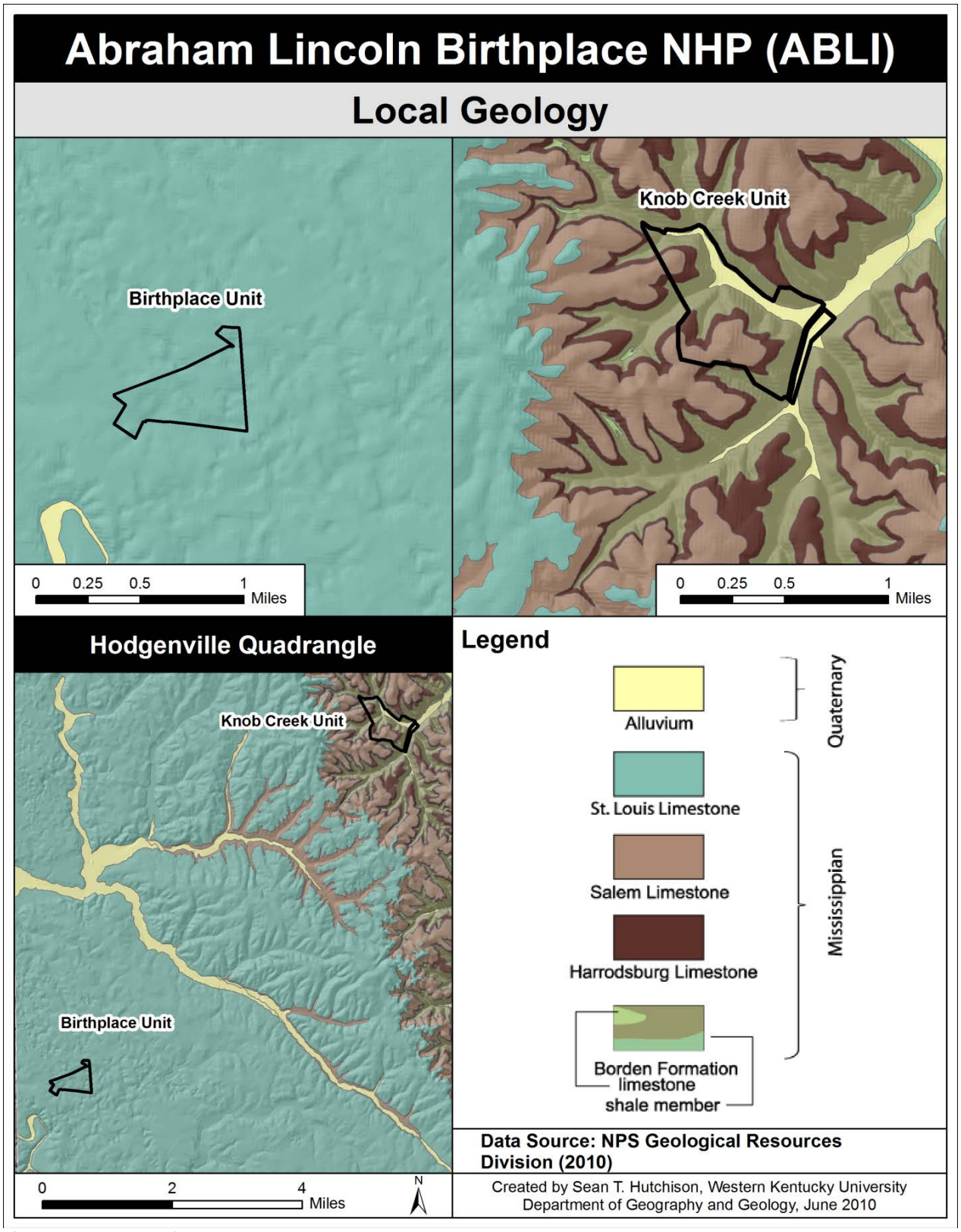

Figure 3. ABLI geology map.

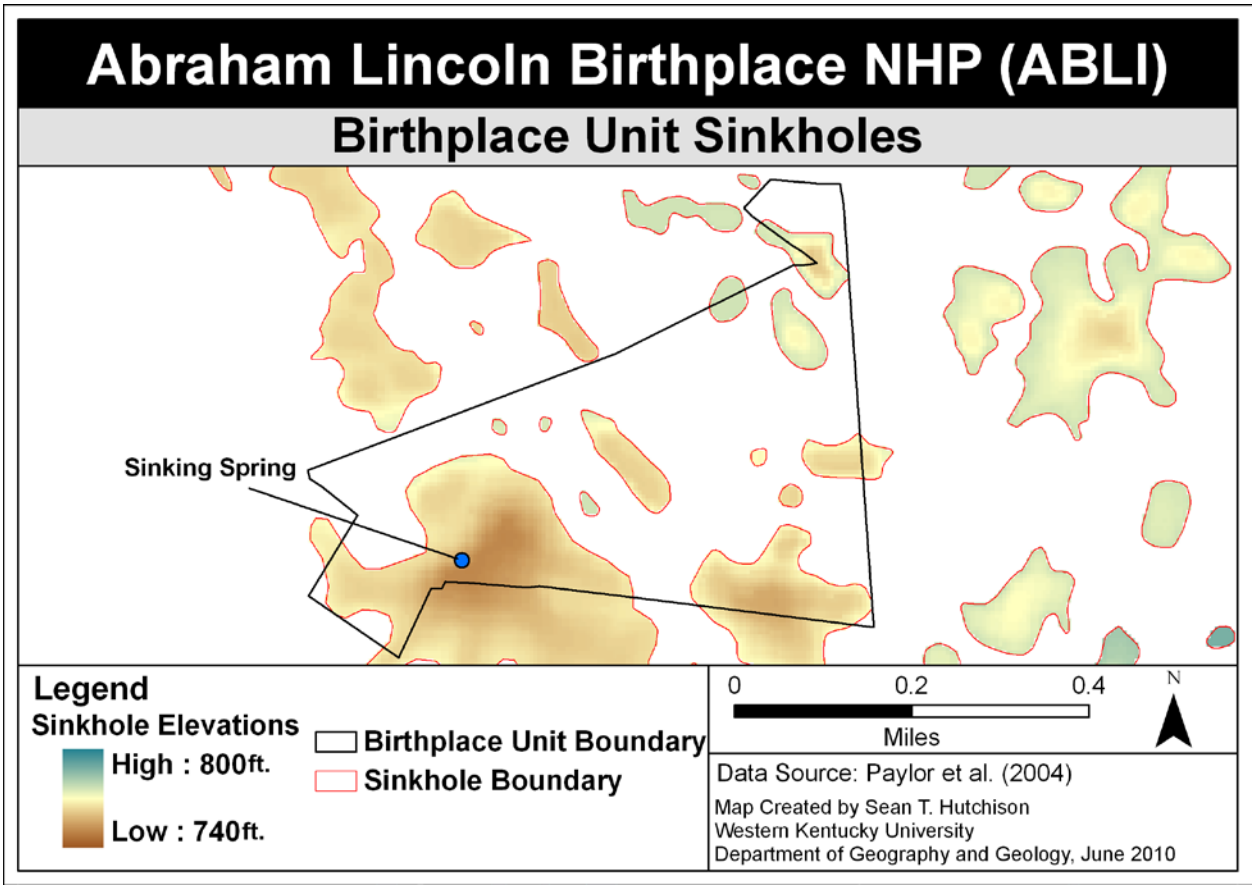

Figure 4. Birthplace Unit sinkhole map.

As one travels north and east toward the Knob Creek Unit, the terrain changes in a descent along the Muldraugh Escarpment which marks the transition between the Pennyroyal Plateau and the Outer Bluegrass or Knobs region. The escarpment itself is highly dissected exposing the underlying geologic units. The Borden Formation, Harrodsburg Limestone, and Salem Limestone are all present within the Knob Creek Unit of ABLI.

The Borden Formation contains seven distinct members and the uppermost, known as the Muldraugh Member, is present within the Knob Creek Unit (Johnson 2005). In the mapped area, the Muldraugh Member is largely undifferentiated as it contains interbedded shales, siltstones, and limestones. At Knob Creek, it displays a fossil-rich crinoidal limestone. The Borden Formation supports steep slopes and can be prone to slumping and sliding due to its clay content which can become plastic when wet.

The overlying Harrodsburg Limestone is characterized by coarse-grained, light olive-gray limestones that contain abundant marine fossils along with some silty and dolomitic limestone interbeds. This unit is prone to karst development and forms springs along its base near the contact with the Borden Formation.

The uppermost exposed unit at Knob Creek is the Salem Limestone which contains abundant coarse-grained limestone, dolomite, shale, and siltstone. This unit also is fossiliferous and prone to karst development.

According to the geology scoping report (NPS 2006), five significant geologic issues were identified at ABLI: caves and karst, fluvial flooding and contamination, mass wasting, disturbed lands, and paleontological resources.

Karst refers to a landscape that has been shaped by the dissolution of bedrock, and is often characterized by caves and rolling sinkhole plains. Kentucky has one of the most well-developed karst regions in the world (May *et al.* 2005). This landscape presents unique challenges in terms of water quality and resource management. Karst acts as a complex subterranean plumbing system that can mix water sources underground that would otherwise never interact on the surface. Point and non-point pollution sources such as industrial waste and agricultural runoff can interact with groundwater more easily in a karst environment, which is a problem in areas where drinking water is drawn from wells or springs. The Sinking Spring is the major karst feature of ABLI. Potential issues with the spring include: adjacent agriculture, highway runoff, septic systems, litter from visitors, and increased development that could lead to a lower groundwater table.

Flooding is an issue at both park units. At the Birthplace Unit the karst features as well as the constructed underground drainage system (discussed in section 5.2.2 of this document) can cause backflow enough to flood the large sinkhole area delineated in Figure 4. At the Knob Creek Unit a portion of the park near the visitor center is on a floodplain. Contamination of the water during flood events is a potential problem, and is highly related to the problems associated with the previously mentioned karst issues.

Mass wasting refers to the downslope gravitational movement of earth materials which can occur as slow creep or as sudden collapse. Although these processes occur in both park units, the Knob Creek Unit is of particular concern owing to the steepness of some slopes there. Moreover, the lithologic composition of the Mississippian-age Borden Formation, which is present at the Knob Creek Unit, can cause stability problems if the slopes become steep or undercut (Thornberry-Ehrlich 2010). Although large rock collapses are seen as unlikely, such events are not entirely dismissed.

Related to the issues already presented is the concept of ‘disturbed lands’, which refers to modification of the natural landcover. Roads, buildings, drainage systems, and other anthropogenic elements of the park units and their immediate surroundings can disturb the natural flow of water and other inputs. The Birthplace Unit is of particular concern because of the karst issues. With proper planning, future environmental impacts may be minimized or avoided.

The final geologic issue concerns the paleontological resources, especially at the Knob Creek Unit. Fossils are an important element of Earth history and are part of the natural resources of ABLI and any other places where they may occur. Unfortunately, in areas where these fossils are exposed, there is a potential for theft and resulting damage to the outcrops. This has been noted in locations along Knob Creek but it is currently unknown to what extent the paleontological resources at ABLI have been damaged or removed.

Figure 5 is a map of the soils at ABLI. The St. Louis Limestone at the Birthplace Unit and surrounding area decomposes into an orange-red, chert-rich, clayey soil of variable thickness.

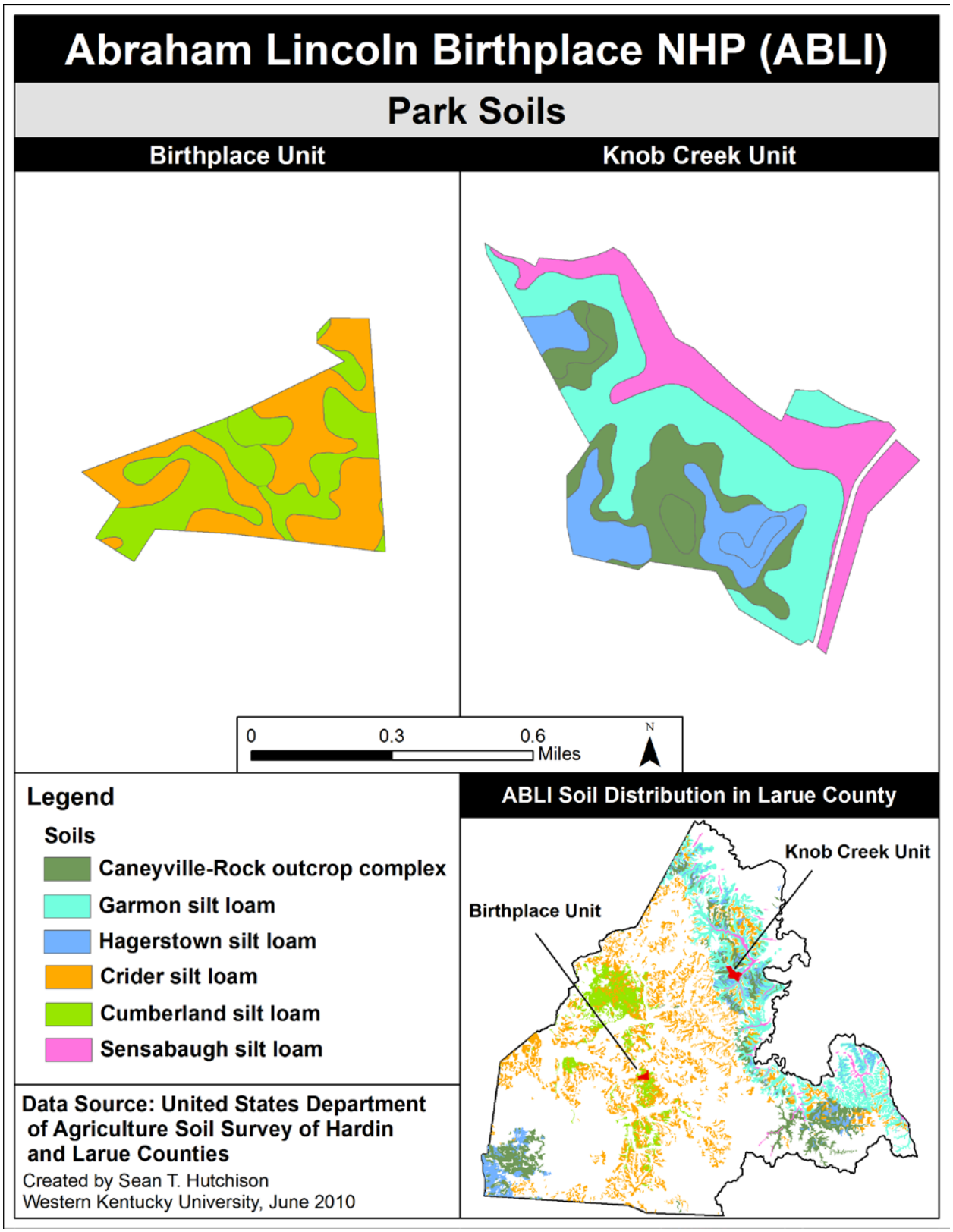

Figure 5. Soils map for ABLI.

According to the Soil Survey of Hardin and LaRue Counties (U.S. Department of Agriculture (USDA) 1979) there are two soil series associated with the Birthplace Unit, the Crider and the Cumberland. The Crider series consists of fine-silty, mixed, mesic Typic Paleudalfs formed from limestone. The Cumberland series consists of fine, mixed thermic Rhodic Paleudalfs also formed from limestone.

Due to a more diverse geology and range of slope steepnesses, there are four soil series in Figure 5 associated with the Knob Creek Unit: the Caneyville, Garmon, Hagerstown, and Sensabaugh. The Caneyville series consists of fine, mixed, mesic, Typic Hapludalfs which are found on hillsides and ridgetops. The Garmon series consists of fine-loamy, mixed mesic Dystric Eutrochrepts formed from limestone and often found on hillsides. The Hagerstown series consists of fine, mixed mesic Typic Hapludalfs which are found on hillsides, ridgetops and karst areas. The Sensabaugh series consists of fine-loamy, mixed mesic Dystric Fluventic Eutrochrepts and is developed on the flood plain of Knob Creek (USDA, 1979).

2.1.3 Hydrography

Water represents a significant aspect of both the natural environment and the historical and cultural legacy of ABLI. The physiographic boundary that separates the two park units (Figure 2) is also a watershed boundary, which is depicted fully in Figure 6. The Birthplace Unit is located in the Upper Green Watershed and the Knob Creek Unit is located in the Rolling Fork Watershed. Through an application of Geographic Information Systems (GIS) using digital elevation models, it was determined that the Upper Green Watershed, which drains both the Nolin and Green Rivers, occupies approximately 3,137 mi^2. The Green River flows westward out of the watershed and joins the Ohio River near Evansville, Indiana. The Rolling Fork Watershed occupies approximately 1,449 mi^2 and drains both the Beech Fork and Rolling Fork Rivers. The Rolling Fork River flows northwest and joins the Ohio River near West Point, Kentucky.

The ABLI park units are located near the boundary between the Upper Green and Rolling Fork Watersheds, where first-order streams are forming. This peripheral positioning of the park units means that only a small areal portion of the overall watershed directly influences their water resources.

The Sinking Spring and Knob Creek dominate the hydrological landscape at the Birthplace and Knob Creek Units respectively. Water quality monitoring at the Birthplace Unit is critical in the context of maintaining suitable habitat for biota of the karst system and historically as a drinking source for previous inhabitants including Abraham Lincoln. The Knob Creek is a seasonally fluxing, second-order stream that is sourced by first-order tributaries less than a half-mile long due to its close proximity to the Rolling Fork watershed boundary. The stream serves as a habitat for fish and other aquatic and semi-aquatic biota.

Qualitative flow measurements are recorded for the Sinking Spring, Knob Creek, and the north branch of Knob Creek as part of an ongoing water quality monitoring program at NPS (discussed in Chapter 4). Discharge is measured also but is only available for Knob Creek and the north branch of Knob Creek. The period of record used to summarize these data is June 2004 to May 2010. As reported by NPS personnel, 11 of the 16 flow measurements made at the Sinking Spring were considered ‘Normal’, three were considered ‘Above Normal’ and two were considered ‘Low’. Discharge at the Knob Creek sampling site ranged from 0 L/sec to a high of

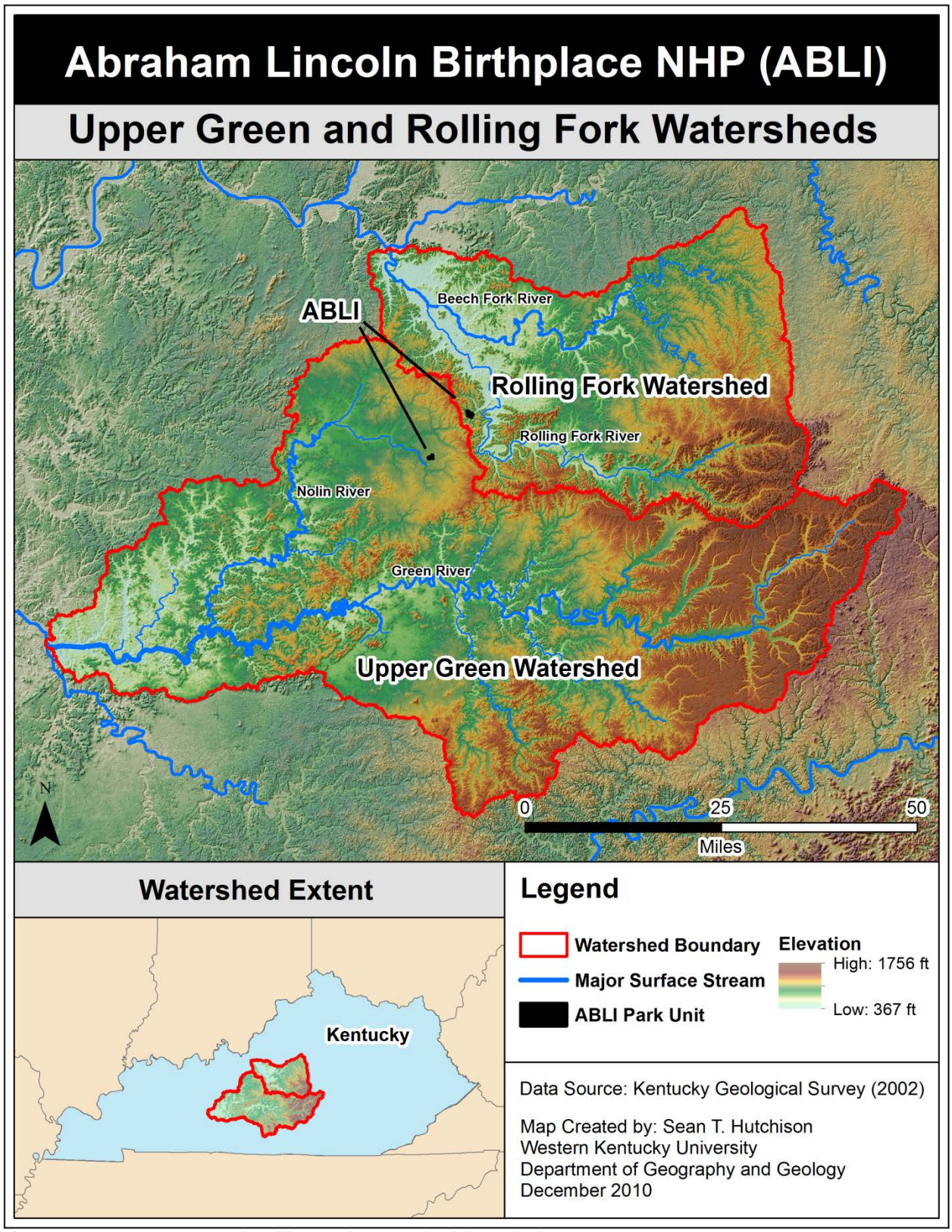

Figure 6. Upper Green and Rolling Fork watershed boundaries.

1,416 L/sec recorded on May 3, 2010, two days after historic rains impacted the region. The average discharge for the Knob Creek sampling site, excluding the May 3 outlier, is 66 L/sec. Discharge at the north branch of Knob Creek sampling site ranged from 0 L/sec to a high of 1,030 L/sec recorded on May 3, 2010. Again excluding the May 3 outlier, the average discharge for this sampling site is 54 L/sec.

During the summer of 2004 an inventory of wetlands was conducted at ABLI (Roberts and Morgan 2006). The goal of the inventory was to identify the wetland areas at both park units, and collect relevant data including hydrology, soil, vegetation, and acreage. Cultural and historical significance also were evaluated at each wetland site. The inventory, using methods outlined in Wetland Delineation Manual (U.S. Army Corps of Engineers 1987), identified nine wetland areas within ABLI, all at the Knob Creek Unit. These wetlands are quite small, accounting for 0.76 total acres with the average size being approximately 0.08 acres.

A study conducted by the U.S. Fish and Wildlife Service for the National Wetlands Inventory (NWI) (http://www.fws.gov/wetlands/) identified only one potential wetland at ABLI. It is a freshwater pond located in the southern part of the Knob Creek Unit encompassing approximately 0.19 acres. The NWI currently has no additional information regarding wetlands within ABLI boundaries.

2.2 History

2.2.1 Enabling Legislation

The Lincoln Farm Association was formed in 1906 to take stewardship of 110 acres of land that was once inhabited by Abraham Lincoln and his family. The purpose of the Lincoln Farm Association was to manage the land and develop the site as a memorial to Abraham Lincoln. On July 17, 1916 Congress passed HR 8531 which enabled United States to accept the land from the association (U.S. House 1916). The land was renamed Abraham Lincoln National Park and put under the control of the Department of War (Peterson 1968). In 2001 the Knob Creek farm, also known as the Boyhood Home, was officially incorporated into the park. The formal name of the park has changed throughout its history. The present name, Abraham Lincoln Birthplace National Historical Park, was established in 2009 (NPS 2009).

2.2.2 Cultural Significance

A report devoted to the cultural significance of ABLI was completed in 2004 which recounts the historical involvement of the Lincoln family with the land up to the present-day condition of the park including its many notable features (NPS 2004). According to that report, Thomas Lincoln purchased a 300-acre farm in 1808. The following year, Thomas and his wife Nancy gave birth to Abraham Lincoln in a one-room log cabin located on the farm. Due to disputed ownership, the Lincolns only stayed on this land for two years before moving approximately eight miles northeast to the Knob Creek farm. The Lincolns left the Knob Creek farm and relocated to Indiana in 1816 when Abraham was seven years old. The land continued to be used for agricultural purposes and passed ownership multiple times until it was acquired by the Lincoln Farm Association in 1906 and eventually converted into a national park.

Chapter 3 Study Approach

The framework developed for this National Park Service NRCA pilot study includes an analysis of biotic and abiotic natural resources as well as the aquatic and terrestrial components of ABLI. Strategies for a 'comprehensive' or a 'focused' approach were considered as each has its own strengths and weaknesses (Shilling *et al*. 2005). A 'comprehensive' approach assesses conditions for numerous components of the study area and results in a broad overview of conditions. Benefits of this approach may include the exposure of unknown problems in the study area or identification of interconnections between resource components. A comprehensive approach may not be as useful in this study because of the relatively small size of the park and limited knowledge of resource interactions. A 'focused' approach identifies critical key resources and issues up front (of all those possible) and then focuses on those. The benefit to this approach is that it may be more useful for future decision making about specific resources or issues. With restrictions of time, money, and available data, the focused approach is more feasible, but it can become too narrow and miss critical issues or overlook broad connections. The NPS pilot program takes the comprehensive approach in that it assesses abiotic and biotic natural resources, but is focused in that it identifies natural resources of interest and related issues (from all those possible) to assess. The challenge was to select a limited, but inclusive, number of indicators and associated metrics to provide an encompassing representation of individual natural resource and park conditions.

3.1 Methods

The research procedures were modified from recommendations by the California Watershed Assessment Guide (Shilling *et al.* 2005):

Step 1: *Define the purpose and objectives of the study and develop a plan for the assessment.*
The purpose of the NRCA was largely determined by the NPS in 2006 during the development of the pilot program. Chapter 1 of this document represents the most recent language describing the purpose and objectives of an NRCA as defined by the NPS. Beyond the goals of the NRCA specific concerns were identified for ABLI through management planning documents and direct input from NPS personnel and external experts.

Step 2: *Collect data and information.*
This step consisted of gathering background information on ABLI and, where appropriate, surrounding areas. Primary sources of information consisted of scientific investigations explicitly concerning ABLI or outside influences with established connections to the park. Additional data were gathered from among various federal and state agencies. Data were evaluated for quality, relevancy, and consistency across sources. All pertinent sources were compiled into a data summary sheet that was used to assess collection completeness and identify information gaps.

Step 3: *Analyze the data.*
The gathered numerical data were then prepared for statistical analysis or extracted from written reports as needed and tabulated for analysis. Spatial data were checked to ensure all layers were geographically aligned with established boundaries and where appropriate, spatial statistics were calculated. In the absence of established or applicable reference conditions qualitative statements

were examined holistically and expert opinions were consulted to frame the appropriate condition for a particular resource.

Step 4: *Integrate and report the data to inform resource management planning.*
The final step involved synthesizing the information and communicating these findings in a concise, useful manner to better inform resource management planning and stewardship strategies. To that end, numerous original geospatial maps and tables were created and incorporated into this report.

3.2 Resources of Interest

The Cumberland Piedmont Network (CUPN) Vital Signs Monitoring Program (VSMP) (Leibfreid *et al*. 2005) is the primary source from which the natural resources of interest at ABLI were identified for this study. The VSMP identified eight high-priority vital signs for monitoring at ABLI: ozone and ozone impact, weather, water quality and quantity, invasive plants "early detection", forest pests, vegetation communities, adjacent land use, and fire. The CUPN Inventory and Monitoring (I&M) Program (or another NPS program) has collected data about these vital signs. Other vital signs, though not identified as high-priority, had baseline reports or data collected through efforts initiated by CUPN.

3.3 Developing the Assessment Framework

In order to build an assessment framework for this study, the various natural resources and related issues at ABLI were grouped into several category levels (Table 1) which were adopted and slightly modified from frameworks or approaches developed by the *NPS Ecological Monitoring Framework* (NPS 2005) and the Essential Ecological Attribute (EEA) categories from the United States Environmental Protection Agency – Science Advisory Board (USEPA-SAB) framework (USEPA SAB 2002). Since data originate from several CUPN I&M Program data sources, it is logical to group natural resources according to the already integrated *NPS Ecological Monitoring Framework* (NPS 2005). The USEPA-SAB framework approach (USEPA SAB 2002) contains a very comprehensive EEA list, which was reviewed to capture any additional resource characteristics of interest.

Table 1. Assessment framework for natural resources of interest and related issues at Abraham Lincoln Birthplace National Historical Park. Source: Rinehart 2008. Categories shaded yellow originate from NPS 2005, green shading originates from USEPA SAB 2002.

LEVEL 1 CATEGORY Level 2 Category	Level 3 Category	Selected Indicator	Status
WATER			
Hydrology	Groundwater Dynamics	TBD	NA
	Surface Water Dynamics	Discharge	D
Water Quality	Water Chemistry	Dissolved Oxygen	A
		pH	A
		Specific Conductance	A
		Sulfate	A
	Nutrient Dynamics	Nitrate	A
		Phosphate	NA

Table 1. Assessment framework for natural resources of interest and related issues at Abraham Lincoln Birthplace National Historical Park. Source: Rinehart 2008. Categories shaded yellow originate from NPS 2005, green shading originates from USEPA SAB 2002. (continued)

LEVEL 1 CATEGORY Level 2 Category	Level 3 Category	Selected Indicator	Status
	Physical Parameters	Temperature	A
	Toxics	TBD	NA
	Microorganisms	*E. coli*	A
	Aquatic Macroinvertebrates	Tolerance Values	A
	Algae	TBD	NA
LANDSCAPE			
Landscape Dynamics	Land Cover and Use	Land Cover Change	A
		Impervious Surface	NA
		Landscape Pattern and Fragmentation	NA
Soundscape	Soundscape	TBD	NA
Viewscape	Viewscape (e.g. building permits, distance from viewscape)	TBD	NA
Nutrient Dynamics	Nutrient Dynamics	TBD	NA
Energy Flow	Primary Production	TBD	NA
GEOLOGY AND SOILS			
Geomorphology	Windblown Features and Processes	TBD	NA
	Hillslope Features and Processes (e.g. falls, slides, flows)	TBD	NA
	Stream/river Channel Characteristics (e.g. sedimentation rate)	TBD	NA
	Lake Features and Processes	TBD	NA
Subsurface Geologic Processes	Cave/Karst Features and Processes	Impacts of Floods and Karst Issues	A
	Seismic Activity	TBD	NA
Soil Quality	Soil Function and Dynamics	TBD	NA
Paleontology	Paleontology	TBD	D
THREATS, STRESSORS, AND DISTURBANCES			
Fire and Fuel Dynamics	Fire and Fuel Dynamics	Fire Location and Frequency	A
Extreme Disturbance Events	Extreme Disturbance Events	Severe Weather	A
Invasive Species	Invasive/Exotic Plants (e.g. extent, risk factor, non-native species diversity)	# Exotic species # Highly ranked species	A
	Invasive/Exotic Animals (e.g. extent, risk factor, non-native species diversity)	# Exotic species # Highly ranked species	A
Infestation, Disease, and Trauma	Insect Pests (e.g. extent, risk factor)	TBD	NA
	Plant Disease/Trauma	TBD	D
	Animal Diseases	TBD	NA
Visitor and Recreation Use	Visitor Use	Number of Visitors	D
BIOTA			
Flora			

Table 1. Assessment framework for natural resources of interest and related issues at Abraham Lincoln Birthplace National Historical Park. Source: Rinehart 2008. Categories shaded yellow originate from NPS 2005, green shading originates from USEPA SAB 2002. (continued)

LEVEL 1 CATEGORY Level 2 Category	Level 3 Category	Selected Indicator	Status
Ecosystems and Communities	Community Extent (e.g. floral class extent)	TBD	NA
	Community Composition (e.g. inventory of species, native species diversity, species richness)	Species Diversity	A
	Physical Structure (e.g. Vertical stand structure, tree canopy height, successional state)	TBD	NA
Species and Populations	Population Size (e.g. number of individuals in the population)	Species Richness	A
	Habitat Suitability (focal species) (e.g. Measures of habitat attributes important to focal species)	TBD	NA
Fauna			
Ecosystems and Communities	Community Extent	TBD	NA
	Community Composition (e.g. inventory of species, native species diversity, species richness)	Species Diversity	A
Species and Populations	Population Size (e.g. number of individuals in the population, breeding population size, number of individuals per habitat area (density))	Species Richness	A
	Habitat Suitability (focal species) (e.g. Measures of habitat attributes important to focal species)	TBD	NA
Focal Species and Communities	Freshwater Invertebrates	TBD	NA
	Terrestrial Invertebrates	TBD	NA
	Birds	Species Richness and Diversity	A
	Herpetofauna (Amphibians & Reptiles)	Species Richness and Diversity	A
	Fishes	Species Richness and Diversity	A
	Mammals (e.g. deer, bats)	Species Richness and Diversity	A
At-Risk-Biota	Threatened & Endangered Sp and Communities		
AIR AND CLIMATE			
Air Quality	Ozone	Ozone Concentration	A
	Wet and Dry Deposition	Total Deposition	A
	Visibility and Particulate Matter	Deciviews and PM Concentration	A
	Air Contaminants	Mercury	A
		pH	A
Weather and Climate	Weather and Climate (e.g. temperature trends, precipitation trends)	TBD	NA

A = ASSESSED, D = DISCUSSED, NA = NOT ASSESSED, TBD = TO BE DETERMINED (NOT BY THIS STUDY)

The *California Watershed Assessment Guide* (Shilling *et al.* 2005) contains a detailed section on watershed issues that provided valuable information on potential natural resource indicators for this study. Items in Table 1 shaded green came from the USEPA-SAB framework and those shaded yellow came from the NPS Ecological Monitoring Framework. The "Selected Indicators" in Column 3 may represent items currently being monitored or that will be monitored through the I&M Program, those that have been identified as resources or issues of interest by NPS personnel, or those identified by the NPS pilot program team as significant for the assessment. The "Status" column identifies which items are assessed (A), discussed (D), or not assessed (NA) in this study. This framework comprises what the NPS pilot program investigators deemed most useful for the assessment of the natural resources at ABLI.

3.4 Information Collection and Evaluation Process

The comprehensive literature search for spatial, qualitative, and quantitative data was conducted using guidelines from *Guidelines for Systematic Review in Conservation and Environmental Management* (Pullin and Stewart 2006). The strategy was to search various databases using key terms and combinations of key terms to extract relevant information about resources and issues identified through the VSMP, CUPN I&M Program or NPS personnel. State and local agency resources were also searched for information too localized to appear in various library databases. Data collection efforts focused primarily on numerical information but included useful qualitative information where numerical information was not available.

'Indicators' are the subset of physical, chemical, and biological elements that were selected through the assessment framework to represent the overall health or condition of a natural resource. For some indicators in this study, a suitable data record already exists owing to the ongoing Inventory and Monitoring (I&M) Program of the CUPN. Some indicators also may have a record of legacy data and some, though identified as important natural resources at ABLI, have little or no historic or current data.

Where an indicator already had an established numerical standard or reference condition at the federal, state, or local level (or through accepted scientific practice), it was used to evaluate the current condition of the indicator. The health of each indicator is expressed as a percentage of its data that are in compliance with its reference condition, *i.e.* its 'percent attainment' (%ATN). Where indicators did not have an established standard, accepted practice and expert opinion were relied upon in order to make the condition statement. Where available, recommendations for management actions (taken from expert opinion and completed resource studies) are provided.

A natural resource was given a summary condition status based on all its indicators. The three applicable condition statements are 'Acceptable', 'Caution', and 'Of Significant Concern'. A three-color or 'stoplight' system is used along with the condition statements. Green corresponds to 'Acceptable', yellow corresponds to 'Caution', and red corresponds to 'Of Significant Concern'. Each possible condition value has a specific meaning defined by this study that does not inherently match the *de facto* meaning outside of this study. An 'Acceptable' status signals that the resource either has achieved its attainment standard and/or is considered to be in good condition by expert opinion. A 'Caution' status may signal that the resource sporadically achieves its attainment standard, and/or does not meet the acceptable level established by the CUPN, and/or the expert opinion warrants attention by park managers. When a resource is

assigned the status ‘Of Significant Concern’ it signals there is little or no attainment of an established standard and/or expert opinion has deemed it to be severely degraded.

Although an ‘Acceptable’ rating may indicate that the resource is currently in good condition it does not imply that monitoring is no longer necessary or that the resource has reached an optimum desired condition. It is the recommendation of this study that all natural resources at ABLI that receive an ‘Acceptable’ rating should continue to be monitored. Those natural resources receiving ‘Caution’ or ‘Of Significant Concern’ ratings may benefit from increased monitoring.

Chapter 4 Natural Resource Conditions

4.1 Abiotic Resources

4.1.1 Water Quality

Monitoring of water quality at ABLI dates to 1979 and a synthesis of that data up to 1999 is available (NPS 1999). The early efforts were sporadic both in terms of sampling intervals and sampling parameters. Two organizations, the NPS and the Kentucky Division of Water (KYDOW), represent the majority of all water quality data. In 2003 a consistent water quality monitoring effort was begun for CUPN parks. Joe Meiman, the hydrologist for the CUPN, began water quality monitoring at ABLI using a fixed set of parameters and a regular sampling interval. Meiman's data are the most reliable in terms of continuity, regularity, and scope and serve as the primary data for the ABLI water quality condition assessment. Other sources of water data for ABLI were gathered and analyzed and are discussed as appropriate.

The set of water quality parameters chosen by Meiman and used in this study are reported in the *Cumberland Piedmont Network Vital Signs Monitoring Plan* (Leibfreid *et al.* 2005). The document specifies priority parameters for long-term monitoring at each park in the CUPN. The six water quality parameters identified for ABLI are dissolved oxygen (DO), *Escherichia coli* (*E. coli*), nitrate (NO_3), pH, specific conductance (SpC), and water temperature. Table 2 summarizes the reference standards for the six selected water quality indicators.

Table 2. Water quality indicators with their respective units and limits.

Water Quality Indicators	Reference Standard	Source
pH (Standard Unit-SU)	6 - 9 SU	KYDOW
Dissolved Oxygen (DO) (mg/L)	> 5.0 mg/L for Cold Water >4.0 mg/L for Warm Water	KYDOW
Specific Conductance (SpC) (µS/cm)	160 to 680 µS/cm	CUPN
Nitrate (NO_3) (mg/L as N)	< 90 mg/L as N	USEPA
Water Temperature (degrees Celsius)	< 31.7°C	KYDOW
E. coli (Colony Forming Units-CFU/100 mL)	< 476 CFU/100 mL	USEPA

The following definitions of water quality parameters are summarized from *United States Geological Survey* (*USGS) Techniques of Water-Resources Investigations Book 9, Chapters A1-A9* (USGS 2001).

Dissolved oxygen (DO) is essential for documenting changes to the environment caused by both natural phenomena and human activities. Sources of DO in water include atmospheric reaeration and the photosynthetic activities of aquatic plants. Many chemical and biological reactions in ground water and surface water depend directly or indirectly on the amount of oxygen present. Insufficient oxygen can occur in bodies of water which tends to diminish the presence of aerobic organisms.

E. coli bacteria are found in wastes of warm-blooded animals. Fecal indicator bacteria are used to assess the quality of water not because they are typically disease causing, but because they are correlated with the presence of several waterborne disease causing organisms (pathogens). The

concentration of fecal indicator bacteria is a measure of water safety for body-contact recreation or for human consumption. The most widely used indicator bacteria are total coliform, fecal coliform, enterococci, fecal streptococci groups, and *E. coli*.

Nitrates (NO_3) are indicators of animal waste and potential fecal coliform problems, which can cause significant human health issues. The *Water Quality Monitoring Program for the Cumberland Piedmont Network* (Meiman 2005) noted that several water bodies within the network have elevated or slightly elevated nitrate levels that are high enough to warrant long-term monitoring.

Values of pH represent the negative logarithm of the hydrogen ion (H^+) activity in water. The pH of water is an important indicator of water system health because it directly affects physiological functions of plants and animal systems. Values less than 7 are considered acidic and values greater than 7 are considered alkaline.

Specific conductance (SpC) is the ability of a solution to carry an electric current and can be useful in estimating the concentration of total dissolved solids (TDS) in water, but there is no universal linear relation between total dissolved substances and conductivity.

Water temperature is an important parameter because it: 1) may indicate thermal pollution; 2) may help in identifying mixing of surface water through surface runoff and groundwater through groundwater drainage; 3) influences most physical, chemical, and biological processes; and 4) must be accurately measured for the determination of dissolved oxygen concentration, specific conductance, pH, rate and equilibrium of chemical reactions, biological activity, and fluid properties.

The record for water sampling at the Birthplace Unit began in 1979 but had never been recorded at the Knob Creek Unit. In 2003, the modern water quality monitoring effort began across the CUPN and three sampling sites were established at ABLI: the Sinking Spring, north branch of Knob Creek, and Knob Creek (Meiman 2005). Figure 7 shows the locations of these sampling sites. Sinking Spring (Station ID: ABLI_SSTS) is a cold water aquatic habitat found near the memorial building at the Birthplace Unit. North branch of Knob Creek (Station ID: ABLI_NBKC) is a warm water aquatic habitat and the most easily accessible stream on the park unit property. Knob Creek (Station ID: ABLI_KCKC) is also a warm water aquatic habitat that briefly intersects with the park property near the highway.

Sampling rounds are performed on a bi-annual basis and three total rounds have been completed since 2003 with the next scheduled to be completed in 2010 for reporting due in 2011. To date, an average of 16 samples have been taken for each parameter except for *E.coli*. For reasons unknown, the Sinking Spring site received two additional samples for each parameter. Thus far, three reports summarizing the cumulative findings have been published by the NPS (Meiman 2009; Meiman 2007; Meiman 2005). The condition of water quality is considered good overall by Meiman (2009) who noted that some parameters should be watched carefully including nitrate and *E. coli*. All parameters but *E. coli* have met their established reference condition for 100% of all samples since 2003.

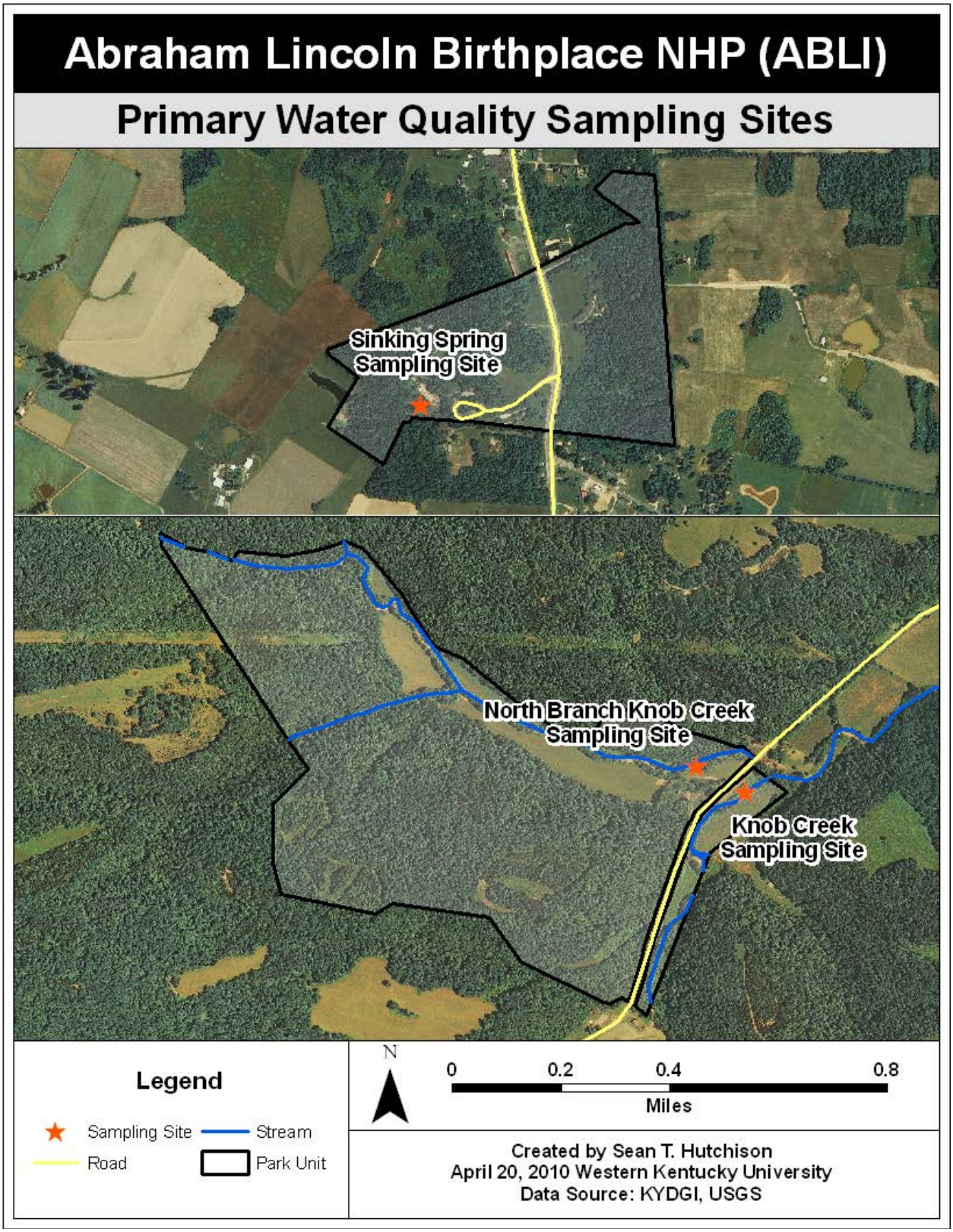

Figure 7. Water quality sampling sites at ABLI as established by NPS hydrologist Joe Meiman.

Primary sampling data were sorted by sampling site and summary statistics were calculated for each parameter. In several cases a replicate sample was taken along with the regular field sample. In these cases the values for the replicate and the regular sample were averaged. In one case a regular field sample recorded a non-numeric value below the quantifiable limit but the replicate sample recorded a standard numeric value. In this case the quantifiable value was used.

Tables 3 to 5 below detail the parameters for each sampling site. It is important to note that one *E. coli* value is non-numeric ('Present>QL'), meaning the value was above the quantifiable limit (QL) of the detection method. In this case the value was included in the count and attainment columns but not the other statistics. When a parameter achieves 95 – 100% attainment (%ATN in the Tables) across all samples it is considered 'Excellent', 75 - 95% is considered 'Fair', and less than 75% is considered 'Poor' (Leibfreid pers. com. 2010).

Table 3. Water Quality at Knob Creek sampling site (Station ID: ABLI_KCKC).

Parameter	Count	Min	Median	Max	Mean	Std Dev	%ATN
pH (SU)	16	7.37	8.10	8.58	8.00	0.30	100%
DO (mg/L)	16	6.78	10.29	13.84	10.31	1.82	100%
SpC (µS)	16	255	400	510	395	69	100%
Nitrate (mg/L)	16	0.07	0.48	2.55	0.85	0.75	100%
Temp (°C)	16	2.3	12.5	23.1	13.4	6.0	100%
E.coli (CFU/100ml)	10	4	85	1092	219	335	90%
Green = Excellent, Yellow = Fair, Red = Poor, %ATN = Attainment, QL = Quantity Limit.							

Table 4. Water Quality at North Branch Knob Creek sampling site (Station ID: ABLI_NBKC).

Parameter	Count	Min	Median	Max	Mean	Std Dev	%ATN
pH (SU)	16	7.00	7.97	8.55	7.97	0.43	100%
DO (mg/L)	16	4.24	9.96	13.41	9.51	2.24	100%
SpC (µS)	16	234	388	480	374	62	100%
Nitrate (mg/L)	16	0.02	0.23	0.95	0.36	0.31	100%
Temp (°C)	16	2.3	12.1	21.6	12.5	5.3	100%
E.coli (CFU/100ml)	10	1	101	345	126	127	100%
Green = Excellent, Yellow = Fair, Red = Poor, %ATN = Attainment, QL = Quantity Limit.							

Table 5. Water Quality at Sinking Spring sampling site (Station ID: ABLI_SSTS).

Parameter	Count	Min	Median	Max	Mean	Std Dev	%ATN
pH (SU)	18	6.94	7.58	8.36	7.59	0.40	100%
DO (mg/L)	18	7.31	8.75	13.16	9.05	1.51	100%
SpC (µS)	18	289	432	610	431	73	100%
Nitrate (mg/L)	18	0.82	4.00	11.50	4.35	2.24	100%
Temp (°C)	18	11.1	14.2	16.2	13.9	1.6	100%
E.coli (CFU/100ml)	12	5	129	Present> QL	290	450	83%
Values of "Present>QL" were not included in calculations except for %ATN. Green = Excellent, Yellow = Fair, Red = Poor, %ATN = Attainment, QL = Quantity Limit.							

In 1999 a report was compiled by the NPS Water Resources Division and Servicewide Inventory and Monitoring Program titled *Baseline Water Quality Data Inventory and Analysis for Abraham Lincoln Birthplace National Historic Site* (NPS 1999). The purpose of that report was to summarize all the water quality data available from an area extending three miles upstream and one mile downstream from ABLI. At the time of its publication, the Knob Creek Unit was not yet part of ABLI. Using the Storage and Retrieval (STORET) database 1,992 observations were retrieved from 15 monitoring stations measuring 224 unique parameters. Of the 15 stations five were within park boundaries for 1124 in-park observations measuring 207 unique parameters (USEPA 2007).

The data retrieved from STORET did not conform to more recent monitoring guidelines developed in the CUPN Vital Signs Monitoring Plan but were instead an amalgamation of drinking water sampling done by the KYDOW and past NPS monitoring efforts. The parameters used in the Meiman primary data set have little overlap with these legacy STORET data making comparisons between the two datasets not worthwhile. In the 1999 report, most samples were considered to be within optimal ranges except for dissolved copper (May 1996) and dissolved thallium (November 1997) both of which were observed at the Sinking Spring site. The report identified municipal wastewater discharges, agricultural activities, stormwater runoff, recreational use, and atmospheric deposition as the most likely sources of negative water quality impacts (NPS 1999).

Individual water quality indicators are rated 'Acceptable' in all categories except *E. coli,* which is rated 'Caution' at two of the three sampling sites. Table 6 summarizes the condition of the selected indicators for water quality using only the Meiman data. Chapter 5 of this document discusses the condition and justification of the assigned water quality condition at ABLI in more detail.

Table 6. Water quality condition at ABLI.

Level 3 Category	Indicator	Condition Status	Reference Condition	Data Source
Water Chemistry	Dissolved Oxygen		cold: >5.0 mg/L, warm: >4.0 mg/L	Meiman (2009)
	pH		6.0 to 9.0 SU	Meiman (2009)
	Specific Conductance		160 to 680 µS/cm	Meiman (2009)
Nutrient Dynamics	Nitrate as Nitrogen		<90 mg/L	Meiman (2009)
Physical Parameters	Temperature		<31.7 ^{o}C	Meiman (2009)
Microorganisms	*E. coli*		<476 CFU/100mL	Meiman (2009)

Green Condition= Acceptable, Yellow Condition = Caution, Red Condition = Of Significant Concern, TBD = To Be Determined, but not through Natural Resource Condition Assessment, NAV = No Reference Condition

4.1.2 Air Quality

Air pollution has been shown to affect ecological conditions, human health, and reduce aesthetic value by decreasing visibility. The National Park Service has monitored air quality within the park system since the 1970s. Many inputs influence air quality, but the primary targets for NPS monitoring are ozone, visibility, and deposition.

Ozone is both a positive and a negative for ecosystem and human health. Ozone in the stratosphere protects the Earth from harmful UV rays, however, ozone at the ground level can induce respiratory diseases and damage vegetation. Decreased visibility is the result of both natural (i.e. water vapor and dust) and anthropogenic factors (i.e. ozone and other emissions). The concern with visibility is primarily over a loss of aesthetic value because of the inherent scenic quality of national parks. Deposition refers to gases and particles such as nitrates and sulfates that accumulate on water or land. Deposition is divided into wet deposition, which is delivered via incorporation into rain, snow, fog, or mist, and dry deposition which is deposited on Earth's surface via air movements.

The United States Environmental Protection Agency (USEPA) is a primary collector of air quality data. The Clean Air Act requires the USEPA to set National Ambient Air Quality Standards (NAAQS) for six air pollutants that are considered harmful to human health. The six pollutants are: ozone (O_3), particulate matter ($PM_{2.5}$ and PM_{10}), carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and lead (Pb). The USEPA Clean Air Status and Trends Network (CASTNet, http://www.epa.gov/castnet) collects data on atmospheric gases, deposition, and certain other data used in various air quality models. The Interagency Monitoring of Protected Visual Environments (IMPROVE, http://vista.cira.colostate.edu/improve) is a well known program that monitors and reports visibility data in collaboration with the USEPA and the Visibility Information Exchange Web System (VIEWS, http://vista.cira.colostate.edu/views/).

The NPS collaborates with the National Atmospheric Deposition Program/National Trends Network (NADP/NTN, http://nadp.sws.uiuc.edu/) that monitors wet deposition and includes the Mercury Deposition Network (MDN) which measures mercury in precipitation samples. The Kentucky Division for Air Quality (KYDAQ, http://www.air.ky.gov) monitors all six NAAQS air pollutants on a county scale to establish an Air Quality Index. Currently there is no monitoring done for LaRue County where ABLI is located, however, a monitoring station is located in Elizabethtown in neighboring Hardin County.

The NPS set specific goals for monitoring and improving air quality throughout the National Park System in a 2007 report (NPS 2007a). Those goals include meeting the NAAQS standards set by the USEPA and achieving stable or improving trends through the park system. According to the report, monitoring stations are "reasonably representative" if ozone and deposition sites are located within 10 miles and visibility stations are located within 60 miles of the park boundary (NPS *ibid.*).

The closest monitoring station to ABLI is located approximately 11 miles away in Elizabethtown, Kentucky, and has been operated by the KYDAQ since 1999. This station records data on ozone and particulate matter ($PM_{2.5}$) and other NAAQS. The nearest NPS or USEPA air quality monitoring station near ABLI is located 36 miles away in Mackville, Kentucky (Station ID: MCK131) and is operated by the USEPA. The Mackville station is strictly a CASTNet program capable of recording ozone and wet deposition data. The second nearest station is located in Mammoth Cave National Park 40 miles away and is operated by the NPS (Station ID: MAC426). Several monitoring programs are active at Mammoth Cave. CASTNet is monitoring ozone and wet deposition, NADP is monitoring pH, MDN is monitoring mercury, and IMRPOVE is monitoring visibility. Figure 8 shows the locations of the Elizabethtown, Mammoth Cave, and Mackville monitoring stations in relation to ABLI.

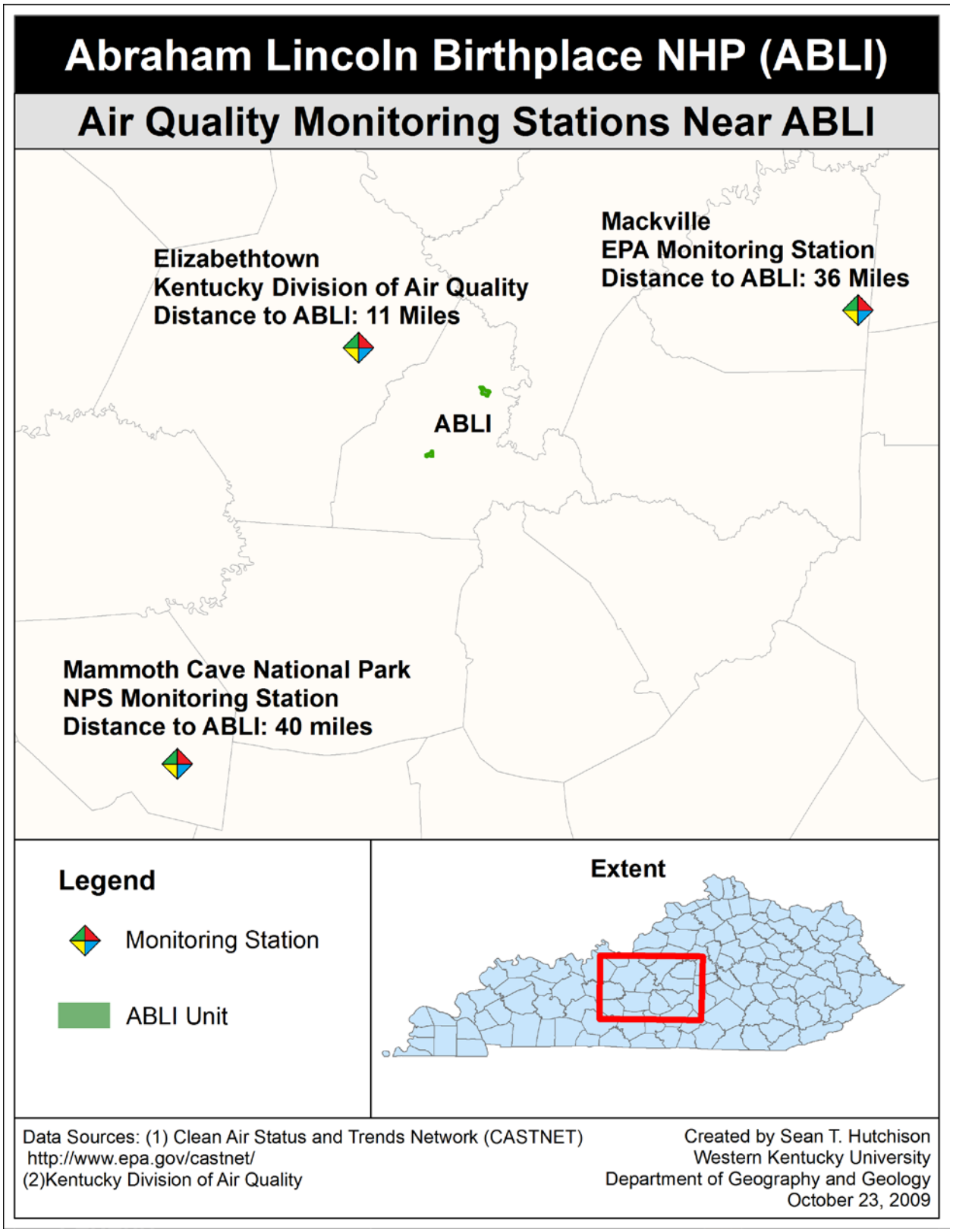

Figure 8. Map of air quality monitoring stations near ABLI.

The following parameters were used to assess the current condition status of air quality at ABLI: 1) ground level ozone; 2) pH; 3) mercury; 4) total deposition-sulfur (S); 5) total deposition-nitrogen (N); 6) fine particulate matter-$PM_{2.5}$; and 7) visibility-deciviews (dv). Table 7 summarizes the reference standards for these seven selected air quality indicators.

Table 7. Air quality indicators with their respective units and limits.

Air Quality Indicator	Reference Standard	Source
Ozone	≤ 76 ppb	EPA
Total Deposition - Sulfur	≤ 3kg/ha/yr	NPS (2010a, 2007a), Fenn *et al.* (2003), Krupa (2003)
Total Deposition - Nitrogen		
$PM_{2.5}$	≤15.0 µg/m^3	EPA
Deciviews	≤ 19.4 dv	NPS 2007a
pH	No standard	
Mercury	No standard	

Ozone samples are collected on an hourly basis during the so called "ozone season" which varies from state to state. The US Code of Federal Regulations (CFR) designate March through October as the period for Kentucky to monitor ozone (40 CFR § 58, 2010). The 8-hour daily maximums are calculated by averaging the eight consecutive hours of ozone measurements that would result in the highest value for that day. An area meets its primary and secondary ozone air quality standards if the average of the fourth highest value of annual 8-hour daily maximum data from three consecutive years is less than 75 parts per billion (40 CFR § 50, 2010).

The latest data from the Mammoth Cave, Mackville, and Elizabethtown monitoring stations are within the attainment standard. Figure 9 below plots the annual 4th highest 8-hour daily maximum ozone concentrations in parts per billion for the Mammoth Cave, Mackville, and Elizabethtown stations. The analyzed period of record for the Mackville station was 1990 through 2009. Between 1990 and 2003 all values were above the attainment value of 75 parts per billion. The analyzed period of record for the Mammoth Cave station was 2002 through 2009, however, data were recorded only from August to October in 2002. The analyzed period of record for the Elizabethtown data was 1999 through 2009. All 3-year averages for the Mammoth Cave and Mackville stations since 2003 have met the attainment value despite the yearly value for 2007 being above the attainment threshold. The Elizabethtown monitoring station achieved the attainment value from 2004-2006 and again in 2009

CASTNet stations record dry deposition only but actively combine their data with wet deposition data recorded by the NADP/NTN. The result is published as total annual deposition for each station. The period of record for the Mammoth Cave station was 2002 through 2008. The average total deposition for sulfur and nitrogen during this period was 8.47 and 6.69 kg/ha/yr respectively. The Mackville station period of record was 1992 through 2008; however, data are missing for 1996 and 1999. The average total deposition for this period for sulfur and nitrogen are 12.64 and 8.42 kg/ha/yr respectively. Figure 10 and Figure 11 show the trend of deposition over time. There is no attainment value or primary standard for total deposition. The NPS suggests values above 3.0 kg/ha/yr present a significant concern (NPS 2010a, 2007a). All values recorded for both wet and dry deposition types at both stations were significantly above the NPS

recommendation. Fine particulate matter (PM) is one of the six pollutants regulated through NAAQS because of its effects on human health, but it affects visibility as well. PM is split into two classes, $PM_{2.5}$ and PM_{10}, which represent the aerodynamic diameter expressed in

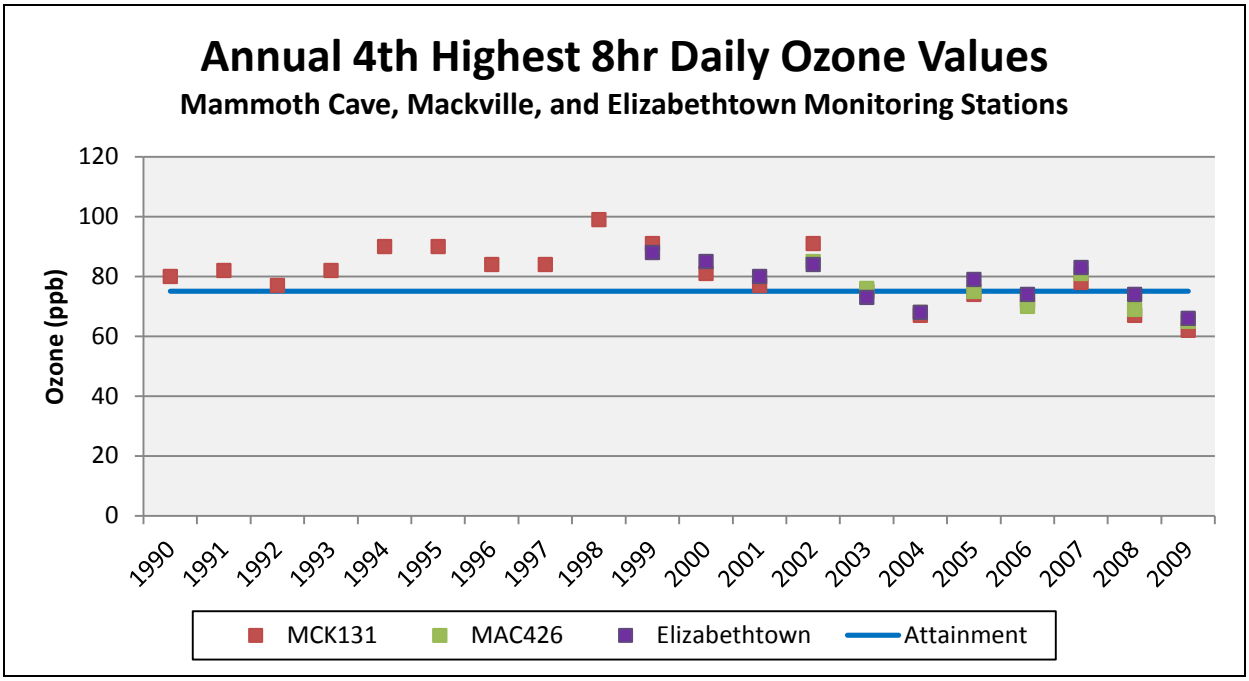

Figure 9. Annual fourth highest 8-hr daily ozone values from monitoring stations near ABLI.

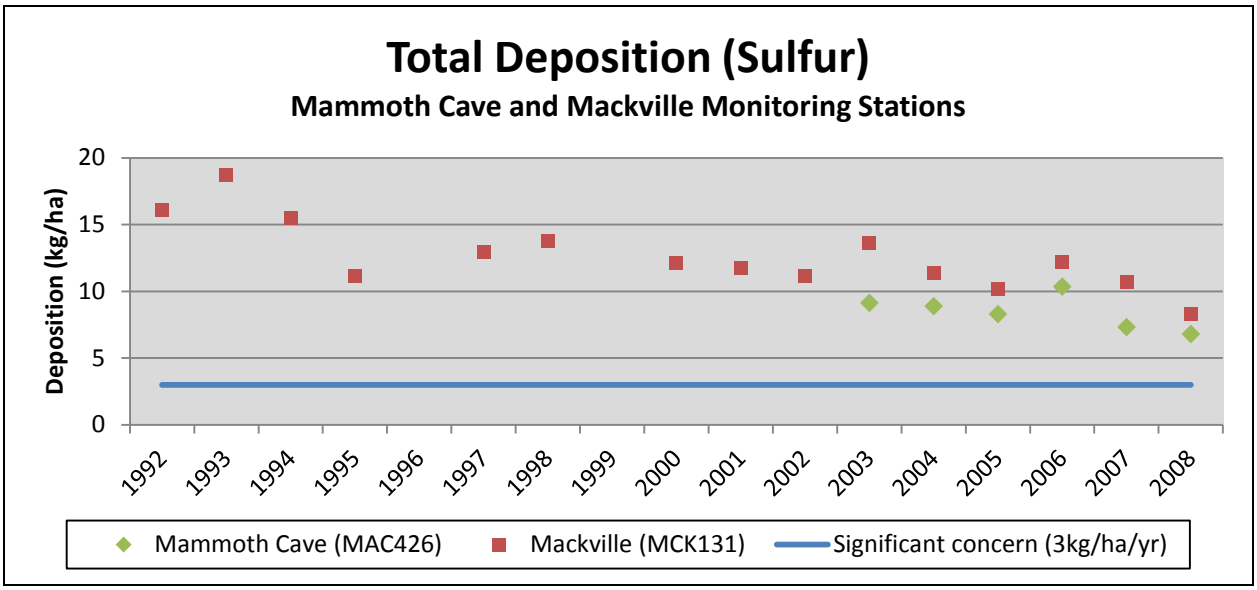

Figure 10. Total annual deposition of sulfur from monitoring stations near ABLI.

micrometers. A region is in attainment for this type of particulate matter if the annual mean is not greater than 15.0 $\mu g/m^3$. All values recorded by the Mammoth Cave IMPROVE station are less

than the established levels and therefore achieve 100% attainment. Elizabethtown also monitors $PM_{2.5}$ and is currently within attainment as shown below in Figure 12.

Visibility can also be expressed in terms of deciviews (dv). The higher the dv value the less a person can see into the distance. An increase of 1 dv amounts to a small but perceptible change

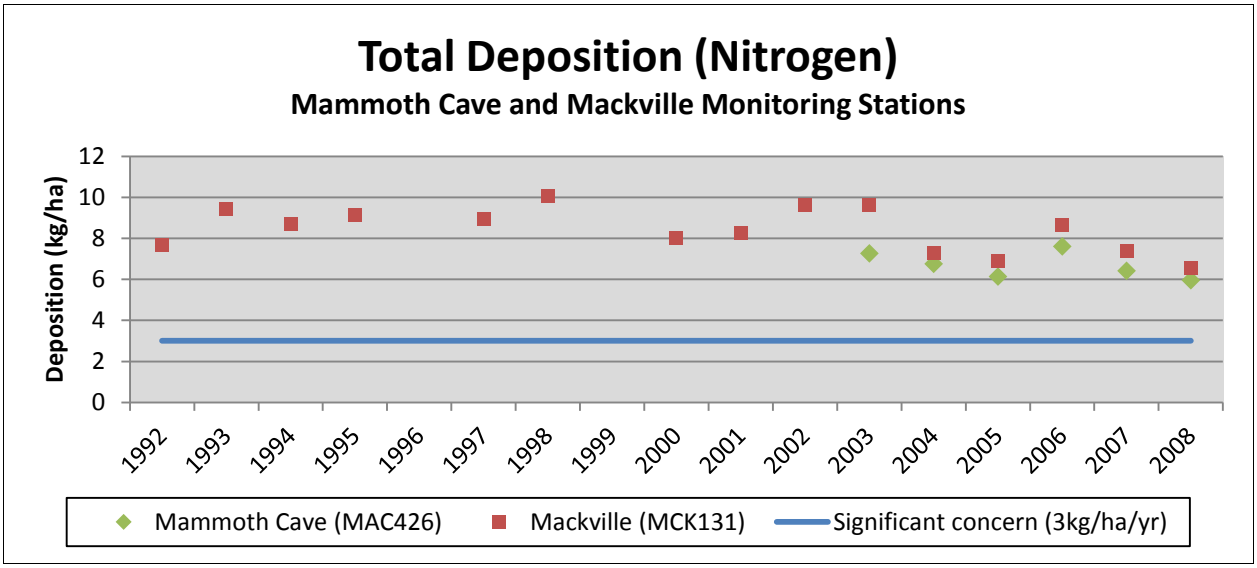

Figure 11. Total deposition of nitrogen from stations near ABLI.

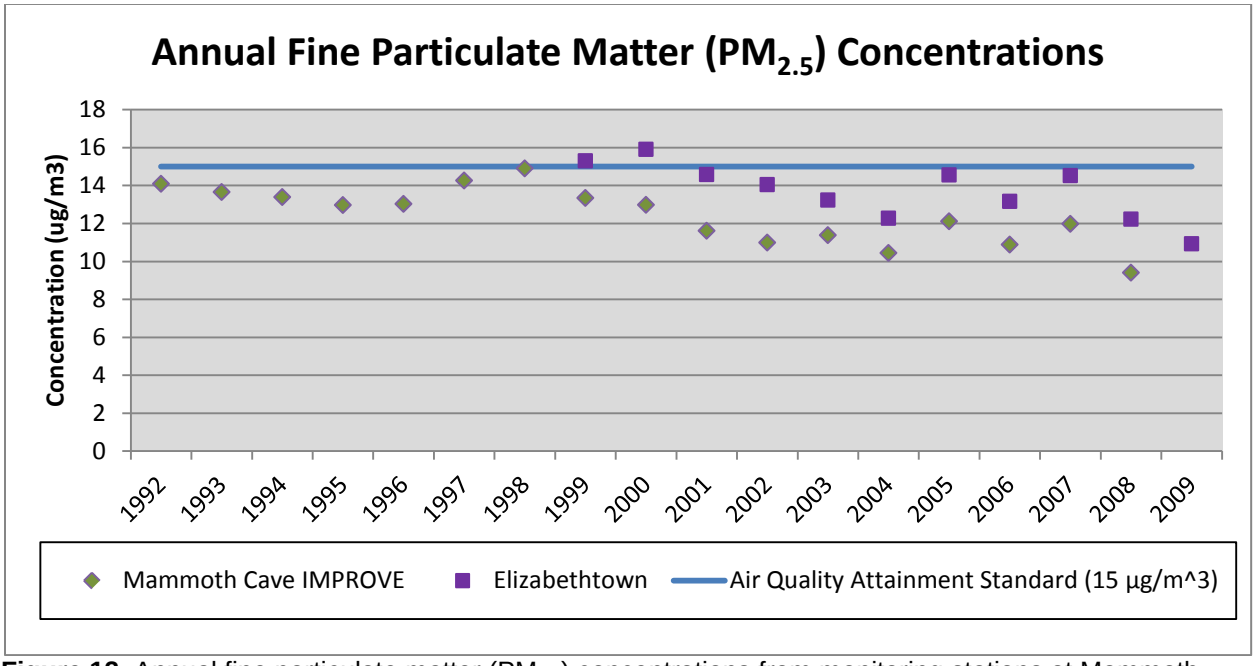

Figure 12. Annual fine particulate matter ($PM_{2.5}$) concentrations from monitoring stations at Mammoth Cave and Elizabethtown.

in scenic visibility. An area is 'of significant concern' if its dv value is greater than 8 dv above the normal background level for the area (NPS 2007a). The background dv value for Mammoth

Cave is 11.4 dv, making 19.4 dv the reference condition to compare data against. Figure 13 shows the dv values recorded at the Mammoth Cave station from 1992-2004, all of which are above the 19.4 dv threshold.

Table 8 summarizes the air quality data from all three monitoring stations near ABLI. Air quality is generally rated 'Caution' to 'Of Significant Concern' in all categories except particulate matter.

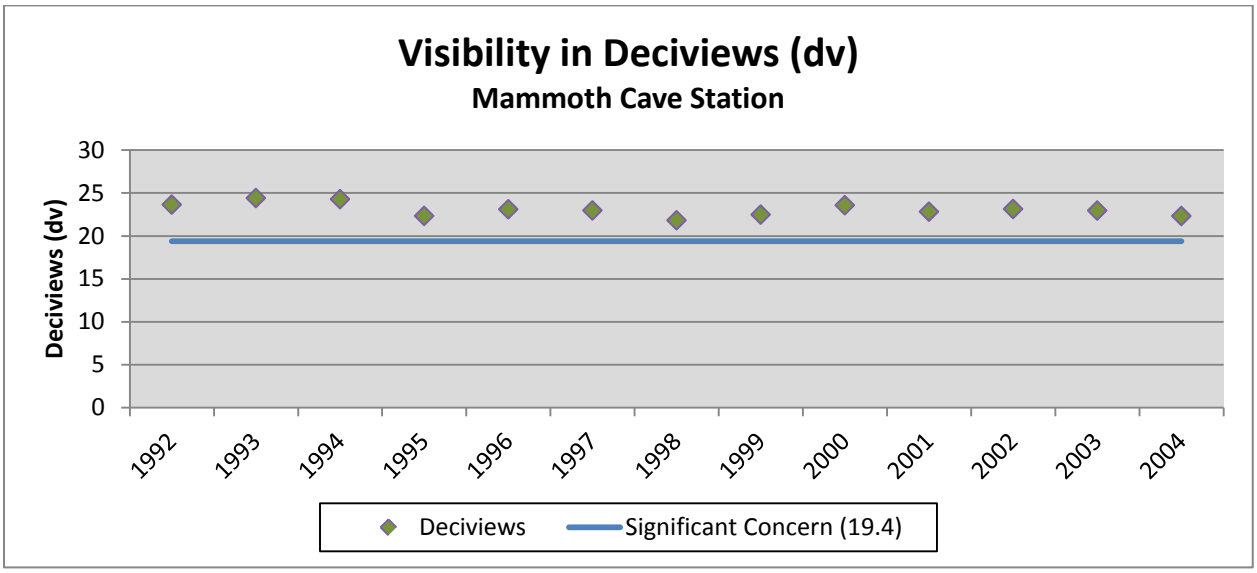

Figure 13. Annual visibility expressed in deciviews from Mammoth Cave.

Table 8. Summary of air quality data collected from the three monitoring stations near ABLI.

Parameter	Period of Record	Min	Max	Mean	%ATN	Source(Station)
Ozone (ppb)	2002-2009	10	100	49.4	83%	CASTNET(MAC426)
	1990-2009	5	113	53	28%	CASTNET(MCK131)
	1999-2009	-	-	-	36%	KYDAQ(ETOWN)
Deposition						
pH (SU)	2002-2008	4.34	5.11	4.71	NA	NADP
Mercury (ng/L)	2002-2008	1.07	45.25	10.15	NA	MDN
Total Deposition-S (kg/ha/yr)	2003-2008	6.81	10.36	8.47	0%	CASTNET(MAC426)
	1991-2008	8.3	18.69	12.64	0%	CASTNET(MCK131)
Total Deposition-N (kg/ha/yr)	2003-2008	5.96	7.61	6.69	0%	CASTNET(MAC426)
	1991-2008	6.56	10.08	8.42	0%	CASTNET(MCK131)
Visibility						
$PM_{2.5}$ ($\mu g/m^3$)	1991-2008	1.3	51.14	12.44	100%	IMPROVE
	1999-2009	-	-	-	82%	KYDAQ(ETOWN)
Deciviews (dv)	1991-2004	9.02	37.93	23.04	0%	IMPROVE
NA = NOT ASSESSED, %ATN = Percent Attainment						

Table 9 summarizes the condition status of the selected indicators for air quality. Chapter 5 of this document discusses the condition and justification of air quality at ABLI in more detail.

Table 9. Air quality condition at ABLI.

Level 3 Category	Indicator	Condition Status	Reference Condition	Data Source
Ozone	Ozone Concentration		≤75 ppb	KYDAQ Etown,CASTNet-MAC426 (02-09), MCK131 (90-09), NAAQS
Wet and Dry Deposition	Total Deposition of Sulfur		Class 2: TBD Class 1 NPS: ≤3 kg/ha/yr Fenn: 3-8 kg/ha/yr Krupa: 5-10 kg/ha/yr	CASTNet-MAC426 (03-08) & MCK131 (91-08), NPS (2007a), Fenn *et al.* (2003), Krupa (2003)
	Total Deposition of Nitrogen		Class 2: TBD Class 1 NPS: ≤3 kg/ha/yr Fenn: 3-8 kg/ha/yr Krupa: 5-10 kg/ha/yr	CASTNet-MAC426 (03-08)-MCK131 (91-08), NPS (2007a), Fenn *et al.* (2003), Krupa (2003)
Visibility and Particulate Matter	Fine Particulate Matter ($PM_{2.5}$) Levels		≤15.0 µg/m^3	KYDAQ Etown,IMPROVE-MAC426 (91-08), NAAQS
	Visibility in Deciviews (dv)		Class 2: TBD Class 1: ≤19.4 dv	IMPROVE-MAC426 (91-04), USEPA 2003
Air Contaminants	Mercury Levels	TBD	NAV	NADP/MDN-KY10 (02-08)
	Acid Rain Impacts (pH)	TBD	NAV	NADP-KY10 (02-08)
Green Condition = Acceptable, Yellow Condition = Caution, Red Condition = Of Significant Concern, TBD = To Be Determined, but not through Natural Resource Condition Assessment, NAV = No Reference Condition				

4.1.3 Land Cover

Surface changes to the environment are a natural phenomenon, yet these changes are typically gradual and are the result of long-term climatic, hydrologic, or geologic processes. Changes measured on a decadal or even shorter time span are often associated with anthropogenic influences except for catastrophic events such as earthquakes and floods. Examining the change in land cover on these shorter time scales is useful for understanding the human impact on an area. Although every region is unique in its resilience to human impacts, even small conversions of natural to human modified areas can have implications on the health of an ecosystem. Landscape dynamics, which encompasses land cover change, is a vital sign monitored by the CUPN at ABLI.

The reported land cover of an area is partly a factor of the spatial resolution of the data and the classification scheme chosen by the investigator. If the data gathered for the land cover analysis are too coarse, several land covers might be generalized to the most dominant type. Alternatively a researcher might limit the classification to a binary system (e.g. natural vs. human modified) or choose a level of detail that might attempt to discern fifty subcategories of vegetation.

Land cover change analysis has evolved from simple comparisons of hand-drawn maps to direct comparisons of aerial photography by computers. Many techniques are available for quantifying the amount of land cover change. There is no definitive procedure for land cover analysis, and in-depth knowledge of the study area and data are needed to produce meaningful results (Campbell 2006).

Land cover data for this study were retrieved from two sources, the Kentucky Land Cover Database (KLCD) (Kentucky Division of Geographic Information (KYDGI) 2004) and the Multi-Resolution Land Characteristics (MRLC) Consortium (MRLC Consortium 2007). Both datasets use the Anderson classification scheme (Anderson *et al.* 1976). This scheme is a hierarchical method of classifying units (or pixels) using codes, with Anderson Level I being the least descriptive and Anderson Level III being the most descriptive. The 2001 KLCD data are the only data available for Kentucky that uses Anderson Level III codes. The MRLC Consortium produces the National Land Cover Database (NLCD) datasets which are currently only available for the years 1992 and 2001. Anderson Level II is the method of classification used in the NLCD land cover data. Both datasets have similar origins and share many properties such as the level of spatial resolution, which is approximately ¼ acre.

The KLCD data were used in the land cover analysis as seen in Table 10 and Figure 14. The majority of land cover at ABLI is mixed deciduous forest which accounts for approximately 57% of the total land area of both park units. Developed areas account for approximately 5% of the total land area, although both the relatively small size and historic purpose of the park account for this percentage.

Table 10. Land cover classes at ABLI derived from KLCD (2001).

Class	Birthplace Unit Acres	Birthplace %	Knob Creek Unit Acres	Knob Creek %	Total %
Mixed Deciduous Forest	46.9	41.5%	147.2	64.4%	56.8%
Oak Forest	26.2	23.2%	30.5	13.3%	16.6%
Deciduous Woodland	9.6	8.5%	17.6	7.7%	7.9%
Developed, Open Space	12.5	11.0%	3.3	1.5%	4.6%
Red Cedar Forest	2.0	1.8%	11.6	5.1%	4.0%
Pasture/Hay	7.6	6.7%	0.4	0.2%	2.3%
Herbaceous	0.4	0.4%	6.7	2.9%	2.1%
Other Mixed Forest	1.3	1.2%	4.0	1.8%	1.6%
Pine Forest	1.6	1.4%	3.6	1.6%	1.5%
Developed, Low Intensity	3.8	3.3%	0.0	0.0%	1.1%
Oak-Pine Mixed Forest	0.0	0.0%	2.4	1.1%	0.7%
Yellow Poplar Forest	0.0	0.0%	0.9	0.4%	0.3%
Shrub	0.7	0.6%	0.2	0.1%	0.3%

Although the 1992 and 2001 datasets are very similar, direct comparisons are strongly discouraged by the MRLC due to variations in collection methods and classifications. Perceiving the demand for land cover change studies using these datasets, the Consortium created the "NLCD 1992-2001 Retrofit Change Product" (Fry *et al.* 2009). Whenever differences were detected between the 1992 and 2001 datasets a ‘from-to’ classification was assigned. Where no change was detected the appropriate code was assigned using Anderson Level I definitions. Table 11 and Figure 15 show the results of this product clipped to the boundaries of ABLI.

Interpreting the ‘from-to’ classifications is valuable in determining the human impact at ABLI. The two classifications of ‘from-to’ identified at ABLI in Table 11 above are "Agriculture to

Forest" and "Forest to Urban" with 0.6% and 0.3% of the total land area respectively. The relatively small amount of land cover change, especially considering changes from natural (e.g.

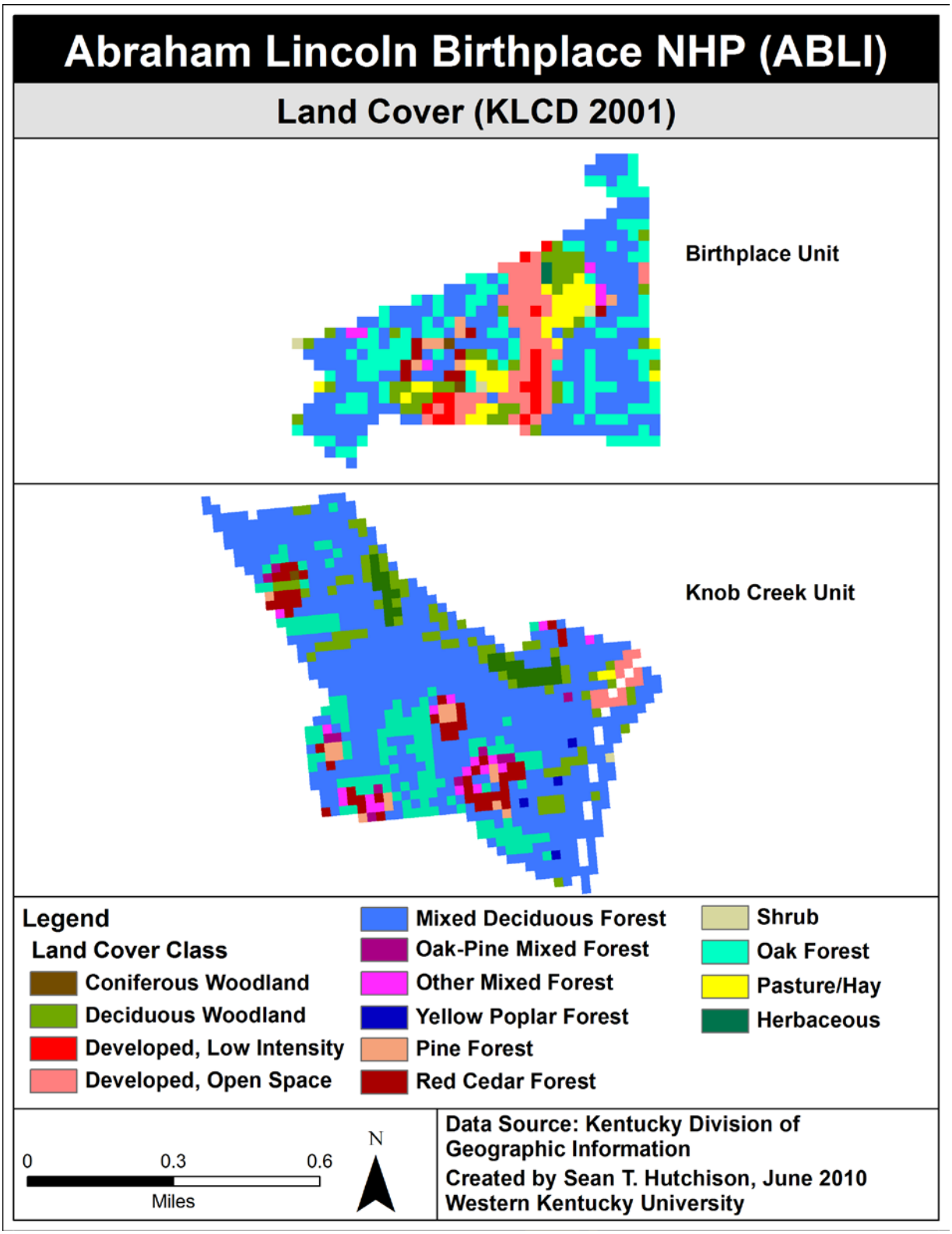

Figure 14. Land cover at ABLI according the KLCD (2001).

Table 11. Land cover change analysis from 1992 to 2001 (NLCD 2001).

Class	Birthplace Acres	Birthplace %	Knob Creek Acres	Knob Creek %	Total %
Forest	90.3	80.3%	216.6	94.7%	89.9%
Urban	14.9	13.2%	3.3	1.7%	5.3%
Grassland/Shrub	0.0	0.0%	6.8	3.0%	2.0%
Agriculture	6.2	5.5%	0.0	0.0%	1.8%
Agriculture to Forest	0.0	0.0%	2.0	0.9%	0.6%
Forest to Urban	1.1	1.0%	0.0	0.0%	0.3%

forests) to human modified (e.g. urban) areas indicates a small human footprint on the area between 1992 and 2001. Assessing the land cover change beyond park boundaries also is important because outside influences can greatly affect natural resources such as water and air quality. Such an assessment might be made at the watershed scale, however, owing to the small size and peripheral location of the park units within their respective watersheds, this scale would provide little insight. Table 12 details land cover changes noted within a buffer of 1,000 meters around both park units. Forest still dominates the landscape around ABLI and agriculture accounts for nearly two-thirds of land cover outside of the Birthplace Unit. Although human activity is more pronounced immediately outside of ABLI the percentage of area that transitioned from natural to human modified (urban and agriculture) is nearly equivalent to that within the park units themselves.

Table 12. Land cover change analysis of 1,000 meter buffer around ABLI 1992-2001 (NLCD).

Class	Birthplace Unit Buffer Acres	Birthplace Buffer %	Knob Creek Unit Buffer Acres	Knob Creek Buffer %	Total %
Forest	457.7	26.8%	1979.3	91.8%	63.1%
Agriculture	1090.8	63.9%	52.7	2.4%	29.6%
Urban	137.9	8.1%	26.5	1.2%	4.3%
Grassland/Shrub	6.4	0.4%	92.5	4.3%	2.6%
Agriculture to Forest	2.4	0.1%	3.6	0.2%	0.2%
Open Water	4.9	0.3%	0.0	0.0%	0.1%
Forest to Agriculture	4.0	0.2%	0.0	0.0%	0.1%
Forest to Urban	2.7	0.2%	0.0	0.0%	0.1%
Forest to Grassland/Shrub	0.0	0.0%	2.2	0.1%	0.1%

Land cover is rated ‘Acceptable’ using the indicator of land cover change. Table 13 summarizes the condition of the selected indicator for land cover. Chapter 5 of this document discusses the condition and justification of land cover at ABLI in more detail.

Table 13. Land cover condition at ABLI.

Level 3 Category	Indicator	Condition Status	Reference Condition	Data Source
Land Cover and Use	Park Unit Land Cover Change		No Reference Condition	MRLC Consortium (1992-2001), KLCD (2001)
Green Condition = Acceptable, Yellow Condition = Caution, Red Condition = Of Significant Concern, TBD = To Be Determined, but not through Natural Resource Condition Assessment, NAV = No Reference Condition				

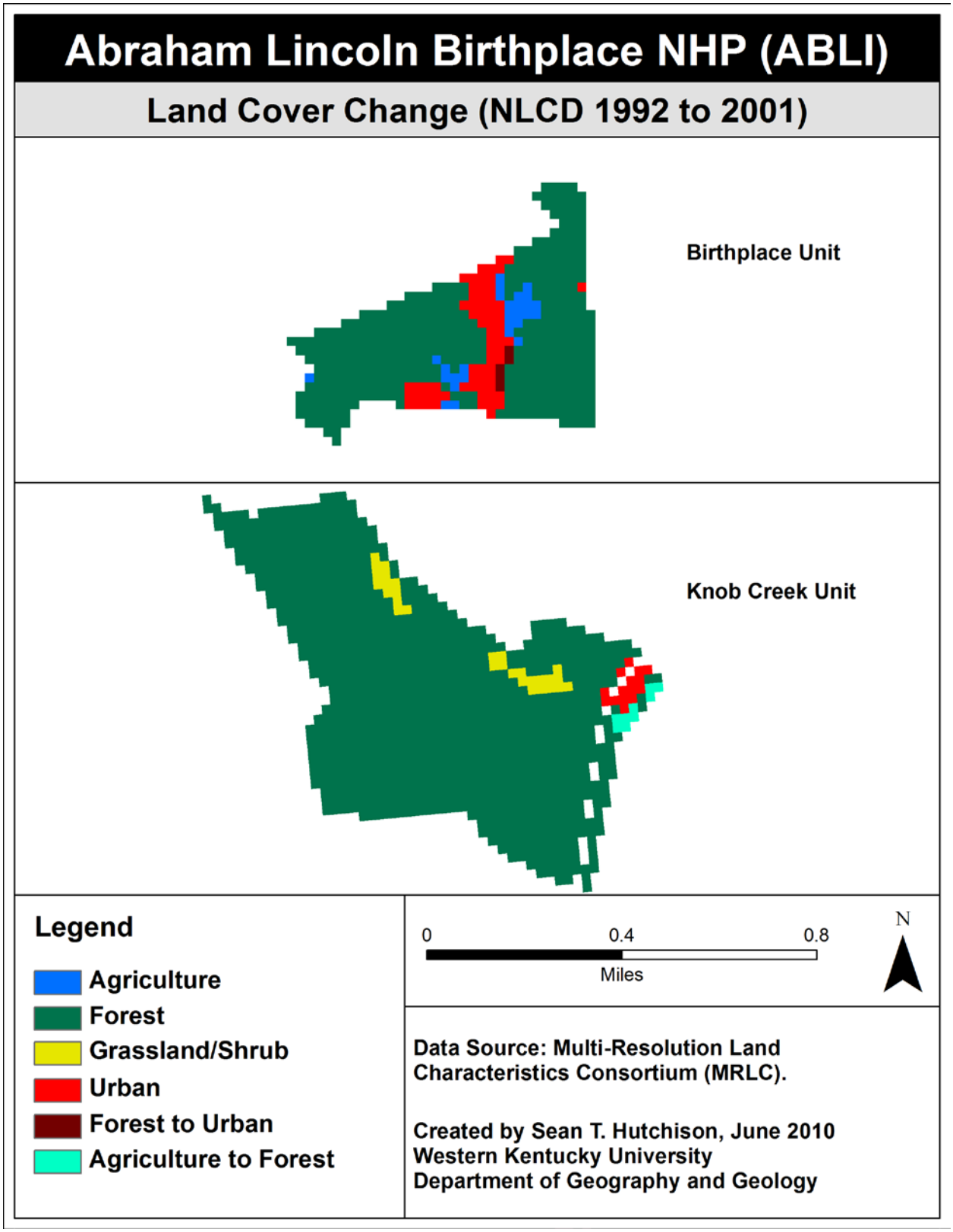

Figure 15. Land cover change at ABLI according to NLCD (2001).

4.2 Biotic Resources

4.2.1 Vegetation

In 1992 the National Park Service, through cooperative agreement with the Commonwealth of Kentucky, contracted Landon E. McKinney to document the vascular plants and map the vegetative communities within ABLI (McKinney 1993). At this time only one park unit (the Birthplace Unit) was operated by the NPS and therefore the Knob Creek Unit was not considered in his study.

McKinney determined that the Birthplace Unit had been considerably altered by human development prior to being incorporated into the National Park System. His methodology was to conduct field surveys to document the vascular plant species and to give particular attention to mapping the boundaries of the dominant vegetation communities. In total, five vegetative communities were described and mapped: landscaped grounds, old field, cedar forest, American ash/sugar maple forest, and oak forest. Field studies conducted approximately every three weeks between March and October of 1993 documented 206 vascular plant species. The author found that none of the species documented were considered rare. Figure 16 is an original geospatial product depicting the five vegetation classes created by McKinney (1993) overlaying an aerial photograph of the Birthplace Unit.

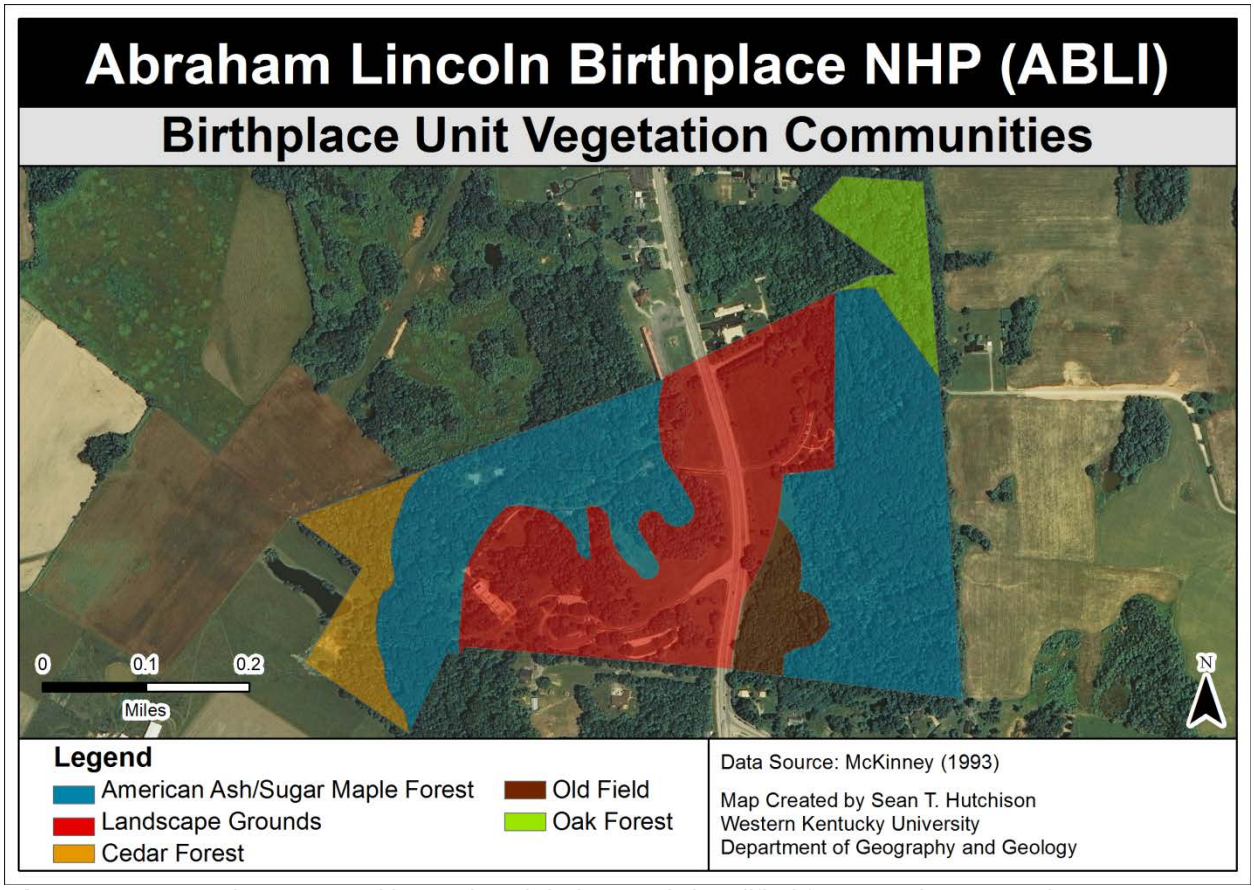

Figure 16. Vegetation communities at the Birthplace Unit (modified from McKinney 1993).

In 2002, the NPS contracted with NatureServe for a detailed study of vascular plants (Jones and Pyne 2008). The goals of this study were to establish permanent plots for current and future monitoring, document the ecological communities according to the National Vegetation Classification Standard (NVCS, http://biology.usgs.gov/npsveg/nvcs.html) and document any vascular species not previously reported by McKinney (1993). The field work was conducted using an established system of permanent sampling plots of one hectare each demarcated through GIS by Nichols *et al.* (2000). No plot included any area outside of the park boundaries. The methodology of Jones and Pyne (2008) was to classify all vegetation communities within the park boundaries using a gridded system comprising 17 permanent sampling plots. Although the permanent plots accounted for a significant portion of the vegetation communities at ABLI, they created and incorporated 10 additional *ad hoc* plots. These additional plots were referred to as 'quick plots'. Figure 17 maps the 27 total sampling plots (17 permanent and 10 quick) that were used by Jones and Pyne (*ibid*.).

The Jones and Pyne (2008) vascular plant study successfully documented 568 species, which they believed represented at least 90% of the plant species within the park. Hundreds of previously undocumented species were included in this total.

According to the authors, invasive species are the most significant threat to the health of vegetation at ABLI. Japanese honeysuckle (*Lonicera japonica*), multiflora rose (*Rosa multiflora*), Japanese stilt grass (*Microstegium vimineum*), winter creeper (*Euonymus fortunei*), Amur bush honeysuckle (*Lonicera maackii*), Oriental bittersweet (*Celastrus orbiculatus*) were considered either to be establishing or already established in the park and were candidates for monitoring and control.

An evaluation of previous biological inventories pertaining to ABLI (Moore 2009) concludes that 94 vascular plant species either documented through inventories or existing in the local area are non-native species. The I-rank system, which is a measure of a species impact on native species and biodiversity, was applied to the non-native species list. The I-Rank, also known as the *Invasive Species Assessment Protocol*, was developed by NatureServe and the NPS and is detailed in Morse *et al.* (2004). The I-Rank classifies species into four categories: 'High' corresponds to a severe threat to native species and ecological communities; 'Medium' corresponds to a moderate threat; 'Low' corresponds to a significant but low threat; 'Insignificant' corresponds to an insignificant threat. According to Moore (*ibid.*) 20 species observed at ABLI received an overall I-Rank of 'High' as shown in Table 14, and all of these species were documented as being established in the park. Ten of these 20 species are also considered to have a high degree of difficulty with regard to their potential control.

Jones and Pyne (2008) also described 13 vegetation communities (classified according to the NVCS) present within the park and one community that has a potential to be restored. Table 15 lists all 14 communities along with their NVCS classification IDs.

Two of the vegetation communities present are globally rare and deserve special attention. Both were found at the Knob Creek Unit (Jones and Pyne *ibid.*). The "Central Limestone Glade" supports herbaceous vegetation and is typically found on south to southwest facing slopes.

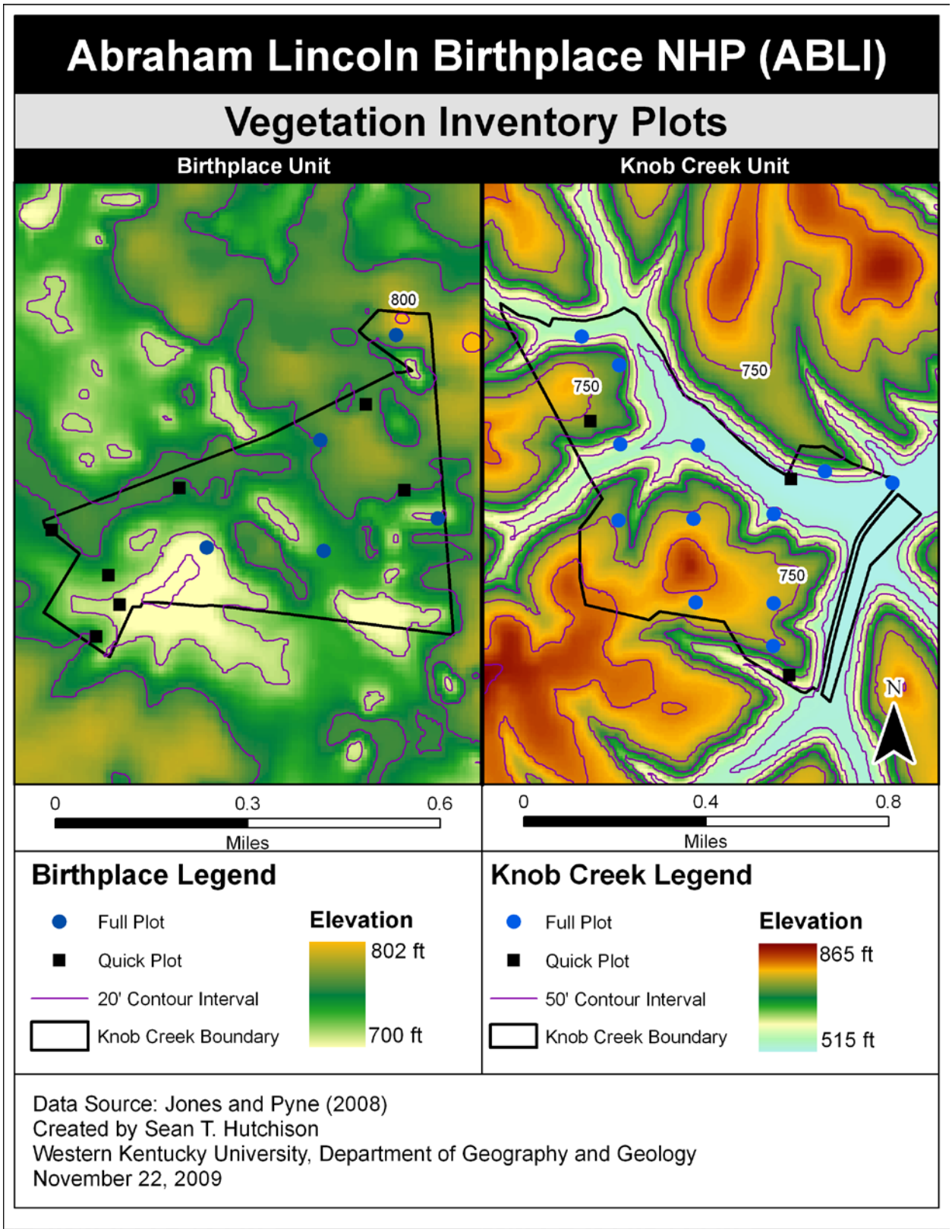

Figure 17. ABLI vegetation plots established by Jones and Pyne (2008).

Table 14. ABLI non-native plants with an I-Rank containing 'High' (modified from Moore 2009).

Common Name	Species	I-Rank	Ecological Impact	Management
Japanese barberry	*Berberis thunbergii*	High/Medium	High/Medium	Insignificant
Musk Thistle	*Carduus nutans*	High/Low	Medium/Insignificant	High/Medium
Oriental bittersweet	*Celastrus orbiculata*	High/Medium	Medium/Low	Medium
Spotted knapweed	*Centaurea biebersteinii*	High/Medium	Medium	High/Low
Autumn olive	*Elaeagnus umbellate*	High	High	Low
English ivy	*Hedera helix*	High/Medium	Medium	Medium/Low
Chinese privet	*Ligustrum sinense*	High/Medium	Medium	Low
Tall fescue	*Lolium arundinaceum*	High/Medium	Medium	High/Medium
Meadow fescue	*Lolium pretense*	High/Low	Medium/Low	High/Low
Japanese honeysuckle	*Lonicera japonica*	High/Medium	Medium	High/Medium
Amur honeysuckle	*Lonicera maackii*	High	High/Medium	Medium
Nepalese browntop	*Microstegium vimineum*	High/Medium	Medium	High/Medium
White mulberry	*Morus alba*	High/Medium	Medium/Low	Medium/Low
Reed canary grass	*Phalaris arundinacea*	High	High	High/Medium
Narrowleaf plantain	*Plantago lanceolata*	High/Low	High/Low	High/Low
Canada bluegrass	*Poa compressa*	High/Low	Medium/Low	High/Low
Roughfruit cinquefoil	*Potentilla recta*	High/Medium	High/Low	Medium/Low
Sweet cherry	*Prunus avium*	High/Low	High/Low	Medium/Low
Johnsongrass	*Sorghum halepense*	High/Medium	Medium/Low	High/Medium
Narrowleaf cattail	*Typha angustigolia*	High/Medium	High/Medium	Medium

Table 15. Vegetation Communities present at ABLI according to Jones and Pyne (2008).

Vegetation Community	NVCS ID	Succession
Beech - Maple Unglaciated Forest	CEGL002411	Natural
Central Limestone Glade	CEGL005131	Natural
Floodplain Canebrake	*CEGL003836*	Potential Restoration
Highland Rim Limestone Cliff/Talus Seep	CEGL004708	Natural
Interior Low Plateau Mesic Sugar Maple-Hickory Forest	CEGL004741	Natural
Rich Levee Mixed Hardwood Bottomland Forest	CEGL008429	Natural
Southern Red Oak - Mixed Oak Forest	CEGL005018	Natural
White Oak - Mixed Oak Dry-Mesic Alkaline Forest	CEGL002070	Natural
Cultivated Meadow	*CEGL004048*	Human modified/Successional
Red-cedar Successional Forest	CEGL007124	Human modified/Successional
Southeastern Successional Black Cherry Forest	CEGL004133	Human modified/Successional
Successional Broom-sedge Vegetation	CEGL004044	Human modified/Successional
Successional Tuliptree Forest	CEGL007220	Human modified/Successional
Virginia Pine Successional Forest	CEGL002591	Human modified/Successional

The "Highland Rim Limestone Cliff/Talus Seep" is thought to occur only once within the park on the north facing slope of the north knob. Figure 18 shows the locations of both these rare communities and highlights the south to southwest facing slopes where additional limestone glades may potentially occur.

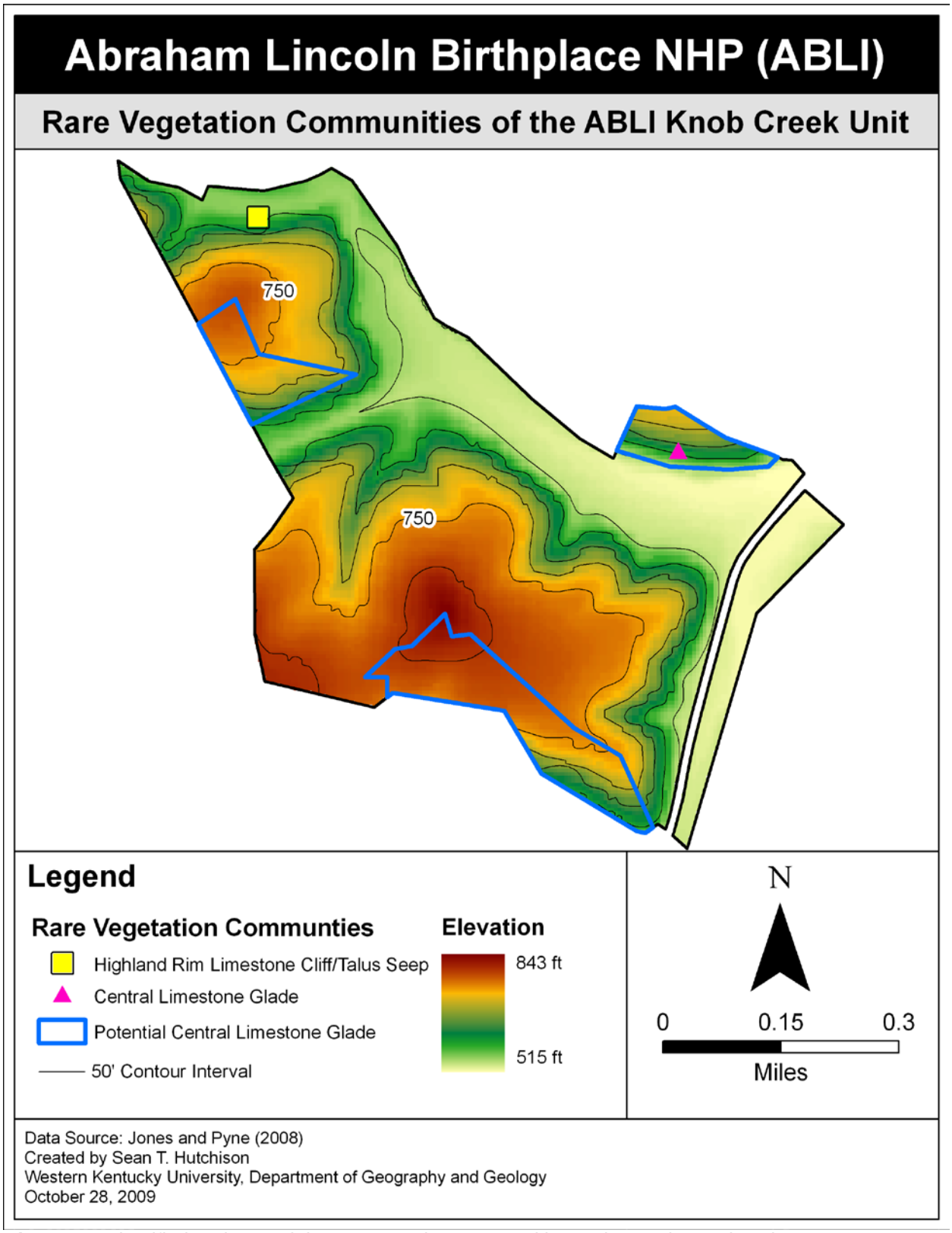

Figure 18. Identified and potential rare vegetation communities at the Knob Creek Unit.

In 2004, the Center for Remote Sensing (CRMS) at the University of Georgia created vegetation maps for ABLI based on orthophotographs and digitized vegetation communities. These maps provided community-level vegetation information for both ABLI park units as well as a 400-meter buffer zone around the units and were more detailed than any previous study. Twenty-four unique spectral classes were identified with 17 of them being actual vegetation communities while the remaining seven were classified as buildings, roads, water, or human-influenced areas. Eleven vegetation communities were shown to exist within the Birthplace Unit with five of them being unique to the unit. Twelve vegetation communities were depicted within the Knob Creek Unit with six of those being unique to that unit.

Table 16 ranks the 24 spectral classes from CRMS based on the percentage of total area covered across both units. The two dominant vegetation types were found to be "White Oak - Northern Red Oak - Chinquapin Oak / Redbud Forest" and "American Beech - Sugar Maple - Tuliptree Unglaciated Forest" accounting for 20.3% and 20.0% of the total land area respectively. Both of these occur only at the Knob Creek Unit. The only other vegetation class accounting for more than 10% of the total land area was "(Tall Fescue, Meadow Fescue) Herbaceous Vegetation" with 14.8%. No rare or threatened vegetation communities were classified by the CRMS study. Additional information, including acreage per unit and combined acreage, are also provided in Table 16.

The criteria for assessing the condition of floral resources differ from those in the assessment of faunal resources. Documenting at least 90% of expected species is a key indicator of faunal health because it leads an investigator to believe these species are both distributed through the park and actively maintaining a presence despite environmental stressors. Floral individuals are stationary and cannot disperse in the same manner as faunal species in response to environmental conditions. That being said an inventory of vegetation, both species and communities, is useful in determining long-term trends and the relative impact of disturbances such as invasive species and human development.

Vegetation at ABLI is rated as ‘Acceptable’ based on species diversity and richness and the relatively low presence and impact of invasive species. Table 17 summarizes the condition of the selected indicators for vegetation. Chapter 5 of this document discusses the condition and justification of vegetation at ABLI in more detail.

Table 16. Vegetation communities by area according to the CRMS (2004). (

Dominant Vegetation	Birth place acres	Knob Creek acres	Total acres	% Birth place acres	% Knob Creek acres	Total %
White Oak - Northern Red Oak - Chinquapin Oak / Redbud Forest	0.0	69.1	69.1	0.0	30.3	20.3
American Beech - Sugar Maple - Tuliptree Unglaciated Forest	0.0	68.1	68.1	0.0	29.9	20.0
(Tall Fescue, Meadow Fescue) Herbaceous Vegetation	19.2	31.4	50.6	17.0	13.8	14.8
Eastern Red-cedar - (Oak species)	10.7	12.1	22.8	9.5	5.3	6.7
Black Walnut - Northern Hackberry Forest	18.7	0.9	19.6	16.6	0.4	5.7

Table 16. Vegetation communities by area according to the CRMS (2004). (continued)

Dominant Vegetation	Birth place acres	Knob Creek acres	Total acres	% Birth place acres	% Knob Creek acres	Total %
Southern Red Oak - White Oak - Post Oak - Black Oak Forest	17.1	0.0	17.1	15.1	0.0	5.0
Sycamore - (Sweetgum, Red Maple) / (Ironwood) / Sensitive Fern Forest	0.5	14.8	15.3	0.4	6.5	4.5
Tuliptree / (Redbud) / (Northern Spicebush) Forest	10.8	3.2	14.0	9.6	1.4	4.1
Sugar Maple - Shagbark Hickory - Black Walnut / Coralberry / Canada Leafcup - Common Eastern Brome Forest	9.6	0.0	9.6	8.5	0.0	2.8
Virginia Pine Successional Forest	0.0	8.9	8.9	0.0	3.9	2.6
Common Broom-sedge Herbaceous Vegetation	3.6	3.6	7.2	3.2	1.6	2.1
Road	6.6	0.2	6.8	5.8	0.1	2.0
White Oak - Northern Red Oak - (Mockernut Hickory, Shagbark Hickory) / Flowering Dogwood Acid Forest	6.6	0.0	6.6	5.8	0.0	1.9
Lawn	5.8	0.0	5.8	5.1	0.0	1.7
Right-of-Way	0.0	5.7	5.7	0.0	2.5	1.7
Chinquapin Oak - Eastern Red-cedar / Little Bluestem - Eastern Agave Wooded Herbaceous Vegetation	0.0	4.9	4.9	0.0	2.1	1.4
Human Influence	0.5	2.6	3.1	0.4	1.1	0.9
Shingle Oak - Shumard Oak - Chinquapin Oak / Northern Hackberry / Dwarf Stinging Nettle Forest	2.3	0.0	2.3	2.0	0.0	0.7
Water	0.1	1.9	2.0	0.1	0.8	0.6
Building	0.5	0.0	0.5	0.4	0.0	0.1
Native Giant Cane (Arundinaria gigantea)	0.0	0.4	0.4	0.0	0.2	0.1
White Pine (Pinus strobus)	0.3	0.0	0.3	0.3	0.0	0.1
Sinkhole	0.0	0.1	0.1	0.0	0.0	0.0
(Tall Fescue, Meadow Fescue) Herbaceous Vegetation with very early successional Virginia pine, Eastern red cedar, Andropogon spp., asters, goldenrod, small oaks, moss, and lichens	0.0	0.1	0.1	0.0	0.0	0.0
TOTAL	112.9	228.0	340.9	100.0%		

Table 17. Vegetation condition at ABLI.

Level 3 Category	Indicator	Condition Status	Reference Condition	Data Source
Vegetation Community Composition	Species Richness		no exotics, detect at least 90% species expected	Jones and Pyne (2008)
	Invasive Species		number of exotics and management difficulty	
Green Condition = Acceptable, Yellow Condition = Caution, Red Condition = Of Significant Concern, TBD = To Be Determined, but not through Natural Resource Condition Assessment, NAV = No Reference Condition				

4.2.2 Birds

Bird surveys are conducted by a number of government agencies and private groups, but many of these surveys take place on a spatial scale that is too large to yield meaningful results for ABLI. Only two bird surveys have focused specifically on ABLI: Sturgeon and Kistler (1994) established an expected avian list totaling 126 species for ABLI and in 2003, as part of the

National Park Service Natural Resource Challenge, an attempt to document at least 90% of all expected avian species was begun (Monroe 2005). According to Monroe (*ibid.*) the relatively small size of ABLI and its emphasis on cultural-historical elements limited opportunities for varied avian populations compared to other parks within the region. In Monroe's opinion the list established by Sturgeon and Kistler (*ibid.*) included species that should not have been expected to occur at ABLI.

A total of 2,154 individuals representing 112 species were recorded by Monroe from 2003 to 2004 and compared against the Sturgeon and Kistler (1994) list of 126 expected species. However, Monroe later revised that list was downward to 119 species after seven species were reconsidered as existing within the general area of the park but not within the park itself. After the survey was completed in 2004, the expected species list was further revised upward to 132 because several additional species had been observed very near the park. The majority of these newly observed species preferred edge and small woodlots.

The survey by Monroe (2005) divided birds into three groups: Breeding, Wintering, and Migrating. Breeding Birds represented 66 of the total observed species (58.9%), and 1,586 of the total individuals (73.6%). Monroe did not quantify the species distribution in the other categories. Unobserved but expected species are thought to be primarily migrants and have little impact on management decisions (Moore 2009). Additionally the park lacks significant water bodies and cannot support waterfowl populations. The current count of bird species at ABLI stands at 115 (Moore *ibid.*).

Nine bird species that were observed at the park and three species that are probably present have been designated rare or imperiled at the state level (Moore 2009). The Kentucky State Nature Preserves Commission (http://naturepreserves.ky.gov/) has designated three observed species (Brown Creeper, Least Flycatcher, and the Red-breasted Nuthatch) as being in danger of local extinction. The remaining nine species were designated as likely to become endangered locally in the foreseeable future or presently require monitoring to ensure continued viability. However, the state listing is specific to breeding populations and none of the 12 are expected to breed on ABLI (Moore *ibid.*).

Three observed species (European Starling, House Finch, and House Sparrow), and one probably present but unobserved species (Rock Pigeon), are exotic. All four species are common throughout North America. None of these four species have been assigned an I-rank (Morse *et al.* 2004) by NatureServe and the management implications for ABLI are unknown.

Other potentially useful bird surveys include The North American Breeding Bird Survey (http://www.pwrc.usgs.gov/BBS/), a long-term initiative of the U.S. Geological Survey that tracks the status of avian populations throughout North America. Data are collected every breeding season at half-mile intervals along established 24.5 mile routes. At each half-mile interval a three-minute count records all birds seen or heard within a quarter-mile radius. These data are used to assess population abundance and trends at varying spatial scales, and are relied upon by organizations such as the U.S. Fish and Wildlife Service and NatureServe. The closest route to ABLI is the Hodgenville route, located approximately 5 miles from the Knob Creek Unit

and 3.5 miles from the Birthplace Unit. A total of 102 unique species have been recorded along this route from 1966 to 2007.

The Christmas Bird Count (CBC) is an annual event sponsored by the Audubon Society (http://birds.audubon.org/christmas-bird-count). Recordings take place between December 14 and January 5, but must occur within a 24-hour calendar day. A CBC counting circle has taken place at the Birthplace Unit of ABLI since 2005-2006 which was the 106th year of the CBC. The number of species recorded each year differs and is distributed as follows: 106th year count recorded 48 species, 107th year count recorded 55 species, 108th year count recorded 75 species, the 109th year count recorded 72 species, and the 110th year count recorded 63 species.

Other sources of bird data exist, but only provide data at spatial scales that are too generalized for ABLI. These include Partners-in-flight (http://www.partnersinflight.org/) and the Kentucky Department of Fish and Wildlife Resources (http://www.kdfwr.state.ky.us/).
The current condition status of birds is rated 'Acceptable' as shown in Table 18. Chapter 5 of this document discusses the current condition status of birds at ABLI in more detail.

Table 18. Bird condition at ABLI.

Level 3 Category	Indicator	Condition Status	Reference Condition	Data Source
Birds	Species Richness		no exotics, detect at least 90% species expected	Monroe (2005)
Green Condition = Acceptable, Yellow Condition = Caution, Red Condition = Of Significant Concern, TBD = To Be Determined, but not through Natural Resource Condition Assessment, NAV = No Reference Condition				

4.2.3 Herpetofauna

The expected species list in this category must be compiled using multiple sources and methods because there is no historical master list of herpetofauna for ABLI. The primary herpetofauna report for ABLI (MacGregor 2007) used distribution maps and field guides to create a starting place for producing such a list. Available habitats were also considered because of the strong correlation between habitat and the numbers and kinds of expected species. Using the various maps and field guides an estimated 54 species were expected at ABLI. However, after an initial site visit, that list was revised downward to 46 because habitat modification had eliminated the possibility of certain species. Another source of expected species data is the Kentucky Department of Fish and Wildlife, which maintains a database of species by county. Their database states that the 36 species of 'Reptilla and Amphiba' have been observed for LaRue county. This database is not currently considered to be authoritative by those who operate it (MacGregor pers. com. 2009).

According to the primary report (MacGregor 2007), 28 out of 46 of the expected species (60.9%) were observed during the study period between 2003 and 2005. A total of 309 individuals were recorded, although the observation methodology employed included breeding choruses, larvae, and egg masses as individuals. The success rate of observing expected species was highly variable, with 9 out of 11 (81.8%) frogs and toads observed while salamanders and turtles each had only a 50% success rate. Table 19 lists the percent of expected species that were observed for each herpetofauna group.

Herpetofauna are rated 'Caution' based on the low number of observed species. Table 20 summarizes the condition of the selected indicators for herpetofauna. Chapter 5 of this document discusses the condition and justification of herpetofauna at ABLI in more detail.

Table 19. Summary of MacGregor (2007) herpetofauna survey results.

Group	Number of Species Expected	Number of Species Observed	Percent Expected Species Observed
Frogs and Toads	11	9	81.8 %
Salamanders	12	6	50.0 %
ALL AMPHIBIANS	23	15	65.2 %
Lizards	4	3	75.0 %
Snakes	15	8	53.3 %
Turtles	4	2	50.0 %
ALL REPTILES AND TURTLES	23	13	56.5 %
TOTAL	46	28	60.9 %

Table 20. Herpetofauna condition at ABLI.

Level 3 Category	Indicator	Condition Status	Reference Condition	Data Source
Herpetofauna	Species Richness		no exotics, detect at least 90% species expected	MacGregor (2007)
Green Condition= Acceptable, Yellow Condition = Caution, Red Condition = Of Significant Concern, TBD = To Be Determined, but not through Natural Resource Condition Assessment, NAV = No Reference Condition				

4.2.4 Mammals

The most recent survey of mammals at ABLI (Gumbert *et al.* 2006) began in 2005 with the compilation of an expected species list from field guides and an earlier statewide survey of small mammals (Thomas 2001). Their final list contained 45 expected species including one marsupial, six insectivores, 11 bats, one lagomorph, 16 rodents, nine carnivores, and one ungulate. Two of the expected species (Gray bat and Indiana bat) are federally listed endangered species and three other species (Rafinesque's big-eared bat, evening bat, and least weasel) have special threat designations on the Kentucky State Nature Preserves Commission list (http://naturepreserves.ky.gov/). During the field survey, 30 species of mammals were recorded representing 67% of the 45 species that were expected, and 242 individual observations of mammals were made. No endangered, threatened, or candidate species for listing as endangered or threatened were noted.

In 2009, a study concerning bats was initiated by a biologist from Western Kentucky University as part of a larger study interested in the bioaccumlation of mercury. Copperhead Environmental Consulting, the same group that undertook the first mammal survey at ABLI (Gumbert *et al.* 2006), was contracted for the bat survey which took place across three national parks including ABLI. The survey at ABLI yielded 22 individuals representing five species, one of which was *Myotis grisescens* or Gray bat. This finding represents the first observation of a federally listed species at ABLI. Only one individual of *Myotis grisescens* was found (at the Knob Creek Unit)

and it is believed that the species most likely uses the park for feeding and traversing purposes and not for roosting (Thomas and Leifreid pers. com. 2010).

Table 21 is a combined summary of the findings from both the mammal survey of 2006 and the bat survey of 2009. The original list of 45 expected species did not need to be updated because no additional species were identified during the bat survey.

Table 21. Summary of ABLI mammal surveys.

Group	Number of Species Expected	Number of Species Observed	Percent Expected Species Observed
Marsupial	1	1	100%
Insectivores	6	6	100%
Lagomorphs	1	1	100%
Carnivore	9	5	55.5%
Bats	11	8	72.7%
Ungulate	1	1	100%
Rodent	16	9	56%
Total	**45**	**31**	**68.8%**

The current condition status of mammals as depicted in Table 22 is considered to be 'Acceptable' based on expert opinion (Gumbert *et al.* 2006) and overall species richness. Chapter 5 of this document discusses the condition status of mammals at ABLI in more detail.

Table 22. Current condition status of mammals at ABLI.

Level 3 Category	Indicator	Condition Status	Reference Condition	Data Source
Mammals	Species Richness		no exotics, detect at least 90% species expected	Gumbert *et al.* (2006)
Green Condition = Acceptable, Yellow Condition = Caution, Red Condition = Of Significant Concern, TBD = To Be Determined, but not through Natural Resource Condition Assessment, NAV = No Reference Condition				

4.2.5 Fish

Only the Knob Creek Unit of ABLI has been investigated for its fish populations. This was done by Carl Zimmerman in 2007 as part of his master's thesis research. Zimmerman's study was not exclusively concerned with ABLI nor was its purpose to document 90% of expected species. Instead, he intended to monitor how fish assemblages fluxed seasonally. Three sites along the north branch of Knob Creek were sampled for three seasons between 2005 and 2006. Table 23 is a recreated summary of his findings.

Zimmerman's data indicate the overall structure of the fish population did vary seasonally. The highest total abundance, highest species richness, and the highest species diversity were all observed in the spring of 2006 while the lowest total abundance was observed in fall of 2005.

Table 23. Abundance, species richness, and species diversity of fish at Knob Creek (ABLI) for Summer and Fall 2005 and Spring 2006. (modified from Zimmerman 2007).

Species	Common Name	Summer 2005	Fall 2005	Spring 2006
Campostoma	Central stoneroller	0	24	60
Luxilus chrysocephalus	Striped shiner	1	0	14
Lythrurus ardens	Rosefin shiner	0	0	1
Rhinichthys obtusus	Western blacknose	47	30	18
Phoxinus erythrogaster	Southern redbelly dace	12	13	15
Pimephales notatus	Bluntnose minnow	1	0	2
Semotilus	Creek chub	43	63	45
Fundulus catenatus	Northern studfish	0	1	0
Etheostoma lawrencei	Orangethroat darter	24	17	27
Etheostoma flabellare	Fantail darter	58	4	21
	Total abundance	186	152	203
	Species Richness	7	7	9
	Species Diversity	1.57	1.59	1.82

The Kentucky Division of Water created the Kentucky Index of Biotic Integrity (KIBI) to be used as an indicator of the health of a given stream. In regard to the Knob Creek tributary, Zimmerman (now with the Kentucky Division of Water) stated, “For a small stream with a 2.6 square mile drainage area the KIBI scores were all greater than 52, which is in the ‘excellent’ category for the Interior Plateau-Bluegrass region.” (Zimmerman pers. com. 2009).

The current condition of the fish population at ABLI is considered to be ‘Acceptable’ based upon species richness, diversity, the Kentucky Index of Biotic Integrity, and expert opinion is summarized in Table 24. Chapter 5 of this document discusses the rationale for this statement of current condition in more detail.

Table 24. Current condition status of fish at ABLI.

Level 3 Category	Indicator	Condition Status	Reference Condition	Data Source
Fishes	Species Richness		no exotics, detect at least 90% species expected	Zimmerman (2007)

Green Condition= Acceptable, Yellow Condition = Caution, Red Condition = Of Significant Concern, TBD = To Be Determined, but not through Natural Resource Condition Assessment, NAV = No Reference Condition

4.2.6 Aquatic Insects

According to the *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers* (Barbour *et al.* 1999) macroinvertebrates, along with fish and algal assemblages, are suitable indicators of local water conditions. The abundance and diversity of macroinvertebrate species can inform a biologist about short-term variations in water quality. Taxa are assigned tolerance values according to their resilience to environmental inputs such as toxins that may indicate diminished or declining water quality. Using the species present along with their respective tolerance values is an established, scientific, and cost-effective method of measuring the water quality of streams (Barbour *et al. ibid.*).

Initiated in 2006, an ongoing study led by Charles "Chuck" Parker, of the USGS Biological Resources Division, is collecting data on aquatic insects (a subset of macroinvertebrates) throughout the Cumberland Piedmont and Appalachian Highland Networks of the NPS. The study focuses primarily on a subset of the aquatic insects, the Orders Ephemeroptera, Odonata, Plecoptera, and Trichoptera, but also is collecting data on additional taxa when scientific interest warrants it. Data are still being collected and conclusions for individual parks are pending, however, the preliminary findings are available for ABLI and are presented in Table 25 (Parker pers. com. 2010).

The Table lists the species present in descending order of their tolerance value. Tolerance values indicate the degree of susceptibility to pollution and environmental variation and range from 0 to 10 with low numbers indicating low tolerance and high numbers indicating high tolerance to changes in the environment. Values of -1 indicate that a tolerance value has not yet been established.

The *Functional Feeding Group* classifications in Column 4 were defined by Parker (*ibid*.) and include, among others: 'Shredders', which feed on dead leaves; 'Collectors' that gather particles from the substrate; Scrapers, which consume directly from the substrate; 'Predators' that eat other animals, and 'Piercers', which derive content by piercing into food such as algal cells. Many species at ABLI are classified in multiple functional feeding groups.

Table 25. Aquatic insect species at ABLI ranked by tolerance value.

Taxon	Order	Tolerance	Functional Feeding Group
Chauliodes	Megaloptera	9.87	Predator-Engulfer
Merope tuber	Mecoptera	8.43	Predator-Engulfer
Diploperla robusta	Plecoptera	8.43	Predator-Engulfer
Helicopsyche borealis	Trichoptera	8.1	Collector-Filterer
Hydropsyche betteni	Trichoptera	4.06	Scraper-Grazer
Potamyia flava	Trichoptera	3.2	Shredder-Herbivore-Chewer
Polycentropus centralis	Trichoptera	2.55	Scraper-Grazer
Pachydiplax longipennis	Odonata	2.02	Collector-Gatherer
Ostrocerca truncata	Plecoptera	2	Predator-Engulfer
Micrasema species	Trichoptera	1.46	Scraper-Grazer
Triaenodes ignitus	Trichoptera	0.65	Collector-Filterer
Lype diversa	Trichoptera	0.56	Shredder-Herbivore-Chewer
Diplectrona metaqui	Trichoptera	0	Scraper-Grazer
Ceraclea species	Trichoptera	-1	Collector-Filterer
Chimarra aterrima	Trichoptera	-1	Collector-Filterer
Chimarra obscura	Trichoptera	-1	Collector-Filterer
Neophylax concinnus	Trichoptera	-1	Shredder-Herbivore-Chewer
Phryganea sayi	Trichoptera	-1	Predator-Engulfer
Protoptila species	Trichoptera	-1	Shredder-Herbivore-Chewer
Ptilostomis postica	Trichoptera	-1	Collector-Gatherer
Setodes incertus	Trichoptera	-1	Shredder-Herbivore-Chewer
Wormaldia moesta	Trichoptera	-1	Collector-Filterer

Species lacking an established tolerance value were omitted from the summary statistics presented in Table 26. Overall, 12 species found at ABLI have an assigned tolerance value with their average being 3.58. Of the species with assigned tolerance values, 8 of 12 (67%) are considered to be either 'intolerant' or 'highly intolerant'.

Table 26. Summary statistics for aquatic insects at ABLI according to Parker (pers. com. 2010).

Tolerance Class	Numbers of Species	Percent of Total Species
Highly Intolerant	4	33%
Intolerant	4	33%
Moderate	1	8%

Tolerance Class	Numbers of Species	Percent of Total Species
Tolerant	0	0%
Highly Tolerant	3	25%
TOTAL	12	
Average	3.58	

According to Parker (pers. com. 2010) the relative abundance of intolerant species indicates that ABLI waters are not problematic. In fact, he offered the opinion that water resources at ABLI are in excellent condition (Parker *ibid.*). A condition statement for aquatic insects is unavailable at this time due to the pending completion of the study and is currently assigned as 'TBD' in Table 27. The purpose of including the preliminary findings in this assessment is to serve as a reference and to aid in making general conclusions about water quality.

Table 27. Current condition status of aquatic insects at ABLI.

Level 3 Category	Indicator	Condition Status	Reference Condition	Data Source
Aquatic Insects	Species Richness	TBD	Abundance of intolerant species	Chuck Parker (NPS)-in progress

Green Condition = Acceptable, Yellow Condition = Caution, Red Condition = Of Significant Concern, TBD = To Be Determined, but not through Natural Resource Condition Assessment, NAV = No Reference Condition

Chapter 5 Discussion and Conclusions

This chapter further details and justifies the current condition status assigned to each selected indicator in the previous chapter and 'rolls up' to further assign a current condition status for the Level 2 categories in the assessment framework presented in Table 1 (Chapter 3). Attending the explanation for the assigned condition status in Level 2 are any known recommendations for management action, identification of data gaps and where possible, trends in the data are noted. The second section of this chapter addresses known threats, stressors, and disturbances to the natural resources of ABLI.

5.1 Condition Assessment Summaries

5.1.1 Water Quality Summary

Condition: Acceptable

The assessment of water quality involved six indicators of health: dissolved oxygen, pH, specific conductance, nitrate, temperature, and *E. coli*. Although the record of water quality monitoring dates back to 1979 the parameters, methods, and sampling locations have been inconsistent or lacked sufficient information to be included with more recent data. Prior to the establishment of regular monitoring intervals and a consistent suite of water quality monitoring parameters in 2004 it was difficult to determine a condition for ABLI waters. However, since then, the data show that water quality is excellent with 100% attainment of existing reference conditions for all indicators except *E. coli*. The North Branch Knob Creek sampling site has achieved 100% attainment for *E. coli*, but the Knob Creek and Sinking Spring sampling sites have achieved 90% and 83% attainment levels respectively. According to the latest NPS monitoring report (Meiman 2009) the water quality at ABLI is rated 'good' except for *E. coli* and nitrate which are of special concern. Meiman also identified a possible worsening trend for *E. coli* and nitrate. The next water quality monitoring interval is scheduled for 2010 and will be reported in 2011. The quality of the dataset, the frequency of monitoring, attainment of the reference condition by nearly all samples, and statements from an expert justify a current condition status of 'Acceptable' for water quality at ABLI.

A data gap exists concerning water quantity, especially at the Knob Creek Unit. Implementation of regular sampling and reporting of water quantity measurements at the Sinking Spring and Knob Creek sites might provide insight into the frequency and severity of flood events of which there is only a scattered record.

Continued monitoring as scheduled, especially for *E. coli* and nitrate, is recommended.

5.1.2 Air Quality Summary

Condition: Of Significant Concern

Air quality is the most severely degraded natural resource at ABLI. Only one indicator, particulate matter ($PM_{2.5}$) received a rating of 'Acceptable'. All other parameters including ozone, total deposition, and visibility received 'Caution' to 'Of Significant Concern' ratings due to insufficient attainment of established reference conditions.

Data used to assess air quality for ABLI were collected from stations located beyond the recommended range of 10 miles. A data gap exists concerning air quality data gathered within this range and preferably from within the park boundaries. In addition, some air quality indicators (pH and mercury) do not have established reference standards although some data for these indicators are available.

Air quality is unique in that management actions undertaken by the park can only seek to mitigate the effects of degraded air and not actually improve the air quality. Continued monitoring of air quality and research into the effects of ozone, deposition, mercury, and other air chemistry on the plant and wildlife communities is recommended.

5.1.3 Land Cover Summary

Condition: Acceptable

Land cover was assessed by quantifying the amount of land that changed from 'natural' (forests, grasslands, etc.) to 'human modified' (roads, buildings, agriculture, etc.). A large amount of change would indicate disturbances and potential negative impacts to the natural resources. The relatively small size of the park units and their proximity to developed or developing areas make them potentially vulnerable to outside influences. The assessment herein showed that only about 1% of the Birthplace Unit and <1% of the Knob Creek Unit had converted from 'natural' to 'human modified' areas between 1991 and 2001. During that same period, about seven acres (<1%) in a 1,000 meters wide buffer around the Birthplace Unit transitioned from 'forest' to 'agriculture' or 'urban' and zero acres transitioned from 'natural' to 'human modified' around the Knob Creek Unit. This small amount of areal land cover change most likely means that natural resources are not being adversely affected to the degree that would require management action.

The NLCD data used to assess land cover are high quality, although the 2001 dataset is due to be replaced. According to the MRLC website (http://www.mrlc.gov) provisional products and data layers for the year 2006 are forthcoming. If land cover change is deemed to be an important aspect to the preservation of natural resources at ABLI then complementary sources should be used to fill the data gap between 2001 and the present. Comparisons with more recent aerial photographs are a suggested method and such photographs are available from the Kentucky Department of Geographic Information Systems (http://kygeonet.ky.gov/) for the years 2005 and 2008. The aerial photographs, used in combination with field studies, would be useful in assessing the influences of recent development in and around ABLI. To that end, the NPScape landscape dynamics monitoring program (http://science.nature.nps.gov/im/monitor/npscape/) offers a new source of land cover data. This program provides digital products used to assess land cover metrics within a 30 kilometer buffer around a national park (NPS 2010b). A product was released for ABLI in December 2009 and was reviewed for this assessment but determined to be too generalized given the relatively small size of the two park units.

There are no known specific management recommendations concerning land cover. Continued monitoring and the incorporation of soon-to-be available datasets are warranted.

5.1.4 Vegetation Summary

Condition: Acceptable

The vegetation within ABLI is considered to be in 'Acceptable' condition. This conclusion was based primarily on the Jones and Pyne (2008) report that stated the vegetation of ABLI has good diversity, more than 90% of the expected species have been documented, and less than 4% of those species are invasive and considered to be threats to ecological integrity. ABLI also contains two vegetation communities, the Highland Rim Limestone Cliff/Talus Seep and the Central Limestone Glade, that are considered rare at the state, national, and global levels. It is important to consider the condition of the vegetation at ABLI both within the context of its role as a historical location and the human development impacts levied before the land was under the protection of the NPS.

A data gap exists pertaining to the spatial extent and impact of the invasive species. A 'Caution' condition is assigned to the 'invasive species' indicator of vegetation communities because of the 20 "high-impact" species (Morse *et al.* 2004; Moore 2009) already discovered there as well as the lack of information concerning their quantity and extent at ABLI.

Jones and Pyne (2008) identified several management considerations within their report:

- Priorities for land management should focus on the seven natural vegetation communities (listed in Table 15) rather than the successional and exotic-dominated vegetation communities.

- The Floodplain Canebrake is a potential eighth natural community at ABLI but would require restoration activities.

- Special attention should be given to protecting the rare Central Limestone Glade communities from invasives (Eastern red-cedar and others). These would occasionally burn under natural conditions but because they are now somewhat protected through fire suppression activities, they are encroaching. The authors suggest that reintroducing fire around the rare vegetation communities should be considered.

- It is recommended that a permanent buffer be acquired near the northern end of the Knob Creek Unit where the Highland Rim Limestone Cliff/Talus Seep community is found near an undisturbed, privately owned area. In the interim the authors suggest monitoring that boundary for changes.

- Invasive species may be the single biggest threat to the park at the current time. Japanese honeysuckle, multiflora rose, Japanese stilt grass are noted as particular threats. The study noted several others that are potentially worthy of monitoring.

The wetlands report (Roberts and Morgan 2006) suggests future research steps are needed to better understand the relationship between the wetland habitats and their role in supporting amphibians and other fauna.

- Investigate the use of wetlands by various animal groups.

- Investigate the duration of water in upland wetlands and their potential utility for use by animals during prolonged dry periods.

Overall the status of the vegetation is in 'Acceptable' condition for a mostly historical/cultural park such as ABLI. Continued monitoring is warranted to establish the severity of invasive species.

5.1.5 Birds Summary

Condition: Acceptable

Although only 87% of expected bird species were identified in the recent survey (Monroe 2005), this category receives a current condition status of 'Acceptable'. According to the author, the small size of the park and its human activities increase the number of bird species that simply fly over or use adjacent lands instead of ABLI proper. Continued surveying over a number of years will likely yield the desired documentation of 90% of the expected species. Monroe also noted the avian populations will always be small at the Birthplace Unit owing to its small acreage, bisecting highway, and visitor use. No management considerations of the twelve rare species discussed in Moore (2009) and the four exotic species have been issued. The state heritage program listing for all 12 birds is limited to breeding populations. Because there are likely no state or federal endangered bird species nesting at ABLI, no particular course of action was recommended (Monroe *ibid.).*

5.1.6 Herpetofauna Summary

Condition: Caution

The current condition status of herpetofauna at ABLI is 'Caution' because only 60% of the expected species were found. According to the author of the herpetofauna report (MacGregor 2007), species that were assumed to be common could not be found despite considerable searching. The Birthplace Unit was especially lacking in species diversity. The relatively small size of the park units and the lack of permanent ponds of water in the uplands were seen as the major limiting factors for herpetofauna at ABLI.

Several recommendations to improve or maintain the herpetofaunal richness at ABLI were made in the MacGregor (*ibid.*) report:

- The creation of upland ponds, floodplain, and forest edge habitats.
- The maintenance of tree cover along stream corridors.
- Preservation of some weedy grasslands and fallen trees to serve as habitats and food sources.
- Restoration of the natural stream meanders at Knob Creek.

5.1.7 Mammals Summary

Condition: Acceptable

Although the goal of documenting 90% of expected species was not met, the current condition of mammals at ABLI is considered to be 'Acceptable' based on author comments from their recent

survey (Gumbert *et al.* 2006). According to the authors, the desired 90% level of documentation was not reached because 1) many of the expected species that were not found during the survey period are rare or cryptic; 2) only two of the missing expected species had been previously documented within LaRue County (both are mice) and 3) the trapping methods employed for the survey might have yielded more individuals had the sampling periods and locations not been adversely affected by inclement weather.

The finding of a single Gray bat, a federally listed endangered species, has potential management implications. Further studies about the how the Gray bat uses the park (feeding, roosting, etc.) are needed before specific management actions can be recommended.

Management recommendations from the mammal survey (Gumbert *et al.* 2006) include:

- Maintain diverse habitats including open grasslands and early successional forests to allow for understory growth.
- Use prescribed fires to maintain early successional habitats.
- Plant native grasses and eliminate exotic species.
- Maintain fallen trees to serve as habitat unless they are a danger to the public
- Restore forested riparian zones and vernal pools in order to increase flight protection and food sources for bats.
- Construct vernal pools in the uplands of Knob Creek to provide needed water sources.

5.1.8 Fish Summary

Condition: Acceptable

The only study of the fish at ABLI (Zimmerman 2005) was conducted at the Knob Creek Unit and did not try to document 90% of expected species. However, when the Kentucky Index of Biotic Integrity is calculated for the data, the result is deemed to be excellent (Zimmerman pers. comm. 2009). This conclusion is the basis for rating the current condition status of fish at ABLI as 'Acceptable' in this study.

There are no reported data concerning fish at the Birthplace Unit nor is there a compiled list of expected species. Moreover, because of the karst landscape at the Birthplace Unit, the potential exists for cavefish and other rare species to be present.

No management recommendations have been made to date concerning fish.

5.1.9 Summary of Natural Resource Condition Assessments

Table 28 is an overall summary chart constructed using the assessment framework presented in Table 1 of Chapter 3. Table 28 lists the selected indicator(s) for every 'Level 3' category where available, the status of assessment for that indicator, and the current condition status as

determined by this study. Additional information includes applicable reference conditions, useful comments, and the primary data sources used in the assessments. This chart is meant to be a concise summary of the selected natural resources at ABLI for use by natural resource specialists and management at the NPS.

Table 28. ABLI Natural Resource Condition Assessment Summary Chart.

LEVEL 1 CATEGORY Level 2 Category	Level 3 Category	Selected Indicator	Status	Current Condition Status	Reference Condition	Comments	Data Source
AIR AND CLIMATE							
Air Quality	Ozone	Ozone Concentration	A		≤75 ppb	MAC426: 83% ATN MCK131: 28% ATN Etown: 36% ATN	KYDAQ Etown,CASTNet-MAC426 (02-09), MCK131 (90-09), NAAQS
	Wet and Dry Deposition	Total Deposition of Sulfur	A		Class 2: TBD Class 1 NPS: ≤3 kg/ha/yr Fenn: 3-8 kg/ha/yr Krupa: 5-10 kg/ha/yr	No standard reference condition, 0% attainment for all three suggested reference conditions	CASTNet-MAC426 (03-08)-MCK131 (91-08), NPS (2007a), Fenn *et al.* (2003), Krupa (2003)
		Total Deposition of Nitrogen	A				
	Visibility and Particulate Matter	Fine Particulate Matter ($PM_{2.5}$) Levels	A		≤15.0 μg/m^3	100% ATN	KYDAQ Etown,IMPROVE-MAC426 (91-08), NAAQS
		Visibility in Deciviews (dv)	A		Class 2: TBD Class 1: ≤19.4dv	0% ATN	IMPROVE-MAC426 (91-04), USEPA 2003
	Air Contaminants	Mercury Levels	A	TBD	NAV	Mean value: 10.15 ng/L	NADP/MDN-KY10 (02-08)
		pH	A	TBD	NAV	Mean value: 4.71	NADP-KY10 (02-08)
Weather and Climate	Weather and Climate (e.g. temperature trends, precipitation trends)	Precipitation, Temperature, and Solar Radiation Trends	NA	TBD	NAV		
BIOTA							
Flora							
Ecosystems and Communities	Community Extent (e.g. floral class extent)	TBD	NA	TBD		13 NVCS vegetation associations, 7 natural associations, 6 altered from natural state, 9 wetlands, 1 rare limestone glade	Jones and Pyne (2008), Roberts and Morgan (2006), GMP 2006, CRSMS UGA (2004)
	Community Composition (e.g. inventory of species, native species diversity, species richness)	Non-native Species, Species Richness	A		no exotics, detect at least 90% species expected	568 vascular plant species, 64 exotic plant species	Jones and Pyne (2008)
	Physical Structure (e.g. Vertical stand structure, tree canopy height, successional state)	TBD	NA	TBD			
Species and Populations	Population Size (e.g. number of individuals in the population)	Biodiversity	NA	TBD	NAV	Insufficient data	GMP (2006)

LEVEL 1 CATEGORY Level 2 Category	Level 3 Category	Selected Indicator	Status	Current Condition Status	Reference Condition	Comments	Data Source
	Habitat Suitability (focal species) (e.g. Measures of habitat attributes important to focal species)	TBD	NA	TBD			
BIOTA							
Fauna							
Ecosystems and Communities	Community Extent	TBD	NA	TBD			
	Community Composition (e.g. inventory of species, native species diversity, species richness)	TBD	NA	TBD		115 bird species, 28 herpetofauna species, 10 fish species, 30 mammal species	Monroe (2005), MacGregor (2007), Zimmerman (2007), Gumbert *et al.* (2006)
Species and Populations	Population Size (e.g. number of individuals in the population, breeding population size, number of individuals per habitat area (density))	Species of Concern Populations	NA	TBD	NAV		
	Habitat Suitability (focal species) (e.g. Measures of habitat attributes important to focal species)	Habitat Limitations	A	TBD	NAV	small park area limit number of bird species, lack of water bodies limit number of herpetofauna and birds, fluctuation of stream discharge limit fish numbers	Monroe (2005), MacGregor (2007), Zimmerman (2007)
Focal Species and Communities	Freshwater Invertebrates (e.g. mussels)	Non-native Species, Species Richness	NA	TBD	NAV		
	Terrestrial Invertebrates	Non-native Species, Species Richness	NA	TBD	NAV		
	Birds	Non-native Species, Species Richness	A		no exotics, detect at least 90% species expected	112 species, 85% OE, small extend of park affect numbers observed	Monroe (2005)
	Herpetofauna (Amphibians & Reptiles)	Non-native Species, Species Richness	A		no exotics, detect at least 90% species expected	28 species, 61% OE, Habitat limitations	MacGregor (2007)

LEVEL 1 CATEGORY Level 2 Category	Level 3 Category	Selected Indicator	Status	Current Condition Status	Reference Condition	Comments	Data Source
	Fishes	Non-native Species, Species Richness	A		no exotics, detect at least 90% species expected	10 species observed, Biotic integrity of area "excellent" according to expert (Zimmerman)	Zimmerman (2007)
	Mammals	Non-native Species, Species Richness	A		no exotics, detect at least 90% species expected	31 species, 68.8% OE, 5 rare species, 2 cryptic species	Gumbert *et al.* (2006)
	Wetlands	# and Area of Wetlands	A	TBD	NAV	9 wetlands covering 0.76 acres	Roberts and Morgan (2006), GMP (2006)
	Glades	# and Area of Glades	NA	TBD	NAV	# acres central limestone glade, # acres of S/SW facing glade	Jones and Pyne (2008)
At-Risk-Biota	Threatened & Endangered (T&E) Species and Communities	Presence, Populations	A	TBD	NAV	9 bird species of concern at state level, 2 globally rare NVCS association,	Moore (2009), Jones and Pyne (2008)
GEOLOGY AND SOILS							
Geomorphology	Windblown Features and Processes	TBD	NA	TBD	NAV		
	Hillslope Features and Processes (e.g. falls, slides, flows)	TBD	NA	TBD			
	Stream/river Channel Characteristics (e.g. sedimentation rate)	Floodplain characteristics	A	TBD	NAV	29 Acres (12.6%) of Knob Creek portions lies within 100-year floodplain	FEMA (2009)
Subsurface Geologic Processes	Cave/Karst Features and Processes	TBD	A	TBD	NAV		Groves (2004) Groves *et al.* (1999)
	Seismic Activity	TBD	NA	TBD			
Soil Quality	Soil Function and Dynamics	Soil Type	A	TBD	NAV	6 Soil Series types, mostly Garmon and Sensabaugh Series (KC) and Cumberland and Crider Series (BP)	USDA (1979)
Paleontology	Paleontology	TBD	D	TBD		No Inventory Data, potential poaching issues	Hunt-Foster *et al*. 2009 Thornberry-Ehrlich (2010)
LANDSCAPE							

LEVEL 1 CATEGORY Level 2 Category	Level 3 Category	Selected Indicator	Status	Current Condition Status	Reference Condition	Comments	Data Source
Landscape Dynamics	Land Cover and Use	Park Unit Land Cover Change	A		NAV	BP: 16.23 (14.63%) Acres Developed; KC: 3.33 (1.46%) Acres Developed; BP: 1.11 (1%) Acre Change to Urban; KC: 2.00 (0.88%) Acre Change to Forest	MRLC Consortium (1992-2001), KLCD (2001)
		Development (Impervious Surface, Population Density)	NA	TBD	<10% Imperviousness		
		Adjacent land cover use/change	A		NAV	Comparable change to Park Unit	MRLC Consortium (1992-2001)
		Landscape Pattern and Fragmentation	NA	TBD	NAV		CRMS UGA (2004), NPScape
Soundscape	Soundscape	TBD	NA	TBD		No Data	
Viewscape	Viewscape (e.g. building permits, distance from viewscape)	TBD	NA	TBD		No Data	
Nutrient Dynamics	Nutrient Dynamics	TBD	NA	TBD			
Energy Flow	Primary Production	TBD	NA	TBD			
WATER							
Hydrology	Groundwater Dynamics	TBD	NA	TBD			Groves (2004) Groves *et al.* (1999)
	Surface Water Dynamics	Discharge	D	TBD	NAV		USGS
		Gage Height	NA	TBD	NAV		USGS
Water Quality	Water Chemistry	Dissolved Oxygen	A		cold: >5.0 mg/L, warm: >4.0 mg/L	100% ATN at 3 sample locations (KC1, KC2, Sinking Spring)	Meiman (2009)
		pH	A		6.0 to 9.0 SU	100% ATN at 3 sample locations (KC1, KC2, Sinking Spring)	Meiman (2009)
		Specific Conductance	A		160 to 680 µS/cm	100% ATN at 3 sample locations (KC1, KC2, Sinking Spring)	Meiman (2009)

LEVEL 1 CATEGORY Level 2 Category	Level 3 Category	Selected Indicator	Status	Current Condition Status	Reference Condition	Comments	Data Source
	Nutrient Dynamics	Nitrate as Nitrogen	A		<90 mg/l	100% ATN at 3 sample locations (KC1, KC2, Sinking Spring)	Meiman (2009)
	Physical Parameters	Temperature	A		<31.7 ^{o}C	100% ATN at 3 sample locations (KC1, KC2, Sinking Spring)	Meiman (2009)
	Microorganisms	*E. coli*	A		<476 CFU/100ml	91% ATN at 3 sample locations (KC1, KC2, Sinking Spring)	Meiman (2009)
	Toxics	TBD	NA	TBD			

A = Assessed and Completed, D = Discussed, NA = Not Assessed through NRCA, IP = In Process of Completion, Green Condition = Acceptable, Yellow Condition = Caution, Red Condition = Of Significant Concern, TBD = To Be Determined, but not through Natural Resource Condition Assessment, NAV=No Reference Condition Available for selected indicator, ATN = Attainment, OE = Observed vs. Expected, KC = Knob Creek, BP = Birthplace

5.2 Threats, Stressors, and Disturbances

Natural resources are constantly subjected to interference that can alter even the most resilient species or system. Threats to the condition of natural resources can come from many sources, even other natural resources, and each park in the CUPN has its own list of vulnerabilities (Leibfreid *et al.* 2005). In that document, stressors and disturbances were defined and used by the CUPN for I&M purposes. Stressors are physical, chemical, or biological inputs, either foreign or inherent, but at excessive levels such that significant changes at the ecological level can take place. Disturbances are discrete events such as droughts, earthquakes, and severe weather that disrupt physical or biological resources (Leibfreid *et al. ibid.*). The CUPN Vital Signs Monitoring Program (VSMP, http://science.nature.nps.gov/im/units/cupn/vitalsigns.cfm) identifies critical park resources to represent overall ecological health. The CUPN regularly monitors vital signs including water quality, invasive species, landscape dynamics, and ozone and foliar injury. Data collected through the ongoing monitoring efforts of the VSMP are important in filling in the data gaps and other unknowns at ABLI.

5.2.1 Fire Threats

Threat: Acceptable

Fire is a moderate disturbance at ABLI. According to the ABLI Fire History Spreadsheet (Caldwell pers. com. 2010), fires there have been sporadic and small. Since record keeping began in 1950, only six fires have been recorded at ABLI. Five of the six struck at the Birthplace Unit and occurred between 1974 and 1981. As observed on the NPS Wildland Fire Report Form (NPS 2007b) every fire is assigned a 'Fire Type' and a 'Protection Type' that indicates the category of fire and its origin. All fires at the Birthplace Unit were designated as 'Fire Type 1' meaning the wildfire was suppressed by NPS action. All but one of these fires was designated 'Protection Type 1' meaning its point of origin was located on NPS land and it was the responsibility of NPS to suppress. A single fire was given 'Protection Type 5' meaning its origin was located on non-NPS land and it was not the responsibility of the NPS to suppress but suppression action was undertaken to prevent spread to NPS land. Table 29 lists the fire history of ABLI since 1950 (Caldwell *ibid*.).

Table 29. Fire history at ABLI (January 1950 through July 2010).

Fire Name	Date	Park Unit	Fire/Protection Type	Cause	Acres Affected
NONE	10/13/1974	Birthplace	1/1	Human	0.1
Big Maples	6/7/1977	Birthplace	1/1	Human	2.0
NE Boundary	11/12/1978	Birthplace	1/1	Human	1.0
County Rd	11/3/1978	Birthplace	1/1	Human	0.1
Bowling	3/14/1981	Birthplace	1/5	Human	0.1
Knob Creek	4/21/2007	Knob Creek	2/1	Human	14.0

The largest fire to date at ABLI and the only one recorded at the Knob Creek Unit occurred April 21, 2007. It should be noted that the Knob Creek Unit was not under NPS management until 2001 so there are no records of earlier fires. This fire consumed 14 acres within the park and less than an acre of land beyond the park boundary. This fire was assigned a 'Fire Type 2' and a 'Protection Type 1' indicating that it was a wildfire originating on NPS land but extinguished by

natural causes and was not suppressed by NPS action. Figure 19 is an original map that shows

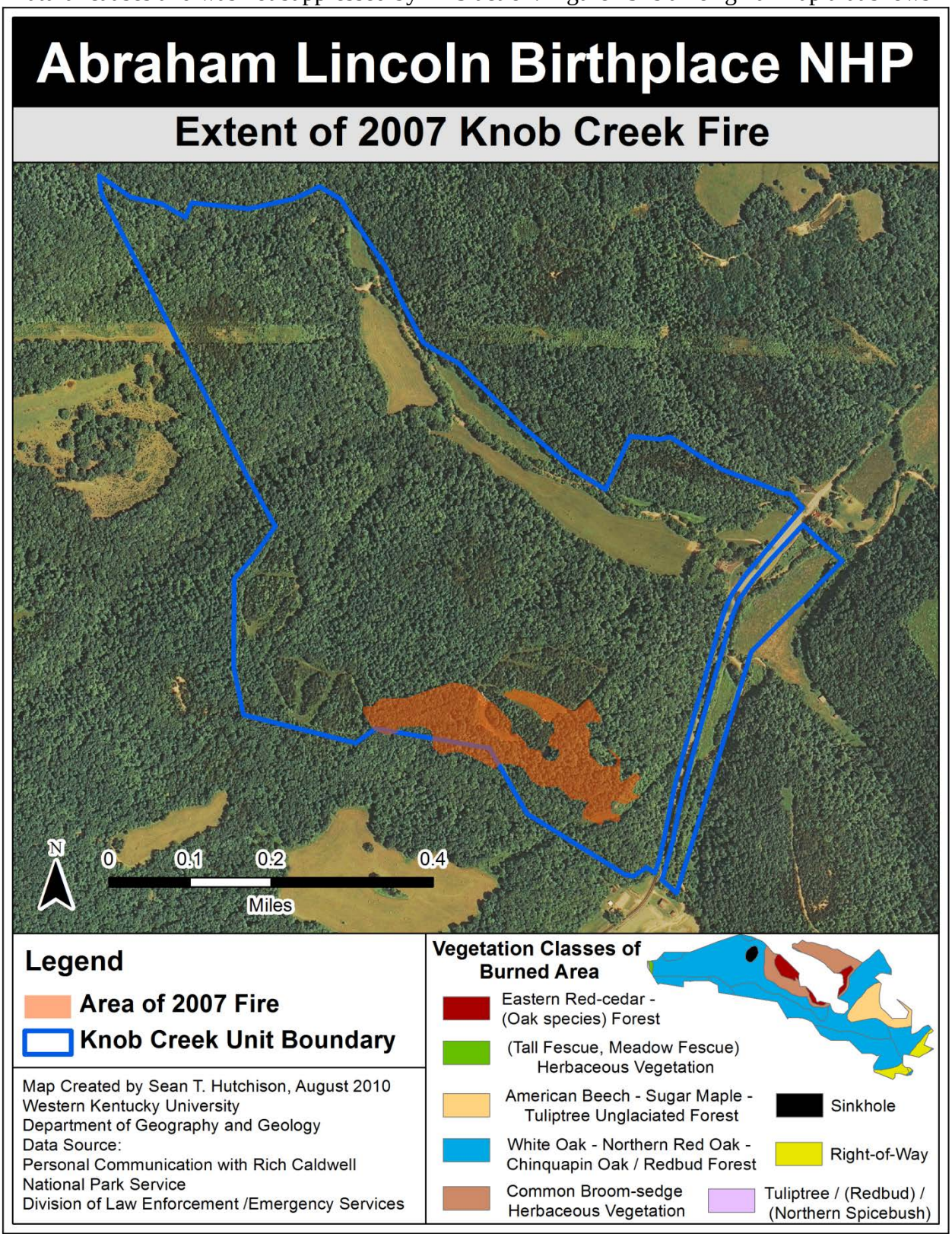

Figure 19. Extent of the 2007 fire at the Knob Creek Unit.

the extent of the burned area together with the affected vegetative communities as delineated by CRMS (2004). The spatial extent of the burned area was obtained by an NPS fire management team through field recordings using a handheld Global Positioning System unit.

5.2.2 Water and Karst Issues

Threat: Caution

The karst landscape of ABLI is considered a moderate threat and recurring disturbance owing to the fact that water quality and quantity can change rapidly in that environment. Karst refers to landscapes that are characterized by soluble bedrock, sinkholes, caves and conduit flow of water through the subsurface. Karst adds complexity to the hydrologic cycle and its potential for rapidly changing conditions must be accounted for when assessing water resources. Karst related flooding is a significant issue at the Birthplace Unit where it can disrupt park visitation while flooding due to overbank flow is a concern at the Knob Creek Unit.

Surface flows are easy to track and generally conform to topography but when the water sinks, it can be difficult to determine precisely how it contributes to the regional hydrology. A study by Joe Ray, a hydrologist retired from the Kentucky Division of Water, determined through dye-tracing that the Sinking Spring at the Birthplace Unit drains approximately 1.2 km southwest to a spring on the south fork of the Nolin River (Ray 1993). Ray also determined through dye-tracing that Boundary Oak Spring and Howell Spring both contribute water to the Sinking Spring. Boundary Oak Spring lies at the southwestern side of the largest sinkhole in the Birthplace Unit as shown in Figure 20. Adjacent agricultural lands have the potential to impact water quantity and quality of the Boundary Oak Spring. Howell Spring is located on private property in a wooded area south of the Birthplace Unit.

A later study by karst hydrologist Dr. Chris Groves (Groves *et al.* 1999) also investigated the surface and groundwater flows that contribute to the Sinking Spring. He repeated previous dye-tracing efforts and established new subsurface connections between the springs at the Birthplace Unit and springs on the south fork of the Nolin River. Groves estimated that the Sinking Spring has an approximate recharge area of 0.5 km^2 which is also shown in Figure 20. He concluded that the water quality at Sinking Spring is subject to minor threats owing to land use issues. Runoff from adjacent agricultural lands, the US 31-E highway, and paved areas within the park were likely the most significant sources of potential contaminants (Groves *et al. ibid.*).

A follow-up report by Groves (2004) examined the effects of two storm events in order to evaluate: 1) the impact of agricultural runoff during a June 2001 storm and 2) parking lot runoff during a September 2002 storm. Analysis of water quality after the 2001 storm event revealed that in the worst cases fecal coliform exceeded 10,000 colonies per 100 mL and nitrate, another indicator of animal and human waste, was present at ambient levels of about 3 mg/L (Groves *ibid.*). Trifluralin was the only pesticide detected, but concentrations were found to be low. Nonetheless, Groves recommended that further research into pesticides is warranted and suggested the potential for bioaccumulation. Analysis of runoff from the parking lot revealed that metals, oil, and grease do not pose a significant threat to visitors. Groves concluded that water

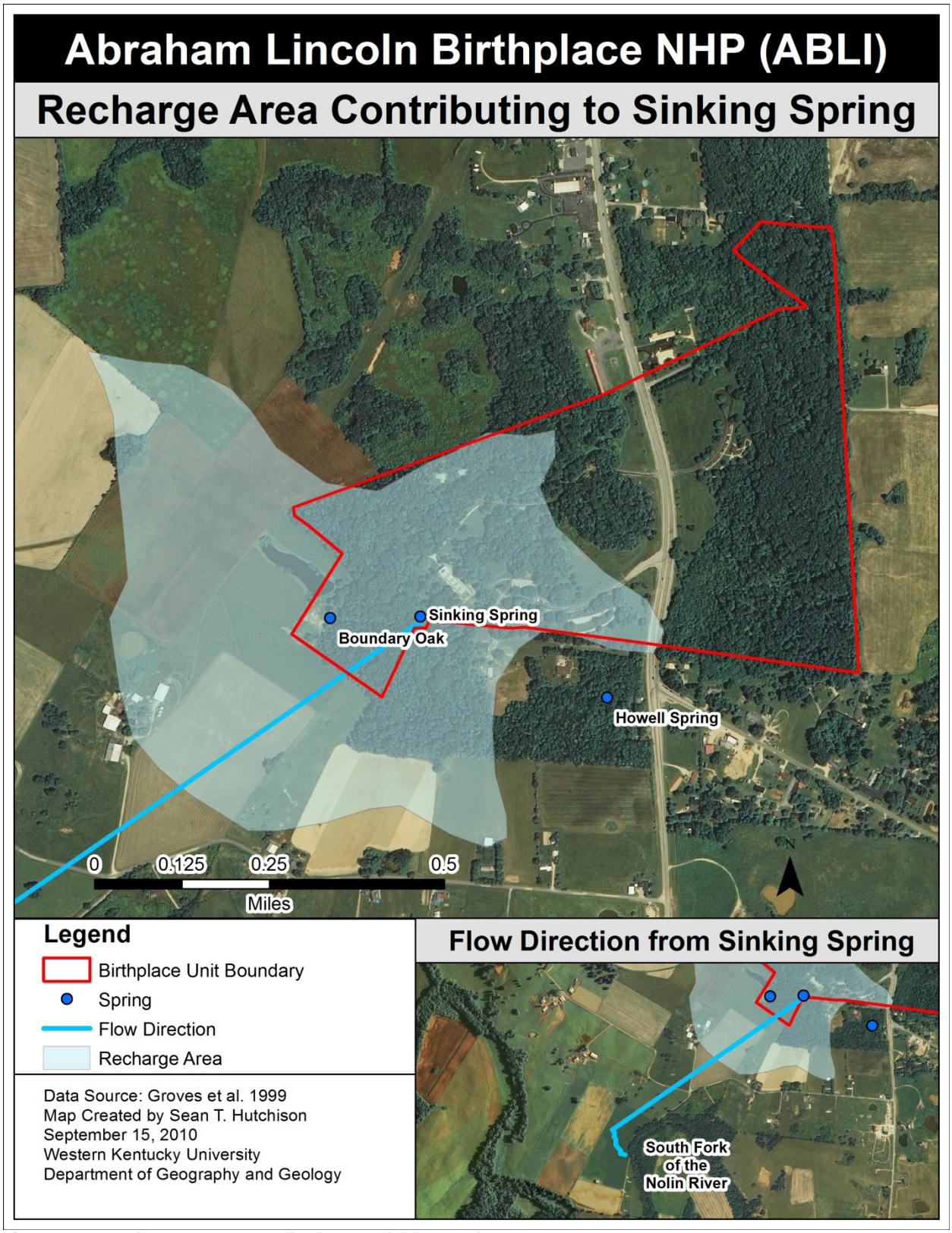

Figure 20. Recharge area contributing to Sinking Spring.

quality is good and the measured parameters fall within the range that is to be expected from an area surrounded by agriculture, residences, and commerce. The primary interaction visitors have with the Sinking Spring is for cultural interpretation and for the most part visitors do not come in direct contact with the water, although a risk is possible.

Flooding is a consistently mentioned threat to ABLI, although few measurements pertaining to its quantity or duration are available. Beginning in 1929, the U.S. War Department attempted to alleviate flooding at the Birthplace Unit by installing a network of subsurface drains. Unfortunately, these drains do not completely prevent flooding. According to Groves *et al.* (1999) flooding occurs at Sinking Spring a few times each decade. During heavy rainfalls water backs out of the Sinking Spring and overfills the surrounding sinkhole, creating a temporary lake up to 600 feet long (Groves 2004). According to Ray (1993) the temporary lake generally drains within a day.

Flooding is also known to occur at the Knob Creek Unit. According to the flood plain maps from the United States Federal Emergency Management Agency (FEMA 2009) approximately 29 acres (12.6%) of the Knob Creek Unit is within the 100 year floodplain.

5.2.3 Severe Weather

Threat: Caution

Severe weather is an unavoidable disturbance with potentially catastrophic impacts for the park. On January 25, 2009 a severe ice storm moved across Kentucky inflicting considerable damage to the state. Much of the lasting damage was in the form of fallen trees onto property and across roads which significantly hampered rescue and recovery efforts. ABLI was directly affected by fallen limbs and the park remained closed and without electricity for days due to the damage. Sandy Brue, the Chief of Interpretation at the time, is quoted by the LaRue County Herald News (Ireland 2009) describing ABLI as a "war zone" following the ice storm. The fallen limbs caused the paths and trails to be closed and celebrations planned for Lincoln's bicentennial birthday were canceled. The trails remained closed due to fallen trees for several months.

The National Oceanic and Atmospheric Administration (NOAA) is a federal agency that provides weather forecasts, climate monitoring, and other scientific data pertaining to climate or oceanic issues (http://www.noaa.gov). A division within NOAA called the Storm Prediction Center monitors and catalogs severe weather occurrences of tornadoes, hail, and wind. Record keeping for tornadoes began in 1950 while hail and wind records began in 1955. To date, five tornadoes have been recorded within a 10 mile radius of the park, but none crossed into either park unit. The closest tornado to ABLI occurred in 1952 approaching within half a mile of the Birthplace Unit. Kentucky has experienced 442 tornadoes since 1950 (NOAA 2009). Inspecting the data in a GIS revealed that the central Kentucky region, where ABLI is located, experienced fewer tornadoes on average than the rest of the state.

Twenty-five instances of hail have been recorded within a ten mile radius of ABLI. The size of the hail ranged from 0.75 inches to 4.5 inches. The spatial record on hail only indicates a central point of impact rather than the total area affected so it is impossible to tell whether either park unit was directly impacted. The same limitation exists with the wind data. Examination of wind

was limited to 'Significant' events only, which is defined as winds of 65 knots (74.8 mph) or greater. Six 'Significant' winds have been recorded within a 10 mile radius of ABLI with the most severe reaching at 87 knots (100.1 mph).

Table 30 lists all 36 severe weather events, in chronological order, that have occurred within a 10 mile radius of ABLI. The third column expresses the scale of the event as a magnitude or size as appropriate. Tornadoes are described using the Fujita scale (F1 to F6), severe weather is given in knots (1 knot equals 1.15 mph), and hail size is given in inches of diameter.

Table 30. Severe weather events within 10 mile radius of ABLI since 1950.

Event Type	Date	Magnitude / Size
Tornado	3/22/1952	F3
Hail	4/2/1956	1 in
Hail	5/25/1962	1.75 in
Hail	8/29/1979	0.75 in
Wind	7/2/1980	87 knots
Hail	8/24/1983	1.75 in
Hail	3/12/1986	0.75 in
Hail	5/14/1986	0.75 in
Hail	5/14/1986	1.5 in
Wind	8/3/1987	83 knots
Hail	4/27/1989	2.0 in
Hail	5/5/1989	2.0 in
Hail	5/15/1990	0.75 in
Hail	9/7/1990	2.5 in
Hail	9/7/1990	1.25 in
Hail	7/30/1992	1.75 in
Tornado	3/28/1997	F2
Tornado	3/28/1997	F2

Event Type	Date	Magnitude/Size
Hail	4/4/1997	0.75 in
Wind	11/9/2000	70 knots
Wind	11/9/2000	70 knots
Hail	3/29/2002	0.75 in
Wind	4/28/2002	75 knots
Hail	5/1/2002	1.0 in
Hail	5/1/2002	4.5 in
Hail	5/15/2003	0.75 in
Hail	1/2/2006	2.0 in
Hail	1/2/2006	0.75 in
Tornado	1/2/2006	F1
Hail	3/13/2006	0.88 in
Hail	4/20/2006	0.75 in
Hail	5/25/2006	0.88 in
Wind	8/10/2006	65 knots
Hail	6/23/2007	1.0 in
Hail	6/23/2007	1.0 in
Tornado	2/5/2008	F2

5.2.4 Invasive Species

Threat: Caution

Through biological surveys and direct NPS input, invasive plant species have been identified as the single largest threat to biological and ecological integrity at ABLI (Jones and Pyne 2008; Leibfreid *et al.* 2005; Southeast Exotic Plant Management Team (SEEPMT) 2003) and can be considered an ecosystem stressor. The monitoring and management of invasive species are established priorities for the park. Invasive species control efforts are overseen by the SEEPMT and assistance with early detection monitoring is a goal of the CUPN as part of the VSMP, which will hopefully detect new invasions before they can cause significant impacts.

The presence of invasive species at ABLI has been documented through several surveys. The Jones and Pyne (2008) vegetation survey identified 65 invasives of which 35 are considered aggressive. Using the I-Rank system (Morse *et al.* 2004), 20 of the 65 species are identified as high-ranking management issues. Separately the SEEPMT identified 48 invasive species of

which 11 are considered important in terms of management implications (SEEPMT 2003). Of the 11 which were identified by SEEPMT only six do not appear on the list of the 20 invasive species with high I-Ranks (Table 14): Common privet hedge (*Ligustrum vulare*), Japanese knotweed (*Polygonum cuspidatum*), multiflora rose (*Rosa multiflora*), Japanese grass (*Microstegium*), Asiatic dayflow (*Commenlina communis*), and bristled knotweed (*Polygonum caespitosum*).

A data gap exists pertaining to the spatial extent, severity, and management priority of invasive species. Updated information is needed to assess the effectiveness of invasive species management.

5.2.5 Air Quality

Threat: Of Significant Concern

Air quality is the most severely degraded resource at ABLI and is a stressor on the ecosystem, especially the flora, as well as a threat to the aesthetic qualities of the park through degraded visibility.

Ozone is of particular concern because it can cause foliar injury to sensitive plants. Ozone and foliar injury is a vital sign that is regularly monitored as part of the CUPN VSMP. ABLI was one of the first three parks to be evaluated for ozone in 2009 (Jernigan *et al.* 2009). This study found that, although some plant species are susceptible to foliar injury due to ozone, no such damage was identified at ABLI. The authors suggested that low levels of ozone during the study period might explain the absence of injury.

Deposition of nitrogen and sulfur are also stressors on the ecosystem. Scientific literature (Fenn *et al.* 2003; Krupa 2003) and NPS reports (NPS 2007a) conclude that deposition of either nitrogen or sulfur above 3kg/ha/yr pose a threat to ecosystem health through acidification and fertilization of soils and surface waters. Records of deposition near ABLI indicate that all measurements are above the suggested safe level.

Visibility, as measured in deciviews (dv), is currently above the recommended attainment value meaning further improvement is needed. However, the levels of $PM_{2.5}$ are currently below (better than) the accepted reference level. This suggests that visibility is being affected by factors other than particulate matter.

Although there is a significant amount of data available concerning air quality, the extent to which it represents ABLI accurately is questionable. The three stations used to derive the air quality data are located between 11 miles and 40 miles away from ABLI.

5.2.6 Water Quality

Threat: Caution

Water quality is a vital sign that is regularly monitored as part of the CUPN Vital Signs Monitoring Program. To date, the only measured indicator of water quality detected beyond an established standard or outside an acceptable range (as determined by expert opinion) is *E. coli*. Since 2004, samples taken at the Knob Creek (KCKC) site (Figure 7) were outside the

acceptable range in just one of 10 cases. Samples taken at the Sinking Spring (SSTS) site were outside the acceptable range for two out of 12 samples. No *E. coli* samples at the North Branch Knob Creek (NBKC) sampling site have been outside the acceptable limit.

5.2.7 Land Cover Change

Threat: Acceptable

Land cover change at ABLI can be a direct threat to park resources, yet prudent planning decisions and actions undertaken by the NPS are likely to limit negative effects. However, land cover change outside the park is a more significant threat to park resources because of the uncontrollable factors and unforeseen consequences of actions potentially miles away. Land cover change is an aspect of 'landscape dynamics', a vital sign that is monitored as part of the CUPN VSMP.

Remote sensing is a preferred tool for examining land cover change. The Multi-Resolution Land Characteristics (MRLC) Consortium produces several land cover products based on remote sensing. The National Land Cover Database (NLCD) 'Retrofit Change Product' was used to quantify land cover changes at ABLI and within the vicinity of the park from 1992 to 2001. Conversions of 'natural' lands (i.e. forests) to 'human modified' lands (i.e. urban and agriculture) were considered to be threatening influences on ABLI.

The small conversion of land from 'Natural' to 'Human Modified' within the park and within a 1,000 meter buffer zone around the park indicates that land cover change between 1992 – 2001 were likely putting an 'Acceptable' amount of stress on park resources. An updated dataset is currently being produced by the MRLC to show changes from 2001 – 2006, and is recommended for future studies.

5.2.8 Infestation, Disease, and Trauma

Threat: TBD

Infestation, disease, and trauma have been identified as significant threats and stressors to the biotic resources of ABLI. Despite being an important indicator of biotic health, insufficient data have been collected to assess the potential impacts. Plant trauma as related to ozone exposure has been investigated at ABLI as part of the CUPN VSMP (Jernigan *et al.* 2009). Although species were identified by the investigation as being susceptible to foliar injury from ozone, none at ABLI could be confirmed as having been injured during the study period. This threat cannot be fully assessed until more information is collected.

5.2.9 Visitor and Recreation Use

Threat: TBD

On average, more than 200,000 visitors utilize ABLI in some capacity every year. This influx of people is a possible threat to many natural resources at ABLI. However, the only established threat from direct human interaction concerns the poaching of paleontological resources. Crinoids and other Mississippian-age fossils in the Borden Formation are well exposed along the banks of Knob Creek, although an inventory has yet to be completed (Thornberry-Ehrlich 2010). Fossils are considered to be an important geologic and cultural resource at ABLI (Hunt-Foster *et*

al. 2009) and it is currently unknown to what extent they have been degraded by poaching or other human activities.

The Geologic Resources Inventory for ABLI (Thornberry-Ehrlich 2010) suggests three management actions for the paleontological resources that include performing a comprehensive inventory, monitoring exposed fossils along cut banks and slopes, and develop an interpretive program of the geologic history of the area that incorporates the fossils.

5.2.10 Threats, Stressors, and Disturbances Summary

Table 31 is a summary chart of the 12 indicators that have been identified as a potential threat, stressor, or disturbance to the natural resources at ABLI. Table 31 has the same format as the earlier summary chart for natural resource conditions presented in Table 28. The condition status assigned to each of the indicators in Table 31 represents the current level of perceived threat to natural resources at ABLI overall and not relative to one another. In other words indicators such as 'Fire Location and Frequency', although rated 'Acceptable', should not be considered less of an overall threat than other threats in terms of their potential impacts.

In some cases Table 28 and Table 31 are not directly comparable. For example, the Level 3 category of 'Cave/Karst Features and Processes' is not assessed as far as its current condition in Table 28, but in Table 31 this category is assigned a 'Caution' ranking because of the known flooding and water contamination issues associated with a karst environment. 'Invasive species' were assessed previously as part of ABLI vegetation resources, but is separately recognized in Table 31 as a threat because of the attention this issue has been given in various studies and park documents.

Table 31. Threats, Stressors, and Disturbances at ABLI.

LEVEL 1 CATEGORY Level 2 Category	Level 3 Category	Selected Indicator	Status	Current Condition Status	Reference Condition	Comments	Data Source
THREATS, STRESSORS, AND DISTURBANCES							
Fire and Fuel Dynamics	Fire and Fuel Dynamics	Fire Location and Frequency	A		Adherence to Fire Management Plan (FMP) Goals	Infrequent and spatially limited fires	Caldwell (2010) NPS (2007b)
Subsurface Geologic Processes	Cave/Karst Features and Processes	Impacts of flooding and karst issues	A		NAV	Minor threats to water quality. Flooding risks at Sinking Spring.	Groves (2004) Groves *et al.* (1999)
Weather and Climate	Weather Events	Severe Weather Occurrences	A		NAV	Lower than average occurrences compared to other counties in Kentucky.	NOAA (2009) Ireland (2009)
Invasive Species	Invasive/Exotic Plants (e.g. extent, risk factor, non-native species diversity)	# Exotic Species # Highly Ranked Species	A		No Exotics	65 exotic plant species, 20 High I-Rank plant species	Moore (2009), Jones and Pyne (2008)
Air Quality	Ozone	Ozone Concentration	A		≤75 ppb	MAC426: 83% ATN, MCK131: 28% ATN ETOWN: 36% ATN	CASTNet-MAC426 (02-09)-MCK131 (90-09), NAAQS
	Wet and Dry Deposition	Total Deposition of Sulfur	A		Class 2: TBD Class 1 NPS: ≤3 kg/ha/yr Fenn: 3-8 kg/ha/yr Krupa: 5-10 kg/ha/yr	No standard reference condition, 0% attainment for all three suggested reference conditions	CASTNet-MAC426 (03-08)-MCK131 (91-08), NPS (2007a), Fenn *et al.* (2003), Krupa (2002)
		Total Deposition of Nitrogen	A				
	Visibility and Particulate Matter	Visibility in Deciviews (dv)	A		Class 2: TBD Class 1: ≤19.4 dv	MAC426: 0% ATN	IMPROVE-MAC426 (91-04), USEPA 2003
Water quality	Microorganisms	*E. coli*	A		<476 CFU/100ml	Avg. 91% ATN at 3 sample locations.	Meiman (2009), USEPA STORET
Landscape Dynamics	Land Cover and Use	Adjacent land cover use/change	A		NAV	Small land cover changes inside and outside of park boundary	MRLC Consortium (2007), KYDGI (2004)
Infestation, Disease, and Trauma	Plant Disease/Trauma	Risk Factor of Ozone Sensitive Plants	D	TBD	NAV	Inconclusive Preliminary Results	Jernigan *et al.* (2009)
Visitor and Recreation Use	Visitor Use	Poaching Risk Factor, Fossil Collecting Incidents	D	TBD	No Poaching Incidences	Approximately 200,000 visitors per year	GMP (2006)

A = Assessed and Completed, D = Discussed, NA = Not Assessed through NRCA, IP = In Process of Completion, Green Condition = Acceptable, Yellow Condition = Caution, Red Condition = Of Significant Concern, TBD = To Be Determined, but not through Natural Resource Condition Assessment, NAV=No Reference Condition Available for selected indicator, ATN = Attainment, OE = Observed vs. Expected, KC = Knob Creek, BP = Birthplace

5.3 Conclusions

This study assessed a selected suite of abiotic and biotic natural resources at ABLI. Existing data for each selected resource were gathered, analyzed, and where appropriate, were summarized as a table, graph, or spatial product. Resource assessments were conducted relative to established reference standards from federal, state, and local sources when available. When they were not available, scientific literature and expert opinion were used to qualitatively assess the resource. The framework for the assessment was developed as a combination of the NPS Ecological Monitoring Framework (NPS 2005) and the USEPA SAB framework (USEPA SAB 2002). This combined framework used selected indicators to aid in assigning the condition of a natural resource. Resources that achieved attainment standards or were considered to be in good condition by expert opinion received an 'Acceptable ' rating. Resources that sporadically achieved the attainment standards or warranted attention from park managers received a 'Caution' rating. Resources that rarely or never achieved attainment standards or were deemed to be severely degraded received the 'Of Significant Concern' rating.

Natural resource categories deemed to be in 'Acceptable' current condition at ABLI are: water quality, land cover, vegetation, birds, mammals, and fish. Natural resource indicators needing attention are: *E. coli*, ozone, sulfur and nitrogen deposition, visibility, invasive species, and herpetofaunal richness. Threats to natural resources not already mentioned include: fires, subsurface geologic processes, severe weather, land cover change; plant infestations, disease, and trauma; and fossil poaching.

In some cases moderate to significant data gaps limited the assessment. Most of these cases involved data gathered at a spatial scale too generalized for ABLI, such as air quality monitoring. In a few cases reliable data had not been gathered for a resource or standards were unavailable.

Overall ABLI has more resources deemed 'Acceptable' than either 'Caution' or 'Of Significant Concern' combined. Although many indicators and resource categories achieved the applicable standard it is the opinion of this study that all resources would benefit from additional inventory and monitoring efforts.

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