HOW CAN PANARCHY THEORY CONTRIBUTE TO THE PERSISTENCE OF A RARE BOG ECOSYSTEM: A PROPOSAL FOR LEWIS CREEK NATURE PARK.

by

MEGAN MAILLOUX

(Under the Direction of Alfred R. Vick)

ABSTRACT

Panarchy theory can be a beneficial tool when designing within landscapes characterized by uncertainty in their ecological systems. Landscape architects must first recognize or restore the identity of a system to successfully relate this theory to design. Then, it is critical to recognize the components of a system that create the panarchy, to discover what aspects enhance potential, connectedness, resilience and identity to keep a system within a desired trajectory. It is the understanding of these elements and processes that will lead to the creation of a design that will contribute to the true conservation of the desired system and enhance innovation. By conserving and restoring the processes that contribute to the persistence of the desired trajectory of the system, it will be more likely to withstand greater disturbances and persist longer.

In this thesis, the generalized framework of panarchy along with the necessary element of identity is used to create design guidelines for designing around a rare bog ecosystem. These guidelines are then applied to the design of the Lewis Creek Nature Park, which includes a 6.5-acre swamp forest bog complex.

INDEX WORDS: panarchy, landscape design, bog, ecosystem

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DEDICATION

This thesis is dedicated to my mom and dad.

I would not be where I am without you.

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CHAPTER 1

INTRODUCTION

> "The outstanding scientific discovery of the twentieth century is not television, or radio, but rather the complexity of the land organism. Only those who know the most about it can appreciate how little we know about it. The last word in ignorance is the man who says of an animal or plant: "What good is it?" If the land mechanism as a whole is good, then every part is good, whether we understand it or not. If the biota, in the course of aeons, has built something we like but do not understand, then who but a fool would discard seemingly useless parts? (Leopold, 1993)."

When dealing with ecological landscapes, there is much uncertainty about how the land mechanism as a whole functions. Even though all the parts of a landscape may contribute to its "good", how does one know what parts contribute the most? As landscape architects, this predicament is consistently encountered in the process of design. Panarchy, a recent ecological theory, can be a beneficial tool when designing within landscapes characterized by uncertainty in their ecological systems. In every landscape, there are multitudes of structures and processes that contribute to its complexity. These "parts" combine to form ecosystems, and these are the basis for panarchy theory.

The term ecosystem was coined in 1935 by Sir Arthur Tansley, an English botanist who began the British Ecological Society (Odum, 1997). Currently, an ecosystem is the basic functional unit of ecology. The term ecosystem refers to the living and non-living components of a system as a single interconnected unit (Odum, 1997). The properties of both the living and nonliving components are influenced by each other. All ecosystems have a specific structure and function and it is necessary to differentiate these from one another. The structure of an ecosystem includes the species along with all the non-living materials that support system functions. Examples of these are soils, hydrology, weather and climate, topographic relief and nutrient regime (*The SER International Primer on Ecological Restoration*, 2004). The function of an ecosystem is comprised of the processes and interactions that occur among its components. These processes form the ecosystem, as well as provide resources to other surrounding systems. Ecosystems exist in a tremendous variety of sizes. An entire forest or even a laboratory culture dish can form an ecosystem. For an ecosystem to sustain its integrity, it must embody all of the fundamental properties relating to time, structure and function along with the flow of energy and physical materials through the system (Thayer, 1994).

A great deal of research has been completed to gain a better understanding of ecosystems and their complexity. Even though we currently understand a great deal more about the environment in which we live and have a greater ability to be good stewards than in the past, it is becoming clear that humans cannot provide definitive evidence of all forms of harm in advance of irreversible damage to the environment. Thus, it is important for those who directly impact systems, such as landscape architects, to become aware of the complexities within ecosystems and to develop a means to reduce the amount of harm done within them. Panarchy theory has the ability to inform designers about the most important aspects of landscape complexity and at the same time it can inspire innovation in the field of landscape architecture.

In this thesis, the underlying framework of panarchy will be used to develop a set of design guidelines that will be applied to a nature park in a Southern Appalachian bog ecosystem. As there is little scientific data available on the structure and function of Southern Appalachian bog ecosystems, a framework for understanding and dealing with this uncertainty is essential for a successful design. In Chapter 2, the current ecological understanding of bog ecosystems and how they are characterized by tremendous uncertainty will be described. This chapter will also delve into the responsibility of landscape architects to deal with this uncertainty. Chapter 3 will introduce the foundations and principles of panarchy theory and how it can be utilized as a means of dealing with uncertainty. Chapter 4 will relate panarchy and bogs and a set of design guidelines for designing with panarchy in bog ecosystems will be developed. An inventory and analysis of a specific bog site for application of the design guidelines will be described in Chapter 5. Then, in Chapter 6, the guidelines will be applied to a specific site, the Lewis Creek Nature Park, which includes a rare Swamp-Forest Bog Complex. Finally, in Chapter 7 a summary of the thesis will be presented and will describe how the design and management of this site can become a model of how to design and manage in the midst of uncertainty in all complex ecosystems.

CHAPTER 2

HOW CAN PANARCHY THEORY CONTRIBUTE TO THE PERSISTENCE OF A RARE BOG ECOSYSTEM: A PROPOSAL FOR LEWIS CREEK NATURE PARK.

BOGS AND UNCERTAINTY

WHAT IS A BOG

The Lewis Creek Nature Park is a mosaic of complex ecosystems, one of which is a bog. A bog is a type of freshwater wetland ecosystem. In the Southern Appalachian Mountain region, where the Lewis Creek Nature Park is located, they are extremely threatened and there is very little scientific understanding about the structure and function of these systems. Freshwater wetlands are one of the most important types of ecosystems on the planet. Freshwater makes up only three percent of the worlds natural water supply and is necessary for the survival of many species. The destruction of freshwater systems has been widespread in recent years. There are several types of freshwater ecosystems that contribute to the world's freshwater supply, all of which are important to care for and conserve. In the Southern Appalachian region of the United States, freshwater wetlands have unique properties unlike any other across the globe.

There has been a great deal of debate on how to classify the freshwater wetlands of the Southern Appalachians (A. S. Weakley & Schafale, 1994). These habitats have the characteristics of both fens and bogs, and are somewhat of an anomaly as far as wetlands are concerned. As the Southern Appalachian Mountains remained relatively untouched by the glaciers during the ice age, these unique ecosystems have persisted and evolved over thousands of years. Since they are so unique, determining exactly how to define them is difficult. A Southern Appalachian bog is a unique combination of a fen and a bog, even though strict definitions demonstrate that fens and bogs are different system types. A bog is defined as a rain-fed wetland system where rain or snow that falls stays at the surface of the landscape and is trapped. A fen is defined as a wetland system that receives groundwater inputs from surrounding soils. Overall, the "non-alluvial wetlands of the southern Blue Ridge vary considerably in the relative influence of seepage and precipitation (A. S. Weakley & Schafale, 1994)." In *Southern Forested Wetlands*, these wetlands are classified as southern mountain fens due to the importance of seepage to the continuity of the system, but many support bog-like flora and fauna (Messina, 1998). The simple term "bog" will be used here and will refer to these fen and bog-like wetland habitats dominated by mosses, herbs and shrubs in the Southern Appalachians.

Bogs by definition can only occur in geographical locations where precipitation exceeds evaporation (Haslam, 2003). Often the term bog brings up imagery of the peat bogs of Northern Europe, which have provided peat bricks as sources of energy for centuries. Bogs and wetlands found in the Southern Appalachians differ from those in northern North America and Europe in that the ones in the south are much older, with highly acidic soils and are generally very nutrient poor systems (A. S. Weakley & Schafale, 1994). Bogs in the Southern Appalachians also do not typically have peat build-up as those in Northern Europe.

As stated before, scientific knowledge about the structure and functions of Southern Appalachian bog habitats is limited. This is due to the fact that scientists are still learning about the intricacies of the ecosystem's structure and function. The most current succinct description of this habitat is from Weakley and Shafale's "Non-Alluvial Wetlands of the Southern Blue Ridge: diversity of a threatened ecosystem." This work presents nine varieties of the habitat type in the Southern Appalachian region. The Lewis Creek Bog is classified as a Swamp Forest Bog Complex. This habitat is described as mostly forested, with small boggy openings in depressions. The boggy areas in Swamp-Forest Bog complexes are usually less than one-acre in size. Dominant tree species are Red Maple (*Acer rubrum*) and Eastern Hemlock (*Tsuga canandensis*). Sphagnum mats may be found in boggy openings, along with several *Carex* spp and *Juncus* spp (A. S. Weakley & Schafale, 1994). As in most Southern Appalachian freshwater wetlands, the soils are mostly acidic and nutrient poor.

According to Weakley and Schafale, the Swamp Forest Bog Complex Typic Subtype is extremely threatened. It was estimated that nearly 1000 hectares of this specific ecosystem type once existed in the Southern Appalachians. Currently, only 100 hectares or 10% of what originally existed remains intact (A. S. Weakley & Schafale, 1994). As Haslam mentions, a bog ecosystem takes a very long time to form as they have more active functioning and need more restricted conditions than other wetland types.

Bog ecosystems in the Southern Appalachians are important for many reasons. In general, freshwater wetlands are incredibly valuable landscapes as they can be considered "the bloodstream of the biosphere (Folke, 2003)." They are home to many endangered species, including the rare Bog Turtle (*Clemmys muhlenbergii*). They also play a large part in the hydrology of their respective watersheds. This includes water storage, flood control, affecting water chemistry and filtering pollutants from run-off. The Lewis Creek Bog is located near the top of its watershed. Storm water run-off from the neighboring residential development and agricultural land enters the bog before it reaches the creek and enters the rest of the watershed. Recent changes in the quantity of run-off have had a negative impact on the system as a whole, but the bog still acts as a reservoir, which cleans the water and enhances water quality.

The factors that lead to the formation of non-alluvial wetlands in the Southern Appalachians are poorly known (A. S. Weakley & Schafale, 1994). For swamp-forest bog complexes specifically, “they may be successional remnants of once more extensive bog areas.” There are several factors that have been speculated to have contributed to the formation of bog habitats: including fires, timber harvesting, grazing, changes in rain chemistry and impacts from beavers. For example, in the Lewis Creek Bog, there are some species that require fire for reproduction such as Pitch Pine (*Pinus rigida).* This leads to speculation that fires made have had a hand in the ecosystem’s initial formation. It is also thought that central Appalachian wetland systems may have been formed in response to the timber harvesting operations in the region, meaning that the formation of the bogs is much more recent than originally supposed (Francl et al., 2004)

One of the most important factors that contribute to the formation and ultimately the continuation of bogs is hydrology. This is also the most understudied aspect of these habitats. According to personal communication with Brenda Wichmann, a bog ecologist, “Hydrology is ultimately the key. No one has studied this in the Southern Blue Ridge Province at a comprehensive scale (Wichmann, 2009).” It is incredibly important to understand the hydrology of a wetland in order to properly conserve or restore it (Bedford, 1996). In recent conversations with Alan Weakley and Ed Schwartzman, a biologist for the North Carolina Natural Heritage Program, it was agreed that the most important element to the survival of this habitat is an understanding of its hydrology (Schwartzman, 2008; A. Weakley, 2008). The hydrology of these systems has been invariably altered over time. It is also agreed that to understand the hydrology of an individual wetland, it should be studied from a landscape scale (Bedford, 1996). As with all landscapes, a bog ecosystem is in a constant state of flux. In terms of hydrology, it is unknown whether the system is undergoing a transformation from dry to wet or vice versa. There is some speculation that beavers originally formed these ecosystems (A. S. Weakley & Schafale, 1994). The removal of beavers and beaver dams for stream restoration practices may have an impact on the hydrology and persistence of the system.

A study done on twenty wetland systems in the central Appalachian region gives some insight into the initial formation of bog ecosystems. Weakley points out "they do not differ in fundamental (processes as opposed to composition) ways from the North Carolina Bogs". The study found that the geology of the site seemed to correlate strongly with the existence of bog systems. A majority of the sites studied had a sandstone or shale layer near the soil surface that impeded drainage from the site, thus keeping a high water table. For this reason they found that sites were able to keep water levels at appropriate levels even during years of drought. These rock layers also influence soil chemistry throughout the sites and lead to the formation of the distinctive flora communities. Another unique finding from this study was that wetland size did not appear to influence the number of species found per unit area, which emphasizes that even small wetlands have great importance and "should not be overlooked in preservation efforts." (Francl et al., 2004).

All of these ideas about the formation of bogs are speculation and uncertainty abounds in these systems. "The lack of information on virtually all ecological aspects of southern mountain fens has hindered the development and implementation of effective management and restoration strategies (Messina, 1998)." The only thing that is certain is that "these complex systems have evolved over thousands of years, and although you can design a landscape to replicate a wetland, there is no guarantee in will remain one ten, fifty or one hundred years from now (Badger, 2007)." When designing in such an ecosystem, recognizing and dealing with this uncertainty is critical.

UNCERTAINTY IN ECOLOGY

Since Eugene Odum made the ecosystem concept popular during the 1960s, a great deal of research has been completed to gain a better understanding of ecosystems and their complexity. Even though we currently understand a great deal more about the environment in which we live and have a greater ability to be good stewards than in the past, it is becoming clear that humans cannot provide definitive evidence of all forms of harm in advance of irreversible damage to the environment. When humans impact an ecosystem, unintended consequences often occur due to the uncertainty of the complex interactions within the system.

The field of ecology is laden with uncertainty. Much of the loss of diversity in ecosystems is driven by the "myth that disciplinary science will resolve most uncertainties (Gunderson, 2000)." As more scientific research is being completed it is becoming apparent that ecosystems are much more complex than we initially thought. As the scientist Carpenter said, “science is as much about clear articulation of what we do not know, as it is about the known (S. R. Carpenter, 2002).”

The typical response to uncertainty in ecological systems is to initiate human control over a specific variable. Often when a shift is perceived between alternative conditions of an ecosystem, it is seen as a resource crisis (Gunderson, 2000; Gunderson & Holling, 2002). For instance, if there are floods, we strive to hold the water back and if there are fires, we suppress them. Yet even with these well-intentioned management decisions being implemented, surprising unintended consequences often occur. A management technique that attempts to create stability in an uncertain system is destined for failure (Gunderson & Holling, 2002).

For example, an ecological issue that has arisen in recent years is the Hemlock Woolley Adelgid infestation that is devastating native Hemlock populations. In an attempt to control the Woolley Adelgid populations, landscape managers have been using a chemical called Imidocloprid. This chemical is supposed to kill the pest populations within a few years. Recent research has led to the discovery of other effects of the chemical on other parts of the complex ecosystem, such as honeybee populations. When a plant is exposed to Imidocloprid, it stores the chemical within its tissues until it blooms. During the blooming period, the chemical is exposed in the nectar and pollen and honeybees are exposed though their collection of pollen to bring to their hives. The chemical has an effect on their olfactory senses, rendering them unable to find food for the hive. This eventually destroys the hive, and has a huge impact on honeybee populations, which in turn has economic effects on humans and agricultural crops.

(Krohn & Hellpointner, 2002). When we suppress a specific disturbance, such as the Woolley Adelgid, the effects of this suppression often reveal themselves in other parts of the system and the system becomes less resilient. The complexity of these connections is often impossible to predict or understand. When controlling a particular variable, such as a pest infestation, the ability of the system to withstand disturbance decreases.

LANDSCAPE ARCHITECTURE AND UNCERTAINTY

> "By knowing how to learn about the ecological processes that function in a place, designers will have a stronger basis for invention. By being more firmly rooted in ecological knowledge, designed landscapes can deepen public understanding of nature rather than confuse it with unfounded rhetoric. By knowing their own responsibility for cultural understanding and landscape innovation, designers will more convincingly prove their own necessity in determining the future of changing landscapes. Landscape change could be the product of discussion that enables both design and ecology to influence the future with more powerful and meaningful effect. (Nassauer, 1997)."

As landscape architects working directly with an ecosystem such as a bog, it is important to recognize this characteristic uncertainty in the design process. Inevitably there is an effect on the ecosystems in which designers work and these designs impact the environment. As Kenneth Boulding mentions in his book, *World as a Total System*: "everything on earth is indeed connected to everything else, and viewing any portion in isolation risks losing perspective on important connections between elements (Boulding, 1985)."

Landscape architects have the capacity to use knowledge of this uncertainty to create successful designs. However, in recent years designed landscapes have been deteriorating at an alarming rate. Many projects that have been constructed over the past twenty years have had to be reconstructed (Kirkwood, 2004). In landscape architecture, when uncertainty is not taken into account, it leads to failure of design. Disturbances and weathering inevitably happen after works are constructed that lead to these failures. As Kirkwood states, "one of the most difficult aspects of landscape architectural design and its place in the built environment is the ability to bridge the gap between a fixed idea in site design and the realization of that built idea over time (Kirkwood, 2004)."

It is when landscape architects limit themselves to exploring only one or two variables as a basis for making design decisions about a system that they miss "critical properties of stability and instability for adequate understanding of predictability and uncertainty for effective policy and action (Holling, 2001)." How then, can other variables be included if it is not understood how a system works due to its inherent complexity? In order to begin to predict the potential unintended consequences of our actions, it is good to have some sort of understanding of why they happen in the first place. How can landscape architects account for the complete unpredictability of natural systems when creating designs for the future?

Humans have created theories to explain the unpredictability of the natural world for thousands of years. Even the ancient Mayan numerical system was an attempt at doing so. Understanding why human interaction with the environment produces unpredictable effects "requires consideration of enormous variety from multiple disciplines (Cooney & Dickson, 2005)." Humans are not separate from natural systems, but instead contribute to their complexity. Recognition of this through theory calls for integration of ecologic, social and economic systems and thus a theory that is applicable on a multidisciplinary level is necessary to understand unpredictability.

Recent examples of theories explaining complex systems stem from Systems Theory, which has a strong diversified basis. Systems Theory became a distinct area of study following World War II, specifically initiated by the Macy conferences in the 1950s. The fundamental ideas of original systems theory are that all phenomena can be viewed as a web of relationships among elements, or a system and all systems, whether electrical, biological, or social, have common patterns, behaviors, and properties that can be understood and used to develop greater insight into the behavior of complex phenomena and to move closer toward a unity of science (Laszlo, 1974). Since then, recent theories on complex systems have evolved within multiple disciplines- including but not limited to– general systems theory, chaos theory, cybernetics, world systems theory, complex adaptive systems, holism, panarchy and resilience theory.

In order to create a model of how to design in the face of uncertainty, a multidisciplinary theory is necessary to inform the process. The discipline of landscape architecture is tightly linked with the discipline of ecology. Thus, strong communication is needed with ecologists since both are working directly with ecosystems and have the capacity to enhance or destroy them. As Girot says, "the recovery of landscape will begin only when we are ready to reconcile our senses with our science (Girot, 1999)." Hence, it is only when a bridge can be made between ecology and landscape architecture that breaks down the language of communication that designed landscapes can be sustainable in ecological structure and function.

The Lewis Creek Nature Park is a good landscape to use as an example for the application of an ecological systems theory as a model for design. This is due to the great deal of uncertainty that is inherent in this system. Since Southern Appalachian Bog ecosystems are rare and in desperate need of conservation, it will bring together disparate disciplines with ecological knowledge and design knowledge. In the next chapter, the foundations and principles of a multidisciplinary theory, panarchy, will be introduced. This theory will provide both landscape architects and ecologists with a theoretical framework with which to better understand the complexity of landscapes that are characterized by uncertainty.

CHAPTER 3

PANARCHY

PANARCHY THEORY

Panarchy is a systems theory that can be a used as a framework for application in landscape architecture design. Though it is the work of several people from various disciplines, its origin stems from the work of Dr Lance H. Gunderson and Dr. C.S. Holling, both prominent figures in the field of ecology. These two ecologists have focused much of their research on Panarchy theory and ecosystem resilience. Through their work they have recognized the importance of multidisciplinary application and cross-scale dynamics. In their book, *Panarchy: Understanding Transformations in Human and Natural Systems*, they demonstrate that this theory is not just limited to ecological systems, but is applicable to social and economic systems too (Gunderson & Holling, 2002).

Panarchy is a means of understanding the evolving nature of complex adaptive systems. It is a theory that embraces both the uncertainty and predictability of systems. This theory attempts to bridge both of these opposites together to explain adaptive potential and innovation within systems (Holling, 2001).

The basic unit of the theory is the adaptive cycle, represented by the symbol of infinity (*Refer to Figure 1*). The image is representative of complex systems and the system cycle can be characterized through three distinct properties: potential, connectedness and resilience (*Refer to Figure 2*). Each of these properties contributes to the complexity of a particular system. The potential of a system (on the Y axis) sets limits for what is possible and determines the number of future possibilities that can exist. Connectedness (on the X axis) represents the linkages between internal controlling elements or processes within a system. This determines the extent of its flexibility or rigidity. Adaptive capacity or resilience (on the Z axis) determines how vulnerable a system is to unexpected disturbances that can break control. All of these together represent the cyclical nature of all systems. (Holling, 2001).

The adaptive cycle can be explained in two distinct phases, a front loop and a back loop (*Refer to Figure 1*). The front loop of the cycle is the exploitation to conservation phase (r to K phase) where capital is accumulated and conserved. As more accumulation occurs, the more resources become tightly bound and the system becomes rigid causing the system to be less resilient to outside disturbances. Thus, when a disturbance occurs at the top of the cycle, it has the potential to push it into the rapid reorganization phase (∂ to Ω phase) and this is where innovation occurs due to high uncertainty and weak control over the system's potential. Since there is little accumulation of capital, resilience is high as the costs of loss are low. (Holling, 2001). Gunderson presents an example of an adaptive cycle in a forest. A forest accumulates nutrients and materials as it matures during the front loop of the cycle and the capital becomes tightly bound within the forest structure. When a disturbance such as fire occurs when the capital is rigid, at the top part of the front loop, it causes a release of the capital and the forest drops into the back loop of the cycle. Reorganizations of the materials and nutrients present novel combinations and the forest changes.

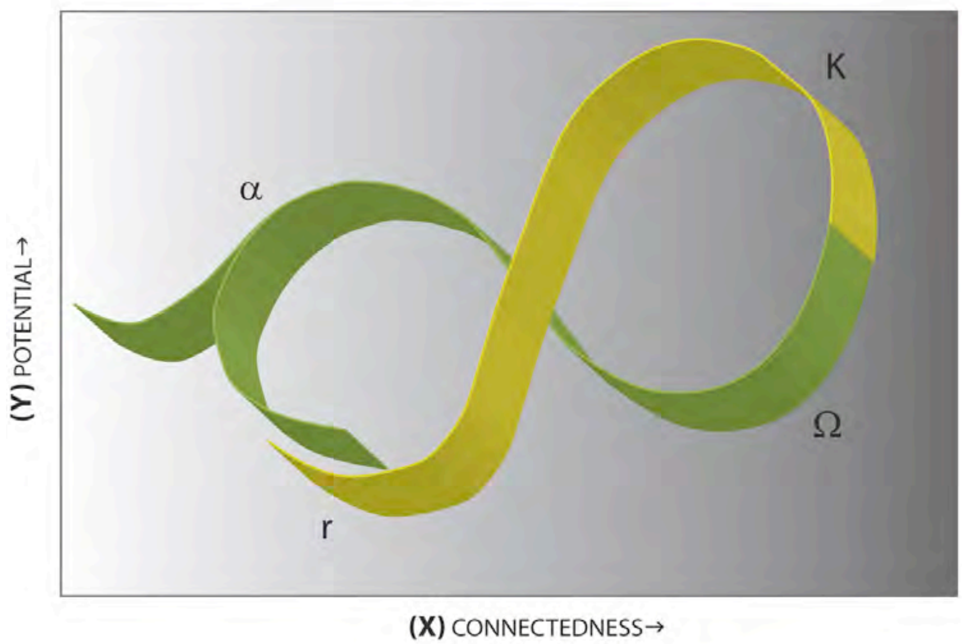


FIGURE 1: Adaptive Cycle – The potential of a system (on the Y axis) sets limits for what is possible. Connectedness or controllability (on the X axis) determines the degree to which a system can control its destiny. Adapted from (Holling, 2001).

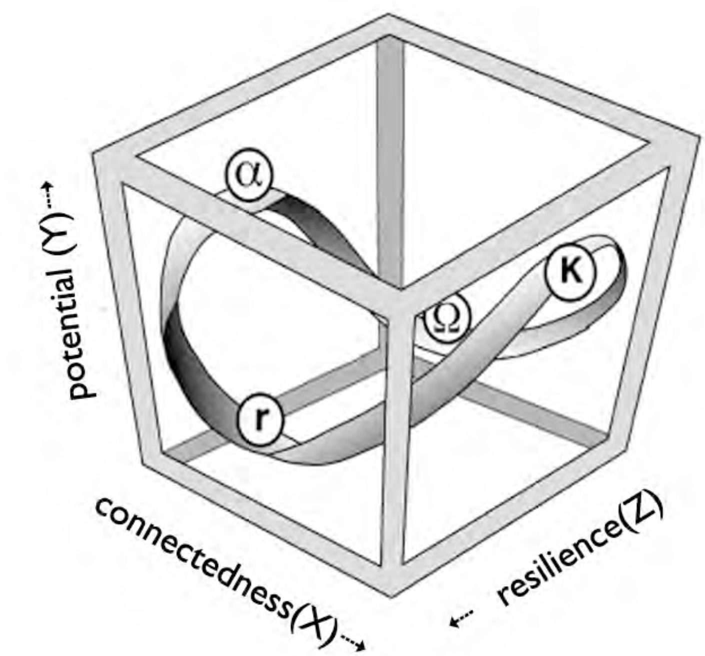


FIGURE 2: Three Dimensions of the Adaptive Cycle- Potential, connectedness and resilience create a system. Adapted from (Holling, 2001)

It is during the rapid reorganization phase, or during the back loop of the cycle, that some of the most influential changes can occur. The innovation that occurs here enhances the ability of the system to adapt to change by creating unique combinations of capital that have the possibility of being more resilient to future disturbances. Thus, unpredictability is important to the perpetuation of the system as a whole.

One of the most important aspects of the adaptive cycle is the element of resilience. This element is represented in the third axis of the adaptive cycle. When added to the adaptive cycle metaphor, it varies throughout the cycle (*Refer to Figure 2*). High resilience occurs when costs of loss are low, such as during the omega to alpha cycle.

When the costs of loss are high and accumulated capital is tightly bound, resilience is low. (Holling, 2001).

From an ecological standpoint there are several ways to define the concept of resilience in an ecosystem. This stems from "a major paradigm shift" in ecological theory in recent years (Pulliam, 2001). One of the most prominent changes is the theory of equilibrium in ecosystems. During the 1960s, Robert MacArthur developed a theory of equilibrium in which he said that all systems were either at or attempting to reach a state of balance with the resources surrounding them (Pulliam, 2001). It has recently been speculated that "ecological systems may have multiple, or no stable state(s) (Pickett, Cadenasso, & Grove, 2004)" and they are constantly being influenced by outside disturbances, which cause a shifting of thresholds from one state to another.

This shift in ecological theory generates two distinct definitions of ecosystem resilience. From the old ecological perspective, resilience can be defined as the ability of a system to return to an equilibrium state after disturbance. Gunderson describes this as "engineering" resilience. Alternatively, when multiple or no stable states are considered, resilience is defined as the ability of a system to adapt or adjust to changing internal and external processes. This is also described by Gunderson as "ecological resilience" which he defines as "the magnitude of disturbance that can be absorbed before the system moves into another state (Gunderson, 2000)." This non-equilibrium concept of resilience "shifts perspective from the aspiration to control change in systems assumed to be stable, to sustain and enhance the capacity of social-ecological systems to cope with, adapt to, and shape change and learn to live with uncertainty and surprise (Folke, 2003)."

Since ecological resilience is a recent concept, there is still a great deal of research needed to understand how to measure it within an ecosystem. One key issue that has been recognized in studies on resilience is the importance of defining scale. Often, resilience can be achieved at one scale at the expense of another (S. Carpenter, Walker, Anderies, & Abel, 2001). For example, a large-scale fire event in a forest may enhance resilience of the forest as a whole even though several individual species were lost in the process. It is also apparent that a system cannot be fully understood by focusing on a single scale. Walker points out that understanding system resilience requires the consideration of three scales- "the scale of interest and at least one above and one below (Lindenmayer, 2007)." In essence, doing so would be a way of relating adaptive cycles throughout a landscape. This refers to what Gunderson and Holling refer to as a complete panarchy. A "panarchy" is a hierarchy of nested adaptive cycles (*See Figure 3*). This is not a hierarchy in terms of the typical top-down dictionary definition, but instead of faster smaller levels nested beneath slower larger levels. These are interconnected and communication between them helps to determine the resilience of a system (Holling, 2001).

There are two connections that are particularly important within the panarchy: revolt and remember (*Refer to Figure 4*). When a disturbance event causes a catastrophic collapse that cascades into a larger slower level this is called "revolt." For example, a local scale forest fire could have an effect on a regional scale by creating new weather patterns due to excessive smoke. Another important connection between scales is called "remember." This occurs when a smaller faster level draws upon the potential that has been accumulated and stored in a larger slower cycle. An example of this is the seed bank in the soils that provide renewal after a forest fire event. The thresholds that exist between remembrance and revolt are always shifting. It is the influence of these elements that reduce or enhance the resilience in a system.

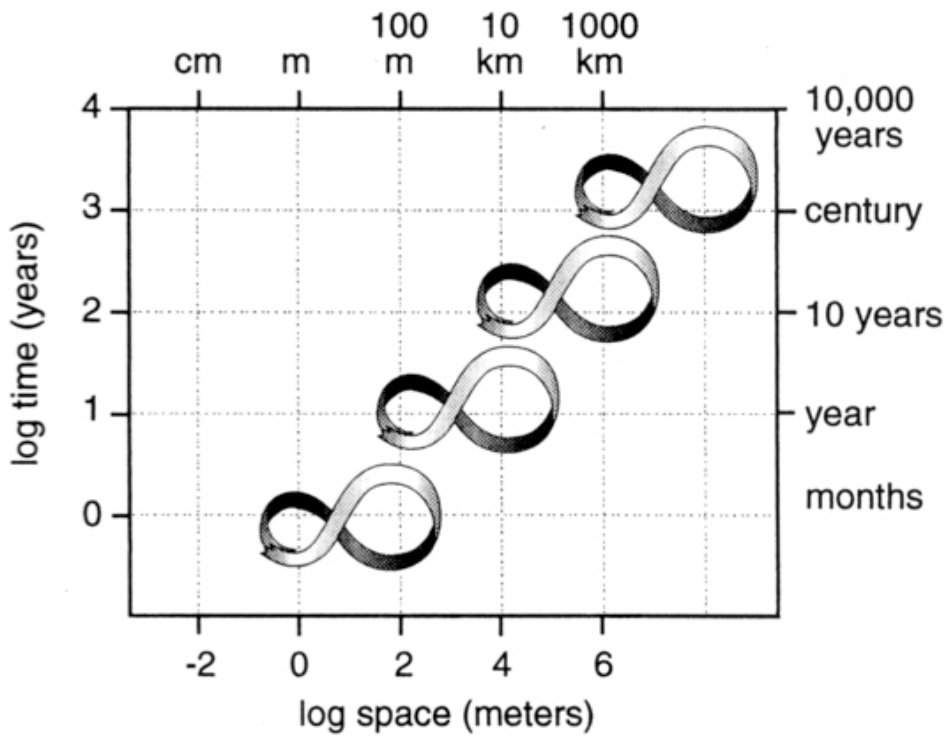


FIGURE 3: Nested adaptive cycles (Holling, 2001)

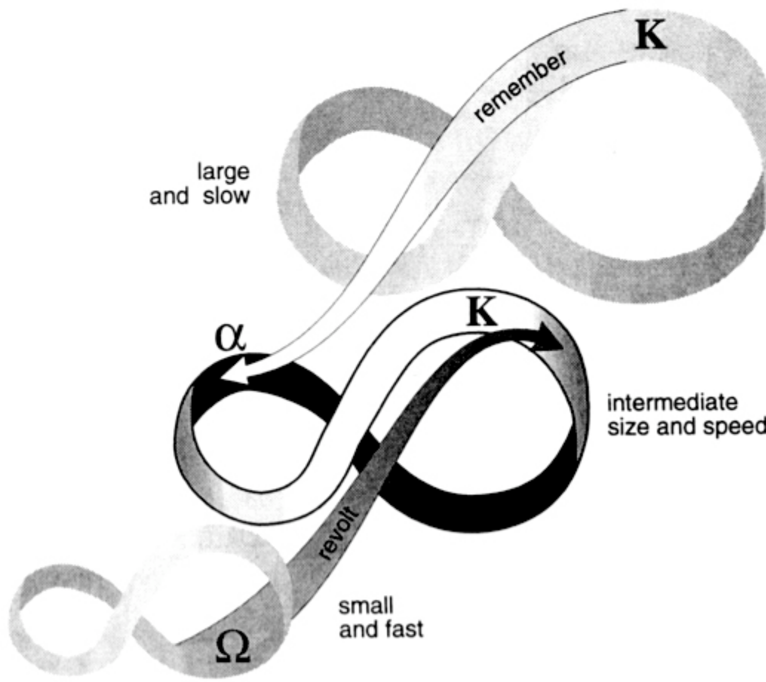


FIGURE 4: Revolt and Remember (Holling, 2001)

Ecosystems have varying levels of resilience and often this resilience is lost over time due to pressures from human society past and present. All ecosystems are a part of a socio-ecologic system or SES, meaning that all ecosystems are in part affected by human influences. Alberti mentions that "simply considering human and ecosystem functions separately may not be adequate to understand system resilience because integrated socio-economic and ecological systems can behave differently than their separate parts (Alberti & Marzluff, 2004)."

Humans have a distinctive ability to manage and restore resilience in social-ecological systems. This is due to the unique property of human systems to create novelty or innovation (Gunderson, 2000). Humans are sense-making animals who use the ability to communicate to "invent and reinvent a meaningful order around them and then act in accordance with that invented world, as if it were real (Westley, 2002)." This ability can be applied in several beneficial ways. A few examples of how system resilience can be enhanced by humans are: increasing buffering capacity, managing for processes at different scales, and nurturing sources of system renewal (Gunderson, 2000). For instance, by maintaining the seed bank and species diversity in a forest resilience is enhanced since these are sources of renewal. However, in order for humans to enact these changes, there must be a social connection to the system. As long as there is meaning, humans will continue to have a connection. A system must have and keep an identity for humans to be motivated to restore resilience.

INCLUSION OF IDENTITY

Loring's article about the resilience of the traveling circus presents an example of how keeping an identity allows for the persistence of a system, in this case referring to a social system rather than an ecosystem. It explains how the circus has changed over time, but has also sustained a persistent identity. Similar to the adaptive cycle metaphor, it has gone through periods of steady success and sudden failures and rapid reorganizations. For example, in the beginning, during the conservation part of the cycle, success was steady and committed audiences were created: a reputation was built and an identity was created. There were also sudden failures in the cycle such as during the bank failures of 1837, which permitted novel combinations. This was the stage of innovation that brought the cycle back to a more stable position. The evolution of the circus clearly correlates with the adaptive cycle, and is a good example of how human defined identity allows for persistence. (Loring, 2007).

In ecology, truly defining the identity of an ecosystem is an important yet difficult task. Often ecologists are asked to ascertain whether an ecosystem is completely changed or destroyed or whether it remains the same (Jax, Jones, & Pickett, 1998). Yet how to scientifically determine whether the "essence" of system still exists is not easy. "Despite the importance of self-identity, there is as of yet no consensus on how to define and measure it (Jax et al., 1998)."

The ancient philosophical problem of Theseus's ship presents a good metaphor for thinking about identity and change in complex socio-ecological systems. It is said that the great hero Theseus returned from winning a battle and was so revered much that the citizens of ancient Greece preserved his ship in perpetuity. Over time, almost all of the materials of the ship were replaced. The ancient Greek Plutarch recorded it as:

> "The ship wherein Theseus and the youth of Athens returned has thirty oars, and was preserved by the Athenians down even to the time of Demetrius Phalereus [~350-280 B.C.] for they took away the old planks as they decayed, putting in new and stronger timber in their place, insomuch that this ship became a standing example among the philosophers, for the logical question of things that grow; one side holding that the ship remained the same, and the other contending that is was not the same (as cited in (Cumming & Collier, 2005; Plutarch, Dryden, & Clough, 1992)."

The Shikinen seng ū or the regular Shinto shrine rebuilding in Japan provides a current example of this challenge. Every twenty years these shrines are destructed and a new one is built beside it. Yet when one asks how long a shrine has been there, a Japanese person would reply that it has been there for centuries. This, like Theseus's ship presents the same question: if something is completely replaced by new materials or capital, when does one know whether the system is still the same system? Through these examples it is shown that there is much ambiguity in what constitutes identity over time.

The inclusion of human perception and meaning in defining identity is a way of accounting for the issue of time. In his article, Loring states "persistence, therefore is not simply whether a predefined set of structures remain, but whether or not stakeholders continue to recognize, respect and feel a belonging to a system after change has happened (Loring, 2007)." Thus, it is important to recognize that identity in a socio-ecological system includes cultural ideals and historical context. In addition, it is not necessarily the exact structures and elements that compose the system that create its identity, but instead the continuation of functions and processes. As Cumming and Collier state, "a reasonable addition to current definitions would be to recognize that system identity resides in the continued presence, in both space and time, of key components and key relationships (Cumming & Collier, 2005)."

The aesthetic experience of an ecosystem largely determines its identity as defined by humans. Spaces are considered aesthetically pleasing due to cultural conventions. For example, Eaton states, "aesthetic experience is marked by perception of and reflection upon intrinsic properties of objects and events that a community considers worthy of attention (Eaton, 1997)." The determination of what is worthy in a landscape culturally is often related to two things: scenic beauty (as portrayed in the 18th century picturesque) and the noticeable influences of humans caring for a landscape (J. I. Nassauer, 1997). When people are attracted to and notice landscapes they are more likely to care for them. In order to restore or improve an identity for an ecosystem, one must "align aesthetic experiences that people already value with ecological health they do not yet know how to recognize (J. I. Nassauer, 1997)."

PANARCHY AND DESIGN

Panarchy theory can be a beneficial tool when designing with uncertainty in ecological systems. In order to use panarchy as a model for design, it is important to recognize the components of a system that create the panarchy, to discover what aspects enhance potential, connectedness, resilience and identity to keep a system within a desired trajectory. It is the understanding of these elements and processes that will lead to the creation of a design that will contribute to the true conservation of the desired system and enhance its creative potentials. Managing processes at different scales can enhance resilience in nested adaptive cycles, allowing for smaller levels to contribute to the conservation of larger slower levels. By keeping and nurturing the processes that contribute to the persistence of the desired trajectory of the system, it will hypothetically be able to withstand greater disturbances and persist longer.

As Nassauer states, “Landscape design is a cultural act about nature, and landscape design constructs ecosystems (Joan Iverson Nassauer, 2001).” In constructing and changing ecosystems, landscape architects have a first hand ability to restore or enhance the potential, connectedness, resilience and identity of a system. Therefore, it is the responsibility of landscape architects to work with other disciplines to understand these aspects of a landscape and incorporate them into design and management.

In particular, the concept of ecological resilience is gaining momentum as a way to work among multiple disciplines by bridging the gap between the ecology and design professions (Woodward, 2008). One cause of this may be the fact that rare and endangered ecosystems are being rapidly lost due to development and urbanization. As Folke states, “we face different, more variable environments with greater uncertainty about how life-supporting environments will respond to inevitable increases in levels of human use. At the same time we are reducing the capacity of these environments to cope with change through the erosion of ecological and social resilience (Folke, 2003)." It is imperative that multiple disciplines respond to these new concepts together. If landscape architects want to stay "in the game" with innovative concepts, it is important to embody these new ideas of resilience through design.

In her work, Woodward focuses on designing resilient landscapes in urban areas in Los Angeles (Woodward, 2008). Environmental changes and releases from maintenance in urban areas have led to a loss of resilience in these landscapes. She states: "the goal for land managers and designers is to anticipate and manipulate variability creatively to avoid catastrophic back loops, but still gain innovation to increase adaptive capacity." Through her research she has found that there are ways to restore resilience in urban landscapes by integrating strategies in design "to increase the potential for retaining function during periods of probable disruption (Woodward, 2008)." This work points towards a new direction for landscape architecture, and begins to bridge the divide between multiple disciplines.

Although Woodward's work applies solely to urban landscapes, the same concepts of adaptive cycles and resilience can be applied to other designed landscapes as well. Panarchy theory has the capacity to inform design and hence create more successful deigned landscapes. Along with the general framework of panarchy, it is also important to note that in order to restore potential, connectedness and resilience in any system, landscape architects must first recognize or restore its identity. "The insight relevant to linking ecology with planning and design is that *human perception, learning, and* *resultant actions are a part of the human ecosystem* (Pickett et al., 2004).*"* The importance of identity in understanding complex systems is a concept that is not emphasized in Gunderson and Hollings work. In order to relate panarchy in its generalized form to landscape architecture design, it is critical to develop a desired trajectory or identity to the system with which one is working. For a design to be measured as successful, it must have a goal to measure up to. The persistence or evolution of the system towards a desired trajectory is a means to develop a connection for humans to the system and also can become a measure of the success of the designed landscape. For this reason, identity is a key concept that must be included with panarchy theory in relation to design.

The next chapter will describe how the four elements of panarchy theory (potential, connectedness, resilience and identity) can be related to a rare bog ecosystem. From this description, a set of guidelines for designing with bog ecosystems will be developed using panarchy as a model. This will aid in the persistence of rare bog ecosystems in the Southern Appalachians.

CHAPTER 4

PANARCHY AND BOGS

ADAPTIVE CYCLE IN BOGS

> "Disturbances associated with such periodic flooding and beaver activities may have also aided in the perpetuation of the bog flora. Thus, one might conclude that, historically, the system has been in a constant state of flux, including prolonged quiescent periods in which little change occurred, followed by more drastic oscillations...." -as cited in (A. S. Weakley & Schafale, 1994) (Mitchell & Niering ~1993)

This quote provides evidence the adaptive cycle metaphor is relevant to a bog ecosystem, with conserving front loops and dramatically changing back loops. A more detailed example of an adaptive cycle within a bog system is shown below in Figure 4. In any bog there are several adaptive cycles, nested together. "The functioning of those cycles and the communication between them determines the sustainability of a system (Holling, 2001)." By recognizing the specific components of a bog that enhance potential, connectedness, resilience and identity the bog can better persist and adapt in the face of inevitable human and natural disturbances.

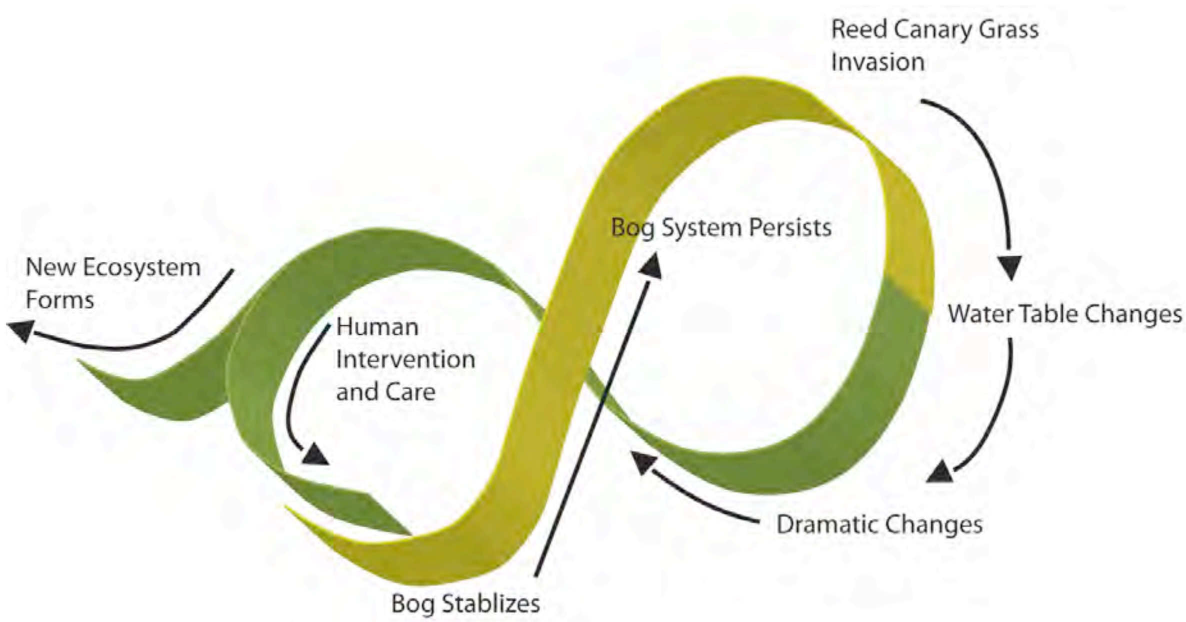


FIGURE 5: Bog Adaptive Cycle

The potential in a bog exists within its accumulated resources. Bogs have a great deal of stored potential, as their history is long and varied. Some of the bogs in the Southern Appalachians have been in existence for over 10,000 years (Weakley, 1994). Examples of elements that contribute to the potential of a bog ecosystem include soils and decaying matter, nutrients stored within vegetation, and species habitat (*Refer to Table 1*).

Bogs have varying levels of connectivity among internal elements mainly due to the pervasive element of water. The fluid property of water moves resources throughout the site and to other levels or scales within the panarchy. When a change occurs in the hydrology of the bog, repercussions spread deep into the intricate levels of the system. This causes the connectivity of the bog to change over time. For example, during periods of drought when there is less water in the system as a whole, there is less connectivity among internal elements because the movement of water is reduced.

From an initial perspective, the resilience of bogs is limited. In recent years, many have been lost rapidly due to agriculture, extreme development pressures and drastic changes in water quantity and quality. Also, since little or no historical data exists about these habitats, it is difficult to determine how well they have held up to past disturbances. The quote at the beginning of the chapter states that bogs have been in “a constant state of flux”, demonstrating that high resilience is evident during some historical periods.

Bog habitats have historically had a very negative human defined identity. They have always presented themselves as haunting and mysterious places. In the past, many people associated bogs with evil. They believed that within them illnesses were born, such as ‘Fen-ague,’ which was a common name for a type of malaria. There are also the tales of the Will o’ the Wisp or Jack o’ Lanterns, which were actually “self-lighting balls of marsh gas” that led weary travelers to get lost in bogs, as they believed they saw welcoming lanterns in the distance (Haslam, 2003). More recently, bogs have been associated with wastelands, as people have used them as dumping grounds. Also, since they appeared to have no relevant function and were impediments to farm cultivation, many were drained for farmland.

As mentioned in Chapter 3, it is important to recognize the specific components and processes that create a panarchy in a system to be able to design within it appropriately. It is resilience and identity in particular, that provide evidence that changes are necessary in order to create a persistent bog ecosystem. In designing the Lewis Creek Nature Park, a foundational model of panarchy can be used to contribute to the true conservation of the system and enhance the creative potentials through innovative design. By allowing the adaptive cycles to function, “transient windows of opportunity

(Holling)" occur on the back loops. It is the elements and processes listed in Table 1 that are the most important aspects to pay attention to when using panarchy as a model for the design process.

TABLE 1: Characteristics of a Panarchy in Bog Ecosystems

POTENTIAL	**Contributions** Accumulated resources- such as seed bank, species, nutrient availability (sources and sinks), carbon/nitrogen/oxygen, soil, decaying matter, groundwater, stable climate **Threats** Depletion or drastic changes in resources - such as water chemistry changes, run-off from development
CONNECTEDNESS	**Contributions** Linkages between elements- resource flows water transport fauna transport (birds) flora transport **Threats** Inhibitions of flows such as invasive species takeover, water level changes, human impact
RESILIENCE	**Contributions** Historic disturbance regime, species diversity, hydrology, surrounding land use, buffers, soils/geology **Threats** Dramatic/ catastrophic disturbances to any of the above
IDENTITY	**Contributions** Education of importance, unique appearance/ aesthetic qualities, rare/endangered species, scenic beauty, access, visibility, perceived economic value, ecosystem services **Threats** Human ignorance and impact, degraded condition or function

As bogs face probable disruption in the future, it is important to know how to design within these landscapes. A resilient bog will adapt to change, shifting between persistence and vulnerability and thus sustain the landscape's function over time. A changed identity will contribute to this resilience by connecting people and consequently initiating proper management and care. By learning how to design within a bog ecosystem and enacting the changes necessary to enhance potential, connectedness, resilience and identity, it can become a model for conserving other threatened bogs in the Southern Appalachian Region.

DESIGN GUIDELINES FOR PANARCHY IN BOGS

"Be both creative and conserving

(Holling, 2001)."

The "difficulty of landscape intervention is how to make certain forces conspicuous and, hence, how to make new forms, to create new feelings and associations (Descombes, 1999)." The following guidelines represent how panarchy can inform the design of the Lewis Creek Nature Park. These were developed by integrating the limited scientific information that is known about these systems with recent landscape architecture theory and the four elements of panarchy in a bog. Each guideline combines components of potential, connectedness, resilience and identity to unite ecology and culture within the design. The guidelines will contribute to the design by "fostering adaptive capabilities while simultaneously creating opportunities (Holling, 2001)."

1. GOAL: Determine functions or elements of persistence and conserve them

"Knowing where you are helps you define what actions need to be taken (Holling, 2001)"

- Recognizing where the system is in the adaptive cycle and conserving the functions or elements of persistence of a bog is the first step in using panarchy as a model for design. As Leopold said, "to keep every cog and wheel is the first precaution of intelligent tinkering (Leopold, 1993)." By keeping and nurturing the processes that contribute to the persistent structure of the system, it will be able to withstand greater disturbances and persist longer. "When designs fail to be sustained in the real world, it is often because designers ignore the processes that shape them during and after construction (Spirn, 1998)."

Strategies:

- Determine what elements and processes contribute to the persistence of the system. This means to discover what contributes to the potential, connectedness, resilience and identity of the system. Remember to look beyond the boundaries of the bog system, and include regional contributions. Attempt to conserve these elements and processes through design and management.
- Elements do not necessarily have to be exact in structure, as long as the process still functions. By continuing the processes, but perhaps presenting them into a design form that is recognizable by humans, the system will still

continue the same function and will also have a connection to humans and culture. Processes are full of metaphor and are a means of presenting and enhancing identity.

2. GOAL: Reduce the chance of catastrophic changes

"Determine destructive constraints and inhibitions on change (Holling, 2001)"

- By eliminating or reducing potential threats to the persistence of a bog, it will reduce the chances of a catastrophic change in a system.

Strategies:

- First identify what the threats are to the potential, connectedness, resilience, and identity of the system are. These can be internal (small loops within the bog) or external (larger regional loops) elements or processes.
- Attempt to eliminate or reduce these threats through design and management. An example of this on a regional level would be to reduce inputs of storm water from a neighboring development that may cause a drastic change in water chemistry within the site or by buffering the site from surrounding regional threats.
- Also, include manageable disruptions "to siphon off catastrophic back loops (Woodward, 2008)." Examples of this could be the implementation of periodic burning or annual invasive species removal.

3. GOAL: Preserve history

"Protect and preserve the accumulated experience on which change will be based (Holling, 2001)"

- "Landscape is never finished or completed, like a can of preserves, it is an accumulation of events and stories, a continuously unfolding inheritance" (Descombes, 1999). The history of a site is a significant part of the panarchy as the layers communicate and inform future cycles. This could also be called a palimpsest, which is defined as "something having unusually diverse layers or aspects apparent beneath the surface ("Merriam-Webster Dictionary," 2009)." By understanding the previous layers and disturbances that have affected the bog ecosystem, the 'memory' can be conserved. The memory is what the panarchy is build upon, and essentially keeps the system from collapsing. When a disturbance event occurs, a smaller level may call upon a larger slower level and "remember". The accumulation of history has led to the development of processes and elements that create a foundation for the system or the potential, and in the end contributes to its resilience. As Gunderson and Holling state, "memory is in the panarchy" through patchiness (Gunderson & Holling, 2002). The mosaic of a bog tells a story, and this story influences the future.

Strategies:

- Research the history of the site and region.
- Identify locations where there is an accumulation of historical elements.
- Conserve the accumulation of history through design and management.

4. GOAL: Include multiple scales within the panarchy

"Slower larger levels set conditions for smaller ones to function
(Gunderson & Holling, 2002)."

- A bog is only a single part of a much larger system as everything is interconnected. Walker points out that understanding system resilience requires the consideration of three scales- "the scale of interest and at least one above and one below (Lindenmayer, 2007)." Awareness of larger slower levels and their effect on smaller faster levels is important. This is also true of the opposite, smaller levels have an effect on larger ones. The scale of the different systems that operate in a bog can help define these levels. For example, soils are at a local site scale, hydrology is on a landscape scale, and climate is a regional scale.

Strategies:

- Observe and account for multiple scales before beginning the design process. For example, look at surrounding regional land use and predict future changes that may occur.
- Understand the flow of resources into and out of the site that are essential for the persistence of the bog. This is a means of communication between different levels of a panarchy and must be considered.
- Predict future changes to resource flows and determine possible impacts and management actions. When and if resource flows change, supplement them in a manner that does not affect the ability of the system to self organize and adapt.

5. GOAL: Utilize Reference Landscape(s)

- A reference landscape represents a healthier more resilient system that can serve as a model for the design and maintenance of the bog. It can be a single location or a combination of several different ones. The designed bog system should eventually emulate characteristics of the reference system(s) (SER).
- As a reference, it can allow designers and managers to know when and if the bog system is remembering, revolting or remaining persistent. It can provide information about what design and management choices should be taken to allow the system to adapt and endure.

Strategies:

- Use a reference landscape to inform design and management decisions. Compare potential, connectedness, resilience and identity of this system to the one that is being designed.

6. GOAL: Scenario Planning

- Predicting scenarios of future changes to the system and preparing for them through design and management can help a system to persist. This particular guideline is important because it integrates the element of the future and implies a trajectory. By considering future adaptive cycles, the entire panarchy is integrated into the design.

Strategies:

- Consider scenarios of what might happen if certain disturbances were to occur. Determine at least three scenarios: if the conditions remain the same, if a large scale natural disturbance occurs, and if a large scale human induced disturbance occurs. Develop strategies and contingency plans in the design so the system can "carry on" after disturbances have occurred.

7. GOAL: Design with impermanence in mind- and make it visible

"Embrace uncertainty and unpredictability (Holling, 2001)"

- A site needs to be free to reorganize if conditions warrant it. As Kirkwood states, "genuine permanence in any work of landscape design, however desirable from a client's or designers point of view, is, with rare exceptions, unobtainable (Kirkwood, 2004)." A bog ecosystem is ever changing, with fluctuations of water levels and species composition. Thus, the design and structures built within it should be impermanent and open to change. "To see materials as static is an illusion (Spirn, 2000)."
- The visual process of weathering and decay can become a record of change in the ecosystem that can contribute to a greater understanding of bogs. "The phenomena of weathering and durability are seen as a method of landscape measurement, a way of determining the passage of both time and activities on the site. Conversely, the built landscape becomes a record of those actions that have taken place (Kirkwood, 2004).
- As Lyle states, "the designer of a human ecosystem who returns to his landscape a few years later will be sadly disappointed if he see precisely the same form that took shape on his drawing board (Lyle, 1985)."

Strategies:

- All structures in the designed landscape should include elements influenced by weathering, decay and impermanence.
- The selection of materials to implement the design should be limited to ones that decompose appropriately and are renewable.
- Visitors to the park should be made aware of the impermanence of the design by making the process of change, weathering and decay visible. "Designers who attempt to register change can do so by deliberately proposing built forms that will fail or will have a restricted or limited life (Kirkwood, 2004)."

8. GOAL: Incorporate Diversity in Design

Functional diversity creates resilience (Holling, 2001)

- By using a diversity of structural conditions within the design (Woodward, 2008), it can allow for back loops and innovation to occur within the bog system. It is important to make sure that structural conditions support the processes of the ecosystem, and do not inhibit them. Spirn states that if materials are "used in ways which contradict intended meaning, they may undermine and obscure it (Spirn, 1998)."

Strategies:

- Utilize of a combination of "sturdy, flexible and ephemeral layers" in the design to support innovation (Woodward, 2008). Sturdy elements, like rocks, demonstrate the foundation and basic form of the design. They survive larger disturbances. Flexible elements, such as species that are adaptable to different conditions, allow for change to occur and still survive. Ephemeral elements, like annual plantings, do not survive disturbances but show an element of human attention and care within the system. (Woodward, 2008).

- Design for fluctuations in adaptive cycles and allow them to occur uninhibited. For example, seasonal water level fluctuations may render portions of the nature park inaccessible for visitors during different times of the year. Allow this to become an intentional part of the design.

9. GOAL: Keep Native Conditions

- Keeping native species and conditions can contribute to the potential and enhance the resilience of the bog system. Invasive species have the potential to create catastrophic changes in a bog system by altering the water table or eliminating native habitat. By keeping native species and eliminating non-native ones, the bog system will be more likely to persist. Local climate conditions also contribute to persistence. There is great value in spontaneous processes from local weather events, as it is these processes that have led to the creation of the bog system as it is today.

Strategies:

- The design and management plan should inhibit invasive species from entering and persisting in the bog system.
- Native species populations should be increased in the bog system. Augmenting habitat or introducing them directly into the system can do this.

- The design should only include elements and processes that are appropriate for the current climate conditions. Allow the processes of weather, precipitation and wind to shape the designed landscape. The design should specify indigenous species as much as possible, as these species can be optimally established in the landscape. The establishment of non-indigenous species may enhance the chance of system collapse or revolt.

10. GOAL: Enhance identity by connecting community and allowing for engagement

- The aesthetic quality of a landscape is essential for connecting humans to a bog. "Aesthetic experience is marked by perception of and reflection upon intrinsic properties of objects and events that a community considers worthy of attention" (Eaton, 1997). How then, can a bog be something that the community considers worthy of attention? Nassauer mentions that evoking a "benign human presence" is a way to engage people with a landscape (J. I. Nassauer, 1997). For example, this can be done by placing a bench or mowing a small strip around the ecosystem. Small gestures like this show that humans are caring for the landscape, and thus it must be worth something.
- The choice of materials used to create the design contributes to the aesthetic experience of a landscape. Spirn states, "materials arouse senses, carry meaning, pose limits (Spirn, 2000)
- It is also important to remember "circumstances change at every moment so perception of place can never be twice the same" Thus, the sense of landing in a bog is a personal experience and first impressions count. (Girot, 1999).

- "In any setting, when people are directly involved in the landscape, for example, by constructing or planting or monitoring it, their sense of ownership may be greater and their attention to the place more sustained over time (J. I. Nassauer, 1997)."

Strategies:

- Evoke a "benign human presence" by integrating obvious human constructions in the landscape.
- Use materials that contribute to the aesthetic of the landscape, that do not contrast and are aesthetically pleasing.
- Emphasize and beautify areas where people experience their first impression of the site.
- Allow people to develop a sense of ownership of the bog. This could mean having the community participate in management and observation of persistence.
- Integrate the use of metaphors of the system components that create the panarchy. By keeping the processes, but perhaps presenting them into a design form that is recognizable by humans, the system will still continue the same function and will also have a connection to humans and culture. Since designs have the ability to be monitored and ideas can be communicated through them, they then become the embodiment of the metaphorical meaning.

11. GOAL: Educate visitors so that the panarchy is identifiable, create vivid processes

"Encourage understanding of change and communicate it to citizens (Holling, 2001)."

- "People will sustain healthy landscapes if they enjoy them, and they will enjoy them when they know more about how to recognize ecological health (Eaton, 1997)." It is important to teach the community about the importance of bog ecosystems in the landscape, ecologically and culturally. As Weakley states, "Education about the significance and values of mountain wetlands is needed to prevent the ongoing destruction and degradation of wetland sites (A. S. Weakley & Schafale, 1994)."
- Like Descombes said of his design in Switzerland, he wanted "walkers to be attracted by the things themselves and not by the instructions (Descombes, 1999)." Creating interest in the landscape by making the processes that create the panarchy visible is also a means of teaching. "Making the weathering of a material visible within the landscape is a design activity that sees the practice of material selection as both artistic and pragmatic (Kirkwood, 2004)."

Strategies:

- Integrate multiple means of educating the community about the bog landscape and regional impacts. Educational signage can be helpful, but should not be the only method of teaching.
- Design elements that provide the visitor with a sense of wonder. For example, including random elements that make people question their purpose in the landscape will lead them to explore further and enhance their knowledge of the system.
- Vivify the processes that contribute to the persistence of the system.

12. GOAL: Adaptive Management

"Management must take surprise and unpredictability into consideration (Holling, 2001)."

- C.S. Holling created the adaptive management concept in the 1970s. As originally defined, adaptive management is "the systematic acquisition and application of reliable information to improve management over time (Wilhere, 2002)." By actively learning about the bog through paying attention to management successes and failures, the uncertainty about the system will be reduced.
- Maintenance of the bog should not be an attempt at controlling the variables of the system. The etymological root of the word maintain is *manus* or 'hand' and *tenere* or 'to hold', thus to maintain is essentially to "hold ones hand" (Woodward, 2008).
- Managing processes at different scales enhance resilience in nested adaptive cycles, allowing for smaller levels to contribute to the conservation of larger slower levels.

Strategies:

- Management practices should implement just enough care to allow for the system to carry on.
- Recognize multiple scales within the panarchy, and manage them appropriately.
- Identify areas of the system that require intense management and those that require minimal management. Utilize this knowledge in the design process.

- Integrate experimental management areas in the design, where practices can be tested for use in other parts of the system. These management practices should be made visible to visitors to encourage understanding.

13. GOAL: Promote consistent research and understanding

Landscape architectures drive to invent frequently overwhelms its need to know (Nassauer,1997).

- By integrating areas for research projects and experiments, the community can gain a further understanding of the structure and function of bog ecosystems. It is also important to incorporate a means of distributing knowledge and information gained from experiments and adaptive management practices. By continuing research and disseminating this information, more will be understood about bogs and conservation of other bog ecosystems in the region will be more likely.

Strategies:

- Design areas for research projects and experiments. Push for further understanding of bogs through quantitative data collection which will lead to a better scientific understanding of how these systems function.
- Develop a means of disseminating information gleaned from experiments. This could be posting results on a kiosk at the site, on the web or presenting the information to the community.

By taking these design guidelines and utilizing them throughout the design process, a bog ecosystem will better suited to persist through disturbances over time.

CHAPTER 5

SITE INVENTORY AND ANALYSIS

CONTEXT

In 2004, Carolina Mountain Land Conservancy purchased 8.34 acres next to the Meadows of Lewis Creek, a Henderson County residential development. The State of North Carolina holds an easement on the property, which is now named the Lewis Creek Nature Park. It is located 1.25 miles southwest of Edneyville, NC. Surrounding land uses include apple farming, pasture grazing, and residential activities. The north and eastern portions of the property are bounded by Lewis Creek, a part of the French Broad River basin.

In 2006 it was determined that 6.5 acres of the site is a rare Swamp-Forest Bog Complex (Schafale, 1990). This particular property provides habitat for native plants and animals, including five plant species that are listed by the NC Natural Heritage Program as rare and one listed as significantly rare (Conservancy, 2008). This habitat type is "one of the most important habitats for rare (endemic and disjunct) plants and animals in the region (A. S. Weakley & Schafale, 1994)." However, much of this habitat type has been lost in the Southern Appalachians. "Bogs and fens of the North Carolina mountains have been reduced nearly six-fold from an original extent of about 2000 ha, so that only about 300 ha remain in reasonably intact condition, and most of the remnants are compromised by hydrologic alteration and nutrient inputs (A. S. Weakley & Schafale, 1994)." Henderson County is one of the fastest growing counties in North Carolina (Conservancy, 2008). As apple farmers struggle to survive in the American economy, more and more of the landscape is turning into prime land for residential development. This dramatic change in the landscape from pastureland to residential developments presents a huge threat to bog ecosystems and meaningful conservation of these habitats is critical.

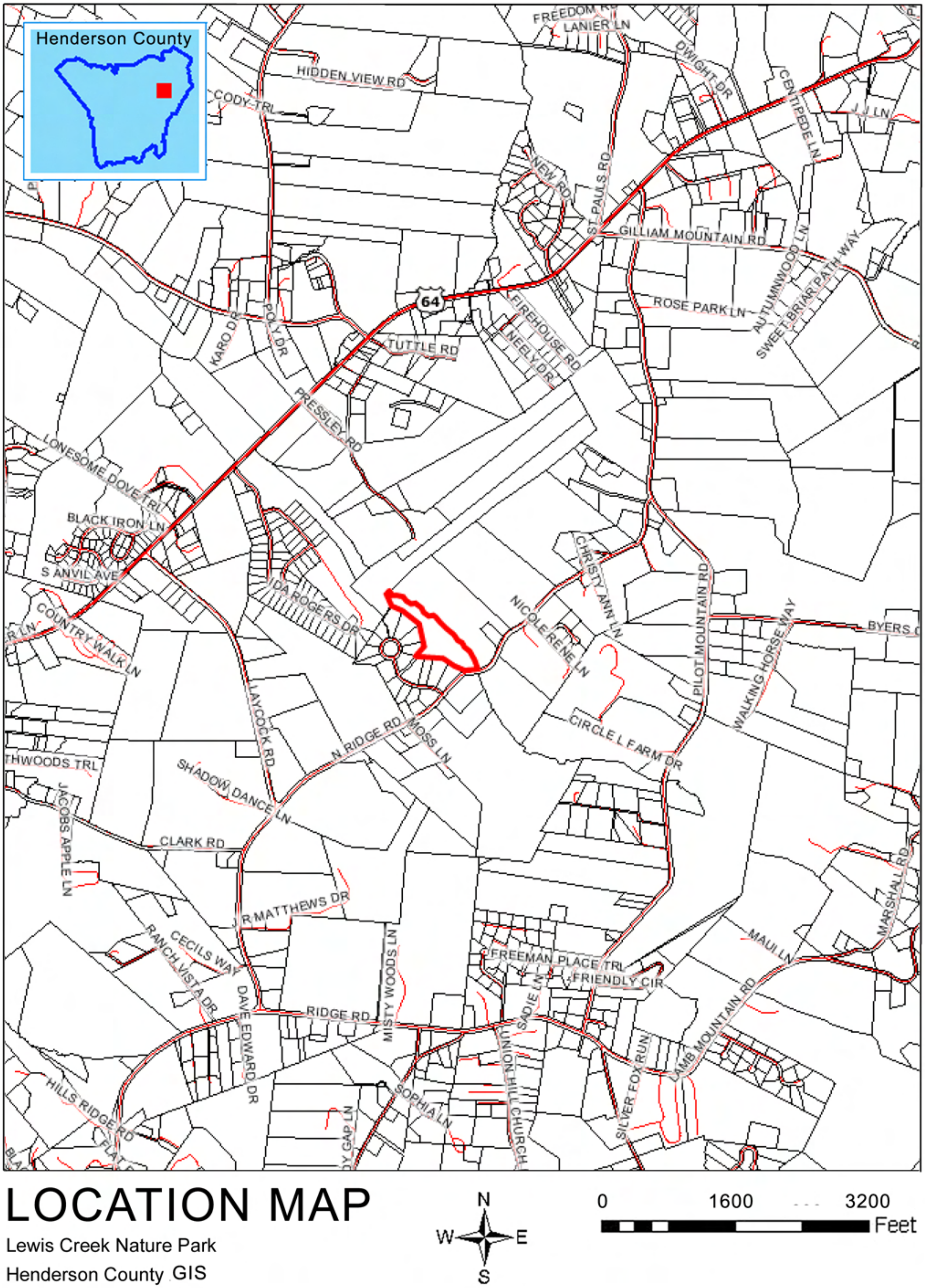


FIGURE 6: Location Map

The Lewis Creek Nature Park site is located in central part of the French Broad River watershed. With its headwaters in Transylvania County, the tributaries of the river join across three counties to create the French Broad River that flows through the heart of downtown Asheville. Agricultural fields, apple farms and new development characterize the region around the site. The site consists of a mosaic of vegetative zones. It is long in shape and is bordered on one side by the Meadows of Lewis Creek development and the other side hugs the edge of Lewis Creek. Several residents of the neighboring development use the site frequently for walking. The surrounding region is moderately populated, becoming more so as agricultural lands are being developed.

LEWIS CREEK NATURE PARK AND DESIGN GUIDELINES

A means of successfully allowing the Lewis Creek Bog to persist in this changing landscape is by adhering to the guidelines presented in Chapter 4. These guidelines reflect how potential, connectedness, resilience and identity can be used as a framework for conserving a Southern Appalachian Bog ecosystem. Below, a short analysis of the Lewis Creek Nature Park site is done in reference to each of the thirteen guidelines. References to inventory materials for specific guidelines are also provided.

1. Determine functions or elements of persistence and conserve them

The following table presents what elements and processes in Lewis Creek bog contribute to the persistence of the system.

TABLE 2: Contribution to Persistence of Lewis Creek Bog

POTENTIAL	Native species Coderus/Hatboro loam soils Stored and decaying matter in soils Nutrients (subsurface, in water, in vegetation) Rare species (Stellaria alsine, Carex collinsii, Quercus imbricata, Chamaelrium luteum, Smilax laurifolia, Toxicodendron vernix, Kalmia carolina) Geologic formation Animal habitat factors (amphibian breeding sites, snags/logs, mast producing species, nectar producing species Bank conditions, water quality
CONNECTEDNESS	*Hydrology:* Flow of water out of site (evaporation, culverts, sheet flow) Flow of water into site (rain events, seeps) Flow of water among elements within site (vegetation, storage in sphagnum, wetland soils) Flow through watershed, through water table *Fauna:* Migratory bird species, water fowl Insects Bog turtles *Flora:* Seed dispersal from plants by dispersal mechanisms, wind and water Boundary of site
RESILIENCE	Historic disturbance regime Effects of surrounding agriculture over time (Lewis Creek straightening, nutrient fluxes) Species diversity Continuation/preservation of hydrology Buffers from development and surrounding agriculture Nutrient regime Mosaic structure and function Filtering and reducing velocity of run-off
IDENTITY	Education of importance and value Unique appearance in increasingly monotonous landscape (species composition, views) Variety of fauna and flora Observance of site and species Perceived economic value as rare habitat Rare species

2. Reduce the chance of catastrophic changes

The following table presents what elements and processes in Lewis Creek bog threaten the persistence of the system.

TABLE 3: Threats to the persistence of Lewis Creek Bog

POTENTIAL	Invasive species such as *Lonicera japonica, Ligustrum sinense,* and *Rosa multiflora* that take habitat of native species and alter hydrology Loss of rare species Run-off events or large disturbance flood that removes stored nutrients, species, or changes water chemistry Nutrients (subsurface, in water, in vegetation) Any sudden loss of accumulated resources
CONNECTEDNESS	Water flow changes or drastic change in hydrology (run-off from development, release of water from site- puncturing or altering underlying soils, changes in greater watershed-more development, cows, agricultural or chemical runoff) Nutrient flow changes - invasive species, water changes, key species loss Animal/habitat change or loss
RESILIENCE	Loss of species diversity Changes in species composition Invasive species Surrounding land use changes Human ignorance and impact Drastic change in mosaic structure and function
IDENTITY	Not knowing importance of site to ecosystem services Not understanding how water flow effects site Use of site for impacting activities (off road vehicles)

3. Preserve history

The historical elements that contribute to the potential of Lewis Creek Bog are: old logs and snags (which create animal habitats), remnants of beavers and their activities, washed away locations from flood events, the mosaic of vegetation zones and sphagnum mat locations. *(Refer to Figures 12 and 14)*

4. Include multiple scales within the panarchy

When beginning to design around the Lewis Creek Bog, regional land usage inevitably affects the processes that occur within the boundaries of the system. The greater French Broad watershed that contributes Lewis Creek has a great deal of influence on the bog.

Smaller scales that are particularly important to be aware of are the connections and processes that influence the sphagnum mats or true bog remnants. This area is a critical component of the system for keeping the desired trajectory. *(Refer to Figures 9 and 10)*

5. Utilize Reference Landscape(s)

Bat Fork Bog is a Swamp Forest Bog Complex that is similar to the Lewis Creek Nature Park site. For instance, Bat Fork Bog is located near Mud Creek, which is incised similar to Lewis Creek. Also, both sites have a slight gradient with a bog wetland area near the bottom of the slope. They both are comprised of a similar mosaic of habitats including a bog complex, successional forests, and wet meadows. There are some analogous species found in both habitats, such as Small Leaved Meadow Rue (*Thalictrum macrostylum*). According to Ed Schwartzman, the interior intact bog portion of Bat Fork Bog is in excellent condition. This particular ecosystem is home to more rare species since it appears to be in better condition. For example, the Bunched Arrowhead (*Sagittaria fasiculata),*is found in the interior of the bog and is a nationally recognized rare species. Bat Fork Bog is a good reference for Lewis Creek Bog as it most closely represents what many of the wetlands in Henderson County were historically. It characterizes the desired trajectory or identity that the Lewis Creek Bog is persisting towards. (Schwartzman, 2009). *(Refer to Figure 15).*

6. Scenario Planning

The following presents three scenarios that may occur at Lewis Creek Bog in the future. These scenarios represent only a limited selection of what may happen, and do not encompass all situations. Each scenario represents a unique type of disturbance and includes multiple scales within the panarchy. The first one represents keeping the current conditions. The second depicts a large-scale natural disturbance event, and the third is a human-induced disturbance event.

1. Conditions or processes remain the same: Current Conditions

Predictions:

- Impacts will increase from neighboring development (run-off, four-wheeling, etc.)
- Hydrology will change (water chemistry changes from run-off, seeps drying from built ponds, water table will lower due to succession)

Preparations:

- Control run-off through rain gardens and swales, move ponds to more appropriate locations
- Implement blockades for off road vehicles
- Adaptively manage succession to move towards desired trajectory of the system

2. A large-scale flood event occurs over the banks of Lewis Creek: Natural Disturbance

Predictions:

- Trail area will be flooded
- Water levels will rise. If prolonged some species may drown or be lost
- Structural elements of design may be swept away
- Visual appearance will be different after, may appear messy and disturbed
- May bring debris and species from other areas into system

Preparations:

- Designed area should assume this may happen and structures should be easily and cheaply replaced
- Utilize an upland area as a nursery for key plant species
- People should be educated that flooding events are OK, and should be exposed to the self-restoration of the system
- Post-flood management plan should be created which will include removing harmful debris or invasive species should they appear

3. Clearing a portion of the site: Human-Induced Disturbance

Predictions:

- Alteration of hydrology, water table changes
- Increased erosion and run-off will occur
- Invasive and successional weedy species will likely appear
- Rare species/ native species habitat may be lost
- Mosaic structure and function will change, connectivity between internal processes will change
- Bog area may be lost

Preparations:

- Educate about the effects of this act
- Visibility of the repercussions of this should not be restricted- vivid processes
- Utilize areas for nurseries for replacement species
- A management plan should be created which includes means of controlling erosion and invasive management

7. Design with impermanence in mind- and make it visible

Previous attempts at creating permanent structures have failed. In a personal communication with one of the residents of the Meadows of Lewis Creek, Tom Grahl, it was mentioned that flooding above the banks of Lewis Creek occurs relatively often. In the past, most structures created for crossing wet areas along the trail have been washed away repeatedly. (Grahl, 2009).

8. Incorporate Diversity in Design

The current materials used on site for the trail are wood, riprap and rail ties. The "trail" area is mowed periodically throughout the growing season and a thick turf grass lines the trail.

9. Keep Native Conditions to build upon potential and enhance resilience

Refer to Appendix 1 for a current list of native species and Figure 14.

10. Connect community and allow for engagement

There have been previous efforts made to connect the surrounding community to the Lewis Creek Nature Park. For instance, there is a homeowners association for the Meadows of Lewis Creek, but in previous years the land trust has been unable to get in contact with them to inform them of events on the park property (Millar, 2009). Also, a couple of times a year, the Carolina Mountain Land conservancy has invasive plant removal days where volunteers can assist in management activities. Previous activities have included privet and multiflora rose pulls and removal of Acer Rubrum trees. Most volunteers that participate in these events are not from the Meadows of Lewis Creek, but are Henderson County residents.

11. Educate visitors so that resilience is identifiable, create vivid processes

Education is critical for the perpetuation of the Lewis Creek Bog. Many of the residents in the Meadows of Lewis Creek residential development appear to be unaware of the significance of this site. This is apparent through the misuse of the site for four-wheeling activities, implementation of ponds and recreational activities in the major seeps in the bog, and large lawns with little or no attention to run-off issues.

The processes that would be most helpful to display as educational elements of the bog site are hydrological cycles and processes (including making run-off impacts apparent), the influence of succession, and impacts from disturbances. (*Refer to Figure 16)*

12. Adaptive Management

There are a number of opportunities for adaptive management in the Lewis Creek Bog. Since the site is in such a degraded state, experimental means of management will be less harmful than if it were in a more pristine state. This site can provide experimental evidence to inform the management of other bog sites in the region. *(Refer to Figure 13)*

13. Promote consistent research and understanding

There has been one event held at the Lewis Creek Nature Park site that included research. In 2005 a group of researchers and biological experts was brought to the Lewis Creek Bog to do field inventory of the site. Since this time there is no knowledge of any other research done on the site (Millar, 2009).

SUMMARY OF INVENTORY AND ANALYSIS

The Lewis Creek Nature Park Site is a prime location for using panarchy as a model for design. It is apparent that there are adaptive cycles working within the ecosystem and that there are multiple factors contributing to the potential, connectedness, resilience and identity of the site. The design and management of the system should take all of this into account.

Overall, the site appears to be in a somewhat degraded condition in comparison to the reference site, Bat Fork Bog. The process of succession currently has a large role in the cycle of the bog system, placing the bog in a back loop of the adaptive cycle. Over a relatively short period of time, the bog remnant portion of the site has receded, as the successional areas appear to be growing in size (Schwartzman, 2009). Random and invasive species are taking up residence throughout the site, and thus the impact of change is amplified. Many outside factors are influencing the current state of the ecosystem. Since a majority of the site is on a gradient, with development and agriculture contributing run off and excess nutrient input from above, the site should be buffered from these sizeable threatening elements to protect the persistence of the system.

The Lewis Creek Nature Park Site can be divided into four categories for design purposes (*Refer to Figure 18*). These are: areas that contribute greatly to persistence, areas that contribute moderately to persistence, areas that contribute little to persistence and areas which require management to contribute to persistence. These locations were deduced through investigation of multiple levels of site inventory. The areas that contribute the greatest to the potential, connectedness, resilience and identity of the system should be conserved. Areas that contribute less are more viable locations for designed structures and elements, as changes to these areas will have less impact on the overall persistence of the system. Additionally through design, these areas may be able to add more to the persistence of the Lewis Creek Bog. The areas that require management should become priorities for adaptive management practices. A combination of inventory results and the analysis map provides insight for the direction of the Lewis Creek Nature Park design and management.

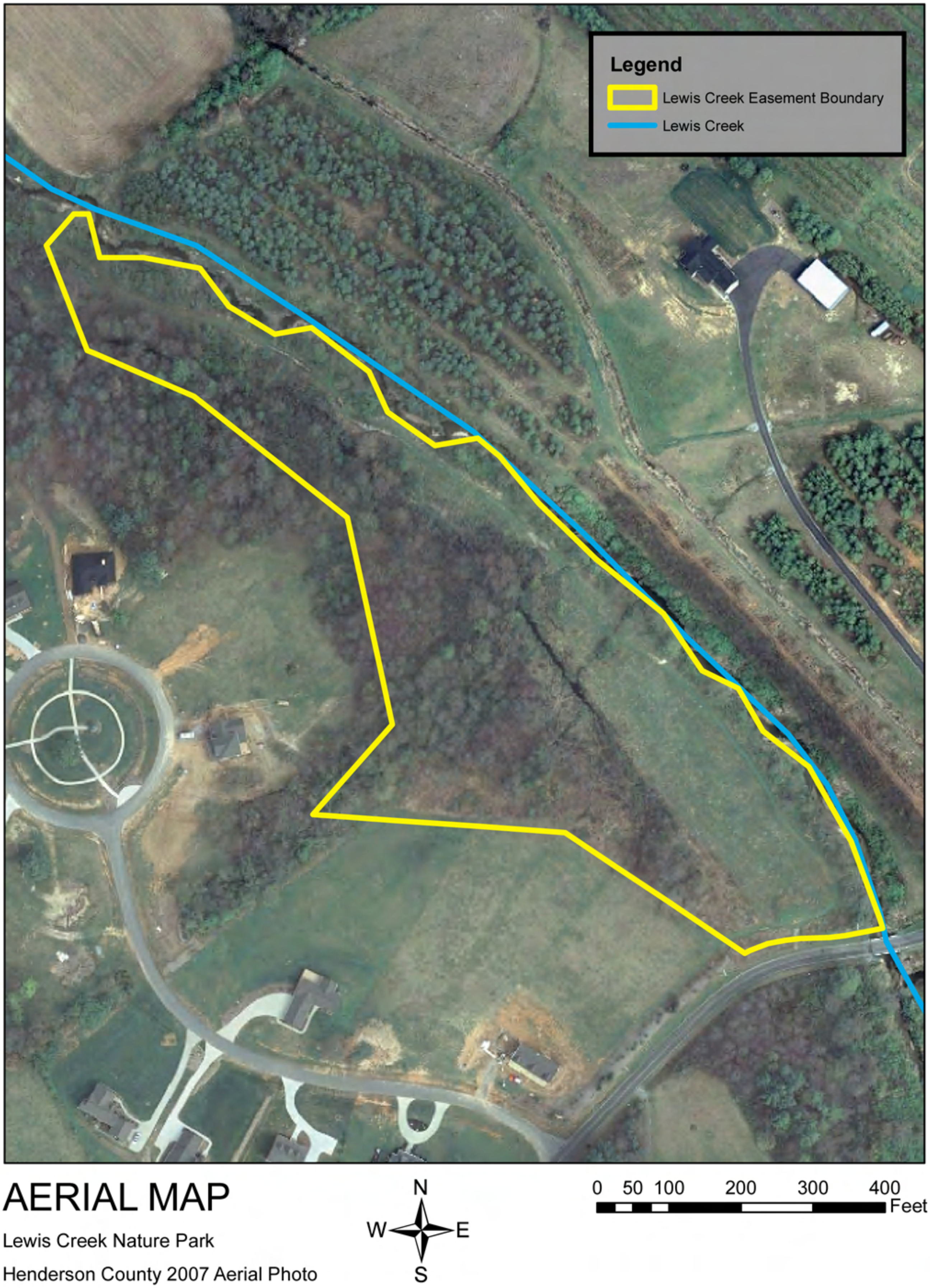


FIGURE 7: Aerial Map

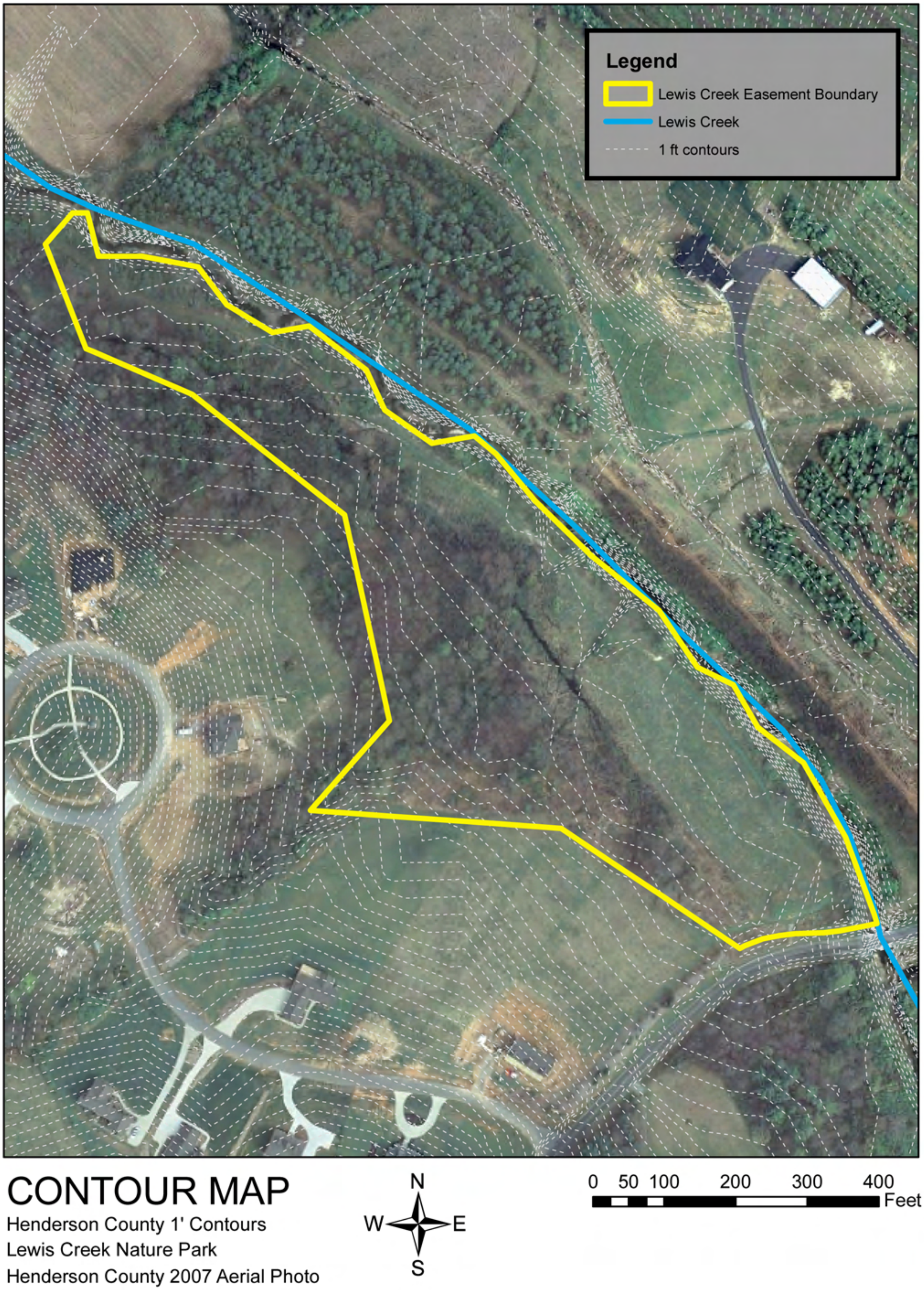


FIGURE 8: Contour Map

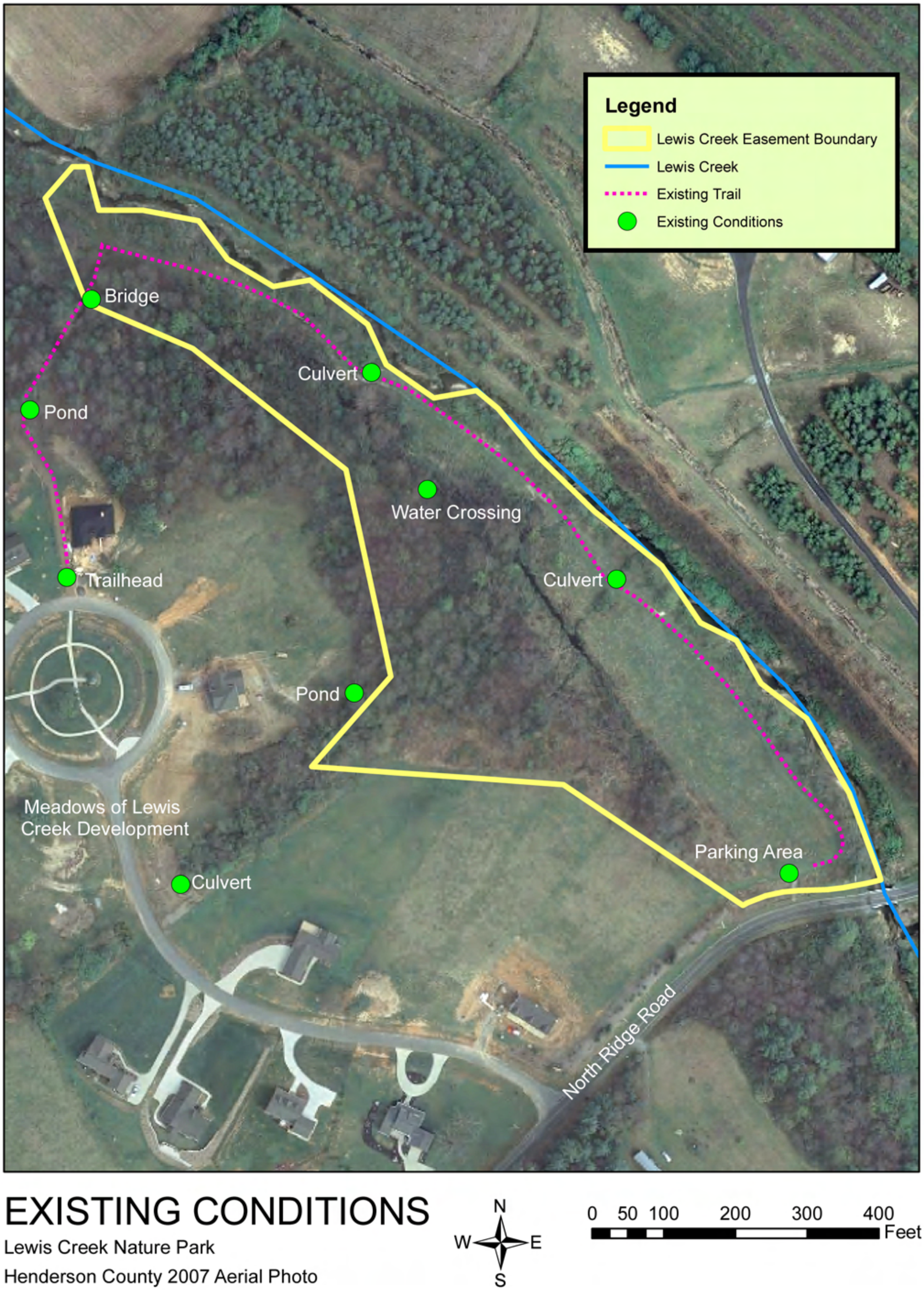
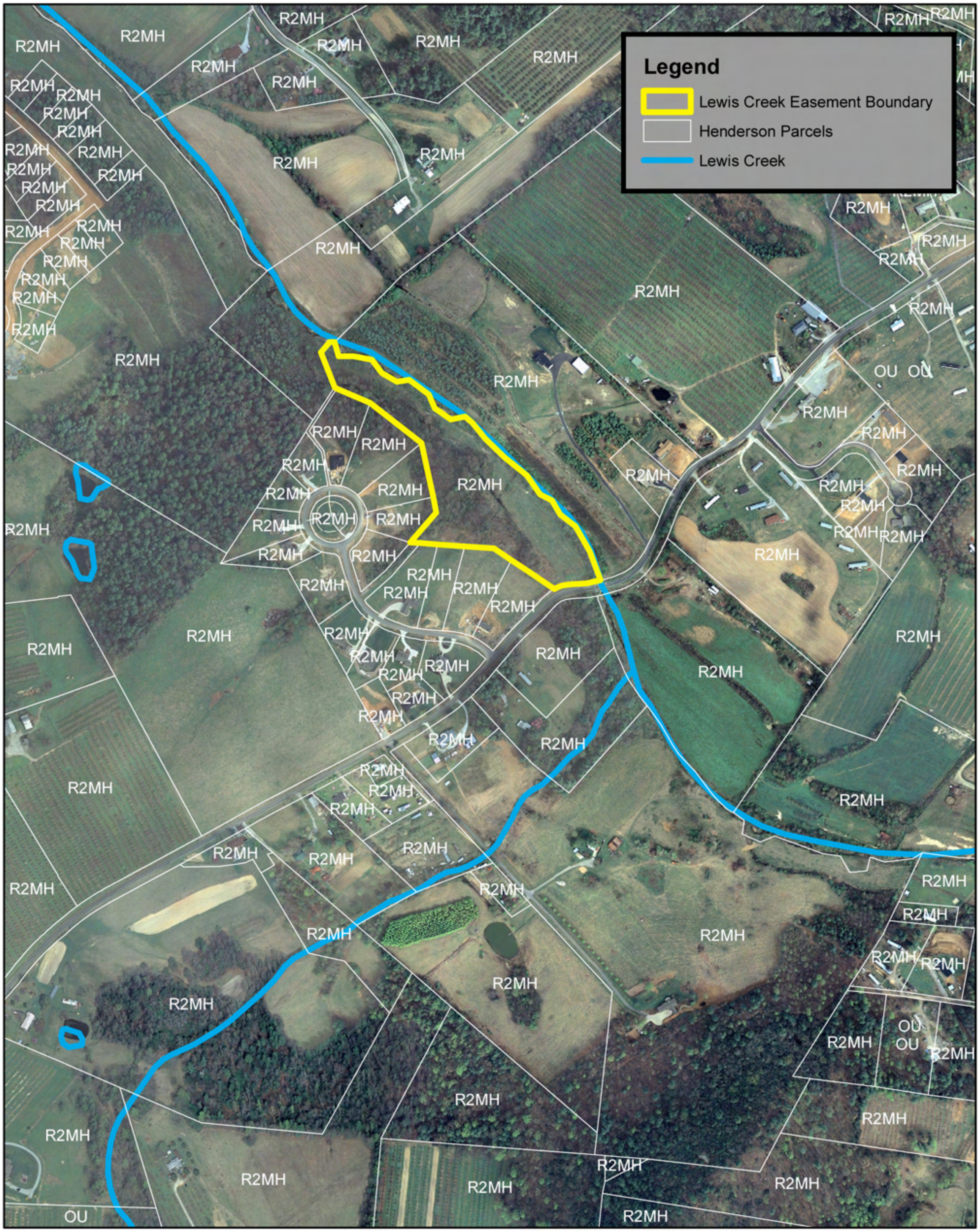


FIGURE 9: Existing Conditions Map



ZONING MAP

Lewis Creek Nature Park

Henderson County 2007 Aerial Photo

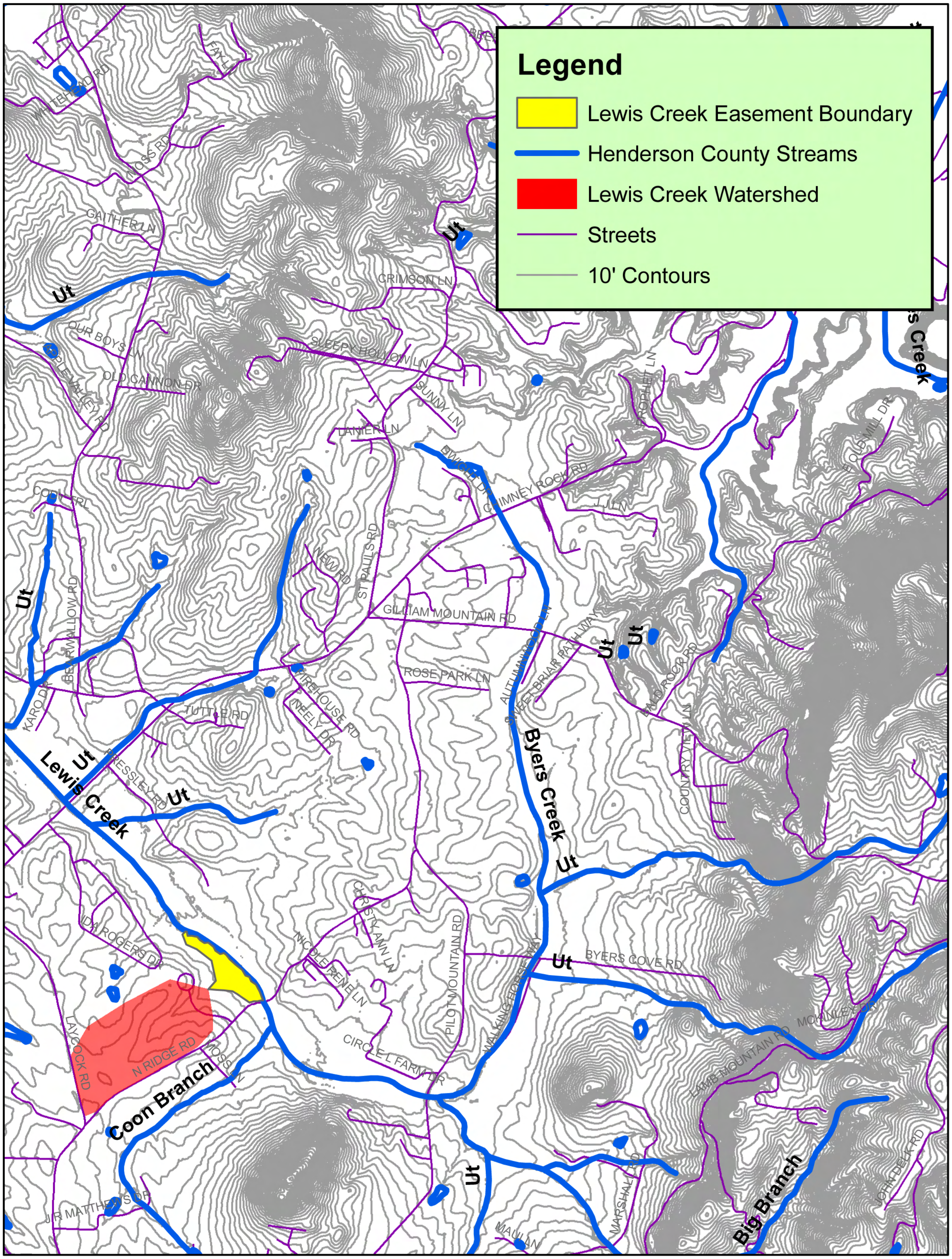
N
W E
S

0 175 350 700 1,050 1,400
Feet

OU = Open Use

R2MH= Residential 2 Manufactured Home

FIGURE 10 : Zoning Map



WATERSHED MAP

Lewis Creek Nature Park

LIDAR 10' Contours

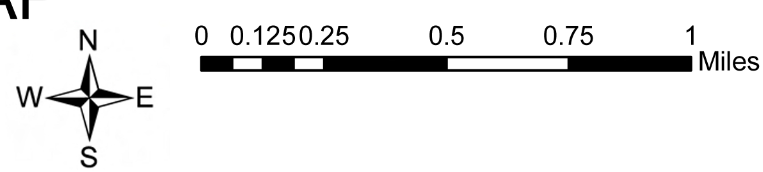


FIGURE 11: Watershed Map

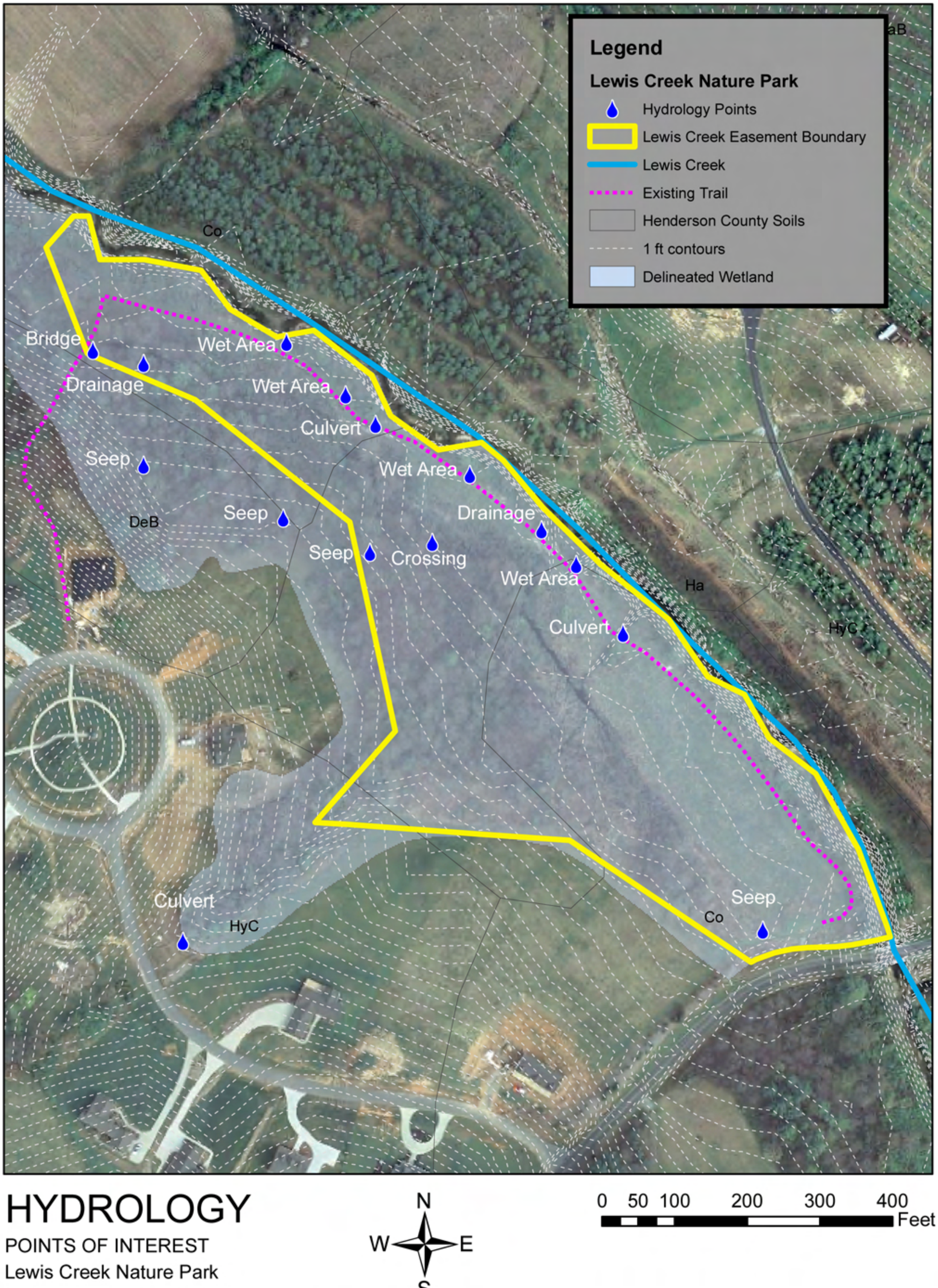


FIGURE 12: Hydrology Map

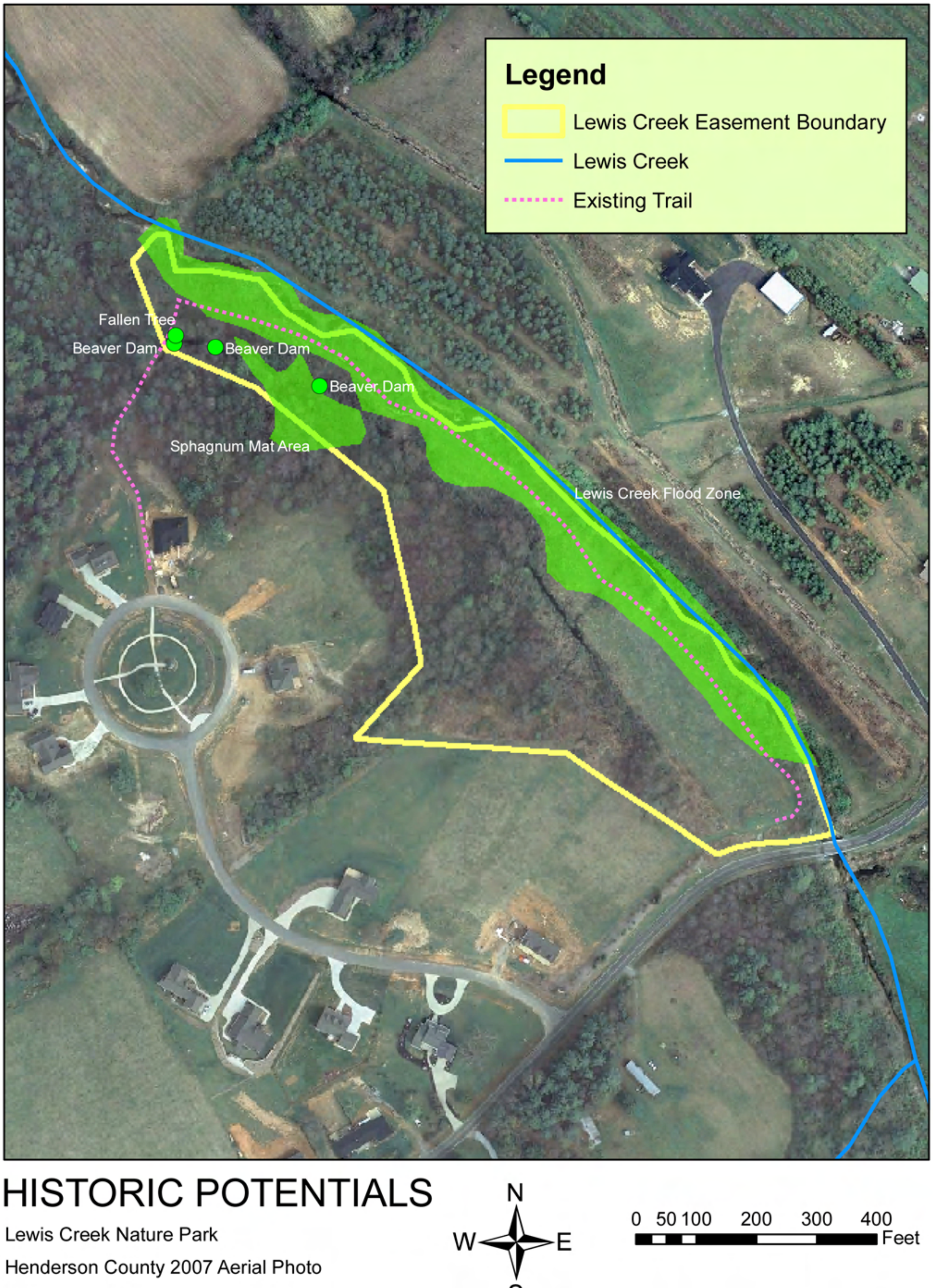


FIGURE 13: Historic Potentials Map

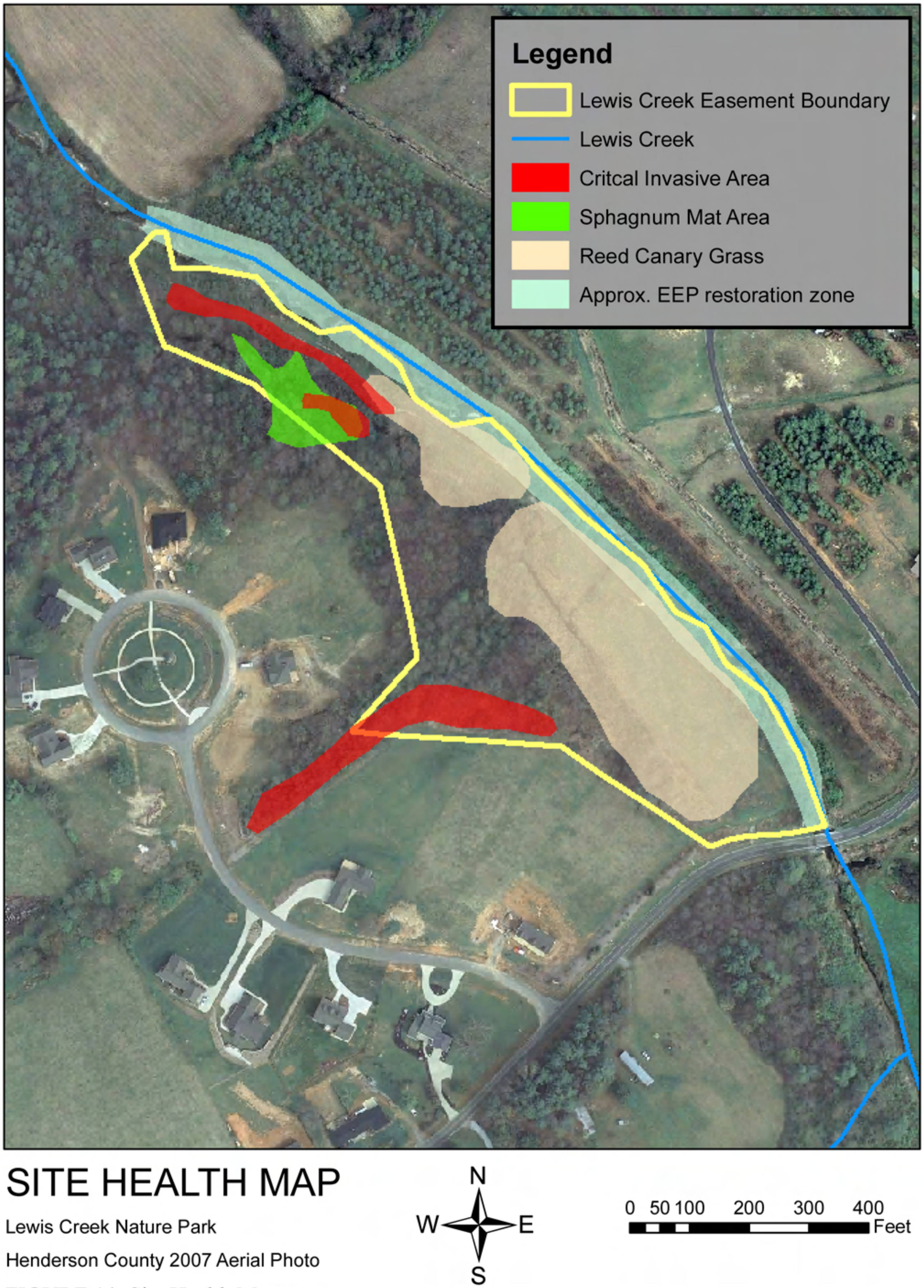


FIGURE 14: Site Health Map

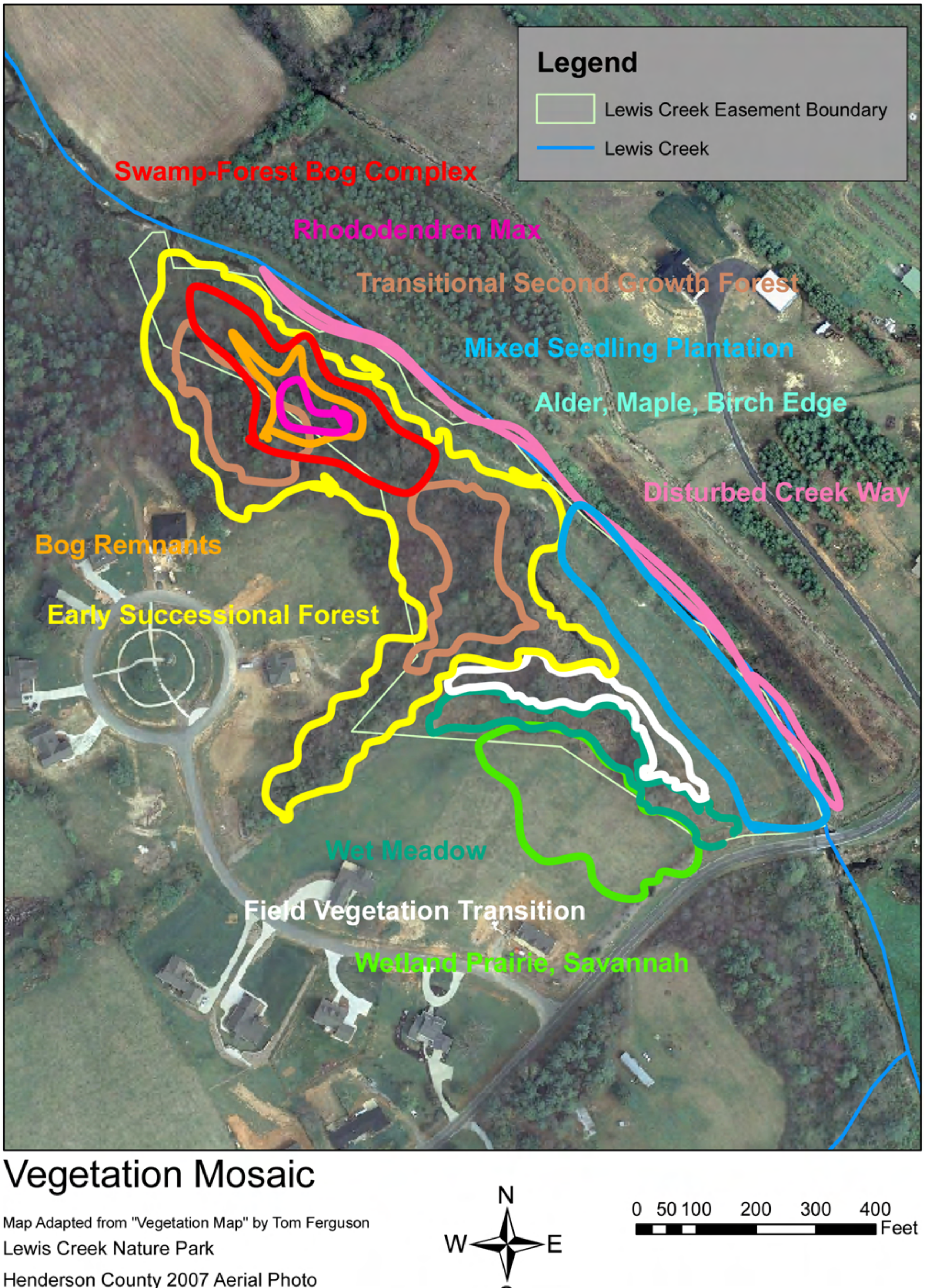
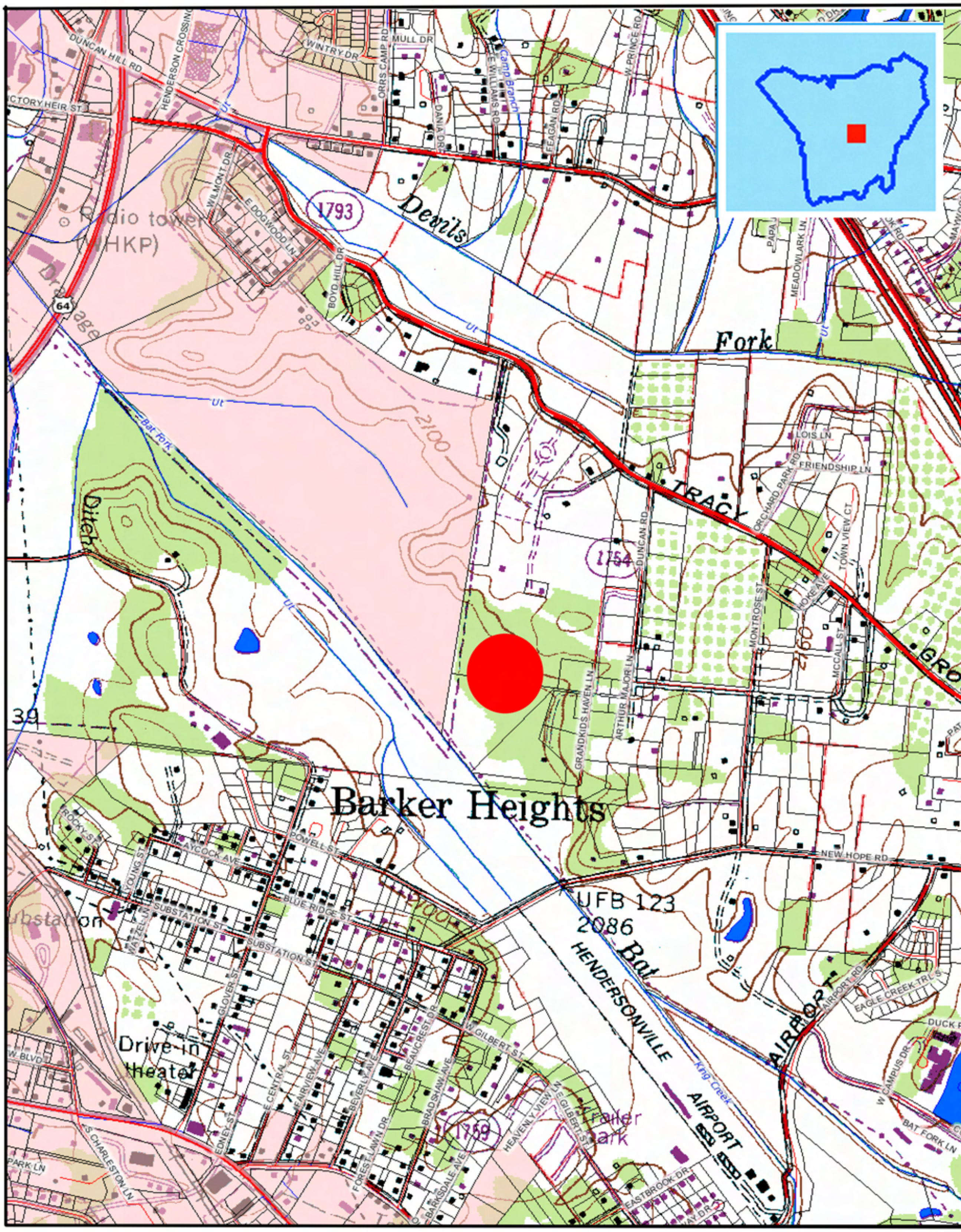


FIGURE 15: Vegetation Mosaic Map



BAT FORK BOG

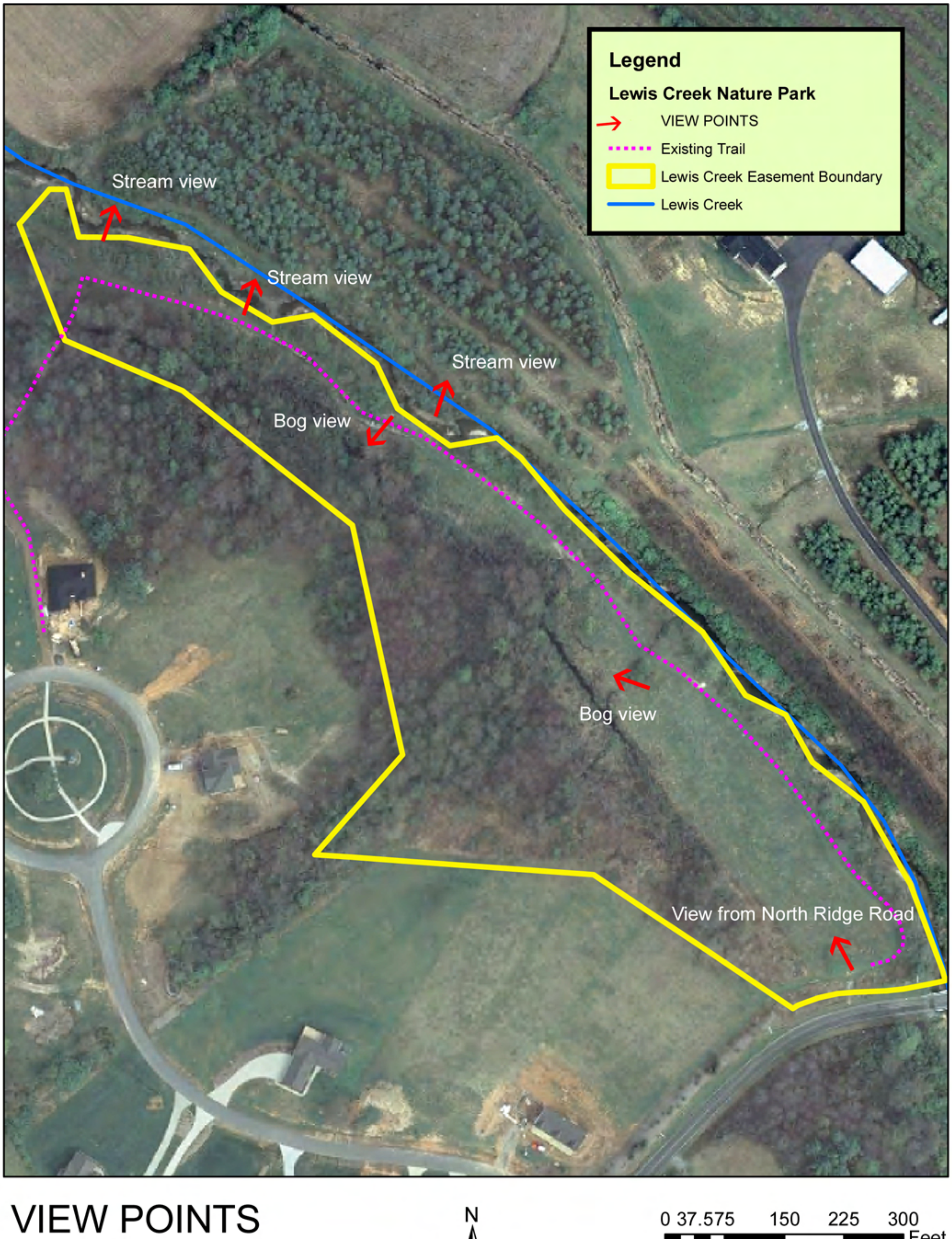
Reference Landscape Map

Henderson County GIS

N W E S

600 1200 Feet

FIGURE 16: Bat Fork Bog Reference Landscape Map

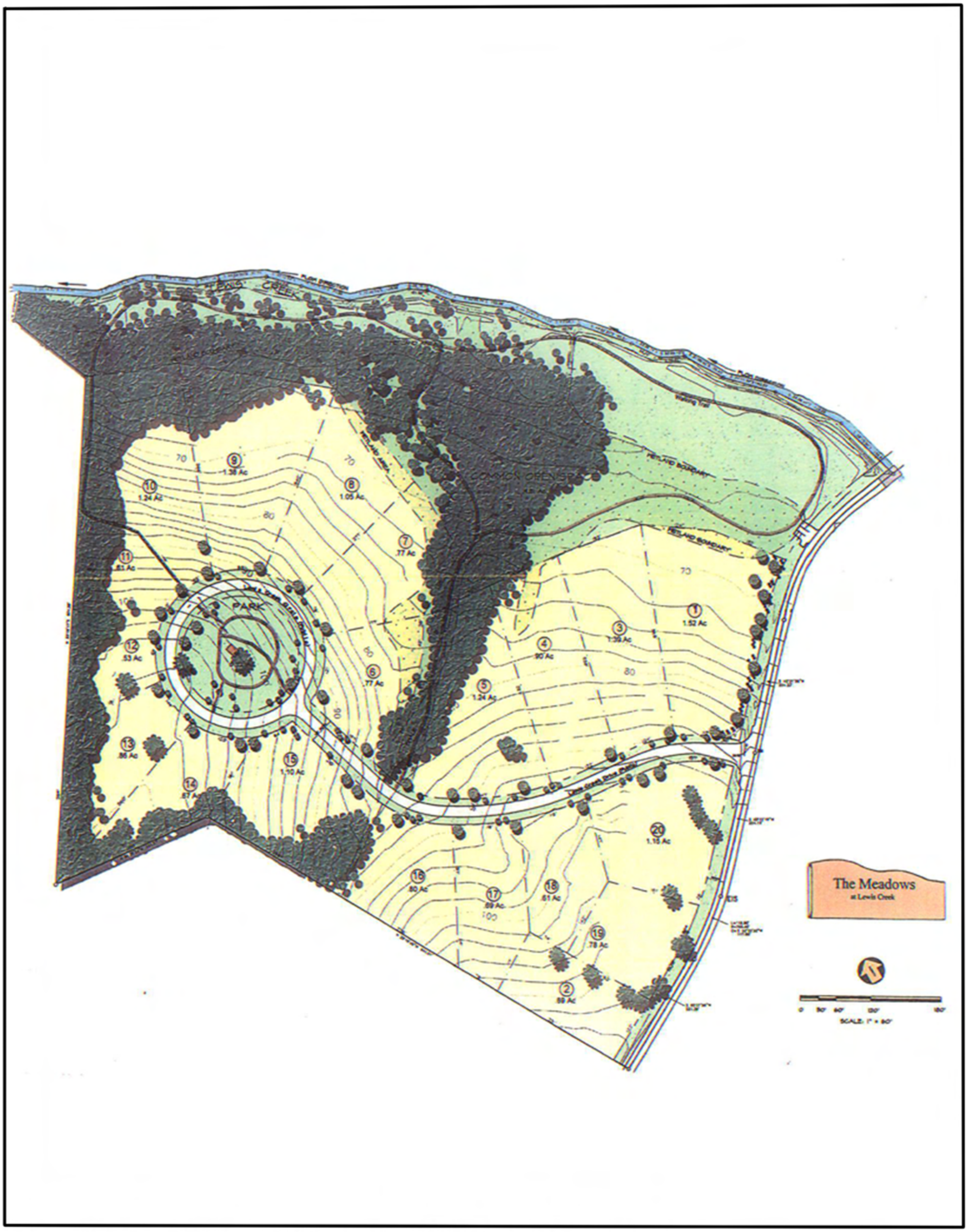


VIEW POINTS

Lewis Creek Nature Park

Henderson County 2007 Aerial Photo

FIGURE 17: Views Map



MEADOWS OF LEWIS CREEK

DEVELOPMENT MAP

BY LUTHER SMITH AND ASSOCIATES

FIGURE 18: LEWIS CREEK DEVELOPMENT MAP

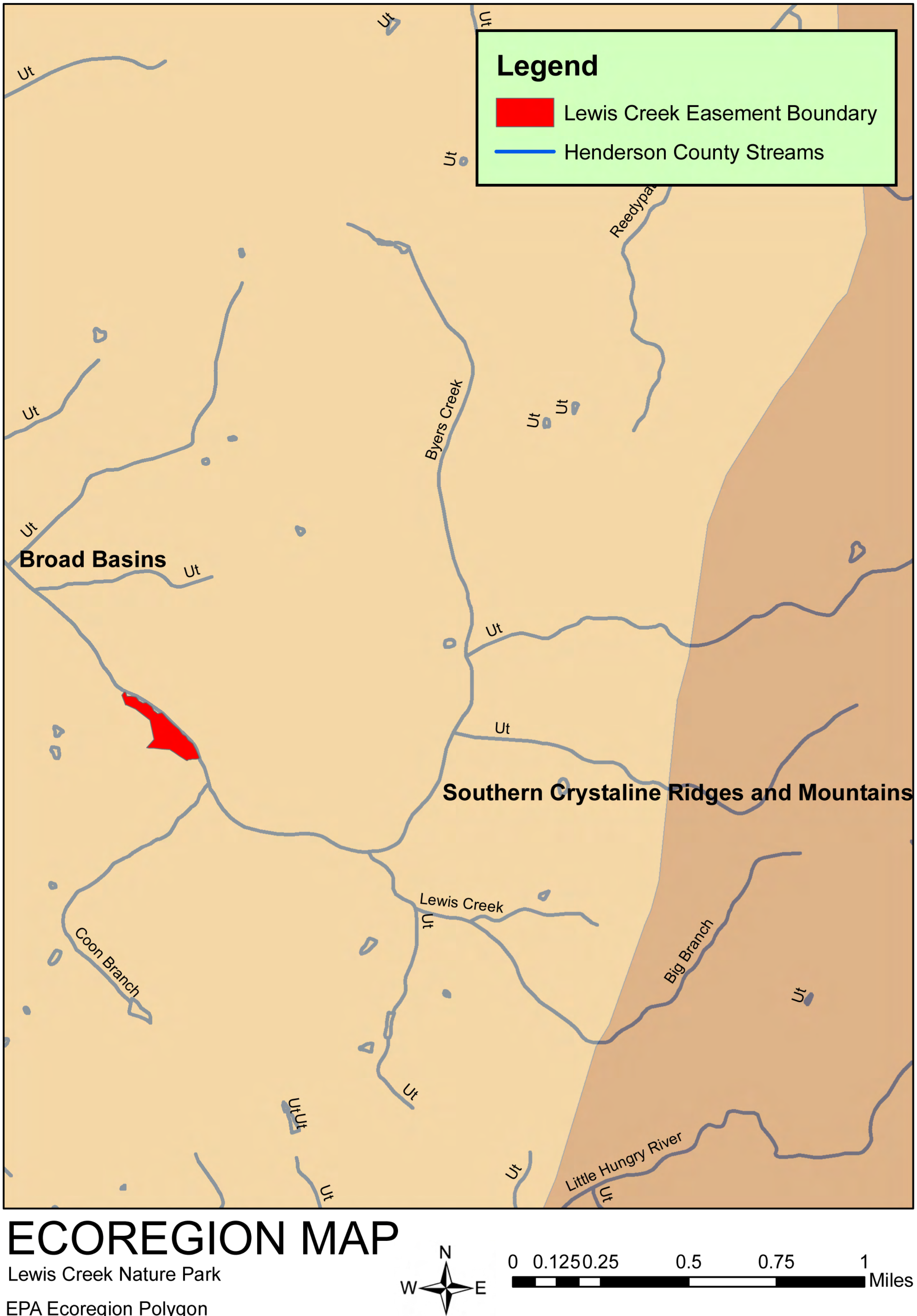


FIGURE 19: Ecoregion Map

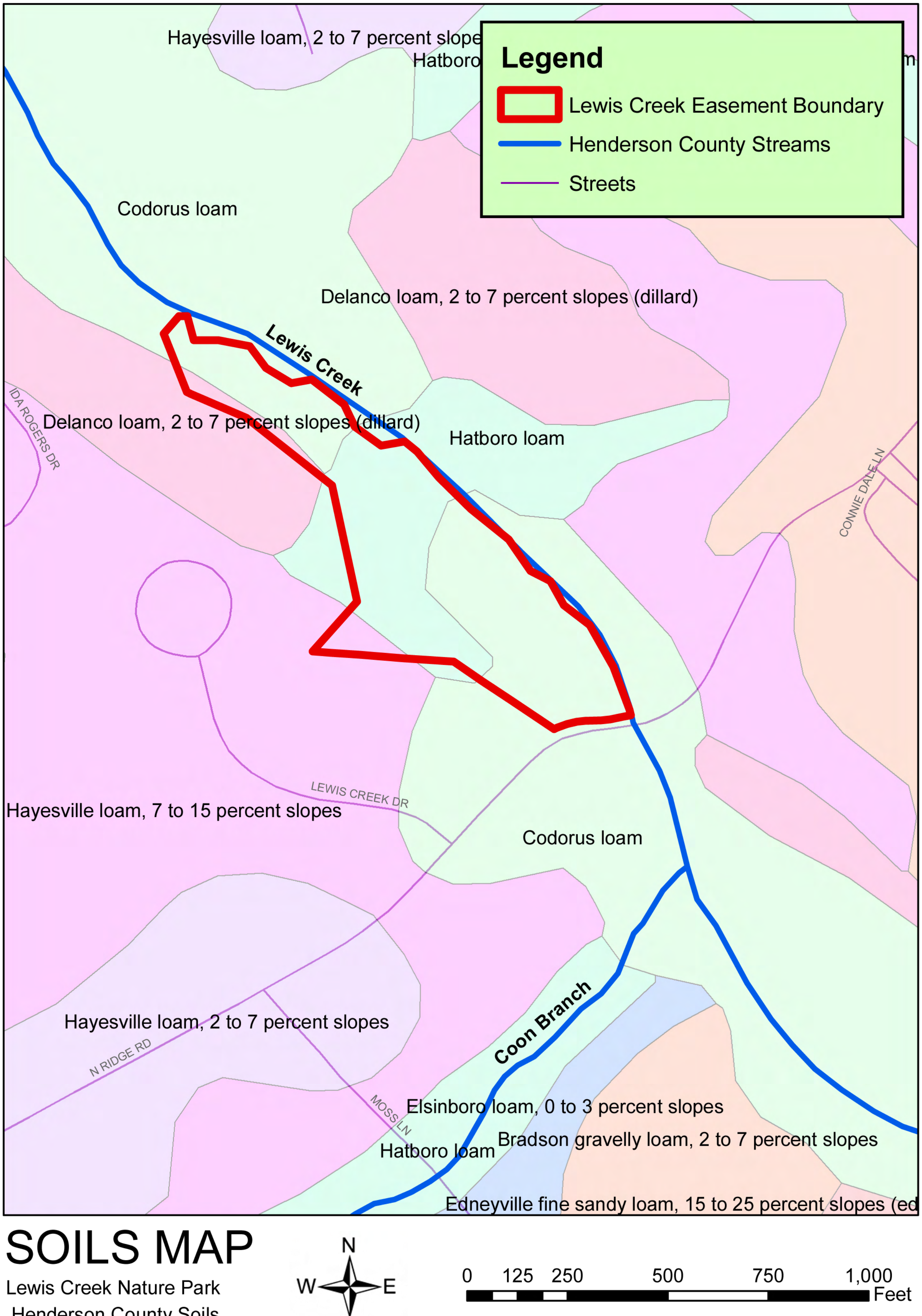


FIGURE 20: Soils Map

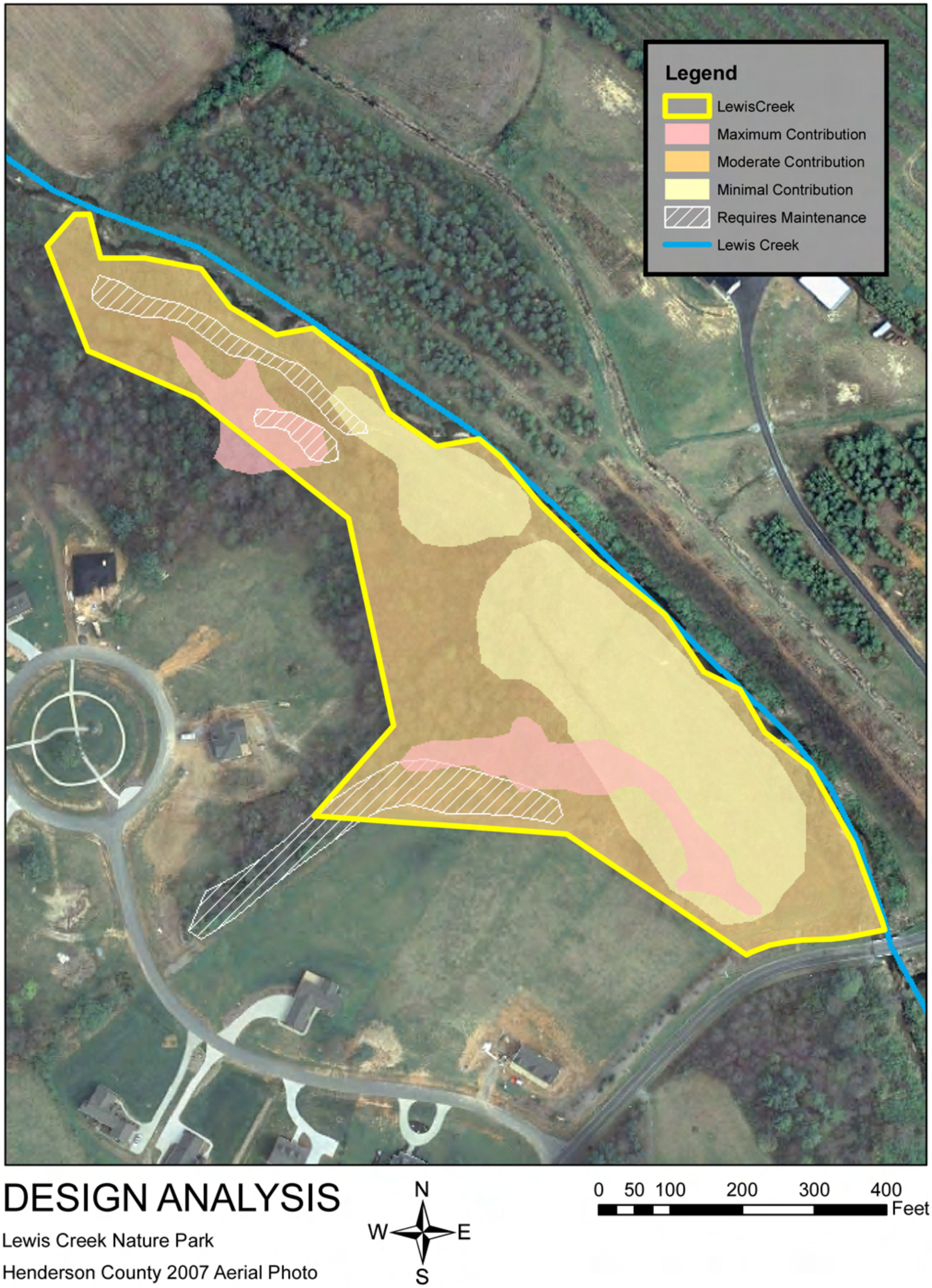


FIGURE 21: Design Analysis

CHAPTER 6

LEWIS CREEK NATURE PARK DESIGN AND MANAGEMENT

MASTER PLAN PROGRAM

The design for the Lewis Creek Nature Park will provide visitors with a multifaceted educational experience while at the same time allowing for the persistence of the ecosystem. The design creates changes in areas that contribute little to persistence and leaves the areas that contribute the most untouched. In order to develop a strong identity for the Lewis Creek Nature Park, the design must aspire to bring the larger community in, even though currently only the residents of the Meadows of Lewis Creek may use it. It must allow for future connections to occur to inspire innovation and foster back loop events.

The trail system and interpretive use of materials throughout the site will create an identity that connects more than just a handful of people. If the park were to become a public space in the future, it could become a destination for school groups or a restful stop along a greater trail system through Henderson County. The design will allow people to simply visit the park once to learn about the inner workings of a bog ecosystem, or they could visit everyday and observe changes over time such as the weathering of materials or resiliency after disturbances. By integrating meanders in seasonal trails and along the main trail, all visitors can move through the site with a sense of suspense and wonder. When and if more people are connected to the bog system over time, they will be more likely to save them in other areas in the region.

In an effort to vivify the processes at work in the ecosystem, several experiential design techniques are used. For example, an artistic metaphor of succession is created along a gradient through the site, leading visitors to discover and interpret its meaning. The design also exposes visitors directly to change and disturbances, making visible the connectivity of water and adaptive management practices.

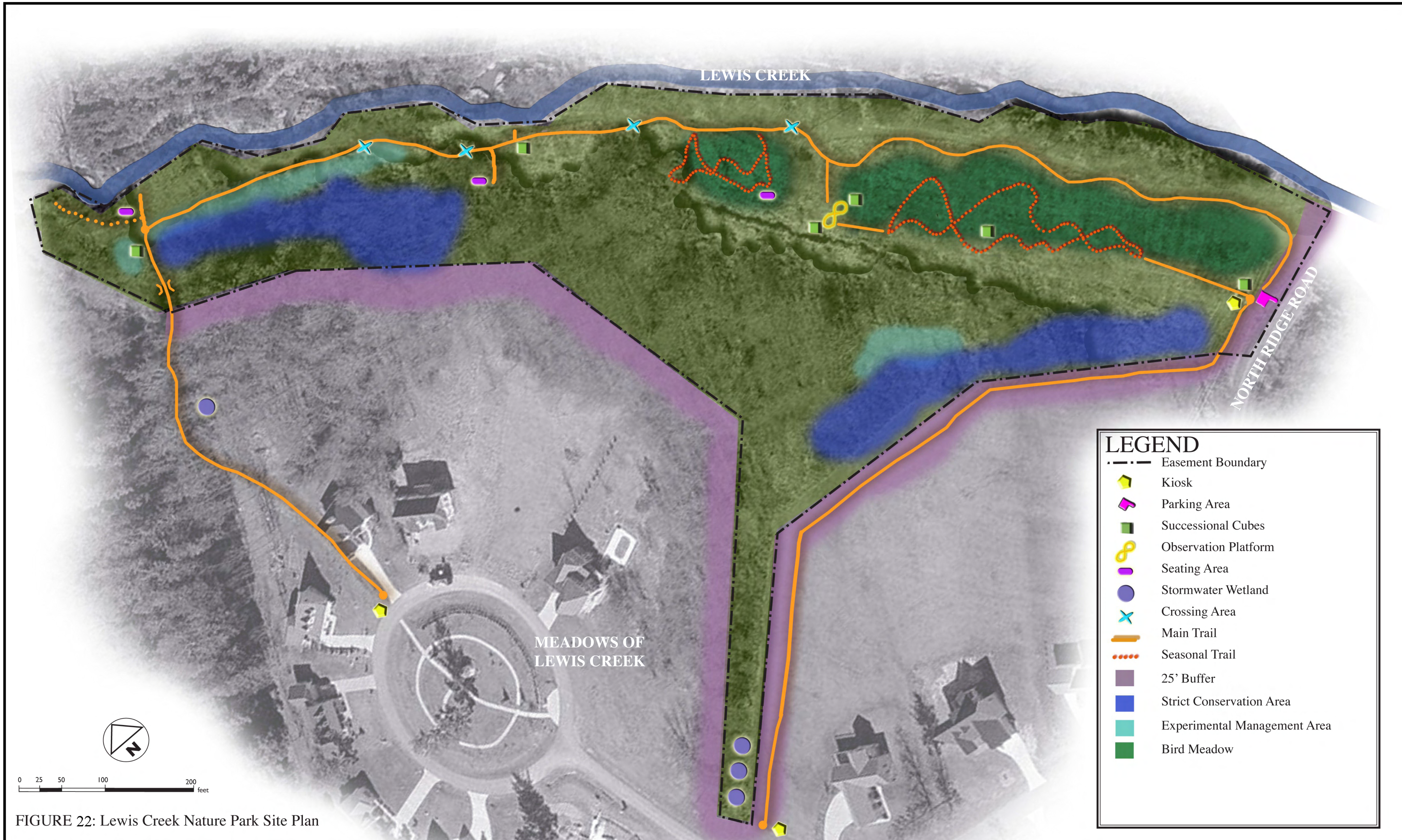


FIGURE 22: Lewis Creek Nature Park Site Plan

ELEMENTS OF DESIGN

Buffers- Buffers should protect the site from outside threats to potential, connectedness, resilience and identity. At minimum of a 25' buffer should be planted and protected around the edge of the site. The buffer areas can also be utilized as a nursery to house native species. These species could then be used to replant in areas of the nature park after large disturbance events. The species should also be ones that provide sources of food and foster habitat for fauna. Suggested species can be found in Appendix B.

Exemplifies design guidelines: 2, 3, 9

Strict Conservation Areas- Areas that have the most impact on the potential, connectedness, resilience and identity of the system should be protected as much as possible. These areas are where rare plants, beaver dams, logs and other elements of historic potential exist. Visitors should be prohibited from entering these areas by utilizing dense plantings and well delineated walking trails. Minimal management should occur in these areas, unless absolutely necessary.

Exemplifies design guidelines: 1, 3, 9

Experimental Management Areas- These areas are located in highly visible locations along the trail to make the disturbances and effects of change visible to visitors. Experiments should be done using different techniques to remove invasive exotic species over time. Successful treatments should be recorded and utilized in the future. These

areas will also create manageable disturbances that will help curb catastrophic changes.
Exemplifies design guidelines: 2, 7, 12, 13

Main Trail- The main trail will be mowed to a width of 5' throughout the growing season, which is narrower than its current size. More meanders should be included along the trail to hinder the direct flow of water during flood events. In some areas it will need to be delineated with the use of wood debris from the site and native plantings, particularly in areas closest to the Meadows of Lewis Creek. The trail should also continue to the Northwest of the site to allow for future expansion and connection to other sites and scales.
Exemplifies design guidelines: 2, 4

Seasonal Trails- The idea of a seasonal trail is to initiate small-scale disturbances to ward off catastrophic changes in the system. Each year, a new path will be mowed between two points. This will create a disturbance in a new area each year and allow for previous trail areas to regenerate, thus enhancing resilience of the site. The trails will thus become ephemeral elements. It will also allow visitors to experience the nature park differently each year and will emphasize the changing state of the system through these experiences.
Exemplifies design guidelines: 2, 7, 8, 10, 11

Parking Area- This is the point of landing for many who will visit the site and is also the only view that passersby have of the nature park from the road. It is a place where visitors make an initial connection to the site. Thus, it is a key aesthetic location in the nature park design. The parking lot surface material should be small sized gravel and should be contained as much as possible using metal edging so it will not wash directly into the bog. Only four parking spots should be included. This will limit the number of visitors and thus limit the human induced impact to the site. Spots will be delineated with parking blocks made of logs, held in place by rebar stakes. The area around the parking area should be planted with a variety of blooming native perennials, such as *Rudbeckia spp* or *Eupatorium purpurea*. This will make the entrance more attractive. A kiosk will also be located next to the lot, but will not impede the vista from the road.

Exemplifies design guidelines: 9, 10

Bird Meadow- The bird meadow will be planted with a variety of species that attract and shelter birds. This will create more habitats and enhance the potential of the site. By attracting more birds, it will also allow for enhanced connectedness, as migratory species may be more liable to visit the site. Suggested species are found in Appendix B.

Exemplifies design guidelines: 1, 9

Observation Platform- The observation platform will provide visitors with a place to view the bog (*See Figure 25*). It will be a permanent structure made of a variety of materials, including steel grating, treated pine, and untreated wood. The structure will consist of two platforms, one for bird watching and one for viewing the bog area. The platforms will be oriented so that the circulation pattern resembles the form of the adaptive cycle. The bird platform will be made from wood. Wooden handrails will have descriptions of the surrounding bird habitat inscribed in them and making people look out into the environment around them. The bog platform will be made of metal grate material and will allow views below. Both will have a large square cube, resembling the successional cubes created from layers of wood that will be benches for resting. At the edge of the platform, a wooden plank will have descriptions of the bog, making people look down into the environment below them. The entire structure will be held in place using Pin Foundations Diamond Piers to ensure stability. Native bog species should be planted around the platforms after installation to blend the structure into the landscape. Also, birdhouses should be placed around the site to increase habitat and bird viewing possibilities.

Exemplifies design guidelines: 4, 7, 8, 10, 11

Kiosks- Kiosks will be made from all natural materials and are simplistic in nature (*See Figure 26*). Recycled wood products should be used in their creation as much as possible. Each kiosk will have an educational sign, which will include information about the rarity of the habitat and how one can assist in conserving them. A location for announcements of workdays and trail maps should also be included.

Exemplifies design guidelines: 10

Crossing Experiments- a variety of crossing options should be employed along the trail, helping to vivify change in the system (*See Figure 28*). Some will be more permanent in nature than others and the materials should vary. Each crossing should be inspected annually to observe the impact of change and weathering. If a flood event should occur, the success of the structures should be noted. Crossings should be replaced with more successful designs over time.

Exemplifies design guidelines: 7, 8, 11, 13

Stepped Storm water Wetlands- A series of storm water wetlands will help to slow, treat and cool run off from the Meadows of Lewis Creek and neighboring agricultural areas (*Refer to Figure 29*). They will be educational and experiential locations for visitors, creating awareness of the hydrologic processes in the bog system. Plants used in the wetlands should be similar to those found in the bog system downstream. This will keep invasive plants from invading the bog. At the site near the road, an educational kiosk will explain how the rain garden works and the benefits it provides to the system.

Exemplifies design guidelines: 2, 3, 4, 9, 10, 11

Benches and Plank Platforms- These simple structures will evoke a benign human presence throughout the site. They will be made of newer or older materials, depending on their location along the "successional gradient." They will be simple in nature so as to blend in among the natural elements of the site and will be moveable as necessary.

Exemplifies design guidelines: 7, 8, 9, 10

Successional Layer Cubes- Small cubes are located throughout the site, each with an etched symbol on a plaque representative of an essential element of the panarchy of the ecosystem (*Refer to Figure 26*). The cubes will also represent the process of succession, as this process is prevalent in the Lewis Creek Nature Park. The word succession brings

to mind a metaphor of age and maturity. To demonstrate this metaphor in the park, a range of materials will be used to create the cubes along a "gradient of succession". In newer successional areas, newer materials will be used. In older successional areas of the park, older, more weathered materials will be used. The blocks are created from layers of the chosen material, representing how several layers of elements connect to create the ecosystem. The form, a block, is an obvious human construction and depicts a benign human presence in the landscape. This will increase the experience of succession throughout the site and lead visitors to be drawn through the site by the objects themselves.
Exemplifies design guidelines: 1, 10

Website- A website should be created for the Lewis Creek Nature Park to support the educational and experiential component of the design. It should include a map for visitors to download, showing highlights. It should also include a history of the site and description of the rare bog habitat. Photos should be displayed and frequently updated to provide community members who are unable to visit often with knowledge about the changes occurring within the park. This could be photos of the same area throughout the seasons of the year, or could be photos uploaded by park visitors of their perspectives.
Exemplifies design guidelines: 10, 11

DESIGN AND MANAGEMENT PHASES

Phase 1 (1 yr.):

- Educate the Meadows of Lewis Creek Homeowners Association about the rare ecosystem they live beside by having a meeting or creating an educational brochure.
- Stop activities that are currently creating large disturbances such as four-wheeling.
- Burn Zone 1, the reed canary grass areas. Herbicide later in the season.
- Implement rain gardens.
- Begin adaptive management practices in Zones 2 and 3.
- Fill in ditches to restore hydrology to system and alter culvert with drawdown devices to extend “detention”.
- Begin scheduling community workdays.
- Begin trail construction by delineating path and mowing throughout season.

Phase 2 (2 yrs):

- Continue to observe reed canary grass populations and herbicide as necessary.
- Plant buffers.
- Create seasonal trails.
- Continue management of Zone 2 and 3.
- Create parking area.
- Install the two kiosks near the development and post workday schedule.

Phase 3 (3 yrs.)

- Implement experimental crossings once trail course is finalized. Observe over the course of the year and amend as necessary.
- Implement experimental management zones
- Build observation platform once reed canary grass populations are controlled.
- Finalize parking area and install adjoining kiosk.
- Plant bird meadow.
- Build and place moveable seating and plank platforms.
- Continue selective management of invasive species.
- Place Successional Cubes

Phase 4 (4 + years)

- Continued annual maintenance of main trail and new creation of seasonal trails.
- Update crossings as needed (use most successful designs from experiments)
- Allow built structures to weather and decay. Only replace if they pose threat to visitor safety.
- Compare with Bat Fork Bog over time.
- Observe surrounding regional land use and its impact on the system.
- Utilize buffer areas as nursery to supply site.
- Annually monitor rare species populations.

General considerations:

- When constructing any structure or changing any part of the system, salvage any plants or materials for use in another part of the system. For example, if removing Red Maples from the site, use the wood to create walkways or benches.
- Changes in the system should be allowed to happen, as this is what will lead to innovation. If a large-scale disturbance occurs, manage minimally afterwards only to avoid safety hazards for visitors or to allow accessibility.
- Make experimental results accessible to the public, either by posting on kiosks or via the web.

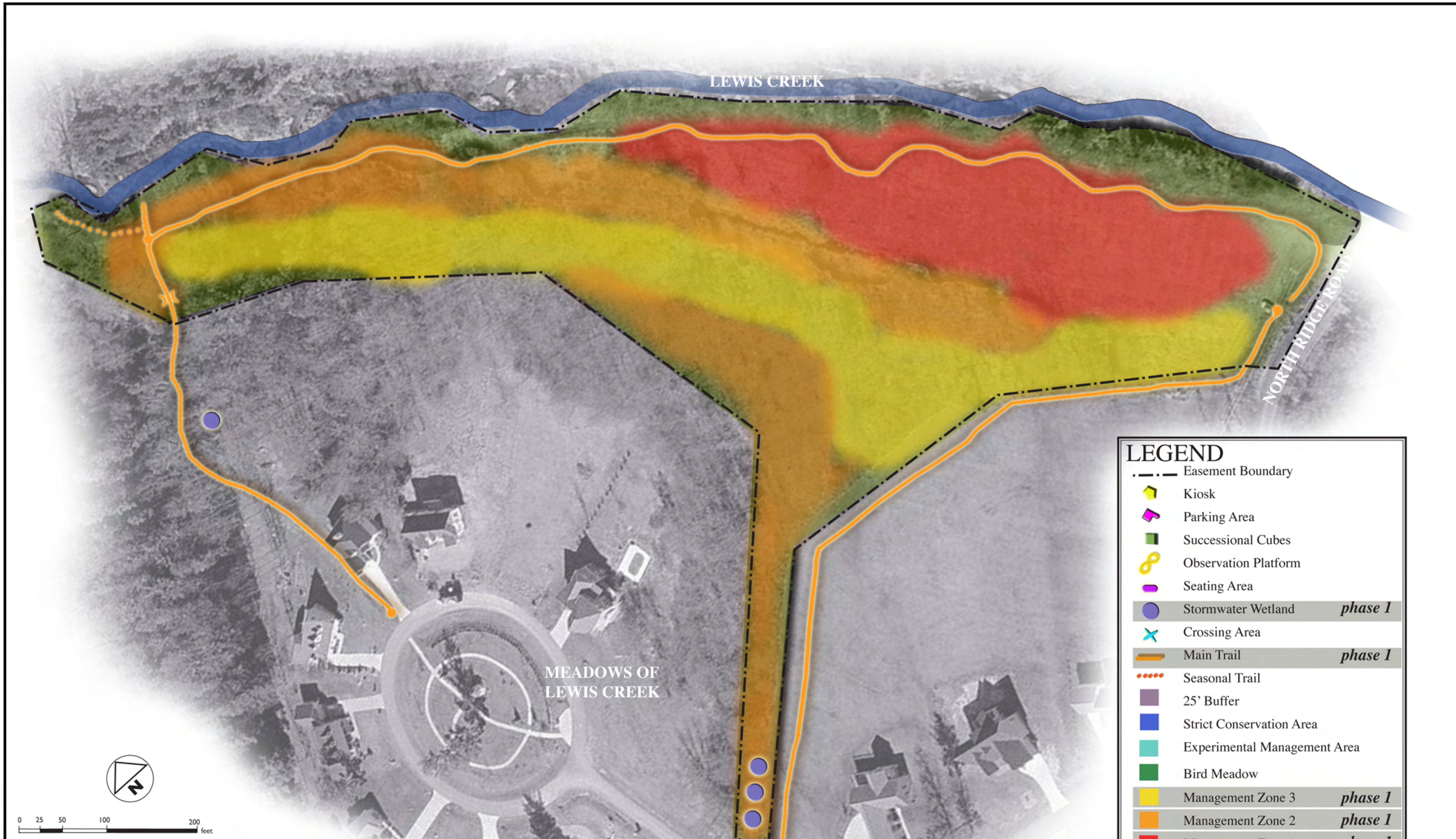


FIGURE 23: Phase 1 Design and Management Plan

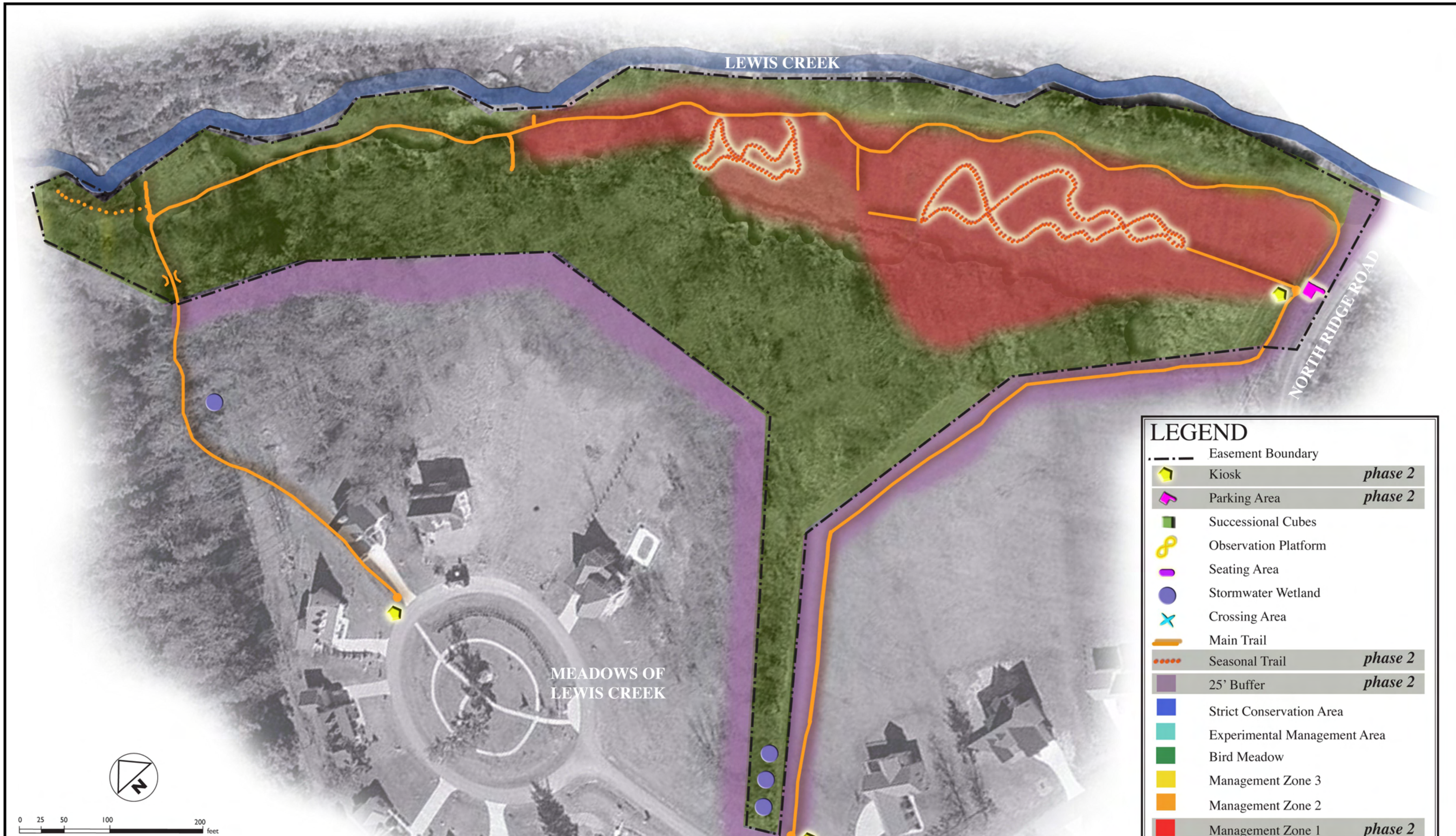


FIGURE 24: Phase 2 Design and Management Plan

FIGURE 25: Phase 3 Design and Management Plan

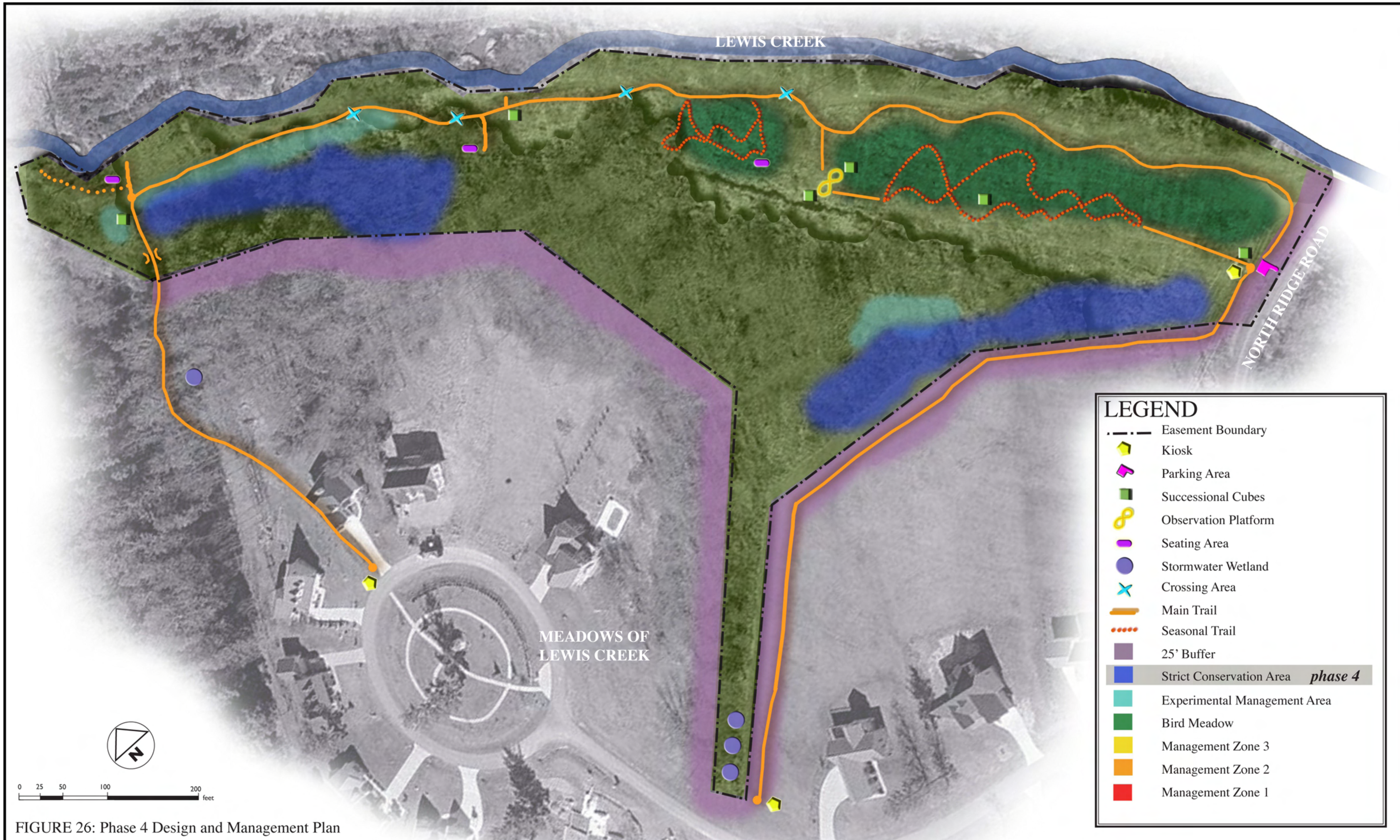


FIGURE 26: Phase 4 Design and Management Plan

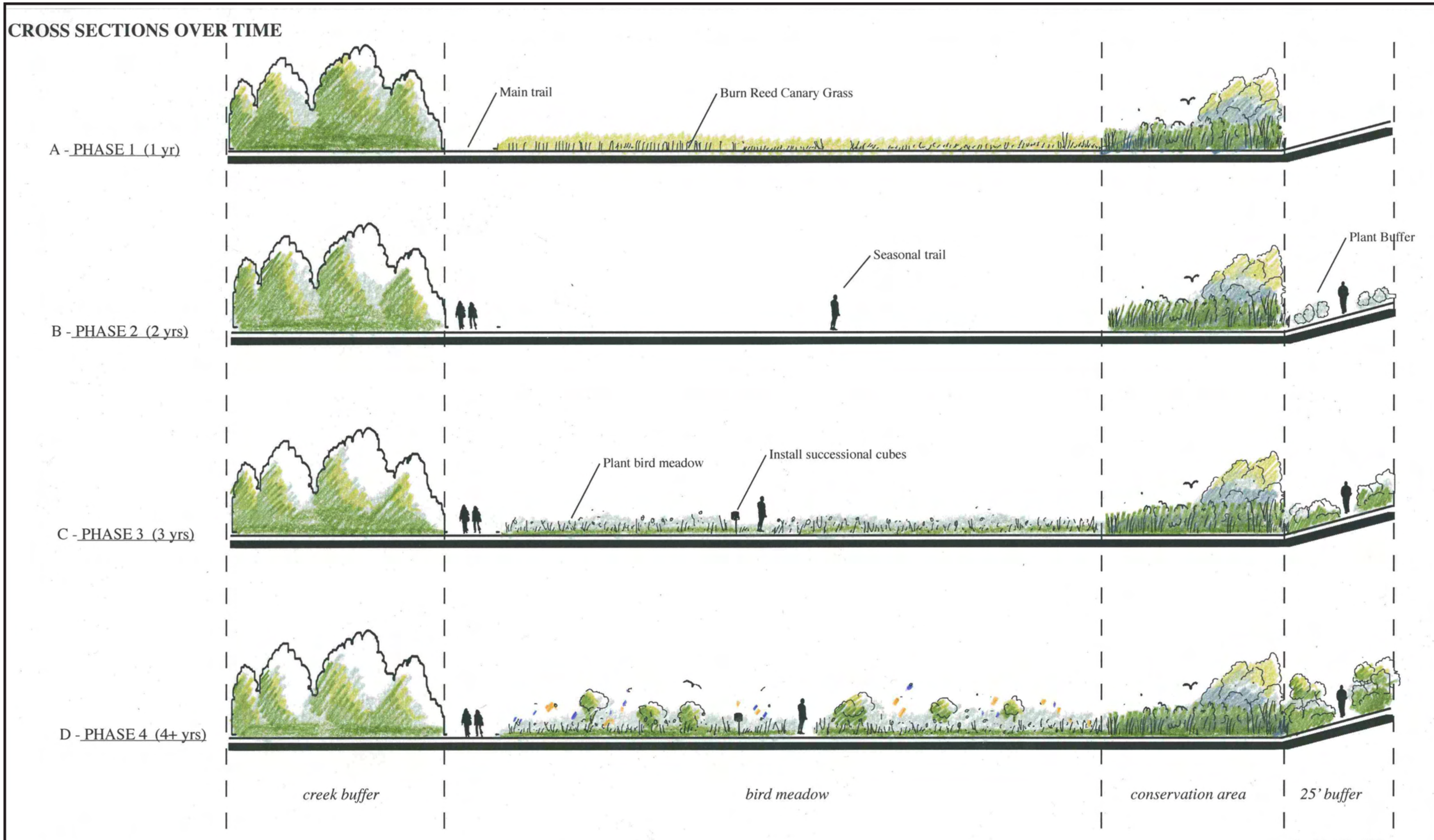


FIGURE 27: Cross Sections Over Time

INVASIVE PLANT MANAGEMENT ZONES

Zone 1- Intense Management Zone

In this zone, Reed Canary Grass (*Phalaris arundinacea)* areas should be burned early in the season. Within the year, approved herbicide should be used on select areas. Multiple applications of approved herbicide should be used as needed until *Phalaris arundinacea* populations are controlled.

Zone 2- Moderate Management Zone

Moderate management of invasive species includes using an approved herbicide in select areas and hand pruning as necessary. This may be used for controlling Privet (*Ligustrum sinense)* and Multiflora Rose (*Rosa multiflora)* populations.

Zone 3- Minimal Management Zone

Minimal management of invasive species includes hand pruning only as necessary. The purpose of this is to do as little harm as possible to the strict conservation areas, and allow processes to occur naturally.

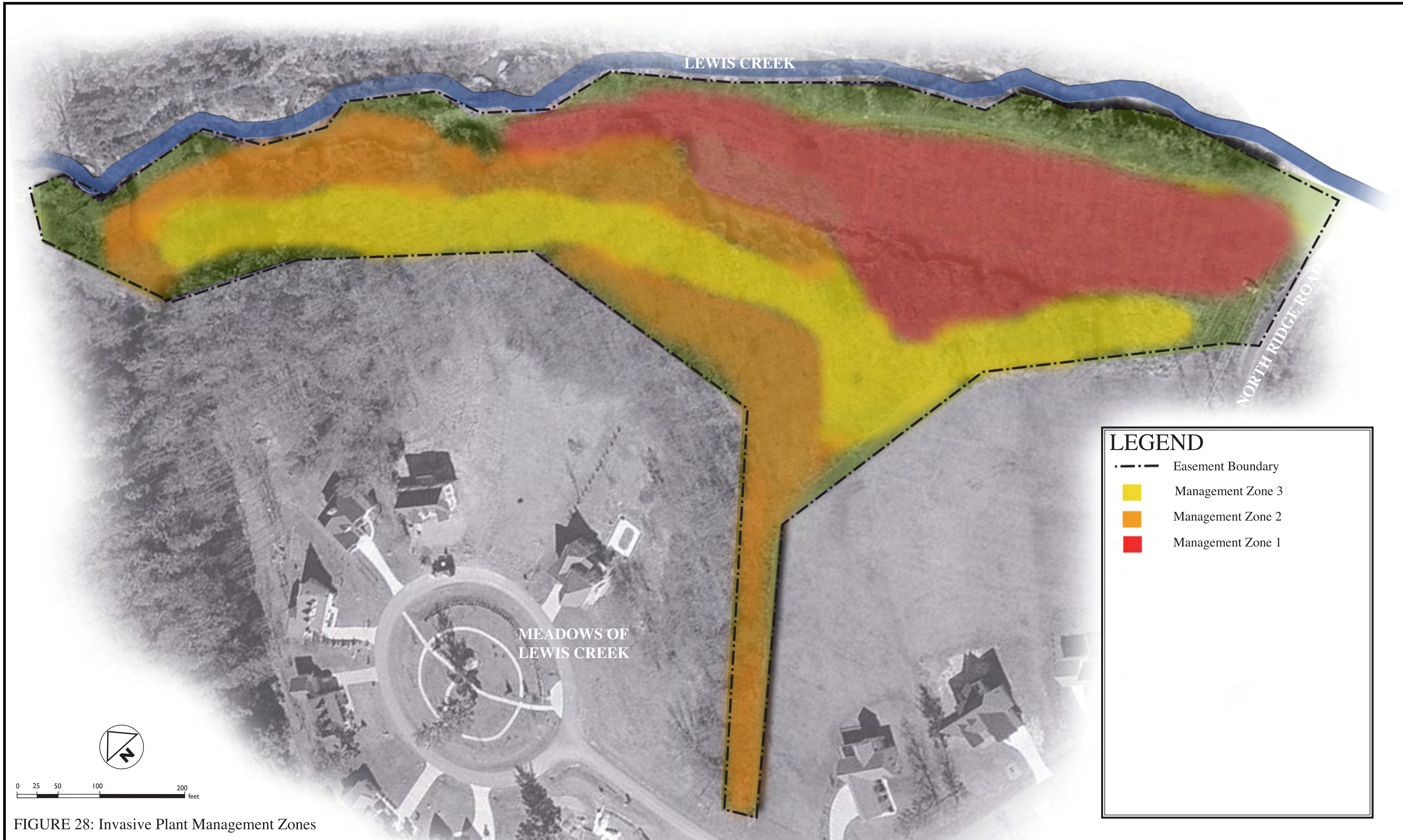
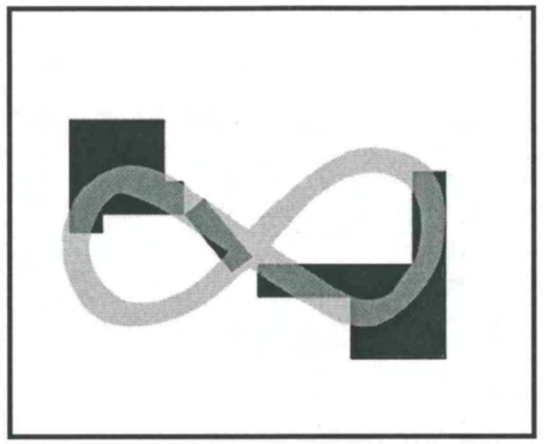
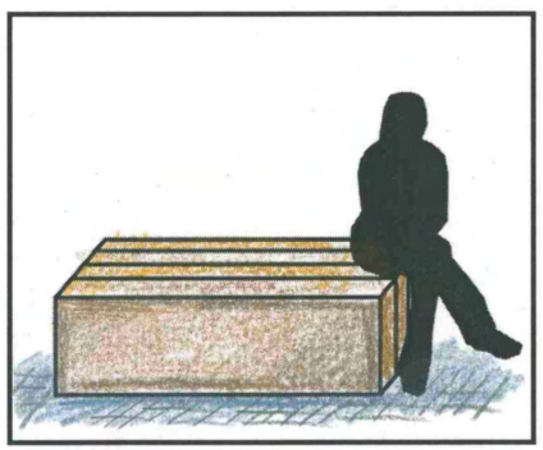


FIGURE 28: Invasive Plant Management Zones

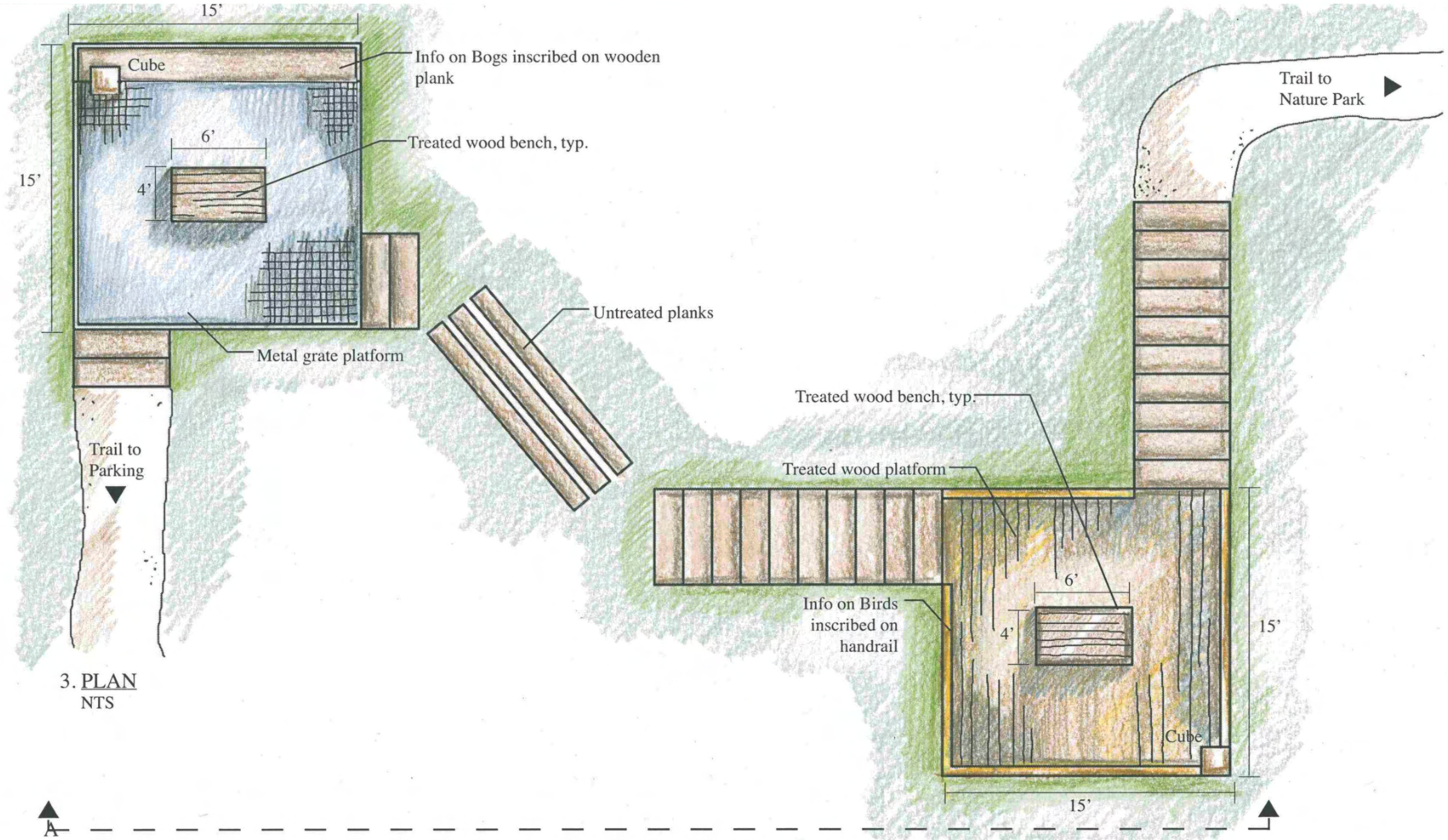
OBSERVATION PLATFORM



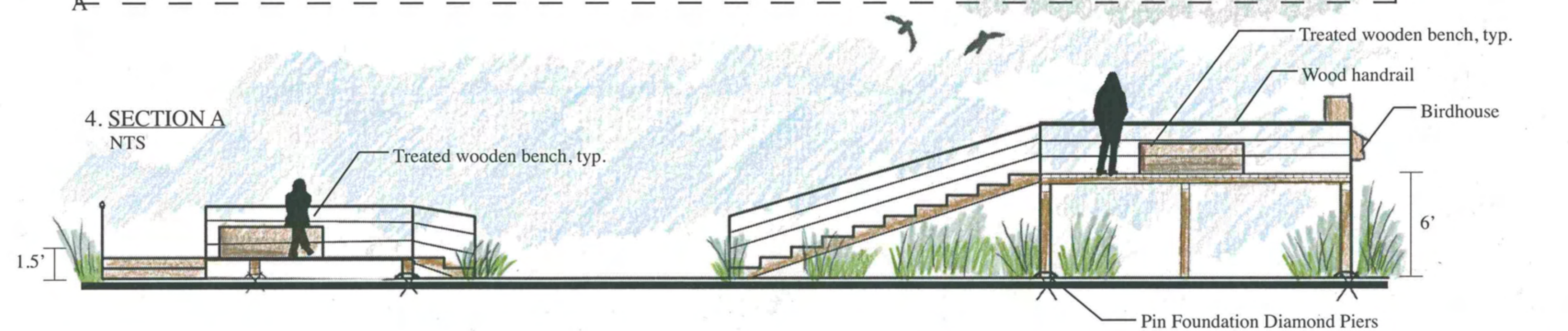
1. SITE CIRCULATION - NTS
symbolizes adaptive cycle



2. TREATED WOOD BENCH, TYP - NTS
mimics successional cube construction



3. PLAN
NTS



4. SECTION A
NTS

FIGURE 29: Observation Platform Detail

SUCCESSIONAL CUBES DETAIL

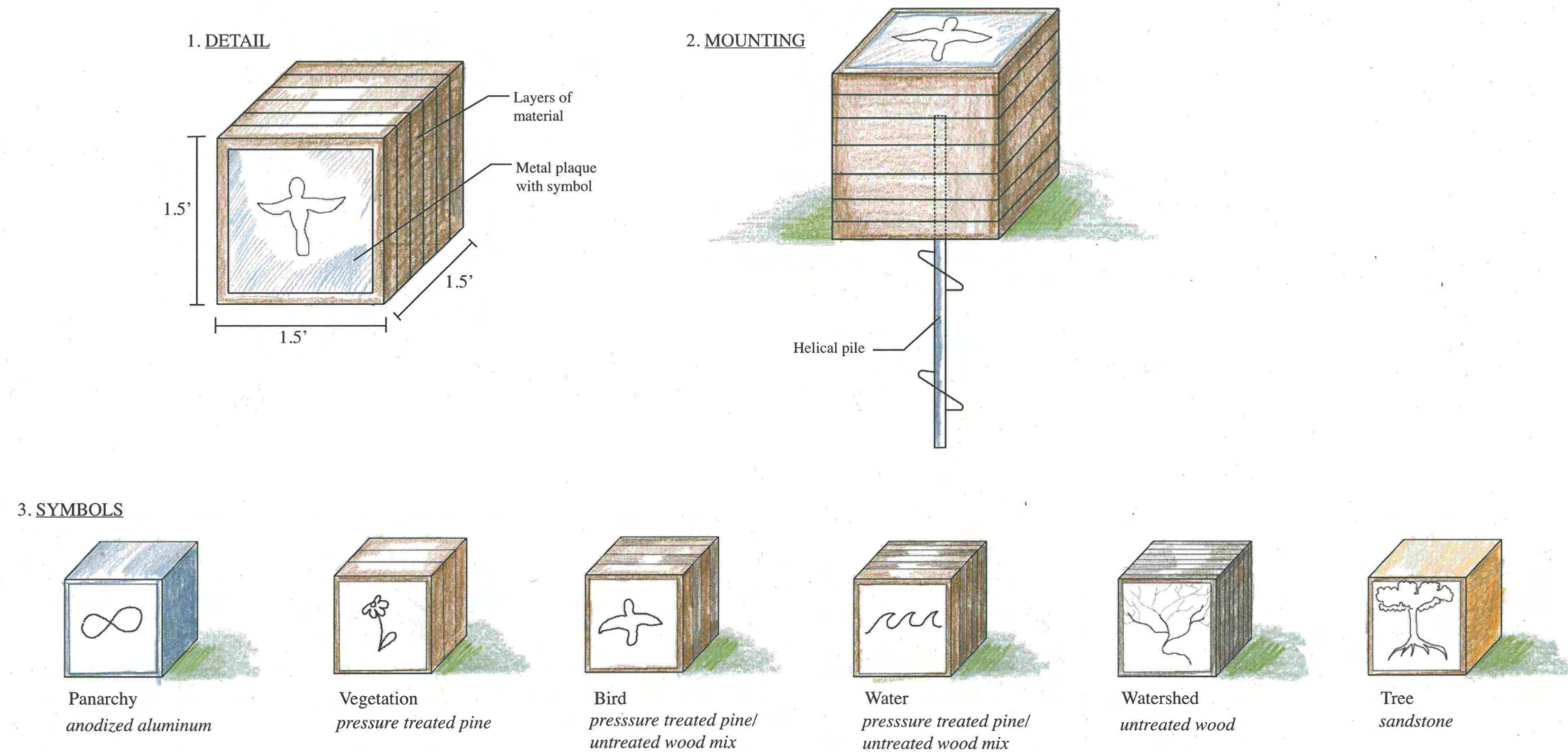


FIGURE 30: Successional Cube Detail

KIOSK PERSPECTIVE

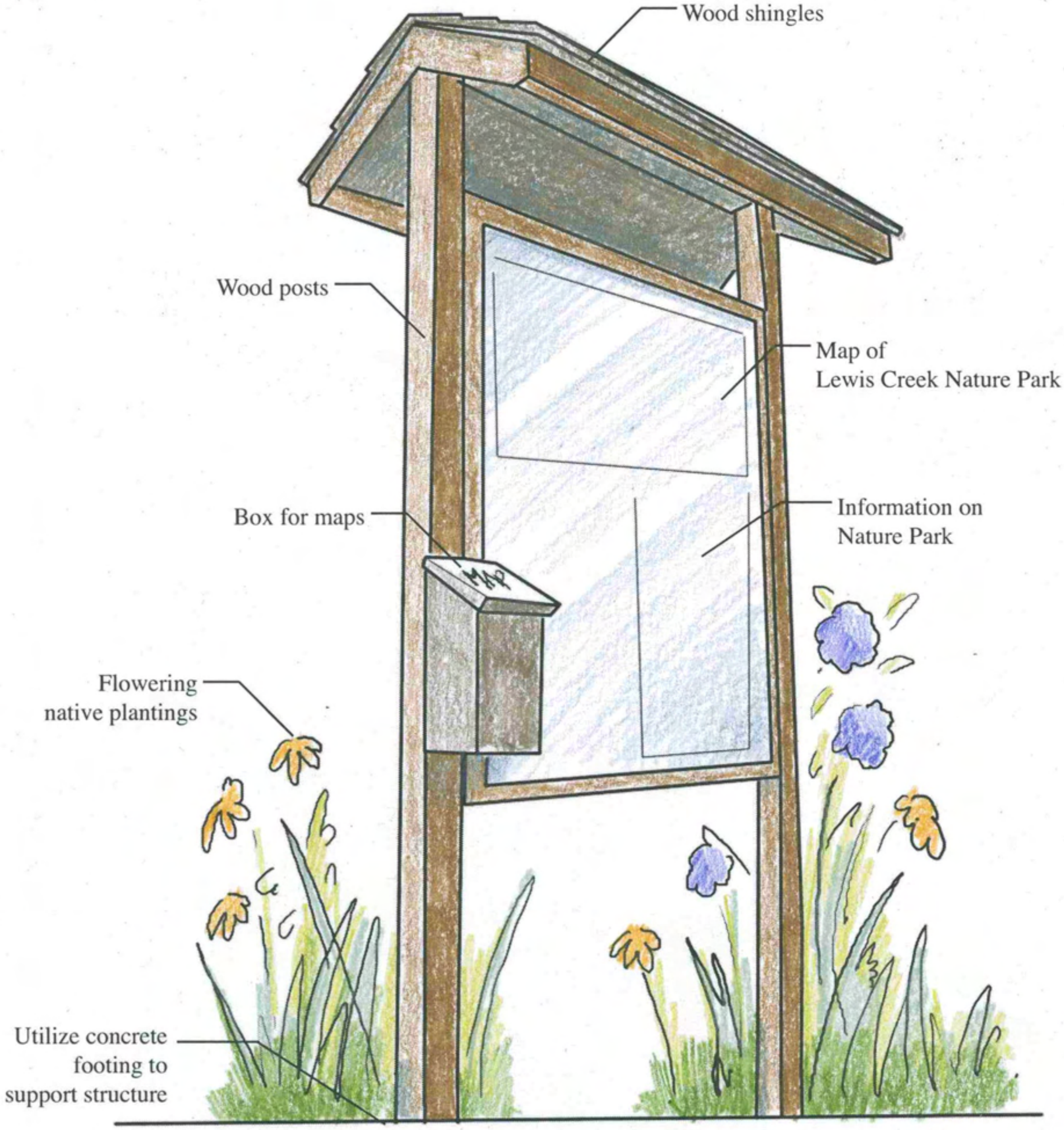


FIGURE 31: Kiosk Perspective

NTS

CROSSING OPTIONS DETAIL

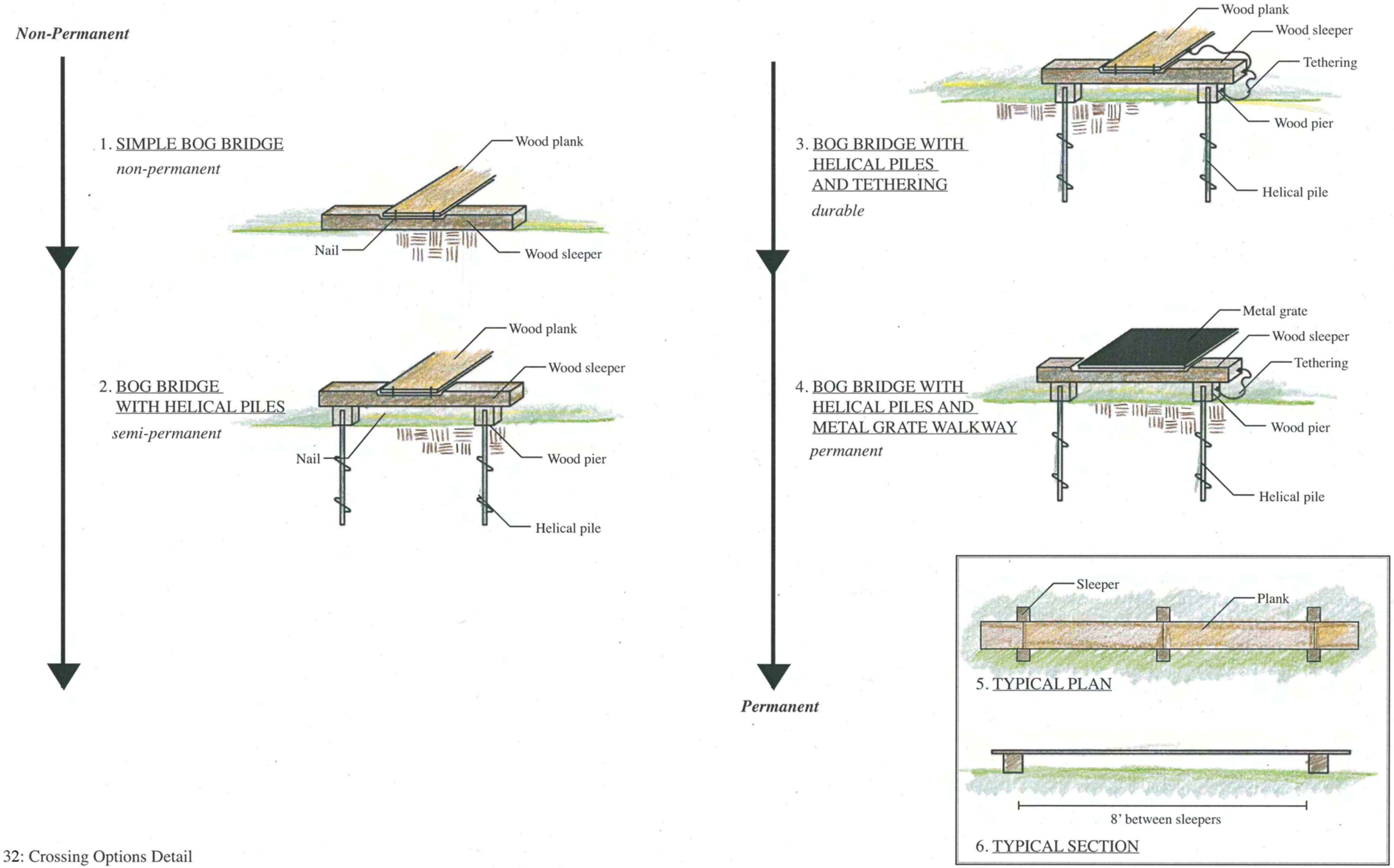


FIGURE 32: Crossing Options Detail

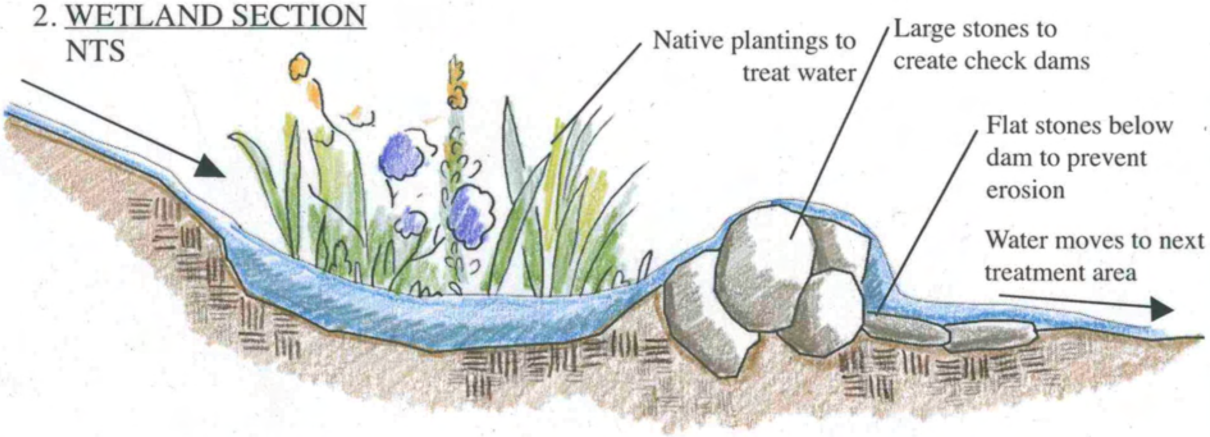
STEPPED STORMWATER WETLAND DETAIL

1. SUGGESTED NATIVE PLANTS

Shrubs
Chokeberry - *Aronia arbutifolia*
Beautyberry - *Callicarpa americana*
Winterberry - *Ilex verticillata*
Inkberry - *Ilex glabra*

Perennials
Cardinal flower - *Lobelia cardinalis*
Blue Star - *Amsonia tabernaemontana*
False Indigo - *Baptisia species*
Turtlehead - *Chleone glabra*
Rudbeckia - *Rudbeckia fulgida*
Gayfeather - *Liatris spicata*
Joe Pye Weed - *Eupatorium maculatum*

2. WETLAND SECTION
NTS



2. WETLAND PLAN
NTS

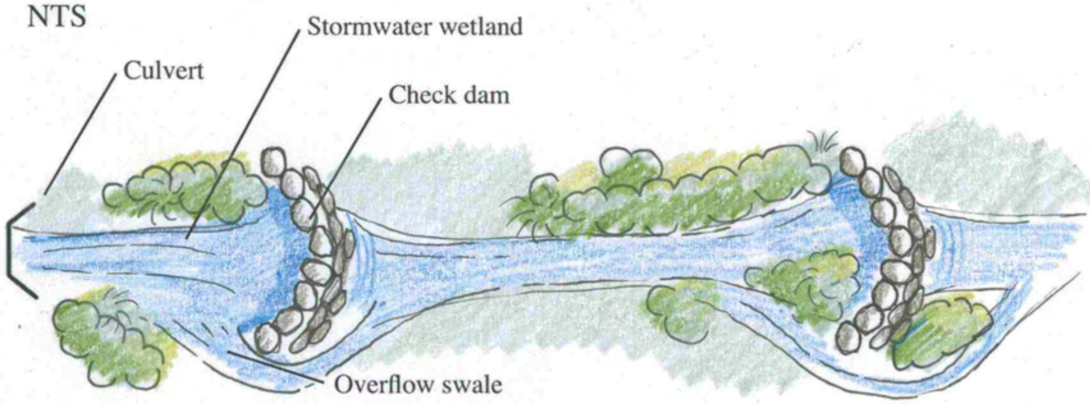


FIGURE 33: Stepped Stormwater Wetland Detail

CHAPTER 7

CONCLUSION

In the midst of a constantly changing world, landscape architects will be faced with inevitable uncertainty in landscape design. In the case of the Lewis Creek Nature Park, uncertainty is inherent within the bog ecosystem. Panarchy, closely tied to the element of identity, is used as a means to inform the process of design in the bog ecosystem. The application of this theory to a design process assists in informing landscape architects about the location of a landscape within its adaptive cycle and fosters plentiful opportunities for innovation through design. It enables thoughtful interaction with landscapes and allows for innovation to occur safely, without destroying chances for future interactions.

The proposed design method takes the foundations of panarchy theory, such as potential, connectedness, resilience and identity, and transforms them into a language for design. This language informs landscape architects about how to deal with the uncertainty inherent in bog ecosystems. This unique process of design inspires innovation in both the capacity of the ecosystem to handle disturbances as well as in the field of landscape architecture.

As Holling states, “a panarchy is both creative and conserving (Holling, 2001).” The meaning of this can move beyond the adaptive cycle front loops and back loops directly represented in ecosystem function. For example, a design influenced by panarchy can be both “creative and conserving” in a metaphorical sense, meaning it can creatively inspire new ideas and methodologies in the field of landscape architecture and still conserve and enhance the ecosystem structure and function. The design for the Lewis Creek Nature Park inspires creativity and conservation in both of these ways.

The success of the design of the Lewis Creek Nature Park site will be measured by the ability of the elements of the design to consistently establish a connection with people while at the same time allowing the ecosystem to both change and persist over time. The phases of implementation of the design and management plan will take several years to complete, but this time will allow for further observation and adjustment as the system reacts to disturbances. Through the use of this method, the Lewis Creek Nature Park can potentially become versatile educational landscape. Not only can it teach the public about the processes that shape the bog ecosystem, but it can also inform other land managers about the best means of conserving these threatened bog systems in the Southern Appalachian region.

There are several potential issues that may arise with the design of Lewis Creek Nature Park that could pose a limit to its success. For example, the management of the park is somewhat complex and requires a high level of commitment from stakeholders. If commitment to a particular method of management is not made by a single entity, the ecosystem could lose a great deal of stored potential through mismanagement. An issue may also arise with the community use of the park. If use of the park is not consistent enough, observation of ecosystem processes and the potential for creating a stronger identity of bog ecosystems would be diminished. Also, if the park becomes connected to other sites in the future, too much use could result in a loss of resilience in the system.

Regionally, the site is surrounded by a rapidly developing landscape. This dramatic change in surrounding land use may dramatically change the connectedness among the nested cycles in the landscape and eventually cause the system to disappear all together. If the bog system disappears, could the design still be successful in connecting the community and allowing the landscape to adapt to these changes?

There are limitations in using panarchy theory as a framework for design. Panarchy is only a framework that allows landscape architects to rationalize the complexity of natural systems. It does not provide any definitive evidence of the structure and function of bog ecosystems. Thus, in order to use this method most effectively, further research should be done. Most importantly, a way to measure the metric thresholds of the bog ecosystem must be created to advance scientific understanding and definitively lessen uncertainty. This will contribute to a better understanding of the small-scale and large-scale interactions that consistently generate the changing bog ecosystem and will also allow for designers integrate these processes more successfully. As Woodward mentions in her work in urban landscapes in Los Angeles that it is “people’s inherent activities as vectors, compactors, igniters, churners and nutrifiers that might be of use in lieu of formalized maintenance (Woodward, 2008).” This human component can also be helpful to understand for bog ecosystems. People that are connected to the system could also play a part in nurturing sources of renewal. Also, as the Lewis Creek Nature Park is in a highly disturbed area and needs help in order to survive; the capacity for designers to interact with the system and contribute to its persistence is much greater. This method should be applied to a much more pristine bog system in the region to determine its relevancy to all bog systems.

Overall, the intention of the design of the Lewis Creek Nature Park is that it will provide the Carolina Mountain Land Conservancy with a successful design that will connect the local community to care for the ecosystem. It will hopefully influence a change in identity of bog systems across the region and thus inspire meaningful conservation of the last remaining bog habitats. This will contribute to the survival of the multitude of rare and unique species that call these habitats home.

For landscape architecture, the process of designing the Lewis Creek Nature Park sheds light on how human actions impact complex adaptive systems. It provides a means to appreciate the complexity of a land organism that we do not understand. The design methodology developed here can be applied to more than just bog systems. Most importantly, the process can foster the ability of landscape architects to work with change in landscapes rather than against it. It provides designers with a new way to perceive the landscape and its complexities when embarking upon the journey of design. It is true that all landscapes are made of living, evolving, changing systems. Thus, designing and managing a landscape should simply become a matter of *holding its hand* through the process of change: by nurturing the processes and elements that create complex systems and utilizing the innovations that stem from back loop transformations.

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APPENDIX A: Lewis Creek Nature Park Species List

Species	Strata	Status S/F	NC	Global	Type
Acer rubrum	Understory				Tree
Agalinis tenuifolia	Herb				Herb
Ageratina altissima	Herb				Herb
Allium canadense	Herb				Herb
Allium vineale	Herb				Herb
Alnus serrulata	Shrub				Shrub
Amelanchier arborea	Understory				Tree
Amianthium muscaetoxicum	Herb				Herb
Andropogon glomeratus	Herb				Grass
Andropogon virginicus	Herb				Grass
Anemone quinquefolia	Herb				Herb
Anthoxanthum odorata	Herb				Grass
Apios americana	Vine				Vine
Aronia arbutifolia	Shrub				Shrub
Aronia melanocarpa	Shrub				Shrub
Asplenium platyneuron	Herb				Fern
Aster puniceus (Symphiotrichum)	Herb				Herb
Athyrium asplenoides	Herb				Fern
Barbarea verna	Herb				Herb
Betula nigra	Canopy				Tree
Botrychium dissectum	Herb				Fern
Botrychium virginianum	Herb				Fern
Calystegia sp.	Vine				Vine
Cardamine pensylvanica	Herb				Herb
Carex atlantica	Herb				Sedge
Carex collinsii	Herb				Sedge
Carex debilis	Herb				Sedge
Carex intumescens	Herb				Sedge
Carex lurida	Herb				Sedge
Carex stipata	Herb				Sedge
Carex stricta	Herb				Sedge
Carex sp.	Herb				Sedge
Carpinus caroliniana	Understory				Tree
Celastrus orbiculata	Vine	Invasive			Vine
Chamaelirium luteum	Herb	W5B	S5	G5	Herb
Chasmanthium latifolium	Herb				Grass
Chelone glabra	Herb				Herb
Chimaphilia maculata	Herb				Herb
Cicuta maculata	Herb				Herb
Cinna arundinacea	Herb				Grass
Clematis virginiana	Vine				Vine
Corylus cornuta	Shrub				Shrub
Cornus amonum	Shrub				Shrub
Cyperus sp.	Herb				Herb
Dacus carota	Herb	Invasive-Naturalized			Herb
Dichanthelium commutatum	Herb				Grass
Dichanthelium sp.	Herb				Grass

Epigea repens	Herb				Herb
Epilobium sp.	Herb				Herb
Erigeron annua	Herb				Herb
Euonymus americanus	Shrub				Shrub
Eupatoriadelphus fistulosus	Herb				Herb
Eupatorium capillifolium	Herb				Herb
Eupatorium perfoliatum var perfoliatum	Herb				Herb
Eupatorium purpureum	Herb				Herb
Fagus grandifolia	Canopy				Tree
Festuca elaitor	Herb				Grass
Fragaria virginiana	Herb				Herb
Fraxinus americana	Canopy				Tree
Galax urceolata	Herb	W5B	SR	G5	Herb
Galium triflorum	Herb				Herb
Goodyera pubescens	Herb				Herb
Glyceria striata	Herb				Grass
Ilex montana	Understory				Tree
Ilex opaca	Understory				Tree
Impatiens capensis	Herb				Herb
Juncus coriaceous	Herb				Rush
Juncus effusus	Herb				Rush
Juncus subcaudatus	Herb				Rush
Juncus tenius	Herb				Rush
Juniperus virginiana	Canopy				Tree
Kalmia latifolia	Shrub				Shrub
Lactuca canadensis	Herb				Herb
Lactuca sp.	Herb				Herb
Leersia sp.	Herb				Grass
Lespedeza cuneata	Herb	Invasive			Herb
Leucothoe fontanesiana	Shrub				Shrub
Ligustrum sinense	Shrub				Shrub
Lindera benzion	Shrub				Shrub
Liriodendron tulipifera	Canopy				Tree
Lobelia amoena	Herb				Herb
Lobelia nuttali	Herb				Herb
Lonicera japonica	Vine	Invasive			Vine
Ludwigia alternifolia	Herb				Herb
Ludwigia palustris	Herb				Herb
Lycopus virginicus	Herb				Herb
Lyonia ligustrina	Shrub				Shrub
Microsteigum virmineum	Herb	Invasive			Grass
Mimulus ringens	Herb				Herb
Mitchella repens	Herb				Herb
Oenothera biennis	Herb				Herb
Onoclea sensibilis	Herb				Fern
Osmunda cinnamomea	Herb				Fern
Oxydendrum arboreum	Understory				Tree
Oxypolis rigidior	Herb				Herb
Packera aurea	Herb				Herb
Parthenocisus quinquefolia	Vine				Vine

Phalaris arundinacea	Herb				Grass
Physocarpus opulifolius	Shrub				Shrub
Pinus rigida	Canopy				Tree
Pinus strobus	Canopy				Tree
Pinus virginiana	Canopy				Tree
Platanthera clavellata	Herb				Herb
Platanthera sp.	Herb				Herb
Platanus occidentalis	Canopy				Tree
Poa sylvestris	Herb				Grass
Polygonum persicaria	Herb				Grass
Polygonum sagittatum	Herb				Herb
Polystichum acrostichoides	Herb				Fern
Potentilla canadensis	Herb				Herb
Potentilla intermedia	Herb				Herb
Prunella vulgaris	Herb				Herb
Prunus serotina	Canopy				Tree
Pteridium aquilinim	Herb				Fern
Pycnanthemum incanum	Herb				Herb
Pycnanthemum verticillata	Herb				Herb
Quercus falcata	Canopy				Tree
Quercus imbricata	Canopy	W1	S3	G5	Tree
Quercus montana	Canopy				Tree
Panicum rigidulum	Herb				Grass
Ranunculus abortivus	Herb				Herb
Ranunculus recurvatus	Herb				Herb
Rhexia virginica	Herb				Herb
Rhododendron maximum	Shrub				Shrub
Rhododendron periclymenoides	Shrub				Shrub
Rhododendron viscosum	Shrub				Shrub
Rhus glabra	Shrub				Shrub
Rhynchospora gracilenta	Herb				Sedge
Rhynchospora sp.	Herb				Herb
Rosa multiflora	Shrub	Invasive			Shrub
Rosa palustris	Shrub				Shrub
Rubus argutus	Herb				Herb
Rubus hispidus	Herb				Herb
Rudbeckia laciniata	Herb				Herb
Rumex crispus	Herb				Herb
Rumex sp.	Herb				Herb
Sabatia angularis	Herb				Herb
Salix caprea	Understory				Tree
Salix nigra	Canopy				Tree
Salix sericea	Canopy				Tree
Salix sp. (introduced)	Understory				Tree
Sambucus canadensis	Understory				Shrub
Sanicula sp.	Herb				Herb
Sagitaria latifolia	Herb				Herb
Saururus cernua	Herb				Herb
Schizachyrum scoparius	Herb				Grass
Scirpus cyperinus	Herb				Sedge
Scirpus expansus	Herb				Rush

Scirpus sp.	Herb				Sedge
Sisyrinchium angustifolium	Herb				Herb
Smilax glauca	Vine				Vine
Smilax laurifolia	Vine				Vine
Smilax rotundifolia	Vine				Vine
Solidago rugosa	Herb				Herb
Solidago sp.	Herb				Herb
Sparganium americanum	Herb				Herb
Spiraea tomentosa	Shrub				Shrub
Stellaria alsine	Herb	SR-L	SH	G5	Herb
Stellaria media	Herb				Herb
Stenanthium sp.	Herb				Herb
Thalictrum revolutum	Herb				Herb
Thelypteris noveboracensis	Herb				Fern
Tiarella cordifolia	Herb				Herb
Tipularia discolor	Herb				Herb
Toxicodendron radicans	Vine				Vine
Toxicodendron vernix	Shrub	W6			Shrub
Typha latifolia	Herb				Herb
Tridens flava	Herb				Grass
Vaccinium arboreum	Shrub				Shrub
Vaccinium corymbosum	Shrub				Shrub
Vaccinium fuscatum	Shrub				Shrub
Valerianella radiata	Herb				Herb
Viburnum cassinoides	Shrub				Shrub
Viccia angustifolia	Herb				Herb
Vernonia novaboracensis	Herb				Herb
Viola primulifolia	Herb				Herb
Viola soraria	Herb				Herb
Xanthorhiza simplicissima	Herb				Shrub

APPENDIX B: Recommended Species for Lewis Creek Nature Park

Suggested Species for native buffer and attracting birds

Trees
River Birch- *Betula nigra*
Green Ash - *Fraxinux pennsylvanica*
Silver Maple –*Acer saccharinum*
Sycamore - *Platanus occidentalis*
Black Gum- *Nyssa sylvatica*
Willows - *Salix species*

Shrubs
Chokeberry- *Aronia species*
Beautyberry- Callicarpa americana
Winterberry – *Ilex verticillata*
Swamp Rose - *Rosa palustris*
Silky Dogwood- *Cornus amomum*
Silky Willow - *Salix sericia*
Possomhaw- *Viburnam nudum*
Spicebush - *Lindera benzoin*
Spirea - *Spirea tomentosa*
Pepperbush - *Clethra alnifolia*
Sweetshrub - *Calycanthus florida*
Buttonbush - *Cephalanthus occidentalis*

Suggested species for bird meadow

Goldenrod - *Solidago species*
Joe-Pye Weed - *Eupatorium fistulosum*
Black-Eyed Susan - *Rudbeckia species*
Butterflyweed - *Asclepias tuberosa*
Coreopsis - *Coreopsis species*
Joe Pye Weed - *Eupatorium maculatum*
Great Blue Lobelia - *Lobelia siphilitaca*
Evening Primrose - *Oenothera lamarckariana*
Coneflowers - *Echinacea purpurea*