Strengthening the Resilience of the Taunton River Watershed: A Tool to Prioritize Local Action



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Glossary

100-Year Floodplain	The area of land surrounding a stream inundated during a flood event that has a 1% probability of occurring in any given year
Active River Area (ARA)	Area defined by The Nature Conservancy representing the lands that contain aquatic and riparian habitats and those that contain the processes that form and maintain river and riparian systems and that interact with and contribute to a stream or river channel over time
Catchment	The subwatershed area providing surface water drainage to a single segment of a stream
Climate Change	Changes in climate measures such as precipitation and temperature from expected historical normal (i.e., averages)
Community Resilience	The ability of a community to withstand and recover from adverse events and conditions in ways that minimize disruptions to society
Conservation	Actions that protect, preserve, or restore natural areas
Core Habitat	As defined within the BioMap2 project conducted by The Nature Conservancy and the Massachusetts Natural Heritage & Endangered Species Program, "specific areas necessary to promote the long-term persistence of species of Conservation Concern, exemplary natural communities and intact ecosystems"
Ecosystem Resilience	The ability of an ecosystem to maintain its ecological structure and function given the impacts of various stressors
Ecosystem Service (ES)	The various ways in which natural systems support and enhance human well-being
Focus Area (FA)	A unit of analysis for this study that looks at instream, riparian, or upland parcels or units within catchments. For riparian and upland units, the FAs are further divided into wetland and forest units
Instream	A segment of a stream and the physical characteristics occurring within the stream channel
Priority Development Area (PDA)	Areas defined by the Southeastern Regional Planning and Economic Development District (SRPEDD) as "having additional development or redevelopment potential for housing opportunities and economic growth that meet regional needs due to either their size, location, or other attributes that would help to achieve regional and state goals"
Project Type	A general characterization of the different management options that can be applied to enhance the health of the watershed by strengthening its resilience and promoting ecosystem services
Riparian	Lands within the 100-year floodplain

Scoring Factor	A physical characteristic used to rate an aspect of one ecosystem service
Scoring Type	Discrete or continuous
Stressors	An occurrence that decreases or devalues an ecosystem service from what would exist in a natural state
Upland	Lands outside the 100-year floodplain
Vulnerability	The potential for future degradation of watershed processes and aquatic ecosystems due to factors such as future climate, land use, and water use change

Executive Summary

The Taunton River Watershed, located in the coastal plain of southeastern Massachusetts, is the state's second largest watershed and is recognized for its rich ecological, recreational, and cultural resources. The Taunton River, which is its main artery, is the longest undammed tidal river in New England and has been designated by the National Park Service as a National Wild and Scenic River.

The location, topography, and economy of the Taunton River Watershed also make it vulnerable to the potential effects of climate change and development pressures, including downstream threats due to sea level rise and storm surges and upstream threats associated with heavy rainfalls and flooding. Municipalities and conservation and environmental advocacy groups have undertaken extensive efforts within the watershed to gather data and to assess, protect, and manage existing resources. However, there is a continuing need to identify and prioritize areas for protection and restoration, to define key actions that would prepare their communities to withstand the likely environmental and economic impacts of climate change, and to maintain the natural support systems (floodplains, wetlands, rivers, lakes, forests, and agricultural land) that provide the ecosystem services for people in the watershed (drinking water, food, clean water, clean air, open space and recreation, flood protection, and biodiversity).

To address these needs, the U.S. Environmental Protection Agency's (EPA's) Healthy Watersheds Program (HWP), in partnership with The Nature Conservancy and local stakeholders, launched a project to help inform how Taunton communities decide on priority actions that would increase their overall resiliency and reduce their vulnerability to the converging impacts of climate change and development. In addition to convening new networking opportunities among the Taunton watershed stakeholders, the Taunton project also inventoried existing data and developed a decision making framework and a database tool. The tool for applying this framework is the focus of this report.

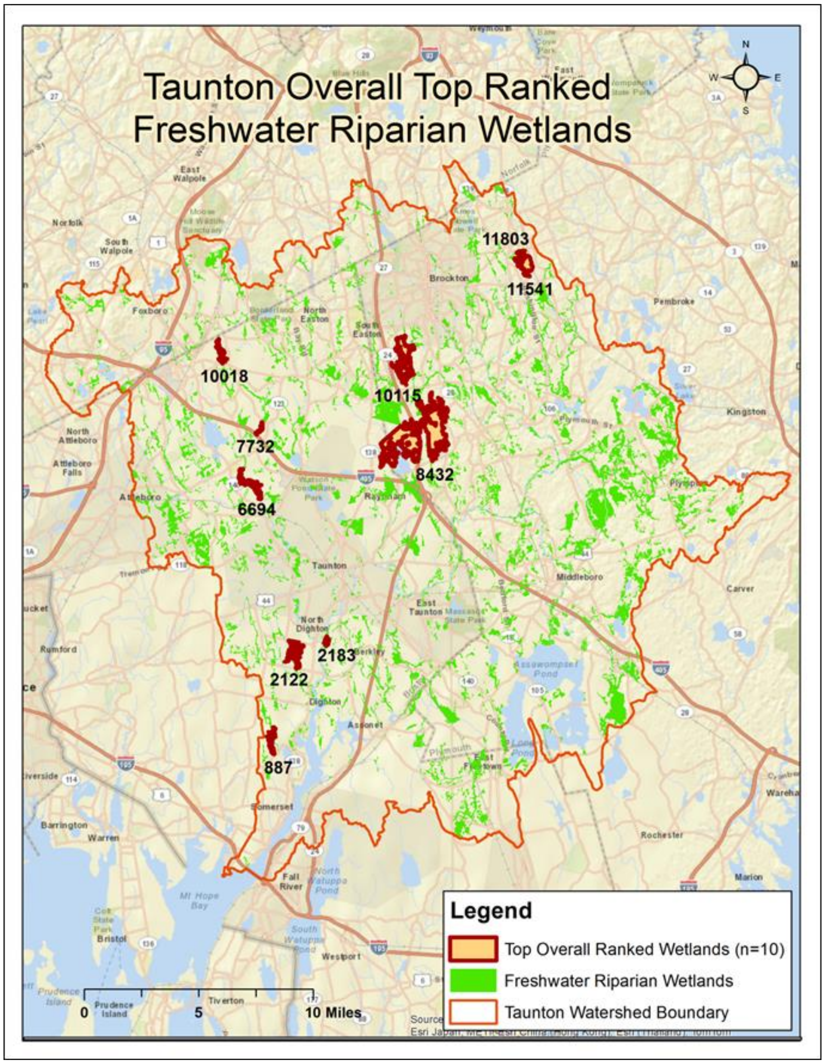
The key ecosystem services considered were protection from extreme events/floods, water quantity protection, water quality protection, habitat protection, air quality protection, and open space preservation. The framework links these ecosystem services to important features of the watershed landscape to create an interactive tool that should help communities find ways to maintain the functions and processes most beneficial to their specific conditions (i.e., to become more resilient). The tool itself is designed so that stakeholders and decision makers can easily weight the ecosystem factors that are of most concern to them for the protection of the various ecosystem services; generate listings of top-ranked areas; and export them for further examination, mapping, and analysis. Generally, the process of developing the tool included the following steps:

- Dividing the watershed landscape into six main "focus area" categories—riparian freshwater wetland, upland freshwater wetlands, saltwater wetlands, riparian forests, upland forests, and stream segments—and identifying currently unprotected spatial units within each category.

- Defining measurable indicators or "factors" to represent the ecosystem services provided by these areas, scoring the factors both individually and in combination for each unit, and then developing a ranking of units based on the ecosystem service score and the overall score.

Figure ES-1 provides one example to illustrate the outputs of the tool and how they can be visualized when exported to mapping software. In this example, individual riparian freshwater wetland units were assigned scores for 22 factors, representing five ecosystem service categories. A combined overall score was generated for each unit by giving equal weight to each factor under each ecosystem service category and equal weight to each ecosystem system category.

Figure ES-1. Example of Mapped Results Using Output from the Decision Support Tool: Overall Top-Ranked Riparian Freshwater Wetlands (Assuming Equal Weighting Across Scoring Factors and Ecosystem Service Categories)



The purpose of this report is to describe the assessment framework and the types of results it can be used to generate. It also provides guidance on how the framework can be applied using the decision support tool and how the tool can be adapted to address the specific needs and interests of users. Making the most effective decisions, at the local and watershed scales, to strengthen the resilience of the watershed will require careful consideration and well-informed decision makers. This tool can inform these conversations and help decision makers keep the Taunton Watershed healthy and resilient, with a strong economy and engaged community.

1. Introduction

The Taunton River Watershed, located in the coastal plain of southeastern Massachusetts, is the state's second largest watershed. Draining an area of over 560 square miles, it is recognized for its rich ecological, recreational, and cultural resources, including the 17,000-acre Hockomock Swamp in the south and the 40-mile-long Taunton River that serves as the watershed's main artery. The Taunton River is the longest undammed tidal river in New England, supporting a diverse range of fish, mussels, and other wildlife and plants, including several rare and endangered species (Horsley Witten Group, Inc., 2008). Recognizing the importance of its outstanding ecological and recreational resources, the National Park Service (NPS) has designated the Taunton River as a National Wild and Scenic River, providing greater protection for its free-flowing condition, water quality, and aquatic ecosystems (NPS, 2009).

The location, topography, and economy of the Taunton River Watershed also make it vulnerable to the potential effects of climate change and development pressures (Polcinski et al., 2012). In particular, the landscape of the watershed is very flat, with only a 20-foot drop in elevation along the entire main stem of the Taunton River, making it especially susceptible to threats from sea level rise and storm surges. The growth of impervious surface cover, combined with development in the floodplain and climate stressors, has also increased the watershed's vulnerability to heavy rainfalls and flooding. Continuing urban and suburban development within the watershed also threatens water quality, landscape condition, and the ecological and recreational services provided by the natural system.

Confronted with these challenges, municipalities and conservation and environmental advocacy groups have undertaken extensive efforts to assess and protect existing resources within the watershed. For example, watershed management plans have been developed, water use and withdrawals within the basin have been assessed, and municipalities have conducted comprehensive municipal water and wastewater resource planning projects. These and other activities have engaged the stakeholder community and raised awareness about the watershed's assets and vulnerabilities.

Despite these efforts, the need remains to identify and prioritize areas for conservation and to define key actions to keep the watershed healthy, maintain the ecosystem services (ESs) it provides, and strengthen the resilience of its ecosystems and communities in the face of threats such as development and climate change.

To address these needs, the U.S. Environmental Protection Agency's (EPA's) Healthy Watersheds Program is conducting this project to develop and implement an assessment framework for identifying high-priority protection areas in the Taunton River Watershed. In particular, it provides a decision support tool to assist in targeting areas that are best suited for conservation projects. This tool is designed for conducting screening-level analyses in the Taunton River Watershed by identifying priority conservation areas under different user-prioritized conditions. It is designed so that stakeholders and decision makers can easily weight the ecosystem factors that are of most concern to them for the protection of the various ESs. Based on these specifications, the tool lists priority spatial units for individual and combined ESs in a simple tabular form. However, to most effectively use and interpret these output results, it is expected that the main direct users of the tool will be environmental analysts with at least a basic understanding of and experience with geospatial data and applications.

The purpose of this report is to describe the assessment framework, summarize the main findings, and provide guidance on how the framework can be applied and adapted to address the specific needs and interests of users.

1.1 Taunton River Watershed Overview

The Taunton River Watershed, as shown in Figure 1-1, is located west of Cape Cod in southeastern Massachusetts. Draining 560 square miles, the watershed consists of all or portions of 42 towns. Figure 1-2 shows the main land cover characteristics, which are predominantly natural land (46%), followed by developed land (27%), water/wetland (22%), and agriculture (5%) (Massachusetts Geographic Information Systems [MassGIS], 2009).

The Taunton River flows southwest for more than 40 miles from the confluence of the Matfield and Town Rivers in Bridgewater to Mount Hope Bay, which is part of Narragansett Bay. The Taunton River is the largest freshwater contributor to Narragansett Bay (Taunton Wild and Scenic River Study Committee et al., 2005). The most downstream 18-mile section of the Taunton River is tidal, which allows the river to support both fresh and salt-water aquatic and riparian species including the most productive river herring run in the state (Executive Office of Energy and Environmental Affairs [EOEEA], 2013). According to the EOEEA (2013), salt water intrusion has reached 12.6 miles inland from the Taunton River outlet.

In addition to the Taunton River itself, several key ecological and recreational resources exist within the watershed. For example, Hockomock Swamp is the largest freshwater wetland in the state, supporting at least 13 rare and endangered species and recreational activities such as wildlife viewing, fishing, hunting, canoeing, and swimming (Massachusetts Department of Conservation and Recreation [MDCR], 2013). The Assawompset Pond Complex (APC), which includes Long Pond and four other interconnected ponds, is Massachusetts' largest natural pond system. The APC provides critical spawning ground for river herring and also serves as a public drinking water supply for more than 180,000 residents in 13 communities (Massachusetts Department of Environmental Protection [MassDEP], 2013). The Nemasket River, which flows from Assawompset Pond for 11 miles to its confluence with the Taunton River, supports the state's most productive herring river run (http://communitypreservation.org/Mass-Gov-EEA-river-herring-viewing-guide.pdf).

The landscape within the Taunton River Watershed is extremely flat, with only a 20-foot drop in elevation along the main stem of the river. The flat terrain makes the watershed and river vulnerable to storm surges and sea level rise due to climate change (Plocinski et al., 2013).

Figure 1-1. Taunton River Watershed in Southeastern Massachusetts

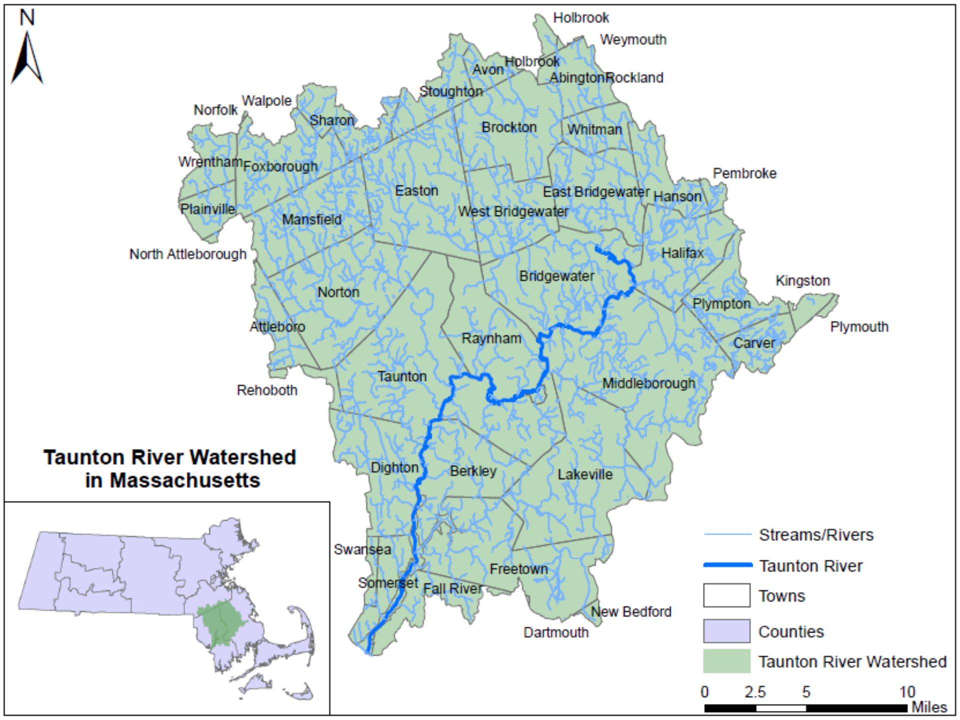
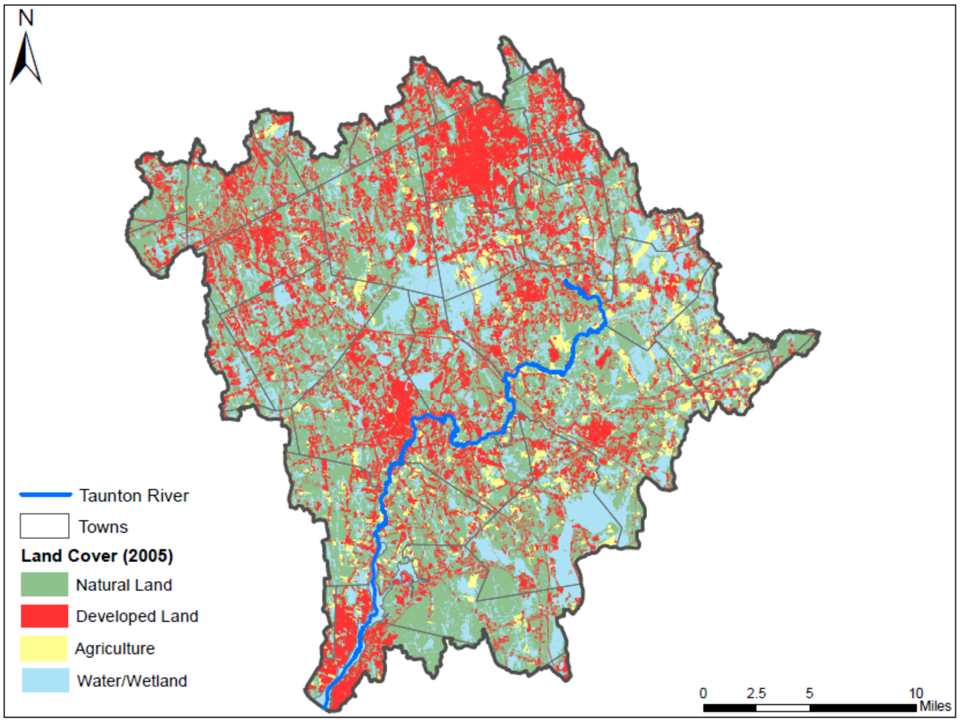


Figure 1-2. 2005 Land Cover in the Taunton River Watershed



Data source: MassGIS (2009).

Rapid development has also been cited as a top concern for the watershed (Horsley Witten Group, Inc., 2008). An assessment by the Massachusetts Audubon Society (Mass Audubon) (2009) notes that although overall growth had slowed, between 1999 and 2005, new home development in several towns within the watershed increased by between 10% and 34%. Of the top 20 towns in Massachusetts with the highest rate of development during that time period, six are within the Taunton River Watershed: North Attleboro, Berkley, Somerset, Abington, Swansea, and Rehoboth. Forested land, natural areas, and agricultural land are being developed at a high rate, particularly in Taunton and Middleborough. Moreover, the town of Berkley is one of the top 20 towns in the state with the highest reported loss of ecological integrity between 1999 and 2005 (Mass Audubon, 2009).

1.2 Healthy Watersheds Program

EPA launched the Healthy Watersheds Program to protect and maintain our nation's remaining healthy watersheds. A healthy watershed is defined as one in which (1) natural land cover supports dynamic hydrologic and geomorphic processes within their natural range of variation, (2) habitat of sufficient size and connectivity supports native aquatic and riparian species, and (3) water quality supports healthy biological communities. The purpose of the program is to protect these natural, intact aquatic ecosystems, prevent them from becoming impaired, and accelerate restoration successes.

The program is being implemented by promoting a strategic systems approach to identify and protect healthy watersheds. This approach for identifying healthy watersheds is based on integrated assessments of landscape condition, hydrology, habitat, water chemistry, and biotic communities, which recognizes that aquatic ecosystems function as interconnected systems within a larger watershed, landscape, and temporal context. As such, it also provides a more comprehensive and coordinated approach to setting priorities for protection and restoration within identified watersheds.

Based on these considerations and statewide assessments in Massachusetts (Woolsely et al., 2010; McGarigal et al., 2012a; Massachusetts EOEEA, 2012), the Taunton River Watershed has been identified as one of the program's priority watersheds for protection. The purpose of this study is therefore to develop an analytical framework to help guide the prioritization of protection and restoration actions within the watershed. This framework applies existing geospatial data for the watershed to identify and map natural areas within the watershed that (1) are most critical for maintaining its resilience against threats from climate change and development pressures and (2) provide the highest levels of ESs to the local community. In particular, it focuses on areas that are known to have intact and connected high-quality aquatic habitat, natural flow regimes, and high-quality biota and water chemistry, as well as other critical healthy and resilient watershed attributes. In addition, it identifies priority areas for restoration based on their potential to strengthen the watershed's health, resilience, and ESs.

1.3 The Nature Conservancy

The Nature Conservancy (TNC) is the leading conservation organization working around the world to protect ecologically important lands and waters for nature and people. Because of the Taunton River's outstanding natural resources, TNC is a leader in efforts throughout the watershed to remove dams to restore aquatic connectivity, implement green infrastructure projects, protect land, and conduct research and monitoring to support adaptive management of the watershed. As a member of the Taunton Wild and Scenic River Stewardship Council, TNC works with federal, state, and local partners to educate the public about the River's values and promote recreation.

TNC staff partnered with EPA Region 1 to launch the Healthy Watersheds Program pilot study and convened a group of watershed stakeholders who met throughout the study process to provide local knowledge, as well as input on the needs of those working to improve the watershed. TNC will continue to work with this group to implement the priorities determined through this study.

1.4 Watershed Resilience and Ecosystem Services

As indicated above, supporting a healthy Taunton River Watershed involves at least two interrelated objectives: (1) strengthening the ecological resilience of the watershed and (2) enhancing the ESs provided by the watershed.

The resilience of natural and social systems refers to their ability to withstand disturbances over time. Walker et al. (2004) define it more precisely as "the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks" (p. 2). As described above, the main sources of stress and disturbance that are of concern for ecosystems in the Taunton River Watershed are those associated with climate change and rapid development.

Strengthening ecological resilience within the Taunton River Watershed therefore implies supporting the natural processes that (1) protect ecosystems and human communities from disturbances (e.g., buffering processes) or (2) allow ecosystems to more easily recover from and endure disturbances. For example, key ecosystem processes that support resiliency occur within the river channel, floodplains, riparian wetlands, and terraces, collectively referred to as the Active River Area (Smith et al., 2008). Protecting the Active River Area directly promotes watershed resiliency, because these areas regulate natural hydrology while buffering the impacts of both floods and droughts. In addition, maintaining connectivity within and between these habitats helps ensure that biotic refugia are available to species of conservation concern.

The concept of ESs refers to the various ways in which natural systems support and enhance human well-being (Daily et al., 1997; Millennium Ecosystem Assessment, 2005). These services include (but are not limited to) the support ecosystems provide for market production activities (e.g., irrigation water for agriculture), for other human activities (e.g., healthy fisheries for recreational anglers), and for protection against damages or losses from environmental disturbances (e.g., avoided flood damage by regulating storm surges).

Enhancing ESs within the Taunton River Watershed therefore implies supporting and strengthening the natural processes that will have the largest positive effect on human well-being. For example, clean water for human uses (e.g., drinking, recreation) and flood protection are two critical ESs provided by healthy watersheds. Intact wetlands, forests, and other vegetated areas filter pollutants from runoff and atmospheric deposition, supporting clean drinking water and healthy aquatic biological communities. This natural filtration process minimizes the need for expensive drinking water and stormwater treatment infrastructure. Vegetated riparian zones also stabilize stream banks, preventing erosion and minimizing sediment and nutrient loading to surface waters (Sweeney et al., 2000). Wetlands, floodplains, and marshes support ground water recharge and mitigate the impacts of floods on urban areas (Postel and Carpenter, 1997). These protections limit the need for construction of costly flood control infrastructure or repairs associated with flood damage.

As these examples show, there are many linkages and overlaps between the objectives of strengthening resilience and enhancing ESs in the watershed. The main connection occurs when strengthening resilience means helping ecosystems maintain the functions and processes that are most beneficial to humans. Depending on the context, this may mean, for example, conserving wetlands that provide the most long-term flood protection for downstream residents or improving river connectivity in areas that will most benefit commercial or recreational fishing activities.

These examples also illustrate how enhancing ESs in the watershed can provide a variety of economic benefits to local residents. Some of these benefits of protecting healthy watersheds can be measured in terms of avoided future costs, such as for water treatment and flood damage repair. Others can be captured through studies that estimate individuals' and households' willingness to pay to acquire or to live in areas where these benefits are available (EPA, 2012).

2. Study Overview

2.1 Objectives

The main objective of the study is to develop and demonstrate an analytical framework that will strengthen the health of the Taunton River Watershed by helping identify and prioritize areas for conservation. In this context, the term “conservation” refers broadly to actions that protect, preserve, or restore natural areas in the watershed. Therefore, the areas identified through the study represent priority locations for policy actions (e.g., protection regulations, management of stream discharges), stewardship (e.g., conservation of specific land elements), and physical actions (e.g., removal of culverts).

To support this objective, the study has been designed to provide stakeholders with (1) an initial set of recommended conservation areas and (2) a decision support tool that they can use to further evaluate and prioritize areas. By identifying priority areas for conservation, the study and tool are designed to assist local analysts, stakeholders, and decision makers with spatial targeting of conservation projects. Using geospatial data, the analytical framework creates an inventory of potential conservation units in distinct categories. For each category, it specifies a flexible system for scoring and ranking alternative areas, based on indicators (or factors) of the ESs supported by each project. The initial recommendations are based on a scoring approach that applies equal weight to each ES indicator. The decision support tool allows users (i.e., stakeholders) to conduct their own evaluations of the available options, by altering the weights assigned to the different ES indicators.

2.2 Analytical Approach

To address the interrelated objectives of strengthening resilience and enhancing ESs in the watershed, we use the conceptual framework outlined in Table 2-1. This framework draws connections between threats to resilience (i.e., stressors), affected ESs, and different types of actions to address these threats in the Taunton River Watershed.

The first column in Table 2-1 lists many of the key stressors that currently threaten the health and resilience of the watershed, most of which are related to increasing development and urbanization and to climate change. The middle columns of Table 2-1 identify six main categories of ESs that are negatively affected by these stressors. This categorization of ESs is a key component of the analytical framework developed for this study. For each category, the table lists (1) the types of ecosystem functions or physical attributes that are affected and (2) examples of the resulting human uses or benefits that are negatively affected.

Table 2-1. Threats to Resiliency, Affected Ecosystem Services, and Potential Actions for Stakeholders

	Ecosystem Service Benefits		Project Types						
Key Stressors	Enhanced Ecosystem Functions/Outputs	Examples of Human Uses/Benefits	Riparian Freshwater Wetland Protection	Riparian Saltwater Wetland Protection	Upland Freshwater Wetland Protection	Forest Protection	Dam Regulations/Removal	Culvert Removal or Upgrade	Sustainable Water Management
	Protection from Extreme Events								
Weather events, land use change	Flood/stormwater control	Avoided damage to property and human life	X	X	X	X	X	X	X
Sea level rise, weather events	Coastal storm surge attenuation	Avoided damage to property and human life	X	X	—	—	X	X	—
	Water Quantity/Drought Protection								
Precipitation change, structures	Maintenance of instream flow	Recreation, water supply	X	—	X	X	X	—	X
Precipitation, land use change	Groundwater recharge	Water supply	X	—	X	X	—	—	X
	Water Quality Protection								
Land use change, discharges	Water filtration/purification	Avoided treatment cost, recreation, aesthetic enjoyment	X	X	X	X	X	X	X
Land use change, erosion	Sediment retention	Avoided treatment/dredging cost, recreation, aesthetic enjoyment	X	X	X	X	X	X	X
Temperature rise, discharges	Maintenance of thermal regime	Recreation	X	X	—	X	X	X	X
	Air Quality Protection								
Carbon emissions	Carbon sequestration	Avoided climate change costs	X	X	X	X	—	—	—
Air pollution emissions	Air pollution control	Avoided health damages	X	—	X	X	—	—	—
	Habitat/Biodiversity Protection								
Land use change, climate change	Aquatic: fish and wildlife support	Commercial/recreational/ subsistence fishing, aesthetic enjoyment	X	X	X	X	X	X	X
Land use change, climate change	Terrestrial: wildlife support	Outdoor recreation; aesthetic enjoyment	X	X	X	X	—	—	—
	Open Space/Natural Beauty Preservation								
Land use change	Open space	Aesthetic enjoyment	X	X	X	X	—	—	—

— means not applicable

Table 2-1 also lists seven types of conservation projects that can be used to minimize threats and strengthen ESs, including conservation of wetlands and forest lands, removal of dams and culverts, and improved water management. For each project type, it marks the specific types of ESs that it is likely to support. The specific links between different conservation actions and ESs are discussed in more detail in the remainder of this report; however, at this stage they can be illustrated with examples. For instance, as shown in the first main row of Table 2-1, climate change and increases in impervious surfaces due to urbanization are expected to threaten the resilience of ecosystems and communities in the watershed by increasing the frequency of extreme flooding events. One important hydrologic function that wetlands and forestlands in the watershed perform is to retain water during storm events; therefore, they benefit local residents by helping avoid damages to human health and property. Consequently, actions to conserve wetlands and forests are expected to strengthen these flood protection services.

As another example from Table 2-1, development activities and climate change are expected to negatively affect fish species by altering and fragmenting their aquatic habitat. These changes will reduce the benefits from recreational and commercial fishing. Projects that alter water flow from dams and remove culverts to improve connectivity between stream segments can be used to offset these threats and the impairments they cause to ESs.

Based on this conceptual framework, we developed an analytical approach for identifying priority conservation areas that involves the following seven main steps.

1. Define categories of focus areas (FAs) for conservation action.
2. For each category, identify discrete spatial FA units within the Taunton River Watershed.
3. Identify ES categories supported by each FA unit.
4. Define measurable indicators (“scoring factors”) for ESs under each FA unit.
5. Generate ES factor scores for all FA units.
6. Generate a total ES score for each ES category in each FA unit.
7. Generate overall scores for all FA units.

Each of these steps is described in more detail below. Additional details on the methods and data sources used are provided in Appendix A.

Step 1: Define categories of FAs for conservation action. For this step, we began by defining two main types of targets for conservation: natural lands and segments within the stream network (i.e., instream areas). As shown in Table 2-2, we then further subdivided these targets into more specific FAs, which can be identified using geographic information systems (GIS) data and methods. Lakes and ponds were not explicitly included within the FAs of this analysis because many smaller waterbodies were captured at least in part by the wetlands and the larger waterbodies contained specific issues that are better addressed in targeted, localized studies.

For natural lands, these FAs distinguish between two main land cover categories—wetlands and forests—that are then further subdivided based on their relation to the surface water network. Riparian natural lands are the hydrologically connected lands surrounding the stream channel defined by the 100-year floodplain. Upland natural lands are areas outside of the riparian zone that do not directly contribute runoff to the stream channel; however, these areas may include pieces of the "Active River Area," as defined by TNC (2008), which are located outside of the 100-year floodplain. In addition to riparian and upland classifications, wetlands are also divided into freshwater and saltwater wetlands.

Table 2-2. General Targets for Conservation with Specific Focus Areas and Categories of Ecosystem Services Provided

Target	Focus Area	Ecosystem Service Category
Natural Lands: Wetlands	Riparian Freshwater Wetlands	Flood/extreme event protection Water quality Habitat/biodiversity Open space Air quality
	Upland Freshwater Wetlands	Water quality Habitat/biodiversity Open space Air quality
	Riparian Saltwater Wetlands	Flood/extreme event protection Water quality Habitat/biodiversity Open space
Natural Lands: Forests	Riparian Forests	Flood/extreme event protection Water quality Habitat/biodiversity Open space Air quality
	Upland Forests	Water quality Habitat/biodiversity Open space Air quality
Stream Network	Stream Segments	Water quantity Flood/extreme event protection Open space Habitat/biodiversity Water quality

The stream segment FA, which includes areas within the stream channel and its flowing waters, allows for assessment of interlinked hydrological targets representing the natural flow regime and aquatic connectivity.

The natural flow regime of a river refers to its naturally occurring fluctuations in water flow over the course of a year. These fluctuations include both the timing and magnitude of streamflows. The natural patterns of the regime are important for maintaining the health and resilience of its aquatic ecosystems. Changes in the timing of streamflow peaks or low flows may affect the ability of aquatic organisms to grow and thrive. Changes in magnitudes of streamflow may impede human water uses for drinking or industrial uses or may cause increases in downstream flooding or loss in property values due to stream channel alteration. Preserving the natural flow regime provides for optimum aquatic health, maximum human water use potential through the predictability of the regime, and least potential impact due to flooding and drought.

Aquatic connectivity refers to availability of dynamic natural pathways through the river and stream network, which contributes to both the ecological integrity and resilience of the watershed (Sundermann et al., 2011). Although the Taunton River itself is undammed, several dams and culverts are present along the watershed's smaller stream and tributaries. These structures can impede passage of aquatic organisms and other wildlife and minimize their spawning success. Strengthening the connectivity of aquatic and riparian habitats in the longitudinal, lateral, vertical, and temporal dimensions can also help ensure that biotic refugia are available to aquatic species, including during floods, droughts, and other extreme events.

Step 2: For each category, identify discrete spatial FA units within the Taunton River Watershed. To define units in each FA category, we applied the methods described below.

Wetlands. The wetland unit layer was derived from MassDEP wetlands data, which were downloaded from the MassGIS data portal.[1] For this analysis, the wetland classes in the DEP wetland layer were grouped into two main types—freshwater and saltwater wetlands—and used to define discrete wetland units. With this GIS wetland layer, we also estimated the area of each discrete unit.

To determine if the wetland unit layer was classified as protected open space, we intersected the protected open space layer from MassGIS with the wetland unit layer. The area of protected open space was joined to each wetland unit and the percentage of protected land was calculated. Wetlands that were greater than 80% protected open space were excluded from this analysis. Small wetlands (less than 1-acre in size) were also excluded from this analysis. Wetland units were then separated into

[1] The wetlands in this layer were interpreted from 1:12,000 scale color-infrared photography. The freshwater wetland classes included Wooded Swamp, Marsh, and Cranberry Bog. The saltwater wetland classes included Salt Marsh, Beach/Dune, and Tidal Flat/Rocky Shore.

riparian and upland areas. Freshwater riparian wetlands included those units that had at least 0.25 acre in the 100-year floodplain; all other units were classified as upland.[2] Saltwater wetlands were considerably fewer and smaller; all saltwater wetlands were determined to be riparian based on their relationship to the 100-year floodplain.

Based on these methods, we identified 2,015 freshwater riparian wetland units, 2,603 freshwater upland wetland units, and 63 saltwater riparian units that were retained for our analysis.

Forests: The forest unit layer was also derived from a layer made available by MassDEP, in this case the land use layer for the state. All forest areas of more than 1 acre were selected from the general land use layer. The same protection threshold of 80% was used to exclude any forests that were already protected over much of their area. Forests were also separated into riparian and upland areas using the 0.25 acre within the 100-year floodplain threshold to determine riparian forests.

Using this geospatial process, we identified 2,427 riparian forest units and 3,347 upland forest units.

Stream Segments: This FA consists of stream segments, which are defined by the catchment (i.e., subwatershed) drainage area boundaries that were created for this project. A detailed technical description of the methods used to define these catchments is provided in Appendix A.

All catchments contain a single stream segment; therefore, a 1:1 relationship existed between stream segments and catchments, resulting in 929 stream units for analysis.

Step 3. Identify ES categories supported by each FA category. Using the six ES categories outlined in Table 2-1, we then identified the main types of ESs supported by each FA. Table 2-2 shows the resulting mapping of FAs to ESs. All of the wetland categories have the potential to provide services for (1) protection from extreme events (floods and storm surge) through their natural buffering capacity, (2) biodiversity by providing habitat for a variety of aquatic and avian species, and (3) open space aesthetics. In addition, wooded wetlands may provide additional benefits by filtering air pollutants and sequestering carbon; riparian wetlands, in particular, can protect water quality in rivers and stream through their ability to absorb and filter pollutants. Forest lands can provide many of the same types of ESs as wetlands, although in different ways. For example, they provide habitats for different types of species and offer open space with different aesthetic characteristics. Additionally, forest lands can maintain natural ground and surface water hydrology.

The FAs associated with the stream network also provide a distinct set of potential ESs. In particular, protecting and enhancing natural flow regimes help preserve and regulate the quantity of water moving

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[2] The 100-year floodplain designation was based on the Federal Emergency Management Agency Q3 Flood Zones designations for Massachusetts, available from MassGIS; however, it is important to note that this area designation is likely to expand in the future as a result of climate change.

through the system for both ecological and human uses, which also supports the aesthetic open space benefits from the stream network. Improving the aquatic connectivity of the stream network by removing or adapting structural barriers such as dams and culverts offers improved and expanded habitat for aquatic species and can also serve to improve water quality within a stream channel.

Step 4: Define measurable indicators ("scoring factors") for ESs under each FA category. For each ES category associated with each FA shown in Table 2-3, the next step is to identify a set of measurable ES scoring factors. Each factor represents an observable (based on geospatial data or analysis) attribute of the land or stream that provides an indicator of the presence, level, or potential to provide the ES. As an example, Table 2-3 shows six ES scoring factors we developed as indicators of the water quality ESs provided by the riparian freshwater wetland FA. They represent the following attributes:

- Characteristics of land use in the wetland's upstream area, such that higher levels of agricultural and urban (i.e., "nonnatural") land cover would indicate a higher expected level of pollutant removal by the wetland[3]
- Number of downstream river miles protected by the wetland
- Location of the wetland in a headwater (i.e., most upstream) catchment, which are particularly influential areas for downstream water quality (Alexander et al., 2007)
- Location of the wetland in a catchment that drains to a surface water protection (SWP) area, indicating that the wetland is expected to protect these types of source waters for drinking water systems
- Location of the wetland in a catchment that drains to a groundwater protection (GWP) area, indicating that the wetland is expected to protect these types of source waters for drinking water systems
- Location within 200 feet of the stream, indicating a higher potential to control and filter runoff to the stream[4]

[3] This screening-level scoring factor does not account for differences in the condition and functional capacity of the different wetland units, which would also affect their ability to filter pollutants.

[4] This 200-foot buffer was selected because it is defined as the riverfront area in the Massachusetts Rivers Protection Act. It does not reflect a zone for development restrictions.

Table 2-3. Example ES Scoring Factors for Water Quality Protection Provided by Riparian Freshwater Wetlands

Focus Area Unit Unique ID	Ecosystem Service (ES) Scoring Factors						Total ES Score Using Equal Weighting of Factors [a]	Final Water Quality ES Score [b]
	% Non-natural Land Use Upstream	Number of Downstream River Miles	Headwater Catchment	SWP Area	GWP Area	Part of 200-ft Stream Buffer		
ES Score Options	**(3-level) 1,2,3**	**(3-level) 1,2,3**	**(2-level) 0,3**	**(2-level) 0,3**	**(2-level) 0,3**	**(2-level) 0,3**	**0–3**	**0–1**
12201	**3** (>53% Altered)	**3** (>49 downstream miles)	**3** (within a headwater catchment)	**3** (SWP within 12 miles downstream)	**3** (GWP within 12 miles downstream)	**3** (within 200 ft of stream segment)	**3**	**1**
408	**2** (<53% and >24% altered)	**1** (<28 downstream miles)	**3** (within a headwater catchment)	**0** (no SWP within 12 downstream miles)	**0** (no GWP within 12 downstream miles)	**3** (within 200 ft of stream segment)	**1.5**	**0.5**
6453	**1** (<24% altered)	**2** (<49 and >28 downstream miles	**0** (not within a headwater catchment)	**0** (no SWP within 12 downstream miles)	**0** (no GWP within 12 downstream miles)	**0** (not within 200 ft of stream segment)	**0.5**	**0.17**

[a] Weights can be applied to the various scoring factors to customize the analysis. With equal weighting (used by default) the weights are equal to one divided by the number of factors, so in this case 1/6 = 0.1667.

[b] Final ESs scores are normalized to 1 by dividing by the highest total ES score.

The precise definition and specification of these ES factors, as well as the individual ES factors for other FAs and ES categories are described in more detail in Section 2.4 (see, in particular, Table 2-5).

Step 5: Generate ES factor scores for all FA unit. Each ES factor score provides either a discrete or a continuous measure of the level of the ES provided. The continuous values were derived through GIS processing of watershed characteristics, including measures such as geographic area, distance, and population counts. For example, as shown in Table 2-3, for riparian freshwater wetlands these measures for water quality protection include (1) the percentage of area upstream from the catchment in nonnatural land use and (2) the number of downstream river miles from the wetland to the estuary.

To simplify and standardize the scores assigned to the continuous measures, they were each converted to a three-level categorical indicator, reflecting a low (1), medium (2), or high (3) level of the ES. In each case, this categorization was accomplished by defining two threshold levels for each continuous measure. For example, as shown in Table 2-3, the continuous downstream distance measure was converted to three levels using thresholds of 28 and 49 miles. Based on this threshold, the first example wetland listed in the table (ID = 12201) receives a score of 3, and the other two wetlands receive scores of 2 and 1, respectively.

For the default settings used in the analysis, all threshold levels were derived using the geometric interval method of classification within the ArcGIS 10.1 software.[5] Because many of the continuous ES scoring factors within the watershed resulted in highly skewed distributions (i.e., many small values and only a few high values), this classification method provides an appropriate means for dividing the data into high, medium, and low rating categories. However, these thresholds can be modified using alternative methods and criteria.

For the ES scoring factors that are discrete with only a value of yes or no (or present or absent), no additional thresholds were required. Any FA unit with a positive rating (i.e., yes or present) for the discrete ES scoring factor received a high (3) score, while all other areas received a null (0) value for the ES scoring factor. For example, in Table 2-3, wetlands located within 12 miles upstream from an SWP area were assigned a score of 3 for this factor.

It is important to acknowledge that this categorical scoring approach provides fairly coarse measures of ESs. Ideally, all of the ESs would be expressed in directly measurable and comparable units, such as monetary values; however, data and resource limitations precluded such an approach for this project. Given these limitations, the intention of the scoring approach is to provide a practical and transparent method for approximating ESs.

Step 6: Generate a total ES score for each ES category in each FA unit. A total score for each ES in each FA can be derived by combining the individual ES factor scores as a summation of each factor score (Fac) times its user-defined weight (Wt).

$$Total\ ES\ Score = Fac_1 Wt_1 + Fac_2 Wt_2 + \cdots + Fac_n Wt_n$$

Weights were applied to each factor to allow a user to prioritize between different aspects of the service (i.e., giving higher priority to naturalized upstream land uses and headwater catchments for conservation of wetlands with less likelihood of contamination than for those more protective of downstream waters). The weights applied must add up to 1 across all the factors. This fraction weighting scheme ensures that the highest score received for an ES is equal to the maximum high score of 3. The simplest approach for combining these individual ES factor scores is to give each factor equal weight. So for the six factors used in Table 2-3 an equal weight of 0.1667 was applied to each factor score before summation to the total ES score. We use this equal-weighting approach as the default setting in our analysis. However, alternative weights can be assigned to each factor, depending on their perceived *relative* importance as an indicator of the ES. As an example, a single factor could be given a weight of 1

[5] According to ArcGIS documentation, "The algorithm creates geometric intervals by minimizing the sum of squares of the number of elements in each class. This ensures that each class range has approximately the same number of values with each class and that the change between intervals is fairly consistent."

and all others 0 to rank the ES by only that scoring factor. After assigning factor-specific weights, the single overall score for each ES of interest was calculated as the sum of the weighted scores for each factor.

Step 7: Generate overall scores for all FA units. A final overall ES score for each FA unit was derived in a similar way, by combining the total ES scores for each ES category. The overall ES score, which we normalize to be between 0 and 1 by dividing by the maximum score calculated for an FA, provides a single value for each unit, which can be used to compare and rank all units within an FA.

To calculate the overall scores for units in each FA, we again applied a weighted sum of the individual scores (in this case, the total ES scores for each ES category). As in the previous step, a user may weight the individual ES scores when combining into the final overall ES score. The default analysis relies on a simple equal weighting approach, but a user of the system has the option to vary these weights in future analyses. For example, if desired, a user could choose to place relatively more weight on the total ES score for water quality and less weight on the total ES score for habitat. Once all the raw overall ES scores are calculated within an FA, the maximum value is determined from these values. The raw scores are divided by this maximum value to calculate the final overall ES score. This normalization process results in final scores that fall between 0 and 1, so that a user can quickly assess how any single unit ranks within the FA category.

For the natural land FAs, we also developed two additional weighting factors, which users can apply to augment the overall scores for each unit. These weighting factors are measures of (1) the total area of the unit and (2) the vulnerability of the unit to future development. The vulnerability score accounts for whether the unit is located in an urbanized areas and whether it is adjacent to or part of an identified Priority Development Area (Southeastern Regional Planning and Economic Development District [SRPEDD], 2013). The reason for including these two factors is that protection of larger sites and sites that are more vulnerable to development should enhance protection of *all* of the ES categories provided by the unit, including water quality, habitat, open space, and flood control. As desired, users have the option to apply one, both, or neither of these factors to weight the overall scores of the natural land units.

For the stream segments, we also included two enhancement factors, which can be applied to the overall scores for each segment. These factors are measures of the increased connectivity and ecological integrity that could be achieved through (1) dam removal or (2) culvert removal upstream from the segment, as defined by assessments of the change in indices of ecological integrity (IEI Delta Scores) of the surrounding landscape using integrated metrics from the Conservation Assessment Prioritization Program developed by the University of Massachusetts at Amherst. Assuming that these restoration actions would enhance all of the ESs provided by the segment, these factors allow the user to prioritize segments not only for protections, but also for enhancement through dam or culvert removal.

Although the findings detailed in Section 3 rely on the overall scores without further adjustments based on these weighting or enhancement factors, the decision support tool explained in Section 2.3 and Appendix B allows the user to specify these factors for ranking FA units for conservation.

2.2.1 Processing of ES Scoring Factors

Multiple methods were used in GIS to quantify the determined scoring factors per ES and FA. Many of the scoring factors for ESs were calculated based on direct spatial relationships. Depending on the scoring factor, FA units were evaluated to determine if they intersected, were adjacent to, or were within a buffered proximity of other spatial attributes. Proximity metrics were evaluated based on relevant data sources and best professional judgment. As described above, some scoring factors were quantified on a continuous scale and some were simple yes/no discrete characteristics.

Table 2-4 provides a comprehensive review of each scoring factor used to value the ESs assessed for each FA. Sources of data used to derive these factors are available in Appendix A.

2.2.2 Weighting and Enhancement Factors for Overall Scores

Table 2-5 summarizes the specification of the weighting and enhancement factors, which can be applied in Step 7, as described above, to adjust the overall scores for FA units.

2.3 Interactive Database Product

A database decision support system was created to house, display, and assess the ES scoring factors and overall scores compiled for this study. The database is meant to be an interactive tool that allows users to craft their own lists of FAs (e.g., freshwater riparian wetlands and/or upland forests) in which to target potential projects. It contains all final scoring data for all FAs. Stakeholders can use the database to define their own criteria and/or weighting to select priority FA units. The database is a Microsoft Access file containing a series of navigable forms, and data tables allow the user to view results and change the weights of scoring factors and ESs to craft their own analyses. Results can be exported from the database for visualization in mapping software. Details on the database and a user guide can be found in Appendix B.

Table 2-4. Details on ES Scoring Factors Used to Value and Rank ES by Focus Areas

Focus Area	ES Category	ES Scoring Factors	Analysis Method	Scoring Type
Natural Lands: Riparian Freshwater Wetlands	Flood/extreme event protection	Upstream drainage area	Upstream drainage area from the target catchment (square miles)	Continuous
		Runoff potential in upstream drainage area	Average curve number (an empirical parameter used to predict runoff from precipitation based on land cover and soil condition) for the upstream drainage area from the target catchment	Continuous
		Vulnerable downstream populations/property	Number of people within catchments that fall up to 12 miles downstream from the target catchment	Continuous
		Vulnerable downstream floodplain populations/property	Number of people in the floodplain for catchments that fall within 12 miles downstream from the target catchment	Continuous
		Vulnerable upstream population/property due to hurricane inundation	Does the wetland intersect the hurricane inundation zone?	Discrete (yes or no)
	Water quality	Protection from contaminant export from upstream land use	Percentage nonnatural land use (urban area + agriculture area) in the upstream drainage area from the target catchment	Continuous
		Downstream river miles	Number of downstream miles from the target catchment to the outlet catchment at Narragansett Bay	Continuous
		Headwater catchment	Is the target catchment a headwater catchment (no other catchments drain to it)?	Discrete (yes or no)
		Within 200-foot stream buffer	Is the wetland part of the 200-foot stream buffer as per Massachusetts buffer rules?	Discrete (yes or no)
		Protection of drinking water supply (2 factors)[a]	Is the target catchment less than 12 miles upstream from a surface water or GWP area?	Discrete (yes or no)

(continued)

Table 2-4. Details on ES Scoring Factors Used to Value and Rank ES by Focus Areas (continued)

Focus Area	ES Category	ES Scoring Factors	Analysis Method	Scoring Type
Natural Lands: Riparian Freshwater Wetlands (continued)	Habitat/ biodiversity	Core habitat (4 factors)[b]	Does the wetland intersect one or more core habitats?	Discrete (yes or no)
		Connectedness	Does the wetland intersect the critical natural landscape (indicating that it is part of a well-connected natural landscape)?	Discrete (yes or no)
		Habitat for species of conservation concern	Does the wetland intersect with the habitat area for a critical species of conservation concern?	Discrete (yes or no)
		Adjacent to protected areas	Is the wetland adjacent to a protected area?	Discrete (yes or no)
	Open space	Adjacent to protected areas open to the public	Is the wetland adjacent to a protected area with public access?	Discrete (yes or no)
		Access to communities	Number of people within walking distance to the wetland (500-meter buffer)	Continuous
	Air quality	Carbon sequestration	Number of unprotected acres of wooded swamp	Continuous
		Protection of air quality for urban populations	Number of unprotected acres of wooded swamp within 1 mile of an urban center	Continuous
Natural Lands: Upland Freshwater Wetlands	Water quality	Protection from contaminant export from catchment land use	Percentage nonnatural land use (urban area + agriculture area) in the drainage area within the target catchment	Continuous
		Downstream river miles	Number of downstream miles from the target catchment to the outlet catchment at Narragansett Bay	Continuous
		Headwater catchment	Is the target catchment a headwater catchment (no other catchments drain to it)?	Discrete (yes or no)
		Within 200-foot stream buffer	Is the wetland part of the 200-foot stream buffer as per Massachusetts buffer rules?	Discrete (yes or no)
		Part of the active river area	Is the wetland part of the active river area?	Discrete (yes or no)
		Protection of drinking water supply (2 factors)[a]	Is the target catchment less than 12 miles upstream from a surface water or GWP area?	Discrete (yes or no)

(continued)

Table 2-4. Details on ES Scoring Factors Used to Value and Rank ES by Focus Areas (continued)

Focus Area	ES Category	ES Scoring Factors	Analysis Method	Scoring Type
Natural Lands: Upland Freshwater Wetlands (continued)	Habitat/biodiversity	Core habitat (4 factors)[b]	Does the wetland intersect one or more core habitats?	Discrete (yes or no)
		Connectedness	Does the wetland intersect the critical natural landscape (indicating that it is part of a well-connected natural landscape)?	Discrete (yes or no)
		Habitat for species of conservation concern	Does the wetland intersect with the habitat area for a critical species of conservation concern?	Discrete (yes or no)
		Adjacent to protected areas	Is the wetland adjacent to a protected area?	Discrete (yes or no)
	Open space	Adjacent to protected areas open to the public	Is the wetland adjacent to a protected area with public access?	Discrete (yes or no)
		Access to communities	Number of people within walking distance to the wetland (500-meter buffer)	Continuous
	Air quality	Carbon sequestration	Number of unprotected acres of wooded swamp	Continuous
		Protection of air quality for urban populations	Number of unprotected acres of wooded swamp within 1 mile of an urban center	Continuous
Natural Lands: Riparian Saltwater Wetlands	Flood/extreme event protection	Upstream drainage area	Upstream drainage area from the target catchment (square miles)	Continuous
		Runoff potential in upstream drainage area	Average curve number for the upstream drainage area from the target catchment	Continuous
		Vulnerable downstream populations/property	Number of people within catchments that fall up to 12 miles downstream from the target catchment	Continuous
		Vulnerable downstream floodplain populations/property	Number of people in the floodplain for catchments that fall within 12 miles downstream from the target catchment	Continuous
		Vulnerable upstream population/property due to hurricane inundation	Does the wetland intersect the hurricane inundation zone?	Discrete (yes or no)

(continued)

Table 2-4. Details on ES Scoring Factors Used to Value and Rank ES by Focus Areas (continued)

Focus Area	ES Category	ES Scoring Factors	Analysis Method	Scoring Type
Natural Lands: Riparian Saltwater Wetlands (continued)	Water quality	Protection from contaminant export from upstream land use	Percentage nonnatural land use (urban area + agriculture area) in the upstream drainage area from the target catchment	Continuous
		Downstream river miles	Number of downstream miles from the target catchment to the outlet catchment at Narragansett Bay	Continuous
		Headwater catchment	Is the target catchment a headwater catchment (no other catchments drain to it)?	Discrete (yes or no)
		Within 200-foot stream buffer	Is the wetland part of the 200-foot stream buffer as per Massachusetts buffer rules?	Discrete (yes or no)
		Protection of drinking water supply (2 factors)[a]	Is the target catchment less than 12 miles upstream from a surface water or GWP area?	Discrete (yes or no)
	Habitat/biodiversity	Core habitat (4 factors)[b]	Does the wetland intersect one or more core habitats?	Discrete (yes or no)
		Connectedness	Does the wetland intersect the critical natural landscape (indicating that it is part of a well-connected natural landscape)?	Discrete (yes or no)
		Habitat for species of conservation concern	Does the wetland intersect with the habitat area for a critical species of conservation concern?	Discrete (yes or no)
		Adjacent to protected areas	Is the wetland adjacent to a protected area?	Discrete (yes or no)
	Open space	Adjacent to protected areas open to the public	Is the wetland adjacent to a protected area with public access?	Discrete (yes or no)
		Access to communities	Number of people within walking distance to the wetland (500-meter buffer)	Continuous

(continued)

Table 2-4. Details on ES Scoring Factors Used to Value and Rank ES by Focus Areas (continued)

Focus Area	ES Category	ES Scoring Factors	Analysis Method	Scoring Type
Natural Lands: Riparian Forests	Flood/extreme event protection	Upstream drainage area	Upstream drainage area from the target catchment (square miles)	Continuous
		Runoff potential in upstream drainage area	Average curve number for the upstream drainage area from the target catchment	Continuous
		Vulnerable downstream floodplain populations/property	Number of people in the catchment and in the floodplain for catchments that fall within 12 miles downstream from the target catchment	Continuous
		Vulnerable upstream population/property due to hurricane inundation	Does the forest intersect the hurricane inundation zone?	Discrete (yes or no)
	Water quality	Protection from contaminant export from upstream land use	Percentage nonnatural land use (urban area + agriculture area) in the upstream drainage area from the target catchment	Continuous
		Downstream river miles	Number of downstream miles from the target catchment to the outlet catchment at Narragansett Bay	Continuous
		Within 200-foot stream buffer	Is the forest part of the 200-foot stream buffer as per Massachusetts buffer rules?	Discrete (yes or no)
		Headwater catchment	Is the target catchment a headwater catchment (no other catchments drain to it)?	Discrete (yes or no)
		Protection of drinking water supply (2 factors)[a]	Is the target catchment less than 12 miles upstream from a surface water or GWP area?	Discrete (yes or no)
	Habitat/biodiversity	Core habitat (4 factors)[b]	Does the forest intersect one or more core habitats?	Discrete (yes or no)
		Connectedness	Does the forest intersect the critical natural landscape (indicating that it is part of a well-connected natural landscape)?	Discrete (yes or no)
		Habitat for species of conservation concern	Does the forest intersect with the habitat area for a critical species of conservation concern?	Discrete (yes or no)
		Adjacent to protected areas	Is the forest adjacent to a protected area?	Discrete (yes or no)

(continued)

Table 2-4. Details on ES Scoring Factors Used to Value and Rank ES by Focus Areas (continued)

Focus Area	ES Category	ES Scoring Factors	Analysis Method	Scoring Type
Natural Lands: Riparian Forests (continued)	Open space	Adjacent to protected areas open to the public	Is the forest adjacent to a protected area with public access?	Discrete (yes or no)
		Access to communities	Number of people within walking distance to the forest (500-meter buffer)	Continuous
	Air quality	Protection of air quality for urban populations	Number of unprotected acres of forest within 1 mile of an urban center	Continuous
Natural Lands: Upland Forests	Water quality	Protection from contaminant exports from catchment land use	Percentage nonnatural land use (urban area + agriculture area) in the drainage area within the target catchment	Continuous
		Downstream river miles	Number of downstream miles from the target catchment to the outlet catchment at Narragansett Bay	Continuous
		Part of 200-foot stream buffer	Is the forest part of the 200-foot stream buffer as per Massachusetts buffer rules?	Discrete (yes or no)
		Headwater catchment	Is the target catchment a headwater catchment (no other catchments drain to it)?	Discrete (yes or no)
		Part of the active river area	Is the forest part of the active river area?	Discrete (yes or no)
		Protection of drinking water supply (2 factors)[a]	Is the target catchment less than 12 miles upstream from a surface water or GWP area?	Discrete (yes or no)
	Habitat/biodiversity	Core habitat (4 factors)[b]	Does the forest intersect one or more core habitats?	Discrete (yes or no)
		Connectedness	Does the forest intersect the critical natural landscape (indicating that it is part of a well-connected natural landscape)?	Discrete (yes or no)
		Habitat for species of conservation concern	Does the forest intersect with the habitat area for a critical species of conservation concern?	Discrete (yes or no)
		Adjacent to protected areas	Is the forest adjacent to a protected area?	Discrete (yes or no)
	Open space	Adjacent to protected areas open to the public	Is the forest adjacent to a protected area with public access?	Discrete (yes or no)
		Access to communities	Number of people within walking distance to the forest (500-meter buffer)	Continuous
	Air quality	Protection of air quality for urban populations	Number of unprotected acres of forest within 1 mile of an urban center	Continuous

(continued)

Table 2-4. Details on ES Scoring Factors Used to Value and Rank ES by Focus Areas (continued)

Focus Area	ES Category	ES Scoring Factors	Analysis Method	Scoring Type
Instream Network: Stream Segments	Water quantity (Natural flow regime)	Sustainable water use	Ratio of the human withdrawals and returns to the cumulative mean annual flow for each stream segment	Continuous (lower ratio receives higher ES score)
		Reservoir storage	Reservoir storage ratio (max storage/mean annual flow)	Continuous (lower ratio receives higher ES score)
		Dam density	Dam density ratio (number of dams/length of stream miles upstream from each stream segment)	Continuous (lower ratio receives higher ES score)
	Flooding/extreme event protection	Runoff potential in upstream drainage area	Average curve number (an empirical parameter used to predict runoff from precipitation based on land cover and soil condition) for the upstream drainage area from the target segment	Continuous
	Open space	Stream reach contains a fishing and/or boating access	Does the stream reach contain a fishing/boating access site?	Discrete (yes or no)
	Water quality	Stream reach impacted by direct pollutant discharges	Does the stream reach or any upstream reach include a permitted discharge?	Discrete (yes or no)
		Headwater?	Is the target segment a headwater (no other segments drain to it)?	Discrete (yes or no)
	Habitat/ biodiversity (protection)	Core habitat (2 factors)[b]	Does the stream segment intersect one or more core habitats?	Discrete (yes or no)
		Habitat for species of conservation concern	Does the stream segment intersect with the habitat area for a critical species of conservation concern?	Discrete (yes or no)

[a] The "Protection of Drinking Water Supply" scoring factor is considered in two separate factors within the Decision Support Tool—one for groundwater and one for surface water supplies.

[b] The "Core Habitat" scoring factor consists of individual factors for up to four different habitat types (depending on FA applicability): Forest Core, Priority Natural Communities, Least Disturbed Wetlands, Aquatic Core, and Vernal Pool Core.

Table 2-5. Details on the Weighting and Enhancements Factors that Can Be Applied to the Overall Scores for the FA Units

<table>
<tr><th>Focus Area</th><th>Factor Type</th><th>Factor Name</th><th>Analysis Method</th><th>Scoring Type</th></tr>
<tr><td rowspan="2">Natural Lands:
All Wetlands and Forests</td><td rowspan="2">Weighting</td><td>Size</td><td>Area of the wetland/forest</td><td>Continuous</td></tr>
<tr><td>Threat of development</td><td>• Is the wetland/forest within an urban center?
• Is the wetland/forest adjacent to a Priority Development Area (PDA)?
• Is the wetland/forest within a PDA?
(Score = number of yes responses to these questions)</td><td>Discrete
(4 levels)</td></tr>
<tr><td rowspan="2">Instream Network:
Stream Segments</td><td rowspan="2">Enhancement</td><td>Increased connectivity via dam removal</td><td>The Index of Ecological Integrity (IEI) Delta Score for the increased ecological integrity from removing a dam. IEI scores were created by integrating metrics applied to the landscape for predicting ecological integrity under a baseline and development scenarios through the Conservation Assessment Prioritization System.</td><td>Continuous</td></tr>
<tr><td>Increased connectivity via culvert upgrade or removal</td><td>The IEI Delta Score for increased ecological integrity from removing or upgrading a culvert</td><td>Continuous</td></tr>
</table>

3. Findings

The following sections display, for each FA, the top-ranked overall ES scored areas as well as the top-ranked individual ES scored areas (e.g., water quality, open space). The maps and results presented rely on the baseline, default analysis using equal weighting of the scoring factors when calculating the individual ES scores and of the individual ES scores when calculating the overall ES scores. Section 4 provides further instructions on how users can customize this analysis by varying these weights.

When possible, the maps and results summarized in this section focus on the top 10 ranked areas within each assessment. For some assessments, multiple areas have the same score before or at the 10th position of the ranking. Rather than arbitrarily stopping the results presentation after listing 10 areas, we included all the highest-ranked areas until there is a clear threshold in score changes. In some cases, only a small number of areas have the same score (e.g., the top-ranked riparian freshwater wetlands for the habitat/biodiversity ES score), while, in other cases, a large number of areas have the same score (e.g., the top-ranked riparian freshwater wetlands for the open space ES score). Most ties in scoring can be eliminated by either applying the additional weighting or enhancement factors described in Table 2-5 to the overall ES score or by varying the weights on the scoring factors during customized analyses.

3.1 Natural Lands

3.1.1 Riparian Freshwater Wetlands

The riparian freshwater wetlands were ranked based on their combined ES score that included the flooding/extreme event, water quality, habitat/biodiversity, open space, and air quality components. In this analysis, each ES was equally weighted, and each ES scoring factor within the ES category was also equally weighted. As shown in Figure 3-1, the overall top 10 ranked riparian freshwater wetlands are spread across most of the watershed area; highly ranked wetlands occur around the greater Brockton area, in the northwest headwaters region, and south of the city of Taunton near the outlet of the basin.

These wetlands were also ranked separately for each ES category. Highly ranked wetlands within the extreme event/flooding ES category are concentrated along the main stem of the Taunton River near the outlet of the basin (Figure 3-2). The top 10 wetlands were selected, but in this case, multiple wetlands were ranked 10th (i.e., the same score), which yielded a total of 27 highest-ranked wetlands for extreme event/flooding protection.

In contrast to the location for highest-ranked wetlands for extreme event protection, wetlands that ranked highly for water quality scoring components were concentrated in the headwaters regions of the river basin (Figure 3-3). For this scoring factor, 21 wetlands were ranked within the top 10 scores for water quality. These wetlands are concentrated in headwater areas that are within the 200-foot stream buffer, are upstream of both surface or groundwater drinking supplies, have long distances to the watershed outlet, and contain moderate to high levels of nonnatural upstream land use. Conservation projects could include protecting these wetlands and other remaining natural lands upstream from these areas.

Figure 3-1. Overall Top-Ranked Riparian Freshwater Wetlands in the Taunton River Watershed

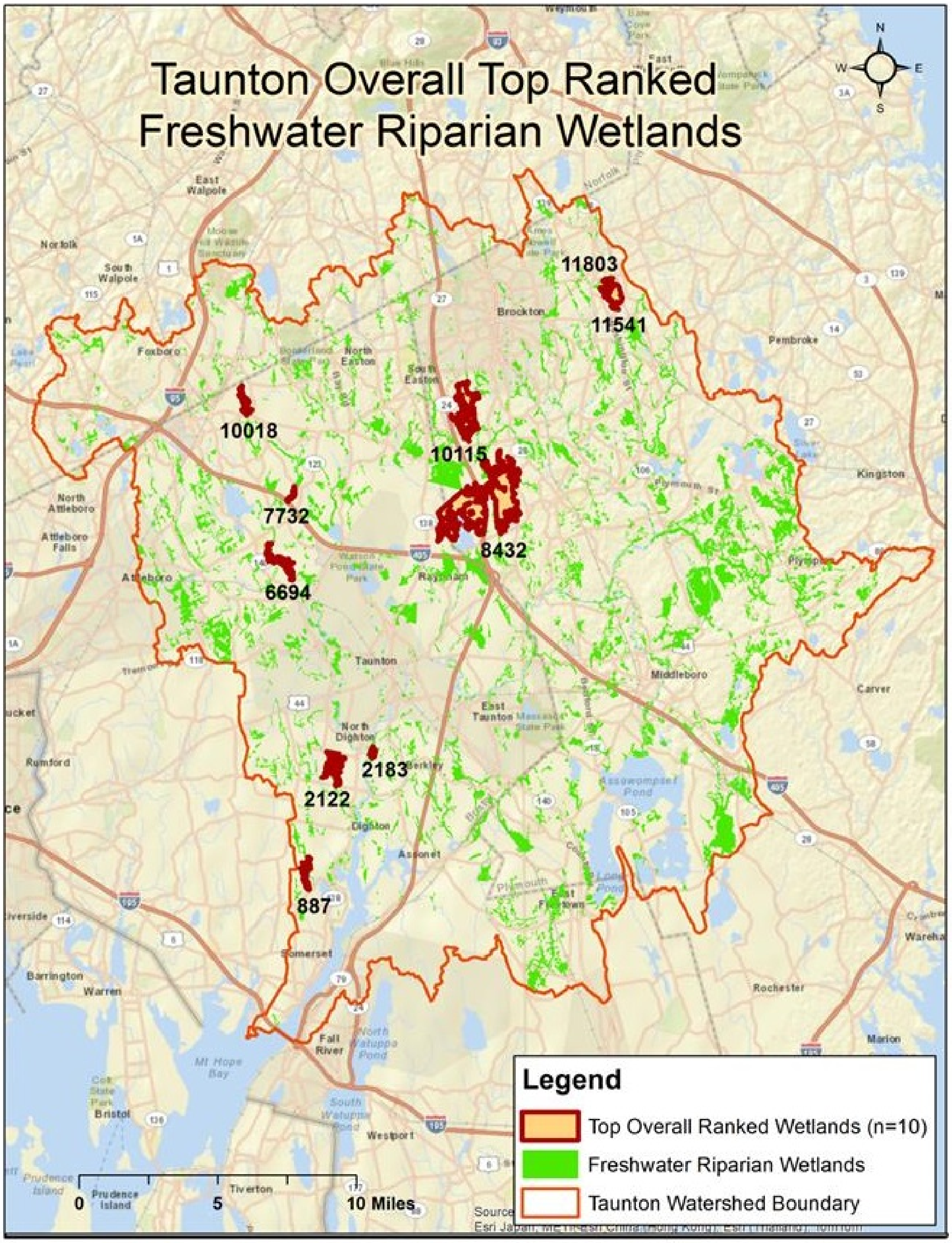


Figure 3-2. Top-Ranked Extreme Event Protection Riparian Freshwater Wetlands in the Taunton River Watershed

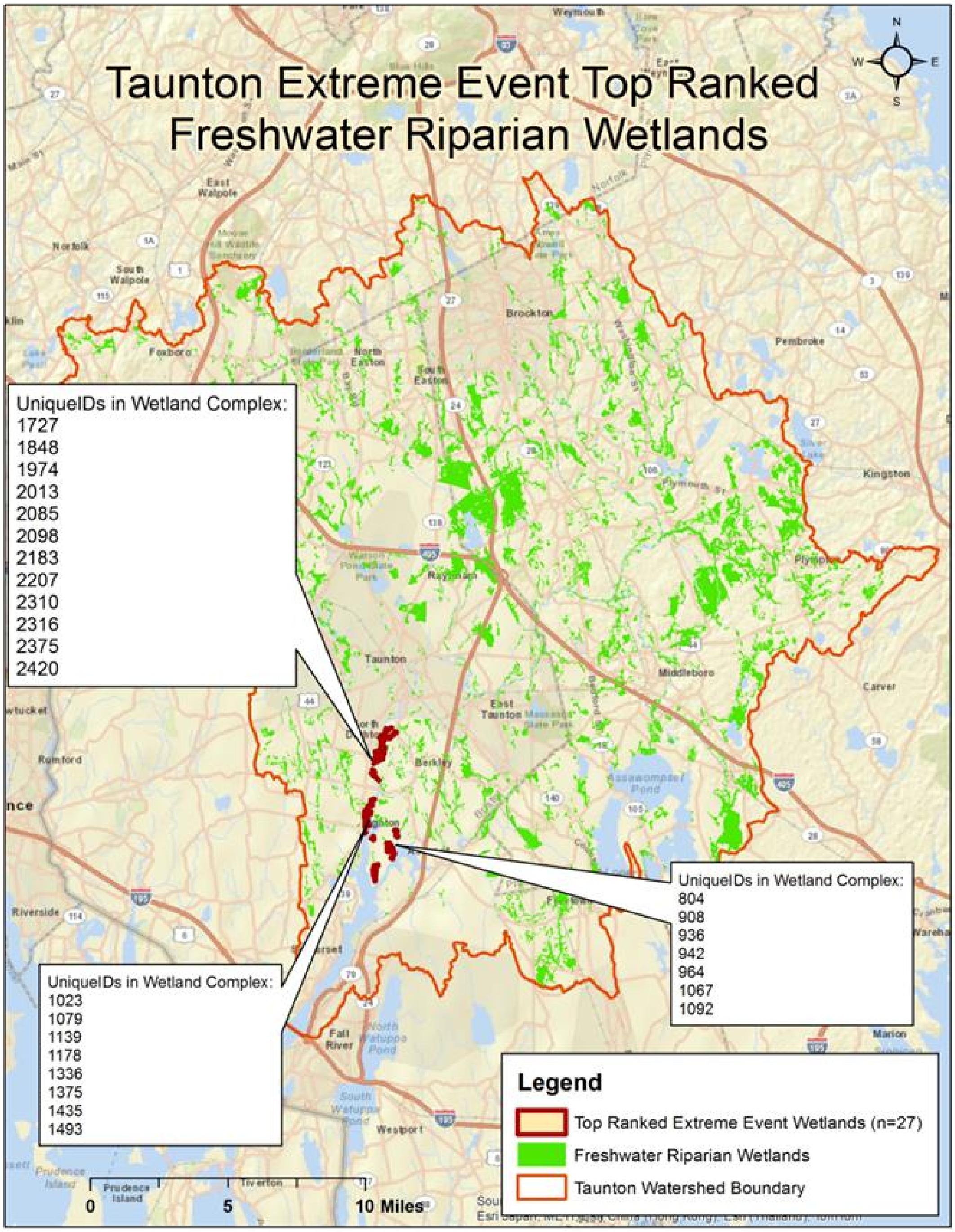
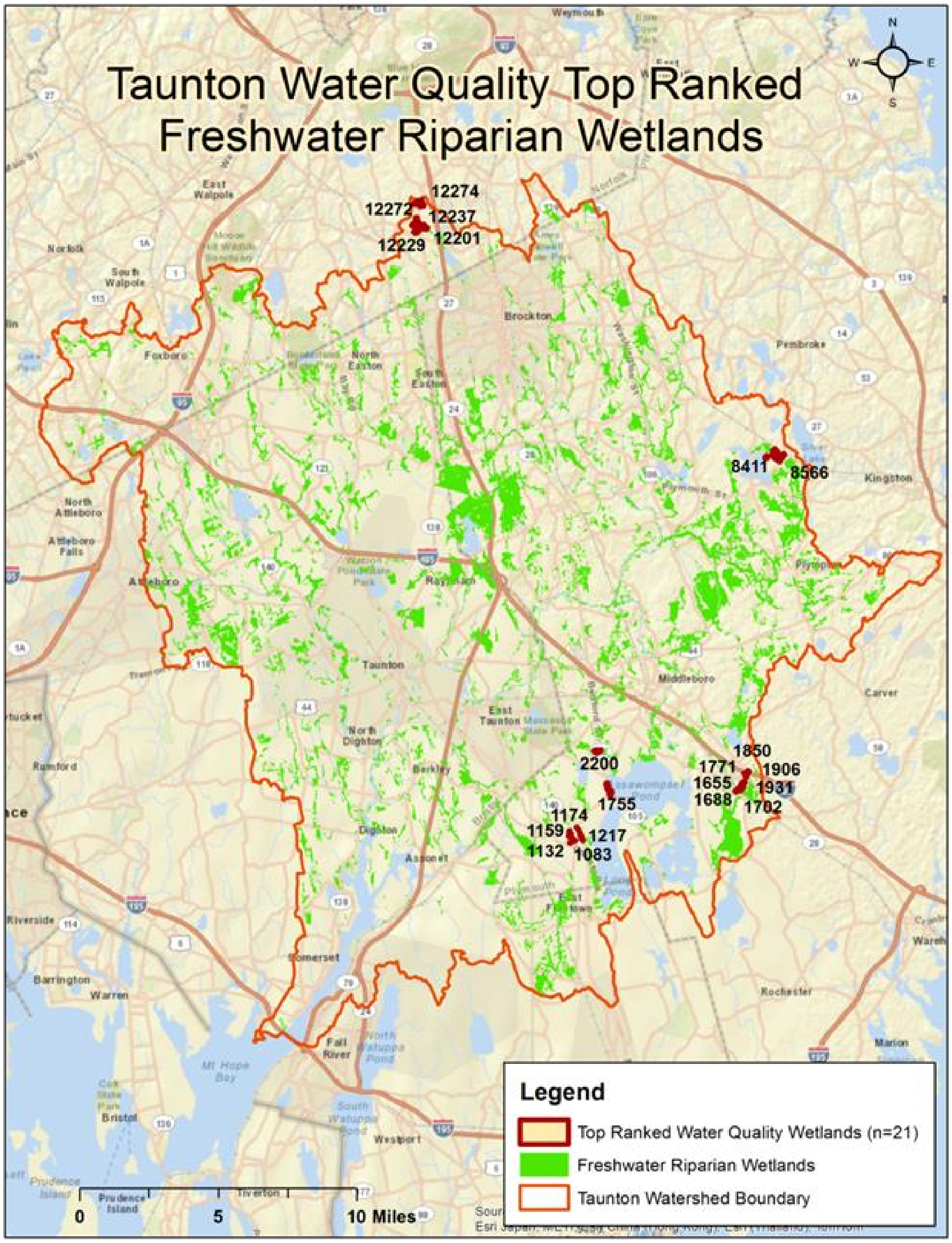
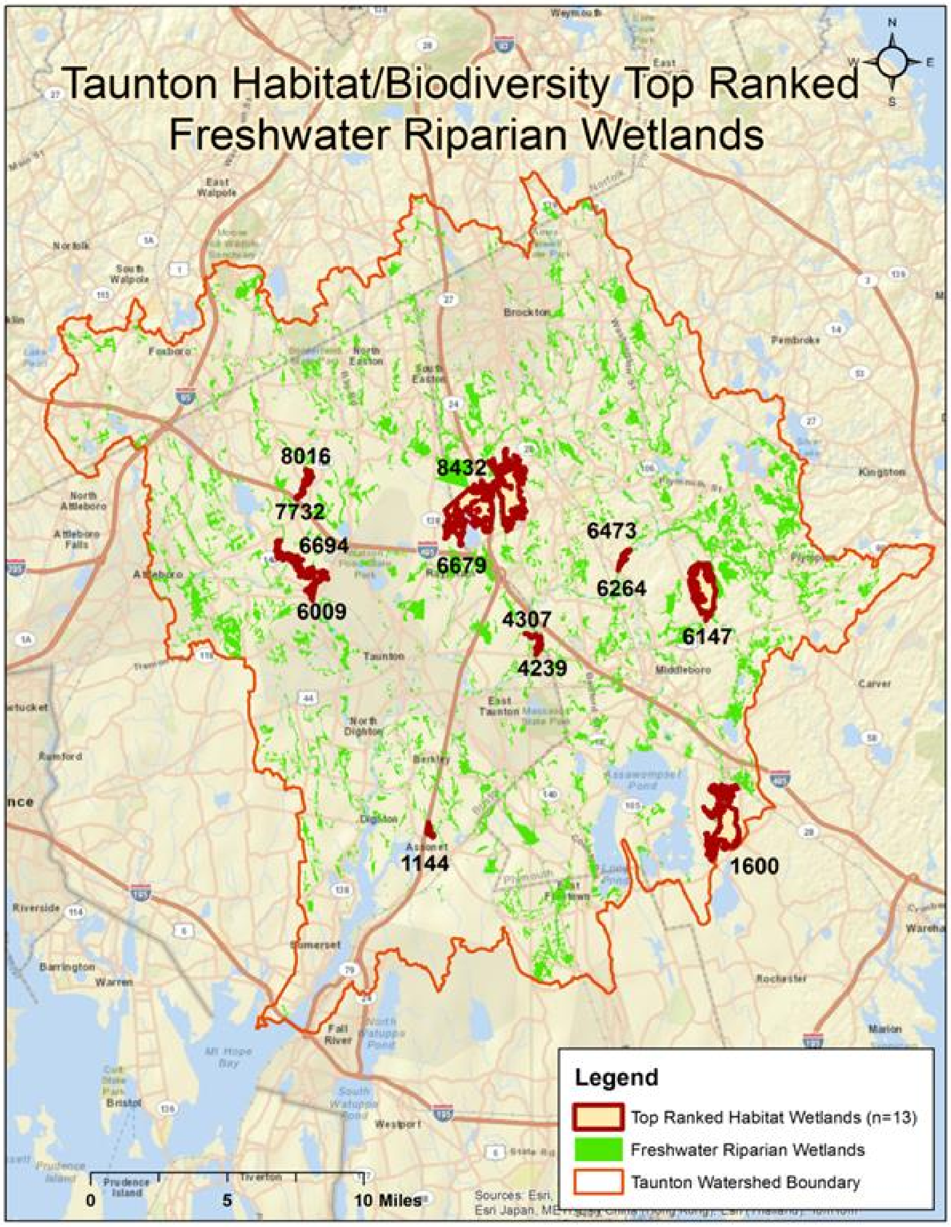


Figure 3-3. Top-Ranked Water Quality Protection Riparian Freshwater Wetlands in the Taunton River Watershed



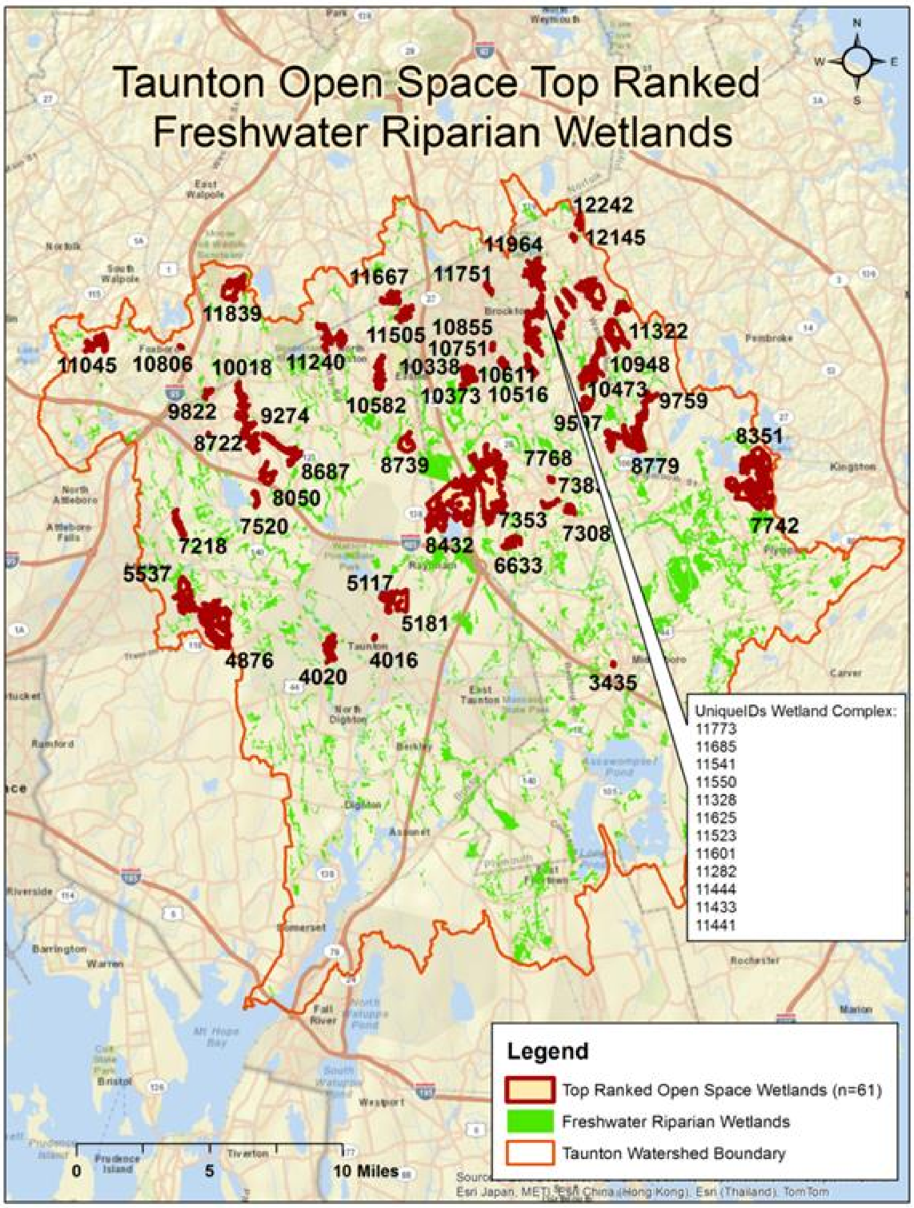
A total of 13 wetlands (three tied for 10th place) scored highest for the habitat/biodiversity ES component in the Taunton River Watershed. Many of these wetlands are located in the central region of the basin near Bridgewater, Norton, and Middleborough (Figure 3-4).

Figure 3-4. Top-Ranked Habitat/Biodiversity Protection Riparian Freshwater Wetlands in the Taunton River Watershed



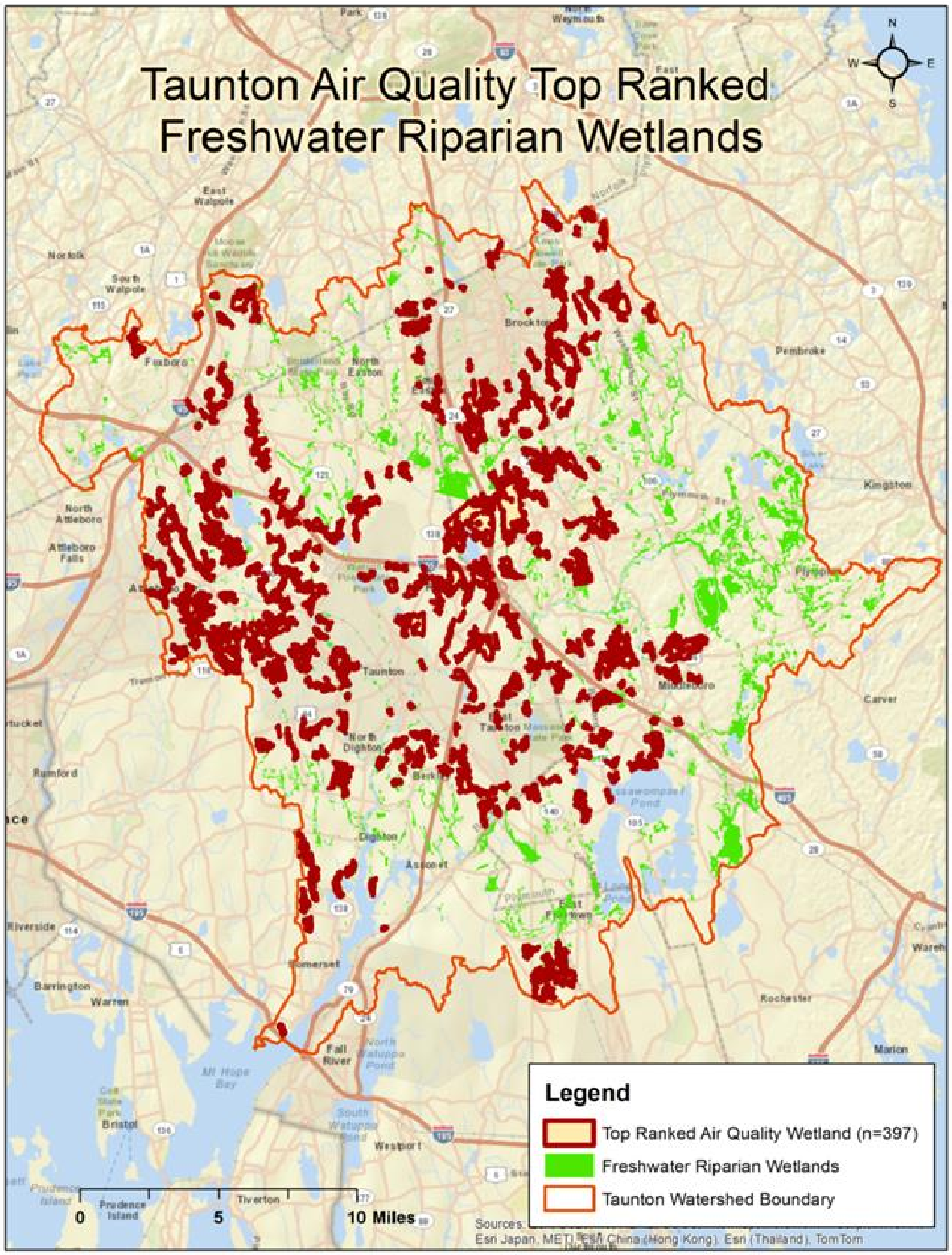
Highly ranked wetlands based on open space protection were concentrated in the northern half of the Taunton River Watershed (Figure 3-5). Because of the smaller number of components, 61 wetlands received the highest rank possible for this ES category. The wetlands that ranked highest were adjacent to already protected open space and had a large population within their immediate vicinity. Protecting these types of wetlands could lead to projects that build on existing open space to create large parks or greenways that could be used for educational or recreational purposes.

Figure 3-5. Top-Ranked Open Space Protection Riparian Freshwater Wetlands in the Taunton River Watershed



Wetlands that ranked highest for air quality protection are primarily wooded wetlands, mostly located near the watershed's urban areas of Brockton, Bridgewater, Taunton, and Middleboro (Figure 3-6). Because the two continuous ES scoring factors used for this category were highly skewed with the majority of areas highly ranked, 397 wetlands received the highest score for this ES.

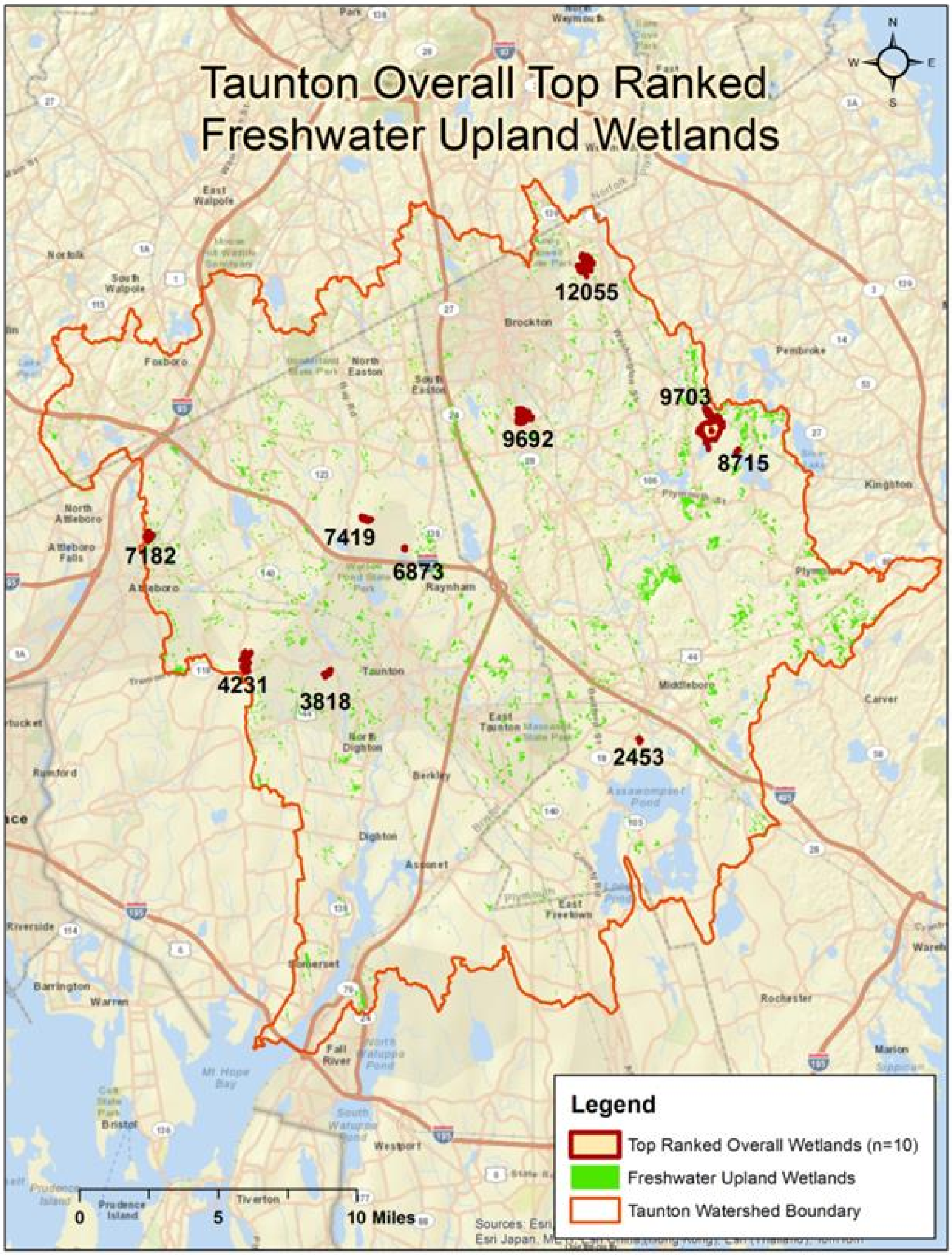
Figure 3-6. Top-Ranked Air Quality Protection Riparian Freshwater Wetlands in the Taunton River Watershed



3.1.2 Upland Freshwater Wetlands

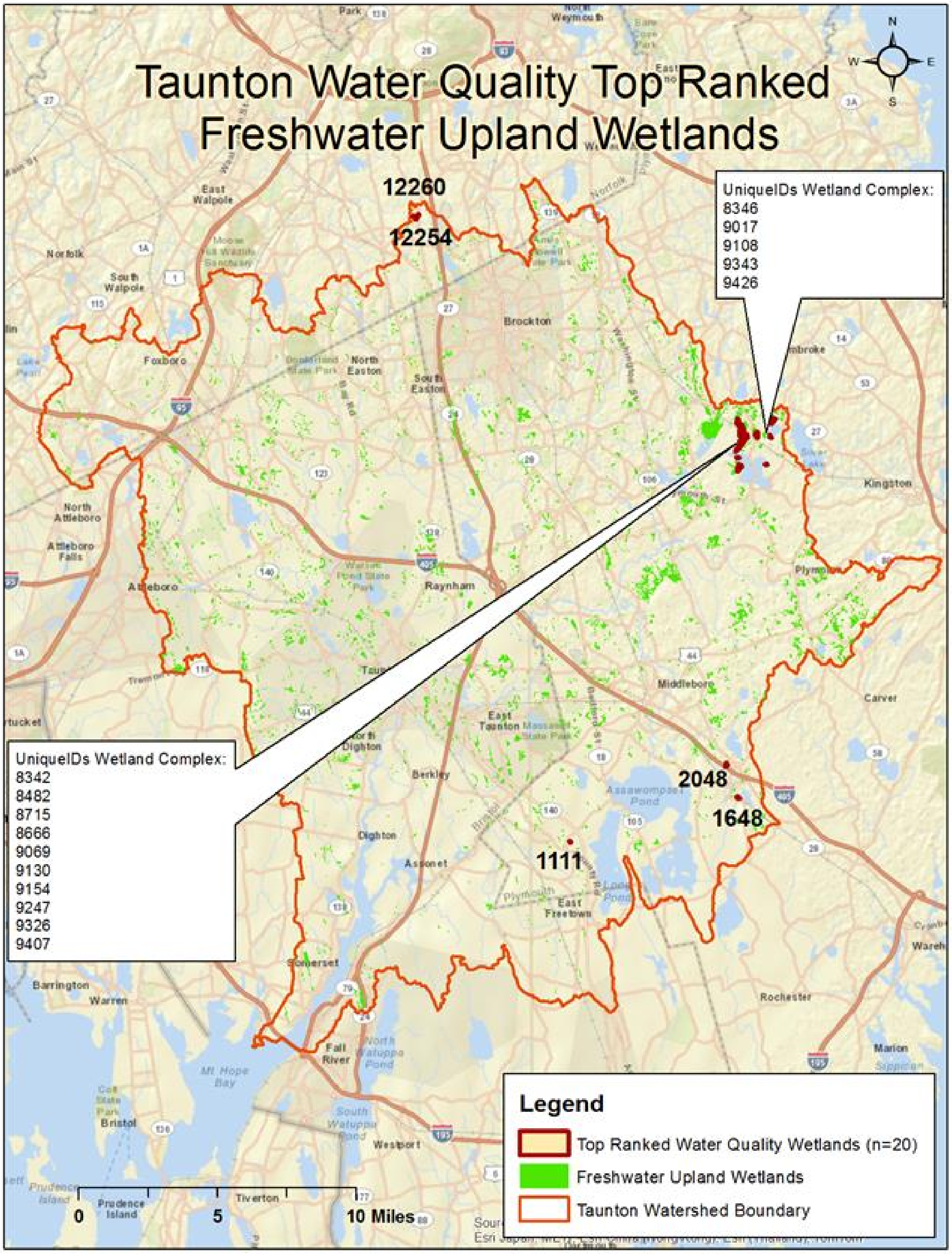
The top 10 overall ranked upland freshwater wetlands were spread evenly across the Taunton River Watershed (Figure 3-7). Some are located near urban areas such as Brockton and Taunton, while others are in the more rural headwater regions near the townships of Hanson and Lakeville.

Figure 3-7. Overall Top-Ranked Upland Freshwater Wetlands in the Taunton River Watershed



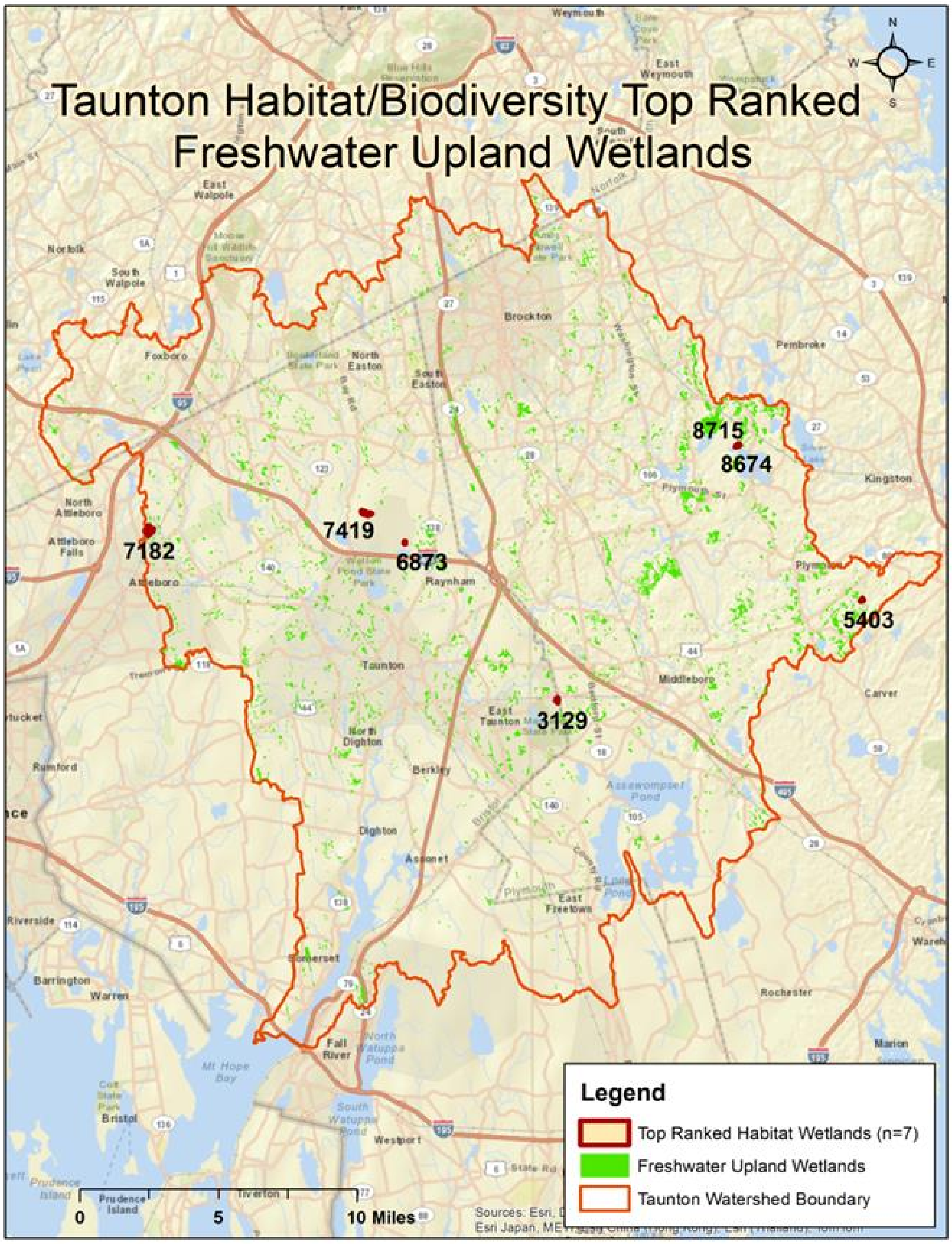
Similar to the riparian freshwater wetlands, the highest-ranked upland freshwater wetlands for water quality are located in the headwaters of the Taunton River Watershed (Figure 3-8). Overall, 19 wetlands received the highest scores for this ES.

Figure 3-8. Highest-Ranked Water Quality Protection Upland Freshwater Wetlands in the Taunton River Watershed



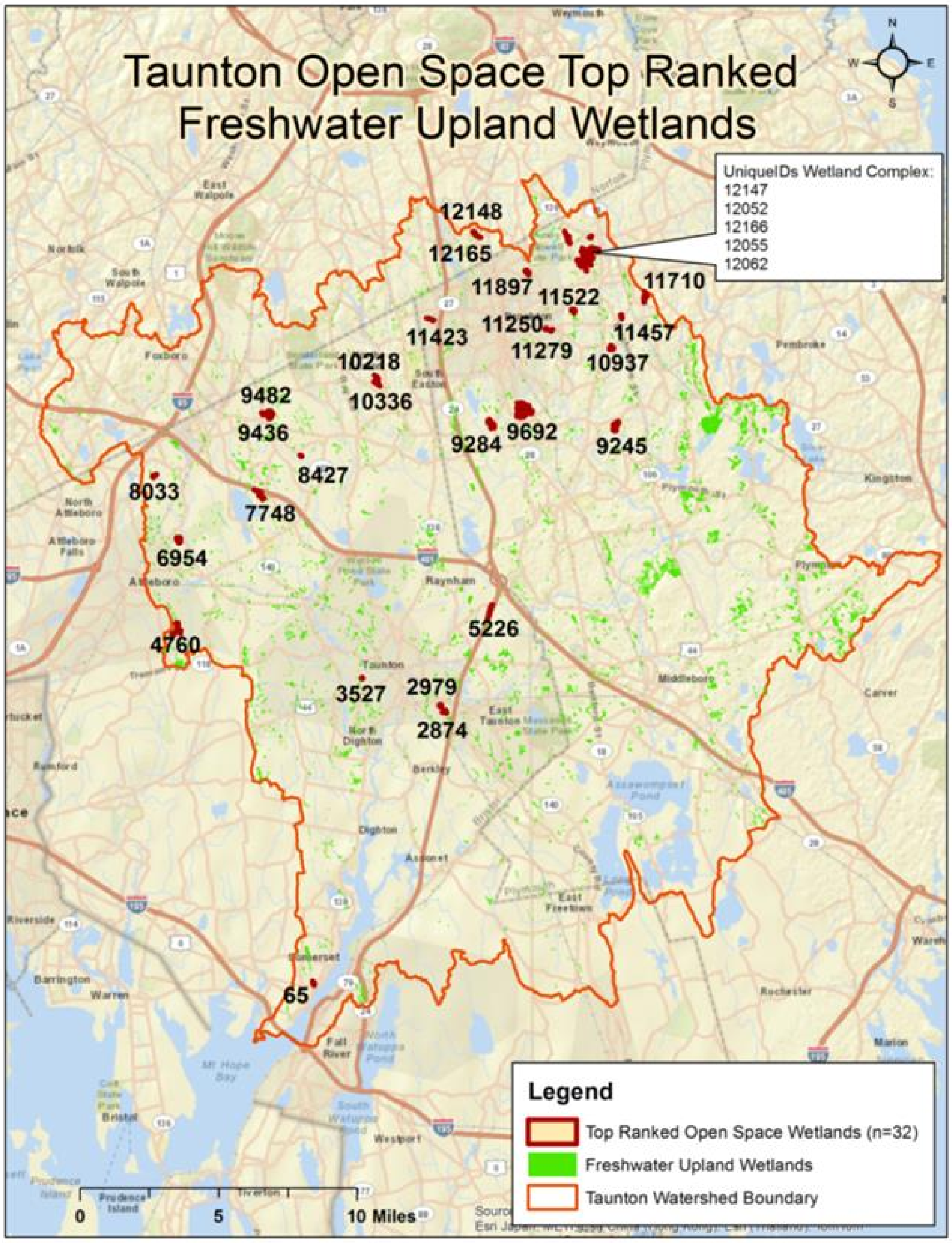
The highest-ranked upland freshwater wetlands for habitat/biodiversity protection are spread evenly across the basin (Figure 3-9). Only the top seven ranked wetlands are included here because a significant break in the overall scores occurred for the next highest-ranked block of wetlands.

Figure 3-9. Highest-Ranked Habitat/Biodiversity Protection Upland Freshwater Wetlands in the Taunton River Watershed



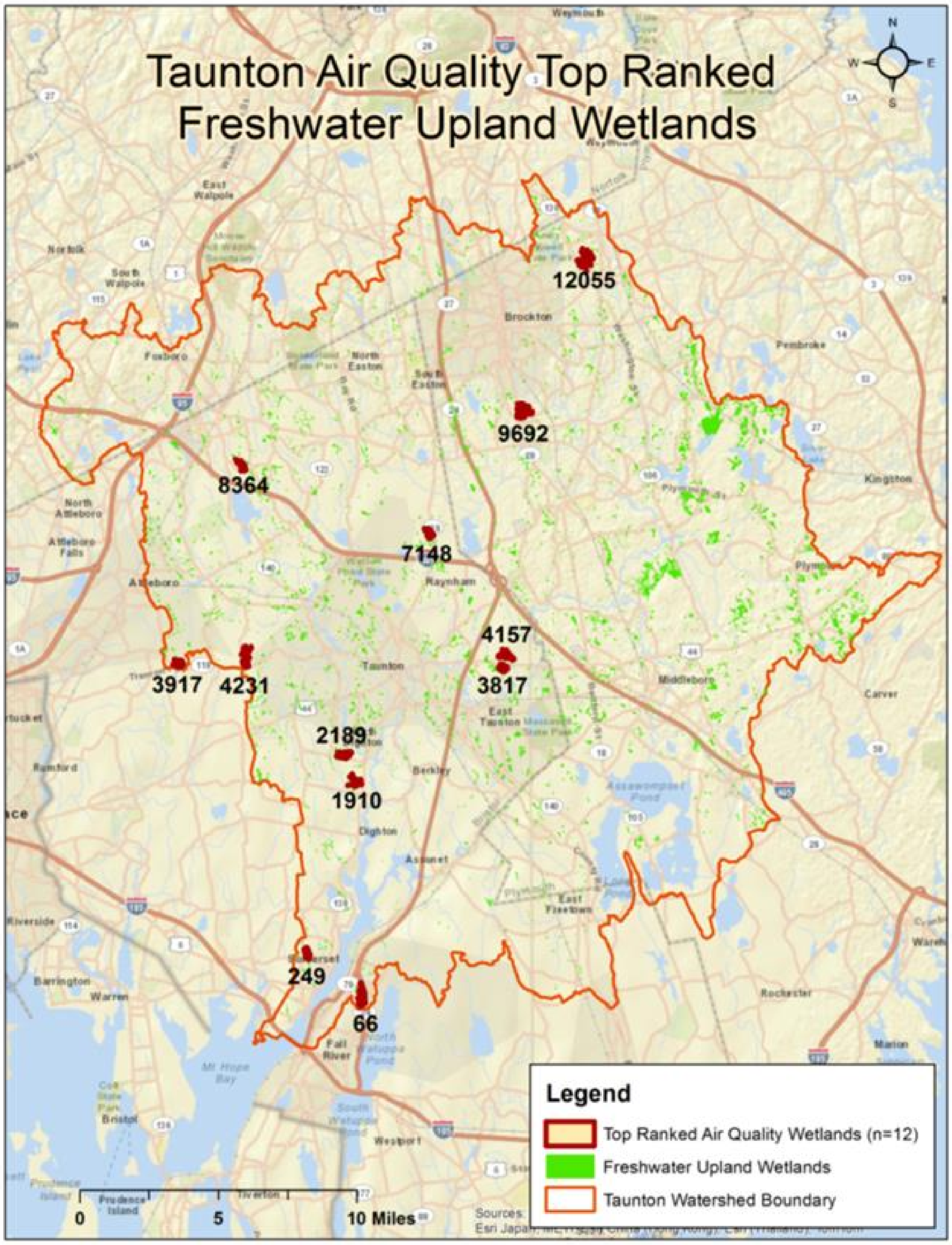
The 32 highest-ranked upland freshwater wetlands for open space protection, based on locations next to protected open space and the amount of people within walking distance, are mostly located in the northern half of the watershed (Figure 3-10). Although most occur in the greater Brockton area, a few are also found near Taunton and one is located near Somerset.

Figure 3-10. Highest-Ranked Open Space Protection Upland Freshwater Wetlands in the Taunton River Watershed



Twelve upland freshwater wetlands received the highest score for air quality protection. These wetlands are located near urban areas such as Brockton, East Taunton, Somerset, and Asheboro (Figure 3-11). Conservation projects aimed at increasing air quality near urban areas could use this target to focus their conservation efforts.

Figure 3-11. Highest-Ranked Air Quality Protection Upland Freshwater Wetlands in the Taunton River Watershed



3.1.3 Riparian Saltwater Wetlands

Far fewer riparian saltwater wetlands than riparian freshwater wetlands are present in the Taunton River Watershed. All saltwater wetlands are located near the main river channel of the Taunton River near the watershed's outlet. The small range these wetlands cover yields fairly uniform results in geographic location for each ES category. The highest-ranked overall categories (Figure 3-12)—extreme event protection (Figure 3-13), water quality (Figure 3-14), habitat/biodiversity (Figure 3-15), and open space (Figure 3-16)—are all concentrated in a small area south of Taunton along the river's main channel. The overall highest-ranked wetlands could be a starting place for conservation groups to focus their efforts that could lead to other projects to connect and restore other areas of saltwater wetlands.

Figure 3-12. Overall Top-Ranked Riparian Saltwater Wetlands in the Taunton River Watershed

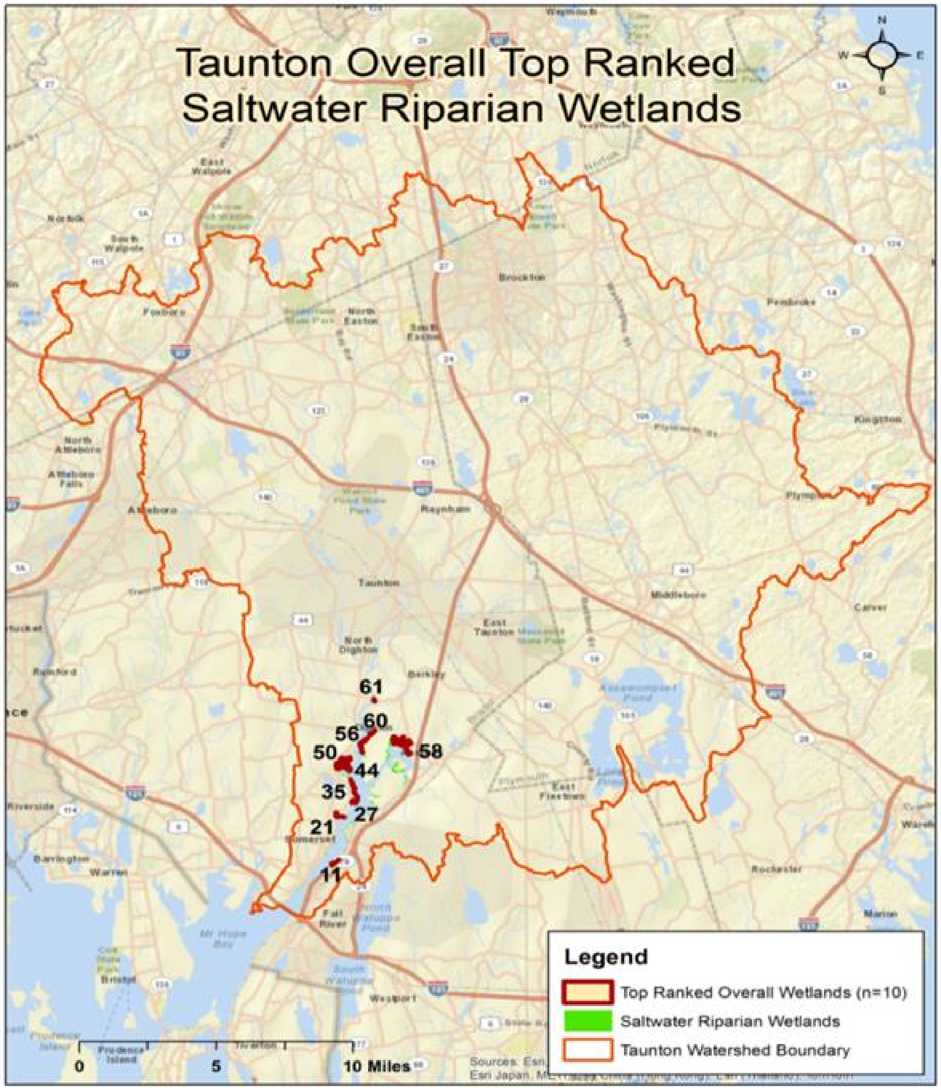


Figure 3-13. Top-Ranked Riparian Saltwater Wetlands for Extreme Event Protection in the Taunton River Watershed

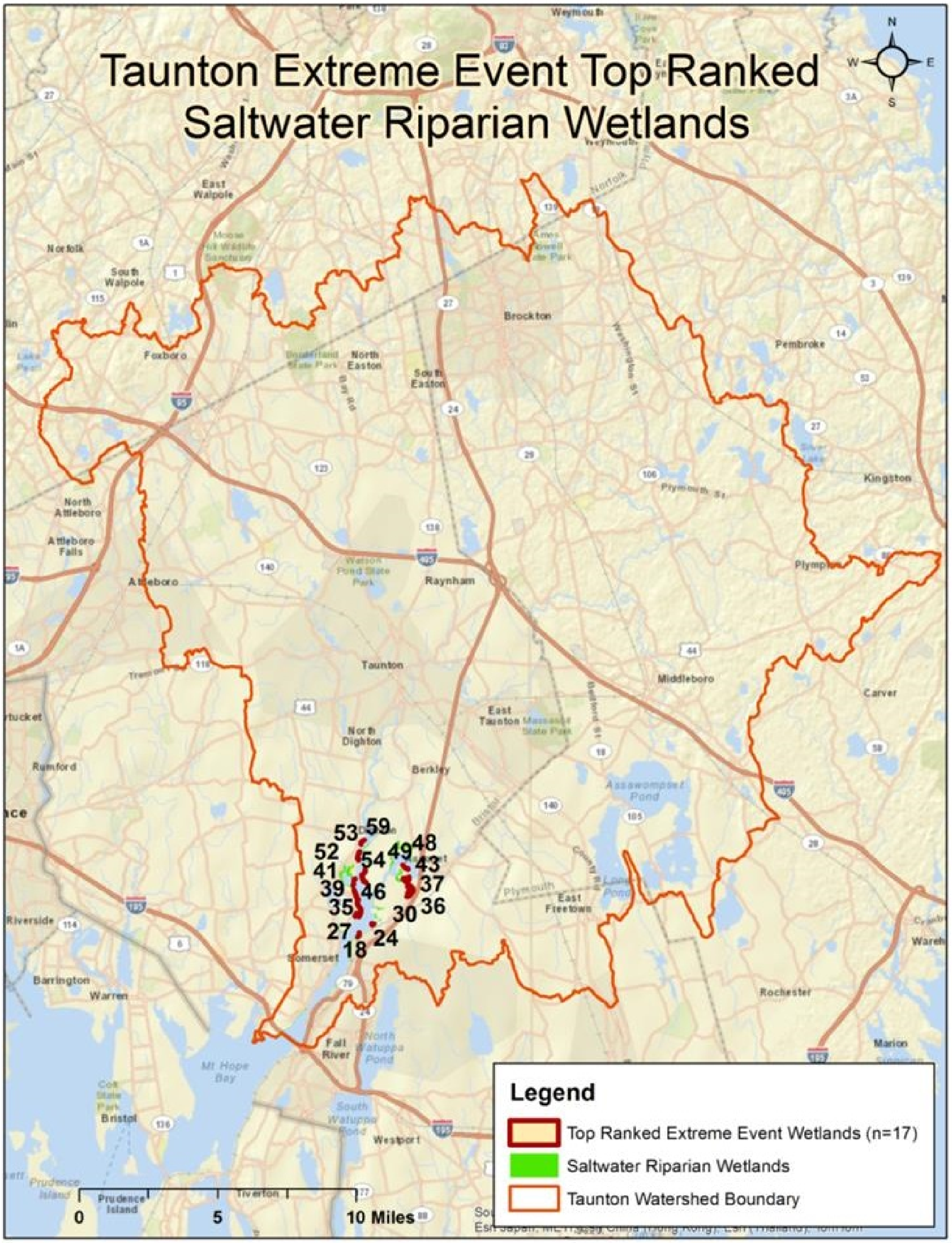
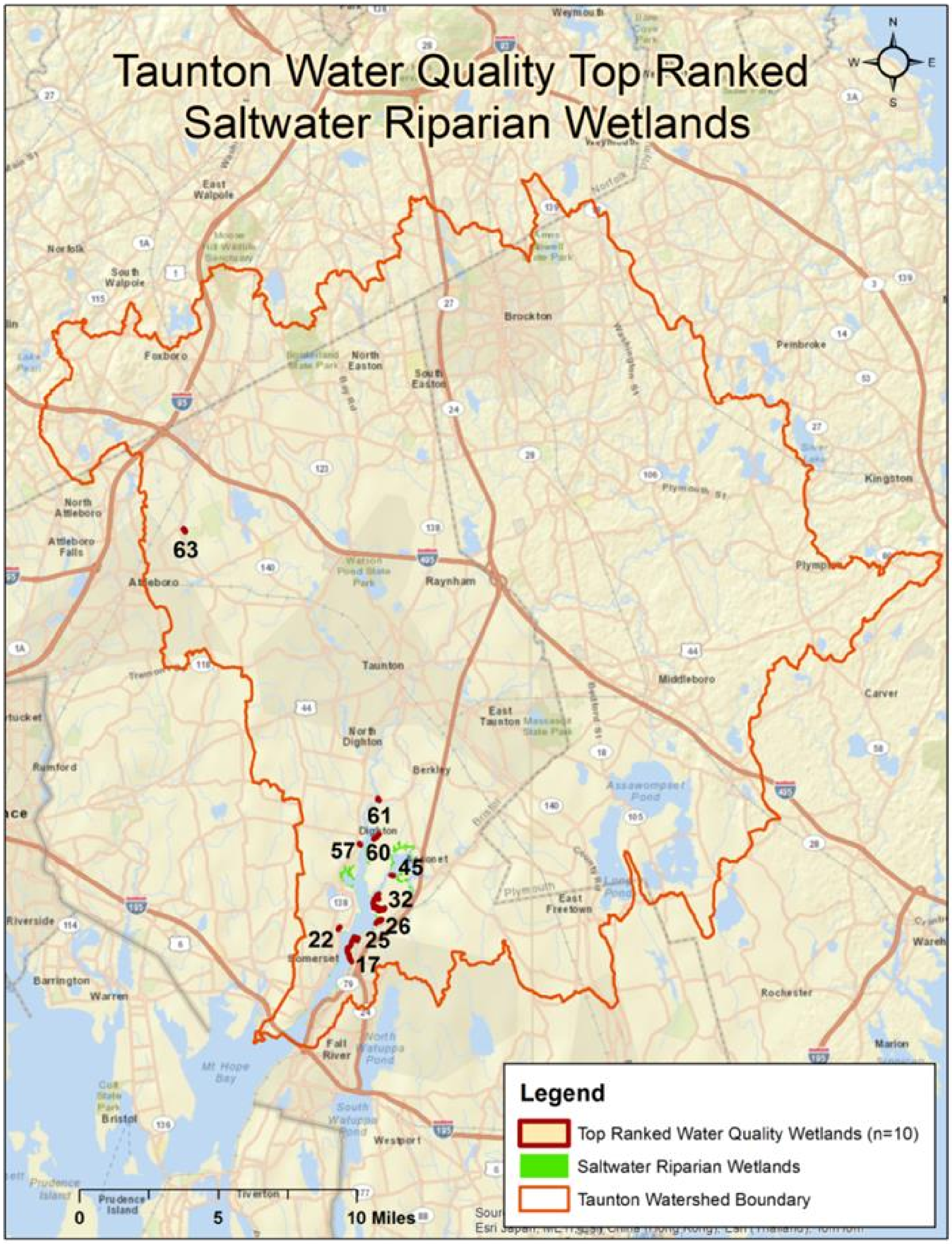


Figure 3-14. Top-Ranked Riparian Saltwater Wetlands for Water Quality Protection in the Taunton River Watershed[a]



[a] Wetland unit number 63 was classified as a saltwater wetland, based on the MassDEP land cover data. No manual adjustments to these data were made.

Figure 3-15. Top-Ranked Riparian Saltwater Wetlands for Habitat/Biodiversity Protection in the Taunton River Watershed

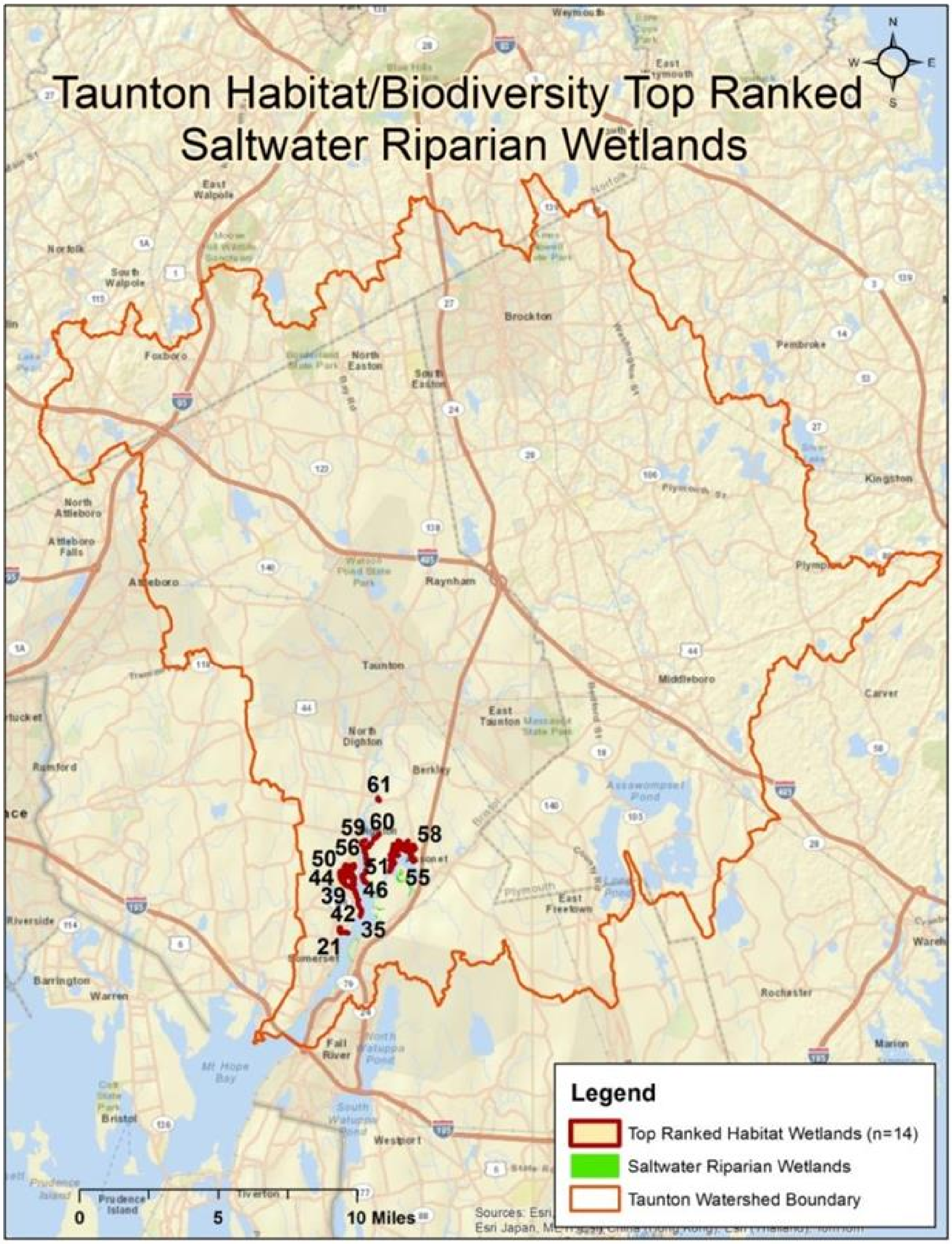
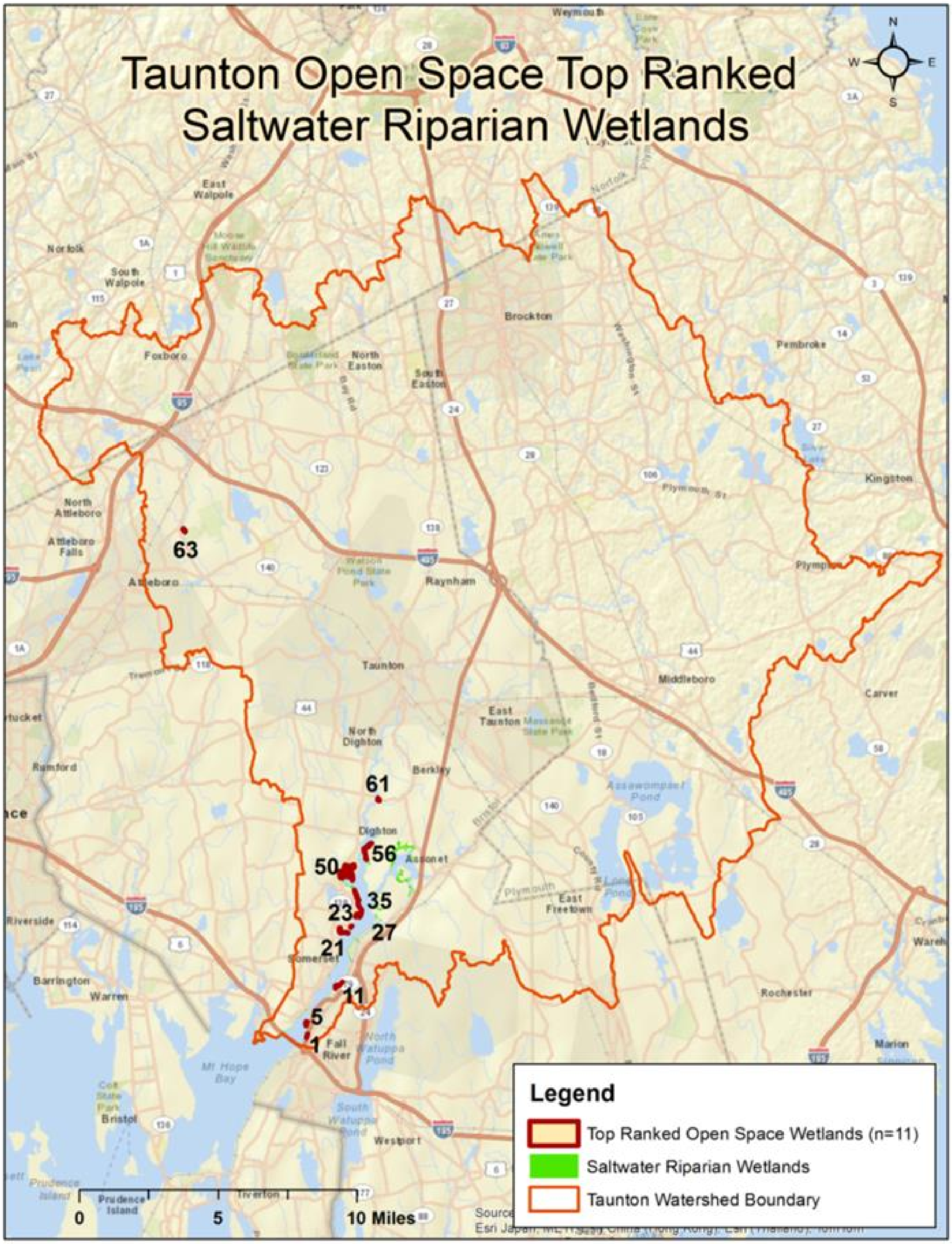


Figure 3-16. Top-Ranked Riparian Saltwater Wetlands for Open Space Protection in the Taunton River Watershed



[a] Wetland unit number 63 was classified as a saltwater wetland, based on the MassDEP land cover data. No manual adjustments to these data were made.

3.1.4 Riparian Forests

Many small areas of riparian forest are located in the Taunton River Watershed. These natural lands are ranked almost identically to the riparian freshwater wetlands, and the results from each ES follow a very similar pattern to the riparian freshwater wetlands. The overall highest-ranked forests are spread evenly across the watershed (Figure 3-17), riparian forests for extreme event protection are located near the outlet of the basin (Figure 3-18), riparian forests providing water quality protection are found in the headwater regions (Figure 3-19), riparian forests providing habitat/biodiversity protection are found in the central portion of the basin (Figure 3-20), and highly ranked riparian forests for open space and air quality protection are generally located near urban areas (Figures 3-21 and 3-22, respectively). Many of these highly ranked riparian forest areas have more than 10 top-ranked units because identical high scores occurred in each category.

Figure 3-17. Overall Top-Ranked Riparian Forests in the Taunton River Watershed

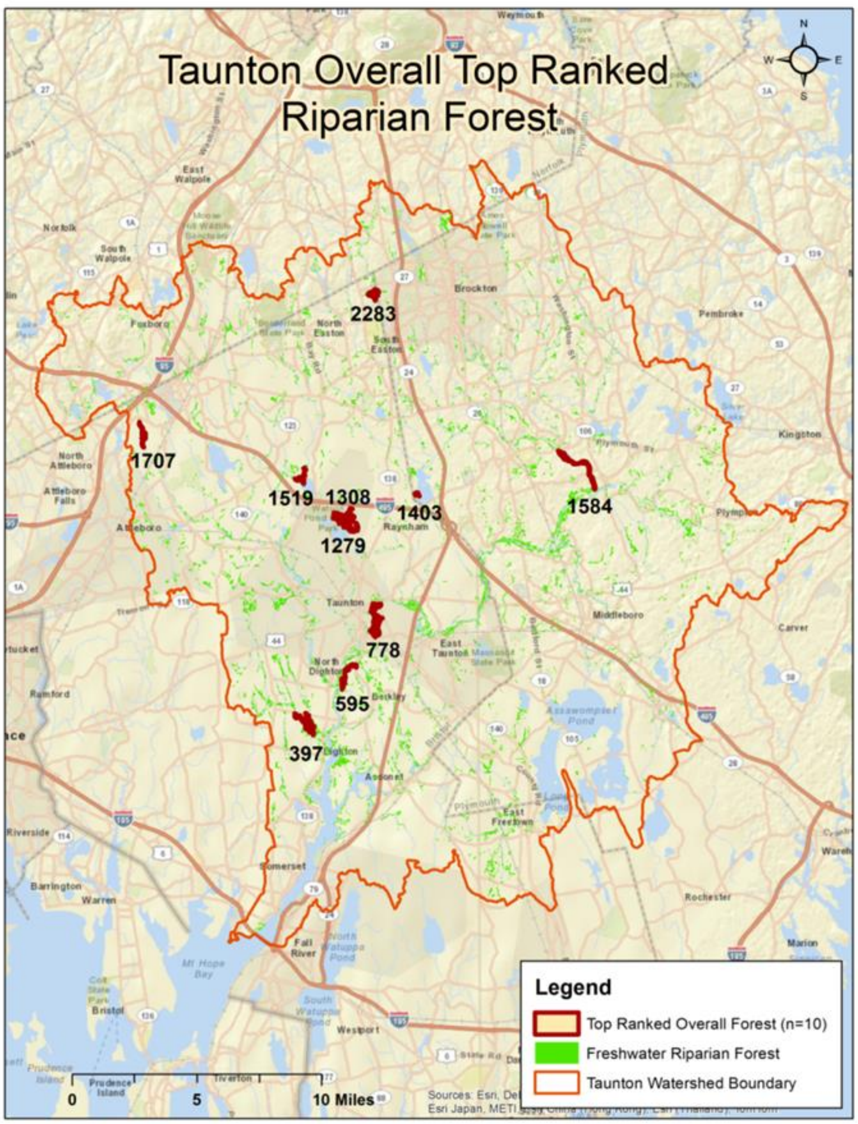


Figure 3-18. Top-Ranked Riparian Forests for Flood/Extreme Event Protection in the Taunton River Watershed

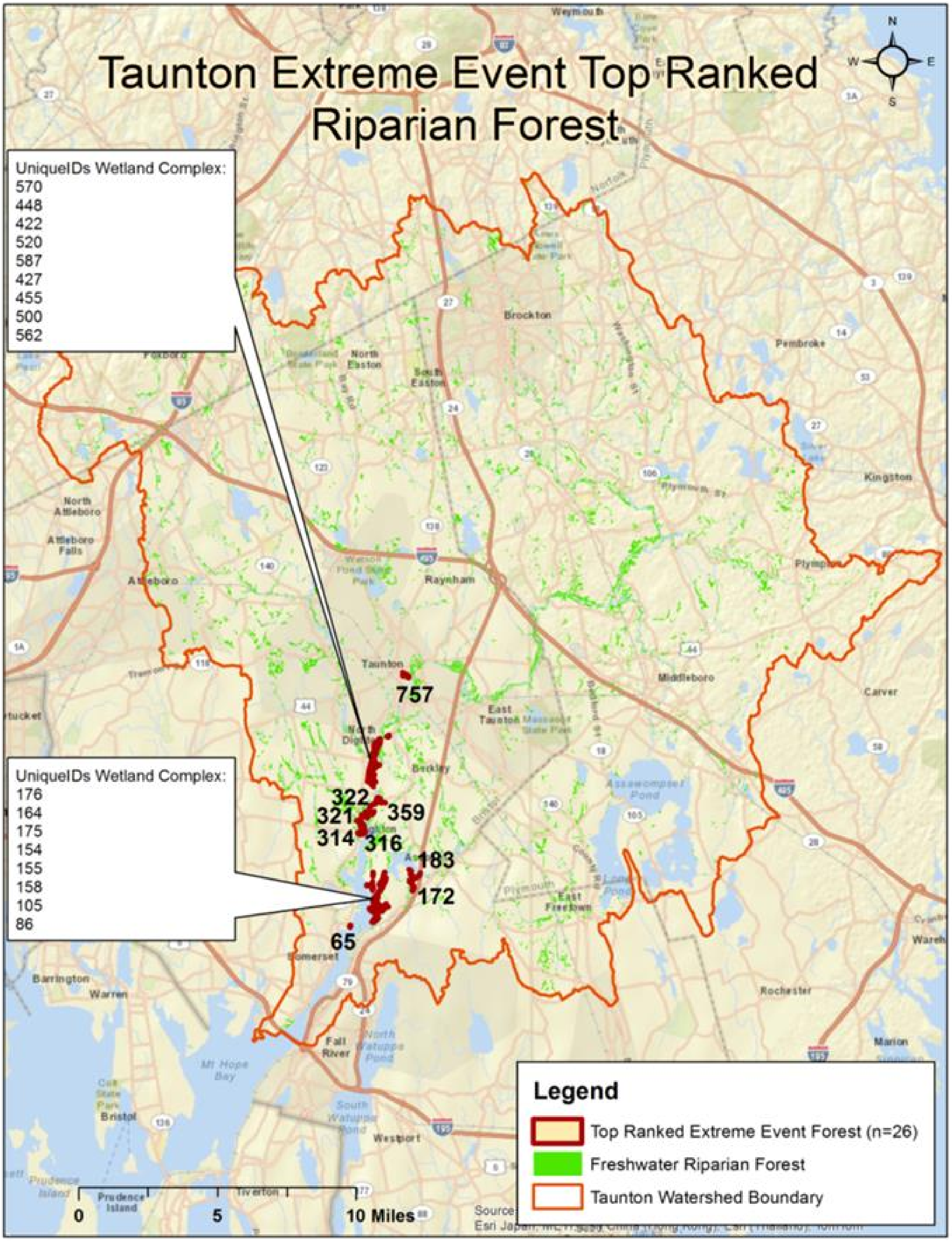


Figure 3-19. Top-Ranked Riparian Forests for Water Quality Protection in the Taunton River Watershed

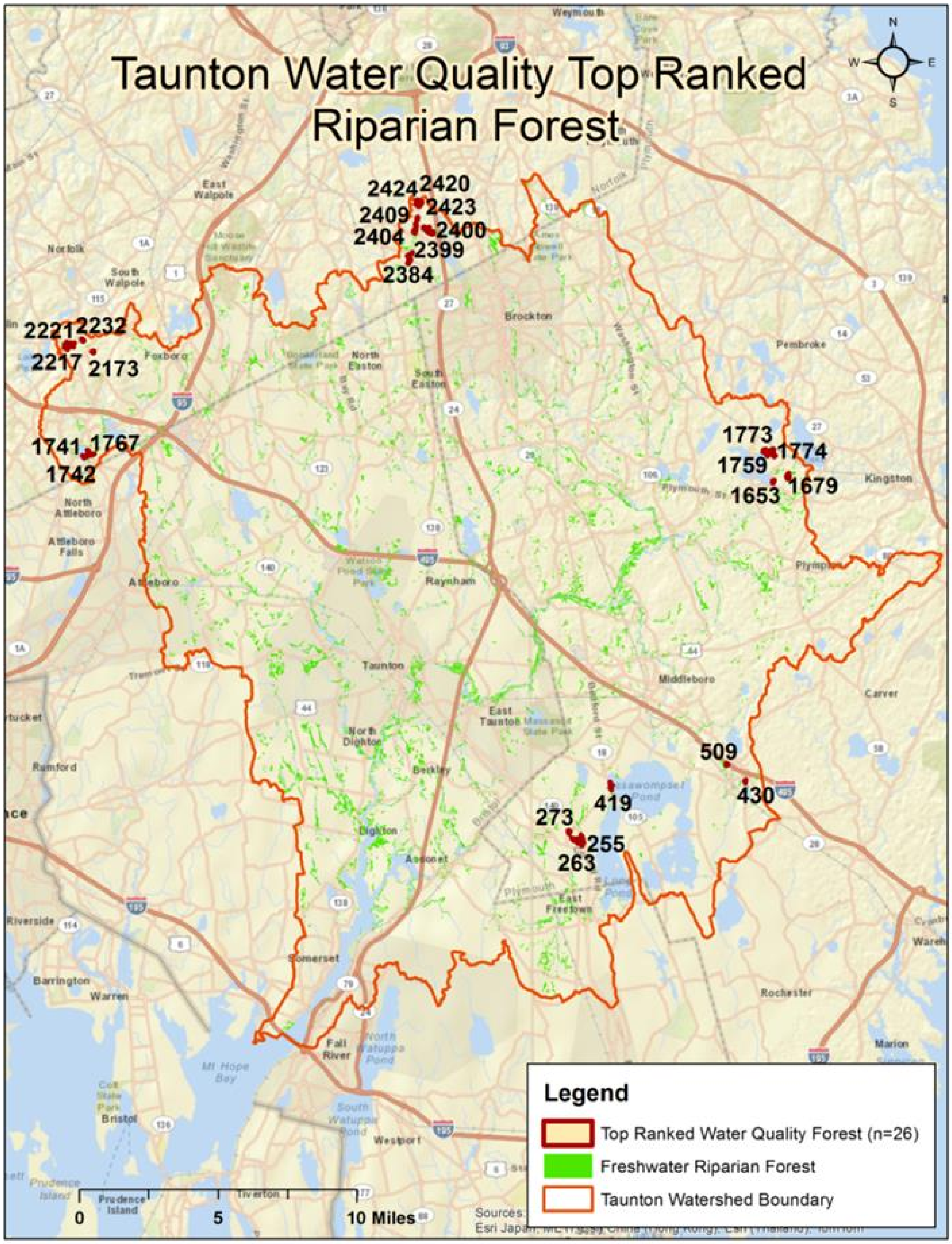


Figure 3-20. Top-Ranked Riparian Forests for Habitat/Biodiversity Protection in the Taunton River Watershed

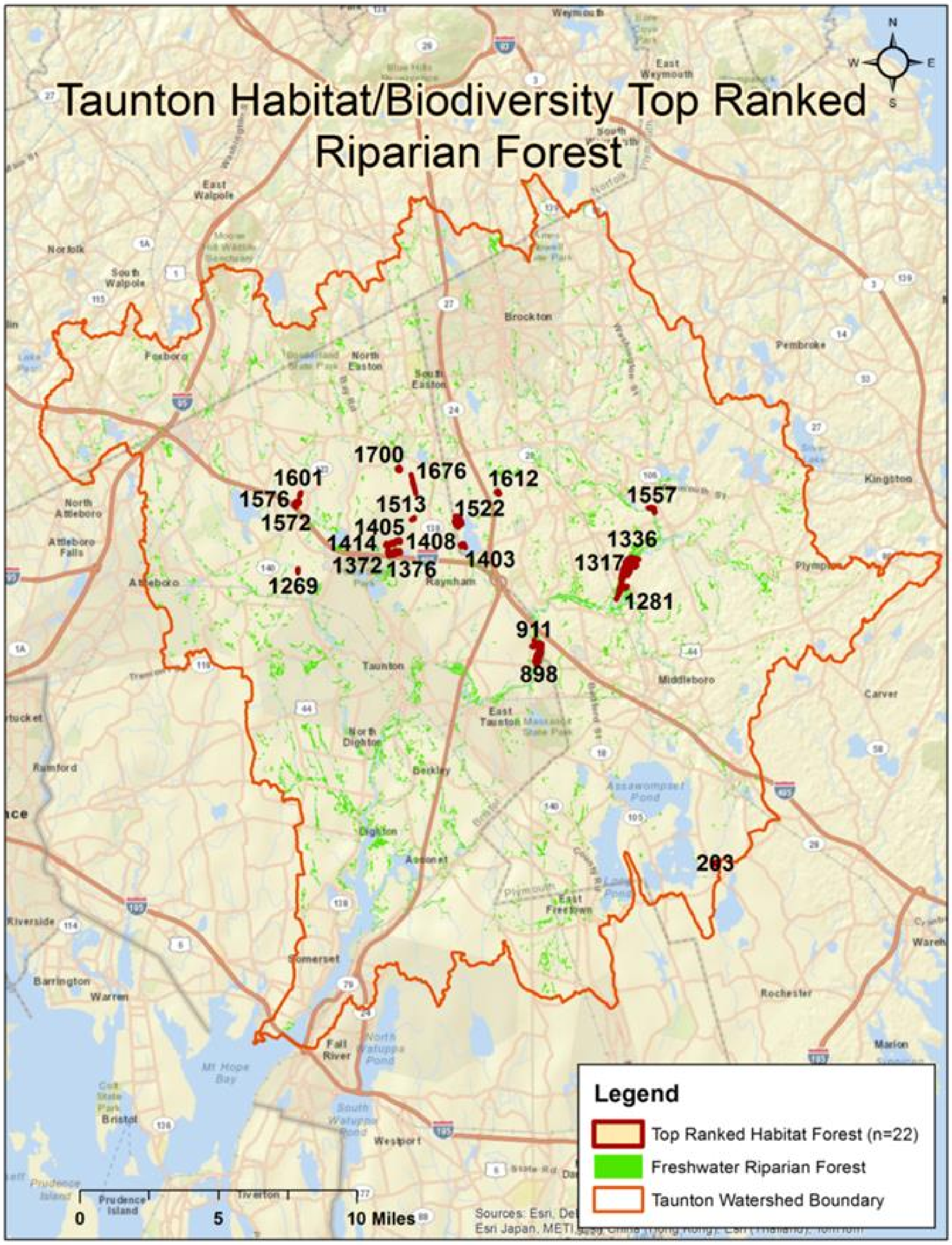


Figure 3-21. Top-Ranked Riparian Forests for Open Space Protection in the Taunton River Watershed

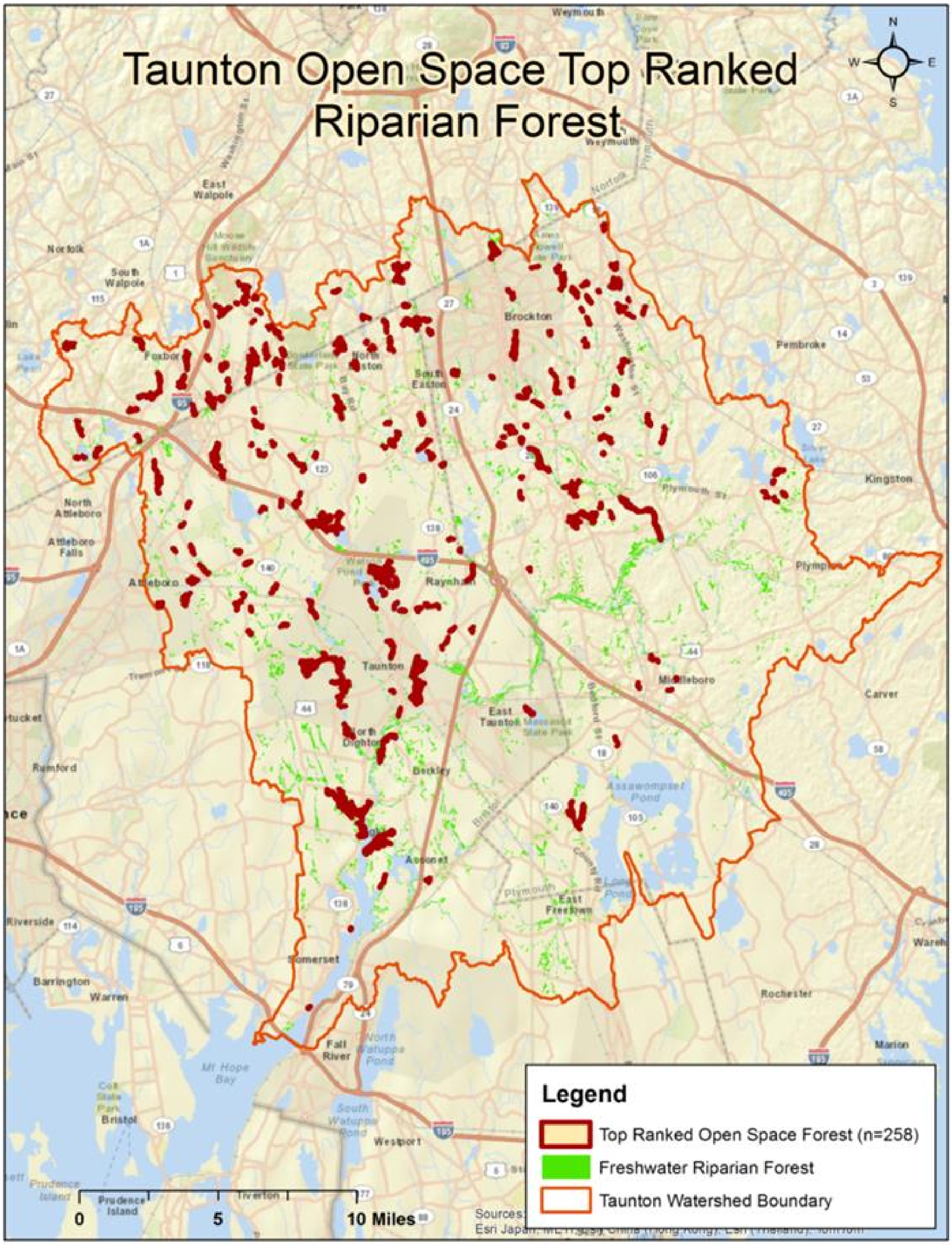
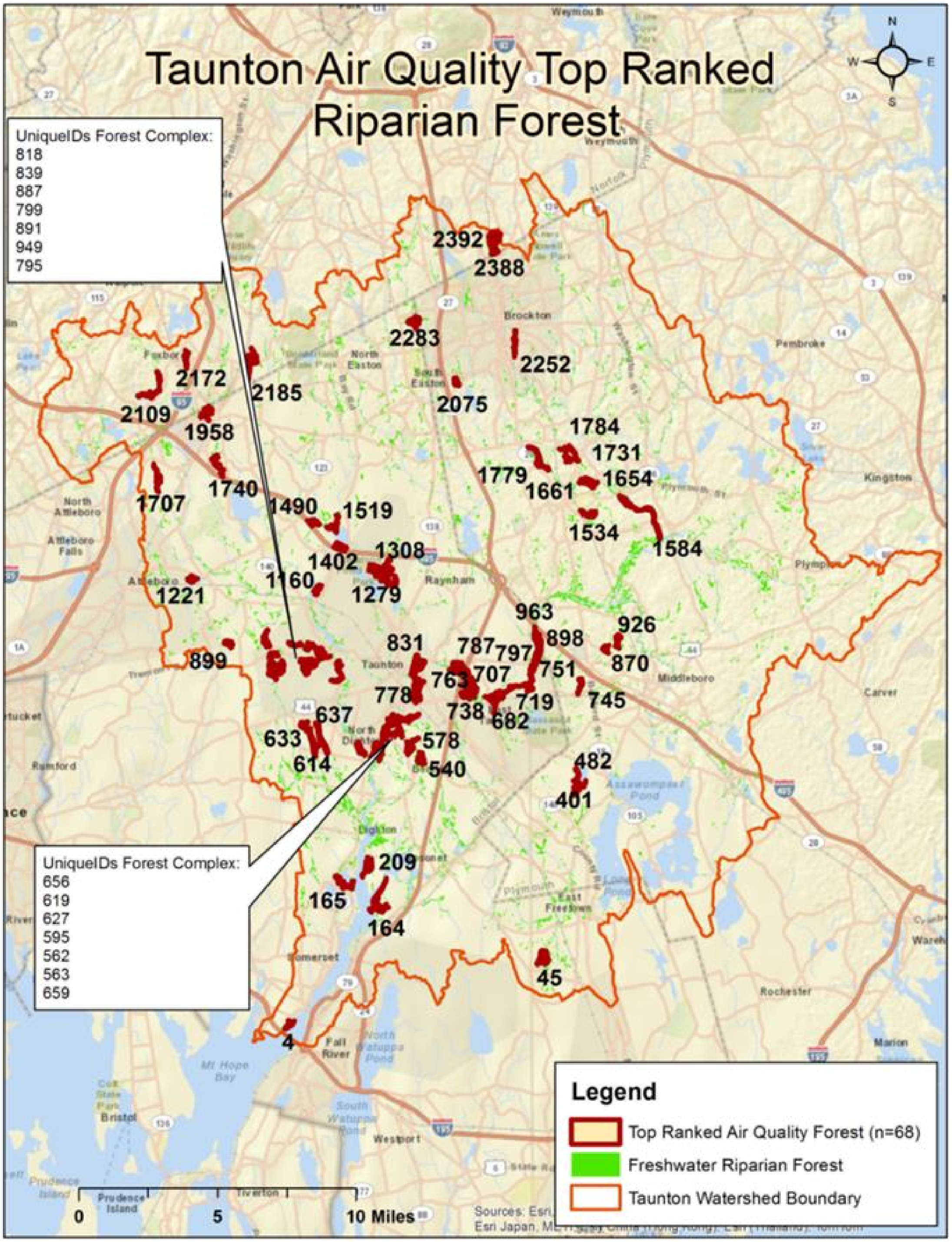


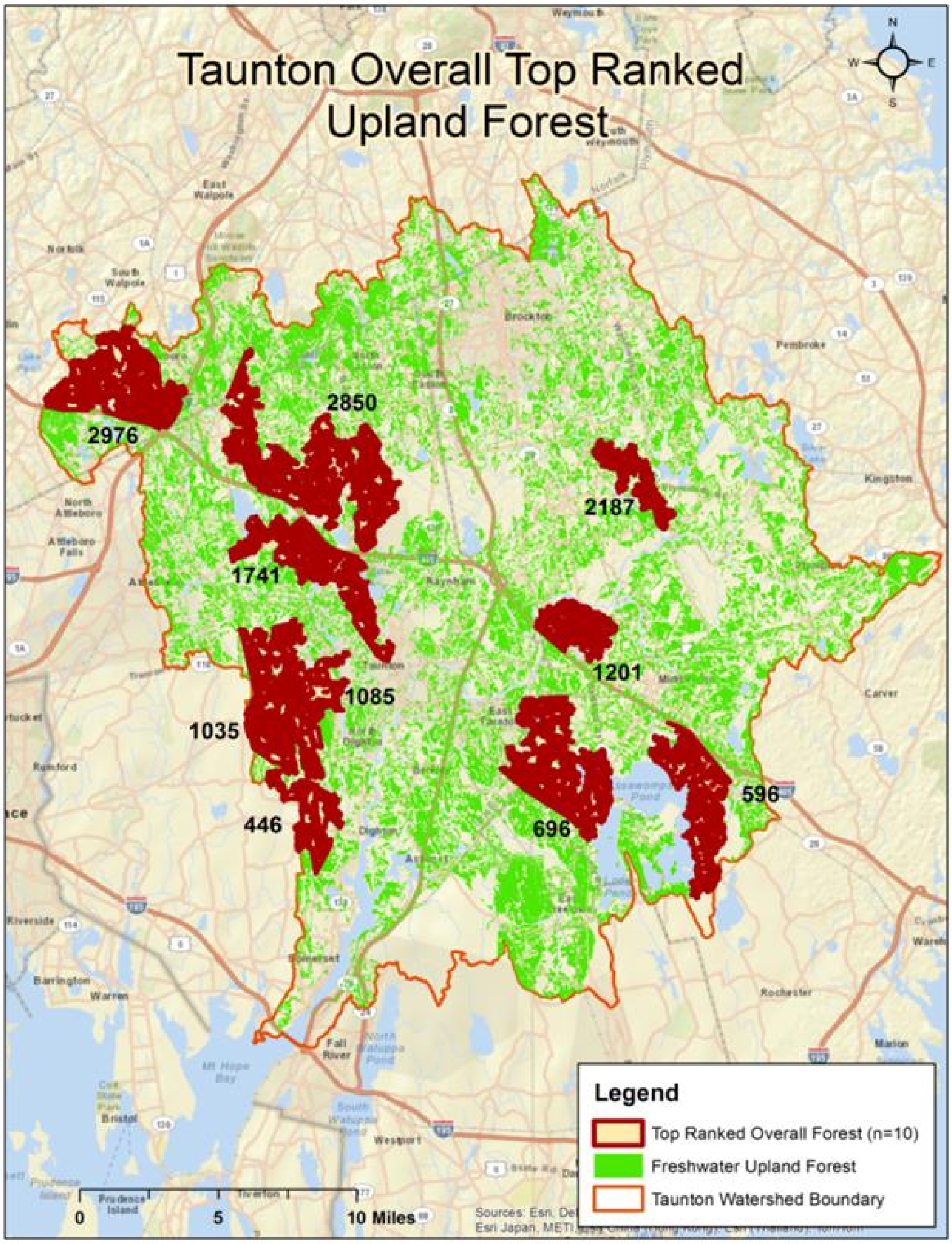
Figure 3-22. Top-Ranked Riparian Forests for Air Quality Protection in the Taunton River Watershed



3.1.5 Upland Forests

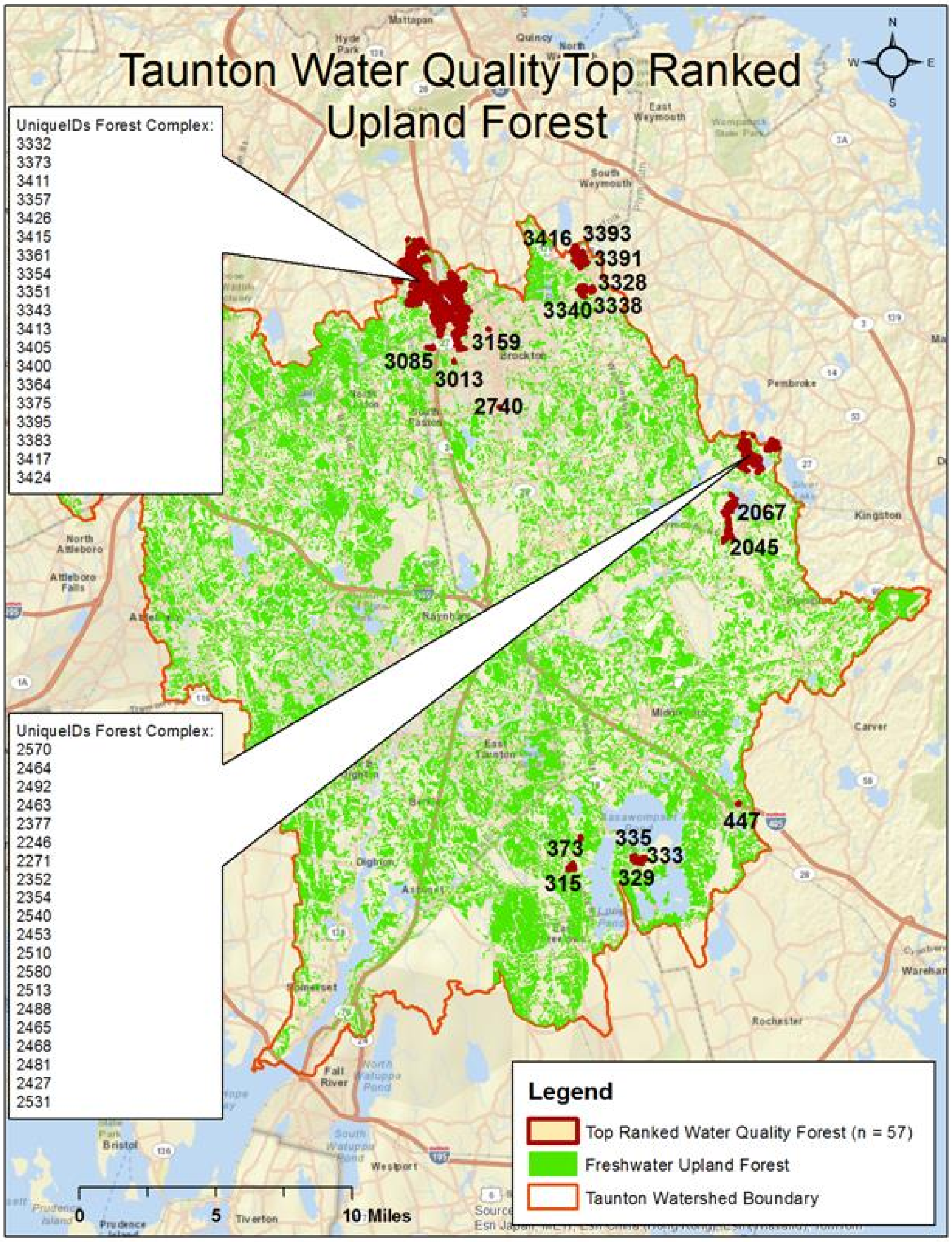
The Taunton River Watershed contains extensive areas of upland forest. The highest-ranked areas of upland forest occur in the northwest headwaters region, near the city of Taunton, and in the southeast headwater region south of Middleboro (Figure 3-23).

Figure 3-23. Overall Top-Ranked Upland Forests in the Taunton River Watershed



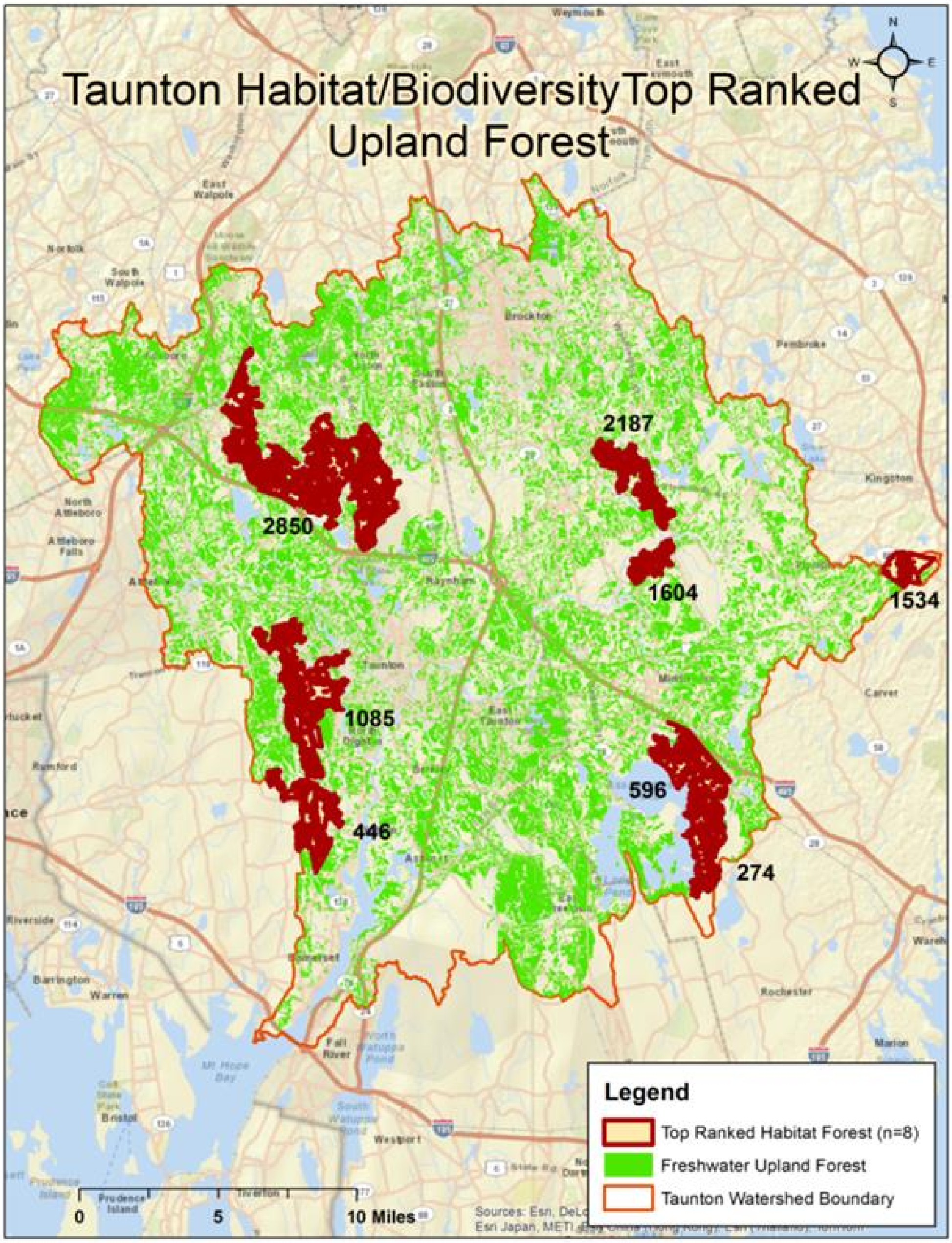
A total of 36 upland forest units were ranked highest for water quality protection in the Taunton River Watershed. These areas of upland forest are located in the headwaters regions near Brockton, Hanson, and Lakeville (Figure 3-24).

Figure 3-24. Top-Ranked Upland Forests for Water Quality Protection in the Taunton River Watershed



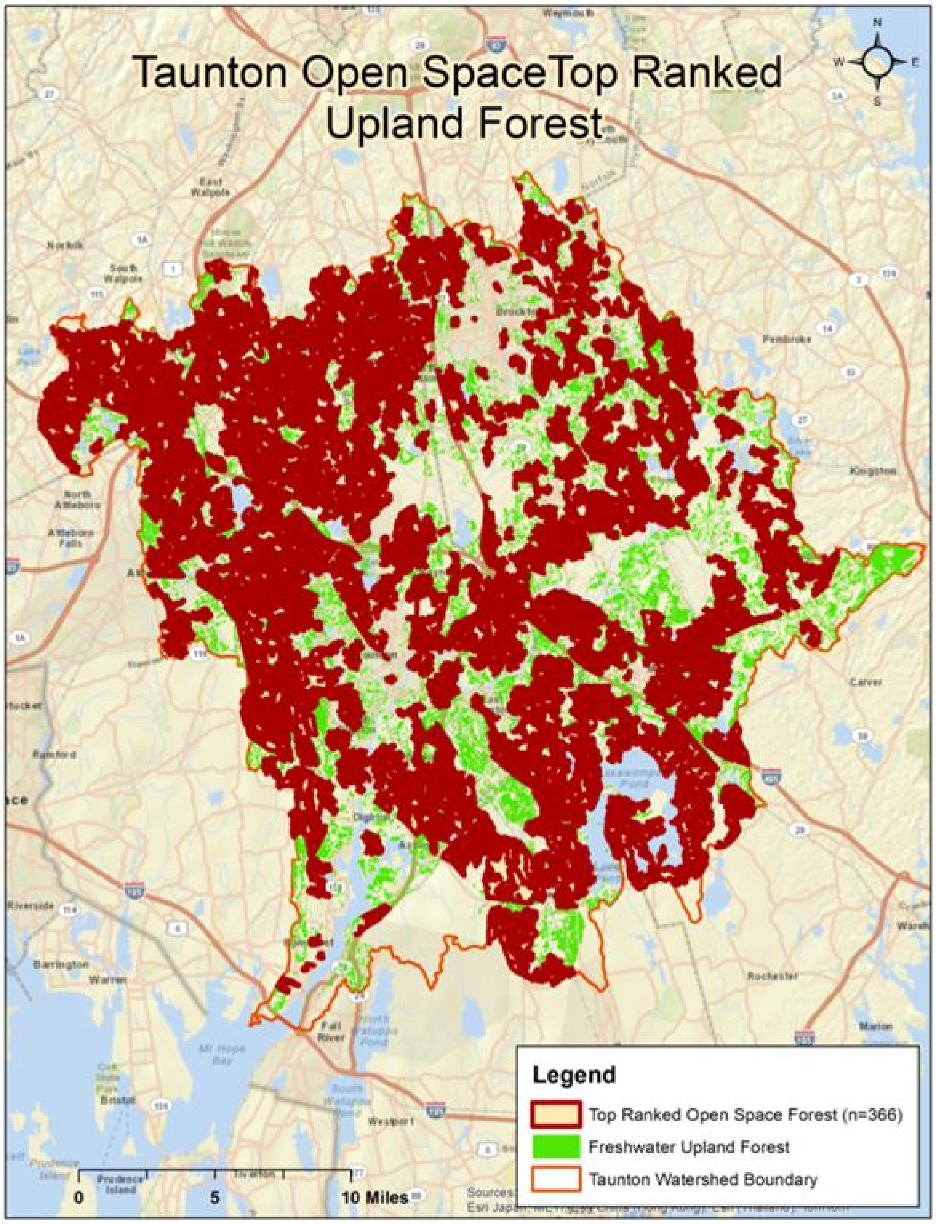
Eight upland forest units were chosen to represent the highest ranking areas of habitat protection. A significant break in the scores occurred for the next block of highly ranked upland forests for this category. These large forest tracts are spread across the basin away from the more urbanized areas (Figure 3-25).

Figure 3-25. Top-Ranked Riparian Forests for Habitat/Biodiversity Protection in the Taunton River Watershed



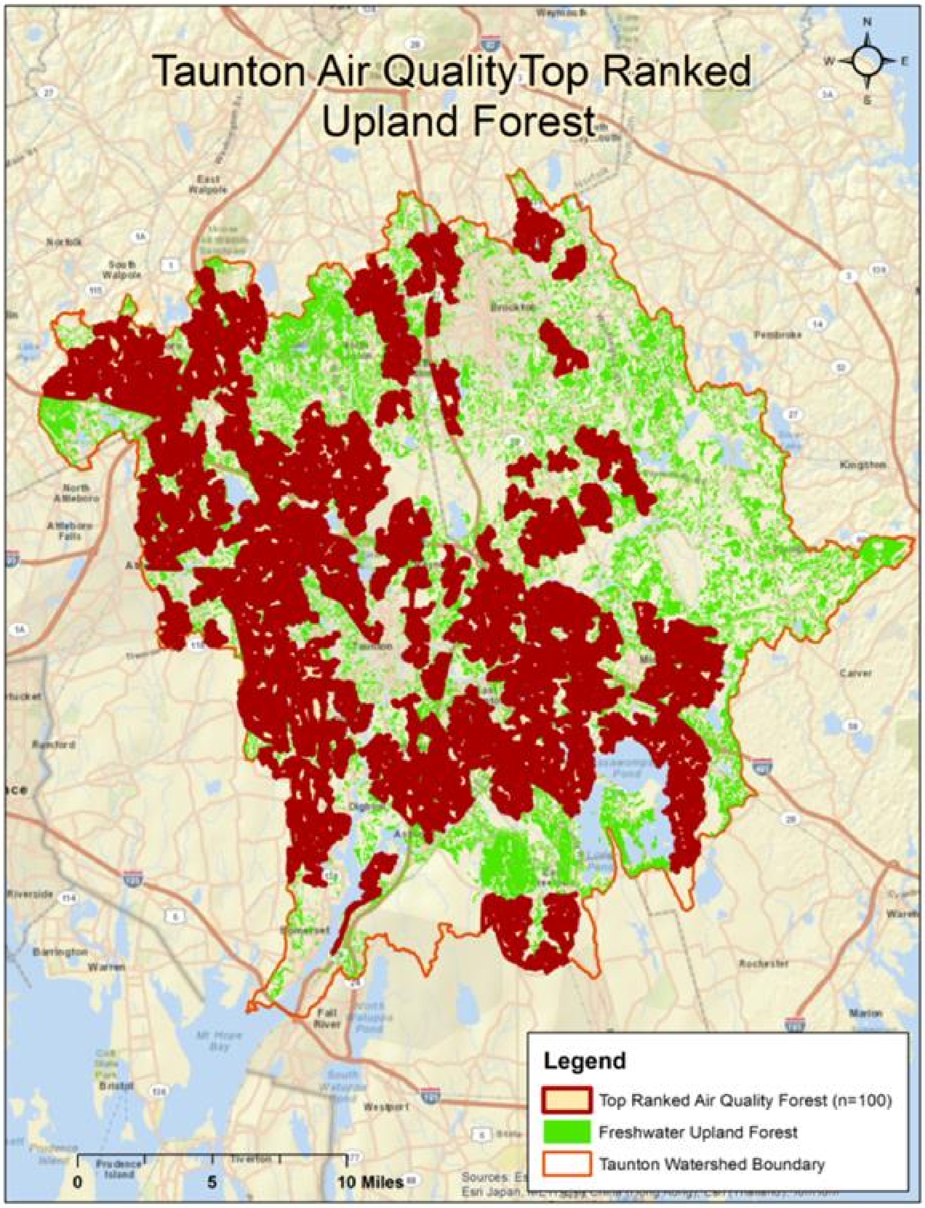
A total of 366 upland forest units scored highest for open space protection primarily because only two discrete ES scoring factors were used to rank this ES. These areas of upland forest covered almost the entire basin except for some areas near the outlet (Figure 3-26). The large number of highly ranked upland forests occurred because of these units' large sizes and therefore because of the higher probability that units would be adjacent to protected open space and would have a high number of people within walking distance.

Figure 3-26. Top-Ranked Riparian Forests for Open Space Protection in the Taunton River Watershed



The top-ranked upland forests for air quality protection followed a similar distribution to the top-ranked forests for open space protection. These tracts of forest are spread across most of the basin with the exception of the eastern headwaters region where fewer urban areas are located (Figure 3-27).

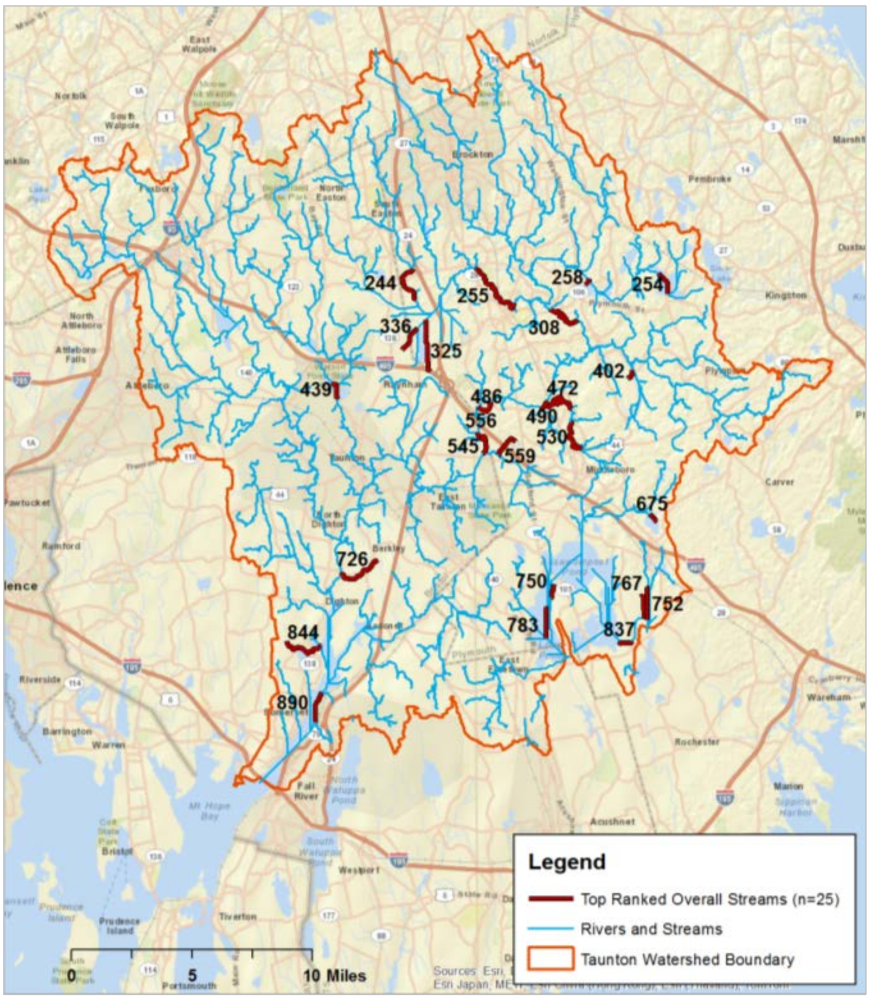
Figure 3-27. Top-Ranked Upland Forest for Air Quality Protection in the Taunton River Watershed



3.2 Instream

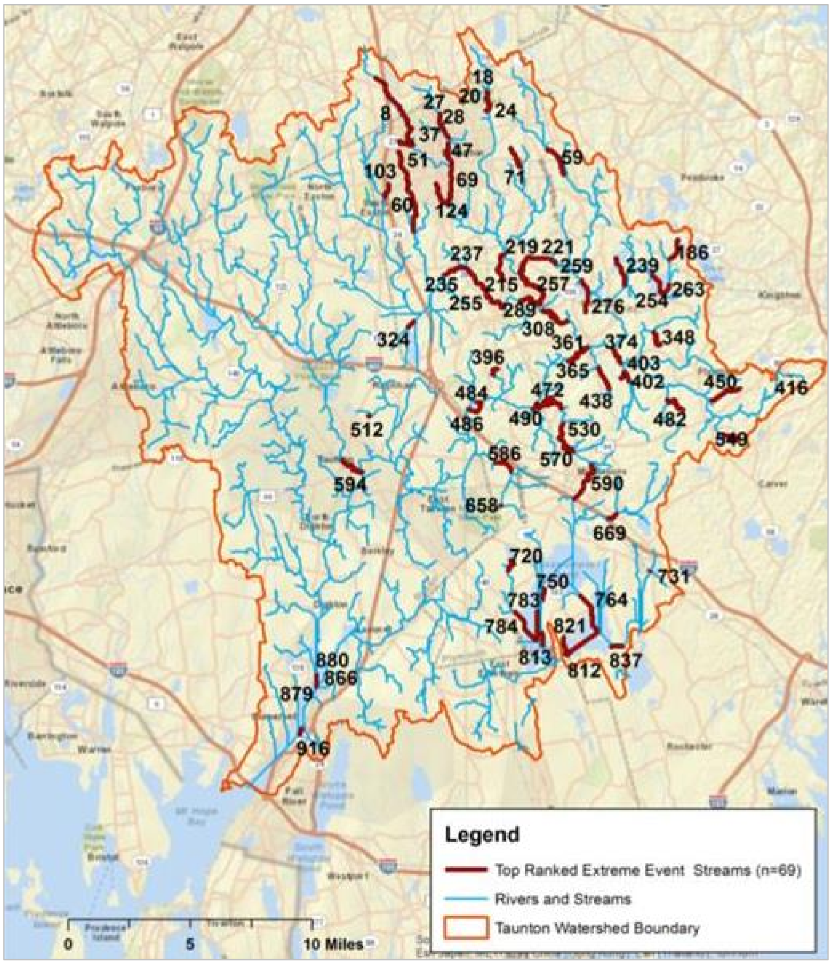
The top 25 overall highest-ranked stream segments for the instream analysis are distributed through the eastern and southern portions of the watershed (Figure 3-28). Bridgewater and Middlesboro contain the largest numbers of highly ranked segments among all the municipalities. These highly ranked segments can serve as targets for protecting the natural flow regime by stabilizing stream banks, protecting aquatic buffers, and regulating human alterations to the watershed.

Figure 3-28. Overall Top-Ranked Stream Segments to Protect the Natural Flow Regime in the Taunton River Watershed



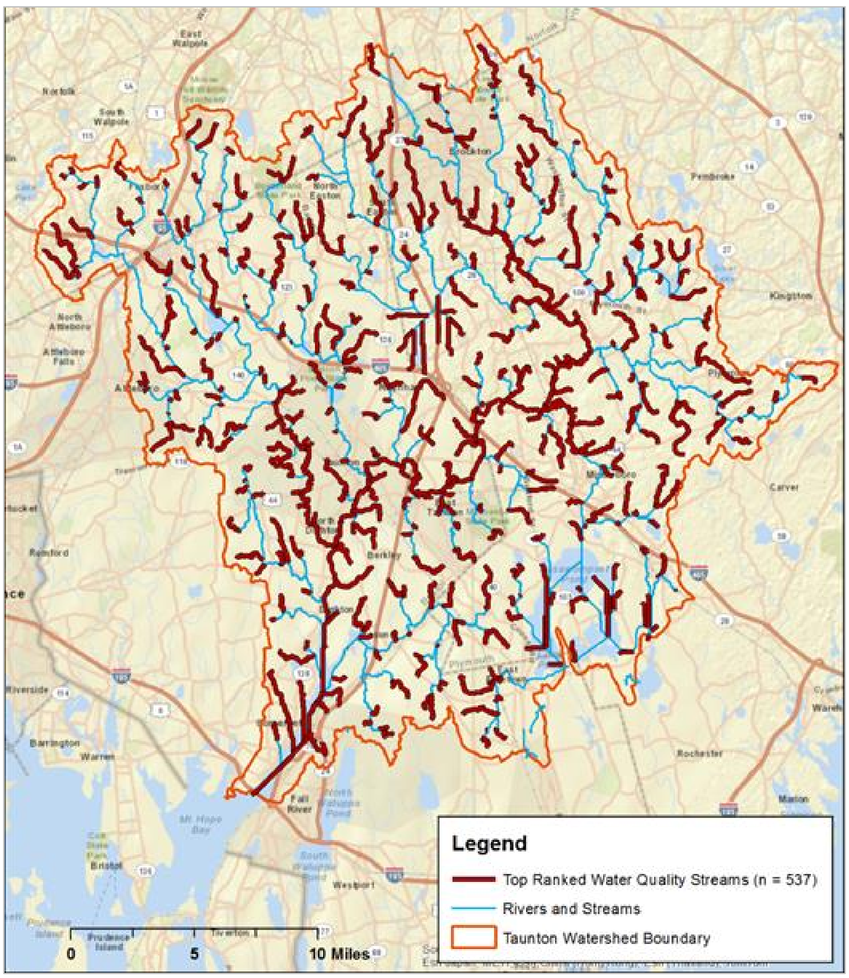
A total of 69 stream segments received the highest score for extreme event/flood protection in the watershed. Nearly all of these segments are located in the eastern portion of the watershed (Figure 3-29). Only one ES scoring factor was used to assess this ES for instream segments; these streams are areas where upstream land use (such as urban development or agriculture) produces a high runoff potential. The eastern region near Brockton and Bridgewater contains many of these segments. These areas could be targeted for conservation projects that use green infrastructure in urban areas to reduce the runoff potential of cities.

Figure 3-29. Top-Ranked Stream Segments for Flooding/Extreme Event Protection in the Taunton River Watershed



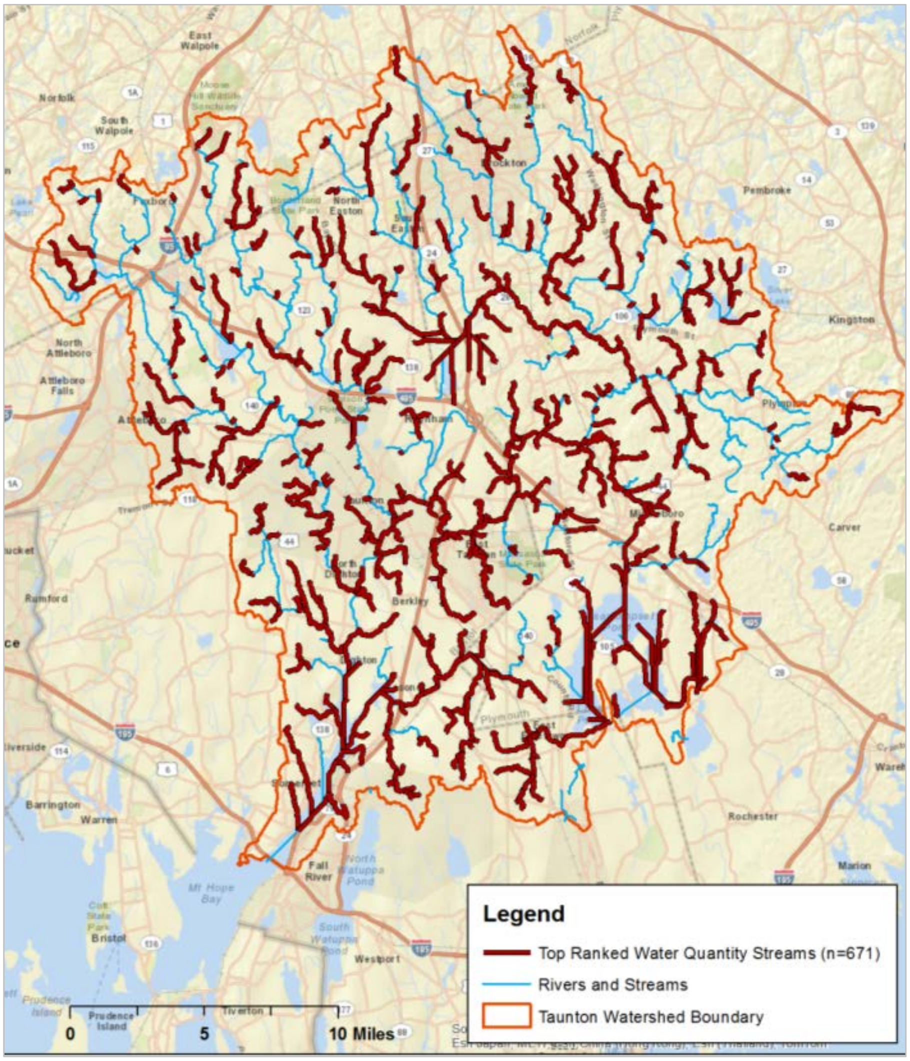
A total of 537 stream segments were highly ranked for protecting water quality because they were headwater streams with no upstream National Pollutant Discharge Elimination System (NPDES) sanitary discharges in their drainage areas or they included the mainstem of the Taunton River, which is protected as Wild and Scenic. Water quality was ranked for instream segments using two ES scoring factors describing the alteration by permitted discharges to the stream (continuous) and whether the segment was a headwater (discrete). The highly ranked stream segments are spread evenly across the basin but do not include some areas near the cities of Taunton and Brockton (Figure 3-30). The highlighted stream segments could provide focus for conservation efforts.

Figure 3-30. Top-Ranked Stream Segments for Water Quality Protection in the Taunton River Watershed



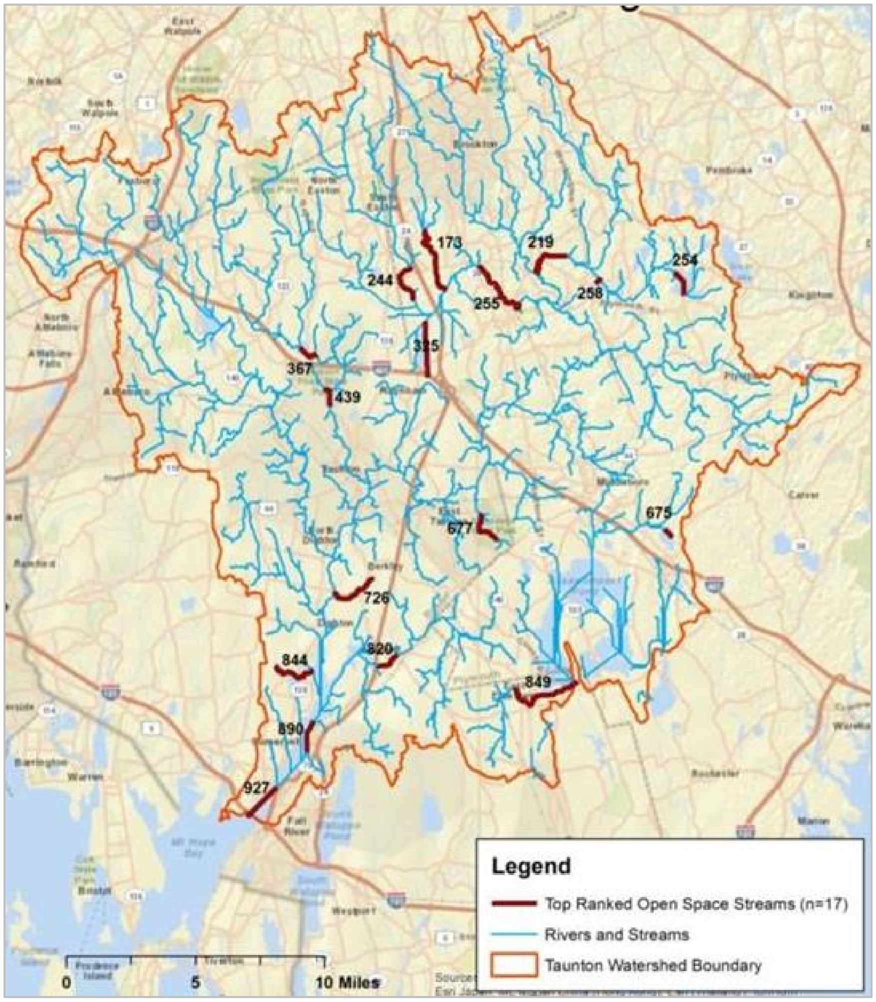
The majority of the stream segments (671) in the basin received the highest ranking for water quantity protection; they are distributed evenly across the watershed (Figure 3-31). These streams are in areas without high levels of human alteration of the natural flow regime due to withdrawals and discharges, reservoir storage capacity, or dam density.

Figure 3-31. Top-Ranked Stream Segments for Water Quantity Protection in the Taunton River Watershed



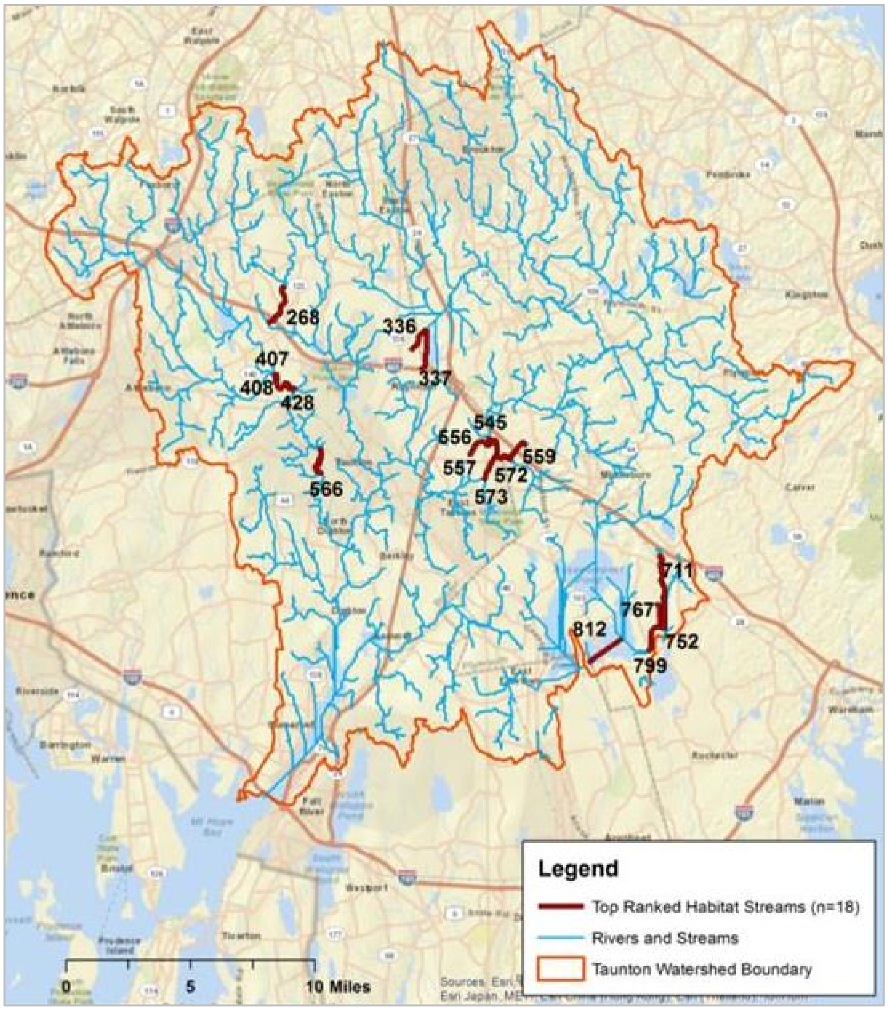
A total of 17 stream segments were ranked highest for open space protection in the Taunton River Basin. These segments are located in almost every region except for the northwest headwaters (Figure 3-32). Each of these streams has a fishing or boating access site and is used for recreation.

Figure 3-32. Top-Ranked Stream Segments for Open Space Protection in the Taunton River Watershed



Eighteen stream segments received the highest-rank score for biodiversity/habitat. The segments are located in the central and southeastern regions of the watershed (Figure 3-33). These stream segments include core habitat areas and species of conservation concern. The highlighted stream reaches can provide a focal point for projects that will upgrade or remove structures such as dams and culverts to increase habitat and connectivity for aquatic species.

Figure 3-33. Top-Ranked Stream Segments for Habitat/Biodiversity Protection in the Taunton River Watershed



4. Customizing and Applying the Assessment Framework

The findings presented in Section 3 depend on a defined set of input assumptions and specifications; however, the decision support tool is designed so that users can customize their own screening-level analyses for identifying priority conservation areas. It allows them to address their particular needs and interests and to apply their own specialized knowledge of the watershed by varying these input assumptions and specifications.

This section describes how the decision tool can be used and customized, with more detailed instructions provided in Appendix B. In addition to describing how the user can define the main inputs and scenarios of interest, it provides step-by-step instructions for transferring the tabular data results into a GIS platform for visualization and mapping. These steps assume that the user has basic proficiency with ArcGIS and Microsoft Access. This section also provides an illustrative example.

4.1 Designing Your Own "Top 10"

The purpose of providing a decision support tool is to allow the stakeholders within the Taunton River Watershed to become users of the data collected and analyzed for this study so that they may refine the results to meet the needs of their organization, study, or regulations. Users have multiple ways to refine the results and create their own top 10. Several of these methods involve altering the way the data are combined in the scoring of the ESs, while other methods simply focus on certain portions of the results. These methods are explained below, with more details provided in Appendix B.

Use different weighting schemes. As described in Section 2, the ES scoring factors are combined into a total ES score for each ES for each FA. Although the default analysis presented in Section 2 uses an equal weighting of all scoring factors when combining them, users can vary these weights within the database tool to apply more importance to certain scoring factors. For instance, users may be interested in what riparian wetlands provide the best protection from excess nutrients in the surface waters. They, therefore, may want to give a greater weight to the headwaters, upstream land use, and stream buffer ES scoring factors while decreasing (or zeroing out) the weights related to downstream distance and groundwater and surface water supply ES scoring factors. If users change these weights, a new top 10 is generated for the water quality ES. Consequently, a new top 10 is also presented for the overall ES scores for riparian wetlands.

Users may also change the weights applied to the total ES scores when combining scores into the overall score. The purpose of changing these weights is explained below in the focus by ES type description.

Change the thresholds used to divide continuous ES scoring factors into low, medium, and high categories. As highlighted in Section 2, the default methods used to categorize the ES scoring factors into low, medium, and high categories relied on specifying thresholds set using the geometric interval calculation function within ArcGIS. This method was intended to break the data into three approximately equally sized (i.e., number of units) groups regardless of what the data represented. In some instances, certain ES scoring factors can be better categorized using thresholds found within nature. Therefore, users may change these thresholds.

Focus by ES type (e.g., water quality). As shown throughout the figures in Section 3, each FA is scored by a series of ESs as well as an overall score. Therefore, users may choose to look at an individual ES rather than the combined score. Often, the FA units ranked as the top 10 are quite different across the different ES categories. Users may also choose to look at the overall score by giving a greater weight to one ES over the others. If users are more interested in protecting the resilience of human communities, they may give a greater weight to the ESs of extreme event protection, air quality, and water quality (as opposed to weighting habitat and open space equally or more highly) when examining riparian FAs, because these three ESs relate more directly to protecting against risks to human health, safety, and property damages.

Focus by location (e.g., municipality). Because many different governing entities are present in the Taunton River Watershed, stakeholders may also like to determine the highest-rated FAs within their area of responsibility. As described below, this type of geographically focused assessment must be completed within the mapping software after exporting all results for the chosen FA, ES combination, and joining of the results. Users may then use the GIS functions to select the FA units within their jurisdiction through an intersection or selection function. They can then sort and analyze the scores presented for the selected units.

4.2 Connecting to GIS and Using this Analysis

The decision support tool (Microsoft Access database) contains all the data analyzed for this study and presents results in tabular form. Each unit within each FA is indexed by a unique identifier code (UniqueID). This UniqueID provides a means to link the tabular data to the spatial data as displayed and labeled in the figures of Section 3. We created a spatial data layer that can be displayed within GIS for each FA. These spatial data layers in conjunction with the decision support tool allow the user to vary the display of the ranked FAs depending on decisions made within the tool.

To link the results created within the tool (see Appendix B for instructions on how to vary the results and refine the top 10 rankings), users must follow several steps first within the database tool and then within the ArcGIS program.

Within the database (see Appendix B for figures visualizing these steps):

- Select the results you wish to display in map form by opening one of the overall or ecosystem scoring tabs for a particular FA.
- Use the export functions from Microsoft Access to save the results as an external Microsoft Excel file. To do this, with the results table open, select the "External Data" menu from the top of the database program window.

- On this menu select the “Excel” button within the Export options section (second set of options after Import & Link options).

- Name the file as you choose and navigate to your desired folder for storing this file. Click OK and then Close.

Within ArcGIS:

- Open the basemap document supplied for the project.

- Activate the FA layer that represents your area of interest (turn off other FA layers if desired).

- Right-click on the chosen FA layer, hover over “Joins and Relates,” and then select “Join… .”

- On the dialog box that opens, in box 1 select the “UniqueID” field.

- In box 2, navigate to the file containing your results from the database, exported using the previous steps, using the browse button to the right of the box.

- Once the file is selected, in box 3 again choose the “UniqueID” field.

- You may then choose either the “Keep all records” or “Keep only matching records” button depending on whether you want to visualize only the top results you have exported (first option) or whether you would like to visualize both the ranked FA units as well as all the remaining units.

- Finally, click Validate Join and then Okay.

- Now use the display options within ArcGIS to vary the visualization of the results. Do this by again right-clicking on the FA layer then selecting “Properties” and then the “Symbology” tab within the dialog box that opens.

- Depending on the results you have chosen to display, you can select different fields and methods for display (e.g., vary by color the quantities reported within the “Final_ES_Score” field for riparian forests).

For further help on changing the display options, please see the ArcGIS help manual.

4.3 An Illustrative Example

The decision support tool can be used to identify highly ranked FA units for each ES category as well as for an overall combined score. As described in Section 2, the overall scores can also be weighted by development threat, unit size (area), or a combination of the two factors. The following example demonstrates how the decision support tool and these weighted factors can be used to identify an FA based on the conservation priorities of an individual user. To determine the scoring for this wetland, the various overall score options results display for riparian freshwater wetlands within the decision support tool are used. The specific results presented below can be found in the "Overall Scored," "Overall Scored Weighted by Development Threat," "Overall Scored Weighted by Area," and "Overall Scored Weighted by both Area and Development Threat" data tables. The results used for this example rely on the default weighting schemes for scoring factors and ESs within the database. Instructions on how to access these different results views are provided in Appendix C.

Table 4-1 shows the scoring results for a specific riparian freshwater wetland unit. This wetland, which has Unique ID of 6009, is shown in green in the map in Figure 4-1. When the weighting factors for area or development threat are not considered, the wetland is ranked 11th overall in the Taunton River Watershed based on its main overall score. However, as shown in the map, this wetland is located near a PDA along the boundary of Taunton and Norton. When the overall scores for all units are weighted by their development threat, this wetland moves up the rankings to number 4 overall. In addition, at just over 150 acres, this is a fairly large wetland. When the overall scores for riparian freshwater wetlands are weighted instead just by their size, this wetland is ranked 6th overall. The user can also choose to weight the results by both area and development threat, which then places this wetland as the third highest overall ranked riparian freshwater wetland.

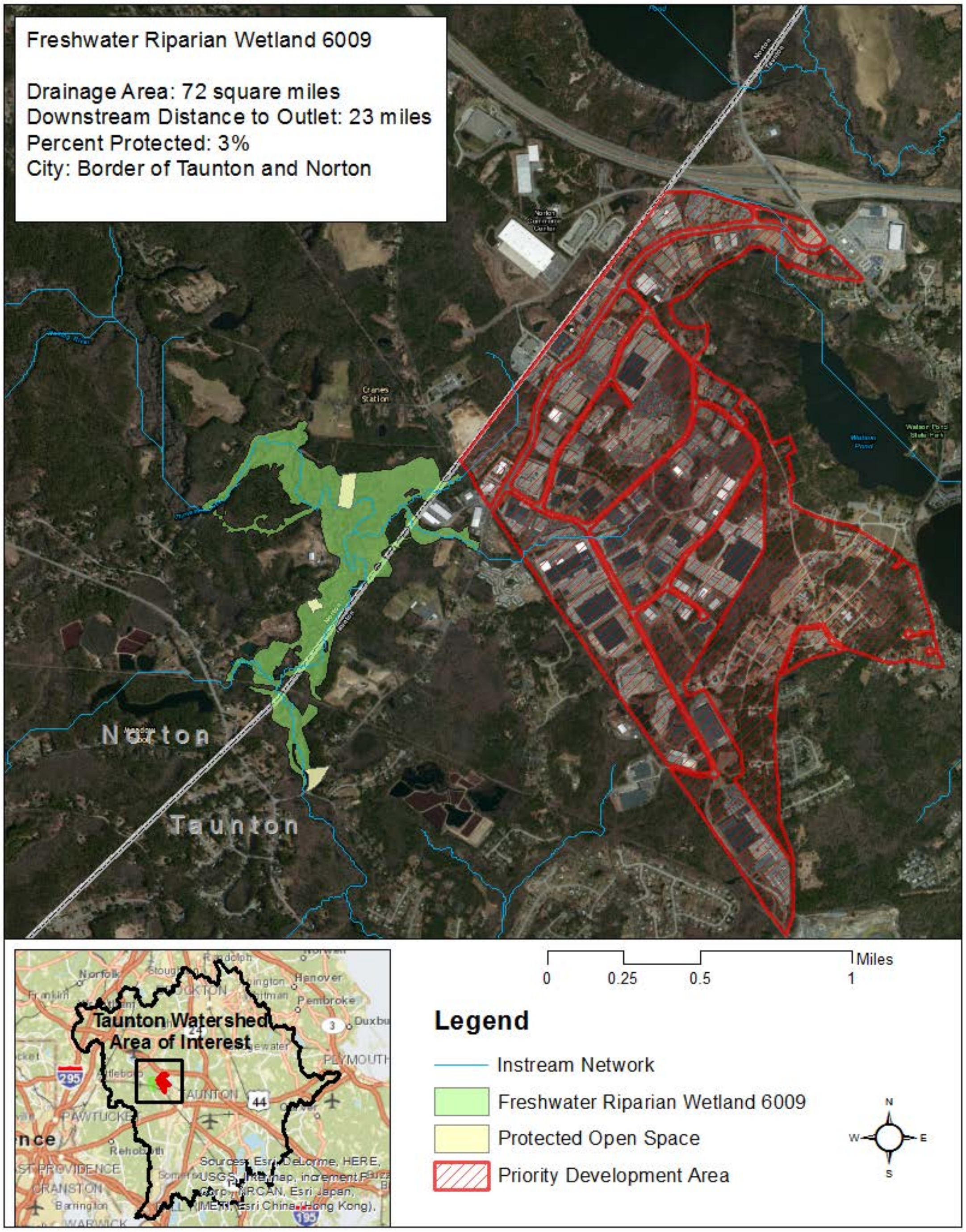
Table 4-1. Conservation Prioirity Rankings for an Example Riparian Freshwater Wetland (Uniquie ID 6009) Under Alternative User Specifications

Score Type and Weighting Method	Rank
Overall score, unweighted	11
Overall score, weighted by development threat	4
Overall score, weighted by area	6
Overall score, weighted by development threat and area	3
Total ES Score for air quality, habitat, and open space, unweighted	Highly Ranked
Total ES score for extreme event/flood protection and water quality, unweighted	Moderately Ranked

This example wetland can be located by joining the Unique ID field from the tabular data to the Unique ID field in the riparian freshwater wetlands spatial dataset (see Section 4.2 and Appendix C). The user can then use local knowledge and geospatial datasets to determine the best project actions for a particular focal area. In this example, stakeholders could choose to purchase or place a conservation easement on the property to prevent further development in the area. Possible improvements and/or restrictions could be made to the wetland site to increase open space or preserve wildlife habitat depending on the site-specific conditions for this example. Additionally, green infrastructure project opportunities could be explored in the neighboring industrial complex. Runoff, sediment, and nutrient loads could be reduced by implementing green infrastructure practices especially along the tributaries that flow into this wetland. These practices could include stream buffers, bioretention areas, bioswales, porous pavement, green roofs, or others depending on site-specific considerations.

This example demonstrates the flexibility of the decision support tool. Each user has the option to weight the overall scores as well as individual ES components to tailor results to the specific conservation priorities of each organization or group. By allowing users to conduct screening-level analyses with the tool to identify priority conservation areas, the results set the stage for these groups to then consider more specific actions at a site-level scale.

Figure 4-1. Example of GIS Map for Riparian Freshwater Wetland Unit



5. Conclusion

This report describes an assessment framework for identifying high-priority conservation areas in the Taunton River Watershed. In particular, it introduces and describes a decision support tool to assist in targeting areas that are best suited for conservation projects. This tool is primarily designed for conducting screening-level analyses in the watershed, allowing users to identify priority conservation areas under a variety of alternative user-specified conditions.

As a screening-level tool, it is intended to set the stage for more in-depth and site-specific analyses. First, although the system is designed so that stakeholders and decision makers can easily specify the input scenarios and conditions, the tool generates results in a simple tabular form. Therefore, to most effectively interpret and visualize these results with maps, it is expected that the main direct users of the tool's outputs will be environmental analysts with at least a basic understanding of and experience with geospatial data and applications.

Second, the framework created for this study also has the potential to be expanded to include additional ESs and/or ES scoring factors depending on data availability and watershed conditions. Users proficient in ArcGIS and Microsoft Access can easily modify or add to the data within the decision support tool as needed.

Finally, more advanced analysis of the trade-offs involved in selecting specific projects, actions, or ESs could be researched and applied to take the steps toward turning this screening-level analysis into a more site-specific or even an economic evaluation tool. As noted above, the ES scoring approach used in this report provides a practical, adaptable, and transparent method for quantifying ESs from natural lands and the stream network; however, the resulting estimates provide rather coarse approximations of the values of these services. A more detailed and data-intensive analysis would allow for more precise indicators of services. For example, the three-level categorization of the continuous scores could, in some cases, be based on ecological thresholds (e.g., literature values for the percentage of impervious cover in a basin that has an adverse impact on aquatic systems) rather than on purely statistical grounds.

To examine the cost-benefit trade-offs involved in selecting conservation actions, a more detailed analysis could also provide estimates of the economic values derived from some of these ESs. In some instances, the economic values of affected ESs can be derived from estimates of the direct and tangible savings or avoided costs to stakeholders. For example, the water quality improvements from wetland and forests in source water areas can translate to avoided drinking water treatment costs. One study found that each 10% increase in forest cover in a source water area can reduce treatment costs by 20% or more (Ernst et al., 2004). Many flood control benefits provided by riparian wetlands and forests can also be measured by the expected repair and replacement costs avoided for flood-damaged properties. In addition, some of the air filtration benefits provided by conserving forests in urbanized areas can be measured by the avoided human health costs. For example, a study by Nowak et al. (2010) estimated that Chicago's urban forests remove 12 pounds of harmful air pollutants per acre at an annual value of $43.3 per acre.

In other instances, the value of the services may be capitalized into the value of personal property, particularly in home values. For example, a recent meta-analysis of property valuation studies by Mazzotta et al. (2014) found that a 10% increase in open space within 500 meters of homes can increase home values by 1% to 2%.

In other cases, the monetary values of ESs are much less tangible but not necessarily less significant. An important case in point is the benefits humans derive from protecting species' habitats. Even if improving biodiversity and species richness does not increase personal income or help avoid costs, individuals' willingness to pay for these benefits is evidence of their inherent value (see, for example, Nijkamp et al., 2008).

Two other issues that are not addressed in this report but nonetheless require consideration for prioritizing conservation actions in the Taunton River Watershed are the costs and potential funding sources for these actions. Finding financing for conservation actions in prioritized areas presents an important challenge; however, there are a number of potential options, such as those described by Gartner et al. (2013) in their review of natural infrastructure investment programs in the United States. These options include a variety of government and utility investment approaches, private-sector initiatives, and market-based mechanisms (such as wetland mitigation banks, forest or conservation banks, and carbon credits) that may be available to Taunton stakeholders.

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Appendix A: Resources, Data, and Methods

A.1 Existing Studies

Because many municipalities and conservation and environmental advocacy groups have conducted studies within the watershed, a large body of literature and available datasets existed from which the ES scoring factors could be derived. Therefore, the first step to implementing our designed approach was to review the available studies from across the watershed and region. Table A-1 provides a synthesis of the major pertinent studies containing guiding information and available data used in the final creation of the ES scoring factors and subsequent analyses. A summary and inventory of other relevant reports and datasets is included in Appendix C.

Table A-1. Synthesis of Key Elements of Available Watershed Assessments and Analyses for the Taunton River Watershed

				Data Sources												Analysis						Findings				Findings Categories								Other		
Study	**Source/ Author**	**Stated Objective**	**Final Format**	**Land Use**	**Impervious Cover**	**Natural Areas**	**Active River Area (ARA)**	**Climate**	**Wetlands**	**Urban Areas**	**Water Quality**	**Biological**	**Dams/Culverts**	**Groundwater**	**Water Use**	**GIS**	**Ecosystem Services**	**Water Balance**	**Statistical**	**Modeling**	**Planning**	**Maps/GIS Layers**	**Benefits Table**	**Economic Assessment**	**Watershed Assessment**	**Green Infrastructure**	**Habitat**	**Water Budget/Hydrology**	**Sea Level Rise**	**Climate Change**	**Agriculture**	**Stormwater**	**Urban Development**	**Stakeholder Involvement**	**Primary Data Collection**	**Regulatory/Policy Stipulations**
Taunton River Watershed Climate Change Adaptation Plan	Manomet Center for Conservation Sciences, Plocinski, VanDoren, Walberg	—	Report	X	—	X	—	X	—	X	—	X	X	X	X	X	X	—	—	—	—	X	X	—	—	X	—	—	X	X	X	X	X	—	—	X
Taunton River Watershed Management Plan, Phase I: Data and Assessment	Multiple: Bridgewater State College, Horsley and Witten	Be a comprehensive long-term roadmap to protect and restore the sensitive natural resources of the Taunton watershed while enhancing the quality of life and vitality of the residents who live, work, and play in the watershed.	Report	X	X	X	X	—	X	X	—	—	—	—	X	X	—	X	—	—	X	—	—	—	X	—	X	X	—	—	—	—	X	X	—	X

— means not applicable

Table A-1. Synthesis of Key Elements of Available Watershed Assessments and Analyses for the Taunton River Watershed (continued)

				Data Sources												Analysis						Findings				Findings Categories								Other		
Study	Source/ Author	Stated Objective	Final Format	Land Use	Impervious Cover	Natural Areas	Active River Area (ARA)	Climate	Wetlands	Urban Areas	Water Quality	Biological	Dams/Culverts	Groundwater	Water Use	GIS	Ecosystem Services	Water Balance	Statistical	Modeling	Planning	Maps/GIS Layers	Benefits Table	Economic Assessment	Watershed Assessment	Green Infrastructure	Habitat	Water Budget/Hydrology	Sea Level Rise	Climate Change	Agriculture	Stormwater	Urban Development	Stakeholder Involvement	Primary Data Collection	Regulatory/Policy Stipulations
Massachusetts Sustainable Water Management Initiative	Multiple agencies: Energy and Environment Affairs, Environmental Protection, Fish and Game, Conservation and Recreation	Create a water allocation program that satisfies ecological and human water use needs, incorporate program into water withdrawal permits.	Report	—	—	—	—	—	—	—	—	X	—	—	X	—	—	X	X	—	—	—	—	—	X	X	X	X	—	—	—	X	—	X	—	X
Critical Linkages Phase I: Assessing Connectivity Restoration Potential	Landscape Ecology Program UMass Amherst, The Nature Conservancy	Assess the potential for restoring functional connectivity by dam removal, culvert/bridge replacement or use of wildlife passages.	Report	X	X	X	—	X	X	X	—	X	X	—	—	X	—	—	X	—	—	X	—	—	—	—	X	X	—	—	—	X	—	—	—	—

— means not applicable

A.2 Methods

The following sections define the specific technical steps taken to create the numeric values used to score and rank the ES scoring factors and ESs themselves.

A.2.1 Catchment Hydrology

Many of the scoring factors we used to score the ESs provided by each FA required the identification of the attributes upstream and/or downstream of the target. To process the upstream and downstream characteristics of all FAs, we needed the units within the areas to be indexed to individual catchments. These catchments have the linked navigation attributes showing the upstream/downstream order for each within the watershed. These navigation attributes allow for the summarization of the characteristics based on location within the watershed (i.e., calculation of upstream drainage area or distance downstream).

In the standard enhanced National Hydrography Dataset (NHDPlus), many of the catchments within the eastern portion of the watershed are very large. Therefore, many FA units would be grouped within a single catchment and the upstream/downstream calculations would be blurred (Figure A-1).

To provide more spatial granularity we created a new set of catchments from the 1/3 arc second (~9 m) national digital elevation data available for the watershed. The upstream-downstream connections between the new catchments are defined in similar fashion to the NHDPlus. The more linear catchment boundaries in the center and southeastern portion of the watershed mainly reflect center lines dividing some of the larger waterbodies and wetlands. However, the land areas of the watershed are well represented by the new catchment divisions (Figure A-2).

The following elements were used to generate the revised (but NHDPlus compatible) catchment segmentation and network for the Taunton River Watershed.

Input Data

- Elevation Data—Raster digital elevation model (DEM) datasets were obtained from the National Elevation Dataset (NED: http://ned.usgs.gov/) at 1/3 arc second resolution (equals approximately 10 meters across for each cell in the raster) for the Taunton River Watershed area. Note: Although higher resolution elevation data are available for Massachusetts, finer resolution elevation data were not needed to delineate the new catchments at the desired scale of this analysis. The scale was intended to capture the major streams and tributaries without creating an overly detailed catchment layer that would have complicated processing and visualization of FA units. In addition, more detailed elevation data would have greatly added to the processing time and level of effort for quality control for the catchment delineation with little gain in the definition of catchments within the watershed.

- Taunton River Watershed Polygons

Figure A-1. NHDPlus Catchments for the Taunton River Watershed

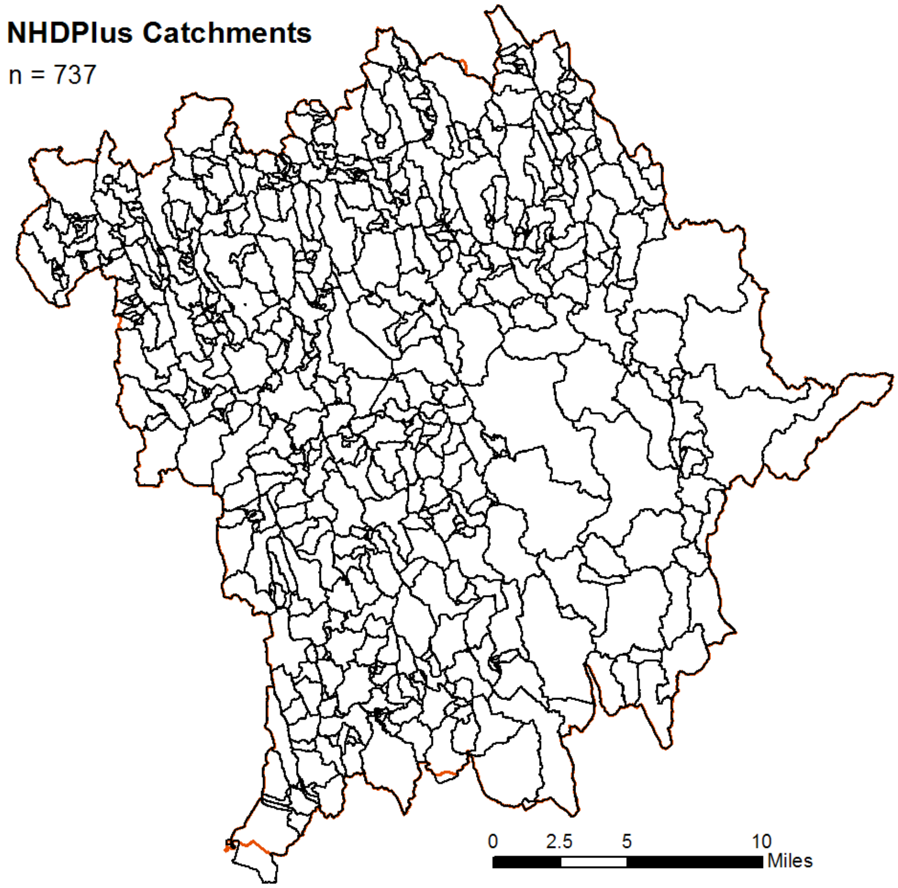
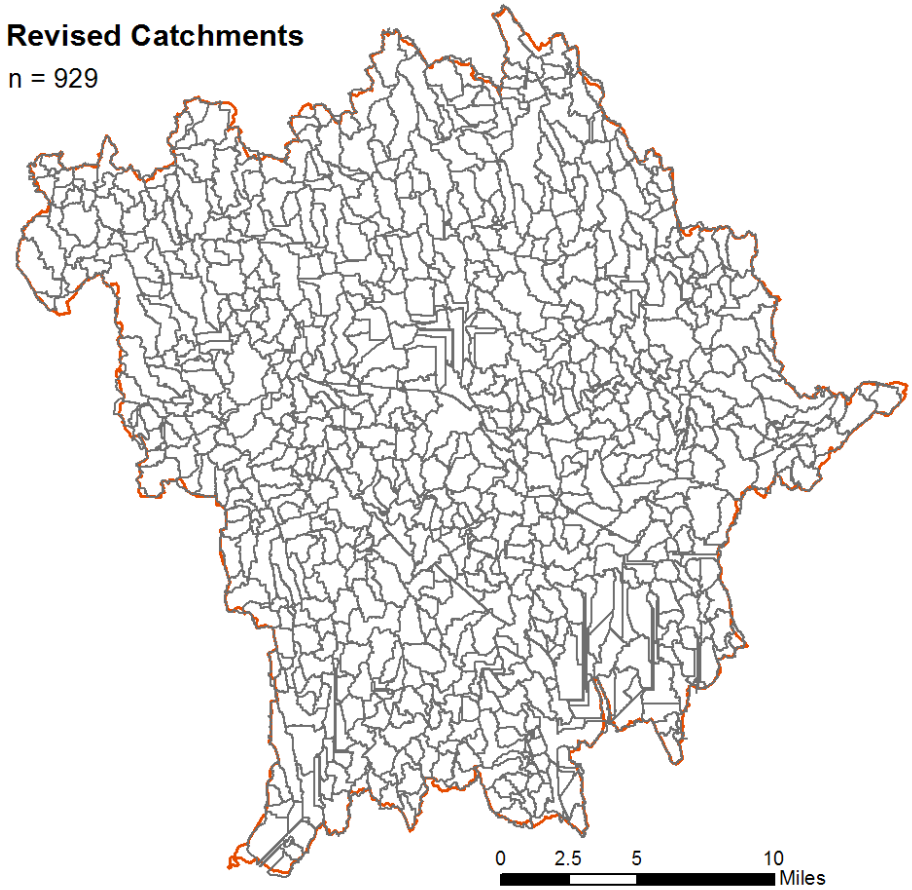


Figure A-2. Revised Catchments Created for this Assessment Based on 1/3 Arc Second Digital Elevation Data for the Taunton River Watershed



Catchments and Flow Lines from Elevation

The processes to create the initial version of the catchments were run within a geographic Information system (GIS), specifically ArcGIS by ESRI. The flow direction (1 of 8 directions) for each elevation cell was first determined with the “Flow Direction” tool. Next, the flow direction values were used to determine flow accumulation values for each cell using the “Flow Accumulation” tool. The flow accumulation values are the count of cells that are upstream of any particular cell. Virtual streams are then defined using these flow accumulation values to select only the cells that have a minimum number of cells upstream of them. We chose 10,000 upstream cells as our criteria to generate approximately 100 catchments within the Taunton River Watershed. These cells form the basis of a virtual stream network and are grouped into stream segments and assigned a unique ID by the “Stream Link” tool. A vector version of the raster stream segment network is created using the “Stream to Feature” tool. The resulting flow lines included the IDs of the flow lines that are upstream and downstream of each flow line so that the new stream network could be navigated. Lastly, the catchments associated with each stream segment (or flow line) were generated with the “Watershed” tool. The “Watershed” tool determined all of the cells that were upstream from all of the cells that make up each stream segment and assigned them the ID of the stream segment. A vector version of the catchments was then produced with the raster to polygon tool for display and further analyses.

Flow Table

The NHD-Plus flow table is used for navigating upstream and downstream within the flow line network and was created from the flow navigation information associated with each vector flow line. Headwater and terminal flow lines were identified and corresponding flow records were created for each case. Flow records were also created for each instance of a flow line flowing to another flow line. The resulting table can be used by tools that are designed to work with NHD-Plus.

Manual Postprocessing

After examining the results of the automated process by navigating upstream from the downstream terminus of the watershed it was found that some of the flow lines (130 of 1,916) were in isolated smaller stream networks and not part of the main network as expected. These isolated networks were reconnected to the main network in the following manner.

The NHD flow lines for the watershed were used as a guide to identify where the remaining disconnected streams should attach to the network. The appropriate disconnected stream line work and its associated flow information was edited to connect to the main network. Where flow lines were added or edited to connect to their correct destinations the associated catchment polygons were also amended as necessary to reflect the changes. We did find that upon closer examination 14 of the disconnected flow lines did actually flow out of the watershed and so were not reconnected to the main stream network.

A.2.2 Data Sources for ES Scoring Factors

Table A-2 provides a summary of the main data sources used to generate the ES scoring factors described in Table 2-4.

Table A-2. Data Sources for ES Scoring Factors

Ecosystem Service Scoring Factor	Data Source
Upstream Drainage Area	RTI catchments. Derived through methods outlined in Appendix A.
Average Curve Number	NLCD Land cover 2006: 16-class land cover classification scheme at a spatial resolution of 30 meters, based on Landsat imagery from 2001-2006 http://www.mrlc.gov/nlcd2006.php SSURGO soils data: collected by the National Cooperative Soil Survey by using soil observations and laboratory testing. Collected at scales ranging from 1:12,000 to 1:63,360 http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_053627
Population within floodplain and catchment	RTI synthetic population data: 2005-2009 US Synthetic Population version 2. https://www.epimodels.org/midas/Rpubsyntdata1.do MassGIS 100-year floodplain: FEMA Q3 Flood Zones, created by scanning FIRM maps and vectorizing the data, consistent with 1:24,000 maps. http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/layerlist.html
Hurricane Inundation Zone	Mass GIS: Hurricane Surge Inundation Zones, developed by the National Hurricane Center using SLOSH Model data. Updated in 2013.
Upstream Land Use	NLCD land cover 2006: 16-class land cover classification scheme at a spatial resolution of 30 meters, based on Landsat imagery from 2001-2006
Downstream River Miles	RTI flowlines. Derived through methods outlined in Appendix A.
Headwater Catchment	RTI catchments with no "from" node. Derived through methods outlined in Appendix A.
200 foot stream buffer	RTI flowlines. Derived through methods outlined in Appendix A.
Surface Water Protection Area	Mass GIS: Surface Water Supply Protection Areas, delineate areas included in the Massachusetts Drinking Water Regulations as Surface Water Supply Zones. Updated in 2013.
Groundwater Protection Area	Mass GIS: MassDEP Wellhead Protection Areas (Zone II), protection areas determined by hydro-geologic modeling approved by DEP's drinking water program. Updated in 2014.
Core Habitat	Biomap2: Developed by the Massachusetts Natural Heritage & Endangered Species Program and TNC in 2010 using specific data and sophisticated mapping and analysis tools. The Core Habitat layer identifies specific areas necessary to promote the long-term persistence of species of Conservation Concern, exemplary natural communities and intact ecosystems. http://maps.massgis.state.ma.us/dfg/biomap2.htm
Critical Natural Landscape	Biomap2: The Critical Natural Landscape layer identifies intact landscapes that are better able to support ecological processes and disturbance regimes and a wide array of species and habitats over long time frames. http://maps.massgis.state.ma.us/dfg/biomap2.htm
Species of Conservation Concern	Biomap2: Footprint of the habitat for species listed in the Massachusetts Endangered Species Act and others in the State Wildlife Action Plan. http://maps.massgis.state.ma.us/dfg/biomap2.htm
Access to Communities	RTI synthetic population data (Wheaton et al., 2009; see Section A.2.3)
Carbon Sequestration (unprotected wooded area)	Mass GIS: DEP Wetlands, developed at a 1:12,000 scale from stereo color-infrared photography. Wooded areas include wetlands categorized as Wooded Swamp. Mass GIS: Protected and Recreational Open Space, contains conservation lands and outdoor recreation facilities as well as levels of protection, ownership and public accessibility. Updated in 2014.

(continued)

Table A-2. Data Sources for ES Scoring Factors (continued)

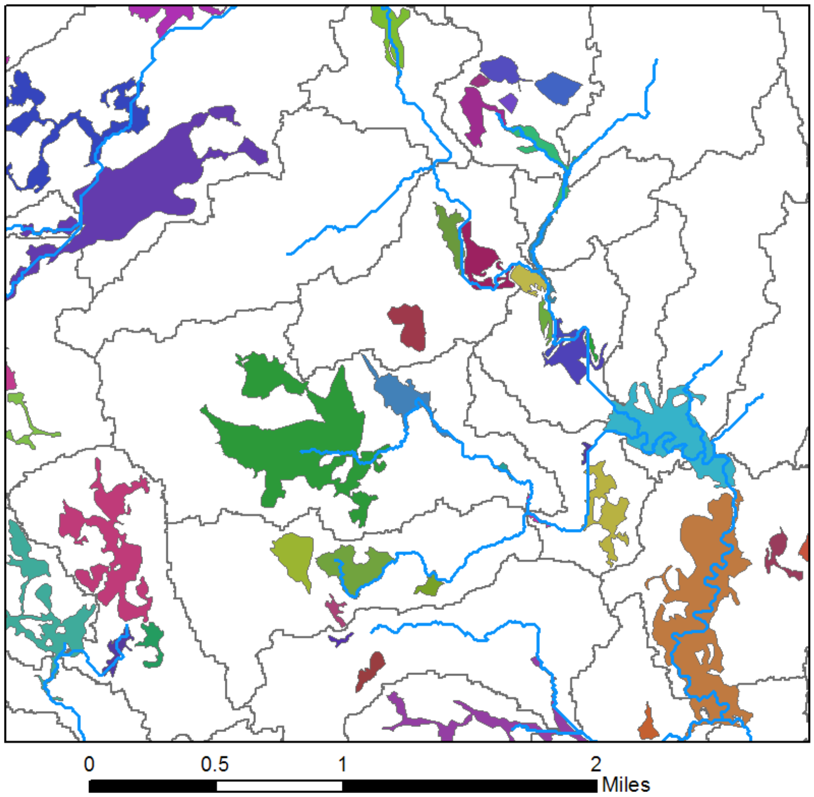
Ecosystem Service Scoring Factor	Data Source
Area of Wetland/Forest	Mass GIS: DEP Wetlands Mass GIS: Land Use (2005), created based on digital ortho imagery from 2005 at 0.5 meter resolution.
Threat of Development	Southeastern Regional Planning and Economic Development District (SRPEDD): priority development areas. Developed by local communities in the South Coast Rail corridor between 2008 and 2013. http://www.srpedd.org/scr-update U.S. Census: Urban Places. Areal locations for populated places in the United States, created between 2010 and 2012.
Active River Area	TNC: Active River Area. This layer includes both aquatic and riparian habitats that contain processes that interact and contribute to a stream channel over time. The layer was converted from a raster dataset to a polygon shapefile for this analysis.
Water Withdrawal and Returns	Horsley Whitten Report: NPDES permitted discharges, MA Water Management Act permit data
Dam Density	National Inventory of Dams (2005): created by the U.S. Army Corps of Engineers, contains technical specifications for each dam. http://geo.usace.army.mil/pgis/f?p=397:12
Reservoir Storage Ratio	National Inventory of Dams (2005): normal storage data, or the total storage space in a reservoir below the normal retention level. http://geo.usace.army.mil/pgis/f?p=397:12
Fishing/Boating Access	Mass GIS: Fishing and Boating Access Sites. Developed by the Massachusetts Department of Fish and Game, based on the public access to the waters of Massachusetts. Updated in 2014.
Increased Connectivity via Dam Removal	Conservation Assessment and Prioritization System (CAPS): Index for Ecological Integrity (best case) for dam removal. Developed by scientists at the University of Massachusetts Department of Environmental Conservation, the index for ecological integrity is based on the ability of an area to support biodiversity and ecosystem processes over the long term. http://www.umasscaps.org/
Increased Connectivity via Culvert Upgrade	CAPS: Index for Ecological Integrity (best case) for culvert removal. http://www.umasscaps.org/
Runoff Potential	NLCD land cover 2006, SSURGO soils data (see Average Curve Number)

A.2.3 Additional Calculations and Data Sources

Although much of the methodology used to derive the ES scoring factors relies on standard spatial processing methods, several decision points require further explanation. Those explanations are provided here.

Scoring for Multiple Focus Area Units in a Single Catchment: In many instances, the scores for location-based metrics (e.g., drainage area, downstream population) will be the same across multiple units in the same FA category, because they are located within the same catchment and, therefore, receive the same upstream/downstream and local rankings. These types of situations are illustrated in Figure A-3 for freshwater wetlands. Different colors are used to distinguish between separate wetland units, which often reside in the same catchment area. However, with 929 catchments, there is still scope for substantial variation in ES scores across units for each FA.

Figure A-3. Distribution of Wetlands (Multiple Colors) within Revised Catchments (Grey Outlines)



Downstream Metrics Calculation. For the metrics that are scored by measuring the characteristics as they occur downstream from a target, we have applied a time of travel threshold of 1 day to restrict the downstream area analyzed for each target. So for any target, we accumulate the characteristics for all catchments that fall within 1 day of travel time, on average, downstream of the target's catchment. We used the NHDPlus Value Added Attributes that include velocity to determine that 1 day's time of travel in the Taunton River Watershed is approximately 12 miles.

Synthetic Population Data. To score population-related metrics, such as number of people living within the floodplain below a wetland, we needed a better spatial representation of the population than can be gained through census data where the smallest unit is a census block group. The block groups are irregular shapes that do not follow hydrologic boundaries and do not provide enough detail to extract population counts for specific downstream areas. As an alternative, we applied the Synthetic Population Data, which were created for the National Institutes of Health's Models of Infectious Disease Agent Study (MIDAS) by RTI and partners (Wheaton et al., 2009). These data were generated using statistical extrapolations from the 2005 to 2009 5-year American Community Survey data. Although they do not represent actual households or locations of actual households, they do provide a statistically valid representation of the spatial distribution of households in the United States. As a result, this dataset allowed us to quantify the population metrics of interest with a higher level of spatial resolution.

Appendix B: Decision Support Tool Database User Guide

The database created to house, display, and assess the ESs-based metrics compiled for this study is meant to be an interactive tool that allows users to craft their own lists of FAs (e.g., riparian freshwater wetlands and/or upland forests) in which to target potential projects. Because the main document explains the concepts of FAs and the methods used to derive, rank, and assess the related ESs and scoring factors, those explanations are not repeated in this appendix. Rather this appendix provides a step-by-step guide to using the database.

The database is a Microsoft Access file that contains a series of navigable forms and data tables that lets the user view results and change the weights of scoring factors and ESs to craft their own analyses. This guide will step through each type of form in the order in which a user would likely progress through an analysis.

The database automatically opens to an introductory form that describes the purpose of the database. From this form, the user can select to view the results for one of the six different FAs assessed by clicking on the corresponding button (Figure B-1). This user guide uses the results of the Freshwater Riparian wetlands analysis to illustrate the database functions (Figure B-1A). The same steps can be followed to complete a similar analysis for the remaining five FAs (i.e., freshwater upland wetlands, riparian saltwater wetland, riparian forest, upland forest, and instream).

As described in the main document, each ES is valued through a series of scoring factors. Then these ESs values are combined to create an overall ranking for each FA unit (e.g., riparian freshwater wetland). The data behind the scoring factors, ESs, and overall ranking are all presented within the database as described below.

After clicking on the “View Freshwater Riparian Wetland Results” button, the user is taken to a form that displays a variety of options for viewing the results for this FA (Figure B-2). A short description of what the user will see and can do is provided to the right of the form for guidance (Figure B-2A). This form has three sections. The first section on the left side of the screen (Figure B-2B) lets a user view results of the combined ESs assessment for the riparian freshwater wetlands. The individual scores from the five ESs valued for the wetlands are combined into an overall ranking. This ranking can then be weighted by either the size and/or development threat of each individual wetland. The second section in the middle of the screen (Figure B-2C) lets a user look at the individual ESs valued for the wetlands one at a time. The third section on the bottom of the screen (Figure B-2D) allows a user to customize the analysis by changing (1) the thresholds used to divide the scoring factors into high, medium, and low ranked categories; (2) the weights assigned to the scoring factors for each ES; or (3) the weights used to combine the ESs into an overall ranking. We will now step through what happens when clicking on the buttons in each of these sections.

Figure B-1. Introduction Form that Is Automatically Displayed upon Opening the Database

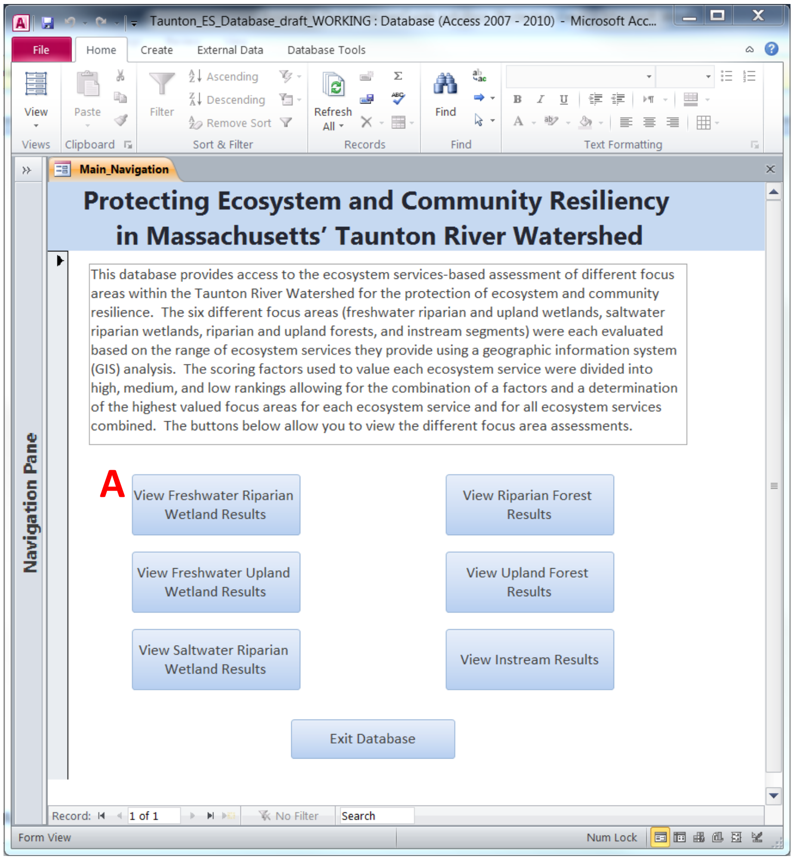
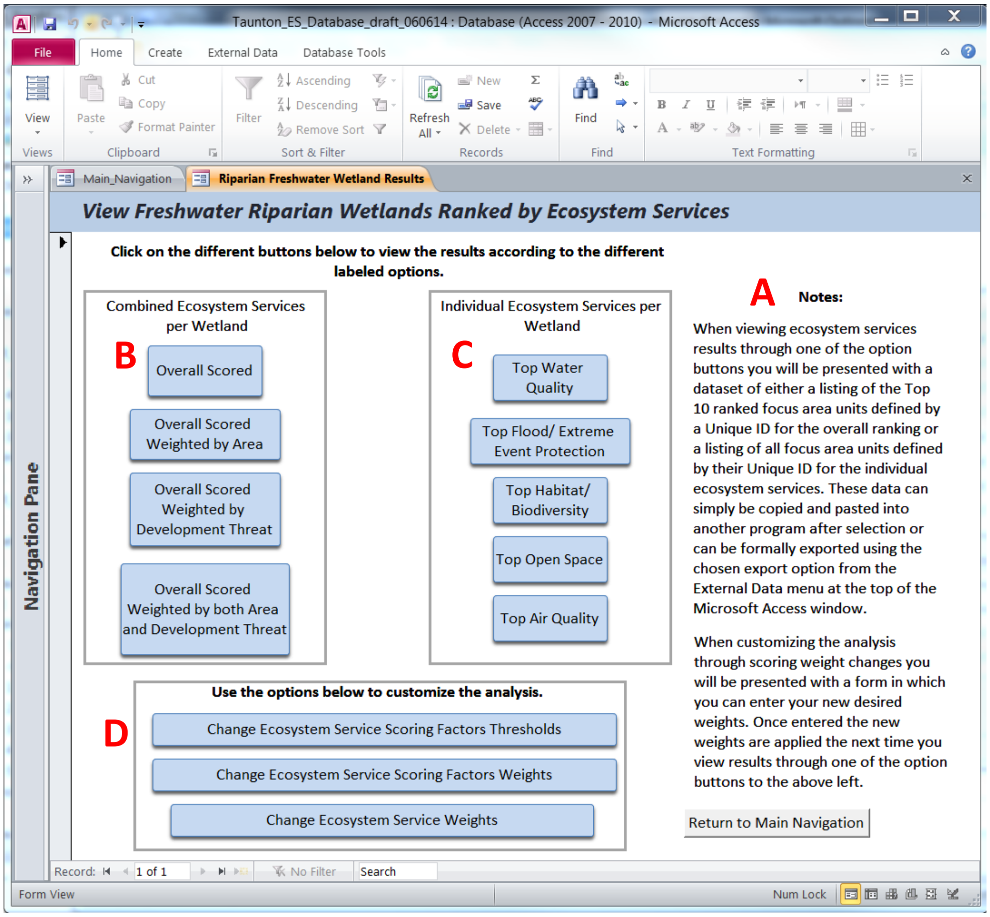


Figure B-2. Form to View Results of the Riparian Freshwater Wetlands Analysis. A Similar Form Is Available for the Other Five Focus Areas as Well

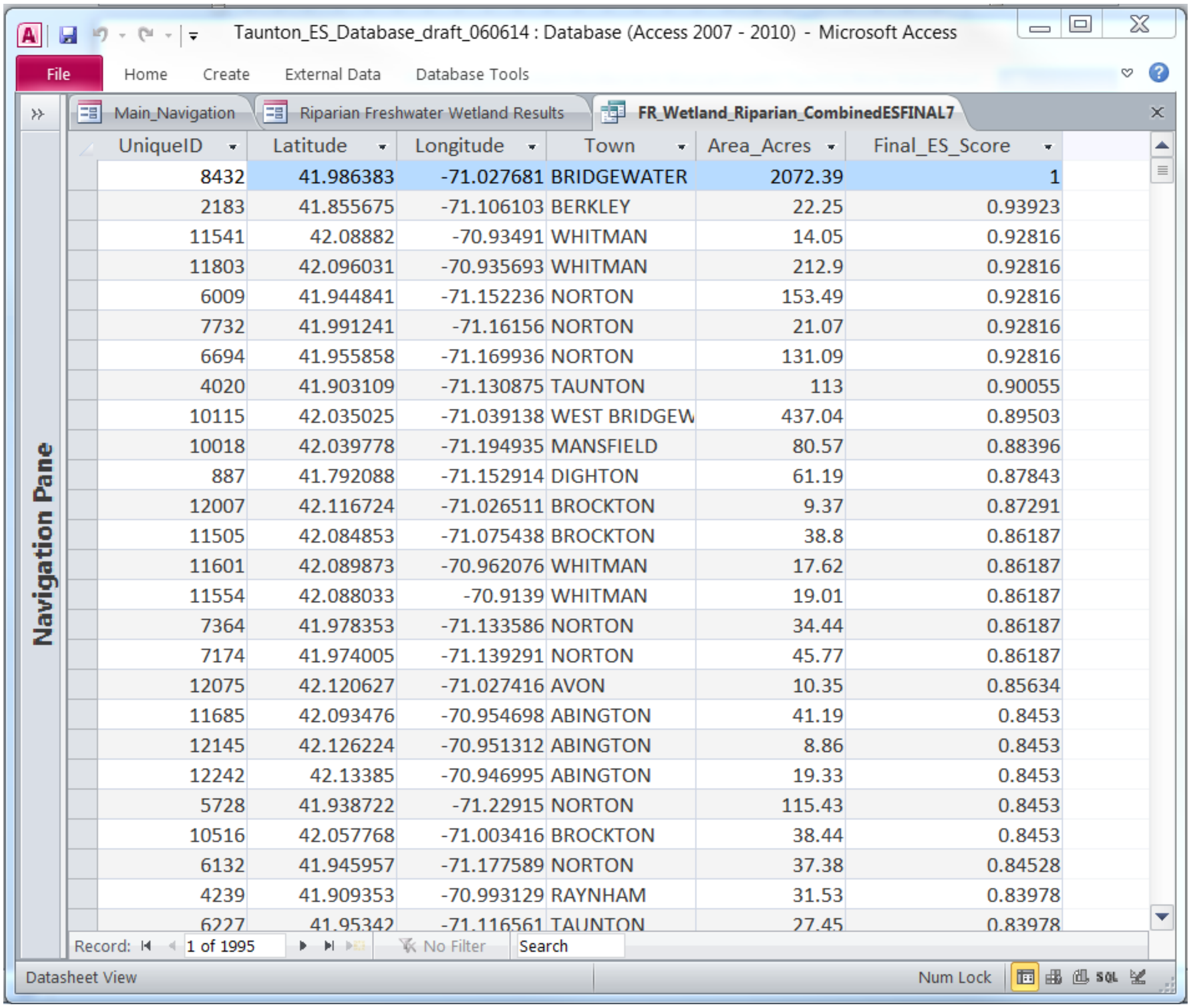


B.1 Combined Ecosystem Services

Click the “Overall Scored” button of the “Combined Ecosystem Services per Wetland” section (Figure B-2B) to start examining the combined, overall ES score for each wetland included in the riparian freshwater wetland FA. A table opens (Figure B-3) that displays the scored wetlands listed from highest to lowest rankings as identified by their individual Unique IDs. All final scores have been normalized on a scale of 0 (lowest ranked) to 1 (highest ranked) so that direct comparisons can be made between individual units. These scores will remain the same unless the user changes the weights on the ESs that are used when creating this overall ranking.

A note on the UniqueID: This identifier code is unique for each of the individual units assessed within each FA. For instance, using the first entry in Figure C-3, there is only one wetland identified by UniqueID 8432. This identifier code can be used to link the tabular results shown within the database to maps within a GIS using the supplied spatial layer for each FA. More information on this display is provided at the end of the document.

Figure B-3. Table Displaying the Top Results for the Overall, Combined Ecosystem Services Value for Riparian Freshwater Wetlands



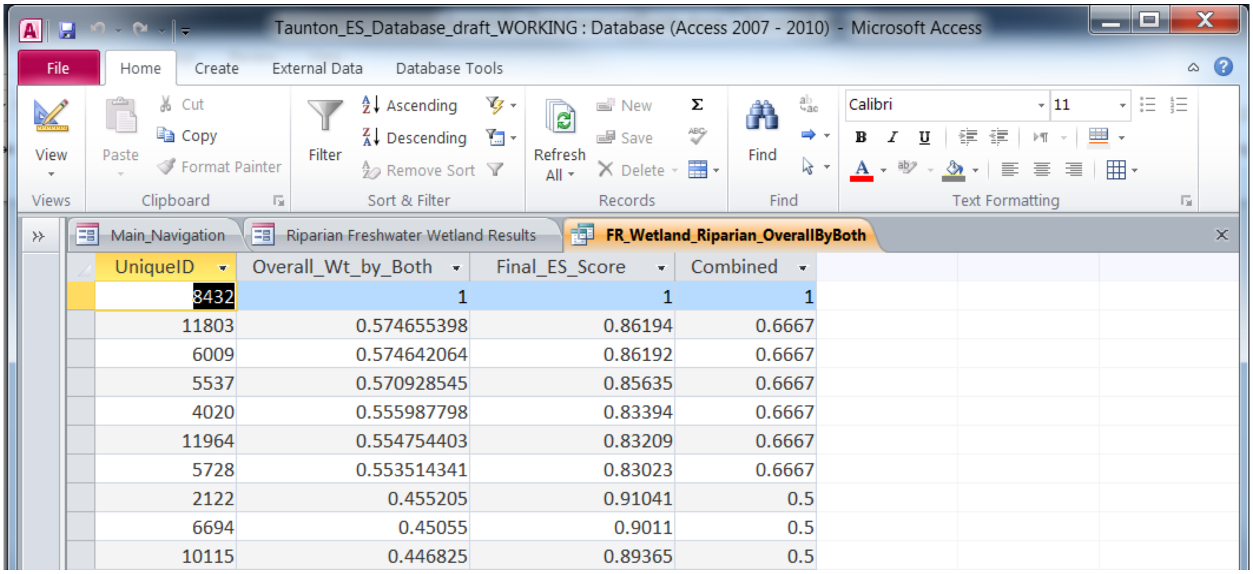
UniqueID	Latitude	Longitude	Town	Area_Acres	Final_ES_Score
8432	41.986383	-71.027681	BRIDGEWATER	2072.39	1
2183	41.855675	-71.106103	BERKLEY	22.25	0.93923
11541	42.08882	-70.93491	WHITMAN	14.05	0.92816
11803	42.096031	-70.935693	WHITMAN	212.9	0.92816
6009	41.944841	-71.152236	NORTON	153.49	0.92816
7732	41.991241	-71.16156	NORTON	21.07	0.92816
6694	41.955858	-71.169936	NORTON	131.09	0.92816
4020	41.903109	-71.130875	TAUNTON	113	0.90055
10115	42.035025	-71.039138	WEST BRIDGEW	437.04	0.89503
10018	42.039778	-71.194935	MANSFIELD	80.57	0.88396
887	41.792088	-71.152914	DIGHTON	61.19	0.87843
12007	42.116724	-71.026511	BROCKTON	9.37	0.87291
11505	42.084853	-71.075438	BROCKTON	38.8	0.86187
11601	42.089873	-70.962076	WHITMAN	17.62	0.86187
11554	42.088033	-70.9139	WHITMAN	19.01	0.86187
7364	41.978353	-71.133586	NORTON	34.44	0.86187
7174	41.974005	-71.139291	NORTON	45.77	0.86187
12075	42.120627	-71.027416	AVON	10.35	0.85634
11685	42.093476	-70.954698	ABINGTON	41.19	0.8453
12145	42.126224	-70.951312	ABINGTON	8.86	0.8453
12242	42.13385	-70.946995	ABINGTON	19.33	0.8453
5728	41.938722	-71.22915	NORTON	115.43	0.8453
10516	42.057768	-71.003416	BROCKTON	38.44	0.8453
6132	41.945957	-71.177589	NORTON	37.38	0.84528
4239	41.909353	-70.993129	RAYNHAM	31.53	0.83978
6227	41.95342	-71.116561	TAUNTON	27.45	0.83978

To return back to the menu of options for riparian freshwater wetlands, simply click the "x" at the top right of the table or right click on the orange-colored tab and select "Close."

The additional buttons within the "Combined Ecosystem Services per Wetland" section (Section "B" in Figure B-2) present the same overall score, but they are recalculated to be weighted by either the size of the individual wetlands, the threat for development to the individual wetlands, or both size and development threat. This weighting is completed by multiplying the original overall score by the corresponding score for the weighting factor. The weighted overall scores are again normalized to be between 0 and 1. Figure B-4 shows the results of weighting the overall scores by both size and development threat (last button in the "Combined Ecosystem Services per Wetland" section). The "Overall_Wt_by_Both" field shows the new weighted overall score, while the next two fields show the original unweighted overall score and the weight that was applied due to the two additional factors.

Note in comparing Figures B-3 and B-4 that Wetland 8432 remains the top-ranked riparian freshwater wetland in both analyses, yet the wetlands ranked numbers 2 through 10 are different between the two cases.

Figure B-4. Table Displaying the Top Results for the Overall Ecosystem Services Scores When Weighted by Both Size and Development Threat for Riparian Freshwater Wetlands



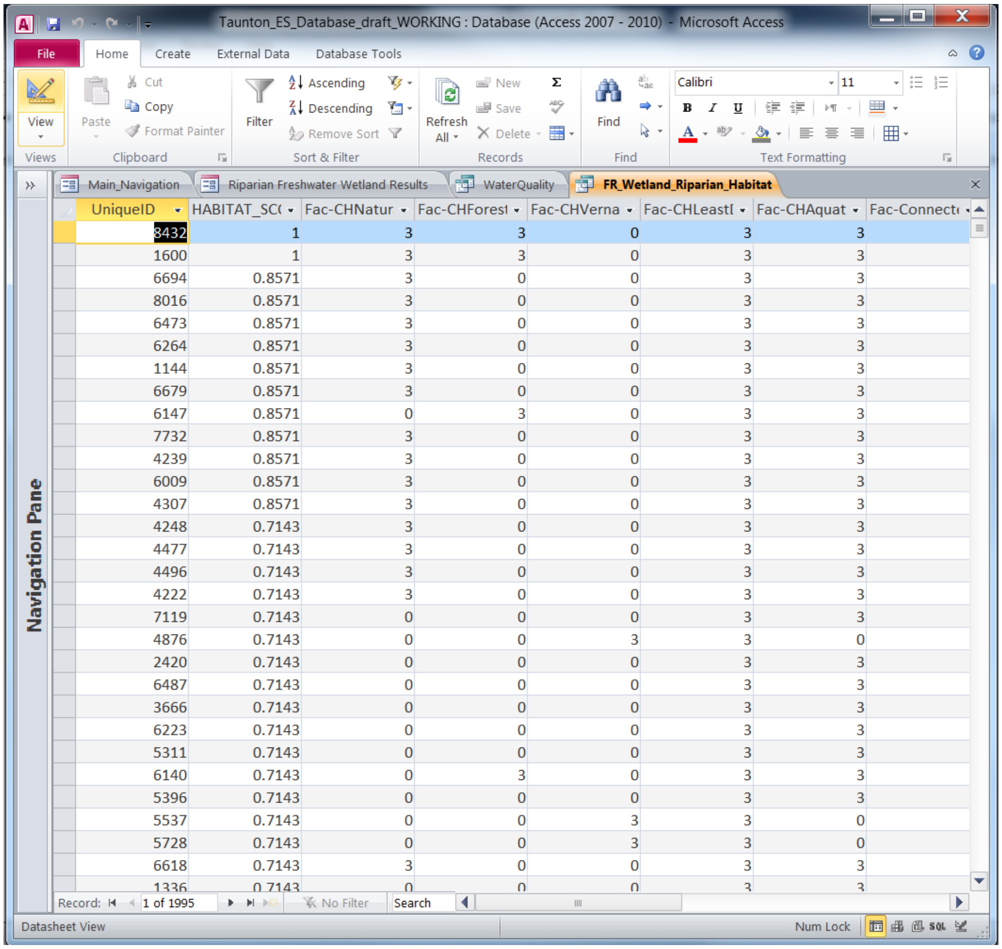
UniqueID	Overall_Wt_by_Both	Final_ES_Score	Combined
8432	1	1	1
11803	0.574655398	0.86194	0.6667
6009	0.574642064	0.86192	0.6667
5537	0.570928545	0.85635	0.6667
4020	0.555987798	0.83394	0.6667
11964	0.554754403	0.83209	0.6667
5728	0.553514341	0.83023	0.6667
2122	0.455205	0.91041	0.5
6694	0.45055	0.9011	0.5
10115	0.446825	0.89365	0.5

To return back to the menu of options for riparian freshwater wetlands, simply click the "x" at the top right of the table or right click on the orange-colored tab and select "Close."

B.2 Individual Ecosystem Services

Next we explore the "Individual Ecosystem Services by Wetland" section (Section "C" in Figure B-2). The buttons within this section correspond to each ES that was valued for the FA. For riparian freshwater wetlands there were five ESs: water quality, flood/extreme event protection, habitat/biodiversity, open space, and air quality. We use the habitat/biodiversity ES to illustrate the information available for each ES. Clicking on the "Top Habitat/Biodiversity" button (Figure B-2) opens the table shown in Figure B-5. Again, each wetland is shown by its UniqueID with corresponding scores for the habitat/biodiversity ES (field "HABITAT_SCORE"). In addition, the ranks for the scoring factors used to derive the ES score are provided for each wetland. The rankings are based on the numeric values derived through GIS analysis (explained in the main document) and represent high (3), medium (2), low (1), or no data (0) values for each scoring factor.

Figure B-5. Table Displaying the Results for Valuing the Habitat/Biodiversity Ecosystem Service for Riparian Freshwater Wetlands. This table includes the final score as well as the rankings of individual scoring factors used to derive that score.



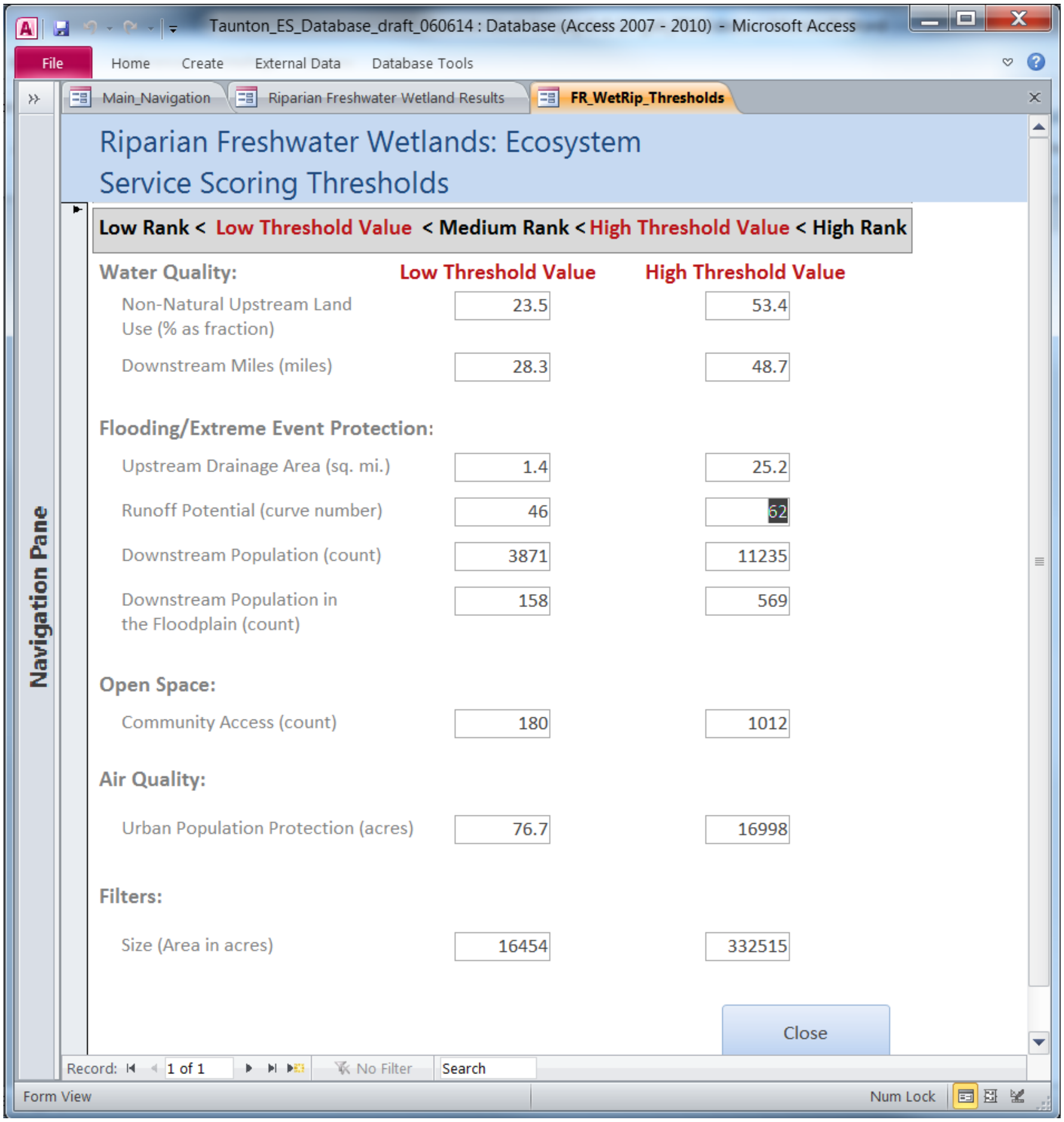
UniqueID	HABITAT_SC(	Fac-CHNatur	Fac-CHForest	Fac-CHVerna	Fac-CHLeastI	Fac-CHAquat	Fac-Connect
8432	1	3	3	0	3	3	
1600	1	3	3	0	3	3	
6694	0.8571	3	0	0	3	3	
8016	0.8571	3	0	0	3	3	
6473	0.8571	3	0	0	3	3	
6264	0.8571	3	0	0	3	3	
1144	0.8571	3	0	0	3	3	
6679	0.8571	3	0	0	3	3	
6147	0.8571	0	3	0	3	3	
7732	0.8571	3	0	0	3	3	
4239	0.8571	3	0	0	3	3	
6009	0.8571	3	0	0	3	3	
4307	0.8571	3	0	0	3	3	
4248	0.7143	3	0	0	3	3	
4477	0.7143	3	0	0	3	3	
4496	0.7143	3	0	0	3	3	
4222	0.7143	3	0	0	3	3	
7119	0.7143	0	0	0	3	3	
4876	0.7143	0	0	3	3	0	
2420	0.7143	0	0	0	3	3	
6487	0.7143	0	0	0	3	3	
3666	0.7143	0	0	0	3	3	
6223	0.7143	0	0	0	3	3	
5311	0.7143	0	0	0	3	3	
6140	0.7143	0	3	0	3	3	
5396	0.7143	0	0	0	3	3	
5537	0.7143	0	0	3	3	0	
5728	0.7143	0	0	3	3	0	
6618	0.7143	3	0	0	3	3	
1336	0.7143	0	0	0	3	3	

To return back to the menu of options for riparian freshwater wetlands, simply click the “x” at the top right of the table or right click on the orange-colored tab and select “Close.”

B.3 Customized Options

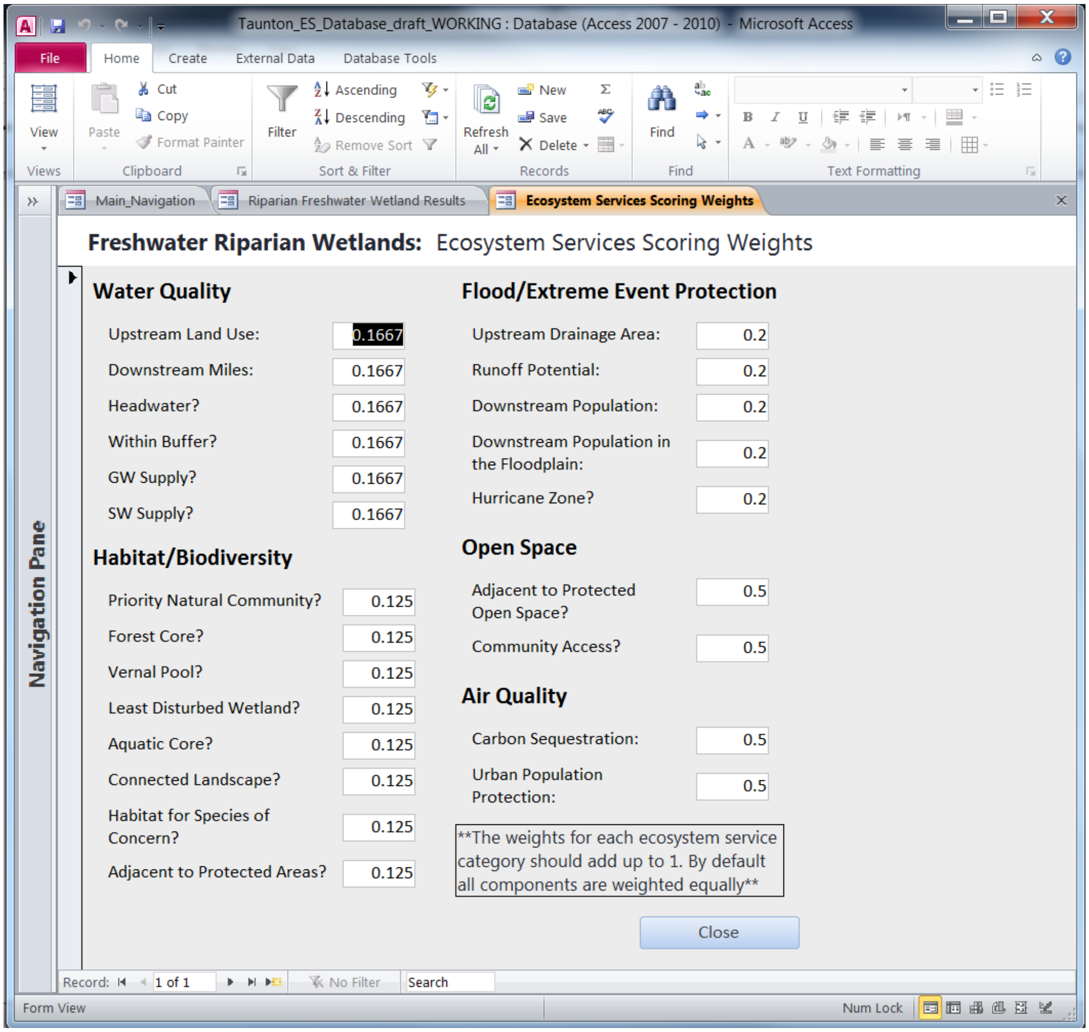
Finally, we explore the options to customize your analysis (Section “D” in Figure B-2). The top button (“Change Ecosystem Service Scoring Factors Thresholds”) allows the user to open a form (Figure B-6) to change the thresholds used to rank the ecosystem scoring factors into high, medium, and low categories. Each continuous scoring factor is listed under its corresponding ES category. Across the top, the user is shown how the two threshold values that can be entered for each factor are used in categorization. For riparian freshwater wetlands, a low rank is assigned to any area with a factor less than the first value (left column), a medium rank is assigned to an area with a factor between the two specified values, and a high rank is assigned to any areas with a factor greater than the second value (right column). The user is able to change these values, for instance, to better represent local knowledge on environmental thresholds.

Figure B-6. Form That Allows a User to Modify the Thresholds Applied to the Scoring Factors Used to Determine the Individual Ecosystem Service Values



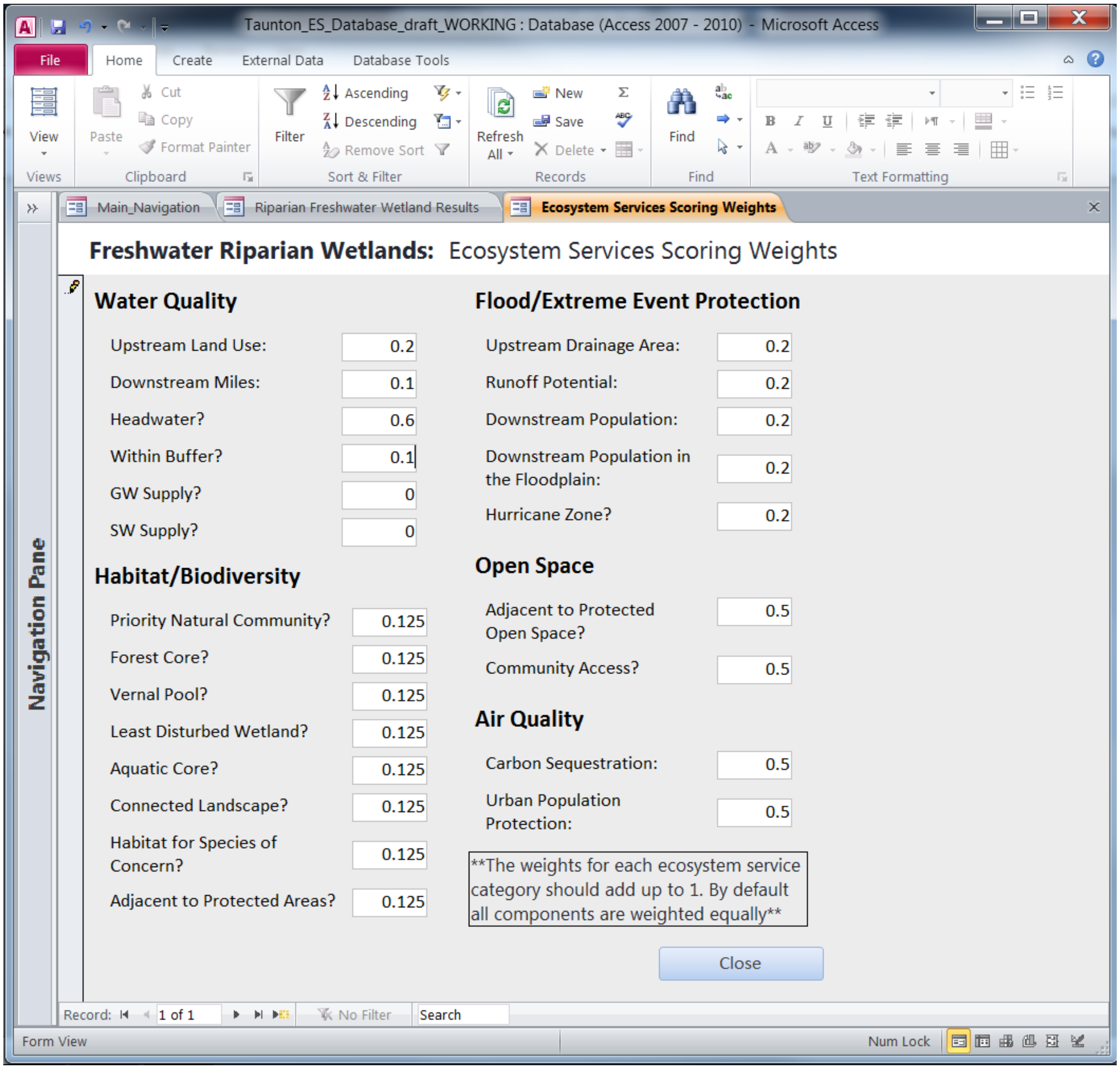
The middle button ("Change Ecosystem Service Scoring Factors Weights") allows the user to open a form (Figure B-7) to vary the weights used to combine the individual scoring factors for each ES. As previously noted, there were five different ESs valued for riparian freshwater wetlands. As shown in Figure B-7, each of these ESs was valued using a series of ecosystem scoring factors (e.g., upstream land use and downstream miles for water quality). The default analysis provides equal weighting to all scoring factors for an ES. For example, flood/extreme event protection used five scoring factors so each factor was given a weight of 0.2. The weights for any individual ES should add up to 1.

Figure B-7. Form That Allows a User to Modify the Weights Applied to the Scoring Factors Used to Determine the Individual Ecosystem Service Values. The default form provides equal weights across all scoring factors per ES.



The user may change these weights to modify the analysis to better focus on the factors of importance to their objective. Figure B-8 shows an example where a user wants to assess water quality from an ecosystem resilience standpoint. The user is most interested in wetlands that are within the headwaters (change weight to 0.6), noting that headwater areas provide high levels of protection for nutrients, and they are also interested although to a lesser extent in wetlands that have less developed upstream areas (change weight to 0.2), are further upstream in the watershed (change weight to 0.1), and are within the 200-ft stream buffer (change weight to 0.1). They have chosen not to assess the impacts to humans using surface and groundwater supply intersections (change weights to 0). By changing these weights, the user may go back to either the overall, combined ESs score or specifically the water quality ES score results to view the new top-ranked wetlands.

Figure B-8. An Example of a User-Supplied Set of Weights for the Water Quality Ecosystem Service Valuation for Riparian Freshwater Wetlands



The "Close" button will return the user to the menu of options for riparian freshwater wetlands.

The third option for user customization (Section "D" in Figure B-2) allows a user to modify the weights applied to the individual ESs when creating the overall, combined ES ranking (Figure B-9). Again, the weights applied should add up to 1. Figure B-10 provides an example where a user has chosen to focus only on wetlands that provide water quality and flooding/extreme event protection.

Figure B-9. Form That Allows a User to Modify the Weights Applied to the Individual Ecosystem Services When Calculating the Overall, Combined Ecosystem Service Ranking

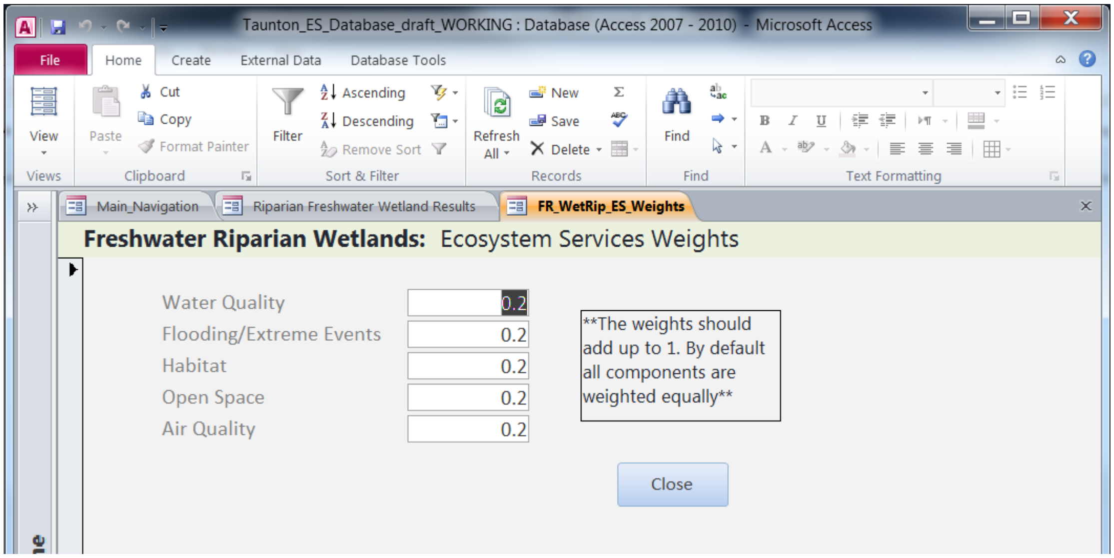
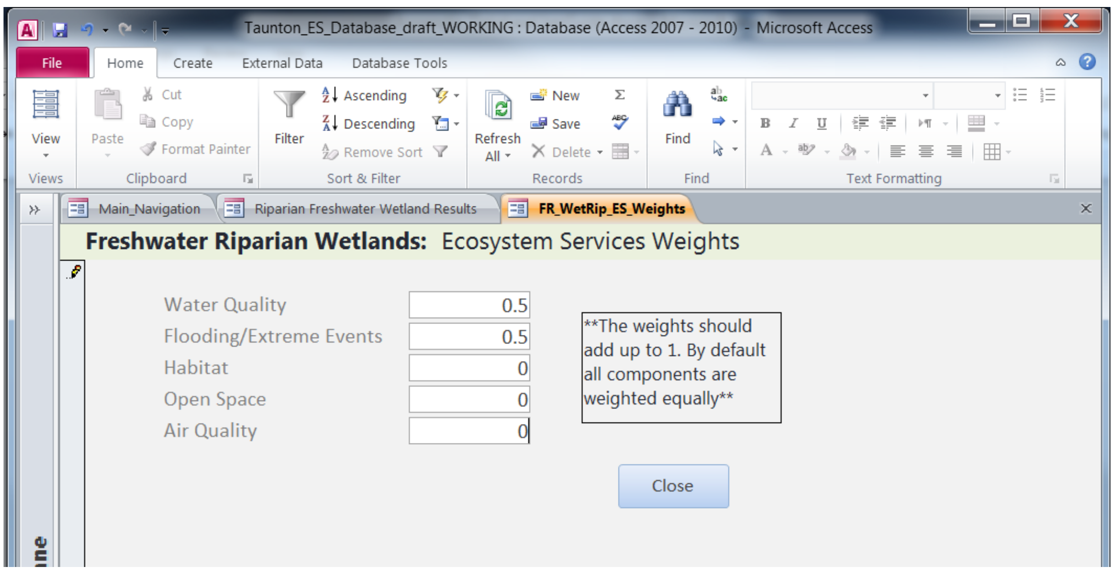


Figure B-10. An Example of a User-Supplied Set of Weights That Focus Solely on the Water Quality and Flooding/Extreme Events Ecosystem Services When Creating the Overall, Combined Ranking



The “Close” button will return the user to the menu of options for riparian freshwater wetlands.

B.4 Exporting Data

The preceding figures in this appendix explain the main functions within the database intended to allow user interaction with the ESs assessment completed for this project. To visualize the database results within map form, a GIS must be used. In any of the table views (e.g., Figures B-3, B-4, or B-5), the user may copy and paste or export the tabular results, which can then be used within a GIS. To copy the records from Access, highlight the fields of interest by clicking the small arrow in the top left corner of the table (highlights all records), clicking in individual cells, or holding your left mouse button down as you select individual rows. Then simply use the copy commands on your keyboard or the copy selection after right-clicking your mouse button to copy the results. Paste them into a spreadsheet or text editor of your choice.

A second option is to export the table as its own file. This is completed by selecting the “External Data” tab at the top of the Microsoft Access screen. Once viewing that tab you may select to export to an Excel file, text file, or another format of your choice.

With the results stored in a separate file, this file can be chosen within GIS to join to the corresponding FA spatial layer provided for the project. For example, you could export the overall, combined ESs ranked riparian freshwater wetlands and then join that file using the UniqueID field to the riparian freshwater wetlands GIS layer. Then you may choose to display the scores for those wetlands using the symbology options within GIS.

A separate ArcGIS shapefile for each FA accompanies this database tool and report:

- FRW_Freshwater_Riparian_Wetland—Freshwater Riparian Wetland units
- FWU_Freshwater_Upland_Wetland—Freshwater Upland Wetland units
- FRF_Riparian_Forest—Riparian Forest units
- FUF_Upland_Forest—Upland Forests units
- SRW_Saltwater_Riparian_Wetland—Saltwater Riparian Wetland units
- Stream_Segments—Stream Segments

In addition, there is a layer of the catchments derived for this analysis simply named Catchments.

Appendix C: Inventory of Taunton River Watershed Assessments and Data[6]

Prioritizing protection areas within the Taunton River Watershed involved developing an inventory of existing datasets and assessments relevant to informing the protection of watershed resiliency. This inventory is not meant to be a comprehensive catalog of all available data and studies for the watershed. A limited review of town ordinances was also conducted to highlight key bylaws, ordinances, and plans that are aimed at preserving open space and protecting water resources. A more complete and detailed review of town bylaws will be needed to understand gaps in protections within the watershed and zoning bylaws that should be enhanced. The accompanying Microsoft Excel workbook *Taunton_Inventory.xls* contains additional detail on the types of datasets available from each of the programs/projects identified in Table C-1 as well as website links to obtain the data.

Table C-1. Inventory of Datasets, Assessments, and a Few Town Ordinances Relevant to Informing the Protection of Resiliency in the Taunton River Watershed

Program or Project Name	Entity	Short Description
BioMap2	MDFG, NHESP, TNC	BioMap2 combines spatial data pertaining to species, ecosystems and landscapes, to identify core habitat and critical natural landscapes. Core habitats are areas that ensure long-term viability of species conservation; critical natural landscapes are larger land areas that support ecosystem processes and wide-ranging species.
Conservation Assessment and Prioritization System (CAPS) and Critical Linkages	U. Mass Amherst	CAPS is a GIS-based program allowing for assessments of ecosystem integrity and the prioritization of land for conservation activities. The CAPS process provides a final Index of Ecological Integrity (IEI) for points within the landscape based on models for each ecological community. Users can review IEI scores, connectedness, road traffic intensity, etc. The Critical Linkages report assesses connectivity restoration potential for culvert replacement, dam removal, and construction of wildlife passage structures.
USGS Flow and Impervious Cover Study	USGS	"Local and Cumulative Impervious Cover of Massachusetts Stream Basins" (Brandt and Steeves, 2009) includes a dataset summarizing the percentage of impervious surface in watersheds across MA using 1-m binary raster data from 2005.
MA Sustainable Water Management Initiative (SWMI)	MDEP	The SWMI Framework defines safe water yield for each watershed in MA and describes how stream flow criteria will be applied when issuing Water Management Act permits. An online interactive map was developed, which displays ground water withdrawal levels and biological categories (percent alteration of fluvial fish).

(continued)

[6] The content of this appendix was prepared by Cadmus Group, Inc.

Table C-1. Inventory of Datasets, Assessments, and a Few Town Ordinances Relevant to Informing the Protection of Resiliency in the Taunton River Watershed (continued)

Program or Project Name	Entity	Short Description
USGS Impervious Cover and Streamflow Alteration Study	USGS	The publication "Indicators of Streamflow Alteration, Habitat Fragmentation, Impervious Cover, and Water Quality for Massachusetts Stream Basins" (Weiskel et al., 2009) discusses streamflow alteration from water use; streamflow alteration and habitat fragmentation caused by dams; dam density; impervious cover; and water quality. The study was based in part, on findings from the Massachusetts Sustainable Yield Estimator.
MA Sustainable Yield Estimator	USGS	"The Massachusetts Sustainable-Yield Estimator: A decision-support tool to assess water availability at ungaged stream locations in Massachusetts" (Archfield et al., 2010) describes a decision-support tool, which provides screening-level estimates of the sustainable yield of a basin. The user may query the database from a basin to obtain the locations of water withdrawal/discharge volumes within the basin and a streamflow time series that includes the effects of these withdrawals and discharges.
Eastern Brook Trout Watershed Maps	EBTJV	EBTJV developed a scoring mechanism to prioritize watersheds and identify areas that are best for restoration, enhancement, or protection based on the predicted status of eastern brook trout. No subwatersheds within the Taunton River Watershed are identified as priority protection areas.
MassGIS Conservation/Protection Spatial Data	MassGIS	*Protected and Recreational OpenSpace* data layer—contains the boundaries of conservation lands and outdoor recreational facilities in MA. The database contains detailed information about each parcel, such as level of protection, public accessibility, and conservation restrictions. *Areas of Critical Environmental Concern* (ACEC) data layer- contains the boundaries of ACEC's, which are parcels displaying high quality landscape/resources, uniqueness, and natural and cultural significance. The areas are nominated at the community level and designated by the State's Secretary of Environmental Affairs.
Massachusetts Forest Stewardship Program	MDCR, MassGIS	MFSP was developed to educate and assist owners of forested land in protecting their land and associated ecosystem services. Landowners voluntarily enroll in the program and a licensed forester develops a site-specific 10-yr forest management plan based on the landowner's goals for protection and management. An available spatial dataset contains the boundaries of properties that have plans under the MFSP (as of 10/01/07).
MassGIS Drinking Water Protection Spatial Data	MassGIS	*DEP Wellhead Protection Areas* data layer—Zone II and Interim Wellhead Protection Area boundaries designated to protect the recharge area around ground water public drinking water supply sources. *Surface Water Supply Protection Areas* data layer—Delineated protection areas for reservoirs and Zones A, B, and C for surface water protection. Areas are subject to the protections in 310 CMR 22.00.
NHESP Habitat Data layers	MassGIS	*NHESP Priority Habitats of Rare Species*; *NHESP Estimated Habitats of Rare Wildlife*; *NHESP Living Core Habitats*; *NHESP Living Waters Critical Supporting Watersheds*. These data layers identify key habitat areas within the state.

(continued)

Table C-1. Inventory of Datasets, Assessments, and a Few Town Ordinances Relevant to Informing the Protection of Resiliency in the Taunton River Watershed (continued)

Program or Project Name	Entity	Short Description
Designated Shellfish Growing Areas	MassGIS, MDFG	Based on data compiled by the MDFG, this spatial dataset identifies shellfish growing areas in the state. These are areas of potential habitat. Data current as of 09/09.
LiDAR Terrain Data	MassGIS	Light Detection and Ranging (LiDAR) data for portions of Massachusetts. LiDAR is an active remote sensing technology that collects high resolution elevation measurements of topography.
FEMA Flood Hazard Maps	MassGIS	The FEMA flood hazard spatial dataset identifies the risk levels for floods, including the 1% (100 year) and 0.2% (500 year) annual chance flood events, and land areas with minimal risk for floods.
Northeast Aquatic Habitat Classification Project	WMI	The project involved developing terrestrial and aquatic classification systems and spatial data to enhance state conservation activities. The spatial data include natural flowing-water aquatic habitat types, in a consistent classification system across the northeast. Classifications include size (e.g., headwater, medium tributary, large river, etc.), gradient, geology, and temperature.
USGS SPARROW	USGS	The SPARROW model was used to estimate incremental nitrogen and phosphorus yields per hectare per year for the northeast. 2002 was used as the base year.
Factors Influencing Riverine Fish Assemblages in Massachusetts	USGS, MDCR, MDEP, MDFG	The study investigated fish assemblages in small and medium sized streams in Massachusetts. The purpose of the study was to determine relationships between fish assemblage characteristics and anthropogenic factors. Modeling results suggest a correlation between a 1% increase in the percent depletion of August median flow, and a 0.9% decrease in fluvial fish relative abundance.
MA Climate Change Adaptation Plan	EOEEA	The report provides a framework for assessing long-term solutions and developing strategies to enable municipalities and natural resources within the state to adapt to climate change.
State Wildlife Action Plan	MDFW	The Plan is a comprehensive strategy for wildlife conservation. The Plan takes a habitat approach to wildlife conservation, recommending the protection of small, medium, and large-scale habitats that are important to specific species in the most need for conservation (e.g., globally rare species; threatened, endangered, and special concern species). Key stressors identified in the plan include habitat destruction and fragmentation, contaminants, and invasive species.
Losing Ground: Beyond the Footprint	MassAudubon	The Losing Ground report researches recent land use changes and the ecological impacts of development in Massachusetts. For the Taunton River Watershed, the website describes land use statistics between 1999 and 2005 based on 2005 land use and protected land area. The report uses the BioMap Core Habitat layer to demonstrate viable habitat for rare species and natural communities as well as the Living Waters core habitat data and Natural Communities data layers from NHESP. Interactive maps on their website also present CAPS data.

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Table C-1. Inventory of Datasets, Assessments, and a Few Town Ordinances Relevant to Informing the Protection of Resiliency in the Taunton River Watershed (continued)

Program or Project Name	Entity	Short Description
Northeast Aquatic Connectivity Analysis	TNC, NEAFWA	TNC and NEAFWA received a grant to assist state resource agencies in the Northeast to strategically reconnect fragmented rivers, streams, lakes, and estuaries by removing fish passage barriers such as dams and malfunctioning culverts. Barriers were assessed and prioritized using five metrics, which were calculated in a GIS- Connectivity Status, Connectivity Improvement, Watershed and Local Condition, Ecological, and Size/System Type. Key datasets used in analyses were dams, natural waterfalls, anadromous fish habitat, and NHDPlus hydrography dataset. BAT is a GIS tool; NCAT allows users to re-rank dams at the watershed (and other) scales and develop modified scenarios.
Climate Change and Massachusetts Fish and Wildlife: Volume 2 Habitat and Species Vulnerability	Manomet Center for Conservation Sciences	The report details ecosystem responses and contains vulnerability evaluations for various ecosystems throughout the state. The report contains maps showing the locations of the habitats, where data is available, though often they are copied maps from other publications.
Massachusetts Rivers Protection Act	MDEP	The Act (1996) protects approximately 9,000 miles of riverbanks, which helps protect water quality, preserve wildlife habitat, and control flooding. The Act creates a 200 ft. buffer along riverfront area (high water line), extending on both sides of the waterbody. In some urbanized areas, the buffer is 25 ft.
Massachusetts Water Management Act	MDEP	The Act (1986) allows the state to regulate water withdrawals from surface water and ground water supplies. Water users could register (up to 01/04/1988) their existing water withdrawals based on their water use between 1981 and 1985. Since 1998, water users planning to withdrawal 100,000 gallons/day or more annually or 9 million gallons during a three month period, must apply for a Water Management Act permit. The Act helps to preserve natural instream flows and ensure water availability for current and future uses.
Massachusetts Farm Viability Enhancement Program	MDAR	This financial and technical assistance program provides farmers between $20,000 and $60,000 to sign 5- or 10-yr agricultural covenants to keep their farmland undeveloped. During FY 2012, the program provided technical assistance to 16 farms; 15 of which received funding through signed covenants protecting over 2,000 acres.
Taunton River Watershed Plan	Horsley Witten Group, Inc.	The purpose of the Plan is to protect and restore the Taunton River as a source of drinking water, and the basin's ecological and recreational values. Developing the Plan involved evaluating current conditions in terms of water use, water withdrawals and transfers, and developing tools and recommendations to protect and restore the watershed. Phase I involved data collection, a watershed assessment, and long-term visioning; Phase II involved implementing target pilot projects to demonstrate management efforts; Phase III will involve implementing the management measures on a wider-scale and adapt as necessary.
RIFLS flow monitoring for ungaged tributaries	MDFG	The RIFLS program developed a map of the Taunton River Watershed, allowing the user to click on site labels to obtain photographs and streamflow data for otherwise ungaged streams. Allows local groups and organizations to document streamflow and restore natural flow regimes in waterbodies that have experienced flow alterations.

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Table C-1. Inventory of Datasets, Assessments, and a Few Town Ordinances Relevant to Informing the Protection of Resiliency in the Taunton River Watershed (continued)

Program or Project Name	Entity	Short Description
Geographic Roadway Runoff Inventory Programs	SRPEDD	The GRRIP program has developed an inventory and assessment of roadway drainage systems in environmentally sensitive areas on federally eligible roadways. The Taunton River Watershed Pilot Project (2010-2011) involved a comprehensive assessment of in-stream barriers and roadway drainage facilities at vulnerable points in the watershed, particularly environmentally sensitive areas. Enables prioritization of transportation projects such as replacing, cleaning and maintaining culverts.
Providing Technical Assistance Tools in the Lower Taunton River Watershed	NEIWPCC	Using MassGIS and BioMap data (pre BioMap2), NEIWPCC identified critical natural resource areas within the towns of Dighton, Berkley, and Freetown, MA. The following layers were used: wetland and stream data, Zone II areas, Interim Wellhead Protection Areas, Aquifers, Core Habitat, Supporting Natural Landscapes, Priority Habitat and Wildlife Habitat. Areas were ranked according to layer overlap. For example areas with overlap from several layers were ranked higher than those with only one layer.
Nemasket River Shoreline Survey	MDEP	An extensive shoreline survey of the Nemasket River was conducted post April 2010 flood. The previous shoreline survey had been conducted in September 2003. The shoreline survey report contains anecdotal information on streambank stability, reach habitat, stream bottom, land use, fish observations, photos and copies of topographic maps.
Taunton Wild and Scenic River Study and Stewardship Plan	TWSRSC, SRPEDD, NPS	The Stewardship Plan provides a vision and strategy for management and protection of the Taunton River and its tributaries. The report contains background information on the watershed and stakeholders, current (as of 2005) management and protection, potential threats to resources, shoreline surveys, and action strategies for management. The Appendices of the report contain matrices of current bylaws and actions taken by towns in the watershed to protect natural resources.
Three Mile River Watershed Stewardship Plan	SRPEDD	The Three Mile River is a tributary of the Taunton River, flowing through the towns of Norton, Dighton, and Taunton. The River serves a critical link between a state designated Area of Critical Environmental Concern (Three Mile River), a federally designated Wild and Scenic River (Taunton River) and a federally recognized estuary and embayment (Narragansett Bay). The report describes the outstanding water and habitat resources within the watershed, as well as recommendations to deal with climate change.
Taunton River Watershed Climate Change Adaptation Plan	Manomet Center for Conservation Sciences	The draft Plan will include consolidated information on climate change and sea level rise models/projections, some discussion of non-climate change factors that impact adaptation (landscape fragmentation, urbanization, dams, aging infrastructure), as well as an assessment of ecosystems and ecosystem services vulnerability within the watershed. The Plan will also propose climate change adaptation strategies for Taunton River watershed.
Target Fish Community Models for Massachusetts Mainstem Rivers	MDFW	The MDFW developed Target Fish Communities (expected fish community composition based on reference area) for mainstem reaches of several rivers. The data were compared to the community actually found in these reaches. Information from these models allows for an increased understanding of the effects of aquatic habitat impairments. Note that the current fish community of Taunton River was unassessed, so there wasn't a comparison in this study.

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Table C-1. Inventory of Datasets, Assessments, and a Few Town Ordinances Relevant to Informing the Protection of Resiliency in the Taunton River Watershed (continued)

Program or Project Name	Entity	Short Description
Mill River Dams Feasibility Study	MA Riverways Program	The study looked at the feasibility of restoring fish passage at three impoundments on the Mill River in Taunton, which flows into the Taunton River. The study found that fish passage and river restoration are feasible, and the report offers concept-level design options for alternatives.
Additional Oxbow Preserve Land Purchase	TNC, Wildlands Trust	On 01/04/13, TNC purchased a 45-acre (1-mile river front) land parcel along the Taunton River. The land will be managed as a wildlife preserve, and is adjacent to the 63-acre Oxbow Preserve, thereby extending habitat corridors. Together, they comprise 175 contiguous acres of land designated for conservation on both sides of the river.
Priority Development and Priority Protection Designation	SRPEDD	SRPEDD is working with each of the 31 towns in the Region to identify and/or update Priority Development Areas and Priority Protection Areas. Original designations were made in 2008/2009 and the 5-yr update process began in December 2012 and January 2013. The website contains an interactive map of the designated areas from 2008/2009.
Massachusetts Community Preservation Act	MassGIS	Under this Act, communities can develop a Community Preservation Fund to raise money through taxes for protecting open space, preserving historic areas, and maintaining affordable housing. The Act also includes a state matching fund. There are Massachusetts Community Preservation Act Points and Towns spatial datasets available.
Taunton Conservation Ordinance	Taunton	The ordinance is designed to protect Aquifer Protection Zones, floodplain districts, control point and nonpoint discharges, and protect resources with commercially important fish, shellfish and vernal pool species.
Norton Wetland Protection District Bylaw	Norton	The bylaw establishes wetland protection districts within the town of Norton. "Dumping, filling, earth transfer, or relocation" are prohibited under the by law, and no new building or structure may be constructed, with few exceptions. In 02/11, Horsley Witten Group, Inc. worked with the town Conservation Agent and Commission to revise and expand protections afforded under the Wetland Protection bylaw though it has not yet been passed.
Open Space and Resource Preservation Development	Middleborough	Goal of the bylaw is to preserve natural open space in the town. Must be at least five acres for consideration. At least 40% of land shall be open space (not including roads or parking lots). Similar to Raynham's requirements.
Waterbody setback and wetlands protection	Mansfield	Sets a 100-ft buffer (high water line) between construction of primary use buildings and the Wading River, Canoe River, Rumsford River (a portion) and Hodges Brook. Buffer must be at least 20 ft from high water line for all other brooks and streams. Buffer of at least 20 ft for lakes and ponds as well. Standard wetland protection guidance.
Conservation Commission By-Law to protect wetlands and water resources.	Dighton	Standard protections, but does provide a 25-ft undisturbed vegetated buffer between wetlands and vernal pools and construction. Also subsurface sewage disposal systems are prohibited within 100 ft of any wetland or 200 ft of any perennial stream.
Open Space Corridor Protection Strategic Plan	Norfolk	The plan examines open space corridors within Norfolk, identifies areas/opportunities to preserve recreational uses and corridors between resources, and makes recommendations based on the analyses.

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Table C-1. Inventory of Datasets, Assessments, and a Few Town Ordinances Relevant to Informing the Protection of Resiliency in the Taunton River Watershed (continued)

Program or Project Name	Entity	Short Description
Master Plan	Norfolk	The Master Plan identifies goals for future growth and development through 2017. Conservation-related goals include: identifying and preserving natural resources and open space areas including wildlife corridors and water resources; acquire future well sites for future growth; prioritize parcels and work with the Community Preservation Committee to acquire water resources.
Rehoboth Agricultural and Natural Resources Preservation Trust Fund	Rehoboth	The committee may identify and purchase land, development rights and conservation restrictions to preserve existing agricultural lands and to use and preserve the natural resources of the town. Unclear what the Fund has been used for to-date.
Wetland Protection Bylaw	Wrentham	In addition to standard wetland and water resource protections, Wrentham's bylaw requires a 100-ft buffer on all streams (intermittent and perennial). Also, the town developed a new bylaw for vernal pools, effective 01/01/13, which creates a 100-ft buffer around all vernal pools. The buffer is greater than that provided under the Wetland Protection Act. Potential vernal pools also require the buffer unless the applicant can prove that it is not a vernal pool. The bylaw protects 'isolated' wetlands, which are not regulated under the state's Wetland Protection Act.
Water Resource Protection Overlay Districts	Raynham	While most towns within the watershed have protection districts which provide restrictions on land use and activities for Zones I (400 ft. radius from well), Zone II (areas that contribute to the aquifer) and Zone III (recharge areas), Raynham provides further protection. In Raynham, development is prohibited in Zone I. Special permits needed for most activities in Zone II, and some development in Zone III.
Wetlands Overlay District	Raynham	Only buildings that were lawfully constructed prior to the adoption of this bylaw are allowed within wetland districts. Development is now prohibited within these districts.
Transfer of Development Rights	Raynham	This bylaw allows for the transfer of development potential. This can effectively protect areas from development, while transferring the potential to an area that will have little impact from increased density. The bylaw encourages low-density development, preservation of open space, and protection of environmental resources.
Open Space and Cluster Zoning Bylaw	Multiple towns	This type of allows for smaller residential lots as long as a specified acreage of land is preserved as permanent open space.
Open Space and Recreation Plan	Multiple towns	The Plans are required by the state of Massachusetts in order for the town to be eligible for certain grants, such as the Self-Help, Urban Self-Help, Land and Water Conservation Funds, and other grant programs administered by the EOEEA. The Plans provide guidance and policy direction on open space and recreation issues within the town.
Regional Open Space Plan	SRPEDD	The Plan is for the towns of Berkley, Fall River, Freetown, and Lakeville. The purpose of the Plan is to encourage collaboration between the four communities in identifying regional issues and implementing regional planning initiatives on open space features such as trails and greenways.