The Duck-Pensaukee
Watershed Approach

Mapping
Wetland Services

Meeting
Watershed Needs

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St. Paul District

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This plan is not intended to be prescriptive or to change the wetland regulatory process; instead, it provides an array of choices for where to invest in either voluntary or regulatory conservation. It provides a first filter for the advance identification and comparison of these opportunities. As a "Level 1" watershed assessment (as defined by EPA's National Wetlands Monitoring Workgroup), existing data are used within a computer mapping (GIS) environment. This level of analysis can help to guide conservation investments toward sites that are most likely to result in conservation gains by comparing their relative potential to provide services, across an entire watershed. Because available datasets may be coarse in resolution, results of the assessment must be verified through on-site visits before developing and implementing site-specific plans.

The Duck-Pensaukee Watershed Approach

Mapping Wetland Services, Meeting Watershed Needs

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EXECUTIVE SUMMARY

Wetlands are the powerhouses of the natural world. They provide critical habitat for wildlife and play pivotal roles in ecosystem processes, often to a much greater degree than the lands that surround them. Wetlands provide the "green infrastructure" necessary to sustain healthy communities and economies – protecting water quality, maintaining water supplies, and reducing flooding issues. All wetlands provide important ecological services for people and wildlife, and the benefits of a wetland-rich landscape are valuable and varied. Clearly, loss of wetlands through draining or filling has high costs for people and nature.

Through development of a watershed context this plan identifies the top tier of sites for preservation and restoration, based on their potential to protect water quality, abate flooding problems, maintain surface water supplies, protect shorelines, store carbon, and provide habitat for fish and wildlife. Results of the plan are intended to guide—but not prescribe—the selection of wetland conservation sites (i.e., preservation, restoration, and management opportunities) in both regulatory and non-regulatory settings.

This plan provides Great Lakes coastal representation in a larger effort by The Nature Conservancy (TNC), Environmental Law Institute (ELI), and others to develop pilot studies for watershed-based conservation of aquatic resource, as outlined in the 2008 compensatory mitigation rule under §404 of the Clean Water Act. As part of this effort, ELI and TNC are working with wetland experts nationwide to develop a handbook that demonstrates the range of planning options for watershed-based compensatory mitigation. Our goal is to describe approaches that are relevant to the 404 program, within other regulatory programs, and also for the voluntary conservation of aquatic resources.

Although this plan offers one example of how to develop a watershed plan that is consistent with the 2008 final mitigation rule, this does not imply approval by the Corps, state agencies, or other regulatory agencies. In the context of the §404 program, it is the sole authority of District Engineers to determine whether a plan is appropriate for use (CWA §332.3(c)(1)). The methods and recommendations offered here represent the views of TNC, ELI, and partners involved in the development of this plan. As part of this pilot study we continue to work closely with the Corps' St. Paul District, Wisconsin Department of Natural Resources, and other Interagency Review Team members to inform decisions related to aquatic resource conservation programs.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

A. INTRODUCTION AND BACKGROUND

All wetlands provide important services to people and wildlife, and the benefits of a wetland-rich landscape are valuable and varied. The Duck-Pensaukee Watershed Approach uses what we know about wetlands – and what we know about wetland resources of this watershed in particular – to identify the top tier of sites for preservation and restoration of these wetland benefits. Using a watershed approach to set goals and to guide where conservation happens, we can work together to more effectively preserve and restore the health and well-being of the Duck-Pensaukee's habitats and communities.

This is a watershed plan for the preservation and restoration of wetland services as well as wetland area – within both regulatory and voluntary contexts. Its scope is not limited to mitigation. The intent is to link compensatory mitigation to local, non-regulatory conservation goals (i.e., preservation, restoration, and management), to the benefit of both. Results and recommendations may be used by a wide array of stakeholders in the watershed, including but not limited to: agency regulatory and protection staff, transportation departments, wetland bankers and private consultants, staff of local governments, other local land use decision-makers, land trusts, and other non-governmental conservation organizations.

A.1. Project context

In 2008 the Environmental Protection Agency (EPA) and the U.S. Army Corps of Engineers (Corps) issued new regulations for compensatory mitigation under §404 of the Clean Water Act (CWA). The "2008 Mitigation Rule" reaffirmed the mitigation hierarchy for regulatory protection of wetlands and waterbodies: first *avoid* impacts, then *minimize* those that are unavoidable, and finally *compensate* for lost resources. Drawing from recommendations provided in a comprehensive study of compensation effectiveness under the CWA (NRC 2001), the Rule also asserted that compensations (e.g., preservation and restoration actions) must be sited with respect to the context and needs of the watersheds in which they occur. Furthermore, compensation should be accounted for in terms of ecosystem services (e.g., water quality protection, flood abatement, provision of habitat) as well as area.

The 2008 Mitigation Rule provided clear guidance on what elements should be considered in a watershed approach, and stated that demonstration of these elements at a proposed compensation site may satisfy the new watershed approach requirement. However, an alternative was provided: to proactively develop a watershed plan that addresses these elements, to the satisfaction of the Corps District Engineer. Proactive planning enables the selection and advance comparison of top-tier sites across a watershed—a distinct advantage to site-by-site watershed approach justification. However, the Rule did not provide a framework for creating a watershed plan out of the listed elements.

In 2009, the Environmental Law Institute and The Nature Conservancy began a partnership to develop pilot projects across the nation for the Watershed Approach. The goals of these pilots are (1) to develop and compare planning frameworks for the advance identification and prioritization of §404 compensation opportunities, and (2) to align future compensation actions with local watershed needs and existing conservation goals. The plan for the first pilot, in the Stones River Watershed of central Tennessee, was recently completed (Palmer and Wisby 2011). The second pilot, in Wisconsin's Duck-Pensaukee Watershed of Lake Michigan's Green Bay Basin, is the subject of this plan. The third and final pilot is currently underway in the Etowah River Basin of Georgia. This portfolio of pilot projects allows for the comparison of an array of methods in different land-use and ecological settings. The Duck-Pensaukee project provides Great Lakes coastal representation in an urbanizing agricultural watershed and focuses on (1) analysis of historical trends in wetland services to set watershed priorities, (2) assessment of wetland services to prioritize individual sites, and (3) alignment with the state Wildlife Action Plan.

A.2. Model Watershed Approaches: A Handbook for States, Tribes and Local Governments

In addition to the three TNC/ELI projects, other Watershed Approach pilots have been developed around the nation, led by a variety of organizations and agencies (e.g., the Corps, EPA, Natureserve, state agencies, and others). Through a new EPA-funded project, ELI and TNC have begun to aggregate and evaluate lessons learned from this broader suite of Watershed Approach projects. With engagement and input from a nationwide panel of experts, a national handbook on watershed approach planning will be produced for use by states, tribes, and local government. Methods developed in the Duck-Pensaukee Watershed are being considered in this nationwide review of projects.

A.3. Wetlands: Viewed through the lens of ecosystem services

Although wetlands cover only a small fraction of the world's land surface, generally estimated at less than 6 percent (Mitsch and Gosselink 2000), they are powerhouses of the natural world. They play a pivotal role for wildlife; 50 percent of animals listed as endangered and threatened in the U.S. require wetland habitat (Niering 1988). And they play pivotal roles for people, too, as they provide "green infrastructure" through protection of water quality and quantity, flood reduction, and other ecosystem services. Recent calculations reveal that wetland loss in the U.S. since the 1950s (almost 10 million acres) has translated to the annual loss of over $80 billion in renewable ecosystem services (Southwick Associates 2011, based on Costanza et al. 1997). This figure likely underestimates the true economic value of wetlands, as not all wetland services were included in the calculations. Acre for acre, the value of wetlands to the U.S. economy is estimated to be ten times the value of its closest contender, upland forests (about $10,000/acre/year for wetlands vs. about $1,000/acre/year for upland forests) (Ingraham and Foster 2008). Clearly, continued loss of wetlands will have disproportionately high costs for people and nature.

The benefits provided by natural systems are often interchangeably referred to as either "functions" or "ecosystem services." For purposes of standardization and clarity, wetland benefits are consistently referred to in this Watershed Approach as "services." The services provided by natural systems can vary widely and fall into several broad categories including supporting services (e.g., nutrient cycling, soil formation), provisioning services (e.g., food, timber), regulating services (e.g., climate or flood regulation), and cultural services (e.g., aesthetic, recreational, educational) (Millennium Ecosystem Assessment 2005). These services range from relatively intangible to clear and specific; similarly, our ability to measure them at a landscape scale with existing spatial datasets ranges quite a bit.

For wetland prioritizations in the Watershed Approach, we selected a suite of services based on: (1) their relative importance to people; (2) the role they play in maintaining watershed health; (3) the degree to which wetlands, specifically, provide them; and (4) the extent to which we can measure them with available data. Based on these criteria, the following seven services were selected for assessment in this project: water quality protection, flood abatement, surface water supply, shoreline protection, carbon storage, fish habitat, and wildlife habitat.

A.4. The Duck-Pensaukee Watershed

The Duck-Pensaukee Watershed spans 318,540 acres (498 miles^2) in portions of Brown, Outagamie, Shawano, and Oconto counties of northeastern Wisconsin (Figure 1). This 8-digit hydrologic unit (HUC 04030103) consists of 15 subwatersheds (12-digit HUCs) that range in size from 7,362 acres to 31,378 acres (average of 21,236 acres) (Figure 2). With a human population of approximately 90,000 (estimated from 2010 census data), the watershed extends along the coastline of Green Bay in Lake Michigan from the City of Green Bay northward to the City of Oconto. Although it is assessed in this plan as a single watershed, this HUC consists of three distinct drainages (Pensaukee River, Suamico/Little Suamico, and Duck Creek) that, along with several smaller streams, drain directly into the Bay. The Duck-Pensaukee Watershed was selected in consultation with the St. Paul District of the Army Corps of Engineers, based on current and anticipated levels of §404 permit applications.

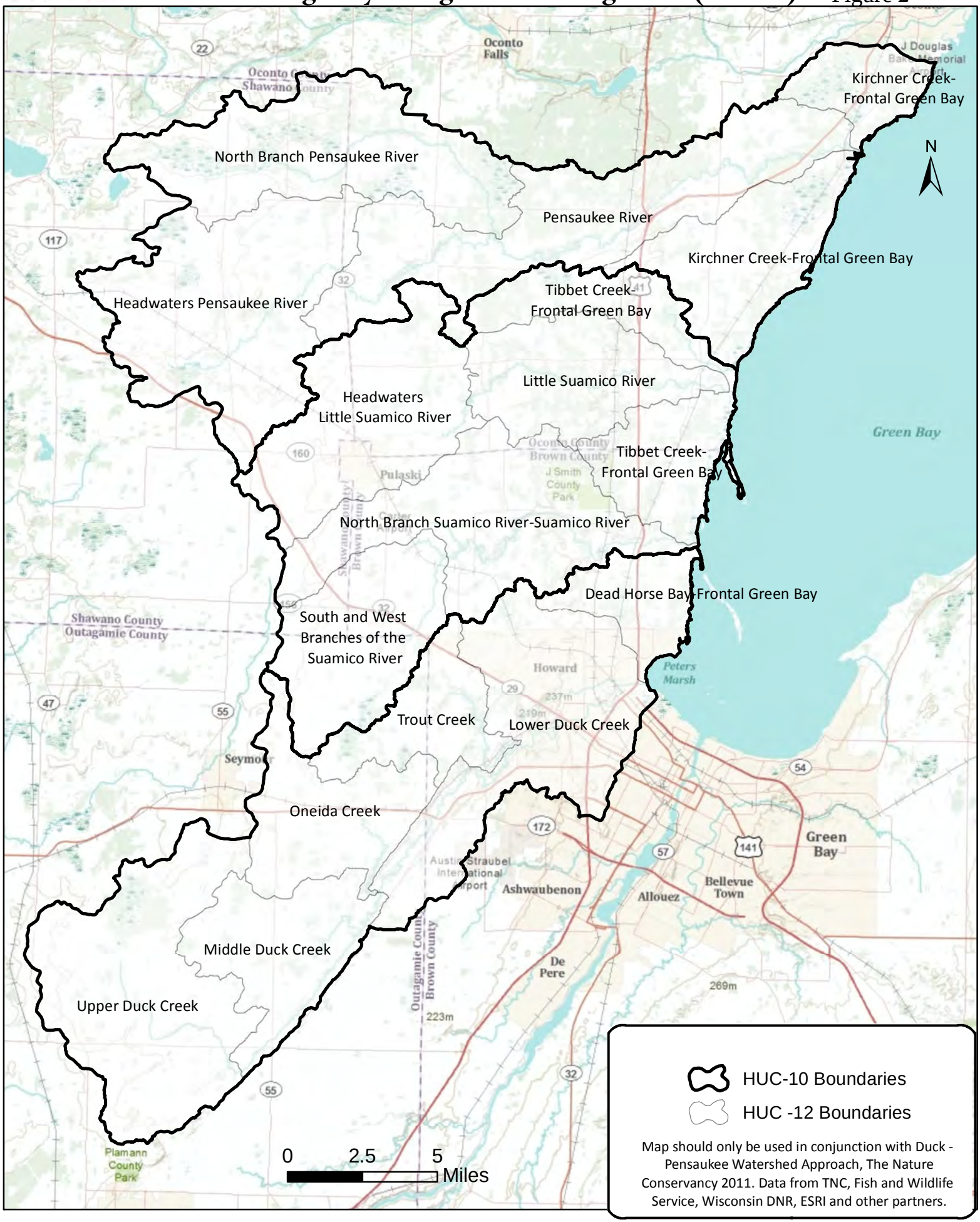
Areas along the coastline contain large expanses of wetland, and historically contained much more (Figure 3). These coastal wetlands of the Duck-Pensaukee are part of the larger Green Bay West Shore Wetlands, which form the world's largest freshwater estuary, a haven for migratory birds and other wildlife. Wetland loss throughout the watershed (approximately 38%) is mostly associated with historical conversion to agricultural land uses through ditching and draining; in more recent decades, suburban and exurban development have contributed to wetland loss (see Figure 4 for current land uses and landcover). This decline in wetland area, along with other impacts that degrade many remaining wetlands, has reduced many of the important services provided by

Duck-Pensaukee Watershed Location Within the Lake Michigan Basin

Figure 1

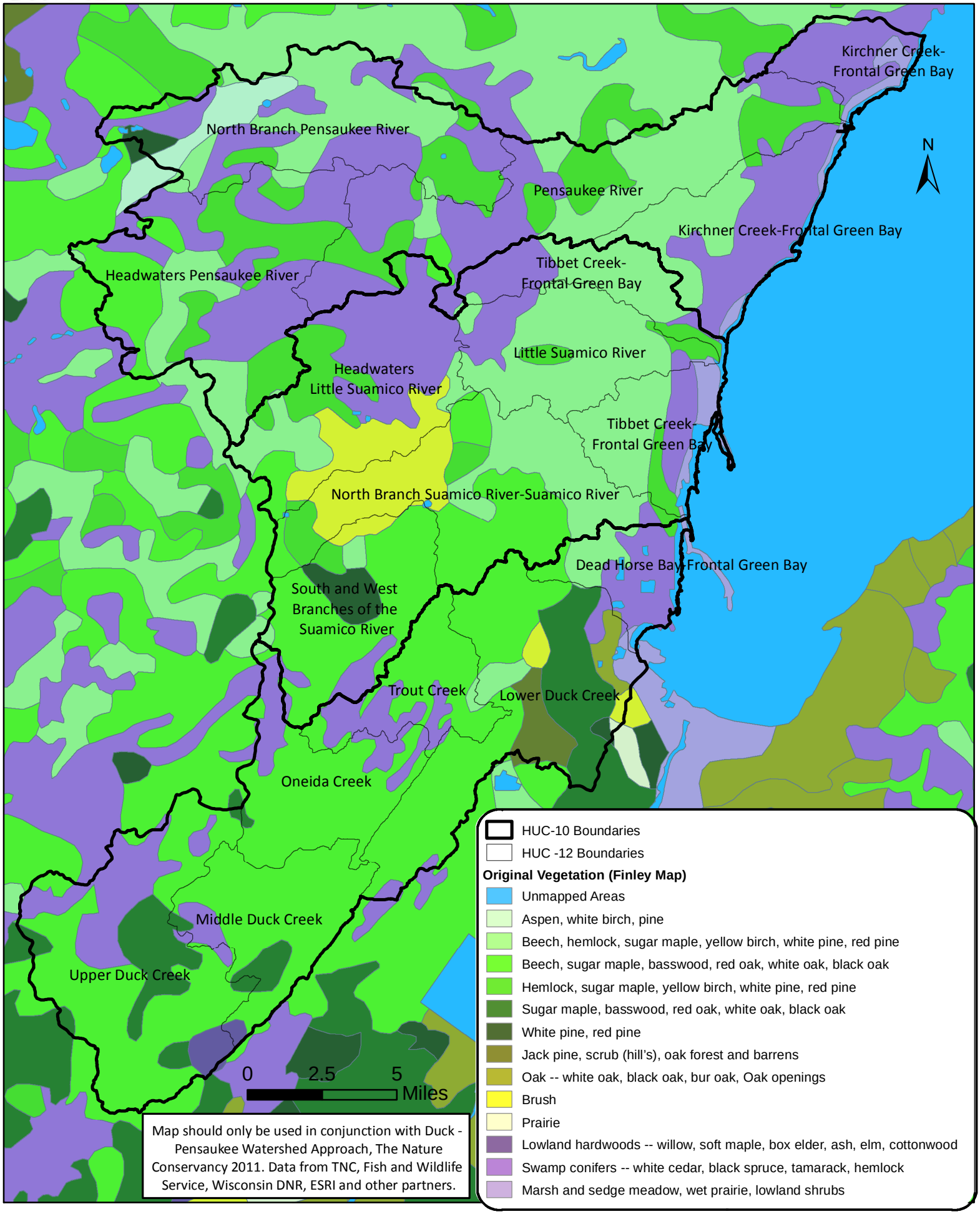
Duck-Pensaukee Basin
12-Digit Hydrologic Accounting Units (HUC´s)

Figure 2



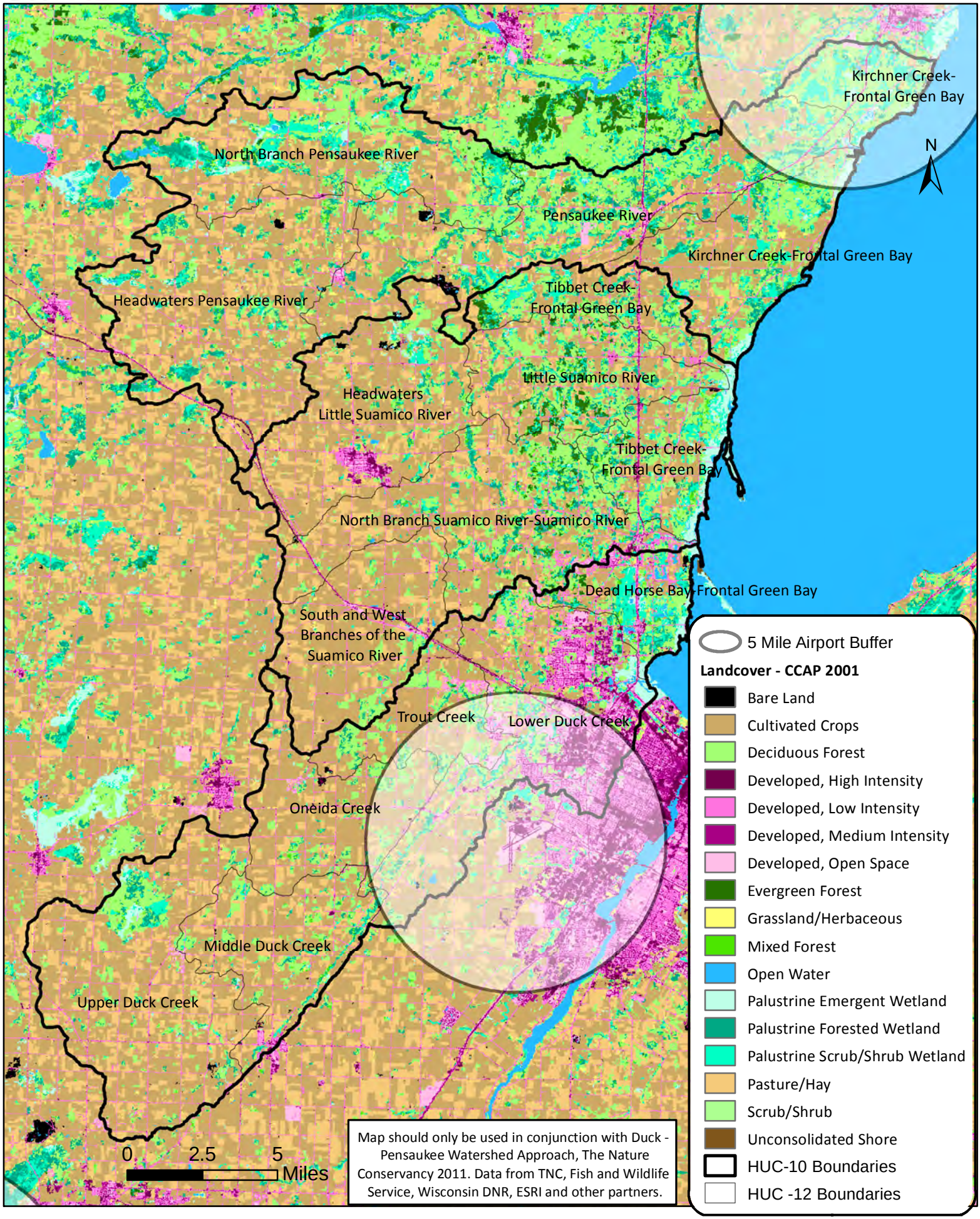
Duck-Pensaukee Basin 1800´s Landcover

Figure 3



Duck-Pensaukee Basin Landcover and Airports

Figure 4



wetlands for people and wildlife within the watershed. However, there is ample opportunity to restore former wetlands and protect remaining wetlands (Figure 5). This plan identifies which of those opportunities have the greatest likelihood of restoring and maintaining wetland services.

B. OVERVIEW OF APPROACH

The intent of this watershed plan is to assess preservation and restoration needs in the Duck-Pensaukee Watershed and also to identify sites that have the greatest potential to meet those needs. An overview of the methods created, adapted, and tested to accomplish these goals may be found in the following paragraphs. Detailed methods are provided in Section E of this plan. In brief, these approaches:

1. locate potential preservation and restoration sites,
2. assess watershed needs, to aid in setting conservation goals for the watershed, based on an evaluation of declines in wetland services since the 1800s, and
3. identify top-tier sites for conservation, based on their relative potential to meet watershed needs and provide an array of services.

The position of a wetland in its watershed influences the ability to provide services. For example, wetlands play an important role in removing nitrogen from water. Wetlands that are situated where nitrogen levels are highest (i.e., those that are low in the watershed or downstream of wastewater and urban or agricultural runoff) will be best able to perform that service (Zedler 2003). Wetlands that occur high in the watershed, in headwater areas, and those that interact with the groundwater table are best able to maintain another service: surface water supply. The methods developed for this Watershed Approach take these watershed positional factors into account.

It should also be noted that a gain in one service at a wetland could jeopardize other services. For example, the restoration of an urban wetland to remove nitrogen would likely lead to dominance by a weedy invasive plant. This may be an acceptable outcome for a restoration project with water quality goals. However, this would decrease the value of the wetland for native wildlife species. The methods described below prioritize preservation and restoration opportunities based on a broad array of services. However, users of this plan should take care to set goals for services that are complementary, tailored to individual sites, and relevant to the location within the watershed.

B.1. Watershed partners

To increase the accuracy and relevance of this plan for watershed stakeholders, a diverse group of partners was engaged twice during the project. Partners that attended these meetings included state, federal, and tribal agencies responsible for natural resource protection and regulation; NGO's active in the area; planning and conservation staff of local government; the

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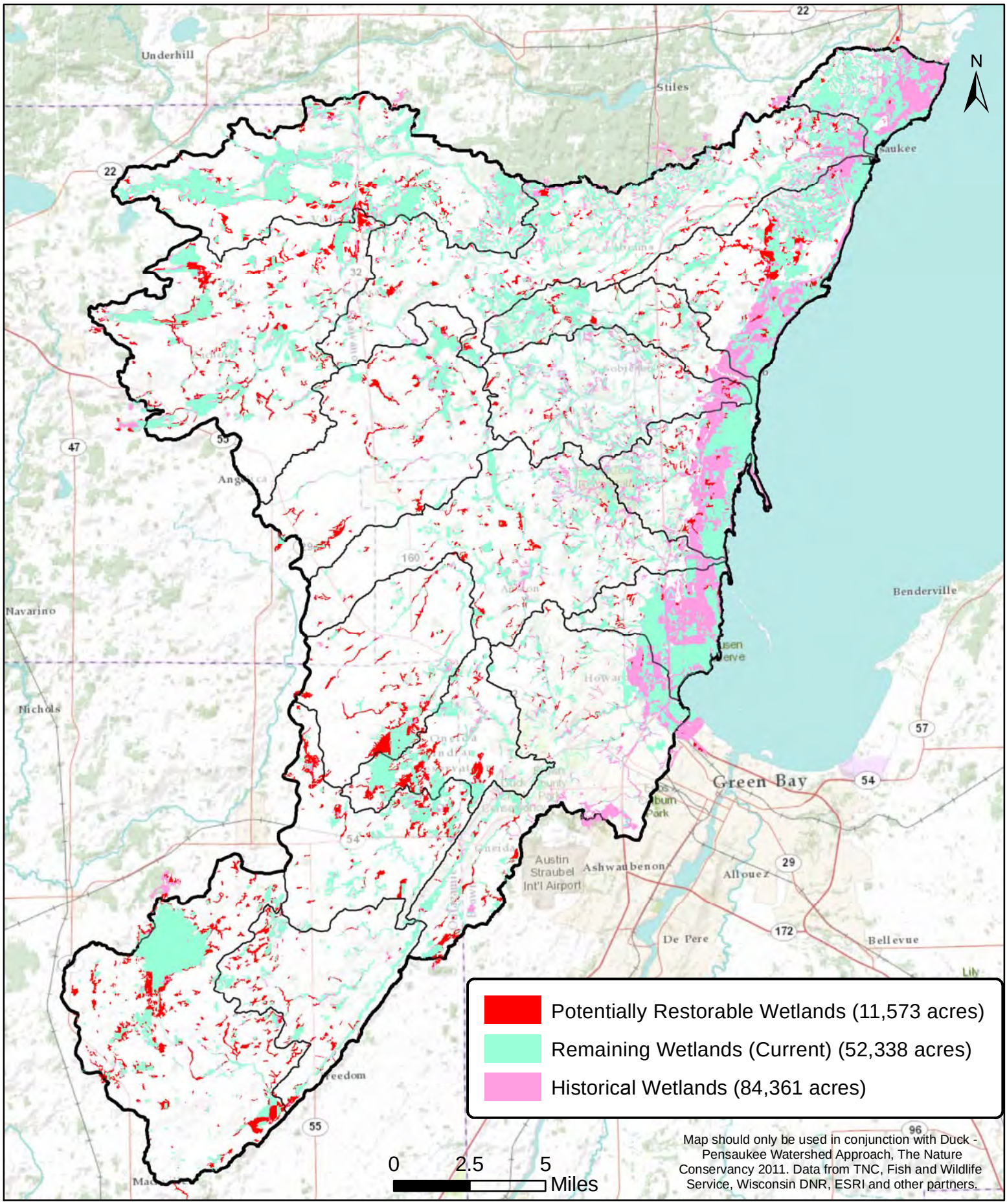
Duck-Pensaukee Potentially Restorable Wetlands

Figure 5



regional planning commission; transportation agencies; university and extension scientists; and concerned citizens. The first stakeholder meeting, held at University of Wisconsin-Green Bay and by WebEx in May 2010, included 30 participants. The purpose of this "kick-off" meeting was to vet the project with partners and to gather input on desired goals and outcomes for this project, ongoing conservation activities in the watershed, and existing datasets that could be used for planning. The second stakeholder meeting in December 2012, also held at University of Wisconsin-Green Bay, included 42 participants (31 in-person, 11 by WebEx). The purpose of this second meeting was to provide a project update to partners, to present preliminary results, and to seek input on final deliverables.

In addition to stakeholder meetings, input was gathered throughout the planning process from experts in wetland ecology, soil science, wildlife ecology, the Duck-Pensaukee watershed, and other topics. Experts were consulted via group meetings, individual meetings, webinars, and phone conferences. Details for expert engagement are provided in Section E of this plan.

Staff from regulatory and conservation agencies were integrally involved throughout the planning process, in particular Wisconsin DNR and the Corps' St. Paul District. This plan was reviewed by partners in key agencies and organizations to ensure that (1) the plan and its prioritizations are suitable and relevant for the Duck-Pensaukee Watershed, and (2) the approach and methods are appropriate for application in other watersheds.

B.2. Identification of potential sites for conservation

Wetland resources may be conserved through a variety of activities, which have been grouped into four major categories: preservation, restoration, creation, and enhancement (USEPA 2008). This plan focuses on the first two categories: wetland preservation and restoration (Table 1). There are two kinds of restoration: re-establishment (restoring wetlands that have been completely destroyed and converted to upland) and rehabilitation (restoring existing wetlands that have been degraded or impaired). Wetland creation and enhancement opportunities were not identified as part of this project because coarse-scale GIS analyses cannot reliably distinguish the best opportunities. For example, the potential to enhance or create wetland hydrology is best identified through on-the-ground site assessments. In addition, potential gains in wetland services from these activities may occur at the expense of other services.

Preservation opportunities in the watershed may be selected from the current extent of wetlands, as mapped by the Wisconsin Wetland Inventory and the National Wetland Inventory. *Re-establishment opportunities* are historical wetlands (i.e., areas mapped as having wetland soil types in the soil survey) that are not currently developed or in a natural land cover (e.g., wetland, forest, shrubland) (Miller and Golet 2001, Kline et al. 2006). *Rehabilitation opportunities* are current wetlands that have been degraded by some sort of impact, limited

to those impacts for which data are available across the watershed. In the Duck Pensaukee, rehabilitation opportunities were therefore limited to wetlands dominated by the invasive reed canary grass, as mapped by DNR (Hatch and Bernthal 2008). Also see Section D.3.b for potential rehabilitation opportunities associated with ditched wetlands.

While reviewing results with local partners, it became clear that certain soil types along the coast are closely linked to water levels in Lake Michigan, and alternate between upland and wetland conditions, in response to lake levels (A. Stranz, *pers. comm.*). Although they are not currently mapped as wetland, these "potential wet areas," or periodic wetlands, present unique conservation opportunities. Protection of these areas would help to maintain wetland services in the watershed.

Table 1. Major categories and types of wetland conservation opportunities identified in the Duck-Pensaukee Watershed.

Category	***Type***	***Description***
Preservation	Current wetlands	Wetlands mapped by Wisconsin Wetland Inventory or National Wetland Inventory
Preservation	Potential wet areas	Coastal soils not currently mapped as wetland that provide wetland services during high Lake Michigan levels
Restoration		
Re-establishment	Potentially restorable wetlands	Destroyed wetlands that are under a "restorable" land use (e.g., agriculture, not developed areas)
Rehabilitation	Invaded wetlands	Wetlands with >50% cover of reed canary grass
Rehabilitation	Partially drained wetlands	Current wetlands with hydrology altered by ditches

B.3. Setting watershed goals: A watershed profile

Before preserving and restoring wetlands on the basis of their potential to provide services, it is important to understand the extent of wetlands and their services across the entire watershed. To provide this context, a "watershed profile" was created for the Duck-Pensaukee to compare the historical levels of wetland service provision (c. 1830) to current levels. The relative amount of loss was measured for each subwatershed for four services: flood abatement, water quality protection, surface water supply, and carbon

storage (Figures 6 - 9), using methods detailed in Section E.5. With these methods, information about each current and historical wetland—from vegetation type to water regime to watershed position—was developed and used to determine which services are provided, and to what degree.

This watershed profile may be used to set wetland service goals and also to identify subwatersheds for wetland conservation. For example, users may choose to target services that have diminished the most. Or, subwatersheds may be selected for conservation work based on the potential amount of gains in services that could be attained.

Although fish and wildlife habitat and shoreline protection services were assessed for the prioritization of individual sites (see Section B.4), they were not assessed for this watershed profile. Losses in suitable wildlife habitat since the 1800s were not assessed due to insufficient data and because the methods used could not take surrounding land-use context into account, which is a major determinant of wildlife habitat suitability. Losses in shoreline protection were not assessed because results would have been confounded by the fact that the number of open waterbodies in the watershed has increased since the 1800s, due to creation of such sites by people.

B.4. Prioritizing sites based on wetland services

Wetlands provide many services, including water quality protection, flood abatement, surface water supply, carbon storage, shoreline protection, wildlife habitat, and fish habitat. The sites with the greatest likelihood of being able to provide these services were identified using the approaches described in general terms below; see Section E for detailed methods. These top-tier sites were those that were assessed as “exceptional” or “high” for each service.

Sites were also prioritized based on their potential to provide multiple services. The “multiple services” map (Figure 10) was created by counting the number of services that scored as “exceptional” or “high” at each site.

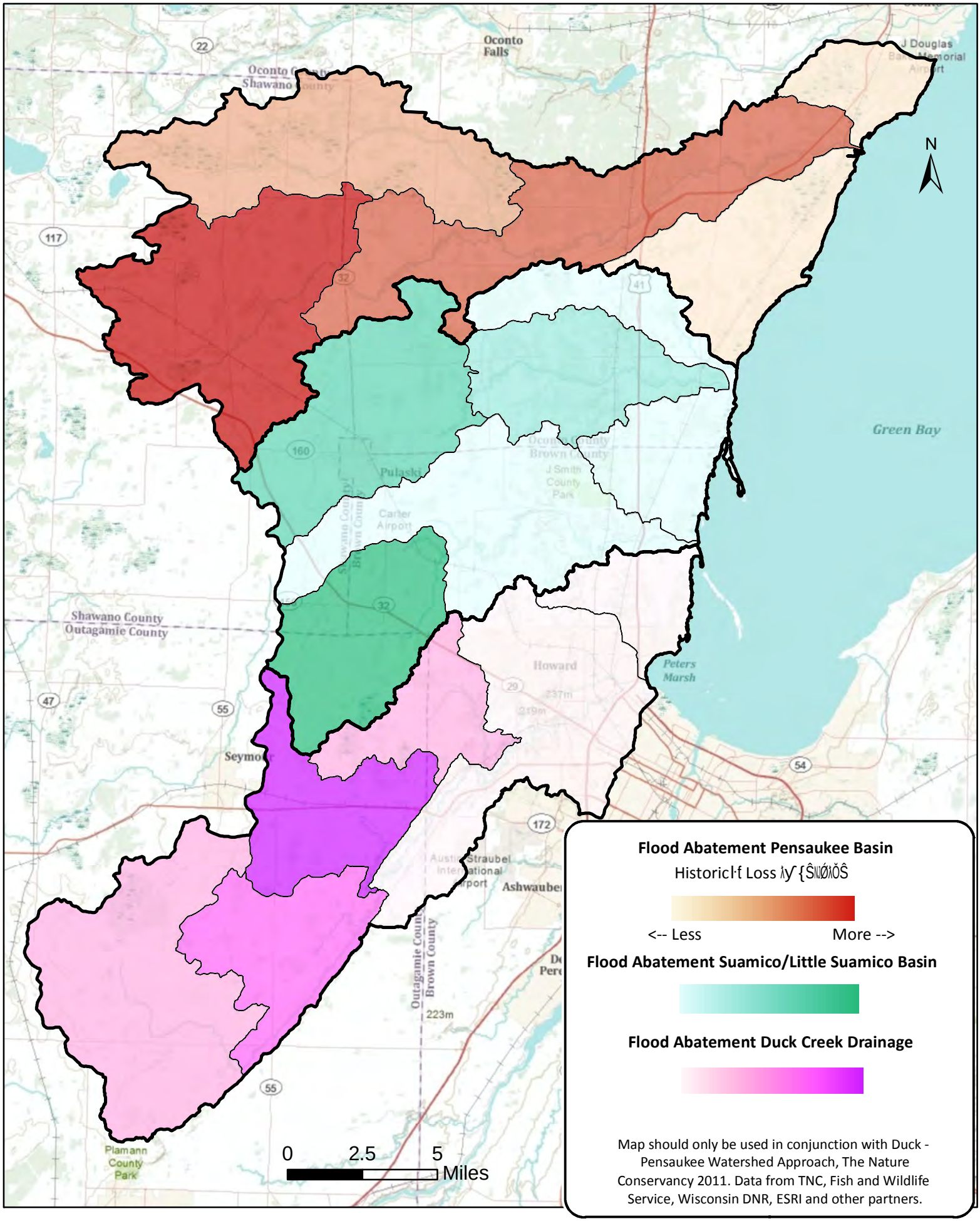
Wetlands not prioritized as “exceptional” or “high” in this plan for one or more services may still be of high value for several reasons: 1) some wetlands (small sites) were not assessed during this project due to wetland data limitations, 2) wetlands that individually provide services at a low level may, collectively, be of high value within a watershed, and/or 3) wetlands provide services (e.g., aquatic invertebrate diversity) that were not considered during the assessment process.

B.4.a. Wildlife habitat

The importance of wetlands to wildlife depends on a variety of factors that include, among others, what types of habitats are available, the size of habitat patches, and proximity to other suitable habitats. Above all, the species and habitats that are important will vary from one

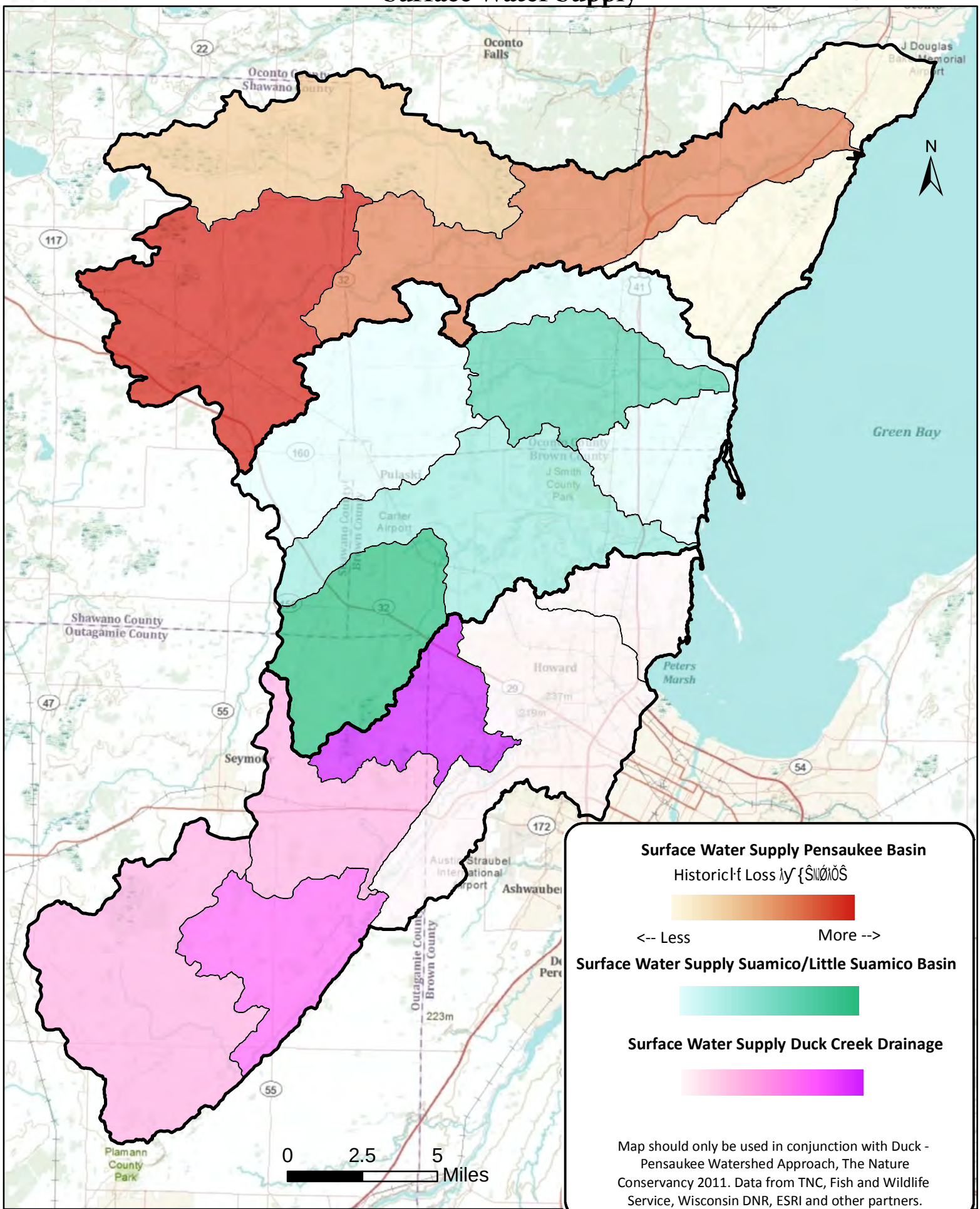
Wetland _q~£uoq X{ q : 1800´s to Present
Flood Abatement

Figure 6



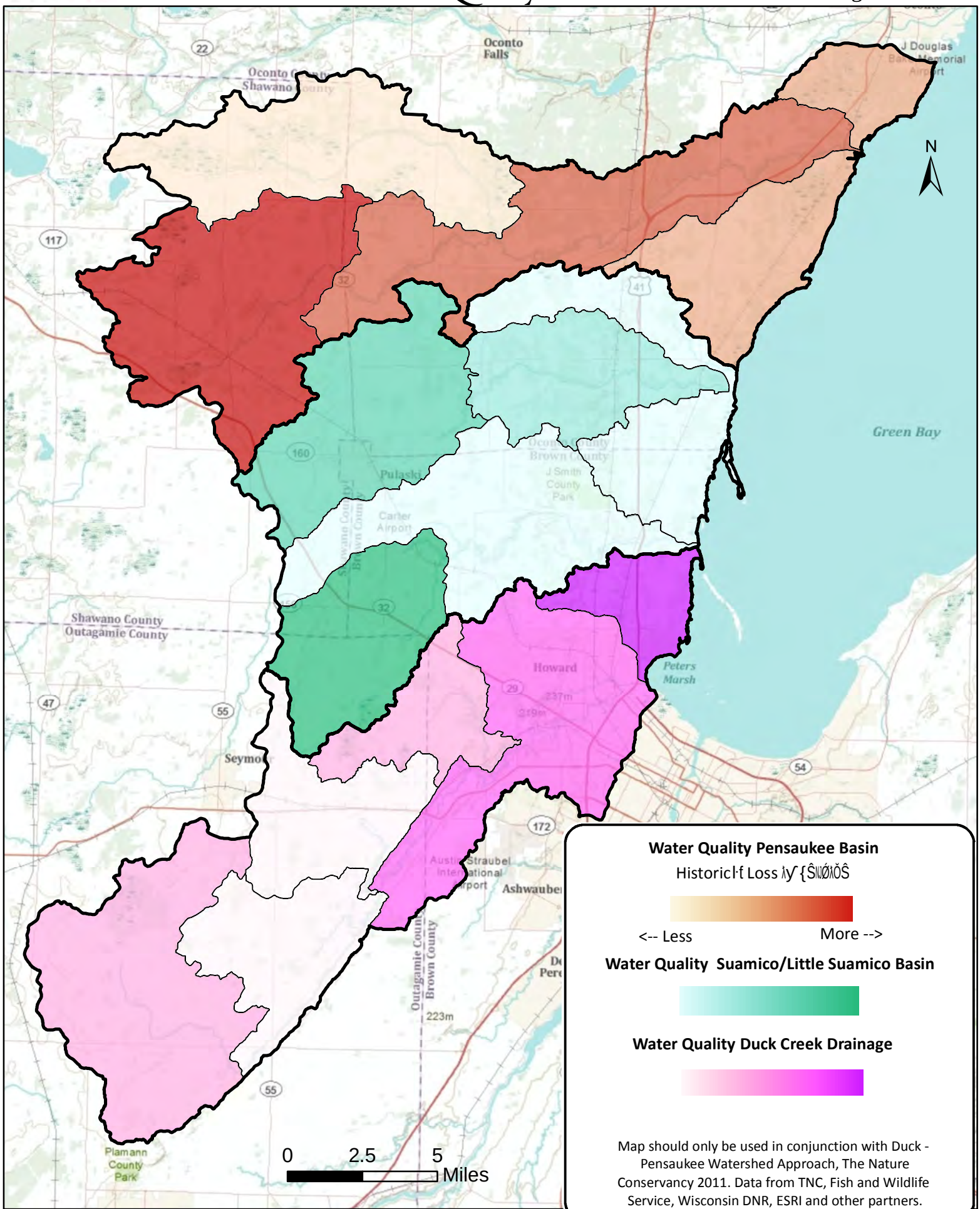
Wetland _q~£uoq X{ q : 1800´s to Present
Surface Water Supply

Figure 7



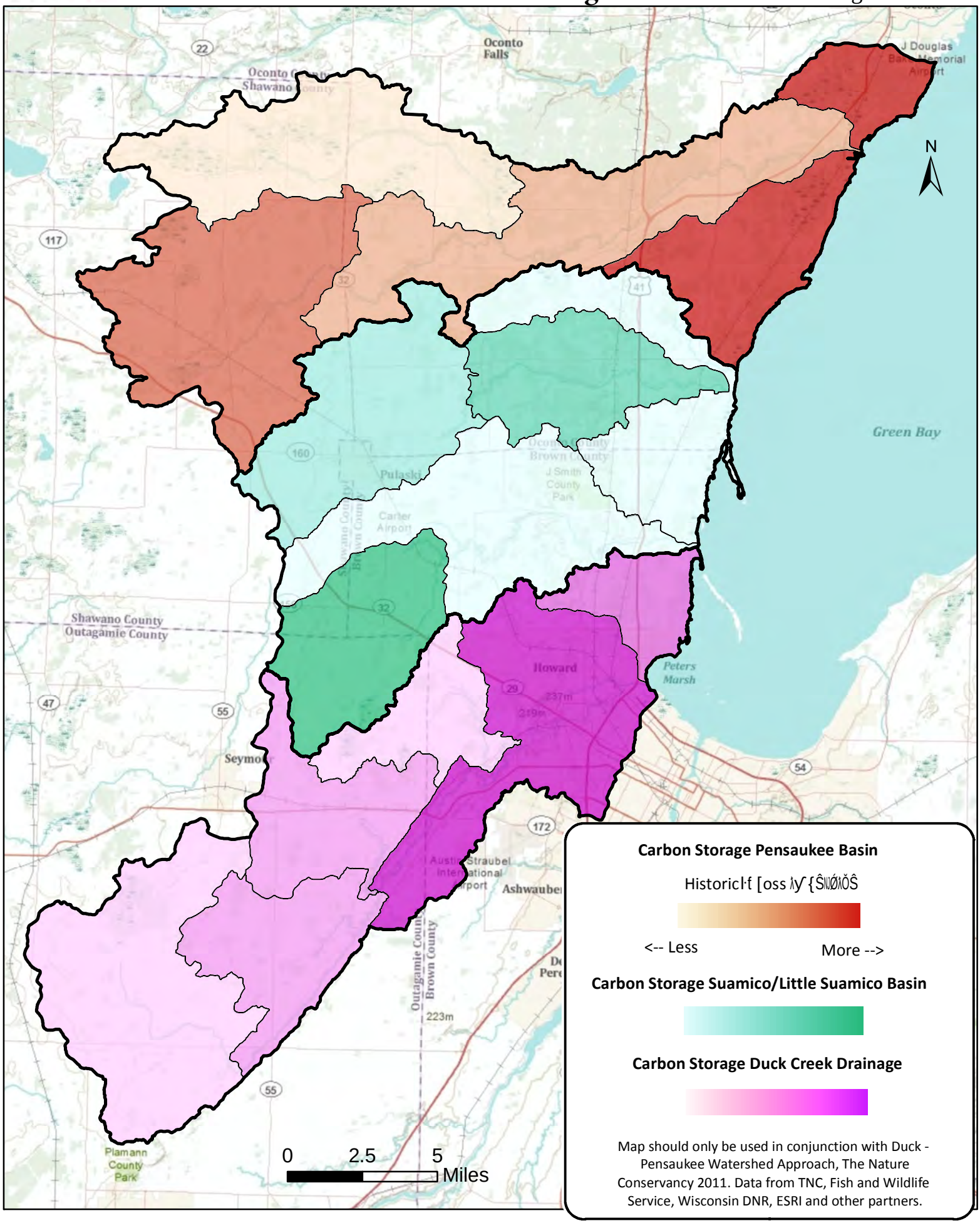
Wetland _q~£ɯoq X{ q : 1800´s to Present
Water Quality Protection

Figure 8



Wetland _q~£ɯoq X{ q : 1800´s to Present Carbon Storage

Figure 9



Duck-Pensaukee Wetland Assessment
All Seven _q~£uoq

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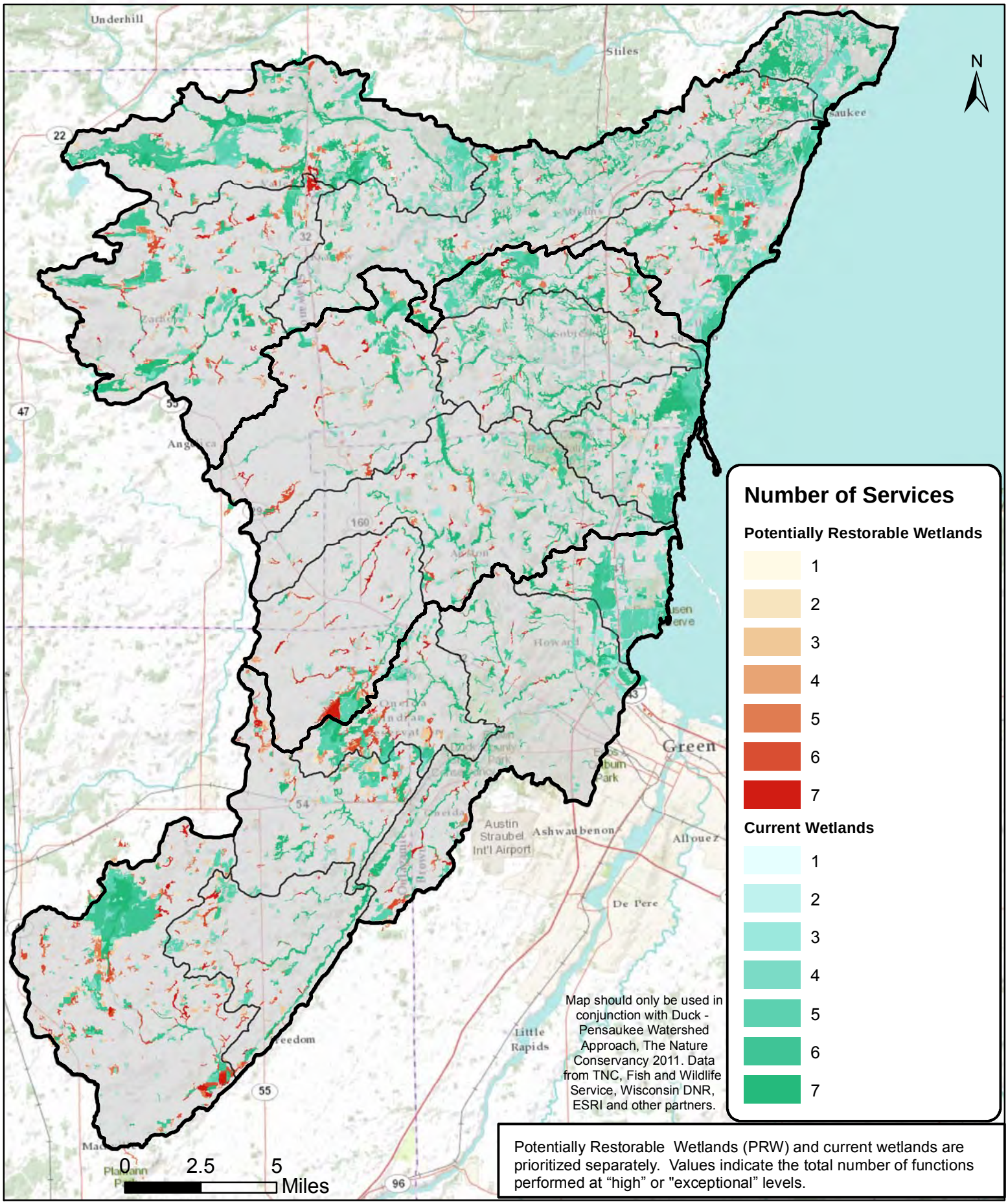
Figure 10



Potentially Restorable Wetlands (PRW) and current wetlands are prioritized separately. Values indicate the total number of functions performed at “high” or "exceptional” levels.

area to another; therefore, ranking of wetlands for wildlife should be tailored to each watershed. We used the Wildlife Tool (Kline et al. 2006) and input from a group of local wildlife experts to: (1) identify key habitats and representative birds, mammals, and reptiles whose presence indicates health of the Duck-Pensaukee Watershed, and (2) rank sites according to the likelihood that they can meet the needs of those representative species. This approach is unique in recognizing that individual wetlands do not function as islands, but instead as parts of an interconnected system that includes both wetlands and uplands. Therefore "sites" that are prioritized include: existing wetlands, potentially restorable wetlands, *and* associated upland habitats. The Wildlife Tool includes models that predict habitat suitability for representative species (see Section E.6 for methods) and also identification of areas that are known to be important for key wildlife species based on observation data. Modeling results are presented in Figures 11 – 18.

This process incorporates data and concepts from Wisconsin's Wildlife Action Plan (WWAP). Conservation of sites identified as high-priority is therefore intended to make meaningful contributions toward WWAP goals, both within the watershed and at a statewide scale.

Maps produced by the Wildlife Tool may be used to identify the top suite of potential conservation sites relevant to a single species or to many species. Target habitats and associated representative species that were selected for the Duck-Pensaukee Watershed are listed below; details about how results were generated are provided in Section E.6, and are summarized in Tables 5a and 5b.

ALL WILDLIFE (Figure 11)
Some sites may have relevance to many species, while others may have relevance to fewer species. A map was created to show the overall suitability of sites to all of the wildlife species evaluated.

Open wetlands and waters: *American bittern, blue-winged teal, black tern* (Figure 12)
The Duck-Pensaukee contains marshes required by these species, including some that have adjacent grasslands needed by teal for nesting, and some that are associated with open water needed by black terns for foraging.

Beaches: *Caspian tern, common tern* (Figure 13)
As a Great Lakes coastal watershed, the Duck-Pensaukee provides important beach-nesting habitat for Caspian and common terns, which also make use of nearby waterbodies and marshes for foraging.

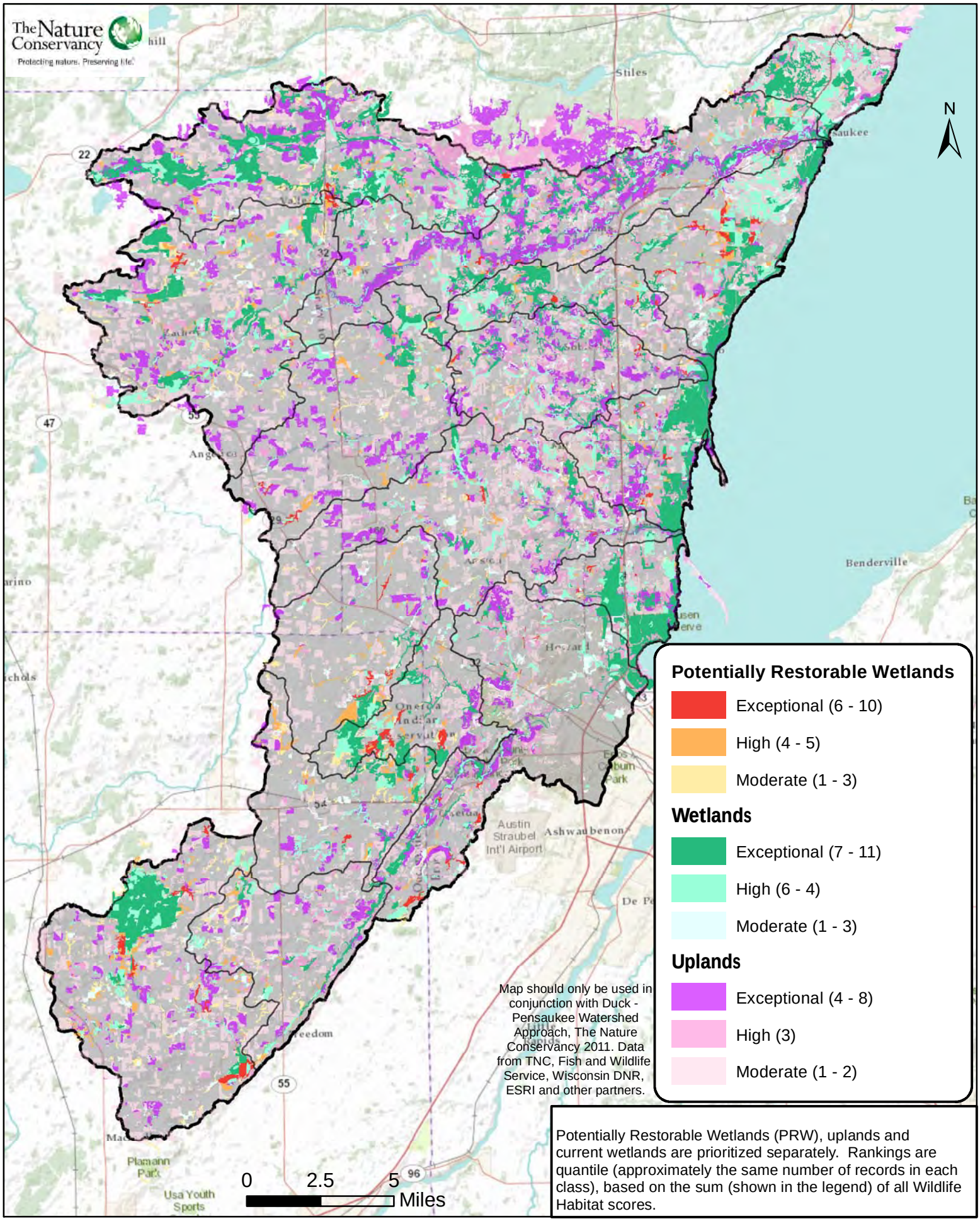
Shrub swamps: *American woodcock, willow/alder flycatchers* (Figure 14)
Shrub swamps are required by willow and alder flycatchers; in addition, woodcock require that these shrubby wetlands be located near other habitats such as upland or wetland forest.

Forested swamp: *Canada warbler, northern flying squirrel* (Figure 15)
Both of these habitat specialists prefer large forested swamps, or more moderate-sized swamps in a largely-forested context (upland or wetland).

Integrated landscape: *Blanding's turtle* (Fig. 16)
In order to thrive, many wetland-dependent species require upland and other wetland habitats that are adjacent or nearby. In the Duck-Pensaukee, the Blanding's turtle was selected to represent "integrated landscapes."

Duck-Pensaukee Wildlife Habitat Summary

Figure 11



Potentially Restorable Wetlands (PRW), uplands and current wetlands are prioritized separately. Rankings are quantile (approximately the same number of records in each class), based on the sum (shown in the legend) of all Wildlife Habitat scores.

Duck-Pensaukee Open Wetlands & Waters

Figure 12

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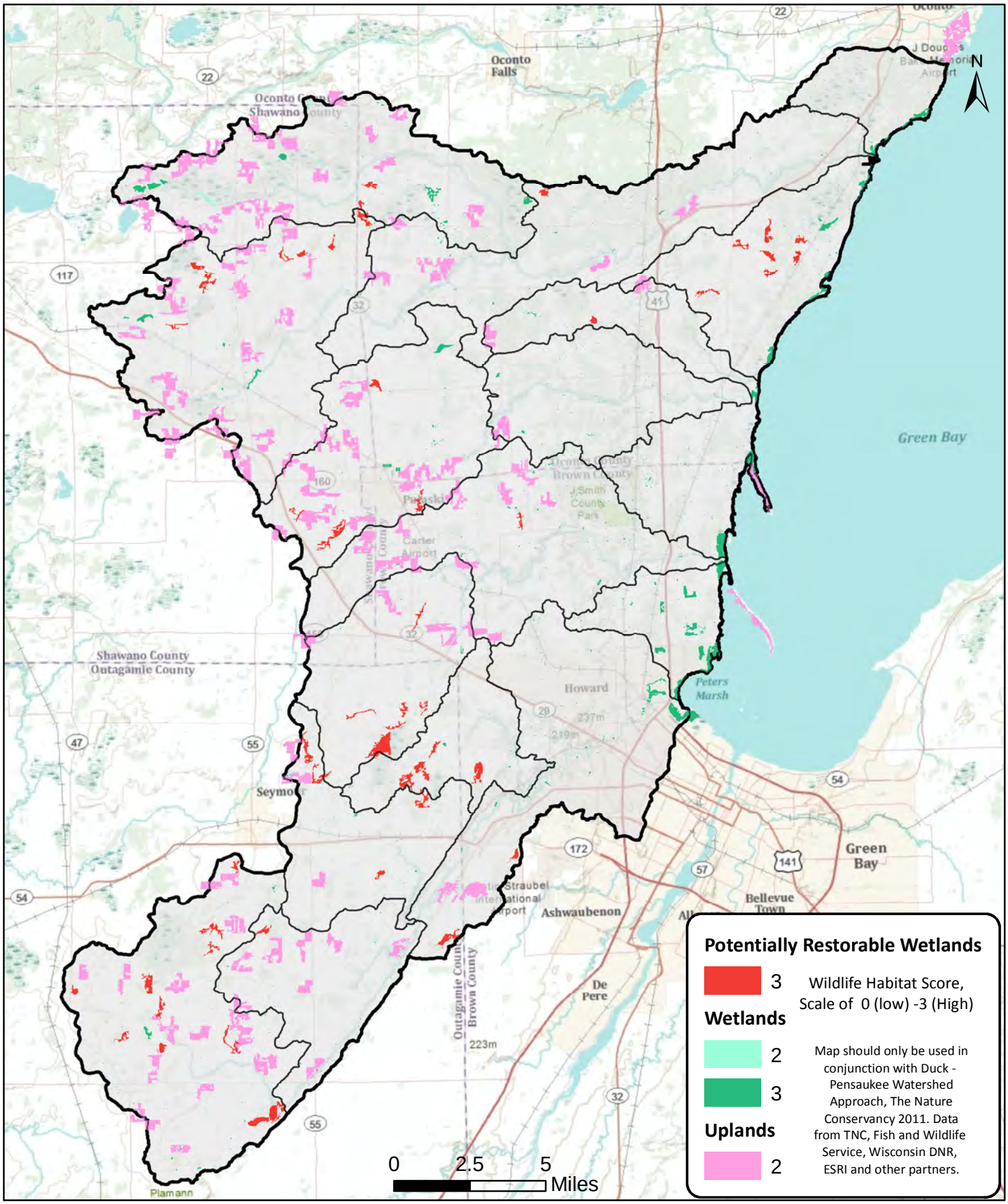
Potential Habitat for American Bittern, Blue-winged Teal, Black Tern



Duck-Pensaukee Beaches

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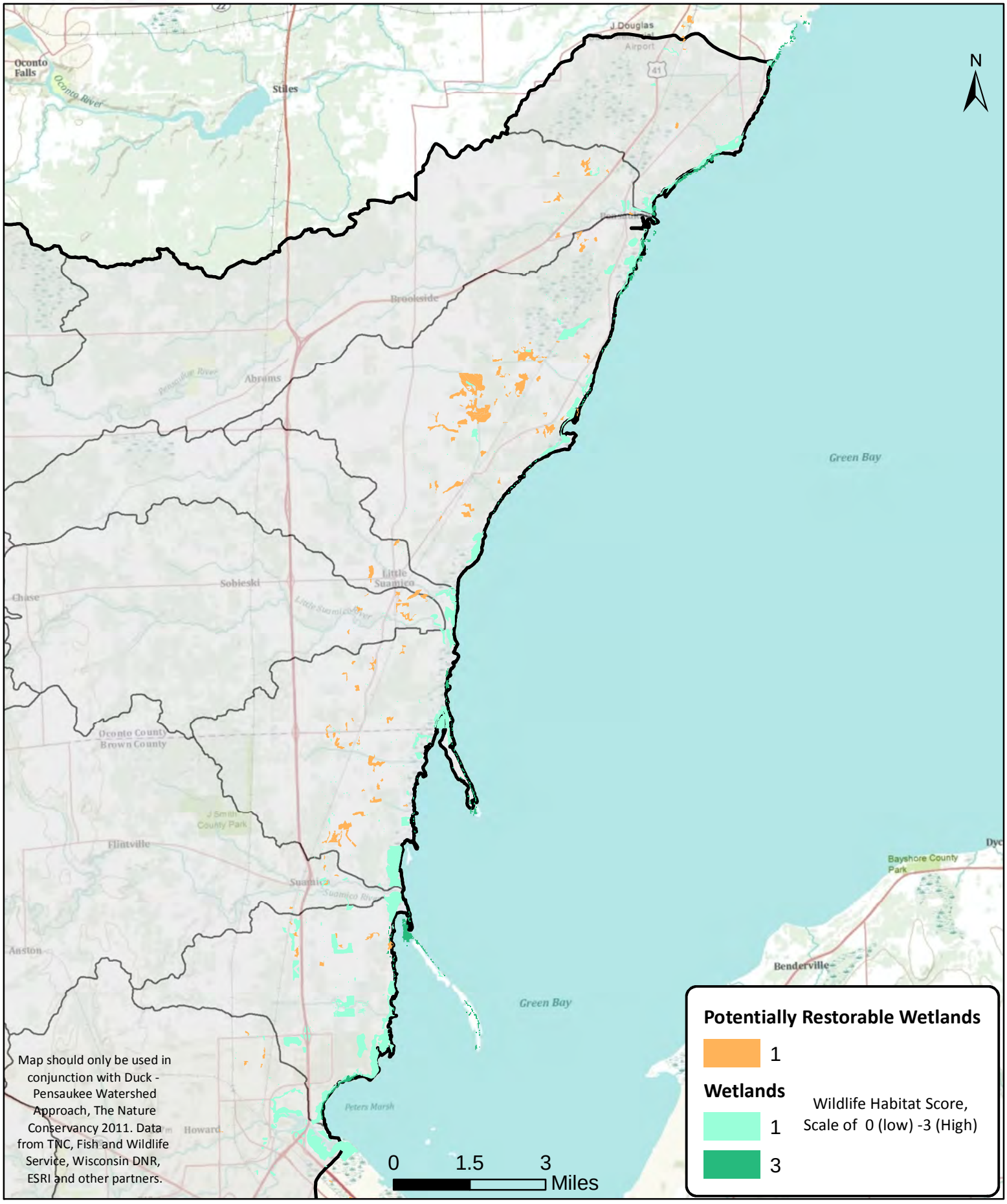
Potential Habitat for Caspian Tern, Common Tern

Figure 13



Duck-Pensaukee Shrub Swamps

Figure 14

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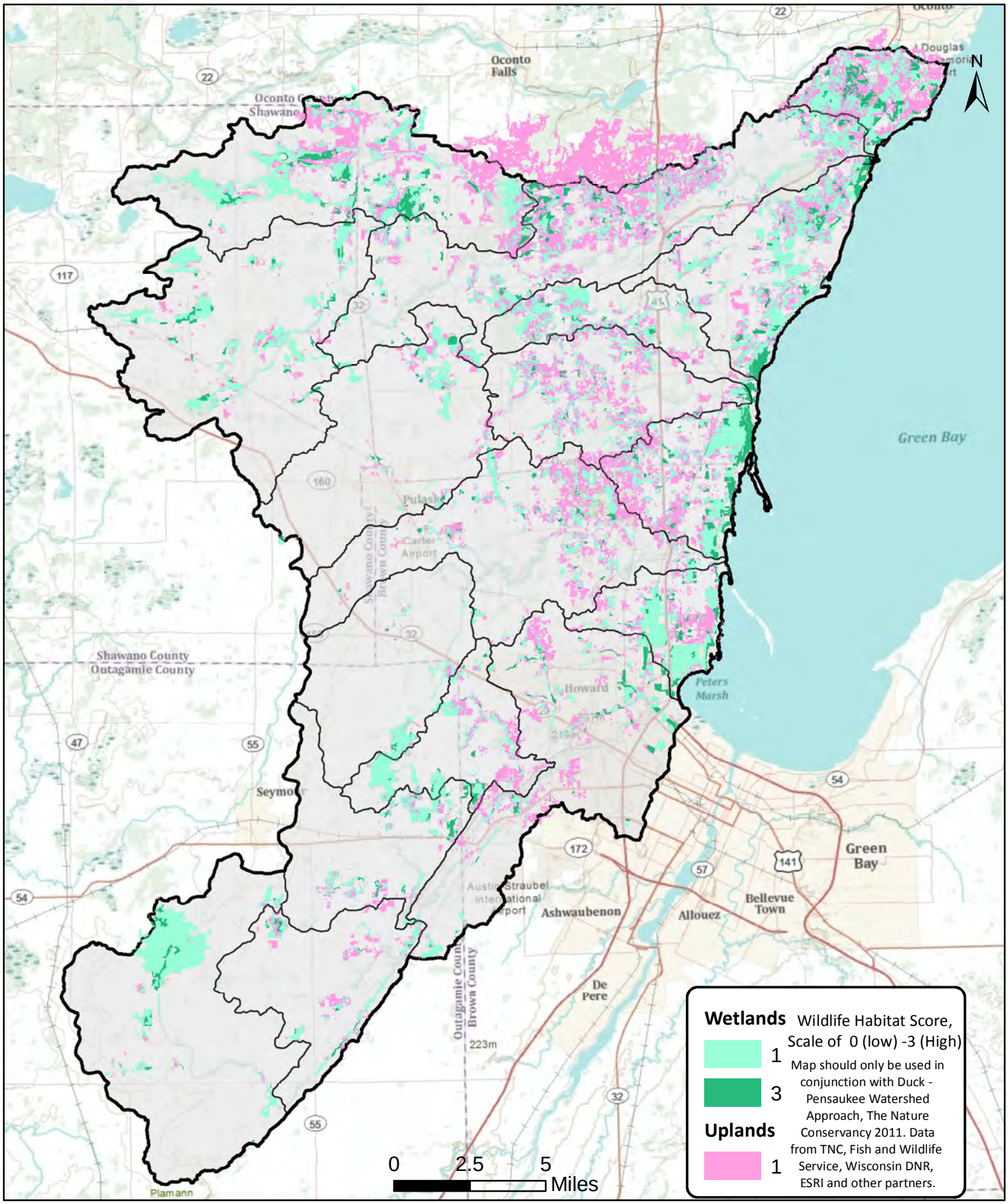
Potential Habitat for American Woodcock, Willow Flycatcher, Alder Flycatcher



Duck-Pensaukee Forested Swamps

Figure 15

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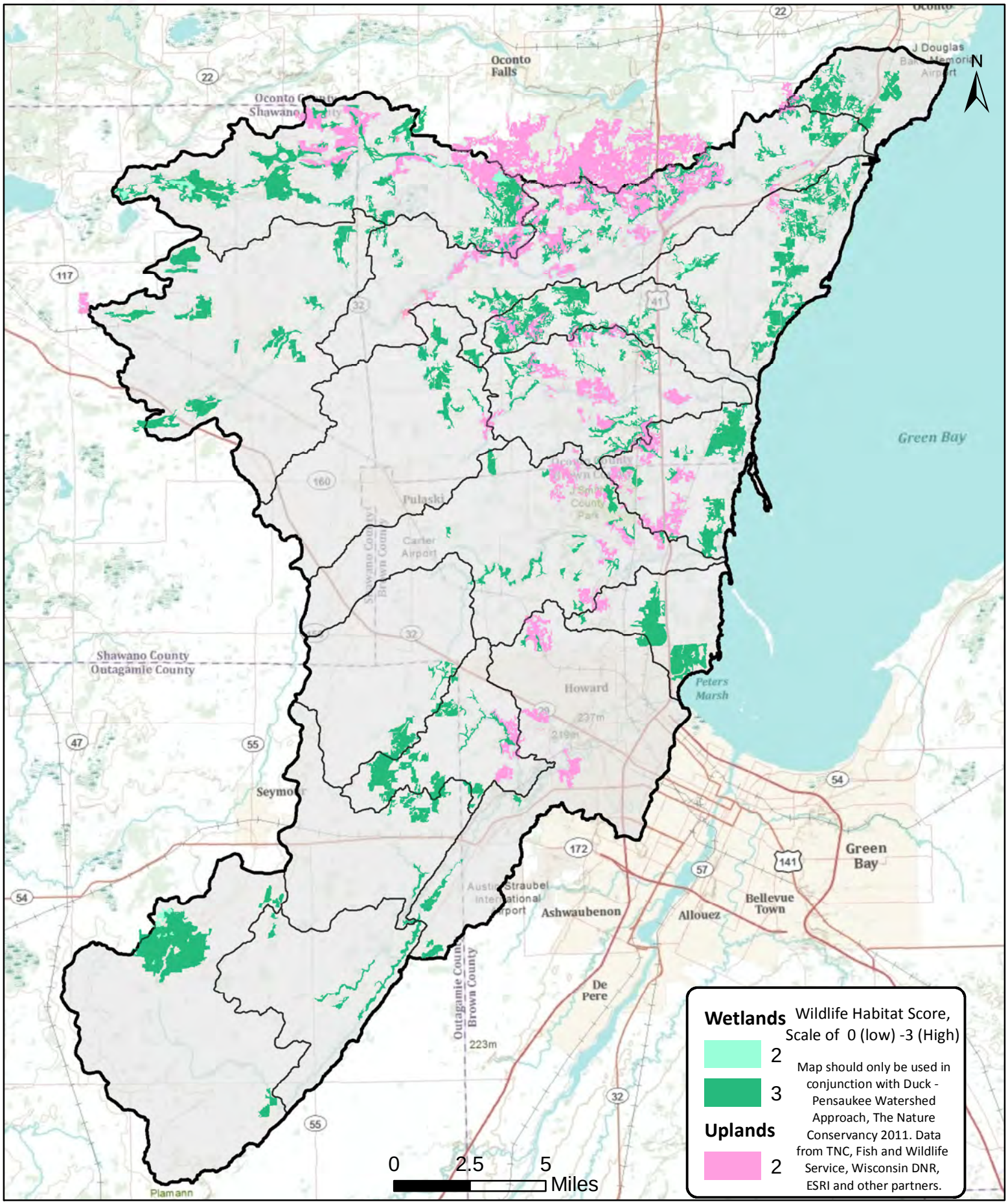
Potential Habitat for Canada Warbler, Northern Flying Squirrel



Duck-Pensaukee Integrated Landscape

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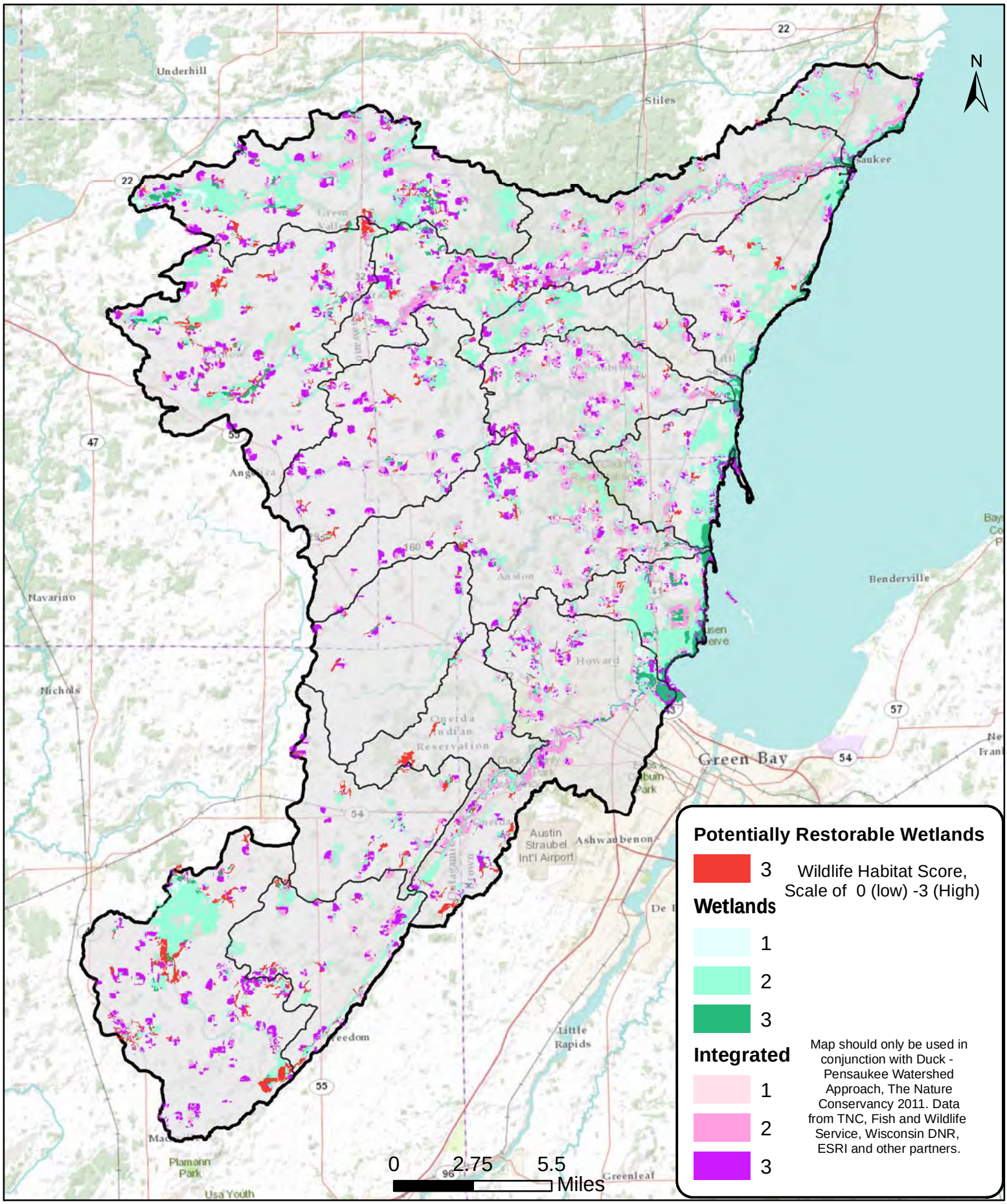
Potential Habitat for Blanding's Turtle

Figure 16



Duck-Pensaukee Riparian Areas

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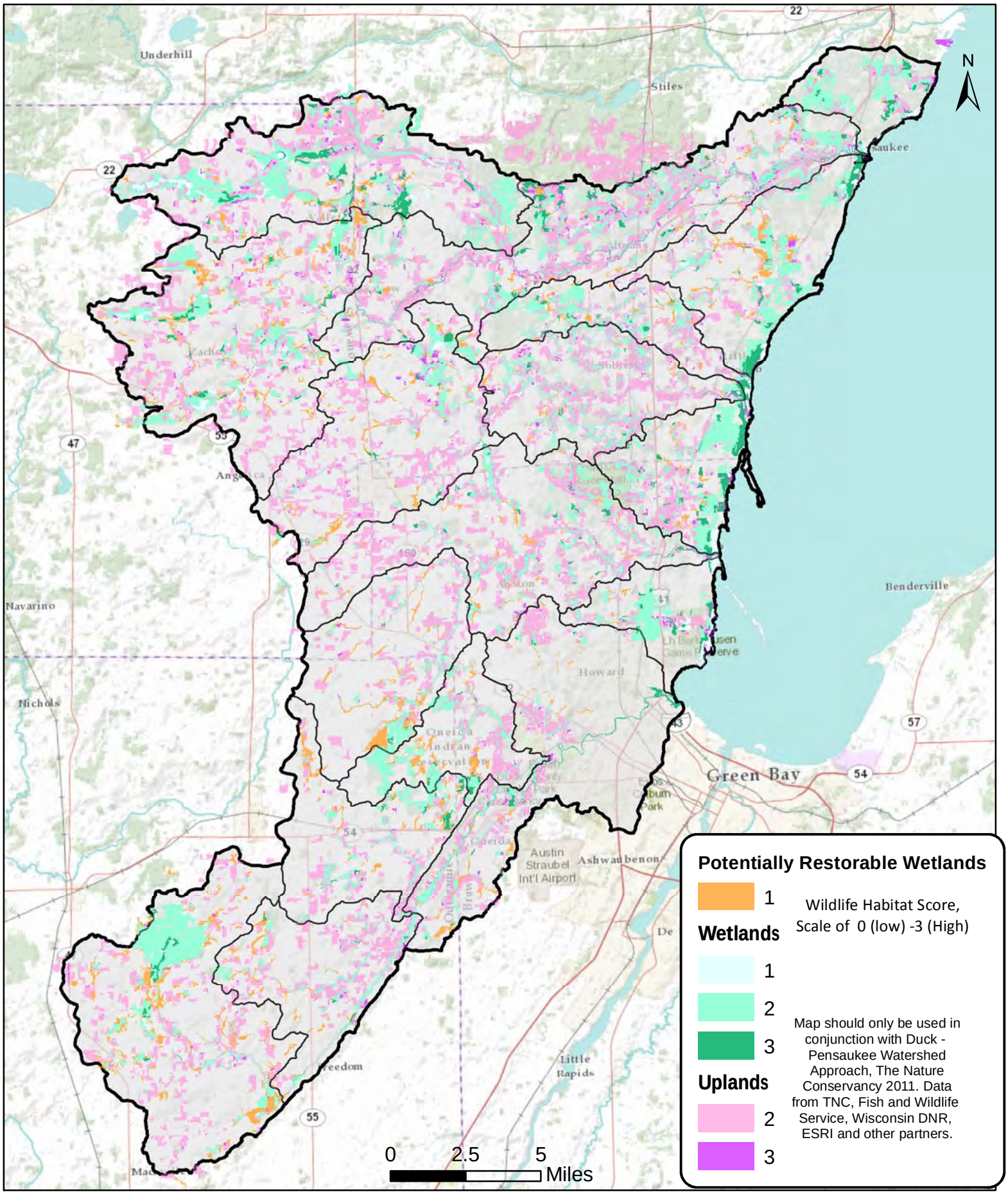
Potential Habitat for Wood Turtle

Figure 17



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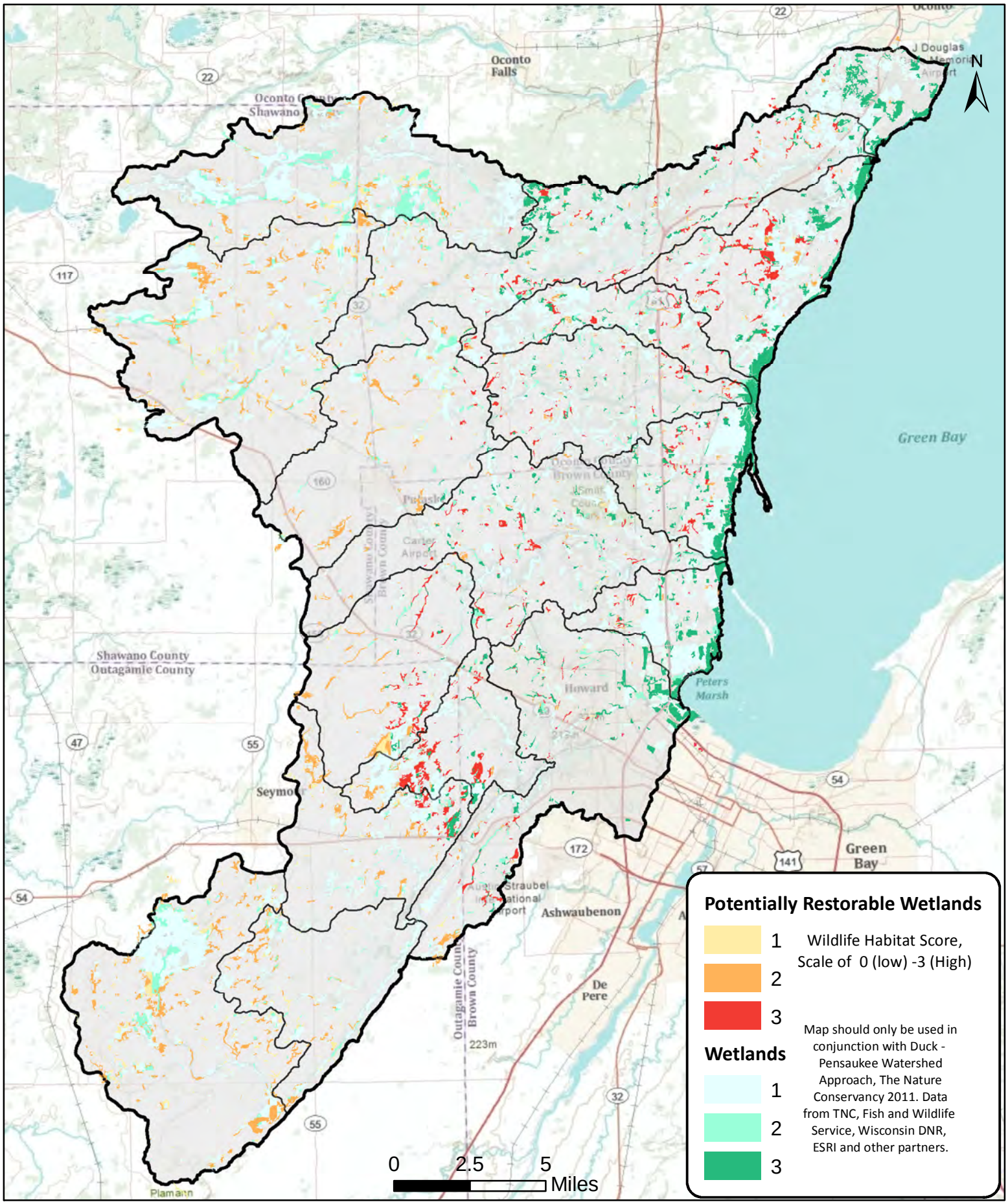
Duck-Pensaukee Migratory Stopover Sites

Potential Habitat for Shorebirds

Figure 18



Riparian habitat: *wood turtle* (Figure 17)
Wood turtles rarely venture far from streams and make use of a variety of natural habitats along stream corridors; therefore, they were selected to represent "riparian" habitats in the Duck-Pensaukee.

Shorebird stopover habitat (Figure 18)
The Duck-Pensaukee Watershed encompasses a portion of the "West Shore Wetlands," one of the world's largest freshwater estuaries. Given this, and its location along a major migratory bird flyway, it provides critical habitat for migratory shorebirds.

B.4.b. Other (non-wildlife) wetland services

Wetlands provide many services beyond wildlife habitat, including water quality protection, flood abatement, surface water supply, carbon storage, shoreline protection, and fish habitat. For these non-wildlife services, a different approach was used that considered three factors for each service: the *opportunity* for the service to be performed, the *effectiveness* of the wetland in providing the service, and the relative *significance* of the site in providing services for people. Fish habitat was included in this suite of services because habitat requirements of in-stream species could not readily be assessed with the Wildlife Tool. The potential for an individual wetland to provide each of these services, relative to other wetlands, was calculated by measuring these three factors, and then combining results into a final score. An overview of factors that were considered and a general description of how they were measured is provided below; details can be found in E.7. Mapped results are presented in Figures 19 – 24.

Flood abatement (Figure 19)
Examples of factors that led to a high score:
Sites surrounded by steep slopes and paved areas, or that have streams feeding into them, receive large amounts of storm water quickly. Wetlands that occur in topographic depressions and have dense vegetation slow floods down. Sites above developed flood-prone areas can help communities with flooding problems.

Surface water supply (Figure 20)
Examples of factors that led to a high score:
"Headwater" wetlands help to maintain water levels by discharging groundwater. Wetlands in the floodplains of streams temporarily hold water from floods, and then release it back into streams during drier periods.

Water Quality Protection (Figure 21)
Examples of factors that led to a high score:
Sites that receive pollutants from pipes or excessive nutrients from urban and agricultural sources are positioned to intercept these inputs and help to keep water clean. Densely vegetated wetlands with fluctuating water levels can help to "process" pollutants. These aspects are particularly important in areas above waters that have been identified as "impaired."

Carbon storage (Figure 22)
Examples of factors that led to a high score:
Sites with deep, organic soils store a great amount of carbon below-ground; dense woody vegetation can store carbon above-ground. Wetlands that don't have outflow can trap organic matter and store its carbon. Conservation of wetlands that are particularly

Duck-Pensaukee Wetland Assessment
Flood Abatement

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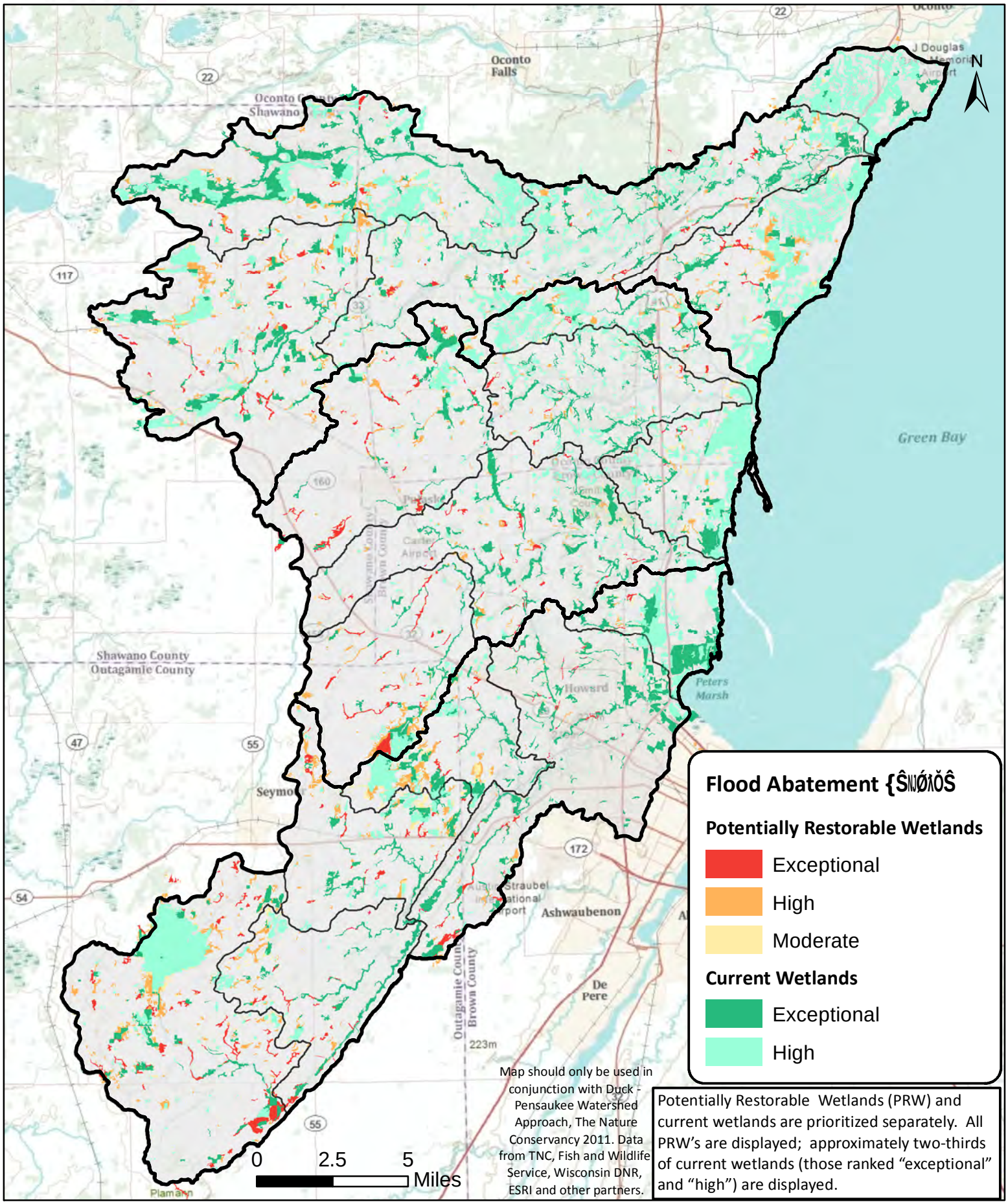
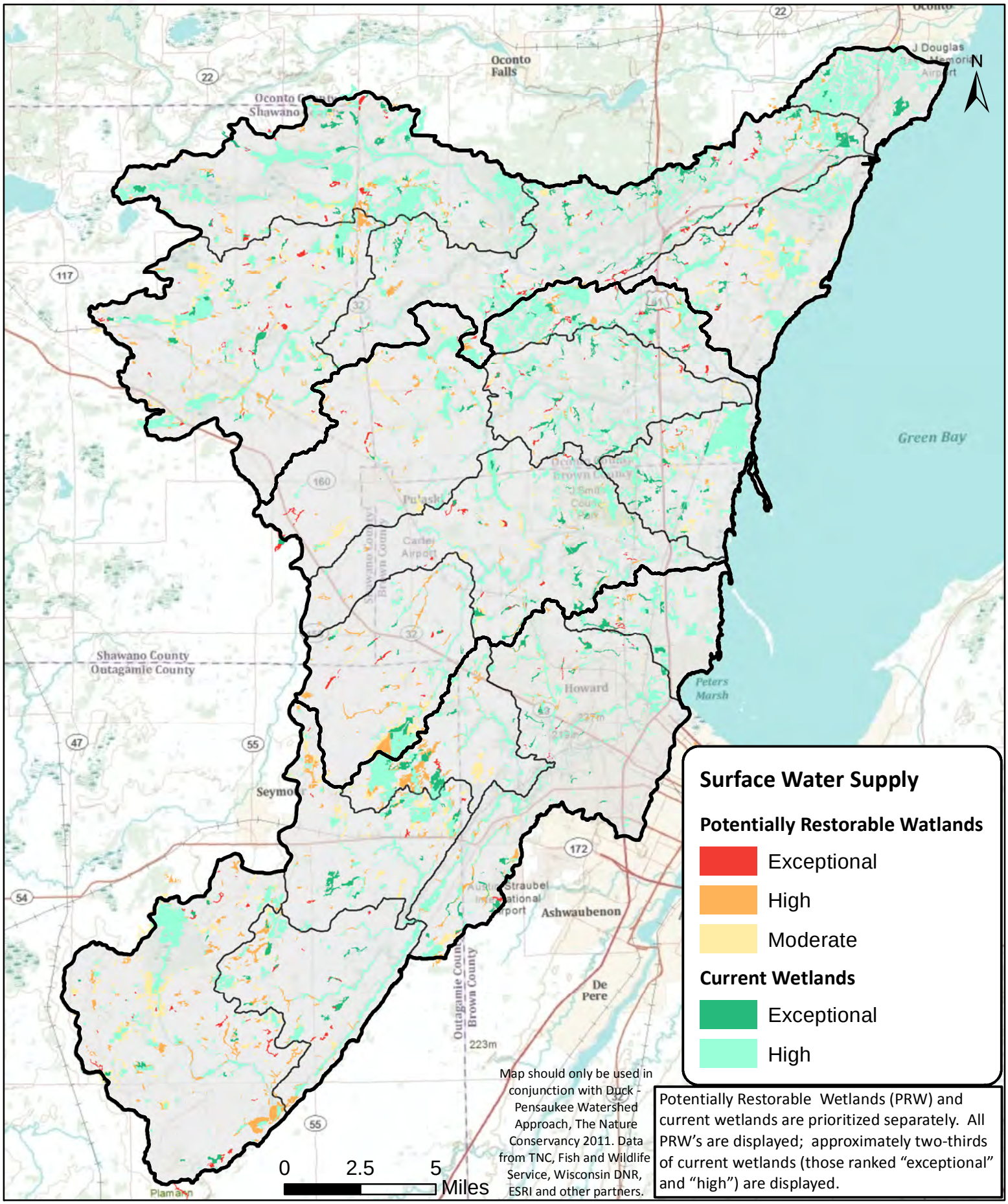
Figure 19



Duck-Pensaukee Wetland Assessment
Surface Water Supply

Figure 20



Duck-Pensaukee Wetland Assessment
Water Quality Protection

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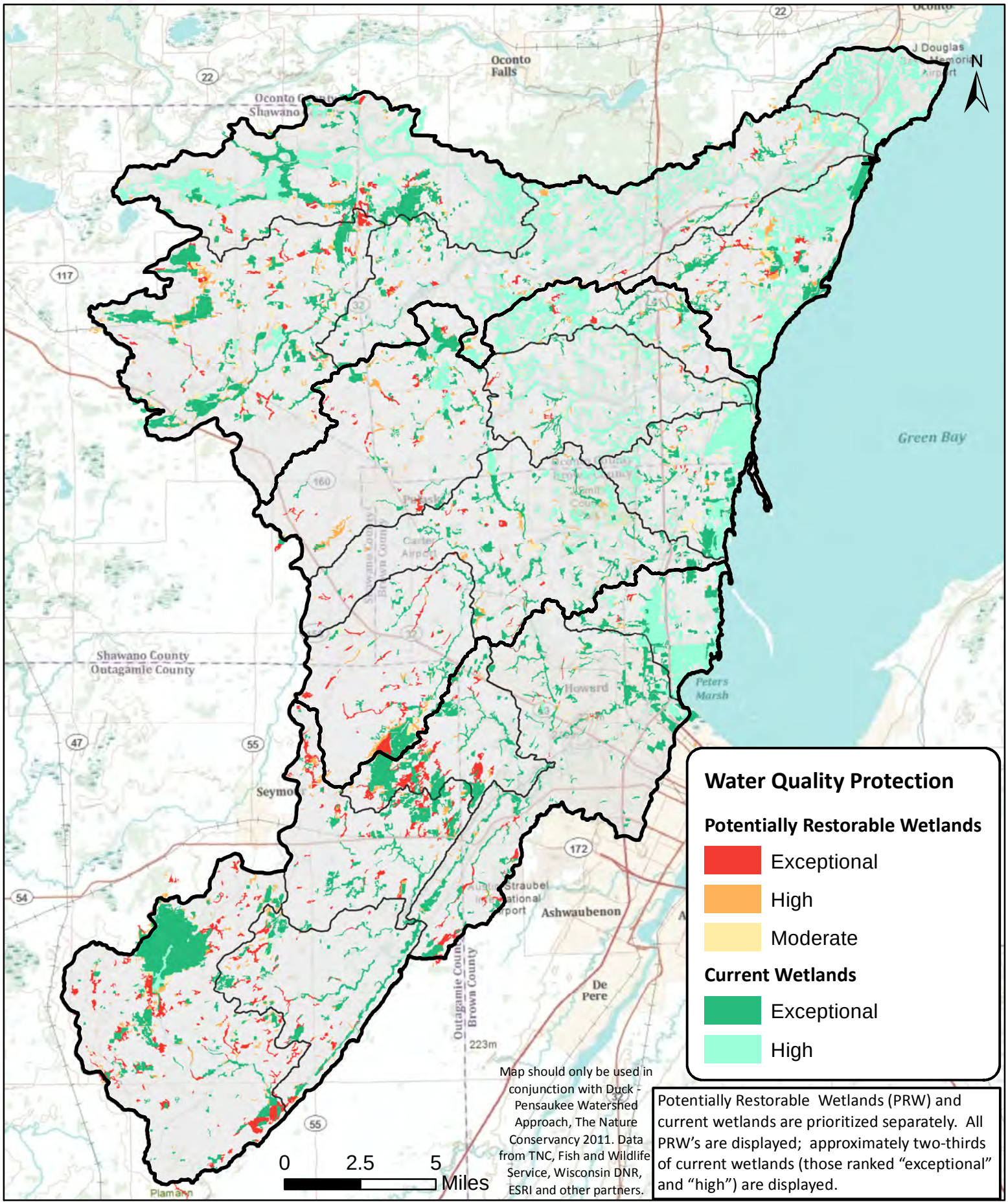
Figure 21



Duck-Pensaukee Wetland Assessment
Carbon Storage

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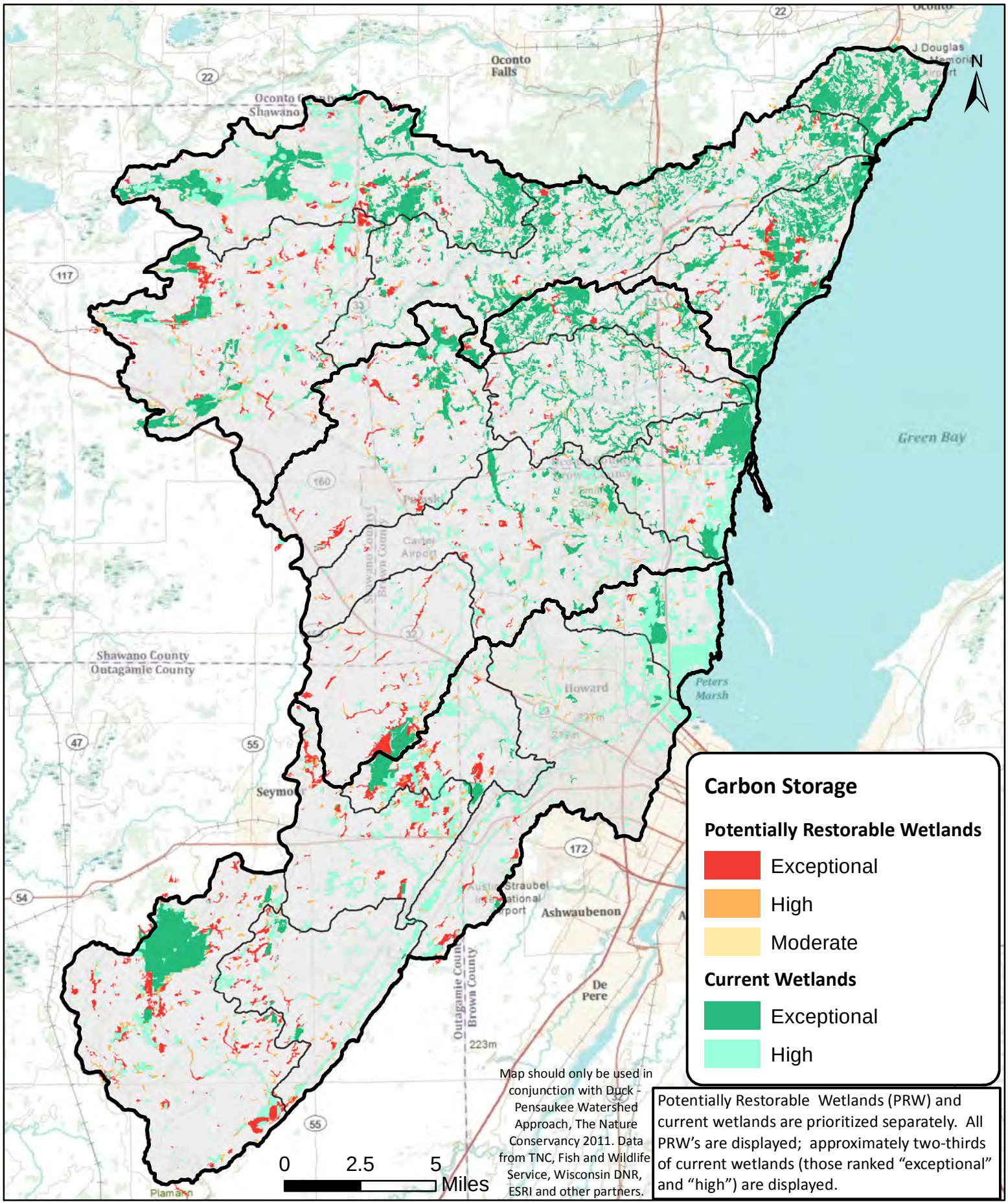
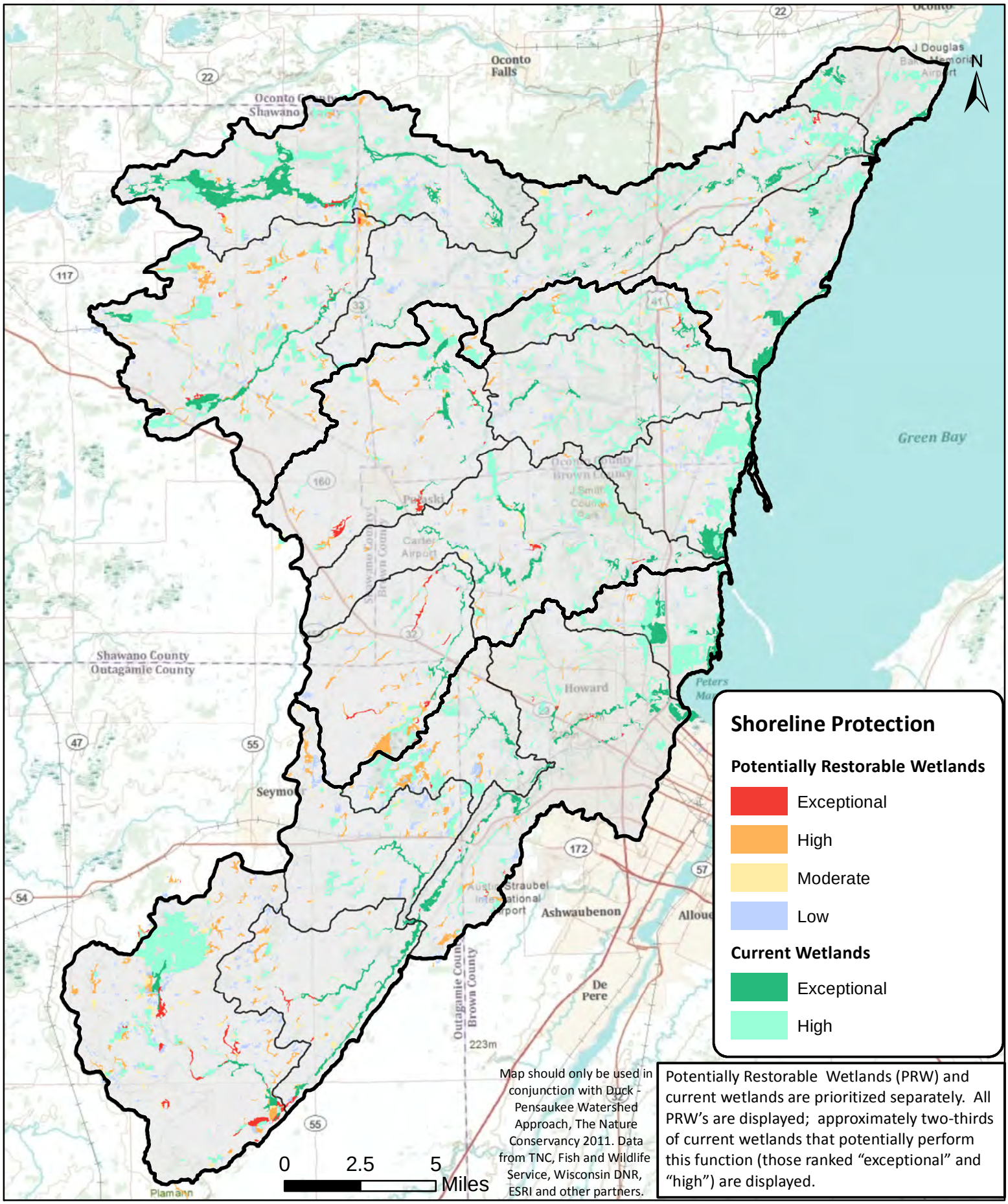
Figure 22



Duck-Pensaukee Wetland Assessment
Shoreline Protection

Figure 23



Map should only be used in conjunction with Duck - Pensaukee Watershed Approach, The Nature Conservancy 2011. Data from TNC, Fish and Wildlife Service, Wisconsin DNR, ESRI and other partners.

Potentially Restorable Wetlands (PRW) and current wetlands are prioritized separately. All PRW's are displayed; approximately two-thirds of current wetlands that potentially perform this function (those ranked "exceptional" and "high") are displayed.

Duck-Pensaukee Wetland Assessment
Fish Habitat

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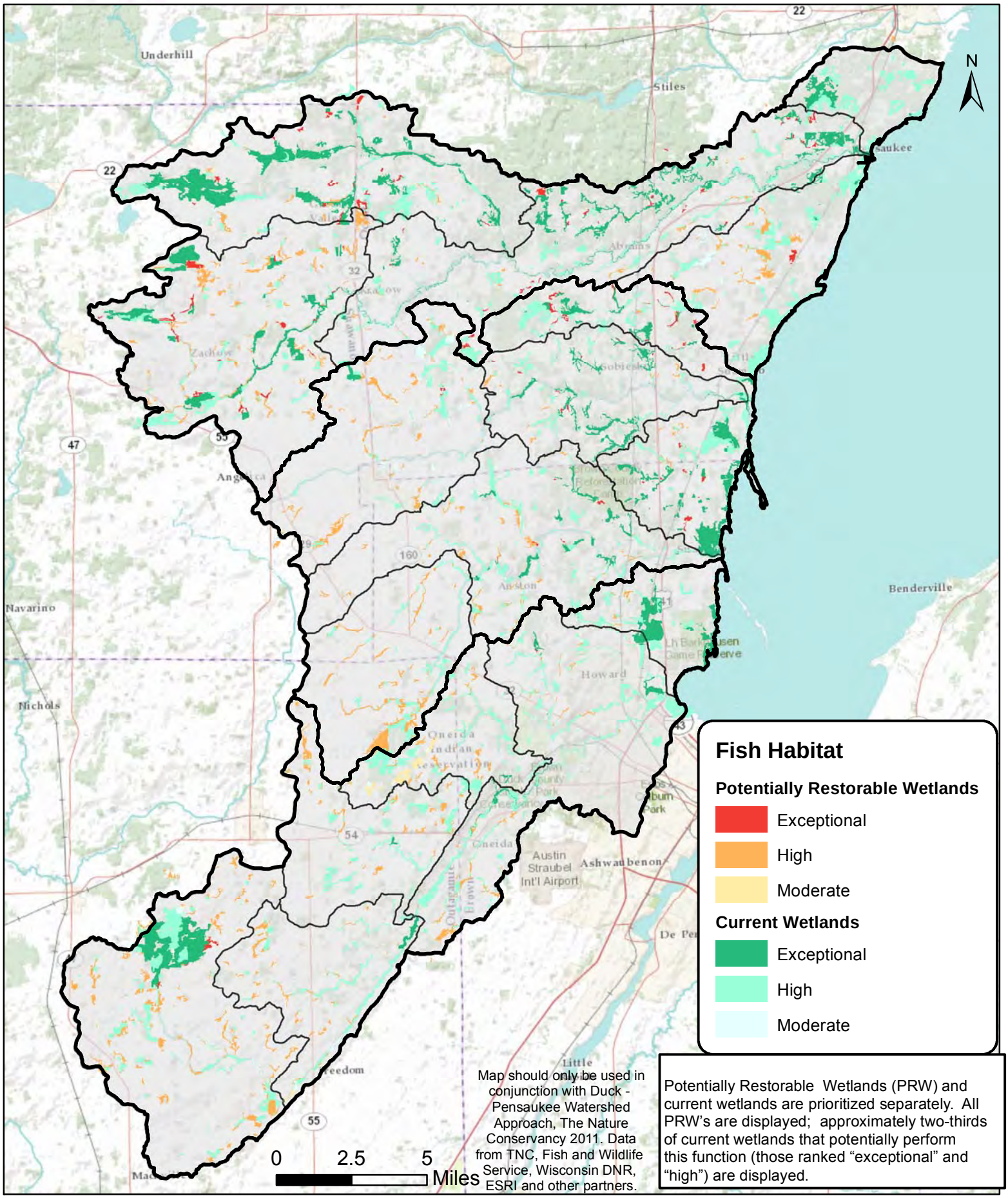
Figure 24



Map should only be used in conjunction with Duck - Pensaukee Watershed Approach, The Nature Conservancy 2011. Data from TNC, Fish and Wildlife Service, Wisconsin DNR, ESRI and other partners.

Potentially Restorable Wetlands (PRW) and current wetlands are prioritized separately. All PRW's are displayed; approximately two-thirds of current wetlands that potentially perform this function (those ranked "exceptional" and "high") are displayed.

effective in storing carbon can help to reduce greenhouse gases and slow climate change.

Shoreline protection (Figure 23)
Examples of factors that led to a high score:
Wetlands next to large waterbodies with high wave energy and rivers with high flow rates can help to slow waters down and protect otherwise erodible shores. Where these wetlands lie between waterbodies and developed areas, they have particular significance because they protect lands and maintain property values.

Fish habitat (Figure 24)
Examples of factors that led to a high score:
Wetlands that are connected to relatively clean waterbodies (lakes, streams) and that are flooded during fish spawning periods. The waterbody is bordered by natural landcover (for shading and nutrient inputs) and the wetland's drainage contains a high proportion of natural habitat.

B.5. Climate change considerations

Wetlands play a critical role in climate change, helping to capture and store carbon, a greenhouse gas. Wetland restorations are particularly effective in this role (Mitsch et al 2012). With ongoing and projected dramatic increases in temperature, heavy storms, and other factors related to climate change (WICCI 2011), many aspects of the lands and waters on which we all depend will be fundamentally altered over the coming decades. Within the Green Bay Basin, these changes will lead, in particular, to increased agricultural and urban runoff issues, and therefore lower water quality in our streams and in the Bay (Harris and Wenger 2010). The prospect of wetland conservation—both preservation and restoration—presents us with major opportunities to reduce and adapt to the effects of climate change. This plan attempts to capitalize on those opportunities, by:

1. Identifying subwatersheds with the greatest potential for storing carbon
2. Prioritizing existing wetlands that are likely sequestering the most carbon, currently
3. Prioritizing potentially restorable wetlands that, if restored, have the greatest chance of sequestering carbon
4. Identifying coastal areas that alternate between upland and wetland conditions, in synchrony with Great Lakes levels. Lake level fluctuations are expected to shift in response to climate change, and protection of these periodic wetlands could help to maintain resilience and wetland services into a future where those services become increasingly scarce.
5. Ensuring that sites prioritized for wildlife today are still priorities in the future, under a different climate. The representative wildlife species in Section B.4.a were selected based on their vulnerability to climate change, and their likelihood of persisting in this landscape.
6. Offering recommendations for climate change adaptation under Section D, such as strategically siting wetland restorations between sources of polluted runoff (expected to increase due to climate change) and valuable freshwater resources.

While all of these factors are intended to help achieve a climate-adapted future for the Duck-Pensaukee Watershed, many additional factors may be considered and integrated into a watershed approach for wetland conservation. A more thorough checklist of climate change adaptation strategies is under development, in collaboration with The Nature Conservancy's Great Lakes Climate Change Team. This checklist will be integrated into the national handbook for watershed approach planning (Section A.2).

C. RESULTS

C.1. Maps: Online and in-print

Results are summarized below and provided via maps in Figures 5 – 24. Similar maps will be available at http://maps.tnc.org/DuckPenTool by late April 2012. These online maps may be more useful for exploring and applying results, as they enable zooming, panning, layering multiple maps, and other interactivity. In addition, this site allows users to download spatial data for use in a GIS environment. Note that digital versions of this plan also allow for zooming and panning within all maps.

C.2. Identification of potential sites for conservation

Of the historical 84,361 acres of wetlands in the Duck-Pensaukee Watershed (see methods for identifying historical wetlands in Sections B.2 and E.4), 52,338 acres of wetlands remain (Figure 5); therefore, the watershed's wetlands have declined by an estimated 38% since presettlement times. Of the 32,023 acres of wetlands that have been lost, 11,573 acres (36%) have been identified as potentially restorable based on current land use and landcover. Although much of this area may not be available for restoration based on factors such as feasibility and land availability, it is clear that this watershed has a great deal of potential for restoration.

In addition to outright loss of wetland area, the health and functionality of many remaining wetlands have been compromised. Preliminary analyses show that many acres of wetland have been invaded and dominated by reed canary grass (Hatch and Bernthal 2008). In addition, most wetlands in the watershed have been degraded through alterations to water flow (ditching and draining), leading to declines in the ability of wetlands to improve water quality and abate floods.

C.3. Watershed profile: Setting goals for the watershed

Since the 1800s, various land uses have degraded and eliminated wetlands and their valuable services in the Duck-Pensaukee Watershed (Figures 6 – 9). Four services were assessed: water quality protection, surface water supply, flood abatement, and carbon storage. Declines in these services result from loss of wetland area (e.g., through conversion to upland habitats or land uses), and also from changes to remaining wetlands (e.g., degradation of remaining wetlands from ditching and altered water flow). Relative decline in services is reported at the subwatershed level (12-digit HUCs) for the Pensaukee Drainage, the Suamico/Little Suamico Drainage, and the Pensaukee Drainage.

C.4. Prioritizing sites by their potential to provide services

Results from the site-based assessments for the seven wetland services may be viewed individually, for each service, or collectively. Wetland preservation and restoration opportunities may be ranked based on their relative ability to support the full range of seven services (Figure 10). Maps have also been produced that show potential provision of non-wildlife services at sites (Figures 19-24). Conservation opportunities for wildlife (in wetlands, potentially restorable wetlands, *and* associated upland habitat) may also be viewed collectively, for all wildlife (Figure 11), or separately for individual species or suites of species (Figures 12-18).

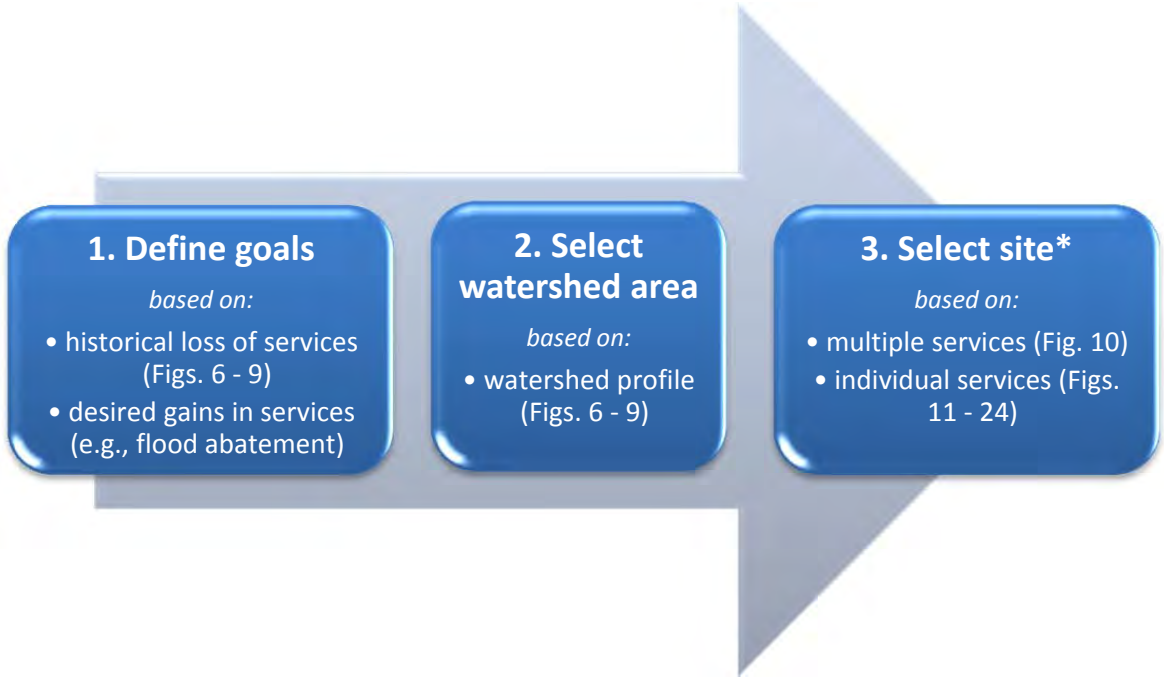
D. CONCLUSIONS AND RECOMMENDATIONS

D.1. How to use this watershed plan

The results of this plan are not intended to be prescriptive; instead, watershed stakeholders are encouraged to consider results to define priorities, identify subwatersheds to work in, and select a specific site in the subwatershed (Figure 25).

All of the data layers and figures referred to here are available online at http://maps.tnc.org/DuckPenTool, to view interactively or to download for use within a Geographic Information System.

Figure 25. Steps to select sites for conservation: an example.



*This is a "Level 1" site assessment based on remotely-sensed data. Additional steps (e.g., in-person site visits) must be taken to determine feasibility and develop detailed site plans.

Example 1. A city experiencing flooding problems could determine where flood abatement has been lost in subwatersheds upstream (Figure 6). Sites most likely capable of helping to abate floods could be identified using Figure 19. Of these, restoration work could be targeted toward sites that are most likely to increase many services (Figure 10).

Example 2. An agency or NGO responsible for increasing waterfowl and marsh bird habitat could use Figure 12 as a first filter. The outcomes of preservation or restoration work could be increased by selecting sites that benefit multiple species and habitats (Figure 11), and that address requirements of Species of Greatest Conservation Need in Wisconsin's Wildlife Action Plan, or sites that increase the delivery of a broad array of services (Figure 10).

Example 3. An individual permittee compensating for wetland alterations might identify sites that maximize contributions to a broad suite of services within the watershed (Figure 10) in areas with known loss of wetland services (Figures 6 - 9), contingent on other regulatory requirements.

Example 4. A wetland mitigation banker might use results as a first step in identifying large sites with a great deal of preservation and restoration potential, in terms of both area and potential returns in wetland services.

D.2. Opportunities for preservation

We recommend that preservation efforts should target a variety of factors, including:

High-performance wetlands. All wetlands provide services, but many factors – including watershed position, wetland type, condition, and others – affect the degree to which those services are performed at individual sites. Figure 10 can be used to select sites that have the greatest potential to perform the most services at an exceptional or high level. Figures 11 – 24 report potential provision of services separately, for each service, so that wetland preservation opportunities can be best matched to the specific goals of individual groups, agencies, and organizations.

Great Lakes coastal wetlands. Freshwater estuaries associated with the Great Lakes are unique, at a global level. While coastal wetlands may at first glance appear to be abundant in the Duck-Pensaukee Watershed, their extent has greatly declined due to drainage for agriculture and the expansion of the footprint of development in coastal areas (Figure 5). These wetlands protect coastal communities from storm surges. They also provide food and habitat for estuarine fish and wildlife specially adapted to these systems, and they play crucial roles in the Great Lakes food web. These services ensure a strong foundation for fishing, tourism, and the economic well-being of coastal communities in our region. Coastal wetlands should be very high priority for preservation in this watershed.

Rare wetland types. Wetlands designated as rare (S1-S3 or G1-G3, per Wisconsin's Wildlife Action Plan) and that have the potential to be found in the Duck-Pensaukee Watershed include: boreal rich fen, some Great Lakes shoreline and beach communities, interdunal wetlands, wetlands of ridge and swale communities, sedge meadow, northern wet-mesic forests (cedar swamps), floodplain forest, wild rice beds, bog relict, and northern hardwood swamp.

Irreplaceable wetlands. Replacement or restoration of any wetland type is difficult and uncertain; many wetland restoration attempts have failed, for a variety of reasons (Turner et al. 2001, Moreno-Mateos et al. 2012). It is generally acknowledged that certain wetland types, including various types of bogs and fens, cannot be restored at all because of their complex hydrology, unique water chemistry, rare vegetation, and other factors. Forested wetlands are also difficult to restore and may take decades to reach maturity. Bogs, fens, and forested wetlands should be targeted in preservation efforts because of their irreplaceability (Miller and Golet 2001).

Large wetlands. With some exceptions, large wetlands provide services in greater magnitude than smaller wetlands. Large expanses of the West Shore Wetlands remain along the Green Bay coastline (Figure 5). In addition, large wetland complexes are found higher in the watershed, in the subwatersheds of Upper Duck Creek; North Branch Pensaukee River; and spanning the Oneida Creek, Trout Creek, and Suamico River-South and West Branch subwatersheds, among others (see Figures 2 and 5).

Wetland-rich areas. Multiple wetlands within an area (e.g., along a stream reach or in a subwatershed) might collectively function at a higher level than any individual wetland. Therefore, preservation of wetland-rich areas could play a large role in maintaining wetland services.

Very small wetlands. Some very small wetlands provide unique services. This is of particular concern because these wetlands are often too small to be mapped, and therefore have not been included in the analyses or results of this plan. Ephemeral ponds in wooded settings provide habitat for a unique assemblage of species, including salamanders and invertebrates that require fishless ponds.

High-condition wetlands. Wetland condition was not specifically addressed in this plan, as it is best assessed on the ground using field-based protocols. The closest proxy this plan provides for measuring wetland condition is the wildlife habitat service (Figures 11 – 18). Sites that score high for wildlife will tend to be in settings that can maintain high wetland condition.

Wetland/upland complexes. The Wildlife Tool identified complexes of habitat—both wetlands and uplands—important to wildlife. Preservation of these combinations of upland and wetland habitats would ensure that wetlands remain an interconnected part of the watershed, rather than becoming islands of habitat in a sea of converted lands. Preservation of uplands adjacent to wetlands also benefits other services, such as water quality protection.

Critical habitat wetlands. Wetlands that are known to currently provide critical habitat (nesting, foraging, denning, etc.) for Species of Greatest Conservation Need (SGCN) should be preserved. Preservation and enhancement of existing SGCN populations and their habitats is important to ensure the persistence of these species in the watershed.

Potential wet areas (periodic wetlands). These coastal areas (Figure 26) are not currently mapped as wetlands, but they function as wetlands during periods of high Great Lakes levels. Therefore, they present unique opportunities for preservation that would help to maintain watershed services. Some possibilities for protection include fee simple acquisition of areas currently in natural habitat, and innovative agricultural easements for areas currently cropped.

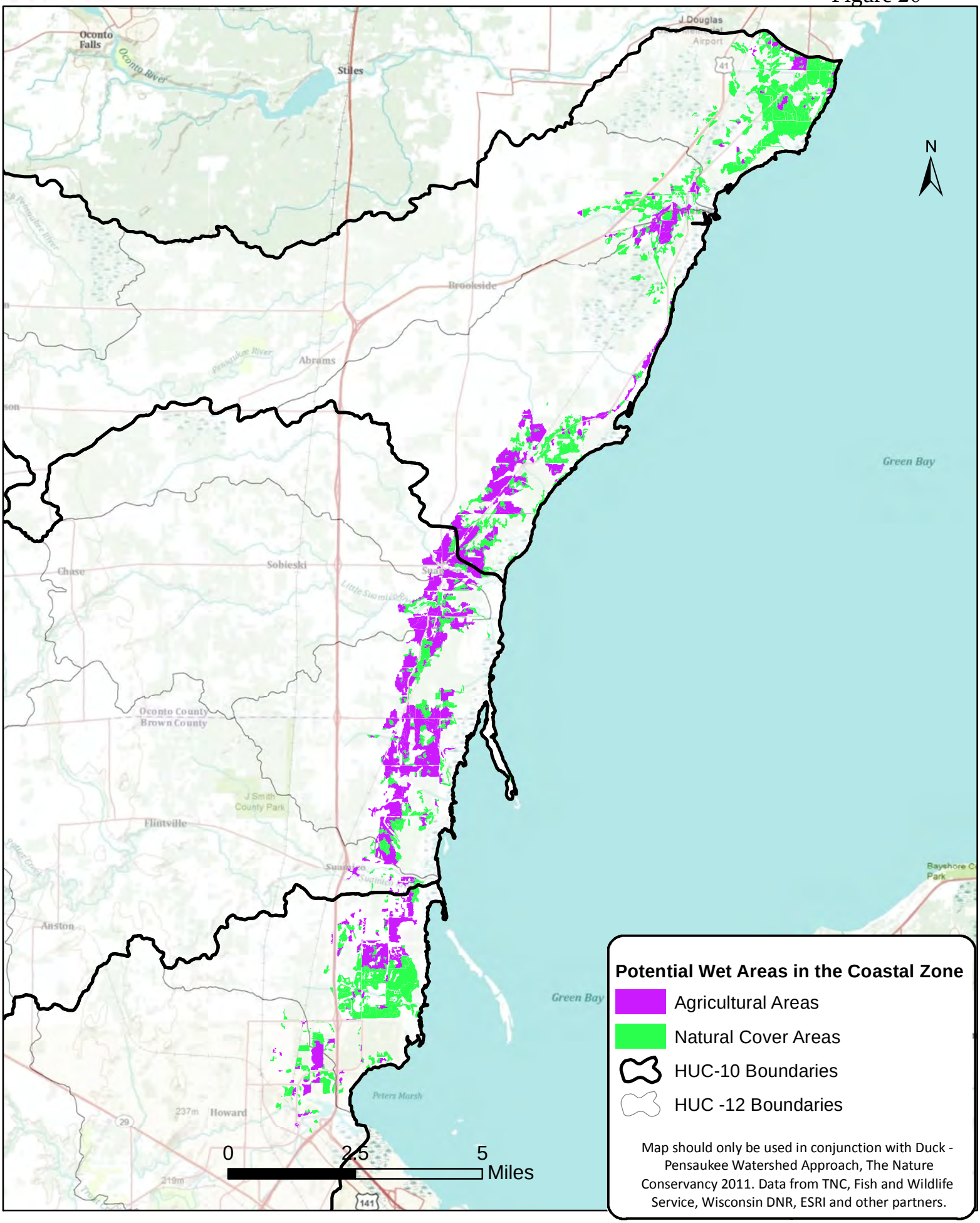
D.3. Opportunities for restoration

Opportunities for restoring wetlands of the Duck-Pensaukee watershed may be divided into two categories: *re-establishment* (restoring wetlands that have been completely destroyed and converted to upland) and *rehabilitation* (restoring existing wetlands that have been degraded or impaired).

While this plan is intended to answer the question of *where* to restore, based on potential returns in ecosystem services, it does not attempt to answer the question of *how* to restore wetlands. The answer to the question of *how* depends on many factors, most of which are site-specific. An excellent starting point for those wishing to restore wetlands in the Duck-Pensaukee Watershed is the *Wetland Restoration Handbook for Wisconsin Landowners* (Thompson and Luthin 2010).

Duck-Pensaukee Basin
Potential Wet Areas in the Coastal Zone

Figure 26



D.3.a. Opportunities to re-establish lost wetlands

Arguably, the greatest gain in wetland services may be attained by re-establishing wetlands where they no longer exist (NRC 2001, Miller and Golet 2001), as these sites are not currently functioning as wetlands. In addition, restoration activities in these areas will likely have lower risks for existing wetlands (e.g., low or no risk of heavy restoration equipment compacting soils or inadvertently introducing non-native species). To maximize gains in wetland services across the watershed, re-establishment opportunities should, in general, receive priority over rehabilitation opportunities.

Wetland re-establishment would be particularly effective for water quality protection at sites located where they could intercept runoff from agricultural or urban sources. Re-establishing wetlands in riparian zones would be especially beneficial for maintaining surface water quality in streams and, ultimately, the Bay. Runoff from agricultural and urban areas, and associated impacts to water quality, have been identified as a top-ranked threat in the Green Bay Basin. A recent analysis on climate change impacts in the Basin indicated that runoff threats will increase disproportionately to other stressors in the Basin (Harris and Wenger 2010). Runoff problems, and associated impacts on water quality, may increase drastically over the coming decades. Wetland re-establishment provides a means to adapt to future runoff conditions under a changing climate, with implications for water quality throughout the watershed and in the Bay of Green Bay. Note, however, that restoration sites subject to high nutrient loading will not be as effective in providing fish and wildlife habitat.

For sites that rank high for wildlife habitat, it should be noted that the priority of an individual site is often contingent on the availability of specific habitats nearby. Therefore, we recommend that restoration projects conducted to support wildlife should expand in scope to encompass adjacent uplands and wetlands important to wildlife (Figures 11 - 18).

Restoration of open water can cause hazards near airports due to potential bird/aircraft collisions. The U.S. Army Corps of Engineers has developed a Memorandum of Agreement with the Federal Aviation Administration providing special considerations for compensatory mitigation restorations (see Section A.1) within 5 miles of FAA-regulated airports (see Figure 4).

D.3.b. Opportunities to rehabilitate degraded wetlands

Statewide mapping of wetlands dominated by reed canary grass (Hatch and Bernthal 2008) reveal that wetlands of the Duck-Pensaukee Watershed have been extensively invaded by this species. Invasion by reed canary grass may degrade certain wetland services (e.g., wildlife habitat), but may be neutral or even beneficial for other services (e.g., water quality protection) (Miller and Golet 2001). While control of this species is difficult, techniques are available and continue to be developed (WRCGMWG 2009). It is arguable whether attempts at wholesale control of reed canary grass are advisable in a watershed that has

been so thoroughly invaded. We recommend limiting extensive control efforts to sites that are considered particularly valuable, rare, or under imminent threat from upstream seed sources; further, we recommend close monitoring at sites that have not yet been invaded.

Ditching and partial draining have had major impacts on current wetlands in the Duck-Pensaukee Watershed, and in many cases have compromised the potential for wetlands to abate floods and protect water quality. Although ditches were not specifically mapped during this project, wetlands with "artificial flow" were identified as part of the development of the watershed profile (Section B.3). Critical services could be returned to the watershed by filling or plugging ditches in large wetlands that have been extensively ditched.

D.4. Next steps

The science and practice of watershed planning is ever-evolving, and new lessons are learned with the development of each new plan. We are just beginning to understand the complexities underlying watersheds and wetlands, and there are many important "next steps" to take.

Several reviewers of this Watershed Approach have proposed a logical next step: to use the information generated about the extent and location of service provision as the basis for determining the economic value of wetlands. A recent statewide economic assessment of Wisconsin's wetlands estimated a cumulative value of between $3.3 and $152.6 billion per year (Earth Economics 2012). Clearly, this is useful information for developing wetland policy. Stepping this analysis down to the watershed scale, and to individual sites, would also help to inform decisions by land-use planners, communities, landowners, and others.

The scope of this plan is limited to wetland preservation and restoration opportunities that are sustainably sited and offer an array of services. However, there are additional conservation activities, beyond this scope, that also aim to improve watershed health and services. For example various kinds of engineered wetlands are often added to watersheds, including stormwater ponds, swales, ditches, and wastewater treatment facilities. Research is ongoing to determine their effectiveness in cleaning water, as well as their collateral benefits in terms of ecosystem services. Out of this research, guidance is being developed to make such structures "greener" (J. Zedler, UW-Madison, *pers. comm.*). Future iterations of the Watershed Approach should attempt to integrate these practices into watershed plans.

In addition, there are other types of plans that are complementary to, and could be combined with, this Watershed Approach. Total Maximum Daily Load (TMDL) plans propose reductions in point-source and non-point source pollutants within a watershed. This information could be used in prioritization of wetland preservation and restoration opportunities. Similarly, the Wisconsin Buffer Initiative identifies primary sources of nutrient runoff from agricultural fields; wetland restoration opportunities could

be prioritized and sited to intercept and address these nutrient issues.

Finally, research should be conducted to determine the degree to which the goals of watershed approach-based plans are achieved. The assumption that such plans lead to greater restoration success and improved delivery of services should be tested. To accomplish this, an experiment could be conducted in subwatersheds of the Duck-Pensaukee, using a BACI study design (before-after control-impact).

E. METHODS TO PRIORITIZE WETLAND CONSERVATION IN WATERSHEDS

E.1. Overview of approaches

This section presents the methods used to create the watershed plan in Sections A-D. It is intended to: (1) provide a foundation for interpreting and understanding results of the Duck-Pensaukee Watershed Approach, and (2) serve as a detailed manual for application of these methods in other watersheds.

The intent of this watershed plan is to assess preservation and restoration needs in the Duck-Pensaukee Watershed and also to identify sites that have the greatest potential to meet those needs. Watershed needs are expressed in terms of wetland services (water quality protection, surface water supply, flood abatement, and carbon storage). Site-specific opportunities are evaluated by their potential to perform those four services, with the addition of wildlife habitat, fish habitat, and shoreline protection services.

As a "Level 1" watershed assessment, this plan uses existing data within a GIS environment. This level of analysis aims to guide conservation investments toward sites that are most likely to result in conservation gains by comparing their relative potential, across an entire watershed, to provide wetland services. However, because of potential issues with data resolution and classification at this scale of analysis, results of the assessment should be verified through on-site visits before developing and implementing site-specific plans.

In addition to identifying potential preservation and restoration sites, the Duck-Pensaukee Watershed Approach builds from three distinct methodologies that aim to assess:

1. how wetland services have changed since the 1800s at the watershed-scale (as a goal-setting exercise),
2. the relative importance of individual sites for the preservation and restoration of wildlife habitat, and
3. the relative importance of individual sites to human health, well-being, safety, and economies.

Each of these methods is described in detail in the following sections. Preservation and restoration priorities were identified for each service and also cumulatively, across all services.

E.2. Expert input and stakeholder engagement

This Watershed Approach is intended to provide as much detailed information as possible for application in other watersheds. However, local conditions (ecological, societal, etc.) and data availability can vary significantly among watersheds. Therefore, application of this framework can and should be adjusted to address unique local watershed considerations. Two ways to tailor watershed plans include engagement with local watershed stakeholders, and close collaboration with local subject-matter experts. Potential stakeholders include: state, federal, and tribal agencies responsible for natural resource protection and regulation; NGO's active in the area; planning and conservation staff of local (county or municipal) government; regional planning commissions; transportation agencies; university and extension scientists; and concerned citizens.

To engage with stakeholders, we recommend:

a. a ***kick-off meeting*** to vet ideas and concepts, familiarize the planning team with stakeholders, and begin to establish common goals and vision for the project;
b. regular ***updates*** to stakeholders (via email) during the planning process;
c. a ***meeting at the end of the planning process***, to vet results with stakeholders; and
d. ***follow-up meetings with key groups and individuals*** to promote implementation of results.

Experts who are familiar with the watershed and with specific topics (e.g., wetland ecology, soil science, wildlife ecology) must also be actively engaged to ensure relevance of results to local conditions. Throughout the following description of methods, specific points where expert input is required have been highlighted. Modes of interaction with experts (e.g., one-on-one meetings vs. group meetings, webinars or phone conferences vs. in-person meetings) will be dictated by the nature of the input sought and the need to reach consensus among multiple experts. In the Duck-Pensaukee, all of these modes were employed.

E.3. Which wetland services and why

Wetlands provide an array of services that are crucial to the health and well-being of people (Millennium Ecosystem Assessment 2005). These services range from fairly intangible and unmeasurable to clear and specific; similarly, our ability to measure them at a landscape scale with existing spatial datasets ranges quite a bit. For wetland prioritizations in the Watershed Approach, we selected a suite of services based on: (1) their relative importance to people; (2) the degree to which wetlands, specifically, perform them; and (3) the extent to which we can distinguish their performance at a landscape scale, using available spatial datasets. Based on these criteria, the following seven services were selected for assessment in this project: water quality protection, flood abatement, surface water supply, shoreline protection, carbon storage, fish habitat, and wildlife habitat.

E.4. Identification of potential sites for conservation

Identification of sites is the first step in prioritization of conservation opportunities. Preservation opportunities include the current extent of wetlands, as defined by NWI (National Wetlands Inventory, US Fish and Wildlife Service, http://www.fws.gov/wetlands/ and WWI (Wisconsin Wetlands Inventory, Wisconsin Dept. Natural Resources, http://dnr.wi.gov/wetlands/inventory.html). Potentially restorable wetlands or "PRWs" (wetland re-establishment opportunities) were defined as sites that formerly supported wetland hydrology and vegetation under appropriate current land use/landcover. In the Duck-Pensaukee Watershed, wetland rehabilitation opportunities were defined as sites that have been degraded through hydrologic alteration (ditching) or invasion by reed canary grass (*Phalaris arundinacea*).

Techniques to identify and categorize historical wetlands were adapted from methods developed in Rhode Island (Miller and Golet 2001) and in the Milwaukee River Basin, Wisconsin (Kline et al. 2006). The Wisconsin methods have been updated and applied statewide by WDNR. All of these approaches define historical wetlands as hydric soils (i.e., soil polygons coded as >85% hydric) that are not currently classified as wetland by WWI or NWI (i.e., they no longer support wetland vegetation and hydrology).

Historical wetlands may be further categorized according to their restoration potential, defined by current land use and landcover (CCAP 2001). Historical wetlands that are classified as residential or developed do not present feasible restoration opportunities. "Restoration" of historical wetlands that are currently in natural landcover (e.g., forests, shrublands) may compromise existing services provided by the natural cover and could present risks to adjacent wetlands; these areas were not considered during the prioritization process. Therefore, potentially restorable wetlands (PRWs) were defined as historical wetlands that are not developed or in natural cover types. In a watershed dominated by agriculture, like the Duck-Pensaukee, this equates to historical wetlands that are currently coded as agricultural in the land use/landcover database. Table 2 provides summaries of key terms and definitions.

Through input from local experts in hydrology and soil science (A. Stranz, *pers. comm.*), it became apparent that local exceptions necessitated adjustments to this process. In the lower part of the watershed, along the coastal plain of Green Bay, experts conveyed that soil polygons with very small amounts of hydric inclusions (<9% hydric, see Appendix X) function as wetlands during cyclically high Lake Michigan levels. As wetland hydrology returns to these areas, wetland vegetation re-establishes, presumably from the seed bank. Experts conjectured that these areas of largely mineral soils may have had organic horizons that were burned off in historic catastrophic fires in the region; therefore, these areas may have been more clearly and more permanently wetlands. Further speculation focused on the possibility that the frequency and range of lake level fluctuations may shift as climate changes, influencing the likelihood that these areas will

function as wetlands. Protection of these areas could accommodate future shifts to wetland conditions, and this may serve as a climate adaptation strategy.

Table 2. Site identification: key terms and definitions.

Wetland category	Definition
Current wetlands	Polygons of NWI/WWI maps
Historical wetlands	Hydric soils minus current wetlands
Potentially restorable wetlands (PRWs)	Historical wetlands minus areas developed or in natural cover
Potentially wet areas ("periodic wetlands")	Partially hydric coastal soils that function as wetlands during periods of high Lake Michigan levels

E.5. Changes in wetland services: Determining watershed needs by considering historical context

The methods described here can be used to evaluate how the distribution and magnitude of wetland services across the watershed have changed over time (Section C.3, Figures 6 – 9). Results should be used to guide watershed-wide conservation objectives and to better understand the watershed context of priority sites identified in sections C and D. Results should not be used to rank or prioritize individual sites for preservation or restoration; due to process and data constraints, that is not the intended scale of application.

This approach is adapted from NWI+ methods, which assign hydrogeomorphic-type modifiers to polygons of National Wetland Inventory maps (Tiner 2003). The modifiers include: Landform, Landscape position, Waterbody type, and Water flow path (referred to as LLWW) (Table 3). These LLWW modifiers help to define the relative position and role of wetlands within their watershed. When coupled with the original NWI data, resulting information can be used to determine likely services provided by each wetland polygon (Table 4). This approach has been further developed to track watershed-level trends in wetland services over time (Tiner 2005, Fizzell 2011), by applying first to the historical distribution and condition of wetlands and then to the current distribution and condition of wetlands. Changes in provision of services over time can result from either wetland degradation (e.g., alterations to water flow paths from ditching) or from the outright loss or destruction of wetlands.

Application of NWI+ in the Duck-Pensaukee Watershed drew heavily from previous applications in Maryland (Tiner 2005), MI DEQ (Fizzell 2011), and the work of St. Mary's University in partnership with the St Paul District of the Army Corps and WI DNR in the St. Croix River Basin (A. Robertson, St. Mary's University, *pers. comm*.). The methods were tailored to the Duck-Pensaukee Watershed through consultation with WI DNR staff and a group of local experts. The overall process is described below, including italicized annotations about how these methods were applied in the Duck-Pensaukee Watershed.

The process

1. Obtain National Wetland Inventory maps
   - *The DNR produces Wisconsin's wetland maps using a classification system that is related to but distinct from the classification system applied elsewhere in the U.S. (Cowardin et al. 1979). Because the NWI+ methods depend heavily on specific codes from the Cowardin-based NWI (especially water regime codes), we used WWI maps converted to NWI map format by USFWS's NWI program (T. Dahl, USFWS National Wetland Inventory, pers. comm.).*

2. Generate LLWW modifiers
   - *See Table 3 for LLWW definitions*
   - *LLWW attribution was automated to the extent possible in a GIS environment; however, some aspects required manual assessment and coding. See Appendix X for detailed steps on LLWW attribution.*

3. Correlate wetland attributes (combinations of NWI and LLWW coding) with wetland services
   - *See Table 4 for correlations of NWI+ modifiers with wetland services, and rationale. These correlations were developed from other applications of the NWI+ methodology in the region. They have been adapted to local conditions in this Great Lakes coastal watershed.*
   - *The number and types of services assessed has varied with each application of the NWI+ approach across the country. In the Duck-Pensaukee, we assessed four services: flood abatement, water quality, surface water supply, water quality protection, and carbon storage. Some services were combined; e.g., nutrient transformation and sediment detention are both aspects of water quality and similar wetland attributes underlie their performance. Some services were omitted due to insufficient data (e.g., locations of ephemeral ponds for assessment of amphibian habitat). In addition, some services (primarily wildlife-related) were omitted because their performance is driven by surrounding land-use context, which is not taken into account by NWI+ methods.*

4. Determine the level of performance for each service within each NWI wetland polygon, based on results of steps 2 and 3, and assign ranks identifying "exceptional" and "high" performing wetland polygons for each service.

5. Calculate the relative change in provision of services since the 1800s, across the entire watershed (8-digit HUC) and in each subwatershed (12-digit HUC).

$$\Delta S = [(H_e + H_h)/H_t] - [(C_e + C_h)/H_t]$$

Where,
ΔS = Relative change in provision of services
H_e = Historical area of wetland providing service at an "exceptional" level
H_h = Historical area of wetland providing service at a "high" level

C_e = Current area of wetland providing service at an "exceptional" level
C_h = Current area of wetland providing service at a "high" level
H_t = Total historical wetland area

6. Using results of the above formula, create maps showing the relative amount of change that has occurred in each 12-digit watershed, for each service.
   - *See Figures 6 – 9 for examples.*

7. Use results as a first filter for identifying potential sites for conservation, to determine, for example:
   a. areas (subwatersheds) in greatest need of wetland preservation and restoration,
   b. areas of opportunity that are upstream of known needs of people in the watershed (e.g., flooding problems in developed areas, surface water quality and quantity),
   c. areas where collaboration among the watershed's conservation community may yield the greatest results, and/or
   d. areas where preservation or restoration of high-priority individual sites (identified in Section C.4) may have the greatest relevance in terms of watershed context.

E.6. The Wildlife Tool: Assessing the importance of individual sites for the watershed's wildlife

The Wildlife Tool (Kline et al. 2006) prioritizes sites – potentially restorable wetlands, existing wetlands, and associated uplands – based on the habitat and life-history requirements of wildlife species that are locally-relevant and representative of a watershed's habitats. This is accomplished through a combination of habitat modeling (anticipating likely areas of species occurrence for selected "target" species) and occurrence data for both sensitive and "target" species (as determined from a variety of data sources, such as WDNR's Natural Heritage Inventory and UW-Milwaukee Field Station's Wisconsin Herpetological Atlas). The Wildlife Tool approach was developed in the Milwaukee River Basin, Wisconsin (Kline et al. 2006) where it is currently being further refined and tested (G. Casper, UW-Milwaukee Field Station, *pers. comm.*). The approach was adapted for use in the Duck-Pensaukee (Tables 5a and 5b) to ensure results were tailored to local conditions (a major goal of the Wildlife Tool), and to ensure close alignment with the state Wildlife Action Plan (a major goal of TNC and ELI's Watershed Approach pilot projects). Because it incorporates data and concepts from Wisconsin's Wildlife Action Plan (WWAP), the conservation of sites prioritized through this process is intended to make meaningful contributions toward WWAP goals, at both regional and statewide scales.

Results of the Wildlife Tool may be used to identify the top suite of potential conservation sites relevant to a single vertebrate species or to many species. Although it is intended as a means to compare the relevance and importance of individual sites, it should still be considered a "Level 1" (landscape-level) assessment. As such, before using results to develop and implement specific plans at any given site, particularly within a regulatory context, we recommend that Wildlife Tool findings be verified through on-site visits by qualified ecologists and in-depth evaluation of specific critical habitat needs for relevant species.

The process

Note: This is an iterative process. The steps described below are sequential, but the results of some steps may require revisiting and adjusting results of previous steps.

1. Seek out and collaborate with experts knowledgeable about wildlife species and habitats, specific to the watershed.
    - *There are many decision-points in this process that require in-depth knowledge of both wildlife species and watershed context, all of which should be vetted with subject experts.*
    - *Application of the Wildlife Tool in the Duck-Pensaukee Watershed was constructed based on analysis of WWAP data with critical input from Gary Casper, Dick Bautz, Noel Cutright, Bob Howe, Mike Grimm, and Nick Miller. Throughout this process, input from local and vertebrate taxon experts was used to fine-tune WWAP input to more local, watershed-specific needs and conditions.*
2. Obtain Wildlife Action Plan data
    - *In Wisconsin, these data (*http://dnr.wi.gov/org/land/er/WWAP/*) identify regionally-important habitats, list key species associated with those habitats, and also rank species-habitat relationships based on strength of association (scale of 0-3). As will be seen in subsequent steps, all of these pieces of information are invaluable for application of the Wildlife Tool.*
    - *Wisconsin's Wildlife Action Plan divides the state into "ecological landscapes," and presents data accordingly. The Duck-Pensaukee Watershed spans two ecological landscapes: Northern Lake Michigan Coastal and Central Lake Michigan Coastal. Data from both landscapes were combined for this process.*
    - *Produce species checklists, gathering all known data on species occurrences, to describe the species richness and state of knowledge of biodiversity in the region. These checklists ideally will rank species presence as known or potential, show conservation ranks (i.e. endangered, threatened, special concern), and provide a basis to select the focal species for modeling.*
3. Select "habitat targets" for the watershed (e.g., see first column in Table 5a)
    - *In the Duck-Pensaukee, we began with WWAP-defined priorities, defined as natural communities that present opportunities for management, preservation, or restoration within given ecological landscapes. These were refined based on expert input; for example, in one instance we expanded the definition of "habitat target" to include upland-wetland connectivity ("integrated landscape," see Table 5a (matrix) and Figure 16 (Blanding's turtle map)).*
4. Identify key vertebrate wildlife species that represent "habitat targets" and, furthermore, are particularly relevant to the specific watershed.
    - *The Wildlife Tool is based on the selection of a suite of "umbrella" species that collectively and in a complementary fashion represent a broader suite of habitat, management, and restoration needs within an area (citation that Gary forwarded).*
    - *In the Duck-Pensaukee we began with WWAP-identified Species of Greatest Conservation Need (SGCN) for this watershed and its two ecological landscapes. For this selection process, we took*

into consideration the "strength of association" (scale of 0-3) assigned in the WWAP for each SGCN in relation to each habitat type.

- *We also recommend that additional species be considered as "species of local conservation interest." These species may not meet state-wide criteria for including as SGCN, but are locally rare, at range limits, important keystone species, and/or otherwise considered locally important to the stakeholders. This process should engage species experts to evaluate Type I and Type II errors in data sources.*
- *Produce species checklists, gathering all known data on species occurrences, to describe the species richness and state of knowledge of biodiversity in the region. These checklists ideally will rank species presence as known or potential, show conservation ranks (i.e. endangered, threatened, special concern), and provide a basis to select the focal species for modeling. Due to time constraints, we did not produce checklists in this project.*
- *Taxa that were considered for selection included wetland-associated birds, reptiles, amphibians, and mammals. Other taxa (e.g., invertebrates, fish) were not considered due to the mismatch between species habitat requirements (e.g., micro-habitat scale, aquatic) and available habitat data (e.g., landscape scale, terrestrially-oriented). Due to the importance of fish and aquatic habitats in this project, we prioritized habitats on the basis of their needs in another section (Section X).*
- *See the first column of Table 5a for wildlife species selected to represent Duck-Pensaukee habitat targets.*

5. For wildlife species selected in Step 4, determine which should be modeled and tracked, and which should be tracked but not modeled
    - *There are two basic approaches to prioritizing sites for wildlife conservation, each with distinct pros and cons:*
        a. *One approach is to identify and prioritize known locations of sensitive or umbrella species. While it is important to conserve locations that have known importance to wildlife, the majority of most landscapes has never been surveyed and such an approach runs the risk of missing key conservation opportunities. Nevertheless, such "presence-only" data is important to acquire, as it identifies known populations and critical habitats, allowing planners to avoid harm to these species ("first do no harm"), and to prioritize where wildlife surveys may be conducted to reduce false absences in occurrence data.*
        b. *Another approach is to determine key factors that influence a species' presence, create maps of where those factors occur, and prioritize sites based on these "projections." This gets around the issue of insufficient occurrence data, but it is a broad-brush-stroke approach that is limited by the scale and resolution of the data used to model habitat availability.*
    - *To capitalize on the benefits of both approaches the Wildlife Tool hybridizes them.*
        a. *A core set of umbrella species is selected for habitat modeling. These are the species with known habitat requirements that are assessable with existing datasets. Occurrence data are used to corroborate model predictions.*

b. *A second suite of species is selected, whose habitat requirements cannot be modeled with existing data. Occurrence data for these species can identify areas of importance in the watershed that cannot be modeled due to data limitations.*

- ***Note**: This plan only presents the results of habitat modeling.*

6. Steps for modeling species:
   a. Identify the range of wetland and upland habitats present in this watershed, at the finest "resolution" possible with available wetlands and land-use/landcover datasets.
      - *See Appendix X for a description of the habitat identification process for the Duck-Pensaukee Watershed.*
      - *See the first row of the matrix in Appendix X for modelable habitat types present in the Duck-Pensaukee Watershed.*
   b. Create a matrix of target habitats (and associated umbrella wildlife species) vs. available habitats
      - *See Appendix X for example of a Wildlife Tool Matrix from the Duck-Pensaukee*
   c. Populate the cells in the matrix with scores that indicate strength of association between target wildlife and available habitats (0 = no association, 3 = strong association)
      - *Scoring should be based on information from the WWAP, and fine-tuned based on input from watershed/wildlife experts. This qualitative ranking can later be tested with quantitative modeling (i.e. ecological niche modeling).*
   d. For each habitat target and associated wildlife species, add "proximity factors"
      - *Proximity factors provide information about landscape-level requirements of species (e.g., habitat area requirements, proximity of primary and secondary habitats). These factors set rules and breakpoints for the GIS modeling. For example, Canada warblers require extensive forest cover surrounding their wooded swamp nesting habitat. For example, wood turtles only use habitat that is close to streams.*
      - *Proximity factors should be based on published literature as well as input from locally-knowledgeable wildlife experts.*
   e. Conduct GIS analyses—for each row in the matrix— to create a map showing the relevance of uplands, wetlands, and potentially restorable wetlands for each habitat target and associated wildlife species.
      - *An exception: In the Duck-Pensaukee Watershed, we made us of an existing migratory shorebird stopover model—created by WDNR, TNC, and teams of shorebird experts—that had already prioritized habitat for these species (citation?). We directly incorporated these results into the Wildlife Tool framework.*
   f. Create a summary map, by "stacking" all target-specific layers in GIS, and summing values across them.
      - *The resulting map shows scores for individual wetlands, based on relevance to the entire suite of wildlife "umbrella" species in the watershed.*
7. Steps for tracking species
   a. Aggregate species observation data (e.g., from Natural Heritage Inventory, Herp Atlas, wildlife ecologists)

b. Identify areas of importance to tracked species. These areas will need to be generalized (e.g., to the 12-digit HUC level) in collaboration with data owners to avoid conflicts with data-sharing and sensitivity issues.

8. Create a final summary map of watershed-specific wildlife habitat priorities, and display each type of conservation opportunity (wetlands, uplands, potentially restorable wetlands) with a distinct color-ramp.
9. Vet results with watershed wildlife experts to ensure they align with input and expectations.

E.7. Other (non-wildlife) wetland service assessments

The relative ability of individual sites to perform non-wildlife-related services is determined via a suite of criteria that are assessed using available spatial data in a GIS environment. Detailed methods for assessing each criterion are presented in Table 6, along with underlying rationale for each criterion. Guidelines for calculating prioritization scores from assessment data are provided in Table 7.

This approach is based on methods developed in Rhode Island (Miller and Golet 2001, Golet et al. 2003) and further refined and applied in the Sheboygan River Watershed, Wisconsin (Miller et al. 2009). Criteria were generated from reviews of wetland functional assessment methods developed by Adamus et al. (1991), U.S. Army Corps of Engineers (1995), Miller and Golet (2001), Wisconsin Department of Natural Resources (1992) and in consultation with ecologists of partner agencies and organizations.

The process

GIS analyses are conducted to determine which criteria are met for each service at each site (Table 6). Each criterion is designated as an "opportunity," "effectiveness," or "special significance" criterion (see Adamus et al. 1987).

> ***Opportunity*** (O) criteria indicate whether a wetland has the chance to perform a certain service. For example, wetlands situated in relatively large catchments with many impervious surfaces receive large quantities of surface runoff during storms; those wetlands have the opportunity to abate downstream flooding problems. In general, opportunity criteria evaluate the surrounding context of wetlands.
>
> ***Effectiveness*** (E) criteria assess the capacity of a wetland to perform a specified service, based on the wetland's characteristics. For example, wetlands that occur in topographic depressions are more effective at temporarily storing floodwaters than wetlands that occur on slopes. In general, effectiveness criteria evaluate the inherent or internal characteristics of wetlands.
>
> ***Special significance*** (S) criteria indicate whether performance of a service at a particular site would have clear benefits to society. For example, the flood abatement service of a

wetland has particular significance if the wetland lies upstream of developed, flood-prone areas.

In some cases, a criterion is deemed "necessary" to a service (indicated in bold-italics in Table 6). If a "necessary" criterion is not met at a given wetland, then it is concluded that the wetland is unable to perform that service. For example, the shoreline protection service cannot be met at a wetland that is not connected to open water.

To generate scores for non-wildlife-related wetland services (see Table 7):

- Opportunity and effectiveness criteria are first used to calculate the probability that a wetland can perform a certain service. For example, there are seven "O" and "E" criteria for the flood abatement service (see Table 6). If GIS assessments reveal that five of the seven criteria have been met for a given wetland, then the probability that the wetland could perform the flood abatement service (i.e., the wetland service score) would be 5 ÷ 7 = 0.71.
- Scores are increased by 0.1 for sites where at least one of the special significance criteria is met. Surface water supply, fish habitat, and carbon storage services do not have special significance criteria, as their relevance to society is either implied, universal, or impossible to assess with available datasets; scores for those services are automatically increased by 0.1. Scores for certain services (flood abatement, water quality, and carbon storage) are then adjusted based on size factors (Table 7). Size factors are not incorporated for services that have magnitudes less directly correlated with size, including fish habitat, shoreline protection, and surface water supply.
- For each service, sites are then assigned to quantiles (established separately for PRWs and existing wetlands) based on their wetland service scores.
    - Top-quantile wetlands and PRWs are considered "exceptional" priorities for each service.
    - Second-quantile wetlands are considered "high" priority.
    - Third- and fourth-quantile PRWs are considered as lower priority for restoration.
    - Third- and fourth-quantile wetlands are not designated as priorities for preservation.

E.8. Ranking sites by their potential to perform multiple services

The following process provides a simple means to rank current wetlands and PRW's by their potential to perform multiple services. These summary scores can be used to maximize the wetland service "return" on conservation investments by highlighting sites that are likely to provide a variety of services at a high level. Considering the ability of sites to perform multiple services could help to align the collective goals, resources, and conservation efforts of many partners.

The process

To prioritize wetlands and PRWs with respect to all seven services, for each site:

1. Count the total number of services performed at "high" or "exceptional" levels (i.e., the top two quantiles). For example, a site that scores "high" for one service and "exceptional" for two services would receive a preliminary score of three.
2. Use resulting scores (ranging from 0 to 7) to create a map with two distinct color-ramps: one for wetland restoration opportunities (PRWs) and one for wetland preservation opportunities (existing wetlands).

E.9. Dataset creation

Analyses were conducted based on existing spatial datasets and the creation of new datasets. Table 8 provides details on datasets and processes used as part of these analyses.

Table 3. NWI+ wetland code definitions

Landscape Position	Code	Description
Terrene	TE1	Surrounded by upland
	TE2	Bordering a pond surrounded by upland
	TE3	Adjacent to but not affected by a stream or river
Lentic	LE	Adjacent to a lake or within a lake's basin
Lotic River	LR	Periodically flooded by a river
Lotic Stream	LS	Periodically flooded by a stream
Landform		
Slope	SL	Occurs on a slope >= 5%
Island	IL	Completely surrounded by open water
Fringe	FR	Occurs in the shallow water zone of a permanent water body
Floodplain	FP	Occurs on an active alluvial plain along a river or stream
Basin	BA	Occurs in a distinct depression
Flat	FL	Extensive, level, precipitation-dominated wetlands (not present in Duck-Pensaukee watershed)
Waterbody Type		
Natural Pond	PD1	Natural waterbody <5 ac
Impounded Pond	PD2	Diked or impounded waterbody <5 ac
Excavated Pond	PD3	Excavated waterbody <5 ac
Natural Lake	LK1	Natural waterbody >5 ac
Dammed Lake	LK2	Dammed waterbody >5 ac
Excavated Lake	LK3	Excavated waterbody >5 ac
River	RV	Flowing water: polygon feature on USGS or NWI map
Waterflow Path		
Isolated	IS	Surrounded by upland; no channelized surface-water inflow or outflow
Inflow	IN	Channelized surface-water inflow; no surface-water outflow
Outflow	OU	Surface-water outflow via natural channels; no channelized inflow
Outflow Intermittent	OI	Surface-water outflow via intermittent channels; no channelized inflow
Outflow Artificial	OA	Surface-water outflow via artificially manipulated or created channels; no channelized inflow
Throughflow	TH	Surface-water inflow and outflow via natural channels
Throughflow Intermittent	TI	Surface-water inflow and outflow via intermittent channels
Throughflow Artificial	TA	Surface-water inflow and outflow via artificially manipulated or created channels
Bidirectional	BI	Adjacent to lake; wetland hydrology influenced by changing lake levels

Table 4. Correlations of NWI+ modifiers with wetland services.[1]

Wetland Service	Level[2]	Wetland Types	LLWW Codes	NWI Codes	LLWW Exceptions	NWI Exceptions[4]	Rationale
Flood Abatement	Exceptional	Vegetated wetlands along streams, rivers, and lakes. Ponds and terrene depression wetlands that have inflow, throughflow, or intermittent throughflow.	LE*, LR*, LS*, *IL*, PD*IS, PD*IN, PD*TH, PD*TI, TEBA*IN, TEBA*TH, TEBA*TI		Sloped wetlands (*SL*)	Unvegetated wetlands (*RB*, *UB*, *US*, *RS*, *ML*)	Wetland vegetation intercepts and slows water during high flows. Wetlands adjacent to surface water and along flood flow-paths are situated to intercept flood waters and abate floods.
	High	All other wetlands except sloped and unvegetated wetlands.	PD*TA, TEBA*TA				Sloped wetlands discharge groundwater and contribute to flows. Unvegetated wetlands cannot slow flood waters.
Surface Water Supply	Exceptional	All headwater wetlands (associated with 1st order streams).	*hw		Ephemeral outflow (*TI, *OI).		Headwater wetlands contribute to surface supplies by discharging groundwater.
	High	Lotic floodplain wetlands. Lotic stream fringe wetlands. Ponds and lakes with throughflow and outflow. Terrene wetlands associated with a pond.	LRFL*, LSFR*, PD*TH, PD*OU, LK*TH, LK*OU, TE2*, TE*OU				Wetlands connected to waterbodies temporarily "hold" water from high, overbank flow; during periods of low flow they discharge back to their associated waterbody.
Water Quality Protection	Exceptional	Vegetated wetlands with frequently fluctuating water levels in these settings: along streams and rivers, or depression wetlands with outflow or throughflow.	LR*, LS*, *IL*, *BA*OU, *BA*OI, *BA*OA, *BA*TH, *BA*TI, *BA*TA, *BA*BI	Water regimes: A, C	Open waters (LK*, PD*, RV*).	Unvegetated wetlands (*RB*, *UB*, *US*, *RS*, *ML*).	Depression wetlands have maximum sediment and nutrient trapping efficiency. Wetland vegetation slows flows, causing sediment and phosphorous to drop out, and uptakes nutrients. Nitrogen removal is most efficient under frequently alternating aerobic and anaerobic conditions (fluctuating water levels). Wetlands that interact hydrologically with flowing water have the greatest opportunity to process nutrients.
	High	Vegetated wetlands that are saturated or inundated throughout the growing season in these settings: isolated depression wetlands; fringe wetlands of lakes, ponds, and streams; terrene wetlands with outflow and throughflow; wetlands associated with a natural pond.	*BA*IS, *FR*, TE*OU, TE*OI, TE*OA, TE*TH, TE*TI, TE*TA, TE2*PD1*	Water regimes: B, F, G, H			Less frequently alternating aerobic and anaerobic conditions remove nitrogen to a lesser extent. Fringe wetland vegetation slows flows but to a lesser degree. Wetlands that interact less, hydrologically, with associated waterbodies process nutrients at more moderate levels.
Carbon Storage	Exceptional	Vegetated wetlands with one or more of the following characteristics: isolated, inflow, deep organic soils (limited to wetlands with >60" of muck and/or peat), or saturated water regime.	*IN, *IS	Water regime: B; Soil modifier: g	Open waters (LK*, PD*, RV*).	Unvegetated wetlands (*RB*, *UB*, *US*, *RS*, *ML*).	Vegetated wetlands store carbon in plants and organic soils. Wetlands with less throughflow serve as carbon sinks. Wetlands that are saturated throughout the growing season experience less decomposition of carbon-rich organic matter.
	High	All other vegetated wetlands.					All vegetated wetlands sequester carbon.

[1]Adapted from Tiner (2003, 2005), Fizzell (2011), and application of NWI+ in the St. Croix by St. Mary's University (A. Robertson, *pers. comm.* ; T. Bernthal, *pers. comm.*).

[2]Wetlands not ranked as "exceptional" or "high" were not further assessed in this process.

[3]A = temporarily flooded, B = saturated, C = seasonally flooded, F = semipermanently flooded, G = intermittently exposed, g = organic soil.

[4]RB = rock bottom, UB = unconsolidated bottom, US = unconsolidated shore, RS = rocky shore, ML = moss-lichen.

Table 5a. Wildlife Tool Matrix: Habitat targets, representative species, and habitat associations in the Duck-Pensaukee Watershed.

	Wetlands														Uplands					
Conservation targets & *Representative species*	**Shrub swamp**	**Shrub bog**	**Forested wetland (broadleaf deciduous)**	**Forested wetland (evergreen)**	**Forested wetland (tamarack)**	**Floodplain forest**	**Forested wetland (ridge & swale)**	**Emergent wetland**	**Stream (cold)**	**Stream (cool)**	**Stream (warm)**	**River (warm)**	**Inland lakes, ponds, impoundments**	**Coast: Beach**	**Upland Forest (deciduous)**	**Upland Forest (mixed)**	**Upland Forest (evergreen)**	**Grassland/ Herbaceous**	**Pasture/Hay (surrogate grassland)**	**Upland Scrub/Shrub**
OPEN WETLANDS & WATERS *Am. Bittern, Blue-winged Teal, Black Tern*		2						3					3					2	2	
BEACHES *Caspian Tern, Common Tern*								1					1	3						
SHRUB SWAMP *Am. Woodcock, Willow/Alder Flycatchers*	3		1		1										1					1
FORESTED SWAMP *Canada Warbler, Northern Flying Squirrel*			3	3	2	1	3		1	1	1	1	1		2	2	2			
INTEGRATED LANDSCAPE *Blanding's Turtle*	2	2	2		1	1	3	3			1	3	3		2	2	1	3	3	2
RIPARIAN HABITAT *Wood Turtle*	3	1	2	1	1	3	1	1	3	3	3	3	1		2	2		3	2	2
SHOREBIRD STOPOVER HABITAT	Scores adapted from Migratory Shorebird Stopover Model[1]																			

Strength of Association: 3 = significant, 2 = moderate, 1 = minimal, Null = none

[1]Wisconsin model unpublished, adapted from model developed in Lake Erie Basin (Ewert et al. 2005)

Table 5b. Wildlife Tool: "proximity factors" for target habitats and representative species of the Duck-Pensaukee Watershed.

Conservation targets & Representative species	Proximity factors
Open wetlands and waters: Am. Bittern, Blue-winged Teal, Black Tern	Grassland or surrogate grassland must be adjacent to wetland and >32 ha; emergent marsh patches must be >10 ha.
Beaches: Caspian Tern, Common Tern	Emergent wetland and open water must be within 2 miles of beach habitat
Shrub swamp: Am. Woodcock, Willow/Alder Flycatchers	Non-shrub-swamp habitats must be within 600m of shrub swamp (otherwise, scored 0)
Forested swamp: Canada Warbler, Northern Flying Squirrel	Wetland forests must be >6 ha and occur within a patch of contiguous forest (upland and/or wetland) >48 ha. Upland forests must be >48 ha and occur on soils that can support mesic (maple-beech) or wetter forests. Streams & lakes must occur within forest (upland and/or wetland) >28 ha.
Integrated landscape: Blanding's Turtle	If "3" wetland types are adjacent to "3" upland types, then all types within 300m receive the indicated scores. If not, then none of the habitat types (wetland or upland) are scored.
Riparian habitat: Wood Turtle	Rivers/streams must be adjacent to natural landcover. All habitats must be within 300m of "clean" channels (i.e., no 303(d) designation or other polluted status). Ponds/lakes must be <1 ha.
Shorebird stopover habitat	N/A

Table 6. Criteria and assessment methods for wetland services.

Code	O,E,S[1]	Criterion	Rationale	Dataset(s)[8]	GIS process
FLOOD ABATEMENT[6]					
FA_O1	O	**Impervious surfaces cover > 10% of the site's catchment[2,3,4]**	Wetlands surrounded by impervious surfaces (e.g., roads, sidewalks, parking lots, buildings) receive large amounts of runoff, more quickly, during storm events.	2001 NLCD Impervious Surface Dataset from USGS via Data Basin, NHDPlus Catchments (14-digit), National Wetlands Inventory (NWI), Potentially Restorable Wetlands (PRW)	Use "spatial statistics as table" tool in Spatial Analyst toolbox, ArcGIS 10.x
FA_O2	O	**Slopes within the site's catchment exceed 15%**	Steep slopes contribute to "flashy" conditions during storm events. Wetlands below these slopes can help to desynchronize floods.	demgw930 (30m DEM distributed by WDNR), NHDPlus Catchments (14-digit), NWI, PRW	Calculate slopes from DEM and identify those greater than 15%. Intersect catchments with > 15% slopes.
FA_O3	O	**Site receives point source inflow**	Runoff aggregated into a single point or channel contributes to "flashiness" during storm events.	NWI+, WI DNR 24k hydro layer, NWI, PRW	NWI+ Landscape position of "Lotic Stream" or "Lotic River." Waterflow path = throughflow or inflow; polygons that are intersected or w/in 10m of a 24k hydro (WI DNR) stream feature with a stream order of 1 or greater.
FA_O4	O	**The catchment area is large relative to the site (> 82% of the catchment is upland)**	Wetlands associated with large drainage areas will intercept and "process" more water during storm events.	NHDPlus Catchments (14-digit), NWI, PRW	Remove NWI and PRW areas from catchment areas
FA_E1	E	**Dominant vegetation is dense and persistent (forest, scrub-shrub, emergent marsh)**	Dense wetland vegetation can reduce downstream flood levels and delay flood crests by reducing floodwater velocity. Persistent vegetation (e.g., woody plants, robust persistent emergents) can provide this service even outside of the growing season.	NWI+, NWI, PRW	Select wetlands with NWI code of *EM, *SS, *FO

Table 6. Criteria and assessment methods for wetland services (continued).

Code	O,E,S[1]	Criterion	Rationale	Dataset(s)[8]	GIS process
FA_E2	E	**Site is in a topographic depression or floodplain setting**	Depressional wetlands can temporarily store floodwater; slope wetlands cannot. Floodplain wetlands receive and "process" floodwaters during periods of overbank flow.	NWI+, Historic Wetland LLWW	NWI+ Landform = "Basin" or "Floodplain"; PRWs with Landform code of "Basin" from the Historic Wetland LLWW layer (select by location PRW is completely w/in Historic polygon)
FA_E3	E	**Flow through the site is not channelized or incised**	Sites that maximize the interface between flowing water and wetland area effectively abate floods.	NWI+, Historic Wetland LLWW	NWI+ Landscape = "Lotic River" or "Lotic Stream"; PRWs with Landscape code of "Lotic Stream" or "Lotic River" from the Historic Wetland LLWW layer (select by location PRW is completely w/in Historic polygon); do not score any polygon where Waterflow = "Artificial Throughflow" or "Artificial Outflow"
FA_S1	S	**Developed flood-prone areas occur downstream, within 5 miles or above the nearest dam**	Wetlands that are connected to flood-prone developed areas during periods of high flow are particularly significant.	NHDPlus Catchments (14-digit), NWI, PRW, Minor Civil Divisions, 24k hydro	Buffer 5 miles from cities and villages, select catchments upstream of city or village w/in 5 miles, select 24k hydro lines whose order is 1 or greater, select wetlands and PRWs that intersect selected streams, then expand that NWI/PRW selection to the associated wetland unit (contiguous NWI polygons create a single wetland unit)
SURFACE WATER SUPPLY					
SW_O1	O	**Site is in a headwater setting**	Headwater wetlands contribute to surface supplies by discharging groundwater.	NWI+, Historic Wetland LLWW	PRWs with modifier code of "headwater" from the Historic Wetland LLWW layer (select by location PRW is completely w/in Historic polygon); select all wetlands/PRWs with LLWW modifier = "headwater"
SW_E2	E	**Site is in a floodplain or fringe setting**	Wetlands connected to waterbodies temporarily "hold" water from high, overbank flow; during periods of low flow they discharge back to their associated waterbody.	NWI+, Historic Wetland LLWW, PRW	NWI+ Landscape = "Lotic River" or "Lotic Stream"; PRWs with Landscape code of "Lotic River" or "Lotic Stream" from the Historic Wetland LLWW layer (select by location PRW is completely w/in Historic polygon)

Table 6. Criteria and assessment methods for wetland services (continued).

Code	O,E,S[1]	Criterion	Rationale	Dataset(s)[8]	GIS process
SW_E3	E	**Site is a pond or lake with perennial throughflow or outflow**	Waterbodies with perennial outflow are helping to maintain baseflow.	Historic Wetland LLWW, PRW	NWI+ Type is "Pond" or "Lake", Waterflow = "Outflow", "Artificial Outflow", "Throughflow", "Artificial Throughflow"; PRWs not ranked
SW_S1		**Implied**			
WATER QUALITY PROTECTION[6]					
WQ_O1	O	**Point source discharge upstream or directly into site**	Wetlands downstream of pollution sources have greater opportunity to improve water quality than wetlands not receiving such inputs.	Wastewater Wisconsin Pollutant Discharge Elimination System (WPDES) Permit Program, NHDPlus Catchments (14-digit), NWI, PRW, 24k hydro	Use Wisconsin DNR "Surface Water Viewer" interactive map to locate permits issued in the watershed. Assign "yes" to any assessment polygon that intersects the 24k hydro line downstream of discharge point within the catchment.
WQ_O2	O	**Site subject to nutrient loading from agricultural sources (row crops cover >42% of catchment)[5]**	Fertilizers applied to row crops can be a significant source of nitrogen and phosphorus.	CCAP 2001, NHDPlus Catchments (14-digit)	Tabulate area of RowCrop (CCAP value = 6) by catchment, and divide area of row crop by catchment area.
WQ_O3	O	**Impervious surfaces cover > 10% of the site's catchment[3]**	Wetlands surrounded by impervious surfaces (e.g., roads, sidewalks, parking lots, buildings) receive large amounts of runoff that may be compromised by salts, increased temperature, pet waste, oils, and other pollutants.	2001 NLCD Impervious Surface Dataset from USGS via Data Basin, NHDPlus Catchments (14-digit), NWI, PRW	Use "spatial statistics as table" tool in Spatial Analyst toolbox, ArcGIS 10.x

Table 6. Criteria and assessment methods for wetland services (continued).

Code	O,E,S[1]	Criterion	Rationale	Dataset(s)[8]	GIS process
WQ_O5	O	**Site is not buffered by surrounding upland vegetation (<50% of land within 200 feet is in natural cover)**	Wetland buffers in natural cover serve as filters for overland flow before it enters wetlands; wetlands lacking such buffers play a larger role in protecting water quality.	CCAP 2001, Wetlands, PRW	Calculate percent natural cover in 200 foot buffer around Wetland Units (contiguous NWI polygons create a single wetland unit) and PRWs
WQ_E1	E	**Site has seasonally fluctuating water levels**	Nitrogen removal is most efficient under alternating aerobic and anaerobic conditions (fluctuating water levels).	NWI+, Historic Wetland LLWW, PRW	NWI+, select polygons with water regime codes A and C ; PRWs given the water regime code from the Historic Wetland LLWW layer (select by location PRW is completely w/in Historic polygon)
WQ_E2	E	**Site occurs in topographic depression**	Depression wetlands retain water for longer periods of time than slope wetlands. Greater retention time permits increased interaction between plants or soil and nutrients or pollutants, as well as settling of suspended solids.	NWI, PRW	NWI+, select landform code = "Basin"; PRWs landform code "Basin" from the Historic Wetland LLWW layer (select by location PRW is completely w/in Historic polygon)
WQ_E4	E	**Dominant vegetation is dense and persistent (forest, scrub-shrub, emergent marsh)**	Dense wetland vegetation can serve as a filter for pollutants and can also impede the flow of water, causing sediments and particulate pollutants to drop out of suspension. Persistent vegetation (e.g., woody plants, robust persistent emergent species) can provide this service even outside of the growing season.	NWI, PRW	Select types NWI code *EM*, *SS*, *FO*

Table 6. Criteria and assessment methods for wetland services (continued).

Code	O,E,S[1]	Criterion	Rationale	Dataset(s)[8]	GIS process
WQ_S1	S	**Wetland occurs in or above a catchment containing 303d waters.**	Wetlands in or above a catchment containing impaired waters help to attain water quality goals (e.g., fishable, swimmable), and therefore contribute to social significance.	24k Hydro WI DNR, 303d listed lines and areas from WI DNR	Wetunits that intersect 303d streams; All of Duck drainage due to Lower Bay being listed.
WQ_S3	S	**Surface connection to a lake, pond, river, or stream**	Wetlands directly connected to open water help to maintain surface water quality, and therefore contribute to social significance.	NWI+, Historic Wetland LLWW, PRW	NWI+ Waterflow path of some type of throughflow or outflow; PRWs given the waterflow path from the Historic Wetland LLWW layer (select by location PRW is completely w/in Historic polygon); also included ponds that have associated Terrene wetlands.
CARBON STORAGE					
CA_E1	E	**Site contains deep peat or muck layers**	Deep muck and peat layers contain undecomposed organic matter, rich in C.	SSURGO database soil mapunit description	Build lookup table of mapunit id's that have full horizons (60 inches) of muck and/or peat; select wetlands and PRWs that intersect muck soils
CA_E2	E	**Dominated by high biomass vegetation (forest, scrub-shrub)**	Dense vegetation of wetlands, particularly woody vegetation, stores carbon.	NWI codes	NWI code of *FO*, *SS*. Only applied to wetlands, not PRWs
CA_E3	E	**Substrates are saturated throughout the growing season**	Wetlands that are saturated throughout the growing season, where buried organic matter is slower to decompose, experience less decomposition of carbon-rich organic matter.	NWI codes	NWI water regieme = B. Only applied to wetlands, not PRWs
CA_E4	E	**Site has potential to serve as a carbon sink (water flow path = isolated or inflow)**	Wetlands with less throughflow can serve as carbon sinks.	NWI+, Historic Wetland LLWW, PRW	NWI+ waterflow path = isolated or inflow, PRWs given the waterflow path from the Historic Wetland LLWW layer; (select by location PRW is completely w/in Historic polygon)
CA_S1	S	**Implied**			

Table 6. Criteria and assessment methods for wetland services (continued).

Code	O,E,S[1]	Criterion	Rationale	Dataset(s)[8]	GIS process
SHORELINE PROTECTION[6]					
SP_O1	O	**Adjacent to or containing a river, stream, or lake**	***This criterion is necessary to the shoreline protection service.*** To protect shorelines, wetlands must be situated next to a waterbody.	24k Hydro WI DNR, Wetlands, PRWs	Select wetland and PRW polygons that touch 1st order streams, lakes and ponds, and NWI+ landform = fringe
SP_E2	E	**Adjacent waterbody is large (lakes > 10 acres; streams > 2nd order)**	Larger waterbodies have greater wind fetch potential and greater potential wave energy. Larger streams and rivers are more likely to have greater flow rates. Channels of higher order streams have increased likelihood of meandering, with associated erosion.	24k Hydro WI DNR, Wetlands, PRWs	Select wetland and PRW polygons that touch, lakes and ponds > 10ac, streams => 3rd order
SP_E3	E	**Densely rooted emergent or woody vegetation (EM, SS, FO)**	Banks stabilized by dense roots are less likely to erode. Woody vegetation can sustain and dissipate greater wave energy.	NWI	NWI code of *FO*, *SS*
SP_S1	S	**Located between (adjacency to) developed area and open water**	Wetlands that shelter developed areas from shoreline erosion have particular significance.	Wetlands, WROC 2010 18" air photography	Visual assessment of developed areas and wetland units using aerial photograph

Table 6. Criteria and assessment methods for wetland services (continued).

Code	O,E,S[1]	Criterion	Rationale	Dataset(s)[8]	GIS process
FISH HABITAT					
AQ_O1	O	**Sites is connected or contiguous with a perennial stream or lake**	***This criterion is necessary to the fish habitat service.*** Wetlands that contain perennial surface water have the opportunity to provide habitat for fish. Wetlands adjacent to perennial surface water also may influence habitat conditions for fish populations.	24k Hydro WI DNR, Wetlands, PRWs	Select wetland and PRW polygons that touch 1st order streams, lakes and ponds, and NWI+ landform = fringe
AQ_E3	E	**Wetland is inundated in Spring (water regimes A, C, F, G, H)**	Wetlands flooded during spring provide access to fish (e.g., for nursery habitat).	NWI+, Historic Wetland LLWW, PRW	NWI+, use water regime code from NWI code ; PRWs given the water regieme code from the Historic Wetland LLWW layer; (select by location PRW is completely w/in Historic polygon)
AQ_E4	E	**Contiguous water body, if present, is NOT 303d-listed**	To remain healthy and viable, fish populations require clean water.	24k Hydro WI DNR, 303d listed lines and areas	Wetunits that intersect 303d streams unselected;
AQ_E6	E	**Adjacent open water is bordered by natural landcover for >50% of its length**	Vegetation bordering water can provide shade and help to maintain cooler water temperatures. Such vegetation may also contribute organic detritus that supports invertebrate prey items.	Wetlands, CCAP 2001, 24k hydro	Convert NWI classed Rivers, Ponds and Lakes polygons to line features, intersect with CCAP natural cover and create a ratio of shoreline that is in natural cover to shore that is not in natural cover. For 24k streams/river, length is for contiguous stream segments of the same order w/in the same catchment; select wetlands for scoring that are adjacent to sufficient reach.

Table 6. Criteria and assessment methods for wetland services (continued).

Code	O,E,S[1]	Criterion	Rationale	Dataset(s)[8]	GIS process
AQ_E7	E	**Natural cover (forest, shrubland, grassland, or other wetland) comprises >40% of land in the wetland's catchment[4]**	Wetlands surrounded by natural cover can maintain water quality and support healthy fish populations.	CCAP 2001, NHDPlus Catchments (14-digit)	Tabulate area of Natural Cover (ccap values = 8 - 18) by catchment, and divide area of row crop by catchment area.
AQ_S1	S	**Implied**			

[1]Type of criterion (per Adamus 1991); O = Opportunity, E = Effectiveness, S = Social Significance

[2]"Site" refers to the unit of assessment (either a current wetland or a potentially restorable wetland)

[3]Center for Watershed Protection (2003)

[4]"Catchment" refers to the drainage area unique to a wetland, approximated using 14-digit HUC delineations

[5]Wang et al. (2008)

[6]Rivers not assessed for this service

[7]Rivers and lakes not assessed for this service

[8]Datasets created as part of this project are described in Table 7

Table 7. Wetland ăŜ₦ØſŎŜ assessments: Steps ű2 calculate scores and generate maps

Prioritizing sites by individual ăŜ₦ØſŎŜă

A. Assess wetlands using methods described in Table 6

B. Calculate a ăŜ₦ØſŎŜ score for each service within each wetland polygon

1. For each service at each site, divide the number of O and E criteria that have been met by the total possible number of O and E criteria
2. Add 0.1 to the resulting service score if one or more Special Significance [S] criteria are met. For services with no S criteria (e.g., wildlife habitat), automatically add 0.1 to the score.

C. Multiply scores for certain services (flood abatement, water quality protection, carbon storage, shoreline protection) by a size factor

1. Do not incorporate size factors for surface water supply or fish habitat services. Wetland size is less directly correlated with magnitudes of these services.
2. For flood abatement, water quality protection, and carbon storage, the magnitude of services is related to wetland area. Size factors:
    a. Wetlands < 2 ac, factor = 1
    b. Wetlands 2 - 5 ac, factor = 1.5
    c. Wetlands > 5 ac, factor = 2
3. For shoreline protection, magnitude of service is related to the linear interface between wetland and open water. Size factors:
    a. Wetland/water interface < 0.25 mi, factor = 1
    b. Wetland/water interface 0.25 to 1 mi, factor = 1.5
    c. Wetland/water interface > 1 mi, factor = 2

D. Determine level of significance for each service, within each wetland unit, relative to other wetlands

1. 1st quantile = exceptional significance; 2nd quantile = high significance; 3rd quantile = medium significance; 4th quantile = lower significance

E. Generate a map of wetland protection priorities for each service, including only those sites that perform each service at "exceptional" or "high" levels.

Prioritizing sites by the total number of services performed

F. For each wetland unit, determine the total number of services that are performed at "exceptional" or "high" levels.

G. Generate a map of wetland protection priorities, color-ramped based on the number of services performed.

Table 8. Methods for dataset creation

Output Feature Dataset	Attribute Field of interest	Input Datasets	Process/Attribute Definition	Comments
Hydric Soils		SSURGO Soils Layer, all soils hydric/part hydric	Download all counties from Soil Data Mart Use Soil Data Viewer for ArcGIS to create hydric soils layers Merge and clip to area of interest	
coastal_zone_expert_reviewed_092011		30 meter DEM HUC 12 basin polygons	ArcGIS 10 Cost Distance analysis on slope calculation of DEM, based from shoreline of 12-digit HUC layer.	Expert review using air photos, FEMA floodplain maps and cross sections, expert on-the-ground knowledge, set break point value at 356. Area where wetlands are under the influence of the bay.
SiteID		Wisconsin Roads(wi_roads00 - WI-LIO/tiger file) Hydric Soils NWI Features Coastal Zone CCAP 2001	• Erase roads buffered by 5m from Hydric Soils (HS) • Erase NWI polygons from HS • Split HS into coastal zone and non-coastal • Select non-coastal HS > 15% hydric • Select all coastal HS • Merge HS back together • Use Eliminate function to minimize sliver polygons • Intersect CCAP and HS polygons • Attribute new SiteID polygons	Adapted from Bernthal et. al. "Milwaukee River Basin Wetland Assessment Project" WI DNR, Report to US EPA Region 5, 2006 and Fizzell et. al., Pre-Settlement Wetland Coverage Creation, Michigan Department of Environmental Quality, 2011 (Draft).
	"SiteCode"		SiteCode types: PRW/Ag = Hydric >15%/Ag CCAP PRW/Urban=Hydric>15%/Urban CCAP PRW/Nat=Hydric>15%/any "Natural" CCAP type PWA/Nat=PartHydric/CoastalZone/any "Natural" CCAP type PWA/Ag=PartHydric/CoastalZone/Ag CCAP	

Table 8. Methods for dataset creation (continued)

Output Feature Dataset	Attribute Field of interest	Input Datasets	Process/Attribute Definition	Comments
Historical Wetlands		Hydric Soils Original Vegetation Coastal Zone NWI Features	• Erase NWI polygons from Hydric Soils • Split HS into coastal zone and non-coastal • Select non-coastal HS > 15% hydric • Select all coastal HS • Merge HS back together • Intersect NWI and CCAP • Intersect CCAP and HS polygons • Merge CCAP and NWI into one feature layer • Attribute new Historical Wetland polygons	Pers. comm., Chad Fizzell; Fizzell et. al. (2011) Pre-Settlement Wetland Coverage Creation, Michigan Department of Environmental Quality (Draft).
	"Attribute" (NWI code)		Use crosswalk table to assign system, subsystem, class, subclass from Original Vegetation type	
	"Water Regime"		• For NWI polygons, use NWI water regime • For Hydric Soils polygons, use soil drainage class to assign water regime, based on crosswalk provided by FWS which they are using in the conversion of WWI to NWI • For polygons current water bodies that were not historical, assign water regime of adjacent NWI or HS polygon	Drainage Class, Cowardin et al. Water Regime Very Poorly Drained, F Poorly drained, C Somewhat poorly drained, A
NWI Plus				Adapted from: • Tiner, Ralph W., National Wetlands Inventory Program, U.S. Fish and Wildlife Service, Dichotomous Keys and Mapping Codes for Wetland Landscape Position, Landform, Water Flow Path, and Waterbody Type Descriptors (2003) • Fizzell, Chad, et. al., Landscape Level Wetland Functional Assessment, Version 1.0, Methodology Report, Michigan Department of Environmental Quality, 2011

Table 8. Methods for dataset creation (continued)

Output Feature Dataset	Attribute Field of interest	Input Datasets	Process/Attribute Definition	Comments
	"Landscape Position"	30m DEM 24k Hydro, WI DNR, arc and polygons Aquatic GAP stream model, Stewart USGS, Lyons WI DNR WROC 2010 18" photography	• Lotic River - ArcGIS Model - Cost Distance model to identify wetland polygons within the floodplain of "rivers" defined by aquatic GAP analysis • Lotic Stream - ArcGIS Model - Cost Distance model to identify wetland polygons within the floodplain of "streams" defined by stream order of > 1 • Lentic - Select by location wetlands adjacent to Lake > 5 acres • Terrene - All other polygons • All polygons then visually reviewed for Landscape position using WROC imagery	ArcGIS models available for Lotic Stream and Lotic River. Output thresholds established using the mapped 100 FEMA extent. All coastal Lake Michigan wetlands were considered Lentic between first road and lakeshore.
	"Landform"	30m DEM 24k Hydro, WI DNR, arc and polygons WROC 2010 18" photography	• Basin (depression) - Default value for this watershed • Floodplain - associated only with Lotic River wetlands • Slope - created slope > 5% layer from DEM, visually inspected polygons that intersected sloped area to identify possible sloped wetlands • All polygons visually reviewed for Landform using WROC imagery	
	"Waterbody Type"	NWI attribute	• Typed from the attribute for River, Lake or Pond • Pond type (natural, impounded, excavated) reviewed using WROC imagery	
	"Waterflow Path"	WROC 2010 18" photography	• All polygons visually reviewed for Waterflow Path using WROC imagery	

Table 8. Methods for dataset creation (continued)

Output Feature Dataset	Attribute Field of interest	Input Datasets	Process/Attribute Definition	Comments
	"Modifiers" all	WROC 2010 18" photography	• All polygons visually reviewed for modifiers using WROC imagery • Headwaters - all wetlands that are in the approximate drainage area of a first order stream; visual interpretation • There is a landscape position modifier that identifies Terrene wetlands contiguous with Isolated ponds; visual interpretation	
Historical NWI Plus				Adapted from: • Tiner, Ralph W., National Wetlands Inventory Program, U.S. Fish and Wildlife Service, Dichotomous Keys and Mapping Codes for Wetland Landscape Position, Landform, Water Flow Path, and Waterbody Type Descriptors (2003) • Fizzell, Chad, et. al., Landscape Level Wetland Functional Assessment, Version 1.0, Methodology Report, Michigan Department of Environmental Quality, 2011
	"Landscape Position"	30m DEM 24k Hydro, WI DNR, arc and polygons Aquatic GAP stream model, Stewart USGS, Lyons WI DNR coastal_zone_expert_reviewed_092011 Original Plat Maps, Board of Commissioners, Wisconsin	• Lotic River - ArcGIS Model - Cost Distance model to identify wetland polygons within the floodplain of "rivers" defined by aquatic GAP analysis • Lotic Stream - ArcGIS Model - Cost Distance model to identify wetland polygons within the floodplain of "streams" defined by stream order of > 1 and used historical plat map to identify streams that possibly didn't exist at time of original vegetation layer. • Lentic - Select by location wetlands adjacent to Lake > 5 acres • Terrene - All other polygons	ArcGIS models available for Lotic Stream and Lotic River. Output thresholds established using the mapped 100 FEMA extent. All coastal Lake Michigan wetlands were considered Lentic within the Coastal Zone.

Table 8. Methods for dataset creation (continued)

Output Feature Dataset	Attribute Field of interest	Input Datasets	Process/Attribute Definition	Comments
	"Landform"	30m DEM 24k Hydro, WI DNR, arc and polygons	• Basin (depression) - Default value for this watershed • Floodplain - associated only with Lotic River wetlands • Slope - created slope > 5% layer from DEM, visually inspected polygons that intersected sloped area to identify possible sloped wetlands • Fringe - Selected wetlands adjacent to lakes, ponds, streams, visually selected from that set smaller wetlands within a well-defined basin as visualized using the 30m DEM	
	"Waterbody Type"	NWI attribute	• All NWI river attributed wetlands were typed as river in the historical cover • Ponds and lakes that appeared in the Original vegetation layer were kept, all others went to the Original Vegetation type.	
	"Waterflow Path"	24k hydro layer, w/ non-historic streams removed 30m DEM	• Throughflow - wetlands intersected by or within 5 meters of an historic stream order 1 or higher. All historical wetlands adjacent to throughflow polygons; run this selection and attribution process until no polygons are returned. Then visually inspect all polygons; • Outflow - wetlands adjacent to throughflow wetlands, but didn't have a wetland "upstream"(required reclassifying "outermost" throughflow wetlands). Wetlands that contained the origin of 24k hydro 1st order arc and not adjacent to another wetland. • Isolated - all remaining wetlands	

Table 8. Methods for dataset creation (continued)

Output Feature Dataset	Attribute Field of interest	Input Datasets	Process/Attribute Definition	Comments
	"Modifiers" all	24k hydro layer, w/ non-historical streams removed 30m DEM	• Headwaters - all wetlands that are in the approximate drainage area of a first order stream; visual interpretation • There is a landscape position modifier that identifies Terrene wetlands contiguous with Isolated ponds; visual interpretation	
NWI_PRW_Merge		NWI Features SiteID layer	Merge NWI+ polygons and PRW polygons from SiteID layer	
NWI_PRW_Merge Wildlife Tool				Wildlife Tool Scoring Matrix and Wildlife Tool Crosswalk Appendix provide details of specific scoring.
	"OpenWetlands" "Beaches" "ShrubSwamp" "ForestedSwamp" "IntLandscape" "Riparian"		Scored each polygon appropriate score, 0 - 3, for each Habitat type according to Scoring Matrix and Crosswalk.	
	"Shorebird"	Shorebird Migratory Habitat Model	Shorebird Migratory Habitat Model is a raster surface with a habitat index of 0 to 5. Process for the NWI_PRW polygons was to use zonal statistics to get an average index score for each polygon. The wildlife tool requires a score of 0 - 3, so this is how the index score was translated from the polygon average. 0 = 0; <=1.76 is 1, 1.76 to <= 3 is 2, and > 3 is 3	Migratory model was adapted for Wisconsin from: Ewert, D.N., G.J. Soulliere, R.D. Macleod, M.C. Shieldcastle, P.G. Rodewald, E. Fujimura, J. Shieldcastle, and R.J. Gates. 2005. Migratory bird stopover site attributes in the western Lake Erie basin. Final report to The George Gund Foundation. Wisconsin model unpublished.
	"Summary"	Sum of wildlife tool attributes	Add all 7 of the wildlife habitat scores together	

Table 8. Methods for dataset creation (continued)

Output Feature Dataset	Attribute Field of interest	Input Datasets	Process/Attribute Definition	Comments
CCAP_Wildtool_final		CCAP 2001	• Wetland types converted to like upland types • Convert raster to polygon	Wildlife Tool Scoring Matrix and Wildlife Tool Crosswalk Appendix provide details of specific scoring.
	"OpenWetlands" "Beaches" "ShrubSwamp" "ForestedSwamp" "IntLandscape" "Riparian"		Scored each polygon appropriate score, 0 - 3, for each Habitat type according to Scoring Matrix and Crosswalk.	
	"Shorebird"		No Value for uplands	
	"Summary"		Add all 7 of the wildlife habitat scores together	

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