Prioritizing Conservation Efforts in the Squam Lakes Watershed using knowledge-based models

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As an increasing number of Americans are leaving urban and suburban areas to live in rural and exurban regions, agricultural and forested land continues to be converted for residential development. This conversion pattern is most prominent in rural regions with attractive natural resource amenities such as aesthetic value and recreational opportunities. One method of preserving rural landscapes has been through the acquisition of conservation easements held by local, regional, or national land trusts. However, no precise formula exists for committing private land to a conservation easement. This project created logic-based models using conservation criteria established by a land trust, the Squam Lakes Conservation Society (SLCS) in central New Hampshire, to address the need for a systematic, data-driven approach to prioritizing conservation easements. The model prioritized areas within the Squam Lakes watershed and evaluated existing conservation easements based on the SLCS criteria. The model was created so that it can adapt as the needs and values of the community that operates through SLCS can change through time.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Chapter 1
Introduction

1.0 Introduction

Drastic land use changes in the United States have occurred over the past 50 years (Brown et al., 2005). As an increasing number of Americans are leaving urban and suburban areas to live in rural and exurban regions, agricultural and forested land continues to be converted for residential development (Alig et al., 2004; Cho and Newman 2005). This conversion pattern is most prominent in rural regions with attractive natural resource amenities such as aesthetic value and recreational opportunities (Deller et al., 2001). One such area is the Squam Lakes Region. The Squam Lakes, Big and Little Squam Lake, are located in central New Hampshire south of the White Mountains and north of Lake Winnipesaukee and its surrounding towns, Holderness, Sandwich, Moultonborough, Ashland, and Center Harbor. The lakes have experienced population and housing growth especially in the past few decades. The Squam Lakes Conservation Society (SLCS), a land trust, was established in 1960 to preserve land within the 41,714 acres of the Sqam Lakes watershed (SLW) to mitigate development. Conservation easements (CEs) held by land trusts are used as a tool to limit the further development of private land for perpetuity to address concerns about the impacts of development. Many CEs seek to preserve private lands that contain ecologically sensitive areas, wildlife habitat, and scenic views (LTA 2006) and the preservation of working landscapes, such as ranches, farms, and specialty crop farms can also be achieved through the implementation of CEs.

Despite their importance as tools for conservation, there is a lack of consistent methods for selecting CEs. Like many land trusts across the nation, SLCS does not have a standardized method for prioritizing conservation values and focusing efforts within the Squam Lakes watershed to evaluate future conservation. Many land trusts have adopted policies and mission statements that concentrate on areas that contain ecologically sensitive areas that are threatened by development, that provide habitat for rare species, and that provide a significant public benefit. These priorities are often evaluated on a case-by-case basis and may not necessarily be considered in the greater context of other conserved lands. For example, one recent study (Cronan et al., 2010) investigated the distribution of conserved land in Maine concluding that many spatial gaps were present within habitat blocks and large contiguous tracts of land. Without an objective system to guide decision making, easements may not be selected using the appropriate criteria to achieve conservation goals. In addition the criteria to be considered in determining conservation priorities are very complex and involve multiple interactions, and the establishment of a system designed to handle the complexity inherent in these relationships is essential for making decisions informed by the range of scientific and social considerations. The rapid growth of land trusts and the number of acres conserved by easements has drastically increased in the last two decades, but the lack of funds and knowledge of private lands has made it difficult to establish a consistent system. To address the lack of a standardized method for selecting future easements the goal of this study was to create a model to spatially represent the areas of greatest conservation value based on the conservation criteria established by the Squam Lakes Conservation Society.

This tool will help SLCS evaluate proposed conservation easements and develop a long-term conservation strategy and the approach developed can be applied in many other settings to inform efforts to achieve conservation objectives. To create this strategy, an organized body of knowledge that provides a formal logical specification for the interpretation of information known as a knowledge base model (Walters and Nielsen 1988; Reynolds 1999) was created based on the SLCS priority conservation criteria. Criteria within the knowledge model were linked to associated data after the knowledge base model was developed and then evaluated using the Ecosystem Management Decision Support (EMDS) system developed by the US Forest Service (Reynolds 1999). EMDS was used to integrate the knowledge based reasoning into the Geographic Information System (GIS) environment to evaluate the existing condition of the SLW. The model was created so that it can adapt as the needs and values of the community that operates through SLCS can change through time, and represents a systematic, data-driven approach others can use to address the challenge of identifying conservation priorities for establishing future conservation easements.

1.1 Historical background of the Squam Lake region

Human settlement over two centuries in the Squam Lakes watershed is representative of the northern New England area. Settled around 1760 following the end of the French and Indian war, the areas surrounding Squam Lakes were predominantly cultivated for subsistence farming (Heald 2002). This practice of farming often led to late succesional forest clear cuts for agriculture and timber extraction. Beginning in the late 1800s and early 1900s with the advance of railroads and decline of subsistence farming, Squam attracted many vacationers and their families (Heald 2002). Although farmers found it difficult to meet their needs through agriculture and lumber sales, the presence of tourism in the Squam Lakes area's economic market contributed greatly to local incomes. Throughout the late 19th and early 20th century, tourists ranged from family visitors to middle class professionals escaping cities such as Boston and Philadelphia to lakefronts in New Hampshire such as Lake Winnipesauke and Squam Lakes (Brereton 1992). The concept of "getting back to the essentials" inspired many tourists to visit the Lakes Region in New Hampshire. During this time, many summer vacationers began to purchase and build "campsteads" around Squam Lake (Brereton 1992). The attractions of Squam Lake were unlike the city, and included a healthier lifestyle, slower pace mentality, and many recreational activities. Fishing, swimming, and summer camps were common attractions at Squam Lake. These summer campsteads were generally small, seasonal cabins established to accommodate summer seasonal visitors and children learned appreciation for the natural environment and outdoor skills.

Unfortunately, the lifestyle of local residents and seasonal visitors caused the quality of the natural environment to show signs of deterioration at the end of the 1800s and beginning of the 1900s (New Hampshire State Board of Health 1908). The drastic depletion of salmon was documented in the late 1760s, although a quick response to these depleted fish populations led to the first official stocking of Squam Lake with smallmouth bass. Fish were not the only biota to experience a sharp decline in population, in addition hunting became extremely popular. In response to environmental decline, Edward Everett Hale founded the Society for Protection of New Hampshire Forests in 1901 in order to protect New Hampshire's most important landscapes while promoting the wise use of its renewable natural resources. Then in 1904, the Squam Lake Improvement Association was established to promote the protection, careful use and shared enjoyment of the lakes, mountains, forests, open spaces and wildlife of the Squam Lakes eventually becoming the Squam Lakes Association (www.squamlakes.org).

Despite the documentation of overfishing and decreased mammal populations, it is documented that 175,000 visitors in 1899 provided the State of New Hampshire with revenue of 6.6 million dollars (Carly 2004). These profits were enough to support many local residents and it has been claimed that many businesses made three-fourths of their yearly income during the summer season. The local economy adapted to meet the needs of visiting campers along the lake. As early as 1900, seasonal campsteads were being built within the Squam Lakes watershed.

This income, however, did not improve the natural ecosystem and the degradation of that ecosystem became apparent through the decline of various wildlife species. For example, the last passenger pigeon was seen in the area in the early 1900s (Bucher 1992). In response, the first federal legislation protecting birds was passed in 1918 as the Migratory Bird Treaty Act (MBTA 1918). As the Great Depression approached, a period of economic downturn was experienced in the Squam Lake area but certainly nowhere near the extent of the rest of the country. “[U]ntil this period, conservation efforts in Squam vicinity had been limited to ridding the lake waters of debris and pollutants and protecting the land from clearing and development through private ownership” (Carley 2004). Over a century of anthropogenic stresses in the form of clear-cutting, agricultural use, and residential development altered the landscape of the Squam Lakes watershed. The decline of quality in natural amenities surrounding Squam Lakes over time could threaten to decrease not only the number of visitors, but also the quality of habitat for both wildlife and human needs. Additional action would be needed from local citizens to protect traditional uses of the land as well as the natural aesthetics of the Squam Lakes.

1.2 Early Squam Lake Conservation Efforts

Concerned residents reacted in a variety of ways to these issues, including the establishment of Squam Lakes Improvement Association and the Society for the Protection of New Hampshire Forests, organizations created specifically to protect the natural environment. In addition others, including Widow Cary Hoge Mead, for example, donated land to the U.S. Forest service. In 1960, Frank Webster II, William S. Barnes, and Harold J. Coolidge Jr. founded the Squam Lakes Conservation Society to preserve privately owned land for perpetuity. From 1961 to 1963 the first complete map of Squam Lake contributed to shoreline measurements as part of land conservation initiatives and in 1966, Margaret Armstrong Howe donated land for the Armstrong Natural Area on West Rattlesnake, a small mountain that provides scenic views and frequent public use from the northern part of Squam Lake, for public use to the University of New Hampshire Forestry Departments. Also in 1966, a residential development proposal for hundreds of quarter-acre lots was lobbied for in the local area surrounding Squam Lake (Carley 2004). Initially, protestors to the development reacted against the construction plans because of its location in wetlands. Despite many efforts to push forward with the development plans, the construction proposal was halted because the area lacked a suitable area for sewage system. Finally, the developers were required to remove much of the soil used to fill the wetlands, but much of the soil had already entered the lake.

These early conservation efforts to protect the area around the Squam Lakes have continued into current times. During the early to mid-1970s, moose and loon populations were targeted as species in population decline despite previous efforts to maintain their numbers. The Audubon Society of New Hampshire and the Loon Preservation Committee worked to understand the reason for the declining loon numbers and facilitate their protection. A portion of the problem was linked to adult loon mortality caused by ingesting lead fishing sinkers (Sidor et al., 2003). These unintended consequences of anthropogenic use of the ecosystem were highlighted by the decline in loon species. Despite the challenges resulting from the unintended consequences of settlement in the Squam Lakes region, as well as much of the State of New Hampshire, constituencies pushed forward in their conservation and protection efforts. Unfortunately in 1979, loons were still listed as a threatened species. The New Hampshire Endangered Species Conservation Act was passed in 1979 in order to strengthen endangered species populations such as the loon (NH Endangered Species Conservation Act, Chapter 212-A:1).

Throughout the 1900s and into the new millennium, tourism and campsteads continued to anchor the local economy. The 1980 film *On Golden Pond* featuring Squam Lake accelerated tourism and the general popularity of Squam Lake (http://www.squamlakeschamber.com/golden_pond.php), and contributed to the consistently high demand for development and recreation on the lake. Reorganization for public access to Squam Lake mandated creation of a Public Water Access Board in 1993, requiring the Lake to have nine access points. The completion of a public boat ramp in Holderness was the result of a cooperative agreement between State agencies and private non-profit groups in 2001 (Carley 2004).

Although traditional land uses around the Squam Lakes are an important component of the local economy, meeting the demands of human land uses can have significant unintended ecosystem consequences (DeFries et al., 2007). These interactions between humans and the natural environment involve complex systems that are rarely understood and the affects are often only measurable over a broad time scale (Liu 2007). In order to begin to assess the roles humans contribute to environmental degradation, ecological knowledge of the ecosystem is a prerequisite to understand the full affect of humans (Kremen 2005). Trade-offs between human demand and ecosystem integrity are not fully understood without a foundation of ecological knowledge for comparison. Conservation easements seek to preserve sustainable human land uses and sometimes help create management plans. Maintaining a healthy ecosystem while simultaneously managing human land uses would be an ideal goal for a land trust (Pidot 2005; DeFries et al., 2007).

Human impact and land use change for the past two centuries continue to influence the dynamics of the coupled human and natural systems of the Squam Lakes. It has largely been due to non-profit local non-governmental organizations and community movements that promoted the need for protection and conservation that impacts of land use changes on natural systems have been minimized. In order to account for the linkages that exist between natural systems and social systems in the watershed, and to plan for conservation effectively a system that accounts for both considerations to direct conservation efforts is needed. This project will combine ecological and social conditions that the SLCS has identified as critical for maintaining the character of the SLW for perpetuity. Because easements last forever, identifying areas that contain both social and ecological conditions will be essential for the Squam Lakes region to still be valued for its sense of place.

Chapter 2
Literature review of development in rural areas, land trusts, and conservation easements

2.0 Introduction

In the case of Squam Lake, the aesthetic value and the natural resources found in this rural environment are necessary to maintain its character and sense of community. As a result of the activities of seasonal visitors, second homeowners, and year-round residents, there are many complex environmental challenges that have arisen and threaten social and environmental well-being in the watershed. Spatially identifying the areas that are essential in preserving both the ecological and social integrity of Squam Lakes watershed could help address many of the land use challenges facing rural communities.

The number of Americans leaving urban areas and moving to rural regions causes pressure to subdivide land for residential development (Wallace et al., 2008). Land-use changes are especially significant in areas where urban development abuts against private and public rural and wildlands, known as the wildland-urban interface (WUI) (Radeloff et al., 2005). In particular, these same areas are currently experiencing high rates of land-use conversion. The most obvious trends of land-use conversion include extremely low-density residential development in rural areas that greatly impact the entire ecosystem (Harte 2000). As land conversion continues in the WUI, the nature of human uses of forested landscapes becomes increasingly complex. The fiber and fuel provided by a forest are accompanied by social, economic, and ecological consequences that result from human demands (Constanza 1998; Daily 1997).

Natural amenities in the WUI such as aesthetic values, recreational opportunities, and other non-market attributes have been shown to be driving population growth and expanding the WUI (Yin and Muller 2007; Deller et al., 2001; Kim et al., 2005). As of 2005, WUI covered 9% of the conterminous United States and contained 39% of all housing units (Brown et al., 2005; Radeloff et al., 2005). The type of land development within the WUI has significant ecological impacts that include loss of forest habitat for plants and animals due to widely dispersed residential development (Hammer et al., 2004). Increased impervious surfaces from road construction and addition of housing units may affect water quality (Carpenter et al., 2008) especially in regions where natural amenity development is often associated with proximity to water bodies (Walsh et al., 2003). Residential development often occurs on agricultural lands, destroys wildlife habitat and affects biological diversity (Hansen et al., 2005). Population and housing growth in rural regions related to natural amenities may also influence the social fabric of communities by yielding higher levels of local unemployment, lower income levels, and generally lower overall economic well-being (Marcouiller et al., 2004). This migration to rural regions by residents who live on, but not off, the land represents a major, fundamental change in settlement patterns and has many possible unintended consequences.

The need for conservation to preserve both the ecological and social integrity of rural regions in the United States is strong. One method of preserving rural landscapes has been through the acquisition of conservation easements (CEs) held by local, regional, or national land trusts. A CE is a legally binding agreement by which a landowner either sells or donates an easement to a conservation organization. Typically, the goal of the easement is to further conservation of a certain region by preservation of biodiversity, wildlife habitat, riparian areas, open space, or agricultural land. CEs usually limit land use by prohibiting subdivisions, commercial and industrial development for perpetuity. They do, however, allow for restricted agricultural and residential uses (Morrisette 2001). The government agency or land trust that holds the CE is required to enforce the term of the easement for perpetuity (McLaughlin 2004). This permanent arrangement is intended to benefit the public by ensuring that conservation values are protected forever (McLaughlin 2004). Land trusts can influence land use directly by either owning the land or holding a CE. Extinguishing development rights of privately conserved lands, local stakeholders are addressing the trends of rural conversion. This is one method used to preserve not only the integrity of ecosystems but also ensure the feasibility of traditional land uses in rural regions.

2.1 Land trusts

According to the Land Trust Alliance, a land trust is a type of nonprofit organization that, as all or part of its mission, actively works to conserve land by undertaking or assisting direct land transactions—primarily the purchase or acceptance of donations of land or CEs (LTA 2000). For the most part, land trusts have charitable status and are exempt from federal and sometimes State income taxes. An unpaid Board of Trustees governs the land trust and the Board is responsible for a variety of decisions, but predominantly manages the land trust assets and approves proposed CEs. The residents and visitors of the region in which a land trust operates who have regular physical or scenic access to land conserved by land trusts are considered the beneficiaries. Nearly half of State, local, and regional land trusts, according to the Land Trust Alliance Census published in 2006, report that land trusts across the nation are protecting river corridors, wetlands, watersheds, open space, farmlands, ranchlands, or endangered species habitat. However, less than 40 percent report protecting amenities such as scenic views, recreational trails, historical and cultural areas, and coastal resources (LTA 2006).

From 1950 to 2000, the number of land trusts in the United States grew from 53 to 1263 (LTA 2000). During the 1980s, the number of CEs increased drastically in part because of the enactment of federal tax incentives to encourage landowners to voluntarily convey CEs for the benefit of the public. In 1980, section 170(h) of the Internal Revenue Code granted a tax deduction tied to the donor's adjusted gross income. To qualify for this deduction, the easement must be granted for perpetuity and the conservation purposes must include: the preservation of land for public recreation or education; the protection of a relatively natural habitat for wildlife, fish, or plants; the preservation of open space that has scenic qualities including farmland and forest land either benefiting the public or pursuant to governmental conservation policy; and the preservation of an historically important land area or certified historic structure (Treasury Regulation § 1.170A-14(d)(1)-5 2001). Currently there are additional types of incentives through State income, estate, and property-tax deductions to motivate landowners to conserve their private land (Gustanski and Squires 2000). Abuse of these incentives, however, became evident to the public when the *Washington Post* in May 2003 published articles addressing donations of CEs that were exploiting the system (Ottaway and Stephens 2003). These articles highlighted cases in which transactions involving CEs included appraisals that were overvalued and tax deductions were received for undevelopable land. The articles also raised serious concerns regarding the use of easements in enhancing the wealth of developers or protecting the view shed of large landowners at public expense (King and Fairfax 2006). Incentives for private landowners are significant and without standardization of CEs and monitoring, it is difficult to identify and ensure that the ecological benefits and outcomes of easements are meeting their original intent.

In recent years, more efforts have been made to standardize the acquisition of CEs by organizations such as the Land Trust Alliance and Congress. The Land Trust Alliance (LTA) is committed to land conservation by providing support to land trusts, educating the public about land trusts, and defending the permanence of CEs. Both Congress and the Internal Revenue Service (IRS) have also joined in this process of standardization, especially in monitoring the charitable deductions of CEs (King and Fairfax 2006). More specifically, the IRS issued a notice warning that it would investigate the claims of federal charitable income tax deductions on conservation easements and intended to impose penalties for those found in violation.

2.2 Challenges to identifying areas for conservation easements

Currently, no precise formula exists for establishing the criteria for committing private land to conservation for perpetuity such as a CE. Instead, the final decision is left to the institution granting the easement so long as it includes 170(h) requirements. In many cases, land trusts have been opportunistic in acquiring easements across the country particularly within the last decade as incentives have provided feasible financial situations for landowners. Prior to the establishment of the Land Trust Alliance and 170(h) requirements very few land trusts had adopted conservation values that prioritized key ecological and social conditions. The process of identifying the areas of greatest conservation need or methods of prioritizing conservation values is complex. Methods have been studied and applied to identify key biodiversity areas (Eken 2004) across all biogeographic regions and taxonomic groups for site-scale conservation. Previous efforts for identifying conservation lands also include the use of utility-maximization frameworks (Davis et al., 2006), multicriteria analysis (MCA) (Strager and Rosenberger 2006), and many other frameworks that are at large regional scales and do not necessarily translate well to the smaller scales that many land trusts in New England target for conservation (5-50 acres). Studies have shown that habitats or ecosystems with a suitably wide buffer zone can be protected in cases including micro-scale species such as rare plants and invertebrates (Poiani et al., 2000). Mesopatch species, however, including plants and animal species with small home ranges occur at a scale of 10 to 1000 hectares usually require larger patches of conserved land (Milder 2007). In many cases, the standardization of scientific data collection needed to focus conservation efforts does not exist (Merenlender et al., 2004). In most cases, land trusts seek to preserve the biodiversity of an ecosystem and the traditional land uses that contribute to the local economy (Kiesecker 2007). Very little, however, is known about the ecological and social outcomes of these CEs (Merenlender et al., 2004).

The impacts of land development are not limited by property boundaries but can affect nearby ecosystems (Hansen et al., 2002). A critical goal for conservation development, then, is to minimize harm to the surrounding landscape. Some studies have used gap analysis to compare the distribution of vegetation types and species in relation to current conservation areas in order to identify "gaps" of under represented landscape features (Jennings 2000; Dietz and Czech 2005). Very few of these studies include a focus on meeting the demands of human land uses while maintaining a healthy ecosystem such as investigating the way land uses can impact land cover in order to evaluate the impacts of humans over time (Miller and Hobbs 2002). Given the complexity of interrelationships involved, a systematic approach for understanding and addressing these issues is needed.

There are significant trade-offs when considering the criteria of land conservation because easements can allow for some private residential and agricultural use (Rissman 2007). The impacts on critical ecological functions can be significant depending on the types of land use allowed. In general, the amount of development allowed on an easement is proportional to its size, and working landscapes tend to require more structural development than any other type of easement. The overall function of agricultural and ranching easements may require greater scrutiny for properties providing core habitat protection (McLaughlin 2002). An overall need for the development of more systems to evaluate the efficacy of land trusts, the methods of prioritizing acquisitions, land-management decisions, and the influence of decision-making of board members has been identified (Merenlender et al., 2004). Addressing this need will require a collaborative approach including the land trust, local government, and the broader community.

2.3 Knowledge base models and the Ecosystem Management Decision Support system

This project used a logic-based model, developed with the NetWeaver system. The model is based on the conservation criteria established by the SLCS and is integrated into the Ecosystem Management Decision Support (EMDS) system to address the previously identified needs for a systematic approach to prioritizing conservation efforts for perpetuity. EMDS is an application framework for knowledge-based decision support of ecological assessments at any geographic scale and integrates knowledge based reasoning into the Geographic Information System (GIS) environment of ArcMap (Environmental Systems Research Institute, Redlands, CA).

After a knowledge based model was created, EMDS was used to provide decision support for the Squam Lakes watershed (SLW). The NetWeaver development system readily supports design of logic specifications for large, complex, and abstract problems.

A NetWeaver knowledge base consists of dependency networks, logic operators, and data links. A dependency network is a hierarchical network that evaluates a proposition about the condition of some ecosystem state or process. The network asserts some proposition concerning the topic it is constructed to evaluate. Networks query their antecedants, evaluate their own state given the state of their antecedants, and inform higher level networks that depend on them about their state (Reynolds 1999). The result of an evaluation is a score (the truth value) that expresses the degree to which preceding information supports or contradicts the proposition that the network is designed to test. A network can be evaluated as part of another network and data links are elementary networks used to read and evaluate data. A data link evaluates a proposition by comparing the argument that defines the reference condition and the value of an observation made in reference to the proposition. Logic operators are used to specify the logical dependency of a network on its antecedents. The most commonly used logic operator is the “UNION” which contains all the conditions of that network according to its antecedents. NetWeaver uses fuzzy logic to evaluate topics of interest and identify missing information. Fuzzy logic can handle approximate information in a systematic way to mathematically represent uncertainty and vagueness in order to deal with imperfect information.

The logic engine can evaluate the influence of missing information on the logical completeness of an assessment and the missing data can be prioritized. It is useful for modeling abstract topics in multi-criteria assessments in which the scores of individual factors are combined into an overall ranking. Other, more traditional modeling approaches such as statistical or simulation models often do not work as well because the elements of the problem or the relationships between the elements are so abstract or there is not enough information or data regarding the elements to effectively implement a mathematical model (Reynolds 1999). In many situations, data may simply not exist and the application of a proxy for the missing information may not be accurate. EMDS can identify the importance of this missing information in the overall ranking. EMDS also allows the decision user to adapt and change various components of the model in many ways. For example the user may weight various logic topics and decision criteria as more important within the overall knowledge structure.

2.4 Conservation Easements of Squam Lakes Conservation Society

Land trusts have identified the need for conserving both ecologically sensitive areas as well as traditional land uses still practiced within an ecosystem. For the Squam Lake Conservation Society, "the mission is to preserve the unique quality and character of the Squam watershed by protecting lands for present and future generations" (www.squamlakes.com). The SLCS currently holds sixty-four CEs and owns twenty-two properties that total 6,528 acres and each easement is unique in its ecological and social characteristics. In order to implement their mission statement, the variety of easements held by SLCS span from small, historical, summer campsteads to large contiguous tracts of forest that contain old growth forest.

For example in March of 1980, the Squam Lakes Conservation Society entered into a conservation agreement with Kate L. and Kingsland Van Winkle. The intent of the landowners was to protect the property from development but to allow forest management and hiking and snowshoeing by the general public. The initial CE deed was postponed until the Althea Hawley Trust acquired the parcel as part of a land exchange/purchase between the Hawley family and the Van Winkle estate around 1996. The easement, named Harvard Point, contains 15.5 acres of land and includes wooded forest type.

Archie and Eleanor Stark first approached SLCS with interest in a CE as part of their will. At that time, the SLCS Board of Directors voted to accept the easement if the Stark's decided to go through with it. It was very much in the planning stage at this point. SLCS maintained property records for the next several years, but it was “dormant” for the most part. Then, in 1998, the Starks decided to forego the easement as part of their will and, instead, place a CE on the property right away. The CE was granted on December 30, 1998. The terms of the easement limit further development of the property. The existing homestead is unaffected by the easement, and an additional building site was reserved for future flexibility. The Starks strengthened the protection of their property with a back-up trust through the Nature Conservancy. The easement was named Pulsifer Hill and consists of 147 acres of even-age temperate broad-leaf deciduous forest. It remains the intent of the landowner to keep the property from being developed “even after he is gone and leaves it to his children”. The Starks are committed to conservation and is an advocate for land protection not only on their own property but also throughout New Hampshire.

In 2005, Guy Stoye donated a 30-acre CE, Lyle/Stoye Woods, to SLCS to restrict the parcel from development before selling it to Bob and Peg Ewell. Guy stated, "It is such a relief to know that the habitat will always be there and that the owners of the land and SLCS will see that it remains protected." The property was transferred from the Ewells to Melissa and Christopher Rolfe in 2008. The property is used by local residents for hiking on a limited basis and has a snowmobile trail along the northern boundary.

Finally, the Coolidge family has long history of land conservation and work with the SLCS; the family (Hoag Island Trust) currently wishes to protect undeveloped portion of island from development, and ensure family’s sustainable ownership. A bargain sale purchase of a CE was agreed upon and with the help of neighborhood fund raising, SLCS now holds 96 acres on Hoag Island and 2 miles of shoreline in conservation. Public picnicking is permitted along the beach and is often used to access the lake.

The commitment of the general community to conserve private land for the benefit of the public and preserve habitat for perpetuity is depicted in these few examples. SLCS generally commits to completing eight conservation projects a year with a total of 91 conservation properties in existence in 2009. A Lands committee meets every other month to consider, evaluate, and discuss potential CEs and address obstacles as they arise. The Executive Director presents these proposals to the Board of Trustees for the approval of final projects. These examples of CEs held by SLCS depict the commitment to preserve the natural environment as well as the social conditions that contribute to the character of the Squam Lakes.

The goal of this study is to use the criteria established by the SLCS to highlight and identify key conservation values within the Squam Lakes watershed to focus future selection of CES in order to balance the human needs, and ecological integrity of the watershed. After creating the logic based model and presenting it to the SLCS, the Lands Committee, Executive Director, Board of Directors, and other staff will be able to adapt it accordingly as the needs and environment of the watershed changes. Although the mission of SLCS has helped guide the selection of current CEs, this project will create a data-driven systematic approach to ensure that future conservation projects preserve ecologically and socially significant areas.

Chapter 3: Methods

3.0 Introduction

A few established methods exist for focusing future conservation efforts. Conservation priorities vary among different land trusts, but efforts from the LTA have helped in the adoption of priorities by accredited land trusts. The conservation criteria adopted by SLCS were used in this study to create the knowledge base model developed with the NetWeaver systems (Miller and Saunders 2002). Creation of the knowledge-based model was an iterative process in which all the criteria were incorporated into the model as logic topics, and then data links were created for the model to associate GIS attribute fields to the model inputs needed by NetWeaver. EMDS (Reynolds 1999) was used as an extension of ArcView® GIS in order to spatially represent the conservation priorities within each catchment.

3.1 Determining Conservation Criteria

Because the model created in this study will be used specifically for the Squam Lake Conservation Society to identify areas of greatest conservation value, the Lands Committee of SLCS was consulted for establishing the conservation criteria. It is common practice for a land trust to have a committee that sorts through possible conservation projects, and either recommends the project to the Board of Directs or approves the project immediately. At SLCS, the Lands Committee approves projects prior to the Board's final approval. Therefore, it was the best approach to consult the Lands Committee at SLCS on their initial criteria screening process. Prior to this project, SLCS had established general criteria for conservation in the watershed, although areas that were being threatened by development or contained an ecologically sensitive component (i.e., shoreline, low wet areas, provided public access or above 800 feet elevation) were generally identified as areas of greatest conservation need.

Other land trusts in the region and local experts also were consulted to create an additional foundation of criteria. Then, through a series of meetings, the Conservation Committee discussed the criteria and agreed on a list of data elements and logic topics that would be considered for each proposed CE (see Figure 1 and 2 below). There are, however, many other data elements and logic topics that could be considered to improve the overall logic design guiding this assessments. Given the spatial extent of SLCS, the Committee felt that these parameters reflected the needs of the Squam Lake watershed in preserving both biodiversity as well as traditional land uses.

In many cases land trusts had established that future CEs that abutted, linked, or expanded existing conserved land was an ideal situation. As discussed above, the benefits of large tracts of conserved land contributes greatly to the entire ecosystem rather than creating isolated 'islands'. The SLCS Lands Committee established that areas abutting or linking existing CEs should be targeted as potential easements. They also agreed that areas of important wildlife habitat, areas that contained rare plants or animals, vernal pools, old growth forest, and late-successional forest blocks are all high priority. Shorelines, wetlands, riparian corridors, and ponds were also considered high priorities for ecological attributes of ideal CEs easements within the Squam Lake watershed. The list below (figure 1) highlights the established criteria although it was recognized that changes might be needed in the future to include other ecologically sensitive areas threatened or critical to the functioning of the ecosystem.

Ecological Conservation Criteria:

- Expansion, buffers or linkages
  - Provides greenways to connect other protected or potentially protected lands;
  - Provides travel corridor for wildlife species;
- Habitat for wildlife and-Native species
  - Contains important wildlife habitat, rare plants or animals, vernal pools or exemplary natural plant communities.
  - Contains old growth and/or late successional forest blocks
- Large blocks of land
  - Contributes to the formation or expansion of large blocks of protected land (which may be owned by single or multiple landowners);
- Water resources
  - Includes, in part or entirely, aquifer recharge areas, wellhead areas, surface waters, or other lands valuable for the protection of drinking water supplies;
  - Includes, in part or entirely, rivers, shorelines, riparian corridors, floodplains, or important wetlands;
  - Includes, in part or entirely, lakes or ponds.

Figure 1: Ecological Conservation Criteria as determined by SLCS Conservation Committee

In addition, there were several social conditions that were also included in the criteria to be considered as highest priority for future CEs (figure 2). Many of the existing easements around Squam Lake allow public access to an extensive trail network. For example the most recent addition of publicly accessible land, the Center Harbor Woods, was a collaborative effort between SLCS, the Lakes Region Conservation Trust, and the town of Center Harbor that connected an existing trail network of eight discontinuous miles. Situated between existing CEs, Center Harbor Woods allows for an additional one and half miles of hiking, cross-country skiing, and snowshoeing trail by connecting the trails. SLCS valued opportunity to provide public access as well as open spaces that increased the scenic views of the SLW.

In terms of maintaining the traditional uses of land within the watershed, the Committee identified working landscapes in which local residents were able to make a living off the land through agriculture, working forests, and/or natural resource extraction. Finally, recreational opportunities available to the public were also considered high priority criteria. As discussed previously in Chapter 2, recreational activities were, and remain today, such a significant attraction to the Squam Lakes that many tourists decided to purchase second homes. However, much of the shoreline of the Squam Lakes is privately owned, and only a few publicly accessible locations exist. One easement held by SLCS, Holderness Beach, allows for public swimming. Areas identified as historically significant to a town or threatened by development were also considered high priority criteria to establish future conservation efforts.

Social Criteria:

- Public Access
  - Property may be made available for public access
  - Provides public access to waterways for fishing, swimming, and low impact boating
  - Provides publicly accessible open space in a part of town that doesn't have much or any.
- Scenery
  - Protects spots from which to observe scenic views
  - Provides scenic views that can be seen from public locations

Social Criteria Continued:

- Working landscapes (rural character)
  - Is actively and well managed agriculture
  - Is actively and well managed for forestry
  - Has soils with important agricultural value (regardless of present use)
  - Is an actively and well-managed water resource
- Outdoor recreation
  - Is suitable for low impact public recreation such as trails for walking/hiking/cross country skiing and enjoying nature;
  - Protects existing trail networks
- Other
  - Provides other significant public conservation benefit in the interest of the town
  - Includes areas of historic value, such as cellar holes and stone walls
  - Threatened by development

Figure 2: Social Criteria as determined by SLCS Conservation Committee

3.2 Creating NetWeaver Models using SLCS criteria

Models can support the exploration of future land-use changes under different conditions from both an ecological and social perspective. This project used an application framework for knowledge-based decision support of ecological assessments called the Ecosystem Management Decision Support system (EMDS), a type of decision-making model. This system incorporates knowledge-based reasoning as an extension to a geographical information system (GIS) to provide decision support for landscape-level ecological assessments (Reynolds et al., 2000). The NetWeaver logic engine is used to create the logic-based model, and it evaluates data against a knowledge base that provides a formal specification for the interpretation of data. This type of model is advantageous in situations where data is incomplete because the logic engine allows partial evaluations based on available information. A second key feature provided by the logic engine is the ability to evaluate the influence of missing information on the logical completeness of an assessment. Because of

EMDS's capabilities to answer complex questions, previous research has used this system to evaluate landscape configurations for conservation suitability, restoration planning (Reynolds and Hessburg 2005), forest sustainability, locating sustainable industrial areas, and social-acceptability of natural resource decision making process (Humphries et al., 2008; Reynolds and Hessburg 2005).

The first step in the application framework is to construct a logic-based model using NetWeaver, a software system that may be used as an extension of GIS. NetWeaver uses dependency networks to represent topics of interest in a problem domain. Each logic topic represents a proposition to be evaluated. Topics are used to specify the logical or mathematical relationships among the network dependencies and their associated data links. These components of the knowledge base evaluate the degree to which a proposition is true regarding the assertions about ecosystem states and processes given existing data. The types of network evaluations used in this project are discussed in more detail later in this chapter. Information is evaluated from the root of the lowest level of the network where actual data, or the acknowledgement of lack of data, input occurs. Networks of factors may then be evaluated in terms of their connections with, and influences on other networks, thus allowing for multiple factors, at multiple scales, to contribute to the knowledge-based evaluation. The following example of a simple network represents the dependency network for evaluating wildlife habitat integrity in the model created for this study (figure 3).

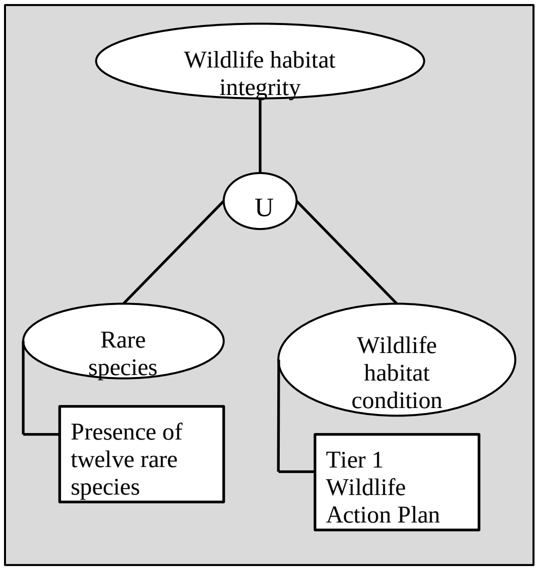

Figure 3: Simple network for wildlife habitat integrity

Wildlife habitat integrity is the network evaluated by the UNION of rare species and wildlife habitat condition. The network is shown as an oval and the data links are rectangles. The final value determined for the network is a value between 1 and -1 called the truth value, and is a measure of the strength of evidence for a proposition, in this case the integrity of the wildlife habitat. The interpretation of truth values is described later in this chapter.

The development of a knowledge base is an iterative process and each network is refined as the complexity of the proposition is defined. The initial phases of this project considered two primary network dependencies: ecological and social criteria. There are many other possibilities that could be considered, such as combining the two primary networks or creating two separate knowledge bases. In the case that the spatial scale of the two primary network dependencies do not align, two separate knowledge bases could be created and then refined to observe where it would be possible to evaluate the knowledge bases together. The final products of an EMDS assessment include maps, tables, and graphs based on the evaluated knowledge base structure, that can help decision makers facilitate future discussion. SLCS, for example, could use these maps in future collaborative projects such as the Center Harbor Woods discussed above in which two land trusts and a town were involved.

A significant advantage of this model is that it allows flexibility for the user to adopt new logic topics or provide for the inclusion of new data, or remove other topics as circumstances or thinking change. For example, SLCS may determine that old growth forest is significantly more important than late-successional forest areas. Either old growth forests could be quantitatively weighted in the model to reflect this change or moved higher in the model structure. The model is dynamic in the sense that new topics can be emphasized over time as ecological changes, conservation needs, and other factors influence critical conservation needs. This is an advance in the field because many models are static in time, difficult to update, or were created by a team of experts with little or no documentation of the reasoning process. An additional advantage of this model enabled the land trust, SLCS, to establish the criteria relatively easily in a transparent way, and the designer of the model simply facilitated the discussion.

The primary dependency networks of this project were based on two propositions derived from the ecological and social criteria established by SLCS that were initially separated into two models. The primary propositions for the ecological and social criteria were at the top of the hierarchy within the knowledge base model. The primary proposition used to evaluate the ecological criteria was “the watershed condition is high” and *watershed condition* was used to represent this proposition in the model below (figure 4). The primary proposition used to evaluate the social criteria was “the social opportunities are high” and *social opportunity* was used at the top of the hierarchy in the second model (figure 5). The *watershed condition* network depended on three lower-level networks: *wildlife habitat integrity, ecological community integrity,* and *impervious surfaces.* Evaluations of wildlife habitat integrity, ecological community integrity, and impervious surfaces depended on networks further down the hierarchy. Figure 3 above outlines the evaluations of the wildlife habitat integrity. *Ecological community integrity* depends on three subordinate conditions: *water quality, rare species,* and *ecological community conditions*. The networks used to evaluate *ecological community condition* include: *structural diversity* and *soil condition*. In the figures below (4 and 5) the networks are shown as ovals, the data links are rectangles, and definitions of the data inputs are presented in table 1 and 2 later in this chapter. The logic operator used in this model was the “UNION” (depicted as “U” within the model). For a proposition to be true, antecedents to the operator incrementally contribute to the evaluation of the UNION (Reynolds 2000, Reynolds 1999). Other logic operators may be used within the model such as an “AND” operator and “OR”.

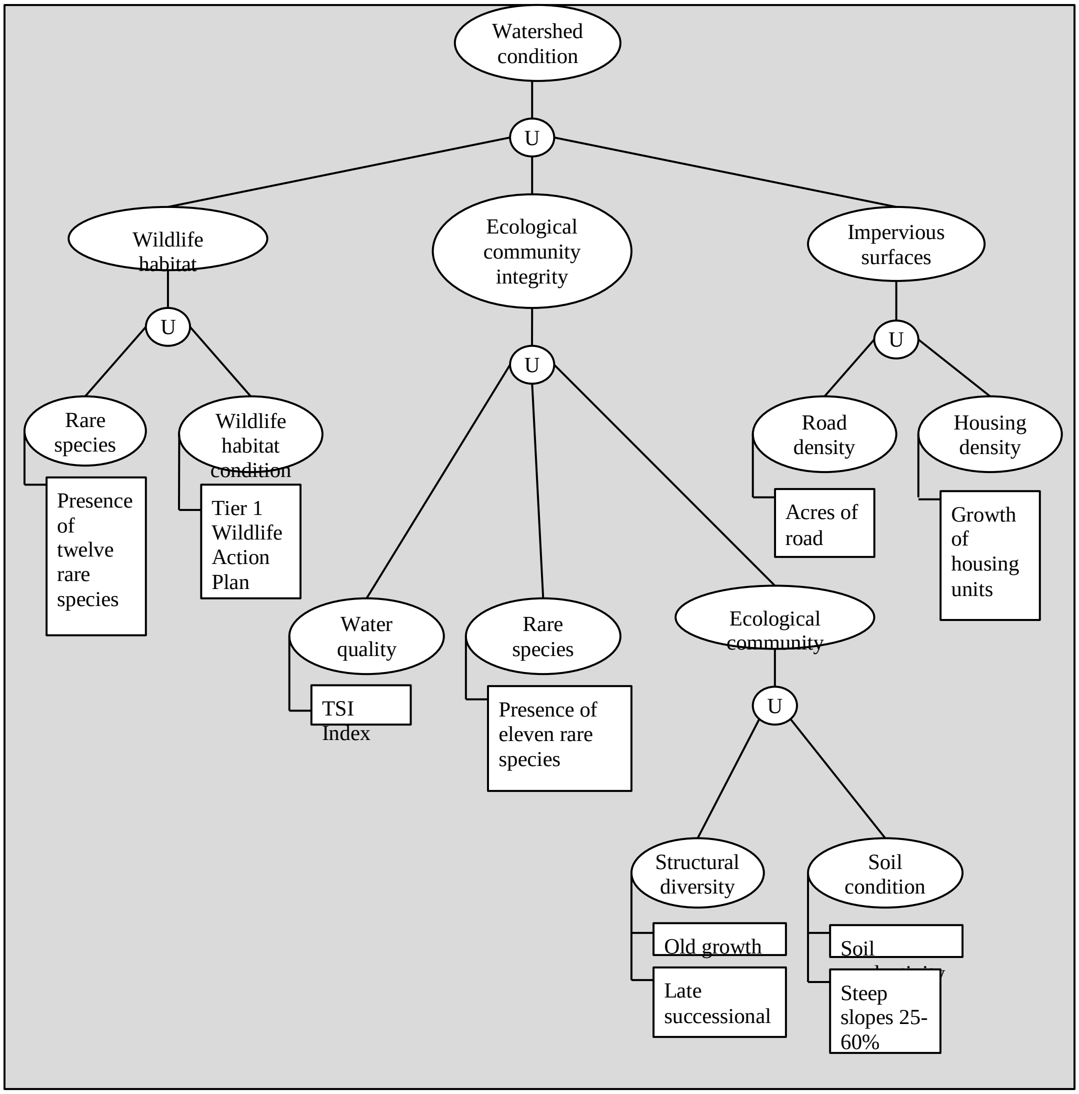

Figure 4: NetWeaver knowledge base model for ecological conditions of the watershed

The *social opportunity* network represented the social criteria established by SLCS and also depended on three lower-level networks: *local growth*, *scenic views*, and *multiple-use landscapes*. Evaluations of these lower-level networks depended on networks further down the hierarchy. Local growth depended on two subordinate conditions: *population growth* and *large parcels*. The data links used to evaluate these two subordinate conditions was the population growth for each town (2000-2009) and the number of parcels greater than 20 acres. Scenic views also depended on two subordinate conditions: *private view* and *public view*. These conditions, however, used more than one data link to evaluate the network. For example, the *public view* consisted of four data links: *from roads, from publicly accessible areas, from scenic spots,* and *quality of view*. Finally, the last of the three lower-level networks was *multiple-use landscape* and it was also evaluated by two subordinate conditions: *recreation* and *current use.*

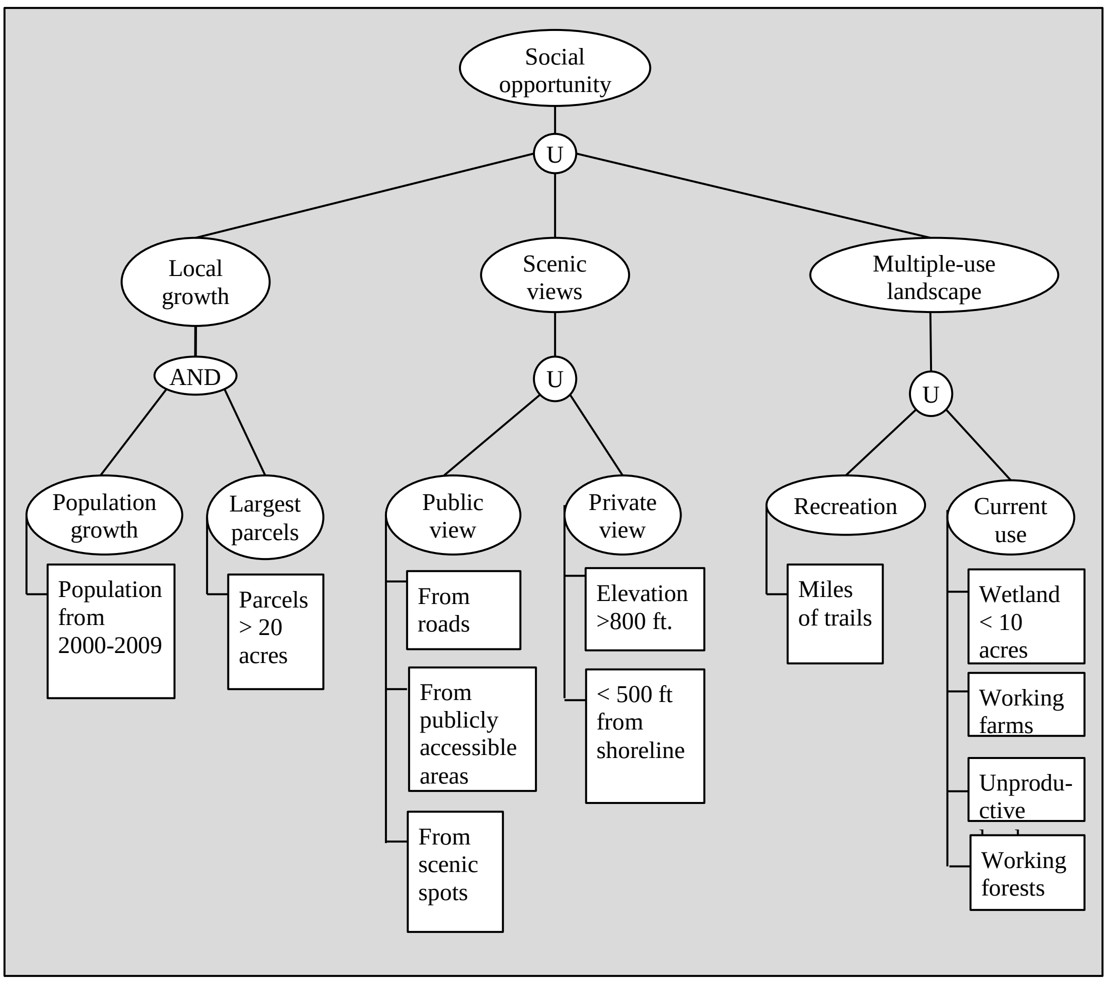

Figure 5: NetWeaver knowledge base model for social conditions within the watershed

3.3 Spatial Extent of the study

Because SLCS works exclusively in one watershed, the spatial extent of the evaluation of this approach is significantly smaller than other typical uses of EMDS. In previous EMDS projects, the spatial extent of analysis extended well beyond the individual watersheds (Reynolds et al., 2000; Reynolds and Hessburg 2005; Dai et al., 2004; Mendoza and Martins 2009). The SLW in particular is relatively small in acreage and this made it difficult to evaluate the appropriateness of data linked to the model because data available was prepared for state-wide use (the NH Wildlife Action Plan). Particular attention was given to avoid the isolated pockets of conserved land discussed in Chapter 2. For example, the parcels of each town varied in size from less than an acre to well over several hundred acres. In addition, many of the ecological parameters defined by SLCS are difficult to determine at such a small scale such as less than an acre. Therefore, for the purposes of this project the watershed was further delineated to a catchment scale. It was determined that this scale would be small enough to target focus areas, but also large enough to reflect the ecological criteria considered to be of greatest conservation value.

3.4 Data

Data were collected and compiled from a variety of sources based on the criteria established by SLCS. In order to align the conservation criteria with their associated dependency network, the following tables (1 and 2) were created with the related data source identified. All of the spatial data was first compiled and stored within a geo-database. Then using a USGS shapefile of the Squam Lakes watershed delineated to a catchment scale from New Hampshire GRANIT data online (http://www.granit.unh.edu/) as well as delineating the town boundaries within the watershed, all of the data was condensed into this shapefile and labeled accordingly within the attribute table. EMDS has the capabilities to complete the GIS geoprocessing tools to analyze data. This project, however, created one shapefile and a geodatabase that would allow SLCS to easily update this one shapefile. Since there were so many sources of data for this project and spatial data had to be created, especially for data provided by the town, it was requested by SLCS that one shapefile would best to fit their existing data management system.

The first table represents the ecological criteria established by the SLCS to evaluate future conservation efforts and easements. As mentioned previously in this Chapter, two logic models were created for this project. The first model addressed the ecological criteria for selecting conservation easements. The proposition for this model was the "watershed condition is high". The subordinate networks and their associated propositions are described in table 1 and 2 below. It is important to note that the models depicted in figure 4 and 5 use key terms in NetWeaver from each proposition described below. For example, the network for the proposition "contains rare species" (table 1) was shortened in NetWeaver as *rare species (figure 4).*

Table 1: Ecological data used in the knowledge base model.

NetWeaver model: Ecological condition				
Primary propositions	**Sub-propositions**		**Data**	**Data Link Source**
Wildlife habitat integrity is high	Contains rare species		Presence of twelve rare wildlife species	SLCS
	Wildlife habitat condition is high		Tier 1 designated habitat condition from NH 2010 Wildlife Action Plan	GRANIT
Ecological community integrity is high	Contains rare species		Presence of eleven rare vegetation species	SLCS
	Ecological community condition is high	Soil condition is high	Unique or important soils	GRANIT
			Steep slopes between 25-60%	USGS
		Structural diversity is high	Old growth forest	SLCS
			Late-successional forest	SLCS
	Water quality is good		Secchi disk data (TSI > 30)	SLA
			Total nutrient (TSI > 30)	SLA
Threats to watershed are high	Impervious surfaces		Road density	GRANIT
			Housing units	Town hall
	Invasive species		Milfoil	SLA

A local ecologist, Rick Van de Poll compiled species inventories in 2007 specific to the Squam Lakes watershed and updated this data for unique species annually. It includes both aquatic and terrestrial unique (rare and endangered) species for the watershed and was most recently updated in 2010. The rare plants included *Arabis drummondii*, *Arabis laevigata, Arabis missouriensis*, *Aureolaria pedicularia v*, *Carex backii*, *Ceanothus Americana, Clematis occidentalis*, *Conopholis ameriana*, *Galium circaezans*, *Megalodonta backii*, *Minuartia michauxii*, *Polygonum douglasii*, and *Triphora trianthophora*. The rare animals identified in the analysis are the spring salamander (*Gyrinophilus porphyrit*), bald eagle (*Haliaetus leucocephalu*), the common loon (*Gavia immer*), American bittern (*Botaurus lentiginosus*), Canada warbler (*Wilsonia canadensis*), great blue heron (*Ardea herodias*), American marten (*Martes americana*), bobcat (*Lynx rufus*), silver-haired bat (*Lasionycateris notviag*), bridle shiner (*Notropis bifrenatus*) and the four-toed salamander.

Using the New Hampshire 2010 Wildlife Action Plan, areas designated as tier 1 were of most importance because these areas are defined as the habitats in the best ecological condition within the state and the degree a particular patch of habitat as good biological diversity (http://www.wildlifeactionplans.org/new_hampshire.html). Data on soil productivity and slope steepness were determined by using New Hampshire GRANIT data provided online and identified as important productive farmland soils. The structural condition of the watershed's forest was assessed to be predominantly an even-age forest by using old maps and historical accounts provided by historical societies. Areas that had been identified by ecologist Rick Van de Poll as old growth and late-succesional forest were considered most important in conservation criteria.

The water quality data contributing to the overall logic structure were provided by the Squam Lakes Association (SLA). SLA has a consistent monitoring program through each summer season to measure the clarity of the lake using secchi disk measurements and total nutrient content. These data were used to calculate the trophic state indices (TSIs) that provide a single quantitative index for classifying and ranking lakes to assess water quality (Carlson 1977). Road density was used as proxy to measure impervious surfaces and the data were obtained from New Hampshire's statewide GIS clearinghouse NH GRANIT. Total housing units were also considered a threat to ecological integrity because it contributes to the impervious surfaces and reflects an increase in subdivision of land. These data were obtained from the US Census and each town (Holderness, Sandwich, Moltonborough, Center Harbor, Ashland, and New Hampton). In combination, these sources of data created the data links for the ecological model used in this project.

The second table depicts the social criteria for identifying future CEs established by the SLCS Conservation Committee and local experts, and their associated data requirements. Each criterion was established based on the contribution to the public benefit and local economy. Again, this data was originally compiled and stored within a geodatabase. However, GIS geoprocessing tools were used to clip and intersect all data to one shapefile of the watershed that was delineated to a catchment scale, and attributes of this shapefile were labeled according to their data type and source. Scenic views were determined by the opportunity to view the lakes based on both public and private availability from a specific lot. As discussed in Chapter 2, the natural amenities of Squam Lake include its aesthetics. For the most part, although mountains are included in the general aesthetics, they were not included in this study based on the fact that they can be seen from nearly every point in the watershed. Determining if a view to the lake was provided by a public area or could potentially provide public access generated the public scenic view sub-proposition. For private landowners that contribute to scenic views of the watershed, it was determined that a view of the lake could be found within 500 feet of the shoreline or above 800 feet elevation.

Table 2: The social criteria data used in the knowledge based model.

NetWeaver Model: Social opportunity			
Primary propositions	**Sub-propositions**	**Data**	**Data Link Source**
Local growth is high	Population growth is high	Three highest population growth towns	US Census
	Number of large parcels is high	Number of >20 acres parcels	Town hall
Provides scenic view	Public view is high	From roads	SLCS
		Publicly accessible places	SLCS
		Scenic spots	SLCS
		Quality of view	SLCS
	Private (homeowner) view is high	Within 500 feet of lake	USGS
		Above 800 foot elevation mark	USGS
Multiple-use landscape	Designated for current use	Farm land	Town hall
		Forest land	Town hall
		Unproductive land	Town hall
		Wetland	Town hall
	Recreation opportunity is high	Miles of trails	SLCS

CEs have also been used to preserve working landscapes such as farms, and working forests. These working landscapes contribute to the local economy but in many cases when a landowner cannot afford to maintain the business, the property must be sold. In order to identify lands that contain multiple-uses, the Current Use designation provided by the state of New Hampshire was considered an appropriate proxy. The Current Use program in New Hampshire was created to preserve traditional uses of land, open space, and the rural character of the region by providing preferential taxation (http://www.nh.gov/revenue/munc_prop/current_use/current_use.htm). The land designated as in Current Use is assessed valuation per acre of open space land based upon the income-producing capability of the land in its current use, and not its real estate market value. This valuation is determined by the assessor in accordance with the range of current use values established by the board and in accordance with the class, type, grade and location of land. Current Use is a designation provided by the state for a property-tax reduction for private landowners that have working farms greater than 10 acres, wetland areas less than 10 acres, and which allow public access to their land for *de minimus* recreational activities (e.g., hiking, cross-country skiing, snowshoeing, swimming). Farmland Current Use designation means any cleared land devoted to or capable of agricultural or horticultural use as determined and classified by criteria developed by the commissioner of agriculture, markets, and food and adopted by the board. Forest land is defined as any land growing trees as determined and classified by criteria developed by the state forester and adopted by the board. Unproductive land, including wetlands, means that by its nature it is incapable of producing agricultural or forest products due to soil or site characteristics, or the location of which renders it inaccessible or impractical to harvest agricultural or forest products.

Finally, a wetland classification is considered for those areas of farm, forest and unproductive land that are inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support a prevalence of vegetation typically adapted for life in saturated soil conditions. The recreational dependency network also included the importance of trail density as well as the designation of Current Use. By incorporating these considerations into the system, SLCS both satisfies its mission as well as the IRS codes in determining CEs to benefit the environment and the public for future generations.

3.5 Evaluation of the SLCS knowledge-base

Operators are used to specify the logical or mathematical relationships among logic networks and their associated data links. The types of logical relationships between network dependencies can include UNION, OR, and AND among others. The most common logical relationship between network dependencies in this project was a "UNION". These components of the knowledge base evaluate the degree to which the set of premises underlying the proposition associated with a logic topic are collectively true. The statement of a proposition associated with a logic topic can be vague particularly at higher levels of logic in the knowledge base, but the meaning becomes clearer as the lower levels provide further details of the logic specification that underlies a logic topic. For example, in the ecological model the broader definition of ecological community integrity is not clearly defined within the model. Only at lower levels, such as the ecological community condition, can it be determined that steep slopes and old growth forests are contributing to the evaluation of the ecological community integrity of a catchment. The information is evaluated from the root of the lowest level of the network where actual data, or the acknowledgement of lack of data, input occurs. At this lowest level of the network where the data inputs are located, an evaluation of the data is included. In the evaluation of the ecological community integrity of a catchment, the data would be linked to steep slopes and old growth forests because they are components of the overall network dependency.

Table 3 describes how the truth values map into strength of evidence for a proposition. Data read by data links may be evaluated against either crisp or fuzzy arguments. Crisp arguments implement simple Boolean logic, and return a result of either -1 (no support) or 1 (full support, Table 3). This type of evaluation is often referred to as bivalent logic. If a proposition is valued at -1.0, there is no support for the statement based on the data provided. Fuzzy arguments, however, use fuzzy math to compute a result on the real interval [-1, 1], thus expressing varying degrees of support for a proposition (Table 3).

Table 3: Interpretation of truth values used in NetWeaver

Interpretation of Truth Values	
Truth Value	**Strength of Evidence**
< -0.6	Very low
-0.6 to -0.2	Low
-0.2 to 0.2	Moderate
0.2 to 0.6	High
>0.6	Very High

In other words, fuzzy logic allows for the possibility that a proposition may be partially true, in which case the truth-value metric expresses some degree of support for a proposition. If a proposition cannot be valued based on insufficient data, or missing data, the truth value is 0. NetWeaver also allows for missing data that can be ranked in order of relative importance to the analysis (Reynolds 1999). Because data rarely exists for privately owned land, the ability to understand the role of missing data in an overall analysis would be extremely helpful in guiding a land trust's monitoring program.

Each table below portrays the logic topics and their propositions mentioned above, but instead of describing the data links and their associated sources, it describes the type of argument that was used, and, in the case of fuzzy arguments, the range that defines the fuzzy function. In many instances, for both ecological and social criteria, a percent of the catchment was determined for the data provided and a fuzzy argument was used to determine the truth value. In other cases, a simple 'presence or absence' was used in the form of a crisp argument. For example, catchments that contained data for an endangered and/or unique species received an evaluation of 1, which provides full support of the statement. This full support of the statement means that each of the networks within the model fully supported the primary proposition of the model. Those catchments without presence of any species were given a -1, for no support of the proposition.

Table 4: Method of data evaluations used for each data link in the ecological condition NetWeaver model.

NetWeaver model: Ecological condition		
Primary propositions	**Data**	**Data Evaluation**
Wildlife habitat integrity is high	Presence of twelve rare wildlife species	Presence or absence
	Tier 1 designated habitat condition from NH 2010 Wildlife Action Plan	Fuzzy argument
Ecological community integrity is high	Presence of eleven rare vegetation species	Presence or absence
	Unique or important soils	Fuzzy argument
	Steep slopes between 25-60%	Fuzzy argument
	Old growth forest	Fuzzy argument
	Late successional forest	Fuzzy argument
	TSI Index	Fuzzy argument
Threats are low	Road density	Fuzzy argument
	Housing units	Fuzzy argument

By using this approach, the decision-maker can either use the default weight of 1 in NetWeaver (all networks are weighted equally in the model) or weight certain criteria as more important than others. Another added benefit is the use of fuzzy arguments. In the case of social conditions identified as significant characteristics within the SLW, the fuzzy argument could be used to evaluate quantitative data as well as qualitative. For example, the quality of view from scenic spots was assigned a value of good, fair, or poor depending on the obstacles preventing a clear of the lake or the ease of access to the scenic spot. A fuzzy argument was used because good views were considered the best situation, a fair view was evaluated as acceptable but not as ideal as a good view, and a poor view meant that it was either very difficult to access the spot or obstacles were present such as tree cover. Although all scenic views were considered important, the fuzzy argument allowed for an evaluation to determine a truth value on a sliding scale.

Table 5: Method of data evaluations used for each data link in the social condition NetWeaver model.

NetWeaver Model: Social condition		
Primary propositions	**Data**	**Data Evaluation**
Local growth is high	Three highest population growth towns	Fuzzy argument
	Number of >20 acres parcels	Presence or absence
Provides scenic view	From roads	Presence or absence
	Publicly accessible places	Presence or absence
	Scenic spots	Presence or absence
	Quality of view	Fuzzy argument
	Within 500 feet of lake	Fuzzy argument
	Above 800 foot elevation	Fuzzy argument
Multiple-use landscape	Farm land	Fuzzy argument
	Forest land	Fuzzy argument
	Unproductive land	Fuzzy argument
	Wetland	Fuzzy argument
	Miles of trails	Fuzzy argument

3.6 EMDS in Geographic Information Systems

As mentioned in Chapter 2, the application framework to evaluate the knowledge-based reasoning as an extension of a geographical information system (GIS) is the Ecosystem Management Decision Support (EMDS) system (Reynolds et al., 2000). The system provides a set of general solution methods (e.g., a framework) for conducting ecological assessments and developing priorities for management activities. Finally, it will also create data, results, and knowledge regarding the watershed that can be applied to a broad array of land-use planning and policy activities that local non-profits like the SLCS is involved in. To conduct an assessment with EMDS, the user 1) constructs a data view that includes all GIS themes that enter into an assessment; 2) designs a knowledge base that describes how to interpret information of interest to the assessment; and 3) designs a decision model for planning management activities based on results of an assessment and possibly other information pertinent to planning such as efficacy and feasibility issues. EMDS integrates the logic engine of NetWeaver (Rules of Thumb, Inc.) to perform evaluations of landscape conditions and the decision engine of InfoHarvest to support decision modeling.

The first step in using the EMDS assessment for this project was to define the problem in terms of primary questions and then design a knowledge base to address the questions. The two primary questions as described earlier in this chapter were to identify areas of greatest ecological and social conservation value. It was important to determine the sources of expertise for answering the questions and learning how to construct a knowledge base model. The SLCS provided staff and board members with extensive knowledge for both the ecological and social characteristics of the watershed. The model was then revised by incorporating the suggestions of various experts and stakeholders. After data were obtained from various sources across the State of New Hampshire, an EMDS analysis was performed. The compilation of data and review of its accuracy was the most challenging step in this project. State-wide availability of data and data from a local ecologist made it possible to complete the final analysis with all the appropriate information present. The results were reviewed and structural problems were identified. After several iterations were completed to the satisfaction of SLCS and its consulting experts, final maps were produced and the results are discussed in the following chapter.

Chapter 4
Results

4.0 Introduction

The assessment of priority conservation criteria using a knowledge-based model are represented spatially and discussed in the following sections. The results of the separate ecological and social assessments are displayed and interpreted first, followed by the combination of these assessments to depict the overall conservation values within the watershed. An interpretation of a lower-level network from each of the ecological and social criteria knowledge based models is also explained. Finally, the evaluation of existing CEs based on the model created in this project is discussed last.

4.1 Ecological conditions

In figure 6 below, only the evaluated state of ecological conditions in the catchments of the watershed is depicted. Each catchment area is depicted according to the truth value determined (between -1 and 1) which indicates the strength of evidence that ecological conservation value is high as determined by the model. Catchments evaluated as low or very low received a truth value less than -0.2. Catchments evaluated above -0.2 are considered as moderate, high, or very high within the conservation values scale. The catchments were also delineated according to town boundaries in order to incorporate data that was evaluated by town into each catchment. For example, in the northernmost section of the watershed, three catchments have received different truth values because parts of these catchments are contained within a different town. Since impervious surfaces were identified as one of the three lower-level networks within the overall watershed condition, it would significantly impact the truth value of the catchment.

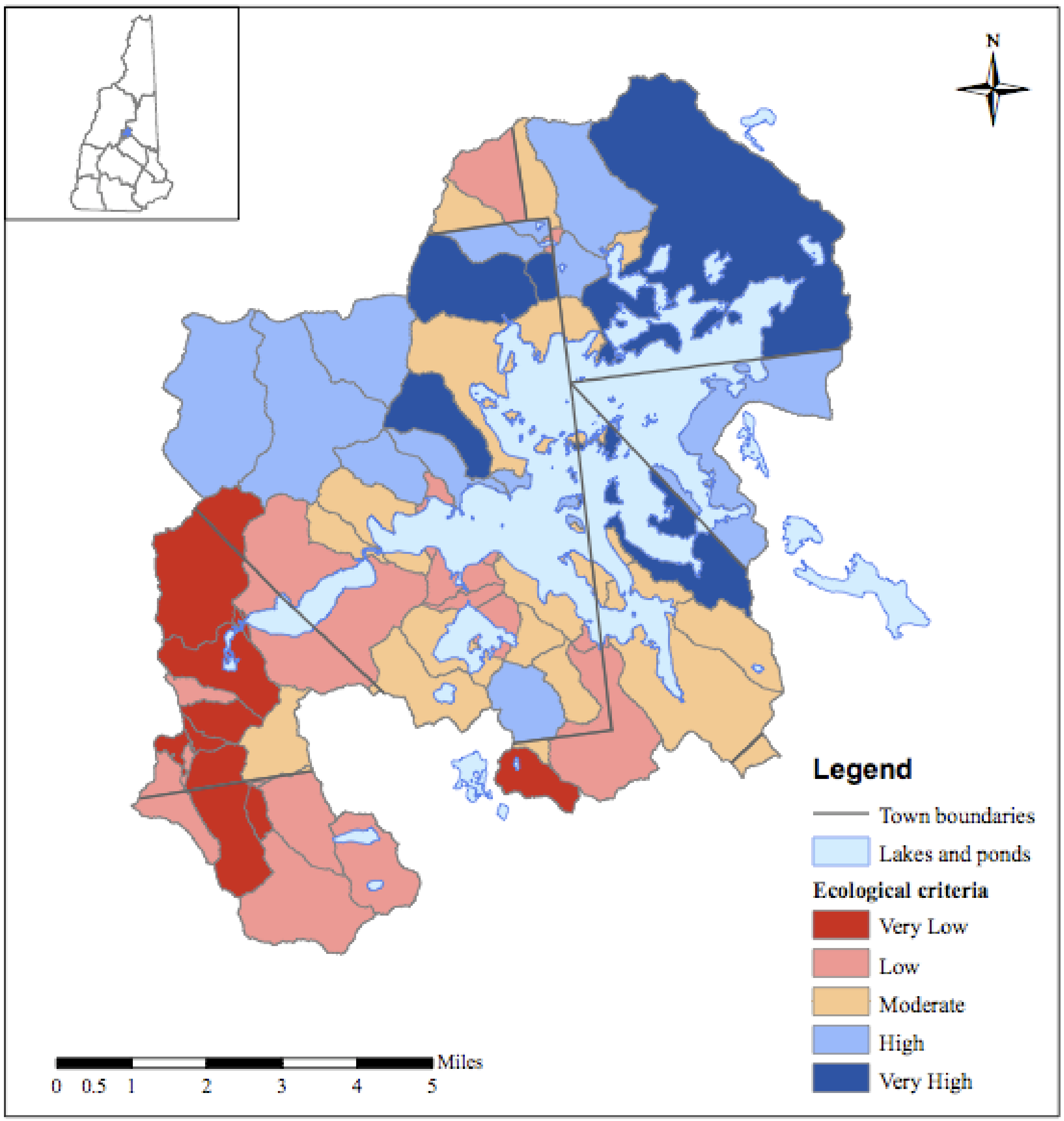

Figure 6: Depiction of ecological conservation values of catchments based on SLCS criteria

Catchments identified as having the highest ecological conditions are located in the northern section of the watershed. This, however, may reflect the fact that the New Hampshire Wildlife Action Plan that does not provide data on habitat condition for the southwestern section of this watershed. The advantage of the logic engine allows for an evaluation of the missing information within those catchments and its overall within the model.

4.2 Social Conditions

Figure 7, below, displays the strength of evidence for social opportunity in this model. These conditions include scenic views, the quality of view, multiple-use landscapes, and quickly developing areas that have parcels of private land greater than 20 acres. Only one section of the watershed received a “very high” truth value (0.87) according to the model. Again, parts of three catchments in this area received different truth values due to the town-wide data that was used to evaluate the lower-level network for the proposition. In this case, it is most likely due to the *local growth* network that used population growth as one data link and the population growth within the northern section of this catchment happened to be the lowest. In this model, there were no data missing. The southern section of the watershed, however, still received the lowest truth values. A combination of high population growth, fewest number of large parcels, and few opportunities for both public and private scenic views could have contributed to this result.

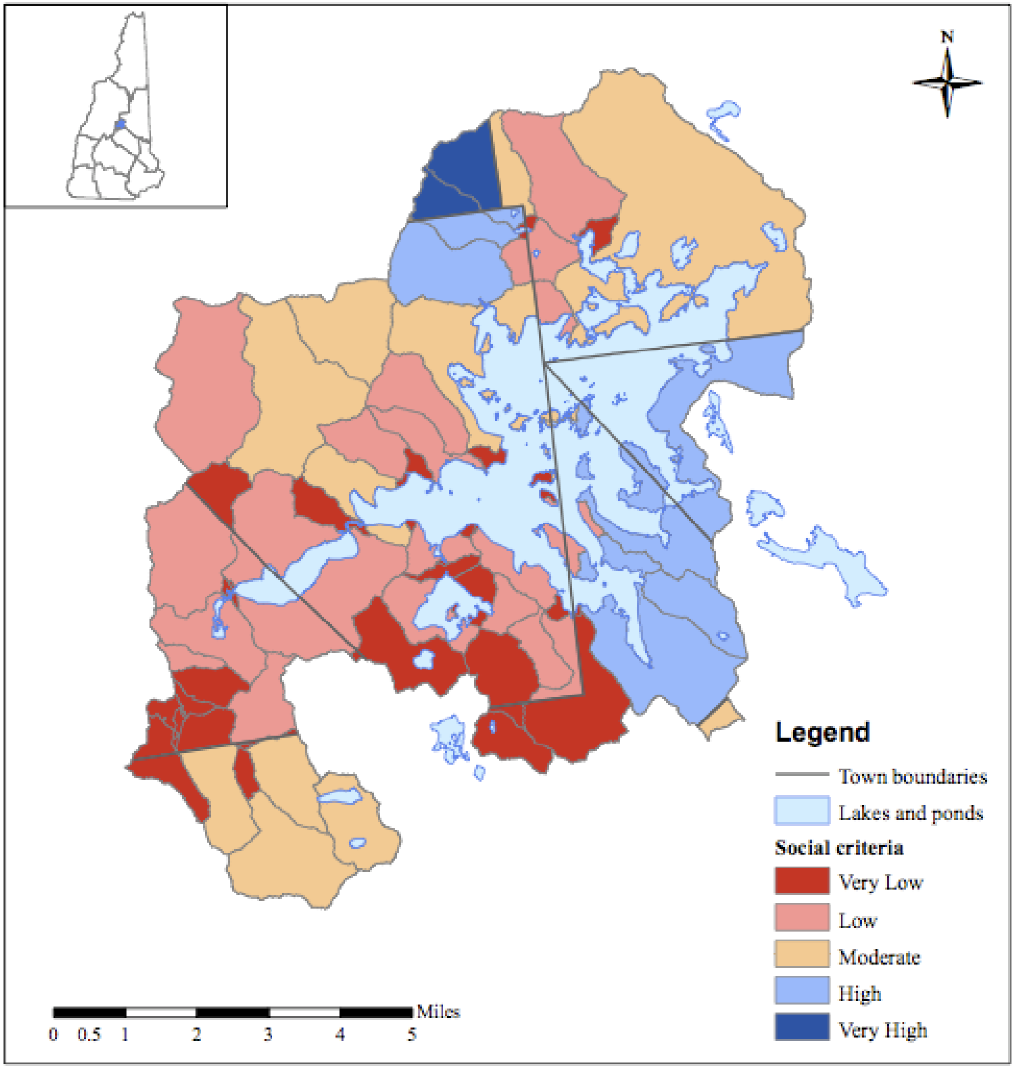

Figure 7: Strength of evidence for high social conditions based on SLCS criteria

4.3 Overall conservation criteria

The map below (figure 8) spatially represents both the ecological and social conservation values combined. The Squam Lake Conservation Society using a combination of criteria from local experts, other land trusts, and existing criteria established by the Lands Committee, determined these criteria. The models were combined to identify the areas of the both ecological and social conservation value. In figure 8, none of the catchments were considered to have "very high" conservation value according to the criteria established, meaning that no catchment received a truth value greater than 0.6 (table 3) from the data evaluations within each network dependency because certain conditions deemed important were not present.

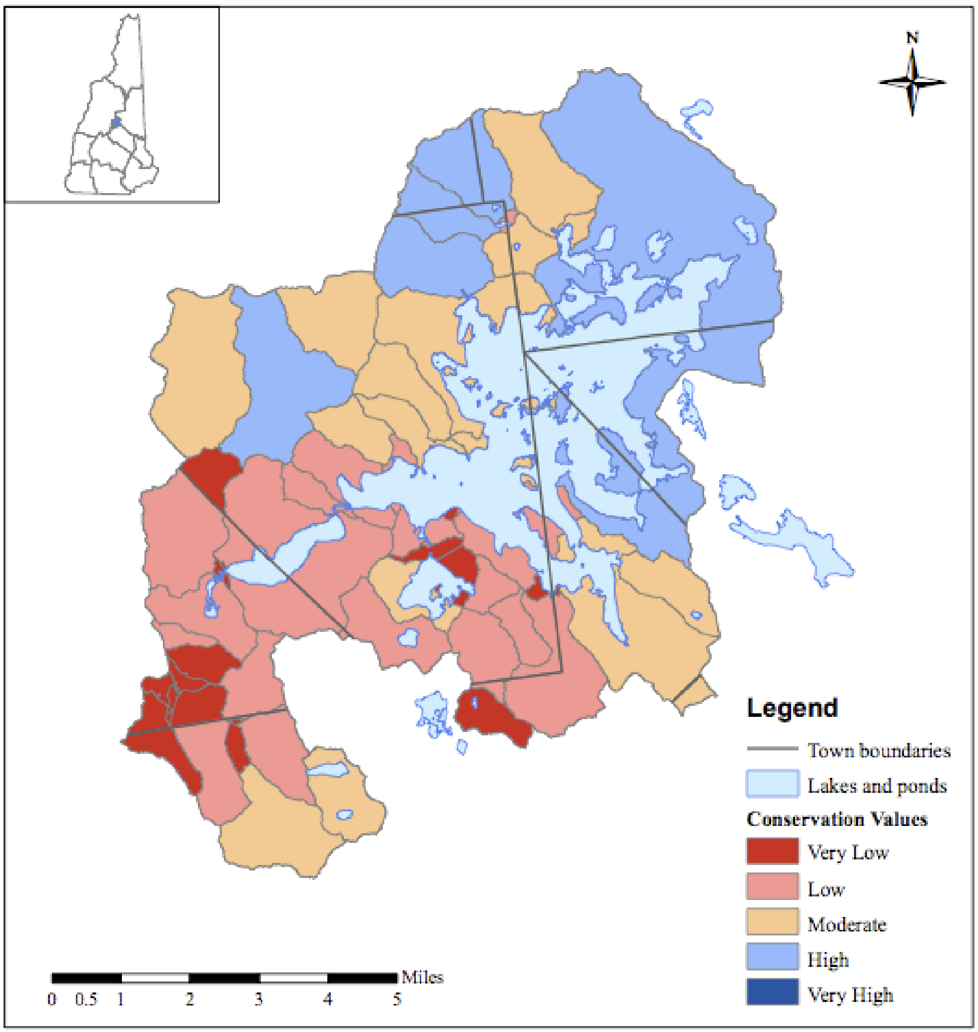

Figure 8: Strength of evidence for both ecological and social criteria

For example, in towns in the southern part of the watershed, data did not exist for habitat condition that met the Tier 1 New Hampshire Wildlife Action Plan. In addition, there were very few rare species identified in these areas as well as having high road densities and few parcels greater than 20 acres. Town boundaries are faintly depicted especially in areas where social criteria were weighted higher in the model hierarchy because conditions were present in some towns and not present in other towns.

Towns with higher road densities received a lower truth value probably between -1 and 0. Towns with a low road density were given a higher truth value, between 0 and 1, because the density had less of an impact on the ecological conditions of the catchment. A part of the catchment may have been valued differently than the rest according to social data that was calculated from either the town wide (e.g., housing density) or the parcel level (e.g., current use designation). Therefore, these conditions were evaluated between -1 and 0 versus areas in the northern section of the watershed that were valued above 0.

4. 4 Lower-level networks within each knowledge base model

In order to consider the contribution of different criteria within the greater context of the model, figure 9 displays only the evaluation of the wildlife habitat integrity. As discussed in Chapter 3, this network included the subordinate conditions of rare species and wildlife condition and a union was used as the logic operator between the two conditions. This emphasizes the areas that contributed the lowest truth value scores (between 0 and -1) that ultimately decrease the overall truth value displayed in figure 8. If SLCS were to change their prioritization of ecological criteria, each lower-level network within the knowledge base model could be considered individually.

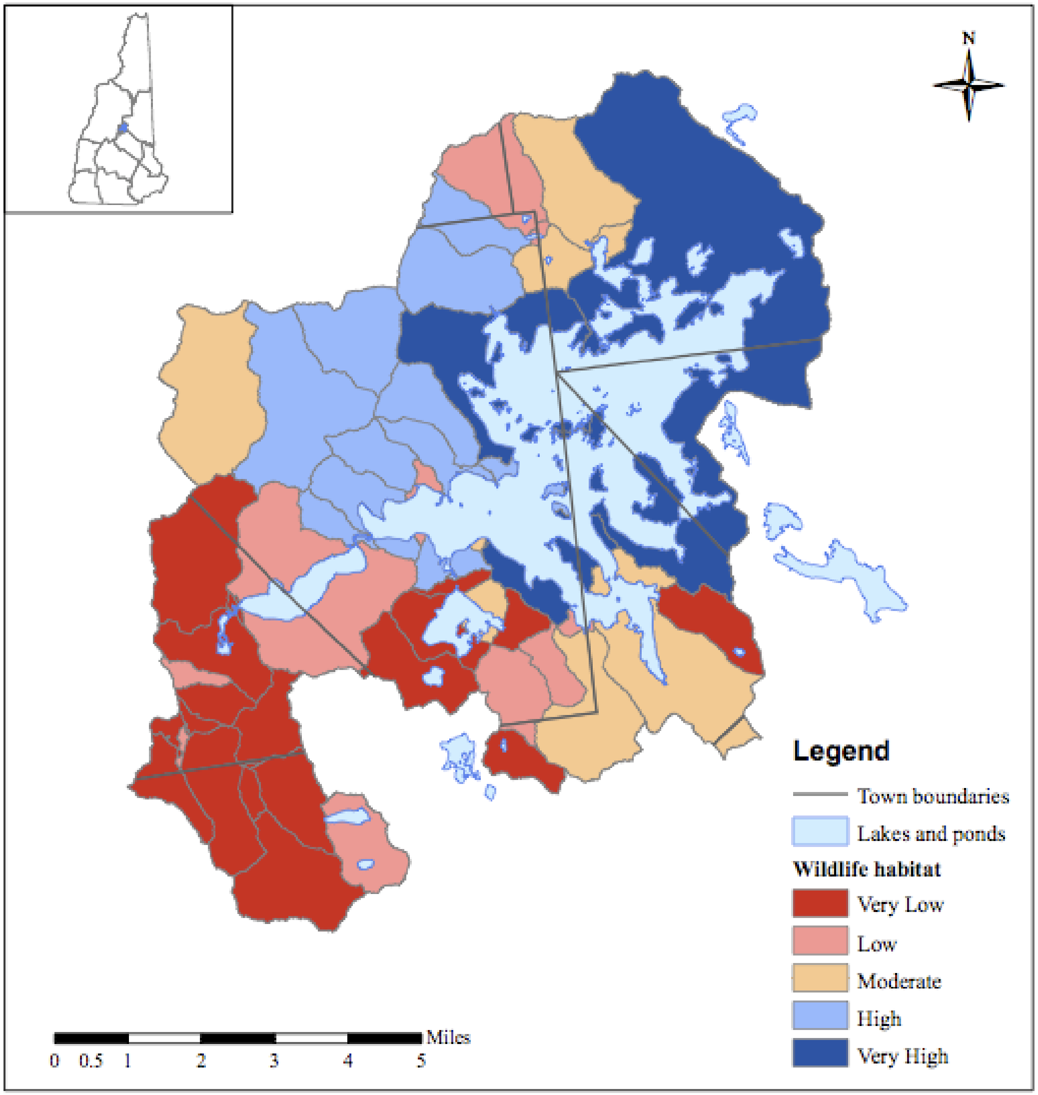

Figure 9: Strength of evidence for high wildlife habitat integrity

For example, SLCS focused its conservation efforts on the Center Harbor Woods CE in 2009 according to many factors but specifically identified the location of a four-toed salamander. Understanding the ecological condition of the watershed could not only help SLCS focus future conservation efforts but also understand where future management efforts may be needed. Because the Center Harbor Woods project was a collaborative partnership between land trusts and the town of Center Harbor, this partnership can move forward in making decisions regarding the preservation of the four-toed salamander habitat as well as allowing public access to the recreation trails.

Finally the map below, figure 10, shows the evaluation of the lower-level network within the social opportunity model for scenic views within the watershed. This network used a union logic operator to evaluate the subordinate conditions of public and private scenic views. The data links included the presence of scenic spots, the quality of those views, the proximity of private land to the shoreline, and the elevation of private land above 800 feet. There was no data missing for the evaluation for this network, but the overall absence of opportunities for scenic views is reflected in this map.

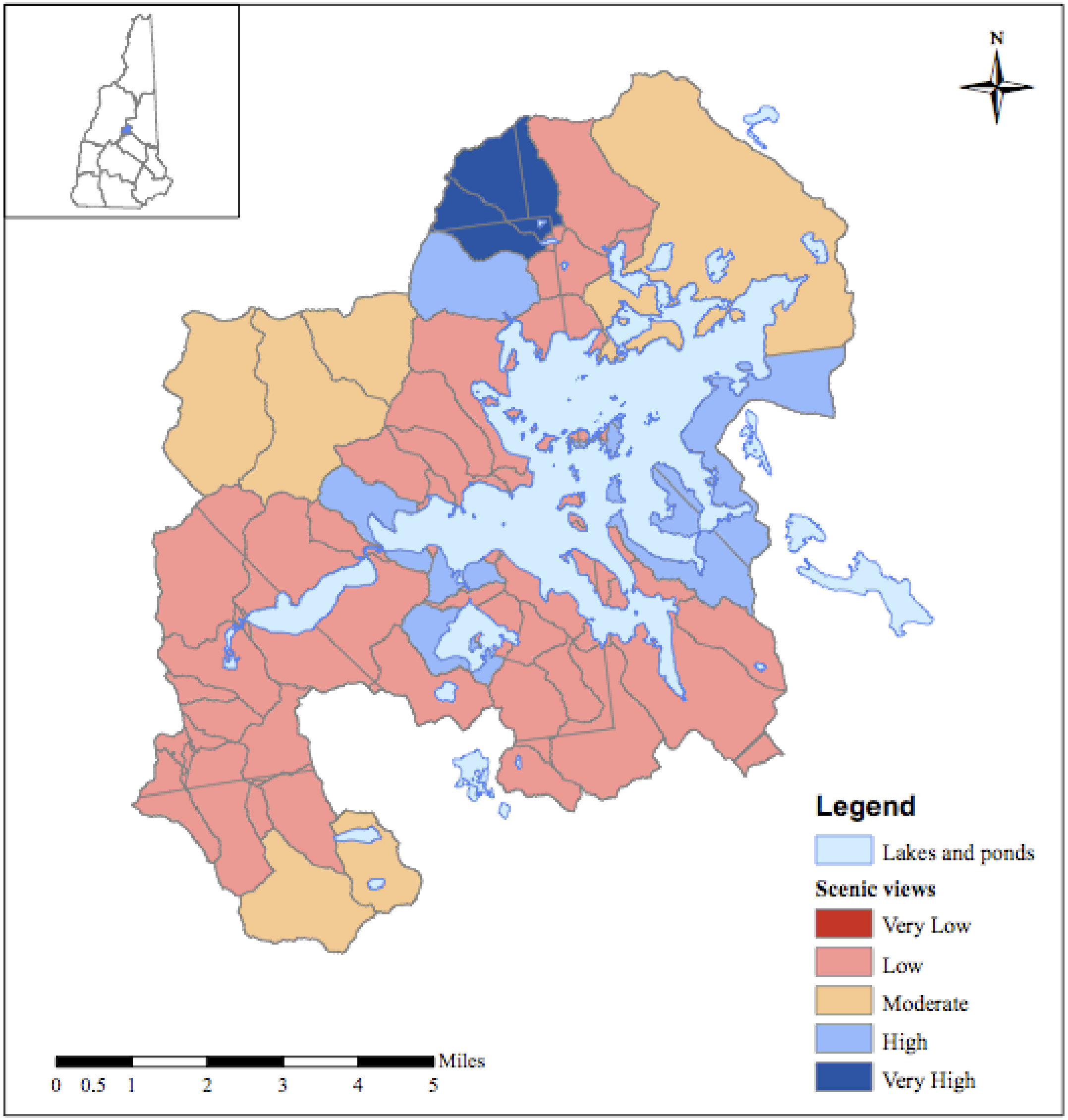

Figure 10: Strength of evidence for high scenic views in catchments of the watershed

4.5 Conservation values and existing conservation easements

Land trusts rarely evaluate the effectiveness of their conservation strategies and conserved lands (Ferraro and Pattanayak 2006). Using the model creating in this project, existing CEs were evaluated according to the criteria established by SLCS. These conservation values are determined based on the existing condition of the watershed. Therefore, by comparing existing CEs to the criteria established by SLCS, it will provide a foundation in order to better target future conservation efforts. The conservation values determined above designated seventy-one percent of currently conserved land within catchments that as “moderate” to “very high” (-0.2 - 1) (figure 11).

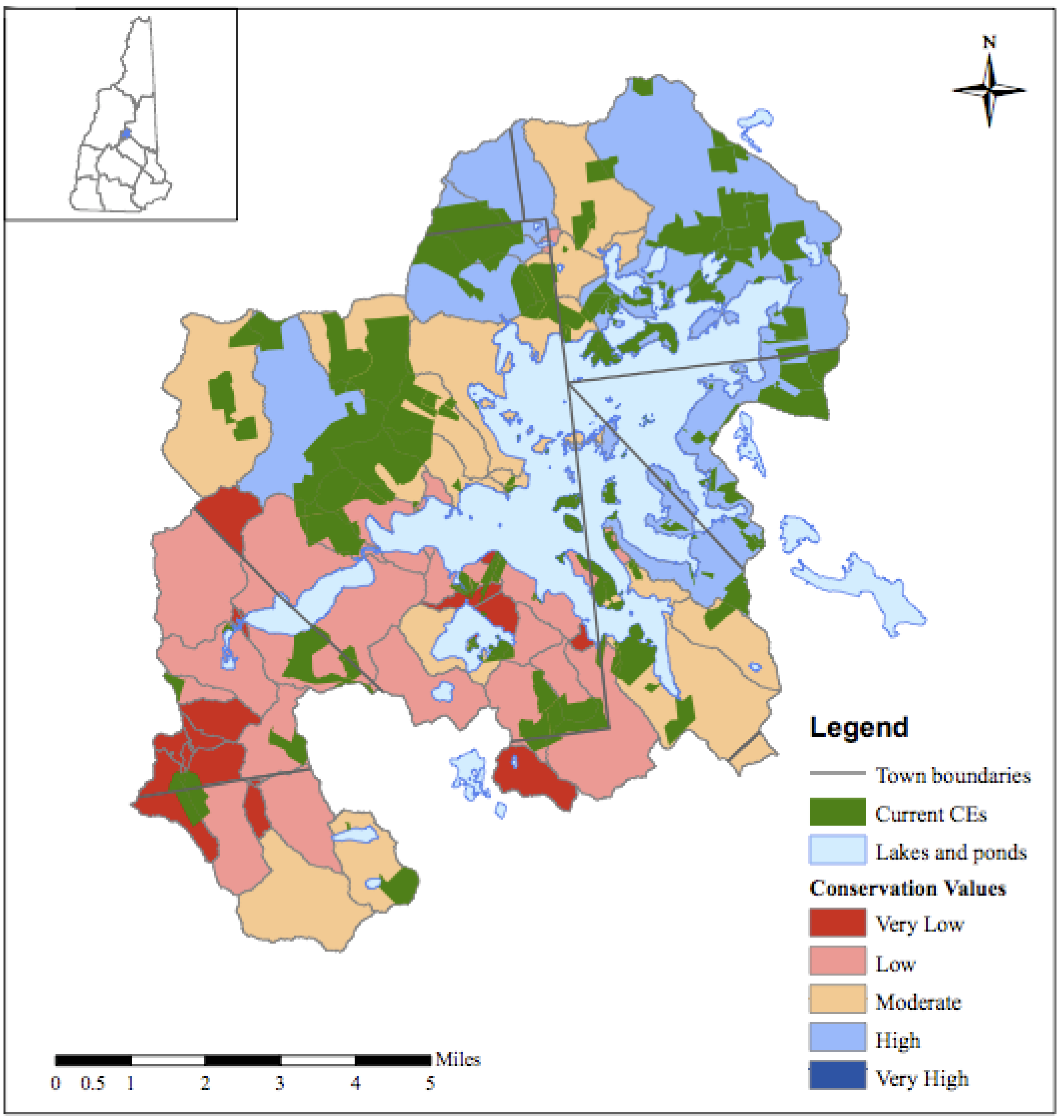

Figure 11: Strength of evidence for current conservation easements

Seventy-four percent of permanently conserved lands, however, are contained within catchments that ranked “moderate” to “very high” ecological conditions. Each existing CE can be evaluated according to the overall criteria established for this model or individual components of the model. For example a CE, Moon Island, is within a catchment that has a truth value of 0.84. This is the highest value of a catchment within the ecological network. On the other hand, only thirty-three percent of all existing conserved lands are within catchments that received a “moderate” to “very high” truth value for social conditions. For example the Burleigh CE received a truth value of 0.68. Examining the model from various components, such as the scenic views network dependency, the Burleigh conservation easement received a truth value of 0.98. This would contribute to its overall “very high” ranking in the social conditions.

By evaluating their existing conserved properties, SLCS can also identify areas that are under-represented within their high conservation priority areas. According to the network results for scenic views, there are very few areas in the watershed that received a high ranking. The same few catchments that received a high ranking for scenic views also ranked high in the ecological condition. By examining the results of individual networks within the overall knowledge base, SLCS can focus their efforts on prioritized criteria in the future. Combining the overall scores helps target certain areas and then allows the user to tease apart the proposition at various levels of the model structure. The ability to adapt the model according to the possible SLCS criteria changes is a significant advantage for the land trust to continue to ensure the needs of the ecological watershed and the community benefiting from its natural environment is balanced with few unintended negative impacts on both systems.

Chapter 5:
Discussion

As rural regions continue to experience human population growth and residential development, land trusts will continue their commitment to conservation of the land as well as the traditional uses of that land. As the use of land trusts and CEs continues to grow, however, strategic goals and plans are needed to focus conservation efforts to be effective for perpetuity. In this project, the conservation criteria and goals of the SLCS were used to create a knowledge-based model in order to target future conservation areas within the SLW. The advantages of knowledge-based models are their ability to address complex and abstract topics, to evaluate missing information within the overall structure, and to use fuzzy logic. In this case study these advantages were explored and applied in order to help the SLCS achieve their conservation mission. A watershed approach allowed the use of regional and local data in a comprehensive GIS-based system to inform decision-makers of a land trust to consider criteria established for potential conservation efforts and easements. The ecological and social trade-offs are highlighted by the existing conditions and can be evaluated by exploring possible futures under different sets of conditions. In this way, land-use suitability models can generate indicators of key ecological patterns and processes, or of vulnerability of places. This is an improvement over current practices among land trusts because this model identifies both areas of conservation priority as well as allows land trusts to evaluate their existing conserved land.

Based on the model created for this study existing SLCS easements often meet the criteria established by the organization. In a few cases of conserved land, however, not all the criteria were present for these lands to be considered highest conservation priority. For the future of prioritizing conservation values within the Squam Lakes watershed this model can be adapted to meet the target goals of SLCS as their mission changes. With the appropriate tools, similar projects may be completed by other land trusts. The land trust would have to identify their conservation criteria and the associated data available within their target area. Other tools required to conduct a similar project would include the NetWeaver software package, GIS 9.2 or more recent, a free downloadable copy of EMDS, and a model designer of the logic based model. Current data limitations were the most constraining challenges discovered during this project and most likely the greatest challenge for other land trusts. Possible downsides to using this system could include the inability of a land trust to update the model if a model designer is not present.

One alternative method that could be the use of a decision based model (Criterium Decision Plus) integrated within EMDS as a second, complementary step to the Netweaver results. Ranking criteria in order importance creates a decision model. Then, the decision model allows for the selection of several alternatives based on how well those alternatives rate against a chosen set of structured and weighted criteria (Reynolds 1999). For example, easements that allow significant land-use activities would be able to consider multiple scenarios based on the existing ecological and social conditions. In addition, this study can be replicated at various scales depending on the availability of data. It is important to emphasize that the construction of a logic model was based entirely on the conditions established by the stakeholder; in this case, the stakeholder was the Squam Lakes Conservation Society. Various sources of expertise were consulted in order to ensure a greater understanding of the ecological and social conditions that were applied. But this study used the construction of this model to facilitate conversation regarding established criteria. Future changes in criteria or prioritization of criteria may be applied and this model allows for the flexibility to meet changes over time.

The spatial characteristics of natural amenities have important implications to regional planning and management. Given the expected levels of population and housing growth in rural regions such as the Squam Lakes watershed and the growth and importance of easements for conservation, this research has created a tool to bring data-driven analyses to the process of prioritizing easement establishment. Land-use planners and policy makers are trying to gain an understanding of shifting natural resource uses and how they may change in the future and using the system created in this work to explore suitability scenarios can highlight potential areas of conflict to represent a tradeoff between land-use possibilities and ecological impact.

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