A Land Conservation Plan for the Merrimack River Watershed of New Hampshire and Massachusetts

TECHNICAL REPORT

Introduction

This document describes the technical steps involved in the development of the Merrimack Valley Regional Conservation Plan. The plan's development was guided by a group of stakeholders who provided their expertise throughout and participated in the Delphi voting that prioritized the data inputs.

The basic steps taken in developing this plan were to:

1. Compile the best available GIS data relating to the region's natural resources
2. Rank data factors through Delphi voting
3. Conduct a co-occurrence analysis with the ranked data
4. Develop conservation focus areas from the results of the co-occurrence analysis

Those steps are detailed below. Part 1 is a thorough description of the datasets that formed the basis of the analysis, and is divided into four sections: 1) Wildlife Habitat, 2) Water Resources, 3) Agriculture and Forestry, and 4) Recreation and Trails. Part 2 presents the results of the Delphi voting to rank the relative importance of the input data factors. Part 3 describes the results of the co-occurrence analysis and the steps taken to refine that analysis. Part 4 details the development of Conservation Focus Areas from the co-occurrence data.

Data Factors

The data that drove the planning process were primarily gathered from the two state data libraries, GRANIT and MassGIS, and from state agencies, such as NH Department of Environmental Services. In addition, some regional and national data sets, such as the National Land Cover Database and The Nature Conservancy's resilience data were included as well.

Three considerations were important when evaluating the data for inclusion in the study:

- Because this is a landscape-scale study, covering more than 3,000 square miles, the planning process applied a "coarse filter" approach using data as consistently as possible across the entire region. Excellent and more detailed data are known to exist at community scale within the study area; however, these data will be more appropriately incorporated during plan implementation.
- Point data or data with very small polygon features such as vernal pools do not lend themselves to broad-scale GIS processing and were therefore avoided.
- Ideally, any data used in the study would have a counterpart in each state. However, some datasets, such as NH's Wildlife Action Plan and MA's BioMap2, while similar to each other, are

not identical in intent or content, and required some manipulation to bring into roughly equal status in both states.

A total of 45 data factors were compiled for the co-occurrence analysis (43 for MA and 41 for NH; as detailed below, there were some differences in data factors between the two states). These data factors are summarized below.

Category	Sub-category	Data Factor
Wildlife Habitat		
	Wildlife Action Plans	Tier 1: Best in State
		Tier 2: Best in Bio-Region
		Tier 3: Supporting Landscapes
	Mapped Habitats (Northeast Terrestrial Habitat Mapping Project)	Cliff & Rock
		Coastal Scrub-Herb
		Freshwater Marsh
		Grassland & Shrubland
		Northeastern Upland Forest
		Northeastern Wetland Forest
		Peatland
	Climate Change Resilience	Highest Resilience from All Perspectives
		Highest Resilience in Setting & Ecoregion Combined
		Highest Resilience in Ecoregion Only
		Connectedness: Average & Higher
	CAPS Model	Top 50% Integrated Ecological Integrity (Massachusetts only)
		Top 50% Connectedness (Massachusetts only)
Water Resources		
	Water Supply Areas	Source water protection areas
		Drinking water protection areas (community wellheads)
	Phosporus Loading	Lowest 1/3 catchment P loading (highest water quality)
		Middle 1/3 catchment P loading
		Highest 1/3 catchment P loading (lowest water quality)
	Nitrogen Loading	Lowest 1/3 catchment N loading (highest water quality)
		Middle 1/3 catchment N loading
		Highest 1/3 catchment N loading (lowest water quality)
	Floodplains	100-year Floodway and/or Flood Zone
	Wetlands	Hydric Soils (poorly & very poorly drained)
	Subsurface Water Resources	Primary recharge zone (entire aquifer surface)
		Sites suitable for municipal development (FGWA)
	River Corridors	NHDES Designated Rivers 1/4 mile buffer (NH only)
		Natural land cover areas within 1/4 mile buffer (NH only)
		Scenic or protected river watersheds (Squannacook River; Massachusetts only)

Agriculture & Forestry		
	Forest Blocks	Blocks 50 - 500 acres
		Blocks 500 - 1,000 acres
		Blocks 1,000 - 2,500 acres
		Blocks 2,500 - 5,000 acres
		Blocks > 5,000 acres
	Prime forest soils on blocks >50 acres	Prime 1, 2, & 3 soils combined (using MA mapping protocol)
	Prime agricultural soils	Prime agricultural soils & soils of statewide significance
	Active agricultural land use	Cropland, hay & pasture land (from land cover data)
Recreation & Trails		
	Rail trails	Unprotected gaps in existing rail trails
		Abandoned rail ROW (potential linkages)
	Public hiking trails	Unprotected gaps in existing hiking trails
	NH Heritage trails	Unprotected gaps in existing heritage trails
	Historic & Cultural Features	Historic sites, farms, estates, other places
	Scenic Landscapes	Mapped polygons (Massachusetts only)

Wildlife Habitat

Wildlife Action Plans

The NH Wildlife Action Plan (NHWAP) uses a weighted modeling approach that estimates the quality of terrestrial and aquatic habitat statewide, resulting in polygons with the following definitions:

- Tier 1: Best in state
- Tier 2: Best in bio-region
- Tier 3: Supporting Landscapes (integrity buffers)

These three layers were used as data factor inputs to the co-occurrence analysis. More information on the NHWAP can be found at http://www.wildlife.state.nh.us/Wildlife/wildlife_plan.htm

BioMap2 in Massachusetts does not develop defined tiers of habitat quality as in NH, so various Massachusetts datasets were grouped in order to approximate a one-to-one relationship in terms of data intent and importance between the two states. The specific data used in building this crosswalk are as follows:

- Tier 1: BioMap2 Core Habitat
- Tier 2: BioMap2 Critical Natural Landscapes
- Tier 3: Areas of Critical Environmental Concern (ACEC)

Significant overlaps occur between the three Massachusetts datasets. Since this is not the case in New Hampshire, the final representation of the three tier approach in Massachusetts removed the overlaps, giving precedence to the tiers in rank order of importance.

Areas of Critical Environmental Concern (ACEC) are designated by the Secretary of Energy and Environmental Affairs in Massachusetts after nomination by local communities, with the intention of creating a framework for local and regional stewardship of critical resource areas and ecosystems. It should be recognized, however, that Tier 3: ACEC is not limited to natural features and can include non-ecological factors such as historic, cultural and scenic resources. However, the ACEC data is space-extensive and does bring in natural features of concern to local communities and state agencies.

For more information on BioMap2, refer to
http://www.mass.gov/dfwele/dfw/nhesp/land_protection/biomap/biomap_home.htm

For more information on ACEC, refer to
http://www.mass.gov/eea/agencies/dcr/conservation/ecology-acec/areas-of-critical-environmental-concern-acec.html

Mapped Habitats: Northeast Terrestrial Habitat Mapping Project

Seven habitat formations from the Northeast Terrestrial Habitat Mapping project (NETHM) were included in the wildlife habitat portion of the co-occurrence analysis. The NETHM was undertaken with the support of the Northeast Association of Fish Wildlife Agencies as part of its Regional Conservation Needs assessment, and completed in 2012. NETHM data are a 30 meter grid that maps upland and wetland wildlife habitats/ecological systems for the Northeast, including all 13 states from Maine to Virginia, west to New York, Pennsylvania and West Virginia. The ecological systems represented in the map are mosaics of plant community types that tend to co-occur within landscapes with similar ecological processes, substrates, and/or environmental gradients, in a pattern that repeats itself across landscapes. Systems occur at various scales, from "matrix" forested systems of thousands of hectares to small patch systems such as cliffs, of a hectare or two.

There are 143 habitat systems mapped in NETHM; these are grouped into 35 “macrogroups” (e.g., Northern Hardwood and Conifer Forest), and these in turn are grouped into “formations” (e.g., Northeastern Upland Forest). The MVRCP study area in New Hampshire and Massachusetts contains 37 habitat systems. Nearly 80% of the area comprises two matrix forest types, developed land, agricultural land, or water. The remaining 20% of the study area comprises 32 patch habitat systems, 22 of which are less than 50% protected. Those 22 habitats were grouped into their seven formations, as shown in the table below. These seven formations were used as data factor inputs to the co-occurrence analysis.

More detailed information on the NETHM project can be found at
https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/edc/reportsdata/terrestrial/habitatmap/Pages/default.aspx

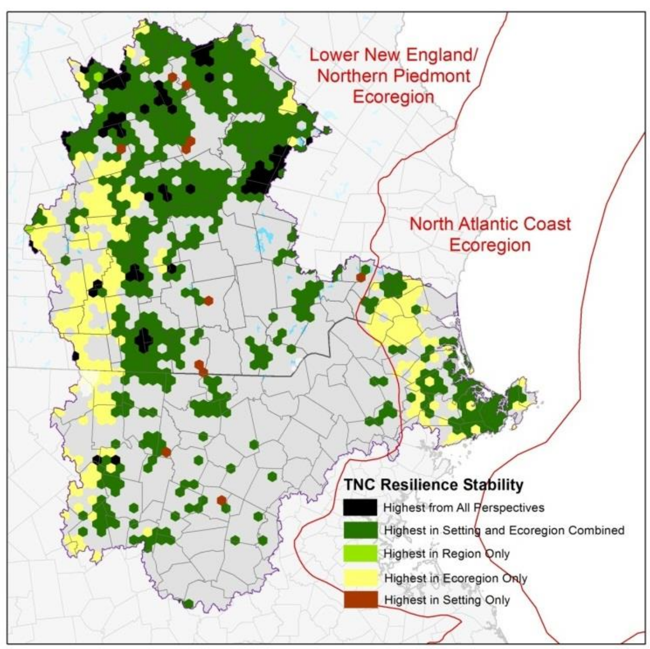
Formation	Macrogroup	Habitat System
Cliff & Rock	Cliff and Talus	Acadian-North Atlantic Rocky Coast
	Rocky Coast	North-Central Appalachian Circumneutral Cliff & Talus
Coastal Scrub-Herb	Coastal Grassland & Shrubland	North Atlantic Coastal Plain Heathland & Grassland
Freshwater Marsh	Emergent Marsh	Laurentian-Acadian Freshwater Marsh
	Wet Meadow / Shrub Marsh	Laurentian-Acadian Wet Meadow-Shrub Swamp
Grassland & Shrubland	Ruderal Shrubland & Grassland	NLCD 52/71: shrublands/grasslands
Northeastern Upland Forest	Central Oak-Pine	Appalachian (Hemlock)-Northern Hardwood Forest: drier
		North-Central Appalachian Pine Barrens
		Central Appal Pine-Oak Rocky Woodland
		Central Appal Dry Oak-Pine Forest
		North Atlantic Coastal Plain Hardwood Forest
		North Atlantic Coastal Plain Maritime Forest
		Northeastern Interior Dry-Mesic Oak Forest: moist-cool
		Northeastern Interior Dry-Mesic Oak Forest: typic
	Northern Hardwood & Conifer	Appalachian (Hemlock)-Northern Hardwood Forest: moist-cool
		Laurentian-Acadian Pine-Hemlock-Hardwood Forest: moist-cool
		Laurentian-Acadian Pine-Hemlock-Hardwood Forest: typic
Northeastern Wetland Forest	Northern Swamp	Laurentian-Acadian Alkaline Conifer-Hardwood Swamp
		North-Central Appalachian Acidic Swamp
		North-Central Interior & Appalachian Rich Swamp
		Northern Appalachian-Acadian Confier-Hardwood Acidic Swamp
Peatland	Northern Peatland	North-Central Interior & Appalachian Acidic Peatland

Climate Change Resilience

The Eastern Conservation Science program of The Nature Conservancy (TNC) has conducted a comprehensive study of a 13-state region in the northeastern United States and the Maritime Provinces in Canada with the purpose of identifying sites that have the greatest potential resilience and long-term stability for plants and animals experiencing the large-scale ecological re-organization expected from climate change. Based on TNC recommendation, the MVRCP planning process considered two outputs of the larger study: aggregated high-value sites and connectedness.

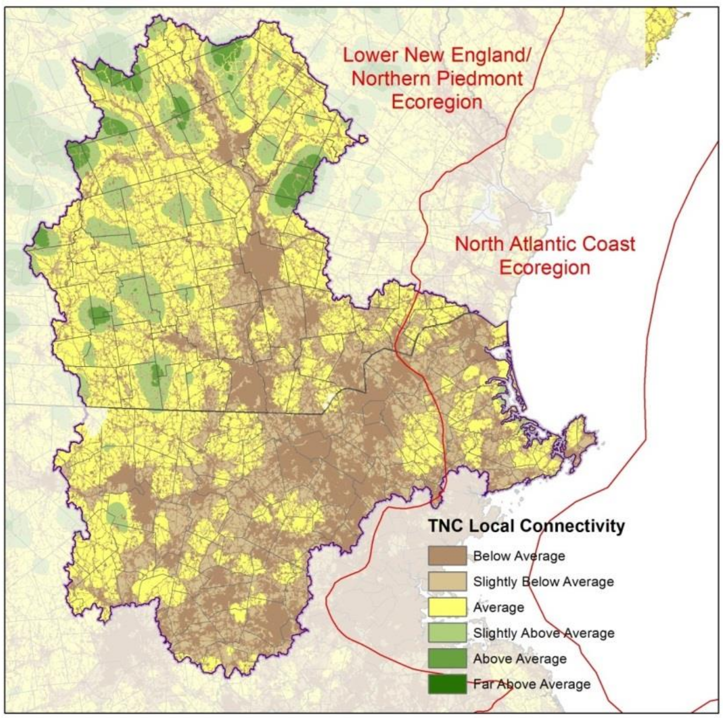
To understand how these data were used, it is important to understand the component frameworks of the data analysis and mapping. The TNC resiliency analysis utilizes four scales of analysis in assessing resiliency:

- Site: the most basic element of the study, a 1,000-acre hexagon grid cell (commonly used in very large-scale regional studies.
- Setting: a geophysical setting comprised of sites with similar geology, elevation, and landform.
- Ecoregion: large units of land with similar environmental characteristics, especially landforms, geology and soils, which share a distinct assemblage of natural communities and species.
- Region: the 13-state and Maritime Provinces study area, spanning the Northeastern U.S. from Virginia to Maine.



The map above is a synthesis of high-scoring sites from the four perspectives listed above for the MVRCP study area. High-scoring means above-average resilience scores at each level of study. The two ecoregions that include the study area are shown in red. The sites shown in black and dark green are the most important areas of climate change resiliency since they aggregate the broadest range of high scores from site to regional scale. However, the yellow and brown site cells are also important at the scale of the MVRCP study since they represent high-scoring areas within the two ecoregions, or in geophysical settings unique to the study area. The lighter green cells are high-scoring in the TNC study region only, and since there are only a few such sites, they were determined to be of lesser importance to the MVRCP study. Therefore, the factors included in the co-occurrence analysis were:

- Highest Resilience from All Perspectives
- Highest Resilience in Setting and Ecoregion Combined
- Highest Resilience in Ecoregion Only



Connectedness refers to the relative connectivity of a site hexagon with its ecological neighborhood when it is viewed as a source. Each site cell was coded for a resistance value/weight based on roads and land cover characteristics within the cell, and a GIS model was run to determine the theoretical spread of a species or natural process outwards from a given cell for a distance of three kilometers.

This modeling exercise is very similar to the connectedness mapping generated for the Massachusetts CAPS analysis, and in fact was done by the same team of scientists (see below).

The Massachusetts portion of the study area is dominated by below average permeability, which is no surprise given the extensive road network and urbanized land cover. However, there are sizeable areas of average connectedness and a few small areas classified as somewhat above average (see the green areas in several western communities and two very small areas near the seacoast). New Hampshire not only has more extensive areas of average connectedness, but also several large areas of slightly above and above average connectedness, due in part to protected land (e.g., Bear Brook State Park) but also large blocks of forested land. No land in the MVRCP study area was rated far above average.

For the purposes of the MVRCP Delphi voting, three classes of connectedness were combined: average, slightly above average, and above average. In Massachusetts, these data factors were augmented by a separate connectedness dataset derived from the CAPS study. That dataset is much more fine-grained and highlighted more localized areas of permeable land cover/habitat, thus offsetting to a degree the more generalized TNC data.

Detailed information on the complete resilience study can be reviewed at https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/edc/reportsdata/terrestrial/resilience/Pages/default.aspx

CAPS Model

The Conservation Assessment and Prioritization System (CAPS) was developed by staff of the Landscape Ecology Program in the Department of Environmental Conservation at UMASS/Amherst and published in 2011. CAPS is a complex and sophisticated ecosystem-based approach for assessing the ecological integrity of lands and waters and prioritizing them for conservation. The CAPS approach results in a final Index of Ecological Integrity (IEI) for each point in the landscape. A full report explaining the methods and products of CAPS is available at http://www.masscaps.org/.

The best application of the CAPS assessment data for the MVRCP were the statewide Integrated Index of Ecological Integrity which represents the top-scoring 50% of the raw IEI data statewide, and the top-scoring 50% connectedness data. The CAPS model addresses habitat connectivity by using the GIS to measure the absolute disruption (barriers), "resistance" to movement in developed and undeveloped landscapes, as well as the similarity of surrounding habitat types. The connectedness data is actually a statistical artifact of the "least cost" model run in the GIS, rather than a reflection of actual physical features on the ground, such as an intact block of forest or a wetland. However, when combined with the IEI data as a reference dataset, it is useful in amplifying connectivity opportunities and therefore was used as a data factor in the MRVCP planning process.

Water Resources

Water Supply Areas

In New Hampshire, Source Water Protection Areas (SWPA) are mapped at watershed level by NHDES. While some SWPA are very large river watersheds, extending beyond the study area, others relate to municipal water supplies. In Massachusetts, Source Water Protection Zones (SWPZ) are closely related to the NH SWPA data. The MA data are broken into three categories of protection of surface water features that flow into drinking water reservoirs, as follows:

- Zone A: 400 foot maximum buffer along streams
- Zone B: 1/2 mile buffer, primarily around lakes, ponds and the reservoir itself
- Zone C: Remainder of the watershed

For the purposes of the MVRCP, only Zone B and C of the Massachusetts SWPZ will be used since Zone A will not provide a legible "signal" in the co-occurrence mapping. No such detailed delineations exist in the NH version of SWPA.

Both Massachusetts and New Hampshire maintain datasets for public water supplies (points representing either wells or surface water intakes on reservoirs) as well as delineated drinking water supply protection areas (DWPA) surrounding each point. Some of those protection zones are discussed above as surface water protection features (SWPA and SWPZ), but DWPA are typically circular zones or hydrologically-defined areas intended to protect the zone of water intake or drawdown around wellheads. There are many more delineated sources in NH than in Massachusetts. Since these DWPA relate directly to maintaining drinking water quality in the wells, they were included as a factor in the co-occurrence analysis.

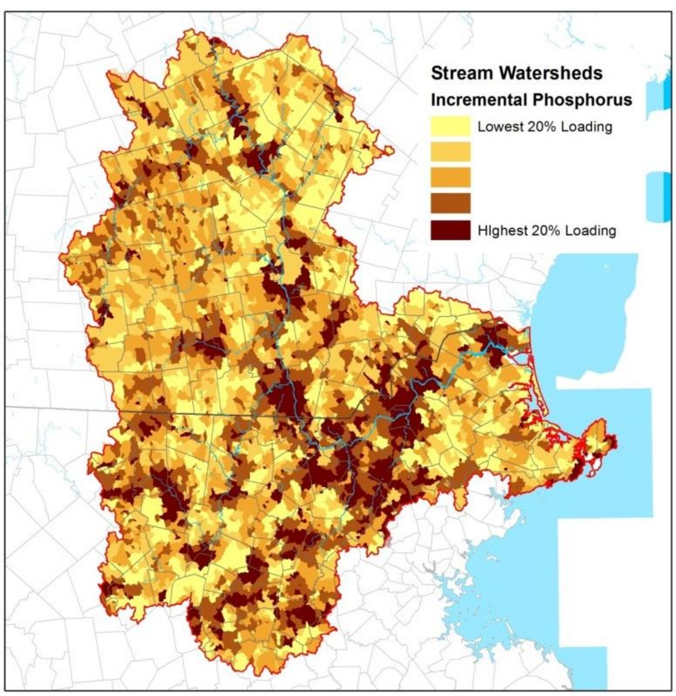
Phosphorus and Nitrogen Loading

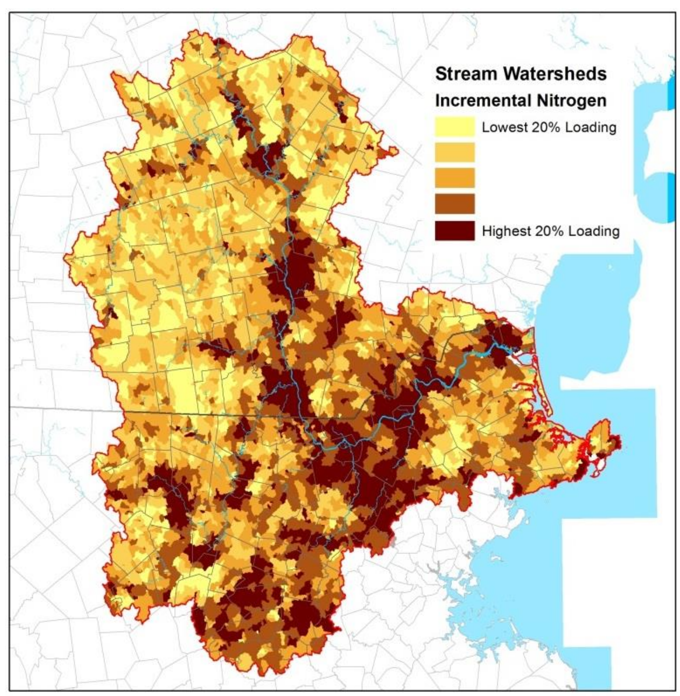
SPARROW (Spatially Referenced Regressions on Watershed attributes) is a model developed by the USGS, initially in the NH/VT regional office for New England (2004), and that now has expanded nationwide with updated inputs and improved modeling. There are actually two models within the SPARROW project: one for nitrogen load delivered to estuaries, and a second for phosphorus loading of lakes and reservoirs. The model and data results are intended to provide detailed information to water resources managers concerned with eutrophication and nutrient issues and management strategies, and it is also possible to identify a range of stream watersheds which have higher water quality, from the standpoint of nitrogen (N) and/or phosphorus (P) loading.

More information on the most current modeling effort for the New England region can be found at: http://onlinelibrary.wiley.com/doi/10.1111/j.1752-1688.2011.00582.x/abstract

An important base data element of SPARROW has been the generation of individual stream watersheds, or catchments, which are used to calculate incremental loading. Within the Merrimack Valley Regional Plan (MVRCP) study area, more than 4,700 stream watersheds are delineated ranging in size from less than one square mile to ~9 square miles in size (mean size = 443 acres). This scale of stream watershed produces a very fine-grained resolution in mapping and GIS statistical analysis.

The figures below show mean annual incremental P and N loading for the stream watersheds in the MVRCP study area. Incremental loading accounts for the contributions of headwaters and tributaries into downstream watersheds, and so typically lower loading will be found upstream and ever-more concentrated loading will occur downstream as streams become rivers that in turn empty into the ocean. The maps both use a 5-step quantile classification scheme, with lighter colors indicating lower loading per stream watershed and darkest colors showing where loading is greatest.





Areas with lower incremental loading are likely those places where natural land cover is significant in headwater tributaries; keeping these areas in conserved land cover is important to downstream water quality. Areas with the highest loading figures will be more urbanized, with little remaining natural land cover or undeveloped land; permanently protecting any remaining riparian corridors, buffers, wetlands complexes, etc., should probably be a priority in these areas. The data for both P loading and N loading were classified into thirds for the co-occurrence analysis:

- Lowest loading/highest quality
- Middle loading/middle quality
- Highest loading/lowest quality

Floodplains

Floodplain mapping relied on the Federal Emergency Management Agency's Digital Flood Insurance Rate Maps (DFIRMs) in both states. 100-year Floodways and/or Flood Zones were used as a factor in the co-occurrence mapping.

For more information about DFIRMs, see http://www.fema.gov/national-flood-insurance-program/map-service-center#3

Wetlands

Wetlands were included in the co-occurrence analysis in the form of hydric soils (poorly and very poorly drained soils), not mapped wetlands. This approach created a seamless dataset of jurisdictional wetlands for use across the two states. The use of National Wetlands Inventory mapping in recent conservation planning has demonstrated its limitations due to mapping errors and delineation using aerial photography which does not identify extensive riparian and forested wetlands areas, so soils mapping gives better accuracy. It should be understood that there may be double-counting of some wetlands since the most critical wetlands are also embedded in the two states' wildlife action plans.

Sub-Surface Water Resources

Sub-surface water resources are defined by sand and gravel mapping in both states. The entire surface area of the aquifer is important as a primary recharge area, and was used as a data factor for the co-occurrence analysis. In addition, aquifers were classified based on ability to yield water to a municipal well using a system developed by NH DES in evaluating sites favorable for future well development, known as the Favorable Gravel Well Analysis (FGWA). This method was used in a rapid-assessment approach in Massachusetts to obtain similar mapping of remaining well sites.

For more information on FGWA, see http://clca.forestsociety.org/pdf/fgwa.pdf.

River Corridors

The data factors representing outstanding rivers corridors were somewhat different for the two states. In NH, the NHDES has a program of Designated Rivers under the Rivers Management & Protection Act. A Designated River is managed and protected for its outstanding natural and cultural resources. A one quarter mile buffer on the Designated Rivers within the study area was included as a data factor for the MVRCP co-occurrence. In addition, the undeveloped areas within this quarter mile buffer were also included as a data factor.

For more information on the Designated River program, refer to http://des.nh.gov/organization/divisions/water/wmb/rivers/desigriv.htm

In Massachusetts, the Outstanding Resource Waters (ORW) dataset aggregates important watersheds. Within the study area, the ORW includes

- Areas of Critical Environmental Concern (the Great Marsh estuary complex is an example)
- Public water supply watersheds (most often relating to drinking water reservoirs)
- Scenic or protected river watersheds (Squannacook River)

Areas of Critical Environmental Concern are included in the MVRCP analysis as Tier 3 of the critical habitats, and public water supply watersheds are included in the drinking water factors (SWPZ). Therefore, these were not repeated as factors, but the scenic or protected river watershed of the Squannacook River was included.

For more information on the Outstanding Resource Waters dataset, see http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/orw.html

Agriculture and Forestry

Forest Blocks

For this study, forest resources were treated as a background matrix of forest blocks, or intact continuous forest cover defined by roadways and large bodies of water. Each forest block may contain significant embedded ecological features and contributes in various ways to water quality, wildlife habitat, economic forestry, and recreation opportunities.

Forest block data were obtained (pre-release) from the TNC Eastern Region office in Boston. The source data for this forest block mapping is the 2001 USGS National Land Cover Dataset (NLCD) with a resolution of 30-meters and an accuracy assessment of 85%, but updates on extent of natural land cover have been made using the similar 2006 NOAA CCAP dataset.

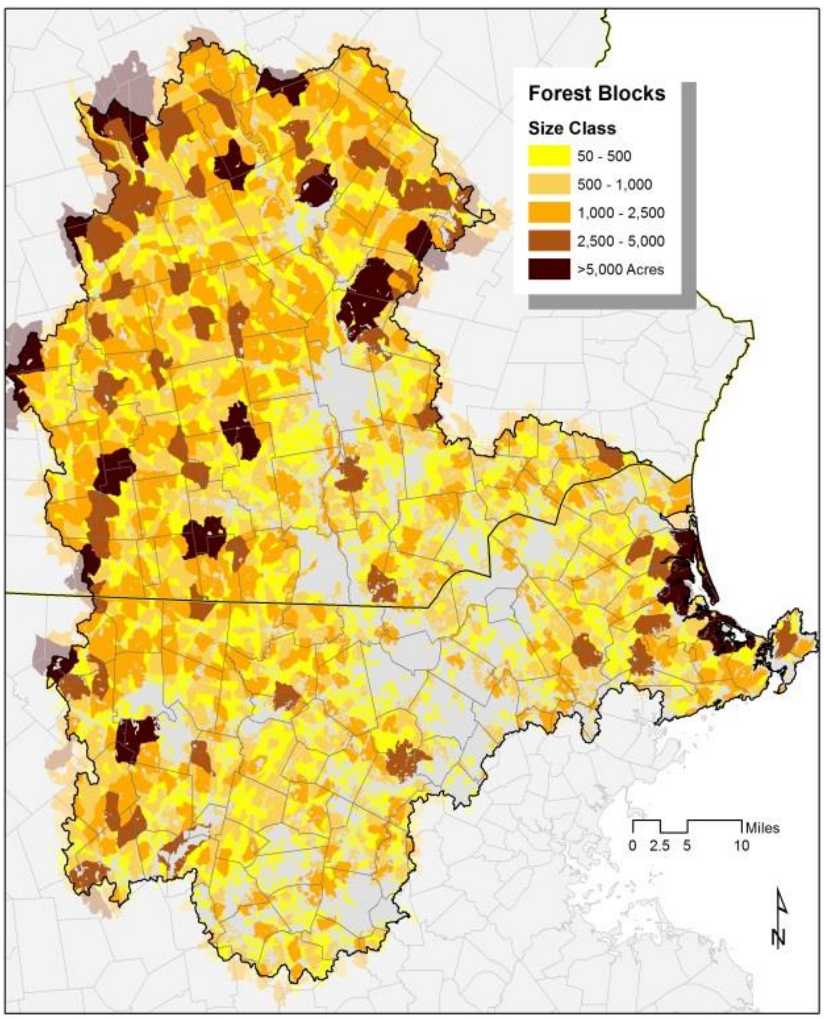
The TNC data differs significantly from previous forest block mapping which will be more familiar to conservation planners, including those forest blocks that were developed for the NHWAP and BioMap2.

- Blocks are not purely forest land cover. Many blocks will contain other types of natural land cover elements (wetlands, grasslands, etc.) which are either embedded within the block or are found at its fringes.
- Blocks are defined by travelled roadways and large water features >10 acres, including rivers. However, buffers are **not** applied to roadways as in previous forest block delineations to account for road frontage development hidden by tree canopy in the source satellite imagery.
- Blocks may contain substantial amounts of developed land or agricultural land uses, but road-bounded blocks that are totally developed or in agricultural use have been eliminated from the mapping.
- Roads are not "burned into" the source land cover data to add accuracy to the developed land component of the mapping. Where roads and other manmade surfaces appear in the land cover data, they are classified as developed.
- Each TNC block contains at least a small amount (.2224 acre) of natural ecological system mapped and designated in the NE Terrestrial Habitat Mapping project (see Wildlife Habitat discussion above).

For the purposes of the MVRCP, the TNC block data has been vetted in two ways:

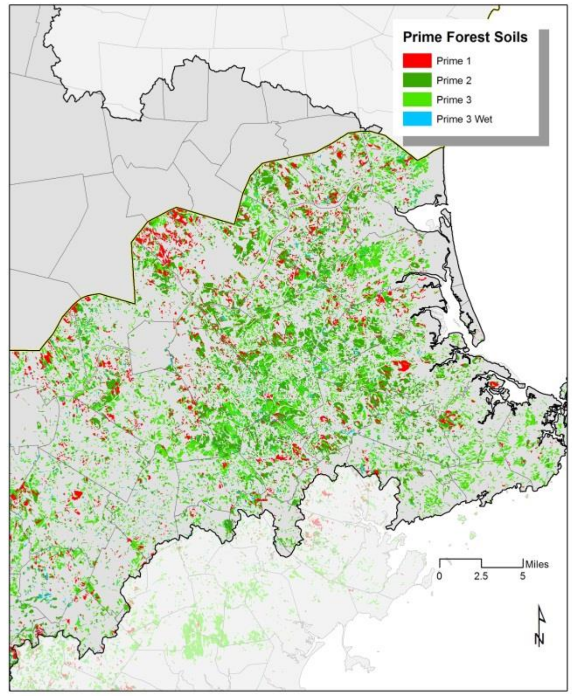
- Only those road-bounded blocks which have 50% or greater natural land cover, including several wetlands types and various agricultural land uses such as cropland, pasture, grasslands, shrublands, and bare land. This has the effect of eliminating many smaller blocks on the fringes of urban areas and along major highway corridors within the study area. This qualification was done by intersecting the 2006 NOAA CCAP land cover dataset and the TNC blocks, and then calculating percent of natural land cover for each block.
- Size classes have been assigned based on a logical breakdown of blocks ranging from a minimum of 50 acres to more than 5,000 acres. The five size classes approximate five equal intervals of 20% of total block area, at least in the lower three size classes, and are rounded to numbers easy to understand (Table 5). Note that blocks size include the <u>total</u> area of each block, regardless of embedded developed areas, and whether or not the block extends beyond the study area boundary.

The resulting forest block dataset is shown below. Note that several large blocks extend beyond the study area boundary.



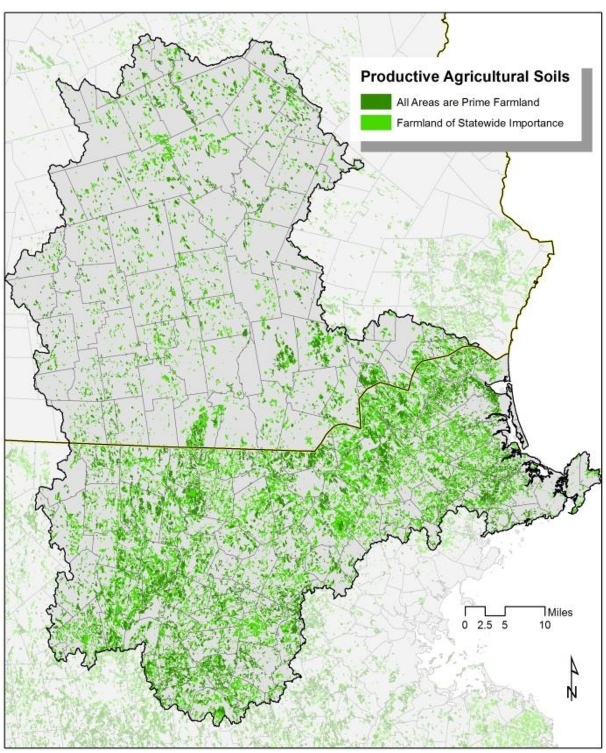
Prime Forest Soils

Massachusetts has mapped prime forest soils for about 85% of the state, including all of the MVRCP study area. The focus is primarily on white pine and red oak with a NRCS site index of 50 or greater, which amounts to the most productive forest soils overall, and builds on work done previously by others (*Prime Forest Land Classification for Forest Productivity in Massachusetts*, MacConnell, et. al., UMass Research Bulletin #705). There are several considerations built into the prime forest soils mapping protocol, including topography, solar aspect, presence of wetlands and riparian corridors, etc., with a resulting classification system of Prime1, Prime2, Prime3, and Prime3 Wetland (all considered prime forest soils), plus a few secondary classifications (see table below).



The MVRCP planning study focused on the first three prime soils as stand-alone categories, but limited those to forest blocks of 50 acres or greater in consideration of increasing potential for economic forestry on larger forest blocks. The Prime 3 Wetlands classification is very limited in extent, and conflicts may exist with ecological sensitivities, so this "prime" category is not considered in the plan.

New Hampshire does not have a prime forest soils dataset to match the Massachusetts mapping. Instead, forest soils are classified as Important Forest Soils Groupings. These groupings depend upon physical aspects of the land in general, and aim towards certain forest species compositions that can be expected under specific management approaches. The New Hampshire data are, by nature, very broad, with extensive areas classified in the more productive groupings. Therefore, a soils dataset similar to the Massachusetts prime forest soils mapping was generated for the New Hampshire portion of the MVRCP to help maintain parallel construction the planning data.



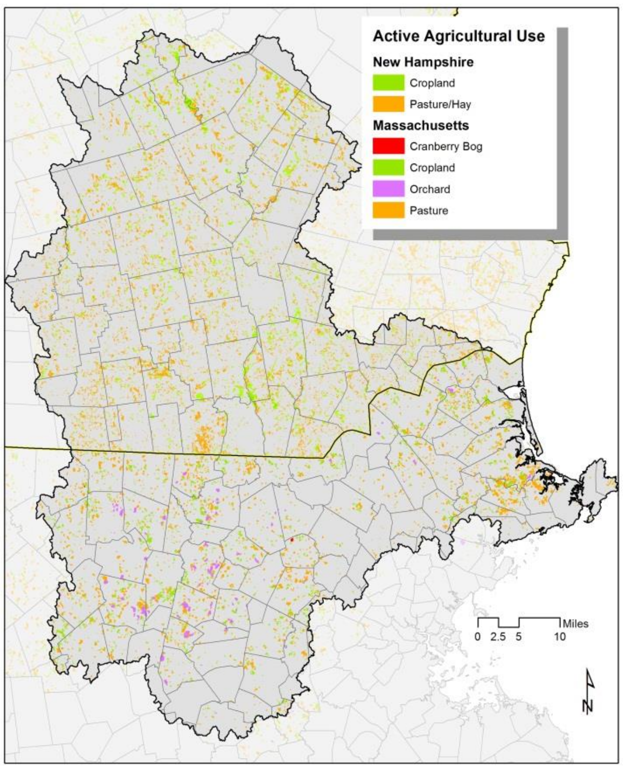
Prime Agricultural Soils

NRCS soils mapping in both New Hampshire and Massachusetts codes productive agricultural soils as follows, per the Farmland Protection Policy Act of 1981 (FPPA):

- Prime Farmland
- Farmland of Statewide Importance
- Farmland of Local Importance
- Unique Farmland

The first three categories are based on physical parameters of the land and the soils (soil type, drainage, slope, stoniness, etc.) in degrees of decreasing value as cropland. Unique Farmland is not based on a soil map unit or physical attributes, but rather on the existence of a high-value agricultural crop, typically orchards. Since any orchards will likely be accounted for in mapping active agricultural lands, this soils group was not included as a classification in the productive agricultural soils component of the MVRCP planning data. Soils in the Farmland of Local Importance soils group are so extensive, especially in New Hampshire, that they were also not included in the voting list.

Developed areas were removed by overlaying the 2006 National Land Cover Dataset (NLCD) in New Hampshire, and the 2005 land use mapping in Massachusetts, which is more detailed than the NCLD. Note that there appears to be a significant difference in the extensiveness of productive agricultural soils between New Hampshire and Massachusetts. In part, this is due to better farming soils in the MA due to geology, terrain, etc., but there may be differences in mapping and decision-making that occurred in each state when designating soils per FPPA.



Active Agricultural Land Use

Agricultural lands in each state were identified using land use/land cover mapping: in Massachusetts, the state's land cover map, and in NH, the National Land Cover Database (NLCD). NLCD data is mapped at 30-meter grid cell size and is approximately 85% accurate; it represents relatively coarse data for land use/land cover mapping, but is the best available in New Hampshire. The Massachusetts data is much higher resolution, and as can be seen the map at right, offers more classifications of agricultural land uses.

Cropland in both datasets means cultivated crops such as corn, vegetables, etc. Pasture may be actual pasture, or hay land, or both in rotation. Orchards in Massachusetts include all scales and types of fruit production, including blueberries. Cranberry production is unique to Massachusetts. All categories of active agricultural land (cropland, pasture/hay, orchard, and cranberry bog) were grouped as one factor in the co-occurrence analysis.

Recreation and Trails

Regional Recreation Trails

Recreational hiking and biking trails have special importance for conservation and open space planning in more urbanized areas. This is especially the case in parts of southern NH and in the Boston metropolitan area of Massachusetts. Currently there is a great deal of interest in developing long-distance, arterial trail connections in the region using abandoned railroad rights-of-way. A hub of these "rail trails" is located in the city of Manchester, NH, with trail corridors radiating in several directions including south into Massachusetts. Similar rail trails flow out from Boston and north towards NH. However, discontinuities exist within each state's current rail trail system, as well as at the state border.

Other trails exist that are not necessarily aligned with railroad corridors. One excellent example is the Bay Circuit Trail which connects coastal Massachusetts south of Boston to the Great Marsh and Cape Ann area north of the city, running in a long "beltway" roughly parallel to Interstate 495. The non-profit organization associated with the Bay Circuit Trail has worked for decades to secure trail easements and in some cases to acquire property to ensure the trail continues to be a recreation resource into the future. Other public trails data is available in both states for long-distance recreation trails and local trails complexes that could serve as connection and nodes in a future bi-state trails system, all of which will be compiled for use in this plan.

Since it is linear data for the most part, and therefore not useful in landscape-scale resource co-occurrence mapping, compiled trails information for the MVRCP was developed as a reference dataset for later use in case-making for land protection in the conservation focus areas. For the co-occurrence analysis, a 500' buffer was cast on either side of existing trails, and unprotected gaps in the trails were included in the data factor list, regardless of on-the-ground feasibility. In this way, a "signal" or "trail signature" was preserved in the final co-occurrence mapping.

Historic and Cultural Features

Both New Hampshire and Massachusetts have developed GIS data for important historic and cultural features. In New Hampshire, the coverage is limited to point data from the National Register of Historic Places (NRHP). The NH digital data was last revised in 1996, but contains 174 features within the MVRCP study area.

The Massachusetts Culture Resource Inventory System (MACRIS) includes a broader range of features significant at local and regional scales in that state. The MACRIS data is current to 2012, and includes polygon features for historic farms, estates, and other places, which can be useful in land conservation planning. In addition, data in Massachusetts include several linear features such as canal districts that may provide linkage opportunities and/or destinations in a regional recreation trail system. More information on MACRIS is available at http://mhc-macris.net/.

Scenic Landscapes

A scenic landscape inventory was conducted in Massachusetts in 1982. It includes polygons of distinctive and noteworthy scenic resources. For more information on the scenic landscape inventory, refer to http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/sceninv.html

Conservation & Public Lands

While not a component of the Delphi voting and co-occurrence analysis, conservation and public lands were used throughout the development of the MVRCP. Both New Hampshire and Massachusetts maintain statewide datasets of conserved and public lands, but the types of lands and land uses included in the data vary considerably between the states. Generally, Massachusetts included many more public opens spaces such as recreation fields, parks, and other land uses that do not meet commonly understood definitions of "conserved land" (land protected in perpetuity and for conservation of its natural resource values).

Therefore, the Massachusetts data on conservation lands has been defined to limit the types of land mapped as conservation land, and to bring it into closer conformance with the New Hampshire data, as follows:

- Under OS_Level_Protection, only codes P (perpetuity) and T (term limited) are used.
- All codes in OS_Interest_Type (type of protection), OS_Type (ownership), are retained.
- Under OS_Primary_Purpose, all codes except Recreation are retained.

Delphi Voting

Reference materials on all data factors and an electronic voting ballot were sent to all stakeholders who participated in the focus group discussions or expressed interest to be included in the planning process. A total of 22 voters representing 18 agencies or organizations in the bi-state area responded. In New Hampshire, 14 votes were recorded from 11 stakeholders; Massachusetts fielded eight voters from seven stakeholders. Four agencies or organizations cast ballots for both states.

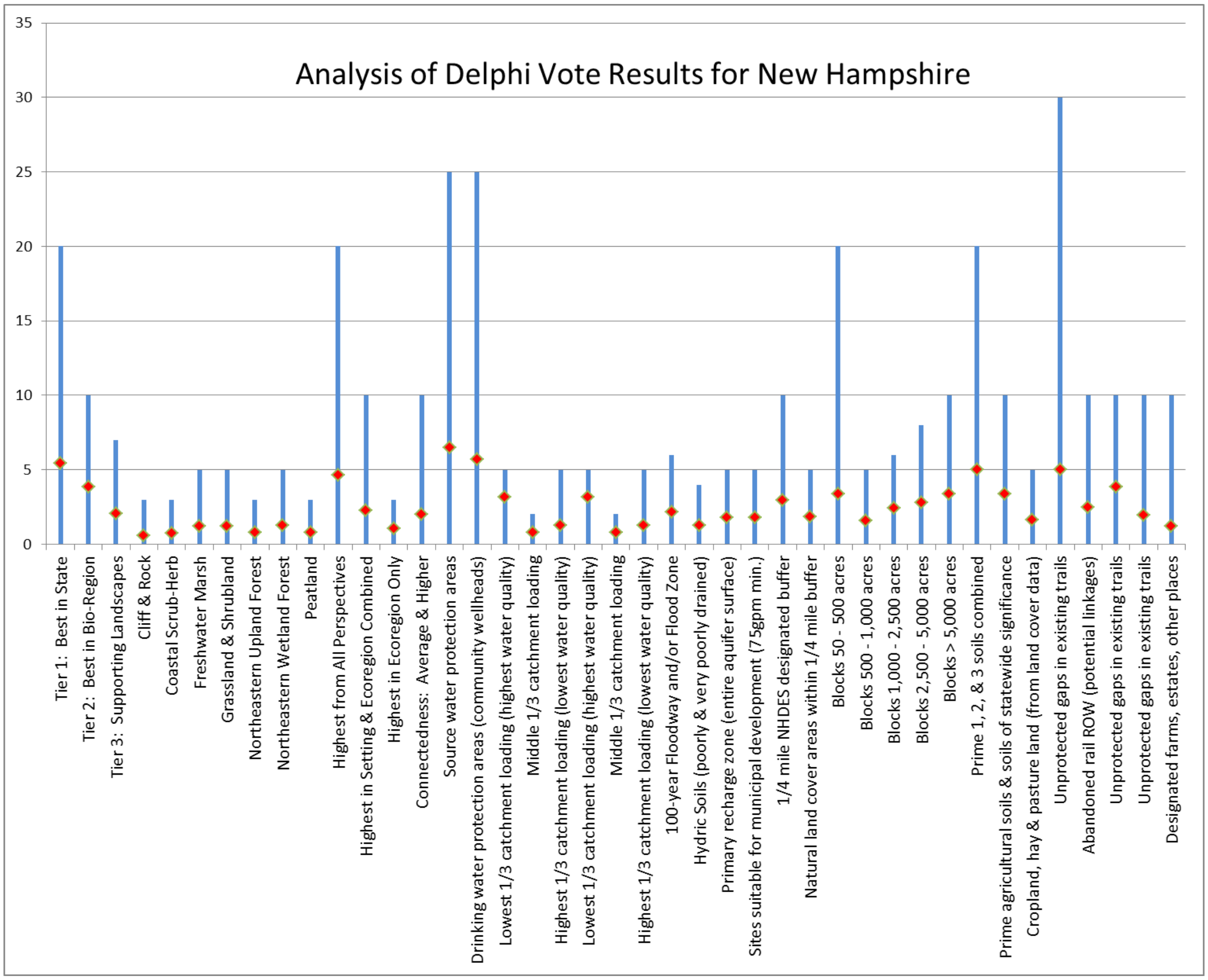
Participants in the Delphi Voting Process

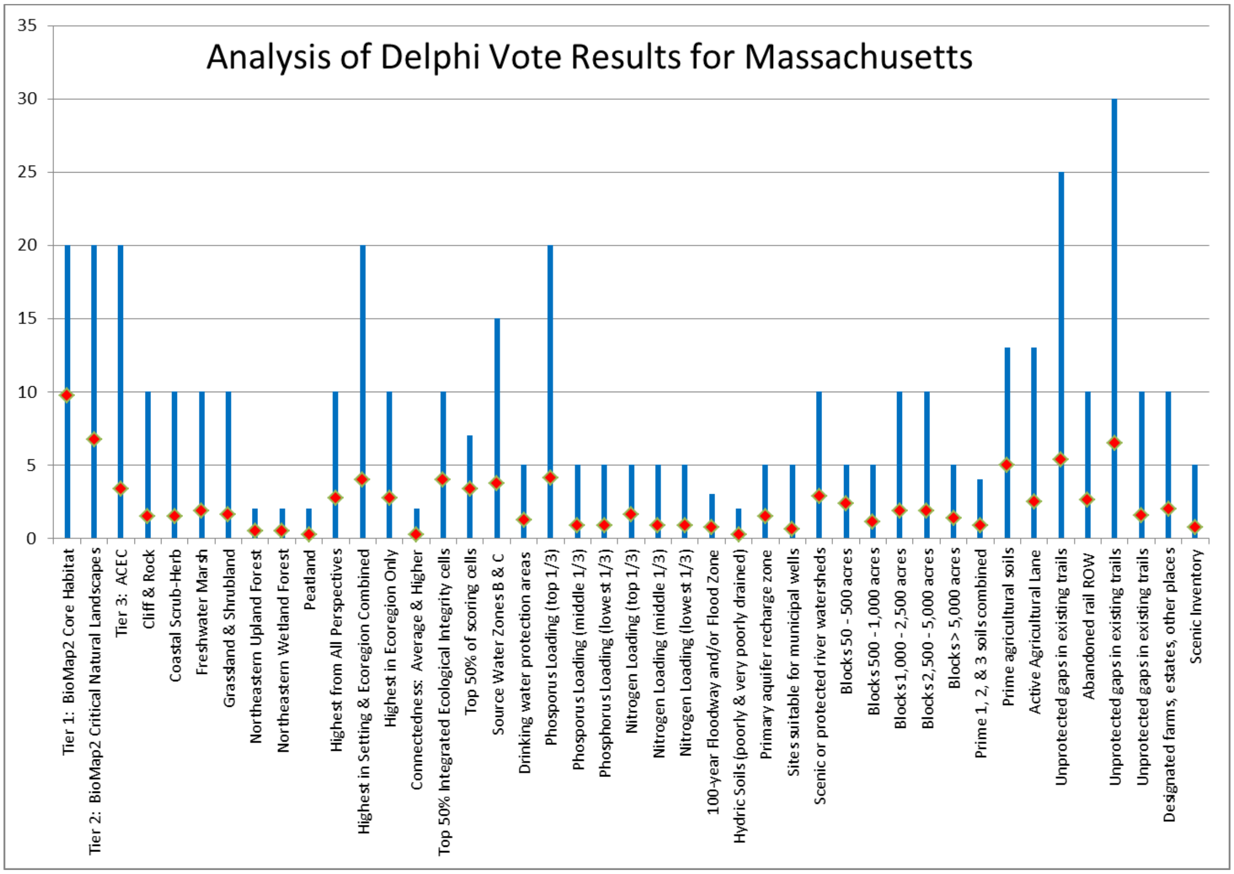
Massachusetts	New Hampshire
Essex County Greenbelt	Lowell Parks & Conservation Trust
Lowell Parks & Conservation Trust	Mass Audubon
MA Dept. of Conservation & Recreation	Nashua River Watershed Association (2 voters)
MA Dept. of Fish and Game	NH Dept. of Environmental Services
Mass Audubon	NH Dept. of Fish & Game
Nashua River Watershed Association (2 voters)	NH DRED Forests & Lands
US EPA	NH Rivers Council
	Piscataquog Land Conservancy
	Rockingham Planning Commission
	SPNHF (2 voters)
	US EPA (2 voters)

The results of the voting are listed in rank order from highest to lowest score for both states in Appendix A. Top scoring data factors in New Hampshire included source water protection areas, drinking water protection areas, Tier 1 WAP, prime forest soils, and unprotected gaps in existing trails. In contrast, top-ranked factors in Massachusetts included both Tier 1 and Tier WAP (BioMap2), unprotected gaps in public hiking and rail trails, and prime agricultural soils.

Voter emphasis in both state resulted in a wide array of data factors, both in terms of resource type (wildlife, water, etc.), and among the classifications within certain factors, e.g., forest block size classes. This tends to indicate very thoughtful allocation of votes across the entire spectrum of data factors generally, with voters weighing and balancing factors against one another. Careful allocation of votes is also evident in the voting summary which shows many more voters "splitting" their points among many factors rather than lumping points into a few factors.

The charts below show the high, low, and mean votes for data factors in the two states. The mean vote values were coded into the GIS datalayers to produce the master co-occurrence map of the entire study area.



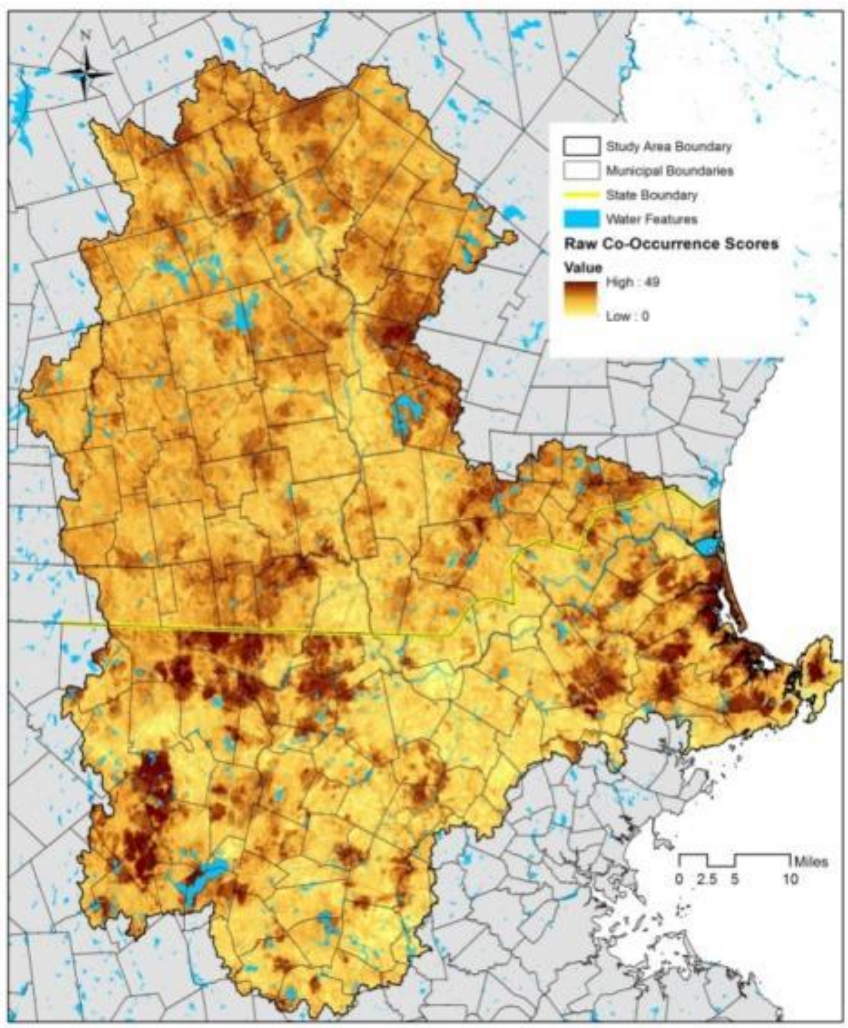


Analysis of Delphi Vote Results for Massachusetts
35
30
25
20
15
10
5
0
Tier 1: BioMap2 Core Habitat
Tier 2: BioMap2 Critical Natural Landscapes
Tier 3: ACEC
Cliff & Rock
Coastal Scrub-Herb
Freshwater Marsh
Grassland & Shrubland
Northeastern Upland Forest
Northeastern Wetland Forest
Peatland
Highest from All Perspectives
Highest in Setting & Ecoregion Combined
Highest in Ecoregion Only
Connectedness: Average & Higher
Top 50% Integrated Ecological Integrity cells
Top 50% of scoring cells
Source Water Zones B & C
Drinking water protection areas
Phosporus Loading (top 1/3)
Phosporus Loading (middle 1/3)
Phosphorus Loading (lowest 1/3)
Nitrogen Loading (top 1/3)
Nitrogen Loading (middle 1/3)
Nitrogen Loading (lowest 1/3)
100-year Floodway and/or Flood Zone
Hydric Soils (poorly & very poorly drained)
Primary aquifer recharge zone
Sites suitable for municipal wells
Scenic or protected river watersheds
Blocks 50 - 500 acres
Blocks 500 - 1,000 acres
Blocks 1,000 - 2,500 acres
Blocks 2,500 - 5,000 acres
Blocks > 5,000 acres
Prime 1, 2, & 3 soils combined
Prime agricultural soils
Active Agricultural Lane
Unprotected gaps in existing trails
Abandoned rail ROW
Unprotected gaps in existing trails
Unprotected gaps in existing trails
Designated farms, estates, other places
Scenic Inventory

Co-occurrence Results

Voting and mapping focused on a total of 45 individual data factors. The mean scores discussed above and found in the lists in Appendix A were coded into each data factor, and then processed from vector to raster data for use in creating a co-occurrence map using ESRI's Spatial Analyst utility. The cell resolution is 30 meters by 30 meters, for a land area of about 1/5 acre. The raster datasets were all coordinated spatially with the NOAA land cover data for 2006, which was used for some of the data factor development, and with the idea that future work using this project data would benefit from being coordinated with standard Federal land use and land cover datasets.

The results of the initial co-occurrence mapping effort are shown below. Darker colors indicate areas with higher score accumulations and therefore higher levels of resources overlaying one another.

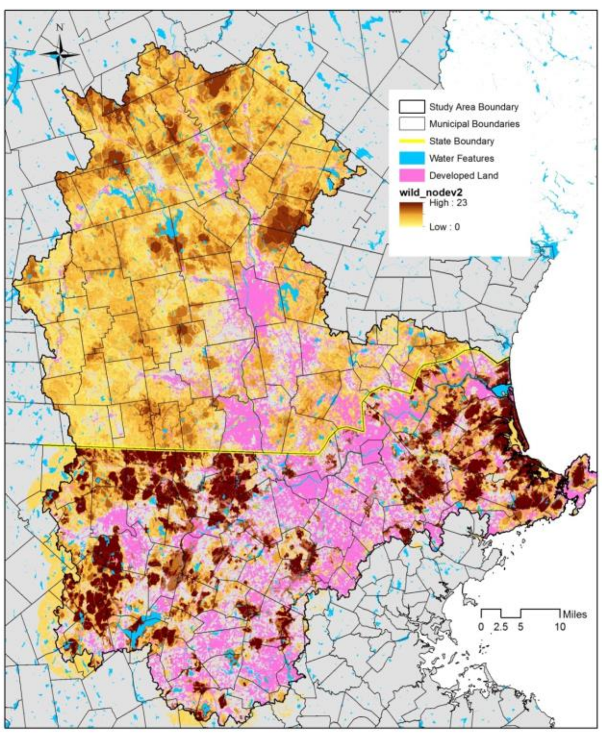


Unprocessed Co-Occurrence Values

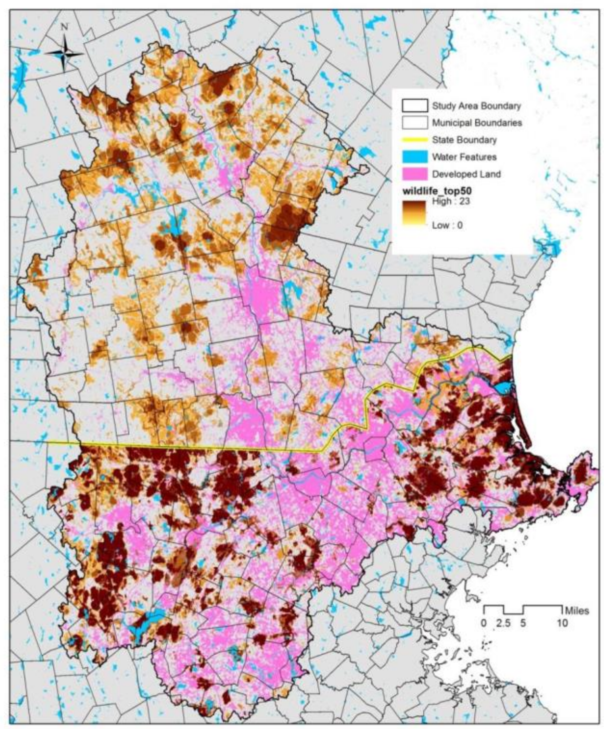
The next step in improving the co-occurrence mapping was to remove all developed lands. Developed lands data taken from the NOAA 2006 land cover mapping was "burned into" the first-pass co-occurrence data to eliminate all scoring cells within more urbanized areas. In the subsequent maps, developed areas are displayed in pink.

In order to refine the results, each of the four topical collections of data factors—wildlife habitat, water resources, forestry and farming, and recreation/trails—was further analyzed. A co-occurrence map was generated for each of these topical areas using only the relevant data factors, and then a basic statistical analysis was performed using the cell counts for each value accrued in the topical co-occurrence dataset.

The co-occurrence map for the wildlife habitat data factors is shown below. Note the dramatic difference in scoring results in New Hampshire versus Massachusetts, which is a reflection of how similar data factors were weighted by voters for the two states. In N.H., there is also a broad, rather homogeneous zone of low- to medium-value scores in much of that state's share of the study area, making it difficult to detect areas of higher conservation priority. Examination of the cell counts by value determined that approximately 50% of scoring cells had a value of 6 or higher, so this break point was selected to narrow the wildlife co-occurrence map. The result of removing the lower scoring cells is shown in Figure 27. Note that even though Massachusetts shows very extensive areas of high conservation value, the higher priority locations in N.H. are now more evident.

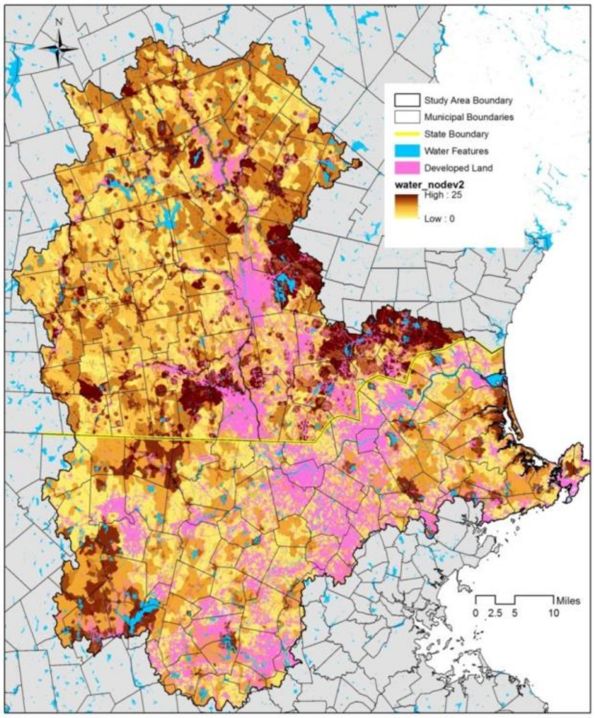


Wildlife Habitat Co-Occurrence

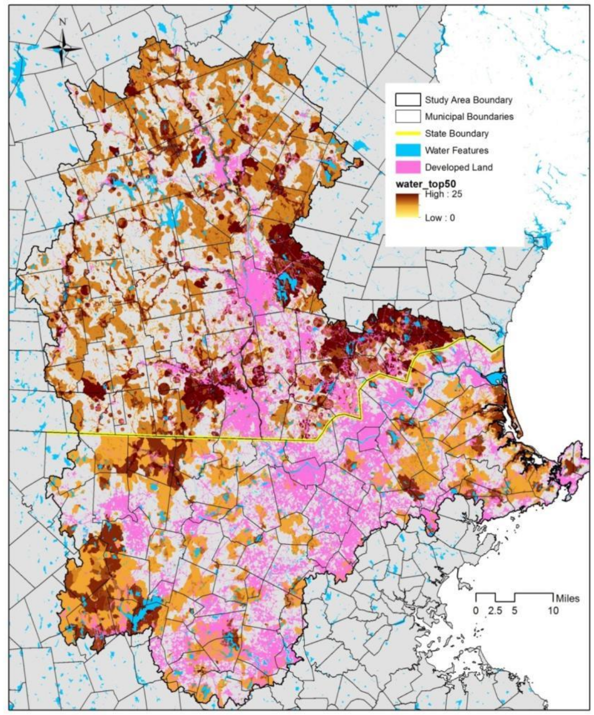


Wildlife Habitat Top 50%

A similar process was used to create a water resources co-occurrence, which also was further vetted to show only the top 50% of scoring cells, which are value 5 and above. Note that in the map of top 50% scores, source water and drinking water protection zones are retained, as are the stream watersheds with better water quality in terms of nitrogen and/or phosphorus loading.

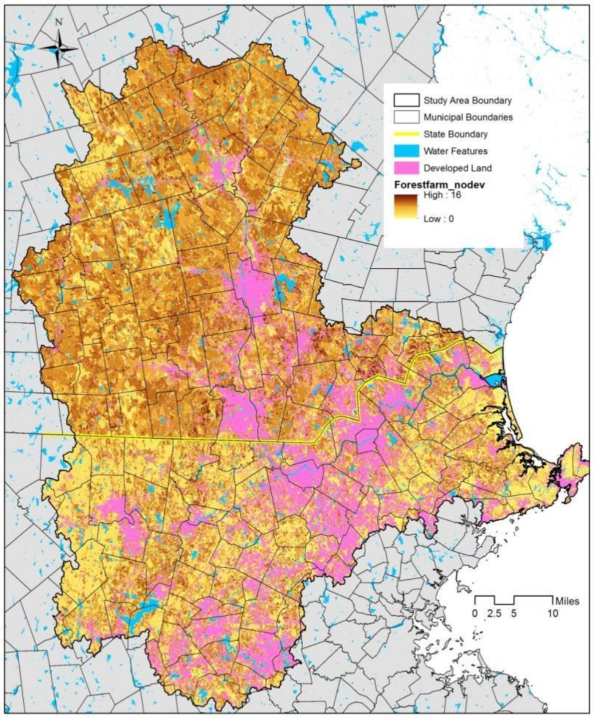


Water Resources Co-Occurrence

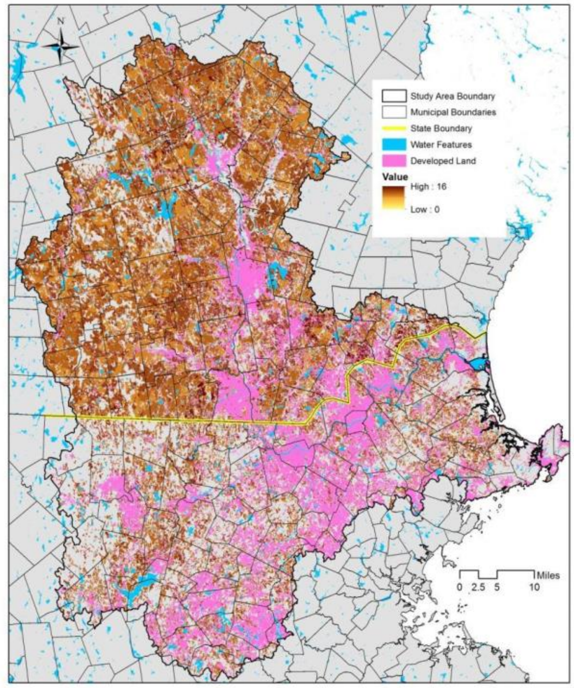


Water Resources Top 50%

The next topical co-occurrence maps pool all data factors under forestry and farmland interest areas. The extensive and rather even distribution of productive forest and farm soils produces a fine-textured spatial pattern unlike the wildlife and water co-occurrence maps above. Scoring is obviously somewhat higher in N.H. than in Massachusetts given the generally darker range of color in one state but not the other. Here again the breakpoint for approximately 50% of scoring cells is value 6 and above.
In this case, narrowing the scoring cells does not produce localized areas of high conservation priority. This is due in part to higher scores for forest blocks in N.H. which lends a backdrop of color and value in that state, but higher scores on soils components also increase importance. In Massachusetts, forest blocks are less extensive due to the more urbanized nature of the region in general, and the higher-scoring soils data is benefiting from both prime forest status collocated with prime agricultural soils.

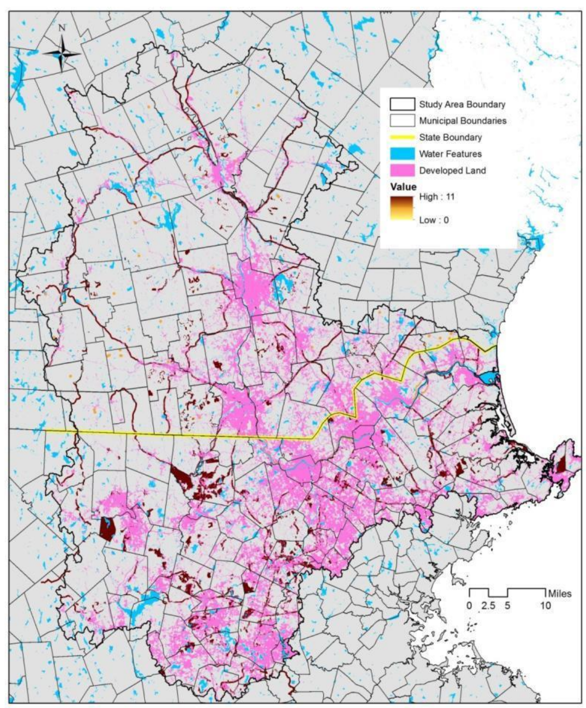


Forest & Farm Resources Co-Occurrence



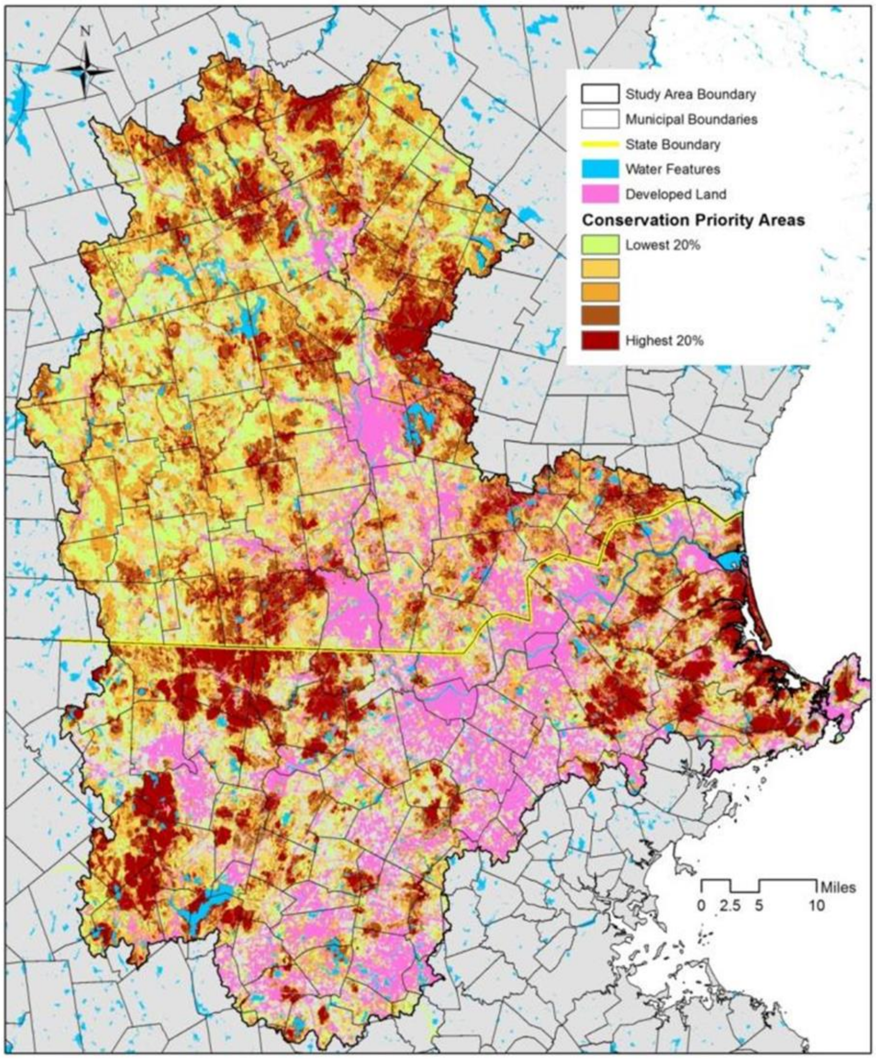
Forest & Farm Resources Top 50%

The final topical co-occurrence map includes the data factors relevant to trails and selected recreation features (Figure 32). No further vetting has been done on this data due to the limited spatial size and extent. It is also important to allow for maximum “signal strength” of this data in the subsequent co-occurrence analysis discussed below.



Recreation & Trails Resources

The last step in narrowing to conservation priority areas involved re-calculating the study area co-occurrence mapping using the four vetted (>50%) topical maps discussed above. The results of that GIS processing are shown in the map below, which is classified by quintile (20% breaks in scoring cell values).



"Vetted" Co-Occurrence Top-Scoring Cells

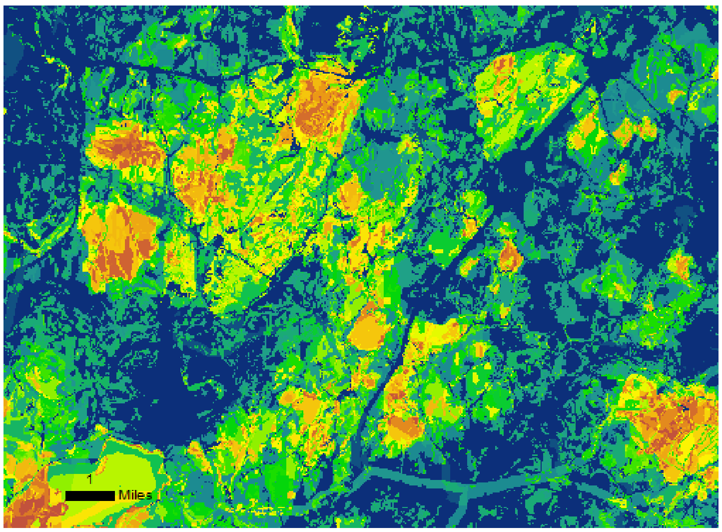
Developing Conservation Focus Areas

The steps taken to develop Conservation Focus Areas (CFAs) for the MVRCP were:

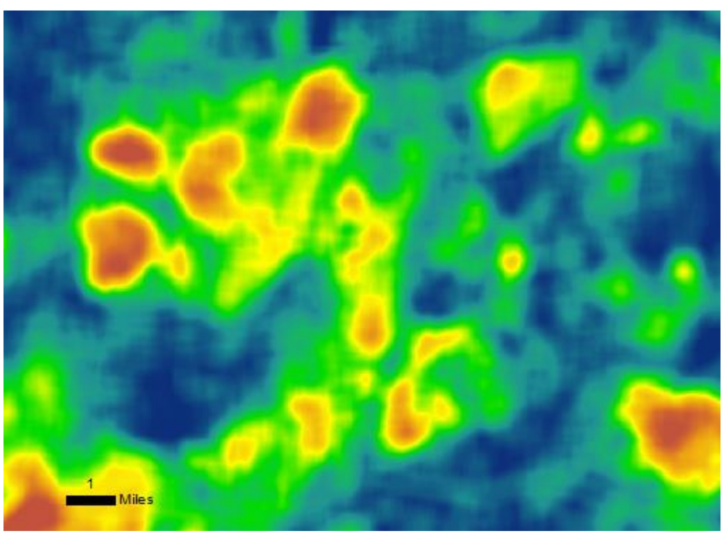
1. Smooth data to remove some of its noise and complexity.
2. Determine cutoff score(s) to use to define a first iteration of polygons ("proto-CFAs"), and convert data above those scores to polygons.

3. Review and refine the resulting polygons. Expand them if necessary to include all of the most important input areas, and restrict them as needed so they do not incorporate any developed areas or major roads.
4. Apply additional reference data, such as connectivity and landscape complexity, to expand the landscape framework for the core CFAs.

The raw co-occurrence data is a finely textured, complex surface. The Focal Statistics tool is used to smooth data such as this by averaging values within a moving window, and applying that average value to the center cell of the window. The larger the window, the more the tool generalizes and smoothes the data. A smaller window retains much of the original data's complexity. Small, high-scoring areas are unlikely to be inadvertently lost, but a lot of noise is retained. Larger windows create larger, smooth "blobs" that more easily convert to polygons. However, small high-scoring areas are more likely to be lost, and the shapes of other areas may be distorted. The stakeholders decided to use a relatively large 27 x 27 focal statistics window.



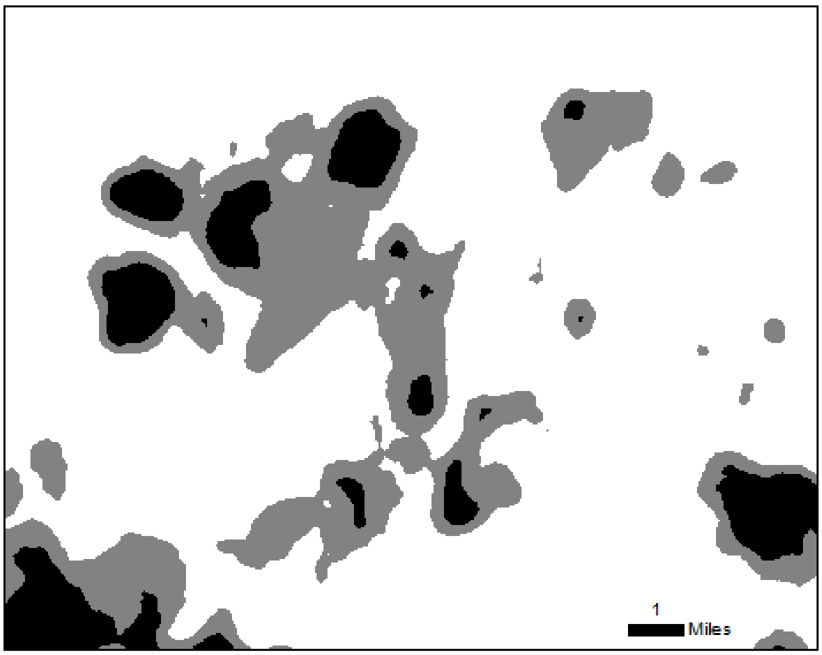
Original vetted co-occurrence with stretched color ramp

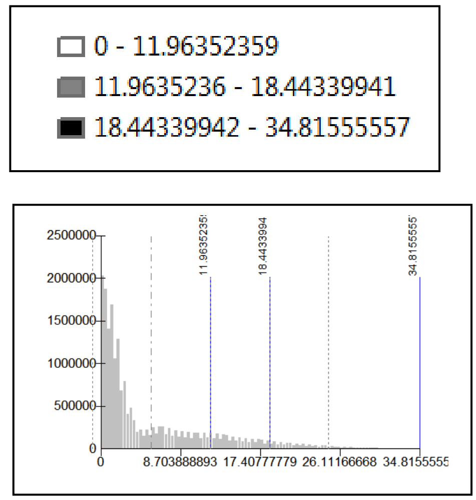


Co-occurrence smoothed with 27 x 27 filter, shown with same stretched color ramp as above

The next step was to determine the points in the continuous co-occurrence data at which to break out top-tier values to form CFAs. In previous studies, many decisions were guided by a target percentage of the study area that would ultimately be represented by conservation focus areas. For example, once a target focus area coverage was selected (say to represent 35% of the total study area), then cut-off thresholds in the co-occurrence data could be identified that would yield that approximate area. For this project, however, stakeholders agreed that they did not want decision-making bound or unduly influenced by a sense of the ideal focus area coverage. Instead, they wanted the data itself to guide the area that would ultimately be represented by CFAs. To this end, the group decided to derive the two highest classes of core CFAs from those areas with co-occurrence scores one and two standard deviations above the mean.

The figure below illustrates the co-occurrence data, smoothed with a 27 x 27 focal statistics window, classified at one and two standard deviations above the mean.





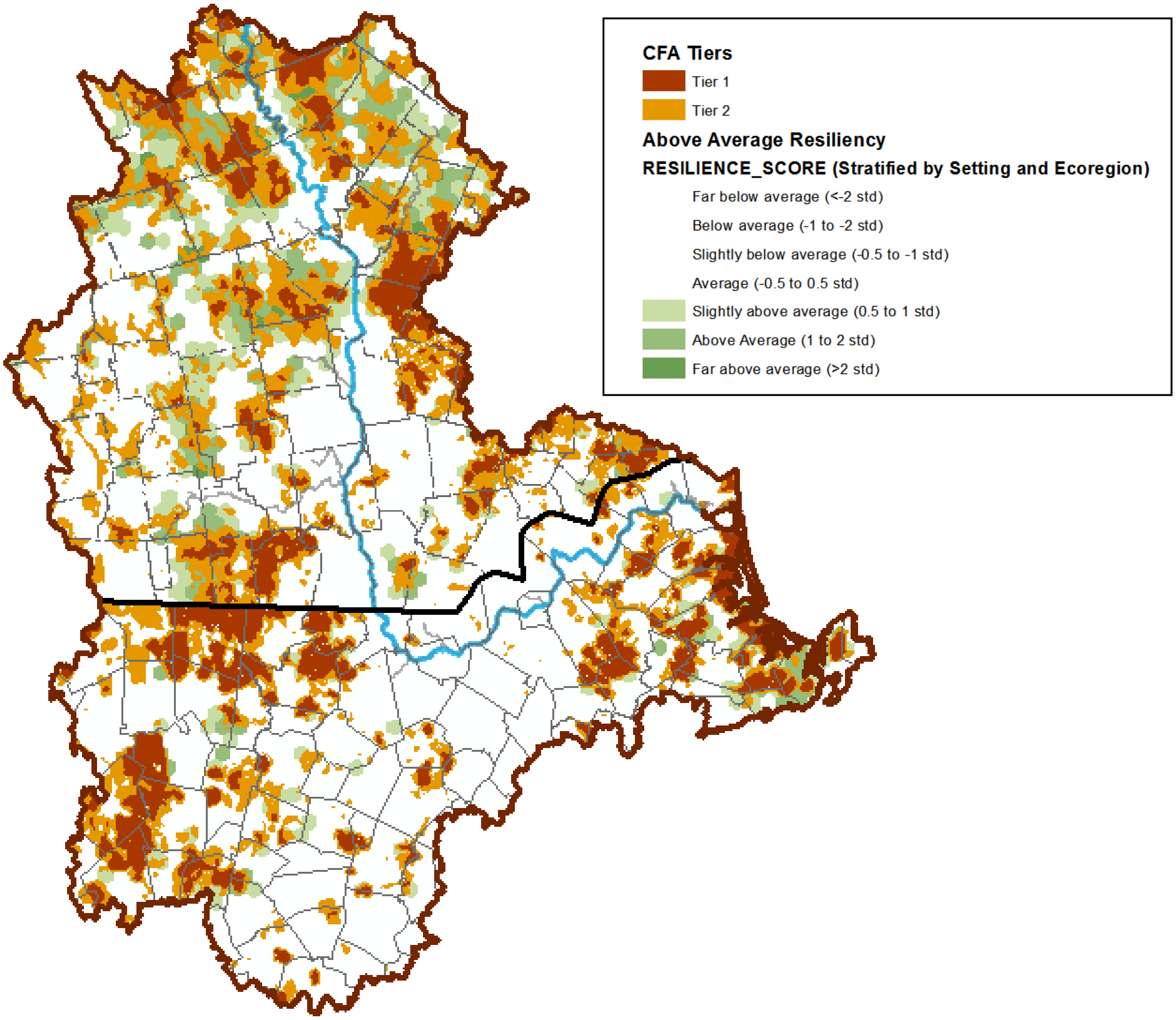
27 x 27 smoothed data, broken out at 1 & 2 Std. Dev. above mean

Areas with scores > 2 standard deviations above the mean became “Highest Scoring” core (sometimes called “Tier 1”); areas with scores between 1 and 2 standard deviations above the mean became “Higher Scoring” core (sometimes called “Tier 2”).

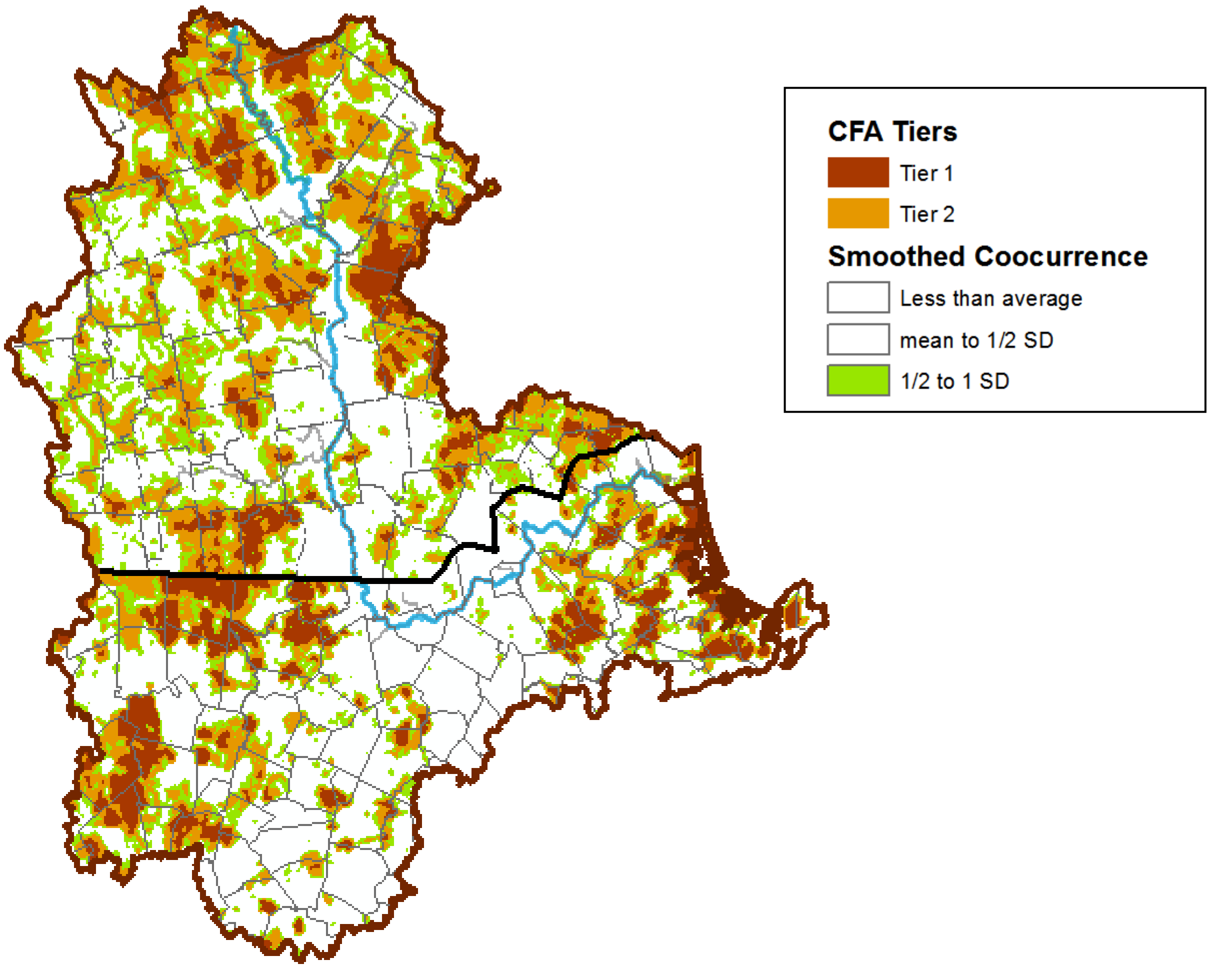
The next step was to remove developed land and roads from the proto-CFAs. This was done by first “burning out” all developed areas from within the highly ranked (> 1 standard deviation above the mean) co-occurrence areas. Then the classified data (ranked at 1 and 2 SD above the mean) were converted to polygons, and roads were removed from them. The roads were derived from NHDOT and Mass DOT statewide roads layers. All arterial and connector roads for each state were included. (In NH, this meant Funct_clas = 1, 2, 6, 7, 8, 11, 12, 14, or 16; in MA this meant Class = 1, 2, 3, or 4.) These roads were buffered to yield polygons representing the entire paved area. The road polygons were then erased from the core CFA polygons.

Because the tiers were derived from a continuous data surface, there were a few instances where there were small “peaks” with high scores. To further simplify the CFAs, any “Highest Scoring” areas less than 100 acres were converted to “Higher Scoring”, and any “Higher Scoring” areas less than 10 acres were deleted.

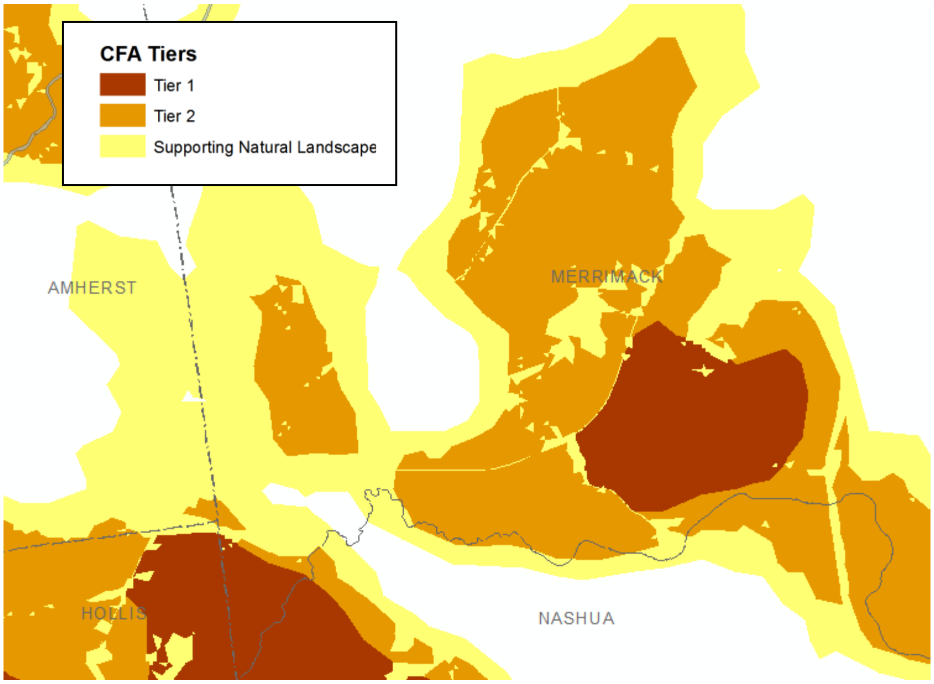
The next step was to identify larger landscape features that support the two classes of highest scoring core areas. Supporting natural landscape typically comprises high-value resources which act as a buffer to protect the integrity of the core areas. To identify other high value areas not already captured in the core polygons, the core areas were reviewed against The Nature Conservancy (TNC) resiliency data, including its components, connectivity and landscape complexity. From this visual review, it appeared that using TNC resiliency data alone to derive supporting natural landscapes would possibly under-represent landscapes in MA.



Other high value areas could be derived from those parts of the original co-occurrence data that received above average scores, but did not reach a high enough threshold to be core "Highest scoring" and "Higher scoring" polygons. The map below shows the core "Highest scoring" and "Higher scoring" polygons (based on co-occurrence scores greater than 2 SD above the mean and greater than 1 SD above the mean, respectively) *as well as* those areas with slightly above average co-occurrence scores (greater than ½ standard deviation above the mean).



The union of these methods seemed to provide the best result. Supporting landscape, or "High Scoring Conservation Focus Areas" were developed from a combination of those areas with above average resiliency scores (greater than ½ standard deviation above the mean) or above average co-occurrence scores (greater than ½ standard deviation above the mean). Any "High Scoring" polygons that were not adjacent to "Highest Scoring" or "Higher Scoring" polygons were eliminated. Note that development and roads were not erased from the supporting landscape. In effect, then, the supporting landscape completely surrounds all core areas, even where development is present.



Finally, the stakeholders considered making manual adjustments to the data – possibly manually including high priority areas, especially along the mainstem of the Merrimack. The central portion of the mainstem, perhaps unsurprisingly, has very little CFA coverage. The group decided not to make any manual adjustments to the CFAs, and instead plan for a future phase of work that would aim to identify the most significant natural areas along the mainstem.

Appendix A. Rank-Ordered Results of Delphi Voting by State

New Hampshire Data Factor	Mean Value
Source water protection areas	6.5
Drinking water protection areas (community wellheads)	5.7
WAP Tier 1: Best in State	5.4
Prime 1, 2, & 3 soils combined	5.0
Unprotected gaps in existing rail trails	5.0
Resilience: Highest from All Perspectives	4.6
WAP Tier 2: Best in Bio-Region	3.9
Unprotected gaps in existing hiking trails	3.9
Blocks 50 - 500 acres	3.4
Blocks > 5,000 acres	3.4
Prime agricultural soils & soils of statewide significance	3.4
Phosphorus Loading (best 1/3)	3.1
Phosphorus Loading (middle 1/3)	3.1
1/4 mile NHDES designated buffer	2.9
Blocks 2,500 - 5,000 acres	2.8
Abandoned rail ROW (potential linkages)	2.5
Blocks 1,000 - 2,500 acres	2.4
Resilience: Highest in Setting & Ecoregion Combined	2.3
100-year Floodway and/or Flood Zone	2.1
WAP Tier 3: Supporting Landscapes	2.1
TNC Connectedness: Average & Higher	2.0
Unprotected gaps in existing heritage trails	1.9
Natural land cover areas within 1/4 mile buffer	1.9
Primary recharge zone (entire aquifer surface)	1.8
Sites suitable for municipal wells	1.8
Cropland, hay & pasture land (from land cover data)	1.6
Blocks 500 - 1,000 acres	1.6
Northeastern Wetland Forest	1.3
Nitrogen Loading (worst 1/3)	1.3
Phosphorus Loading (worst 1/3)	1.3
Hydric Soils (poorly & very poorly drained)	1.3
Freshwater Marsh	1.2
Grassland & Shrubland	1.2
Designated farms, estates, other places	1.2
Resilience: Highest in Ecoregion Only	1.1
Northeastern Upland Forest	0.8
Peatland	0.8
Nitrogen Loading (middle 1/3)	0.8
Phosphorus Loading (middle 1/3)	0.8
Coastal Scrub-Herb	0.7
Cliff & Rock	0.6

Massachusetts Data Factor	Mean Value
WAP Tier 1: BioMap2 Core Habitat	9.8
WAP Tier 2: BioMap2 Critical Natural Landscapes	6.8
Unprotected gaps in existing hiking trails	6.5
Unprotected gaps in existing rail trails	5.4
Prime agricultural soils	5.0
Phosporus Loading (best 1/3)	4.1
Resilience: Highest in Setting & Ecoregion Combined	4.0
CAPS Top 50% Ecological Integrity	4.0
Source Water Zones B & C	3.8
WAP Tier 3: ACEC	3.4
CAPS Connectivity Top 50% of scoring cells	3.4
Scenic or protected river watersheds	2.9
Resilience: Highest from All Perspectives	2.8
Resilience: Highest in Ecoregion Only	2.8
Abandoned rail ROW	2.6
Active Agricultural Lane	2.5
Blocks 50 - 500 acres	2.4
Designated farms, estates, other places	2.0
Freshwater Marsh	1.9
Blocks 1,000 - 2,500 acres	1.9
Blocks 2,500 - 5,000 acres	1.9
Grassland & Shrubland	1.6
Nitrogen Loading (best 1/3)	1.6
Unprotected gaps in existing heritage trails	1.6
Cliff & Rock	1.5
Coastal Scrub-Herb	1.5
Primary aquifer recharge zone	1.5
Blocks > 5,000 acres	1.4
Drinking water protection areas	1.3
Blocks 500 - 1,000 acres	1.1
Phosporus Loading (middle 1/3)	0.9
Phosphorus Loading (worst 1/3)	0.9
Nitrogen Loading (middle 1/3)	0.9
Nitrogen Loading (worst 1/3)	0.9
Prime 1, 2, & 3 soils combined	0.9
100-year Floodway and/or Flood Zone	0.8
Scenic Inventory	0.8
Sites suitable for municipal wells	0.6
Northeastern Upland Forest	0.5
Northeastern Wetland Forest	0.5
Peatland	0.3
TNC Connectedness: Average & Higher	0.3
Hydric Soils (poorly & very poorly drained)	0.3