V. Pulling it All Together: Applying Recommended Conservation Strategies to Identified Priority Areas

5.1 Recommended Conservation Strategies for Freshwater and Tidal Ecosystems

In addition to identifying priority places for conservation, a second and equally important component of this project is to help focus the most appropriate types of protection, restoration, and management actions within these priority places. To do this, we used our ecosystem condition assessment, which highlights attributes of an ecosystem which are likely to be functioning well or may be degraded and in need of restoration. Understanding basic condition of each ecosystem helps identify which conservation actions would be most likely to be beneficial in each priority area to maintain or enhance habitat condition and ecological function that supports biodiversity.

Throughout this section, we use the word *conservation* very broadly to describe any action whose intent is to benefit ecological targets, be it through maintenance, improvement, or enhancement. This includes *protection,* meaning the acquisition or easement of land. This also includes *restoration* or assisting the recovery or resilience of ecosystems that have been degraded, damaged, or destroyed. It may also include ongoing *management* of lands, waters, or fish and other biota, like marine shellfish, to sustain or restore populations or ecological functions. We also recognize that protection, restoration, and management often all have a role at specific places, depending on the combination of ecosystems present, the current condition, and the long-term objectives.

This broad definition of *conservation* encompasses the majority of recommended action categories aimed at our ecosystem targets:

- Forest Conservation
- Non-Tidal Wetland Conservation
- Agricultural Land Protection and Conservation
- Aquatic Connectivity Restoration
- Streamflow Management
- Groundwater/Baseflow Conservation
- Tidal Marsh Restoration
- Shoreline Conservation
- Marsh Room to Move Protection

In this section, we provide some examples of projects that fall within these broad categories. We also highlight some of the existing programs and funding sources that can be used to for implementation.

Forest Conservation

Forest conservation is a critical strategy within the Basin. Not only are forests important habitat in the Delaware Basin in terms of the biodiversity they contain and the ecological functions they serve, but a recent USDA Forest Service report for the Northeastern Area of the United States also emphasizes that the connection of "forest to faucet" is of vital importance to people in the Northeast. Forests are a critical first filter to aid in the protection of drinking water, and managing forests for source water protection is becoming more important as population and water demand increase. Fifteen million people depend upon the Delaware River and headwaters as their primary source of drinking water.

This strategy focuses on the conservation of headwaters areas throughout the basin where large forested tracts remain intact; the protection and/or restoration of floodplain and riparian corridors; and the protection of undeveloped upstream watershed areas in the Coastal Plain to help maintain tidal marsh condition. Forest conservation can be achieved in a number of ways and through a variety of programs and partnerships. For example, forested headwaters can be protected through state and local regulations, through outright fee-acquisition, or by conservation easements. Forests can also be managed through the implementation of public and private forest stewardship plans, or through various certification and management plans. Forests in the basin can also be restored through innovative public-private partnerships, such as the Pinchot Institute for Conservation's Common Waters Fund (sidebar).

Floodplain Forest Community, Upper Delaware River Floodplain
© Gregory Podniesinski

Pinchot Institute's Common Waters Fund

*In February 2011, the Pinchot Institute launched its **Common Waters Fund**, a grant program for private landowners in Pennsylvania, New York, and New Jersey to implement forest conservation practices on their land. The Common Waters Fund will provide incentives to qualifying landowners to implement forest stewardship plans, watershed forestry management practices, and/or conservation easements over the next two years.*

Grants of up to $25,000 are available for eligible landowners, qualified land trusts, and timber harvesting operators to help develop forest stewardship plans; offset the costs of implementing certain forest management practices that will improve forest health and protect water quality; assist with expenses related to placing a conservation easement on a property; and defray the cost of construction, purchase, or rental of portable timber/skid bridges to minimize erosion and sedimentation on streams in priority areas.

More than two dozen partner organizations are part of the Common Waters initiative, including the Delaware River Basin Commission, county conservation districts and planning departments, the National Park Service, and state forestry agencies.

Non-Tidal Wetland Conservation

Basin-wide there is a need for the protection and restoration of non-tidal wetlands. In December 2008, the DRBC's first *State of the Basin Report* noted that over the past 300 years, the Delaware River Basin has lost perhaps 50 percent of its natural marshes. Ranking high in biodiversity, non-tidal wetlands serve as important habitat for many species of wildlife and plants. They also provide a number of other benefits to communities that often go unrecognized, such as helping to control flooding and thereby reducing storm damage, and preventing sediment and pollutants from entering waterways. Consequently, this strategy focuses on the direct protection or restoration of individual forested, scrub-shrub, and emergent headwater and riverine wetlands and surrounding upland buffers.

Acquisition, through fee acquisition or conservation easement, of non-tidal wetlands is a viable strategy to protect non-tidal wetlands in the basin. Wetland laws also regulate the activities that can occur in wetlands; however, regulations do not address the past degradation of wetlands. Restoring non-tidal wetland habitat can take many forms and can occur on public and private lands across the basin.

A number of funding sources are available for restoration and management of wetlands and of wetland buffer areas. One way to implement this conservation strategy is to directly engage private land owners in those areas noted as priorities for non-tidal wetland restoration and protection. Federal funding sources are also available for the protection of important wetlands through fee acquisition or for wetland restoration projects. Habitat improvement achieved through restoration directly benefits key species of concern (sidebar).

Fen Northeast Pennsylvania, Delaware River Basin
© Harold E. Malde

Federal Funding for Wetland Conservation

The U.S. Fish and Wildlife Service's (USFWS) ***North American Wetlands Conservation Act*** *(NAWCA) provides matching grants to non-federal partnerships to carry out wetland conservation projects throughout the U.S. that benefit wetlands-associated migratory birds. NAWCA projects also benefit other fish and wildlife species, including rare, threatened, and endangered species that are dependent on wetlands ecosystems.*

The conservation non-profit group, ***Ducks Unlimited****, has led projects throughout the Delaware River Basin to protect migratory birds along the Atlantic Coast Flyway. Projects include on-the ground wetland conservation projects as well as research on migratory species, such as exploring the decline of black duck populations along the Atlantic Flyway.*

The protection of key wetland habitats can also be funded through the ***Land and Water Conservation Fund****, which provides matching grants for land acquisition. In October 2010, LWCF funds were used to fund the initial land purchase for the* ***Cherry Valley National Wildlife Refuge****, which will grow to encompass more than 20,000 acres near the Delaware Water Gap. Cherry Valley is home to 85 rare species, including the federally threatened bog turtle.*

Agricultural Land Protection and Conservation

Farming has occurred throughout human history in the Delaware River Basin and, in some areas, agricultural practices continue to be a dominant influence. Well-managed farms provide environmental benefits including wildlife habitat and the potential for groundwater recharge. While the continuation of agriculture in the basin is critical for the culture and economy of the region, conservation projects that can take place on current and former agricultural lands would benefit the aquatic resources and the people of the basin. In the estuary, agricultural lands adjacent to tidal marshes need to be preserved and managed to allow for the natural migration of tidal marshes as sea levels rise. Restoring old agricultural fields to forests improves water quality and reduces flooding potential in vulnerable areas. Protecting and managing agricultural lands can help us both conserve aquatic resources in the basin and maintain the rural, working landscape that is an important part of the Delaware River Basin.

This strategy focuses both on the protection and best management of current agricultural lands for ecological value. The four Basin states already have programs that promote and fund the protection of agricultural lands primarily through land purchase from willing sellers either in fee or by conservation easements. These programs serve several purposes that range from preserving a land base in order to support and sustain agricultural operations to protecting rural landscapes. This strategy also includes conservation activities such as the restoration of retired agricultural areas in floodplains or the compatible management of agricultural lands in the floodplain to allow for episodic flood storage while still meeting the needs of active agricultural production.

Recently a number of environmental NGOs have recognized the value of partnering with the agricultural community to advance conservation interests (sidebar). This conservation strategy is tailor-made for implementation by U.S. Department of Agriculture (USDA), its Farm Services Administration (FSA), Natural Resources Conservation Service (NRCS), and local conservation districts through its Farm Bill-authorized programs.

U.S. Farm Bill

*A recent report authored by a coalition of conservation groups, **Conserving Habitat Through the Federal Farm Bill: A Guide for Land Trusts and Landowners**, states that the federal Farm Bill is the greatest source of private land conservation funding in the United States.*

*Through Farm Bill funding, landowners can plant trees to improve water quality; access financial assistance through **Environmental Quality Incentive Programs (EQIP)** to achieve and implement conservation practices on their land; participate in the wildlife habitat incentive program (WHIP) and obtain cost share funding to assist with the implementation of wildlife habitat development practices. Landowners can also access a voluntary **Wetland Reserve Program (WRP)** to enable them to establish conservation easements on wetlands on their property as well as funding for 100% of the wetland restoration costs.*

NRCS has identified targeted watersheds in the basin that they consider priorities. Where these priorities overlap, conservation NGOs and funders should build upon existing Farm Bill conservation programs and develop additional incentives that are attractive to private landowners to undertake projects that support the protection and restoration of biodiversity on their lands.

Ⓒ Aquatic Connectivity Restoration

Free-flowing rivers provide uninterrupted habitat for fish and aquatic wildlife, clean water for drinking, and recreational opportunities for many people. A history of dam-building has left some of the Delaware's tributaries fragmented and suffering the impacts of altered patterns of water flow and downstream transport of sediments and nutrients. These stream alterations have reduced fish populations by blocking fish movement up and downstream, leading to decreased fishing opportunities. They also have negatively affected water quality and recreational opportunities like swimming and kayaking. Downstream marshes also may be more vulnerable to sea level rise where they are not receiving as much sediment from rivers upstream as they did before dam construction. Fortunately, as awareness grows of the benefits of removing defunct dams, an increasing number of opportunities to restore connectivity of the Delaware River's tributaries will become feasible.

The aquatic connectivity restoration strategy applies to headwaters, tributaries, floodplains, and tidal marshes that have been fragmented by dams, culverts, and other structures that block access to habitat or constrict flow. This strategy aims to improve access and passage for fish and other aquatic organisms and to move, remove, or alter the operations of infrastructure that blocks or constricts natural tidal flow of coastal rivers. In recent years in the Delaware Basin, aquatic connectivity restoration has gained momentum. A few examples include multiple dam removals on the Schuylkill and Musconetcong Rivers, and dam removal feasibility studies on the Brandywine and Lehigh Rivers.

All of these efforts have involved multiple partners, including federal agencies like the U.S. Fish and Wildlife Service, the U.S. Army Corps of Engineers, National Oceanic and Atmospheric Administration, and the Natural Resource Conservation Service; state agencies including the Pennsylvania Fish and Boat Commission, Pennsylvania Department of Environmental Protection and New Jersey Department of Environmental Protection; and non-profit organizations such as Trout Unlimited, American Rivers, Delaware River Keeper, and the Musconetcong Watershed Association.

American Rivers and the National Oceanic and Atmospheric Administration (NOAA) Community-based Restoration Program

*For over ten years, **American Rivers** and **NOAA** have maintained a grants program to support barrier removal projects for diadromous fish, those species that migrate between saltwater and freshwater in order to complete their lifecycle. The program funded over 120 restoration projects in its first nine years and now supports projects along both the Atlantic and Pacific Coasts of the U.S. Grants can be used to complete feasibility analyses for restoration projects, as well as the engineering designs and actual construction phases of a project.*

In addition to financial support, NOAA and American Rivers also offer technical assistance, such as advice on project design, finding matching funds and contractors, staying within compliance of permits, and engaging the local community.

Streamflow Conservation

Natural variations in seasonal streamflow are critical for sustaining healthy riverine and floodplain systems. However, the Delaware River Basin Commission (DRBC) report, Water Resources Program FY 2010-2015, notes that "Water supply planning in the basin generally has not taken into account the instream flow needs of aquatic communities. Recent reviews of several DRBC water supply dockets indicate that flows in some surface waters could be substantially impacted should withdrawals increase to current allocation limits. While scientific investigation continues across the basin to determine the flow needs of aquatic communities, changes to current allocations or the application of permit conditions may be warranted to maintain adequate flows in the tributaries and the River."

Streamflow in the basin is affected by surface and groundwater withdrawals and releases from reservoirs built for water supply, energy production, flood control, and recreation purposes. The basin states, DRBC, and New York City have over 50 years of history of joint water management of the three Upper Delaware reservoirs that are part of New York City's water supply system. Releases from these and other basin reservoirs are made to address downstream considerations, including stream temperature, salinity in the lower river, and downstream water demand. In addition to reservoir management, individual and cumulative water withdrawals that are of sufficient magnitude relative to the source stream can cause impacts to aquatic resources.

Ecologically-based streamflow management requires assessments of water availability, current water use, and an understanding of how aquatic species respond to changes in streamflow. Natural resource agencies within the basin, including DRBC, US Geological Survey, and state natural resource and regulatory agencies have expressed a clear desire for an approach to evaluating the impacts of flow alteration on aquatic resources that is applicable within the basin and throughout the basin states. The development and application of "instream flow" or "environmental flow" criteria is central to this goal. These criteria can provide a basis for managing water withdrawals and reservoir releases by defining the acceptable levels of flow alteration that still allow aquatic resource goals to be met.

WaterSMART

*In 2011, through the U.S. Bureau of Reclamation's **WaterSMART Program**, the U.S. Geological Survey (USGS) will be initiating a study of Delaware River Basin issues related to water use and availability as one of three national pilot basins. Issues such as the impact of land-use change on nutrient loading and water quality, climate change and sea-level rise impacts on water supply, and increased water withdrawals and their impact on water availability or ecologically sustainable flows, have been identified for potential consideration within this study.*

USGS will develop and implement the study plan in coordination with DRBC and other natural resource and regulatory agencies and stakeholders. The Delaware study is expected to take three years and USGS researchers will be funded at about $500,000 for each of those years to conduct the studies.

Riverine Scour and Shrubland Community in Upper Delaware Floodplain
© Gregory Podniesinski

Baseflow/Groundwater Conservation

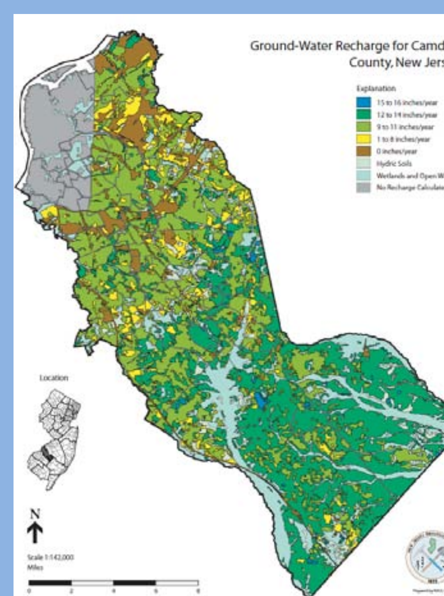
The Delaware River Basin's groundwater resources provide vast amounts of water for natural ecosystems and human use every day. Shallow aquifers help keep streams running and prevent wetlands from drying out—this function is particularly important in the Coastal Plain, where baseflow (groundwater that flows at the surface) accounts for approximately 90% of total streamflow. Many communities and rural residents throughout the basin are completely dependent upon groundwater for their drinking water. Though this resource is not readily visible, it needs to be conserved; groundwater depletion, caused by excessive withdrawals in the Coastal Plain, has already caused saltwater contamination in areas where freshwater aquifer levels have dropped significantly.

This strategy focuses on the conservation of headwaters where groundwater availability is high and use is low. It targets headwaters that are predominantly in natural cover with limited industrial, commercial, and agricultural groundwater use. In some of these areas where groundwater-dependent ecosystems like wetlands are particularly abundant there are opportunities to keep ecosystems functioning by conserving those intact forests, maintaining recharge into aquifers, and limiting input of contaminants. In other areas of the basin, groundwater conservation can be more challenging due to high demands.

Several agencies are working to protect water supplies in these areas and across the basin. For example, the DRBC has established ground water protection areas with special regulations, the U.S. Geological Survey has studied water demands and projected supply scenarios, and the New Jersey Geological Survey has mapped recharge rates for the whole state. Some of New Jersey's efforts to help protect and restore groundwater resources through funding sources that can target identified areas of high recharge value are highlighted (sidebar).

New Jersey's Natural Resource Restoration Program Initiative

*Dating back to the early 1990s, New Jersey has had a program in place to collect funds for damages to natural resources to be applied to "replacement" restoration and protection efforts. Groundwater has always been a target of this program, which is currently called the **Natural Resource Restoration program**. Funding through this program is available for acquisition of land to protect or restore aquifer recharge. Protecting high recharge areas is one way to help ensure plentiful and clean groundwater supplies for people and nature. About 40% of the state's drinking water comes from groundwater.*



NJ Geologic Survey map of recharge rates in Camden County, NJ, in inches per year

Tidal Marsh Restoration

Tidal marshes are the characteristic feature of the Delaware Estuary, providing habitat for wildlife and ecosystem services to the people of the region. However, the State of the Basin report notes that, over the past 300 years, the Delaware River Basin has lost perhaps 50 percent of its natural marshes and that perhaps only five percent of pre-settlement tidal freshwater marshes remain. And as climate change brings about sea level rise and salinity changes in the estuary, new threats have emerged to tidal marshes and to the human communities that lie adjacent to them. To continue to provide the important services to people and nature, restoration of degraded and vulnerable freshwater and saltwater/brackish tidal marshes is an important strategy in the Delaware River Basin.

Tidal marsh restoration conservation strategies are recommended for vulnerable brackish and salt marshes with relatively low elevation compared to the surrounding marshes or for those that have been severely altered. Freshwater tidal marshes in the urban corridor between Wilmington, DE and Trenton, NJ are the largest complexes remaining on the East Coast; however, habitat conversion has led to severe losses. Strategies are recommended for freshwater tidal marshes where their restoration could improve water quality and increase wildlife habitat in a heavily urbanized landscape.

Restoration activities may range from small-scale living shorelines projects in tidal creeks to large-scale sediment management on marsh surfaces. These activities can be carried out by non-profit organizations and state and federal agencies, many that are part of the Estuary Restoration Act's interagency Council (sidebar). One example of large-scale restoration in the Delaware Bay began in the 1990s when Public Service Enterprise Group (PSEG) purchased and restored over 20,000 acres of former salt hay farm marshes and *Phragmites australis*-dominated tidal marsh and adjacent uplands to mitigate for fish intakes at their cooling towers in Salem, NJ.

The Estuary Restoration Act

*The **Estuary Restoration Act** was established to "encourage the restoration of estuary habitat through more efficient project financing and enhancing coordination of Federal and non-Federal restoration programs."*

Through an interagency council established by the Estuary Restoration Act, NOAA, U.S. Fish and Wildlife Service, the Environmental Protection Agency, and the U.S. Army are working together to carry out the act's directives of promoting a coordinated Federal approach to estuary restoration, forging effective partnerships between public and private sectors, providing financial assistance, and developing monitoring and research capabilities.

Funding through the Council can be obtained from NOAA Fisheries. Projects must address the directives set forth by the Council and support the Council's Estuary Habitat Restoration Strategy. Priority is given to projects that address climate change impacts, occur in watersheds where other beneficial habitat projects are ongoing, and demonstrate innovative technologies or approaches to estuary restoration.

Shoreline Conservation

Natural gently sloped, low energy shorelines along the Delaware Bay provide spawning grounds for horseshoe crabs and critical feeding opportunities for migratory shorebirds. Shorelines also protect tidal marshes and allow for the natural movement of marshes as sea levels rise in the brackish/salt and freshwater tidal marshes of the estuary.

Many Delaware Bay shorelines are free from infrastructure and are currently protected; however, protecting natural shorelines that are not currently held in conservation, through land acquisition and conservation easements, is recommended in the Delaware Bay and estuary regions of the basin. There are also opportunities to restore degraded and eroded shorelines. For example, remnants of old coastal towns are scattered across the bay's shorelines and are in need of restoration. In many circumstances, healthy natural systems are required to protect human communities behind the shorelines as sea levels rise and storms cause damage to natural and human communities. In conjunction with tidal marsh restoration strategies, shoreline conservation addresses the threats to our coastal habitats and adjacent human communities.

Acquisition of undeveloped natural beaches can be accomplished by state or federal agencies, as well as non-governmental conservation organizations. The New Jersey Department of Environmental Protection, Delaware Department of Natural Resources and Environmental Control, U.S. Fish and Wildlife Service, The Nature Conservancy, Natural Lands Trust, and other environmental NGOs own and manage natural Delaware Bay beaches.

Thompson's Beach, New Jersey
© TNC staff

The National Coastal Wetlands Conservation Grant Program

While there is no direct funding source for shoreline conservation, funding to acquire undeveloped natural beaches or for beach restoration is available through a variety of state or federal agencies, the U.S. Fish and Wildlife Service and the U.S. Army Corps of Engineers. For example, the U.S Fish and Wildlife Service's ***National Coastal Wetlands Conservation Grant Program*** *was established by the Coastal Wetlands Planning, Protection, and Restoration Act in 1990. Annually the U.S. Fish and Wildlife Service provides between $18 and $21 million in matching grant money to coastal states for conservation projects, including acquisition, restoration, enhancement, and management of coastal wetlands throughout the United States.*

Coastal Wetlands Program funds encourage partnerships, support watershed planning, and leverage on-going projects to maximize the benefits of limited funding.

In addition, throughout the Delaware Bay, reach restoration work is carried out through New Jersey DEP's Bureau of Coastal Engineering and Delaware Department of Natural Resources & Environmental Control (DNREC) Division of Soil and Water Conservation. In Delaware, the Division of Soil and Water Conservation's Shoreline and Waterway Management section regulates coastal construction in beach areas and protects and enhances Delaware's beaches.

Marsh Room-to-Move Protection

The tidal marshes of the Delaware Bay provide food and habitat for a wide range of plants and animals that are important to the aquatic biodiversity of the Delaware Basin. These marshes are a critical link in the estuary's food web and are an important nursery ground for a number of recreationally and commercially important coastal fish species, crabs, and other crustaceans. These marshes are also vitally important in protecting coastal areas from flooding and storm surges. The tidal marshes of the Delaware Bay support a wide range of recreational activities including hunting, fishing, and wildlife viewing.

These marshes are now being threatened by sea level rise, currently projected to be up to 10mm per year over the next century (Kreeger et al. 2010). Tidal marshes are able to respond to sea level rise in two ways. They can accrete inorganic and organic sediment, thereby increasing elevation to keep pace with sea level rise, or they can migrate inland over natural lands with gentle slope and elevation. To allow for this natural process to occur, the protection of natural lands adjacent to tidal marshes, through land acquisition or conservation easements, is a recommended conservation strategy in the bay and estuary regions of the basin. Wise management of lands adjacent to tidal marshes can assist in the migration of tidal marshes inland.

Allowing for marsh migration is a relatively recent conservation strategy that is being evaluated by a number of coastal states. In order to increase the accuracy of tidal marsh migration predictions, additional data collection and analysis by both the states of New Jersey and Delaware will be required. Delaware currently has a project underway to do just this. The highlighted example to the right suggests a way to incorporate the map products in this report and the conservation strategy of providing marshes "room to move" into the State's adaptation planning.

Protection of marsh room-to-move lands can be carried out by U.S. Fish and Wildlife Service, New Jersey Department of Environmental Protection, Delaware Department of Natural Resources and Conservation, and conservation non-profit organizations, such as The Nature Conservancy, Natural Lands Trust, and the New Jersey Conservation Foundation.

Delaware and Sea Level Rise

*The **State of Delaware's Coastal Programs** office has established a Sea Level Rise Advisory Committee that is comprised of a representative from each State of Delaware Cabinet Department and representatives from municipal government, business advocacy organizations, and citizen advocacy organizations. This group is charged with helping develop an Adaptation Plan that recommends a wide-range of potential solutions to reduce risk of sea level rise impacts.*

*The nexus between Delaware's efforts to address and plan for the impacts of sea level rise and this report is clear. As the state moves forward to implement its Adaptation Strategy, this project's **"marsh room-to-move protection"** approach can be easily incorporated. For example, once the state completes its tidal marsh vulnerability assessment for its Adaptation Plan, the assessment can be easily compared to this project's tidal wetlands priority protection and restoration areas for aquatic biodiversity. It is anticipated that the overlap will be considerable especially in places that the state has already identified as priorities in its **Coastal and Estuarine Land Conservation Program** (CELCP) plan. That program, established by Congress to provide matching funds to acquire coastal and estuarine lands or interests therein for permanent protection if applied strategically, can be used to implement a marsh room to move strategy.*

5.2 Recommended Conservation Strategies for Marine Bivalve Habitats

The next two conservation strategies offer an array of actions to conserve oysters and ribbed mussels in the Delaware Estuary. Traditional shellfish restoration tactics are presented as well as new and experimental options. Bivalve shellfish restoration and management must be grounded in existing ecological and management paradigms; therefore, we discuss policy impediments and restrictions that might slow implementation of best current and future measures. In addition, conservation strategies for bivalves should be revisited every few years as new information develops.

Bivalve shellfish habitats can be enhanced through protection, restoration, and other management actions. Since conservation strategies are species-specific, the best tactic will therefore depend on conservation and/or management goals and the targeted bivalve species. The implementation of any of the oyster conservation strategies must work in concert with these existing management groups in order to achieve full success. Please refer to the full PDE shellfish priorities report for more background, discussion, and references regarding conservation priorities for marine bivalve shellfish (Kreeger et al 2011a).

Shellfish Restoration

This strategy focuses on methods to restore or create new populations of shellfish in the Delaware Bay.

EXAMPLE ACTIONS:

SP *Shell Planting*: Strategic shell planting is a top recommended conservation tactic for oysters, because it has been the most effective tactic for boosting oyster production in the Delaware Estuary (see, for example, the Delaware Bay Oyster Restoration Project (PDE 2007), and because it is highly cost-effective. Funding and project management for shell planting has been overseen by an Oyster Restoration Task Force comprised of agency, industry, non-profit, and academic partners from Delaware and New Jersey. Sites for shell planting are selected based upon existing or historic oyster setting patterns, reef habitats, and the most recent monitoring data. When oyster larvae are most abundant in the water (late June to early July), targeted reefs are planted with clam and oyster shell, providing hard substrate to which oyster larvae attach. The new recruits (spat) remain on these beds. Sustained significant funding for shell planting is critically needed. To sustain a positive shell budget, stabilize and enhance oyster stocks, and ensure a continued commercial industry, the task force estimates that an annual shell planting budget of $1 million is needed.

DS *Designed Shellfish Reef:* Vertical reefs can be used to create more surface area in the water column to attract spat and build more multi-dimensional oyster reefs. One example of a vertical reef involves using a cage device. Shell is placed inside the cage (probably made of metal). The holes of the cage are large enough to attract new larvae to colonize on the shell inside, but small enough to prevent poaching. Over time animals will settle on top of animals, until the cage structure will completely disappear into the new reef. For shallow areas, a variety of commercial reef construction products are also now available. “Reef-Blok” and “Wave Attenuation Devices” are other commercial products that have been shown to be effective in areas along the Gulf of Mexico

(The Reef Ball Foundation 2011). In order to test artificial reefs, pilot projects could be developed as part of living shoreline projects or in tributary areas, and later potentially expanded to other shallow marginal areas.

G *Gardening:* Gardening refers to any small scale activity which grows shellfish on a temporary non-reef structure. Shellfish gardens are often used to promote conservation through community participation by schools, parks, businesses, watershed groups, and waterfront property owners (VDEQ 2010). The PORTS program in New Jersey (seen in maps of Areas 2 &3) successfully incorporated some forms of oyster gardening concepts in earlier programs to educate school children about oyster restoration. In Delaware Bay, the major constraint on oyster gardening is the human health risk associated with consumption of oysters grown in poor quality waters. New Jersey recently banned gardening of any commercial species in tributaries and other closed waters because of sanitation concerns. The New Jersey ban does not apply to ribbed mussel gardening because they are not a commercial species; therefore, shellfish gardening methods should be developed for ribbed mussels.

LS_I *Living Shorelines – Intertidal Zones:* Living shorelines are shoreline stabilization projects that can be used to offset wave energy and sea level rise effects while also enhancing ecological values. They range in complexity from modest biological modifications in low energy areas to hard structures in high energy areas. The Delaware Estuary Living Shorelines Initiative (DELSI), piloted in New Jersey salt marshes, was intended to stabilize eroding tidal marsh shorelines in low to moderate energy areas, partly by the binding action of ribbed mussels and plants within fibrous logs and mats and shell bag treatments. This method bolstered the resilience of marsh plants by stabilizing erosion while also encouraging recruitment of shellfish communities. In addition to these benefits, fish and wildlife use the mussel-rich edges of salt marshes. Shellfish-based living shorelines could be expanded as a tactic to both promote bivalve populations and to stabilize coastal habitats such as tidal wetlands.

LS_B *Living Shorelines – Subtidal Breakwater:* Near-shore oyster breakwaters in shallow subtidal areas may help to stem shoreline erosion and prevent flooding for coastal properties, especially when combined with intertidal living shorelines and hybrid arrangements. Potential options for nearshore oyster breakwaters in Delaware Bay include places where historic reefs existed in shallow nearshore areas and places where the current habitat is marginal for tonging or dredging (too shallow or rocky). Reef balls, reef block, or other materials can be used to create nearshore reefs as breakwaters. Success of this tactic depends on wave energy, bottom type, navigation conflicts, and the fit with area management goals. We recommend that pilot oyster breakwater projects be completed, which could be expanded or replicated if successful. Pilot projects might be more easily permitted within the State of Delaware than in New Jersey, allowing for demonstration sites to build awareness.

Shellfish management

This strategy focuses on the many ways to affect the management of shellfish (primarily oyster) resources in the Delaware Bay.

<u>EXAMPLE ACTIONS</u>:

HG *Harvest Guidelines:* Due to the long track record of successful stock maintenance and an adaptive and proactive management structure, the Delaware Bay oyster fishery has been declared "sustainable" according to the Stock Assessment Review Committee (SARC). Harvest should remain at sustainable levels, and any changes to oyster harvest guidelines to improve management should be made in concert with the SARC and vested parties, and with careful consideration of the socio-historical and economic importance of oysters. Ribbed mussels are not commercially or recreationally harvested; therefore, no harvest guidelines are recommended.

SM *Special Management Areas:* Special management areas (SMAs) are manipulation-free sanctuaries for aquatic life, designed to preserve aquatic biodiversity and native ecology (Edgar et al. 2007). In the Delaware Estuary, no formal SMAs have been established to restrict oyster harvesting, although harvest is prohibited in certain waters because of shellfish sanitation concerns. We recommend three types of special *oyster* management areas (SOMAs) in the Estuary:
1) Marginal beds which are shallow and unsuitable for oyster boats to navigate, including areas where no reefs currently exist but where future reefs might become established, such as the area around the C&D Canal (see Area 4). 2) Areas where more monitoring and study need take place on the upper oyster beds (Liston Range, Hope Creek, Fishing Creek), or where oysters are moved to replenish other beds down bay following harvest and natural mortality. 3) Tributary rivers, which are closed to harvest and present opportunities for habitat expansion as sea levels rise and tributary embayments widen.

Two types of special management areas are possible for the *ribbed mussel*: habitat preservation and scientific study. Despite protections under the Clean Water Act, salt marshes (and ribbed mussels) are still being lost due to erosion and sea level rise (Kraeuter and Kreeger 2010). Implementation of erosion control projects would buy more time for the inland migration of these habitats, thereby helping to preserve ribbed mussels and their numerous ecosystem benefits (Kreeger and Kraeuter 2010). More study is recommended to understand the life history, ecology, and habitat requirements of ribbed mussels so that desired outcomes from shellfish enhancement efforts can be maximized.

HS *Hatchery/Seed Production/Population Augmentation:* Hatcheries throughout Delaware Bay can be used not only to boost shellfish populations for harvest, but also to support ecological restoration of depleted stocks, especially when natural recruitment is low. Hatcheries can also be used to breed disease-resistant oysters that are more resilient to salinity rise from climate change (see Area 4). Some hatchery and aquaculture facilities in the bay are currently run by Rutgers

University, and there are several small commercial hatcheries along the Atlantic Coast. The University of Delaware also maintains a small research hatchery in Lewes. .

SR *Spat Collection & Relaying*: Relaying, the process of transplanting live bivalves to a new location, has been used as an oyster management technique for centuries. Relaying of spat (baby oyster) and adults currently occurs in Delaware Bay on the upper seed beds. In the lower portion of the bay, spat recruitment is high, but survival is low because mortality from predation, disease and sedimentation is high in the higher salinities. A proven tactic is to put shell out to catch spat, and then move the shell and settled spat to lower disease zones to mature. This strategy was successfully used as part of the Delaware Bay shell planting project where spat were collected on shell placed in the NJ Cape Shore area. Methods for collecting natural recruitment of ribbed mussels have yet to be developed. Lower bay spat collection and relaying should continue as a means to replenish and expand the populations harvested by commercial oystermen. We also recommend research to develop methods for collecting natural recruitment of ribbed mussels.

AE *Extensive Aquaculture:* Extensive aquaculture refers to cultivation that exerts relatively limited control of the cultivated organism, and is often carried out in natural waters rather than tanks. The oyster fishery is arguably a form of extensive aquaculture given the level of manipulation of the organism, which includes transplanting oysters from upper to lower seedbeds, planting shell to improve bottom habitats for oyster recruitment and relaying spat from the lower bay. Extensive aquaculture should be permitted where supported by the market. Successful aquaculture enterprises should be encouraged rather than discouraged with unjustified barriers. Although aquaculture is not an enhancement priority, it will have enhancement benefits, so a “do not hinder” approach is recommended.

AI *Intensive Aquaculture:* Intensive aquaculture, involving much more control of the organisms’ life cycle, may include hatchery production, a nursery phase, and cage or bag culture during grow out. The recommendation here is similar for Extensive Aquaculture above: do not hinder as long as siting for intensive aquaculture is selected to ensure any environmental effects are negligible or beneficial.

DR *Promote Disease Resistance:* The oyster diseases MSX and Dermo are two primary factors limiting oyster populations in Delaware Bay. Salinity largely determines disease levels and distribution, hence the management of freshwater inputs from the upper watershed is a high priority for oyster health. Development of disease-resistant stocks can be achieved through aquaculture and oyster gardening. In Delaware Bay, data from the Haskin Shellfish Research Laboratory indicate that the native oyster population has become MSX-resistant through natural selection (Ford and Bushek in prep). Unfortunately, resistance to Dermo has yet to be developed despite extensive experimental breeding programs. For this reason, there is a critical need to support more research on Dermo disease.

POTENTIAL FUNDING SOURCES FOR SHELLFISH MANAGEMENT AND RESTORATION

- *Federal Agencies*. Through an appropriation to the Army Corps of Engineers, $5 million was directed to oyster shell planting between 2005 and 2010, resulting in up to 50-fold increases in spat recruitment on planted areas and a net positive, bay-wide shell budget by 2010. Grants from the National Science Foundation, NOAA Sea Grant, and Army Corps of Engineers also have supported various scientific studies on bivalve shellfish that benefit managers and conservation planners.

- *State Agencies*. The States of Delaware and New Jersey, and the interstate Delaware River Basin Commission, have provided both financial and staff support for shell planting by the Delaware Bay Oyster Restoration Task Force. State environmental agencies also undertake or support important shellfish sanitation and water quality monitoring.

- *Non-Governmental Organizations.* Entities such as the National Fish and Wildlife Foundation, Partnership for the Delaware Estuary (PDE), American Littoral Society, and The Nature Conservancy have provided grants, in kind resources, or staff to facilitate the restoration, monitoring, and scientific study of bivalve populations. In addition to funding oyster projects, these groups have recently been active in developing living shoreline tactics that promote other species such as ribbed mussels.

- *Oyster Industry.* Commercial oystermen have traditionally recognized the importance of sustaining shell budgets and managing stocks to both boost harvests and ensure long-term sustainability. This culture of self-policing and reinvestment continues today as evidenced by the industry's active support for scientific monitoring, area management, and self-taxing for cultch fund contributions.

- *Other Industries.* Numerous companies that operate within the Delaware Estuary and its watershed have often provided support for conservation of various natural resources, including bivalves. For example, the DuPont Clear into the Future program has supported scientific research on oyster diseases and recently contributed to the shell planting effort. PSEG has supported research on the role of ribbed mussels in sustaining salt marsh health.

- *Academic Institutions.* Numerous regional universities, most notably the Rutgers Haskin Shellfish Research Laboratory, have provided in-kind support, staff, and students to perform critical monitoring and scientific study of the area's bivalve resources.

5.3 Priority Conservation Area Maps and Recommended Strategies

The resulting priority areas and recommended conservation strategies are presented in a series of sub-basin packages. Each package includes:

- A map with the identified priority conservation areas within the sub-basin and the broad recommended conservation strategies – described in the previous section – applied to watersheds within that sub-basin.

- A general ecological description of each sub-basin and outline some of the projects and partners that are currently working on these conservation strategies.
- Additional maps for each sub-basin that depict land use, protected lands, and the identified priority areas displayed by ecosystem type in each of the sub-basins.

For marine bivalve habitat, five conservation strategy areas have been identified and appear in maps labeled *Area 1 – High Productivity Oyster Beds*, *Area 2 – Marginal (harvest) Areas*, *Area 3 – Hybrid Oyster-Mussel Areas*, *Area 4 – Climate Future Targets*, and *Area 5 – Ribbed Mussel Target Areas*. Each map is accompanied by a table explaining the recommended strategies for each area. The strategies also appear directly on each map. These strategies are not limited to the five types of target areas and can be applied more broadly across the Delaware Estuary. Future iterations of this study are expected to yield additional target areas and new restoration tactics. The five maps presented in this report provide examples of the best areas for implementation of highest priority tactics based on best current knowledge.

THE UPPER DELAWARE RIVER:

PRIORITY CONSERVATION AREAS AND STRATEGIES

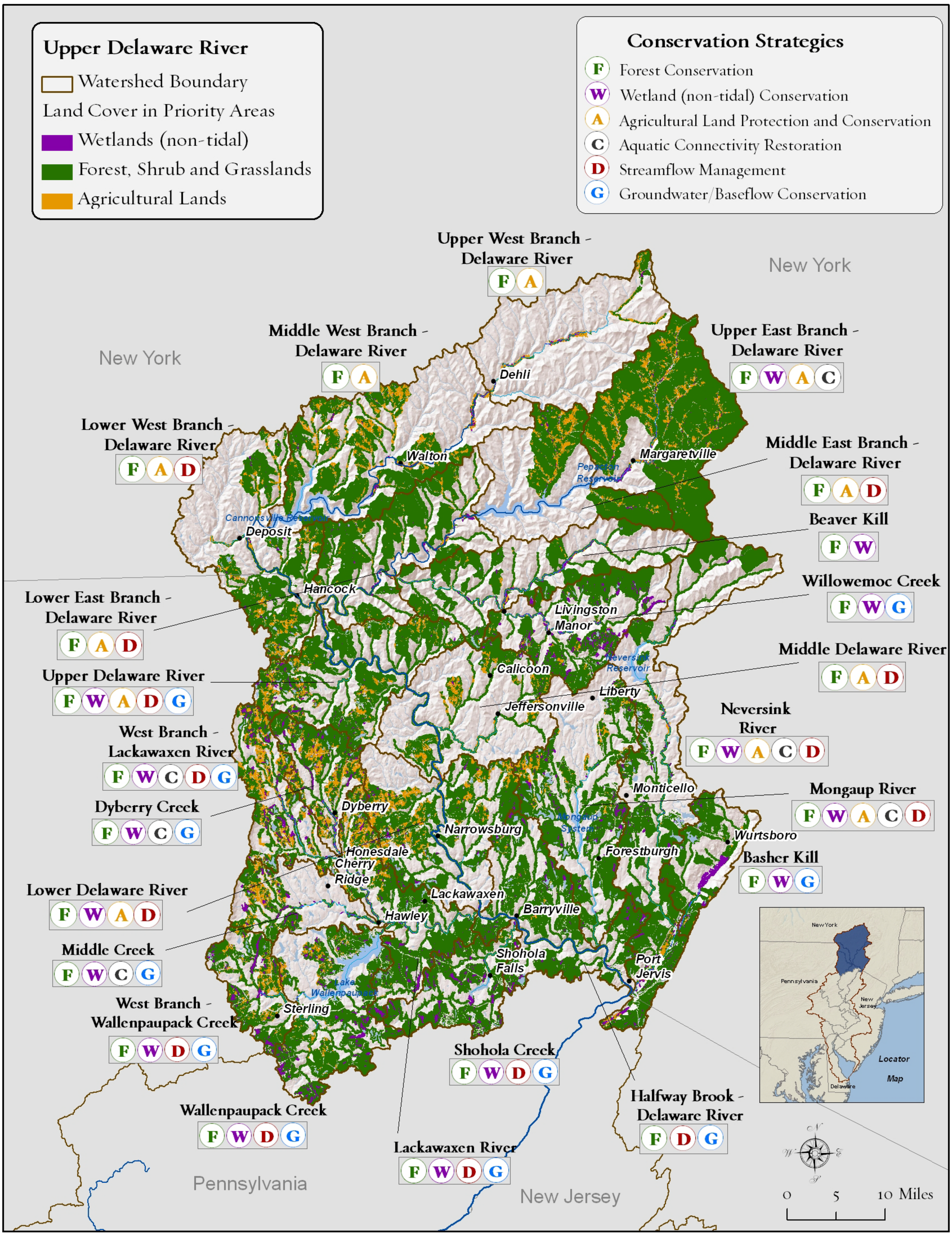


Figure 5.1. Priority Conservation areas and recommended conservation strategies in the Upper Delaware River

The Upper Delaware River

The Upper Delaware River ~ The Upper Delaware River, including the Neversink-Mongaup, East-West Branch, and the Lackawaxen sub-basins, extends 77 miles from Hancock, NY to Port Jervis, NY and Matamoras, PA. Draining an area of approximately 3,500 square miles, this area is located in the Appalachian Plateau physiographic province, specifically the Glaciated Pocono Plateau and the Catskill Sections. Elevation ranges from nearly 4,200 feet at Slide Mountain in the Catskills to 400 feet at Port Jervis, NY and Matamoras, PA.

By the 1800s, industry and commerce were booming in the area due to the construction of the Delaware and Hudson Canal, which brought coal to New York City from eastern Pennsylvania. The second heyday for the Upper Delaware was tourist-driven, as the Catskills were a popular vacation spot from the 1920s through the 1960s. In many communities on the NY side of the basin, aging resorts and bungalow communities persist today. The Pocono Mountains are still a very popular vacation destination; Pike and Wayne Counties (PA) are the most rapidly growing areas within the basin.

Several large dams were constructed on major tributaries in the early to mid-1900s to provide water and electricity for nearby populations. These include three large reservoirs on the Neversink and the East and West branches of the Delaware River that supply drinking water to New York City. In 1926 Pennsylvania Power and Light built a hydroelectric dam on Wallenpaupack Creek, a major tributary of the Lackawaxen River. These reservoirs have caused a significant reduction in streamflow and have altered the natural flow regime, impacting aquatic communities. Over the past decade considerable progress has been made in managing the NYC reservoirs to balance the need to protect drinking water with the needs of aquatic life downstream.

Today this upper portion of the Delaware River basin is mostly forested, with a few small towns/cities dotting the landscape (Figure 5.2). Recreation, tourism, and natural resource management and extraction are the primary drivers of the economy. The Upper Delaware River is a designated National Wild and Scenic River for 73 miles from just north of Port Jervis to Hancock, NY. Significant portions of the watershed are in protected status, and water quality is considered some of the best on the East Coast (Figure 5.3).

Eastern Brook Trout ~

Eastern Brook trout (*Salvelinus fontinalis*) are an iconic species in the Upper Delaware. Theodore Gordon, considered the father of modern American fly fishing, perfected his dry-fly techniques on the Neversink River in the 1800s, and fisherman flocked to the Catskills and Poconos to fish for the native brook trout. Today, as a result of competition with introduced brown and rainbow trout, habitat destruction, sedimentation, acid rain, and increased water temperatures, brook trout populations are just shadows of their former glory (EBTJV 2006). The Eastern Brook Trout Joint Venture prioritizes brook trout strongholds in tributaries to the Delaware River in New Jersey, Pennsylvania, and New York. In light of climate change and other persistent threats, it is critical to prevent the loss of populations that contribute to the overall genetic variation in the basin. Watersheds with naturally reproducing brook trout, including the **Beaverkill** and **Willowemoc** (NY), should receive the highest priority for protection and restoration (TU 2009).

Conservation Highlights ~

The map on the reverse (Figure 5.1) highlights watersheds within the Upper Delaware River Basin where **Forest Conservation, Wetland Conservation, Agricultural Land Protection and Conservation, Aquatic Connectivity Restoration, Streamflow Management,** and **Groundwater/Baseflow Conservation** strategies would help protect and restore basin biodiversity. In addition, Figure 5.4 illustrates the identified priority conservation areas within this region by ecosystem type, without associated land cover. Specific conservation strategy examples include:

(F) Forest Conservation: Headwaters

In the headwaters of the Upper Delaware, forest conservation is a priority conservation strategy. Several large unfragmented forested areas provide cores for expanding headwater conservation, especially in the **Neversink**, **Beaverkill**, **Willowemoc**, **East Branch**, and **Shohola watersheds**. In this region, several funds and programs are available to help landowners protect forested headwaters. For example, the *Common Waters Fund* provides funding to support the development of forest stewardship plans, to implement forest management practices, and for conservation easements. For lands within the New York City watershed, the *NYC Department of Environmental Protection's Land Acquisition Program* protects lands either through fee simple acquisition or conservation easement. In addition, The Nature Conservancy has developed a forest conservation program, *Working Woodlands*, which uses revenue from certified forest products and carbon markets to catalyze private forest protection in this region and throughout Pennsylvania.

(W) Wetlands Conservation: Headwaters

The Neversink-Mongaup sub-basin includes significant wetlands. The **Bashakill wetland** is a 3,000-acre emergent marsh formed as a result of large floods that repeatedly deposited natural dams in the early part of the 19th century. Today the water level is maintained by a very small dam that was installed by NY DEC after farmers drained the wetland. The historically deep and meandering Basher Kill flows through the marsh, eventually draining into the Neversink River. Over 200 species of birds have been documented here, and it is home to the only occurrence of the iron color shiner, *Notropis chalybaeus* in New York. The Bashakill also supports a diverse amphibian population, and wild rice, *Zizania aquatica,* occurs here as well. Although the wetland itself is protected as a wildlife management area, priority headwaters surrounding the wetland also are important.

(G) Groundwater/Baseflow Conservation: Headwaters and Wetlands

Baseflow conservation is also an important conservation strategy within the Upper Delaware region. The watersheds of the Lackawaxen River exhibit high baseflow and low groundwater use. The Neversink watershed also overlaps with the Port Jervis trough, which is recognized regionally as an important groundwater area. Several of the larger tributaries in the Upper Delaware watershed provide colder water to the mainstem, which is especially important during summer (PFBC 2007). Maintaining groundwater recharge, forest and wetland conservation, and managing water use is necessary to maintain base flow and provide thermal refugia.

(D) Streamflow Management: Major Tributaries and Upper Mainstem

Since the New York City water supply reservoirs were completed, the four basin states and New York City have worked together to manage reservoir releases for multiple objectives. Interim implementation of the most recent program, the *Flexible Flow Management Program* (FFMP), began in 2007. FFMP is "a framework for managing diversions and releases for multiple objectives, including water supply, drought mitigation, flood mitigation, protection of the tailwaters fishery, a diverse array of habitat needs in the main stem, estuary and bay, recreation and salinity repulsion" (DRBC 2007). Since interim implementation began, experimental adjustments have been made each year in an effort to balance human and ecosystem needs and adjust to changes in river conditions.

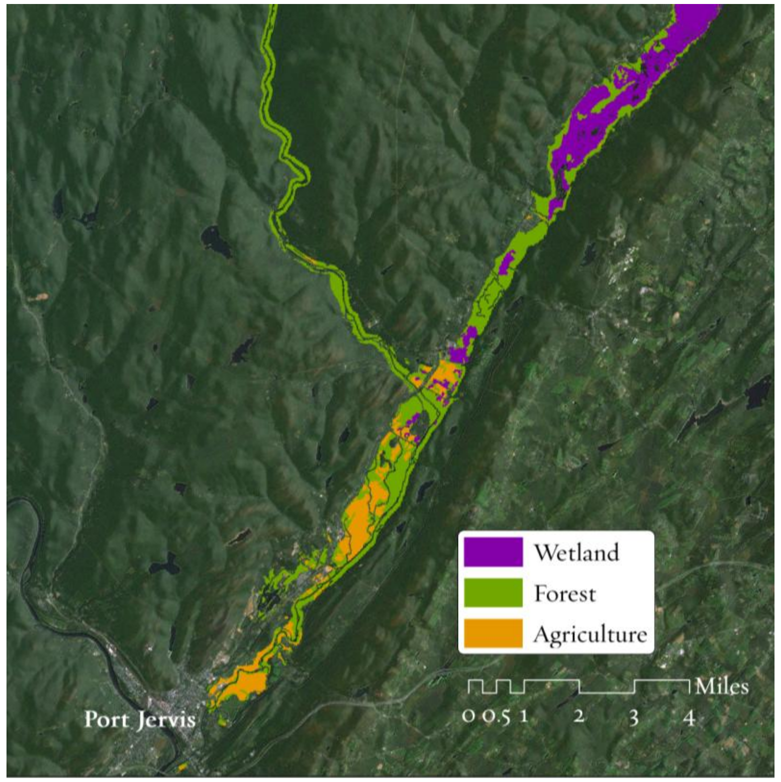


Figure 5.5. Neversink River floodplain complex

(F) (W) (A) Forest and Agricultural Land Conservation: Floodplains

The significant floodplain complex on the **Neversink River** (Figure 5.4) connects to a floodplain complex on its largest tributary, the **Basher Kill**. This complex has been identified as a conservation priority. The lower portion of the complex occurs on an ancient alluvial floodplain above the large Port Jervis aquifer. The water table is very high in the floodplain and provides excellent opportunities for floodplain and riverine wetland restoration opportunities. A large protected floodplain forest community occurs within this complex, which also includes successional grassland and shrub communities, beaver ponds, emergent wetlands, a red maple swamp, and active and fallow agricultural lands. Conservation opportunities include reconnecting the floodplain and expanding the existing floodplain forest community. Some high priority parcels are still in private ownership and should be the focus of protection efforts.

Figure 5.2. Land use in the Upper Delaware River

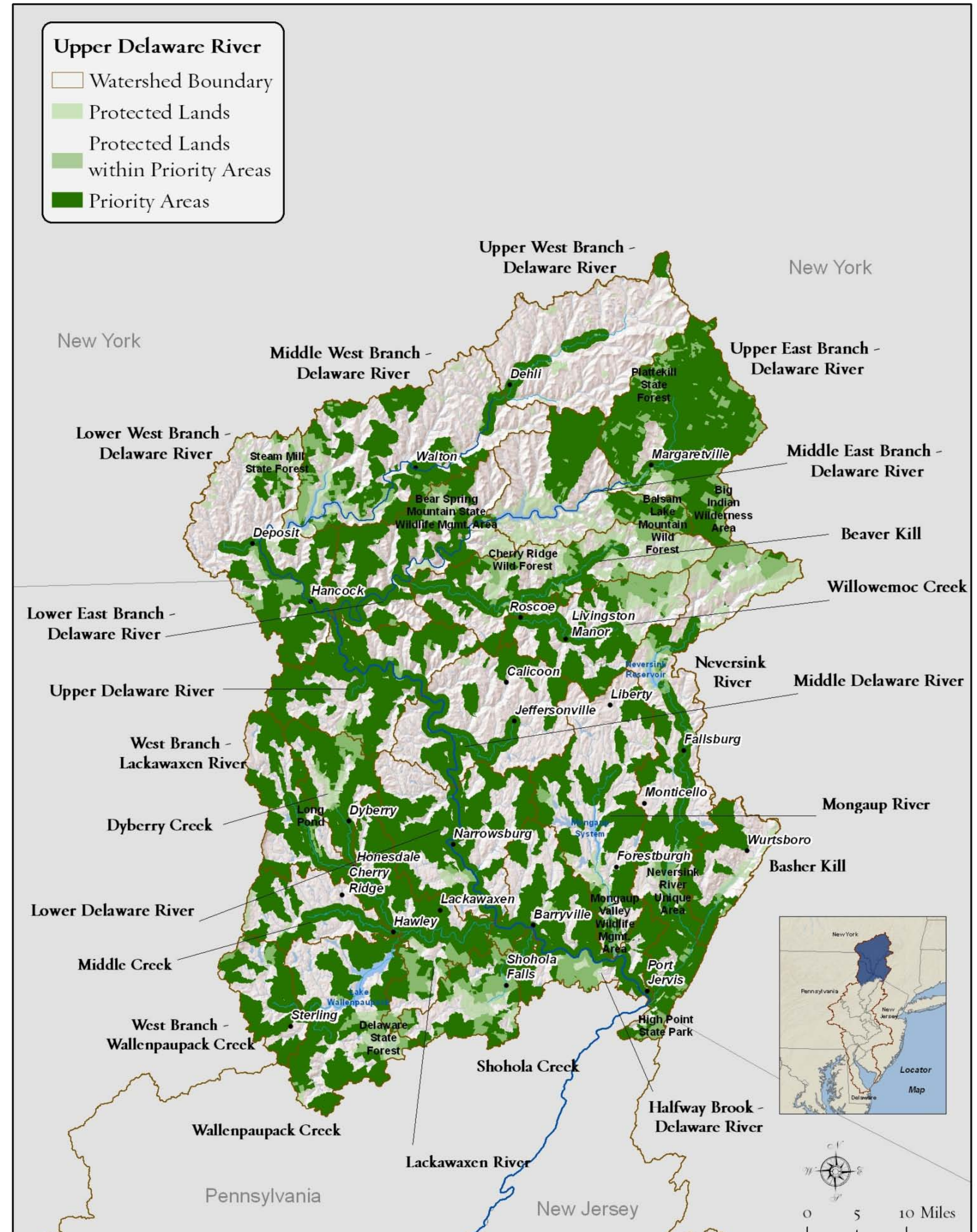


Figure 5.3. Protected lands in the Upper Delaware River

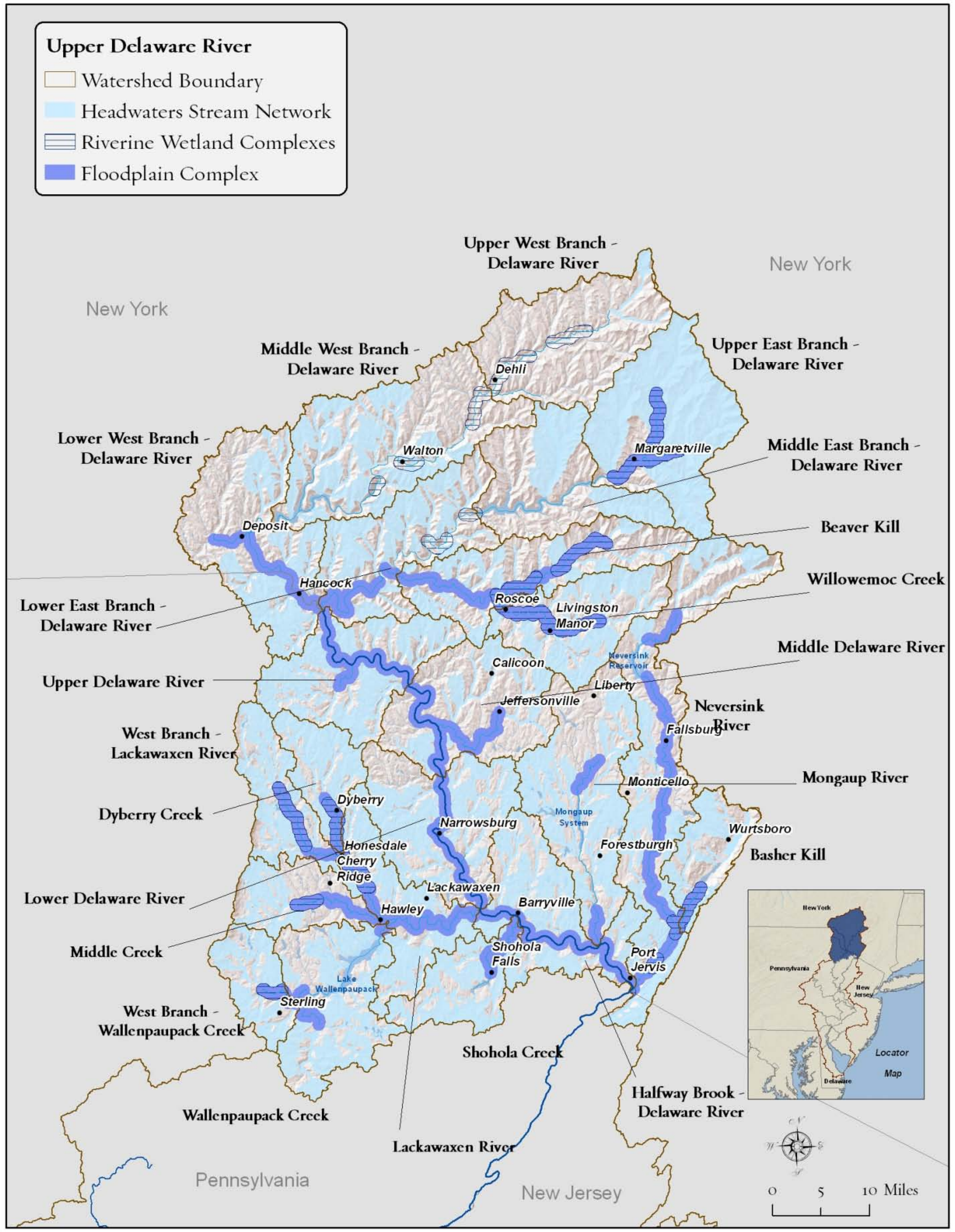


Figure 5.4. Priority conservation areas in the Upper Delaware River by ecosystem type

Watershed Name	Freshwater System Priorities	Priority Strategies					
		Forest Conservation	Wetland Conservation	Agricultural Land Protection and Conservation	Aquatic Connectivity Restoration	Streamflow Management	Groundwater/ Baseflow Conservation
		F	W	A	C	D	G
Upper West Branch	Headwater Wetlands; Riverine Wetlands	●		●			
Middle West Branch	Headwater Networks; Riverine Wetlands; Headwater Wetlands;	●		●			
Lower West Branch	Floodplain Complexes; Headwater Networks; Headwater Wetlands	●		●		●	
Upper East Branch	Headwater Networks; Riverine Wetlands; Headwater Wetlands	●	●	●	●		
Middle East Branch	Headwater Networks	●		●		●	
Lower East Branch	Floodplain Complexes; Headwater Networks	●		●		●	
Beaver Kill	Floodplain Complexes; Headwater Networks; Riverine Wetlands; Headwater Wetlands	●	●				
Willowemoc Creek	Floodplain Complexes; Headwater Networks; Riverine Wetlands; Headwater Wetlands	●	●				●
Upper Delaware River	Floodplain Complexes; Headwater Networks; Headwater Wetlands	●	●	●		●	●
Middle Delaware River	Floodplain Complexes; Headwater Networks; Headwater Wetlands	●		●		●	
Neversink River	Floodplain Complexes; Headwater Networks; Riverine Wetlands; Headwater Wetlands	●	●	●	●	●	
Mongaup River	Floodplain Complexes; Headwater Networks; Headwater Wetlands	●	●	●	●	●	
Basher Kill	Floodplain Complexes; Headwater Networks; Riverine Wetlands; Headwater Wetlands	●	●				●
West Branch – Lackawaxen River	Floodplain Complexes; Riverine Wetlands; Headwater Wetlands	●	●		●	●	●
Dyberry Creek	Floodplain Complexes; Headwater Networks; Riverine Wetlands; Headwater Wetlands	●	●		●		●
Lower Delaware River	Floodplain Complexes; Headwater Networks; Headwater Wetlands	●	●	●		●	
Middle Creek	Floodplain Complexes; Headwater Networks; Riverine Wetlands; Headwater Wetlands	●	●		●		●
West Branch – Wallenpaupack Creek	Floodplain Complexes; Headwater Networks; Riverine Wetlands; Headwater Wetlands	●	●			●	●
Wallenpaupack Creek	Floodplain Complexes; Headwater Networks; Headwater Wetlands	●	●			●	●
Lackawaxen River	Floodplain Complexes; Headwater Networks; Riverine Wetlands; Headwater Wetlands	●	●			●	●
Shohola Creek	Floodplain Complexes; Headwater Networks; Headwater Wetlands	●	●			●	●
Halfway Brook	Floodplain Complexes; Headwater Networks; Riverine Wetlands; Headwater Wetlands	●				●	●

Table 5.1. Freshwater priorities in Upper Delaware River by watershed

THE CENTRAL DELAWARE RIVER:

PRIORITY CONSERVATION AREAS AND STRATEGIES

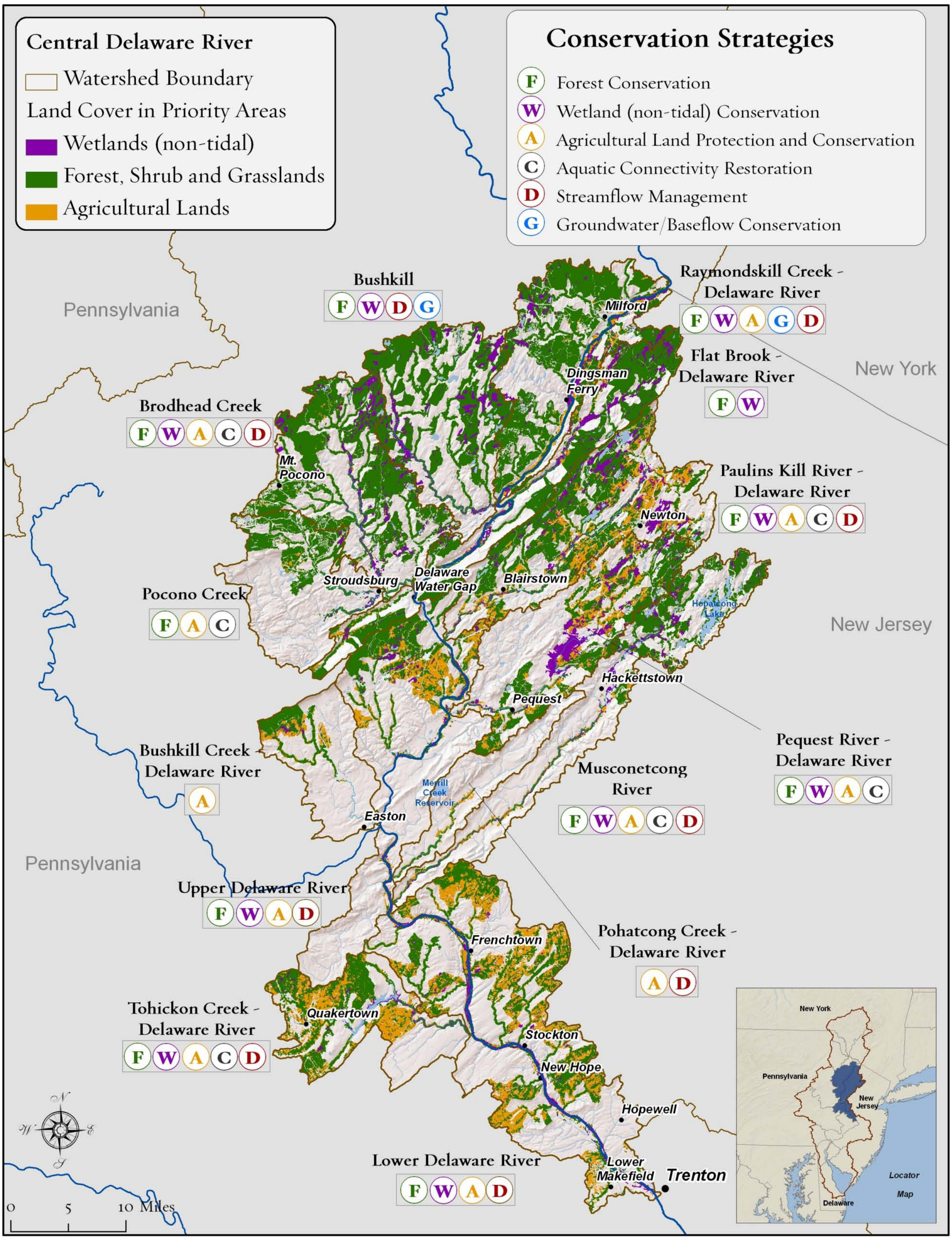


Figure 5.6. Priority conservation areas and recommended conservation strategies in the Central Delaware River

The Central Delaware River

The Central Delaware River ~

The central Delaware River, including the Upper and Lower Sub-basins, extends 121 miles from Matamoras, PA and Port Jervis, NY downstream to the fall line near Trenton, NJ (DRBC 2008). Turning abruptly to the south, the river flows between the ridgelines of the Appalachian Plateau and the Ridge and Valley and is underlain by extensive glacial deposits (Carswell et al 1979, Fletcher et al, 1970, Reynolds 2007, Witte 2001). At the Delaware Water Gap, the river slices through the Ridge and Valley before encountering a series of limestone rapids, notably Foul Rift. Crossing into the Piedmont, the river broadens and becomes increasingly shallow until reaching Trenton Falls, the geologic "Fall Line", created by a narrow wedge of resistant metamorphic rock exposed in the channel. The fall line marks the transition from the tidal to non-tidal Delaware River (DRBC 1991).

Over its course, the river drops approximately 413 feet, crossing the Kittatinny Ridge at the Delaware Water Gap. Tributaries in the region include the Bush kill and Brodhead Creeks in PA and the Flat Brook, Paulins Kill and Musconetcong Rivers in NJ. While forest cover dominates the portions of the basin upstream of the Delaware Water Gap, forests give way to agriculture and urbanization moving downstream (Figure 5.7). In these areas, water quality concerns are most often related to urban, industrial, and agricultural activities (United States Geologic Survey, 1999).

This region was first inhabited by the Lenape Indians who fished and foraged along the banks of the river. By the early 1700s, the Walking Purchase of 1737, smallpox, measles, and escalating conflicts over land and trade forced the Lenape inland away from the Delaware Valley. This opened the way for Europeans to clear the forests for agriculture, build mills to process grain and to manufacture textiles and paper. The Delaware Canal met the need for a better transportation system, running for 60 miles, parallel to the river, from Easton to Bristol, from 1832 to 1931. Today the canal and 830 surrounding acres are designated as the Delaware Canal State Park.

Protected areas are prevalent in this sub-basin (Figure 5.8). While numerous dams have been constructed on tributaries, the mainstem Delaware River remains the longest free-flowing mainstem river east of the Mississippi and is part of the National Wild and Scenic System, which includes two parks: the Delaware Water Gap National Recreation Area and the Lower Delaware Wild and Scenic River. Two major tributaries to the Delaware also have received special protection status; sections of the Musconetcong River in New Jersey also are designated as Wild and Scenic, and in Pennsylvania, the Cherry Valley National Wildlife Refuge, established in 2009, exists along Cherry Creek.

While water quality in many parts of the Basin has improved during the past 25 years due to higher water quality standards, required permits for discharges, and improved enforcement of pollution control programs, impacts still exist in this region. Fish consumption advisories are in place for the entire mainstem due to mercury and polychlorinated biphenols (PCBs). Aquatic life standards are not being met for the mainstem downstream of Easton. Dissolved oxygen and nutrients also are of concern due to point and non-point pollution sources (DRBC 2008).

Bog Turtle © TNC Staff

Bog Turtle ~ The bog turtle (*Glyptemys muhlenbergii*) is one of the world's smallest turtles, growing to only 3-4 inches. In addition to its size, it is readily distinguished by orange blotches on both sides of its neck. As its name suggests, the species inhabits wetlands, specifically, wet meadows and bogs dominated by tussock sedges and grasses. It requires deep mucky soils fed by groundwater seeps and springs (Pennsylvania Natural Heritage Program year, 2010b). Due to the species' specialized habitat requirements and wetland losses, the species is currently listed as endangered in PA, NJ, and DE, and is federally threatened. Bog turtle habitats are scattered throughout the basin with the **Cherry Valley** National Wildlife Refuge being noteworthy among them. Other important strongholds occur in the **Ridge and Valley** and in the **limestone areas of the Piedmont Provinces**. **Wetland Conservation** and **Agricultural Land Protection and Conservation** are critical strategies for the preservation of this and other species.

Conservation Highlights ~

The map on the reverse (Figure 5.6) highlights sub-watersheds within the Upper and Lower Central sub-basin where Forest Conservation, Wetland Conservation, Agricultural Land Protection and Conservation, Aquatic Connectivity Restoration, Streamflow Management, and Groundwater/Baseflow Conservation strategies would help protect and restore basin biodiversity. In addition, Figure 5.9 illustrates the identified priority conservation areas within the sub-basin by ecosystem type, without associated land cover. Specific conservation strategy examples include:

F Forest Conservation: Headwaters

In the headwaters of the Upper sub-basin, forest conservation is a priority conservation strategy. Several large unfragmented forested areas provide cores for expanding headwater conservation, especially in the **Brodhead, Bushkill, Raymondskill,** and **Flat Brook** watersheds. Several funds and programs are available to help landowners protect forested headwaters in this region. For example, the *Common Waters Fund* provides funding to support the development of forest stewardship plans, to implement forest management practices, and for conservation easements. In addition, The Nature Conservancy has developed a forest conservation program, *Working Woodlands*, which uses revenue from certified forest products and carbon markets to catalyze private forest protection in this region and throughout Pennsylvania.

W Wetland Conservation: Headwaters

Wetland conservation is also a high priority conservation strategy, particularly in the Upper Central sub-basin. The greatest diversity of wetlands in the state of Pennsylvania is within the glaciated portions of the Allegheny Plateau, where many Delaware Basin headwater streams originate (Davis 1993). Boreal conifer swamps, oligotrophic kettlehole bogs, cranberry and bog-rosemary peatlands, and acidic broadleaf swamps occur throughout the region. **Long Pond** (**Pocono Creek** watershed) and **Mashipacong Bogs** (**Flat Brook** watershed) reveal the region's boreal heritage, harboring species tolerant of cooler temperatures. Other unique wetland communities are found along the Limestone Valley, where rich groundwater provides the minerals to support calcareous fens, seepage swamps, and limestone wetlands. Cherry Valley National Wildlife Refuge and the Mt. Bethel Fens in PA and the Johnsonburg and Sussex Swamps in NJ contain examples of these systems. Vernal pools are also scattered throughout the region, with concentrations along the toeslopes of the Kittatinny Ridge.

F A Forest and Agricultural Land Conservation: Floodplains

Three major floodplain complexes along the mainstem Delaware River also are identified as conservation priorities (Figure 5.10): the **Delaware Water Gap Floodplain Complex**; the **Middle Delaware Floodplain Complex** (from the Paulins Kill to Martins Creek); and the **Lower Delaware Floodplain Complex** (from Lehigh to Trenton). The Delaware Water Gap floodplain complex extends approximately 31 miles, includes 3,700 acres (58% is in natural cover), and much of it is within protected lands. It is a relatively large mosaic of interconnected floodplain communities, including high and low terrace floodplain forests, shrublands, grasslands, wetlands, and other herbaceous communities. This floodplain complex also links to tributary floodplain complexes along the **Bushkill Creek** and **Flat Brook**. Conservation opportunities include reconnecting the floodplain, some of which is in agriculture, to the river. This management strategy allows for inundating the floodplain to provide ecological benefits and potentially to reduce flood damage locally and downstream (American Rivers 2010). Recently-completed flood inundation mapping by the National Weather Service exists for several areas along the mainstem. These maps show the spatial extent of expected flooding and, in addition to helping to predict which roadways, streets, buildings, airports, agricultural fields, etc., are likely to be impacted by floodwaters, they can be used to identify potential natural and open areas that could be inundated to restore some floodplain functions.

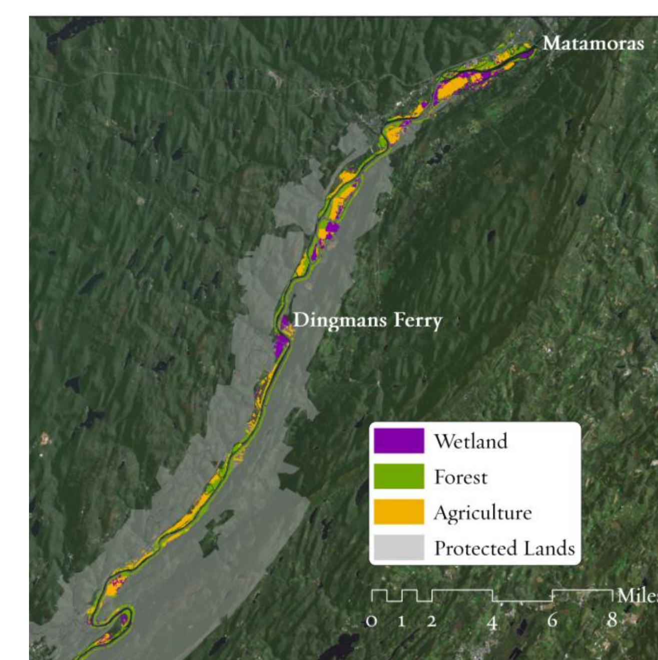


Figure 5.10. Delaware Water Gap floodplain complex

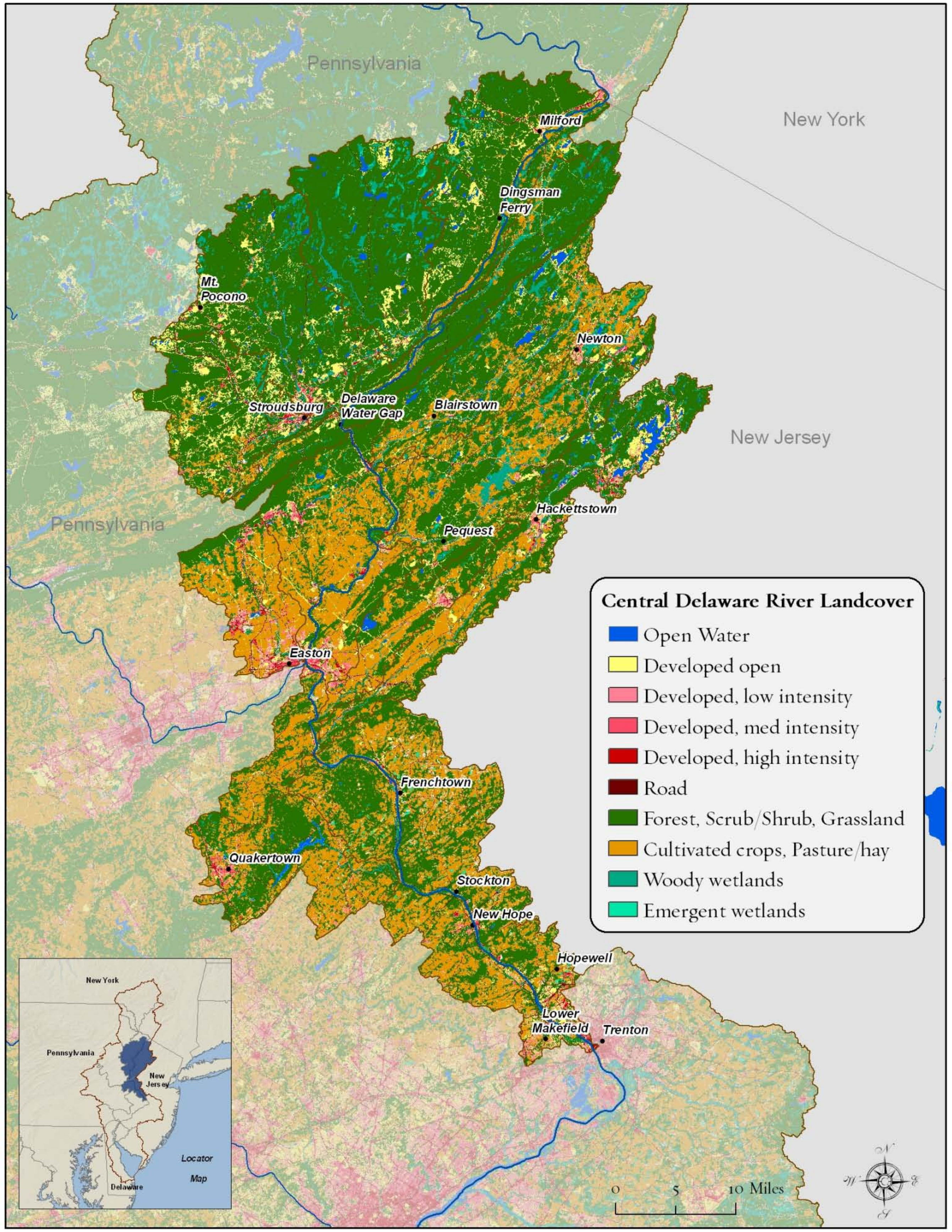


Figure 5.7. Land use in the Central Delaware River

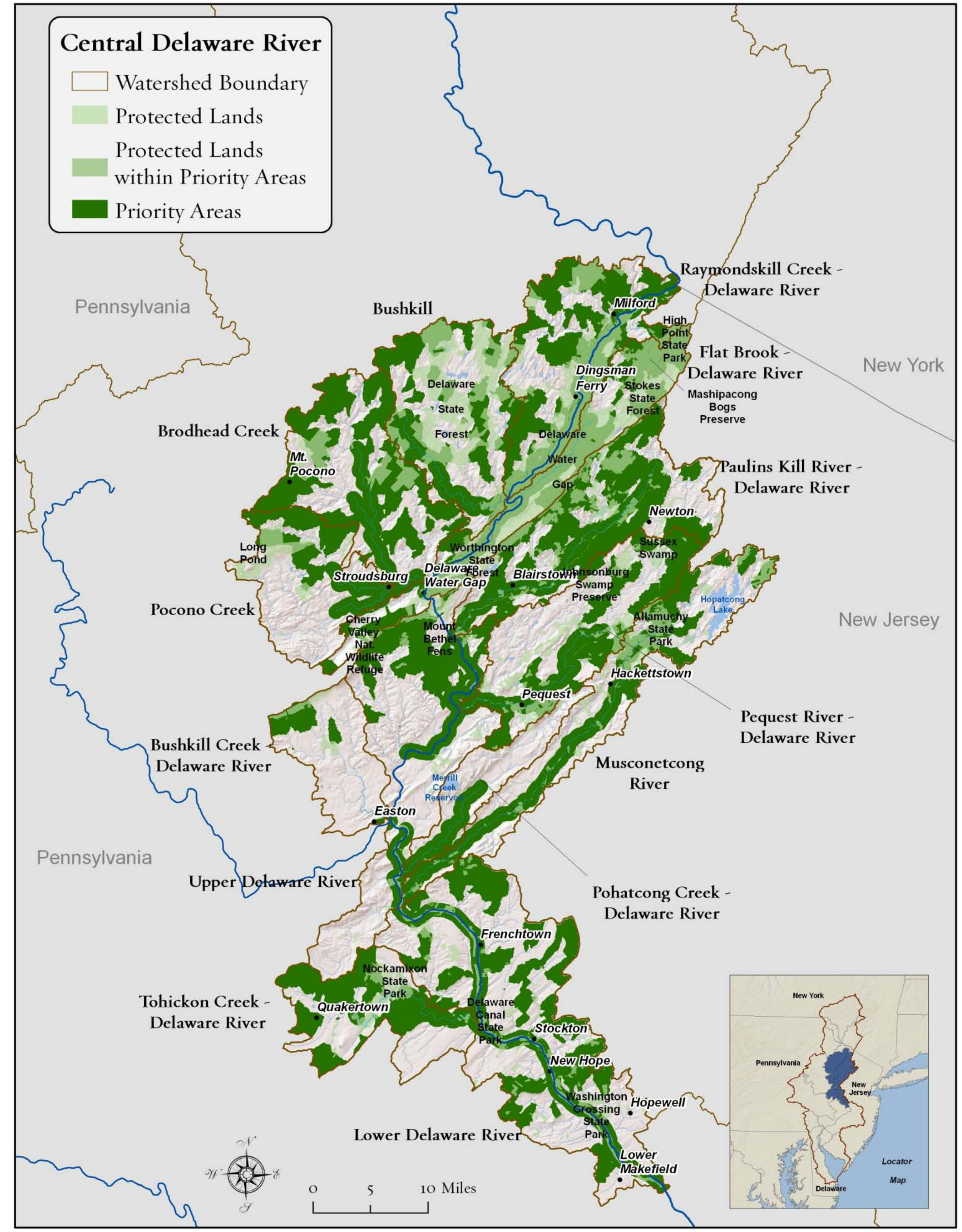


Figure 5.8. Protected lands in the Central Delaware River

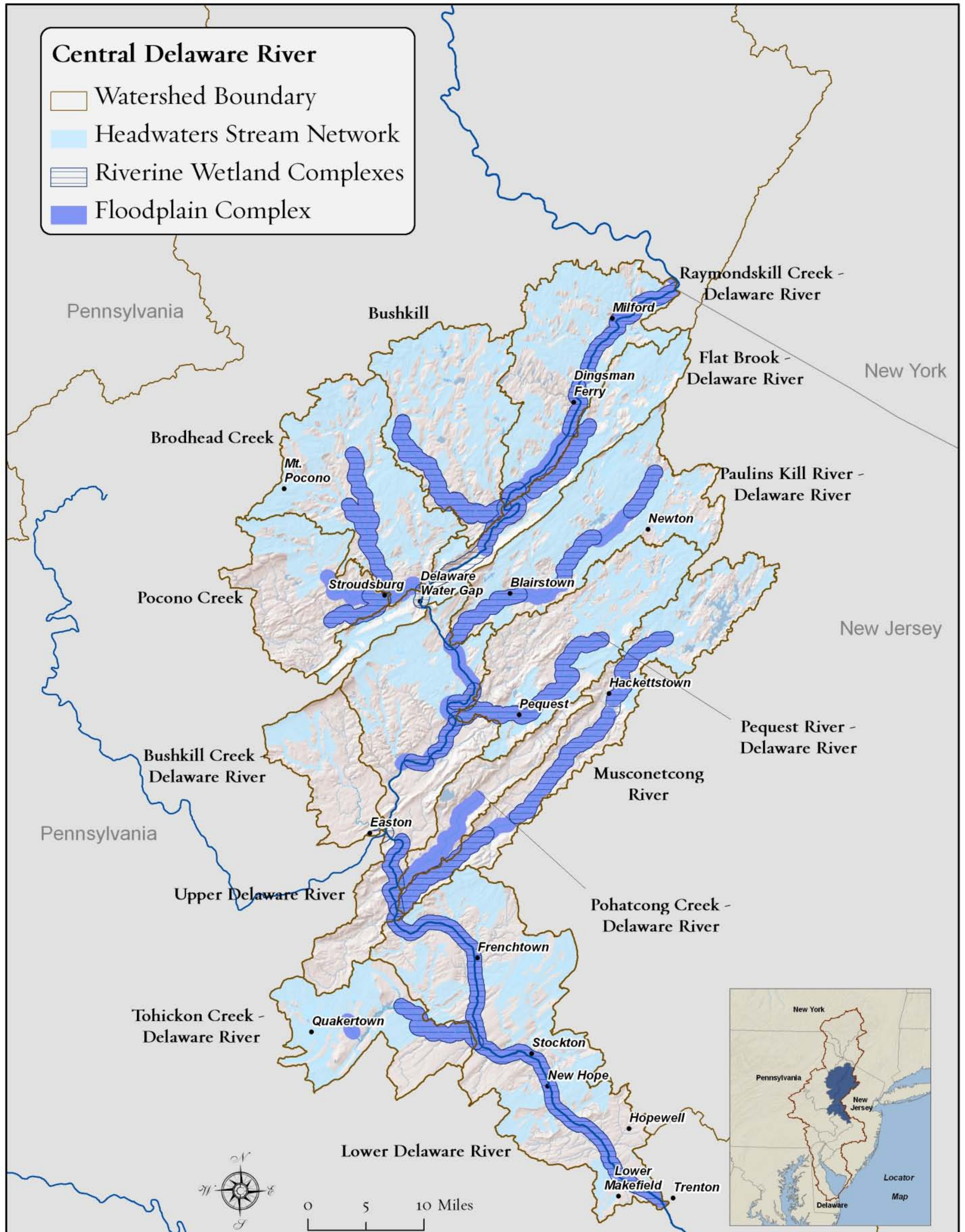


Figure 5.9. Priority conservation areas in the Central Delaware River by ecosystem type

Watershed	Freshwater System Priorities	Priority Strategies					
		Forest Conservation	Wetland Conservation	Agricultural Land Protection and Conservation	Aquatic Connectivity Restoration	Streamflow Management	Groundwater/ Baseflow Conservation
		F	W	A	C	D	G
Bushkill	Floodplain Complexes; Headwater Networks; Headwater Wetlands; Riverine Wetlands	●	●			●	●
Raymondskill Creek - Delaware River	Floodplain Complexes; Headwater Networks; Headwater Wetlands; Riverine Wetlands	●	●	●		●	●
Flat Brook - Delaware River	Floodplain Complexes; Headwater Networks; Headwater Wetlands; Riverine Wetlands	●	●				
Paulins Kill River - Delaware River	Floodplain Complexes; Headwater Networks; Headwater Wetlands; Riverine Wetlands	●	●	●	●	●	
Brodhead Creek	Floodplain Complexes; Headwater Networks; Headwater Wetlands; Riverine Wetlands	●	●	●	●	●	
Pocono Creek	Floodplain Complexes; Headwater Wetlands; Riverine Wetlands	●		●	●		
Pequest River - Delaware River	Floodplain Complexes; Headwater Networks; Headwater Wetlands; Riverine Wetlands	●	●	●	●		
Bushkill Creek - Delaware River	Headwater Wetlands			●			
Musconetcong River	Floodplain Complexes; Headwater Networks; Headwater Wetlands; Riverine Wetlands	●	●	●	●	●	
Upper Delaware River	Floodplain Complexes; Headwater Wetlands; Riverine Wetlands	●	●	●			
Tohickon Creek - Delaware River	Floodplain Complexes; Headwater Networks; Headwater Wetlands;	●	●	●	●	●	
Lower Delaware River	Floodplain Complexes; Headwater Networks; Headwater Wetlands; Riverine Wetlands	●	●	●		●	

Table 5.2. Freshwater priorities in Central Delaware River by watershed

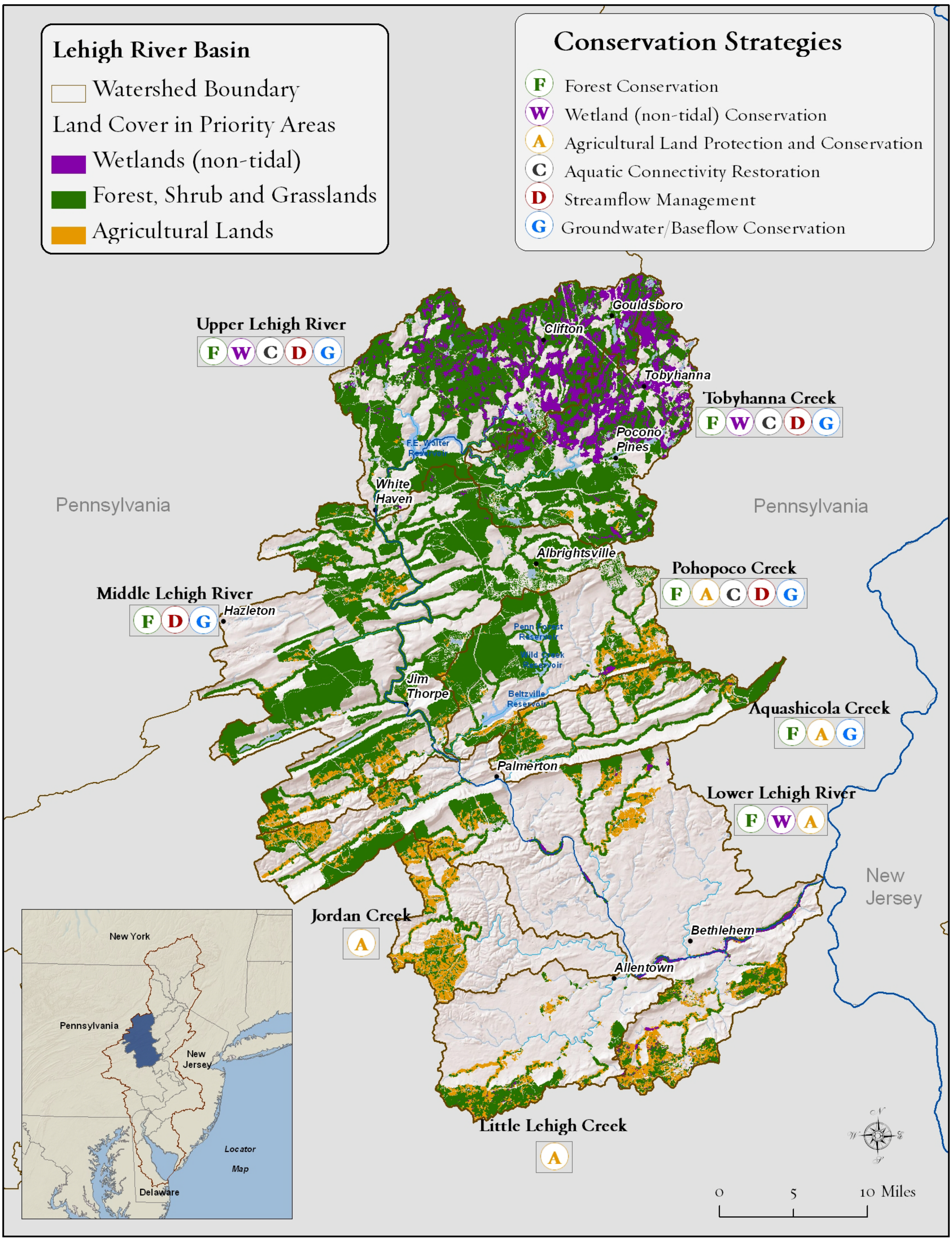


Figure 5.11. Priority conservation areas and recommended conservation strategies in the Lehigh River basin.

The Lehigh River Basin

The Lehigh River Basin ~

Located in northeastern Pennsylvania, the Lehigh River is the second largest tributary to the Delaware River, draining approximately 1,345 square miles. It drops nearly 2,000 feet in elevation, arising from glacial bogs in its headwaters, then flowing across Blue Mountain at Lehigh Gap to its confluence with the mainstem Delaware at the town of Easton, PA (Figure 5.12). The unique character and natural resources of each physiographic region, including the Appalachian Plateau, Ridge and Valley, New England, and Piedmont Provinces, significantly shaped the history and land use of the Lehigh watershed.

From the late 1700s until the early 1900s, major industries, economies and towns were developed in the area, altering the landscape and water quality of the Lehigh watershed. In 1829, The Lehigh Coal and Navigation Company opened a 72-mile long series of locks and dams to transport raw materials downstream to manufacturing centers. Cities such as Bethlehem and Coplay used these raw materials and water from the river to produce steel and cement. In 1873, the Lehigh Valley region was the number one producer of iron-ore in Pennsylvania, and until 1907 the region produced more than half of all the Portland cement used in the United States.

Starting in the 1820s, the mainstem Lehigh River also became fragmented by the construction of four dams. Three dams, the Easton, Chain, and Hamilton Street Dams, supplied water to the canal system, while the fourth, Northampton Dam, was constructed to supply water to Whitehall Cement Company. Local and regional railroads replaced the canal system; however, the mainstem dams remained. Fish passage structures are currently in place for three of the four lower mainstem dams, although they are not sufficiently effective to restore American shad to the Lehigh River (PFBC 2007).

The Industrial Revolution left its mark on the watershed and on the waters of the Lehigh River. However, per the Lehigh River Watershed Conservation Plan, the Lehigh River is cleaner now than anytime during the past 150 years (Wildlands Conservancy 2007).

The upper portion of the Lehigh exhibits only minor water quality issues, specifically low dissolved oxygen levels and high temperatures due to the abundance of small ponds and wetlands in the region. In the middle portion of the basin, acid mine drainage (AMD) from four tributaries – Sandy Run, Buck Mountain, Black Creek, and Nesquehoning Creek – results in elevated metal concentrations and low pH. In the lower portion of the basin, areas of carbonate geology help to buffer the impacts of upstream AMD; however, agriculture and development have caused other water quality issues. Thermal impacts, sedimentation, excess nutrient loading, and polluted stormwater contributions are seen in the lower Lehigh and its tributaries. In addition, twelve superfund sites occur throughout the Lehigh basin.

Over 100 years later, approximately 59% of the watershed is in natural cover with 55% being forests and 4% being wetlands. The remainder is primarily a mixture of agriculture (21%) and urban (17%) lands. Preserved lands occur throughout the watershed, but are concentrated north of Blue Mountain (Figure 5.13). Lands preserved by federal, state, and non-profit organizations account for over 180,000 acres, or approximately one third of the forested land cover in the watershed.

Louisiana Waterthrush ~ Headwater Conservation

Louisiana waterthrush - ©Lloyd Sputnik

The Louisiana waterthrush (*Seiurus motacilla*) is a forest interior songbird that breeds in the headwater regions of the Delaware River Basin. Its reliance on high-quality aquatic and terrestrial systems makes the species a potential indicator of ecological integrity of headwater stream systems (O'Connell et al. 2003; Mattsson and Cooper 2006).

The waterthrush is most frequently found along medium- to high-gradient, 1st to 3rd orderheadwater streams of mature, forested watersheds. In northeastern Pennsylvania, specifically the Pocono Region, they show an affinity for shady eastern hemlock-dominated ravines and are found primarily along the Pocono Plateau perimeter, where such streams are prominent (Ross et al. 2004; Master pers. comm. 2007)

Because they depend on aquatic macroinvertebrates for food, the Louisiana waterthrush is sensitive to water quality degradation. By conserving high-quality **headwater systems** and **riparian corridors**, we also preserve these areas for a diversity of other wildlife and maintain the functional services these systems provide.

Conservation Highlights ~

The map on the reverse (Figure 5.11) highlights sub-watersheds within the Lehigh River basin where Forest Conservation, Wetland Conservation, Agricultural Land Protection and Conservation, Aquatic Connectivity Restoration, Streamflow Management, and Groundwater/Baseflow Conservation strategies would help protect and restore basin biodiversity. In addition, Figure 5.14 illustrates the identified priority conservation areas within the basin by ecosystem type, without associated land cover. Specific conservation strategy examples include:

Forest and Wetland Conservation: Headwaters and Floodplains

Forest and wetland conservation are key conservation strategies, particularly in the upper half of this watershed. Although natural resource extraction was extensive in this region, second growth forests, many of which are already preserved, have reestablished along the floodplains and in the headwaters. The area of the Lehigh Gorge, a 32-mile long stretch of the mainstem Lehigh River between the Francis E. Walter Dam and the town of Jim Thorpe, PA, provides the backbone for future floodplain conservation efforts. The floodplain complex contains approximately 3,224 acres of natural cover, 53% of which is already preserved. Core forests also exist outside the Lehigh Gorge, including the many headwater systems particularly in the **Upper Lehigh River** and **Tobyhanna Creek** watersheds. Forest and wetlands in existing protected areas serve as the building blocks for future headwater catchment and riparian corridor conservation. Expanding upon existing preserved lands, including the Lackawanna State Forest, Gouldsboro and Tobyhanna State Parks, and State Game Lands 91, 127, 135, and 312, as well as those along the Lehigh Gorge and Blue Mountain, is essential to maintaining water quality and quantity for downstream ecosystems and water users (Figure 5.15). The conservation of headwater areas can be achieved using riparian buffers and other tools. Wenger (1999) suggests that riparian buffers include a base width that can be expanded as necessary to include the full extent of the floodplain, including adjacent wetlands and their associated buffers. To provide habitat for forest interior species such as the Louisiana waterthrush, at least some preserved riparian tracts should be 300 to 600 ft wide (PGC and PFBC 2005; Wenger 1999).

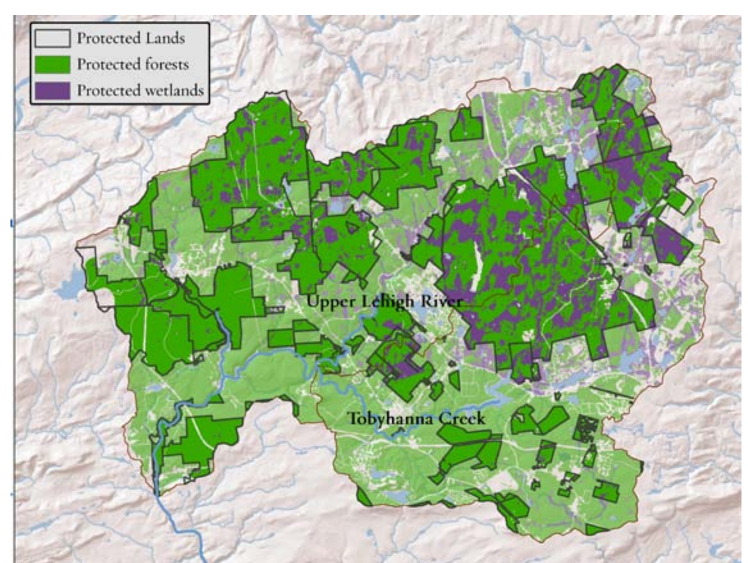


Figure 5.15. Forests and wetlands, Upper Lehigh and Tobyhanna watersheds

Aquatic Connectivity: Connected Rivers

Five dams occur on the **mainstem Lehigh River**: the Easton, Chain, Hamilton Street, Northampton, and F. E. Walter Dams. From Hamilton Street Dam to F.E. Walter Dam, the Lehigh River is unfragmented for approximately 61 miles. In addition, numerous unfragmented tributaries are connected to this portion of the mainstem, creating a network of over 300 miles of connected stream habitat. Efforts are underway to evaluate the feasibility of full or partial removal of the two lower dams to further improve fish passage to levels that support the return of a healthy American shad population.

Groundwater/Baseflow Conservation: Headwaters and Wetlands

Baseflow conservation also is an important conservation strategy within the Lehigh watershed. The forested headwaters of the **Upper** and **Middle Lehigh Rivers**, **Tobyhanna**, **Pohopoco** and **Aquashicola Creek** watersheds exhibit high baseflow contributions and low groundwater use. Although some stream systems in this area are impacted by AMD and heavy metal contamination, several of the larger tributaries provide colder water to the mainstem, which is especially important during summer (PFBC 2007). Maintaining the ecological integrity of these watersheds through forest and wetland conservation, while also managing water use, is necessary to maintain baseflow and provide thermal refugia.

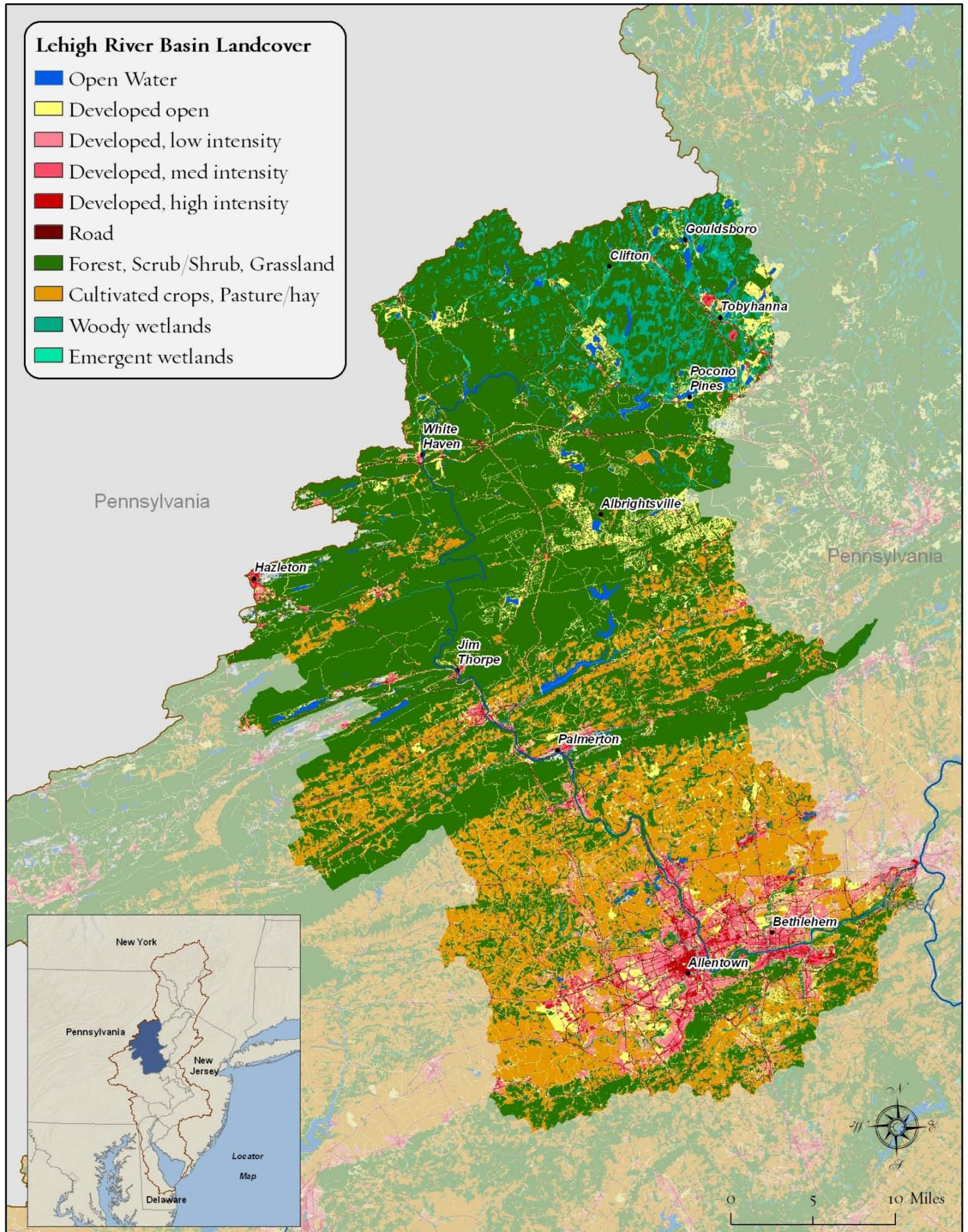


Figure 5.12. Land use in the Lehigh River basin

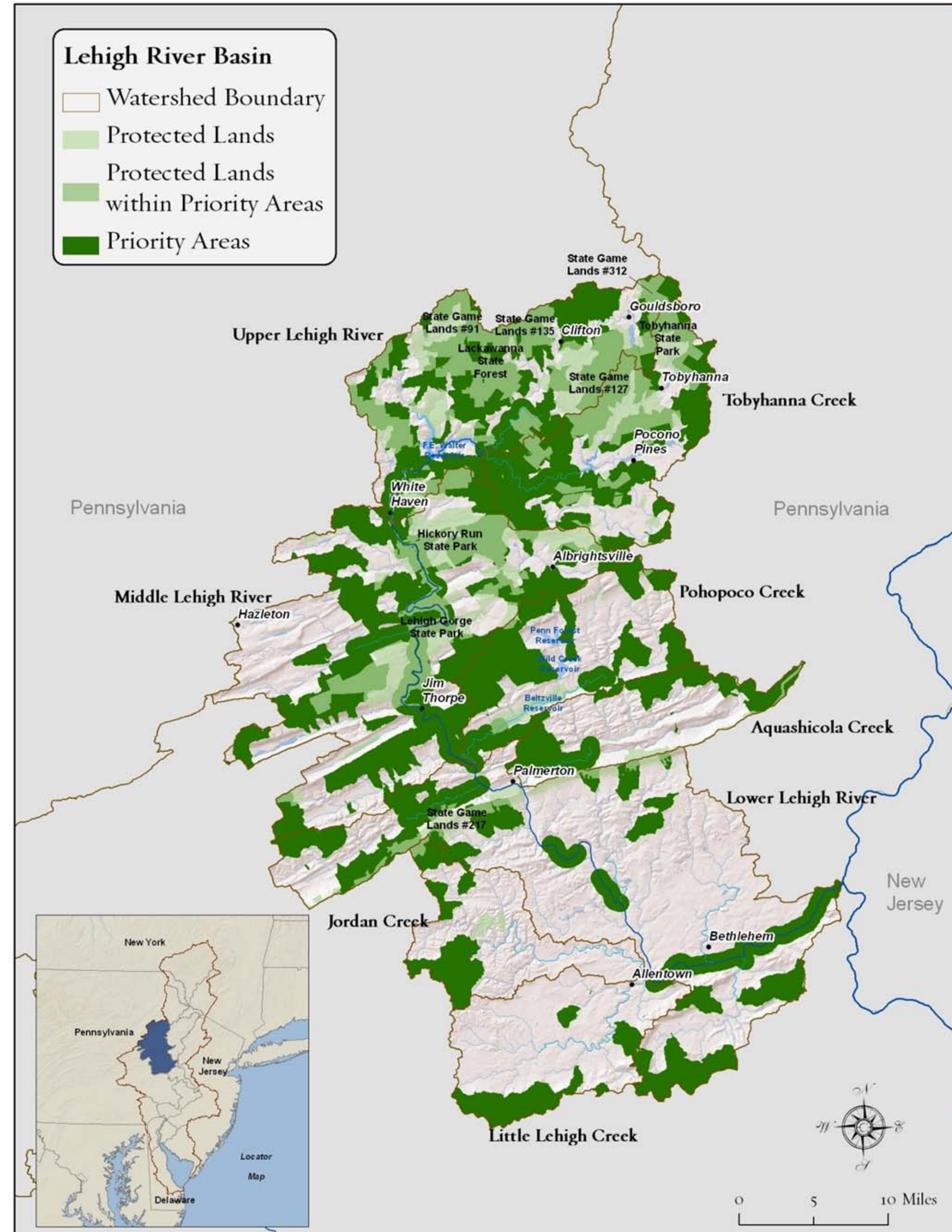


Figure 5.13. Protected lands in the Lehigh River basin

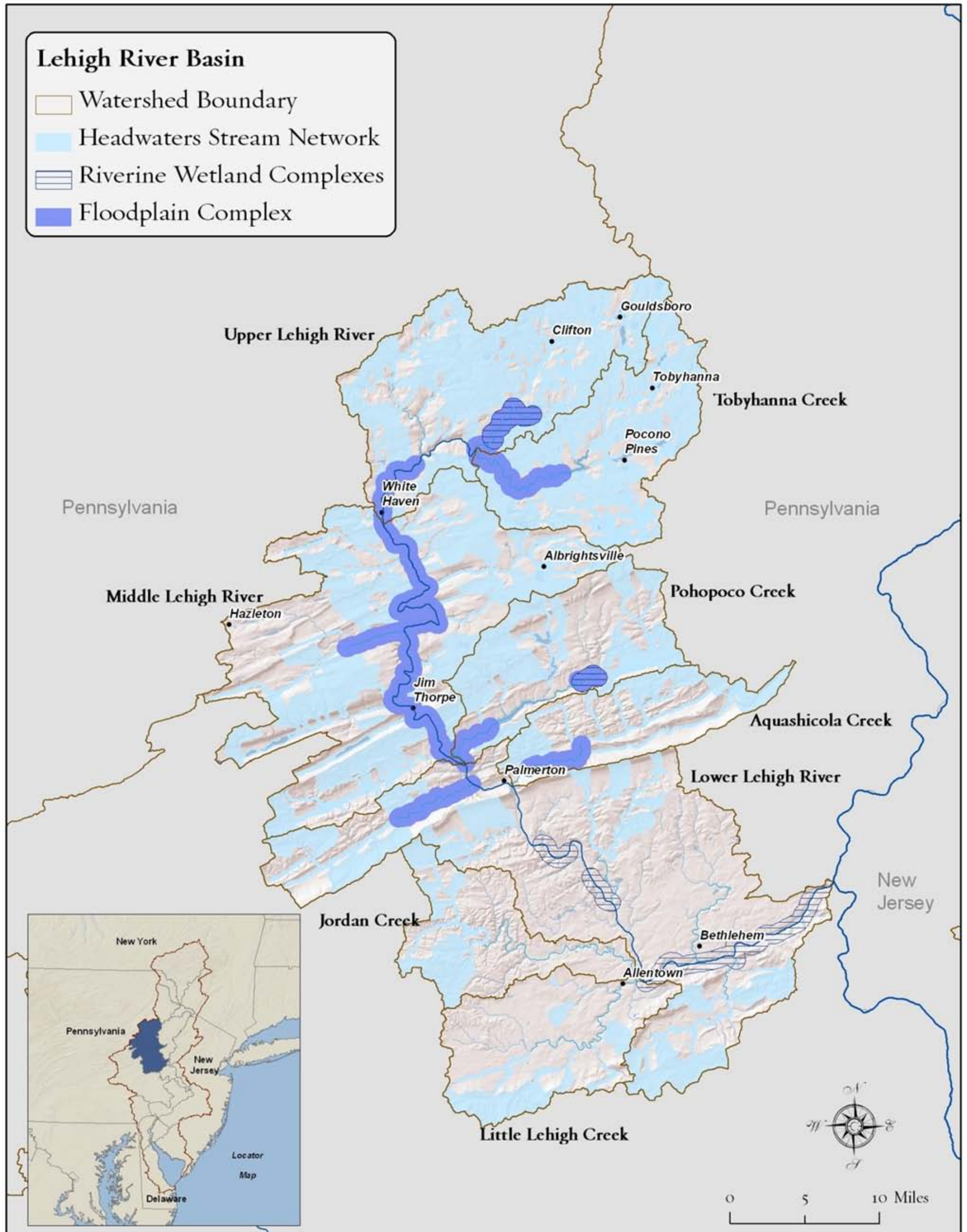


Figure 5.14. Priority conservation areas in the Lehigh River basin by ecosystem type

Watershed	Freshwater System Priorities	Priority Strategies					
		Forest Conservation	Wetland Conservation	Agricultural Land Protection and Conservation	Aquatic Connectivity Restoration	Streamflow Management	Groundwater/ Baseflow Conservation
		F	W	A	C	D	G
Upper Lehigh River	Floodplain Complexes; Headwater Networks; Headwater Wetlands; Riverine Wetlands	●	●		●	●	●
Tobyhanna Creek	Floodplain Complexes; Headwater Networks; Headwater Wetlands;	●	●		●	●	●
Middle Lehigh River	Floodplain Complexes; Headwater Networks;	●				●	●
Pohopoco Creek	Floodplain Complexes; Headwater Networks; Headwater Wetlands; Riverine Wetlands	●		●	●	●	●
Aquashicola Creek	Floodplain Complexes; Headwater Networks	●		●			●
Jordan Creek	Headwater Wetlands			●			
Lower Lehigh River	Floodplain Complexes; Headwater Networks; Headwater Wetlands; Riverine Wetlands	●	●	●			
Little Lehigh Creek	Headwater Wetlands; Riverine Wetlands			●			

Table 5.3. Freshwater priorities in Lehigh River basin by watershed

Schuylkill River Basin:

Priority Conservation Areas and Strategies

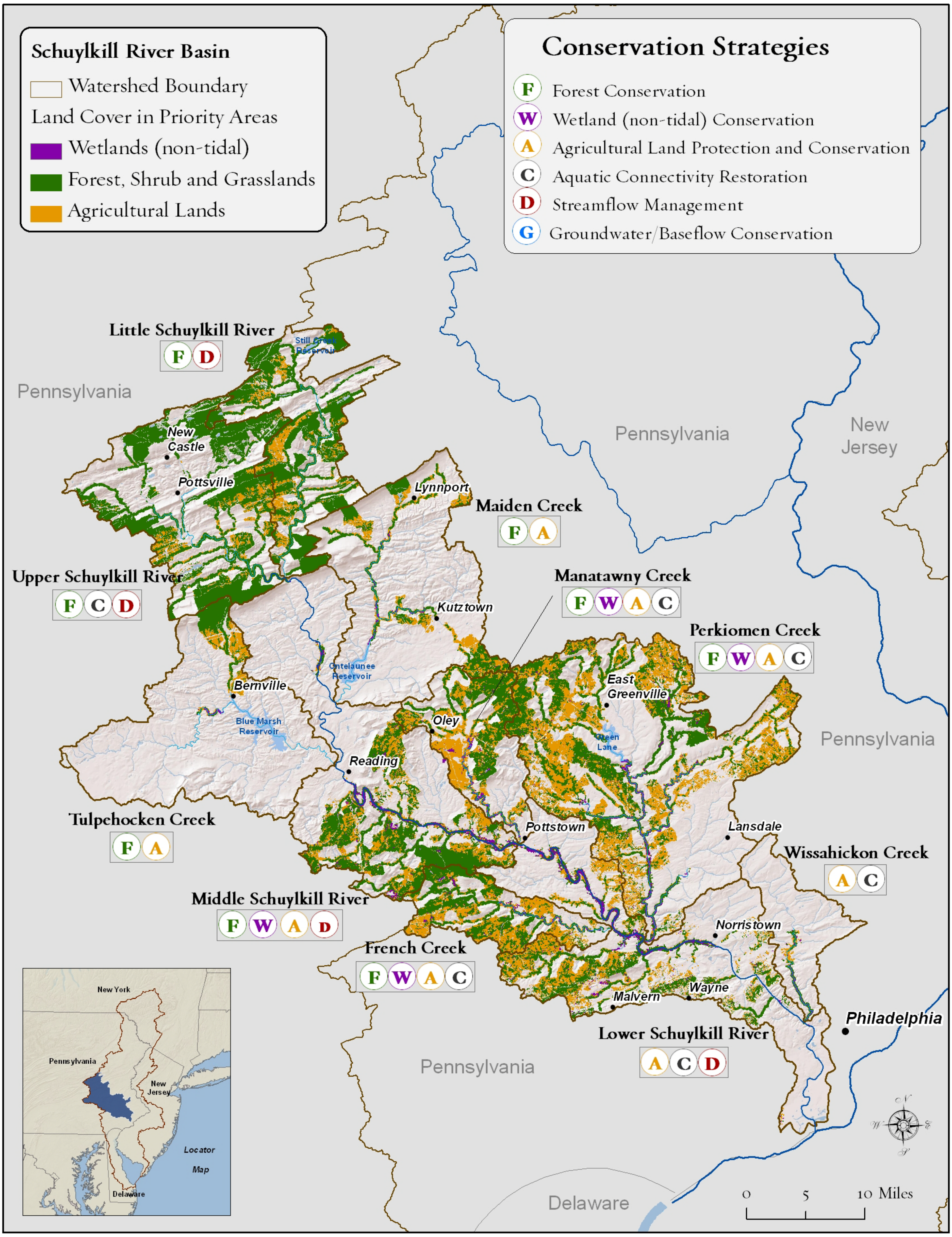


Figure 5.16. Priority conservation areas and recommended conservation strategies in the Schuylkill River basin

The Schuylkill River Basin ~

Located in southeastern Pennsylvania, the Schuylkill watershed, draining almost 2,000 square miles, is the largest major river tributary to the Delaware mainstem, supplying approximately one quarter of the mainstem's flow (Durlin and Schaffstall 1997). Its major cities include Philadelphia, Norristown, Pottstown, and Reading .

The historical legacy of the Schuylkill is as varied as its physiography, which includes the Ridge and Valley, New England, Piedmont, and Coastal Plain Provinces. The Lenape Indians, the Dutch, and the Swedes historically inhabited the watershed, as did William Penn, George Washington, and Benjamin Franklin. Early settlers relied heavily on agriculture for their livelihoods, but vast natural resources of coal, iron ore, and hardwood also fueled thriving industries that depended on the river as a transportation conduit. Each brought temporary economic prosperity and population growth, but each also left behind legacies of habitat destruction, fragmentation, and water pollution. Pollution was so severe that surveys conducted by the city of Philadelphia between 1886 and 1946 recommended that the Schuylkill and Delaware Rivers be abandoned as drinking water sources (Philadelphia Water Department 2010).

In the headwaters of the Schuylkill, acid mine drainage (AMD) and sediment loading are the major water quality problems, impairing miles of headwater streams. In the upper-central and central portions of the basin, agricultural impacts emerge (Figure 5.17). In the lower-central and lower portions of the basin, approximately one-third of the impaired streams are impacted by urban runoff, most of which occur in the highly developed areas of Philadelphia and surrounding suburbs. Along much of the Schuylkill mainstem, fish consumption advisories continue, reflecting the legacy of polychlorinated biphenyls and mercury contamination. Numerous permitted industrial point source and sewage discharges occur throughout the watershed, many of which are located along the mainstem (The Conservation Fund 2003).

Yet today, the Schuylkill River Watershed shows signs of recovery. Approximately 24% of the watershed is designated as high quality or exceptional value waters. More than 16,000 acres of abandoned mine lands have been reclaimed in Schuylkill County alone. Although dominant species such as the towering American chestnut have all but disappeared, forests are returning to the basin. Seven percent of the watershed is in conservation lands, some of the largest of which are French Creek State Park and Hopewell Furnace National Historic Site, Valley Forge National Historic Park, and conserved lands along the Kittatinny Ridge and around the Blue Marsh Reservoir (Figure 5.18).

American Shad ~ The Schuylkill is one of the most storied rivers in the history of American shad (*Alosa sapidissima*) (McPhee 2002). The Delaware River Basin and its tributaries supported some of the largest landings of American shad ever recorded (11-17 million lbs) (Stevenson 1899; Chittenden 1974). In spite of the species' importance and cultural significance, dams and water pollution led to its demise. In 1813, the Shawmont and Reading Dams closed the upper Schuylkill to migrating shad. By 1820, the Fairmont Dam, constructed at the mouth of the Schuylkill, effectively blocked the mainstem for shad passage. For more than 150 years, American shad disappeared from the Schuylkill River. **Aquatic Connectivity Restoration** at appropriate locations along the mainstem Schuylkill and its tributaries could help improve overall shad populations.

Conservation Highlights ~

The map on the reverse (Figure 5.16) highlights sub-watersheds within the Schuylkill River Basin where Forest Conservation, Wetland Conservation, Agricultural Land Protection and Conservation, Aquatic Connectivity Restoration, and Streamflow Management strategies would help protect and restore basin biodiversity. In addition, Figure 5.19 illustrates the identified priority conservation areas within the basin by ecosystem type, without associated land cover. Specific conservation strategy examples include:

(F) Forest Conservation: Headwater and Riparian Corridors

Large unfragmented forests of the **Upper and Little Schuylkill River** watersheds stem from a network of state game lands and state parks clustered around and near the Kittatinny Ridge. Over 40,000 acres of forest reserves, connected by forested riparian corridors of headwater streams, protect water quality, habitat, and the aquatic diversity of these and downstream watersheds. Future headwater riparian corridor conservation can build on these existing preserved areas (Figure 5.18). In the central and lower portions of the Schuylkill, specifically the **Manatawny**, **French**, **and Perkiomen Creek** watersheds, forested areas are generally smaller, more fragmented, and more likely to be privately owned than in the upper portion. Here, forest lands are interspersed among agricultural, residential, and commercial uses. Future riparian conservation can be anchored around large preserved lands, including French Creek State Park and Hopewell National Historic Site, an approximately 7,500 acre forested area within a highly developed portion of southeastern Pennsylvania. Valley Forge National Park and Evansburg State Park also provide core protected lands. Several smaller state game lands exist in this area, but many forested headwaters are in private ownership. Landowner outreach to increase awareness of conservation options – including acquisition, conservation easements, and forest management – could help build contiguous, forested headwater and riparian networks in both public and private ownership.

(F) (W) (A) Forest and Wetland Conservation: Floodplains and Riverine Wetlands

Conservation of floodplains and the wetlands within them is critical to maintain floodplain functions, such as storing floodwaters and sediment, trapping and filtering nutrients, and providing essential wildlife and recreation habitat. In the **Middle and Lower Schuylkill River** watersheds, floodplain forest and riverine wetland conservation are essential conservation strategies, and there is potential to manage agricultural lands in the floodplain to restore some floodplain functions. A nearly continuous floodplain complex occurs between Reading and King of Prussia (approximately 35 miles). However, major highways (such as Rt. 422), railroads, development, and agriculture directly impact this complex. Approximately 50% of this 4,000 acre floodplain complex is in natural cover, including approximately 630 acres of riverine wetlands. In this complex, protection needs to be coupled with restoration and management to enhance the floodplains' functional value. For example, in areas of the floodplain where agricultural use has been retired, floodplain restoration is a conservation option; however, in areas of active agriculture, best management practices aimed to reduce runoff and increase flood storage capacity are potential conservation strategies. The Schuylkill River Trail, proposed to extend from Pottsville to Philadelphia, provides an opportunity to engage the public, various regional, county, and municipal planning agencies, and non-profits in a cooperative effort to preserve and restore this riverine system.

(C) Aquatic Connectivity Restoration: Schuylkill Mainstem and Tributaries

Along the mainstem, ten major dams once blocked fish access. In the 1980s, PFBC began efforts to bring shad back to the Schuylkill. Now, four of these dams have fishways in place: Fairmont, Flat Rock, Norristown, and Black Rock Dams. Three dams – Plymouth, Vincent, and Felix Dams – are now breached or are planned to be breached. These efforts have re-opened the lower and middle Schuylkill River to migrating shad (PFBC 2011).

Dams are also widespread on the Schuylkill's tributaries. Over 200 dams, many of them low-head dams, still exist in the watershed. Yet some large connected stream networks, ranging from 25 to 100 stream miles in length, exist in the **Upper Schuylkill River**, **Tulpehocken**, **Manatawny**, **French Creek**, and **Perkiomen Creek** watersheds. Several of these connected stream networks are disconnected from the mainstem Schuylkill by major reservoirs, including the Blue Marsh Reservoir (Tulpehocken watershed) and the Green Lane Reservoir (Perkiomen watershed) (Figure 5.20). These reservoirs not only fragment the river, but also can impact the river's natural flow regime.

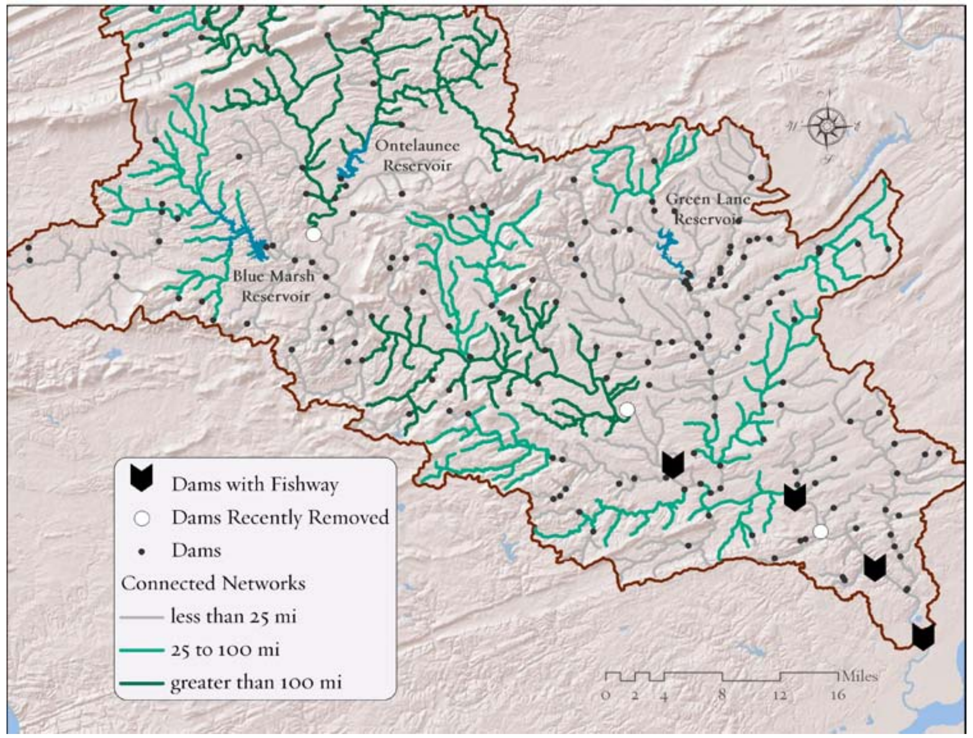


Figure 5.20. Reservoirs in Schuylkill tributaries

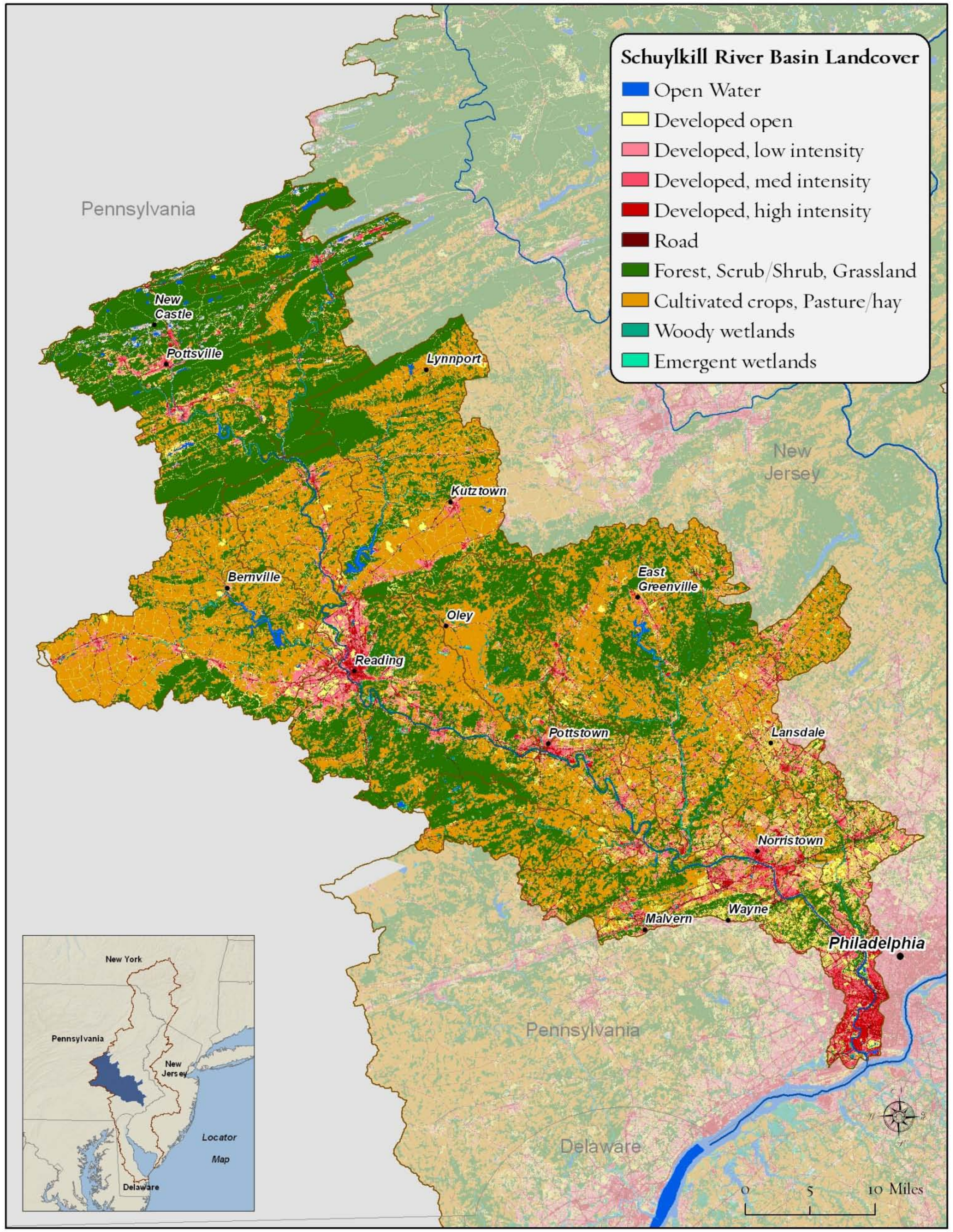


Figure 5.17. Land use in the Schuylkill River Basin

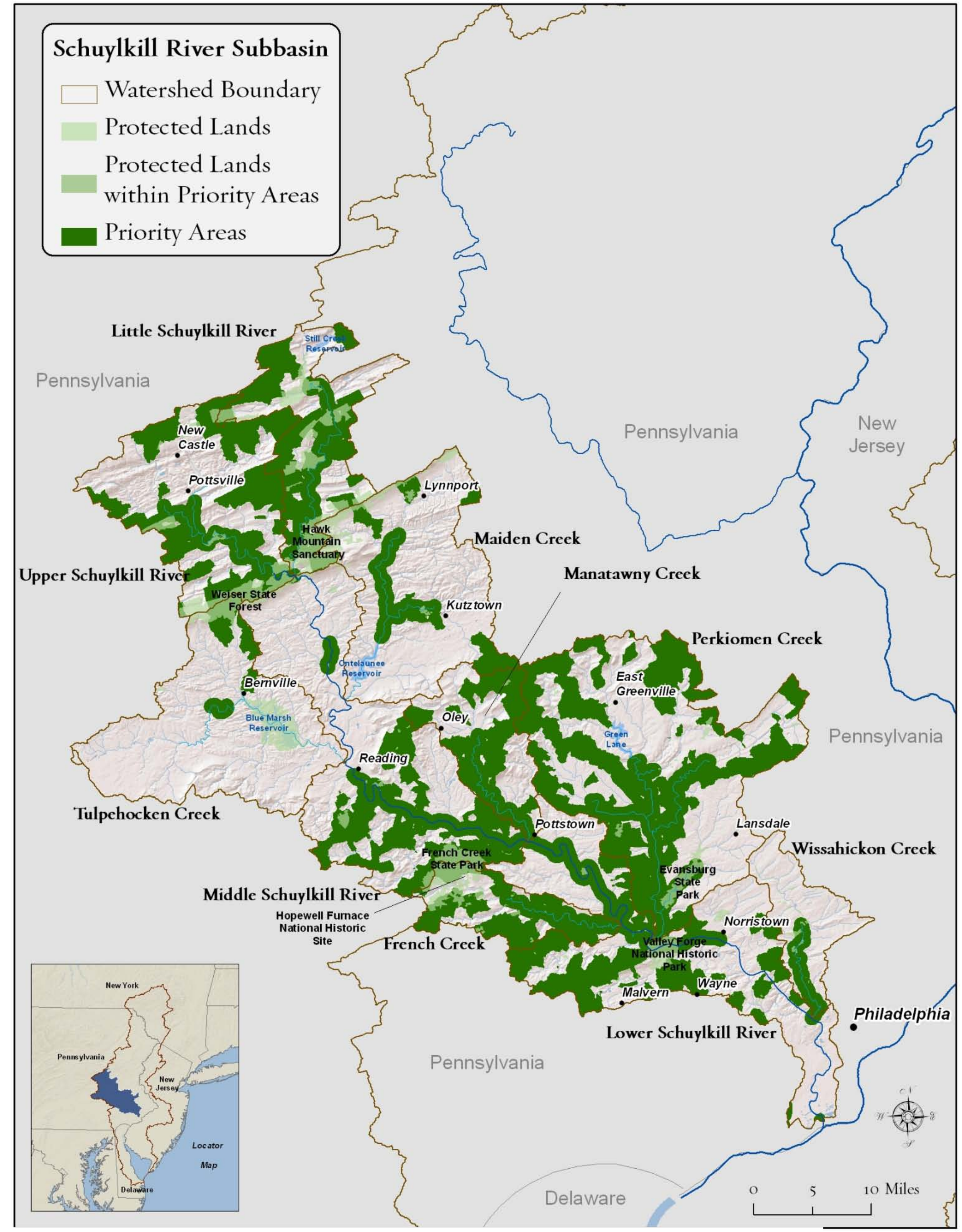


Figure 5.18. Protected lands in the Schuylkill River Basin

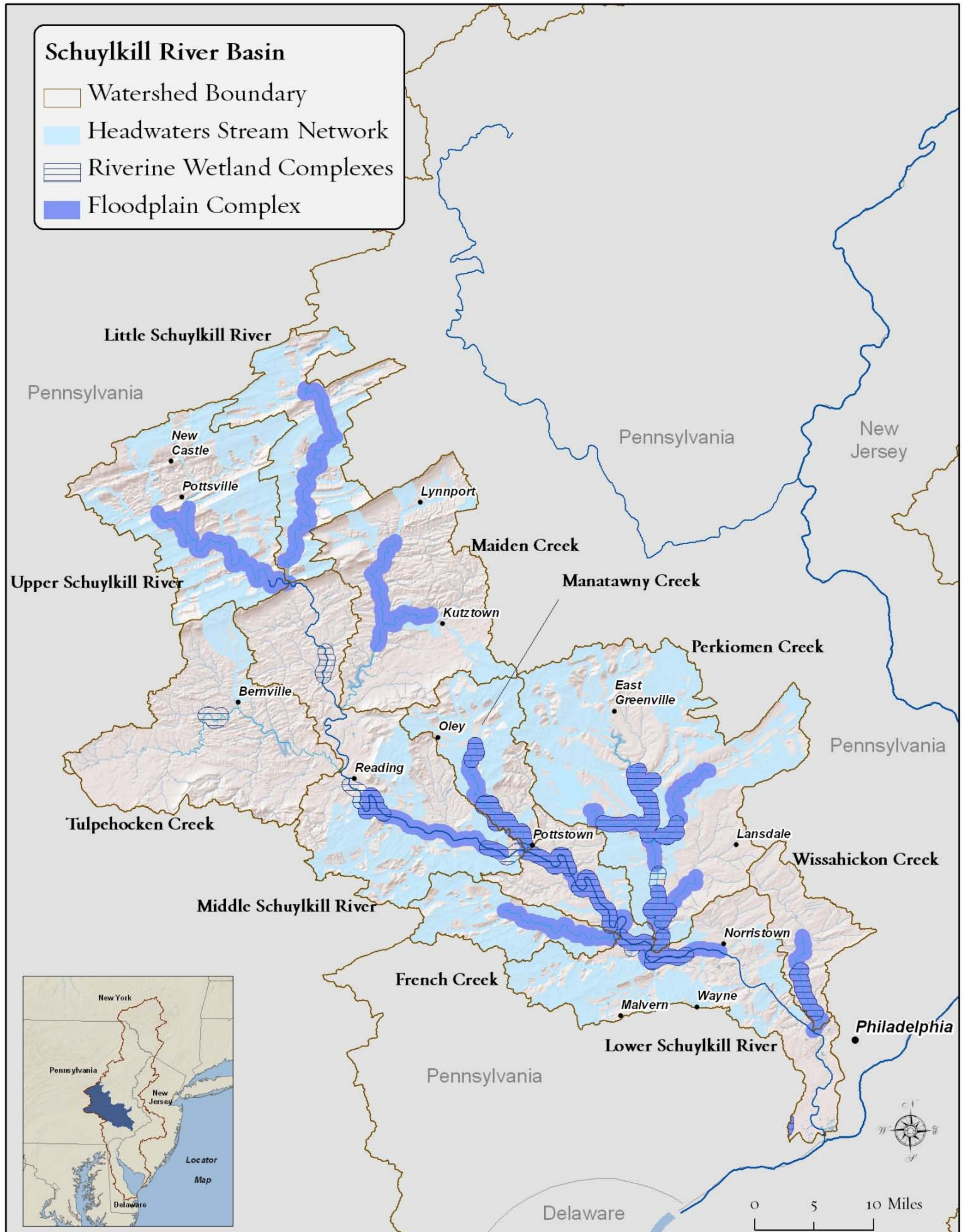


Figure 5.19. Priority conservation areas in the Schuylkill River Basin by ecosystem type

Watershed Name	Freshwater System Priorities	Priority Strategies: Forest Conservation F	Wetland Conservation W	Agricultural Land Protection and Conservation A	Aquatic Connectivity Restoration C	Streamflow Management D
Little Schuylkill River	Floodplain Complexes; Headwater Networks	●				●
Upper Schuylkill River	Floodplain Complexes; Headwater Networks	●			●	●
Maiden Creek	Floodplain Complexes; Headwater Networks	●		●		
Tulpehocken Creek	Headwater Networks; Riverine Wetlands	●		●		
Manatawny Creek	Floodplain Complexes; Headwater Networks; Headwater Wetlands; Riverine Wetlands	●	●	●	●	
Middle Schuylkill River	Floodplain Complexes; Headwater Networks; Headwater Wetlands; Riverine Wetlands	●	●	●		●
French Creek	Floodplain Complexes; Headwater Networks; Headwater Wetlands	●	●	●	●	
Perkiomen Creek	Floodplain Complexes; Headwater Networks; Headwater Wetlands; Riverine Wetlands	●	●	●	●	
Wissahickon Creek	Floodplain Complexes; Riverine Wetlands			●	●	
Lower Schuylkill River	Floodplain Complexes; Headwater Wetlands; Riverine Wetlands			●	●	●

Table 5.4. Freshwater priorities in Schuylkill River Basin by watershed

DELAWARE RIVER ESTUARY:

PRIORITY CONSERVATION AREAS AND STRATEGIES

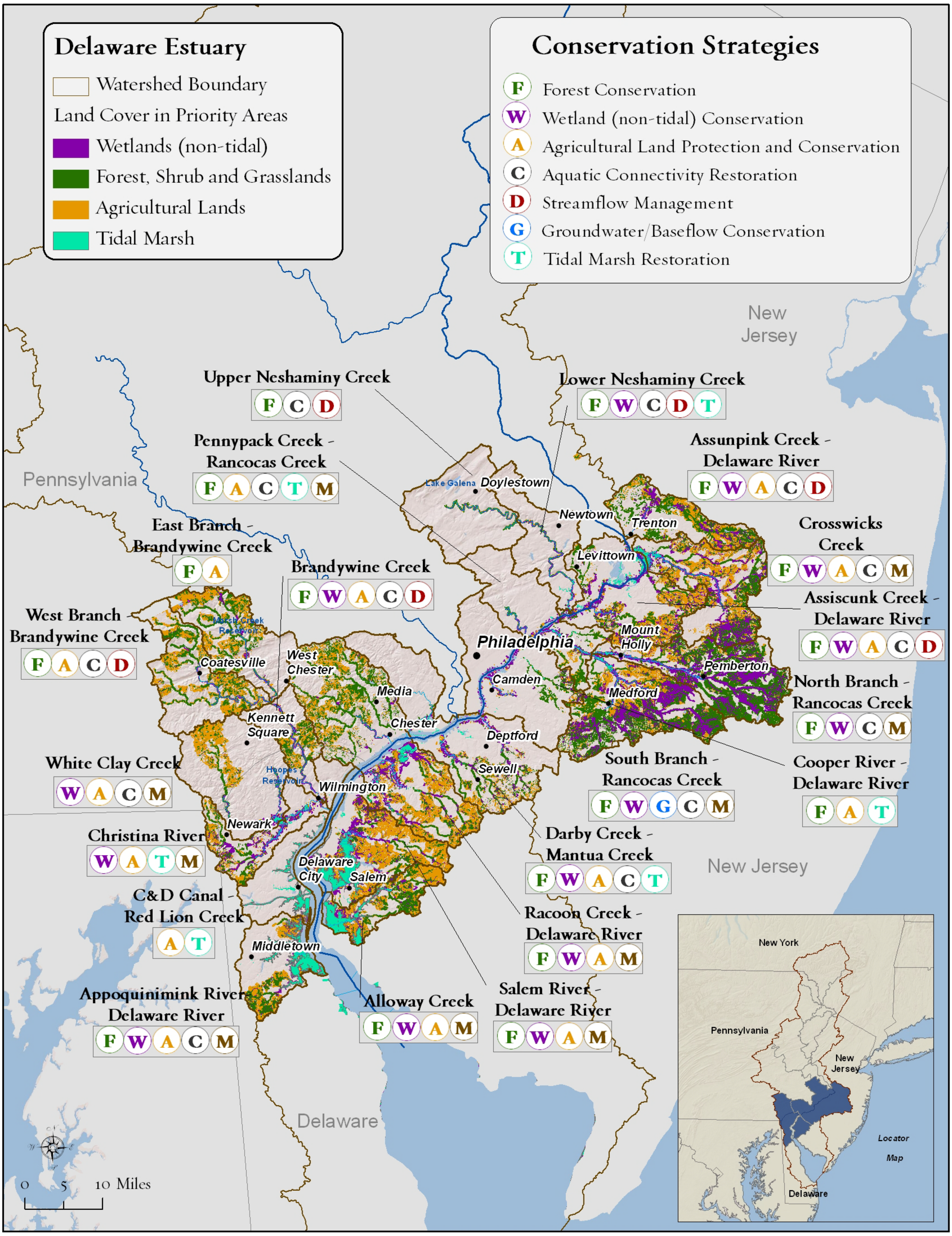


Figure 5.21. Priority conservation areas and recommended conservation strategies in the Delaware River estuary

The Delaware River Estuary

The Delaware River Estuary ~

The two estuary sub-basins of the Delaware River contain the entire tidal stretch of the mainstem Delaware River, from the head of tide at Trenton, NJ to where the river enters the bay near Wilmington, DE and Salem, NJ. Major tributaries include the Neshaminy Creek in Pennsylvania, the Brandywine Creek in Delaware, and the Rancocas Creek in New Jersey. In Pennsylvania and Delaware, this area includes the edge of the Piedmont and the Coastal Plain provinces; the latter province covers this area in New Jersey.

The estuary is home to the largest cities in Pennsylvania (Philadelphia) and New Jersey (Trenton). The Pennsylvania side of the estuary, the most densely populated area in the Delaware Basin, is highly developed compared to amounts of natural and agricultural cover in other portions of the basin (Figure 5.22); however, protected areas are still signifcant (Figure 5.23). Developed land cover is lower in DE and NJ than in PA, but this section is also the most developed in the basin on the New Jersey side. Brackish and salt marshes found in the downstream portion of the estuary, which provide especially critical habitat for species such as bottom-dwelling sturgeon, are less fragmented than the freshwater tidal marshes found upstream in the urban corridor.

Historically water quality in this stretch suffered so much from industrial and urban inputs that low dissolved oxygen formed an effective block to the migration of diadromous fish for much of the early 20th century; regulations and changed practices led to dramatic improvements in water quality in the late 1900s and a much-recovered river system today. However, the prevalence of urban land cover in this area makes the existing natural ecosystems all that more critical to maintaining function of the overall system and providing habitat for estuarine species.

The John Heinz National Wildlife Refuge contains important freshwater tidal wetlands in the Philadelphia area. Marsh Creek State Park in Pennsylvania, C&D Canal Wildlife Area in Delaware, Supawna Meadows National Wildlife Refuge in New Jersey, and Brendan T. Byrne State Forest in New Jersey are all additional significant protected areas. White Clay Creek, both its headwaters in Pennsylvania and its downstream portions in Delaware, is designated National Wild and Scenic.

Freshwater Mussels ~

Tidewater Mucket © A. Barlow

This undammed stretch of the mainstem Delaware also provides habitat for seven species of highly threatened freshwater mussels, including yellow lampmussel (*Lampsilis cariosa*), alewife floater (*Anodonta implicata*), and tidewater mucket (*Leptodea ochracea*). The latter species was previously thought to have been extirpated from this area of Pennsylvania, which emphasizes how critical the estuarine section of the Delaware River is for certain aquatic species. **Restoring freshwater tidal marsh** and **restoring aquatic connectivity** are important strategies in order to ensure that mussel populations can persist and continue to reproduce into the future.

Shortnose Sturgeon @ Cody Meshes, USFWS

Anadromous Fish ~

For fish like river herring and American shad, this estuarine corridor provides critical access to further upstream spawning grounds in the non-tidal portions of the Delaware River Basin. For Atlantic sturgeon, this tidal stretch of the mainstem provides critical habitat for spawning, maturation, and feeding. Spawning occurs above the salt line up to near Trenton, and positive evidence of breeding (captured young-of-the-year) was noted in 2010, the first time in over 50 years. For federally endangered shortnose sturgeon, the estuarine stretch of the Delaware River is equally critical, as this species uses the river most intensively in the upstream portion of the estuary, even as far north as Lambertville, NJ. Important spawning areas occur between Scudder's Falls and the Trenton Rapids, and juveniles and foraging adults in summer use river stretches further downstream to Wilmington and Artificial Island. Maintaining habitat in all of these areas is an important strategy because of the limited availability of suitable habitat in the basin; ensuring good water quality and the existence of fringing freshwater tidal marshes over time through **marsh room-to-move protection** is one priority strategy to help protect diadromous fish like these sturgeon. **Restoring freshwater tidal marsh** in the urban corridor also is extremely important to maintain estuarine river quality.

Conservation Highlights ~

The map on the reverse (Figure 5.21) highlights watersheds within the estuary sub-basins where Forest Conservation, Wetland Conservation, Agricultural Land Protection and Conservation, Aquatic Connectivity Restoration, Streamflow Management, Groundwater/Baseflow, Tidal Marsh Restoration, Shoreline Conservation, and Marsh Room-to-Move Protection would help protect and restore basin biodiversity. In addition, Figure 5.24 illustrates the identified priority conservation areas within the estuary by ecosystem type, without associated land cover. Specific conservation strategy examples include:

Aquatic Connectivity Restoration

Opportunities exist for increasing fish passage in watersheds where barriers downstream on tributary rivers (near their confluence with the Delaware River) block the movement upstream of diadromous fish like shad, but often a suite of dam removals is required to open up significant habitat for fish. Efforts are underway to remove a series of dams along the downstream portion of **White Clay Creek** to help open up access for fish; allowing fish to pass through the locations of the first two dams will open up more than seven miles of habitat. Nearby, efforts are also ongoing to restore aquatic connectivity on the **Brandywine River**. Additional opportunities for barrier mitigation to increase the connectivity of rivers along significant floodplain complexes or of headwaters stream networks also occur in this stretch of the basin, including in the **Lower Neshaminy Creek**, **Crosswicks Creek**, **and North Branch-Rancocas Creek**. For freshwater tidal marsh, dams also can block migration of a marsh upstream and can disrupt natural water flow and sedimentation, affecting marsh accretion and condition. Dams most likely to be affecting freshwater tidal marshes (and thus for which mitigation measures should be a priority) occur in the **Appoquinimink River-Delaware River**, **Lower Neshaminy Creek**, **and Crosswicks Creek watersheds**.

Tidal Marsh Restoration

The urban and industrial landscape of the Delaware Estuary has severely degraded freshwater tidal marshes, reducing wildlife habitat and negatively affecting water quality. Due to the loss of freshwater tidal marshes and the ecosystem benefits they provide, increasing tidal marsh acreage in the most highly developed urban area in the basin is a priority strategy. Watersheds identified for tidal marsh restoration or creation in the estuary include the **Christina River**, **C&D Canal-Red Lion Creek**, **Darby Creek,** and the **Cooper River watersheds**. Above Philadelphia and Trenton, the **Lower Neshaminy Creek** watershed is a priority for freshwater tidal marsh restoration. The Pennsylvania Environmental Council and Philadelphia Water Department Office of Watersheds mapped and assessed freshwater tidal marshes along approximately 8 miles of the Delaware River in North Philadelphia to identify existing wetland areas, wetland enhancement areas, and potential wetland creation areas (PEC 2009). (Figure 5.25).

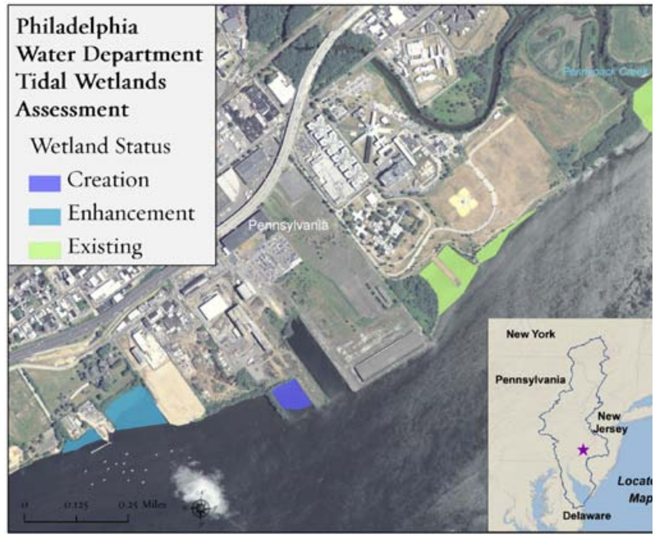


Figure 5.25. Freshwater tidal marshes along the Delaware River

Marsh Room-to-Move

The lower estuary contains the northern-most extent of brackish tidal marshes, ending at the C&D Canal in Delaware and the Salem River in New Jersey. The brackish tidal marshes in the **Appoquinimink River** and **Salem River** watersheds are adjacent to natural lands that should be protected to allow for marsh migration as sea levels rise. In the future, freshwater tidal marshes also may require adjacent natural lands for marsh migration. Protecting natural lands adjacent to freshwater tidal marshes is a priority strategy in the **White Clay Creek** and the **Christina River** in Delaware, and the **North Branch of Rancocas Creek**, **Raccoon Creek**, **and Alloway Creek** in New Jersey. Raccoon Creek contains a large freshwater tidal marsh with adjacent natural lands that, if protected, will allow for upstream marsh migration as sea levels rise.

Forest Conservation Wetland Conservation Agricultural Land Protection and Conservation

Opportunities for forest, wetland, and agricultural conservation in headwaters, floodplains, and wetlands occur throughout this region but are most abundant in the New Jersey Coastal Plain. Forested headwaters play a critical role in maintaining watershed condition downstream, including the tidal marshes that characterize this section of the basin and the important concentrations of non-tidal wetlands that occur both in headwaters and floodplains. Protecting and managing forests, wetlands, and surrounding agricultural areas for ecological value applies to significant areas in the **North and South Branch Rancocas Creek**, **Raccoon Creek-Delaware River**, **Crosswicks Creek**, **and Salem River-Delaware River Watersheds**.

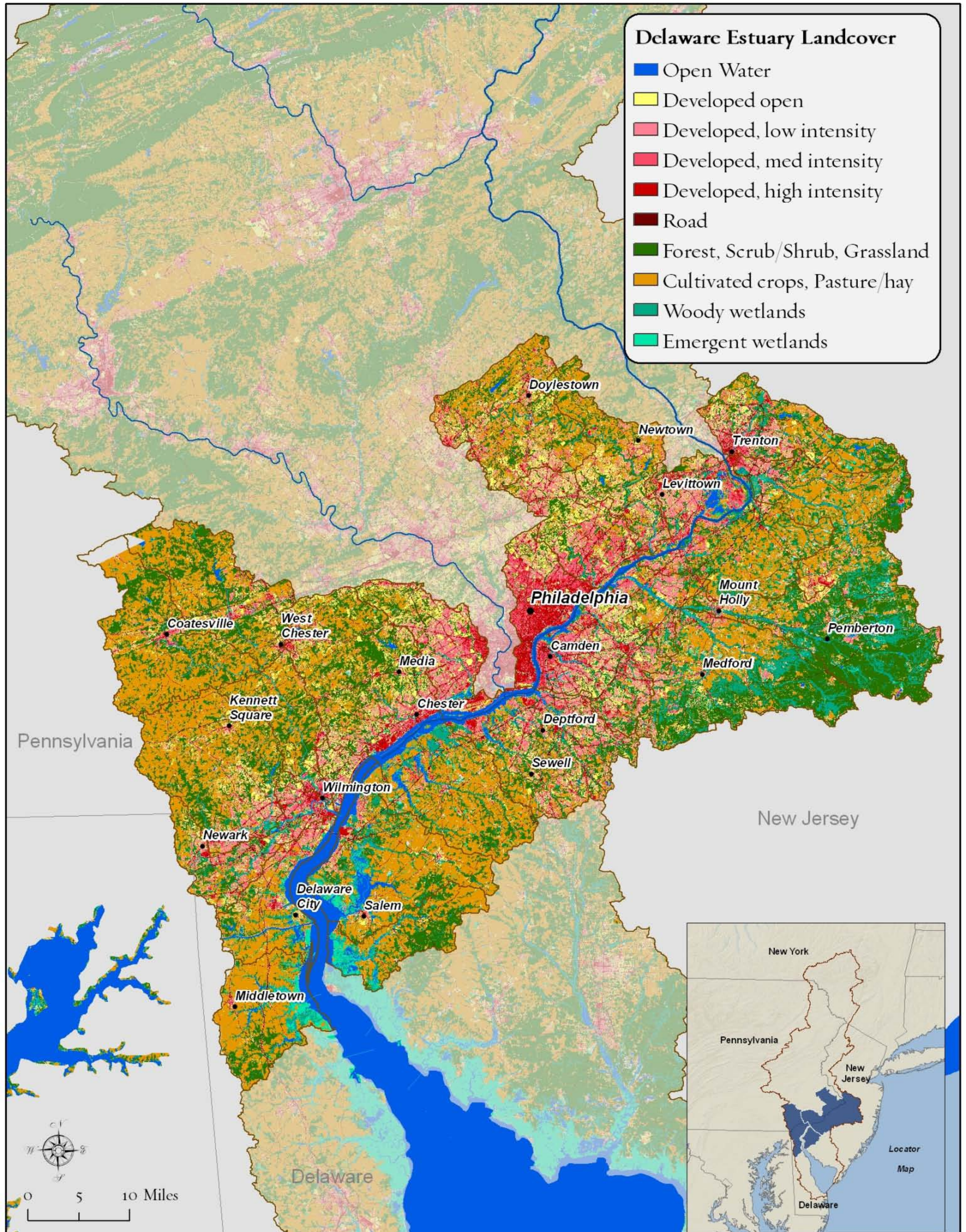


Figure 5.22. Land use in the Delaware River Estuary

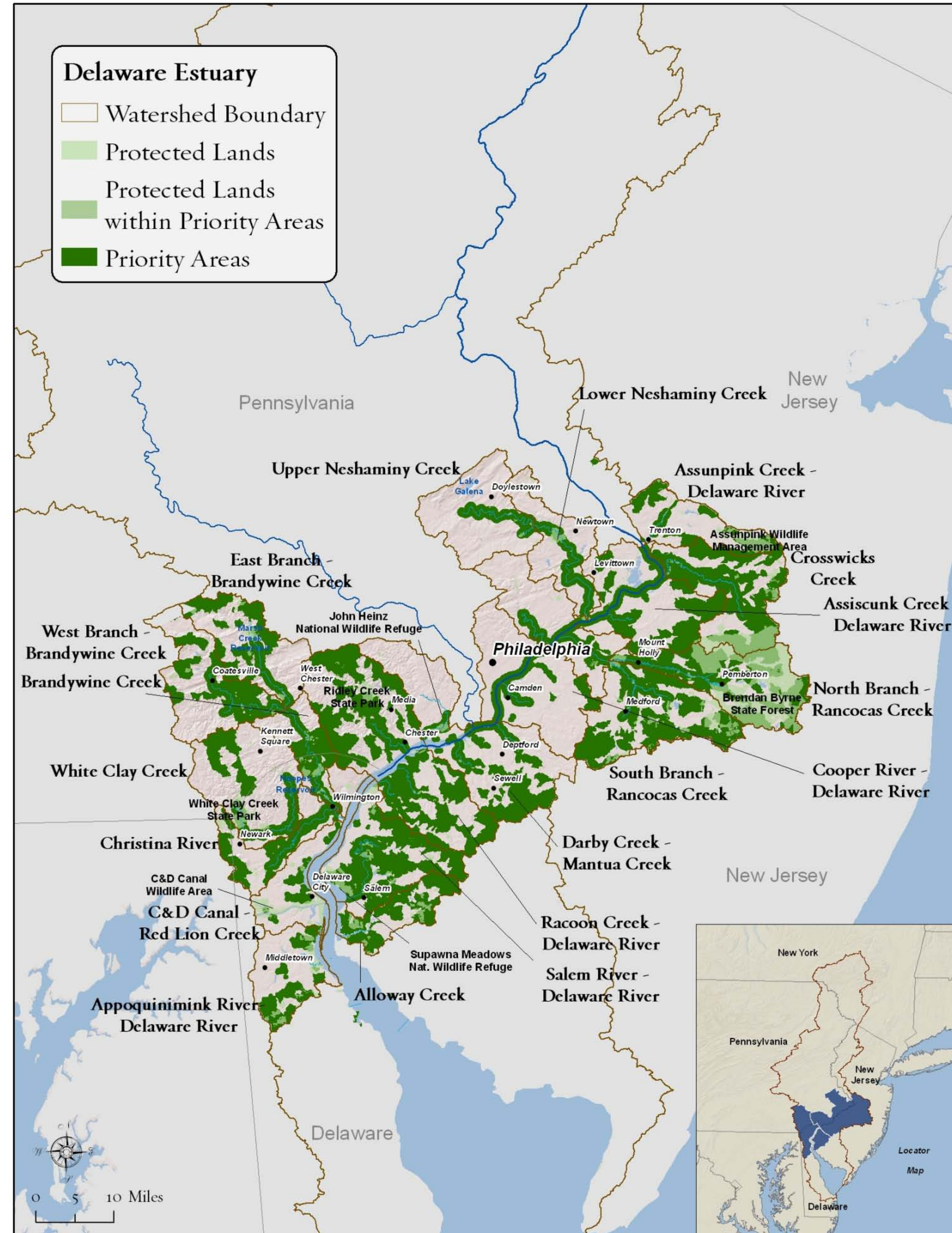


Figure 5.23. Protected Lands in the Delaware River Estuary

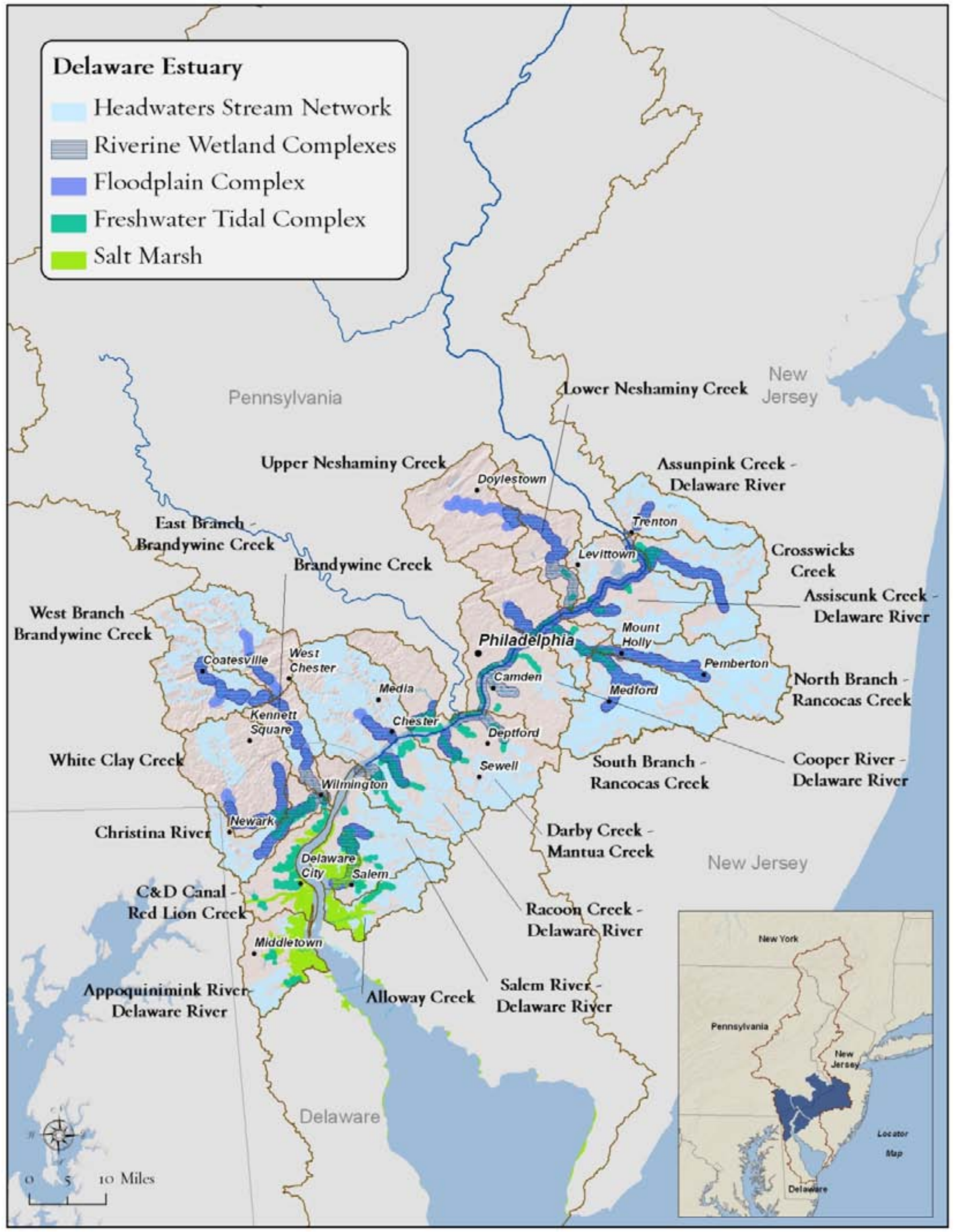


Figure 5.24. Priority conservation areas in the Delaware River Estuary by ecosystem type

Watershed Name	Freshwater and Tidal System Priorities	Priority Strategies							
		Forest Conservation	Wetland Conservation	Agricultural Land Protection and Conservation	Aquatic Connectivity Restoration	Streamflow Management	Groundwater/ Baseflow Conservation	Tidal Marsh Restoration	Marsh Room-to-Move Protection
		F	W	A	C	D	G	T	M
Upper Neshaminy Creek	Floodplain Complexes	●			●	●			
Lower Neshaminy Creek	Floodplain Complexes; Freshwater Tidal Marshes	●	●		●	●		●	
Assunpink Creek-Delaware River	Floodplain Complexes; Headwater Networks	●	●	●	●	●			
Crosswicks Creek	Floodplain Complexes; Headwater Networks; Freshwater Tidal Marshes	●	●	●	●				●
Assiscunk Creek-Delaware River	Floodplain Complexes; Headwater Networks; Freshwater Tidal Marshes	●	●	●	●	●			
North Branch Rancocas Creek	Floodplain Complexes; Headwater Networks; Freshwater Tidal Marshes	●	●		●				●
South Branch Rancocas Creek	Floodplain Complexes; Headwater Networks; Freshwater Tidal Marshes	●	●		●	●	●		●
Pennypack Creek-Rancocas Creek	Floodplain Complexes; Headwater Networks; Freshwater Tidal Marshes	●		●	●			●	●
Cooper River-Delaware River	Freshwater Tidal Marshes							●	
Darby Creek-Mantua Creek	Floodplain Complexes; Headwater Networks; Freshwater Tidal Marshes	●	●	●	●			●	
Raccoon Creek-Delaware River	Floodplain Complexes; Headwater Networks; Freshwater Tidal Marshes	●	●	●					●
Salem River-Delaware River	Floodplain Complexes; Headwater Networks; Freshwater Tidal Marshes; Salt Marshes	●	●	●					●
Alloway Creek	Headwater Networks; Freshwater Tidal Marshes; Salt Marshes	●	●	●				●	●
East Branch Brandywine Creek	Headwater Networks	●		●					
West Branch Brandywine Creek	Floodplain Complexes; Headwater Networks	●		●	●	●			
Brandywine Creek	Floodplain Complexes; Headwater Networks	●	●	●	●	●			
White Clay Creek	Floodplain Complexes; Headwater Networks; Freshwater Tidal Marshes		●	●	●				●
Christina River	Floodplain Complexes; Headwater Networks; Freshwater Tidal Marshes		●	●				●	●
C&D Canal-Red Lion Creek	Freshwater Tidal Marshes			●				●	
Appoquinimink River-Delaware River	Headwater Networks; Freshwater Tidal Marshes; Salt Marshes	●	●	●	●				●

Table 5.5. Freshwater and tidal priorities in Delaware River Estuary by watershed

DELAWARE BAY SUB-BASIN:

PRIORITY CONSERVATION AREAS AND RECOMMENDED STRATEGIES

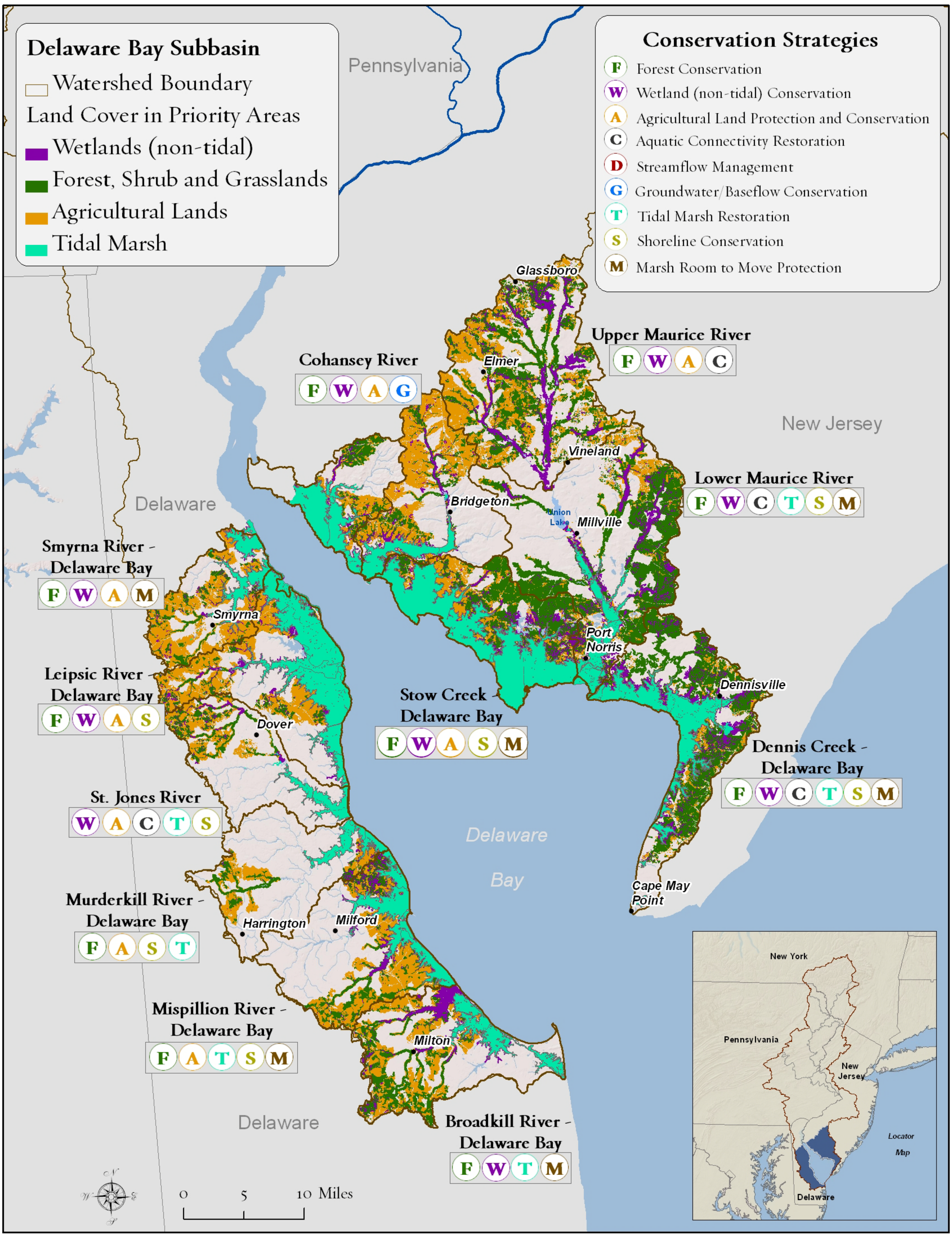


Figure 5.26. Priority conservation areas and recommended conservation strategies for the Delaware Bay sub-basin

The Delaware Bay Sub-Basin

The Delaware Bay Sub-Basin ~

The Delaware Bay sub-basin is located in the lower salt water and brackish tidal portion of the Delaware River Basin. This sub-basin is distinguished by a contiguous band of salt and brackish tidal marshes that extends around the Delaware Bay (Figure 5.27). In addition to critical salt and brackish tidal marshes, non-tidal habitats also play a key role in the biodiversity of the Delaware Bay. In addition to providing habitat for terrestrial species, forests in the Delaware Bay protect water quality for aquatic species, especially in the headwaters and floodplains of the rivers and streams that flow into the bay. Small tidal freshwater systems occur at some of the upper reaches of the tide, and a few large freshwater river systems occur in the sub-basins that drain directly into the Delaware Bay. The majority of the Delaware Bay landscape is forested in New Jersey and is agricultural in Delaware. The few population centers in the Delaware Bay occur in Millville and Vineland, NJ and in Dover and Milford, DE.

Approximately 244,000 acres of land in the Delaware Bay sub-basin is protected (Figure 5.28). The Maurice River in New Jersey is a federally-designated Wild and Scenic River. U.S. Fish and Wildlife Service National Wildlife Refuges within the Delaware Bay include Prime Hook, Bombay Hook, and Cape May. PSEG's Estuary Enhancement Program (EEP) has restored and protected approximately 32 square miles of coastal wetlands and adjacent uplands along the Delaware Bay. The Delaware Bay is also a part of the Delaware Estuary National Estuary Program, one of 28 across the United States.

The species distributions in the Delaware Bay are driven by salinity that decreases in concentration from the mouth of Delaware Bay to where the bay's waters meet the Delaware River at New Castle, DE and Salem, NJ. Alewife (*Alosa pseudoharengus*) and other diadromous fish move through the bay to spawning grounds in the mainstem Delaware River and the many rivers and streams that drain directly into the bay. Removing barriers on alewife spawning rivers could benefit alewife in the Delaware Bay significantly. The blue crab (*Callinectes sapidus),* an aquatic species important both ecologically and commercially, breeds and feeds along the tidal marshes.

Black Duck~

Wetlands of the Delaware Bay support the largest concentration of overwintering black ducks in the world, while the Delaware River Basin provides both black duck breeding and migratory stopover habitats.

The **tidal marsh restoration** strategy will increase valuable habitat for black ducks, while the **marsh room-to-move** protection strategy will help ensure the continued existence of tida marsh habitat in the future by allowing marshe to move inland as sea levels rise. **Forest and wetland conservation** strategies will protect and restore black duck habitat inland of tidal marshes.

Red knots and horseshoe crabs on New Jersey beach. ©TNC staff

Migratory Shorebirds, such as the red knot (*Calidris canutus rufa)*, use the Delaware Bay as a critical stopover area during spring migration. The shorebirds arrive at the bay just as horseshoe crab (*Limulus polyphemus)* spawning begins, and they feed on the abundance of eggs deposited by crabs on bay beaches. Recent shorebird population declines are linked to declines in spawning horseshoe crabs in the Delaware Bay (McGowan et al. 2011). Therefore, protecting and restoring Delaware Bay beaches is important for conservation of both the horseshoe crab and migratory shorebirds. **Shoreline conservation strategies** include the protection of natural beaches and the restoration of degraded beaches. The bay's characteristic tidal marshes provide nesting grounds for avian species like the black duck (*Anas rubripes*) and saltmarsh sparrow (*Ammodramus caudacutus*).

Conservation Highlights ~

The map on the reverse (Figure 5.26) highlights sub-watersheds within the bay sub-basin where Forest Conservation, Wetland Conservation, Agricultural Land Protection and Conservation, Aquatic Connectivity Restoration, Streamflow Management, Groundwater/Baseflow, Tidal Marsh Restoration, Shoreline Protection, and Marsh Room-to-Move Protection would help protect and restore basin biodiversity. In addition, Figure 5.29 illustrates the identified priority conservation areas within the sub-basin by ecosystem type, without associated land cover. Specific conservation strategy examples include:

F W G **Forest and Wetland Conservation and Groundwater/Baseflow Conservation:** While the NJ and DE landscapes differ, forest conservation is a priority strategy in most watersheds in the Delaware Bay. In New Jersey, the Pinelands Conservation Fund could be used to acquire forests within the Pinelands boundaries. Important concentrations of non-tidal wetlands occur both in headwaters areas and within the riverine wetland complexes associated with larger floodplains. The **Cohansey River** watershed in the Delaware Bay ranked as one where conserving groundwater is likely to be a key strategy in protecting the health of headwater stream networks**.** A variety of actions, such as managing land use and protecting and restoring forests in high recharge areas, will be important to undertake as part of the groundwater/baseflow strategy.

A **Agricultural Land Protection and Conservation:** Maintaining and managing agricultural areas, especially where they surround headwater or riverine wetlands, is a critical conservation strategy that is especially important in watersheds where significant acreage of wetlands and agriculture coincide: the **Lower Maurice River, Upper Maurice River, Cohansey River, Stow Creek, Saint Jones River, Mispillion River, Murderkill River, Leipsic River, Smyrna River.** Where agricultural lands fall within the tidal marsh room-to-move lands, agricultural land protection and conservation strategies aim to protect agricultural lands from development in order to allow for marsh migration in both Delaware and New Jersey.

Tidal Marsh Restoration: Low elevation tidal marshes in this sub-basin are vulnerable to the effects of sea level rise and are priorities for strategies to enhance elevation to mitigate these effects. Utilizing elevation models, we identified the **Dennis Creek, Lower Maurice River, Mispillion River, Saint Jones River, Murderkill River, and Broadkill River** watersheds to be priorities for tidal marsh restoration in the sub-basin because of the presence of low elevation marshes. Example actions that could take place in these areas include utilizing natural infrastructure at the bay-marsh fringe and sediment management on marsh surfaces. Opportunities for tidal marsh restoration exist within the U.S. Army Corps of Engineers Regional Sediment Management Program. The PSEG tidal marsh restoration projects present an example of large scale restoration in the sub-basin.

S **Shoreline Conservation**

Natural beaches occur throughout the sub-basin, providing important habitat for spawning horseshoe crabs and foraging opportunities for migratory shorebirds. The remains of abandoned towns on the bay shore have degraded certain beaches and now present opportunities for restoration. Example opportunities occur in the **Dennis Creek** watershed at Thompson's Beach and Moore's Beach, and in the Maurice River cove within the **Lower Maurice River** watershed. In Delaware, the **Mispillion River** and **Murderkill River** watersheds require beach replenishment and restoration for horseshoe crabs and shorebirds.

M **Marsh Room-to-Move Protection**

Protecting natural lands adjacent to tidal marshes to allow for marsh migration as sea levels rise can be undertaken through fee acquisition, conservation easement, or private-lands management. In New Jersey, the **Dennis Creek** (6,518 acres in room-to-move/50% unprotected) (Figure 5.30), **Lower Maurice River** (2,428 acres in room-to-move/65% unprotected), and **Stow Creek** (5,771 acres in room-to-move/54% unprotected) watersheds are priorities for marsh room-to-move protection. In Delaware, the **Mispillion River** (5,998 acres in room-to-move/83% unprotected), **Broadkill River** (3,418 acres in room-to-move/90% unprotected), and **Smyrna River** (4,881 acres in room-to-move/79% unprotected) are priorities for tidal marsh room-to-move protection. In New Jersey, the Pinelands Conservation Fund could be used to acquire marsh room-to-move lands that fall within the boundaries of the Pinelands National Reserve. The Dennis Creek and Maurice River watersheds contain portions of the Pinelands within their boundaries.

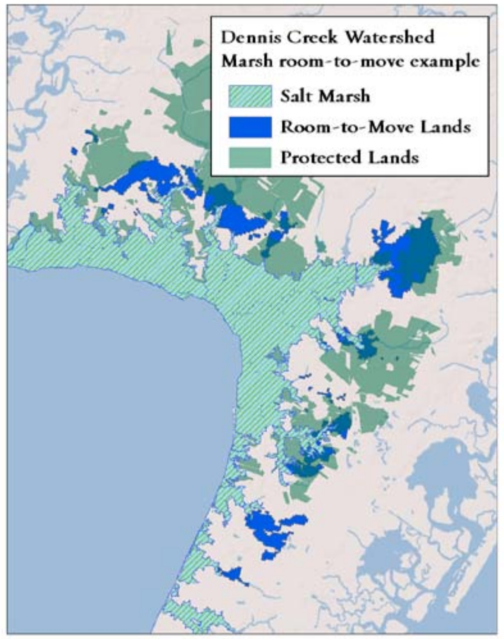


Figure 5.30. Marsh room-to-move example in the Dennis Creek, NJ watershed.

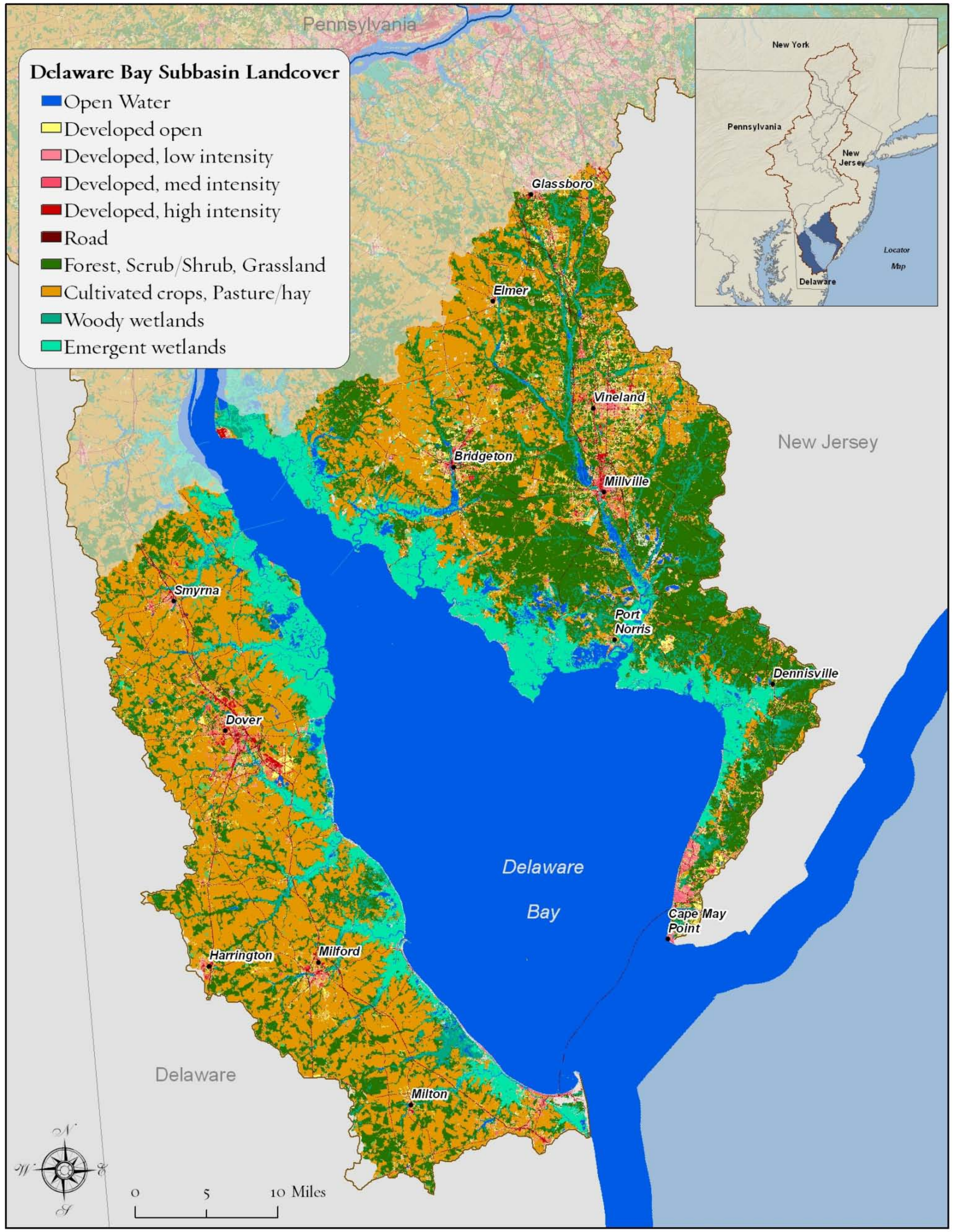


Figure 5.27. Land use in the Delaware Bay sub-basin

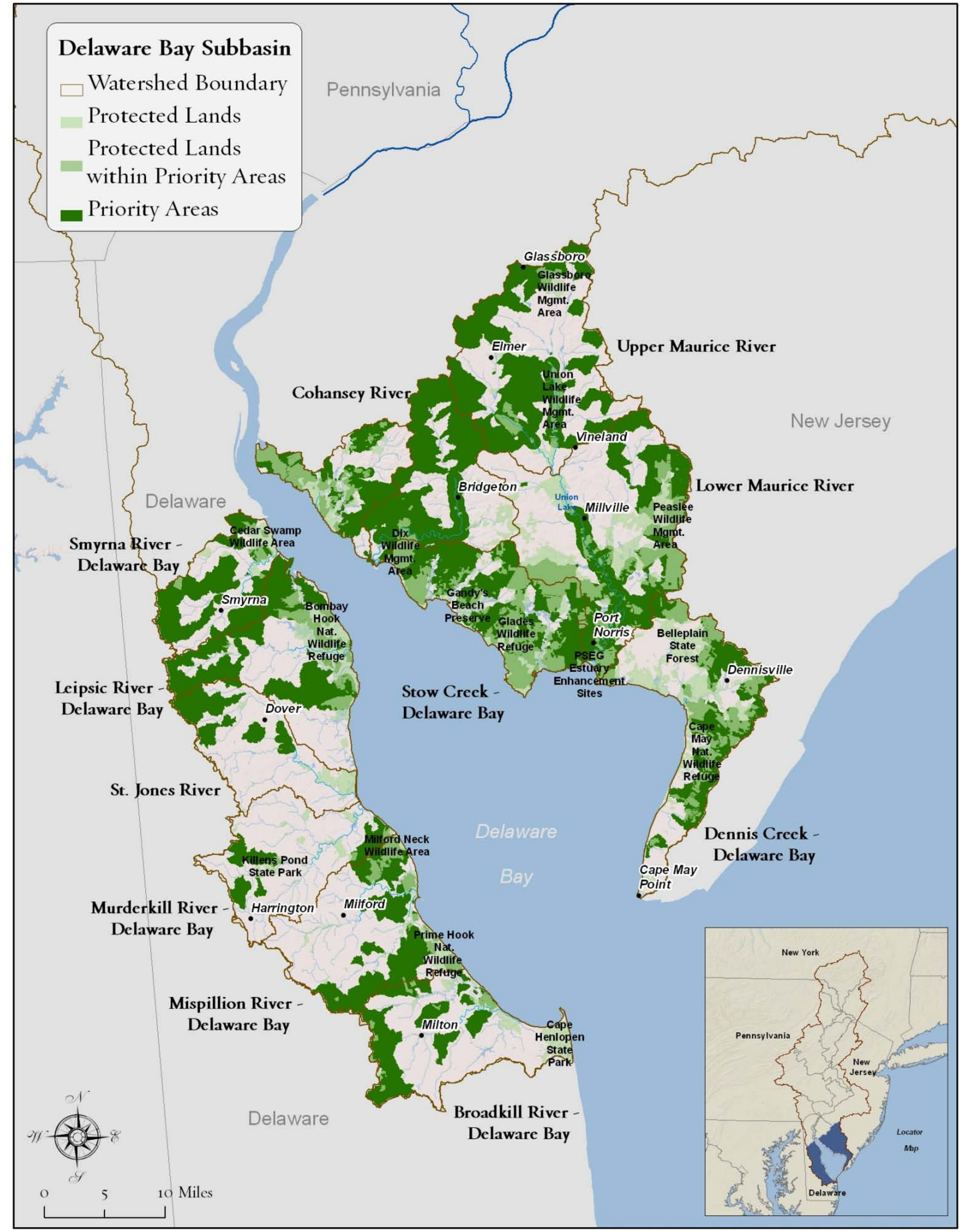


Figure 5.28. Protected lands in the Delaware Bay sub-basin

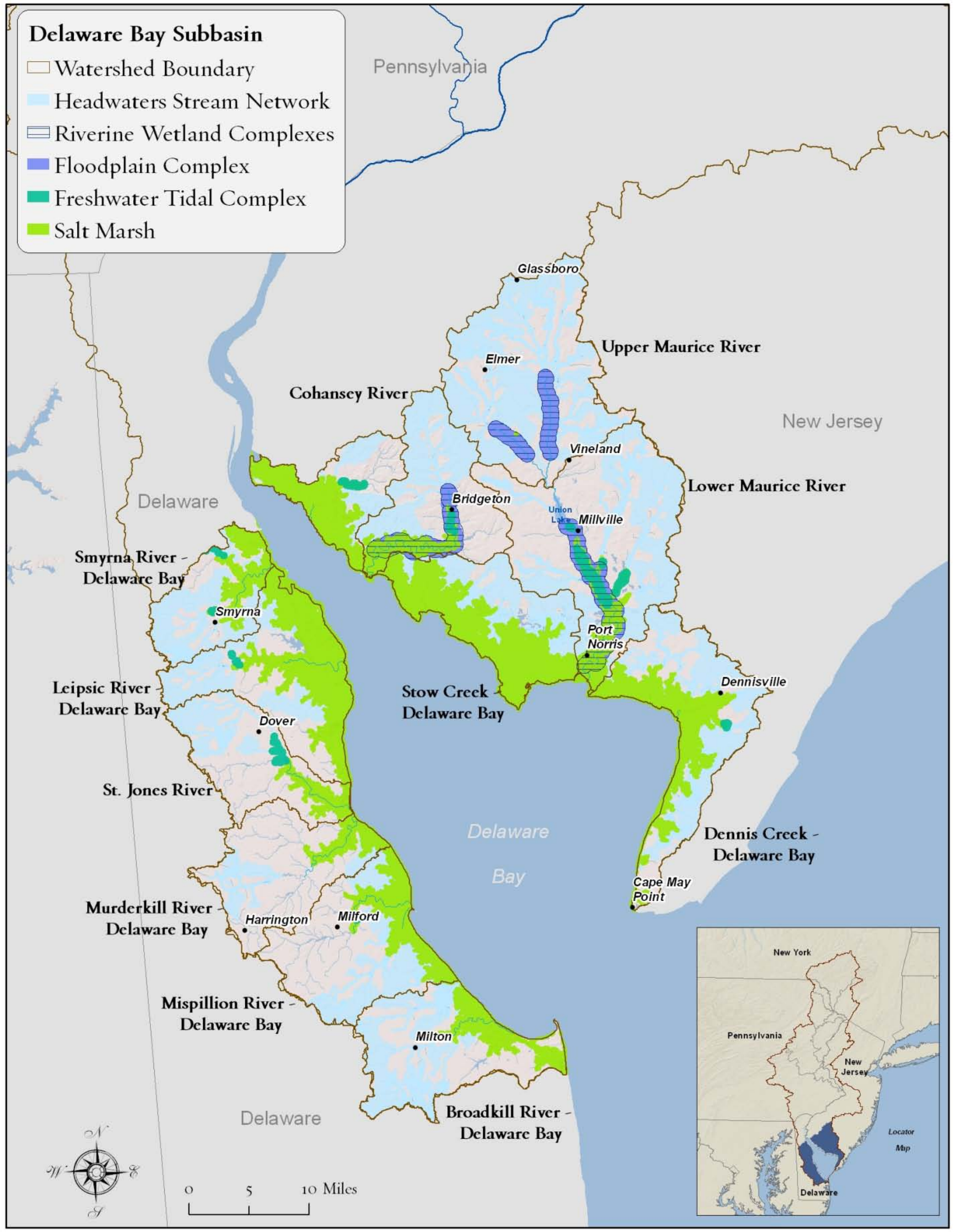


Figure 5.29. Priority conservation areas in the Delaware Bay sub-basin by ecosystem type

Watershed	Freshwater and Tidal System Priorities	Priority Strategies							
		Forest Conservation	Wetland Conservation	Agricultural Land Protection and Conservation	Aquatic Connectivity Restoration	Groundwater /Baseflow Conservation	Tidal Marsh Restoration	Shoreline Conservation	Marsh Room-to-move Protection
		F	W	A	C	G	T	S	M
Cohansey River	Floodplain Complexes; Headwater Networks; Salt marshes	●	●	●		●			
Stow Creek	Floodplain Complexes; Freshwater Tidal marshes; Salt Marshes	●	●	●				●	●
Upper Maurice River	Floodplain Complexes; Headwater Networks; Salt marsh	●	●	●	●				
Lower Maurice River	Floodplain Complexes; Headwater Networks; Freshwater Tidal Marshes; Salt marshes	●	●				●	●	●
Dennis Creek	Headwater Networks; Freshwater Tidal Marshes; Salt Marshes	●	●		●		●	●	●
Smyrna River	Headwater Networks; Freshwater Tidal Marshes; Salt Marshes	●	●	●					●
Leipsic River	Headwater Networks; Freshwater Tidal Marshes; Salt Marshes	●	●	●				●	
St. Jones River	Headwater Networks; Freshwater Tidal Marshes; Salt Marshes		●	●	●		●	●	
Murderkill River	Headwater Networks; Salt Marshes	●		●			●	●	
Mispillion River	Headwater Networks; Salt Marshes	●		●			●	●	●
Broadkill River	Headwater Networks; Salt Marshes	●	●				●		●

Table 5.6. Freshwater and tidal priorities in Delaware Bay sub-basin by watershed

Recommended Oyster Conservation Areas with Tactics

Marine Bivalve Priority Area 1: High Productivity Oyster Beds

The "central beds" of the oyster seed beds (appearing in pink), which have the highest productivity since the onset of oyster diseases, include Shell Rock, Upper Middle, Middle, Ship John, Cohansey, and Sea Breeze. These central beds achieve the highest productivity because of their strategic position in the system: they are far enough south to take advantage of high food quality and relatively consistent recruitment, and far enough north to escape high disease mortality. While disease is even lower in the upper beds, food quality and recruitment there are lower, resulting in slower growth and sporadic recruitment (Figure 5.31). Strategies proposed in this central region of the bay aim to keep these beds at a highly productive level, which is imperative to sustaining both a commercial fishery and overall population abundance. Currently, shell planting is a major tactic being employed in this area, in part using funding from the Oyster Restoration Task Force. Other recommended strategies for Area 1 can be found in Table 5.7.

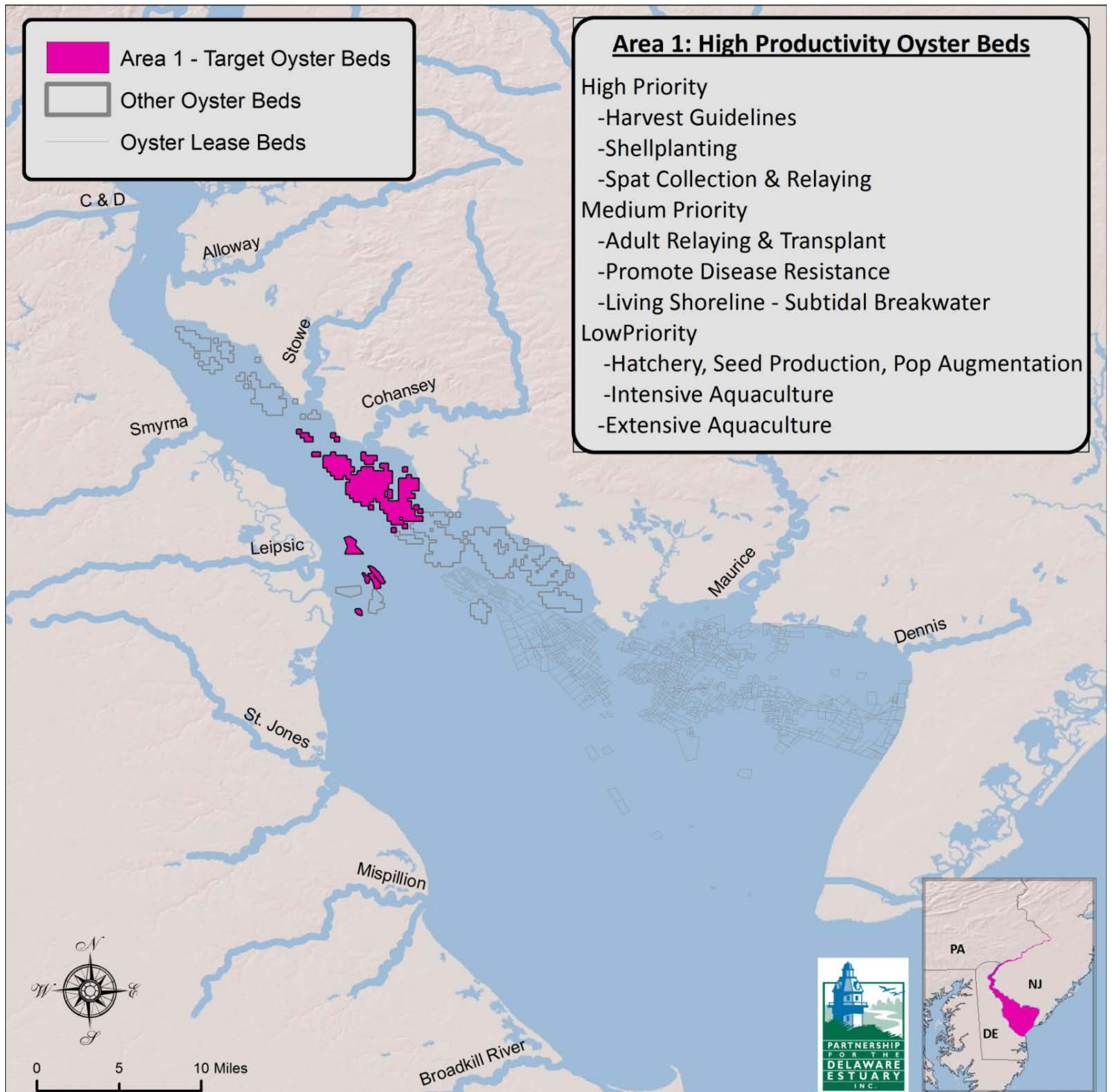


Figure 5.31. Area 1: High productivity oyster beds in the Delaware Bay

High Priority		Medium Priority		Low Priority	

HG **Harvest Guidelines**
Harvest guidelines, aimed at keeping the middle beds highly productive, . should continue to rely on annual monitoring surveys and science-based adaptive management by the Shellfish Advisory Committee.

SP **Shell Planting**
Shell planting maintains and increases extant populations by enhancing natural recruitment and replacing shell lost to natural erosion or harvesting. Target areas should ideally have a good probability of recruitment and relatively high survival and growth.

SR **Spat Collection & Relaying**
Shell planting in the lower bay where recruitment is high but survival is low can be an effective strategy for collecting young oysters before they die and moving them to more productive areas for grow-out, e.g., collect spat on shell from Cape Shore and move it to Area 1.

AR **Adult Relaying & Transplant**
Adult oysters can be collected from areas of low survivorship or low productivity and transplanted to areas of high productivity and moderately low mortality, such as the central beds. Movement of adults from the very low mortality (upper) beds should be carefully considered and monitoring and research are needed to understand shell and oyster population maintenance on these beds. Because recruitment is usually low on the upper beds, planting of spat on shell (either from the hatchery or natural set) should be considered here, possibly using disease-resistant stocks. In any case, shell replacement must be considered from source areas.

DR **Promote Disease Resistance**
Enhancing oyster populations in medium and high disease zones encourages the breeding of disease-resistant oysters. Funding is needed to sustain disease resistance research and monitoring in relation to managing Area 1.

LSB **Living Shoreline – Subtidal Breakwater**
A subtidal nearshore oyster breakwater is recommended as a pilot project in Area 1. If effective, this approach could then be expanded to other places. The shallow waters bordering Sea Breeze are a candidate test location since this is a marginal area where oyster harvesting is reportedly difficult. Subtidal oyster breakwaters might also be constructed as part of a hybrid tactic combined with living shorelines.

HS **Hatchery, Seed Production, Population Augmentation**
Oysters can be grown in a hatchery and transplanted to the middle beds to increase oyster abundance in the high-productivity Area 1. However, this tactic is assigned low priority as long as collection of natural spat remains less expensive and effective.

AI **Intensive Aquaculture**: This could not be conducted in this area without significant changes in regulations

AE **Extensive Aquaculture**: This could not be conducted in this area without significant changes in regulations

Table 5.7. Recommended tactics for Area 1 - High Productivity Oyster Beds.

Marine Bivalve Priority Area 2: Marginal (Harvest) Area Targets

Marginal (harvest) areas (Figure 5.32) are defined as areas which are not as good for oyster harvest for one of four reasons: 1) the area is too shallow for oyster boats to get into, 2) the bottom is rocky or sparse in shell cover, 3) oysters are in tributaries that are closed to harvest, or 4) the area has high disease pressure. Since most of these areas are included in area management planning, care must be taken to work with the Stock Assessment Reivew Committee. Marginal harvest areas have potential to be prime areas for conservation or ecological restoration. Marginal areas that cannot be effectively dredged for commercial harvests due to depth or bottom conditions (#1 and 2 above) might represent places to install shallow subtidal, nearshore reefs. There are several places along the New Jersey Bayshore where historic oyster reefs were reported that could be candidates for nearshore oyster reef enhancemen - denoted as green stars in Figure 5.32. Some of these locations are located in NJDEP prohibited or special restricted waters for shellfish (NJDEP 2011), which could necessitate use of construction tactics that thwart poaching. In addition, tongers might still work some of these shallow nearshore marginal areas, and more (local) research would be needed to determine if these users would be affected. Additional opportunities exist in Delaware waters near the mouth of the Leipsic, St. Jones, or Murderkill Rivers in suitable nearshore marginal areas.

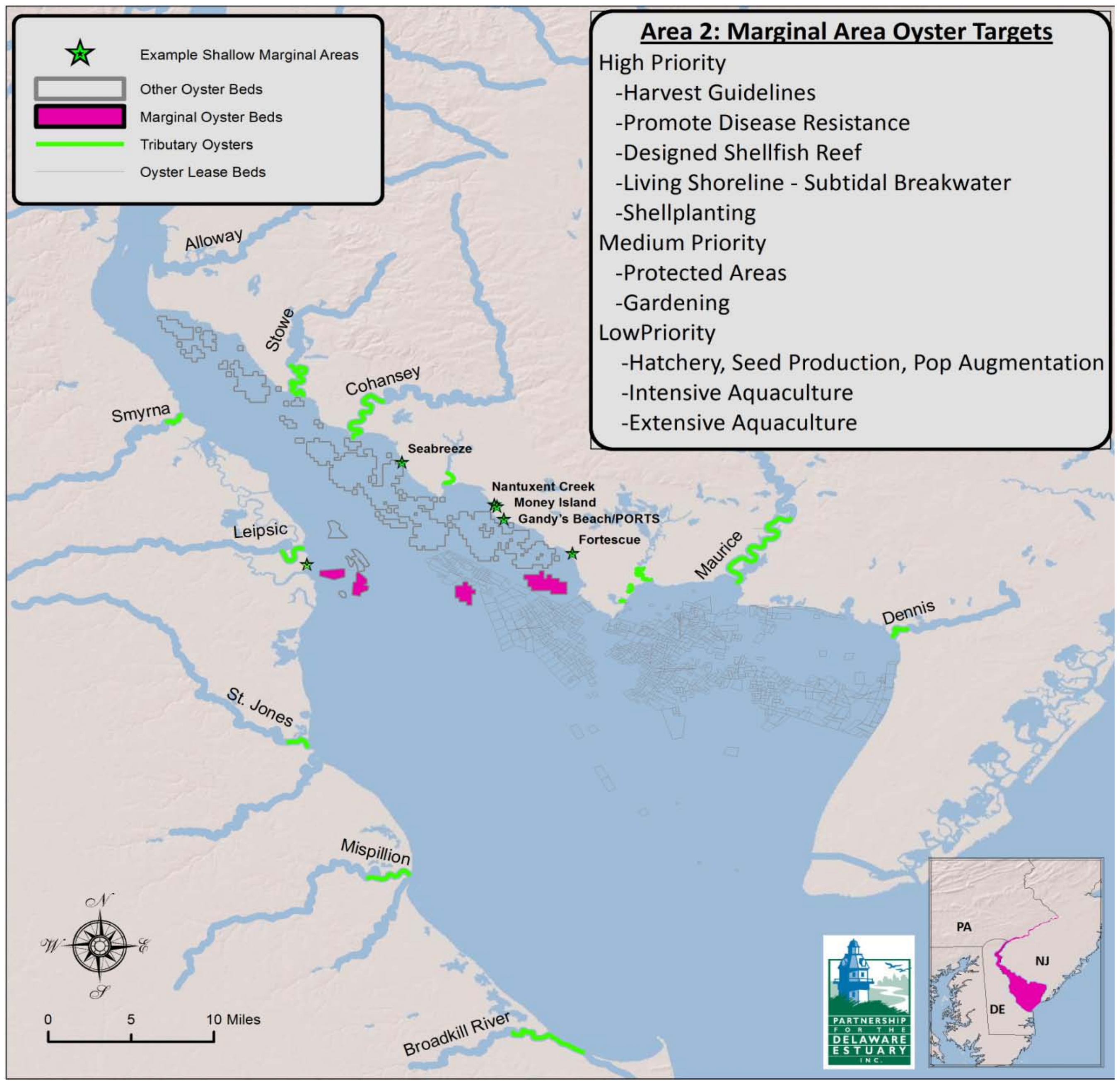


Figure 5.32. Area 2: Marginal (harvest) areas in the Delaware Bay

*High disease marginal areas include the beds of **Ledge and Egg Islands**. Although disease pressure is high on these two beds, there is still potential for oyster conservation projects here. These beds could be managed for rotational harvests to provide dual benefits of supporting oyster harvests (because most will die anyway) and increased disease resistance (because this is where disease pressure drives selection fastest as long as oysters do not experience 100% mortality).*

High Priority		Medium Priority		Low Priority	

HG **Harvest Guidelines**
A rotational harvest pilot is recommended for the seed beds of Egg Island and Ledge which are marginal because of high disease pressure. Each (pilot) bed would be subdivided into a larger harvest section and a smaller disease resistance promotion section, which could be augmented with shell cleaning, shell planting, or seeding with disease resistant seed. The smaller set side area would be designated for no harvest for 1 to 2.5 years to allow for natural selection. After that time period, harvest would be allowed again. Disease resistance monitoring is essential to deduce success.

DR **Promote disease resistance**
The oyster beds identified in this area are within the medium to high mortality areas. Any activities which enhance oysters using disease resistant stocks in these zones should contribute to disease resistance promotion. See harvest guidelines for an example project.

DS **Designed Shellfish Reef:**
Shallow marginal areas could be potential sites for reef creation or enhancement of existing shellfish, while also furnishing additional ecological services.

LS **Living Shoreline – Subtidal Breakwater**
Shallow marginal areas that are nearshore represent key places to install pilot 000 oyster breakwaters, possibly in conjunction with other tactics as hybrid living shorelines.

SP **Shell planting:** Shell planting is recommended on Egg Island, which is a marginal area.

SM **Special Management Areas:**
Marginal areas in tributaries or in waters that are too shallow for oyster boats to access could become special management areas on a rotating basis (green stars on Figure 4). Many of these locations are in high productivity areas that are also closed or provisional waters for direct market harvest. Establishment of special shellfish management areas will need to balance the considerations of industry, state shellfish sanitation personnel, and the viability of oysters themselves. We also recommend that efforts be made to find the sources of shellfish closures and to have water quality remediated directly.

G **Gardening**
Oyster gardening represents a tactic to be used in some tributaries if state shellfish sanitation concerns can be addressed, possibly following examples from other states. Oyster gardening might become possible in DE before NJ, but until the conflicts between shellfish sanitation policies and ecological restoration goals are resolve this tactic will remain medium to low viability.

HS **Hatchery, Seed Production, Population Augmentation**
This tactic is a low priority as long as collection of natural spat and cultivation is effective and less expensive.

AI **Intensive Aquaculture**
Some local low salinity areas in the creeks might be used for seed growth areas so that diseases could be avoided. until the oysters reach a size that could be transplanted to leased areas.

AE **Extensive Aquaculture:**
Some shallow areas may benefit from extensive aquaculture, but this should be determined by the market.

Table 5.8: Recommended tactics for oysters in Area 2 - Marginal Areas

Tributary oysters, highlighted as green lines in Area 2, provide additional opportunities for conservation or restoration projects.Because fFreshwater input lowers the salinity in tributaries, disease is generally lower there, too. Oysters in the tributaries are not part of the harvested seed beds or leased beds, and in NJ many of these tributaries are within prohibited or special restricted areas. As climate change causes warmer water temperature and saltier conditions, oysters may find increasing refuge in tributaries leading to habitat expansion possibilities.

Marine Bivalve Priority Area 3: Hybrid Tactic Zones

Hybrid tactics provide opportunities to enhance shellfish using two or more conservation strategies, possibly leading to synergistic outcomes. For example, mussel-based living shorelines (intertidal, low energy) might be paired with oyster-based breakwaters (subtidal, moderate energy) to collectively reduce wave energy and enhance ecological value as a hybrid living shoreline. Similarly, oyster breakwaters near creek mouths might enhance available oyster seed stock (by augmenting larvae) for beds in the tributaries, or vice versa. Red stars in Figure 5.33 represent areas potentially suitable for living shorelines with oyster breakwaters, though many other areas may be suitable for hybrid tactics. Green lines show locations where potential tributary oyster reefs overlap with nearby breakwater/living shoreline hybrids. All of these strategies have the potential to improve nearshore oyster reefs. The salt marshes shown in yellow are also key areas for conservation, incorporating another component into the hybrid model.

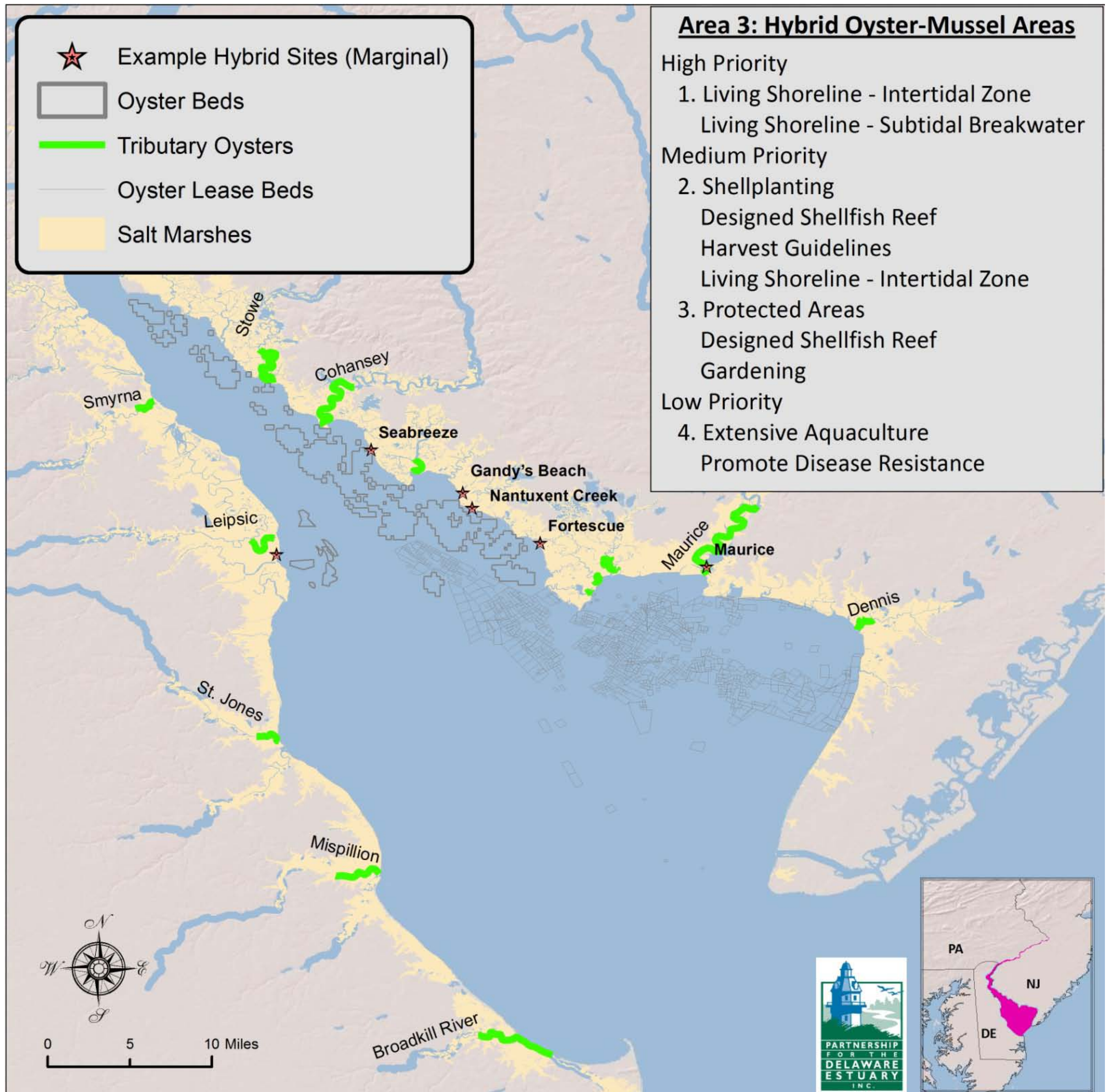


Figure 5.33. Area 3: Locations of potential hybrid tactic areas incoporating living shorelines, oyster breakwaters, and tributary oyster beds

High Priority		Medium Priority		Low Priority	

Table 5.9a. High priority – Design and implement a pilot hybrid living shoreline along the bay shore, and then expand if successful.

LS[I] **Living Shoreline – Intertidal Zone**
The red stars indicate areas which are recommended for mussel-based living shoreline tactics along salt marshes.

LS[B] **Living Shoreline – Subtidal Breakwater**
These areas are recommended for subtidal breakwater structures using oysters. Structures such as gabions can be used to contain oyster shell so that they are not readily harvested, possibly addressing shellfish sanitation concerns.

Table 5.9b. Medium Priority – Design and implement a pilot project on main seed beds that combines four conservation strategies.

SP **Shell Planting**
Shell planting could be employed to boost the oyster beds in a marginal area.

DS **Designed Shellfish Reef**
Construct a shellfish reef in the same marginal area.

HG **Harvest Guidelines**
See Table 5 for a full description of this strategy. Rotate harvests across pilot sites in different years, and monitor and compare oyster population success and disease resistance between harvested and unharvested sections of the project site.

LS[I] **Living Shoreline – Intertidal Zone**
The red stars indicate areas which are recommended for living shoreline tactics adjacent to salt marshes.

Table 5.9c. Medium priority - Design and implement a pilot project to enhance nearshore oysters in a shallow, marginal place using three conservation strategies.

SM **Special Management Area**
Marginal areas that are included in the project would be specially managed under the area management plan, providing ample protection (see Table 5 for more information).

DS **Designed Shellfish Reef**
The marginal oyster population at the pilot site would be augmented with reef creation tactics.

G **Gardening**
Oyster plots at the marginal pilot site could be installed and tended using oyster gardening concepts (see Table 5) contingent on addressing shellfish sanitation concerns.

Table 5.9d. Low priority – design and implement a pilot project to produce disease resistant stocks and outplant them, thereby using two conservation strategies together.

AI **Intensive Aquaculture**
Intensive aquaculture could be used to produce animals from hatchery stock, to provide enough oysters (or ribbed mussels) for outplanting (see Table 5).

DR **Promote Disease Resistance**
Outplant disease resistant stocks into medium to high mortality disease zones (red stars on map) to enhance disease resistance build-up in the population at the pilot site. More scientific study and discussion is warranted before implementation of this tactic. Tributary oysters might represent an ideal marginal area for outplanting disease-tolerant strains of oysters because oysters in those places might develop their own resistance slowly.

Table 5.9. Recommended tactics for Area 3 - Oyster and Mussel Hybrid Areas

Marine Bivalve Priority Area 4: Climate Change Area Targets for Future Planning

Increasing sea levels and channel deepening are likely to increase the volume of the tidal estuary, thereby allowing more seawater to move farther up Delaware Bay. Combined with increasing demands for freshwater from aquifers and the Delaware River, the Delaware Bay is expected to become saltier (Kraeuter and Kreeger 2010). Since oyster diseases are more prevalent in saltier conditions, future oyster populations will likely expand up-bay, whereas down-bay populations will be reduced due to increased disease mortality. The mortality areas will shift north and may already be changing (Kraeuter and Kreeger 2010). The current low mortality beds in the upper bay may become the new high productivity beds of the future. We therefore recommend focusing more scientific research and long-term sustainability planning on the low and very low mortality beds, which include Hope Creek, Fishing Creek, and Liston Range. New bed creation should therefore carefully consider climate change combined with expected watershed change as areas further up bay from the current seed beds become higher priorities for area management of oyster stocks. Potential oyster bed locations have been identified using acoustic data from DNREC bathymetric mapping. From these scans, two areas have been identified which might have suitable bottom, located north of current upper beds on either side of the C&D canal (Figure 5.34). Prioritizing the upper beds for protection, careful management, and possibly establishing new beds could help oyster populations to adapt to changing climate (Kraeuter and Kreeger 2010).

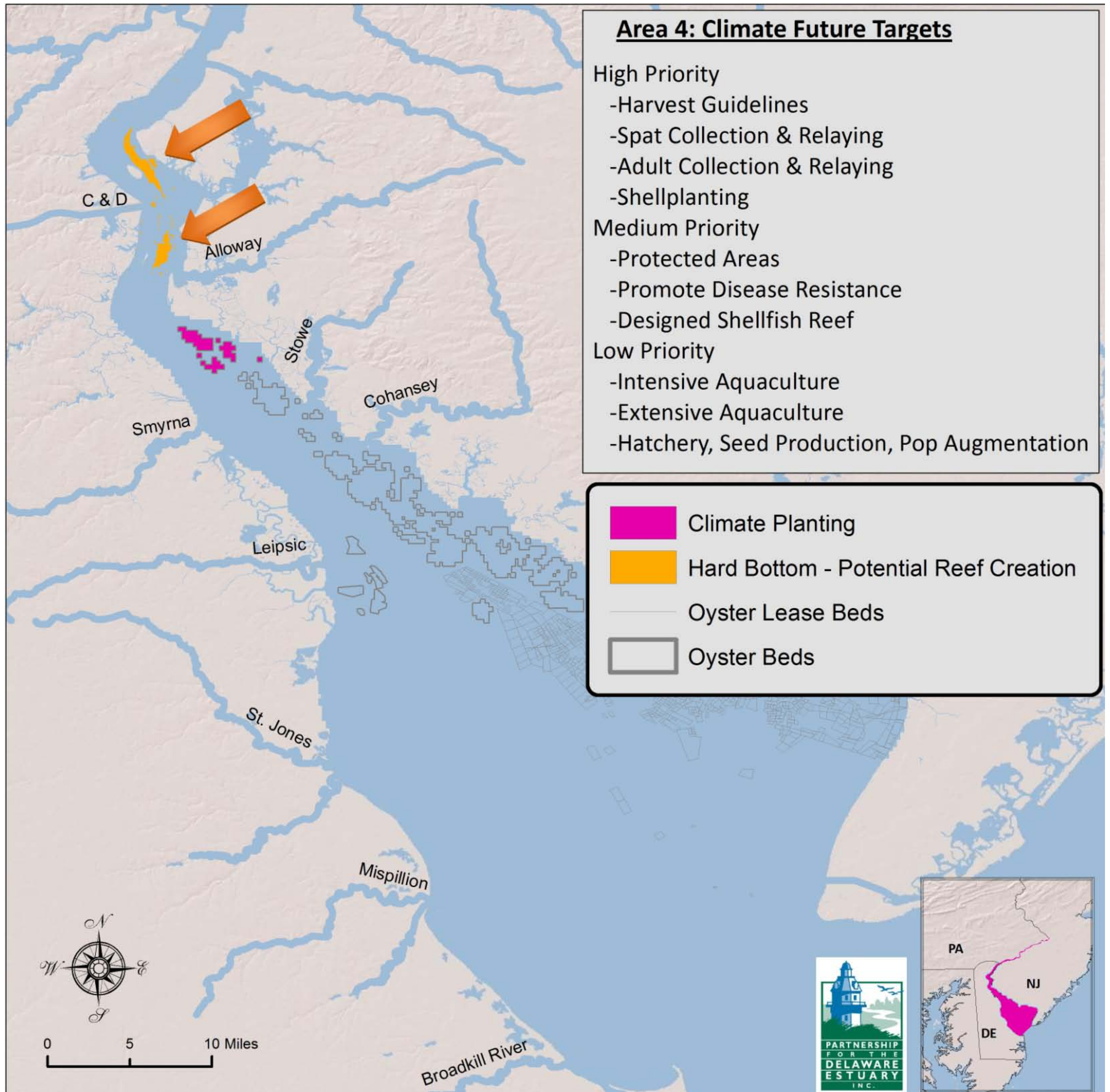


Figure 5.34. Area 4: Climate change targets for future oyster enhancement on extant upper beds, and potential areas for oyster bed creation

High Priority		Medium Priority		Low Priority	

HG Harvest Guidelines
The very low mortality beds are within special restricted zones, so no direct harvest for market is allowed. However, oysters are moved from these beds to the more southern beds so that they can be harvested later. It is imperative that these upper beds be studied and monitored to deduce basic population dynamics and biology so that area management and climate planning are strategic.

SR Spat Collection & Relaying
In the future, spatted shell might be placed on the very low mortality beds to augment naturally low recruitment and replace removed shell.

AR Adult Collection & Relaying
Currently a limited number of adult oysters are removed each year from the very low mortality beds to augment the high productivity beds in the mid-bay region. If monitoring and research indicate that oyster or shell abundance becomes depleted due to this practice, then the reverse could be considered whereby adults could be collected and relayed to the upper beds from high mortality areas or spat on shell from Cape Shore. Relaying is expensive and this tactic would need to be justified and funded.

SP Shell Planting (Future)
Since oysters grow slowly in the low and very low mortality areas, shell accumulation will curtail enhancement without shell plant augmentation. However, this approach would only be desirable if the shell had spat (e.g., from Cape Shore). Currently, natural recruitment up-bay is too sporadic to waste valuable shell resources without a better chance of success, but this could be an option for the future if recruitment dynamics change.

SM Special Management Areas
If new beds are created in the areas surrounding the C&D canal, these areas could be set aside for special investigations. Special area management of the newly developing or created beds may be desirable if they become more productive. Basic monitoring of environmental conditions and food availability should be undertaken before SMAs are adopted. Possibly, experimental lots of oysters could be placed in prospective areas for new bed creation and set aside on a 2-5 year rotation to confirm sustainability therein.

DR Promote Disease Resistance
If adults are relocated into Area 4 to augment beds or seed new beds, preference should be given to disease-resistant stocks, such as from the high mortality beds, thereby promoting broader integration of disease resistance across the bay.

DS Designed Shellfish Reef
The areas surrounding the C&D canal (Figure 6) are recommended for eventual new reef creation where the bottom substrate is already firm. This should be undertaken only when surveys show that conditions are conducive to establishment of oysters, and is more of a future strategy priority.

AI Intensive Aquaculture: See Table 5.8 for a description.

AE Extensive Aquaculture: See Table 5.8 for a description.

HS Hatchery, Seed Production, Population Augmentation: See Table 5.7 for a description

Table 5.10. Recommended tactics for Area 4 – Climate Change Target Areas

Marine Bivalve Priority Area 5: Recommended Ribbed Mussels Enhancement Areas with Tactics

All salt marshes in the Delaware Bay, the habitat of marsh mussels, have been identified as conservation priorities (Figure 5.35). By winter 2012, the Partnership for the Delaware Estuary will be releasing an inventory of living shoreline priority areas, which targets salt marsh and marsh mussel habitat. This inventory should be a useful tool for further refining ribbed mussel priority areas for direct enhancement. In addition, more ribbed mussel survey data and ecosystem services studies are needed to better prioritize specific areas for ribbed mussel enhancement in the future. Priority areas for ribbed mussels include wetland edges (where ribbed mussels can achieve greatest population biomass) and tributary watersheds in need of water quality improvements as a result of nutrient loadings, pathogens, and suspended solids. In addition, shoreline stabilization tactics using ribbed mussels or other tactics such as construction of oyster breakwaters should be prioritized to address increasing erosion energies and fetch and thereby preserve larger tracts of marsh, or protect crucial infrastructure and coastal communities. PDE is also collaborating with Rutgers to prepare a Practitioner's Guide to mussel-based living shorelines in the Delaware Estuary, expected in June 2011.

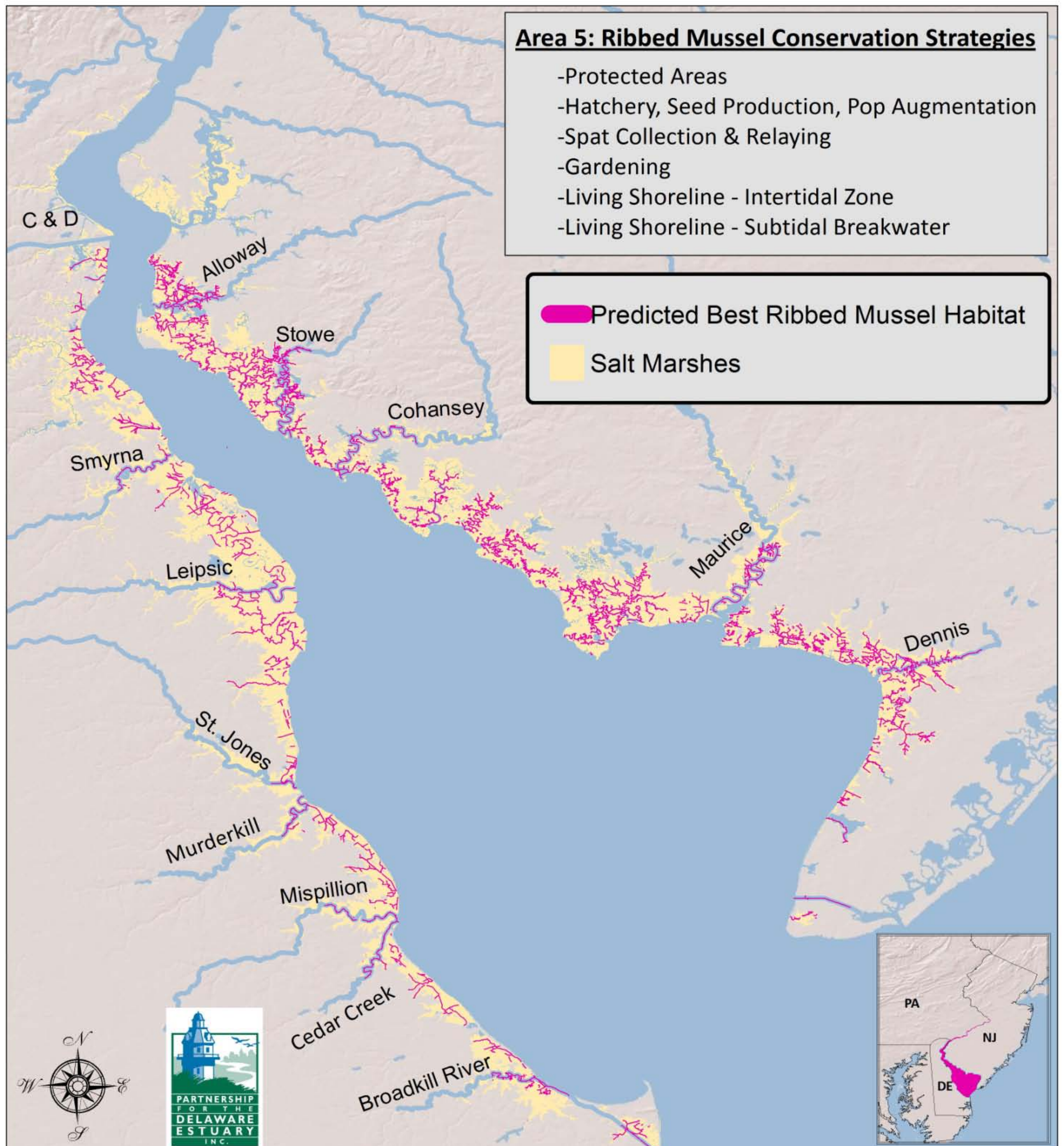


Figure 5.35. Area 5: Ribbed mussels live throughout salt marshes but are most dense along intertidal creeks and edges, which are shown here as their best habitat.

SM **Special Management Areas**
Ribbed mussels live in salt marshes, which merit their own protection for many reasons. More must be done to stem the loss of these tidal wetlands.

HS **Hatchery, Seed Production, Population Augmentation**
Spawning ribbed mussels in a laboratory has been accomplished, however, funding to develop large-scale methods that can be used for restoration and enhancement of ribbed mussel populations is needed. Such methods could grow seed mussels and plant them along salt marshes to stabilize edge erosion. Mussel seed can also be furnished to shellfish gardeners.

SR **Spat Collection & Relaying**
In salt marshes, structures might be positioned to catch ribbed mussel spat for use in restoration projects. Little is known about factors that govern ribbed mussel recruitment, which appears spatially variable. More research is needed to identify areas where mussel spat can be reliably collected and to develop spat collection methods. Natural spat collection could eventually be less expensive than hatchery propagation. Relay techniques also need R&D.

G **Gardening**
The same principles of oyster gardening could easily be applied to ribbed mussels, minus the shellfish sanitation concerns because ribbed mussels are not a commercial species. Mussel gardening would provide an educational activity and could help to raise mussels for restoration purposes and water quality improvement, potentially also benefitting oysters in impaired waters. Research is needed to determine if there is an optimal size for planting mussels, and mussel gardening could provide cost-effective research opportunities.

LS **Living Shoreline – Intertidal Zone**
Living Shorelines incorporating ribbed mussels is a new restoration tactic that appears effective at helping to stem erosion in low to moderate energy areas along salt marshes. The approach takes advantage of the stabilizing benefits of mussel byssal threads and their mutualism with *Spartina* plants. This restoration boosts populations of ribbed mussels, while also providing other ecological benefits.

LS **Living Shoreline – Subtidal Breakwater**
Subtidal (oyster) breakwaters indirectly protect ribbed mussel habitat by reducing wave energy forces, and protecting against marsh erosion. When used together with intertidal living shorelines, this tactic may be effective at collectively boosting shellfish habitat for several species.

Table 5.11. Recommended tactics for Area 5 to improve ribbed mussels in salt marshes that fringe Delaware Bay