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A heuristic for local land planning: Linking ecological function and policy-in context to Charlotte, North Carolina-

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A Heuristic for Local Land Planning:
Linking Ecological Function and Policy

— In context to Charlotte, North Carolina —

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**Master of Science in Sustainable Environmental Resource
Management / Master of Science in Integrated Science &
Technology**

University of Malta
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A Heuristic for Local Land Planning:
Linking Ecological Function and Policy

– In context to Charlotte, North Carolina –

A dissertation presented in part fulfillment of the requirements for the Degree of Master of
Science in Sustainable Environmental Resource Management / Master of Science in
Integrated Science and Technology

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November, 2010

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ABSTRACT

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– In context to Charlotte, North Carolina –

Ecological systems and services are foundational to human well-being, and in recent years have received increasing scholastic attention. The functional ability of these systems is influenced however, by human-induced land transformation related to conventional patterns of growth and development. Such land transformations, which commonly occur as single-family residential development, are criticized as being wasteful and inefficient, leading to issues like air and water pollution, diminished forests and wetlands, and habitat loss and fragmentation. In the United States a patchwork of policy exists aimed at addressing such ecological concerns. Despite best efforts, most local governments and planning offices still miss the mark, creating policy that only peripherally addresses ecological function. The research presented herein aims to deal with this; by way of a new heuristic, designed to link ecological function and land-use policy, this research offers direction to local land-use planners and policymakers who wish to integrate the preservation of ecological systems in local policy creation.

KEYWORDS: LAND-USE, PLANNING, ECOLOGICAL FUNCTION, GROWTH, DEVELOPMENT, LOCAL POLICY, ECOSYSTEM SERVICE, HEURISTIC

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To: those who believed in me during this process; your support has been essential. Also, to my nephews, Aiden, Evan, and Carter, whose vivacious spirits offered the most delightful and crucial distractions – you brought tremendous joy to this truly challenging process.

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CHAPTER 1

INTRODUCTION

“I walked the deserted prospect of the modern mind where nothing lived or happened that had not been foreseen. What had been foreseen was the coming of the Stranger with Money. All that had been before had been destroyed: the salt marsh of unremembered time, the remembered homestead, orchard and pasture. A new earth had appeared in place of the old, made entirely according to plan. New palm trees stood all in a row, new pines all in a row, confined in cement to keep them from straying.”

– Wendell Berry, “Santa Clara Valley”

“One of the most pervasive aspects of human-induced change is the widespread transformation of land via efforts to provide food, shelter, and products for use” (Dale, et al. 2000, 640). In the United States, land-use and land-cover change has been strongly influenced by single-family residential developments, related to the spreading out of the population and the desire for homeownership, and has highlighted the need for land planners and local governments to more actively prepare for expansion within local jurisdictions. Although popular, this conventional development pattern is criticized as being wasteful and inefficient. Air and water pollution, diminished forests and wetlands, threatened farmland, habitat loss and fragmentation, and reduced access to open and green space are cited as some of the relevant ecological ills of this type of land development (Cieslewicz 2002, 23-36). Contributing to this environmental degradation is the multitude of independent land-use policies, the result of autonomous local government decision-making typical in the U.S. In aggregate, these land-use policies have broad-scale ecological impacts, and often overlook or undervalue the fundamental natural resources and services of the very land they govern. The outcome is an ecologically fragmented approach to land-use and planning that constrains, reduces or diminishes the environmental functions and processes that support humans and the natural world. As explained by Jon Harte:

The current land conversion rate of approximately 3 million acres per year represents a loss of 0.2% per year of the total privately held land area of the United States. This trend is creating patchworks of ecologically incoherent micro-landscapes that, as a whole, cannot support the diversity of species and the ecological functions of the habitats that previously existed on the land. (Harte 2001, 962)

The importance of such ecological systems cannot be overstated. All of humanity depends on the services provided by these ecological arrangements, such as the provisioning of food and water, the cycling of essential nutrients, and the regulation of life-sustaining processes. Only intact functional ecosystems can sustainably support the growing demand on such services, as the population continues to increase. Ironically, as demands grow due to human activities like urban expansion we degrade the very life-sustaining systems that we rely upon (Lamont 2006, 5). The success or failure in reversing this trend is ultimately critical to the future of the ecological integrity and human well-being of the United States. This pattern does not need to continue; there is another way to manage growth and preserve ecological integrity. With the appropriate framework to link ecological considerations and local policy, we can respect, preserve, and maintain ecological function and also accommodate continued growth and development.

Over the last forty years significant strides have been made to better our understanding of the importance of ecological systems and services and the functional value of land. The work of Dr. Robert Costanza has been central to exploring the interface between economic and ecological systems, and has taken the lead in the valuation of ecosystem services, biodiversity and natural capital (The University of Vermont 2010). Samuel D. Brody is another scholar and author who helped shape this field of study; Brody is one of the few to directly link and put in context the relationship between ecosystem management and local land-use planning; his research in Florida examined the ability of comprehensive plans to effectively incorporate principles of ecosystem management. Brody wisely acknowledged that local planning must be a consideration of the management of ecological systems, and asserted that “some of the most powerful tools that threaten or protect natural habitat are in the hands of county commissioners, city councils, town boards and local planning staff” (Brody 2003, 512). V.H. Dale et al. also contributed to the goal of linking ecological science and policy; their work proposes specifying ecological principles as a foundation to

ecologically based land-use decisions (Dale, et al. 2000, 644). With regard to comprehending the vast array of information on ecological function, the work of Rudolf de Groot, Matthew A. Wilson, and Roelof M.J. Boumans is paramount to providing a coherent organizational framework for understanding. Presented in Chapter Three, the typology that these authors created to describe, classify, and value ecosystem functions is the foundation to the heuristic developed in this thesis. Finally, work conducted by the United States Environmental Protection Agency and James M. Omernik on the ecological regions of the United States offered an appropriate construction of the vast and varied ecosystems of the conterminous land areas within this country and the scales at which these systems are interrelated.

Regarding policy, a handful of recent works inform this thesis. Reports published by the Environmental Law Institute put forward authoritative reviews and guidelines for land-use planning and management in context to habitat, biodiversity, and conservation, critical to connecting policy with ecology. In terms of drafting and compiling the policies used within the heuristic displayed in Chapter Four, the work of James M. McElfish (*Nature Friendly Ordinances*) and Randall Arendt (*Growing Greener - Putting Conservation into Local Plans and Ordinance*) supplied an abundance of information relevant to greening the policy and development processes. Finally, the New Hampshire Department of Environmental Services' document, *Innovative Land Use Planning Techniques: A Handbook for Sustainable Development*, offered a comprehensive guide for environmental and land-use planning techniques that are mindful of regional environmental considerations and include model ordinances and guidance on innovative land-use regulations authorized by New Hampshire state law. This document was crucial to understanding the language and applicability of such ecologically-minded policies in a real-world forum.

Despite the sound research of the resources described above, there still exists a gap between policy and ecology. Previous research efforts have failed to integrate theories in a comprehensive practical application of policy. To clarify, what we lack is an inclusive approach to harness and organize the vast array of services associated with ecological function, and link policy to the preservation and maintenance of such functions over the long-

term. Without this, it is likely that local policy and decision-making will go on excluding such considerations from its core mechanisms. As described by Stein (2007, 52):

Many land use planning decisions still only incorporate ecological principles and biodiversity considerations in a cursory way, if at all. And many conservation scientists are still largely disconnected with how their research could have real-world application. What are the reasons for this continued disconnect, and what barriers exist that inhibit better integration of science-based information into the land use planning process?

This thesis a.) addresses this gap between ecological science and policy, b.) develops a method to organize the vast array of ecological information in a manner that is succinct and relevant to both planner and scientist, and c.) links ecological functions to examples of local policies that could be implemented for their preservation. The ultimate goal is to create a method to help facilitate ecosystem management considerations at the local scale, and to provide direction to local land-use planners and policymakers interested in integrating ecological considerations into local policy.

Attempting such an effort raises a series of questions that must be addressed. First, can local policy protect ecological function, and ecosystem services, while accommodating residential growth and development? Second, what tools or resources would be needed to integrate such ecological considerations into local land-use planning? And finally, is it feasible to create a land-use methodology that links ecological function and policy, and can be applicable anywhere in the United States?

These questions are important and relevant for several reasons. First and foremost, policy must be complimentary to the need and desire for growth and development; Americans have the right to choose how we live, and a settlement blueprint that involves spreading outward, in single-family dwellings, away from urban centers, is the demonstrated preferred choice (United States Census Bureau 2005). This is part of American culture, and change will not come easily – especially not at the whim of revised local policy measures. Next, should a land-use planner or policymaker be inclined to incorporate ecological considerations in their planning efforts, the resources to assist in this effort should be apparent and available to them. Often times taking the first step in a new direction is the

hardest part; by addressing and presenting the resources which can assist in the process, it may just provide the incentive necessary to move local policy beyond a cursory inclusion of ecological data. Lastly, developing a method for linking ecological science and policy will help unite, rather than further fragment, the independent, individualistic policies created by local governments. Developing a basic heuristic puts us one step closer to policy creation that is comprehensive and ecologically effective. In sum, the issues connected to ecological function and land-use policy are of significant importance because they affect and threaten the very quality of our lives, the future of our towns and cities, the sustainability of our lifestyles, and the integrity of the resources we leave to future generations.

This thesis argues that the development and policy patterns of the past, which have fragmented our landscapes and degraded ecological function, do not need to continue. It is possible to facilitate ecosystem management at the local scale by giving planners and policy-makers the resources necessary to make more informed decisions with regard to ecology and policy. The thesis explains the resources needed to do so, and develops a heuristic for linking ecological function and policy in a framework customized to the Piedmont ecoregion of the United States.

CHAPTER 2

LAND-USE PLANNING IN THE UNITED STATES

THE HISTORY AND EVOLUTION OF LAND-USE PLANNING: AN OVERVIEW

When considering the history of land-use planning and policy in the United States we see that its early stages were largely reactionary. In 1916 New York City adopted the first comprehensive zoning scheme built upon a specific matter of dispute resolution. However, “prior to 1916 and for most of the early years of this country’s history, courts resolved land-use disputes pursuant to the law of nuisance. Because prevailing views at that time held private property rights paramount, landowners generally were left to do with their property whatever they wished so long as their activity did not injure another person’s property” (Attkisson 2009, 984). It soon became apparent however, that a case-by-case handling of dispute resolution was too cumbersome, “eliminated any semblance of predictability for landowners in developing new parcels,” and left many land-use issues unresolved (Attkisson 2009, 985). In response to these criticisms, legislatures like that of New York City began to adopt zoning ordinances to more effectively regulate and manage land-use disputes.

While nuisance law reactively responds to land-use issues, zoning is considered a proactive land management tool. In 1926 The U.S. Department of Commerce issued the Standard State Zoning Enabling Act (SZEA). This Act enabled state governments to delegate land planning power to local officials, thereby providing common legal grounds for zoning by local governments. This delegation of authority was reasoned by the fact that each locality deals with a different set of problems, most of which are best addressed at the local level. The SZEA also granted local governments the authority to divide communities into zoning districts, as long as the zoning ordinances served a legitimate purpose such as promoting health, safety, morals and the general welfare of communities. Additionally, the SZEA required local land-use regulations to be in agreement with a comprehensive plan; this protected land owners from arbitrary zoning decisions and facilitated a sense of consistency

in the creation and enforcement of land-use laws. Despite a comprehensive plan requirement, many local governments strayed from this obligation as a result of varying interpretations of the Act.

In 1928 the U.S. Department of Commerce further complicated the matter by publishing the Standard City Planning Enabling Act (the “Standard Planning Act”). The Standard Planning Act is a process-oriented statute that gives local governments the discretion to develop planning policies and made optional the mandatory planning act of the previous legislation. This inconsistency between Acts led to the reluctance of many state courts to require consistency between zoning regulations and separately adopted land-use plans. As a result, a precedent was set that hindered future planning, and the foundation for undesirable development patterns emerged (Attkisson 2009, 991-994).

Government & the absence of a national land-use policy

The United States is different from most other countries in that there exists no national land-use planning law, nor any other national law accepted as national land-use policy. Although the national government was the original impetus for land-use planning, it never proceeded further in its assertion of authority (Kayden 2000, 449). As such, the planned American landscape is largely the work of independently-minded county and local governments. This delegated land-use authority is seen by some as the root cause of the variation in land-use patterns and plan quality thought to induce fragmented landscapes and barriers to addressing broad-scale environmental issues. To remedy this, there have been some efforts to reintroduce national government back into the land-use planning realm. In 1970 for example, Senator Henry M. Jackson pitched the federal government on the establishment of a national land-use policy. Senate Bill S. 3354, the “National Land-use Policy Act of 1970”, aimed to “encourage and assist the states to more effectively exercise their constitutional responsibilities for the planning, management, and administration of the Nation’s land resources through the development and implementation of comprehensive ‘Statewide Environmental, Recreational and Industrial Land-use Plans,’ and management programs designed to achieve an ecologically and environmentally sound use of the nation’s land resources.” The proposed law was intended to engage federal, state, and local

governments in a process of exchange with regard to matters of land-use. It did not however authorize the national government to plan or to regulate the use or development of land, or the location of infrastructure. Regardless, the plan was met with strong opposition, and only a watered down version of the Bill was approved in the Senate, eventually failing in the House of Representatives (Kayden 2000, 448).

Several factors help explain the strong opposition to a national land-use policy and resilient preference for local planning. First, constitutional federalism and States' rights, second, size and geographic variation of the United States results greater variation in topographic, economic, social, and cultural variations that are arguably better managed from a local perspective, and third, private property supremacy and common preference for private market principles in the U.S. create a strong counterweight to government authority (Kayden 2000, 453).

That is not to say that the U.S. federal government is entirely extraneous in matters of land-use; according to Kayden (2000) it does have some sway in land-use planning via a "patchwork" of laws and actions that together and on their own may significantly affect the use and development of land.

This patchwork has arisen in response to specific problems that suggest national solutions, and is composed of five principal patches: environmental regulation; management of nationally-owned land; transportation policy and finance; housing and economic development subsidies; and anti-land-use planning regulation. (Kayden 2000, 454)

Examples of federal legislation that have influenced local planning and policy include the Urban Renewal Act, the Clean Air Act, the Coastal Zone Management Act and the Housing and Community Development Act (Anthony 2008, 1374). Important federal environmental policies, such as the National Environmental Policy Act (NEPA) and the Clean Water Act (CWA), have also influenced local land planning and policy; these will be discussed in more detail on pages twenty and twenty-one of this chapter.

Public policy and American culture

It's important to consider the role of public policy and American culture in shaping the landscape patterns and blueprints of today. In the early part of the 20th century much of the United States was marked by compact urban centers and few small neighborhood shops in residential areas. Suburbs grew coherently with the extensions of streetcar and rail lines and typically extended only as far beyond a streetcar line that a person might walk (United States Environmental Protection Agency 2001, 4). However, development has undergone some significant changes. In the aftermath of World War II a cultural shift began inspired by changes in public policy. The Federal-Aid Highway Act of 1956 made available federal funding for the construction of highways, which opened large new areas of land for development, and the G.I. Bill of rights and federal home mortgage tax deductions incentivized the building of new homes on low-cost land. Government subsidies also footed the bill on the construction of new water and sewer systems for suburban development. As a result, Americans started to spread out, seeking homeownership as an essential part of the American Dream, and preferred private residences away from urban centers. Large tracts of undeveloped land were divided creating the single-family land parcels we are so familiar with today (Cieslewicz 2002, 26). On these grounds, a diffused style of residential development became the norm in the United States, and the single-family subdivision became the preferred blueprint for residential communities nationwide. The comparatively low cost of land due to the geographic size of the United States has only exacerbated this issue.

LAND-USE PLANNING: PROCESS AND PRECEDENCE

Three legal traditions take precedence in U.S. land-use planning and policy: 1.) reducing harm and nuisances, 2.) ensuring orderly timing of development and associated services, and 3.) protecting public values. Government constraints on land-use are intended to ensure that these needs are met, and aim to deal with externalities that have the potential to affect surrounding owners (Dale, et al. 2000, 646). Land-use planning can be defined as a “process conducted by public officials to analyze and recommend in a comprehensive manner, from social, economic, environmental, infrastructure capacity, aesthetic, and other

relevant aspects, the best present and future uses of geographically specified land areas” (Kayden 2000, 446-447). While largely effective, this traditional approach to planning and zoning excludes the key role of ecological systems in preserving and maintaining vital life-supporting and economic conditions (Dale, et al. 2000, 646).

Plans and plan making

A plan is an adopted statement of policy; it includes text, maps, and graphics used to guide action, both public and private, that may affect the future. Plans offer decision-makers relevant information necessary to make informed decisions about long-range social, economic, and physical growth in a community (Steiner and Butler 2007, 3). All plans include goals, objectives, and assumptions. Goals describe, in a general way, a desired future condition; objectives describe a future condition to be attained within a specific and stated period of time; and assumptions are statements of present or future conditions that describe the physical, social, or economic setting within which the plan will be used. At the local level, these assumptions can include accepted boundaries of urban growth, probable rate of growth, and the expected or desired character of the community. Typical data needed for plan preparation includes: maps and images, natural environment, existing land uses, housing, transportation, public utilities, community services, population and employment, local economy, and special topics / concerns (Steiner and Butler 2007, 4-5).

Types of plans

In the U.S. every state has its own planning statutes, most of which authorize the creation of Comprehensive Plans by county or local governments. Comprehensive Plans address a range of topics and identify important relationships among the economy, transportation, community services, housing, the environment, and land-use, and as well addresses the long-range future of a community within time horizons of 20 to 50 years. Comprehensive Plans enable planners and decision-makers to see “the big picture”, give guidance to landowners and developers by establishing a sound basis in fact for decisions, consider a broad array of interests in discussions about a community’s long-range future, and

build an informed constituency. A really good Comprehensive Plan will address these things in the context of a wider geographic region (Steiner and Butler 2007, 6).

In recent years Comprehensive Plans have gained a principal position in land-use planning and law. Courts have recognized the costs of zoning without a plan, and as a result have assigned local government plans “constitutional status.” Now, courts will only uphold zoning regulations that are decidedly consistent with an existing local plan. Concurrently, state governments like those of California and Florida, are requiring that Comprehensive Plans be created before enacting any zoning regulation at all. Most states have not adopted this requirement however, and have left the decision of whether or not to follow a Comprehensive Plan in the hands of local independently-minded municipal governments (Attkisson 2009, 992-994).

Other types of plans exist as well; Regional Plans, for example, extend beyond the boundaries of individual governments and include geographic areas that share common characteristics; these may be social, economic, political, cultural, natural-resources-based, or defined by transportation. A region may be delineated in a variety of ways by a variety of factors, some of which include geographic and topographic features (especially watersheds); political boundaries; population distribution; metropolitan areas or urbanized areas as identified by the U.S. Census Bureau; interrelated social, economic, and environmental concerns; and transportation patterns. A Regional Plan may be functional or comprehensive. Functional Regional Plans cover such aspects as parks and open space, bikeways, sanitary sewerage, and water supply. The most typical Regional Functional Plan is the Regional Transportation Plan. Comprehensive Regional Plans are “intended to address facilities or resources that affect more than one jurisdiction and to provide economic, population, and land-use forecasts to guide local planning, so that local plans and planning decisions are made with a set of common assumptions” (Steiner and Butler 2007, 14). Public and private agencies both prepare Regional Plans; however state statutes usually define the elements that are required in a Regional Comprehensive Plan. Such required elements may include population trends and projections, existing land-use, transportation system overview, regional

housing trends and needs, agricultural lands, natural hazards, regional density study, urban growth areas, and regional growth and policy statements (Steiner and Butler 2007, 14).

MECHANISMS OF LAND PLANNING

Implementing the objectives and policies of a plan may involve several mechanisms including zoning, subdivision regulations, historic preservation controls, and more. These mechanisms are controlled by federal and state constitution law, federal or state statutory law, and common law – notably that of nuisance (Steiner and Butler 2007, 347). The two that we will focus on here are Zoning and Subdivision Regulations.

Zoning

Zoning helps to create land-use patterns that are logical; it is based on a local Comprehensive Land-use Plan and is one of the primary ways a plan is implemented. Typical elements of Zoning regulations include general provisions, use standards, density and intensity standards, dimensional standards, general development standards, development standards for hazard areas or sensitive lands, nonconformity standards, and development review procedures (Steiner and Butler 2007, 364). Zoning regulations may also determine certain areas to be single-family homes, multi-family, or areas of historic or cultural significance (FindLaw, a Thomson Reuters business 2010). Zoning ordinances contain standards that are common to all districts and procedures for administering and enforcing its regulations. Maps are used to demonstrate precise boundaries for various Zoning districts (Steiner and Butler 2007, 364).

In a basic sense, Zoning regulations are meant to help communities use resource more efficiently and help protect private investment by giving a sense of certainty about the future of land-use and development. While Zoning may vary from place to place, certain essential elements will always be present. Zoning ordinances always include two primary components – the official map (or series of maps) and the ordinance text. Changing a Zoning district classification of any land area requires Zoning map amendment, also known as rezoning

(Steiner and Butler 2007, 364). Zoning regulations will reference its legal authority, and also include a statement of public purpose to be achieved by the Zoning regulations (Huntington 2001).

A summary of common zoning districts

Common Zoning districts include Residential, Commercial, Industrial, Agricultural, Rural, and Combination districts. In Zoning documents, districts are commonly represented by symbols that include letters of the alphabet as code abbreviations (to identify the approved land-use of a physical geographic area), paired with numbers, which often indicate some quantifiable restriction associated with the land area – like acreage requirements or the square-footage requirements for houses (FindLaw, a Thomson Reuters business 2010). Figure 1 displays an example of this via a Future Land-Use Map, created by the Charlotte-Mecklenburg Planning Commission. Zoning districts are delineated by color and pattern, and the key at the bottom of the map relays district information.

Residential Zoning districts normally include single and multi-family residences, apartments, duplexes, trailer parks, co-ops, and condominiums. Residential Zoning may address such issues as the number of buildings allowed per property, whether or not home-based businesses are allowed, and can even limit types of animals that may be kept on a property (FindLaw, a Thomson Reuters business 2010).¹ Commercial Zoning typically includes several categories and depends upon the business use or expected number of business patrons. Almost any kind of real estate, other than single-family homes and single-family lots, can be considered as commercial real estate and fall within Commercial Zoning regulations. Some typical examples include office buildings, shopping centers, hotels, and certain warehouses and apartment complexes. Industrial Zoning is similar to Commercial Zoning in that it can be specific to the business type. Environmental factors are often determinants as to which industrial category a business would be placed. Setback

¹ In the Charlotte-Mecklenburg region of North Carolina five different single-family districts exist: R-3, R-4, R-5, R-6 and R-8. These districts have been established to promote and protect the development of single family housing and limit public and institutional uses. Districts R-3 and R-4 cover suburban single-family living while R-5, R-6, and R-8 are geared toward urban single-family living. Density requirements limit the number of units per acre, and this is indicated by the numerical identification attached to each district symbol (Charlotte-Mecklenburg Land Planning Commission 2010).

requirements are normally higher for industrial zoned properties. Agricultural Zoning typically comes into play within communities where the economic viability of their agricultural activity is of concern. Agricultural Zoning restricts non-farm uses of land and commonly limits the density of development allowed. Agricultural zoning is often used to protect farming communities from fragmentation as a result of residential development. Rural zoning districts are those which typically allow for horses or cattle, and often site farms or ranches. Combination Zoning districts simply are those places in which a community has adopted a combination of multiple zoning types.

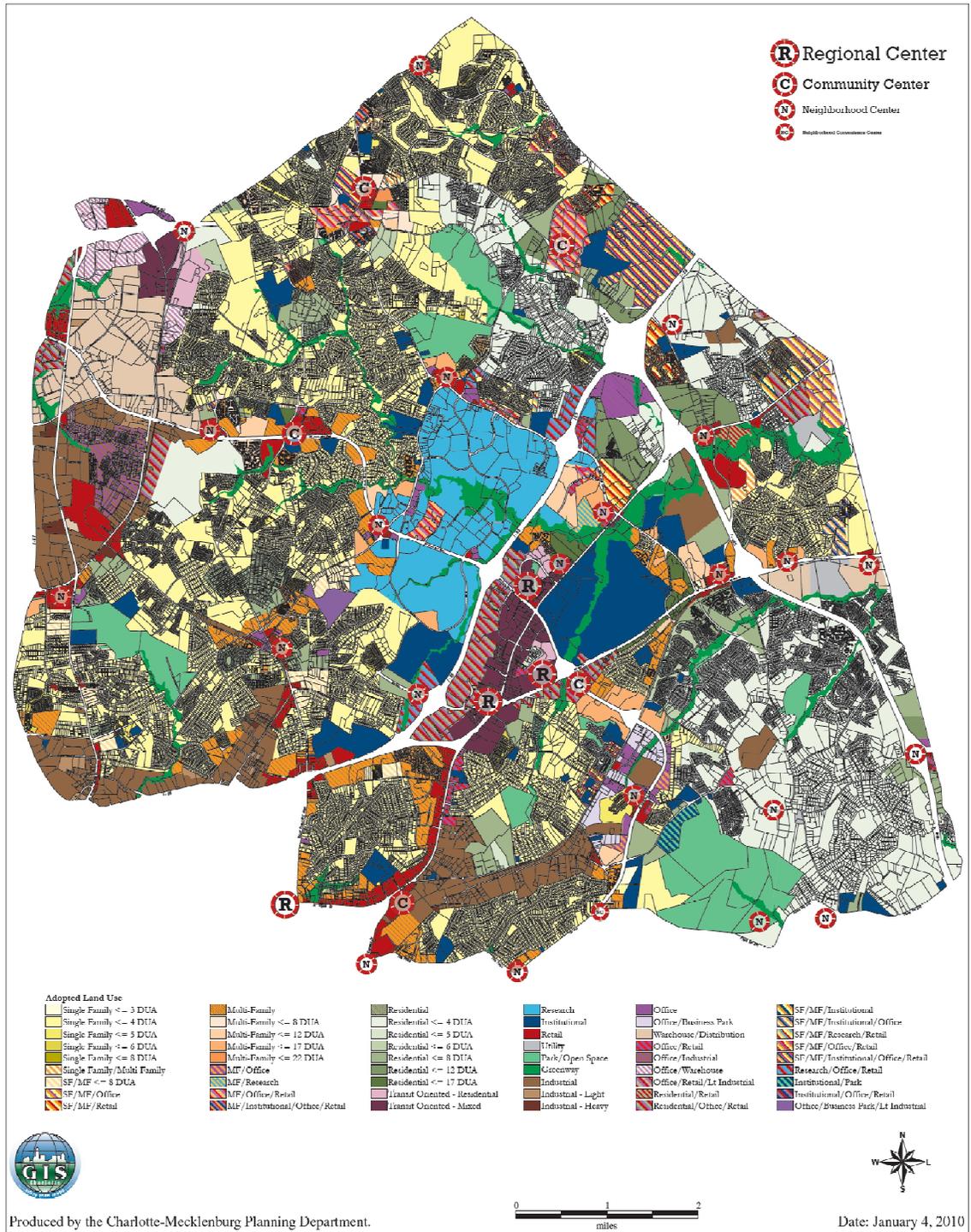


Figure 1: Map displaying different zoning districts. Charlotte-Mecklenburg Land Planning Commission, Future Land Use Map of the Northeast District.

Subdivision regulations

Subdivision Regulations control the division of a tract of land for development purposes; it includes standards for the design and layout of lots, streets, utilities, public improvements, and as well offers procedures and requirements that ensure public improvements are available when the time comes to develop the lots. Procedures and standards for subdivisions vary across states, and even among local governments within a state, however most subdivision ordinances contain a set of standard elements. These elements include general provisions, review procedures, performance guarantees, vested right provisions, and development standards.

Subdivision regulation in most states is principally the responsibility of a local governments' planning commission, and is largely a technical exercise involving a determination that proposed subdivision plans comply with technical standards for street and utility design. Increasingly, environment requirements must also be satisfied. (Steiner and Butler 2007, 368).

Subdivision Regulations and development standards affect the layout and design of lots and streets, and as well define lot standards (size and width requirements), block standards (minimum and maximum width and length), street standards (right-of-way, width, roadway design), utility standards (prescribed size and location of facilities), stormwater management standards (street drainage requirements, runoff retention and detention), and open space standards (set-asides for recreational use, natural hazard areas, or environmentally sensitive lands) (Steiner and Butler 2007, 368).

PLANNING AND GROWTH MEASURES

Most states have adopted legislation that enables local governments to use both Zoning and Comprehensive Plans to manage land. However, beginning in the 1960s some governments began to realize the deficiency of these tools to fully address the spatial progression of growth within jurisdictions, and the associated environmental problems that sometimes result; in effect, growth regulations were formed (Anthony 2008, 1373).

Growth management

Growth Management generally includes planning techniques that shape the amount, direction, rate, and type of growth and channel it into specific areas (Sierra Club - Minnesota North Star Chapter n.d.). Several stages of growth regulation have evolved over the past half-century. Initially, growth measures included just the restriction of development activity by way of limiting the number of new development permits, and by using spatial restrictions like urban growth boundaries. This method of Growth Management is seen by some as too authoritarian, and consequently policies of this kind have been difficult to enact and are highly scrutinized. Aiming to avoid opposition and impediment, supporters of growth regulations have instead moved away from a control approach, to one of management (Anthony 2008, 1373). The management approach links market processes with social and environmental concerns in the development process. This has proved to be only limitedly affective however as a Growth Management policy. Rising interest in environmentalism in the 1980s and '90s, along with growing public concern over expanding haphazard development, has led to another approach to Growth Management – Smart Growth (Anthony 2008, 1373).

Smart growth

Conceived in the 1990s, Smart Growth is rooted in Growth Management principles but is notably different; more inclusive in scope, it integrates social, design, and aesthetic issues into planning and policy (Anthony 2008, 1374). It reduces the amount of growth on newly urbanized land, farmland, and environmentally sensitive areas, and instead refocuses growth in inner suburbs, central cities, and areas already served by established infrastructure (O'Connell 2008, 1357). As noted by the United States Environmental Protection Agency:

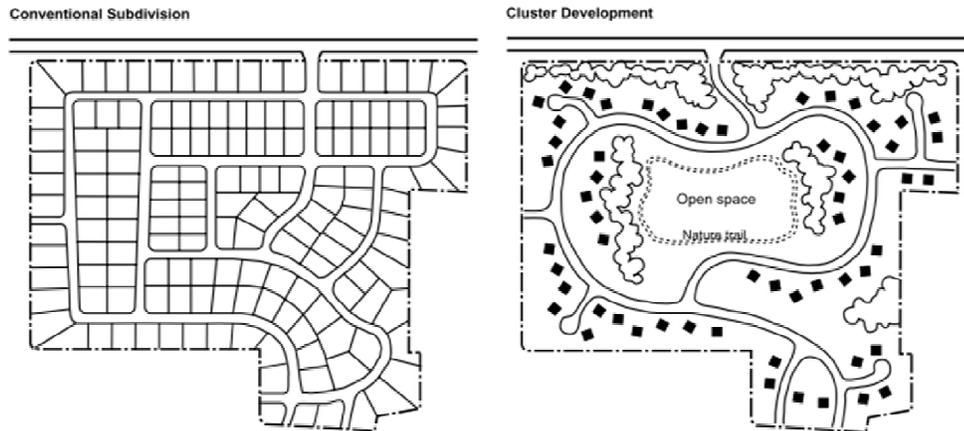
Development guided by smart growth principles can minimize air and water pollution, encourage brownfields clean-up and reuse, and preserve natural lands. The built environment – the places where we live, work, shop, and play – has both direct and indirect effects on the natural environment. Smart growth practices can lessen the environmental impacts of development with techniques that include compact development, reduced impervious surfaces and improved water detention, safeguarding of environmentally sensitive areas, mixing of land-uses (e.g., homes,

offices, and shops), transit accessibility, and better pedestrian and bicycle amenities. (U.S. Environmental Protection Agency 2010)

Cluster development

Related to Smart Growth is a land planning method known as Cluster Development. In most places current zoning for residential development is centered on the establishment of minimum lot sizes, setbacks, and lot widths; these basic standards tend to promote development patterns that exploit the land by fitting the largest number of lots possible on each parcel or tract of land. In contrast, Cluster Development enables the development of property, but protects environmental resources and rural character by grouping built structures close together in order to preserve adjacent land.

For example, if a land ordinance requires a two acre minimum lot size on a 30 acre tract of developable land, 15 units could be built. In contrast, Cluster Development would still enable 15 units but the lot sizes would vary, requiring perhaps a maximum of one-acre per parcel, which leaves 15 acres of land available for common open space. In Cluster Developments this space is available to residents as recreational space (sometimes linked via an internal trail network to the developed acreage), and other times municipalities may require the land be set aside for agriculture or as a wildlife refuge. Cluster Development has been noted to include such positive benefits as reducing costs of infrastructure due to its ability to provide storm water and wastewater management, and increasing social benefits by promoting interactions between neighbors, walkable streets, and better supervision of neighborhood children playing in shared spaces (State Government of Indiana n.d.). Cluster Development, also known as Open Space Development or Conservation Subdivision Design, typically applies to residential areas with objectives such as the preservation of open space, the protection of wild and ecological environments, and the conservation of agricultural land (State Government of Indiana n.d.). Figure 2 below demonstrates the layout of a Cluster Development as compared to a conventional development design.



Source: David Listokin and Carol Walker, *The Subdivision and Site Plan Handbook*.

Figure 2: A comparison of traditional or conventional development (left) versus cluster development (right) courtesy of the Southeast Michigan Council of Governments (Southeast Michigan Council of Governments 2003, 24).

Sustainable communities and green development

Growth that occurs in accord with Sustainable Community Design and Green Development follows three basic tenets: environmental responsiveness; resource efficiency; and community and cultural sensitivity (Smart Communities Network 2004). As such, siting and land-use considerations, water and energy conservation, careful use of resources, and protection of natural and open spaces are characteristic of this type of growth. “In order for a housing development to have a sustainable approach, the developer / planner must consider land use, site planning, and building design in a sustainable manner, and consider land-use issues as paramount in the overall planning process. For this reason, it is difficult to find examples of subdivisions that are sustainable” (Smart Communities Network 2004).

Smart Growth, Cluster Developments and Sustainable Design Communities signify progressive thinking in terms of land-use planning and environmental considerations, and they are perhaps the latest evolution in American land planning and policy. Unfortunately, they represent the views and interest of only a relative minority of land-use planners and local governments.

ENVIRONMENTAL POLICY

Policymakers have come to realize that land-use and development decisions significantly affect the natural environment (United States Environmental Protection Agency 2001, 1). As efforts to mitigate development-related environmental impacts increase, it's useful to understand the historic role of environmental planning in the United States with regard to land-use management and policy. On New Year's Day, 1970, President Richard Nixon signed into law one of the nation's most sweeping environmental decrees – the National Environmental Policy Act of 1969 (NEPA). As the nation's first environmental policy, NEPA brought about a greater awareness of the environment and included such goals as “to create and maintain conditions under which man and nature can exist in productive harmony,” as well as to ensure the “safe, healthful, productive and aesthetically and culturally pleasing surroundings” (Marsh, Porter and Salvesen 1996, 130).

Of particular significance in NEPA is the requirement mandating Environmental Impact Statements (EIS) for every proposed major federal action that may affect the quality of the human environment. Environmental Impact Statements have been called the “heart” of NEPA, and require the detailed description of a.) the environmental impact of proposed actions, b.) adverse environmental effects that cannot be avoided if the proposal is implemented, c.) alternatives to the proposed action, d.) the relationship between local short-term uses of the environment and the maintenance and enhancement of long-term productivity, and e.) any irreversible and irretrievable commitments of resources that would be involved in the proposed action (Steiner and Butler 2007, 358). An EIS often can take more than a year to complete, involves extensive analysis, and considerable interagency review. An Environmental Assessment (EA) may be performed as an alternative to the EIS. The Environmental Assessment, which is suitable for most NEPA projects, is like a brief EIS, usually completed in a few days or weeks, and describes project purpose, likely environmental impacts, provides an analysis of alternatives and indicates whether the proposed project will include significant environmental impact (Marsh, Porter and Salvesen 1996, 131).

NEPA remains the cornerstone of Federal environmental policy. It has spawned similar legislation in the form of State environmental policy acts and local governmental requirements for the evaluation and review of the potential environmental impact of public and private projects. By most accounts, NEPA has been a success. It has forced permit applicants to be more sensitive in designing and siting their projects, required Federal agencies to consider the environmental impact of proposed projects, and has prevented many environmentally damaging projects from proceeding. (Marsh, Porter and Salvesen 1996, 131)

Following the installation of NEPA, a series of other environmental laws regarded as “command and control” were enacted to protect the environment. These laws required adherence to a set of detailed rules and regulations in order to obtain development permits, and include such legislation as the Clean Air Act (CAA) of 1970, the Clean Water Act (CWA) of 1972, and the Endangered Species Act (ESA) of 1973. The Clean Water Act and the Endangered Species Act are thought to have perhaps the greatest impact on local development and land-use. Both have come under assault by landowners and developers as pitting private property rights against public interest for the purpose of natural resources protection (Marsh, Porter and Salvesen 1996, 130). The ESA, administered by the U.S. Fish and Wildlife Service and National Marine Fishers Service, has been called the most powerful land-use law in the United States. The principle aim of the act is to “provide a means whereby the ecosystem upon which endangered and threatened species depend may be conserved” (Marsh, Porter and Salvesen 1996, 134-135). The ESA enables the Federal Government to stop the progress of any development project that may threaten a species listed as endangered. As a result, the government can literally alter development plans overnight.

U.S. LAND-USE PLANNING: A SUMMARY

In summary, the evolution of land-use planning and policy in the United States has been an amalgamation of federal, state, and local efforts. While no single national land-use policy exists, a handful of federal legislative acts influence and impose certain incentives and restrictions on the shape and direction of our expanding municipalities and jurisdictions. Although it is believed, and arguably true, that the land-use planning power of local

governments makes sense in terms of being able to respond to the specific and varied needs of each unique locale, the ways in which planning has traditionally approached this task largely ignores environmental impacts. This local authority has led to the variation and disparity in land-use patterns and plan quality, a circumstance that is particularly problematic when faced with efforts to manage broad-scale environmental issues. Although some local governments and land planners have recognized the shortcomings of traditional planning and have reached for more progressive solutions (such as Smart Growth techniques or Cluster Development requirements) there still exists a need for tools and mechanisms that can assist planners in integrating regional environmental considerations with local land-use plans and decision-making. In the meanwhile, Comprehensive Plans, Zoning, and Subdivision Regulation remain the primary mechanisms by which land-use planning and policy is addressed and implemented.

CHAPTER 3

LANDSCAPE ECOLOGY, CONSIDERATIONS OF SCALE, AND SUB-REGIONAL ENVIRONMENTS

HUMANS, LANDSCAPES, AND ECOLOGICAL SYSTEMS

Landscape is often the result of the interaction between human and natural forces – physical, biological, and social. The terrestrial result is a mix of ‘natural’ and human-managed patches of land that vary in size, shape, and arrangement (M. G. Turner 1989, 174). Maintaining ecological systems and services within these landscapes must be considered in a regional context, and also in the planning and land-use decision making process.

Inherent dependence

“Landscapes have traditionally been seen as canvases to be improved upon by human intervention” (Tarlock 2007, 660). In the United States, this intervention seems to take shape as either fenced off land areas removed from progress, or conversely as what appears to be boundless growth and dispersed low-density development (Tarlock 2007, 655-659). We increasingly grow outward and exercise a sense of entitlement over our landscapes, and yet we do so with an often unnoticed, yet inherent, dependence on natural systems.

Unfortunately, a great disparity exists between today’s land development decision-making processes and the wisdom of ecological science (Dale, et al. 2000). The result is a use of land that degrades nature’s ecological integrity. As the complex interdependent systems of our environment break down, so too does the health of the human system.

The United States first acknowledged this relationship more than a century ago (Harte 2001, 930-931). Since then, more comprehensive views of land and resource management have progressed along with acceptance of such holistic concepts as the protection of ecological systems and services, known as ecosystem management. Ecosystem management is a strategy based on the integration of ecosystem science and socioeconomic principles, and

is considered by some to be vital in addressing long-term needs and issues of land planning and policy. Ecosystem management “implies an interdisciplinary, holistic, environmental approach to maintaining natural diversity and productivity of the landscape, while sustaining human culture” (Szaró 1998, 3). The primary interest of ecosystem management is protecting essential ecosystem services.

Introduction to ecosystem services

Ecosystem services are numerous and complex. One way to define them is as the benefits humans obtain from natural ecosystems that have a positive impact on our well-being and livelihoods. Examples of ecosystem services include purification of air and water as provided by forests, flood protection as a service of wetlands, and food and fiber production as a result of fertile soils. Ecosystem services also include the enhancement of our general well-being by way of recreational and cultural opportunities. Land development impacts these services by altering the ability of ecosystems to function as intact networks; these networks operate on such a large scale, and in such complex and intricate ways, that their services are simply irreplaceable by any stretch of human or technological invention (Daily, Alexander and al. 1997, 15). Federal and non-government institutions, such as the U.S. EPA and The Heinz Center, work to develop tools and fund research to support a deeper understanding of ecosystem services and land ecology. One such initiative of these efforts is the Ecosystem Services Research Program, which aims to “deliver the science necessary to identify and evaluate the complex interactions of ecosystems and how the services from nature may be impacted by man-made changes to the environment” (U.S. Environmental Protection Agency 2009).

AN INTRODUCTION TO LANDSCAPE ECOLOGY

Ecosystem services are a manifestation of the integrity and health of landscape ecology. Various definitions of landscape ecology exist, however shared among them is the principle importance placed on spatial heterogeneity in the functioning of ecological processes (M. G. Turner 2005, 1967). Landscape ecology has also emerged as a research

field that has greatly contributed to our understanding of the relationships between land-use, pattern, and ecological process. As the name implies, the field of landscape ecology involves the study of landscapes. In recent decades landscape ecology has undergone progressive development in both theory and application, and has established itself as a new ecological paradigm (Wu 2008, 18).

Two schools of thought

The term “landscape ecology” was conceived first in Europe by German biogeographer Carl Troll in 1939; the subject grew in close association with land planning and developed rapidly after ideas from Europe were introduced to scientists in North America. As a result, two primary schools of thought on landscape ecology exist – the European and the North American (M. G. Turner 2005, 1967-1968). European landscape ecology takes a practical view of landscape, with a problem solving approach to social-economic-landscape systems. Landscape ecology is well integrated into European land-use planning processes, and principles of landscape ecology are taken as the scientific basis for land management, conservation, and development (Golubiewski 2008). Humans play a central role in the European view of ecology, and are the main focus of land planning (Monteith and Schrader 1996).

In contrast, North American landscape ecologists tend to focus more on spatial dimension, arrangement, distribution and content of ecosystems. The North American school also tends to place special emphasis on the flows of energy and matter from one landscape to the next (Monteith and Schrader 1996), and underline the broad spatial scales and ecological effects of spatial patterning. More specifically, it looks at the development and dynamics of spatial heterogeneity; the interactions across heterogeneous landscapes; influence of spatial variety on biotic and abiotic processes; and the management of such diversity (M. G. Turner 1989, 172). Unlike its European counterpart, the North American school has traditionally decoupled humans from ecological systems; recently however, this position has begun to change and humans are more often included as an essential element in understanding ecology.

Landscape ecology – structural elements

The ecological function of a landscape is strongly tied to the structure of that landscape (M. G. Turner 1989, 174). Foundational to landscape ecology are the spatial elements of landscape and land pattern; these include patches, corridors and matrix. It is rationalized that every terrestrial point will fall within one of these three spatial configurations; this concept is largely accepted and known as the “patch-corridor-matrix model” (Forman 1995, 7). Patches and corridors have long been a main focus of human activity. A patch is defined as a wide, relatively homogeneous area that is different from its surroundings. Patch attributes – large or small, rounded or elongated, straight or convoluted – are thought to have prevalent ecological implications on such things as biodiversity, soil and water. Generally, large patches are considered superior to small patches because they provide comparatively significant environmental benefits like protection of water quality and shelter for interior and multihabitat species. Maintaining large patches of intact ecosystems, and their associated benefits to society, is only possible with careful planning and protection (Forman 1995, 47-48). Small patches provide supplemental benefits, like acting as habitat stepping stones for species dispersal.

A corridor is defined as an area that differs from its surroundings and permeates the land in strips. Corridors can be natural, such as streams, ridges, and animal trails, or man-made, such as roads, power lines, ditches, and walking trails. Nature’s corridors tend to be curvy and continuous (until human interference is superimposed upon them), whereas human corridors are typically narrow, angular and require maintenance. Vegetated corridors are said to provide ecological and societal benefits like protection of biological diversity, enhancement of water resources management, control of soil erosion by acting as a wind break, providing recreation opportunities, and creating dispersal routes for otherwise isolated species (Forman 1995, 145-151).

It is said that when you are in the middle of nowhere, you are likely to be in the matrix. The matrix covers an extensive area and has significant control over landscape and regional dynamics. It is highly connected, and encloses and affects both patches and corridors. In many cases, identification of the matrix is straightforward and obvious; for

example it may be observable that the majority of an area is forest, residential development, or wetlands. However in some instances it may be unclear which land-cover type functions as matrix. In these cases, three sequential attributes are used to identify the matrix: area, connectivity and ‘control over dynamics’. First, total area of land type would be evaluated. If the total area of any one land type does not clearly delineate itself as the matrix, then the next attribute, connectivity (i.e. less fragmentation) would be evaluated. In rare instances where total area and connectivity do not indicate the matrix, ‘control over dynamics’ must be taken into account. This is a more difficult approach and essentially relies upon the discovery of which element type would exert the greatest influence in determining the future of a landscape, in the event of climate change, natural disturbance regimes, or hardwearing human activity (Forman 1995, 277-278).

Essential landscape configurations

One approach to land planning that is theorized to have numerous ecological benefits is the “aggregate-with-outliers” model, proposed by Richard T. T. Forman – one of the foundational thinkers on the subject of landscape ecology in the United States. Forman asserts that only a few essential elements exist for any land-use plan; these elements include:

- large natural vegetation patches able to sustain healthy inland species, natural disturbance regimes, and large vertebrates
- wide vegetated corridors to protect water courses
- connectivity for movement of key species among large patches
- small patches and corridors to provide heterogeneous pieces of nature among developed areas

For these things, he argues, there is no substitute to their ecological benefit (Golubiewski 2008). The implications of these elements suggest that planners consider the location and contiguity of human development, as well as the spatial arrangement, natural land-cover characteristics, and connectivity of land-cover. Forman’s theory on essential landscape configuration is known as the “aggregate-with-outliers” model; it states that one should “aggregate land uses, yet maintain corridors and small patches of nature throughout

developed areas, as well as outliers of human activity spatially arranged along major boundaries” (Forman 1995, 437). It is theorized that this model can be applied to any landscape, from desert to forest and agriculture to suburb, although the range of scales to which it may apply is unknown.

Landscape function and process – a closer look at ecosystem services

To more fully understand the function and value of landscape and land ecology, a closer look at ecosystem services is essential. Researchers and scientists have taken to developing classification and organizational tools that lend to human understanding of these relationships and benefits. In developing its classification tool, the researchers of the Millennium Ecosystem Assessment (MA) found that 60 percent of the world’s ecosystem services are either degraded or used unsustainably; moreover, 70 percent of the services that regulate nature are in decline. The MA predicts that the degradation of ecosystem services will intensify during the first half of this century, substantially affecting human well-being (Collins and Larry 2007, 5). The Millennium Ecosystem Assessment is just one approach to classifying ecosystem services; however other classifications of similar content and structure exist, such as the Ecosystem Services Framework (G. Daily 2000) and the devised typology for the classification of ecosystem services by De Groot, Wilson and Boumans (2002).

De Groot, Wilson and Boumans (2002) have classified ecosystem functions into four primary categories: Regulation Functions, Habitat Functions, Production Functions, and Information Functions. Regulation Functions are those that relate to the capacity of natural and semi-natural systems to regulate ecological processes. Biogeochemical cycles and biospheric processes fall within this category. Regulation Functions also have direct and indirect benefits to humans, such as clean air, water and soil, and biological control services. Habitat Functions are natural ecosystems that provide refuge and reproduction habitat for animals and plants, and contribute to the conservation of biological and genetic diversity. Production Functions are those that utilize photosynthesis and nutrient uptake and convert energy, carbon dioxide, water and nutrients into a range of carbohydrate structures, consumed by secondary producers. These carbohydrate structures provide food, raw materials, and energy resources. Information Functions are those that contribute to the maintenance of

human health by providing opportunities for reflection, spiritual enrichment, recreation, cognitive development, and aesthetic experience. Most human evolution occurred within the context of undomesticated habitat, and therefore, natural ecosystems serve as an essential reference point of the human experience (de Groot, Wilson and Boumans 2002, 395).

Table 1 on the following page provides an overview of 21 main ecosystem functions and their corresponding human benefits, developed by de Groot, Wilson and Boumans (2002). Originally devised of 23 ecosystem functions, Table 1 modifies the list slightly to include 21 functions by combining three elements from the Information Function category – aesthetic, cultural, and spiritual and historic. Each of these functions shares similar and overlapping intangible and subjective benefits; therefore their combination does not diminish the integrity of the category.

Table 1: Functions, goods and services of natural and semi-natural ecosystems; derived from R.S de Groot, Wilson and Boumans (2002)

Functions	Ecosystem Processes and Components	Human Benefit (Goods & Services)
REGULATION FUNCTION	<i>Maintenance of essential ecological processes and life support systems</i>	
1. Gas regulation	Role of ecosystems in bio-geochemical cycles (e.g. CO ₂ /O ₂ balance, ozone layer, etc.)	1.1 UVb-protection by O ₃ (prevents disease) 1.2 Maintain good air quality 1.3 Influence on climate (see also function 2.)
2. Climate regulation	Influence of land cover & biologically mediated processes (e.g. DMS-production) on climate	2.0 Maintain favorable climate
3. Disturbance prevention	Influence of ecosystem structure on dampening environmental disturbances	3.1 Storm protection 3.2 Flood prevention (e.g. by wetlands & forests)
4. Water regulation	Role of land cover in regulating runoff & river discharge	4.1 Drainage & irrigation 4.2 Medium for transport
5. Water supply	Filtering, retention & storage of fresh water	5.0 Provision of water for consumptive use
6. Soil retention	Role of vegetation root matrix & soil biota in soil retention	6.1 Maintenance of arable land 6.2 Prevention of damage from erosion / siltation
7. Soil formation	Weathering of rock, accumulation of organic matter	7.1 Maintain productivity on arable land 7.2 Maintain natural productive soils & ecosystems
8. Nutrient regulation	Role of biota in storage and re-cycling of nutrients (e.g. N, P&S)	8.0 Maintain healthy soils & productive ecosystems
9. Waste treatment	Role of vegetation & biota in removal or breakdown of xenic nutrients & compounds	9.1 Pollution control / detoxification 9.2 Filtering of dust particles 9.3 Abatement of noise pollution
10. Pollination	Role of biota in movement of floral gametes	10.1 Pollination of wild plant species 10.2 Pollination of crops
11. Biological control	Population control through trophic-dynamic relations	11.1 Control of pests & diseases 11.2 Reduction of herbivory (crop damage)

(Continued on next page)

Table 1: continued

Functions	Ecosystem Processes and Components	Human Benefit (Goods & Services)
HABITAT FUNCTION	<i>Providing habitat (suitable living space) for wild plant and animal species</i>	
12. Refugium function	Suitable living space for wild plants & animals	12.0 Maintain biological & genetic diversity (and thus the basis for most other functions)
13. Nursery function	Suitable reproduction habitat	13.1 Hunting, gathering of fish, game, fruits, etc. 13.2 Small-scale subsistence farming & aquaculture
PRODUCTION FUNCTION	<i>Provision of natural resources</i>	
14. Food	Conversion of solar energy into edible plants & animals	14.1 Building & manufacturing (e.g. lumber, skins) 14.2 Fuel & energy (e.g. fuel wood, organic matter) 14.3 Fodder & fertilizer (e.g. krill, leaves, letter)
15. Raw materials	Conversion of solar energy into biomass for human construction and other uses	15.1 Improve crop resistance to pathogens & pests 15.2 Other applications (e.g. health care)
16. Genetic resources	Genetic material and evolution in wild plants & animals	16.1 Drugs & pharmaceuticals 16.2 Chemical models & tools 16.3 Test and essay organisms
17. Medicinal resources	Variety in (bio)chemical substances in, and other medicinal uses of, natural biota	17.0 Medicinal application
18. Ornamental resources	Variety of biota in natural ecosystems with (potential) ornamental use	18.0 Resources for fashion, handicraft, jewelry, pets, worship & decoration
INFORMATION FUNCTION	<i>Providing opportunities for cognitive development</i>	
19. Aesthetic, spiritual, historic & cultural information	Attractive landscape features, variety, spiritual & historic value	19.0 Enjoyment of scenery, use of nature for religion, heritage values
20. Recreation	Variety in landscape with (potential) recreational uses	20.0 Eco-tourism, outdoor sports
21. Science & education	Variety in nature with scientific & educational value	21.0 Use of natural systems for school excursion and scientific research

It should be noted that the processes and services identified here do not always show a one-to-one association; for instance it is possible for a single ecosystem service to be the product of two or more processes, whereas in other cases a single process may benefit by supplying more than one service (de Groot, Wilson and Boumans 2002, 395). It is precisely this dynamic and complex nature that makes the preservation of ecosystems and ecological services critical, and demand attention from decision-makers and policymakers from the local to global scale.

Present scientific understanding of ecosystem services is substantial, wide reaching, and extremely policy-relevant, and merits urgent attention by decision makers, since current patterns of human activity are unsustainable and threaten to impair critical life-support functions. Failure to foster the continued delivery of ecosystem services undermines economic prosperity, forecloses options, and diminishes other aspects of human well-being; it also threatens the very persistence of civilization. While the academic community remains a long way from a fully comprehensive understanding of ecosystem services, the accelerating rate of disruption of the biosphere makes imperative the incorporation of current knowledge into the policy-making process. (G. C. Daily 1997, 10)

Considerations of scale

“Effective and comprehensive land-use planning must be carried out at multiple spatial scales” (Noss 2007, 7). In the United States however, planning mostly occurs within limited jurisdictional bounds that more often than not ignore the larger regional and ecological context of the land. In effort to facilitate local ecosystem management and the consideration of ecosystem services as a component of planning and land-use decision making, it is critical to understand the relationship of scale to the efforts undertaken. Three components of scale may come into play, namely ecological scale, temporal scale, and political scale. Ecological scale is relevant to the delineation of ecological system boundaries, which ultimately change depending upon the viewpoint of the persons or groups making the determination. As the scale at which ecological systems are considered or reviewed increases, the identifiable ecosystem services change. As such, local services that might be evident in a local assessment may no longer be visible when viewed from a regional or global scale (Alcano, et al. 2003, 123). However, in order to integrate ecological system

considerations into the planning process, a recognized delineation of such systems may be necessary.

A practical approach to the spatial delimitation of an ecosystem is to build up a series of overlays of significant factors, mapping the location of discontinuities—for instance, in the distribution of organisms, the biophysical environment (soil types, drainage basins, shared markets), and spatial interactions (home ranges, migration patterns, fluxes of matter). A useful ecosystem boundary is one where a number of these relative discontinuities coincide. (Alcano, et al. 2003, 125)

The consideration of temporal scales in reviewing ecological function, and determining appropriate planning horizons, is equally as important. Depending on the temporal scales associated with the objectives and focus of a land-use plan, the ecological priorities may differ. For example, a plan may prioritize short-term ecosystem concerns such as those already threatened, like the provision of fresh drinking water, or food production. Conversely, planners may have more concern over the ecological consequences that may take place over decades or even centuries, in which case they may prioritize issues related to the carbon balance, or resilience in biodiversity (Alcano, et al. 2003, 123). Regarding political scale, planners should be aware of mismatch between the scale at which ecological processes occur, and the scale at which planning decisions are made. While planners and decision-makers can plan for ecological considerations within local jurisdictional bounds, to be truly effective at preserving ecological processes, inter-jurisdictional collaboration and planning should be a consideration.

UNITED STATES LAND ECOLOGY

By simply looking around the United States, or even reviewing a land-cover map, it's fairly plain to see that the U.S. contains a variety of geographic regions. Urban areas, grasslands, wetlands, forests – land-cover types such as these spread across our Nation and together form the mosaic that is our environment and landscape. Environmental managers and ecologists have come together to assess, for better understanding, the ecological components that comprise our national landscape, and to define principal ecosystems in order

to better manage land resources. This is no easy task; ecological systems are highly interrelated and the boundary between one system and the next is often fuzzy.

Major U.S. ecosystems

Work conducted by the United States Forest Service, R.G. Bailey, and others has helped greatly to identify and enhance our understanding of U.S. ecosystems and land ecology. Introduced as early as 1976, the concept of ecoregions is used to explain and address the land ecology and ecosystem geography of our Nation (Bailey 1995). Ecoregions can be thought of as ecosystems of regional extent, however many definitions and iterations of ecoregions have evolved in the U.S. and elsewhere. Consensus on ecoregion delineation is increasing, although considerable disagreement still exists as to the precise definition. The issue of scale and hierarchy also comes into play here; ecosystems are present at different levels and their boundaries are imprecise. This means that different ecosystem levels do not necessarily 'nest' perfectly and can therefore become confused in delineating boundaries (Omernik 2004, S28:S29). Despite its imperfections, "ecoregions have proven to be an effective aid for inventorying and assessing national and regional environmental resources, for setting regional resource management goals, and for developing biological criteria and water quality standards" (U.S. Environmental Protection Agency 2009).

The work of R.G Bailey and James Omernik represent two popular approaches to the concept of ecoregions in the United States. Bailey's ecoregions distinguish areas that share common climatic and vegetation characteristics and organize them into a four-level hierarchy – domains, divisions, provinces, and sections. The Omernik ecoregion system considers spatial patterns of both biotic and abiotic components of a region such as geology, physiography, vegetation, climate, soils, land-use, wildlife, water quality, and hydrology. This paper relies upon Omernik's view of ecoregion delineation.

Four levels exist within Omernik's ecoregion hierarchy. Level I divides North America into fifteen broad regions. These are the backdrop to the U.S. ecological mosaic, and highlight major ecological areas. Level I ecological regions include: Arctic Cordillera, Tundra Taiga, Hudson Plains, Northern Forests, Northwestern Forested Mountains, Marine

West Coast Forests, Eastern Temperate Forests, Great Plains, North American Deserts, Mediterranean California, Southern Semi-Arid Highlands, Temperate Sierras, Tropical Dry Forests and Tropical Wet Forests. Level II ecological regions describe national and sub-continental overviews of ecological patterns and are nested within the Level I ecoregions. Level II includes 50 ecological regions that offer more detailed insight into the larger ecological regions established by Level I. Level III contains 182 ecological regions; these provide even more fine-grained detail on the ecosystems across the U.S. and enhance regional environmental monitoring, assessment, reporting and decision-making. The fairly small size of Level III regions also allow for locally-defined characteristics to be identified and management strategies to be made clear (U.S. EPA 2010). Examples of Level III regions in the state of North Carolina include: Piedmont, Middle Atlantic Coastal Plain, Southeastern Plains, and Blue Ridge (U.S. Environmental Protection Agency 2009). Figure 3 below depicts Levels II, III and IV providing a visual reference to the varying land ecology of the United States.

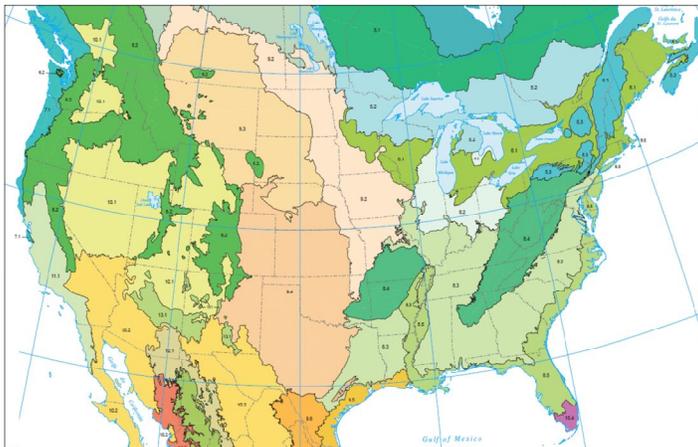
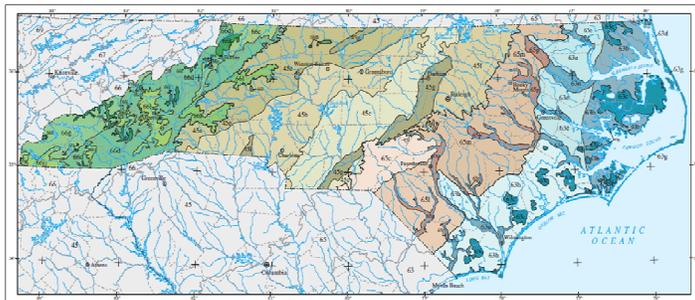


Figure 3:

Top map: Level II ecoregions of the U.S.
Image by the CEC and EPA,
ftp://ftp.epa.gov/wed/ecoregions/cec_na/NA_LEVEL_II.pdf



Bottom map: Level III and IV Ecoregions of the North Carolina. Image by Griffith, et al. 2002. ftp://ftp.epa.gov/wed/ecoregions/nc/nc_eco_pg.pdf

Sub-regional environments

Level IV ecoregions are a work in progress; these ecoregions occur at a scale that is applicable to local analysis. Work on Level IV ecoregions has been a collaborative effort between United States Environmental Protection Agency, National Health and Environmental Effects Laboratory (NHEERL) – Corvallis, OR, the U.S. Forest Service, Natural Resources Conservation Service, and a variety of other state and federal resource agencies (U.S. Environmental Protection Agency, Western Ecology Division 2010). Level IV ecoregions are currently viewable by state-level mapping. In North Carolina for example, twenty-seven Level IV ecoregions are nested within the four Level III ecoregions mentioned

above (Griffith, et al. 2002).

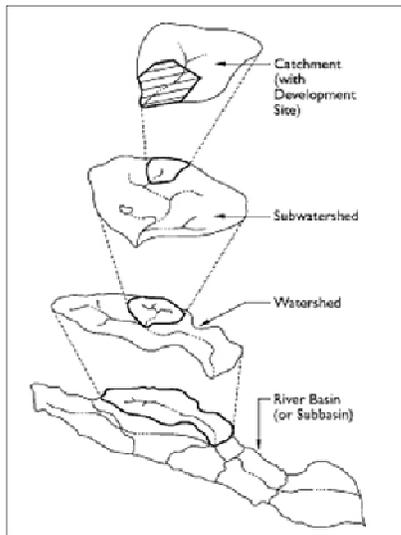


Figure 4: Watershed units. To conceptualize the way in which different ecosystem levels nest within one another, it may help to visualize the nesting of watershed units, as displayed here. Image sourced from Steiner and Butler, 2007, 61.

THE REGIONAL CONTEXT OF LOCAL PLANNING

Regional environmental management

Regional planning in the United States first emerged in the 1920s as a result of debates regarding how to best manage the distribution of resources across large land areas. Planners at the forefront of this dialogue aimed to create “conditions that would establish a harmonious relationship between human beings and nature, grounded in a bio-ethics that would show a deep respect for the limits of human intervention in natural processes, and limit the cancerous growth of cities” (Roberts 1994, 781). Despite the original intent, regional

planning efforts evolved largely *without* an emphasis on the relationship between humans and nature. Instead, it tends to favor an unwritten philosophy that proclaims human domination over nature and its processes (Roberts 1994, 782).

Filling the gap that traditional planning has left other agencies and organizations have stepped up to address environmental management at the regional scale. These efforts are hosted mainly by non-profits and government agencies interested in protecting and preserving ecological features and functions of our natural landscapes. Examples include conservancies and land trusts, state government departments of natural resources and regional planning, and watershed protection agencies.

The disconnect

At the most basic level, regional planning, whether for human interest or that of the environment, just makes sense. By taking into consideration a broader spatial realm, we can more easily harmonize our individualized efforts and goals. Indeed regional planning and coordination is a valuable effort. As previously suggested, one of the greatest environmental challenges of our time is the degree and rate at which humans influence, convert and change land and impact natural processes. This change is predominantly the result of development practices occurring at the local scale, which in aggregate exert regional, national, and global effects. ***The problem, or ‘the disconnect’, is that while efforts to protect and plan for the environment more commonly occur at the regional scale, the very root of the problem exists in localized, fragmented decision-making and privatized development endeavors.***

The fact of the matter is people must live somewhere, and therefore our cities will continue to grow, and land will be developed. Urban growth management and comprehensive plans will designate land-use, zone, and regulate in effort to manage and keep track of land resources. Environmental considerations will be brought into local plans via required project-specific Environmental Impact Statements, or possibly ordinances requiring set-asides, green space, or tree cover. At a broader, regional scale environmentalists may pursue conservation and preservation endeavors, such as wildlife preserves and green infrastructure plans, to incorporate environmental protections outside of government action.

In this conventional model, we are still missing the mark. While each of these efforts serves a meaningful purpose, collectively they fail to produce an end result that achieves effective planning, optimizes human fulfillment, and prioritizes ecological needs.

A variety of systems and tools have been developed to help bring environment, planning and development together. These efforts range from the federally mandated Environmental Impact Statement, to local government planning measures such as Natural Resources Inventories, Environmental Assessment Checklists, and Ecological Due Diligence.² These methods assist in adding environmental information to the planning and development process; however, “adding ecological or environmental information is not really enough. It may result in somewhat fewer bad decisions, but until the analysis goes beyond multidisciplinary lists and is an integral part of a comprehensive, forward-looking planning process, there is neither a basis nor an incentive for true linking of environment and development” (Slocombe 1993, 291). Figure 5 on the next page illustrates this.

² An example of an Environmental Assessment Checklist is that used by the State of New Jersey, www.state.nj.us/dep/opsc/docs/env_assessment_ord_checklist.pdf; for a Natural Resources Inventory; see the Minnesota Department of Natural Resources, <http://files.dnr.state.mn.us/assistance/nrplanning/community/nrchecklists/inventory.pdf>; and for Ecological Due Diligence, the South Florida Water Management District, www.sfwmd.gov/portal/page/portal/xrepository/sfwmd_repository_pdf/rog_pres_nov_bd_envassess.pdf

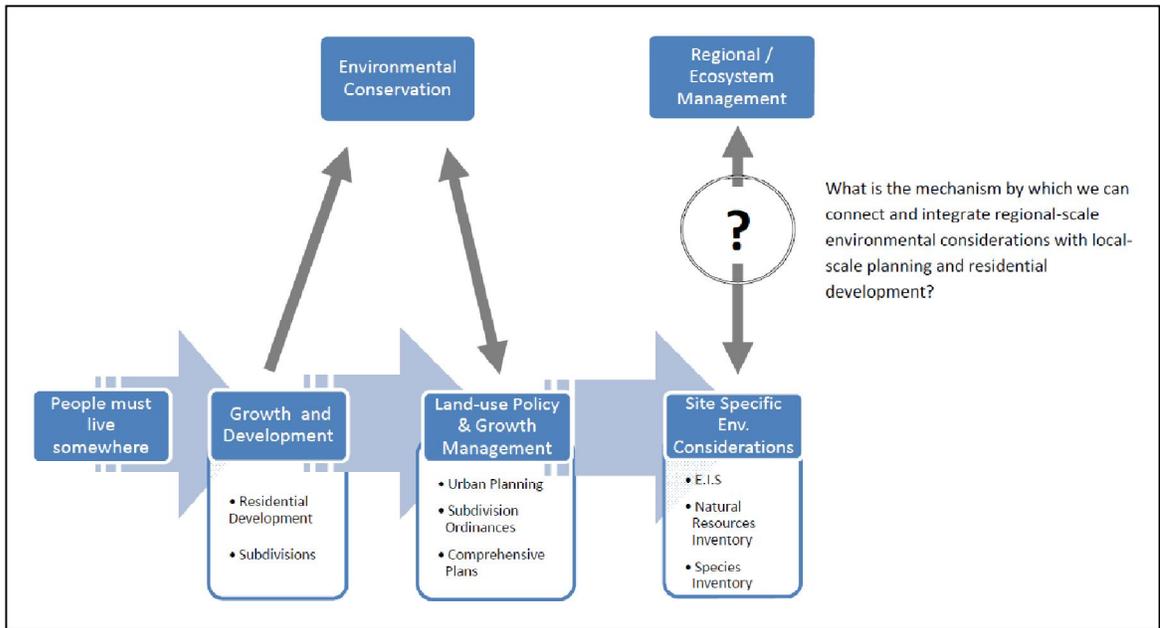


Figure 5: Diagram of the disconnect that exists between environmental considerations at the regional scale and local-level planning and environmental protections.

Little applied research has been done to figure out how local jurisdictions can include principles of ecosystem management into planning and regulatory frameworks (Brody 2003, 512). However, the effective, long-term success of ecological approaches to land management will depend upon the ability of local plans to capture ecological principles and functions.

A 21ST CENTURY CHALLENGE

We enter the 21st century with a pressing challenge: to bring continued growth and development into balance with the ecological systems and services that sustain us. Rapid, poorly planned growth and the division between short-term economic incentives and long-term societal and environmental well-being is a major strain that threatens ecological systems all across the U.S. (Daily, Alexander and al. 1997, 12). The longer it takes to reconcile this disparity, the more at risk we place ourselves and the environment. A multiplicity local land-

use regulations and the absence of a national land-use policy fragment coherent ecological planning and policy.

In the realm of policy and regulation, efforts to protect ecological systems (rather than land parcels and political boundaries) have historically been met with deliberate resistance. Despite opposition, some progress has been made; ecosystem management tactics, sustainable development efforts, and other affiliated factions have gained credibility in the valuation, management, and planning of land resources. However, a need still stands for tools and policy measures that embed the value of ecosystem services, and introduce a holistic approach to landscape ecology into decision making frameworks (Daily, Alexander and al. 1997, 15).

This thesis contributes to the integration of environmental and ecological considerations into traditional land-use planning and decision-making processes. It develops a heuristic that links ecological function and local land-use policy in order to help make coherent the complex dynamics of ecological systems, and simplify the process of developing policies, regulations, and ordinances that may protect them. Chapter Four develops this framework and heuristic.

CHAPTER 4

A HEURISTIC FOR LINKING LOCAL LAND-USE POLICY AND ECOLOGICAL FUNCTION

“We straightened streams. We filled wetlands. We built levees along rivers. We tried to eliminate fire. We exterminated large predators. Today we are literally paying the price for wetland loss, soil erosion, massive floods, pest explosions, and ‘forestlessness.’ We know many of the standards are misguided, but society finds itself painted into a corner.”

– Richard T. T. Forman

INTRODUCTION

As stated in the introduction of this document, the last forty years of research have offered significant strides in our understanding of the importance of ecological systems and the functional value of land. However, what we still lack today is an inclusive approach that harnesses and organizes the ecological information associated with these systems and services, and links policy to their preservation and maintenance over the long-term. As such, this heuristic was created to facilitate ecological considerations at the local policy level, and to provide direction to local land-use planners and policymakers interested in integrating ecological considerations into planning and policy.

Literature on ecosystem services

In preparing for the development of this heuristic, a great deal of literature was reviewed on ecosystem services, ecosystem management, and landscape ecology. Throughout this research I sought to understand the foundational ecosystems processes from which humans benefit and are able to sustain healthy lives. What I have discovered is that ecosystems, and the services they provide, are highly complex and dynamic, and human understanding and explanation of such systems is still emergent. Regardless, sufficient data

is available, which address the processes and components of ecosystems, and organizes such data into useable frameworks.

Principal research reviewed for the purpose of organizing and structuring the heuristic include such models as Ecosystem Service Districts; the Ecosystem Services Framework; the Millennium Ecosystem Assessment classification of ecosystem services; the de Groot et. al. Typology for the Classification of Ecosystem Function, Goods and Services; the National Parks Conservation Association Natural Resources Assessment and Ratings Methodology, and the Harwell et. al Framework for an Ecosystem Integrity Report Card. Each of these resources informed some aspect of my heuristic model. More than any other resource however, the de Groot et. al. Typology for the Classification of Ecosystem Function was the single-most influential piece of research from which I was able to devise the start to my heuristic framework.

The *Typology for the Classification of Ecosystem Function* (de Groot, Wilson and Boumans 2002) presents a conceptual framework, developed in order to make possible, the comparative ecological economic analysis of the value of goods and services provided by natural and semi-natural ecosystems. The framework describes and classifies twenty-three different ecosystem functions, twenty-one of which are presented in Chapter Three. Table 1 of this document. This typology was foundational to the framing of my heuristic in that it offered me the first view of the vast and complex ecological services organized into distinct categories, and associated with processes and components. These categories, as defined by de Groot et. al includes regulation functions, habitat functions, production functions, and information functions.

The *Millennium Ecosystem Assessment classification of ecosystem services* (Alcano, et al. 2003) is the next most-influential in the development of my heuristic. The Millennium Ecosystem Assessment (MA) views ecosystem services as the benefits people obtain from ecosystems, with biodiversity being the source of many ecosystem goods and services. Their definition relies strongly upon the work of Dr. Robert Costanza, and Gretchen Daily – two significant researchers in the field of ecosystem services.

The MA definition follows Costanza and his colleagues in including both natural and human-modified ecosystems as sources of ecosystem services, and it follows Daily in using the term “services” to encompass both the tangible and the intangible benefits humans obtain from ecosystems. (Alcano, et al. 2003, 56)

The MA classifies ecosystem services along functional lines within the Millennium Assessment, and uses categories of provisioning, regulating, cultural, and supporting services. The MA framework differs from other frameworks in that it explicitly includes multiscale considerations. “Assessments conducted at different geographic and temporal scales will inevitably focus on different issues and reach different conclusions” (Alcano, et al. 2003, 42).

The *Ecosystem Services Framework (ESF)*, as presented by R.K. Turner and G.C. Daily, highlights the long-term role of healthy ecosystems in the sustainable provision of human well-being, economic development, and poverty alleviation. Recognizing that the world is faced with unprecedented and intensifying pressures to deplete natural resources, traditional arguments of conservation are not sufficient to protect vital ecological systems, nor do those arguments capture the absolute dependence of human well-being on “natural capital”. As such, the ESF offers an analytical and practical decision-making framework that aids in capturing the benefits of ecosystem services, and can help guide decision making processes, assisting in making ecosystem conservation a compelling moral and economic choice. There are four key elements of the Ecosystem Services Framework; these include a.) identification of ecosystem services, b.) characterization of services, such as ecological and economic attributes, c.) the establishment of safeguards based on the desired mix of ecosystem service production and means of securing such production, and d.) monitoring the services / evaluating the safeguards (G. Daily 2000, 337). As with the Millennium Ecosystem Assessment framework, the ESF also recognizes the maintenance of biodiversity as an intermediate and final ecosystem service.

Based on the U.S. Man and Biosphere project on ecosystem management, *The Framework for an Ecosystem Integrity Report Card* (Harwell, et al. 1999) was developed to help managers address the effectiveness of management decisions, in order to recommend effective source control policies that result in ecosystem recovery and sustainability. The proposed framework is arranged hierarchically, and is structured as follows: the highest tier

states the environmental goals; the second tier, objectives; the middle tier defines the essential ecosystem characteristics (EECs), which capture a limited number of major ecological features of a given ecosystem; the next lower tier, ecosystem endpoints, reflects those ecological attributes that, if changed, would alter the integrity of the ecological system; and finally ecosystem measures comprise the last tier, and reflect those attributes that require monitoring over time in order to characterize the state of ecosystem endpoints.

Lastly, the *National Parks Conservation Association Natural Resources Assessment and Ratings Methodology* was developed to support the goal of the National Park's Conservation Association's Center for State of the Parks in providing timely information on park natural and cultural resource conditions. In that aim, the natural resource assessment methodology integrates a range of information about the ecological and anthropogenic conditions that affect a park's natural resources. The principal task of the methodology is to evaluate the integrity of natural systems, with special emphasis on biological diversity. The development of this methodology and many of its conceptual features rely upon previous works, such as *The State of the Nation's Ecosystems*, produced by the Heinz Center, and the resource examination protocol of the Nature Conservancy – the “Five S’s”. The Five S’s are defined as systems, stressors, sources, strategies, and synthesis (National Parks Conservation Association 2003).

Goals of the heuristic

An underlying goal of this heuristic is that it be functional, simple, and straightforward in its use. This, I feel, is essential to its success in traditional land-use planning realms where planners, managers and developers may not be well-versed in landscape ecology or familiar with different ecological processes. As such, this heuristic aims to inform these stakeholders (planners, managers, developers) of the processes and functions present on each tract of land, zoned and considered for development, and offer a variety of land-use policies that may protect essential ecological functions while still accommodating development. This heuristic is not a fully-developed rubric. It does not grade or score the integrity of ecological functions and systems. The task of assigning gradable criteria to this heuristic is far from trivial and would require a level of understanding

of ecosystem structure and scale dependencies that is beyond the scope of this research. Instead, this heuristic acts as the foundation for further developments, and shortens the gap between ecological understanding and policy creation.

Underlying assumptions

An underlying assumption of this research and heuristic is that by protecting ecological functions, we correspondingly uphold some degree of ecological integrity. Five goals of ecosystem integrity are frequently endorsed. These include: 1.) maintaining viable populations of native species in situ, 2.) representing, within protected areas, native ecosystem types across their natural range of variation, 3.) maintaining evolutionary and ecological processes like disturbance regimes, hydrological processes, nutrient cycles, etc., 4.) managing land and ecosystems over periods of time long enough to maintain the evolutionary potential of species and ecosystems, and 5.) accommodating human use and occupancy within these constraints (Grumbine 1994, 31). It is the position of this research that the stressors that degrade ecological integrity are human in origin, and relate mostly to the anthropogenic manipulation of the environment through land-cover change and development. Furthermore it is assumed that, “independent of human influence, ecosystems will self-regulate, evolve and change, ultimately maintaining ecological integrity as a consequence of their nature” (National Parks Conservation Association 2003, 4).

Application and use

The proposed heuristic can be applied to the local land-use and decision making process. It offers a conceptual starting point for decision-makers, land-use managers, and policymakers in order to incorporate fundamental ecological processes and considerations into planning and zoning resolutions geared toward residential development and growth. The heuristic is designed as an Excel spreadsheet. It is meant to be a flexible tool that can be customized to reflect the specific ecological features of a land parcel / tract, as manifested by the location’s Level III and Level IV ecoregion. In the case of this particular research study, the heuristic has been designed according to the ecological region and major land-cover features of Charlotte, North Carolina and the Southern Outer Piedmont region. In using this

heuristic as a tool, a land-use manager or policymaker could scroll through each of the major land-cover and land-use features, and see a relevant list of ecological functions associated with that land-cover feature. Each of the ecological functions presented are described in detail throughout this chapter. The heuristic is also designed such that it can assist the user in keeping track of the particular land parcel / tract for which the heuristic was consulted. At the top of the heuristic is a label that can be filled out with reference to the location, identification of the particular land parcel or tract, and the relevant regional context, being the associated ecoregions, and their corresponding major land-cover types. Within the heuristic, a tracking utility exists under each ecological feature category heading; the utility displays a box for “yes”, “no” and “remarks”, which enables the user to keep track of the presence or absence of specific ecological features. For demonstration purposes, these boxes have been arbitrarily checked in the heuristic displayed at the end of this chapter.

THE HEURISTIC FRAMEWORK EXPLAINED

Layout and structure

The layout and structure of this heuristic link ecological function with policy. The layout follows a designed template that displays and explains ecological feature and function, presents a variety of tools and resources that can be used to assess the presence or absence of such features and functions, and links to a series of sample policies for the preservation of such functions. At the closing of the chapter, the actual heuristic is presented, making evident the structure described herein.

Ecological features and functions is a structural category that hosts all of the organized ecological information presented within the heuristic. Four organizational groups are displayed within the ecological features and functions category; these groups include land-cover features, soil, slope, and green infrastructure. Each of these groups is relevant to the overall ecological workings of land. Within the heuristic these groups are color-coded and contain a list and description of the primary ecological functions associated with that group. The intention of this category is to neatly summarize in a few short words the primary

role and significance of each of the listed functions. A limited but inclusive set of descriptions explain the overall ecosystem function and process.

For example, “land-cover features” is the first group presented under the ecological features and functions category. The land-cover feature group is comprised of five subcategories that indicate the primary land-cover types and land uses within the ecoregion; these include: forest cover, active agricultural and pasture land, transitional land, surface waters and wetlands, and altered landscapes (Henderson and Walsh 1996, 139). The suite of ecological functions displayed in this category include: habitat function, regulation function, support function, provisioning function, and human experience function. Each of these will be explained in more detail beginning with page fifty-four of this chapter.

The next structural category, resources, acts as a reference list. It offers an overview of a variety of resources and tools that can help the user determine the presence, absence, extent, and possible condition of each of the different land features. Each of the four main ecological features groups is associated with a tailored list of resources.

Finally, policies, ordinances, strategies provide sample policies and regulations relevant to each of the identified groups and associated ecological functions. While not exhaustive in scope, the goal of this part of the heuristic is to provide model concepts and suggested language in order to help close the gap between ecological science and policy. Specific policies are reviewed and discussed in detail in Chapter Five.

Lastly, at the bottom of the heuristic is a separate category titled additional resources. The purpose of this category is to inform the user of additional resources, agencies and organizations, which may add value to local planning efforts by providing ecological information, aiding in regional insight, or by the building of partnerships for land management and stewardship.

The remainder of the chapter will offer a detailed look at the ecological functions associated with land, in order to make apparent the fundamental importance of these systems to nature and human well-being.

IN DETAIL: ECOLOGICAL FEATURES

Land-cover features

As mentioned above, the land-cover features presented in the heuristic are based upon the major land-cover and land-use categories for the Piedmont region, which include forest cover, active agricultural and pastures land, transitional land, surface waters and wetlands, and altered landscapes. In the Charlotte area, pine, mostly loblolly and shortleaf, predominate on former field sites and pine plantations; mixed oak forest can be found in areas less heavily altered (Griffith, et al. 2002). Active agricultural and pasture land includes mostly that of hay, cattle, dairy, and poultry production with some barley, oats, and wheat (U.S. Environmental Protection Agency 2003). Transitional land is comprised of abandoned cropland, pasture, or orchard, or land in early phases of forest succession (Godfrey 1997, 135). Surface waters include streams, lakes, ponds, springs, seeps and wetlands.³ Altered landscapes may include drained wetlands, retired cropland, former forest, or diverted hydrologic systems and drainage patterns; altered landscapes should be evaluated prior to any approval on proposed development plans.

Soil

Soil is an important and valuable resource that affects many aspects of a region ranging from habitat suitability to planning and development requirements. Soil is unconsolidated mineral and organic particles that originate from the breakdown of solid rock and decaying organic material. The soil formation process creates soil layers, known as horizons, of which up to six layers are typical. Soil information, such as texture, depth, bulk density, porosity, and organic matter content, are used in a variety of applications including resource protection planning, agricultural management, site design, stormwater management, erosion control, and building foundation design (Steiner and Butler 2007, 81). In order to be

³ Unfortunately, the river basins in the Piedmont have the highest percentage of impaired waterways, and as the most heavily populated and industrialized region in the state, the Piedmont places the greatest demands on clean water for consumption, industrial uses, and recreation. Piedmont wetlands have mostly been affected by the conversion from wetland to agricultural land, and the creation of reservoirs to meet consumption demands of the rapidly growing urban population (North Carolina State University Cooperative Extension 1997).

ecologically viable, soils must contain nutrients and trace minerals that originate from the underlying parent material and cycle with organic matter.

Soil is considered a non-renewable resource because of the extremely long time scales associated with its formation. Because of this, soil loss due to erosion and degradation is a serious concern. During development and construction activities it is common for soil to undergo compaction, which is a physical form of degradation. Another form of soil degradation is the accumulation of xenobiotic agents; xenobiotic agents are those that are foreign to a biological system and may include artificial substances that did not exist prior to anthropogenic influence (National Parks Conservation Association 2003, 16). Unfortunately, in the United States, many of the most productive soils in the nation have been “buried forever beneath tons of concrete and asphalt roadways, parking lots, house foundations, and massive warehouse complexes and shopping malls” (Honachefsky 2000, 94).

Prior to development, two essential soil mechanics must be evaluated; these include soil compaction and soil shear strength (Steiner and Butler 2007, 81-82). Other limiting factors of soil include shallow depth to bedrock, high seasonal water table, perched water tables, or altered subsurface soil layers that restrict water flow and root penetration. As a result, the review of soil maps is crucial from both ecological and development perspectives (Honachefsky 2000, 91). Soil mapping has been done for most if not all of the U.S. by the National Resource Conservation Service (NRCS), which has published soil surveys on a county-by-county basis, including maps and written descriptions.⁴ Soil survey maps delineate regional soil groups, and provide a range of information on the suitability of individual soils for a variety of uses, including agriculture, forestry, wildlife habitat, site development, wastewater disposal, use in construction materials, and water management. As such, reviewing soil survey information is an important component for most planning studies, at both the watershed scale and local project scale. Although the soil survey provides a good

⁴ One characteristic of soils which the NRCS soil surveys overlook is the calculation of each soil to effectively capture and recharge precipitation. The state of New Jersey has actually developed such a methodology to account for these calculations and has made it available for public consumption. This tool is particularly useful to municipalities which are dependent upon locally-derived groundwater, as it enables them to delineate prime recharge areas within the jurisdiction so that they may be addressed and protected in a comprehensive plan. The report is known as “A Method for Evaluating Groundwater Recharge Areas in New Jersey”, published by the New Jersey Geological Survey (NJGS) (Honachefsky 2000, 93-94).

start to understanding and evaluating soils, an onsite *in situ* evaluation is often the best decision, as soil texture can vary over short distances and depths (Honachefsky 2000, 93-94).

Slope

Topography is an important consideration in both development and ecological function. Slope affects the design of roads and structures, and also dictates land stability and erosion potential. Sloped land may host unique habitat and vegetation arrangements as a result of microclimates, differences in soils, and distinct disturbance regimes. Ecological concerns associated with slope and development include adverse effects on water quality as result of increased erosion and sedimentation, viewshed concerns, drainage and stormwater runoff considerations, soil stability and landslides, and impacts on hydrology and soil nutrients (McElfish 2004, 124).

Many local regulations will stipulate maximum allowable slope possible for development. This is often between five percent and ten percent (Steiner and Butler 2007, 79). Steep slopes are often classified as having a grade of 15 percent or greater; this means there is 15 feet of increased elevation over each 100 feet in horizontal distance (New Hampshire Department of Environmental Services 2008, 176). In instances where slope is greater than this, and development is approved to proceed, site grading may be required. Site grading involves either removing or adding soil to create the desired slope, and is associated with a range of environmental concerns.

An important characteristic of slope is aspect. Slope aspect is the direction in which a sloping land surface faces relative to cardinal points, measured in compass degrees. In combination slope, aspect, and relief tend to affect microclimate conditions. Aspect is also important in assessing solar orientation, either to maximize passive solar gains for building construction, or to determine how solar illumination may support or restrict agricultural use of land (Steiner and Butler 2007, 80).

Robert Olshansky, an expert of hillside development, outlines ten factors important to slope development and regulation. First is topography; a community should be in consensus as to what constitutes a “steep slope.” As stated earlier, many communities define steep slope

as having a 15 percent gradient or greater. Second, slope stability must be considered – both prior to development and also after grading and manipulation has occurred. Development will change slope equilibrium, putting it at far greater risk to experience erosion or landslides. Third, water drainage is an important factor of slope stability as well; it must be understood what impacts changes to slope may have on drainage patterns. This requires collecting drainage and erosion data to identify major watersheds and drainage courses, areas prone to flooding, and facilities and structures downstream of hillside drainageways. Changing drainage patterns and possibly increasing sedimentation due to erosion can degrade water quality. Fourth, infrastructure must be a consideration of steep slope development; extending infrastructure to hilltop neighborhoods can be expensive to implement and maintain, and is also difficult to engineer. Fifth, access is yet another factor; access roads and driveways can be especially challenging in slope development; rules of safety require roads and driveways on steep slopes to have more curves and switchbacks than those of flatter terrain, which means more impact on the land and hillside and the possibility of greater erosion and runoff. Sixth, hillside and slope development should induce closer attention to detail, and the inclusion of a natural resources inventory, as animal species often take refuge on undeveloped hillsides, particularly when preferred native habitat has already been destroyed or developed. Seventh, depending on the location the sloped area, fire hazards may be of concern, as controlling fires on hillsides rather than on flat areas is notably more difficult. Eighth, when developing regulations and ordinances, the recreational value of slopes and hillsides may also be a relevant point of consideration; slopes and hillsides afford many popular recreational activities like hiking, climbing, and wildlife observation. Ninth, aesthetics is another related concern, although developing regulations strictly on this rationale is difficult. And finally tenth, slope may do well to serve as open space in terms of slope management and regulation; opportunities may exist to include slopes in greenways, wildlife habitat preservation and conservation areas (New Hampshire Department of Environmental Services 2008, 176-178).

Green infrastructure and spatial configuration

“The size, shape, and spatial relationships of land-cover types influence the dynamics of populations, communities, and ecosystems” (Dale, et al. 2000, 654). As such, green infrastructure addresses the spatial configuration of land-cover and includes three crucial spatial aspects of land configuration – matrix, corridor, and patch. Each of these plays a different but collaborative role in the overall operation of land systems and ecological functions, and is highly dependent upon and related to scale. The matrix, as previously described in Chapter Three, covers an extensive area and influences landscape-scale and regional dynamics. Matrix land-cover acts as a source for native plants, and it also helps sustain keystone predators that are critical to the structure and regulation of species and food web dynamics (Forman 1995, 277). Generally, if a land tract includes matrix vegetation and habitat, it should be considered for incorporation in site design as a protected landscape element.

Patches are spatial units at the landscape-scale that are surrounded by matrix. Patches tend to be relatively homogenous, but different from the surround landscape, and may be connected to other patches by corridors (Steiner and Butler 2007, 83). Patch attributes like size, shape, and location are thought to impact such ecological components as biodiversity, soil, and water. Generally, large patches are thought to be better than small ones because comparatively they are able to provide more significant environmental benefits, like water quality protection and the ability to offer habitat and shelter for interior and multihabitat species (Forman 1995, 47). “Patch size, shape, and distribution of habitat across the landscape influences population sizes and dispersal patterns and can determine whether the habitat will provide long-term support to a particular species” (National Parks Conservation Association 2003, 12). “Nodes” are particular patches with special conservation value due to high diversity or the presence of target species of interest (Steiner and Butler 2007, 83).

Corridors are areas that differ from surrounding land-cover, and permeate the land area in strips; corridors may be natural or man-made (Forman 1995, 145). They can be thought of as elongated patches that connect one patch to another (Steiner and Butler 2007, 83). Natural, vegetated corridors are of particular importance in maintaining ecological

integrity and processes, and provide five major landscape functions including: habitat, providing conduits for animal movement, and acting as filters, sources and sinks. The habitat function of a corridor is generally well understood, however it is not well documented in many areas. Edge and generalist species tend to predominate in corridors, however disturbance-tolerant, riparian, or the occasional interior species may at times be present in central pieces of certain corridors. Typically, rare and endangered species are absent from corridors except for those passing through, unless the corridor contains remnant native vegetation otherwise found in short supply in the surrounding area (Forman 1995, 150). Corridors provide channel movement, which helps to preserve adjacent land-cover; stream corridors move water, sediments, nutrients, and organic matter and terrestrial corridors move energy, wind, and seeds within and adjacent to their paths. Animals move along corridors in general dispersal, mating and migration movements (Forman 1995, 151). When corridors act as filters it means that they separate land areas, resulting in species composition differentiation and the possibility of higher total biodiversity. Corridors act as a source by providing a mechanism through which different objects – like animals, water, and people – may spread out into the matrix; therefore, the corridor as a source will have a range of effects on the matrix. Finally, opposite the concept of a corridor as a source is the corridor as a sink; instead of distributing objects into the matrix, the corridor may also sink or trap objects, preventing their dissemination or return to the matrix. For example blowing snow, soil, and seeds may be trapped in vegetated corridors; pesticides and water eroded particulates may accumulate in stream corridors; or animals may be killed attempting to cross a road or river (Forman 1995, 151).

Each of the five corridor functions described above is strongly affected by two structural attributes; these include width and connectivity (Forman 1995, 152-153). The width requirements of a corridor will vary depending on the objective, however in general wider corridors are thought to be better, as they likely enhance all five functions. Connectivity in a corridor relates to the number of gaps that break-up the corridor into segments; the fewer gaps the stronger the connectivity. As with width, higher levels of connectivity lead to higher levels of each of the five functions (Forman 1995, 156). It's important to note however, that the actual impact and success of corridors is debated among some ecologists:

For more than 20 years, conservation biologists have emphasized the potential benefits of connecting fragmented pieces of habitat with habitat corridors. However, a lack of empirical evidence regarding the success of corridors has prevented planners and land managers from recommending their use. Several studies now show that corridors work for certain species, but not all. As would be expected, species that tolerate human presence in general are best suited for corridors. Landscape ecologists and conservation biologists are split on the issue. Critics argue that reserves with elaborate corridors are expensive to construct and maintain, and probably do little to conserve biodiversity. Supporters counter that they may be the last and best hope for preserving large areas of habitat in an increasingly fragmented world. (Steiner and Butler 2007, 84)

This thesis adopts the perspective that corridors are an essential structural element; they are inherently vital to maintain continuity and connectivity throughout the natural landscape, and not to succumb to total fragmentation.

IN DETAIL: ECOLOGICAL FUNCTIONS

Generally, ecosystem function addresses biological, chemical, and physical processes that regulate and produce natural change. Ecosystem functions direct the flow of energy and matter into and through ecosystems and their uninterrupted functionality is essential for long-term ecosystem sustainability (National Parks Conservation Association 2003, 12). Many approaches have been taken in effort to organize and define the ecological functions and processes of landscapes and the services they provide. Many of these efforts have focused on the delineated goods provided by ecosystems, like seafood, game animals, timber, and pharmaceutical products. What is less appreciated are the fundamental ecosystem services that provide life-sustaining functions powered by the Earth's natural cycles (Daily, Alexander and al. 1997, 1). The latter is the focus of the ecological functions expressed in the heuristic, described in detail below.

Habitat functions

Ecological systems are the very basic foundation for all wild plants and animals; they are the living spaces and habitats essential for the provision of all ecosystem goods and services. Ecosystems offer refuge, reproduction, and migration habitat and thereby contribute

to the conservation of biological and genetic diversity, and evolutionary processes. The availability of this function is based upon physical attributes of the ecosystem niche within the biosphere, of which different requirements exist for different species groups (R. de Groot 2006, 177). The two primary functions of habitat, as defined by de Groot, Wilson and Boumans (2002, 400) are described below.

- Refugium function: Natural ecosystems provide living spaces for wild plants and animals, both for resident and transient (migratory) species. As such, natural ecosystems are essential to maintaining biological and genetic diversity on earth; they can be considered a storehouse of genetic information. To maintain the viability of this genetic library, built across 3.5 billion years of evolution, maintenance of natural ecosystems, as habitats for wild plants and animals, is of utmost importance.
- Nursery function: Many ecosystems provide the breeding and nursery grounds for species, which as adults, live elsewhere. These critical ecosystem areas are often unknown, or ignored, and as a result are transformed into more direct 'economic' uses; ecological and socio-economic results of such transformations can be disastrous.

Biodiversity is perhaps the paramount objective of habitat considerations; it exists across a range of organizational scales, from genes within localized populations of an individual species, to the variety of species in a habitat (the most common measure), and even further to the variety of habitats that form a regional landscape.

More than 80 percent of biologically important habitat types are under private ownership in the U.S. (Harte 2001, 951), placing them at risk of development. As a result of increasing anthropogenic pressures, huge areas of once ecologically healthy land and habitat are gradually being converted to land with little ecological value. Much degradation is a result of suburbanization and the vegetation planted on these renovated landscapes. This vegetation is often a.) nonnative or for other reasons provides unsuitable habitat for native wildlife, b.) unmatched to local climate conditions, and therefore may require scarce water resources, c.) incapable of moderating local climate, and d.) dependant on chemical pesticides and fertilizers. Fences, roads, water diversions, human presence, and other anthropogenic

factors interrupt habitat functions and disturb the movement of wildlife, the flow of water, and dispersal of plants (Harte 2001, 962).

Benefits to humans, as a result of the services of the habitat function, are sometimes difficult to pin point, often overlooked, and easily taken for granted. A fairly recent discovery acts as a prime example; in the San Francisco Bay area Lyme disease is relatively rare despite the fact that the tick vector is prevalent; the reason is the fence lizard. The fence lizard has a means of detoxifying ticks when they attach themselves to the reptile. However, as the Bay area continues to undergo land transformation as a result of development, the habitat of this lizard is disappearing. As it does, so too will this beneficial ecological service (Harte 2001, 951-952).

Regulation functions

Regulation functions relate to the ability of natural and semi-natural ecosystems to regulate essential processes and life-support systems. Direct and indirect benefits, such as clean air, water and soil, and biological control services, result from regulation functions (de Groot, Wilson and Boumans 2002, 395). Regulation functions help maintain ecosystems at different scales. At the biosphere level they provide and maintain the essential conditions for life on earth; as such, it can be said that regulation functions afford the necessary pre-conditions for all other functions. The primary regulation functions, featured prominently at the local scale, are displayed below (de Groot, Wilson and Boumans 2002, Alcano, et al. 2003).

- Water regulation / hydrologic regimes: Functional ecosystems can provide for the maintenance of natural irrigation and drainage, regulate channel flow, water purification and quality, water flow regulation, availability of water supplies, and the timing and magnitude of runoff, flooding, and aquifer recharge. These things are strongly influenced by changes in land-cover, including modifications that alter the storage potential of ecological systems, such as the conversion of wetlands, or the replacement of forests with croplands, or cropland with urban and suburban development.

- Erosion control: Erosion control and soil retention functions depend on structural aspects of ecosystems, particularly root systems and vegetation. Tree roots stabilize soils and foliage intercepts rainfall and prevents compaction and erosion of bare soil. These services are essential to agricultural activity and help prevent damage due to mass erosion, such as landslides and dust bowls.
- Biological control: Research suggests that more than 95 percent of all potential pests of crops and carriers of disease are controlled by natural ecosystem processes. Millions of years of evolutionary processes have resulted in biotic communities of natural ecosystems developing interactions and feedback mechanisms that have led to stable life-communities, and that prevent the outbreak of pests and disease. Changes in ecological systems may affect the balance of biological control.
- Climate regulation: Local weather and climate are the result of complex interactions between regional and global circulation patterns, influenced by local topography and vegetation. Changes in land-cover can affect temperature, humidity, and precipitation.
- Hazard mitigation / disturbance prevention: Ecosystem structure can dampen environmental disturbances like storms, floods, and droughts by providing storage capacity and surface resistance. Vegetation may act as an impact filter to severe winds and weather, helping provide safety for human life and built structures.
- Nutrient regulation and cycling: Life on earth relies upon the continuous cycling and recycling of roughly thirty to forty chemical elements occurring in nature. Basic nutrients like carbon (C), oxygen (O), and hydrogen (H), along with key macronutrients like nitrogen (N), sulfur (S), and phosphorus (P) are vitally important. A combination of supplementary macronutrients and trace elements, like iron (Fe), zinc (Zn) and others, are needed to maintain life; the availability of these nutrients is often a limiting factor of growth and occurrence of life. Structural and functional aspects of ecosystems facilitate nutrient cycling, such as soil organisms that decompose organic matter and release nutrients to plant matter, and the migration of

animals (birds, fish, and mammals) which distribute nutrients between ecosystems. Benefits derived from nutrient cycling correlate mainly to the sustenance of healthy productive soils. Note that de Groot, Wilson and Boumans (2002) recognize nutrient cycling as a regulation function, however the MA classifies nutrient cycling as a Support function; this is somewhat dependant on the time scale and the immediacy of its impact on people (Alcano, et al. 2003, 59).

- Pollination function: Essential to most plants for reproduction, including commercial crops, this ecosystem function is provided by wild pollinator species such as insects, birds, and bats. Without it, many plant species would go extinct, and the cultivation of most modern crops would be impossible. Note that the MA recognizes pollination as a support function (Alcano, et al. 2003).

Support functions

Support functions are those necessary for the production and maintenance of all other ecosystem functions and processes. They differ from other ecological functions in that their impacts on people are either indirect, or occur over extremely long periods of time; comparatively, changes in other ecosystem functions have a fairly direct, short-term impact on people. For example, humans do not directly use soil formation services however changes in this service would indirectly impact people through the loss of vegetation or crops. Examples of support functions are displayed below (de Groot, Wilson and Boumans 2002, Alcano, et al. 2003).

- Soil formation: Soil-formation is a very slow process; natural soils are generated at a rate of only a few centimeters per century. After erosion, soil formation and regeneration rates vary from one-hundred to four-hundred years per centimeter of topsoil created from bedrock. Soil eventually becomes fertile via the accretion of organic matter from plants and animals. Services derived from this function correspond to the maintenance of crop productivity and the function and integrity of natural ecosystems. Note that de Groot, Wilson and Boumans list soil formation as a regulation function.

- Nutrient cycling: As described above, benefits derived from nutrient cycling correlate mainly to the sustenance of healthy productive soils. Note that de Groot, Wilson and Boumans (2002) recognize nutrient cycling as a regulation function; however the MA classifies nutrient cycling as a support function.

Provisioning functions

The provisioning function provides goods and services, and readily-available renewable resources, which are obtained directly from ecosystems. These resources contribute to the ecological system and supply benefits for human use; food is a prime example of a product of the provisioning function. Food may include a range of products sourced from plants, animals and microbes. Today most foods are derived from cultivated crops and domesticated animals; however a significant portion of the global human diets still derives food from wild plants and animals. In the context of U.S. land resources, and for the purpose of this heuristic, food is not meant to address only cultivated agricultural land for the purpose of human consumption, but also includes food for animals. Fundamentally, the provisioning of food relates to the concept of primary production, or the flow of energy that originates from the sun's radiation and begins the process of energy transformation. Primary production reflects a net accumulation of energy and nutrients used by green plants; regarding the flow and transfer of energy, primary production is vital. The significance of primary production was well expressed by G. Tyler Miller, Jr., when he said, "three hundred trout are needed to support one man for a year. The trout, in turn, must consume 90,000 frogs, that must consume 27 million grasshoppers that live off of 1,000 tons of grass" (University of Michigan, Global Change Curriculum 2008). Freshwater is also a prime provisioning service; be aware that the provision of fresh water is linked also to the regulation function. Note also that provisioning functions are identified as production functions in the typology devised by de Groot, Wilson and Boumans (2002).

Human experience function

The human experience functions are the nonmaterial benefits obtained from ecosystems for spiritual enrichment, cognitive development, reflection, recreation, and

aesthetic experiences. Known in the Millennium Assessment as cultural services, and by de Groot, Wilson and Boumans (2002) as information functions, these functions provide humans with a vital connection to nature. “Because the longest period of human evolution took place within the context of undomesticated habitat, the workings of the human brain for gathering information and a sense of well-being are very strongly tied to the experience of natural landscapes and species diversity” (de Groot, Wilson and Boumans 2002, 401). Examples of human experience functions are displayed below (de Groot, Wilson and Boumans 2002, Alcano, et al. 2003).

- Aesthetic value: Many people find beauty and value in various aspects of ecological systems; this is demonstrated by people’s support for parks, preservation of scenic vistas, and economic implications, such as the higher cost of real estate near “attractive” settings.
- Spiritual / Cultural / Inspirational value: Natural ecosystems and elements offer a sense of continuity and understanding of our place in the universe. Religious experience is often connected to nature, and it provides an important basis also for folklore and local culture. Ecosystems also provide a rich source of inspiration for art, architecture, and more.
- Sense of place: Many people highly value a strong “sense of place” that connects them with their surroundings via recognizable features of their environment, including aspects of the ecosystem.
- Recreation function: Natural ecosystems offer places for rest, relaxation, and recreation. The range of aesthetic qualities, and the variety of landscapes offered by natural environments, provides many such opportunities for activities like walking, hiking, fishing, swimming, and nature study.

In summary, the capacity of ecosystems to provide human benefits and services will depend largely upon the related ecosystem processes, functions, and components that support

them. All ecological functions within a system are important, however, the integrity of the regulation and habitat functions are paramount.

THE HEURISTIC

The remainder of the chapter presents the heuristic in its entirety. The references associated with the heuristic, as marked by the numeric subsets, can be found in Appendix I.

LANDSCAPE FEATURES & ECOLOGICAL FUNCTIONS		
LOCATION LAND PARCEL / TRACT	Charlotte, North Carolina	** Some research indicates forests will decrease water supplies during both wet and dry seasons
REGIONAL CONTEXT ECO-REGION, LEVEL III AND IV MAJOR LAND COVER TYPES	Piedmont / Southern Outer Piedmont Forest, Agriculture, Developed Land, Transitional Land, Water	
ECOLOGICAL FEATURES & FUNCTIONS		RESOURCES
LAND-COVER FEATURES		POLICIES, ORDINANCES, STRATEGIES
FOREST COVER		
YES	NO	REMARKS:
		ASSESSMENT RESOURCES
		EXAMPLE POLICIES
Habitat Function		Aerial Imagery & Land Cover Maps
	<ul style="list-style-type: none"> Refugium function: Suitable living spaces for wild plants and animals. Nursery function: Suitable reproduction habitat for local & migrating animals. Biological diversity: Maintain biological and genetic diversity. Special consideration habitat: Habitat which serves keystone species, native vegetation, endangered species. 	<p>U.S. Geological Survey (USGS) 24 http://earthexplorer.usgs.gov</p> <p>U.S. Natural Resources Conservation Service (NRCS) Geospatial Data Gateway 26 http://datagateway.nrcs.usda.gov/GDGHome_StatusMa</p> <p>Google Maps 27 www.google.com/maps</p> <p>Multi-Resolutino Land Characteristics Consortium (MRLC) National Land Cover Database 28 http://www.mrlc.gov/index.php</p>
		Sample Policies for Habitat Function
		<ul style="list-style-type: none"> Core forest habitat areas should be identified and expressed explicitly on zoning maps. 10 (45) The evaluation of a tract's woodlands shall be undertaken by a forester or other qualified natural resources professional; a minimum of 60 percent of habitat shall be conserved in order to sustain long-term populations of area-sensitive species and rare species. 12 (14) Forest cover removed in connection with development shall be minimized; the retention of undisturbed forest particularly valuable for biodiversity, like riparian areas and corridors connecting to other forested habitat, shall be a priority. 10 (127) At least 200 feet of forest must be maintained from the perimeter of core habitat areas and construction-related disturbances; construction of homes should be avoided within 300 feet of important mast stands. 11 (194) Natural resource inventories and site assessments are required as part of developer application process; key areas for protection and associated buffers must be identified in site plan. 11 (194) <ul style="list-style-type: none"> Development, including roads, must be directed away from ecologically sensitive, or regionally important, land and habitat areas.
Regulation Function		Habitat & Environmental Attribute Data
	<p><i>Climate Regulation</i></p> <ul style="list-style-type: none"> Microclimate: Shade & moist conditions cool refuge and decrease local temperatures. 	<p>Forest Inventory and Analysis National Program 29 http://www.fia.fs.fed.us/</p> <p>GAP Analysis Program 23 http://www.nbil.gov/portal/server.pt/community/gap_</p>
	<p><i>Hazard Mitigation</i></p> <ul style="list-style-type: none"> Impact filter: Absorb and filter direct impact of severe wind & weather. Water retention: Root systems store and retain water to mitigate drought conditions. Land stabilization: Root systems provide structure and resist landslides. Absorption: flood conditions... 	<p>U.S. Natural Resources Conservation Service (NRCS) 25 www.nrcs.usda.gov/technical/dataresources/</p>
	<p><i>Hydrologic Regimes</i></p> <ul style="list-style-type: none"> Water purification and quality: Filter contaminants and excess nutrients benefitting water users. Flow regulation: Forest cover can regulate surface and groundwater flows, mitigating hazard events. Water supply: Forests can increase base flows during dry season** Aquatic productivity: Forests as protective buffer to upstream watersheds, the condition of which influence downstream lakes and ponds. Recharge: Forest soils soak up rain, recharging aquifers and releasing high-quality water for downstream use. 	<p>U.S. Natural Resources Conservation Service (NRCS) Geospatial Data Gateway 26 http://datagateway.nrcs.usda.gov/GDGHome_StatusMa</p> <p>State Natural Heritage Programs 30 http://www.natureserve.org/visitLocal/index.jsp</p> <p>NatureServe 31 http://www.natureserve.org/explorer/</p>
	<p><i>Erosion Control</i></p> <ul style="list-style-type: none"> Soil stabilization: Forest tree and vegetation roots hold soil together and anchor it in place. Aeolian filters: Forest trees and plants mitigate erosion from wind. 	<p>LandScope America 32 http://www.landscape.org/map/</p>
		Sample Polices for Regulation Function
		<ul style="list-style-type: none"> A range of woodlands conditions, from young stands to mature mixed forest, should be maintained as the diversity provide for services including ameliorating harsh microclimate conditions in summer and winter, acting as soil stabilizers, and buffering hazardous weather conditions. 13 (183) Forests which lie within the 100-year flood plain must be designated as a "vegetation and soil protection zones" (VSPZ), satisfying the following: 9 <ul style="list-style-type: none"> Construction impacts from site development shall not decrease the capacity of the VSPZ to support desired vegetation (forest) . Construction activities outside VSPZ shall not change drainage patterns nor alter microclimate effects within VSPZ. Forested riparian buffers must be maintained or enhanced 150 feet from water's edge, on both banks, for permanently flowing water bodies. All forest vegetation not approved for removal must be protected by adequate marking, temporary fencing around the drip line of trees, or temporary transplanting as necessary. 11 (287) Forests shall be used, when possible, as stormwater management structures to intercept, infiltrate, and treat runoff from planned developed areas distributed throughout the site. 11 Reforestation efforts must occur within two growing seasons of a completed development project, and bond must be posted to assure performance of reforestation or afforestation efforts. 10 (128) Any subdivision or land development plan submitted for approval must contain forest delineation and include an acceptable forest conservation plan, providing for retention and reforestation, subject to local government goals. 10 (128)

<p>Pollination</p> <ul style="list-style-type: none"> Support for pollinators: Forests biotopes provide preferred habitat of bumblebees (<i>Bombus affinis</i>) which is an important key pollinator species; bees provide better pollination, improving regeneration of trees and biodiversity. 8 <p>Biological Diversity & Control</p> <ul style="list-style-type: none"> Biological diversity supplies the genetic and biochemical resources essential to sustain life. Species maintenance: Forests may support keystone species, native vegetation, or species important for biodiversity. 	<p>Landfire 33 http://www.landfire.gov/</p> <p>Regional Landscape Maps</p> <p>U.S. EPA Western Ecology Division 34 http://www.epa.gov/wed/pages/ecoregions/level_iii_iv.</p> <p>U.S. Natural Resources Conservation Service (NRCS) Geospatial Data Gateway 26 http://datagateway.nrcs.usda.gov/GDGHome_StatusMa</p>	<ul style="list-style-type: none"> Ordinances shall stipulate the compensatory mitigation of any forest cover lost on-site when possible; priority / preferred areas of reforestation shall be specified based on ecological and biological criteria. 10 (128) <ul style="list-style-type: none"> When on-site reparations are not possible, off-site ecological priority areas will be considered (such as riparian areas). Developers may be required to afforest non-forested development areas in situations where existing forest cover is minimal. 10 (128) 						
<p>Human Experience Function</p> <ul style="list-style-type: none"> Aesthetic value: Forests are places of beauty. Spiritual / Cultural / Inspirational: Forests provide the physical and symbolic venue for cultural & spiritual practice and self-reflection. Recreation function: Forests provide access to nature for walking, biking, exploring, camping and more. Sense of place: Forests offer 'sense of place' associated with recognizable features of the environment. <p>Support Function</p> <p>Soil Formation</p> <ul style="list-style-type: none"> Soil contribution: Forest organic litter contributes to the formation of the organic layer profile. Temperature: Maintenance of soil temperature for biological control. <p>Nutrient / Biogeochemical Cycling</p> <ul style="list-style-type: none"> Nutrient mobilization: Forest tree roots mobilize nutrients. Macronutrient processing: Forest trees cycle phosphorus & nitrogen to surface and organic soil layers. Nutrient supply: Organic leaf litter decomposition adds nutrients to forest floor. 	<p>Pollinator Maps</p> <p>Distribution Maps of Important Pollinator Species http://www.natureserve.org/getData/pollinatorMaps.js</p> <p>Biological Diversity & Control Data</p> <p>Purdue National Agricultural Pest Information 36 http://pest.ceris.purdue.edu/stateselect.php</p> <p>U.S. Animal and Plant Health Inspection Service 37 http://www.aphis.usda.gov/</p> <p>Cornell University Biological Control 38 http://www.nysaes.cornell.edu/ent/biocontrol/</p> <p>Visual Assessment / Walk-about</p> <p>Local Foresters & Natural Resource Specialists</p>	<p>Sample Policies for Human Experience Function</p> <ul style="list-style-type: none"> Subdivision ordinance shall require applicants to submit development plans which include natural areas, walking trails, and other approved measures which serve the interest of human interaction with nature. 14 Open space standards apply to all major residential subdivisions and land developments. 10 (60) <ul style="list-style-type: none"> Site calculations and resource protection standards shall be used to develop open space ordinances; ordinances should align when possible with critical resource areas and secondary conservation areas for protection. On predominantly wooded sites, developers shall be required to conduct tree surveys, noting trees over a certain diameter (12 inches) by species; identified specimen and corresponding drip lines shall be protected from disturbance and removal. 13 (58) <p>Sample Policies for Ecosystem Support Function</p> <ul style="list-style-type: none"> Site disturbance must be minimized to only those areas reasonably required for construction activities; project disturbance area must be depicted on site plans submitted as plan review process. 11 (163) <ul style="list-style-type: none"> Forest and associated vegetation outside of direct project disturbances must be maintained and protected during construction and post development. No ground disturbed as a result of site construction and development shall be left as bare soil upon project completion; area must be subsequently planted with a combination of living native vegetation and forest species. 11 (163) Developers must provide adequate protection of mature trees during and after construction; important mast stands and associated vegetation must be clearly marked, including area hosting the drip line of the tree(s). 11 (195) No construction materials are to be stored over tree root zones 						
<p>LAND-COVER FEATURES</p>								
<p>ACTIVE AGRICULTURAL & PASTURE LAND</p>								
<table border="1"> <thead> <tr> <th>YES</th> <th>NO</th> <th>REMARKS:</th> </tr> </thead> <tbody> <tr> <td></td> <td></td> <td></td> </tr> </tbody> </table>	YES	NO	REMARKS:				<p>ASSESSMENT RESOURCES</p>	<p>EXAMPLE POLICIES</p>
YES	NO	REMARKS:						
<p>Provisioning Function</p> <p>Food</p> <ul style="list-style-type: none"> Food resources: Active agricultural land provides local food for humans and animals. 	<p>Aerial Imagery & Land Cover Maps</p> <p>U.S. Department of Agriculture NRCS - Acres of Prime Farmland, 1997 39 www.nrcs.usda.gov/technical/NRI/maps/meta/m4983.h</p> <p>U.S. Natural Resources Conservation Service (NRCS) Geospatial Data Gateway 26 http://datagateway.nrcs.usda.gov/GDGHome_StatusMa</p>	<p>Sample Policies for Provisioning Function</p> <ul style="list-style-type: none"> Subdivisions planned for active agricultural or pasture land are required to preserve at least 51 percent of the land tract for continued active agricultural purposes. 10 (48) <ul style="list-style-type: none"> Language of the ordinance should be written to allow for uses on the agricultural parcel which are consistent with conservation goals, so that the lands could be wooded, contain wildlife areas, horticultural areas, and other compatible uses. Ordinances should be certain to accommodate the appropriate size for residual agricultural activities; failure of adept size results in "farmettes" which cannot support farming economically and contribute to fragmentation. 						

<p>Support Function</p> <p><i>Nutrient Regulation</i></p> <ul style="list-style-type: none"> Nutrient retention function: Minimum tillage practices improve soil structure and increase nutrient retention. Nutrient cycling: Decomposition of plants accounts for majority of nutrients recycled through ecosystems. 7 <p>Regulation Function</p> <p><i>Biological Diversity & Control</i></p> <ul style="list-style-type: none"> Heterogeneity: Agricultural land may contribute spatial & landcover heterogeneity thereby aiding in biodiversity. <p>Human Experience Function</p> <ul style="list-style-type: none"> Sense of place: Farmland may offer 'sense of place' associated with recognizable features of the environment. Aesthetic value: Farmland may be associated with scenic vistas and preferred aesthetic settings. 	<p>Multi-Resolutino Land Characteristics Consortium (MRLC) National Land Cover Database 28 http://www.mrlc.gov/index.php</p> <p>U.S. Geological Survey (USGS) 24 http://earthexplorer.usgs.gov</p> <p>Biological Diversity & Control Data</p> <p>Purdue National Agricultural Pest Information 36 http://pest.ceris.purdue.edu/stateselect.php</p> <p>Cornell University Biological Control 38 http://www.nysaes.cornell.edu/ent/biocontrol/</p> <p>Environmental Attribute Data</p> <p>GAP Analysis Program 23 http://www.nbil.gov/portal/server.pt/community/gap_</p> <p>U.S. Natural Resources Conservation Service (NRCS) 25 www.nrcs.usda.gov/technical/dataresources/</p> <p>State Natural Heritage Programs 30 http://www.natureserve.org/visitLocal/index.jsp</p> <p>LandScope America 32 http://www.landscape.org/map/</p> <p>Visual Assessment / Walk-about</p>	<ul style="list-style-type: none"> Authorizing low-intensity home-based businesses in agricultural districts can assist in maintaining the economic viability of farming and conservation uses. 10 (56) <p>Sample Policies for Support Function</p> <ul style="list-style-type: none"> No development may occur, and no restrictions may apply, on at least 60% of the land area which may prevent it from being easily converted back to farmland for agricultural production if necessary. 9 The subdivision of agricultural land must be done under strict oversight; development activities and land uses for retired / non-active agricultural land which would render the land permanently unusable for agricultural purposes, and biodiversity conservation shall be prohibited. 10 (45) Soils defined by the NRCS as prime farmland, unique farmland, or farmland of statewide importance shall not be stripped from an off-site location for important and use on site of interest. 9 <p>Sample Policies for Regulation Function</p> <ul style="list-style-type: none"> In the event open spaces exist on adjacent lands / properties, proposed subdivisions planned for agricultural land must provide a connection to this space, if possible. 10 (49) Areas planned and / or zoned for development, which contain prime farmland, unique farmland, or farmland of statewide importance, must designate and delineate at least 60% of the land area as a "vegetation and soil protection zone" (VSPZ) requiring the following: 9 <ul style="list-style-type: none"> Not more than 10 percent of the total area of a VSPZ may contain development, and only minimal impact development shall be approved. 9 "Vegetation and soil protection zones" must be physically delineated during construction processes as to protect the land from construction equipment, parking, storage of materials, etc. 9 <p>Sample Policies for Human Experience Function</p> <ul style="list-style-type: none"> In designated farm communities and resource preservation districts, cluster-style subdivisions are required for new land development; subdivision may be grouped on to no more than 20% of the site. 10 (54) Agricultural land should be protected and preserved in large contiguous blocks in order to maintain a "critical mass" of farms and agricultural land. 16
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LAND-COVER FEATURES

TRANSITIONAL LAND (abandoned cropland, pasture, or orchard; land in early phases of forest succession)

YES	NO	REMARKS:	ASSESSMENT RESOURCES	EXAMPLE POLICIES
		<p>Habitat Function</p> <ul style="list-style-type: none"> Refugium function: Living spaces for wild plants and animals. Biological diversity: Transitional land contributes to biological and genetic diversity and abundance. Nursery function: Transitional land may offer suitable reproduction habitat for local and migrating animals and birds. 	<p>Aerial Imagery & Land Cover Maps</p> <p>Multi-Resolution Land Characteristics Consortium (MRLC) National Land Cover Database 28 http://www.mrlc.gov/index.php</p> <p>U.S. Geological Survey (USGS) 24 http://earthexplorer.usgs.gov</p> <p>U.S. Natural Resources Conservation Service (NRCS) Geospatial Data Gateway 26 http://datagateway.nrcs.usda.gov/GDGHome_StatusMa</p>	<p>Sample Policies for Habitat Function</p> <ul style="list-style-type: none"> Development applications for previously forested land may not be submitted for approval until five years has passed since the last clearing of land. 10 (127) Control and manage known invasive plants found on site. 9 Local patterns of succession should be evaluated and estimated, with the help of local resource specialists, for its role in site development across 20, 50, or 100 years. 3 (61)

Regulation Function			Sample Policies for Regulation Function		
<i>Hydrologic Regime</i>	<ul style="list-style-type: none"> Recharge: Soils and vegetation soak up rain, recharging aquifers and releasing high-quality water for downstream use. 	Habitat & Environmental Attribute Data GAP Analysis Program 23 http://www.nhii.gov/portal/server.pt/community/gap_ State Natural Heritage Programs 30 http://www.natureserve.org/visitLocal/index.jsp LandScope America 32 http://www.landscape.org/map/ Visual Assessment / Walk-about	<ul style="list-style-type: none"> Performance zoning shall stipulate that former forest land, now open space in succession, must require forestation efforts in combination with development plans; reforestation should occur at a standard of 680 trees per acre, planted in a random pattern. 10 (60) 		
<i>Hazard Mitigation</i>	<ul style="list-style-type: none"> Flow regulation: May aid in regulating surface and groundwater flows, and mitigating hazard events. 		<ul style="list-style-type: none"> Planned post-construction vegetation introduced to the project area must be native plant and tree species. 10 (46) 		
<i>Biological Diversity & Control</i>	<ul style="list-style-type: none"> Heterogeneity: Transitional land may contribute spatial and landcover heterogeneity thereby aiding in biodiversity. 		<ul style="list-style-type: none"> Foliage height diversity must be maintained in order to provide for a range of habitat through layers of vegetation such as ground covers, shrubs, and trees. 11 (195) If floodplains are present, ordinances shall recognize and state the specific importance and function of floodplains; vegetated buffer area shall be defined within which no permanent structures are authorized; if vegetation is presently absent, native replantings are required within the zone. 10 (116) <ul style="list-style-type: none"> Consider the specification of retention trees or the percentage of land to be covered by specific types of vegetation within buffer area. 		
LAND-COVER FEATURES					
SURFACE WATERS & WETLANDS					
RIVERS & STREAMS					
YES	NO	REMARKS:	ASSESSMENT RESOURCES	EXAMPLE POLICIES	
Habitat Function			Hydrology & Watershed Maps	Sample Policies for Habitat Function	
		<ul style="list-style-type: none"> Refugium function: Suitable living spaces for wild plants and animals including hyporheic organisms; offer unique and changing habitats for flora and fauna. 18 Biological diversity: Maintain biological and genetic diversity. Nursery function: Offers suitable reproduction habitat for local & migrating animals and amphibians. 	U.S. EPA Surf Your Watershed 40 http://ctpub.epa.gov/surf/locate/index.cfm USGS Water Resources of the United States 41 http://water.usgs.gov/maps.html GeoData.gov - Federal, State & Local Geographic Data & Maps, Inland Water Resources 43 http://g0s2.geodata.gov/wps/portal/g0s/kcxml/04_Sj9S	<ul style="list-style-type: none"> Streams and rivers which have been artificially modified shall be rehabilitated: 60 percent of the full length of a stream or river channel within the project area must be restored to stable condition using geomorphologic and vegetative methods. Native plant communities, aquatic habitat, floodplain connections, water quality improvements. 9 	
Regulation Function			Flood & Hazard Maps	Sample Policies for Regulation Function	
<i>Hydrologic Regime</i>	<ul style="list-style-type: none"> Collection & conveyance: Rivers and streams collect and recirculate precipitation as part of the hydrological cycle. 	N.C. Division of Water Quality 44 http://portal.ncdenr.org/web/wq/ps/csu/maps	FEMA Mapping Information Platform 42 https://hazards.fema.gov/femaportal/wps/portal	<ul style="list-style-type: none"> Introduced hardscape surfaces and features shall include permeable-alternative materials for XX percent of the developed area. Planned developments are subject to 'Designed Landscape Water Requirement' (DLWR) evaluations for project sites, which must be in accordance with the local water budget, as estimated by the U.S. EPA water budget tool. (http://www.epa.gov/owm/water-efficiency/docs/home_final-waterbudget508.pdf) 9 (49) <ul style="list-style-type: none"> Turf grasses and other planned vegetation should be regionally appropriate to minimize post-establishment requirements for irrigation. 9 (50) Regulations prohibit the grading, removal of vegetation cover and trees, paving, and new structures within 50 feet of intermittent streambanks, 75-100 feet of perennial streambank in residential zoning districts. 10 (116) Existing site hydrology shall not be modified so as to disrupt on-site or adjacent surface waters; development applicants must provide proof that this standard can be achieved and maintained over time. 11 (163) <ul style="list-style-type: none"> Surface waters, including lakes, ponds, rivers, perennial and intermittent streams, wetlands, vernal pools, and natural swales shall be protected by a 50 foot no disturbance vegetated buffer. In the event stream and wetland crossings cannot be avoided, they must comply with state recommended design standards, to minimize impacts to flow and animal passage. Development applicant shall provide pre and post-development peak flow rates; these calculations must comply with ecological standards for hydrological integrity, as determined by scientific support and natural heritage information. 11 (164) <ul style="list-style-type: none"> Sites previously wooded in the last five years shall be considered undisturbed woods for the purposes of calculating pre-development total runoff volumes. 	
<i>Hazard Mitigation</i>	<ul style="list-style-type: none"> Runoff capture: Rivers / streams are the downgradient interceptors and collectors of precipitation that has escaped infiltration and absorption. Flood management: Floodplains surrounding rivers and streams absorb stream flow surge. Pollution control: Rivers also contribute to pollution control through transport and removal of pollutants and excess nutrients. 10 (6) 				
<i>Climate Regulation</i>	<ul style="list-style-type: none"> Microclimate: Rivers and streams offer moisture and decrease local temperatures. 		GAP Analysis Program 23 http://www.nhii.gov/portal/server.pt/community/gap_ State Natural Heritage Programs 30 http://www.natureserve.org/visitLocal/index.jsp		

		LandScope America 32 http://www.landscape.org/map/			<ul style="list-style-type: none"> Maximum effective impervious cover shall not exceed 10 percent of a development area or subdivision. 11
Human Experience Function		U.S. Fish & Wildlife Service, Species Report 46 http://ecos.fws.gov/tess_public/StateListing.do?state=al			Sample Policies for Human Experience Function
	<ul style="list-style-type: none"> Aesthetic value: Rivers and streams can be places of beauty. Spiritual / Cultural / Inspirational: Rivers / streams offer physical and symbolic venue for many cultural & spiritual practices, as well as self-reflection. Sense of place: Appreciation of the 'sense of place' associated with recognizable features of the environment. Recreation function: RSP&L provide exposure to nature for recreation in the form of fishing, swimming, exploring, boating and more. 	Local Hydrologists & Natural Resource Specialists			<ul style="list-style-type: none"> Watercourse shall be linked when possible to a larger regional plan for waterways, greenways, and protected areas; at a minimum the watercourses plan shall be prepared in consultation with the state's natural heritage program. 10 (120)
Support Function					Sample Policies for Support Function
<i>Nutrient Transport</i>	<ul style="list-style-type: none"> Contribute to pollution control through transport and removal of pollutants and excess nutrients. 18 (6) 				<ul style="list-style-type: none"> Stormwater management systems shall not discharge to surface waters, or subsurface waters within 100 feet of surface water, within a water supply intake protection area. 11
<i>Nutrient Cycling</i>	<ul style="list-style-type: none"> The metabolic activity of a river depends on nutrient cycling, and downstream coastal fisheries depend on the inflow of nutrients from rivers to replenish nutrient supply. 18 (6) 				<ul style="list-style-type: none"> Riparian zones are essential to nutrient cycling, as such these areas must be protected during construction and maintained post-construction; it shall be the responsibility of the developer to restore these areas with native vegetation on proposed development sites. <ul style="list-style-type: none"> Riparian buffers of 150 feet from water's edge, on both banks, shall be required for permanently flowing water bodies. This can be particularly important in regions where human activity drastically increases the nutrient load, such as heavily fertilized agricultural fields. 19
Provisioning Function					Sample Policies for Provisioning Function
<i>Fresh Drinking Water</i>	<ul style="list-style-type: none"> Rivers and streams may be the direct source, or contribute to, drinking water supplies. 				<ul style="list-style-type: none"> Rivers passing through wetland areas shall not be obstructed or diverted for any reason. 18 (6)
<i>Food</i>	<ul style="list-style-type: none"> Rivers and streams may host local fisheries and act as a food source for animals. 				<ul style="list-style-type: none"> Drinking Water Protection Overlay Districts may be used to identify, regulate and protect surface waters, the primary and secondary buffer protection zones associated with them, and perennial surface waters leading to drinking water supply source. 11 (225) <ul style="list-style-type: none"> Scientific literatures suggests that common non-point pollutants require vegetated buffers of 100-300 feet to attenuate those pollutants. However, given varying natural site conditions buffer distance necessary to protect drinking water should be determined by a natural resources professional.
PONDS, WETLANDS & VERNAL POOLS					
YES	NO	REMARKS:	ASSESSMENT RESOURCES		EXAMPLE POLICIES
			Hydrology & Watershed Maps		Sample Policies for Habitat Function
			U.S. Fish & Wildlife National Wetland Inventory 45 http://137.227.242.85/wetland/wetland.html		<ul style="list-style-type: none"> Ordinance may regulate lighting, especially outdoor lighting, in vicinity of wetlands or watercourses as this can be critically important to habitat function for some wildlife, particularly amphibians. 10 (20)
			U.S. EPA Surf Your Watershed 40 http://cfpub.epa.gov/surf/locate/index.cfm		<ul style="list-style-type: none"> Create a Wetlands Conservation Overlay District to protect wetlands and establish vegetated buffers; the Conservation Overlay District shall include surface waters, wetlands of any size, and buffers 100 feet wide around bogs over 1,000 square feet, and vernal pools over 500 square feet. 11 (205) <ul style="list-style-type: none"> Be sure to review DES Wetland rules before proceeding with a wetland ordinance; field-conducted identification and evaluation of soils, hydrology, and plants by a wetland scientist will be pertinent.
			USGS Water Resources of the United States 41 http://water.usgs.gov/maps.html		
			GeoData.gov - Federal, State & Local Geographic Data & Maps, Inland Water Resources 43 http://gos2.geodata.gov/wps/portal/gos/kc/xml/04_S9S		Sample Policies for Regulation Function
					<ul style="list-style-type: none"> Development planned for land tracts which include ponds and wetlands are required to undergo on-site assessment by a wetland scientist to determine the baseline condition of resources, including soils, hydrology, and plants, prior to commencement of development and construction activity. 14

<p>hydric soils and the maintenance of ecosystem habitats. 20</p> <ul style="list-style-type: none"> Water purification and quality: Wetlands filter contaminants and excess nutrients, benefitting water users. Collection & conveyance: Ponds, lakes and wetlands collect and recirculate precipitation as part of the hydrological cycle. <p>Hazard Mitigation</p> <ul style="list-style-type: none"> Runoff capture: Wetlands intercept and collect precipitation that has escaped ground absorption. Flood mitigation: Wetlands absorb and filter high water influges, streamflow surges, and excess precipitation. <p>Sediment & Erosion Regulation</p> <ul style="list-style-type: none"> Retention: Wetlands provide retention of soils and prevention of structural change (such as coastal erosion, bank slumping, and so on). 1 (31) <p>Pollution Control & Detoxification</p> <ul style="list-style-type: none"> Retention, recovery, and removal of excess nutrients and pollutants. 1 (31) 	<p>N.C. Division of Water Quality 44 http://portal.ncdenr.org/web/wq/ps/csu/maps</p> <p>Flood & Hazard Maps</p> <p>FEMA Mapping Information Platform 42 https://hazards.fema.gov/femaportal/wps/portal</p> <p>Habitat & Environmental Attribute Maps</p> <p>GAP Analysis Program 23 http://www.nbii.gov/portal/server.pt/community/gap_</p> <p>State Natural Heritage Programs 30 http://www.natureserve.org/visitLocal/index.jsp</p> <p>LandScope America 32 http://www.landscape.org/map/</p> <p>U.S. Fish & Wildlife Service, Species Report 46 http://ecos.fws.gov/tess_public/StateListing.do?state=al</p>	<ul style="list-style-type: none"> Developer shall be responsible for ensuring that post-construction condition of ponds and wetlands meets or exceeds the condition of pre-construction. Developers may be required, as a condition of their right to develop, to enhance and rehabilitate existing degraded wetlands. <ul style="list-style-type: none"> Residential development occurring near lakes, ponds and wetlands must adhere to the following performance standards: 10 (60) <ul style="list-style-type: none"> Lakeshore development must occur no closer than 300 feet from shoreline: 90% of the 300 ft. buffer must be protected. Wetland margins and pond shores within 150 feet from shoreline must be 80% protected. Regulations shall strictly prohibit the grading, removal of vegetation cover and trees, paving, and new structures of any kind within 75-100 feet of wetlands in residential zoning districts. 14, 10 (116) <ul style="list-style-type: none"> If removal of vegetation within defined buffer limits of wetlands is necessary, the request must be submitted for approval as part of the site development application, and plans for revegetation efforts must accompany it. 10 (121) Regulations prohibit impervious surfaces to exceed 10 percent of a development or subdivision whose land tract contains ponds, lakes, or wetlands. 11, 14 Development must minimize disruption of natural drainageways, and be timed so as to minimize impact on wetland areas. 10 (120) <ul style="list-style-type: none"> Consultation with qualified wetland scientists, hydrologists, or natural resource specialists shall be required to coordinate timing of activities. Developers shall be required to design and implement "soft" structure stormwater management systems (wetlands, grass swales, buffers) for residential development projects, unless an obvious barrier to this approach exists. 10 (122) <ul style="list-style-type: none"> Local government / planning commission shall have full discretion to reject projects which opt for "hard" structures when no reasonable barriers exist to proceed with soft structure stormwater management systems. Subdivision regulations shall stipulate that environmentally sensitive areas, such as wetlands, buffers, and floodplains, are not buildable and these areas shall be excluded from density calculations for the tracts. 10 (79)
<p>Human Experience Function</p> <ul style="list-style-type: none"> Aesthetic value: Wetlands and vernal pools can be places of beauty and offer unique habitat. Spiritual / Cultural: Wetlands and vernal pools may offer physical and symbolic venue for cultural & spiritual practices. Recreation function: Wetlands may provide exposure to nature for recreation in the form of bird watching, exploring, boating and more. 	<p>Local Hydrologists & Natural Resource Specialists</p>	<p>Sample Polices for Human Experience Function</p> <ul style="list-style-type: none"> Waterbodies shall be linked when possible to a larger regional plan for waterways, greenways, and protected areas; at a minimum the watercourses plan shall be prepared in consultation with the state's natural heritage program. 10 (120) Open space standards may apply to all major residential subdivision and land development. 14 <ul style="list-style-type: none"> Ponds, lakes and wetlands shall be entirely protected, and may not be drained, filled, or graded. Site calculations for open space shall exclude areas containing ponds, lakes, wetlands and vernal pools.
<p>Support Function</p> <p><i>Nutrient / Biogeochemical Cycling</i></p> <ul style="list-style-type: none"> Nutrient Cycling: Wetlands provide the storage, recycling, processing, and acquisition of nutrients. 1 (32) 		<p>Sample Polices for Support Function</p> <ul style="list-style-type: none"> Vegetation and Soil Protection Zones (VSPZ) may be created for areas within 100 feet of any wetland(s), or as according to more stringent setback distances which may be prescribed by state or local law. 9 <ul style="list-style-type: none"> The VSPZ for wetland(s) must not contain development. 9 Construction and development activity which interferes or negatively influences wetland(s) VSPZ zone shall be held accountable for the restoration of land within this area. VSPZ must be physically delineated during construction processes to protect the land from construction equipment, parking, storage of materials, etc. 9 Upland wetland buffers are essential to wetland functions; the entire length of the upland wetland buffer shall be protected and marked with highly visible construction tape during full duration of construction. 11 (210) <ul style="list-style-type: none"> Developer may be required to place a permanent identification monument at all points of the lot lines which intersect with the wetland buffer.
<p>Provisioning Function</p> <p><i>Fresh Drinking Water</i></p> <ul style="list-style-type: none"> Ponds, lakes and reservoirs may provide the primary water source for drinking water supplies. 		<p>Sample Polices for Provisioning Function</p> <ul style="list-style-type: none"> Establish a Drinking Water Protection Overlay District to identify, protect and regulate the surface water bodies used as a drinking source, the primary and secondary buffer protection zones associated with them, and perennial surface waters leading to drinking water supply source. 11 (225)

SOIL FEATURES

SOIL FEATURES				
YES	NO	REMARKS:	ASSESSMENT RESOURCES	EXAMPLE POLICIES
Habitat Function			Soil Data (NRCS) Web Soil Survey (WSS) 47 http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm Soil Data Mart 48 http://soildatamart.nrcs.usda.gov/	Sample Policies for Habitat Function
		<ul style="list-style-type: none"> Refugium function: Habitat for plants and animals including many species of bacteria, protozoa which contribute to functions like decomposition and recycling of nutrients. 		<ul style="list-style-type: none"> Soil compaction on site shall be minimized by using the lightest equipment possible, and minimizing travel over areas which will be revegetated. 11 (163) Prime soils shall be delineated on zoning maps and incorporated into Comprehensive Plan protections.
Regulation Function				Sample Policies for Regulation Function
<i>Hydrologic Regime</i>		<ul style="list-style-type: none"> Filtration function: Filter contaminants and excess nutrients preventing impairment of water quality in lakes and streams. Aquifer recharge: Soils soak up rain helping to recharge aquifers. 		<ul style="list-style-type: none"> Areas identified as having the greatest permeability, where precipitation is most likely to infiltrate and recharge the groundwater, shall be addressed through careful planning of vegetation and land disturbance activities, and the placement of streets, buildings, and other impervious surfaces. 13 (183) Developer plans must delineate water infiltration areas; excavation equipment is not permitted to be placed in the base of any infiltration area during construction. 11 (163) Annual average pre-development groundwater recharge volume (GRV) for the major hydrologic soil groups found on-site must be maintained, except where prohibited. 11 (165)
<i>Gas Regulation Function</i>		<ul style="list-style-type: none"> Carbon sink: Soils play an important role in the sequestration and storage of carbon. 5 		
Support Function			Sample Policies for Support Function	
<i>Soil Formation</i>		<ul style="list-style-type: none"> The formation and very existence of soil is the precursor for the production of all other ecosystem services. 2 (57) 	<ul style="list-style-type: none"> Diversion swales and vegetated buffer strips are to be utilized to reduce the amount of water entering a construction site for the purpose mitigating soil erosion, nutrient loss, and generally preventing the disturbance of soil onsite. 11 (298) <ul style="list-style-type: none"> Developers shall utilize biological or recyclable materials for temporary measures to control sedimentation and erosion, such as mulch berms, as opposed to those items which must be disposed of upon completion of construction. 	
<i>Nutrient Cycling</i>		<ul style="list-style-type: none"> Soil Nutrient Cycle: Essential biological-geological-chemical cycling occurs in soils. 22 		

SLOPE

SLOPE					
YES	NO	REMARKS:	ASSESSMENT RESOURCES	EXAMPLE POLICIES	
		Does the land area of interest reside on a slope, or contain sloped areas, of more than fifteen degrees?	Topographic Maps The National US Topo Map http://nationalmap.gov/ustopo/index.html Habitat & Environmental Attribute Data LandScope America 32 http://www.landscape.org/map/ Hydrology & Watershed Maps GeoData.gov - Federal, State & Local Geographic Data & Maps, Inland Water Resources 43 http://goss2.geodata.gov/wps/portal/goss/kcxml/04_Sj9S	<ul style="list-style-type: none"> Development engineering plans are required to be prepared by a professional engineer, and show the specific methods to be used in order to control erosion and sedimentation, soil loss, and excessive stormwater runoff both during and after construction. 11 (183) A hydrology, drainage, and flooding analysis must be conducted and included in applications, showing the effect of the proposed development on water bodies and / or wetlands in the vicinity of the project. 11 (183) Slope / hillside vegetation and landcover must be inventoried, and a proposed rehabilitation plan must accompany development applications. 11 (183) Steep slopes, determined to be sensitive areas, must retain 75% of the area as open space; the remaining 25% if developed, must be in accordance with underlying zoning and no adverse visual or environmental impacts shall affect the community. Development designation should be based on consultation from natural heritage information; given permission for development on steep slopes, vegetation disturbed or removed during construction activities must be replaced with native species. 10 (124) <ul style="list-style-type: none"> Some slopes may be subject to complete restriction, entirely off limits to construction, if data concludes erosion, slope failure, water pollution, threat to downslope habitat areas and water bodies, or destruction of unique habitats. 	

GREEN INFRASTRUCTURE SPATIAL CONFIGURATION				
MATRIX				
YES	NO	REMARKS:	ASSESSMENT RESOURCES	EXAMPLE POLICIES
<p>Is there evidence of matrix land cover and habitat?</p> <p>NOTE: The matrix has the greatest control over landscape and regional dynamics. The matrix may be a source of seeds for native plants, contain herbivore herds, and sustain keystone predators. 4</p>			<p>Aerial Imagery & Land Cover Maps</p> <p>U.S. Geological Survey (USGS) 24 http://earthexplorer.usgs.gov</p> <p>U.S. Natural Resources Conservation Service (NRCS) Geospatial Data Gateway 26 http://datagateway.nrcs.usda.gov/GDGHome_StatusMa</p> <p>Google Maps 27 www.google.com/maps</p> <p>Multi-Resolutino Land Characteristics Consortium (MRLC) National Land Cover Database 28 http://www.mrlc.gov/index.php</p>	<ul style="list-style-type: none"> Spatial arrangement of land cover and suitable habitat areas is critical: developers should consult with local natural resource specialists to preserve strategic features of the land area and matrix. 12 (14) Performance standards shall stipulate that infrastructure and lot lines be laid out to avoid fragmentation. 10 (60) <ul style="list-style-type: none"> Open space area must be contiguous and interconnected and not include parcels smaller than three acres, have a length-to-width ratio of less than 4:1, nor be less than 75 feet in width, with exceptions. The use of overlay zones can help to maintain contiguous habitat areas that cut across use districts. 10 (42) Eliminate "strip commercial zones" to prevent misuses of rural highways, maintain character, and discourage the spreading out of amenities which propel the migration of subdivisions further out creating fragmentation. 10 (41) Residential districts zoned for new development, for which subdivisions of greater than 10 acres will be established, must obtain a special permit which requires cluster-type subdivisions. 10 (49) <ul style="list-style-type: none"> Development shall be limited to 20% - 30% of the site, depending on the makeup and features of the proposed community layout.
CORRIDOR				
YES	NO	REMARKS:	Hydrology & Watershed Maps	
			<p>GeoData.gov - Federal, State & Local Geographic Data & Maps, Inland Water Resources 43 http://gos2.geodata.gov/wps/portal/gos/kcxml/04_SJ9S</p>	
<p>Does the land contain, or is it part of, a natural corridor?</p> <p>NOTE: Corridors perform five major functions in landscapes: habitat, conduit, filter, source and sink. Width and connectivity of corridor affect these functions. Width and degree of connectivity greatly affect corridor functionality. 4</p>			<p>Habitat & Environmental Attribute Maps</p> <p>GAP Analysis Program 23 http://www.nhii.gov/portal/server.pt/community/gap_</p> <p>State Natural Heritage Programs 30 http://www.natureserve.org/visit/Local/index.jsp</p> <p>LandScope America 32 http://www.landscape.org/map/</p> <p>U.S. Fish & Wildlife Service, Species Report 46 http://ecos.fws.gov/tess_public/StateListing.do?state=al</p>	<ul style="list-style-type: none"> Develop performance standards which encourage the preservation of habitat areas that are as large and circular as possible, and connected by wildlife corridors large enough to maintain interior habitat conditions. 10 (45) Key habitat connections and corridors should be identified and protected by explicit designation on zoning maps. 10 (45) Fencing and other structural barriers are prohibited for use within areas determined to be wildlife corridor areas. 10 (46) Developers are required to identify and conserve wildlife corridors, at a minimum of 300 feet, which may cross through the development site / property, in order to facilitate wildlife movement. 11 (195) Corridors which run adjacent to the proposed development site must be maintained and activities to protect the corridor during construction and development activities must be submitted as part of the application for development
PATCH				
YES	NO	REMARKS:	Resource Specialists & Landscape Ecologists	
<p>Does the land contain, or is it part of, natural vegetation patches?</p> <p>NOTE: Large natural vegetation patches in suburban settings often play a key role in microclimate, act as hydrologic sponges absorbing rainfall and reducing floods, and may contain interior plant and animal species. 4</p>				<ul style="list-style-type: none"> The edge-to-interior ratio of a habitat patch should be as low as possible to minimize detrimental edge effects; therefore, circular habitat reserves should be employed to protect core habitat from adjacent environmental and or human pressures. 12 (9) <ul style="list-style-type: none"> Long thin reserves should be avoided, as proportionally more edge, and thus more negative edge effects, result.

ADDITIONAL RESOURCES	NAME	WEBSITE	DESCRIPTION
REGIONAL AGENCIES <i>Agencies and organizations, which may add value to local planning efforts, in terms of ecological insight and regional considerations.</i>	North Carolina State Parks - Natural Resource & Regional Planning Division	www.ncparks.gov/About/agency_organization.php	North Carolina Department of Parks and Natural Resources.
	North Carolina Native Plant Society	www.ncwildflower.org/	Aims to promote the enjoyment and conservation of North Carolina's native plants and habitats through education, protection, propagation, and advocacy.
	The EPA Southeastern US Ecological Framework Project	www.geoplan.ufi.edu/epa/index.html	A GIS-based analysis to identify ecologically significant areas and connectivity in the southeast region of the US.
	The Land Trust for Central North Carolina	www.landtrustcnc.org/about_landtrust.asp	Works to thoughtfully and selectively preserve North Carolina lands, vistas and the essential nature of its region.
	Piedmont Land Conservancy	www.piedmontland.org/	Works for the protection of Piedmont lands, rivers and streams, natural and scenic areas, wildlife habitat, and farmland.
	Community Forestry Resource Center	www.forestrycenter.org/about.cfm	Promotes responsible forest management by encouraging the long-term health and prosperity of small, privately-owned woodlots, and their owners.
	North Carolina Ecosystem Enhancement Program	www.nceep.net/pages/abouteep.html	Aims to restore, enhance, preserve and protect the functions associated with wetlands, streams and riparian areas of North Carolina.
	Center for Watershed Protection	www.cwp.org/about-us/mission-and-vision.html	Works to protect and restore streams, rivers, lakes, and wetlands by creating viable solutions and partnerships for responsible land and water management.
	North Carolina Natural Heritage Program	www.ncnhp.org/	The program inventories, catalogues, and supports conservation of the rarest and the most outstanding elements of the natural diversity of our state.
	One North Carolina Naturally - Conservation Planning Tool	www.onencnaturally.org/pages/ConservationPlanningT	The CPT is composed of multiple assessment layers that can be used independently and supports land use planning efforts throughout North Carolina.
N.C. League of Municipalities - Green Challenge	www.ncml.org/programs-services/Pages/Green-	The NCLM Green Challenge recognizes the commitment of cities and towns to preserve natural resources and the many innovative and exciting projects underway to save energy, resources and money.	

CHAPTER 5

RECOMMENDED POLICIES, ORDINANCES AND STRATEGIES

INTRODUCTION

“Land use planning is a process that takes place in the context of strong political, economic, and social currents, and there will always be contentious issues that arise out of competing values” (Stein 2007, 58). Planning for environmental and ecological systems is one such point of contention; despite the difficulties however human influence requires that environmental priorities be established and policy created (G. Daily 2000, 333).

Science plays a role in informing land-use debates and helps to establish environmental agendas, but most land-use decisions are made with little input from ecological science. More often is the case that these decisions are influenced by economics, personal values, politics, and tradition (Dale, et al. 2000, 664). If we are to get to a place where ecological science can guide land-use decisions, and have a positive impact on our communities and local and regional ecosystems, it is essential that relevant science is communicated clearly and reliably. This requires scientists to identify and explain pertinent scientific issues within the framework of the land-use planning and decision-making process (Dale, et al. 2000, 664). For now, the planning community and the ecological community have not converged on a particular mechanism to incorporate ecological science into land-use policy. However, “specifying ecological principles and understanding their implications for land-use and land-management decisions are essential steps on the path toward ecologically-based land use” (Dale, et al. 2000, 644).

The designed heuristic expressed in Chapter Four aims to alleviate this gap between science and policy. The heuristic presents a range of ecological functions alongside ninety-two sample policies; at least one sample policy is identified per landscape feature and

ecological function. The sample policies presented within the heuristic reflect an assortment of actual implemented legislation, modified or customized legislation created from a combination of existing policy tweaked to reflect ecological goals, and hypothetical policies that seek environmental and ecological ideals. Throughout this chapter an overarching review of policies relevant to each major ecological function will be presented, along with a handful of specific sample policies that will be reviewed in greater detail. Discussion on the challenges and opportunities for implementing such policies in the real world will be addressed at the conclusion of the chapter.

GUIDELINES FOR THE LAND-USE DECISION MAKING PROCESS

Setting a mental model for policy

Before exploring the policies presented in the heuristic, I think it important to review a set of ecologically-based guidelines, as proposed by Dale et al. (2000). These guidelines, eight in total, “give practical rules of thumb for incorporating ecological principles into land-use decision making”, and are meant to be flexible, apply to diverse land-use situations, and to recognize that the same parcel or tract of land can be used to accomplish many goals (Dale, et al. 2000, 639). Accordingly, decisions must be made within appropriate spatial and temporal context.

The first guideline suggests that the impact of local decisions should be examined in a regional context. Spatial arrangement, habitat, and ecosystems all help to shape local conditions, and by the same reasoning, local conditions may influence and stimulate broad landscape-scale impacts. This logic requires two considerations for planning. First, that the surrounding regions, which may affect and be affected by the local project, should be identified; second, the land management tactics in adjoining jurisdictions should be assessed (Dale, et al. 2000, 656).

The second guideline is to plan for long-term change and unexpected events. This time-related principle is an important factor in understanding not only the ecology of land

generally, but also impacts of land-use and land-use decisions. The ecological responses to today's land-use decisions will play out over the long term, either as delayed ecological responses, or cumulative impacts. Delayed impacts may not be seen for years or even decades, whereas cumulative impacts are the result of a series of events that together determine a trajectory of effects, which likely could not be predicted from one single event. While planning for the long term and preparing for unanticipated events is an undoubtedly a difficult task, it should be done; at a minimum the possibility of events such as temperature variations, or changed precipitation patterns, should be considered (Dale, et al. 2000, 659).

Preserving rare landscape elements and associated species is the third guideline. This is an essential part of providing a sense of place for the human experience, and assisting in regional biological diversity. An inventory and analysis of vegetation, hydrology, soils, and physical features that identify the presence and location of rare elements is pertinent, along with the estimated effects of alternative land-use decisions on these landscape elements, so that strategies may be developed to avoid serious ecological impacts (Dale, et al. 2000, 659).

The fourth guideline suggests aiming to avoid land uses that deplete natural resources over broad areas. From my point of view, this particular guideline is a bit paradoxical; the incremental development of land in and of itself creates cumulative effects that have broad, sweeping impacts on large areas of land and natural resources. Therefore, a strict interpretation of this guideline may imply the avoidance of development all together. Nevertheless, the intended interpretation of this guideline is such that it seeks to prevent the rapid or gradual demise of resources. The guideline requires a determination of resources at risk, and also calls for land development alternatives that avoid damaging natural resources (Dale, et al. 2000, 660).

The next guideline, retain large contiguous or connected areas that contain critical habitats, derives from both the sense of place principle and landscape principle. The relative size and degree of connectivity of an area provides important ecological benefits, and may host habitat critical for the survival of certain species and populations. Determining the spatial connectivity of an area is the first step to implementing this guideline; next,

opportunities for connectivity should be promoted and planners should look for occasions where this may complement other planning needs (Dale, et al. 2000, 660).⁵

The sixth guideline reminds decision-makers to minimize the introduction and spread of nonnative species. Often nonnative species are introduced through mechanisms like terrestrial and aquatic vehicle transport. Land-use decision-makers should take seriously the risk of nonnative species, and identify activities that can prevent such an incursion. By working to maintain native species, adapted to local conditions, planners can help mitigate invasive species risk (Dale, et al. 2000, 660).

Next, effort should be made to avoid, or to compensate for, effects of development on ecological processes, and impacts of proposed projects should be examined at relevant scales. For example, the particular placement of a road may influence dispersal patterns of key local species; at a broader scale, the imposed impervious surface may interrupt or change drainage patterns that affect overall watershed processes (Dale, et al. 2000, 661).

The final guideline is to implement land-use and land-management practices that are compatible with the natural potential of an area. The natural potential is determined by the physical and biotic conditions that contribute to ecological process. “Therefore, the natural potential for productivity and for nutrient and water cycling partially determine the appropriate land-use and land-management practices for a site” (Dale, et al. 2000, 661). Overall, land-use plans that recognize these ecological limits tend to be more cost effective, and impose fewer future costs.

With these guidelines in mind, we shall explore the policies for the preservation of ecological function in the next section.

⁵ While maintaining or establishing connectivity is valuable in most instances, it can on occasion create problems within ecosystems, as corridors can promote the spread of invasive species and disease (Dale, et al. 2000, 660).

POLICIES FOR THE PRESERVATION OF ECOLOGICAL FUNCTION

Policy for habitat function

As discussed in Chapter Four, habitat function is essential to all ecosystem goods and services, and is especially important to local and regional biodiversity. Much of the ecological degradation associated with suburbanization and land development has a direct impact on habitat function, as land is commonly converted from one land-cover type to another. Such activity can interrupt the movement of wildlife, the flow of water, and the dispersal of native plants. Species extinction and the elimination of species metapopulations are possible consequences of such disruption. Due to the fact that habitats exist in many forms, under various conditions and scales, addressing the preservation of the habitat function is notably challenging.

Policy for the preservation of habitat function can be implemented broadly, as goals and objectives of comprehensive and master plans, or directly as specific regulations of development and subdivision ordinances. The majority of policies put forth in the heuristic take one of two approaches to habitat function; the policies either establish protection and conservation standards by setting certain areas off-limit to development, or, they make use of vegetation requirements and land disturbance limitations in order to promote and accommodate ecological buffers. Often natural resources inventories will be used to identify unique habitat, special features, and species of concern, prompting local governments to utilize their authorities to protect such factors critical to biodiversity (American Planning Association 1999). Vegetation requirements tend to promote native plant species, and place emphasis on maintaining vegetated corridors and areas of contiguous habitat. Policies that focus on limiting disturbance can take a variety of forms. One particular example from the heuristic is a subdivision ordinance that regulates lighting in the vicinity of wetlands and watercourses. Lighting can be a critically important factor in the biology of certain wildlife species, especially amphibians (McElfish 2004, 20), as such, this policy aims to limit such disturbance, thereby providing support to the habitat function.

Other policies address habitat function by requiring consultation with natural resource specialists in the evaluation of land and development decisions, or by assigning compensatory and rehabilitative responsibilities to land developers. This may apply to the rehabilitation of habitat disturbed by the development process itself, or, it may apply in a proactive manner to restoration efforts beyond the compensation of direct ecological impacts of the project. For example, a developer may be obliged to restore former prairie habitat on a certain portion of a proposed project site, even though that prairie may have been degraded or lost due to some prior activity not related to development interests.

Policy for regulation function

Regulation functions are those that manage the essential processes and life-support systems that make up our world, resulting in both direct and indirect benefits like clean air, water and soil, and biological control services (de Groot, Wilson and Boumans 2002, 395). Regulation functions are dynamic, host a range of services that are largely integrated and overlap, and can easily be disturbed by construction and development activities. As previously mentioned, the regulation function is paramount in the overall workings of an ecosystem; as such it should be noted that it is possible to damage regulation functions to a non-recoverable extent, triggering a domino effect of ecological disrepair.

Policy designed to address the regulation function tends to be rather specific, and is perhaps best suited for performance-based zoning regulations and development standards of subdivision ordinances. The policies presented in the heuristic focus a lot on maintenance of vegetation as a policy strategy; this makes sense as vegetation plays a direct role in each of the seven primary regulation functions identified in Chapter Four. For example, vegetation is notably critical to erosion control and soil retention, and can strongly influence water regulation. Second to vegetation requirements, many policies focus on the hydrologic aspect of the regulation function, and deal directly with onsite hydrologic integrity and the management of stormwater. Protection and conservation regulations, along with standards for hard and soft infrastructure requirements, also comprise regulation function policy. Infrastructure requirements may specify the use of forests as alternatives to hard

infrastructure for the management of stormwater and runoff, for example, while the creation of “vegetation and soil protection zones” (VSPs) may be used as a form of protection and conservation policy. As displayed in the heuristic, VSPs can designate certain areas to be off-limit to development, like sensitive groundwater recharge areas and other lowland areas, which may be critical to the hydrologic regime and the regulation of water quality (Arendt 1999, 183). Other policies that address the regulation function focus on rehabilitative and ecological compensation efforts, such as the maintenance or preservation of vegetation or hydrologic pathways affected by development activities; these policies may stipulate proactive rehabilitation efforts as a condition of a developer’s right to build. Overall, given the significance of the regulation function and its impact on ecosystems at various scales, it is sensible for policy to insist on consultation with natural resource specialists to shape the specific details of regulations, as well as the design of development.

Policy for support function

Addressing the support function presents a unique challenge. Long time scale associated with the workings of this function, as well as the indirect way in which humans experience it, make it especially tricky to address with policy. Soil formation and nutrient cycling are the two primary support functions of ecosystems; soil formation is a very slow process that occurs over hundreds of years, and yet indirectly it impacts our everyday lives. How might a local planner or policymaker safeguard such a process?

Seemingly, the best way to ensure that the support function remains intact is to plan for the preservation of ecosystem conditions that enable it. Take again soil formation as an example; soil is produced from the erosion of underlying bedrock, and it depends on the accretion of organic matter from plants and animals in order to be fertile (de Groot, Wilson and Boumans 2002, 399). In this case, planning for the protection of land succession and habitat may help maintain this service. Due to the time scales associated with this function, a lasting vision and long-term plan is needed for its success; as such, policy as part of comprehensive or master plans may be the best option. Planning for the preservation or creation of habitat, which can host native plants and animals, may also assist in the

preserving the soil formation process. Given this example, it is probably no surprise that nearly all support function policies presented in the heuristic are aimed at vegetation requirements and disturbance limitations. In fact these two approaches are commonly used together to form collaborative policies. An example policy, borrowed from the New Hampshire Department of Environmental Services, stipulates that no ground disturbed during construction may be left as bare soil, and accordingly, it must be subsequently planted with a combination of native vegetation and forest species (New Hampshire Department of Environmental Services 2008, 163).

Protection and conservation regulations also make up some of the policies for the support function. These policies are most directly applicable to developers, appearing as development standards within subdivision ordinances or zoning regulations. Many of these policies recognize and preserve key areas of vegetation, which contribute to support function processes, by protecting them during and post construction. For example, wetland vegetation is important for nutrient cycling; one particular policy recognizes vegetated upland buffers as essential to wetland function, and therefore protects these areas and requires them to be marked in a highly visible way during construction. Following construction, a developer may be further required to place permanent identification monuments at all points where lot lines intersect with the wetland buffer. (New Hampshire Department of Environmental Services 2008, 210).

Policy for provisioning function

Contrary to the long time scales and indirect allowances of the support function, the provisioning function provides benefits readily available from ecological systems. Most notably, the provisioning function provides food and fresh drinking water for humans and animals. Development activities impact the provisioning function, and in some cases even compete for the same ecological aspects on which the provisioning function depends. For example, well-drained soils and moderate slopes are ideal conditions for vegetation and crop cultivation. However, developers also tend to prefer these conditions; as development occurs on this land, not only is the local food provision lost or degraded, but commonly so too is the

ability for an ecological system to supply clean drinking water. Impervious surface associated with development can significantly impact local drainage basins and watersheds; as an area reaches ten percent impervious-cover stream denigration has already begun, and by thirty percent a watershed is officially considered degraded (Natural Resources Defense Council 1999).

Policy that addresses the provisioning function may be addressed broadly as goals and objectives of a comprehensive plan, or be applied via conventional zoning and overlay districts. For example, a comprehensive plan may stipulate that a certain percentage of farmland must be retained within a community, in order to mesh with the overall vision of the community's character. Many of the policies described in the heuristic utilize land protection and conservation measures in order to address this function; others focus on the importance of utilizing natural resource specialists to plan for it. One policy example from the heuristic is the use of a Drinking Water Protection Overlay District (DWPOD). Overlay districts are common in conventional zoning plans, and offer additional regulations that supplement underlying zones in certain areas (U.S. Department of Transportation Federal Highway Administration n.d.). The DWPOD may be used to regulate and protect surface waters, the primary and secondary buffer protection zones associated with them, and perennial surface waters leading to drinking water supply sources (New Hampshire Department of Environmental Services 2008, 225).

Policy for human experience function

The human experience function is an intangible ecological service. It provides a vital link to nature and is viewed by many as essential to human health and well-being. The Millennium Ecosystem Assessment (MA) defines human well-being as the elements needed to obtain a "good life;" this includes both basic needs of survival and also the manifestation of cultural, spiritual and personal values (Conservation International n.d.), which are often tied to the natural environment. Services of the human experience function are most immediately relevant and important to those people who live in close proximity with nature. However, it is arguable that it is equally as important to those who do not have direct access. Regardless,

policy that respects the role of nature in our lives serves both the interests of the human community, and likely benefits local ecological communities as well.

Policy for the preservation of the human experience function can be implemented as part of the strategic vision of a comprehensive or master plan, or, in detailed ordinances of local development and planning. The policies expressed in the heuristic all reflect, to at least some degree, measures that employ the protection and conservation of land and water. While some policies promote the protection and linkage of waterways others look to conserve portions of the natural landscape in conjunction with development activity. For example, one ordinance stipulates that on predominately wooded sites developers must conduct tree surveys, inventory trees over 12 inches in diameter, and ultimately protect (from disturbance or removal) the identified specimen and their associated drip lines. Through the use of modern technology, like Global Positioning Systems (GPS), a task such as this is easily manageable. As well, the protection of such natural features can add significant value to the aesthetics of a development, and does much to create a sense of place for its residents (Arendt 1999, 58). It may even contribute, ever so slightly, to local habitat and biodiversity needs.

It is important for land planners to remember that any area designated as open space is still land that requires management. For example, a municipality may decide that the agricultural land in the center of town is essential to its rural character, and therefore residential development must follow a cluster-style development blueprint to preserve this quality. Through subdivision ordinance the municipality may further define that only twenty percent of the land may be built on, and the remaining eighty percent must be protected as workable farmland. To fully support such planning requirements, a land management plan should be formulated, addressing such considerations as practices to manage soil erosion control, or crop rotation schedules necessary to safeguard soil fertility (Honachefsky 2000, 85). Other management aspects of planning for the human experience function may include wildlife management plans, or the design of facilities that support human-nature interactions.

OTHER ASPECTS OF ECOLOGICAL FUNCTION: GENERAL POLICY

The designed heuristic is organized to express ecological function and policy as relevant to the major landscape features and land-use types of the ecoregion. However, other aspects of landscape ecology also apply. Altered landscapes, slope, and the spatial configuration of land all exert influence on ecological function. As such, these factors must be considered, and policy must be created, to address their role in preserving the function and integrity of such ecological systems.

Altered landscapes

All landscapes have a history; however understanding the relative ecological importance of this history can be a challenge. Consideration of past land-use at multiple scales can help planners better understand the landscape patterns of today, and may also provide the insight necessary to ensure land-use decisions going forward are made with ecological systems in mind (M. G. Turner 2005, 322). Evaluating past land-uses should be done with the help of a natural resource and land-use professional; the implications of altered landscapes, like drained wetlands, retired cropland, former forest, or diverted hydrologic systems and drainage patterns, should be evaluated prior to any approval given on any future development plans.

Policies to address altered landscapes may be implemented as regulations within development standards and subdivision ordinances. The policies presented in the heuristic are comprised of those that require consultation with natural resource specialists to evaluate altered land; the use of compensatory and rehabilitation efforts when development is planned for previously altered landscapes; and vegetation obligations. One policy, for example, stipulates that consultation with a natural resource specialist is necessary in order to inform the design of the development plan, stipulating the places most suited for development, and those areas that are best served by rehabilitation efforts (Arendt 1999, 58).

Slope

As a fundamental element of traditional land-use planning, the foremost concerns associated with development on steep slopes are health, safety, and standard environmental considerations. Slope is a prominent landscape characteristic that directly affects regulation and support functions, and may also impact habitat function. For example, slope is one of the most important abiotic factors that control the soil formation process at the local scale (Gong, et al. 2007, 313); furthermore, slopes provide distinct habitat and vegetation complexes as a result of microclimates, differences in soils, and distinct disturbance regimes (McElfish 2004, 124).

Local governments that desire to regulate steep slope development should address the matter in the land-use or natural resources chapters of their master plans (New Hampshire Department of Environmental Services 2008, 179). Supplementary to this, more specific ecological impacts of slope development may be addressed via development ordinance. The policies expressed within the heuristic cover a variety of approaches, ranging from protection of environmentally-sensitive areas, to the requirement of engineering plans to control erosion, soil loss, and excessive stormwater runoff during and after construction.

Spatial configuration

As we already know, residential development and local land-use decisions can significantly alter landscape configuration and ecological processes (Dale, et al. 2000, 654). Fragmentation is often a primary concern of development-related land-cover change. Fragmentation is associated with loss of native plant and animal groups, invasion of exotic species, increased soil erosion, and decreased water quality; the magnitude of these impacts is influenced by the size, connectivity, shape, context, and heterogeneity of fragmented land (Collinge 1996, 71).

The policies presented within the heuristic aspire to maintain strategically pertinent spatial configurations, and to reduce fragmentation resulting from development. Addressing spatial configuration is best accomplished via the strategic vision of master plans and

designations on zoning maps, and residential development regulations and subdivision ordinances may also come into play. For example, a zoning map may display key habitat connections and protect them by explicit designation; additionally, developers may be required to take proactive measures to buffer wildlife corridors that run adjacent to, or intersect with, a project development site. Policies related to the protection and conservation of land are also prominently featured in the heuristic. These measures are applicable to maintaining viable patches of land in order to combat fragmentation issues; a number of policies also speak to the size, shape, and context of patches within an area. One such policy recommends that developers be held to performance standards that stipulate that infrastructure and lot lines be laid out in such a way as to avoid unnecessary fragmentation; relatedly, open space areas shall be contiguous and interconnected, may not include parcels smaller than three acres, have a length-to-width ratio of less than 4:1, nor be less than 75 feet in width (McElfish 2004, 60). Ultimately, any plans or policy that address spatial configuration must interpret these decisions in context to the surrounding regional landscape (Dale, et al. 2000, 655-656). Therefore, some of the expressed policies require input from natural resource specialists or landscape ecologists, in order to assess and preserve strategic ecological features as relevant to the matrix (Environmental Law Institute 2003).

THE ADEQUACY OF POLICY TO ADDRESS ECOLOGICAL FUNCTION

Overview

The growing demand for ecosystem services, and related impact on ecological systems, places a strain on our environment that requires policy intervention (Lamont 2006, 5). The adequacy of policy to address ecological systems rests upon a multitude of variables that range from general challenges of policy adoption to the intricacies of local politics and personal values. In order to successfully address ecological function via policy implementation, land-use planners must strike a balance between the promoting the human benefits of ecological systems, and maintaining the ability of those systems to provide services at a sustainable level. Because stakeholder interests can differ significantly, this only

further complicates that matter. Many different views exist about how to prioritize ecological function, and varying judgments stand as to the right balance between achieving short-term benefits (like economic growth) as compared to securing long-term ecological stamina (Lamont 2006, 6). While careful consideration of local tradition, stakeholder values, and sound scientific and ecological information will assist in efforts to adequately address ecological function, an assortment of barriers still exist.

BARRIERS TO THE IMPLEMENTATION OF SOUND ECOLOGICAL POLICY

“Despite the popular notion that science drives decision-making, it is clear that even under the best circumstances science informs but does not dictate policy” (Stein 2007, 53). As such, ecological policy is subject to a range of obstacles presented both by the planning process itself, as well as by the constituents of land-use decision making. A sampling of barriers and challenges, which impact the ability of policy to adequately address ecological function and preservation, are presented below.

Weak plans for ecological protection

Although some communities have been able to implement specific ecological policy into local plans, studies have shown that such policies are imbalanced, and do not take a holistic approach to guiding development, and protecting ecological function and natural resources. Of thirty high-quality comprehensive plans reviewed, many of which have received awards from national or state chapters of the American Planning Association, the majority concentrated only limitedly on specific components of sustainable development values. Instead, these policies tend to focus on aspects of livability, like sense of place and social cohesion. In contrast, activities and policies that support essential ecological functions received considerably less attention (Berke 2007, 59-60). A study in Florida, which reviewed the integration of watershed protection concerns into local planning, indicated poor plan quality and noted the weakest dimension as being the application of watershed science-based information. These studies are indicative of the lack of science-based information in local

plans and implementation practices. Therefore, it seems that even when communities actively engage in addressing sustainability, and plan for ecological harmony, they tend to still fall short in essential ecological policy creation and implementation (Berke 2007, 59-60).

The land-use management paradox

The land-use management paradox is a result of the reactive strategies of land-use planning; communities tend to adopt plans and policy as a reaction to an ecological crisis, rather than by proactive planning. Even jurisdictions that favor having a strong fact base, like resources inventories and urban development statistics, tend not to create policy for natural resource protection unless they face a direct threat from urban development impacts. This paradox is not a new phenomenon, and studies suggest that without the signals of habitat fragmentation, biodiversity loss, and water quality degradation, communities will lack the motivation necessary to take action on ecological policy creation. The challenge is that once these warning signs appear, ecological functions are often already significantly degraded (Berke 2007, 60-61).

Spatial mismatch – local governance and regional landscapes

“A spatial mismatch exists between the scale at which local governments need to plan and manage to effectively protect landscape ecological resources, and the scale at which land-use planning and decision-making is traditionally carried out” (Berke 2007, 61). This mismatch creates consequences for policy development, as it tends to favor the protection of isolated patches of habitat and fails to take advantage of existing natural areas that may span jurisdictional boundaries. Furthermore, fragmented regulatory authority over land weakens government influence; landscapes divided into dozens or hundreds of governing entities may be too small to deal with the growing challenges of suburbanization and impacts on landscape ecology. These fragmented governments divide regions that otherwise represent single, interconnected ecological communities, and complicate efforts for cooperative planning and coordinated ecological decision-making. Some research even goes so far as to propose that fragmented governments actually motivate sprawl-inducing competition, as jurisdictions vie for desirable tax bases (Berke 2007, 61-62).

Real and perceived value conflicts

Although there is an emerging body of knowledge, which demonstrates that healthy ecosystems are vital to long-term sustainability and economic prosperity, a clash in values commonly reduces the importance of such issues to down to simplistic arguments that undermine the significance of the issues at hand. Value clashes, like the debate of jobs vs. the environment, are often the result of disguised or ambiguous causal beliefs, and make difficult the task of clearly understanding one another in decision-making forums. Without full transparency of beliefs and values, efforts to incorporate science-based information into planning processes can be diluted by lack of trust (Stein 2007, 53) – an essential component for creating sound policy able to reach implementation. For example:

Because many in the conservation biology field come to the profession out of a profound sense that too much of our natural world already has been lost, they often bring an implicit set of values that focuses on the protection or preservation of natural features. While this may be a perfectly rational (and indeed, laudable) set of values, working productively with planners who are attempting to balance a variety of values requires that, at a minimum, this be made explicit. (Stein 2007, 53)

Scientific uncertainty and the dynamic nature of ecosystems

Although uncertainty exists in all aspects of life, planners and policymakers prefer concrete answers, especially when it comes to development and the natural world. Unfortunately, scientific understanding of ecological dynamics is imperfect, and even those things that are “known” come with conditions (Stein 2007, 53). As dynamic views of the natural world become more accepted by the scientific community, and scientific models move away from traditional equilibrium-based paradigms of ecological stability, scientists are put at even further at odds with respect to the “hard truths” desired by planners and policymakers (Stein 2007, 54). At a minimum, slow or impeded forward action on ecological policy is likely; moreover, such conflicting views may lead to irreconcilable differences in the collaboration for policy formation.

Local capacity

As stated in earlier chapters, land-use planning in the United States typically takes place at the local level via county planning departments or municipal offices. While some of these planning operations may be well stocked and sophisticated, many local planning offices are afforded only a small staff and limited resources. As such, limited expertise in ecological sciences and restricted capacity to maintain and run sophisticated software tools challenge their ability to create and implement effective ecological policy. Compounding this problem is the fact that many of the tools and scientific databases that local planners are able to get their hands on have been developed by scientists, for scientists, and lack the functionality necessary to communicate with a planning community's large and diffuse constituency. As a consequence, planning offices tend to rely on environmental consulting firms to address ecological issues only "when the need arises." Unfortunately, this type of limited engagement can result in missed opportunities for holistic incorporation of ecological considerations in routine planning decisions (Stein 2007, 54).

Political and ecological time-frames

The time-frames and cycles associated with the political world are grossly out of synch with that of the natural world. As such, the implementation of ecological policy may be stalled due to the inability of the political realm to internalize the long-term planning and foresight needed to address the continued preservation of ecological function (Lamont 2006, 11).

OPPORTUNITIES FOR ADVANCING THE INTEGRATION OF ECOLOGICAL POLICY

Despite the barriers that exist for the development and implementation of effective ecological policy, there is also progress and room for opportunity. Particularly important here is increasing number of individuals in scientific and planning communities who are committed to understanding each other's needs. There seems also to be a greater willingness

on the part of scientists to involve themselves in the lengthy land planning processes that shape much of our natural world (Stein 2007, 55). Four opportunities that give support to the development and implementation of ecological policy are described below.

Data

Reliable data is essential to the integration of ecological information into the planning process. Particularly important is the ability to separate fact from the interpretation of facts, which can help clarify where issues really exist, and where they don't. This sometimes reveals that conflict is less significant than initially perceived, and it may offer more options for resolving possible land-use planning problem. With today's technology, some excellent data sources are available to address the needs of planning and environmental management. Some examples include state natural heritage program biological data; the national coordination and technical support of non-profit organizations like NatureServe; state and regional-scale conservation plans, like the federally funded State Wildlife Action Plans; the Nature Conservancy's identification and mapping of important biodiversity areas; the introduction of green print plans; and the EPA's Southeastern Ecological Framework. A variety of data sources exists within individual states as well, although finding these sources can sometimes be difficult (Stein 2007, 55-56). The bottom line is that access to reliable ecological data is easier than ever before, and it can help planners, policymakers, and stakeholders to improve the creation and implementation of ecological policy in planning.

Tools

The variety of technological tools now available to planners makes ecological data, analyses, and expertise more accessible than ever before. New generations of mapping and visualization tools are now being deployed online, providing planners the opportunity to view the landscape and as well to add user-defined features. In addition, the Web has proven significant as a social force initiating virtual communities that address scientific and planning-related issues, and providing unprecedented opportunity for citizen participation in scientific endeavors and planning processes (Stein 2007, 56).

Adaptive management as a state of mind

It is evident in planning and in life generally, that there exist critical uncertainties in the human knowledge base that provide a continuous supply of surprise events. Being it likely that humans will never have access to perfect information, we are likely better off accepting uncertainty, and adjusting our states of mind to be adaptive to continual change. Applying this to the world of planning and resource management requires a more formal process known as adaptive management. One definition of adaptive management explains it as treating economic uses of nature as experiments, so that knowledge may be obtained efficiently from the experience. It is a continual process of action-based planning, monitoring, researching, and adjusting, with the aim to improve implementation and achieve the goal of more resilient policy (Lessard 1998, 81). Conditions favoring adaptive management include: the need to take action in the face of uncertainty; the desire of decision-makers to improve outcomes over biological time scales; when the preservation of pristine environments is no longer an option; when human intervention cannot produce outcomes predictably; when institutional culture encourages learning from experience; and finally when there is sufficient stability to measure long-term outcomes (Lessard 1998, 83). Planning to adapt to change and surprise events creates a proactive rather than reactive decision-making culture well suited for the preservation of ecological function (Lessard 1998, 86).

Learning and stakeholder engagement

“Learning is an inherent feature of public policy decision-making. It is how people discover the range of public values and how those values can complement and conflict with each other” (Daniels and Walker 1996, 73). Mutual learning is therefore an essential component of integrating ecological science and policy. Decision-makers, planners, policymakers, and scientists involved in ecological policy creation should be mindful of this mutual learning opportunity, and be careful not to impose one-way, directional “answers” in the process of such policy creation. All parties should be open to learning from one another, and local governments should continuously look for new ways to involve and engage the public (Daniels and Walker 1996, 75). With openness toward mutual learning, those

involved in policymaking are in a better position to create clear, well-articulated strategies and rational responses, thereby advancing the opportunity to integrate ecological policy into local planning.

CHAPTER 6

SUMMARY OF FINDINGS AND CONCLUSION

In closing, I restate that a dire need exists in the United States to bring into balance growth and development with the ecological systems and services that sustain us. The degradation of these systems, as a consequence of residential development and urban expansion, has intensified steadily and has pressed local planners and policymakers to find solutions. The matter is a serious one and without action we will inevitably face more severe threats of air and water pollution, diminished forests and wetlands, threatened farmland, habitat loss and fragmentation, and reduced access to open and green space.

Despite the complexity of the matter I have proposed that it is possible to accommodate growth and development and to correspondingly maintain essential ecological systems and functions by way of informed policy creation. The solution I have proposed is the formation of a framework that organizes and displays critical ecological functions alongside local policy measures aimed at their protection and preservation. The creation of this framework, referred to within as the heuristic, was central to this research and alleviates the gap that exists between ecological science and policy. The heuristic does the job by succinctly organizing a vast range of ecological information and presenting it side-by-side with sample policies that are ecologically-mindful, but development-oriented.

The value of this research, from a planning and policy perspective, is in the organization and display of ecological data coupled with sample policies. In all of the extensive research reviewed during the creation of this body of work, I was unable to find the two measures directly connected to one another in practical application. As such, the creation of this heuristic marks a starting point for more research; it sets the tone and creates a structure from which more research can be organized and presented in a way that is informative to both the potentially ecologically-uniformed local planner, and the policy-deprived ecological scientist. As this tool and others like it are created and refined,

ecological considerations are more likely to be included in the mechanisms of planning and local policy creation.

Also presented at the start of this manuscript were a series of questions, raised to challenge and explore the idea and aims of the creation of such a heuristic. The first question asks whether local policy can protect ecological function and ecosystem services, and also accommodate residential growth and development. The short answer is, I don't know. We are only beginning to understand the dynamic and interconnected workings of ecological systems and ecosystem services. To say with certainty that policy can definitively address and preserve such systems would discount the phenomenal workings of the natural world. We simply just do not yet know, and the reasons are two-fold: 1. the depth of knowledge we have about ecological systems is far from comprehensive or complete, and 2. There are relatively few local governments that have developed policy of this kind, and we do not yet have the temporal perspective needed to critically evaluate whether or not the policies are in fact effective at maintaining ecological function. Broader pools of research subjects are needed, as well significant periods of time – relevant to ecological time scales – in order to make judgments as to whether or not policy can protect ecological function and accommodate continued development. In concert with this, ecological limits may be better understood, and a system may be devised that enables the identification of and quantification of ecosystem 'tipping points.'

The second question asks: what tools or resources are needed in order to integrate ecological considerations into local land-use planning? One such tool is the heuristic developed herein. The heuristic was designed to be functional and informative, yet simple and straight-forward in its use; I believe these are essential characteristics that enable the introduction of this tool into already established planning processes. The heuristic can be used as a reference guide to ecological function, informing or reminding planners and policymakers of the diversity of services present on a given tract of land, or it may act as a resource to assist in new policy creation by offering sample ordinances and regulations designed to address ecological function. Both of these things are useful in bringing ecological considerations into the local planning process. Furthermore, the heuristic offers a

range of supplementary information and data sources that can assist the user in gathering ecologically relevant local knowledge.

Beyond the heuristic being a tool to integrate ecological considerations into local land-use planning, I believe that planning education and instructional institutions also are essential to this integration. The field of urban planning is studied at a masters or doctoral levels; curricula typically cover topics such as housing, economic development, urban policy and management, public administration, community development, architecture, and education (GradSchools.com n.d.). It is here, within the standard curriculum, that environmental resources and tools should be incorporated, in order to infuse planners early on with ecological information relevant to planning and long-term strategy. To be clear, many graduate planning programs recognized by the Association of Collegiate Schools of Planning (ACSP) do offer environmental planning as an area of planning specialization. Within these specializations it is common for a program to include courses such as ecological concepts, environmental economics, environmental philosophy, environmental psychology, and sustainability, and offer applied knowledge courses such as environmental design, Geographic Information Systems, Environmental Impact Analysis, environmental law and policy, and site planning (White and Mayo 2005, 34). However, a “lack of common ground within environmental planning pedagogy” has led some observers to describe the field as “highly fragmented” (White and Mayo 2005, 33). Overall, I believe that environmental education, resources, and tools should be covered in the touchstone courses for every accredited professional planning program – regardless of the area of specialization an individual may pursue – and that the likely result will be a more seamless integration of ecological considerations in the planning process.

The third and last question raised is can a methodology be developed to assist in linking policy to ecological science and function? I believe it can. At the start of this research project, I set out to create such a methodology. My aim was to produce a tool that could individually assess the ecological function of any given tract of land, based upon ratable ecological criteria as relevant to ecosystem function, and guide the user toward tailored ecological policy suggestions, given the assessment conducted. It did not take long

to recognize the massive scope of such work; given the limitation of my own experience, research abilities, and constraints of time determine I soon discovered it was impossible for me alone to achieve this aim. Instead of this methodology, I developed the heuristic. To clarify the distinction between the two, a methodology offers a defined procedure for the purpose of analysis; and a heuristic serves more simply as an aid to learning or problem-solving (Merriam-Webster n.d.). As described above, this heuristic is a starting point; however it is valuable in its own right as a stepping stone toward a more fully-developed methodology. For now, the heuristic marks a placeholder – a place from which additional research may pick up and possibly one day lead to a fully developed methodology, able to provide in depth analysis of ecological function, and correspondingly, reliable ecological policy fit to the particular needs and conditions of the land. As stated, the creation of such a methodology is a huge undertaking; it would require collaborative efforts on the part of landscape ecologists, environmental planners, natural resource specialists including geographers, hydrologists, and more, and the expertise of land-use planners and policymakers. As described by Philip R. Berke, on the subject of new directions in land-use planning:

In sum, at the start of the twenty-first century, the field of land use planning is well positioned to reform conventional urban development practices that do not give sufficient attention to biodiversity and landscape conservation. Landscape ecological concepts offer new thinking about how to guide the planning agenda for the new millennium. Indeed, the complexity of the task requires holistic and integrative thinking, a task that should be a feasible ideal for land use planners who play central roles as stewards of the public interest. (Berke 2007, 68)

I do believe the creation of such a tool is possible, and I am expectant that the end result would provide a valuable contribution to the planning process. However, until one is developed and used practically in the field, the effectiveness of such a tool to inform and create effective ecological policy will remain unknown.

Given the discussion above, it is clear that more research is needed in the fields of landscape ecology, urban planning, environmental planning and policy, and ecosystem management; however, perhaps more necessary than advancement in any one field individually is the coming together of these subjects in both academic and professional

realms. Should such collaboration ensue, with the result being the implementation of new ecological policies, a couple of matters require attention. First, it is important to create policy that is measurable so that its effectiveness in meeting its goals and objectives can be assessed, and possibly revised and adapted. A plan or policy is only as useful or effective as it is proven to be, therefore this point should not be understated. Without a means to review performance it is impossible to get to a state where policy is truly effective at achieving the preservation of ecological function. Although advances in measurement and data collection have occurred, local plans still commonly fail to put in place indicators to monitor and evaluate such plans and policies. In some areas, like Seattle, WA and Santa Monica, CA, some forward-action has been made by introducing sustainability indicators as part of comprehensive monitoring programs and comprehensive plan review (Berke 2007, 62).

Another important matter to be considered is that of climate change. In the wake of the changing climate, we are positioning ourselves as ill-prepared for the prospect of what may come. Ecological disturbance and degradation influence effects of a changing climate, and contribute to such change (Harte 2001, 948). Harte elaborates this point with the following:

Land use practices have demonstrably altered climate in the past and are likely to do so at an even greater pace in the future. Indeed, at local to regional scales, land use impacts on climate can be comparable to, or greater in magnitude than climate changes anticipated from, say, a doubled carbon dioxide level in the atmosphere. Land use directly affects climate principally by altering the amount of sunlight reflected from the surface of the land and by altering evapotranspiration rates. (948)

In a basic sense, if we continue with land-use planning practices that put us at odds with the ecological systems that support us, we only further aggravate our relationship to the land, and reduce the potential for our own adaptability as we face the calamitous potential of a changing climate.

In final closing, I would like to reiterate a point made in the introduction of this document: the value of our ecological systems cannot be overstated. All of humanity depends on the services that these ecological arrangements provide. In the most basic, self-interested, human sense, it is only practical to address the gap between land-use policy and

ecological science, for without the preservation of ecological systems, we will surely propel ecological degradation further as a result of continued growth and development. An inclusive approach in academic and professional circles is needed to understand and organize the vast array of ecological data and fully integrate such considerations into the land-use planning process. The very quality of our lives, the future of our towns and cities, the sustainability of our lifestyles, and the integrity of the resources we leave to future generations depend on it.

APPENDIX I

Reference number	Title	Type	Author(s) or Editor(s)	Published	Year
1	Ecosystems and Human Well-Being: Wetlands and Water, <i>Synthesis</i> A Report of the Millennium Ecosystem Assessment	Report	Jose Sarukhan, Anne Whyte, and MA Board of Review Editors	World Resources Institute	2005
2	Ecosystems and Human Well-Being: Current States and Trends, Volume 1 Millennium Ecosystem Assessment	Book	Rashid M. Hassan, Robert Scholes, Neville Ash	Island Press	2005
3	Practical Ecology for Planners, Developers, and Citizens	Book	Dan L. Perlman and Jeffrey C. Milder	Island Press	2005
4	Land Mosaics: The Ecology of Landscapes and Regions	Book	Richard T.T. Forman	Cambridge University Press	1995
5	Agricultural Ecosystems: Facts and Trends	Report	World Business Council for Sustainable Development / International Union for Conservation of Nature		2008
6	Ecosystems and Human Well-Being: A framework for Assessment - Ch.2 Ecosystems and Their Services	Report	Joseph Alcamo et. Al	Island Press	2003
7	Environment, Power, and Society	Book	H.T. Odum	Wiley-Interscience New York	1971
8	The Importance of Bees in Nature	Report	Food and Agriculture Organization of the United Nations	United Nations	2009
9	The Sustainable Sites Initiative: Guidelines and Performance Benchmarks 2009	Report	American Society Of Landscape Architects: Lady Bird Johnson Wildflower Center	Sustainable Sites Initiative	2009
10	Nature Friendly Ordinances	Book	James McElfish	Environmental Law Institute	
11	Innovative Land Use Planning Techniques: A Handbook for Sustainable Development	Report	Eric Williams, NH Department of Environmental Services	N.H. Department of Environmental Services	2008
12	Conservation Thresholds for Land Use Planners	Report	Environmental Law Institute	Environmental Law Institute	2003
13	Growing Greener - Putting Conservation into Local Plans and Ordinances	Book	Randall Arendt	Island Press	
14	Self designed standard / strategy / policy / or ordinance		Kim Robertella		2010
15	Wisconsin Wetland Association	Website	Alice L. Thompson and Charles S. Luthin.	http://www.wisconsinwetlands.org/restorationassess.htm	2004
16	Policy Guide on Agricultural Land Preservation	Website	American Planning Association	http://www.planning.org/policy/guides/adopted/agricultural.htm	1999
17	Global Resoration Network - Rivers and Streams	Website	Society for Ecological Restoration International	http://www.globalrestorationnetwork.org/ecosystems/freshwater/riversstreams/	2010
18	Free Flowing Rivers - Economic Luxury or Ecological Necessity?	Report	World Wildlife Fund	http://assets.panda.org/downloads/freeflowingriversreport.pdf	2006
19	Chemical Properties of Rivers	Website	The Encyclopedia of Earth	http://www.eoearth.org/article/Chemical_properties_of_rivers#gen2	2008
20	Groundwater Recharge and Discharge		Maryland Department of the Environment	http://www.mde.state.md.us/Programs/WaterPrograms/Wetlands_Waterways/about_wetlands/discharge.asp	
21	Ecologically Based Municipal Land Use Planning	Book	Honafchesky	Lewis Publishers	1999
22	Nutrient Cycling in Soils	Website	Nova Scotia Agricultural College	http://nsac.ca/pas/staff/cml/cs320nut.htm	
Reference number	Title	Type	Description	URL	
23	The GAP Analysis Program	Website	Land-cover data based on NatureServe Ecological Systems Classification; aids in the identification of habitat of common species to assist in the management of biological diversity on both regional and national scales, and planning conservation areas. Includes impervious surface information.	http://www.nbio.gov/portal/server.pt/community/gap_home/1482	
24	U.S. Geological Survey (USGS) EarthExplorer	Website	Satellite images, aerial photographs, maps, available for purchase or download	http://earthexplorer.usgs.gov	
25	U.S. Natural Resources Conservation Service (NRCS)	Website	Numerous maps, including soil, access to database of North American plants.		
26	U.S. Natural Resources Conservation Service (NRCS) Geospatial Data Gateway	Website	JPEG and GIS files for land use and land cover, transportation, hydrography, topographic images, soils, geology, climate and more.	http://datagateway.nrcs.usda.gov/GDGHome_StatusMaps.aspx	
27	Google Maps	Website	Global satellite and road maps available at varying scales	http://www.google.com/maps	
28	Multi-Resolution Land Characteristics Consortium (MRLC) National Land Cover Database	Website & Database	A 21-class land cover classification scheme applied consistently over the United States, provided on a state-by-state basis.	http://www.mrlc.gov/index.php	
29	Forest Inventory and Analysis National Program	Website	The FIA reports on status and trends in forest area and location; in the species, size, and health of trees; in total tree growth, mortality, and removals by harvest; in wood production and utilization rates by various products; and in forest land ownership.	http://www.fia.fs.fed.us/	
30	State National Heritage Programs	Website	In-depth information on regional biodiversity; documents the status and distribution of the rarest plants and animals by working closely with experts from across the state and in cooperation with the U.S. Fish and Wildlife Service, and others.	http://www.natureserve.org/visitLocal/index.jsp	
31	NatureServe	website	Authoritative source for information on more than 70,000 plants, animals, and ecosystems of the United States and Canada.	http://www.natureserve.org/explorer/	
32	LandScope America	Website	Searchable national map which indicates conservation priorities, protected areas, threats, plants & animals, and ecosystems; a partnership of NatureServe and National Geographic	http://www.landscape.org/map/	
33	Landfire	Website	The nation's most collaborative source of geospatial maps and data, offering consistent and comprehensive landscape-scale data layers. View and download geospatial layers and data products that depict the nation's major ecosystems, wildlife habitat, vegetation or canopy characteristics, landscape features, and wildland fire behavior, effects, and regimes.	http://www.landfire.gov/	

34	U.S. EPA Western Ecology Division	Website	Level III and IV Ecoregions of the Continental United States Requested by the USGS and developed by NatureServe: a detailed range maps of five pollinator species, selected using several criteria: each species is a true pollinator, has a wide distribution, pollinates a broad range of plants, is not domesticated, is representative geographically and taxonomically, and is well known.	http://www.epa.gov/wed/pages/ecoregions/level_iii_iv.htm
35	Distribution Maps of Important Pollinator Species	Website		http://www.natureserve.org/getData/pollinatorMaps.jsp
36	Purdue National Agricultural Pest Information System	Website	Exotic pest detection by state.	http://pest.ceris.purdue.edu/stateselect.php
37	U.S. Animal and Plant Health Inspection Service (APHIS)	Website	In depth information on invasive species; continually updated with info on new outbreaks of pests and diseases.	http://www.aphis.usda.gov/
38	Cornell University Biological Control: Natural Enemies in North America	Website	Photographs and descriptions of biological control (or biocontrol) agents of insect, disease and weed pests in North America; information also on biological control and integrated pest management (IPM).	http://www.nysaes.cornell.edu/ent/biocontrol/
39	U.S. Department of Agriculture NRCS - Acres of Prime Farmland, 1997	Website	Provides a reference map of total acres of 1997 prime farmland; this map may not be used for site-specific information	http://www.nrcs.usda.gov/technical/NRI/maps/meta/m4983.html
40	U.S. EPA Surf Your Watershed	Website	Watershed data including impaired waters, stream flow information, citizen-based groups working within the watershed, and links to National Estuary Programs	http://cfpub.epa.gov/surf/huc.cfm?huc_code=02040106
41	U.S. Geological Survey (USGS) Water Resources of the United States - Maps & GIS Data	Website	Downloadable spatial data files for exploration and analysis.	http://water.usgs.gov/maps.html
42	Federal Emergency Management Agency (FEMA) Mapping Information Platform	Website	Tools and map resources for flood and hazard information.	https://hazards.fema.gov/femaportal/wps/portal
43	GeoData.gov - Federal, State & Local Geographic Data & Maps, Inland Water Resources	Website	The Inland Water Resources category includes data on rivers, lakes, wetlands, canals, glaciers, dams, wells, floods and flood hazards, streamflow, water use, and similar themes.	http://gos2.geodata.gov/wps/portal/gos/kcxml/04_Sj9SPykssy0xPLMnMz0vM0Y_CjzKl9443cnlFSYGYpb6kehCFgghb31fj_zcVPOA_YLc0lhyROVfABDAZMDI/delta/base64xml/L3JldyEvUUki3QndNOSEvNEIVRS82X0tINEFD
44	North Carolina Division of Water Quality, DENR	Website	Water supply and watershed maps and GIS downloads	http://portal.ncdenr.org/web/wq/ps/csu/maps
45	U.S. Fish & Wildlife National Wetland Inventory	Website	Map and national inventory of wetlands and associated riparian features.	http://137.227.242.85/wetland/wetland.html
46	U.S. Fish & Wildlife Service, Species Report	Website	Threatened and Endangered Species listed in each state based on published historic range and population data	http://ecos.fws.gov/tess_public/StateListing.do?state=all
47	U.S. Natural Resources Conservation Service (NRCS) Web Soil Survey (WSS)	Website	Web Soil Survey (WSS) provides soil data and information produced by the National Cooperative Soil Survey. It is operated by the USDA Natural Resources Conservation Service (NRCS).	http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm
48	NRCS Soil Data Mart	Website & Database	Provide a single point of delivery of official soil survey data & information nationwide: information available by state and county.	http://soildatamart.nrcs.usda.gov/
49	The National US Topo Map	Website & Database	Digital topographic maps from the U.S. Geological Survey. Arranged in the traditional 7.5-minute quadrangle format; modern technical advantages that support wider and faster public distribution and enable basic, on-screen geographic analysis.	http://nationalmap.gov/ustopo/index.html

REFERENCES

- Alcano, Joseph, Neville A Ash, Colin D Butler, JB Callicott, Doris Capistrano, and Stephen R Carpenter. *Millennium Ecosystem Assessment, Ecosystems and Human Well-being: A Framework for Assessment*. A Report for the Conceptual Framework Working Group of the Millennium Ecosystem Assessment, Washington, DC: Island Press, 2003.
- American Planning Association. *Policy Guide on Endangered Species and Habitat Protection*. April 25, 1999. <http://www.planning.org/policy/guides/adopted/endanger.htm> (accessed September 28, 2010).
- Anthony, Jerry. "Exploring Causes of Smart Growth Policy Adoption: Many Challenges Persist." *Social Science Quarterly*, 2008: 1373-1377.
- Arendt, Randall. *Growing Greener - Putting Conservation into Local Plans and Ordinances*. Washington, DC: Island Press, 1999.
- Attkisson, Lesley R. "Putting a Stop to Sprawl: State Intervention as a Tool for Growth Management." *Vanderbilt Law Review*, 2009: 980-1015.
- Bailey, Robert G. *Description of the Ecoregions of the United States*. March 1995. <http://www.fs.fed.us/land/ecosysgmt/> (accessed July 18, 2010).
- Berke, Philip R. "Ecology and New Directions for Land Use Planning: Barriers and Opportunities to Change." In *Lasting Landscapes: Reflections on the Role of Conservation Science in Land Use Planning*, by Environmental Law Institute, 59-68. Washington, DC: Environmental Law Institute, 2007.
- Brody, Samuel D. "Implementing the Principles of Ecosystem Management through Local Land Use Planning." *Population and Environment*, 2003: 511-541.
- Charlotte-Mecklenburg Land Planning Commission. "CharMeck.org." *Zoning Ordinance (City of Charlotte)*. April 19, 2010. <http://www.charmeck.org/Planning/ZoningOrdinance/ZoningOrdCityChapter09.pdf> (accessed July 18, 2010).
- Cieslewicz, David J. "The Environmental Impacts of Sprawl." In *Urban Sprawl - Causes, Consequences & Policy Responses*, by the Urban Institute Press Editorial Advisory Board, 23-38. Washington, DC: The Urban Institute Press, 2002.
- Collinge, Sharon K. "Ecological consequences of habitat fragmentation: implications for landscape architecture and planning." *Landscape and Urban Planning*, 1996: 59-77.

- Collins, Sally, and Elizabeth Larry. *Caring for our natural assets: an ecosystem services perspective*. Environmental, Washington, DC: United States Department of Agriculture, Forest Service, 2007.
- Colorado Sprawl Action Center. *Growth Management Toolkit*. January 26, 2006. <http://www.sprawllaction.org/toolkit/2impactfees.html> (accessed December 22, 2009).
- Conservation International. *Cultural Services*. <http://www.conservation.org/learn/culture/Pages/overview.aspx> (accessed September 30, 2010).
- Daily, G, P Alexander, and Erlich et al. "Ecosystem Services: Benefits Supplied to Human Societies by Natural Ecosystems." *Issues in Ecology* (Ecological Society of America), no. 2 (Spring 1997): 1-13.
- Daily, Gretchen C. "Introduction: What Are Ecosystem Services?" In *Nature's services: societal dependence on natural ecosystems*, by Gretchen C Daily, 1-10. Washington, DC: Island Press, 1997.
- Daily, Gretchen. "Management Objectives for the Protection of Ecosystem Services." *Environmental Science and Policy*, 2000: 333-339.
- Dale, VH, et al. "Ecological Principles and Guidelines for Managing the Use of Land." *Ecological Applications* 10, no. 3 (June 2000): 639-670.
- Daniels, Steven E, and Gregg B Walker. "Collaborative Learning: Improving Public Deliberation in Ecosystem-Based Management." *Environmental Impact Assessment Review*, 1996: 71-102.
- de Groot, Rudolf. "Function-analysis and valuation as a tool to assess land use conflicts in planning for sustainable, multi-functional landscapes." *Landscape and Urban Planning*, 2006: 175-186.
- de Groot, Rudolf S, Matthew A Wilson, and Roelof M J Boumans. "A typology for the classification, description and valuation of ecosystem functions, goods and services." *Ecological Economics*, 2002: 393-408.
- Environmental Law Institute. *Conservation Thresholds for Land Use Planners*. Research Report, Washington, DC: Environmental Law Institute, 2003.
- FindLaw, a Thomson Reuters business. *Land Use and Zoning Basics*. 2010. <http://realestate.findlaw.com/zoning/home-land-use-zoning-overview.html> (accessed July 18, 2010).
- . *Types of Zoning*. 2010. <http://realestate.findlaw.com/zoning/types-of-zoning.html> (accessed July 18, 2010).

- Forman, Richard T T. *Land Mosaics - The ecology of landscapes and regions*. New York: Cambridge University Press, 1995.
- Godfrey, Michael A. *Field Guide to the Piedmont: The Natural Habitats of America's Most Lived-in Region, from New York City to Montgomery, Alabama*. Chapel Hill, NC: The University of North Carolina Press, 1997.
- Golubiewski, Nancy. "Encyclopedia of the Earth." *Landscape ecology: Its role as the scientific underpinning of land-use planning*. February 18, 2008.
http://www.eoearth.org/article/Landscape_ecology:_Its_role_as_the_scientific_underpinning_of_land-use_planning (accessed July 15, 2010).
- Gong, J, L D Chen, B J Fu, and W Wei. "Integrated effects of slope aspect and land use on soil nutrients in a small catchment in a hilly loess area, China." *International Journal of Sustainable Development & World Ecology*, 2007: 307-316.
- GradSchools.com. *Urban Planning Curriculum*. <http://www.gradschools.com/article-detail/urban-planning-curriculum-252> (accessed October 22, 2010).
- Griffith, G.E., et al. "U.S. Environmental Protection Agency, Western Ecology Division." *Ecoregions of North and South Carolina (color poster with map, descriptive text, summary tables, and photographs)*. 2002.
http://www.epa.gov/wed/pages/ecoregions/ncsc_eco.htm (accessed July 26, 2010).
- Grumbine, Edward R. "What is Ecosystem Management?" *Conservation Biology* 8, no. 1 (March 1994): 27-38.
- Harte, J. "Land Use, Biodiversity, and Ecosystem Integrity: The Challenge of Preserving Earth's Life Support System." *Ecology Law Quarterly*, 2001: 929-966.
- Harwell, Mark A, et al. "A Framework for an Ecosystem Integrity Report Card." *BioScience*, 1999: 543-556.
- Henderson, Bonnie M, and Stephan J Walsh. "Plowed, Paved, or in Succession: Land-Cover Change on the North Carolina Piedmont." *Southeastern Geographer*, 1996: 132-149.
- Honachefsky, William B. *Ecologically Based Municipal Land Use Planning*. Boca Raton, FL: Lewis Publishers, 2000.
- Huntington, Stuart. "Land Use Series - The Zoning Ordinance." *Iowa State University - University Extension*. February 2001.
<http://www.extension.iastate.edu/Publications/PM1868G.pdf> (accessed July 19, 2010).
- Kayden, Jerold S. "National Land Use Planning in America: Something Whose Time has Never Come*." *Festschrift* 3 (2000): 445-472.

- Lamont, Averil. "Policy Characterization of Ecosystem Management." *Environmental Monitoring and Assessment*, 2006: 5-18.
- Lessard, Gene. "An adaptive approach to planning and decision-making." *Landscape and Urban Planning*, 1998: 81-87.
- Marsh, Lindell, Douglas Porter, and David Salvesen. "The Impact of Environment Mandates on Urban Growth." *Cityscape: A Journal of Policy Development and Research* (U.S. Department of Housing and Urban Development), September 1996: 127-154.
- McElfish, James M. *Nature-Friendly Ordinances*. Washington, DC: Environmental Law Institute, 2004.
- Merriam-Webster. *Methodology, Heuristic*. <http://www.merriam-webster.com/dictionary/heuristic?show=0&t=1288123756> (accessed October 29, 2010).
- Monteith, Nancy, and Rich Schrader. *University of New Mexico: Landscape Ecology & Macroscopic Dynamics*. May 1996.
<http://sev.lternet.edu/~bmilne/bio576/instr/html/res13131//finaleuro.html> (accessed July 18, 2010).
- National Parks Conservation Association. *Natural Resources Assessment and Ratings Methodology*. Special Report, Fort Collins, CO: Center for the State of the Parks, 2003.
- Natural Resources Defense Council. *Paving Paradise - Sprawl and the Environment*. 1999.
<http://www.nrdc.org/cities/smartGrowth/rpave.asp> (accessed December 22, 2009).
- New Hampshire Department of Environmental Services. "Innovative Land Use Planning Techniques: A Handbook for Sustainable Development." *New Hampshire Department of Environmental Services*. October 2008.
http://des.nh.gov/organization/divisions/water/wmb/repp/documents/ilupt_complete_handbook.pdf (accessed September 8, 2010).
- North Carolina State University Cooperative Extension. *1997 Natural Resources Inventory of North Carolina*. 1997. <http://www.ces.ncsu.edu/nreos/ncnatres/> (accessed September 2, 2010).
- Noss, Reed F. "Conservation Thresholds: Overview and Commentary." *Lasting Landscapes: Reflections on the Role of Conservation Science in Land Use Planning*. Washington, DC: Environmental Law Institute, 2007.
- O'Connell, L. "Exploring the Social Roots of Smart Growth Policy Adoption." *Social Science Quarterly*, 2008: 1356-1372.
- Omernik, James. "Perspectives on the Nature and Definition of Ecological Regions." *Environmental Management* 34 (2004): S27-S38.

- Roberts, Peter. "Sustainable Regional Planning." *Regional Studies*, 1994: 781-787.
- Sierra Club - Minnesota North Star Chapter. *Glossary of Planning Terms*.
<http://northstar.sierraclub.org/campaigns/open-space/land-use/planningGlossary.html#G>
 (accessed July 9, 2010).
- Slocombe, Scott D. "Environmental Planning, Ecosystem Science, and Ecosystem Approaches for Integrating Environment and Development." *Environmental Management*, 1993: 289-303.
- Smart Communities Network. *Green Development Benefits & Basic Elements*. January 30, 2004. <http://www.smartcommunities.ncat.org/greendev/benefits.shtml> (accessed July 19, 2010).
- Southeast Michigan Council of Governments. "Southeast Michigan Council of Governments." *Land Use Tools and Techniques: A Handbook for Local Communities*. March 2003. www.semcog.org (accessed August 28, 2010).
- State Government of Indiana. *Directing Development and Growth - Cluster Development*. http://www.in.gov/indot/div/projects/i69planningtoolbox/_pdf/Cluster%20Development.pdf (accessed July 18, 2010).
- Stein, Bruce A. "Bridging the Gap: Incorporating Science-Based Information into Land Use Planning." In *Lasting Landscapes: Reflections on the Role of Conservation Science in Land Use Planning*, by Environmental Law Institute, 52-58. Washington, DC: Environmental Law Institute, 2007.
- Steiner, Frederick R, and Ken Butler. *Planning and Urban Design Standards - Student Edition*. Hoboken, New Jersey: John Wiley & Sons, Inc. , 2007.
- Szaro, R. "The Emergence of Ecosystem Management as a Tool for Meeting People's Needs and Sustaining Ecosystems." *Landscape and Urban Planning*, 1998: 1-7.
- Tarlock, A. "Land Use Regulation: The Weak Link in Environmental Protection." *Washington Law Review*, 2007: 651-666.
- The University of Vermont. "Gund Institute for Ecological Economics." *Fellows and Personnel*. 2010.
http://www.uvm.edu/giee/?Page=about/Robert_Costanza.html&SM=about/about_menu.html
 (accessed October 12, 2010).
- Turner, Monica G. "Landscape Ecology in North America: Past, Present and Future." *Ecology*, 2005: 1967-1974.

- Turner, Monica G. "LANDSCAPE ECOLOGY: The Effect of Pattern on Process." *Annual Review of Ecology and Systematics*, 1989: 171-197.
- Turner, Monica G. "Landscape Ecology: What is the State of the Science?" *Annual Reviews*, 2005: 319-344.
- Turner, RK, and GC Daily. "The Ecosystem Services Framework and Natural Capital Conservation." *Environmental and Resource Economics*, 2007: 25-35.
- U.S. Department of Transportation Federal Highway Administration. *Land Use Policies*. <http://www.walkinginfo.org/develop/policies-land.cfm> (accessed September 29, 2010).
- . *Land Use Policies*. <http://www.walkinginfo.org/develop/policies-land.cfm> (accessed September 29, 2010).
- U.S. Environmental Protection Agency. *Ecoregions of the United States*. April 2, 2009. <http://www.epa.gov/bioiweb1/html/usecoregions.html> (accessed July 17, 2010).
- . *Environmental Benefits of Smart Growth*. July 1, 2010. <http://www.epa.gov/smartgrowth/topics/eb.htm> (accessed July 8, 2010).
- "U.S. Environmental Protection Agency, Western Ecology Division." *Level IV Ecoregions*. June 28, 2010. http://www.epa.gov/wed/pages/ecoregions/level_iv.htm (accessed July 26, 2010).
- U.S. EPA. "Ecological Regions of North America, Level II Ecoregions." *U.S. Environmental Protection Agency Western Ecology Division*. May 3, 2010. ftp://ftp.epa.gov/wed/ecoregions/cec_na/NA_LEVEL_II.pdf (accessed July 25, 2010).
- United States Census Bureau. "Historical Census of Housing Tables Units in Structure." *Census of Housing*. December 16, 2005. <http://www.census.gov/hhes/www/housing/census/historic/units.html> (accessed October 13, 2010).
- United States Environmental Protection Agency. *Our Built and Natural Environments: A Technical Review of the Interactions between Land Use, Transportation and Environmental Quality*. Environmental Publication, Washington, DC: U.S. EPA, 2001.
- University of Michigan, Global Change Curriculum. *The Flow of Energy: Primary Production to Higher Trophic Levels*. October 31, 2008. <http://www.globalchange.umich.edu/globalchange1/current/lectures/klings/energyflow/energyflow.html> (accessed September 10, 2010).
- White, Stacy Swearingen, and James M Mayo. "Environmental Education in Graduate Professional Degrees: The Case of Urban Planning." *The Journal of Environmental Education* 36 (2005): 31-38.

Wu, Jingle. "Toward a Landscape Ecology of Cities: Beyond Buildings, Trees and Urban Forests." *Landscape Ecology*, 2008: 10-28.

