2019 REVISION

A Comprehensive Conservation & Management Plan

FOR THE

Delaware Estuary

Connecting people, science, and nature for a healthy Delaware River and Bay

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From 2016 to 2018, the Partnership for the Delaware Estuary (PDE) led a process to revise the Comprehensive Conservation and Management Plan (CCMP) for the Delaware Estuary working with members of the Steering Committee, Estuary Implementation Committee, Science and Technical Advisory Committee, PDE Board of Directors, members of the ad hoc Forests and Strong Communities Teams, and PDE's staff. The result is this 2019 CCMP. We wish to thank these committees' members for going above and beyond the call of duty by providing input and spending many hours representing their agencies and community members to provide insight for this plan. RK&K provided workshop process design, meeting facilitation, and technical editing services. Meridian Institute provided planning and facilitation services. Professional editing services were provided by Editor World. Janet Andrews, LookSmartCreative, supported layout and design.

The Delaware Estuary Program also would like to thank all the local partners, experts, and stakeholders who attended meetings and workshops, provided comments, and worked with the program during the CCMP revision process.

Themes, Goals, and Strategies of the Revised CCMP for the Delaware Estuary

THEME 1 | CLEAN WATERS

GOAL 1: Reduce Nutrient Pollution and Its Impacts

HOW WE WILL MEASURE SUCCESS:

- ***Continuing progress to increase dissolved oxygen levels in the Estuary***
- ***Progress to improve ecosystem health in the Delaware Estuary by addressing other nutrient-related impacts***
- ***Decreases in nutrients in the Estuary and its tributaries***
- ***Increased installation of non-point source nutrient BMP sites/projects throughout the Delaware Estuary***

Strategy W1.1: Promote infrastructure-related improvements to reduce pollutants from point-sources

Strategy W1.2: Support innovative planning and design practices to reduce nutrients from stormwater and agricultural runoff through promotion, education, and implementation

Strategy W1.3: Promote land use planning by local municipalities that prevents, reduces, and/or more efficiently manages stormwater runoff to prevent pollution

Strategy W1.4: Provide outreach and information to property owners to assist in reducing non-point sources of nutrients

Strategy W1.5: Conduct research and monitoring on nutrient impacts in the Delaware Estuary for biological and ecological endpoints

GOAL 2: Reduce Other Pollutants and Their Impacts

HOW WE WILL MEASURE SUCCESS:

- ***Reduce fish consumption advisories issues by states (DE, NJ, PA)***
- ***Reduce the discharge of contaminants***
- ***Reduce PCBs from point and non-point sources***

Strategy W2.1: Conduct outreach and technical assistance programs to reduce non-point sources of contaminants

Strategy W2.2: Promote the identification, cleanup, and revitalization of contaminated sites

Strategy W2.3: Support adaptive management and reporting of pollution reductions

Strategy W2.4: Coordinate and promote research and monitoring efforts (chemical, physical, biological) associated with the causes of water quality impacts throughout the Delaware Estuary

Strategy W2.5: Conduct and coordinate (where appropriate) education, research, monitoring, and communication about fish and shellfish consumption to protect human health

Strategy W2.6: Improve, sustain, and enhance spill communication and response with Delaware Estuary partners

GOAL 3: Sustain Flow for Drinking Water and Ecosystems

HOW WE WILL MEASURE SUCCESS:

- ***Achieve and maintain flow at key locations for the protection of downstream users***
- ***Develop and meet targets for flow/salinity for fish, shellfish, and wetlands***
- ***Improve water efficiency through water conservation projects/programs***

GOAL 3: Sustain Flow for Drinking Water and Ecosystems

continued

Strategy W3.1: Inform and collaborate with decision-makers and water resources managers to ensure that main-stem Delaware River flow meets the needs of the Delaware Estuary
Strategy W3.2: Conduct research and monitoring on water quality and habitat requirements of estuary dependent species
Strategy W3.3: Promote water conservation and water efficiency by utilities and industrial water users
Strategy W3.4: Provide outreach and technical assistance to promote water conservation and infiltration by residential and commercial users and communities
Strategy W3.5: Promote and assist in implementing Regional Sediment Management

THEME 2 | STRONG COMMUNITIES

GOAL 1: Increase Community Resilience And Access

HOW WE WILL MEASURE SUCCESS:

- ***Improve working waterfronts by reducing brownfield areas, increasing wetland areas, and supporting more visitors***
- ***Increase access to the Delaware River; sustain and enhance access to the Bay***
- ***Increase protected land for community benefits***

Strategy C1.1: Restore working waterfronts
Strategy C1.2: Provide tools and technical assistance to waterfront communities & partners to improve economic and environmental resilience
Strategy C1.3: Protect and enhance natural areas and public access
Strategy C1.4: Connect people to natural areas and waterfronts in the Delaware Estuary

GOAL 2: Improve Public Awareness And Stakeholder Engagement

HOW WE WILL MEASURE SUCCESS:

- ***Improve access to information about the Estuary***
- ***Improve the engagement of citizen scientists, stewards, and key stakeholders***

Strategy C2.1: Through marketing and communications, build awareness and brand for the Delaware River and Bay
Strategy C2.2: Utilize events to increase stewardship and engage new people
Strategy C2.3: Develop and promote programs that engage teachers and schools in stewardship of the Delaware Estuary
Strategy C2.4: Develop and promote programs with local communities and partners that foster volunteer stewardship and experiential learning
Strategy C2.5: Publish and share outreach materials and scientific results
Strategy C2.6: Engage key stakeholders to coordinate science and management of the Delaware Estuary
Strategy C2.7: Monitor, develop, and promote opportunities to assess impacts of outreach

THEME 3 | Healthy Habitats

GOAL 1: Prevent Wetland Loss

HOW WE WILL MEASURE SUCCESS:

- ***Minimize loss of wetland areas***
- ***Improve wetland conditions***
- ***Increase protected and restored wetland acres/sites***

Strategy H1.1: Establish clear baselines for tidal wetland conditions and track changes over time
Strategy H1.2: Restore, enhance, and manage tidal wetlands for maximum health and resilience
Strategy H1.3: Develop and implement natural and nature-based techniques to stabilize and restore eroding shorelines, and to build and protect wetlands, infrastructure, and other key resources
Strategy H1.4: Protect, enhance, and improve non-tidal wetlands

GOAL 2: Stem Forest Loss

HOW WE WILL MEASURE SUCCESS:

- ***Minimize loss of forest cover***
- ***Improve forest management***
- ***Increase protected and/or restored forest acres/sites***

Strategy H2.1: Inventory, map, and increase connectedness and resilience of forests for water quality
Strategy H2.2: Promote stewardship practices by local partners for the health and sustainability of forests for water quality
Strategy H2.3: Protect and manage high-value and threatened forests for water quality

GOAL 3: Increase And Improve Fish And Shellfish Habitat

HOW WE WILL MEASURE SUCCESS:

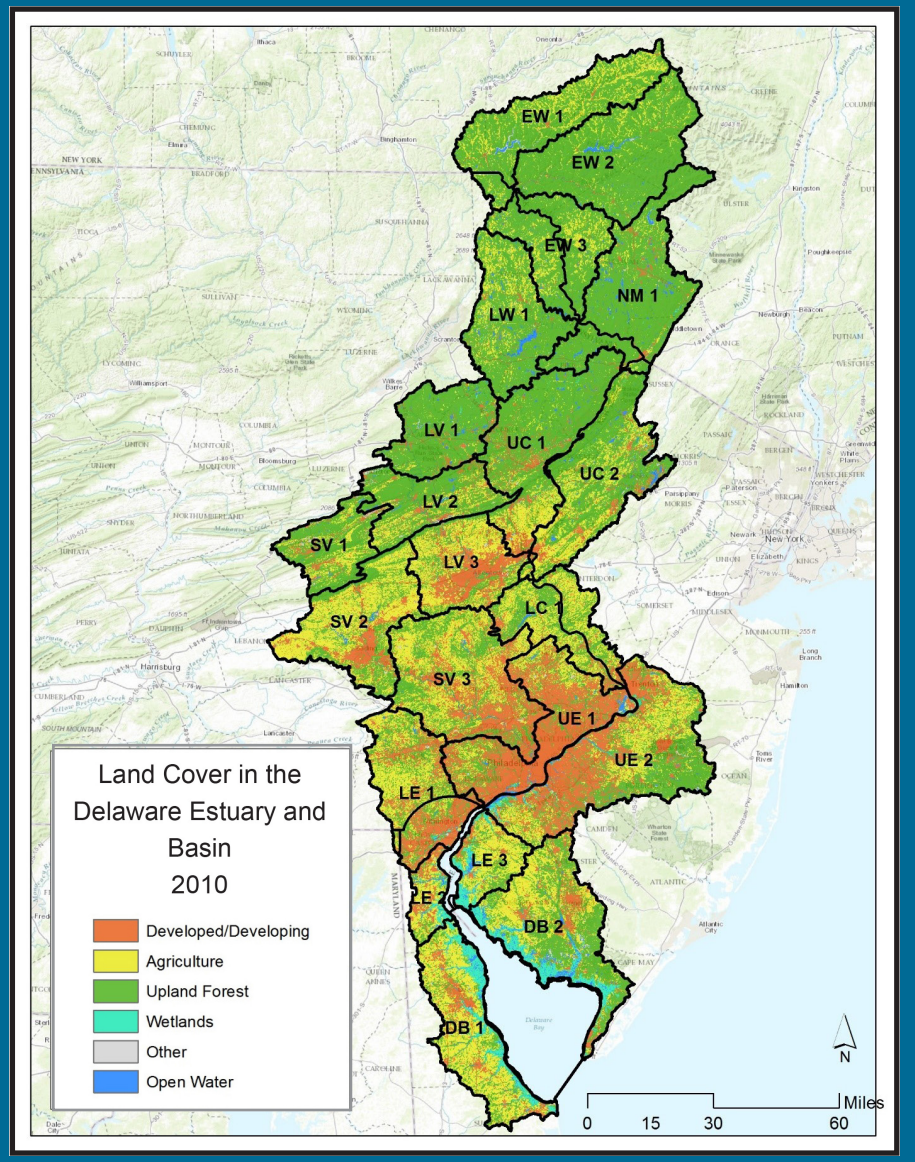
- ***Improve shellfish habitat and abundance and oyster productivity***
- ***Improve habitat for fish and crabs***
- ***Increase and improve fish/shellfish restoration projects***

Strategy H3.1: Inventory, map, protect, and enhance habitat critical for fish and crabs
Strategy H3.2: Restore oyster beds and productivity in and around the Delaware Bay
Strategy H3.3: Inventory, restore, and manage mussel populations
Strategy H3.4: Protect and restore horseshoe crabs and their habitat
Strategy H3.5: Manage and improve populations of rare, endangered, or otherwise important native species in the Delaware Estuary

Introduction & Background

THE DELAWARE ESTUARY IS A GEOGRAPHICALLY DIVERSE, AND economically and ecologically productive system. From its fresh waters at Trenton to its brackish waters at Philadelphia, Camden, and Wilmington, and its salt waters at Cape Henlopen and Cape May, the system covers a diverse set of geographies and ecological conditions. Each region is supported by unique rivers and tributaries, such as the wild and scenic Delaware River above Trenton that provides the mainstem flows necessary to sustain life in the Estuary; the mighty Schuylkill, Cooper, and Christina Rivers that fuel the growth of cities and industry in the region; and the coastal plain rivers including the Broadkill and Maurice that support farms and fisheries. These natural resources sustain vibrant communities of fish, wildlife, and people in the watersheds that surround them. These watersheds include a diversity of land uses and types, including heavily developed and industrial areas, residential areas, agricultural lands, forests, tidal wetlands, and open waters.

The Delaware Estuary is one of 28 National Estuary Programs (NEP). Created by amendments to the Clean Water Act (section 320) in 1987, the NEP provides a vehicle and resources for stakeholders to work together using the best science available to protect and enhance our nation's most important estuaries. Often seen as the non-regulatory element of the Clean Water Act, the NEP focuses on using collaboration, science, research, outreach, and education as tools to complement regulatory efforts to keep estuarine waterways clean and healthy. In 1988, the governors of the states of Delaware, New Jersey, and Pennsylvania nominated the Delaware Estuary Program (DELEP) for inclusion in the NEP, and the Delaware Estuary Program Management Conference was convened officially in July 1989.

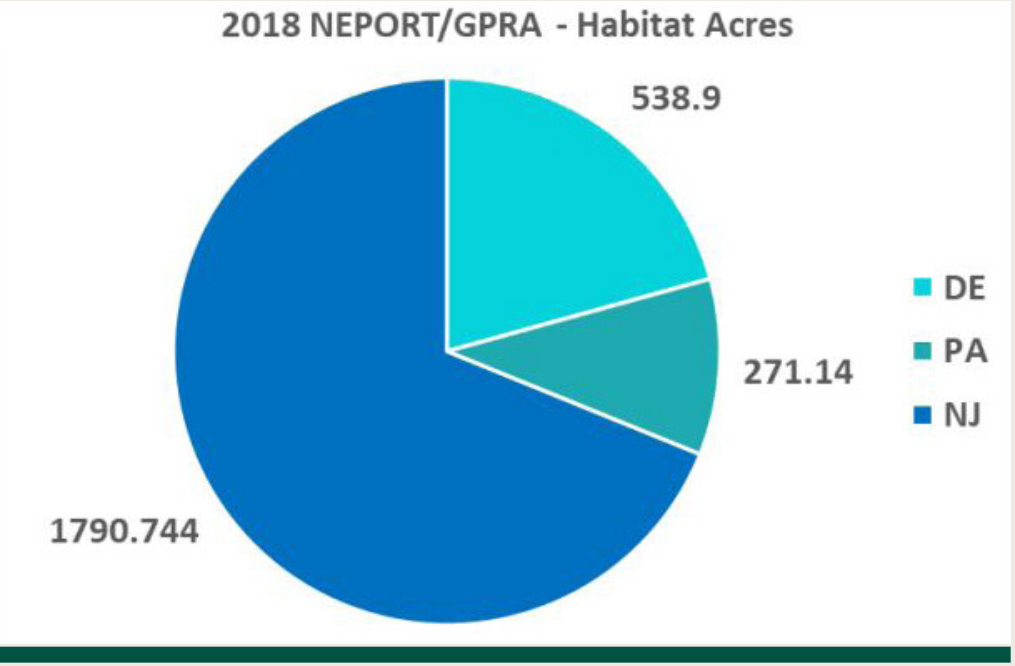


Land Cover Category	Developed/Developing	Agriculture	Upland Forest	Wetland	Open Water	Other
% of Basin	16.3%	24.4%	47.4%	9.4%	2.1%	0.4%

Distribution of land cover types across the Delaware Estuary and Basin. See 2017 TREB Section 1.2 Current Land Cover for more information.

As part of the process of designating the Delaware Estuary a NEP, hundreds of stakeholders worked together over many years to develop a Comprehensive Conservation and Management Plan (CCMP) for the Estuary that was approved in September 1996. The CCMP was intended to guide the collective efforts of environmental agencies and organizations in the region to protect and enhance the tidal Delaware River and Bay. The CCMP included over 77 actions in the areas of land management; water use management; habitat and living resources; toxics education and involvement; and a monitoring/regional information management system (RIMS) for a wide variety of federal, regional, and local agencies and other partners to undertake (see Original CCMP).

To implement this plan, environmental agencies and stakeholders from around the region, including the federal government, Commonwealth of Pennsylvania, and the states of Delaware and New Jersey, formed a Management Conference and pledged to work together to implement the actions in the CCMP. The Management Conference became known as DELEP. The "Evolution of Partners" section below provides more information on the evolution of DELEP partners and its committees.



2018 Habitat acres restored/protected by state as reported by Core Partners for the Government Performance and Results Act (GPRA) using the National Estuary Program Online Reporting Tool (NEPORT).

Over the years, both DELEP and the Delaware Estuary have undergone many changes. For example, scientific research, Hurricane Sandy, and other meteorological events have heightened our understanding and awareness of vulnerabilities associated with climate change significantly. Despite these and other changes and advancements, the CCMP has been a remarkably effective tool for DELEP for over two decades. Its successes included working to protect and enhance over 44,000 acres of fish and wildlife habitats and leveraging over $86.7 million for water quality and habitat improvement efforts in just the past 10 years. These acres and dollars are collected and reported annually to the U.S. Environmental Protection Agency (EPA) through the Government Performance and Results Act (GPRA) reporting process, using the National Estuary Program Online Reporting Tool (NEPORT).

Why Revise the CCMP?

The EPA indicated that tracking mechanisms and measurable goals are critical in understanding short- and long-term trends in water quality improvement. In its 2009 DELEP program evaluation, the EPA encouraged establishing better defined measurable goals and improved tracking. In response, the Partnership for the Delaware Estuary (PDE) assessed the status of CCMP implementation with the Estuary Implementation Committee (EIC) and Science and Technical Advisory Committee (STAC) in 2012. This assessment found that the original CCMP's overarching vision and goals presented below were still relevant and applicable:

Environmental and economic improvements, brought about by the cooperatives efforts of private citizens, industry, environmentalists, and local, state, and federal governments;

An adequate water supply for the 21st century and beyond, with improved water quality conditions for all living things and sustainable use of aquatic resources;

A watershed approach to management that values interconnected habitats, preserved land, and planned efforts to protect and enhance the Estuary's natural resources, while maintaining the economic viability of the region;

Increased public education and involvement through timeline, accurate, and accessible information provided to the public regarding all known and planned activities that may significantly affect the watershed;

An expanded number of public access points within the Estuary watershed and increase, but ecologically responsible, use of these public access facilities.

The 2012 assessment also found that the vast majority of the 77 actions in the original CCMP were still valid and some were completed or still ongoing (although some of the details were outdated, such as who was responsible for the action, when it would be completed, and the way it was being implemented). However, a few actions were sufficiently outdated to require immediate attention. These changes were made with the Steering Committee's (SC) approval and posted online (see 2013 CCMP updates).

This assessment also confirmed the need to track and measure results from the original CCMP more effectively and efficiently. This tracking challenge stemmed largely from two issues: the breadth of partners with implementation responsibilities in the CCMP who were not accountable directly to the Management Conference, and the inconsistency of the level at which the CCMP was written (i.e., some actions were very detailed, others very general).

To address this need, the Management Conference developed a set of measurable goals in 2013 derived from the original CCMP objectives to provide a basis for tracking progress over time. Subsequently, the EPA issued new requirements for CCMP updates and revisions for all NEPs as part of its FY15-16 guidance document. In response, the Management Conference decided to revise the CCMP for the Delaware Estuary to focus on actions that could be implemented during the next 10 years, using the following process and principles:

- Start with measurable goals that came from the original CCMP and was informed by State of the Estuary work (further described below);
- Develop more consistent strategies to consolidate activities under a common goal;
- Streamline the CCMP to focus on achievable activities and capabilities of today's Management Conference and partners;
- Identify systems and responsibilities to track implementation over time that are feasible considering current/anticipated resources;

Thus, the three themes of clean waters, healthy habitats, and strong communities became the organizing framework for the revised CCMP. The actions in the CCMP are those experts and stakeholders identified as the most important to address these goals, given the watershed's characteristics and needs.

Of course, there are other compelling reasons to revise a 20-year-old plan, including changes in the Delaware Estuary and in the people and organizations working to improve it, advances in understanding of current and future opportunities, and threats to its health and productivity. Revising the CCMP provided the opportunity to address all of these.

The Evolution of Partners

Since the DELEP was created in 1988, the partners and their roles and responsibilities have evolved considerably. At the heart of the Management Conference is a set of core partners committed to implementation of the CCMP through a written agreement. Originally, these Core Partners included EPA through its Regions 2 and 3; the Commonwealth of Pennsylvania, through its Department of Environmental Protection (PADEP); the State of New Jersey, through its Department of Environmental Protection (NJDEP), and the State of Delaware, through its Department of Natural Resources and Environmental Control (DNREC). Over time, the Delaware River Basin Commission (DRBC), the Philadelphia Water Department (PWD), and PDE were added to this core group of partners (see 2014 DELEP Partner Agreement).

DELEP's leadership also has evolved. Originally, the states (DE, NJ, PA) rotated leadership and alternated administering EPA funds to support partner coordination to implement the CCMP. When the DRBC joined the Core Partners, it became the ongoing "host," providing administration and coordination, including filling a critical monitoring role. PDE was established as a non-profit organization in 1996 to serve as DELEP's education, outreach, and fundraising non-profit. In 2004, PDE joined the Core Partners and assumed the host role. Since then, PDE has expanded its programs and capabilities beyond outreach and fundraising significantly, filling vital needs related to scientific coordination, research, monitoring, and restoration. By convening diverse workshops, scientific conferences, and teaching curricula, PDE has become DELEP's public face. These efforts now complement and help coordinate long-term DELEP partners', such as the DRBC, continued work, which continues to lead and coordinate the CCMP actions related to water resources. Thus, the DRBC fills a critical water resource management and monitoring role and works closely with the other Core Partners.

Today, these Core Partners have standing representation on the SC, EIC, and STAC, all of which PDE coordinates. The SC consists of top management officials from the seven organizations that comprise DELEP. The EIC includes those organizations and may

A CCMP for the Future – The Process of Revising the CCMP

Inputs from partners outside the Management Conference have helped shape PDE and DELEP's priorities and strategies over the years. Some of these partners are engaged through collaborations such as the Schuylkill Action Network, South Jersey Bayshore Coalition, and the Christina Basin Clean Water Partnership & Task Force. Others are involved through such topically organized collaborations as the Delaware Bay Oyster Restoration Task Force, the Delaware Living Shoreline Committee, New Jersey Coastal Collaborative, and the Aquatic Research and Restoration Center partnership. Further, others are involved through individual projects with communities and corporations. PDE's work with local partners has grown and intensified over the years and provides an important avenue for these stakeholders to engage in activities in the Delaware Estuary that shaped the revised CCMP' priorities and strategies.

Involving these stakeholders, as well as the Management Conference, and using the best science available informed by the STAC's many contributions and others over the years, was a major focus in the CCMP revision process. This process began in late 2016 with a series of thematic workshops to obtain input from hundreds of experts on the strategies needed for clean water, healthy habitats, and strong communities. The process continued in early 2017 when these experts assessed these strategies' vulnerability to climate change's effects. In mid-to-late 2017, the process continued with a series of open-house-style workshops and targeted meetings for local partners and interested members of the public to provide input on these strategies (see Phase 2 Stakeholder Engagement Summary Report). Contributions

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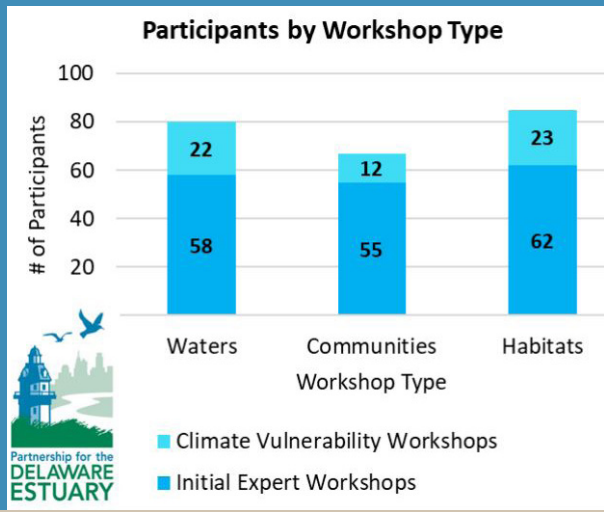
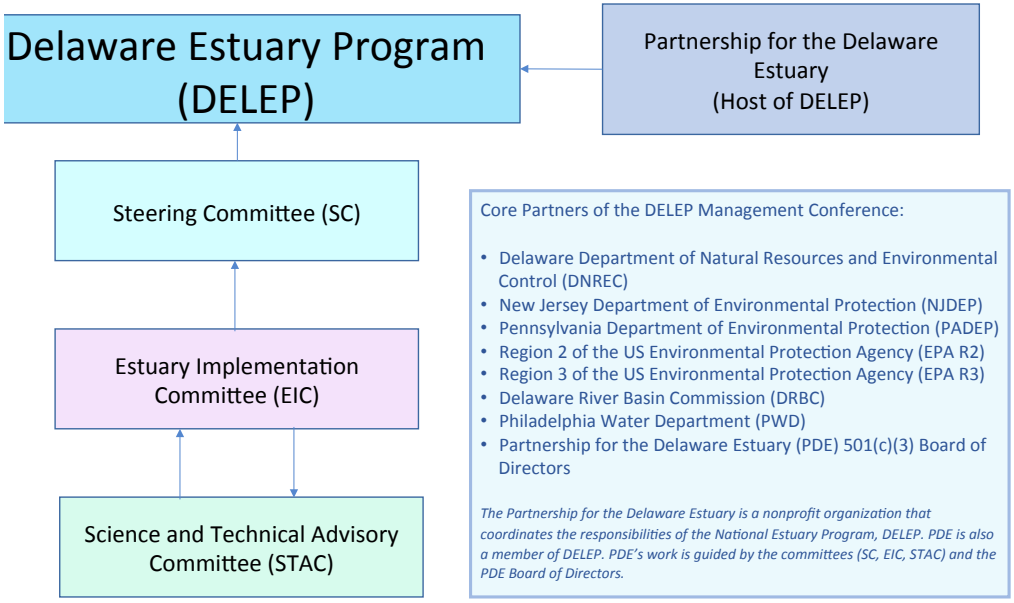


Participation in CCMP expert and climate vulnerability workshops, by workshop type.

include additional agency and stakeholder representatives, provided they receive consensus from the EIC. Currently, additional members include representatives from the U.S. Fish and Wildlife Service and the National Park Service. The STAC consists of 21 members, including seven standing representatives of the core DELEP partners and 14 elected representatives from different sectors of the scientific community. The Chairman of PDE's Board of Directors represents PDE on the SC. The Board includes up to 20 elected representatives from the private and/or local sector, which complements the EIC's interests in a robust public-private partnership. Together, these entities—the SC, EIC, STAC, and Board—comprise the Management Conference.

More detailed information on DELEP's history and structure is available in the form of a Frequently Asked Questions document available online (see NEP DELEP Frequently Asked Questions [FAQ]).

The Management Conference works closely with a wide variety of partners to undertake



Delaware Estuary Program (DELEP) Organizational Chart

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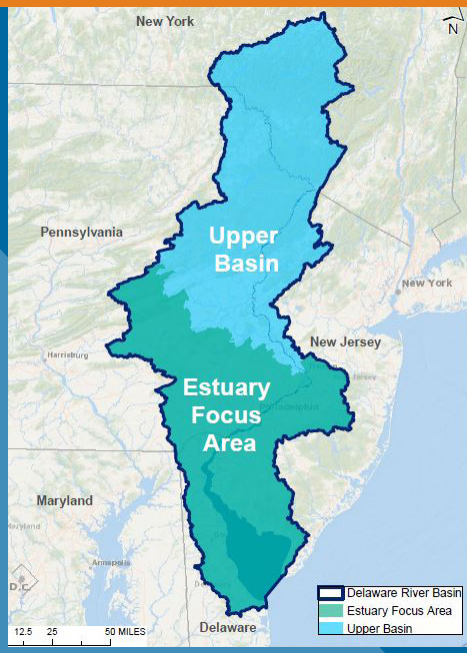
from these workshops shaped the CCMP strategies and their key activities' development into a full draft revised CCMP. After a review by Core Partners, a draft was posted online for a 60-day public comment period. Because of the ongoing opportunities for the public to provide input throughout this process, few formal public comments were submitted, although the comments received still resulted in several minor changes in the plan (see Revised CCMP Public Comment Period Summary Report).The Management Conference provided detailed guidance and input in each phase in this process, which engaged over 230 expert participants from over 70 organizations, and nearly 300 additional partners and members of the public.



Focus area for the Delaware Estuary Program (DELEP).

The result is a revised CCMP that PDE and the Management Conference have committed to implement with support and collaboration from the broader community of local, state, regional, and federal partners, as well as the private sector.

While the revised CCMP was he Core Partners agreed that revising the CCMP line by line was not only impractical, but also would not address key concerns about the original plan, which included a lack of focus, inconsistencies, and ambiguous levels of accountability.

Instead, partners chose to use the measurable goals framework developed from the original CCMP as a starting point for the revision. After a core set of strategies was identified through expert input, they were compared to the actions in the original CCMP to ensure that the revision would address critical elements (see CCMP Index of Actions).

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on-the-ground projects and programs to implement the CCMP. These include a growing number of sub-watershed collaborations that coordinate or participate with one or more Core Partners, or can include one or more ad-hoc partners on specific projects or programs. This is a necessity in a watershed as large and diverse as the Delaware Estuary

The CCMP is a plan for all partners, not only the Core Partners.

Ideally, the CCMP helps guide all partners' actions in their efforts to protect and enhance the Delaware Estuary and relies on resources beyond those of the Core Partners and the Management Conference. However, strategies included in the CCMP must have a meaningful nexus to Core Partners who are willing and able to provide some measure of their success to ensure that results can be tracked.

No explicit changes are proposed to the Management Conference as a result of revising the CCMP. However, the revision process generated significant conversation among Core Partners about the need to explore new ways to engage stakeholders in vulnerable communities and the importance of seeking feedback from local partners and stakeholders on work-plan priorities. PDE has had more success involving local stakeholders through the biennial Science and Environmental Summit, but it recognizes that this mechanism does not reach some key stakeholders. Developing an effective engagement mechanism to address this need is included in the strategies of this revised CCMP.

State of the Estuary

Over the 20 years since the original CCMP was created, some important contributions have been made that improve our understanding of the Delaware Estuary and its watershed. Perhaps the most important has been continuing research and studies that improved the data and information available on the status and trends of health indicators for the Delaware Estuary.

An initial The State of the Estuary Report was completed as part of the 1996 CCMP. Since then, PDE has led the creation of *The State of the Estuary Reports* in 2002, 2008, and 2012, with significant improvements each time. The 2012 report was grounded in a new technical compilation, referred to as *The Technical Report for the Delaware Estuary and Basin* (TREB). The STAC led the TREB with support from DRBC's Monitoring Advisory and Coordination Committee (MACC) and other scientific contributors. It compiled, analyzed, and interpreted data on more than 50 environmental indicators' status and trends. Results from the 2012 TREB provided the foundation for the subsequent public-friendly *The State of the Estuary Report* and DRBC's *The State of the Basin Report.*

To ensure that the goals, strategies, and actions in this CCMP revision are grounded similarly in science and reflect current conditions in the Delaware Estuary, the STAC, MACC, and others representing academic, agency, and non-profit entities worked to prepare the 2017 TREB. Similar to the 2012 TREB, this online document summarizes the status and trends associated with more than 50 indicators, including future projections and actions recommended to improve conditions and track changes. State of the Estuary reporting (beginning with the original CCMP, and most recently, the 2017 TREB) provides a detailed picture of the Estuary, its conditions over time, and the way various stressors affect resources.

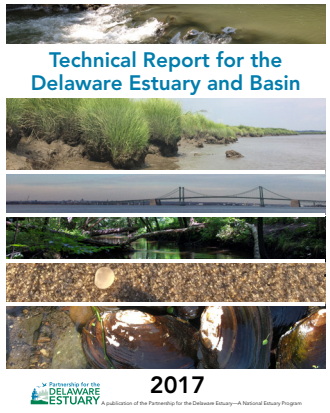
Generations of State of the Estuary (SOE) (Cover pages for State of the Delaware Estuary 2002, 2008, 2012 reports in chronological order from top to bottom).

TREB status and trends data were instrumental in guiding the development of CCMP strategies for the next 10 years. Here are a few resource-specific examples:

- The 2017 TREB revealed that several hundred acres of coastal wetlands are being lost annually, and projected that this rate will increase as sea levels rise at increasing rates. As a result, the revised CCMPs goals for tidal wetlands are designed to minimize loss, and achievable CCMP actions for the next 10 years focus on protecting wetlands in critical locations, improving understanding of the causes of wetland degradation and loss, and developing new tactics to enhance coastal wetlands cost-effectively to slow loss rates.
- Data in the 2017 TREB also revealed that migratory fish can now access 100 miles of rivers that dams blocked formerly, suggesting that further improvements are attainable. Hence, the revised CCMP includes strategies to extend this success and improve passage for a variety of fish further.
- Tracking forest cover as an indicator beginning in 2008 and continuing in 2012 and 2017 led DELEP partners to recognize that forest loss in the basin is a potential threat to water quality in the Estuary. The TREB noted the accelerated rate of forest loss from 1996 to 2010 and its likely effects on water quality downstream. This led to including strategies in the revised CCMP to stem forest loss basin-wide (as discussed below).

The results of the Technical Report for the Delaware Estuary and Basin [TREB] are vital for measuring progress made toward implementing the CCMP. Completed in the winter of 2017, this report analyzes current data on environmental indicators across the Estuary and Basin. By tracking indicators and assessing their status and trends every 5 years, periodic revisions and updates to CCMP goals can be responsive to changing conditions.

Partnership for the Delaware Estuary, 2017. Technical Report for the Delaware Estuary and Basin 2017. L. Haaf, S. Emberger, D. Kreeger, and E. Bambaugh (eds). PDE Report No. 17-07. 379 pages.



2017 Technical Report for the Delaware Estuary and Basin (TREB).

cont'd from page 5

This process also enabled partners to create a CCMP that is:

More focused and trackable. Using the measurable goals framework as a starting point helped make trackable results a focus for the revised CCMP. Attention was paid to relating strategies back to goals, ensuring that goals are measurable, and identifying accountable partners and roles for the strategies included in the revised CCMP and throughout the process.

More consistent. In revising the CCMP, efforts were made to keep all strategies at a consistent and sufficiently high level to cover a broad geography and timeframe, but specific enough to provide clear guidance and focus. For some strategies, this meant less detail was required than in the original CCMP; for others, it meant more. This consistency also will make it easier to track the results.

Shorter and more reader-friendly. The Core Partners agreed that a shorter and more organized document would be easier to reference and use. The revised CCMP includes public-friendly language and graphics that communicate the work to the public more clearly and simply. The revised CCMP also is linked to a number of documents that are available online for those who want additional details.

More geographically inclusive. The geographic area considered for this estuary management plan considers the full extent of the Delaware River Basin, which drains into the Delaware Estuary ultimately. In the original CCMP, the study area was limited to the lower half of the Basin, where over 80% of people in the Basin live (Partnership for the Delaware Estuary [PDE], 2017). The revised CCMP does not propose to change the study area, but to consider it the Estuary Focus Area within the Delaware River Basin instead. This acknowledges that this area will continue to be the focus of DELEP partners' work together, while also recognizing DELEP partners' need to consider upstream areas in Estuary resources management. Driven by these needs, work by PDE and DELEP partners has expanded beyond the Estuary Focus Area in cases where Estuary priorities require it and where there are partners and resources to support it.

Navigating the Revised CCMP

In addition to guiding specific CCMP strategies with resource-specific data, the climate chapter of the 2017 TREB was essential in understanding whether, and in what way, CCMP strategies needed to consider changing climate conditions. For example, projected changes in temperature provided the basis for more ambitious goals for intertidal oysters in living shoreline projects to reduce freezing winter kills. These changes led to more tempered goals for some freshwater mussel species with a lower tolerance for warmer water and greater stormwater runoff. Understanding key environmental indicators' status and trends is paramount to set achievable goals that reflect changing ecological baselines.

Over the years, PDE also has worked with STAC partners to contribute other significant scientific works that informed the priorities articulated in the revised CCMP. The 2005 *White Paper on Science and Technical Needs in the Delaware Estuary* was the outcome of a two-part conference on science and management that identified the Estuary's top 10 needs. The 2008 *Regional Restoration Initiative (RRI) Blueprint* proposed a set of regional restoration priorities based on the ecosystem services' values (i.e., "natural capital"). The 2010 *Climate Change in the Delaware Estuary* report assessed climate vulnerabilities and ranked climate adaptation options for three key Delaware Estuary resources: drinking water, shellfish, and tidal wetlands. All of the research above was factored into the development of measurable goals for the Delaware Estuary in 2013, which provided the framework for this CCMP revision.

Other important works PDE commissioned during this timeframe were of a social science and/or planning nature. These included an assessment of *Financing Opportunities for the Delaware Estuary* the University of Maryland's Environmental Finance Center completed in 2007 that helped shape the priorities of PDE's first Strategic Plan 2007-2013. An assessment of the Economic Value of the Delaware Estuary the University of Delaware's Water Resources Center completed in 2011 helped reframe the Estuary's value in economic terms and shaped PDE's second Strategic Plan 2013-2018.

These are just a few key pieces of work that have shaped the PDE and DELEP's priorities and strategies over the past 20 years using the best science and information available that led to the revised CCMP. The full array of DELEP and PDE publications, including all State of the Estuary reports and Estuary News issues, are available online at www.DelawareEstuary.org.

Camden, NJ | Credit: Richard Fallstich

Themes

The revised CCMP is organized according to three themes: Clean Waters, Strong Communities, and Healthy Habitats, each of which includes a brief introduction to the theme and each of its goals. Two to three goals address specific problems for each theme. Within each of these goal areas is a suite of strategies to help achieve them. Each strategy uses a similar format for consistency and identifies the partners necessary to implement the strategy.

PDE staff and partners shucking oysters at the annual Experience the Estuary Celebration marking PDE's 20th Anniversary in October 2016. | Credit: PDE

While each goal has its own section in the CCMP in which strategies are grouped and organized, it is important to note that many strategies serve to achieve multiple goals. For example, actions to restore wetlands and shellfish (which are in the Healthy Habitats section of the CCMP) not only improve habitat, but also reduce nutrients for clean waters, and protect shorelines for strong communities. In this way, the three themes are meant to be mutually supportive, not mutually exclusive. The highest priority actions for PDE

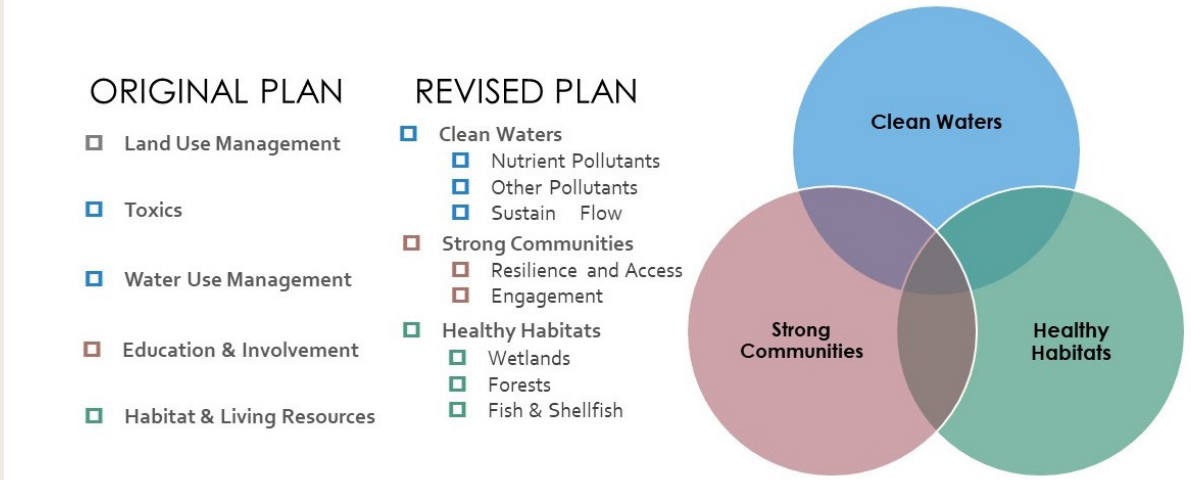
and collaboration among DELEP partners are those that are at the intersections of the ven diagram at right, and address multiple goals.

Partners

To promote consistency and define the partner organizations' roles, responsibilities, and expectations clearly, the following definitions were used to characterize the partners in the revised CCMP:

- Core Partners are organizations on the SC that are committed through a written agreement to work together in DELEP and provide strategic direction for the design and implementation of the CCMP. These Core Partners contribute directly to the strategy and action implementation by providing time, expertise, information, funds, and other resources to support successful implementation. They also contribute information needed to track implementation of strategies and actions over time.
- Key Partners are organizations that work closely with Core Partner organizations and others to implement actions that support the CCMP strategies. They are not represented on the SC (although some may be represented on the EIC) and may not formally have expressed a commitment to support CCMP design and implementation or track and report results. Nonetheless, their work is essential to the CCMP's successful implementation and PDE and Core Partners consulted and coordinated with Key Partners regularly. In most cases, Key Partners also contribute information needed to track implementation over time, directly or through a Core Partner.
- Contributing Partners are organizations or other entities the missions and actions of which support the Delaware Estuary's healthy waters, communities, and habitats, and therefore contribute in meaningful ways to achieve the CCMP's goals. However, these organizations may or may not coordinate directly with PDE or Core Partners in taking those actions. They also are not expected to contribute information to track CCMP implementation over time (although they might in some specific cases).

Contributing Partners and Key Partners will evolve over time.



1996 Original CCMP action plans and 2018 Revised CCMP goal areas.

External Constraints

Another important element most strategies address are external constraints that could affect success and are beyond the Core Partners' control. Funding, political will, and changing watershed conditions are recognized as potential external constraints for all strategies in the CCMP, even if not stated explicitly in each. Where there are particular ways in which these (or other) external constraints will affect a strategy, that information is included at the end of the description section.

Climate Change

DELEP partners acknowledge climate change as an overarching issue that is important to consider for all aspects of the CCMP. During a series of climate vulnerability workshops, attendees considered climate change's effects for each strategy by completing a vulnerability assessment as part of the revision process (see Climate Vulnerability Assessment Report). For strategies in which significant effects are anticipated in the short term, these are mentioned as external constraints. For others, the goals, objectives, and strategies themselves were formulated to address climate change effects based on the "2010 Climate Change and the Delaware Estuary" study.

Environmental Justice

DELEP partners also acknowledge environmental justice as an overarching need important for all aspects of the CCMP to consider. The Strong Communities section includes a commitment to environmental justice, as well as key activities in each strategy to act on this commitment. However, environmental justice and promoting diversity, equity, and inclusion will be applied to all CCMP implementation activities.

Focus on Non-Regulatory Approaches

An important element that the CCMP strategies do not address directly, but is critical to recognize, is regulatory programs' and actions' role in meeting the CCMP's goals. Regulatory programs, infrastructure improvements, and treatment and technology-driven regulations have been major reasons for improvements in water quality in the Delaware River and Bay since the formation of the Delaware River Basin Commission (DRBC) in 1961 and the passage of the federal Clean Water Act in 1972. Wetland regulations, total maximum daily loads (TMDLs) for different types of pollution, and plans to meet those requirements, as well as regulations on water withdrawals, wastewater discharges, and stormwater, are just a few of the many regulatory efforts that have driven, and will continue to drive, improvements in the Delaware Estuary's health. Most DELEP partners are agencies that play a significant regulatory role; however, the focus of their work together in DELEP is decidedly non-regulatory. There was an intentional effort to refrain from including regulatory actions in the revised CCMP, which must follow a different set of rules and process. Relatively early in the CCMP revision process (2016), the Steering Committee agreed that:

The revised CCMP should not include actions that involve making new regulations or amendments to existing regulations. It should include actions that are complimentary to and supportive of regulatory objectives, e.g., through management strategies, outreach and education, research and monitoring, and coordination of activities, among others.

Throughout the revision process, DELEP partners and stakeholders were challenged to identify ways to use non-regulatory approaches to address many of the same objectives also being addressed by regulation. Thus, in collaboration with the regulatory agencies, the program will continue its efforts to support the Clean Water Act's core programs, such as water quality standards, TMDLs, National Pollutant Discharge Elimination System, nonpoint source pollution (NPS), and wetlands protection.

A Living Document

The revised CCMP is intended to be a living document that will be revisited periodically (at least every 10 years) to adapt to current conditions. Core Partners recognize that new environmental challenges, ideas, and projects will emerge over the course of the next 10 years and will be worthy to pursue, so partners will work

together to determine whether these new ideas and projects warrant changes to the CCMP.

Tracking Progress on Implementation

Core Partners will track progress on, and results of, CCMP implementation on an annual basis using a simple spreadsheet-based tool that will collect and compile data from partners based on lessons learned here and in other national estuary programs (NEP). For maximum efficiency, PDE will modify and use the current process to report habitat restoration projects and leverage partners' data, as described in the Monitoring Approach section. The Core Partners will use this tool and system to contribute to PDE information on their implementation efforts, using "projects" as the primary deliverable and metrics to show the scale/results of each (e.g., acres, linear feet, people, data, reports, etc., depending on the type of project). The project types and metrics will be defined in the tool created to gather this information so that results can be compiled and reported easily across partners, projects, and geographies. The EIC and STAC will review the information collected annuallyto help plan and guide work for future years.

Costs and Funding of Implementation

Each strategy includes an estimate of the cost of implementation over 10 years using symbols to provide a range and identifying possible sources of funding. We provide a key to the symbols used to estimate cost levels for each strategy below. Ranges (and sometimes ranges of ranges) are broad, given the breadth of strategies, variety of partners involved in implementing them, and extent of unknowns over a 10-year timeframe. In most cases, the symbols are based on best professional judgment and current known costs provided by DELEP partners, and may not capture the full costs likely to be funded by other programs for other reasons (e.g., the construction of a wastewater treatment plant). Estimating costs in which significant improvements for traditional or innovative infrastructure are expected was particularly challenging. Infrastructure costs are high and likely to be funded/financed in some way other than with NEP funding; however, infrastructure effects also are high and DELEP partners felt that these investments should be recognized and included in some way.

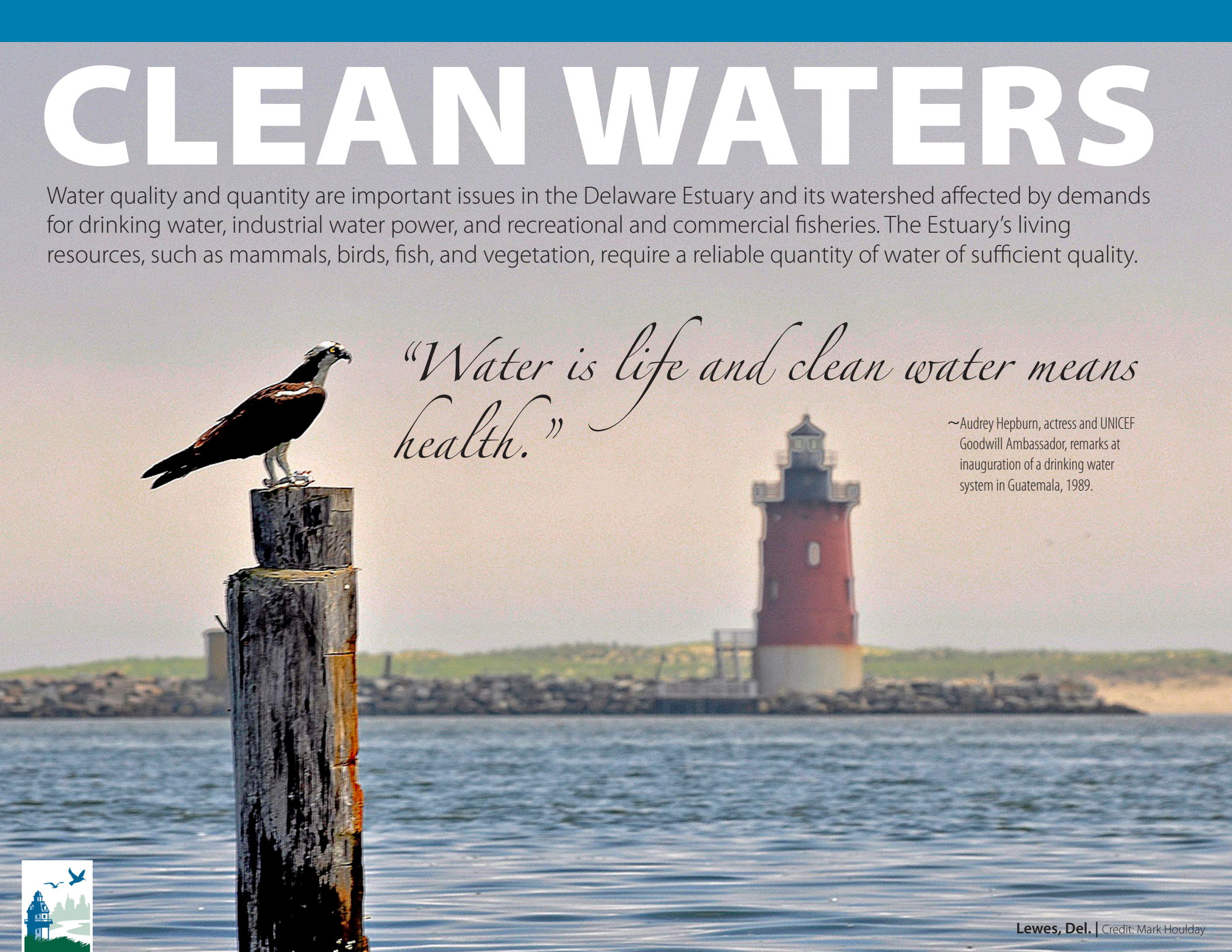
Possible sources of funding were identified based largely on past experiences and DELEP partners' knowledge of funding sources. NEP funding is a potential source of funding for any of the strategies in the CCMP. However, it is identified mainly as such for strategies that traditionally have been heavily reliant on it, because of the central role these strategies play in meeting NEP requirements, and/or because they are unlikely to be funded in other ways (please see the Finance Strategy section for more details on funding/support).

Key to Cost Estimate Symbols

Low End of Range	High End of Range	Symbol Used
50,000	500,000	$
500,000	1,500,000	$$
1,500,000	5,000,000	$$$
5,000,000	15,000,000	$$$$
15,000,000	150,000,000	$$$$$
150,000,000	500,000,000	$$$$$$

CLEAN WATERS

Water quality and quantity are important issues in the Delaware Estuary and its watershed affected by demands for drinking water, industrial water power, and recreational and commercial fisheries. The Estuary's living resources, such as mammals, birds, fish, and vegetation, require a reliable quantity of water of sufficient quality.



"Water is life and clean water means health."

~Audrey Hepburn, actress and UNICEF Goodwill Ambassador, remarks at inauguration of a drinking water system in Guatemala, 1989.

Lewes, Del. | Credit: Mark Houlday

CLEAN WATERS GOAL 1

REDUCE NUTRIENT POLLUTION AND ITS IMPACTS

Nutrients are necessary to support a sound and robust aquatic ecosystem, but in excess, they can affect water quality and aquatic life adversely. Nutrients serve as fertilizers that increase algae and other aquatic plants' growth (biomass). Excessive algal growth and resulting algae bloom decomposition can decrease oxygen in waters to levels that are dangerous to aquatic life. These detrimental effects may cause increases in water treatment costs; degradation of wetland health, and effects on boating, fishing, and other recreational activities. Harmful algal blooms (HABs) have presented public health concerns in other parts of the country recently where there have been toxins detected in certain species of algae. Fortunately, toxic algal blooms have not been a major concern in the Delaware Estuary itself, even though they have been identified in smaller, slow-moving bodies of water (e.g., ponds and lakes) in areas of the upland watershed.

The recovery of the Delaware River is a clean water success story: biological and nutrient reductions from wastewater treatment system improvements led to improved DO and the return of fish to urban stretches of the river. | Credit: Andre Cole

Nutrients such as nitrogen and phosphorus enter the Delaware Estuary through point sources such as discharges from industrial and municipal wastewater treatment plants, as well as nonpoint-source runoff. The effect of ammonia, one type of nutrient discharged from industrial and municipal wastewater treatment plants, is of particular concern in the Estuary, as it leads to lower dissolved oxygen. A related concern is ammonia's direct toxicity to aquatic life, as it can be toxic at high levels. Nutrients from turf fertilizer and animal manure also contribute to pollution via runoff from farmland and residential yards to surface waters (See TREB Chapter 1 for more information on land use in the watershed).

From the early 20th century through the 1980s, a dead zone persisted in the urban reaches of the Delaware Estuary between Philadelphia, Camden, and Wilmington. The local community referred to this zone as the "pollution block" because oxygen-

depleted waters prevented fish from migrating freely. Requirements the DRBC imposed in the late 1960s, followed by implementation of the 1972 Clean Water Act, led to improvements in wastewater discharges. By 1984, significant upgrades in municipal sewage treatment plants reduced pollutants found in wastewater by 95%, and by the mid-1990s, dissolved oxygen in the Estuary achieved targets set in the late 1960s. As a result, the dead zone and pollution block disappeared and fish returned to the urban Delaware Estuary. DRBC and the states (DE, NJ, PA) now are evaluating whether or not to revise water quality standards to a level that would support fishes' spawning and survival, including striped bass, American shad, and the endangered Atlantic sturgeon. Land-use planning and best management practices (BMP) on farms and lawns also are being used to reduce nutrient runoff, which is increasingly important as the human population in the coastal zone continue to increase.

Through all of these efforts, fish populations are rebounding as dissolved oxygen in the Estuary's waters has improved, although nutrient levels are still some of the highest in the United States.[11] To continue improving nutrients' control in the Estuary, DELEP and its partners need to conduct further studies of nutrient dynamics to examine whether and in what ways critical nutrient parameters are related to impairments in tributaries, tidal wetlands, and other aquatic resources. Treatment technologies, nonpoint-source BMPs, and other often costly controls are available to reduce nutrients significantly.

HOW WE WILL MEASURE SUCCESS:

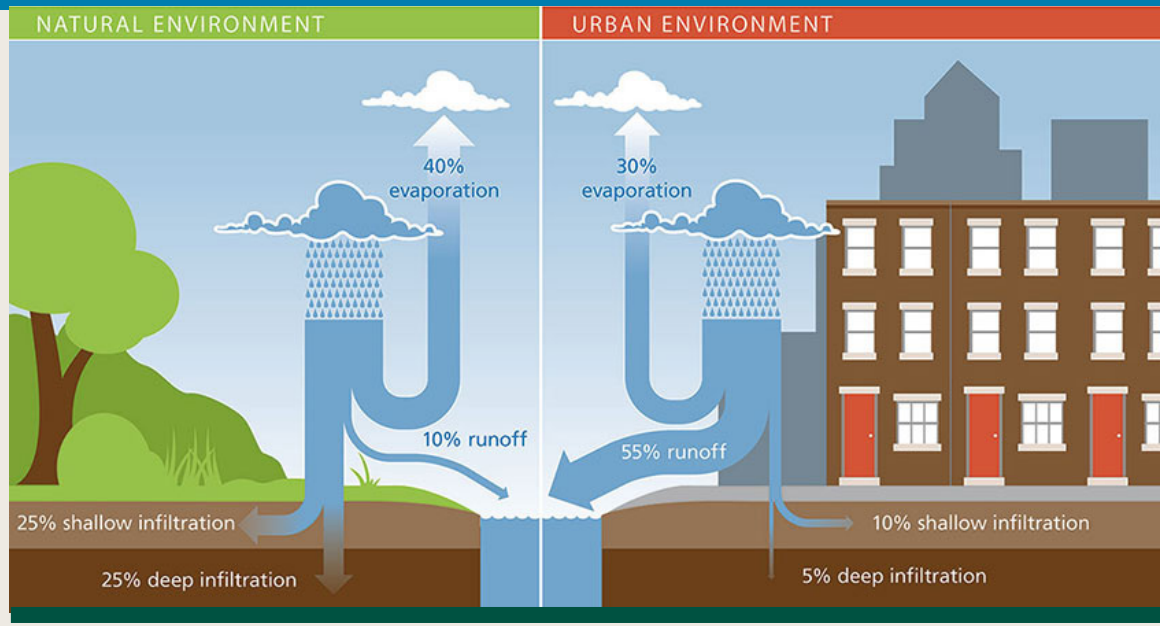
- Continuing progress to increase dissolved oxygen levels in the Estuary
- Progress to improve ecosystem health in the Estuary by addressing other nutrient-related impacts
- Decreases in nutrients in the Estuary and its tributaries
- Increased installation of non-point source nutrient BMP sites/projects throughout the Estuary

Camden, NJ | Credit: Dumitru Tomsa

STRATEGY W1.1: Promote infrastructure-related improvements to reduce pollutants from point sources

Description

Capital investments of over $2.0 billion in the widespread construction and operation of wastewater treatment infrastructure led to historical improvements in estuarine water quality, particularly dissolved oxygen. While great improvements in water quality have been observed since the 1970s, we need to continue working to reduce nutrient discharges. To do this, we need to review and reconsider existing wastewater treatment infrastructure, funding, and the implementation of new technologies.



The effect of urbanization on the water cycle. Land development (construction of new buildings, roads, parking lots) can lead to increased stormwater runoff and pollution. | Credit: PWD

To work to reduce targeted parameters further, PWD and other large regional municipal utilities will share strategic utility planning and technology evaluations, while regional regulatory agencies consider changes in water quality criteria. Infrastructure capabilities, limitations, and affordability are critical to reduce pollutants in the Delaware Estuary further in the future. Core partners and collaborators will work to implement the following activities to advance widespread adoption of best technologies available to reduce nutrient pollution from urban areas:

- **Promote the use of green infrastructure tools and techniques.** The City of Philadelphia's *Green City, Clean Waters* program is a good example of the way to reduce runoff to stormwater and combined sewer systems using widespread implementation of green infrastructure. By using strategic combinations of green infrastructure tactics, including pervious pavements, green roofs, and tree trenches, PWD is reducing the stormwater that runs into the combined sewer system and overflows from the system into local streams, thereby reducing nutrients. PWD and partners will continue to advance these tactics' use in Philadelphia and promote their use in other communities (particularly in municipal separate storm sewer system [MS4] communities) to improve nutrient reductions.

- **Promote research and development of nutrient reduction and impact mitigation techniques.** Identify and share among partners and collaborators the techniques to reduce pollutants in wastewater discharges while identifying opportunities to enhance the aquatic environment and reintroduce targeted species. PWD will work with PDE and other partners to explore opportunities to use green infrastructure to reduce nutrient effects, both in and out of the water. Recent research by PDE suggests that natural habitats, such as tidal wetlands and beds of freshwater mussels, can help reduce nutrients, thereby providing a cost-effective, natural approach to complement

traditional mitigation tactics. PDE and PWD will continue to work with diverse partners to explore and implement nature-based technologies to remediate nutrients, such as developing a mussel propagation and restoration program centered in Philadelphia and using hatchery-reared mussels to populate living shorelines that include tidal wetlands and mussel beds. Recently, PWD and PDE launched a planning effort to identify living shoreline opportunities along the southeastern Pennsylvania coastline, and PDE is designing living shorelines for Camden, New Jersey. Use of nature-based approaches to enhance water quality should be encouraged throughout the Delaware Estuary.

- **Promote new management and treatment approaches.** This involves planning and research at the utility scale for wastewater treatment process infrastructure modifications and identifying the most economical advanced technologies to reduce pollution. This also could involve surveying wastewater treatment plants to learn which are removing phosphates and nitrates from their final discharges and which are doing this most efficiently and economically. Innovative technologies could be explored, e.g., deammonification, which shows promise in short-cutting the nitrification/denitrification process to convert ammonia to nitrogen gas directly while reducing the energy and carbon required.
- **Progress in implementing methods to reduce nutrient loads.** Reductions in nutrient loads are needed to obtain the water quality that will protect key aquatic species and their various life stages using tools that may include existing regulatory mechanisms or innovative approaches that include adaptive management approaches.
- **Identify opportunities for increased sources of funding for wastewater infrastructure.** Collaborate with state (DE, NJ, PA) and federal partners to identify funding sources for anticipated implementation of advanced wastewater infrastructure.

Increasing temperature, sea levels, salinity, and storminess could affect the viability of using natural infrastructure to sustain and enhance water quality. Political will and equity issues are other external constraints that could affect this strategy's implementation in the long term.

Performance Measures and Key Deliverables

- New tools and techniques developed and demonstrated
- Track number and results of innovative infrastructure and nature-based projects

Costs and Funding

- **Estimated Cost Range:** $$$$–$$$$$$
- **Possible Funding Sources:** State (DE, NJ, PA), federal, local, utility funding, and/or grants

Purpose

Share strategic planning processes and technology evaluations among utilities and regulatory agencies working to reduce urban sources of pollutants.

Core Partners

Delaware River Basin Commission, Partnership for the Delaware Estuary, Philadelphia Water Department, States (DE, NJ, PA), United States Environmental Protection Agency

Key Partners

Camden County Municipal Utilities Authority, City of Wilmington, and other dischargers

Contributing Partners

Water Resources Association of the Delaware River Basin

Timeframe

Evaluate infrastructure upgrades that reduce nutrients and funding opportunities by 2021

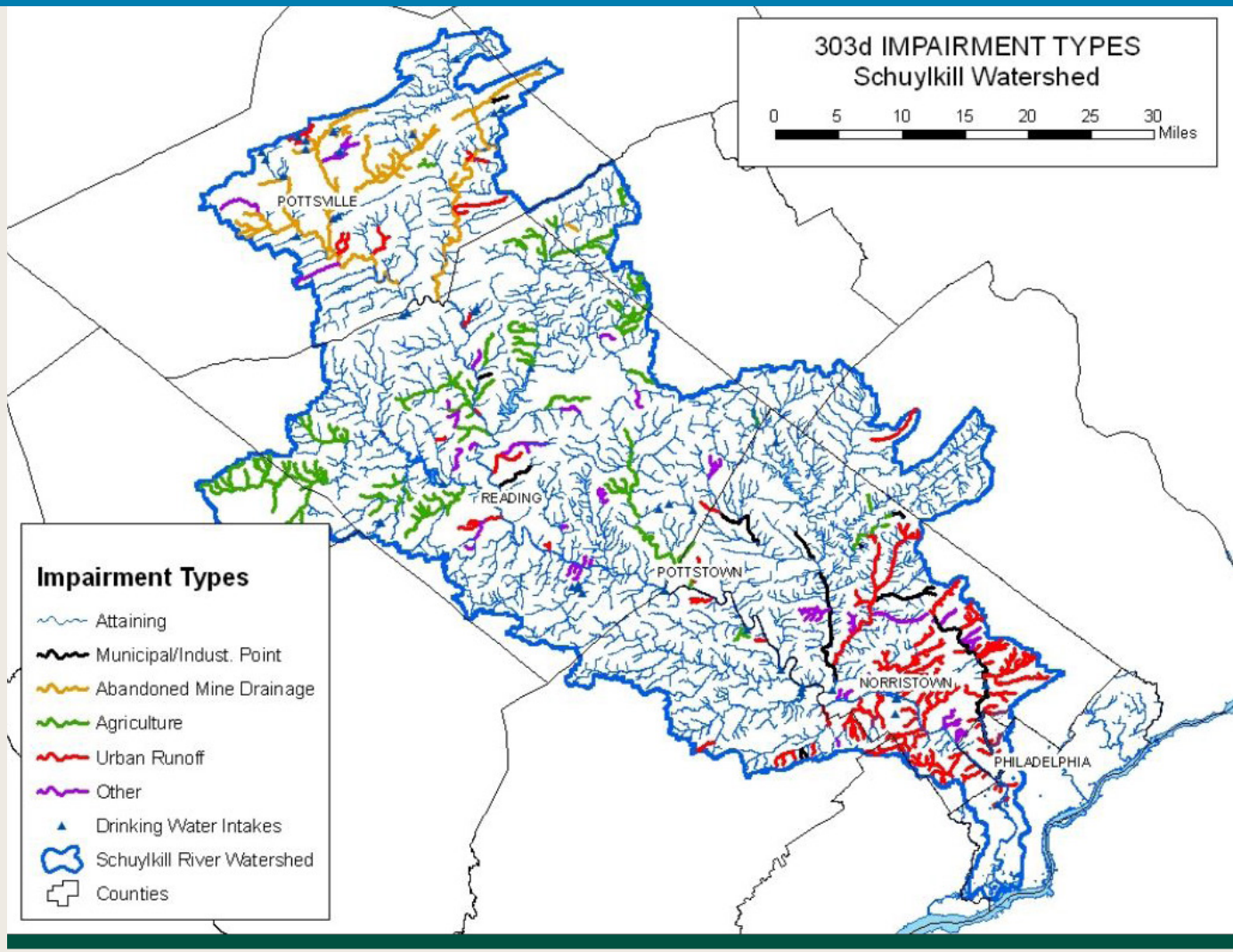
STRATEGY W1.2: Support innovative planning and design practices to reduce nutrients from stormwater and agricultural runoff through promotion, education, and implementation

Description

Stormwater runoff's infiltration and drainage are natural processes that alter landscapes, increase impervious cover, and redirect runoff. Human activities often disrupt these processes. Innovative planning and design practices can prevent or mitigate stormwater's effects by managing the quantity and quality of runoff from developed and agricultural land.

Educating local communities, particularly large landowners, about practices they can implement to control and diminish nutrient runoff pollution is fundamental in preventing nutrients from entering waterways. These best management practices (BMP) can be promoted by using watershed partnership networks, such as the Schuylkill Action Network (SAN), outreach events taking place in the region, as well as by seeking out and creating new opportunities such as stormwater management educational programs and outreach materials for large landowners.

Providing large landowners and their managers and contractors with tools and technical assistance, and implementing demonstration projects to showcase innovate new practices also are ways to support innovative planning and design practices. Important practices to promote include the following:



This map, based on preliminary PA DEP 2004 303d list data shows where and how streams in the Schuylkill River Watershed are impaired, and helped prioritize efforts of the Schuylkill Action Network. | Credit: SAN

- **Promote low-impact land management, preservation, and/or restoration, including use of native species and control of non-native/invasive species.** Low-impact land management entails integrating natural, native landscapes as ways to reduce or eliminate runoff rather than traditional practices of redirecting stormwater runoff into waterways. Minimizing developed areas and impervious surfaces (e.g., parking lots) and planting and retaining vegetation, particularly native species (which require less water and fertilizer) can prevent sediment, nutrients, and other chemicals from running off the land. Land conservation options, such as conservation easements, can ensure that good stewardship practices will continue in perpetuity, and conservation plans can provide guidance and technical assistance. It is highly important to making landowners aware of these resources.
- **Promote the use of riparian corridors (including streams, wetlands, and floodplains).** Riparian corridors are vegetated ecosystems along a waterbody that buffer it from runoff's effects by providing filtering, bank stability, recharging, rate attenuation, and volume reduction, as well as shading. Buffers and re-connecting floodplains are some of the best BMPs to prevent and reduce nutrient runoff pollution. Promoting the value, benefits, and tools/techniques to create or sustain wetlands and vegetated buffers in riparian zones and floodplains along existing stream contours can help landowners understand the importance of these BMPs. Monitoring changes in vegetative cover over time can help assess these buffers' effectiveness in controlling or reducing nutrients and target areas for outreach and technical assistance.
- **Promote nature-based tactics for stormwater management (*Green City, Clean Waters* techniques).** Urbanization contributes to waterway degradation by removing natural features, such as trees and soils, that absorb nutrients and replacing them with hard structures and surfaces that do not. "Green" or "nature-based" infrastructures are man-made, but designed to use materials and processes to mimic natural features. In 2011, PWD unveiled an ambitious program, *Green City, Clean Waters*, using green infrastructure to control runoff throughout Philadelphia. Practices that include tree trenches, green roofs, and pervious parking lots are constructed in urban spaces to control runoff, while technical assistance and supportive local policies help large landowners implement these new practices. Continuation of this program and transferring information, tools, and techniques to other communities, including large landowners in developed areas, will help reduce stormwater pollution in the Estuary and its tributaries.
- **Provide outreach and technical assistance for agriculture conservation practices.** Some of the largest properties in more rural parts of the watershed are farms that contribute large amounts of nutrients from fertilized crops and livestock. Outreach and technical assistance in application of fertilizers, including choice of product, timing of application, and volume of fertilizer applied, can reduce nutrient runoff. Agricultural communities also can employ conservation practices designed to exclude livestock from stream areas and manage manure and barnyard runoff. The SAN Agriculture Work Group and the closely aligned Middle Schuylkill Cluster of the Delaware River Watershed Initiative (DRWI: funded by the William Penn Foundation and others) have developed a coordinated outreach and engagement program that is an important component of nutrient management efforts in one of the largest agricultural areas of the watershed. These partnerships use the Conservation Reserve Enhancement Program for farmers, along with other resources. Continuing these efforts and transferring the information, tools, and techniques to other communities and farms will help reduce nutrient pollution in the Estuary, and particularly certain tributaries and watersheds. In addition to the SAN and DRWI, the Nature

Conservancy's Delaware River Basin Conservation Initiative also provides guidance to promote agriculture conservation practices in the watershed (see Delaware River Basin Conservation Initiative for more information).

PDE is a lead implementer of this strategy, working in collaboration with local partners, including PWD, SAN, large landowners, and communities. States (DE, NJ, PA) and conservation districts also play major roles in providing landowners with technical assistance related to management and soil conservation practices and can direct those looking for assistance to funding opportunities. Conservation organizations that own and manage land and conservation easements play important roles in helping large landowners protect and preserve their properties. PDE relies on these partners to involve the local community and landowners through direct contact, outreach, projects, and programs. PDE also can promote innovative planning and design practices by producing and distributing informational materials and delivering information through its website and newsletter, social media, and demonstration sites.

Climate changes can lead to warmer weather and more prolonged wet weather events, which can have cascading effects on nutrients, as well as habitats and invasive species (which might cause other adverse nutrient effects in the future). Overall, the problems nutrients cause (e.g., eutrophication) are expected to worsen with increased temperatures, thus leading to a greater need for innovative planning and design practices.

Performance Measures and Key Deliverables

- Ability to measure nutrient reductions in at least two to three key locations
- Track number and results of nature-based infrastructure projects, practices, and workshops on riparian buffers, stormwater, agriculture, and stream restoration
- Produce and disseminate materials to promote nutrient-reducing BMPs in print and online

Costs and Funding

- **Estimated Cost Range:** $$–$$$$
- **Possible Funding Sources:** National and regional foundation grants (for example, National Fish and Wildlife, William Penn Foundation), states (DE, NJ, PA)/federal grants (Coastal Zone Management, 310, State Revolving Fund) Farm Bill programs (Natural Resources Conservation Service [NRCS], Department of Agriculture)

Purpose

To support and educate local stakeholders about practices they can promote and implement in their communities to reduce the nutrient pollution burden from nonpoint sources. Also, to strengthen and foster partnerships to restore and protect these resources.

Core Partners

Partnership for the Delaware Estuary, Philadelphia Water Department, and states (DE, NJ, PA)

Key Partners

Delaware River Watershed Initiative: Middle Schuylkill, Schuylkill Highlands, Kirkwood Cohansey Clusters

Natural Resources Conservation Service Schuylkill Action Network, United States Department of Agriculture, and Upstream Suburban Philadelphia Cluster

Contributing Partners

Christina Basin Task Force, Conservation Districts, Delaware River Watershed Initiative and other clusters, South Jersey Bayshore Coalition

Timeframe

Annual workshops, ongoing

STRATEGY W1.3: Promote land use planning by local municipalities that prevents, reduces, and/or more efficiently manages stormwater runoff to prevent pollution

Description

Stormwater runoff, a type of nonpoint-source pollution, often is laden with nutrients and other chemicals from buildings, yards, and roads. As we continue developing land across the Delaware Estuary region, we create more impervious (or non-porous) surfaces from which water cannot drain into the ground. The Center for Watershed Protection, a nonprofit organization dedicated to research and education on watersheds, has established a clear link between the area of impervious surface in a watershed and the water quality in its streams. Thus, managing land use to prevent and reduce stormwater is a key strategy to reduce nutrient pollution.

Local planning, controlled mostly by local governments (counties and municipalities) in the Delaware Estuary Watershed, is largely responsible for determining where and how development occurs. This can affect stormwater runoff in many ways, from preventing runoff with plans and zoning that encourages low-impact development, to controlling runoff during construction with erosion and sedimentation requirements and managing runoff after development with stormwater management requirements and practices. Many urbanized municipalities are now also subject to MS4 permits that require stormwater management. However, municipalities often need considerable support from external partners to implement these practices.

Opportunities to assist and promote municipalities' good land-use planning and stormwater management include the following:

Stormwater runoff is commonly transported through Municipal Separate Storm Sewer Systems (MS4s). The runoff is often discharged, untreated, into local water bodies. | Credit: DNREC

- **Facilitate and/or Support public engagement by municipalities.** Provide communications and promotional support for public meetings, facilitating issue-based working groups, and coordinating storm drain marking or community cleanups. This also could include involving the public in more technical tasks, such as illicit discharge detection by deploying trained citizen-scientists.
- **Collaborate in the development and execution of internal and external education and outreach programs.** This could include helping municipalities develop high-quality outreach materials that

support permit compliance (e.g., printed materials, educational videos). It also could include providing training on pollution prevention and good housekeeping techniques for facilities owned and maintained municipally.

- **Provide technical assistance in effective planning and regulation through model ordinances and post-construction stormwater management tools.** Each of the Estuary states (DE, NJ, PA) has organizations with model ordinances (i.e., rulings by a municipal authority) that cover a range of stormwater issues, including minimum requirements for structural and nonstructural BMPs; protection of sensitive areas (i.e., wetlands, riparian zones, steep slopes, etc.); cluster/compact development incentives; and impervious cover and runoff volume limitations, among others. Local governments may need help adopting such ordinances in a way that complies with existing codes and addresses resource concerns.
- **Identify opportunities to mitigate existing stormwater problems and collaborate with local governments in implementation.** Providing capacity and expertise to assess stormwater runoff sources and develop mitigation plans at the municipal or county levels can help municipalities identify and prioritize potential projects. Monitoring on the part of citizen-scientists and trained professional staff can provide some of this capacity and expertise. Engaging the community in the design and installation of a project can help satisfy a municipality's permit requirement for public involvement, and educational signage at the site once the project is complete can help satisfy some of the education and outreach requirements. Such projects also can serve as demonstration sites that not only educate residents and practitioners alike about the nature and benefits of nature-based stormwater practices, but also encourage their voluntary adoption on private property.
- **Explore opportunities to advance a regional vision to form a network of technical assistance providers and municipal recipients.** For example, under the leadership of the Delaware Valley Regional Planning Commission (DVRPC), a group of partners, including PDE, has developed a series of recommendations to provide training and technical assistance for municipal officials and professionals to help achieve water quality improvements. Its purpose would be to coordinate, enhance, and brand educational and networking programs on municipal best practices to improve water quality and match technical assistance providers with receptive municipalities (see the DVRPC Action Plan and Recommendations and the "Delaware River Watershed Initiative Academy" strategy for more information).
- **Provide information to municipalities regarding funding mechanisms and credit programs for voluntary BMP installations.** There are many examples of successful assistance programs for municipalities in the watershed. The PDE has collaborated extensively with municipalities, including Philadelphia and New Castle County, to help with the range of activities described here. In other parts of the watershed, PDE relies heavily on external partners to implement these strategies successfully. For example, the Perkiomen Watershed Conservancy has a program to help develop outreach materials to municipalities; Green Valleys Watershed Association works with local municipalities to install BMPs (e.g., rain gardens, basins, bioswales, and buffers); and Rutgers University's Water Resources Program provides training to local municipal staff on best practices to reduce pollution from vehicle maintenance and washing, storage yards, and other municipal facilities.

Nonprofits and regional agencies with expertise in environmental planning, including the DVRPC, the Association of New Jersey Environmental Commissions (ANJEC), the Brandywine Conservancy, and the Natural Lands Trust, support municipalities as they craft local

regulations that prevent future runoff problems and encourage low-impact development. Many municipalities in New Jersey and Pennsylvania also have environmental commissions that could be excellent resources and partners. PDE will continue pursuing the basic strategy of working with major municipalities to promote good land use and stormwater management and seek ways to promote, enhance, and share the successes of local partners' efforts.

Greater frequency and intensity of storm events in the future could make it challenging to develop meaningful stormwater policies. However, and increased problems with flooding and stormwater runoff highlight the need for improved management and lower-impact development overall. Historically, the dominant attitude about stormwater runoff has been to move it as quickly as possible to a nearby waterway, and changing this thinking in areas where municipalities have a strong preference for traditional techniques can be a challenge. However, continuing education for stormwater professionals and township officials is making this transition possible, and demonstration projects are a key component of this re-education effort.

Local jurisdiction for land-use planning also is a challenge in a region with so many municipalities (over 838 in the Delaware River Basin). To address this challenge, municipalities are beginning to be more receptive to working together, particularly on stormwater management. Finally, partnerships and funding to implement this strategy comprehensively, such as through the Watershed Academy, require a significant amount of additional effort. Thus, PDE is working with DVRPC and others to identify additional partners and resources.

Performance Measures and Key Deliverables

- Examples of successful outcomes from municipal assistance in DE, NJ, and PA
- Tracking numbers and results of technical assistance projects on municipal outreach, stormwater, and planning/zoning
- Producing and disseminating materials for MS4 outreach (in print and online) and educational signage for BMP demonstrations

Costs and Funding

- **Estimated Cost Range:** $$–$$$
- **Possible Funding Sources:** Regional foundation grants, state grants (DE, NJ, PA), municipalities

Purpose

To encourage municipalities to use institutional management tools, including zoning, ordinances, and education, to reduce nutrient and sediment-laden stormwater runoff.

To enable the installation of BMPs throughout the estuary and basin through regulatory compliance with the municipal separate storm sewer system (MS4) requirements.

Core Partners

Partnership for the Delaware Estuary, States (DE, NJ, PA)

Key Partners

Association of New Jersey Environmental Commissions, County Planning Departments, Delaware Valley Regional Planning Commission, Schuylkill Action Network, Pennsylvania Environmental Council, Upstream Suburban Philadelphia Cluster

Contributing Partners

League of municipalities, local municipalities and environmental commissions, non-governmental organization partners, conservation districts

Timeframe

Ongoing as opportunities/needs arise

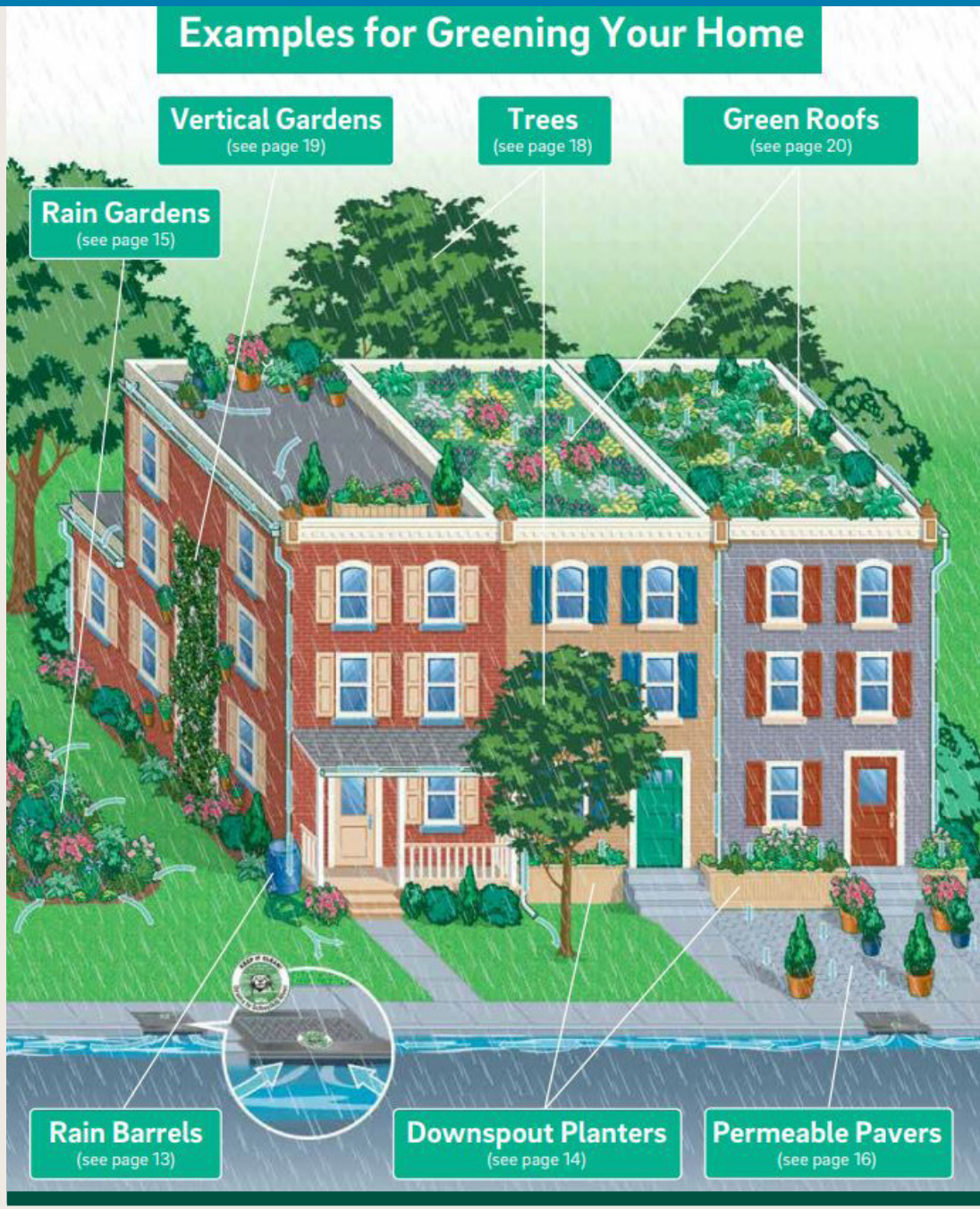
STRATEGY W1.4: Provide outreach and information to property owners to assist in reducing non-point sources of nutrients

Description

The greatest challenge in addressing nonpoint-source pollution is that it does not derive from one or several large, easily identifiable sources, but from millions of small sources distributed throughout the watershed. In a region like the Delaware Estuary, every street, house, yard, and business may be a source. Persuading millions of people to change their behavior to reduce nonpoint-source pollution is an enormous challenge and can only be addressed reasonably through education and communication over a long period.

PDE and other partners have been engaging people in nonpoint-source education and communication for 20 years, reaching thousands of people annually. With over six million people in the Delaware Estuary Focus Area alone, and increasing annually, there still is a great deal of work to be done.[11] However, PDE and others have developed key educational programs and tools that are important to reduce nutrients in our waterways, including the following:

- **Provide education on septic system maintenance.** Many residents and businesses are in areas without public sewers and thus rely on individual or community septic systems. If maintained or located improperly, septic systems can leach nutrients, bacteria (e.g., *E. coli*), and other pathogens into groundwater that connects with streams and bays. This is especially problematic in areas with shallow groundwater. Outreach, education, and technical assistance



These Examples for Greening Your Home are from the *Homeowners Stormwater Handbook* produced by PDE and the PWD (available online at http://www.delawareestuary.org/manage-stormwater-runoff/)

for homeowners with septic systems are critical to prevent or mitigate nutrient pollution from septic systems.

- **Provide education on fertilizer use.** Fertilizer applications are another source of nutrient pollution in rivers and bays. Fertilizer that is excessive or applied improperly runs off rather than being absorbed by crops or lawns, thus wasting money and causing nutrient pollution. Recent studies have found that, acre for acre, residential areas contribute more nutrient runoff from fertilizers than do farms. Educating homeowners and certifying local lawn care businesses can help prevent this pollution. Programs like Livable Lawns in Delaware are designed to enable homeowners to make small changes in lawn care practices for better stewardship, and these practices should be promoted.
- **Provide education on dog waste management.** Dog waste contributes to nutrient runoff pollution and other water quality issues, including bacteria and other pathogens. Pets in the U.S. produce waste sufficient to cover more than 5,000 football fields 10 feet deep annually.[5] In some areas, this is a problem not only for water quality, but for human health and quality of life. Water quality testing can help identify these areas. Educating dog owners and service providers about the dangers of dog waste and providing tips and tools for them to clean up after their pets are the most cost-effective solutions in these areas. These can include distributing tip cards and dog waste bags, putting up signage and bag dispensers, and promoting and sharing model behavior though entertaining programs for dog owners (e.g., Philadelphia's Spokesdog Competition).
- **Promote good stormwater management at home, work, and in the neighborhood.** Homeowners and businesses can use rain barrels and rain gardens to capture stormwater and allow it to infiltrate the ground rather than running off into storm drains and streams. They also can plant native trees and other plants to absorb more water when it rains, after which these plants will require less water and fertilizer. Promoting these activities to homeowners through the media, social media, and newsletters, as well as advertising and information and other resources, can reduce nutrient pollution and spread an ethic of stewardship.

PDE plays a leading role in providing estuary-centric education and messages about nonpoint sources of pollution in the Delaware Estuary, and every Core Partner agency provides information and resources on this challenging topic. Some of the primary tools PDE uses to implement this strategy include the production and distribution of publications, such as the *Homeowner's Stormwater Handbook* and *Rain Gardens: Gardens with Benefits,* that are designed to appeal to homeowners and meet the specific needs described above. Newsletters, websites, and advertising are other effective ways to reach large numbers of people with information about nonpoint-source pollution. PDE features educational information and activities regularly at DelawareEstuary.org and in *Estuary News.* PDE also seeks opportunities to work with local partners on more targeted programs.

The most challenging external constraint on this strategy's success is the difficulty demonstrating and articulating residential nonpoint source pollution's harmful effects and management benefits. It is critical that partnering organizations and funders see the continued need for, and measurable effects of, these efforts to ensure committed funding for them. Few, if any, of the funding sources available for this work cover the kinds of costs involved to assess changes in behavior or attitudes over time.

Performance Measures and Key Deliverables

- Continuous increase in Estuary News and delawareestuary.org newsletter subscribership, website traffic, and press hits
- Track number and results of outreach programs and projects on nutrients, including publication, newsletter, website, and social media content

Costs and Funding

- **Estimated Cost Range:** $$
- **Possible Funding Sources:** Municipal separate storm sewer system (MS4) municipalities, state grants (DE, NJ, PA) and contract support

Bombay Hook National Wildlife Refuge | Credit: Norma Worley

Purpose

To educate homeowners and businesses about ways to reduce nutrient contributions.

Core Partners

Delaware River Basin Commission, Partnership for the Delaware Estuary, Philadelphia Water Department, States (DE, NJ, PA), United States Environmental Protection Agency

Key Partners

Delaware River Watershed Initiative Kirkwood Cohansey Cluster, Upstream Suburban Philadelphia Cluster

Contributing Partners

Christina Basin Task Force, Conservation Districts, Delaware River Watershed Initiative and other clusters, South Jersey Bayshore Coalition

Timeframe

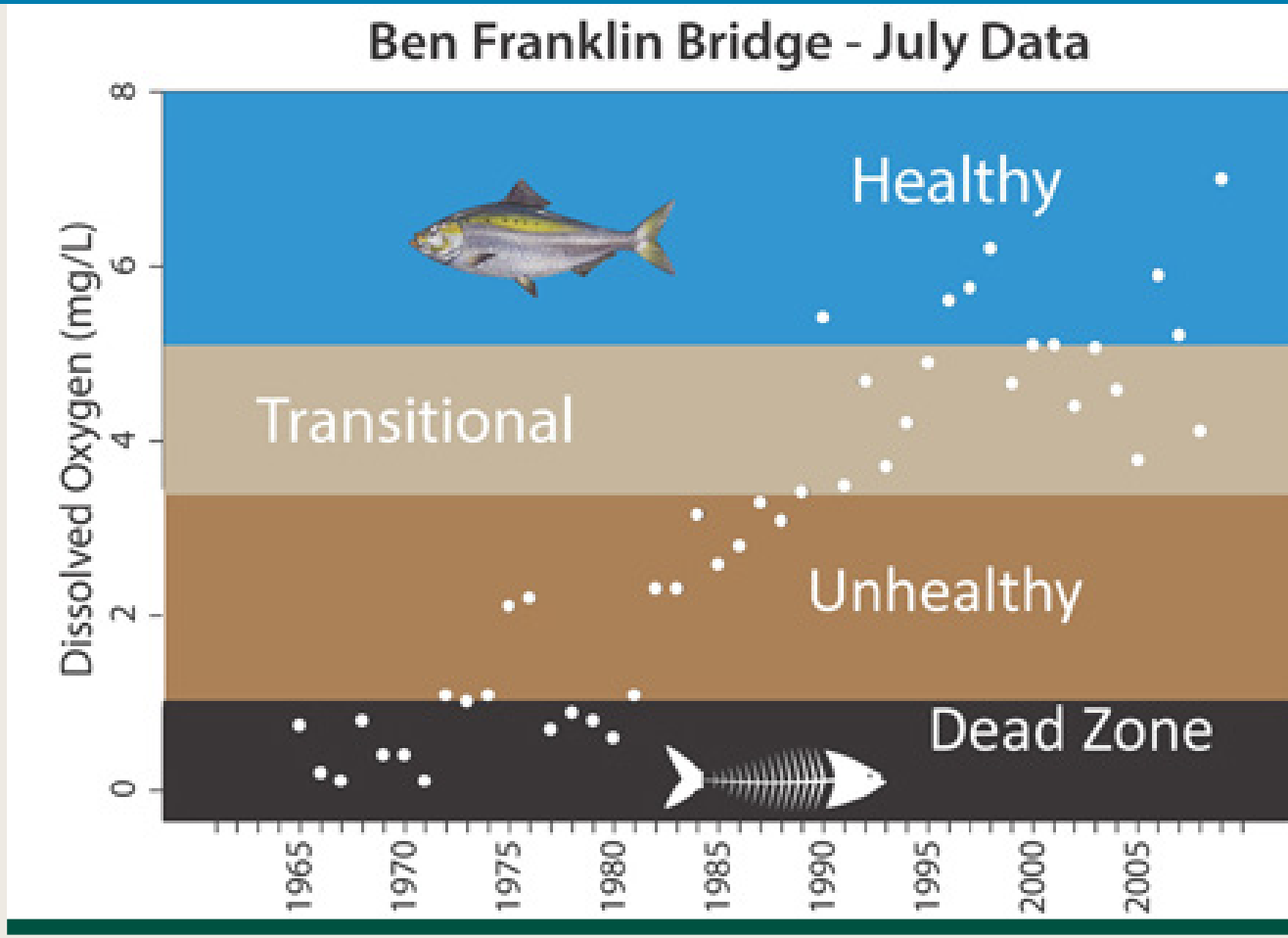
Ongoing, with some outreach focused on recurring annual activities

STRATEGY W1.5: Conduct research and monitoring on nutrient impacts in the Delaware Estuary for biological and ecological endpoints

Description

Nutrients' effects, including those of nitrogen and phosphorus compounds, have received more attention since the initial CCMP was signed in 1996. The U.S. EPA prioritized the establishment of water quality criteria for nutrients in a June 1998 document entitled, "National Strategy for Development of Regional Nutrient Criteria," and more recently, in a March 2011 memorandum from Nancy Stoner, acting assistant administrator, entitled, "Working in Partnership with States to Address Phosphorus and Nitrogen Pollution through Use of a Framework for State Nutrient Reductions."

Nutrients' effects differ from those of other pollutants. Other pollutants can be conventional, such as total suspended solids (TSS) and toxic pollutants, which include certain metals and organic compounds. They generally do not have direct toxic effects on aquatic life and are not attributable solely to an individual nutrient pollutant. An exception to this is ammonia, which is toxic to aquatic life directly. The most common result of nutrient pollution is eutrophication, which is the enrichment of a water body with an excess amount of nutrients. Eutrophication encourages the growth of plants and algae and may result in oxygen fluctuations and depletions of the water body when growth is excessive.



July dissolved oxygen (DO) data in the Delaware River at the Ben Franklin Bridge, Philadelphia, PA. Over time, DO has gradually increased at this monitoring station to levels that are healthy for the survival of fish. | Credit: DRBC

The Delaware Estuary and Bay have been the focus of research and nutrient monitoring since the 1960s. Many of these efforts focused on the severe oxygen depletion in the urban reaches of the Estuary attributable to industrial and municipal wastewater treatment facilities' discharge of wastewater.

This strategy will focus on using and augmenting the research that has

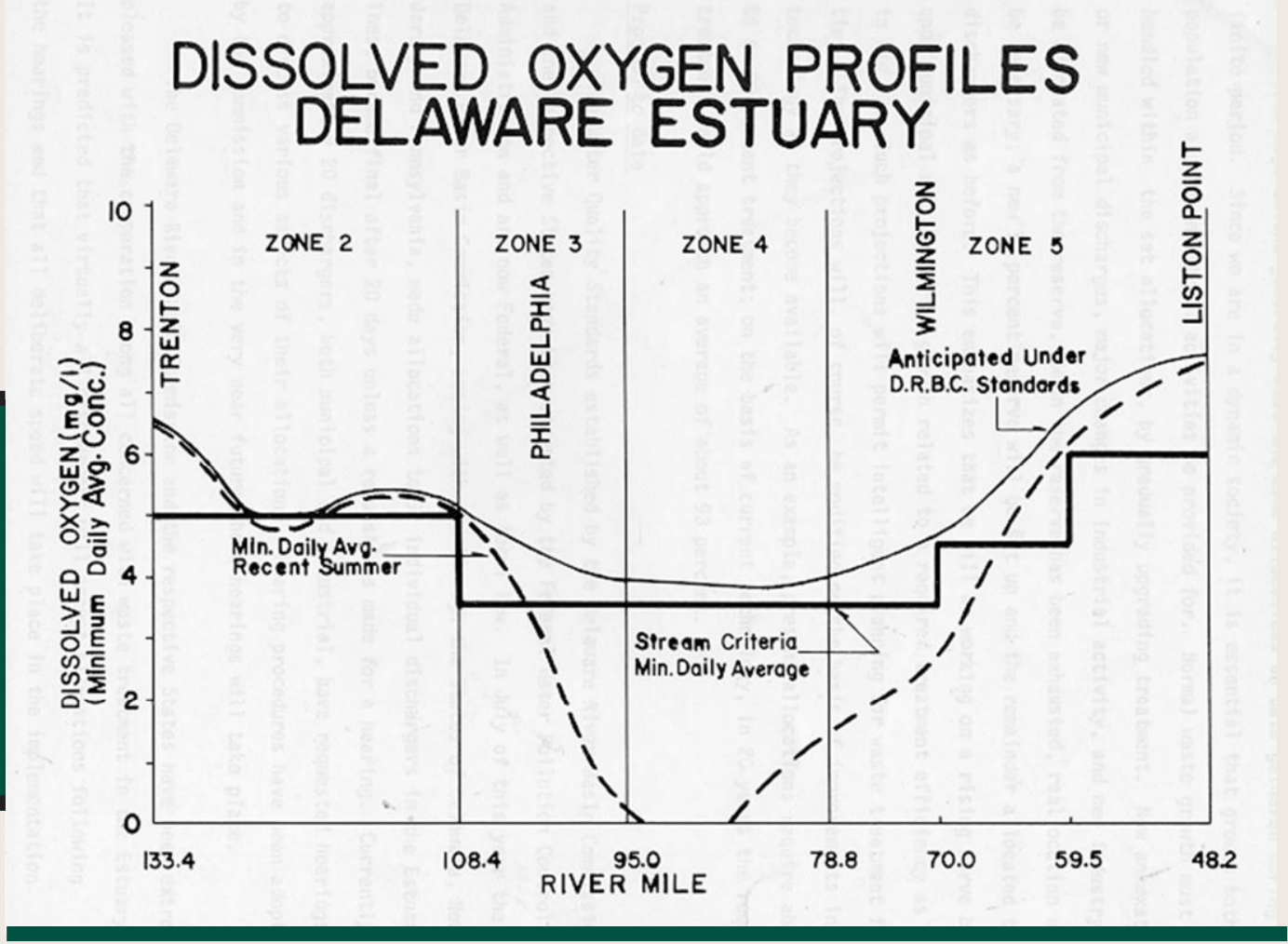
been conducted to date. The emphasis will be on additional research to complete the development and calibration of a new eutrophication model of the Delaware River and Bay that will support studies and provide input data for the model, as well as data on the kinetic processes. Identification of nutrients' effects on specific species, community composition, and ecosystem processes also will be emphasized.

Initial efforts in the 1960s by DRBC focused on the oxygen demand from carbon-containing pollutants, although the demand from nitrogen-containing pollutants was also recognized. As dissolved oxygen conditions improved, the focus of research and regulatory efforts was redirected to the oxygen demand from nitrogen compounds. Initial studies conducted by HydroQual, Inc. for DRBC concluded that there was approximately a 2.0 mg/L oxygen demand in the urban reach of the river from nitrogen-containing pollutants.

DRBC is leading the implementation of this strategy, with the regulated community and universities as key partners.

Major components of this strategy include:

- **Complete a Delaware River and Bay Eutrophication Model.** As early as 1993, DRBC considered the establishment of new and revised water quality criteria, but delayed any action pending the completion of a new eutrophication model for the Delaware Estuary that could be used to establish load allocations for nutrients that increase ambient dissolved oxygen levels. DRBC is conducting technical studies, including the development of a new eutrophication model for the Estuary, and will use the results to lead a collaborative effort among the states (DE, NJ, PA) and private and public entities to identify and work to achieve water quality criteria that support important uses for various zones in the Estuary to protect fish and wildlife populations.



Historical Dissolved Oxygen Conditions in the Delaware Estuary. | Credit: DRBC

- **Continue to develop water quality and ecological monitoring programs to provide data for model development and calibration and identify targets for nutrient parameters to protect key species.** Because of the complexities of nutrient pollution's effects, water quality and ecological monitoring are necessary to document nutrient loads and develop input parameters for the important chemical and biological processes in the water quality model. The model then can be used to simulate water quality and biological changes attributable to reduced nutrient loads. The modeling effort's initial focus will be on the dissolved oxygen levels in the Delaware Estuary, but as other nutrient-related targets are identified, these also can be assessed.
- **Evaluate operation practices and treatment technologies that could be used to reduce key nutrients' loads, and assess the physical, chemical, biological, social, and economic factors that affect the attainment of aquatic life uses.** Identifying water quality targets that will protect important fish species and other aquatic life requires an evaluation of the capital and operating costs needed to optimize the best technology available or apply innovative technologies able to achieve increased protective levels of dissolved oxygen. This also will require an evaluation of the social and economic factors that affect achieving these levels and ultimately the Estuary's aquatic life uses.

Funding and allocation of staff resources to complete the tasks identified during a 3.5-year period is the challenge to complete this strategy. Climate change also may affect the achievement of the protective criteria identified through this strategy and the results of scientific and technical studies the DRBC has planned. These effects would be associated with the warmer temperatures predicted that will affect the amount of dissolved oxygen that the Estuary waters can sustain, changes in the Delaware River Basin's hydrology, and rising sea levels.

Performance Measures and Key Deliverables

- Development of the Delaware Estuary eutrophication model
- Track numbers and results of research projects on nutrients

Costs and Funding

- **Estimated Cost Range:** $$$
- **Possible Funding Sources:** Agency operating funds.

Purpose

To conduct research and monitor nutrient effects in the Estuary to determine nutrient reductions needed to meet important water quality and biological endpoints.

Core Partners

Delaware River Basin Commission, Partnership for the Delaware Estuary, Philadelphia Water Department, States (DE, NJ, PA)

Key Partners

Academia, regulated community, other science and technical advisory Committee member organizations

Timeframe

Ongoing with a six-year timeframe to address the appropriate designated use and associated water quality criteria for dissolved oxygen. Ten to 15 years to address nutrients' other effects

CLEAN WATERS GOAL 2

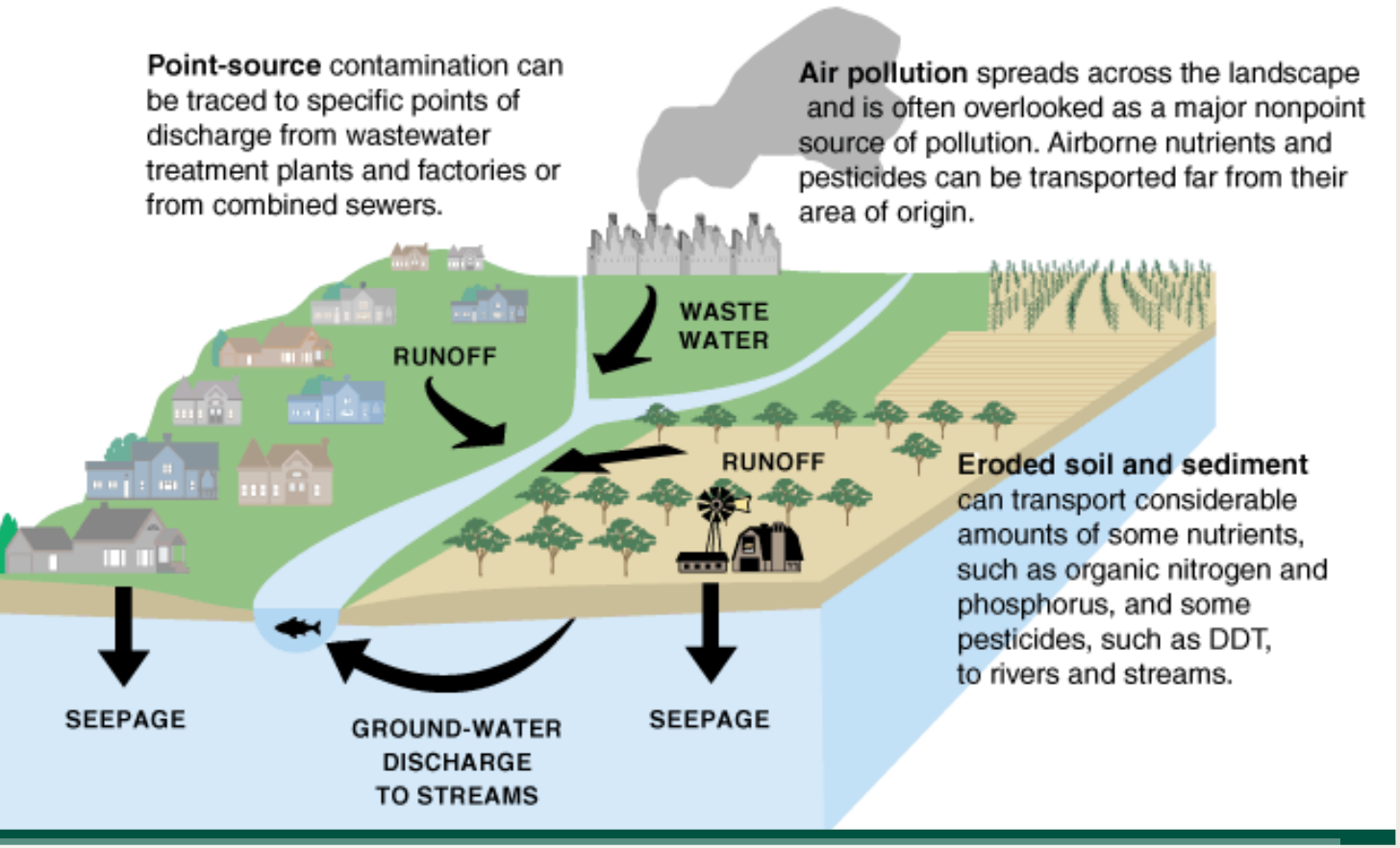
REDUCE OTHER POLLUTANTS AND THEIR IMPACTS

Fortescue, NJ | Credit: Aaron Maffei

In addition to nutrients, other pollutants are detrimental to the Delaware Estuary's health, such as metals, bacteria, and industrial chemicals (e.g., polychlorinated biphenyls [PCBs]) that can affect aquatic life and human health through consumption of fish. Other hazardous substances include contaminants of emerging concern, as well as pesticides, road salt, oil, and other pollutants that spill or run off the land. Contaminants are also a concern for water suppliers that rely on the Estuary as a drinking water source.

Hazardous substances enter the Estuary through a variety of pathways, including point-source discharges from wastewater treatment plants, spills, and such nonpoint sources as run-off from streets, storm drains, contaminated land, and a process referred to as air deposition that transmits pollution from the air to land and water. These sources may pollute the Delaware Estuary or tributaries or groundwaters that flow into the Estuary directly. Government agencies have established safe levels or standards for many substances for the Estuary and fish consumption advisories to prevent human health effects. However, many substances, including chemicals introduced recently, have no standards yet.

The 1996 CCMP lists substances of concern for the Estuary. PCBs, a class of chemicals that is slow to degrade and known to bioaccumulate, were a parameter of concern in the 1996 CCMP and remain so today. DRBC, in cooperation with the states (DE, NJ, PA) and



Examples of potential sources of contamination for surface water supplies | Credit: USGS

HOW WE WILL MEASURE SUCCESS:

- Reduce fish consumption advisories issued by states (DE, PA, NJ)
- Reduce the discharge of contaminants
- Reduce PCBs from point and non-point sources

the EPA, initiated a program to control PCBs that has reduced loadings to the Delaware Estuary by 64% since 2005.[2] Efforts also have been made to reduce pollution from other well-known contaminants since the DELEP was created in 1996, including advances in drinking water protection, programs to identify contaminants in fish, and identification of measures to prevent and improve response to spills after the Athos I spill in the Delaware River in 2004. Historic sources have been identified (many listed as Superfund sites) and cleanup measures are being implemented. While these efforts continue, there are emerging contaminants that have yet to be understood or regulated fully. Maintaining healthy waters also will require the reduction of emerging contaminants such as pharmaceuticals, ingredients in personal care products, industrial manufacturing chemicals, microplastics, antibacterial additives, insecticides, and repellents.

Many of these pollutants are being monitored throughout the Delaware Estuary, and some progress has been made in addressing them and educating the public about their harm to drinking water supplies. In the future, monitoring, analysis, and public education are needed to address this diverse group of pollutants.

STRATEGY W2.1: Conduct outreach and technical assistance programs to reduce nonpoint sources of contaminants

Description

Crafting successful outreach programs and campaigns is critical to reduce nonpoint sources of pollution in the Delaware Estuary. Each target audience must be educated about nonpoint sources of pollution and what simple behavior changes they can make to be a part of the solution. A sense of responsibility and the feeling that every person can make a difference is critical.

PDE installs storm drain marking artwork with students in Wilmington, DE. | Credit: PDE

Major components of this strategy include:

- **Educate residents about the connection between storm drains and waterways.** By collaborating with volunteers, storm drains will be marked in municipalities throughout the region. PWD has taken the lead in marking storm drains within the city as part of its MS4 program. Additionally, SAN now has its own storm drain marker for municipalities within the Schuylkill River Watershed. Both PWD and SAN can be used as models to develop storm drain marking programs in other parts of the Estuary. The states (DE, NJ, PA) also have, and will continue to, offer storm drain marking and other education programs. Marking storm drains educates residents, businesses, and other individuals that only rain should go down the storm drains and not trash or toxic substances, such as oil, paints, and other chemicals.
- **Educate residents about handling and disposing household hazardous waste, electronic waste, and appliance "white" waste properly.** PDE has a webpage that describes proper ways to dispose of chemicals that could be used and expanded to include links for proper disposal of hazardous, electronic, and appliance waste (see PDE Dispose of Chemicals webpage for more information). PDE will promote this information throughout the region to ensure that more people are aware of where and how to dispose these types of wastes properly. Working with local counties offers another opportunity to develop disposal resources. PDE has worked with the Delaware Department of Transportation to create a fact sheet about disposing household hazardous waste properly, and a brochure about recycling oil for each county. PDE will continue to expand this messaging to other parts of the Delaware Estuary to address household hazardous waste issues.

- **Support and promote pharmaceutical take-back programs and the use of "green" personal care products**. Develop an outreach campaign about disposing pharmaceuticals properly and using "green" personal care products. For example, this could be a local campaign as a pilot program, working with local drug stores, or a Delaware Estuary-wide online campaign promoting pharmaceutical take back days and drop-off locations throughout the region
- **Support and conduct outreach to boaters and marinas.** Encourage clean marinas using NJ and DE Clean Marinas Program materials and strategies as resources. These programs provide green tips to both boaters and marina owners, such as proper cleaning and maintenance, sewage and waste disposal, and petroleum control.
- **Develop and implement plans to reduce litter and plastic debris in and around waterways, including coordinating and conducting river cleanups.** Participate in existing efforts within agencies, such as with the EPA Trash Free Waters program, and National Oceanic and Atmospheric Administration's (NOAA) Marine Debris program, to reduce plastic and other types of litter found in waterways. Local partners include Keep American Beautiful, PWD, United by Blue, and others working to coordinate river cleanups, such as the Schuylkill Scrub, Christina River Cleanup, and Coastal Cleanup. Work with local partners in NJ and DE to develop state affiliates for Keep America Beautiful or other partners for technical assistance; partner with Keep PA Beautiful for technical assistance in PA. Encourage and promote the use of reusable water bottles and bags through education and incentives.
- **Provide property owners and managers, municipalities, and transportation departments education about road and vehicle maintenance.** Support programs that explore alternative methods to remove snow and ice (to reduce use of road salt). Promote the use of green stormwater infrastructure to mitigate stormwater effects from roadways, including through social media.
- **Support local efforts to provide education about abandoned mine discharges' effects.** Through the SAN, partners in Schuylkill County will continue to implement abandoned mine treatment systems. Because mines are abandoned, no party is responsible for mitigation. Schuylkill County partners, such as Schuylkill Headwaters Association and Schuylkill County Conservation District, will work with private landowners to educate them about abandoned mine drainage effects and opportunities to use private land to install treatment systems.

Performance Measures and Key Deliverables

- Continuous growth/improvement of cleanup activities throughout the Estuary (Schuylkill Valley, Upper Estuary, Lower Estuary, Bayshore)
- Track number and results of outreach programs and projects on contaminants, including materials for storm drain marking and pollution prevention on the part of households and businesses

Costs and Funding

- **Estimated Cost Range:** $$–$$$
- **Possible Funding Sources:** MS4 municipalities, state grants (DE, NJ, PA), and contract support

Purpose

To educate and engage various target audiences about ways to reduce nonpoint pollution.

Core Partners

Delaware River Basin Commission, Partnership for the Delaware Estuary, Philadelphia Water Department, States (DE, NJ, PA), United States Environmental Protection Agency

Key Partners

Christina Conservancy, Delaware Nature Society and Delaware Clean Water Alliance, Schuylkill Action Network

Contributing Partners

Conservation Districts, Keep America Beautiful, Private sector: med/pharma companies, marinas, landowners, other cleanup partners, watershed associations, and volunteers

Timeframe

Ongoing

STRATEGY W2.2: Promote the identification, cleanup, and revitalization of contaminated sites

Description

Contaminated sites continue to be a significant source of pollution in waterways in the Delaware Estuary Focus Area. This region has a long and prosperous history as a hub of industry. Much of that industry was situated on lands near waterways because of their need to use water for power, cooling, and transportation of materials and products. The soils and sediments in and around our rivers tell this industrial chemical story through the contaminants found in them: substances such as PCBs, dioxins and furans, mercury, pesticides, and others that are harmful to aquatic life, wildlife, and people.

Although there has been much progress in remediating contaminated sites over the past several decades, there are still a number of contaminated sites in the Delaware Estuary Focus Area known to contribute to PCBs, as well as other brownfields, such as abandoned industrial sites that likely are contaminated. In addition to these traditional contaminated sites, abandoned mine sites in the upper part of the Schuylkill River Watershed discharge acidic groundwater and metals, including iron, copper, and aluminum, into our rivers and streams. Stormwater runoff from these sites may transport residual contaminants into rivers and streams flowing into the Delaware Estuary.

Release of toxic pollutants via soil erosion and/or the discharge of contaminated groundwater can enter adjacent surface waters

Passive abandoned mine drainage treatment system in Schuylkill County, PA allows for iron and other heavy metals to settle out and pH to rise before waters flow into the headwaters of the Schuylkill River. | Credit: SAN

and potentially affect human health. In the past, these situations were not always considered explicitly when decisions were made to reestablish a contaminated site (i.e., older sites may neither have been contained nor maintained properly, resulting in releases of contaminants). Fortunately, there is growing awareness of the way contaminated sites can affect adjacent surface waters indirectly, and the need to remediate not only the sites, but also their associated "off-site" areas. Activities intended to advance this strategy include the following:

- **Remediating sites by removing contaminants and/or preventing their effects on surface water by leveraging private sector resources.** This approach also allows these sites to be put back into productive use, creating jobs, and generating revenue. State and federal agencies have made great strides in identifying, remediating, and revitalizing contaminated sites through federal and state programs such as the Superfund, Brownfields, and other programs. However, more remains to be done identifying and remediating abandoned mine drainage in the upper Schuylkill Watershed strategically with passive treatment systems. Projects designed to prevent infiltration of stormwater into mines is the focus of collaboration between local, state, federal, and private partners in the SAN. Continued funding and support for these programs and efforts and the private sector resources they leverage are critical, and collaboration, cooperation, and focus are keys.
- **Advances in monitoring, assessing, and remediating toxic pollutants in the Delaware Estuary.** These advances, when implemented on a watershed-scale, provide a better understanding of the connection between upland sources, in-place contamination (e.g., contaminated sediments affected by historic release), and the spatial distribution of the contamination in a drainage area. Taking a watershed-scale approach to characterize toxics' magnitude and spatial distribution can help identify hot spots (e.g., waste sites, tributaries, point sources, etc.) that then can be targeted for additional investigation, resources, and remediation. DNREC has developed an approach, the Watershed Approach to Toxics Assessment and Restoration (WATAR), that uses a watershed-scale evaluation framework and applies it to persistent, bioaccumulative, and toxic contaminants, their sources, transport pathways, sinks, and associated risks. The approach and its components allow for prioritization of agency-wide efforts and resource allocation to maximize positive results. The approach combines the efforts of multiple sections of the agency—those that address site investigation and remediation, and those that handle watershed assessment and management—and promotes the use of innovative technologies (e.g., activated carbon, apatite-based fish bone, reactive mats) to reduce contaminants' effects in water, sediment, and fish.
- **Documenting and inventorying remediation sites, efforts, and successes.** Each state has a different process to identify and prioritize remediation activities, as well as information on those activities. Tracking progress on this strategy requires developing a way to collect information about remediation across the Estuary, both to track progress and tell the story of the Estuary's recovery.

The federal government and states (DE, NJ, PA) are primarily responsible for implementing this strategy to identify, clean up, and revitalize contaminated sites because of their robust programs, expertise, and ability to implement remediation activities. State remediation laws support state activities, as well as the federal Superfund program, the Toxic Substances Control Act (TSCA), the Resource Conservation and Recovery Act (RCRA), and Brownfield programs that EPA administers. Many contaminated sites are located within major cities, making city agencies such as PWD, Wilmington Public Works Department, and the Camden County Municipal Utilities Authority important partners in this strategy as well.

PDE can support this strategy by promoting the importance of these state, federal, and local remediation programs and efforts by providing

opportunities to share information and lessons learned about remediation, and finding ways to track progress and tell the story of the Estuary's recovery.

Funding for site identification and remediation is a key constraint in continuing to expand programs. Contaminated sites along waterways may be at risk of contributing additional pollutant loading because of climate change effects (e.g., rising sea levels, more intense rain events) and should be prioritized accordingly. Anticipated increases in precipitation attributable to climate change also could lead to more runoff from contaminated sites and should be factored into remediation designs.

Performance Measures and Key Deliverables

- Examples of successful outcomes in each state (DE, NJ, PA) by tracking reductions
- Track number and results of contaminated site cleanups

Costs and Funding

- **Estimated Cost Range:** $$$– $$$$$$
- **Possible Funding Sources:** Federal and state programs (Superfund, Brownfield, Bureau of Abandoned Mine Drainage) and local development corporations

West Philadelphia Rain Gardens | Credit: Stephanie Rindosh

Purpose

To clean up contaminated sites so that they no longer contribute toxic pollutants to waterways significantly.

Core Partners

Delaware River Basin Commission, States (DE, NJ, PA), United States Environmental Protection Agency

Key Partners

Cities/Counties, Urban Waters Federal Partners, and other federal collaborations

Contributing Partners

Private sector developers and investors

Timeframe

The remediation of a contaminated site can take many years to accomplish; the goal is steady progress to address the most significant of these sites within the next 10 years

STRATEGY W2.3: Support adaptive management and reporting of pollution reductions

Description

Under the Clean Water Act, parties are required to establish water quality criteria for specific pollutants, assess whether these criteria are exceeded in a water body, and thus impair its uses, and issue a National Pollutant Discharge Elimination System (NPDES) permit containing limitations on the discharge of that pollutant.

Until TMDLs began to be developed actively in the late 1990s, this approach did not consider cumulative impacts of all sources of pollutants to a water body. The approach rather regulated each individual discharge of pollutants through limitations on NPDES permits, assuming that by addressing each discharge individually, the cumulative impacts of these discharges would also be addressed.

PCB load reduction from top ten (10) NPDES point sources from 2005 to 2016. | Credit: DRBC

Permit limitations were set frequently without requiring an investigation of source reduction or treatment technology changes to decrease pollutant loads to achieve the permit limitation, leaving the means to achieve compliance the discharger's responsibility. Because of the costs associated with the reductions, this program approach often resulted in legal proceedings that may have affected achievement of the water quality criteria.

An alternative approach is based upon the principle of adaptive management that involves imposing data/information-gathering requirements in the permit, and managing requirements to reduce pollutant loads based upon the information received. Such an approach was employed following the establishment of TMDLs for PCBs in the Delaware Estuary and Bay in the early 2000s.

Two requirements were imposed on the 90+ NPDES permittees with wastewater discharges containing PCBs. The first recommendation was collecting effluent data using the uniform method. The second requirement was to develop and implement a Pollutant Minimization Plan (PMP) that provides for the identification of sources and their continual reduction/removal through comprehensive sets of measures, including track down studies; all should be process modification; material substitutions; treatment technologies; BMPs; and/or procedures tailored to the facility or site. Review of monitoring data collected between 2005 and 2013 indicated that a 64%

reduction has been achieved in the PCB loads on the part of these 90+ point sources. More aggressively, 71% load reductions were observed on the part of the top 10 point source discharges during the same period, and a 76% reduction was achieved on the part of the top 10 point source discharges based on effluent data for year 2016. Using this type of approach also allows for regulated sources of the toxic pollutant of concern to implement changes through capital and process improvements that focus on pollutant reductions over time.

This strategy will focus on maintaining this alternative approach to achieve water quality criteria to meet designated uses for PCBs. It will also apply the adaptive management approach to other legacy-hydrophobic pollutants for which this alternative approach would be more appropriate to achieve this goal than the traditional approach. The adaptive management approach may be appropriate when dealing with pollutants that adsorb to particles and settle into the sediment of water bodies, as they will continue to contribute pollutants to the overlying water until their sources are reduced and the sediments are allowed to cleanse themselves through the addition of clean sediment. It is important to note that this approach requires a long- rather than a short-term focus with the concurrent allocation of resources to support it. However, we need to ensure continued progress while being mindful of the schedule to avoid undue delay.

Major components of this strategy include:

- **Support achievements in monitoring and evaluation programs to track PCB reductions.** In December 2003, EPA Regions 2 and 3 established TMDLs for PCBs that were identified as a pollutant of concern through fish tissue data DRBC and the states (DE, NJ, PA) collected. In December 2006, the two EPA regions established TMDLs for PCBs for Delaware Bay. These TMDLs were implemented subsequently through an adaptive management approach led by DRBC that required PCB monitoring of wastewater discharges and the development and implementation of Pollutant Minimization Plans or PMPs. Monitoring is being conducted currently at 90+ facilities identified in the TMDLs report and the data are reported to DRBC for input into a database for evaluation. Required PMP reports and annual reports are submitted to DRBC and state permitting agencies for review. DRBC is completing an updated report on the TMDLs that will provide wasteload allocations and an additional requirement for NPDES permits. Continued evaluation of monitoring data and PMP reports are anticipated for the next five-year NPDES permit cycles.
- **Use adaptive management techniques to explore and use new information and technologies.** These techniques can include those applied to nutrients in Strategy 1.5, using the eutrophication model and technical studies to inform collaborative efforts. This modeling will be a collaborative effort on the part of the states (DE, NJ, PA), and private and public entities to improve water quality and, in turn, fish and wildlife populations.
- **Support identification of other pollutants of concern through research and monitoring.** Regulatory agencies, including the DRBC and the states (DE, NJ, PA), monitor ambient water sediments and fish tissue to identify pollutants that may compromise the designated uses of the Delaware River, Estuary, and Bay, which are not identical throughout the area. For example, drinking water is a designated use of the Estuary in the upper portion between Trenton, NJ and the Walt Whitman Bridge, while the successful propagation of fish and other aquatic life is not a designated use in the urban reaches of the river. These monitoring programs support regulatory programs under the federal and state clean water programs, including developing and reporting lists of impaired waters, developing fish consumption advisories, and assessing the trends in pollutants' concentrations in the Estuary's waters.
- **Promote the use of BMPs and treatment technologies to**

reduce pollutants. EPA has identified technologies to treat pollutants through the development of effluent guidelines. These are national regulatory standards for wastewater discharged to surface waters and municipal sewage treatment plants. EPA issues these regulations for industrial categories based on the performance of treatment and control technologies. Current issues, such as emerging contaminants of concern, will require identifying technologies and practices available that can achieve the nutrient loads that will protect water quality and aquatic life. EPA will take opportunities to pilot and champion innovative technologies. For example, it is initiating a nationwide, multi-year study on nutrient discharges from publicly-owned treatment works (POTW) to establish a statistically representative, nationwide baseline for nutrient discharge and removal at these facilities. This study will characterize operation and management practices that result in improved nutrient reduction (see EPA's webpage on the National Study of Nutrient Removal and Secondary Technologies for more information)

- **Report progress on pollutants reduction.** The reductions in pollutant concentrations in the Delaware River and Estuary, for those pollutants that are subject to TMDLs, are assessed typically by monitoring the ambient waters, sediments, fish tissue, and point and nonpoint sources. Continued support of these monitoring programs is essential, as other private and academic entities do not support ongoing monitoring programs typically. Ambient monitoring programs are expected to determine adaptive management programs' success. Indirect assessment of progress also can be accomplished by reporting pollutant load reductions from point and nonpoint sources. Examples of this are the 64% reductions in PCB loads from point sources between 2005 and 2013 that DRBC has reported and load reductions from tributaries, including the Delaware River at Trenton, NJ and the Schuylkill River

Funding and allocations of existing staff resources will be needed because these adaptive management approaches are long term in nature. These approaches also require a high priority to enable analysis of monitoring data and pollutant minimization plans that will form the basis for adjustments in reduction efforts. Resources also must be allocated to develop TMDLs and associated implementation plans for new or emerging contaminants.

Climate change also may influence the degree of the Delaware Estuary's capacity to assimilate a specific pollutant by reducing freshwater inflow and altering tidal effects.

Performance Measures and Key Deliverables

- Track PCB reductions and assessing current/emerging pollutants
- Track management coordination projects and activities on toxics' number and results, including reporting PMPs, impaired waters, pollution load reductions as required

Costs and Funding

- **Estimated Cost Range:** $$$
- **Possible Funding Sources:** Agency operating funds

Purpose

To support adaptive management approaches that achieve reductions in pollutants that affect aquatic life, wildlife, and human health.

Core Partners

Delaware River Basin Commission, States (DE, NJ, PA), United States Environmental Protection Agency

Key Partners

National Pollutant Discharge Elimination System Permittees

Timeframe

Adaptive management is the preferred approach for legacy and current pollutants that require source identification, removal and remediation, and monitoring. This approach will require multiple permit cycles (five years) and periodic adjustment to identify the most effective actions and techniques.

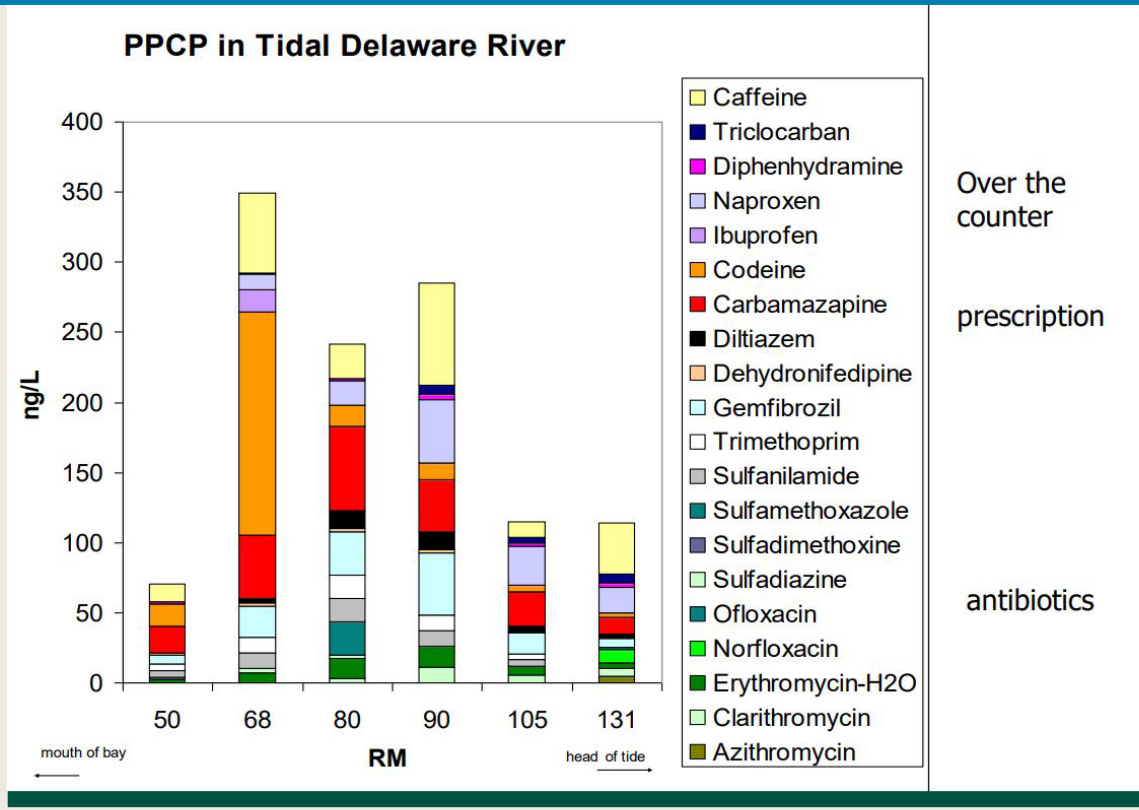
STRATEGY W2.4: Coordinate and promote research and monitoring efforts (chemical, physical, biological) associated with the causes of water quality impacts throughout the Delaware Estuary

Description

Historically, poor water quality in the Delaware Estuary was associated with oxygen-demanding pollutants, including chemical compounds containing carbon or nitrogen. These pollutants produced an anoxic zone (an area depleted of dissolved oxygen) in a reach of the river adjacent to Philadelphia, Camden, and Wilmington, near northern New Castle County. As oxygen levels improved, fish populations that were excluded from this reach formerly returned to reproduce. However, concentrations of toxic pollutants still were present, and resulted in effects attributable to chronic or long-term exposures and the accumulation of hydrophobic chemicals in fish tissues. NPDES permits issued to point source dischargers generally have included limitations on the discharge of conventional and toxic pollutants. These pollutants have technology-based guidelines or water quality criteria upon which the permit limitations are based.

In the past decade, the focus has shifted to contaminants of emerging concern (COC). These include per- and polyfluorinated alkyl substances (PFAS), polybrominated diphenyl ethers (flame retardants), and pharmaceutical and personal care products (PPCP).

The DRBC conducted initial studies on COCs between 2007 and 2009, the results of which are summarized in a report entitled "Contaminants of Emerging Concern in the Tidal Delaware River, Pilot Monitoring Survey, 2007–2009, August 2013." [10]



Pharmaceuticals and personal care products (PPCP) in the Tidal Delaware River (mg/L) in 2008. | Credit: DRBC

These studies indicated that PFAS and PPCP concentrations were elevated. One of the issues hampering the assessment of these chemicals' potential effects on aquatic life and human health is the lack of benchmarks for individual compounds and data on their interactions. In addition, some of the original emerging contaminants, such as PFASs, are being phased out with concurrent reductions in ambient water concentrations, but replacement compounds are being manufactured and used. Therefore, the next generation of COCs needs to be tracked and analytical methods developed to assess their potential effects.

This strategy will focus on supporting monitoring programs that both will track changes in the concentrations of emerging contaminants that have been identified and support research to develop benchmarks. These benchmarks can be used to evaluate potential effects of the release of current and new COCs into the Delaware River Watershed and methods to measure new COCs, such as replacements for PFAS and flame retardants.

DRBC, academic institutions in the region, U.S. Geological Survey (USGS), PDE, PWD, and the DE, NJ, and PA environmental agencies are the lead implementers of this strategy.

Major components of this strategy include:

- **Support monitoring programs and research on analytical methods to identify and track new COCs.** Through the Commission's MACC and PDE's STAC, the U.S. EPA and USGS support efforts to continue and expand research to develop analytical methods for new COCs and support monitoring programs to track the trends in current and new COCs' concentrations in ambient waters and fish tissue
- **Support research to establish benchmarks for COCs**. Support efforts of federal agencies, such as the EPA and USGS and state agencies (DE, NJ, PA), to develop benchmarks for current and new COCs. For example, the Drinking Water Institute of the NJDEP has developed a draft MCL for perfluorononanoic acid. These studies can form the basis to establish DRBC and state environmental agencies' water quality criteria to help assess and control COCs. Substitute PFAS also are being introduced as replacements for current PFAS that have been documented to contaminate drinking water and fish tissue

Funding and internal resources available will be the constraint for such monitoring and research on COCs. This may be overcome by prioritizing the types of COCs that present the greatest risk in the Delaware River Basin and monitoring COCs on a periodic basis or on a rotating watershed basis. Coordination of resources between governmental and university researchers also can overcome these constraints.

Performance Measures and Key Deliverables

- New data/outcomes shared and considered in decision-making
- Track number and results for research projects on toxics

Costs and Funding

- **Estimated Cost Range:** $$$
- **Possible Funding Sources:** Redirection of agency funds

Purpose

To coordinate and promote research and monitoring efforts (chemical, physical, and biological) associated with other pollutants that affect water quality in the Delaware Estuary.

Core Partners

Delaware River Basin Commission, Partnership for the Delaware Estuary, Philadelphia Water Department, States (DE, NJ, PA), United States Environmental Protection Agency

Key Partners

United States Geological Survey, Science and Technical Advisory Committee and Monitoring Advisory, and coordination committee member organizations

Timeframe

Short-term support for periodic surveys of ambient waters and fish tissue, and research on methods to analyze new contaminants of emerging concern. Long-term support for benchmark research studies and coordination of monitoring programs.

STRATEGY W2.5: Conduct and coordinate (where appropriate) education, research, monitoring, and communication about fish and shellfish consumption to protect human health

Description

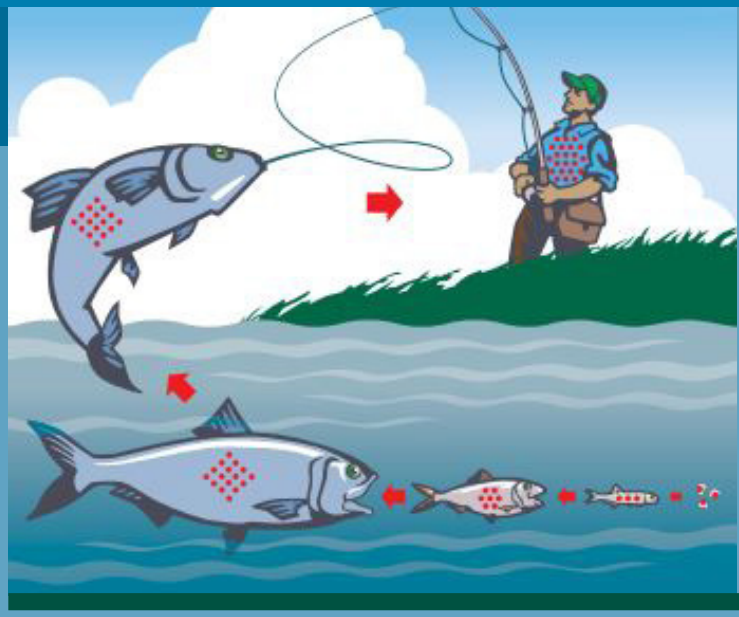
Fish and shellfish are important economic and food resources for the Delaware Estuary region and help sustain some of the area's most economically vulnerable communities. For example, the Delaware Bay oyster industry contributes $3.6 million annually to the region and is a crucial source of income in communities around the Bayshore.[7]

Recreational fishing is an active pursuit in both urban and rural areas and is valued at $52 million annually in the Delaware Estuary.[7]

However, fish and shellfish from

Can climate change affect contaminant levels in fish and shellfish?

Climate change is likely to affect contaminant levels in fish and shellfish in different ways, depending on the type of contaminant and ecological route by which these materials are accumulated. For example, concentrations of chemical contaminants may increase in the atmosphere due to changes in weather patterns and temperature. Subsequent deposition onto land and water may increase polluting chemicals in waterways. Increases in extreme weather events, flooding and more frequent and pronounced runoff may transport more sediments and associated pollutants into waterways. Erosion of legacy pollutants along shorelines can also increase because of sea level rise. By leading to greater concentrations of polluting chemicals in the water, these climate change factors can lead to higher contaminant levels in fish, shellfish, and other animals that live and feed in the water, putting human health at higher risk. These relationships are complex and potentially magnified by warmer water temperatures that may also increase the release of chemical contaminants from sediments and promote faster uptake by fish and shellfish.



Pollutants can bioaccumulate, or increase in quantity as they move up the food chain. This can happen when a small fish ingests contaminants, a larger fish consumes the small fish, and people catch and eat them. The longer the fish lives, the more time it has to bioaccumulate pollution. | Credit: Frank McShane (Image from Estuary News Volume 27, Issue 2, Winter 2017)

Biological contaminants are also likely to increase in the water with warming temperatures, potentially impairing fish and wildlife directly, as well as increasing health risks to people who consume them. There is evidence that some shifts in biological communities are already occurring as a resulting of warming. The base of the food chain is very sensitive to changes in light, oxygen, nutrients, temperature, and salinity, all of which can be affected by changing weather patterns and climate. Invasive and opportunistic species, including many biological pathogens that affect human health or cause animal diseases, often are favored under disturbed and warmer conditions. For example, the non-native disease that kills oysters in Delaware Bay (Dermo) is more virulent and prevalent in warmer and saltier conditions, which are expected to increase with climate change and sea level rise. Human health risks from consuming raw oysters are similarly increased because warmer temperatures are also more conducive for many pathogens that accumulate in oysters which can harm people (such as some species of *Vibrio*).

certain areas may not always be safe to eat. For example, in areas with higher pollutant concentrations, fish and shellfish species can accumulate harmful contaminants and shellfish can accumulate harmful bacteria as well. Shellfish sanitation programs protect consumers and the industry by monitoring bacteria and contamination levels. Fish consumption advisories also protect people by announcing closures to a potentially contaminated area. Materials such as fishing license brochures also include the risks associated with eating fish and shellfish from an area with high pollutants. Improving water quality conditions should reduce the need for closures and fish consumption advisories over time. However, in the meantime, these are important mechanisms to minimize harmful effects on human health.

Conducting education, coordinating research (where appropriate), monitoring the Estuary, and communicating about fish and shellfish consumption risks to human health include several key activities:

- **Monitor pollutants in fish, water, and sediments.** There are a number of contaminants of concern for fish consumption. Many are hydrophobic legacy pollutants that are accumulating in the sediments and tissues of resident and anadromous fish species. They take many years to empty out of the waters of the Estuary because of continued contributions from the sediments. Some of these contaminants can bioaccumulate in fish over time and reach levels unsafe for frequent human consumption. These include contaminants such as PCBs; dioxins and furans; mercury; dieldrin (an insecticide); pesticides—dichlorodiphenyltrichloroethane, dichlorodiphenyldichloroethane, and dichlorodiphenylchloroethylene (DDT, DDD, and DDE, respectively, with DDT the chlorinated pesticide known most well)—chlordane, and heptachlor epoxide. Monitoring these and other emerging COCs in water, sediments, and fish is critical to assess risks and develop advisories, and therefore, these efforts need to continue.

Delaware Department of Natural Resources and Environmental Control and Department of Health and Social Services fish consumption advisory sign. | Credit: Delaware Surf Fishing

- **Support shellfish sanitation programs.** Certain bacteria and viruses in waterways can render oysters and other shellfish unfit for human consumption, particularly during warmer weather. Ensuring that oysters grown in the Delaware Bay are safe for people to eat is a top priority for both the industry and state shellfish sanitation programs. Through rigorous water quality testing, designation of harvest areas, and communication with growers and the public, state shellfish sanitation programs prevent and detect problems, and close shellfish beds to harvest quickly if/when needed.
- **Provide coordination and education about consumption advisories.** Each of the states—Delaware, New Jersey, and Pennsylvania—develops fish consumption advisories for the water bodies in those states (Links to NJDEP 2018 Advisories, DNREC 2018 Advisories, and 2018 PADEP Advisories). The purpose of these advisories is to inform the public of potential health risks of consuming tainted fish. Some important strides have been made to improve these advisories' effectiveness,

including coordination between Delaware and New Jersey to use similar standards and practices to provide consistent advice to the public. Efforts on the part of PDE and Pennsylvania Sea Grant also have increased and improved communication of advisories to the public (for example, by translating them into different languages). However, continued attention to keep these advisories current, reach the right audiences, and coordinate risk assessment and communication practices and messaging regarding these advisories is an ongoing need.

The states (DE, NJ, PA), are the lead entities that implement this strategy and have existing personnel and programs devoted to these activities. The DRBC also plays an important role in implementing monitoring activities and managing toxics overall, such as PCBs in the Delaware Estuary. Academia plays a significant research role in increasing our understanding of the human health risks various pollutants, including new ones, pose, and pathways by which they travel through the ecosystem to fish and shellfish. PDE and Sea Grant programs in all three states play important roles in communicating and amplifying shellfish consumption advisories to reach people. Key audiences that need this information include sensitive populations (including infants, children, and women of childbearing age), waterfront communities, and ethnic and/or underserved populations more likely to consume fish and shellfish taken from the Delaware Estuary.

There are no major effects on fish consumption anticipated from climate change, but it is complicated, and the possibilities have not been explored fully. For example, increasing water temperatures could increase the incidence of disease-causing bacteria or viruses. Rising sea levels and increased rainfall also may transport more contaminants to the waterways from un-remediated sites. Warming water and a longer growing season have the potential to increase the types and extent of harmful biological agents in shellfish, such as viruses and bacteria, potentially offsetting pollutant reduction gains. Oyster populations also may shift their ranges within closer proximity to sources of contamination.

Performance Measures and Key Deliverables

- Evidence of reaching key audiences in each state and decreases in number/extent of advisories and closures
- Track number and results for consumption advisories projects and programs, including issuing/re-issuing advisories

Costs and Funding

- **Estimated Cost Range:** $$$–$$$$
- **Possible Funding Sources:** State and DRBC budgets, National Estuary Program (NEP), grant programs

Purpose

To prevent pollutants' harmful effects on people through the consumption of fish and shellfish.

Core Partners

Delaware River Basin Commission, Partnership for the Delaware Estuary, States (DE, NJ, PA)

Key Partners

Academia, Sea Grant Programs, United States Food and Drug Administration

Contributing Partners

Waterfront communities

Timeframe

Monitoring and sanitation efforts are ongoing, as is communication about fish consumption advisories. Advisories are revisited/produced annually to every two to three years.

STRATEGY W2.6: Improve, sustain, and enhance spill communication and response with Delaware Estuary partners

Description

After the 2004 Athos 1 Oil Spill, the Delaware River and Bay Oil Spill Advisory Committee was formed and produced recommendations for improving spill prevention and response. | Credit: Delaware Sea Grant

The Delaware Estuary is the second largest petrochemical center in the nation and the world's largest freshwater port. Thousands of vessels carrying over 70 million tons of cargo service the port complex annually, many of which import and export oil and other refined products. Since 1974, there have been at least 10 oil spills of more than 100,000 gallons into the Delaware River; smaller spills are a more frequent occurrence. As a strategic national port, these spills disrupt normal port operations and cause substantial economic harm to recreational fishing, boating, and ecotourism activities. Following a significant spill, the responsible party is required to pay for damages to natural resources and economic losses.

In response to the November 26, 2004 spill of 265,000 gallons of crude oil from the Athos I, the Department of Homeland Security called for the formation of a Federal Advisory Committee to provide recommendations for measures to improve the prevention and response to future oil spills in the Delaware River and Bay. The resulting Delaware River and Bay Oil Spill Advisory Committee (DRBOSAC) Report of 2010 contains 20 recommendations to improve the prevention of future spills' response, recovery, and mitigation.[4]

The mission for Strategy W2.6 is to help implement a subset of the DRBOSAC report's non-regulatory recommendations. Major components of this strategy include:

- **Identify, obtain, and catalogue completed and ongoing scientific research, provide public access, and ensure the protection of environmentally sensitive areas through data outlined in the DRBOSAC report (DRBOSAC Report R-18).** Despite the frequency

and magnitude of oil spills in the Delaware Estuary, there has been very little research on their ecological effects on the indigenous fauna, flora, and ecological relations of spills from different types of oil and other substances. There is no central repository of completed spill studies or technical group of ecological experts. DRBOSAC spill response managers noted that this lack of information and access to expertise on environmentally sensitive areas and species hampers the ability to target spill responses and perform damage assessment.

Therefore, this action works to gather and disseminate information with respect to key natural resources that are most vulnerable to future spills' location and sensitivity. The DRBOSAC recommendation is as follows:

"Provide dedicated funding to an appropriate agency or organization, such as the Congressionally-authorized Delaware Estuary Program, to catalogue and share existing data on oil-associated environmental effects, including effects of spills, and on the ecological status of the Delaware Estuary; to identify information gaps; and to work with all Delaware Estuary program partners to support oil spill-related scientific analysis and research to fill vital information needs. Develop a mechanism for ensuring that all present and future research is catalogued and made publicly available."

Specific actions to accomplish this goal are to:

- ▷ Inventory existing data on the health, habitats, effects, and needs in the Delaware Estuary
- ▷ Perform a gap analysis to ensure a thorough understanding of all research needed to understand oil spills' individual and cumulative effects
- ▷ Develop a strategy and dedicated funding to fill data gaps, including possible baseline monitoring for oils in the system
- ▷ Create an open process by which data are made available
- ▷ Ensure that this work is revisited every five years. Strategies to accomplish these actions include white papers, symposia, work groups, and grants

- **Identify and prioritize restoration needs and mitigation projects (DRBOSAC Report R-19)**. Following a spill of oil or another injurious material, restoration often is required to repair the damage to natural resources, as well as offset any economic consequences. Although this mitigation via beneficial environmental projects is intended to restore ecosystem health and function, in practice there often are insufficient appropriate restoration projects that are ready to be implemented. Lack of understanding of spills' full ecological effects complicates restoration project prioritization further. As a result, mitigation projects that do not support the restoration of resources a spill affects directly often are selected, and sometimes are located in areas outside the Delaware Estuary. To facilitate more direct and effective mitigation of spill damages, the DRBOSAC recommendation is to:

  "Provide dedicated funding to an appropriate agency or organization, such as the Congressionally-authorized Delaware Estuary Program to identify and prioritize restoration needs for mitigating the harm of oil spills large and small and to identify existing and/or emerging restoration projects that can be implemented."

Specific actions to accomplish this goal are:

- ▷ Provide dedicated funding to support PDE's Regional Restoration Initiative to identify, catalogue, and prioritize restoration activities and projects needed for the Delaware Estuary) and ensure that restoration decisionmakers are provided science-based tools
- ▷ Operate a competitive grants program through the DELEP to support initiatives and entities to fill project gaps, and catalogue

restoration efforts underway currently or planned in the region

- ▷ Provide a competitive grants program to support restoration activities and projects that do not meet the constraints of the Natural Resource Damage Assessment program (restoration of direct damages by a responsible party)

The Regional Restoration Initiative (RRI), a project registry, and technical and management workgroups already exist, but no funding has been available to sustain the effort since 2015. Therefore, the primary strategy to accomplish these actions is to identify and obtain sustained funding.

Rising sea levels and salinity, warming, and other climate changes are certain to alter the distribution of key natural resources that exist in harm's way, including spills of oil and other harmful substances. This will require more frequent surveys and mapping of environmentally sensitive species and habitats. Because high temperatures and/or more turbulent weather events will stress or weaken some native plants and animals, their sensitivity to chemically-mediated stress, such as chronic toxicity to spilled substances, could be reduced because of additive or synergistic physiological responses. However, rising sea levels should provide a greater depth of water for larger vessels to navigate safely, which could decrease spills associated with striking submerged objects, but more intense storms also could increase maritime transportation incidents.

Performance Measures and Key Deliverables

- Develop inventories or other tools
- Track number and results of spill communication response projects and tools

Costs and Funding

- **Estimated Cost Range:** $$$$
- **Possible Funding Sources:** U.S. Coast Guard, Natural Resource Damage Assessment, Congress via Oil Pollution Act of 1990, and Oil Spill Liability Trust

Cape May, NJ. | Credit: PDE

Purpose

To help respond to oil and other harmful products spills into the Delaware Estuary and Conduct research and strategic planning to guide restoration following spills.

Core Partners

Delaware River Basin Commission, Partnership for the Delaware Estuary, Philadelphia Water Department, States (DE, NJ, PA), United States Environmental Protection Agency

Key Partners

Delaware Bay and River Co-op, United States Coast Guard, Sector Delaware Bay Local Area Committee, United States Fish and Wildlife Service

Contributing Partners

Mariners' Advisory Committee for the Bay & River Delaware, National Oceanic and Atmospheric Administration

Timeframe

The Area Committee meets several times annually. Research and planning is ongoing. Spill restoration is case-by-case in response to incidents.

CLEAN WATERS GOAL 3:

SUSTAIN FLOW FOR DRINKING WATER AND ECOSYSTEMS

Brandywine Creek in Wilmington, DE | Credit: Kristen Neal

Approximately 15 million people rely for their water needs from the Delaware River Basin. On average, over 6.0 billion gallons of Delaware River Basin water are used daily. A system of reservoirs in the Upper Basin stores water for export to New York City and makes compensatory releases to maintain water temperatures immediately below the reservoirs and flows in the river in the Upper Basin. Water also is exported through the Delaware & Raritan (D&R) Canal for New Jersey residents. Within the Basin, uses related to power generation (thermoelectric) account for the majority of water withdrawals (59%), with the next largest use for public water supplies (13%). Additional releases also are made from reservoirs in the Lower Basin to maintain freshwater inflows to the Estuary (See TREB Chapter 2 for additional details on water uses and withdrawals).

An estuary is a unique water body that is a mixture of fresh and saline waters, and is a transition zone between fresh water flowing from rivers, streams, and lakes and the salt waters of the ocean. Human and ecological communities in this transition zone rely on a balance of fresh and salt waters commensurate with their location in the estuary. Maintaining this balance requires decision-makers across communities, sectors, and jurisdictions to work together. The "salt line" is an estimated location along the tidal Delaware River where

the seven-day average chloride (e.g., salt) concentration equals 250 mg/L. The salt line plays an important role in the Delaware River Basin's water quality and drought management programs. This is because upstream migration of brackish water from Delaware Bay during low-flow and drought conditions could increase chloride concentrations in large public water supplies and industrial intakes, presenting potential treatment and corrosion challenges. Aquifer depletion and saltwater intrusion into groundwater aquifers are also concerns in some areas.

Regional sediment management is another topic that requires cooperation and collaboration and can affect flow. In the Delaware River Basin, sediment erodes away from river banks and bottoms, and coastal wetlands, and can create problems for flow and navigation when it is deposited along river channels and near marinas. Sediment can be dredged and relocated as waste, or, if it is the right size and type, it can be used in places to replenish wetlands and protect coastal areas.

Regional sediment management addresses this challenge. In many ways, sediment management actions are associated more closely with actions in the wetlands section of this plan rather than they are with flow management. However, the DELEP partners included sediment management in this section because of the nexus between sediment and water, the regional nature of sediment management, and the U.S. Army Corps of Engineers' (USACE) extensive involvement in sediment management.

HOW WE WILL MEASURE SUCCESS:

- Achieve and maintain flow at key locations for the protection of downstream users
- Develop and meet targets for flow/salinity for fish, shellfish, and wetlands
- Improve water efficiency through water conservation projects/programs

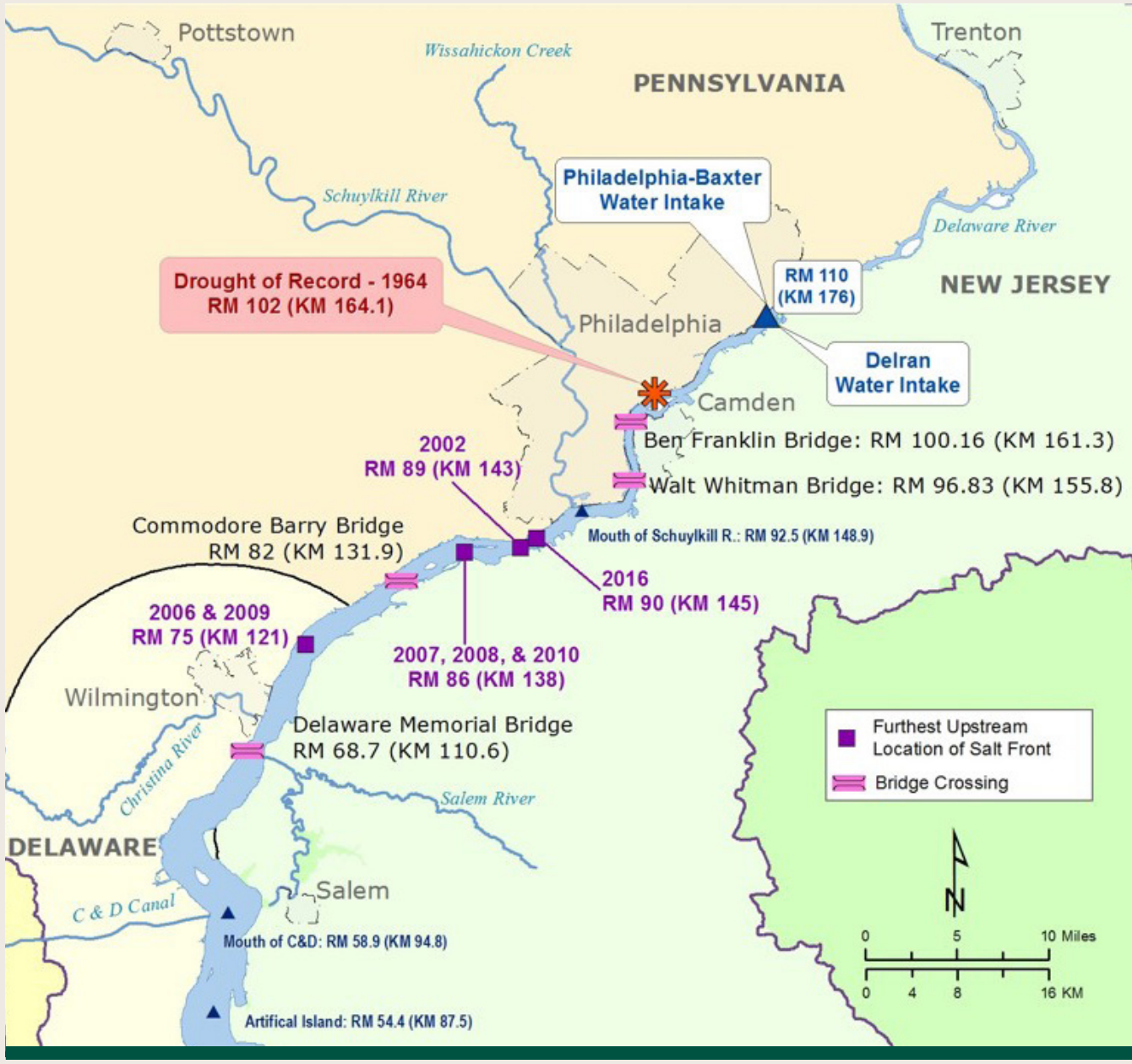
Flow management strategies have been providing the Delaware Estuary with adequate freshwater and restricting the upstream movement of the salt line successfully, which has protected drinking water intakes effectively in the most densely populated area of the Delaware River Basin. Water conservation efforts have kept residential consumption rates down, but water conservation and management will be critical increasingly with growing populations, uses, and climate change. Flow has been managed well for drinking water in the past, but changing environmental conditions could lead to new concerns and challenges in the future.

STRATEGY W3.1: Inform and collaborate with decision-makers and water resources managers to ensure that main-stem Delaware River flow meets the needs of the Delaware Estuary

Description

Ensuring the balance of freshwater and salt water in the Estuary is critical for ecological health, and also is crucial for vital human uses of water resources, such as drinking water supply and power generation. Species, such as oysters, shad, and the Atlantic sturgeon, require specific levels of dissolved oxygen and salinity (often different levels during different periods of their life-cycle) which can be managed, in part, by freshwater flows into the Estuary. The City of Philadelphia, as well as other water purveyors, use the Estuary as a water source, so high levels of salinity can create water quality challenges.

The competing needs for water resources in the Delaware River Basin change constantly and the amount of water available to meet all uses desired is finite. Over the years, water resource managers have worked together, and with interested stakeholders as well, to develop flow management programs to meet the evolving needs within and outside the Delaware River Basin. Predicted trends in climate may affect the water available to meet these needs based on



Map of historic salt front (line) locations along the Delaware Estuary. Salinity is a concern for municipal water systems as well as species ranges. | Credit: DRBC

the effects attributable to precipitation, evapotranspiration, and rising sea levels, which are expected to be substantial in the region. Water resource management programs related to flow may need to be adjusted and new sources may be required to address the Basin's water needs.

Research is needed to evaluate existing flow management programs' ability to meet the Estuary's freshwater flow needs today and into the future. By collecting and synthesizing the results of such research, regulators, water resource managers, and other decision-makers will be better informed about the potential effects of human ecological system alterations and climate change, including rising sea levels, changing temperatures, storms/droughts' frequency, and other factors.

Regional, state, and local agencies involved in flow management decisions that affect the Estuary will be the primary implementers of this strategy, with DRBC as the principal agency involved in flow management efforts. DRBC will rely on the utilities, industries, and research community to inform the technical analysis of human and climate factors to manage the basin's flow, water quality, and water resources.

Key efforts for this strategy will require the DELEP partners to:

Delaware River, Philadelphia, PA | Credit: Richard Fallstich

- **Promote collaborative management.** Promote collaborative management of storage and flow for the Delaware Estuary and Bay through initiatives of PDE's STAC and participation in public forums, such as DRBC's Regulated Flow Advisory Committee and its Subcommittee on Ecological Flows.
- **Participate in scoping activities.** Participate in scoping activities for studies related to flow management and water needs. Such participation may be possible by collaborating with such agencies as the William Penn Foundation, Academy of Natural Sciences, Federal Agencies such as U.S. Fish and Wildlife Service (USFWS), EPA, USGS, and USACE, as well as area regulators and others.
- **Support for research on flow needs.** Provide support for research on flow needs and the amounts of water required to meet the criteria. This may include providing data to researchers, identifying grant opportunities, and providing in-kind matches and/or letters of support.
- **Synthesize ecological flow research.** Synthesize and summarize research on ecological flow needs and the effects of climate change and rising sea levels on the Estuary's freshwater/saltwater balance by collecting and reviewing studies, comparing research results, and summarizing the results in a comprehensive educational package for decision makers.
- **Promote water protection.** Encourage and promote water suppliers' source water protection efforts as a way to sustain stream flows.

Available funding for research or its review, including the correct type (relevant to the decisions being made), staff resources, decisionmakers' receptiveness, and politics may affect this objective's success. However, providing information about current flow needs, effects observed already, and preliminary results of current research may overcome some of these constraints.

Performance Measures and Key Deliverables

- New data/outcomes shared and continued improvement in flow management to meet the Estuary's human and ecological needs
- Track number and results of management coordination and research projects/activities to address flow needs

Costs and Funding

- **Estimated Cost Range:** $$$
- **Possible Funding Sources:** To be identified as research issues are identified

Brandywine Creek Wilmington | Credit: Thomas Davis

Purpose

To inform and collaborate with decisionmakers and water resource managers to ensure that main-stem Delaware River flow meets the Estuary's needs.

Core Partners

Delaware River Basin Commission, Philadelphia Water Department, States (DE, NJ, PA)

Key Partners

United States Army Corps of Engineers, State of NY/NYC

Contributing Partners

Natural Resources Conservation Service, United States Fish and Wildlife Service, Water Resources Association of the Delaware River Basin, large-scale water users (public and private)

Timeframe

Long-term with ongoing and continuous outreach to researchers, stakeholders, water resource managers, and decisionmakers

STRATEGY W3.2: Conduct research and monitoring on water quality and habitat requirements of estuary-dependent species

Description

PDE monitors freshwater mussel populations in the Delaware River near Camden, NJ. | Credit: PDE

Every species has unique physical and chemical needs critical to their function and survival, including temperature, salinity, water quality, and other water quality characteristics. Similarly, certain types of habitats are essential to the survival of species, and can vary with life stage. Resource managers sometimes refer to these as "critical habitat." Typically, animals and plants can function successfully within a range of conditions, and growth and reproduction are optimal somewhere in the middle of that range.

Implementation of this strategy will provide scientists and resource managers an understanding of the lower, upper, and optimal requirements for water quality and habitat for species that depend on, and are ecologically significant in, the Delaware Estuary. Ecologically significant species include animals and plants that supply the greatest ecosystem services (e.g., water filtration, flood protection, carbon sequestration, pollutant remediation), support economic interests (e.g., fisheries, shellfisheries, ecotourism), or are rare and protected (e.g., threatened and endangered species). Currently, there is a shortage of information available regarding these key species' water quality and habitat needs.

As one of the world's largest freshwater tidal estuaries, the Delaware system has many important species that are sensitive to salinity conditions (e.g., freshwater tidal vegetation, freshwater mussels, and migratory fish species, including Atlantic sturgeon). In addition to salinity, water chemistry also affects animals and plants. Species that cannot move to escape conditions, such as bottom-dwelling organisms (e.g., shellfish, vascular plants, phytoplankton) are particularly vulnerable.

Water management practices in the Delaware Estuary have the potential to affect species dependent on the Estuary by altering habitat quality and water quality and quantity. DRBC assesses water management practices via information provided through the commission and state agencies.

- **Conduct research on water quality/quantity and habitat requirements.** Existing studies and monitoring data may contain important information about water quality, quantity, and habitat requirements for ecologically significant species that depend on the Delwaware Estuary. These studies will be reviewed to determine what information exists and gaps in our knowledge.

  ▷ The brief the STAC prepared in 2014, based on current knowledge regarding Atlantic sturgeon in the Upper Estuary's dissolved oxygen requirements, is an example of the way partners have collaborated to synthesize data and information. This synthesis identified key research gaps and presented research recommendations that led to studies that are currently in progress to fill an important information gap. However, water and habitat requirements for many ecologically significant species, such as oysters, freshwater mussels, and dominant plants in coastal wetlands remain largely unknown. By understanding these and other key species' responses to salinity change, new research may show the way to protect Estuary-dependent natural resources by maintaining sufficient river flow to sustain a suitable salinity regime in the Delaware Estuary. Understanding critical habitat needs can help managers establish flow objectives that protect existing areas that are particularly vital to restore degraded habitats.

- **Provide research and support for efforts to model and monitor salinity in the Estuary**. In addition to studying rising sea levels, human-ecological system alteration, and other factors that affect the Estuary, additional research may be required to study factors that govern the volume of the tidal freshwater Estuary, as well as identify additional sources of chlorides in the Delaware River Basin (such as from road salts and industry). Continued evaluations of flow targets at Trenton, NJ are necessary to safeguard the salt line in the Estuary, particularly from environmental influences, including rising sea levels, and factors such as flooding, erosion, storms, and natural hazards. The region needs to continue to improve water withdrawal information's accuracy and comprehensiveness and provide it to the states (DE, NJ, PA) and the DRBC. Studies on potential growth in the thermoelectric sector are needed to understand potential new demands on the system, and support could be provided to identify and manage water loss in the Delaware River Basin. A more detailed assessment of withdrawal and discharge volumes applied at the small watershed scale also is needed.

- **Identify monitoring, tracking, and other research needs.** Many ecologically significant species depend on the Delaware Estuary, but monitoring programs to track their population health and distributions are currently inconsistent and need to be revamped. Long-standing monitoring programs exist to assess such hallmark species as red knots, oysters, and horseshoe crabs, and, as a result, there is a relatively strong understanding of their habitat requirements and locations. Some questions remain to be answered for these species, such as the way changing salinity conditions in the Delaware Estuary may be altering food and predator relations, as well as recruitment. There is much less known about the state, trends, water and habitat needs of important species, such as freshwater mussels, herring, and menhaden because of inconsistent monitoring, mapping, and research. Mammals also are sensitive to salinity and flows, and those such as the otter can be important indicators of water quality and may be important research subjects as well. Thus, an inventory of past and current monitoring and mapping is needed to identify, prioritize, and fill information gaps.

Climate change may cause shifts in community species' composition within wetlands that could make them more susceptible to degradation. Increased salinity will drive salt marshes' succession into freshwater marshes and forests. Rising sea levels also affect the hydroperiod, which can influence wetland productivity and resilience in turn. Studies suggest that climate change will include warmer water temperatures and higher salinities, which could affect oysters' recruitment dynamics, disease susceptibility, food quality, and habitat available. The availability of critical habitat and freshwater that freshwater mussels need is likely to decrease with saltwater intrusion into the upper Estuary, particularly for species that exist only in tidal freshwater habitats. Except for an expected decrease in dissolved oxygen in warmer water, climate change's effects in changing water quality and quantity are not understood well, and continuous monitoring and updated modeling will be needed into the future.

Performance Measures and Key Deliverables

- Research priorities identified and outcomes produced/shared for two to three key species
- Track number and results of research projects on flow/salinity needs of Estuary species

Costs and Funding

- **Estimated Cost Range:** $–$$
- **Possible Funding Sources:** Federal agencies/ grants (U.S. Geological Survey, U.S. Environmental Protection Agency), state revolving funds, wildlife initiatives, industry funding (e.g., oyster industry)

South Street Bridge, Schuylkill River, Philadelphia, PA | Credit: Richard Fallstich

Purpose

To develop a better understanding of the habitat and water quality requirements of ecologically significant species that inhabit the tidal estuary so that flows can be managed better.

Core Partners

Delaware River Basin Commission, Partnership for the Delaware Estuary, States (DE, NJ, PA), United States Environmental Protection Agency

Key Partners

Academia, United States Geological Survey, United States Fish and Wildlife Service

Contributing Partners

Conservation Districts, Delaware Bay and River Co-op, National Oceanic and Atmospheric Administration

Timeframe

Habitat Requirements: 5-10 years

Model, Monitor Salinity: 2-10 years

Monitor, Track Research: 1-10 years

STRATEGY W3.3: Promote water conservation and water efficiency by utilities and industrial water users

Description

As the human population continues to grow, so does the demand for treated water supplies. However, an increased public awareness of water use and the evolution of water conservation technologies has mitigated this increased demand over the past 40 years and led to a more efficient use of public and commercial water and a decline in demand overall.

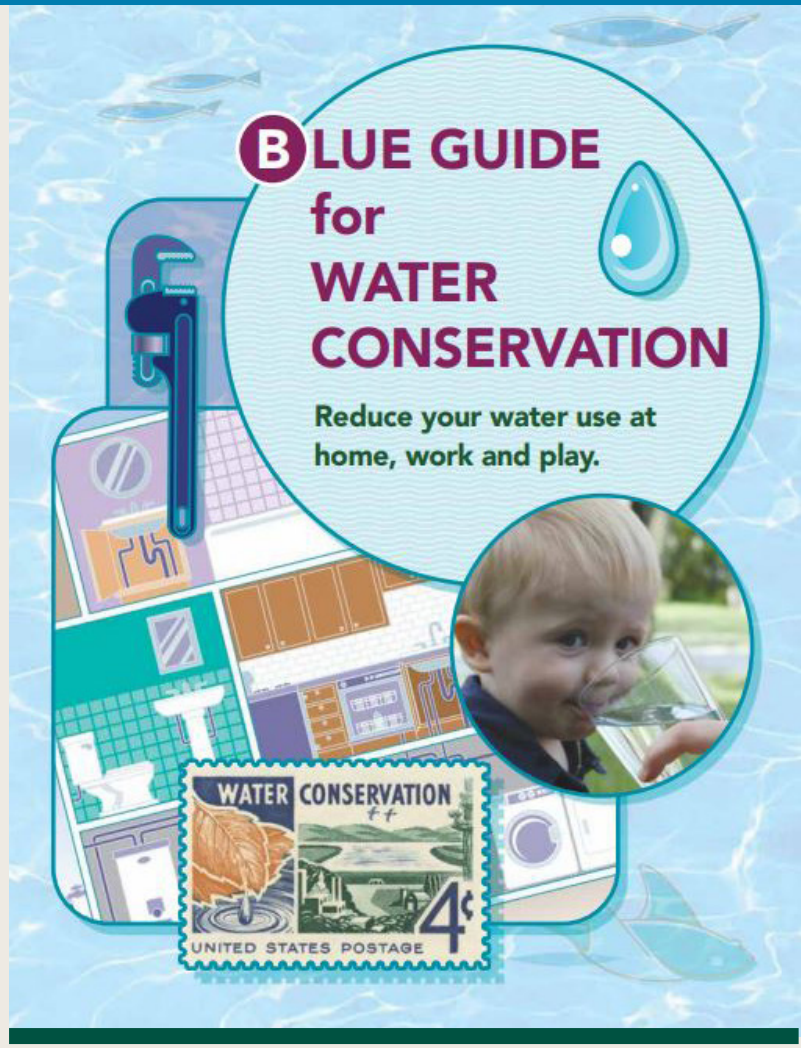
Conserving water ensures there is enough water flow both for people and ecological systems, which is important to sustain the water quantity and quality above and below ground. Regional, state, and local agencies involved in water use in the Estuary (DRBC, DE, NJ, PA, Philadelphia, etc.) will be the primary implementers of this strategy and will rely on the research community and trade organizations, as well as public and private purveyors, to implement water conservation fully.

Water efficiency efforts will focus on priority areas of the Estuary, including:

- Aquifer areas, such as the Potomac-Raritan-Magothy, Kirkwood-Cohansey, and Triassic formations that are sensitive to depletion and saltwater intrusion and affect people as well as natural habitats
- Designated groundwater protection areas
- Areas with potential water shortages and/or streams with low-flow problems

Major components to promote water conservation in the Delaware Estuary include:

- **Apply advanced methods and programs.** Many opportunities exist for future water and energy conservation in the Estuary. The WaterSense program has helped transform water efficiency from a drop in the bucket to more than 2.1 trillion gallons of water saved in the United States from 2006 through 2016.[14] WaterSense also labels products that reduce water and energy used in cleaning, showering, etc. Energy STAR is an international standard for energy-efficient consumer products, which the EPA and the Department of Energy created in 1992. Because water supply requires energy and energy generation requires water, reductions in either or both would conserve both



The Blue Guide for Water Conservation **provides information for local residents to learn about water efficiency and how to take positive actions to reduce water use.** (Support for the Blue Guide was provided by ALS, ANJEC, DNREC, PEC, NJDEP, PWD, SAN, WPF, UDEL, City of Newark, and Schuylkill River National State & Heritage Area with funding provided by the U.S. Environmental Protection Agency)

- **Promote use of updated plumbing standards.** The Uniform Plumbing Code (UPC) is a model code the International Association of Plumbing and Mechanical Officials (IAPMO) developed to govern the installation and inspection of plumbing systems as a way to promote the public's health, safety, and welfare. The UPC is designed to provide consumers with safe and sanitary plumbing systems while allowing latitude for innovation and new technologies simultaneously. The public at large is encouraged and invited to participate in IAPMO's open consensus code development process. This code is updated every three years.

- **Research and promote use of administrative tools such as water loss audits.** Nationwide, an estimated six billion gallons of water is taken from water resources daily and never reaches the customer. This is sufficient water to supply the drinking water needs of the 10 largest cities in the United States.[3] In the Delaware River Basin, this number is estimated at 150 million gallons per day.[3] Water suppliers are experiencing real water losses attributable to physical infrastructure failures and apparent losses resulting from inaccurate meter readings and erroneous billing practices.

  ▷ As demand for water increases, it is essential to ensure that water supplies and the infrastructure that delivers water are dependable and move the water from source to customer efficiently. In the past, water system audits have been conducted in the absence of consistent definitions and standards and often have used inappropriate metrics to measure the water supply's efficiency. Not surprisingly, some systems bill only half, or less, of the total water they treat, pressurize, and put into the distribution system. In 2009, DRBC amended its Comprehensive Plan and Water Code to implement an updated water audit approach to identify and control water loss in the Basin. The new approach is consistent with the International Water Association (IWA) and American Water Works Association (AWWA) Water Audit Methodology that is considered a BMP in water loss control. Use of these tools resulted in a clearer understanding of the causes of water loss and allowed system operators, utility managers, and regulators to target their efforts to improve water supply efficiency. Other tools also may be used to promote conservation in the Estuary as they are developed.

- **Research and disseminate information related to conservation rate structures.** The concept of conservation rate structures compels utility customers to consume less water by increasing the price as they purchase larger volumes of water. This strategy must be balanced with a water purveyor's need to recover its fixed costs regardless of actual water use.

  ▷ The financial justification for conservation rate structures is based on the premise that a large portion of the water purveyor's infrastructure and distribution costs are used to meet daily and seasonal peak demands. Water efficiency reduces operating costs and delays the need for system expansion and acquiring additional water supplies and storage capabilities. DRBC Water Code encourages conservation pricing structures for new or expanded withdrawals of more than 1.0 million gallons daily. Users that require more than that must submit water conservation plans and include a feasibility assessment with respect to implementing a pricing structure that encourages savings. Further research on conservation pricing structures and an outreach program to water purveyors in the Delaware Estuary Watershed would continue the efforts DRBC and others started to reduce water use through incentive pricing

- **Promote infrastructure improvements.** Drinking water systems in the United States are up to 100 years old in some places. The AWWA has estimated that it will cost nearly $1 trillion in the next 25 years to

repair and expand our drinking water systems to meet the growing population's demands.[1] Other challenges include warming temperatures, which can affect the water supply, and contamination of water sources. Outreach programs for customers in the Delaware Estuary may help heighten the public's awareness of infrastructure's value and acceptance of large capital improvement projects and costs. For example, PDE is currently engaged in an outreach campaign in collaboration with other non-governmental partners in Delaware to raise awareness about the need for dedicated funding for clean water improvements, including infrastructure, among other things.

- **Advance water conservation outreach programs.** In addition to the utility level outreach programs described above, outreach to individuals, businesses, and industries is needed to continue the successful conservation efforts we've seen over the past four decades. Outreach may include dissemination of information at regular events held in the Estuary, such as Coast Day, Bay Day, and Earth Day. It also may include direct mail, email, and web promotions, as well as information provided to customers in their utility bills.

Funding available for research on conservation measures may affect this goal's success. The costs these conservation tools impose on utilities and customers also may be a constraint. Further, climate change may influence this goal, as utilities may have difficulty meeting demands during more frequent drought conditions, and hotter, drier conditions could make conservation difficult. However, advancing the use of conservation tools before droughts occur and repairing infrastructure to accommodate water demand may overcome some of these constraints.

Water Sense is a voluntary partnership sponsored by the U.S. Environmental Protection Agency (EPA) to label water-efficient products and help people learn how to save water.

Performance Measures and Key Deliverables

- Examples of successful outcomes in each state, including information or materials to promote infrastructure investment and/or tools for utilities' conservation efforts
- Track number and results of water conservation projects/utilities

Costs and Funding

- **Estimated Cost Range:** $–$$$$$
- **Possible Funding Sources:** Public and private entities (municipalities, counties, utilities), AWWA, Water Environment Federation, IWA for research and software, state grants (Department of Community and Economic Development), federal rebates (Energy Star)

Purpose

To develop sustainable practices to promote efficiency and reduce water use throughout the Delaware Estuary

Core Partners

Delaware River Basin Commission, States (DE, NJ, PA), United States Environmental Protection Agency

Key Partners

Conservation districts, water utilities (public and private)

Contributing Partners

American Water Works Association

Timeframe

Continuous improvement over time by employing Environmental Protection Agency and American Water Works Association methods

STRATEGY W3.4: Provide outreach and technical assistance to promote water conservation and infiltration by residential and commercial users and communities

Description

PDE works with volunteers to install a rain garden in 2016 at Newark High School, DE | Credit: PDE

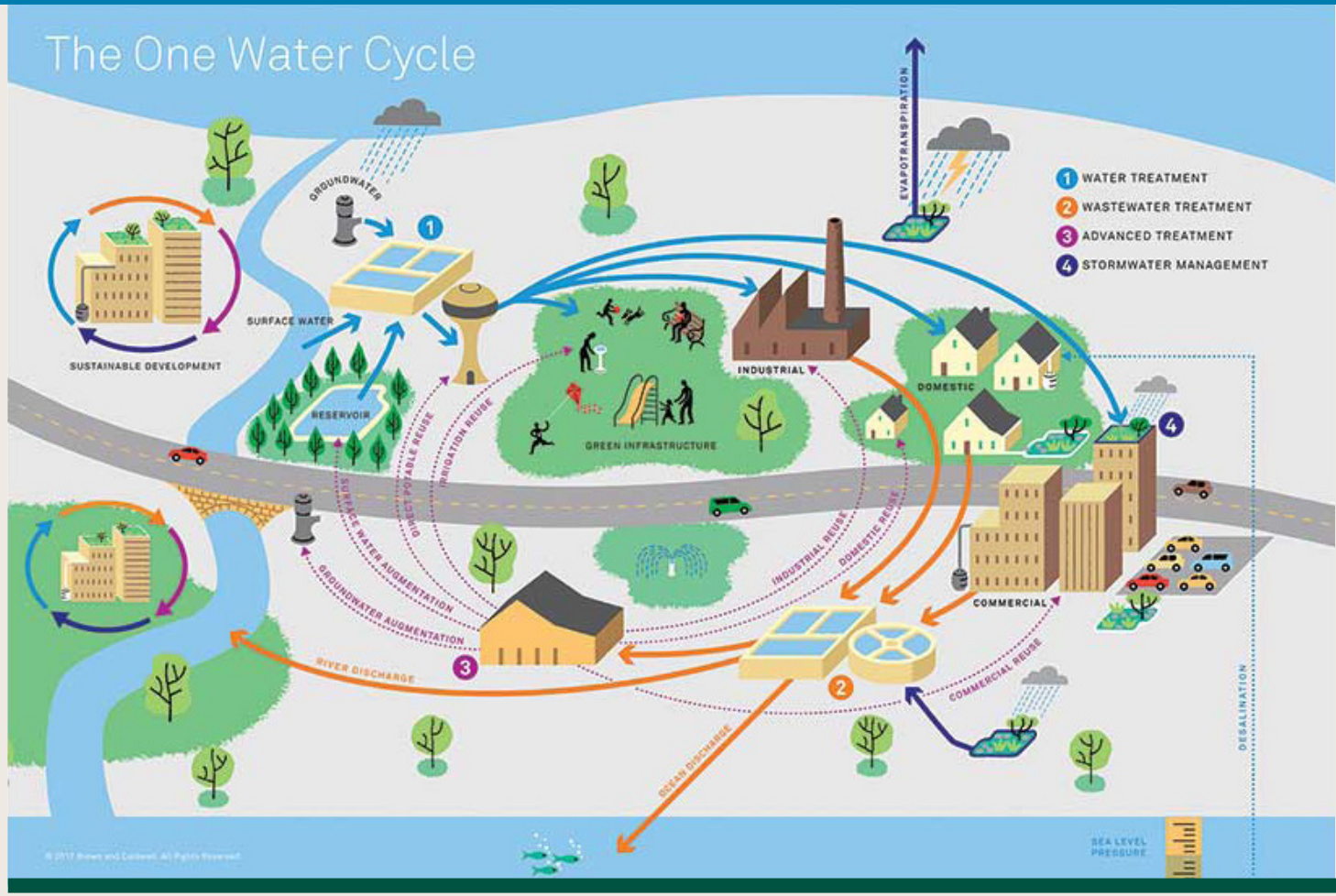
Water is essential to all life on earth, and generally is available readily in streams and waterways or when it rains. However, water often is over-used, and it is easy for communities to waste water without even realizing it. For example, an average family of four uses approximately 400 gallons of water daily and may not be aware of simple actions they can take to reduce their use. Water conservation can support cleaner streams and more abundant drinking water. This strategy will become increasingly important as more areas are developed, thereby exerting more pressure on source waters.

In addition to conserving water in the home, outreach and technical assistance should target stormwater infiltration and agriculture and irrigation BMPs. These techniques can increase awareness of water conservation's importance and serve as "on-the-ground projects" that infiltrate water back into the ground actively and help keep pollutants out of streams and waterways.

Major components of this strategy include:

- **Provide outreach on water reuse.** Keeping water out of storm drain systems, especially those with combined sewage systems, will take pressure off waste-water treatment plants and reduce flooding in urban areas. Practices such as rain barrels serve as an easy water reuse strategy and can increase the amount of water infiltrating back into the ground, where it can be recharged as groundwater in some cases. On a larger scale, large or commercial property owners can use cisterns as large as 2,000 gallons as a water reuse alternative. Outreach to homeowners and "giveaways" are good tactics to promote reuse strategies.

- **Implement stormwater infiltration BMPs.** Stormwater BMPs are designed to keep stormwater and runoff from rain events out of storm drains, and help filter out pollutants and infiltrate water back into the ground. Rain garden systems are engineered as shallow depressions that capture and infiltrate stormwater runoff, and can incorporate native plants and pollinator habitats often. Permeable pavement also is a useful BMP to manage stormwater. These surfaces allow water to drain through the pavement to underlying soils, in contrast to traditional pavement that traps water at the surface and results in increased runoff and less infiltration.



The One Water Cycle. | Credit: Brown and Caldwell

- **Provide support to implement agriculture and irrigation BMPs.** Rain and/or melting snow that drains off land can bring soils, animal waste, and excess fertilizers with it, potentially polluting local waterways. In areas of the watershed where groundwater is sensitive to depletion and/or salt water intrusion (e.g., the southern part of New Jersey underlain by the Kirkwood Cohansey aquifer), agricultural BMPs are critical to minimize water use. BMPs exist that farmers can apply to reduce water use as well as soil and nutrient runoff, while saving money on labor, irrigation, machinery, etc. Agricultural BMPs are site-specific, and include practices such as no-till and cover crops that help increase soil nutrient content, prevent soil loss, and minimize irrigation needs. Farmers should consider micro-irrigation systems, such as drip systems, which have an efficiency of 85%–95%, much higher than that of other types of irrigation, such as stationary/traveling gun or central pivot systems.

Key actions to implement this strategy include outreach to homeowners

and farmers, as well as technical and implementation assistance with on-the-ground BMP projects. Behavioral change campaigns should be used, but messaging is important too, and water conservation campaigns and programming should emphasize co-benefits, such as savings on energy and utility bills. Workshops on installing rain barrels are an effective way to promote reuse among homeowners, and workshops for farmers can heighten awareness of water conservation and BMPs tailored to their needs. The State Departments of Agriculture, local conservation districts, and cooperative extension programs play leading roles in providing information and technical assistance to landowners, particularly farmers.

The PDE and other local nonprofit partners can play supportive roles by providing educational information, materials, and programs, and coordinating water conservation efforts in key areas to track and monitor results (e.g., in the Kirkwood Cohansey aquifer area).

Many partners are involved in promoting this goal and will continue to work on these initiatives as support for these BMPs increases throughout the Estuary.

Performance Measures and Key Deliverables

- Examples of successful outcomes in each state
- Track number and results of water conservation programs, including materials for homeowners, businesses, and/or farmers promoting water conservation

Costs and Funding

- **Estimated Cost Range:** $–$$
- **Possible Funding Sources:** Foundation grants, local municipalities (MS4), Natural Resource Conservation Service, County Conservation Districts

Pennsburg, PA | CREDIT: Carol Tersine

Purpose

To encourage residents, commercial users, and communities to use practices that conserve water and improve infiltration to sustain flows and groundwater resources

Core Partners

Delaware River Basin Commission, Partnership for the Delaware Estuary, Philadelphia Water Department, states (DE, NJ, PA), United States Environmental Protection Agency

Key Partners

Academia, conservation districts, Delaware River Watershed Initiative Kirkwood Cohansey Cluster, United States Department of Agriculture–Natural Resources Conservation Service, Upstream Suburban Philadelphia Cluster

Contributing Partners

Conservation Districts, Natural Resources Conservation Service, New Jersey Water Works, private sector, United States Geological Survey

Timeframe

Ongoing

STRATEGY W3.5: Promote and assist in implementing regional sediment management

Description

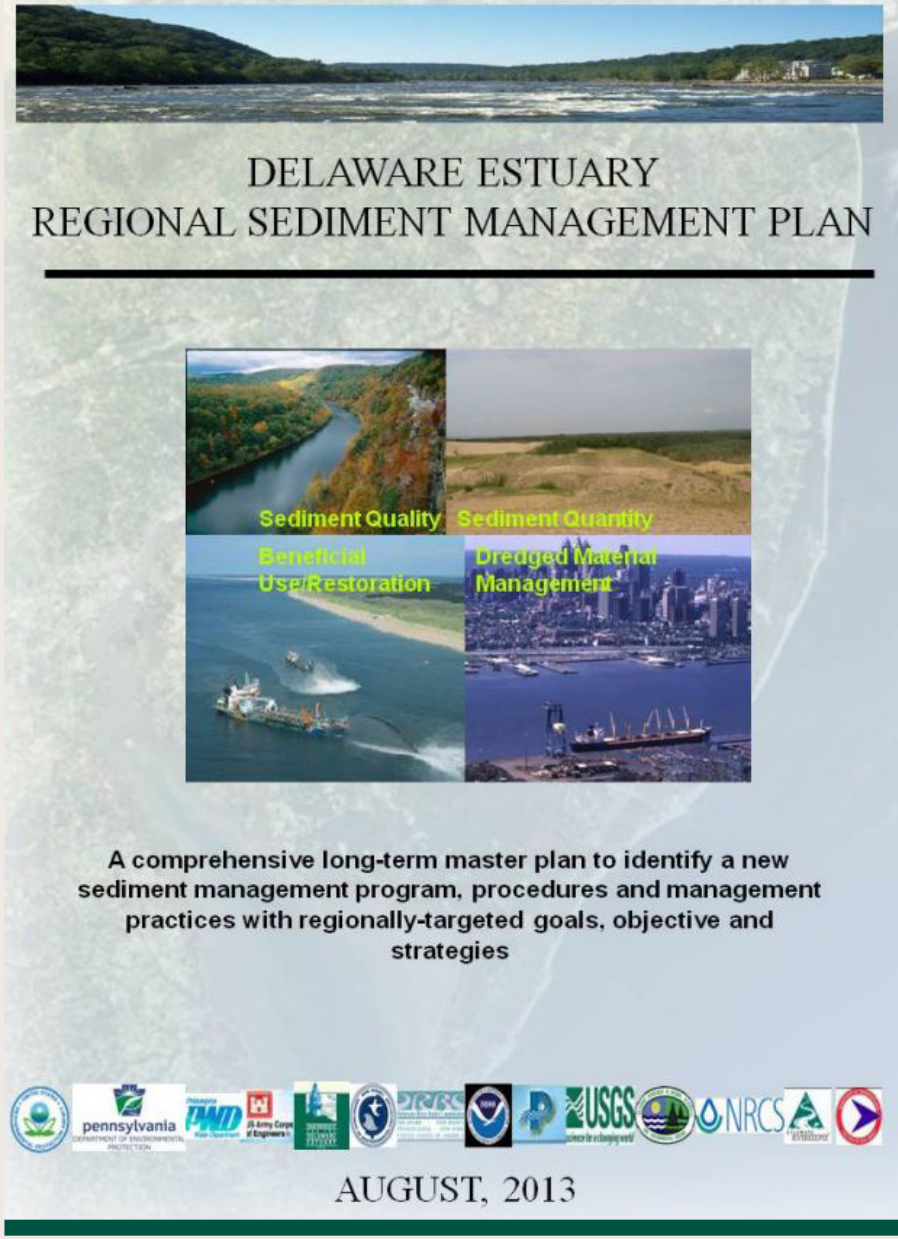
Most estuaries in the world, including the Delaware Estuary, are traps for sediment eroded from upstream. Sediments collect primarily in the areas between fresh and saltwater, which are situated between Marcus Hook, PA, and the Chesapeake and Delaware (C&D) Canal. This zone is a naturally turbid area where there often is insufficient light in the euphotic zone (uppermost sunlit layer of the ocean) of the water column for photosynthesis to occur.

Photosynthetic marine organisms, such as microscopic algae (e.g., phytoplankton), are critical to the world's oceans, as they are the primary food source for other organisms and are the base of the oceanic food chain.

The photosynthetic organisms rely on sunlight for food and therefore are restricted in this zone. When there is insufficient light in the water column, phytoplankton cannot photosynthesize, and therefore cannot support other marine life. Curtailing erosion from the watershed, such as that from stormwater, is an important way to reduce suspended sediment's, which is considered a pollutant for many organisms. Accordingly, programs to control sediment pollutants should be continued.

On the other hand, some natural resources in the tidal Delaware Estuary, such as wetlands, depend on sediments derived from rivers to build elevation and keep pace with the rising sea levels. Therefore, sediments can be both a pollutant and a critical limiting resource, depending on their location within the watershed. Thus, sound management of the Delaware Estuary's natural resources requires an understanding of sediment's benefits, costs, and movements in different areas of the system.

Sediments are managed actively via dredging, erosion control, and other habitat alterations. For example, in tidal channels, sediments are removed by maintenance dredging to sustain navigation, and the amount removed annually exceeds river inputs. Thus,



The Delaware Estuary Regional Sediment Management Plan includes strategies for keeping sediment out of waterways where it's not wanted, and into tidal wetlands where it's needed.

diminishing sediment supplies may be contributing to marsh loss rates. Regional sediment management provides an opportunity to link ecological restoration to active sediment management projects.

In 2014, the Delaware Estuary Regional Sediment Management (RSM) workgroup, comprised of federal, state, regional, non-governmental organizations, and commercial entities, completed a Regional Sediment Management Plan (RSMP), to identify and address sediment-related problems collaboratively and holistically. The RSMP summarizes issues associated with sediment quantity, quality, and dynamics, dredging and dredged material, and needs and opportunities associated with restoration and beneficial use[12] (see the RSMP for additional information on sediment in the Delaware Estuary). The Plan made 16 recommendations and provided 33 actions to promote sediment management that achieves better coordination, lower costs, and more beneficial environmental outcomes. This strategy's goal is to promote and help implement non-regulatory elements of the RSMP important for the Delaware Estuary's health. Key activities of this strategy include:

- **Participate and assist the Regional Sediment Management Implementation Workgroup (RSMIW)**. Following completion of the RSMP, a workgroup was formed to work collaboratively to address recommendations and implement actions. The RSMIW includes representatives from the USACE, U.S. EPA, USGS, DNREC, PADEP, NJDEP, DRBC, PDE, and other interested parties. Continued operation and participation in the RSMIW will foster more strategic and beneficial sediment management in the Delaware Estuary
- **Fill science and research needs.** The RSMP recommended 9 actions to address key knowledge gaps that need to be filled to manage sediments more efficiently and beneficially. The following are CCMP priorities:
  - ▷ 0SRN-2A - develop a better understanding of sediment's importance in ecological processes/habitats in particular wetlands
  - ▷ 0SRN-2B - implement demonstration projects to acquire additional knowledge
  - ▷ 0SRN-3B - develop an interagency workgroup to develop regional criteria for the beneficial use of dredged material in aquatic restoration projects
- **Address environmental concerns.** The RSMP recommended 5 actions to identify ways that management and BMPs can help enhance habitats dependent on sediment. The following are CCMP priorities:
  - ▷ 0EM-1A - identify tidal wetlands at risk to protect them through application of dredged material for beneficial use, living shorelines, etc.
  - ▷ 0EM-1B - coordinate RSMP implementation with other habitat restoration plans
- **Address operational concerns.** The RSMP recommended 4 actions to identify ways to facilitate beneficial use of dredged material. The following are priorities:
  - ▷ 0OM-2A - develop an estuary-wide database of potential sites for beneficial use of dredged material

There are numerous other recommendations and actions in the RSMP that will involve various DELEP partners. The components included here focus on non-regulatory matters that relate best to other CCMP strategies best. For example, research and monitoring needed to understand tidal wetlands' sediment needs can be coordinated with strategies to prevent wetland loss, including the need for restoration planning and demonstration projects and the regional restoration initiative's continued advancement. Although such efficiencies are possible, most of these strategies will require new funding. PDE is willing and able to take a

leadership role in many of these strategies; other partners' participation and continued support, and leadership for the RSMP at the federal level, will be critical for successful implementation.

Increases in sea levels and salinity are key climate change variables that likely are causing shifts in sediment dynamics in the Delaware Estuary already, such as tidal wetlands' increased erosion and a shift in the salinity regime that affects the location of the most turbid waters. Continued development of the watershed and more effective stormwater management could lead to further changes in the amount of sediment entering the Estuary via river runoff. The Delaware River Main Channel Deepening Project is expected to promote more frequent visits by larger ships, which could increase wake-associated shoreline erosion. Increased erosion from dwindling marshes could force more frequent channel dredging, especially in smaller tributaries, leading to faster export of sediments and continued marsh loss. Wave and current energy could increase, leading to more dynamic sediment fluxes and erosion because of increasing wind fetch over wider water bodies, combined with larger tidal volumes from rises in sea level. These effects reinforce the need for effective regional sediment management.

Performance Measures and Key Deliverables

- Development of registry/inventory and 2-3 research/demonstration projects
- Track number and results of RSM projects (demonstration, research, inventory)

Costs and Funding

- **Estimated Cost Range:** $ - $$$$
- **Possible Funding Sources:** Existing dredging projects, regional restoration funding plan linking navigation and restoration interests needed

Silver Run, Smyrna. DE | Credit: Credit: Kurt Philipp

Purpose

To promote and implement key actions that support more strategic and ecologically beneficial sediment management.

Core Partners

Delaware River Basin Commission, Partnership for the Delaware Estuary, Philadelphia Water Department, States (DE, NJ, PA), United States Environmental Protection Agency

Key Partners

United States Army Corps of Engineers, United States Geological Survey

Contributing Partners

Academia, other regional sediment management partners

Timeframe

The Regional Sediment Management Implementation Workgroup currently meets several times annually. Planning and project coordination is ongoing. The timing of scientific studies depends on funding.

STRONG COMMUNITIES

Strong communities value their natural resources and work to protect and enhance them both for economic and environmental health. Climate change and rising sea levels are intensifying storms and floods' effects on waterfront communities. Planning for these changes now will help prepare for the future. To protect and support the Delaware Estuary resources and waterfront communities, and foster a sense of pride in these places, people need to be able to access them. Providing access and information will help the public create a special connection to the Delaware Estuary.

"When we see land as a community to which we belong, we may begin to use it with love and respect."

~Aldo Leopold, A Sand County Almanac

Fowler's Beach in Milford, DE.
Credit: Jodi Brown

STRONG COMMUNITIES GOAL C1

INCREASE COMMUNITY RESILIENCE AND ACCESS

Communities around the watershed rely on clean and healthy streams and natural areas for recreation, health, and quality of life overall. Waterfront communities are particularly important to the Delaware Estuary's health, and to its economic uses that are essential to the region. Waterfront communities are also especially vulnerable to certain climate change effects, including rising sea levels, and more intense storms and floods, which must be taken into consideration when planning for the future.

Protected lands include public lands and those under conservation easement, which also are very important to Estuary communities. Protected lands help ensure healthier rivers and streams and host public access points to the Delaware River and Bay for boating, fishing, and recreational activities. Working waterfronts and protected lands offer opportunities to restore and preserve natural features, build coastal resilience, provide public access, and encourage jobs.

Working waterfronts in the Delaware Estuary range from very urban and industrialized to very rural and dependent upon natural resources. After decades of development and unmitigated pollution, new trails and parks were established in the 1960s and 1970s, and the Delaware

A Commitment to Diversity and Environmental Justice

One overarching challenge DELEP partners face when trying to achieve Strong Communities in the Delaware Estuary is involving underserved communities and those subjected to environmental injustice. DELEP recognizes that standard approaches to the way environmental efforts are organized can create barriers to diverse groups' engagement. Its partners are committed to find ways to remove or overcome these barriers. Involving underserved communities in priority areas and issues in the CCMP is critical. Key activities for doing so are included in the following Strong Communities strategies.

Mullica River in Shamong, NJ. | Credit: Jerry Franklin

Estuary's waterfronts began to transform into hotspots for recreation and tourism. Once booming with the bounty of natural resources, working waterfronts around Delaware Bay now are threatened by floods, erosion, and economic hardship. These threats make investments in infrastructure for water access and resilience challenging. Sea levels in the Delaware Estuary have risen by approximately a foot in the last century, which is a faster rate than that in the previous 15 centuries.

Waterfront restoration of the Delaware Estuary is attracting attention. Waterfront communities are beginning to recognize the value of "green infrastructure," such as living shorelines, which can improve shoreline resilience to storms and rising sea levels. As of 2016, 15% of the land in the Basin was protected, and there was a density of approximately one access point for every 2 miles along the 330 miles of the Delaware River and Bay. This amounts to approximately 150 access points, including public lands and private marinas.[11] There are many working waterfronts, protected lands, and public access points around the Delaware Estuary, but many need new investments to improve and sustain access, ecological function, and productivity into the future.

The vision for waterfront communities' economic and environmental sustainability extends well beyond what DELEP alone can achieve measurably. Finding ways to encourage and build local communities' ability to address these challenges with their own projects and programs to become more economically and environmentally resilient is a key component of this goal.

HOW WE WILL MEASURE SUCCESS:

- Improve working waterfronts by reducing brownfield areas, increasing wetland areas, and supporting more visitors
- Increase access to the Delaware River; sustain and enhance access to the Bay
- Increase protected land for community benefits

Herring Landing, Rehobeth Bay | Credit: Kurt Philipp

STRATEGY C1.1: Restore working waterfronts

Description

Working waterfronts are areas where uses with high economic value intersect with those of high ecological value. Working waterfronts are economically important for a variety of reasons—in some places because of their draw for tourism-related businesses (e.g., Penn's Landing in Philadelphia, the Wilmington Riverfront) —and others because of their importance to fisheries dependent on the Estuary (e.g., Bivalve, NJ and Leipsic, DE). Restoring these waterfronts' natural resources is needed to increase and improve important ecosystems, such as tidal wetlands, and keystone species, such as shellfish. Restoring these working waterfronts for ecological and economical productivity is critical, and will be pursued in the following ways:

- **Rehabilitating degraded waterfront properties.** Unfortunately, many of the Estuary's waterfronts are home to

Delaware River and Philadelphia, from Camden, NJ. | Credit: Barry Plimpton

a large number of other industrial sites formerly developed and now abandoned. Most require some level of rehabilitation to be reinstated for productive use (e.g., new businesses or community spaces). Cleaning up these sites and attracting new users will fall largely on local communities, with guidance and support of state Brownfield Programs. Through its Brownfields Community of Practice, the Urban Waters Federal Partnership provides an important venue to share best practices between Brownfield Programs and communities in need.

- **Facilitating natural and nature-based infrastructure.** The use of nature-based tactics for stormwater management and coastal resilience can increase a community's capacity to manage both persistent and event-based flooding, while helping maintain and improve ecological function and resiliency of key ecological habitats. Depending on a community's location within the Estuary, these habitats can include: freshwater and brackish wetlands; salt marshes; dunes, and/or floodplains. A variety of green infrastructure tactics have been developed for stormwater management through Philadelphia's Green Cities, Clean Waters initiative and can be adapted for use in other communities. PDE and others are working actively to expand wetland and shoreline restoration tactics to be suitable for freshwater, tidal, and developed areas. PDE will seek to engage local partners in efforts to expand and share information about these tactics to empower local communities, state agencies, and contractors to adopt them in working waterfront restoration efforts.
- **Ensuring public access.** Public access should be considered and available in all working waterfront restoration efforts where it is safe and feasible. Effective, public-friendly access to waterfronts provides communities both educational and recreational opportunities that historically have been disconnected from the water, as well as potential for tourism and recreation to benefit local businesses and economies. The first step in reconnecting these communities to the water is ensuring that access is available, safe, and easy to use. Waterfront restoration projects—whether cleanups or ecological enhancements—are opportunities to include or improve public access, including appropriate amenities such as trails, boardwalks, walkways, fishing piers, boat launches, and public restrooms (or connections to these features nearby). State or local communities own many established or potential public access sites, and as such, take the lead incorporating these features. PDE and others can support these efforts by providing information and technical assistance and promoting successes.
- **Engaging local communities affected in waterfront restoration projects, particularly underserved communities.** Some of the most vulnerable and underserved communities in the region are in close proximity to waterfronts.

Efforts will include supporting community-wide sustainable development plans for key infrastructure, and conducting outreach to redevelopment organizations to facilitate resilience, green infrastructure, and access in primary features of their plans. The scope of these efforts will be Estuary-wide, focusing on urban and rural communities along the Delaware River, Bay, and major tributaries, with the goal of connecting and benefiting communities with potential environmental justice concerns. Place-based activities include supporting the installation of natural and nature-based infrastructure projects in areas of high vulnerability and engaging underserved, economically underprivileged communities in waterfront redevelopment projects. All agencies and partners involved in urban waterfront restoration will play roles in ensuring these are considered and included in projects.

Waterfront communities are vulnerable to climate change effects, and need support to become more resilient. Bolstering community resilience to climate change is a major driver for this strategy. Emphasizing and

focusing on waterfronts' restoration of natural habitat and access for recreation and natural resources-dependent activities discourages other uses that expose people and property to greater risks of climate change effects. Rising seasonal temperatures and sea levels, and increasing storm frequency and magnitude throughout the Estuary will affect the types and distributions of natural habitats along waterfronts. Efforts to facilitate natural and nature-based infrastructure projects will also need to account for changes in these environmental factors with targets suitable for a variety of potential future conditions.

Performance Measures and Key Deliverables

- Improve resilience in at least 2-3 key locations
- Improve access in at least 2-3 key locations
- Track number and results of nature-based infrastructure projects/practices in waterfront communities

Costs and Funding

- **Estimated Cost Range:** $$$
- **Possible Funding Sources:** Federal grants (U.S. Environmental Protection Agency, National Oceanic and Atmospheric Administration), state grants

Prime Hook National Wildlife Refuge, Milton, DE | Credit: Martha Gery

Purpose

To restore underused sites and ecosystems in waterfront communities with features that improve environmental and economic conditions.

Core Partners

Partnership for the Delaware Estuary, Philadelphia Water Department, States (DE, NJ, PA), United States Environmental Protection Agency

Key Partners

Alliance of Bayshore Communities (DE), Camden County Municipal Utilities Authority and other waterfront utilities and municipalities, South Jersey Bayshore Council, and other federal collaborations

Contributing Partners

Alliance for Watershed Education of the Delaware River, Army Corps of Engineers, Circuit Trails, Conservation Districts, National Oceanic and Atmospheric Administration, Sea Grant

Timeframe

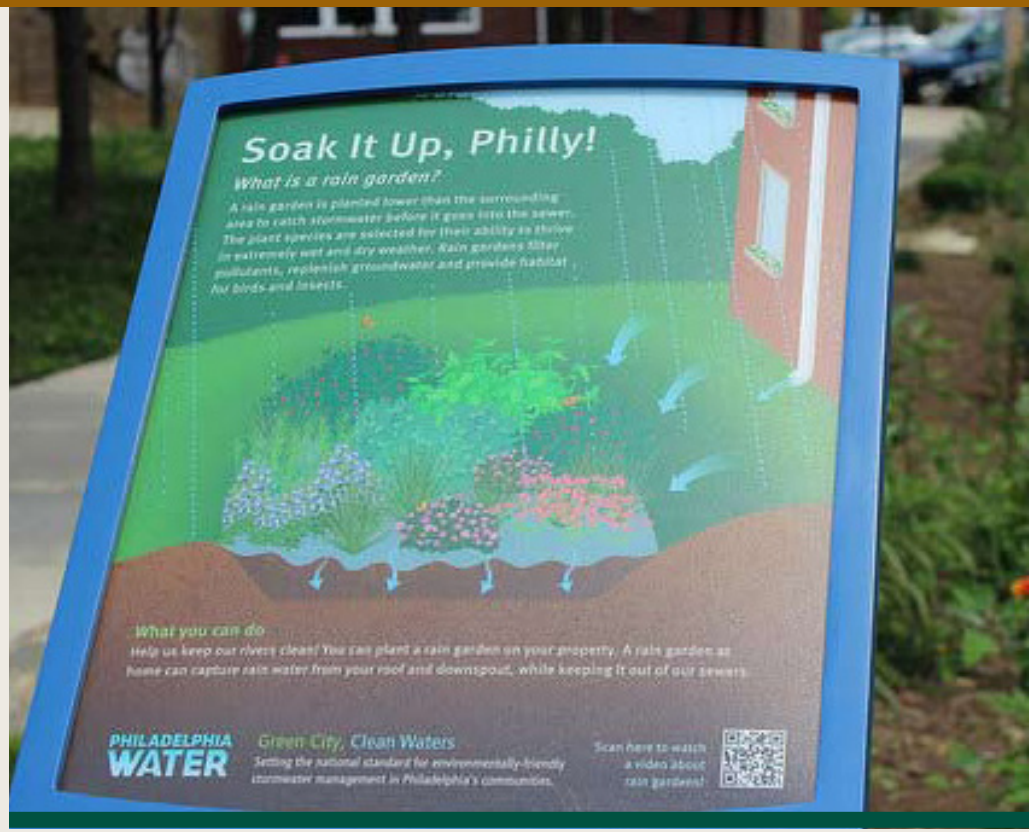
Ongoing

STRATEGY C1.2: Provide tools and technical assistance to waterfront communities & partners to improve economic and environmental resilience

Description

For waterfront communities, improving environmental and economic resilience go hand-in-hand. Improving both requires investments that can be challenging for communities who lack sufficient tax revenue, political will, or both. Yet, for most, these investments are critical to the local economy—whether to support tourism and recreation, or water-dependent businesses and industries. Investment in waterfront communities can increase tourism and coastal jobs, benefiting the local economy ultimately, and therefore, must be encouraged and facilitated. This strategy will be achieved through collaboration with and between communities, with a focus on providing tools and technical assistance for the following key activities:

- **Adding or enhancing public access sites.** Local communities can both benefit from, and contribute to, efforts to inventory public access points (described further in Strategy C1.3). PDE will seek to engage local communities and partners to assess these points and collaborate with local groups that use these areas regularly, including watermen and hunters. PDE will share the results as a tool to use in local/regional campaigns to promote and enhance access.
- **Removing the barriers to safe, enjoyable public access in a way that engages people as stewards.** Making visits to public access points a safe and enjoyable experience will help connect and attract people. Projects that prevent and remove debris from waterfront areas—including cleanups, marine debris removal, fishing line recycling, and hydrations stations—also can engage local residents as stewards. PDE will take advantage of opportunities to implement and share information with local partners about projects like these.



Rain Garden created as part of the Green City, Clean Waters program in Philadelphia, PA. | Credit: PWD

- **Improving resilience to the effects of climate change.** Sharing information, success stories, and existing resources between communities and partners will help them improve community planning for resilience. PDE will continue to host and coordinate its Climate Change Roundtable as a Community of Practice for the Urban Waters Federal Partnership and update its Weathering Change program to include new resources, information, and support for communities planning for adaptation.
- **Enhancing local economies based on natural resources.** Outreach and publicity to promote the virtues of low-impact recreation and stewardship will draw new users and stewards to these areas. PDE will collaborate with

the Alliance for Watershed Education of the Delaware River to coordinate and co-market activities designed to engage recreational users. PDE also will collaborate with the NJ Bayshore Council, the Alliance of Bayshore Communities in Delaware, the South Jersey Bayshore Coalition, and DNREC's Bayshore Initiative to co-brand and market the Bayshore region as a destination. Scenic Byway designations are now in place on both the Delaware and New Jersey sides of Delaware Bay, which connects with the Cape May-Lewes Ferry and presents new opportunities. Further, PDE will seek to raise awareness and prioritize resilience projects critical to protecting infrastructure needed to sustain fisheries and related businesses' economic viability.

- **Prioritizing efforts on underserved waterfront communities.** Some of the most vulnerable and underserved communities in the region are in close proximity to waterfronts. Ensuring that these communities can access and benefit from their waterfronts should be a priority.

Many partners are involved in this strategy in the ways identified here, and by working with and within various committees, tasks forces, and workgroups—sometimes as a leader, other times as a participant. Executing this strategy successfully will require new resources and collaboration with key partners from all three states (DE, NJ, PA). Many groups that focus on byways, trails, and trail networks could be involved, while PDE's focus will be on encouraging recreational users to appreciate the Estuary's natural attractions and forging/focusing collaborations with partners to meet common goals. Among these natural attractions, fishing, spawning, and stopover sites will be a high priority, given the way potential stewards can experience signature species en masse reliably at these locations.

Funding is a constraint for nearly every CCMP strategy. However, the false perception that PDE has funding to provide local communities support for these activities can create tension with local partners. To address this, PDE often seeks opportunities to write grants and raise funds on behalf of, or in collaboration with, local partners. Erosion, flooding, rising sea levels, storms, and long-term neglect may threaten to destroy prospective project sites before partners can take action, but they can minimize such loss through rigorous prioritization.

Performance Measures and Key Deliverables

- Improve resilience and/or access in at least 5 communities
- Convene practitioners conducting outreach on climate adaptation annually
- Update or redesign climate adaptation outreach materials (Weathering Change)
- Track number and results of technical assistance projects on community access and resilience

Costs and Funding

- **Estimated Cost Range:** $$
- **Possible Funding Sources:** Federal grants (U.S. Environmental Protection Agency, National Oceanic and Atmospheric Administration, Federal Emergency Management Agency), foundation grants

Purpose

To empower waterfront communities with tools and resources to improve economic and environmental resilience.

Core Partners

Partnership for the Delaware Estuary, Philadelphia Water Department, States (DE, NJ, PA), United States Environmental Protection Agency

Key Partners

Urban Waters Federal Partnership, Waterfront Municipalities, Delaware Valley Regional Planning Commission Municipal Technical Assistance Advisory Panel, Non-Governmental Organization partners

Contributing Partners

Circuit Trails, Riverfront development organizations and collaborations of municipalities, watermen

Timeframe

Ongoing

STRATEGY C1.3: Protect and enhance natural areas and public access

Description

Protected natural areas provide critical access points for people to learn about and enjoy the Delaware Estuary. There are over 1,950 square miles of publicly-protected lands in the Delaware River Basin—lands that the public owns, or that are protected by conservation easements held by public agencies.[11] Additional lands are owned or protected by conservation easements held by land trusts. Many, but not all of these conserved lands, offer some form of public access or recreation. Conserved lands include nature preserves, parks, and trails, and also offer scenic views from public roadways. Those that do not offer public access currently, may have the potential to in the future.

2015 Christina River Watershed Cleanup in Wilmington, DE. | Credit: PDE

Public access to these natural areas promotes human health, education, and ecotourism, but is not always assured. For example, in many urban waterfront areas, industry, including both active facilities and historical operations that have fenced off contaminated sites, often impede access. In bay-front communities, shoreline erosion prevents or has degraded several former towns and access points to the water.

The protection of natural areas and public access points is the first step in ensuring that these places are preserved. Ongoing management is needed to keep these areas safe and healthy, to allow the public to appreciate and enjoy them. Improving these areas with infrastructure appropriate for their natural features and uses is the final step.

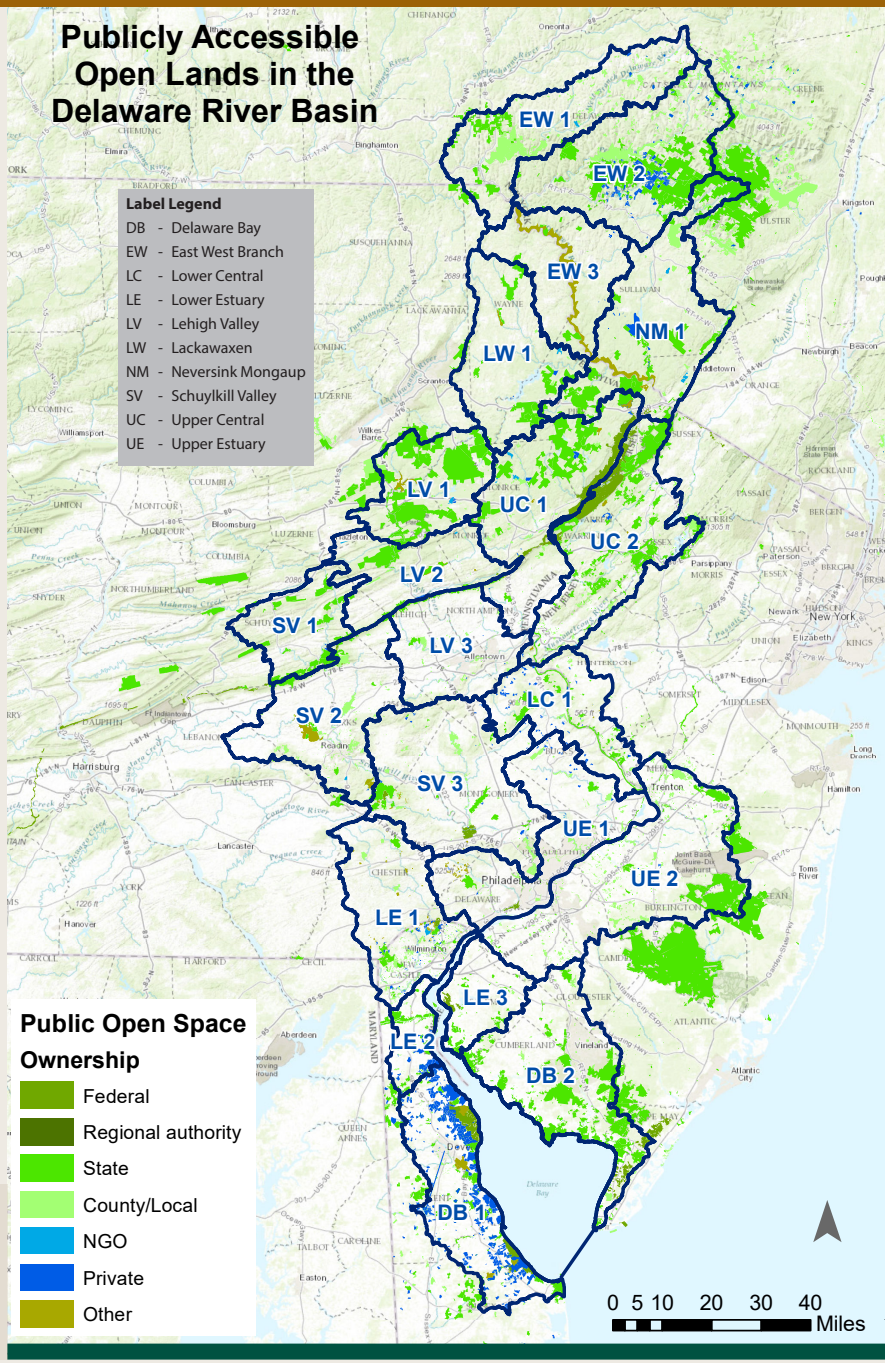
Key activities include:

- **Continue, support, and promote land protection programs.** Focus efforts on protecting waterfronts, riparian corridors, and other areas critical to sustaining resilience to flooding and climate change, and providing access to waterways. Structures and processes are in place in each of the Delaware Estuary states (DE, NJ, PA) to support public agencies and/or land trusts' permanent protection of land. Such programs as Green Acres in New Jersey, the Open Space Preservation Program in Delaware, and Growing Greener in Pennsylvania have been successful and should continue. Creative new efforts, such as the land conservation sponsorship option available to borrowers from the Clean Water State Revolving Fund also show promise, and should be used and encouraged. Providing incentives (or removing disincentives) to communities with

large amounts of conservation lands also is a critical part of this strategy.

- **Manage protected lands to encourage and provide appropriate public access.** This includes managing natural areas' health, as well as creating and managing trails, boardwalks, viewing platforms, boat ramps, piers, parking, restrooms, and other improvements appropriate for waterways and other natural resources' protection and appreciation. The focus of these efforts should be on sustaining and improving access to waterways with particular attention to the inclusion of underserved communities. Remediating urban working waterfronts and stabilizing eroding bay-front shorelines provide opportunities to incorporate improved public access. Continued development of the Circuit Trail system in Philadelphia and the surrounding region, the East Coast Greenway, Northern Delaware Greenway, and scenic byways along the Bayshore in Delaware and New Jersey are important actions to advance. The Bayshore Initiative in Delaware is an example of a new and innovative combination of land protection and access improvements that promises to benefit the economic and environmental resilience of local communities as well as the state.

- **Involve local partners to inventory and assess public access points to the Delaware River and Bay to identify opportunities and gaps.** As part of the 2012 State of the Estuary report, 150 access points were identified along the Delaware River and Bay, including public lands and private marinas (one access point per 2 miles). However, these access points were identified on paper only, and the data do not reflect their condition and utility for different uses, or the way they are (or should be) maintained or improved. By collecting and compiling data on these points, a basis for more strategic actions can be developed to improve access, and work with local partners to find efficient ways to track and maintain access. This inventory also will be used to advance other strategies to increase



Spatial distribution of publicly accessible open space in the Delaware River Basin in 2016 by ownership type *(See 2017 TREB Chapter 1, Section 1.5 Public Open Space for more information).*

community resilience and access, as noted in other sections.

- **Prioritize natural areas accessible to underserved communities' protection and enhancement.** Ensuring that these communities have access to, and can benefit from, natural areas is a priority.

The states (DE, NJ, PA) will play a leading role in this strategy as major waterfront land owners and managers along both sides of the Delaware River and Bay in New Jersey and Delaware. Major cities, including Philadelphia, Camden, and Wilmington, realize their waterfronts' value for public enjoyment and access increasingly, and can play major roles in these efforts as well, working with riverfront development corporations and organizations devoted to their waterfronts. The PDE can play a supporting role by promoting appropriate uses and green infrastructure, supporting continued funding for land protection, fostering collaborative projects and sharing between communities, and inventorying/assessing access points.

Climate change and continued development are major factors to consider—both as a driver for actions in this strategy, and a threat to some of the infrastructure needed for access. Boat ramps, piers, and boardwalks are major investments that are highly vulnerable to damage from coastal storms and flooding, which are anticipated to increase with climate change and rising sea levels. Careful deliberation and design of these types of infrastructure are needed to inform investments, ideally using natural infrastructure (e.g., wetlands, shellfish beds) to increase resilience and ecosystem function. However, using coastal areas for improvements that support natural and recreational uses can preclude them from less environmentally sensitive and climate resilient uses, keeping people and major infrastructure out of harm's way. Smart designs will combine recreational and resilience benefits (e.g., parking areas for recreational users that also can serve as flood retention areas during storms) when people are less likely to be enjoying the outdoors.

Performance Measures and Key Deliverables

- Improved protection and access in at least 2-3 locations
- Increased protection and access in at least 2-3 locations
- Access points inventory development
- Track number and results of land protection and improvement projects on natural areas and access

Costs and Funding

- **Estimated Cost Range:** $ - $$$$$
- **Possible Funding Sources:** State budgets and open space programs (funded through bonds or dedicated fees), federal grants, foundation grants (William Penn, Open Space Institute-OSI)

Purpose

To increase community resilience and access by providing opportunities for the public to enjoy protected natural areas.

Core Partners

Philadelphia Water Department, States (DE, PA, NJ)

Key Partners

Urban Waters Federal Partnership, Waterfront municipalities, Land Trusts, New Jersey Bayshore Council Tourism and Economic Development Task Force & Byway

Contributing Partners

Circuit Trails, East Coast Greenway, Northern Delaware Greenway, Pennsylvania Water Trails

Timeframe

Ongoing, with the likelihood that an access inventory can be completed within several years.

STRATEGY C1.4: Connect people to natural areas and waterfronts in the Delaware Estuary

Description

The Delaware Estuary region is rich with accessible parks, preserves, trails, and waterfronts, and showcase the Estuary's natural beauty and ecology. Most of these places are in close proximity to the millions of people who live in the region, many of whom enjoy hiking, biking, running, strolling, dining, and other outdoor activities. These natural areas and waterfronts are ideal places to reach people as we seek to build their connections to the Estuary. Key activities for this strategy include the following:

- **Promoting, supporting, and creating education programs, displays, and signage.** These education and outreach tactics can offer users information and experiences that provide a connection between the places and activities they enjoy and a healthy Delaware Estuary. PDE has a long history of working with local partners on programs, displays, and signage to increase awareness, appreciation, and a unique sense of ecological place. PDE will continue to work with these partners to explore new opportunities to use these tools and strategies. Some examples of anticipated efforts include:

  - ▷ Working with PWD and others to continue, enhance, and promote displays and programs at the mussel hatchery exhibit at Fairmount Water Works, including expanding them potentially to new locations, such as the mussel production hatchery anticipated at Bartram's Gardens
  - ▷ Working with DNREC and staff at the Delaware Nature Center at the Mispillion Harbor to expand the Delaware Estuary educational displays to include information on living shorelines that visitors can view from the Center's deck
  - ▷ Working with waterfront communities to explore opportunities to add/improve

In 2015, The Nature Conservancy surveyed 250 tourists from 9 states visiting New Jersey's Delaware Bayshore. Their top reason for visiting was to view wildlife. 99% said they would return, and half said they visit at least five times a year. They also expressed a desire for more information and advertising.

New Jersey Bayshore Heritage Byway wayfinding sign and TNC survey sidebar. | Credit: PDE

signage tailored to tourists and recreational users as a way to enhance access. Developing an inventory of existing Delaware Estuary signage is a need that will be pursued as part of this strategy

- ▷ Seeking and responding to new opportunities to hold programs and implement demonstration projects in places where the natural features and functions provide hands-on experience and context to program content, potentially in partnership with the Alliance for Watershed Education of the Delaware River (a network of over 20 nature centers in the watershed collaborating on programs and messaging)

- **Promoting ecotourism and recreation opportunities in and around the Delaware Estuary.** Raising awareness of these opportunities and encouraging people to take advantage of local natural, as well as cultural and historic resources, available will facilitate experiences that connect people to the Estuary. PDE also has a history of working with local partners to promote outdoor activities. Here are several opportunities on the horizon:

  - ▷ Improving/expanding EcoDelaware.com. For over 10 years, PDE has maintained this site to promote outdoor recreation and experiences, primarily in Delaware. Using information local partners provide, EcoDelaware includes places to visit and things to do that continue to attract a great deal of traffic. There are new opportunities to add content, use the site more strategically, and potentially promote and offer activities and opportunities on both sides of Delaware Bay, including virtual eco-tours to key spots in the Estuary

  - ▷ Fostering collaboration and co-marketing and promotion of nature-based tourism between communities and across Delaware Bay. New Scenic Byway designations on both sides of Delaware Bay, and bayside communities' increasing efforts to collaborate (e.g., Alliance of Bayshore Communities, the South Jersey Bayshore Council, the Bayshore Tourism and Economic Development Task Force) present new opportunities that PDE will explore

  - ▷ Exploring opportunities to work with partners in the Alliance for Watershed Education of the Delaware River. This new collaboration on the part of nature centers offers opportunities for PDE to work with local partners to promote recreational activities and opportunities on the Delaware River and major tributaries. For greater effect, both PDE and local partners can share public messaging to engage more people. Continued expansion of the East Coast Greenway and The Circuit Trails in Philadelphia offer new opportunities to promote trail experiences

- **Expanding "Green Job" opportunities.** Fostering youths' interests in pursuing careers in conservation and the environment can create a deep and meaningful connection between them and the Estuary, while also adding new capacity for stewardship of trails and natural areas. In recent years, PDE has worked with other local partners to develop summer "Green Jobs" programs in Wilmington, Camden, and Newark. Philadelphia and Camden have developed job corps to recruit, train, and employ young adults to maintain green infrastructure. Delaware State Parks has developed a Youth Conservation Corps that works in the parks system. These programs engage residents from local areas, including neighborhoods that are challenged economically and environmentally, and offer them educational, training, and/or career opportunities. PDE and partners will seek to continue and expand these types of programs to new areas and uses.

- **Focusing educational, recreation, and employment opportunities on underserved communities.** Some of the most vulnerable and underserved communities in the region are in close proximity to waterfronts, and are most in need of these opportunities

PDE will play a leading role in promoting places and experiences to connect people and partners. States and local partners will promote and provide the access to those places, while PDE will use its mass communications capacity and tools (described in the next strategy) to achieve these goals.

External constraints pertaining to this strategy are related largely to funding and the ability to implement these strategies holistically and strategically. Climate change effects are not anticipated to influence this strategy dramatically in the next 10 years. However, as many of the activities described here will take place in waterfront areas, it will be important to plan and design them for resilience (particularly signage, e.g., any signage/displays in waterfront locations need to be waterproof, or raised or moved easily in case of flooding).

Performance Measures and Key Deliverables

- Complete new/updated ecotourism website and increase visitor counts
- Inventory/assess existing exhibits and signage and add new exhibits, displays, or materials on living shorelines and freshwater mussels
- Track number and results of outreach programs and projects on ecotourism and recreation, including engagement of youth in green jobs programs

Costs and Funding

- **Estimated Cost Range:** $
- **Possible Funding Sources:** State and federal grants/ support; new funding needed

Brandywine Creek, Wilmington, DE | Credit: Pat Fallon

Purpose

To use natural areas and waterfronts as opportunities to engage recreational users.

Core Partners

Partnership for the Delaware Estuary, Philadelphia Water Department, States (DE, NJ, PA)

Key Partners

Alliance for Watershed Education of the Delaware River, Urban Waters Federal Partnership, Waterfront municipalities

Contributing Partners

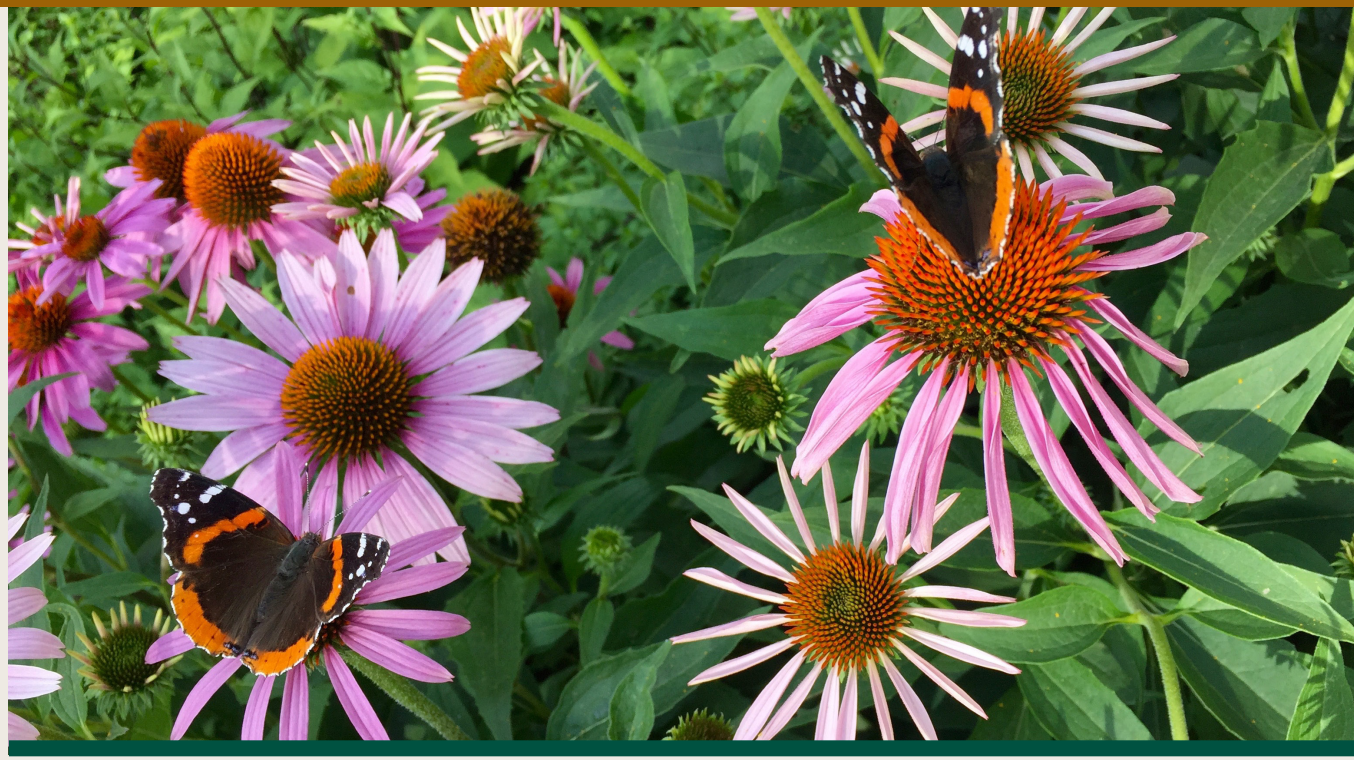
Circuit Trails, Non-Governmental Organization partners, United States Fish and Wildlife Service

Timeframe

Ongoing, with some activities occurring annually.

STRONG COMMUNITIES GOAL C2:

IMPROVE PUBLIC AWARENESS AND STAKEHOLDER ENGAGEMENT



West Philadelphia, PA. | Credit: Stephanie Rindosh

Engaging people is a key part of conservation efforts, from rural and agricultural areas to suburban communities and urban waterfronts. If people do not care about their natural resources, conservation efforts will have little value to them or future generations. People of all ages and backgrounds should be given the proper tools to understand the problems facing the Delaware Estuary to generate positive changes for the future. Decision-makers and managers must work together across state lines and other jurisdictions to share information, pool resources, and manage the Delaware Estuary effectively.

Engagement is a continuum that begins with interest and culminates with stewardship. PDE acts as the public face of DELEP, engaging people on a daily basis using a variety of tools and tactics that are designed to involve people all along that continuum to improve their awareness, knowledge, and ultimately, stewardship of the Estuary's resources. PDE reaches audiences online, on the airwaves, in writing, and in person. PDE works with partners to provide citizens science opportunities, such as freshwater mussel surveys, teacher workshops, volunteer activities, and many other outreach projects to relate the NEP's work to the people it affects. PDE's unique management structure involves stakeholders in the private and non-profit sector together with public agencies' decision-makers and scientists from across the region to work in concert to develop and implement actions to improve the Delaware Estuary.

PDE brings a science and a regional approach to foster collaboration on local and sub-regional challenges, provides solutions grounded in science, and fosters regional collaboration to achieve effective and lasting solutions.

Annual visits to Delawareestuary.org and EcoDelaware.com have increased by 400% since 2003, with over half a million views in the past 10 years. Over 50,000 people have volunteered for various events, including river cleanups over the last 10 years. More people can be reached by focusing on target audiences (e.g., teachers, local leaders, other decision makers) using tailored tools and messages. By working with local partners and other collaborators in and around sub-watersheds, messages can be even more tailored geographically and reach new audiences. Through past efforts, PDE has informed many people and communities about the NEP's work and the Delaware Estuary's resources.

HOW WE WILL MEASURE SUCCESS:

- Improve access to information about the Estuary
- Improve the engagement of citizen scientists, stewards, and key stakeholders

Delaware River, Philadelphia, PA | Credit: Kerri Yandrich

STRATEGY C2.1: Through marketing and communications, build awareness and brand for the Delaware River and Bay

Description

With a population of over six million across the region and including several major metropolitan areas, mass communications and marketing are essential to spread the word about the great work and events throughout the Delaware Estuary. Because of its industrial heritage, the river suffers from unfavorable public perceptions that call for different marketing and communications strategies than in other watersheds and across sub-watersheds. Fostering affinity for this under-appreciated resource is the first step in building a sense of stewardship and creating a brand of value and meaning for the Estuary. This is a significant focus for the PDE's marketing and communications efforts, which will work with partners to employ marketing and mass communications, including the following key activities:

Participants visit a viewing platform created by DNREC at the Ashton Tract of the Augustine Wildlife Area in Middletown, DE during a 2018 Delaware Bayshore Initiative tour. | Credit: PDE

- **Publishing *Estuary News***. Redesigned recently, this publication is produced and distributed by email quarterly and by mail twice annually. *Estuary News* typically reaches over 20,000 people in print and nearly 10,000 via email. PDE uses Salesforce, a cloud-based content management system, to manage and increase newsletter distribution, and benefits from a grant program that provides Salesforce to PDE at a greatly reduced cost. PDE will seek to continue and expand its distribution.
- **Maintaining and improving DelawareEstuary.org.** This web page was redesigned recently and provides information on PDE and its partners' activities, and makes information and publications accessible online for partners and the public to use and share. PDE will continue to host, populate, and increase web traffic to the site to provide information and introduce new people to the Delaware Estuary. PDE uses Google ads to promote website content thanks to a grant through Google Ad Words that provides these services at greatly reduced cost. Google Ad Words is Google's advertising system in which advertisers can use keywords for clickable ads to appear in Google search results.
- **Promoting through traditional media.** PDE seeks to take advantage of traditional media (e.g., newspapers and other publications), typically with over 100 media placements related to the Delaware Estuary

annually. PDE will continue to increase its media presence by distributing press releases, media advisories, and fact sheets, and building relationships with the press.

- **Promoting on social media.** In recent years, PDE also has increased its presence on social media, with an increasing number of followers on Facebook, Twitter, Instagram, and other platforms. PDE will continue posting social media updates, sharing partners' related posts, and cultivating relationships with followers to keep increasing and improving the Delaware Estuary's presence on social media.
- **Branding the Delaware River and Bay.** In addition to the components above, PDE will explore opportunities with partners to implement a campaign (or campaigns) to brand the Delaware River and Bay using advertising to reach and change the perspectives of the over 8.3 million residents in the Delaware River Basin. Throughout the watershed, there is a growing awareness of the need for more coordinated and sophisticated messaging about water resources' importance and creating an identity for the Delaware River, Bay and Watershed to which people relate. The DRWI's development in recent years has heightened this awareness and brought new perspectives, resources, and expertise to this issue. PDE also will seek to use these factors, as well as the upcoming 25-year and 30-year anniversaries in 2021 and 2026, respectively, to develop and advance a branding campaign. This is one of the most ambitious activities envisioned in the revised CCMP, and, to be successful, would involve collaboration to coordinate messaging with a vast network of partner organizations, media outlets, and local communities. With the appropriate resources, PDE is positioned well to lead/coordinate an effort like this, which local partners throughout the watershed have indicated is a need repeatedly.
- **Capitalizing on opportunities with partners.** In addition to taking the lead on the initiatives above, PDE also will take advantage of opportunities its partners lead to reach new audiences through mass communications.

Map of the Delaware Bay Byways highlighting primary routes (map does not display side roads to the Bay). | Credit: Frank McShane (Map from *Estuary News* Volume 27, Issue 2, Winter 2017).

Examples include working with national partners on initiatives (e.g., National Estuaries Week, the "I heart estuaries" social media campaign), with the Philadelphia International Airport to develop and promote an in-terminal educational display on living shorelines and Delaware Bay oysters, and with the Delaware Nature Society and others on the statewide Clean Water, Clear Choices campaign.

- **Prioritize reaching underserved residents.** DELEP partners will explore, use, and share tools and techniques to ensure that marketing and communications efforts include underserved people and communities.

PDE will work with its partners to develop and use content on science, issues, and activities in the Delaware Estuary for all of the above, including recruiting authors to write diverse, high-quality Estuary News articles. In addition to this content and information, a core message PDE seeks to relay through all marketing and communications is that the Delaware Estuary is an amazing resource in need of stewardship and protection that offers ways for everyone to be involved. Core partners will continue to help support this role through communications and associated activities across the Estuary.

Information overload and the need to compete for people's attention is an external constraint over which the NEP has no control and very limited advertising dollars with which to compete. Changes in internet, social media, and even traditional media's standards and practices can influence the costs and effects of advertising and tracking results in unanticipated ways. Fortunately, PDE has grants from Google AdWords and content management systems, such as Salesforce, that reduce the cost of advertising and tracking data and information on contacts (e.g., addresses) greatly, which helps manage marketing and communications costs.

Performance Measures and Key Deliverables

- Continuous increase in distribution/exposure and examples of success in each state, with at least one major regional marketing campaign
- Track number and results of outreach programs and projects (marketing and communications), including increased distribution of Estuary News (2-4 issues annually) and use of DelawareEstuary.org (refreshed weekly) and social media

Costs and Funding

- **Estimated Cost Range:** $$ - $$$
- **Possible Funding Sources:** National Estuary Program funding, supplemented by state, federal, and foundation grants for campaigns; new source needed for major regional marketing/branding campaign

Purpose

To change people's perceptions of the Delaware Estuary and reflect on the Delaware Estuary Program's collective efforts over the past 20 years that have resulted in a cleaner Bay. To provide basic information so more people appreciate the value of the Estuary's long-term recovery and help us achieve a focused collaborative effort over the next 10 years.

Core Partners

Delaware River Basin Commission, Partnership for the Delaware Estuary, States (DE, NJ, PA), United States Environmental Protection Agency

Key Partners

Estuary News authors and distributors, Association of National Estuary Programs/Restore America's Estuaries partners, Delaware River Watershed Initiative and Alliance for Watershed Education of the Delaware River partners

Contributing Partners

Local/regional media

Timeframe

Ongoing

STRATEGY C2.2: Utilize events to increase stewardship and engage new people

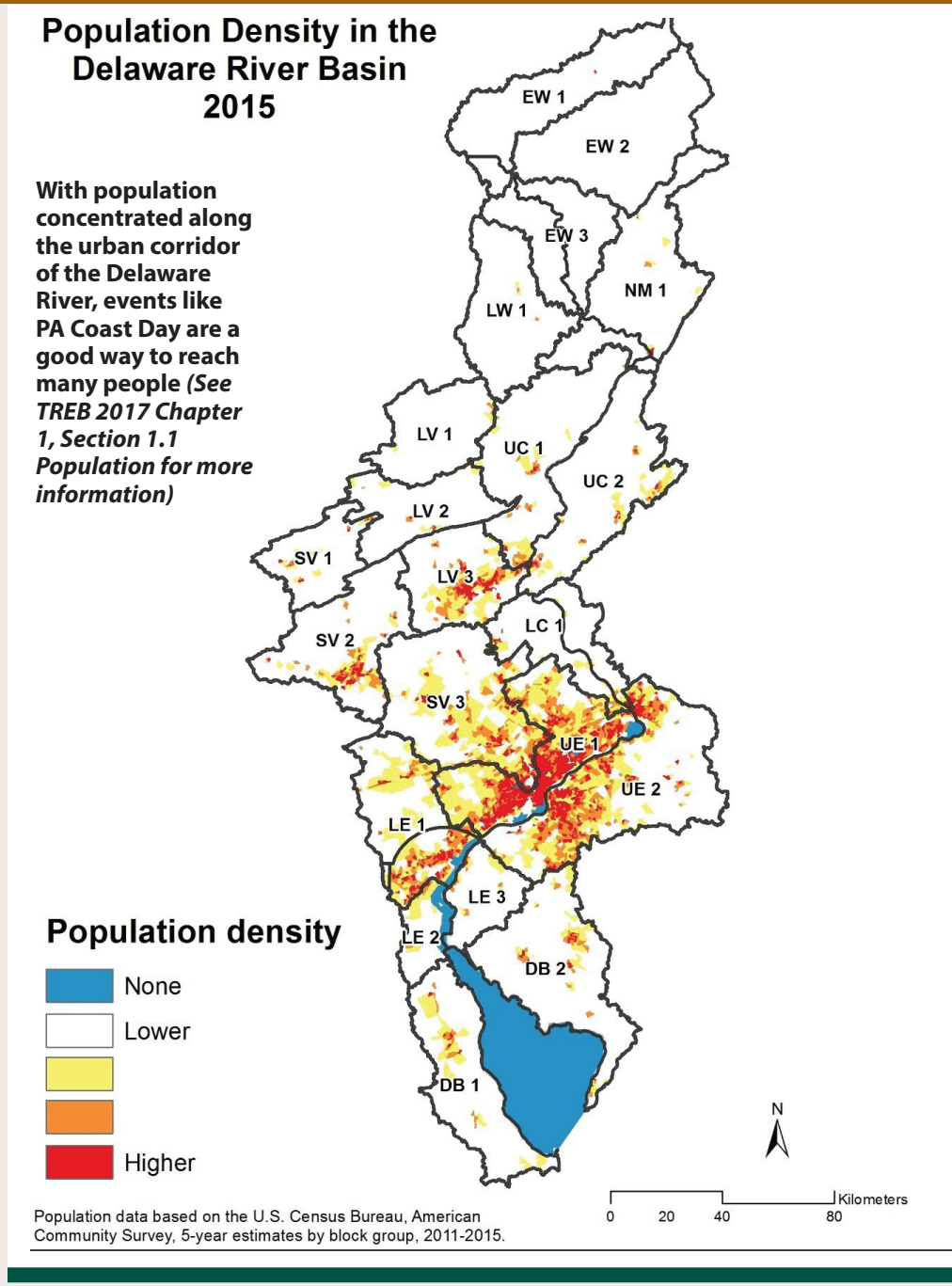
Description

Engaging people as Delaware Estuary stewards begins with heightening awareness of the Estuary's resources, functions, and issues. Events are one of the primary tools available to make that initial introduction, and invite them to become more involved. The Delaware Estuary is fortunate to have a large number and variety of community and/or environmental events held regularly in locations throughout the region. These events range from annual festivals that engage a large number of the general public, to events targeted to audiences' specific local communities, interests, or needs.

PDE implements this strategy primarily, but relies heavily on a host of partners to do so fully and successfully. These partners range from event hosts to co-hosts, sponsors, and exhibitors, all of whom are integral to the events' success.

Major components of this strategy include:

- **Host, co-host, and/or support annual Coast Day/Bay Day events with experiential learning opportunities.** For over 10 years, a Coast Day or Bay Day has been held in each of the Delaware Estuary states (DE, NJ, PA)—a tradition that is building affinity for the coast and bay and a sense of place for the Delaware Estuary over time. Traditionally, the Bayshore Center at Bivalve has hosted Bay Day in Port Norris, NJ in June. PDE has hosted Pennsylvania Coast Day in Philadelphia, PA in September, and the University of Delaware's Sea Grant program has hosted Delaware Coast Day in Lewes, DE in October. Each of these events features a large array of coastal-themed activities and information tables, including interactive experiences with direct relevance to the Delaware Estuary, and engages thousands of interested members of the public. PDE and Core Partners



will continue to build these events' momentum by continuing to implement and support them.

- **Participate in festival-style events held by others in each state and major watersheds.** Annually, PDE is invited to participate in a variety of festival-style events in different locations throughout the watershed, including co-hosting an Earth and Arbor Day event with the City of Wilmington in Delaware. Many are "tabling" events, at which PDE and partners have tables that provide information and activities to raise public awareness and interest in the Delaware Estuary. Establishing a key message with supporting materials and activities tailored to each events' audience is an important part of this strategy. Annually, PDE and Core Partners will select and attend a series of events that offer the best combination of geographic diversity, attendance, and likelihood of reaching key stakeholders/users.
- **Participate in events and give presentations to groups of key stakeholders/users.** In addition to the festival-style events to which PDE is invited (and which usually have a broad environmentally-related theme), PDE seeks out events and presentation opportunities to reach key audiences. The target audiences for these events are groups with a special interest in the Estuary, including nature lovers, recreational users, businesses, watermen, and others whose work depends on natural resources, particularly in rural areas. Annually, PDE and Core Partners will identify and participate in those events that provide the best opportunities to reach key audiences.
- **Prioritize and/or tailor events to be accessible and engaging to underserved communities.** This includes holding or selecting events that are low or no cost, and that are accessible to local communities within walking distance or by public transportation. Key messages and activities would be tailored to these audiences.

Conducting public outreach on the water-filtering value of shellfish with a two-tank demonstration at Pennsylvania Coast Day in Philadelphia. | Credit: PDE

To ensure robust attendance at events, PDE and Core Partners will use traditional and online advertising; share information through social media, websites, email, and newsletters; and conduct outreach to local partners/businesses. They also will continue to explore opportunities to build new partnerships to promote and cross-promote events for greater participation and impact. PDE collects and tracks attendance and newsletter sign-ups from each event that are stored in a contact database for future engagement. The core message PDE seeks to relay through events is that the Delaware Estuary is an amazing resource that needs

stewardship and protection and offers ways for everyone to be involved (with different sub-messages tailored to specific audiences).

The vast majority of events to implement this strategy are held outdoors, and depend on weather; some are held in coastal areas where storms and flooding can have an even greater effect. Poor weather conditions can prevent robust attendance, and lead to cancellations. For example, in 2015, the University of Delaware canceled Coast Day in Delaware because of Hurricane Joaquin. With a changing climate, increased precipitation and more severe weather events are expected, so this strategy may become more challenging and less effective over time. However, events also are opportunities to provide information and raise awareness about climate change. Other conditions outside DELEP's control that will affect this strategy include partnerships and funding—most events will rely on partners to organize, participate in, or fund them, so significant benefits to partners and funding in the watershed could affect the ability to meet event goals.

Performance Measures and Key Deliverables

- Continuous improvement in event attendance (# of people/events annually)
- Examples of reaching key audiences in each state successfully, including hosting/supporting at least one major event annually
- Track number and results of outreach programs and projects related to events

Costs and Funding

- **Estimated Cost Range:** $$
- **Possible Funding Sources:** National Estuary Program funding, major municipalities, corporate and partner support; federal grants (National Oceanic and Atmospheric Administration Coastal Zone Management Program)

New Hope, PA | Credit: Jerry Franklin

Purpose

To introduce people to the Delaware Estuary, provide them with information, and build their awareness through engagement at events.

Core Partners

Delaware River Basin Commission, Partnership for the Delaware Estuary, Philadelphia Water Department, States (DE, NJ, PA), United States Environmental Protection Agency

Key Partners

Organizers/partners/exhibitors of major events, including Coast Day/Bay Day, City of Wilmington, Delaware Nature Society, Shad Fest and other event hosts

Contributing Partners

Conservation Districts, Watershed organizations and other Non-Governmental Organizations involved in events

Timeframe

Coast/Bay Days and other festival events often are held annually

STRATEGY C2.3: Develop and promote programs that engage teachers and schools in stewardship of the Delaware Estuary

Description

Teachers, schools, and nature centers are venues to reach youth groups as key audiences to educate them to increase their appreciation of the Estuary and its natural resources' value. Every teacher affects the lives of many students during his or her career. Because educators and their administrators are valuable leaders and messengers within their communities, their engagement often is key in providing programs or projects at schools with an Estuary focus. As some of the largest landowners in many sub-watersheds of the Delaware Estuary, schools and nature centers are valuable and visible demonstration sites for their surrounding communities. For these reasons, developing and promoting programs that engage these key audiences in Estuary stewardship is critical. Activities include:

2015 PDE Teachers workshop at DuPont Environmental and Education Center in Wilmington, DE. | Credit: PDE

- **Developing and providing teachers with training, tools, and materials** that allow them to undertake and promote stewardship in their schools and classrooms, and such programs as teachers' workshops give teachers skills, tools, and ideas for teaching about the Delaware Estuary. Resource guides and classroom materials facilitate teachers' efforts to incorporate Delaware Estuary concepts in required curriculum that can be made available online for easy access.
- **Providing opportunities for schools and classrooms to be hubs** for community engagement and/or involved in experiential learning. Critical activities include contests that challenge youth to use creativity to learn about, and illustrate issues in, the Estuary, and outdoor and floating classrooms that give children and teachers hands-on experience with the Estuary's resources. These also can provide opportunities for volunteers and citizen scientists in the community to be involved, and serve as demonstration opportunities for practices that other members of the community can replicate (e.g., rain gardens, other stormwater management practices).
- **Partnering with institutions of higher learning** can extend the stewardship experienced to older students, and engage those students, from citizen to professional scientists. Making internships and fellowships available to current students gives them in-depth, hands-on experiences, advances their careers, and accomplishes projects that benefit the Delaware Estuary and local communities.
- **Prioritize and/or tailor educational opportunities to be accessible and engaging to underserved communities.** This would include focusing on schools and teachers with predominantly underserved students, and holding low- or no-cost programs accessible to local communities (within walking distance or by public transportation) with key messages and activities tailored to the audiences.

2015 PDE Teachers workshop at DuPont Environmental and Education Center in Wilmington, DE. | Credit: PDE

In addition to schools and nature centers, many organizations and agencies provide valuable environmental educational programs and resources to teachers and schools in the watershed on many topics important to the Delaware Estuary. PDE takes the lead in programs and projects designed to connect schools and educators with local partners, filling gaps and providing services to those local partners, and creating and providing unique Delaware Estuary-centric experiences. For example, PDE works closely with PWD and its Fairmount Water Works interpretive center to provide programs for teachers and classrooms in Philadelphia, and with partners in SAN to implement programs for classrooms and schools in the Schuylkill River Watershed. The Alliance for Watershed Education in the Delaware River Watershed includes over twenty nature centers, many of which PDE has worked with. The Alliance offers new and more partnering

opportunities to implement this strategy over the next 10 years.

The core message that PDE wishes to relay to educators and their institutions through these activities is that there are a variety of ways to use the Delaware Estuary and its resources as valuable teaching tools to engage students and improve their success. A significant focus of these efforts is on providing these audiences with opportunities for experiential learning through creative and hands-on activities, volunteer stewardship opportunities, and citizen science.

Changing school environments and teachers' educational standards and requirements can be a challenge in implementing this strategy and is beyond PDE's control. Providing teachers continuing education and professional development credits and other incentives, and tailoring programs to changing curricula, standards, and teachers' schedules are strategies PDE will continue to employ to address this challenge. Eventually, climate change may affect the ability to conduct outdoor activities with teachers and students. In the meantime, climate change is becoming an important educational topic for teachers quickly, and is a valuable Science, Technology, Engineering, and Math (STEM) learning opportunity that will shape the educational content of the materials covered and produced as part of this strategy.

Performance Measures and Key Deliverables

- At least one effective program for teachers/schools in each state and a growing community of teachers, schools, and students they reach
- Track number and results of outreach programs and projects related to teachers and schools, including production and distribution of classroom materials and guides, and creation/use of internships and outdoor/floating classrooms

Costs and Funding

- **Estimated Cost Range:** $$ - $$$
- **Possible Funding Sources:** National Estuary Program funding, major municipalities, state, federal, foundation grants

Pennsylvania Coast Day 2017 | Credit: PDE

Purpose

To engage educators, schools, and nature centers as Estuary stewards both directly and through their effects on students and communities.

Core Partners

Partnership for the Delaware Estuary, Philadelphia Water Department, States (DE, NJ, PA)

Key Partners

Alliance for Watershed Education of the Delaware River, Schuylkill Action Network

Contributing Partners

Delaware Association for Environmental Education and other environmental education organizations

Timeframe

Many PDE programs for educators and their classrooms take place annually. Most projects with schools can be completed in a 1- to 2-year timeframe. Building relationships with educators and their institutions to facilitate these kinds of programs/projects is ongoing.

STRATEGY C2.4: Develop and promote programs with local communities and partners that foster volunteer stewardship and experiential learning)

Description

Providing opportunities for experiential learning through topical programs and citizen science projects helps involve local residents in regional restoration projects in a very meaningful way. Whether they develop a greater appreciation of biodiversity through volunteer monitoring, or simply answer a question about marine debris, these teachable moments provide the opportunity to discern current environmental challenges and solutions.

While PDE promotes programs and volunteer stewardship via this strategy, many other partners in the watershed offer programs that provide experiential learning and/or involve volunteers and citizen scientists. PDE will rely heavily on collaborations with partner organizations and their programs, as well as volunteer networks, to implement them.

Major components of this strategy include:

Volunteers participate in bagging recycled shell to be used in restoration projects. | Credit: PDE

- **Using storm drain marking and associated activities to engage local communities in preventing stormwater runoff pollution.** In urbanized areas, the most prevalent path for this pollution is through storm drains and lack of awareness of this is a large part of the problem. Involving local residents in marking storm drains with "no dumping–drains to river" medallions raises their awareness and engages them in doing the same with others on a local level. Since 2000, PDE has collaborated with hundreds of organizations and more than 50 municipalities and their volunteers to mark approximately 100,000 storm drains. In Philadelphia, PDE will continue working closely with PWD to involve residents in storm drain marking that also will attract attention to local watersheds otherwise hidden from view. In other areas of the watershed, PDE will continue to encourage and facilitate storm drain marking on the part of community groups by promoting its value and making marking kits (including instruction manuals, safety vests, adhesive, medallions, and education cards) available to municipal officials, property managers, retail businesses, homeowners' associations, farmers, and school groups. PDE will work with PWD and other interested partners to expand and improve storm drain marking with new tracking technology and resources, and creative new approaches (e.g., street art stickers).
- **Engaging volunteers in monitoring and citizen science to gather information on our waterways' quality and current status of our living resources.** Citizen science involves enlisting enthusiasts rather than scientists to collect data, and offers interested members of the public the opportunity to participate in research. One of the benefits of using volunteer monitoring includes deriving data from a much larger pool of collectors to provide a higher volume of results across a large geographic area. The collection of this information might be impossible otherwise because of the limited amount of research that organizational staff can conduct. One of the primary ways PDE uses citizen scientists is by recruiting and training volunteers to search for and report on freshwater mussels in local waterways. Since 2012, over 70 volunteer surveys have been completed, with more than 60 volunteers trained by PDE staff annually. PDE will continue to expand this network by holding and promoting volunteer training workshops with partners, continuing to collect data through its online portal, and using results to identify sites for scientific surveys. PDE also will work to expand its citizen science opportunities by developing and implementing new volunteer monitoring programs, like one for wetlands/shoreline monitoring under development currently in partnership with NJDEP and the Barnegat Bay Partnership.
- **Engaging volunteers through oyster shell recycling.** In 2015, PDE started an oyster shell recycling program that collects shells from restaurants so that they can be returned to the Bay. Bagged shells were installed in living shorelines and other conservation projects to increase the number of shells available on which young oysters grow. Through this shell recycling initiative, PDE engages restaurants and their patrons in education about oyster restoration. PDE also encourages volunteers to help collect and bag shells and works with partners, including the PWD, to identify and host new shell management areas. Since the program's inception, more than 150 volunteer hours have been logged for shell pickup and bagging, in which 13 restaurants have participated. PDE will continue shell recycling efforts in Wilmington, DE and seek to expand them to Camden, NJ and Philadelphia, PA.
- **Hosting, promoting, and participating in river and watershed cleanups.** Cleanups are excellent ways to immerse residents in the outdoor environment while also enlisting them to clean our waterways. For example, the Schuylkill Scrub is a watershed-wide cleanup that takes place every spring and engages tens of thousands of volunteers across the Schuylkill Watershed. PDE also hosts the Christina River Watershed

Cleanup in partnership with DNREC, and Delaware River cleanups in partnership with PWD, each of which attracts hundreds of volunteers annually. Other partners host and/or participate in additional clean-up activities, such as the Coastal Cleanup DNREC hosts in sites along Delaware's coast. PDE will work with these and other partners to expand and improve volunteer involvement, and apply citizen science to assess sources and materials of concern.

- **Promoting horseshoe crab volunteer opportunities.** A number of programs partners around Delaware Bay coordinate seek to engage volunteers and citizen scientists in horseshoe crab conservation. These include Development Group's (ERDG) "Just Flip Em" program and New Jersey's "ReTURN the Favor" program, both of which encourage volunteers to flip horseshoe crabs stranded on bay beaches. They also include horseshoe crab and shorebird counting and tagging programs that USFWS and others coordinate, and ERDG's Horseshoe Crab Sanctuary Communities program. PDE will continue to promote volunteer activities associated with these programs, and provide financial support periodically for items, including signage, when feasible.

Volunteers learn to survey streams for the presence or absence of freshwater mussels. | Credit: PDE

- **Involving communities and corporations in hands-on projects to improve habitat and water quality.** Over the years, PDE's involvement of corporations and communities in hands-on habitat and water quality improvement projects has evolved considerably. The Corporate and Community Environmental Stewardship Program has continued to enlist local partners and volunteers in planning and conducting projects on corporate and community lands. However, corporations increasingly are establishing their own stewardship and grant programs to which PDE applies for specific projects and activities,

and are branching out to become involved in projects at local schools and/or parks. PDE will continue to evolve its efforts in response to these changes, and find ways to involve corporate and community volunteers in meaningful projects where they live and work.

- **Prioritizing and/or tailoring experiential learning opportunities to be accessible and engaging to underserved communities.** This could include providing low or no cost opportunities that are accessible to local communities within walking distance or through public transportation. Key messages and activities would be tailored to these audiences.

In addition to these major ongoing programs, PDE will continue to encourage and facilitate volunteerism in specific projects, like the water quality and habitat improvement detailed in other strategies. To coordinate and promote volunteer opportunities across these activities and geographies better, PDE will consider adding staff or volunteer capacity to manage volunteers and use apps or other new technologies.

A majority of these stewardship opportunities take place in an outdoor setting and depend on weather, including along waterways or areas prone to stormwater flooding. Climate change effects may lead to cancellations of events, workshops, organized volunteer activities, and decreased participation rates with respect to some of the more expansive projects. Other obstacles beyond NEP's control that can affect this strategy are contingent upon the availability of funding and long-term partnerships. Volunteer availability and reliability are essential for programs that take place regularly throughout the year and require flexible, yet dependable assistance to operate the program efficiently. The extent of the Delaware Estuary and nature of many of PDE's projects makes developing a reliable corps of volunteers challenging without a robust program to recruit, train, and manage them (which PDE currently lacks, but is interested in developing).

Performance Measures and Key Deliverables

- Assess and increase corps of volunteers and citizen scientists with new data/outcomes shared/used annually, including shell bags produced, storm drains marked, debris removed
- Track number and results of outreach programs and projects related to volunteers and citizen scientists

Costs and Funding

- **Estimated Cost Range:** $$
- **Possible Funding Sources:** National Estuary Program funding, major municipalities, state, federal, foundation grants

Purpose

To engage residents in activities that benefit the Estuary, while also improving their understanding, knowledge, and support.

Core Partners

Delaware River Basin Commission, Partnership for the Delaware Estuary, Philadelphia Water Department, States (DE, NJ, PA), United States Environmental Protection Agency

Key Partners

Academia, cleanup partners, mussel survey training partners, shell recycling partners, Penn State Extension Master Watersheds Stewards, United States Fish and Wildlife Service, Upstream Suburban Philadelphia Cluster, other horseshoe crab and shorebird monitoring partners

Contributing Partners

Volunteers, interns/fellows

Timeframe

Large-scale volunteer cleanups are held annually. Citizen science, storm drain marking projects, and actions related to shell recycling are ongoing, with annual monitoring of programs (attendance and evaluations)

STRATEGY C2.5: Publish and share outreach materials and scientific results

Description

Sharing scientific research and creative outreach materials with local residents can inspire them to learn more about the role they play in enhancing the Delaware River and Bay. Information relayed through scientific reports also provides readers with insights into the current status and trends of their region's natural resources. Sharing scientific results periodically across regions and sectors helps support organic, bottom-up transfer of valuable scientific data and outreach/education techniques.

Poster presentations during the Delaware Estuary Science and Environmental Summit in Cape May, NJ. | Credit: PDE

Publishing and publicizing findings of current environmental research also provide opportunities for new or emerging research projects through inter-institutional and interdisciplinary grant proposals, and support for future funding. Working with key agency partners, the PDE will continue to provide and share the most accurate, current scientific information on topics critical to the Delaware Estuary to use to make decisions and raise awareness and understanding on the part of the interested public and next generation of scientists.

Major components of this strategy include:

- **Producing and sharing public-friendly publications to improve public awareness and knowledge.** Producing science-based publications is essential to build public awareness and promote involvement through education. Every 3 to 5 years, PDE publishes the State of the Estuary Report (often as a public-friendly version of Estuary News) which serves as an overview of the tidal Delaware River and Bay's current status. Other products for the public include guides on topics including stormwater, household hazardous waste, and adapting to climate change. These guides translate science into layman's terms for non-science audiences who may be interested in taking action. PDE publications also include products like the Annual Report, which is meant to provide the public with information about programs and priorities, and a window into opportunities for involvement.

- **Producing and sharing technical reports and publications related to the Estuary's environmental conditions.** It is critical to share scientific information to encourage learning, collaboration, and decision-making among scientists in different parts or sectors in the region. The purpose of the Technical Report for the Delaware Estuary and Basin (TREB) is to relay information on the status and trends of environmental indicators of the Delaware Estuary and River Basin's health by analyzing the best current quality data. To compile this report, PDE relies on the time and expertise of a variety of partners and scientists on the STAC from agencies, academic institutions, companies, and non-profit entities. The production of a technical report, including the TREB, also can be used for multiple purposes: to provide information for public-friendly documentation, as well as other agency technical reports (e.g., State of the Delaware River Basin Report). Examples of other technical reports PDE produces with the help and input of partners include the Regional Restoration Blueprint and Climate Change in the Delaware Estuary reports. PDE will continue to develop and share such reports to communicate findings with other experts and the engaged public about ongoing projects and associated research.
- **Holding and attending the Delaware Estuary Science & Environmental Summit and other meetings and conferences.** Conferences provide the opportunity to share information and develop new collaborations. More than learning about inspiring stories, attendees can learn the way others have solved similar problems that they also may be facing, which helps individuals, as well as entire organizations, surmount roadblocks in their work. Since the Delaware Estuary Science and Environmental Summit's inception in 2005 (and biennially thereafter), this event has allowed scientists, managers, educators, and the public to learn about, and collaborate on, practical solutions to challenges faced in and around the Delaware River and Bay. In addition (and often between Summit years), PDE hosts other workshops on key issues that need sharing and collaboration. PDE will continue to do both, based on needs partners identify, and post presentations/results on the PDE website for additional learning/sharing. Workshop topics for the near future include monitoring, working with the DRBC and DNREC, and tech transfer between Bayshore communities. PDE also will work with partners in the region who host similar events (e.g., the Coalition for the Delaware River Basin's Delaware Watershed Forum), to explore ways to coordinate and co-promote events to encourage transfer between audiences, and make participation in both events easier for partners who attend both. In addition to these PDE-hosted conferences and meetings, PDE staff participate in a wide array of conferences annually to share expertise and learn from one another. These include annual National Estuary Program meetings, as well as scientific conferences, other regional conferences, and workshops on topics of interest/concern.
- **Making materials, publications, and technical information available and engaging to underserved communities.** This could include tailoring and presenting information in a way that is relevant to diverse communities, providing materials and publications at low or no cost and in multiple languages, and using special invitations and/or scholarships to invite underserved community presenters and attendees to the Summit.

Potential barriers beyond NEP's control that affect this strategy include funding and partner constraints. Drafting, compiling edits, and collaborating with writers for reports, including the TREB, can be a lengthy and demanding process for PDE and contributing partners/authors. Sponsorships fund the Summit primarily, and are becoming more difficult to obtain from public agencies, as well as registration fees, where funding relies on participant organizations with healthy budgets.

Performance Measures and Key Deliverables

- Continue hosting the Delaware Estuary Science & Environmental Summit biennially, and involve more stakeholders at each event (300 people or more, 100 presentations or more)
- Distribute and share reports, publications, and other literature online at DelawareEstuary.org (4,500 annually)
- Produce and distribute reports on accomplishments annually and reports assessing the state of the Estuary's conditions and trends every 3-5 years
- Track outreach programs and projects through products scientists, managers, and practitioners publish

Costs and Funding

- **Estimated Cost Range:** $$
- **Possible Funding Sources:** State and federal grants and sponsorships, partner and business sponsorships, registration fees

New Hope, PA | Credit: Jerry Franklin

Purpose

To educate scientists, practitioners, and the public involved by sharing information on the status, trends, and latest research on the Delaware Estuary.

Core Partners

Delaware River Basin Commission, Partnership for the Delaware Estuary, Philadelphia Water Department, States (DE, NJ, PA), United States Environmental Protection Agency

Key Partners

Academia, other Science and Technical Advisory Committee and Monitoring Advisory Coordination Committee member organizations, Science & Environmental Summit partners/sponsors

Contributing Partners

Meeting/event exhibitors, attendees, presenters/authors

Timeframe

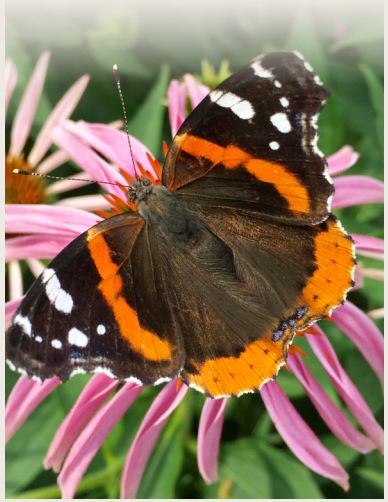
Annually to every 3-5 years

Strategy C2.6: Engage key stakeholders to coordinate science and management of the Delaware Estuary

Description

A critical role of any NEP is the coordination of science and management based on stakeholders' input. This role is particularly important in the Delaware Estuary, where multiple states (DE, NJ, PA), hundreds of local communities, and a variety of federal and regional agencies share its resources' management. The DELEP's Management Conference was designed to incorporate input from these and other stakeholders at multiple levels. Stakeholders are involved through a network of working groups and committees, each of which requires strategic leadership and coordination. Effective communication is needed among these groups to inform and guide collective efforts to protect and enhance the tidal Delaware River and Bay. Key activities include:

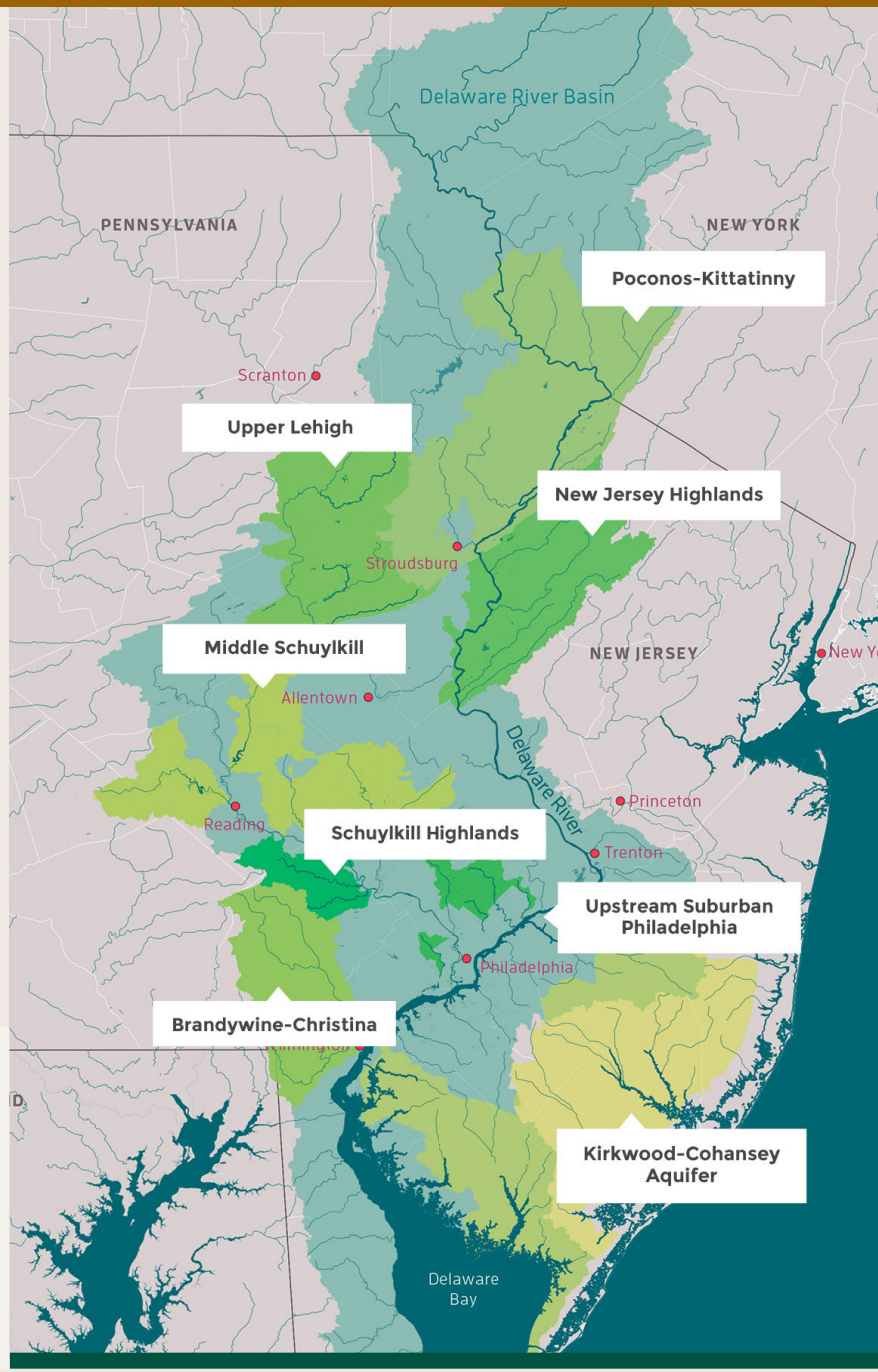
- **Coordination of the Steering Committee to provide policy-level guidance for DELEP's Core Partners collective efforts.** This committee consists of leadership-level appointees from the Core Partners identified on the right. The Steering Committee meets twice annually, with leadership rotating between the states (DE, NJ, PA) every two years, in accordance with the agreement among DELEP partners (most recently, in December 2014). This structure ensures Core Partners' consistency and high-level support, which PDE will continue to facilitate with their participation and leadership.
- **Coordination of the Estuary Implementation Committee (EIC) in conjunction with the PDE Board of Directors.** Coordination of the EIC and PDE Board will continue to provide ongoing input from key stakeholders to develop and implement an annual work plan using NEP funding. The EIC includes Core Partners' management-level appointees, as well as other selected government agencies (currently the USFWS and National Park Service). The EIC, which convenes at least quarterly under the PDE Executive Director's leadership, includes joint meetings with the PDE Board of Directors. The PDE Board of Directors consists of up to twenty representatives from the private, non-profit, or local government sectors elected and operating in accordance with the organization's by-laws Additional topical committees, meetings and/or phone calls are used as needed to meet NEP requirements and involve individuals with expertise on important topics and issues. This coordination allows both groups an opportunity to provide regular guidance and collaboration in implementing the annual work plan, which PDE has continued to coordinate and submit with Core Partners' participation.
- **Coordination of the STAC to provide a sound scientific basis for PDE and Core Partners' activities on a wide range of scientific topics.** The STAC includes up to 21 elected scientists with diverse expertise and associations with other technical groups, who provide DELEP with robust peer review and technical guidance. As described in its charter, the STAC develops reports on environmental indicators to assess status and trends in the Estuary over time as part of the State of the Estuary reporting all NEPs require every three to five years. The STAC also plays an instrumental role in developing and implementing the scientific content at PDE conferences and workshops, including the Delaware Estuary Science & Environmental Summit held semiannually. The STAC meets with the MACC (described below) annually to assess and update monitoring activities and Delaware Estuary needs. The STAC also meets with the EIC (described above) annually to provide a direct link between science and management groups. The STAC convenes



West Philadelphia | Credit: Stephanie Rindosh

at least quarterly under an elected Chair and the PDE Science Director's leadership. It reports to the EIC, and is available on request to provide peer review and/or develop briefs on topics of concern the EIC requests. As a fundamental part of this strategy, PDE will continue to coordinate STAC with participation and support for Core and other partners.

- **Coordination of the Monitoring Advisory and Coordinating Committee (MACC), Toxic Advisory Committee, and Water Quality Advisory Committee.** DRBC's coordination of these committees provides additional input on technical topics relevant to CCMP implementation. The DRBC staff created and coordinated these committees to provide input and guidance required for DRBC activities and programs, but also to provide valuable input and guidance on these topics to PDE and other DELEP partners. As a regional river basin commission, DRBC plays a critical role in conducting monitoring activities on the main stem of the Delaware River, and linking its monitoring programs with those of PDE and others. Coordination of monitoring related to water quantity and quality, fish and shellfish, key habitats, and other features provides the most comprehensive and efficient way to track changing conditions in the watershed. Monitoring coordination on DRBC's part helps fulfill its own responsibilities/requirements, as well as some of the NEP's key requirements, such as State of the Estuary tracking and reporting.
- **Coordination of, and participation in, sub-watershed collaborations to build and enhance local capacity, partnerships, and stakeholder input to implement the CCMP.** In a watershed as large and diverse as the Delaware Estuary's sub-watershed, collaborations have proven an effective way to engage local stakeholders, including watershed organizations, conservation districts, local governments, and interested citizens, to work collectively to identify and implement local projects and programs of shared value. A prime example of this is the SAN, where PDE and Core Partners, including the PWD, PADEP, and DRBC, have played a leadership role since 2003 in coordinating over 100 local partners' activities to address water quality issues in the Schuylkill River Watershed. Over the next 10 years, PDE will work with these and other Core Partners to strengthen and advance the SAN's work and that of the many other sub-watershed collaborations.
- **Use of a variety of other mechanisms to involve different key audiences.** PDE has engaged with audiences outside of its management structure, including sub-watershed collaborations



The Delaware River Watershed Initiative identified eight priority areas across the Delaware River Basin where restoration and protection projects can have a lasting impact. | Credit: DRWI

(local conservation partners), attendees at the Delaware Estuary Science & Environmental Summit (scientists, outreach specialists) and the Annual Experience the Estuary Celebration, Corporate & Community Environmental Stewardship Program members (corporate campuses, local communities), as well as participants in local projects and workgroups. These activities provide some limited opportunities for stakeholder input on NEP priorities outside of the Management Conference structure. The PDE Board of Directors also brings additional local and private-sector resources, input and guidance to the table within the Management Conference. To develop a more meaningful way for an even broader audience to provide input is a challenge that requires a new, innovative approach. PDE will work with the EIC to develop, fund, and implement this concept and design it in a way that includes underserved communities.

PDE will be this strategy's primary lead implementer, except for DRBC committees' coordination described above. However, all the Core Partners mentioned above, as well as the various other participants in these committees and groups, will play critical roles in its implementation and success. This role includes participation, and in some cases, leadership and/or funding for implementation. Activities in this strategy provide the foundation on which to coordinate water quality and resource management and collaboration on projects and programs for greater effect to benefit the Delaware Estuary.

Changes in political administrations and staffing and Core Partners' funding have a significant effect on this strategy's success. Because of the Steering Committee's composition, there is nearly constant change in leadership attributable to state, federal, and local elections. These changes affect agency priorities, staffing, and funding that is beyond NEP's control. This makes PDE (Board and staff) and the EIC's consistent leadership particularly important. Accordingly, PDE and all partners' flexibility and agility in responding to changes and stepping in to fill leadership gaps as needed also are important.

Performance Measures and Key Deliverables

- Sustain and improve leveraging (through involvement/coordination)
- Continue to convene EIC, STAC and PDE Board of Directors' meetings (at least quarterly) and SC (biannually) to coordinate the management conference
- Track and expand additional meetings and other activities to engage new stakeholders and promote collaboration to address key issues in sub-watersheds

Costs and Funding

- **Estimated Cost Range:** $$$$
- **Possible Funding Sources:** NEP funding, federal, state, and local grants/contracts, foundation grants

Purpose

To coordinate diverse scientific, management, and stakeholder groups to protect and restore for the Delaware Estuary's resources most efficiently.

Core Partners

Delaware River Basin Commission, Partnership for the Delaware Estuary, Philadelphia Water Department, States (DE, NJ, PA), United States Environmental Protection Agency

Key Partners

Delaware River Watershed Initiative, National Park Service, Schuylkill Action Network, United States Fish and Wildlife Service, other Science and Technical Advisory Committee and Monitoring Advisory Coordination Committee member organizations, other sub watershed collaborations

Contributing Partners

Delaware Bay and River Co-op, National Marine Fisheries Service, United States Army Corps of Engineers

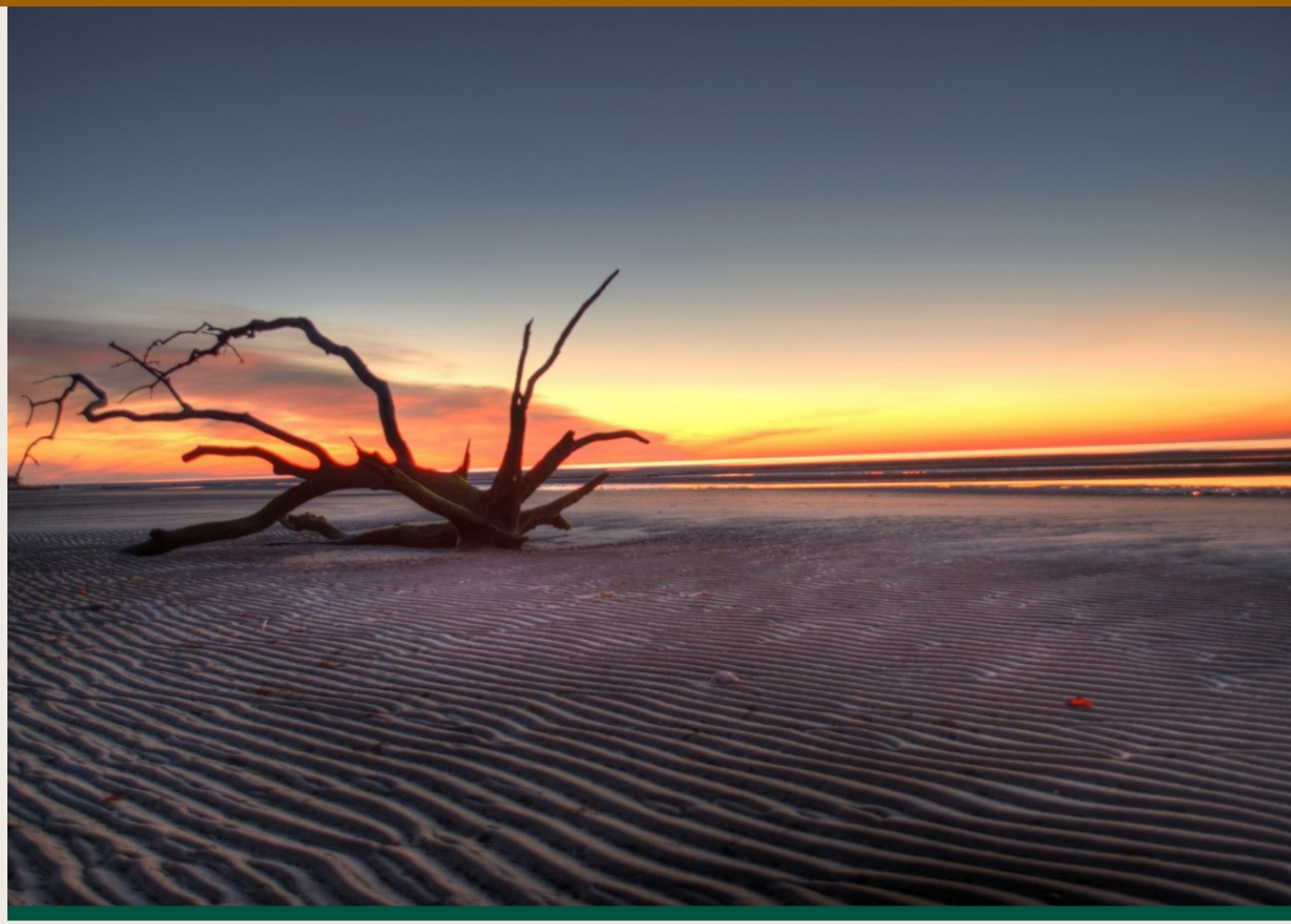
Timeframe

Ongoing

Strategy C2.7: Monitor, develop, and promote opportunities to assess impacts of outreach

Description

Assessing outreach effects over time is challenging. Ideally, outreach efforts build awareness, change behavior, and instill an ethic of stewardship in a critical mass of people who can make a measurable difference in the Delaware Estuary over time. Behavioral changes can range from direct effects (e.g., ceasing to use pesticides) to indirect effects (e.g., teaching young children about horseshoe crabs). Effective outreach activities include:



Green Creek, New Jersey. | Photo Credit: Aaron Maffei

- **In the short-term, use program attendance and evaluations to measure outreach effects.** This could include tracking program participation and the degree to which participants represent target audiences (although this may require some estimating, as most activities do not involve the collection of demographic or economic information on the people involved). The PDE will track and report program attendance and survey results in its annual work plan, and seek ways to collect and incorporate similar data from Core Partners involved in outreach programs.
- **In the short-term as well, identify and pursue efforts to track the extent to which DELEP programs and activities are engaging underserved communities**. Again, this may be challenging, as most DELEP activities do not involve the collection of demographic or economic information.
- **In the mid-term, use focus groups and surveys as cost-effective ways to obtain feedback on outreach programs' effects.** These can target very specific audiences (e.g., program participants) or samples

from certain geographies and demographics. In 2013, PDE engaged a marketing and communications contractor to conduct three focus groups and an email survey to provide feedback on communications/branding for PDE and the Estuary. To gauge effects, focus groups and other methods (e.g., surveys) could be repeated and compared to track changes over time.

- **In the long-term (decades and generations), determine the way outreach efforts contribute to environmental improvements, as indicated by changes in environmental indicators, such as those the State of the Estuary reporting tracks.** PDE will explore new and improved ways to track behavioral changes over time, outreach efforts' effectiveness, and environmental improvement. There are some exciting new opportunities underway in the watershed, including communication efforts under the DRWI and the new Alliance for Watershed Education for the Delaware River that could contribute to environmental improvements over time.

Just as many organizations are conducting outreach within this watershed important to the Delaware Estuary, many are involved in assessing results. PDE will continue to take the lead on outreach and communications specific to the Delaware Estuary, and their tracking and reporting for the NEP's purposes. If there are opportunities to advance research and practices in this arena that could benefit from everyone working in the watershed, we will seek them out and pursue them where feasible with partners' input and support.

The greatest barrier to measuring outreach effectiveness is scarcity of funding. For many of the outreach programs and projects PDE undertakes, a rigorous assessment of their effects on behavioral change would cost more than implementing the project itself. A second and related barrier is the lack of data and cost-effective best practices to assess the effects, which may lead funders to under invest in outreach programs. This strategy is designed to help address this constraint, and new technologies that can help control costs associated with measuring results (e.g., Survey Monkey for post-surveys will be explored).

Performance Measures and Key Deliverables

- Conduct focus groups and surveys
- Identify and implement new performance measures for outreach
- Track numbers and results of research projects on outreach

Costs and Funding

- **Estimated Cost Range:** $
- **Possible Funding Sources:** Outreach program partners, state/federal grants, foundation grants

Purpose

To measure and demonstrate outreach efforts' effectiveness to report results and fine-tune programs.

Core Partners

Partnership for the Delaware Estuary, Philadelphia Water Department, States (DE, NJ, PA)

Key Partners

Program partnersand participants, contracted experts

Contributing Partners

Alliance for Watershed Education of the Delaware River

Timeframe

Focus groups and surveys repeated every 5-10 years would allow results to be compared over time

HEALTHY HABITATS

Healthy Habitats for fish and wildlife are important to water quality, the economy, and human and environmental health. Key habitats in the Delaware Estuary and Basin include wetlands, forests, and fish and shellfish habitat

"Without habitat, there is no wildlife. It's that simple." ~ Jean Cinqq-Mars, Editorial for the *Forestry Chronicle*, 2001

Port Norris, NJ | Credit: Kurt Philippe

HEALTHY HABITATS GOAL 1

PREVENT WETLAND LOSS

The Delaware Estuary is unique in the extent of tidal freshwater wetlands it hosts, including these at the John Heinz National Wildlife Refuge, PA. | Credit: PDE

Wetlands are one of the Delaware Estuary's most important and characteristic habitats. Many scientists consider wetlands a waterway's "kidneys," as they help absorb pollutants, contaminants, and carbon. They are places where fish and wildlife live, feed, and reproduce, making them crucial to their survival. Wetlands also protect coastal communities, acting as sponges that absorb floodwater and storm surges and providing a buffer and sink for pollution from upland areas. Beyond this, wetlands are beautiful recreation areas for kayakers, anglers, birders, and boaters. The Convention on Wetlands of International Importance designated the Delaware Bay Estuary (Delaware, New Jersey, and Pennsylvania) as one of 38 sites in the United States with international importance. Recognizing their importance, Delaware, New Jersey, and Pennsylvania have developed state-based wetland strategies and various other initiatives to promote their management, protection, and restoration, and educate the public about why they are so valuable.

Before people realized wetlands' ecological value, many were diked, drained, filled, developed, and used for solid waste disposal. Regulations now prohibit tidal wetlands' destruction. If effects are unavoidable, wetlands must be replaced on a 1:1 basis at a minimum. However, despite these protections, as cities and towns grow, new roads, schools, and commercial and residential housing developments still affect wetlands. While there have been some successful wetland replacement projects, others often have limited success. This leads to acreage lost or degraded

wetland health. In addition, wetlands are habitats in constant flux, moving and responding to natural and human-induced changes in surface and ground water conditions. Human development can put up a hard barrier that disturbs the flow of water and mud into and out of wetlands which prevents them from shifting naturally. At the same time, rising sea levels and storms are submerging and eroding many wetlands. Unhealthy, eroded wetlands provide fewer ecosystem services and are less valuable wildlife habitats. If coastal wetlands disappear, areas along shorelines will be more susceptible to erosion attributable to wave energy and storms.

It is estimated that the Delaware Estuary has lost more than half of its coastal wetlands since the earliest settlers arrived. Recently, some of the most significant losses of acreage have been in salt marshes along Delaware Bay where rising sea levels and erosion are widespread. Future projections suggest that these losses will increase, perhaps rapidly, and likely result in a dramatic shift in the lower Estuary ecosystem's character and function. Coastal wetlands in the upper portion of the Delaware Estuary have experienced the greatest percentage of losses in recent decades, but these declines appear unrelated to climate change and instead, have been associated with past, as well as recent, conversion attributable to residential and commercial development and shoreline alterations developments. For example, the wetlands of the tidal Schuylkill River were almost entirely replaced by bulkheads. This trend suggests that regulation does not guarantee protection and may not capture the complexity of influences on wetland loss. When assessed across the entire watershed and analyzed within the context of a regional monitoring and assessment network, the Delaware Estuary currently is losing approximately an acre of tidal wetlands daily.[11] Although non-tidal wetlands are not at risk from coastal erosion, they face many of the same development threats. To combat these losses and protect communities, partners are testing new ways to prevent and even reverse losses with wetland restoration tactics (e.g., living shorelines, the reuse of dredged sediment).

Tidal wetlands are some of the most productive habitats in the world, and arguably the most ecologically and economically important type of natural habitat in the entire Delaware River Basin. Current trends suggest that tidal wetlands, particularly salt marshes, and hence the ecosystem services and the direct financial and aesthetic benefits they provide, are being degraded and lost throughout all areas of the Delaware Estuary. Thus, a recommitment to wetland protection and finding new, creative ways to manage and sustain wetlands and their health is warranted. Expanded outreach to the public and decision-making elected officials also is required to build awareness of wetlands' critical benefits and vulnerability.

HOW WE WILL MEASURE SUCCESS:

- Minimize loss of wetland areas
- Improve wetland conditions
- Increase protected and restored wetland acres/sites

STRATEGY H1.1: Establish clear baselines for tidal wetland conditions and track changes over time

Description

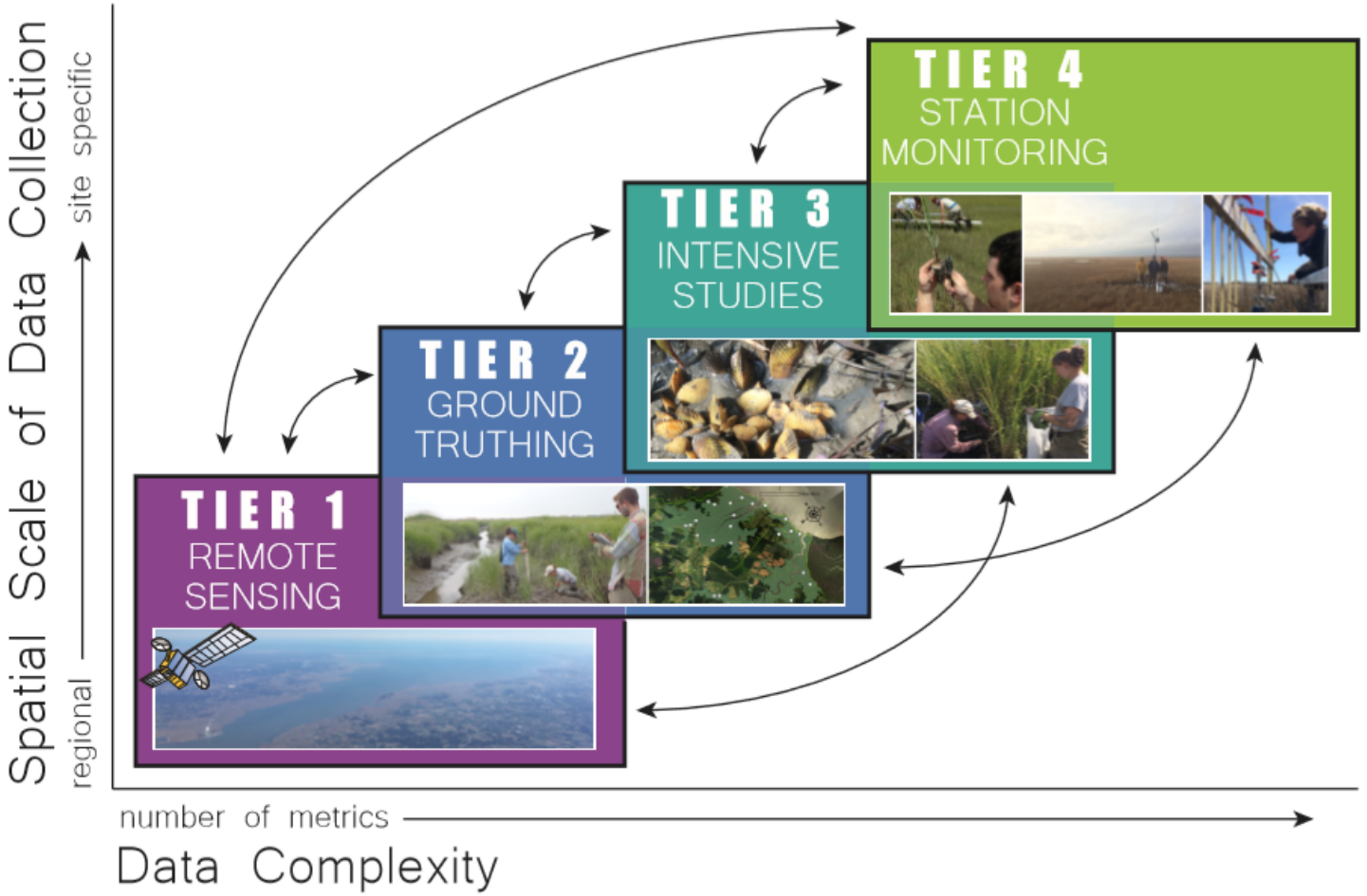
Tidal wetlands, also referred to as coastal wetlands, are at high risk of degradation because of human disturbance, rising sea levels, and climate changes. They provide such services as flood abatement, storm surge attenuation, nutrient sequestration (in addition to other coastal habitats, including dunes and maritime forests). Further, tidal wetlands play a key role in the life cycle of many commercially important fisheries. These services make these habitats a high priority for inventorying and studying current conditions, as well as the way they are changing over time.

PDE Site Specific Intensive Monitoring (SSIM) of wetlands along Dennis Creek, NJ with the Barnegat Bay Partnership. | Credit: PDE

Considering tidal wetlands' importance, it is vital to track changes in their acreage and health over time. In Delaware, rapid assessment studies of tidal wetland conditions have been carried out for all the watersheds along Delaware Bay, and a comprehensive inventory of statewide wetland acreage is planned during 2018. It is vital to establish baseline conditions where they currently do not exist. Areas that are changing rapidly, such as in the urban corridor, warrant periodic resurveys of tidal wetland conditions, and their extent overall should be monitored carefully over time. These data feed directly into loss intervention planning by prioritizing

specific coastal wetlands that either are at risk most or have the highest ecological service value.

The Mid-Atlantic Coastal Wetland Assessment (MACWA) was established in 2006 as a way to provide a consistent, robust way to accumulate multi-agency data on mid-Atlantic coastal wetland conditions and geographic extent. State and federal agencies, and academic and non-profit organizations collaborate on MACWA, which PDE coordinates within the Delaware Estuary study area. In addition to tracking tidal wetland acreage and conditions, program partners also conduct research on coastal wetland dynamics, study causes of wetland degradation, and work to promote awareness about the tidal wetlands' importance. The MACWA program has four tiers that support landscape-level remote sensing data (Tier 1), rapid ground assessments across large areas (Tier 2), intensive studies to examine ecosystem relations and cases of degradation (Tier 3), and long-term monitoring at permanent stations (Tier 4).



The 4-Tier approach to the Mid-Atlantic Coastal Wetlands Assessment (MACWA). | Credit: PDE

Since 2006, seven long-term monitoring stations have been installed in The Delaware Estuary under MACWA's auspices, and more than 400 wetland sites' health has been assessed. To provide a regional context within which to interpret findings, additional MACWA surveys and monitoring stations exist outside the Delaware Estuary focus area. State agencies also maintain wetland management plans and inventories for regulatory and conservation purposes that are complimentary to MACWA. As the 2017 Technical Report for the Delaware Estuary and Basin discussed, results from

MACWA and other monitoring efforts show that a diverse array of stressors are affecting tidal wetlands, which vary widely among different watersheds of the region. Large areas remain unsurveyed, so more data are needed. These data are vital to identify and design cost-effective intervention tactics that can be used to stem coastal wetland habitat loss.

The techniques, policies, and plans used to prevent coastal wetland loss and restore degraded areas rely heavily on the continued collection of high-quality scientific data and translation of their findings for coastal resource managers, restoration practitioners, and the public. As MACWA serves as an important data repository, it is integral that this (and other related) wetland programs are sustained and expanded as the need for these data increases.

The major components of this strategy are:

- **Sustain and grow MACWA.** MACWA, and synergistic state-based programs, can be supported by continuing annual monitoring at least every 10 years at long-term stations, completing rapid assessments in watersheds that have not yet been assessed to develop a comprehensive baseline, and repeating rapid assessments in watersheds where changes are occurring more quickly.
- **Use monitoring data that MACWA gathers and maintains.** Monitoring data can be used to identify areas that are most vulnerable to rising sea levels and other stressors, and prioritize coastal wetland areas for planning and management.
- **Provide restoration recommendations.** Recommendations can be used to guide the design and management of various restoration or intervention projects that alleviate site-specific stressors best, and provide a monitoring framework to gauge success.

PDE conducts rapid wetlands assessments on the Maurice River in NJ. | Credit: PDE

- **Conduct research.** Conduct research to answer key questions regarding mechanisms of tidal wetland loss to guide management and restoration.
- **Develop State of the Wetlands reports.** Synthesize data from MACWA's four tiers and complimentary state wetland programs to develop State of the Wetlands reports every 5 years for use in subsequent State of the Estuary Reports.
- **Conduct outreach.** Perform outreach to elected officials and the public to foster awareness of tidal wetland status and trends, highlighting the ecological and economic importance of proactive wetland management and monitoring. The primary constraint affecting this strategy's success is lack of dedicated funding. Sustaining and increasing wetland monitoring programs such as MACWA has relied thus far on short-term grants and partners' in-kind contributions. A primary purpose of this strategy is to collect and synthesize data to understand coastal wetland processes better, especially as those processes react to external stressors such as storms, rising sea levels, eutrophication, toxins, climate change (precipitation or temperatures), and anthropogenic disturbance. Climate change certainly will affect tidal wetland function and potentially the ability to collect data at long-term stations. Monitoring wetlands and surveying conditions requires continued investment in both time and money. Political climates, private-sector interests, governmental funding (state and federal) available overall, and partner organizations' capacity can pose threats to this strategy's success overall.

Performance Measures and Key Deliverables

- Complete baseline rapid condition assessments (e.g., Mid-Atlantic Tidal Wetland Rapid Assessment Method) for all watersheds adjoining the Delaware Estuary by 2025.
- Maintain landscape-level inventory maps (e.g., National Wetland Inventory) no more than 10 years old for all watersheds adjoining the Delaware Estuary.
- Repeat rapid condition assessments in rapidly-changing watersheds (e.g., urban areas) every 10 years.
- Produce one research report or product annually and an integrated report every five years to identify wetland stressors, translate outcomes, and guide tidal wetland management and restoration, respectively.
- Track monitoring and research on tidal wetlands within the Delaware Estuary focus area and vicinity.

Costs and Funding

- **Estimated Cost Range:** $$$ - $$$$
- **Possible Funding Sources:** Agency operating funds, federal, state, and private grants

Purpose

To develop robust scientific datasets on coastal wetland conditions to understand and manage their change over time.

Core Partners

Partnership for the Delaware Estuary, States (DE, NJ, PA)

Key Partners

Academia, The Nature Conservancy, United States Fish and Wildlife Service

Contributing Partners

Barnegat Bay Partnership, South Jersey Bayshore Coalition

Timeframe

Ongoing, with 11 stations monitored annually and a minimum of 60 rapid assessments annually for completion of baseline by 2025

STRATEGY H1.2: Restore, enhance, and manage tidal wetlands for maximum health and resilience

Description

The Delaware Estuary is bordered by approximately 165,000 acres of coastal, tidally-influenced wetlands that constitute the hallmark landscape of the Delaware Bay. These tidal wetlands also serve as habitat for unique plants and animals, while also providing critical services to our economy, health, safety, and way of life.

Tidal wetlands in the Delaware Estuary continue to be lost and degraded through anthropogenic and natural causes that threaten these habitats' health, function, resilience, and future.

This strategy focuses on stemming the loss of tidal wetland acreage, achieving a net increase in protected tidal wetlands' extent, and improving their health and function through restoration, enhancement, and strategic management efforts.

An example of a tactic that may stem the loss of tidal wetlands in areas threatened by rising sea levels is the beneficial reuse of dredged sediments that are placed

Installation of a living shoreline along the Nantuxant Creek in NJ. | Credit: PDE

on vulnerable areas of the wetland platform (e.g., by thin-layer spraying). This emerging approach is similar to traditional beach replenishment, and likely will need to be repeated periodically according to rising sea levels. In addition to the potential ecological benefit, this approach could be cost-effective in some areas by reducing costs of dredged material disposal, as suggested in the 2013 Regional Sediment Management Plan for the Delaware Estuary.

Delaware and New Jersey recently have begun to test thin-layer placement of dredged sediments in pilot wetland areas. Although this tactic may prove to be beneficial for some tidal wetlands, the 2017 Technical Report for the Delaware Estuary and Basin indicates that this approach to elevate the marsh platform does not address the greatest vulnerability in most areas, lateral erosion. Scientific concerns also have been raised about site selection, placement method, and type and depth of sediments placed. Therefore, beneficial sediment projects and any other new tactics designed to enhance tidal marsh conditions or acreage require further research, monitoring, and standards development to assist with permitting decisions and restoration project designs. Once a new practice is proven viable and beneficial to tidal wetlands, it also is necessary to train restoration practitioners properly and educate landowners about their restoration options.

Key activities include:

- **Use MACWA data for protection and restoration.** Use MACWA data to identify high-value wetland protection and restoration opportunities and strategies, evaluate results (marsh futures, monitoring protocols), and bolster the amount of useful monitoring data by coordinating methodologies and compiling results from multiple sources.
- **Use traditional practices**. Study and integrate traditional practices for ongoing efforts such as mosquito management and Phragmites eradication, and coastal impoundment restoration in ways that increase health and resiliency.
- **Conduct Research.** Use research to develop and evaluate new practices (e.g., thin layer placement, living shorelines) and ecosystem service valuation to inform/improve restoration and management while considering climate change effects.
- **Apply RSMP recommendations.** Implement key RSMP recommendations (e.g., beneficial use of sediment).
- **Protect and restore tidal wetlands' natural buffers.** Work with partners to identify areas where tidal wetlands will migrate and help develop a plan to conserve these areas to allow natural migration
- **Promote water quality improvements.** Continue to promote and develop new strategies to improve water quality using shellfish (e.g., oysters, ribbed mussels, freshwater mussels).

Changes in climate likely will bring the Estuary warmer summers and winters, rising sea levels, increased storms and droughts, and salinity variations, all of which may disrupt wetlands restoration, enhancement, and management. The strategy to maximize wetland health and resiliency may still be attainable if adjustments are made, but climate change effects may be extensive throughout the watershed, and either are occurring already, or will in the next 10 years. Shifts could occur in community species composition, and flow and salt lines could be altered. An increase in the number of violent storms may harm wetlands, making restoration more difficult. Further, rising sea levels will compromise wetland health and make managing them more difficult.

Performance Measures and Key Deliverables

- Use MACWA data and mapping tools to identify and implement five pilot projects by 2022 to restore or avert the loss of 100 acres in different

tributary watersheds along the Estuary's salinity gradient.

- Produce one research or monitoring report annually to guide successful implementation of nature-based tactics.
- Use research and monitoring to identify ways to increase wetland health and resiliency via practices such as Phragmites, mosquito, hydrology, and buffer management.
- Track restoration, management, research project numbers, and results on tidal wetlands.

Costs and Funding

- **Estimated Cost Range:** $$$ - $$$$
- **Possible Funding Sources:** Environmental Protection Agency Regional Applied Research Effort grants, U.S. Army Corps of Engineers, National Oceanic Atmospheric Administration Office of Response and Restoration, National Fish and Wildlife Foundation, Wetland Program Development Grants, Natural Resources Conservation Service

St. Jones River, Bowers Beach, DE | Credit: Leigh Schuck

Purpose

Increase tidal wetlands' acreage, condition, and resilience through habitat protection, restoration, and enhancement.

Core Partners

Partnership for the Delaware Estuary, States (DE, NJ, PA)

Key Partners

Delaware Nature Society, National Fish and Wildlife Foundation, The Nature Conservancy, United States Fish and Wildlife Service, Local municipalities and Non-Governmental Organization partners

Timeframe

Ongoing

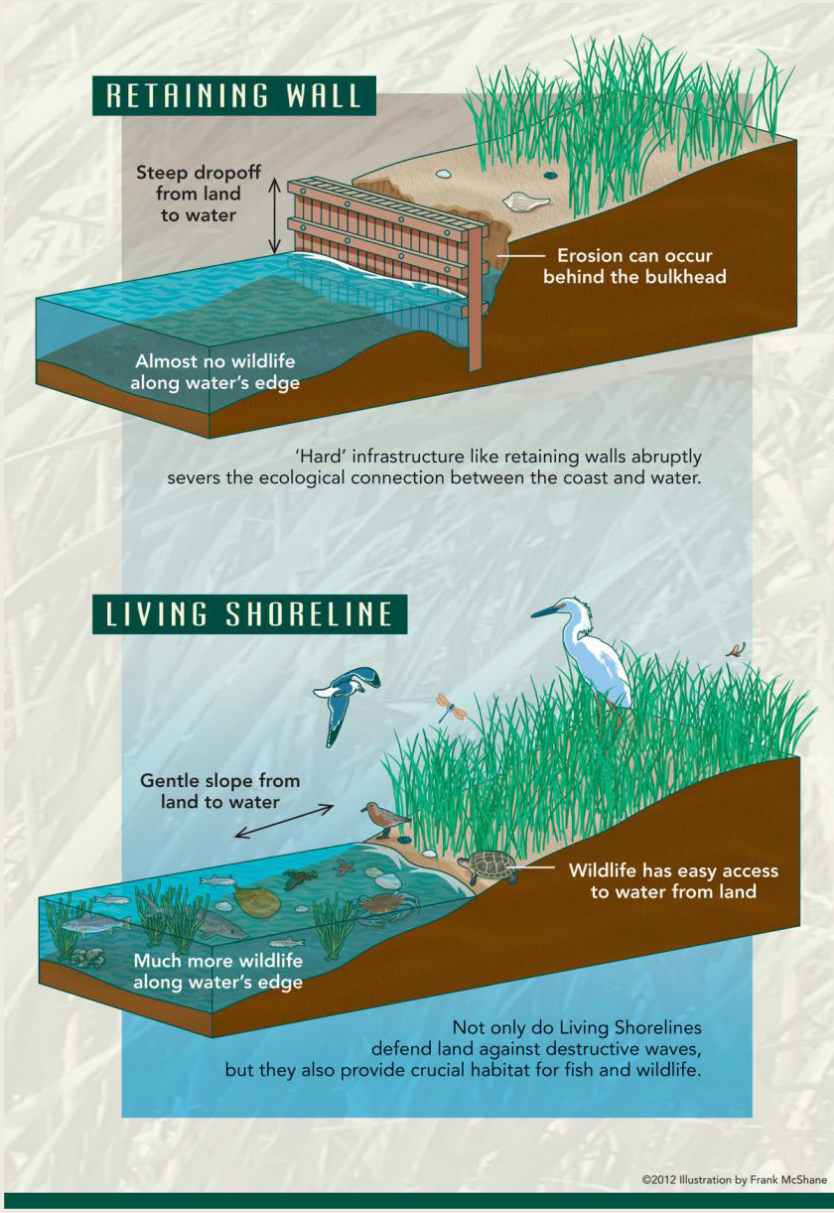
STRATEGY H1.3: Develop and implement natural and nature-based techniques to stabilize and restore eroding shorelines, and to build and protect wetlands, infrastructure, and other key resources

Description

More than 100 acres of tidal wetland in the Delaware Estuary are lost annually,[11] and the future net loss is expected to reach nearly 119,000 acres by 2100[6,8]. Most of the current loss is occurring because of shoreline erosion and increased inundation. Natural and nature-based infrastructure can be used to stabilize and restore eroding wetland shorelines and build and protect wetlands.

Implementation of natural and nature-based infrastructure requires methods to identify site-specific vulnerabilities and match them with appropriate intervention techniques, including living shorelines or thin layer sediment placement (see "beneficial use of sediment" in previous strategy). Tools, such as PDE's Marsh Futures, allow physical and biological data to be integrated over time and space, while programs such as the MACWA serve as relative measures against which site-specific marsh health can be evaluated. Innovative tools and methods like these that key partners are adopting currently will help minimize wetland loss by facilitating the identification and prioritization of intervention needs throughout the Estuary.

Living shorelines include diverse types of shoreline stabilization and enhancement tactics. They differ from traditional approaches, such as use of bulkheads and rip rap, by promoting some stabilization because of healthy ecological communities' resilient properties. Interest in living shoreline approaches has grown rapidly in the past 10 years, and PDE and academic partners, such as Rutgers University, have been at the forefront of this effort by designing and implementing the Delaware Estuary Living Shoreline Initiative (DELSI). This initiative includes efforts to: 1) research and develop new nature-based tactics that are appropriate for the system's unique ecology; 2) develop science-based tools to prioritize areas for treatment and choose the methods that match site-specific goals and ecological conditions; 3) coordinate diverse groups via leadership on technical work groups; 4) promote technology transfer to the private sector; 5) manage



Graphics from PDE's *Living Shorelines: Healthy Shores, Healthy Communities* publication, showing how living shorelines are different from a traditional retaining wall.

projects adaptively using monitoring data both scientists and the public collect, and 6) perform outreach about living shorelines to educate the public, private landowners, and elected officials.

By using natural and nature-based tactics, native plants and animals' ecological benefits also can contribute to water quality and biological diversity. Target species for DELSI projects typically include dominant wetland vegetation and bivalve shellfish. Species selected for use in living shorelines must be appropriate for the specific site, because the Delaware Estuary varies widely in salinity from fresh to saltwater. Shellfish, ranging from freshwater mussels to saltwater oysters and ribbed mussels, usually are paired with vascular plants because scientists consider them ecological engineers that enrich plants, finfish, birds, and other wildlife's habitat quality when abundant.

Interest in nature-based restoration approaches has been growing rapidly throughout the United States, especially with respect to living shorelines approaches. As evidence, the US. Army Corp of Engineers adopted a first-ever Nationwide Living Shoreline permit recently. In the Delaware Estuary, Delaware and New Jersey also have modified their permit rules to accommodate many types of living shoreline approaches more easily. In 2013, the State of Delaware created a Delaware Living Shoreline Committee, which has worked closely with PDE and dozens of other partners to promote awareness, train contractors, assist with permitting, and share scientific outcomes related to living shorelines. Similar collaborative efforts have been coalescing in New Jersey, especially in the wake of Hurricane Sandy, which spurred greater interest in coastal wetlands' protective value.

To help stem wetland loss, natural and nature-based infrastructure will be used to stabilize and restore eroding wetland shorelines and build and protect wetlands through the following key activities:

- **Identify, implement, and use demonstration projects that show natural and nature-based approaches.** Use these sites and experiences to promote local awareness of non-traditional methods of shoreline management among landowners and contractors and provide study opportunities to quantify long-term ecological benefits and maintenance costs. Taking an active role in demonstrating nature-based approaches' effectiveness, such as the numerous ways living shorelines can be used rather than traditional techniques (e.g., bulkheads), is needed to change current thinking and practice, and generate data on costs and effects to show homeowners and contractors alternate options. Ideally, there will be demonstration sites accessible to communities for every major living shoreline type developed, including urban freshwater hybrid designs under development currently.
- **Use new restoration tactics to stem shoreline erosion, including combinations of tactics and large-scale natural and nature-based projects**. Projects could include living shorelines, as well as hybrid approaches that pair innovative, nature-based principles with traditional methods. To date, most projects have been modest in size, but making a significant difference in wetland loss requires expanding these tactics to landscape-scale. A large-scale project's goal is to address shoreline erosion holistically over a larger area, such as the mouth of a river, or an extended stretch of shoreline protecting an important area of habitat or community resources. This could be a single project (such as an offshore living shoreline that extends for a mile or more and protects a contiguous stretch of beach or marsh), or a combination of many projects/tactics designed to work together (such as the combination of approaches that has been proposed to stabilize the mouth of the Maurice River).
- **Develop, apply, and standardize new science-based tools and approaches (e.g., marsh futures, water resources research).** Science-based tools and approaches can be used to prioritize, monitor, and manage tidal wetland restoration projects adaptively, such as living shorelines, thereby promoting greater success and ability to track outcomes. These include monitoring approaches to gauge natural

and nature-based projects' outcomes, as well as decision-making tools to guide the selection of appropriate project sites, tactics, monitoring, and adaptive management based on local vulnerability and conditions. Decisions important to selecting sites and techniques should consider not only the positive effects on tidal wetlands, but also benefits in protecting community infrastructure (e.g., roads and access points) as well as benefits to other important key resources (e.g., fish, shellfish). New tools and approaches also can be shared as they become common practice.

- **Sustain and enhance collaboration. Collaboration** among state and federal agencies, non-profits, academic organizations, restoration practitioners, and regional watershed groups is used to advance science and the use of tools and tactics. Partner collaboration supports efforts to identify and prioritize tidal marshes that require protection or restoration, use science-based tools to choose appropriate tactics that are matched with site-specific ecological needs, and develop managers' decision support tools for regulatory and permitting decisions.

PDE will play a leading role in undertaking these activities in partnership with Rutgers University, the Nature Conservancy, private businesses, and state and federal agencies that manage wetlands and shellfish.

Rising seasonal temperatures, storm frequency and magnitude, salinity, and sea levels across the Estuary are expected to affect natural habitats' health and distribution, especially tidal wetlands. Efforts to facilitate natural and nature-based infrastructure projects will need to account for changes in these environmental factors. Targets chosen should be sustainable, and adaptive management of sites and specific projects will be vital.

Performance Measures and Key Deliverables

- Produce at least one new report, guidance product, or training annually to share research and development of new and innovative nature-based tactics and decision support tools to sustain, enhance, or restore tidal wetlands. Implement 5 new living shoreline projects spanning the salinity gradient over 10 years, including at least one large-scale project.
- Produce one monitoring report annually to assess and translate outcomes from at least one living shoreline project.
- Track the number and results of restoration projects that use nature-based methods such as, but not limited to, living shorelines.

Costs and Funding

- **Estimated Cost Range**: $$$ - $$$$
- **Possible Funding Sources:** State, federal, foundation and corporate grants, (319, Coastal Zone Management, State Revolving Fund, Sea Grant, U.S. Environmental Protection Agency Wetland Program Development Grants, Flying Fish, Geraldine R. Dodge Foundation, Welfare Foundation)

Purpose

To prevent wetland loss and promote ecological resilience through the targeted application of appropriate natural and nature-based infrastructure.

Core Partners

Partnership for the Delaware Estuary, Philadelphia Water Department, States (DE, NJ, PA), United States Environmental Protection Agency

Key Partners

Local municipalities and Non-Governmental Organization partners, National Fish and Wildlife Foundation, National Oceanic and Atmospheric Administration, Rutgers University, The Nature Conservancy, United States Army Corps of Engineers, United States Fish and Wildlife Service

Contributing Partners

Academia

Timeframe

Preventing wetland loss is an on-going priority contingent on resources. Living shoreline projects typically take 2-3 years to implement, with monitoring and periodic maintenance thereafter. At least one project newly completed annually is expected

STRATEGY H1.4: Protect, enhance, and improve non-tidal wetlands

Description

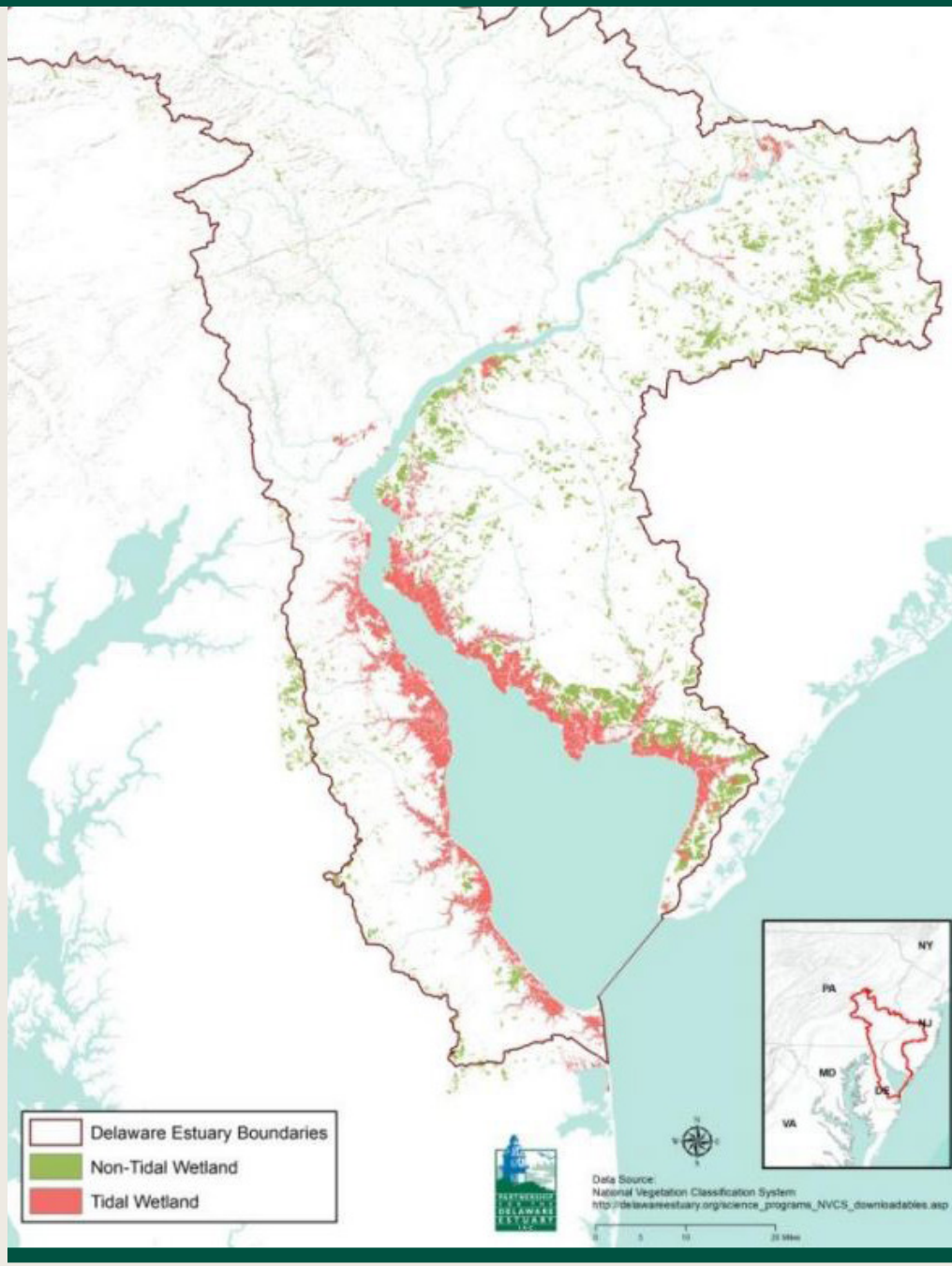
The Delaware Estuary is fed by an extensive network of tributaries that connect the upper reaches of every watershed together to the Delaware River and Bay. Those tributaries are flanked and fed by almost 248,000 acres of non-tidal wetlands which serve as headwater filters, forested habitats, floodplain storage units, and biologically-rich isolated wetlands.[11]

Non-tidal wetlands in the Delaware Estuary continue to face the pressures of direct effects (conversion for agriculture and development) and secondary effects (human encroachment, natural hydrology disruption, contamination from excess nutrients and pollutants, and the effects of rising sea levels and climate change).

This strategy focuses on minimizing non-tidal wetland areas' loss, achieving a net increase in their acreage, and improving their health and function through restoration, enhancement, and targeted management approaches. Wetland mitigation projects required by regulatory agencies and the establishment of wetland banks provide additional mechanisms to restore and enhance wetlands.

Key activities include:

- **Protect high-value wetlands.** These wetlands can be protected through land acquisition, conservation easements, or other methods identified. Use combined mapping resources to prioritize areas for restoration or protection.
- **Use ecosystem service and natural capital values to educate and motivate stewardship.** Acquire more



Tidal and non-tidal wetlands in the Delaware Estuary Focus Area (See Living Shorelines in the Delaware Estuary: Best Practices from Lessons Learned and Information Collected by the Partnership for the Delaware Estuary and the Rutgers Haskin Shellfish Research Laboratory, 2008 – 2012 for more information).

accurate, local, and current valuation figures for non-tidal wetland functions.

- **Support voluntary stewardship.** Promote voluntary stewardship practices that focus on non-tidal wetlands.
- **Provide outreach.** Increase efforts to educate, share information through outreach programs, and transfer technologies.
- **Promote restoration and protection**. Collaborate with other organizations to promote and increase non-tidal wetland and stream restoration and protection.
- **Improve habitat.** Enhance efforts to improve habitats of key indicator species, such as freshwater mussels.
- **Involve stakeholders.** Promote establishment of wetland banks that meet non-tidal wetlands' performance standards and provide ecological uplift by involving local stakeholders and existing state programs.
- **Support stewardship for buffers.** Protect, restore, and promote stewardship of natural or forested buffers adjacent to non-tidal wetlands.

External constraints that may affect the success of this strategy include differing levels of regulatory protection for non-tidal wetlands among the states (DE, NJ, PA) and federal government, which may require different actions/approaches in different places. Funding limitations and federal cutbacks to the programs that support implementation of freshwater wetland protection and restoration also would affect success.

Protecting non-tidal wetlands is still an attainable strategy provided that adjustments are made, but moderate disruptions are anticipated with climate change, including salinity changes and rising sea levels, which likely will result in salt water intrusion and habitat conversion. Further research is needed on climate change's effects on non-tidal wetlands.

Performance Measures and Key Deliverables

- Identify, plan, and prioritize high-value non-tidal wetlands to protect in each state by 2025
- Increase protection and restoration of non-tidal wetlands with at least one successful example in each state annually
- Produce at least one outreach product annually to promote non-tidal wetlands' stewardship, protection, and restoration
- Track number and results of projects for non-tidal wetlands' restoration and protection

Costs and Funding

- **Estimated Cost Range:** $$$
- **Possible Funding Sources:** Federal Farm Bill programs (Wetland Reserve Program)

Purpose

Increase and improve non-tidal wetlands' acreage, health, and ecological functions through habitat protection, targeted restoration, and focused enhancement.

Core Partners

Partnership for the Delaware Estuary, Philadelphia Water Department, States (DE, NJ, PA), United States Environmental Protection Agency

Key Partners

Local municipalities and Non-Governmental Organization partners, National Fish and Wildlife Foundation, National Oceanic and Atmospheric Administration, Rutgers University, The Nature Conservancy, United States Fish and Wildlife Service, United States Army Corps of Engineers

Contributing Partners

Academia

Timeframe

Ongoing

HEALTHY HABITATS GOAL 2:

STEM FOREST LOSS

Natural lands, particularly forests and wetlands, provide benefits that developed lands typically do not. Most notably, they absorb and filter more water and support more wildlife than do developed lands. When forested lands in the Delaware River Basin are converted to lawns, buildings, and paved areas, many of these benefits are lost, which affects water quality and habitats downstream and in the Estuary adversely. Large blocks of forested areas also provide unique coastal habitats critical to the species that call it home. The Delaware Estuary is notable as a migratory bird stopover. Birds moving south during the fall rely on the coastal habitats, particularly forested habitat, for

Green Lane, PA. | Credit: Carol Tersine

food and shelter while they rest and recover before continuing their migration south.

At the time of colonization, the Delaware River Basin largely was forested, with extensive wetlands areas. With the influx of colonists and the onset of the Industrial Revolution, the watershed underwent rapid changes. Many of these changes resulted in a vast reduction of forests and wetlands, which were cleared by lumbering or converted for housing, farming, and commercial development for the increasing population. Based on 2010 data, forests constitute 48% of the Basin's land area and play an important role in the water supply and quality for streams, wetlands, and people.[11] Forests also produce clean air, absorb rainfall, inhibit erosion, and provide food and habitat for wildlife. In urban areas, forests reduce extreme heat from roads and other paved surfaces, and can provide valuable wood products.

Between 1996 and 2010, forest cover in the Basin declined by nearly 51 square miles.[11] Conversion of natural land for development for a growing population largely was responsible for this forest loss. Based on past growth, the Basin's population is projected to grow from 8.3 million in 2015 to 9 million by 2030. Meeting this growing population's needs will lead to continued forest loss unless forested lands are protected and forest conservation and management practices are used. Fortunately, the watershed contains a significant amount of forested land. However, losing forests faster than they can be restored or protected will have negative consequences for habitat and water quality in the future. Thus, sustaining forests in the Upper Basin is critical to sustain the quality and quantity of fresh water that reaches the Estuary and drinking water for millions of people, which has led the DELEP to make forest preservation a Basin-wide priority.

HOW WE WILL MEASURE SUCCESS:

- Improve access to information about the Estuary
- Improve the engagement of citizen scientists, stewards, and key stakeholders

Bombay Hook National Wildlife Refuge, Smyrna, DE. | Credit: Kim Cahill

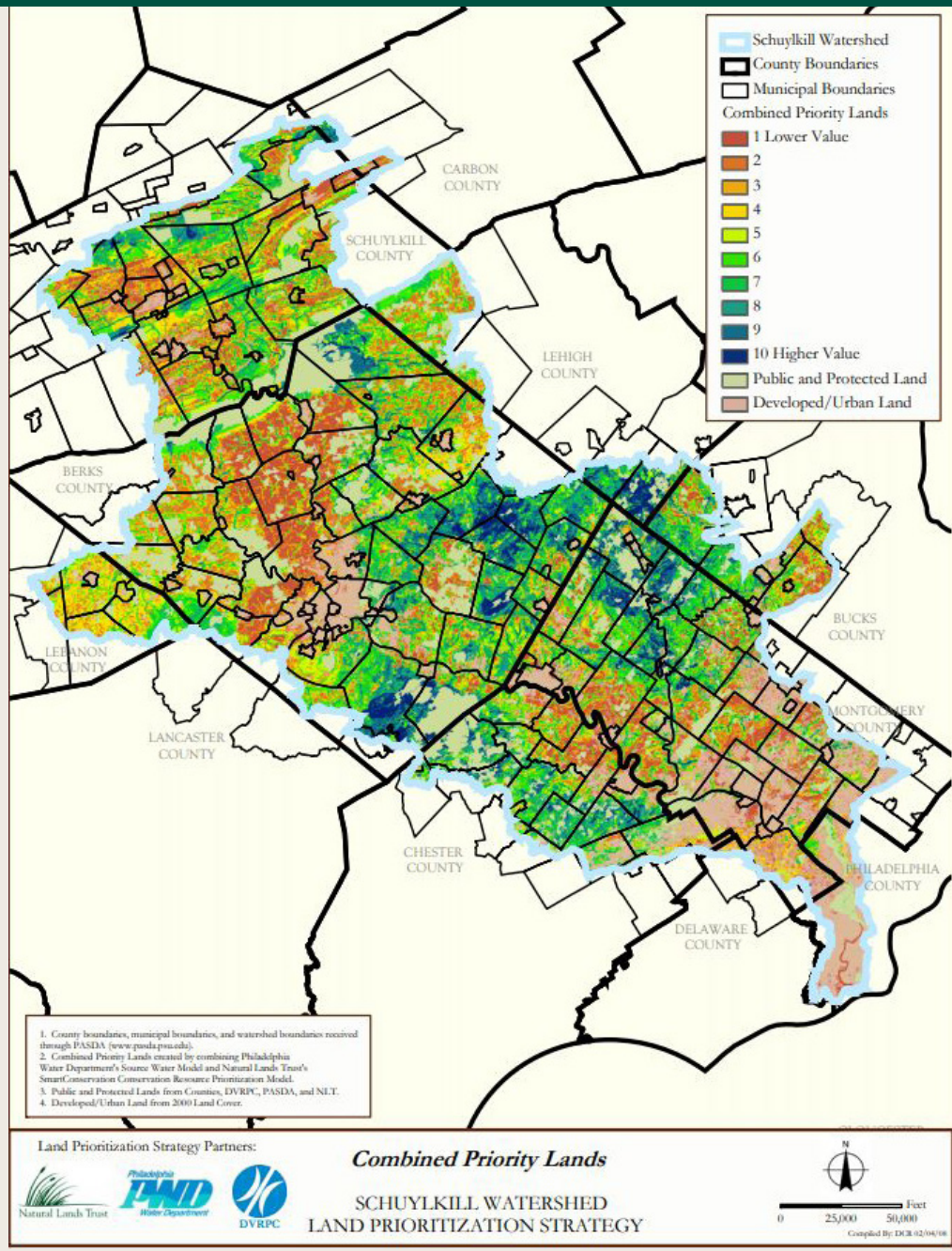
STRATEGY H2.1: Inventory, map, and increase connectivity and resilience of forests for water quality

Description

The Delaware River Basin includes over 6,000 square miles of forest, as well as many forest landowners, and limited resources for forest protection and stewardship. These forests are critical to sustain water quality in the Delaware River and Bay, and thus, assessing and establishing priorities is essential. This is especially true for a NEP, which recognizes the value of forests in the upper Delaware River Basin, but traditionally has worked primarily in the lower Basin. Through State of the Estuary tracking and reporting, there is sufficient basin-wide information on forest cover, but little about the conditions needed to prioritize forests for resilience, connectivity, and water resource protection.

The first and most critical element of this strategy is establishing a clear baseline by cataloging forests' current conditions in the Delaware Estuary's watershed (the Delaware River Basin) using existing data and researchers and practitioners' input. The exact methodology to accomplish this has yet to be determined; however, potential options are identified below. In addition to identifying the extent and location of forest cover, this baseline will define and measure:

- **Forest Health.** Numerous stressors, including high deer populations, invasive plants, insect pests, and climate change, affect forests within the Basin. This criterion will assess cumulative effects and identify forests suffering little to no degradation to prioritize them for protection.
- **Forest Loss.** Forests face an imminent threat from land conversion, primarily through residential and commercial development, which has accelerated in recent years as the economy improves. This criterion will assess development patterns and ideally identify forests under greatest threat of conversion.



The Schuylkill Priority Lands tool identified and mapped the highest priority lands to protect for water quality, most of which are forested. | Credit: SAN

- **Resilience/Connectivity.** Forests and their wildlife residents benefit if they are connected to facilitate plant and animal migration. This criterion will evaluate forests' proximity to each other and ideally identify those with the greatest value for connectivity.
- **Water Resource Protection.** Forests provide multiple water quality and quantity benefits. This criterion will assess forests' ability to perform functions, including infiltration, and highlight high-value forests for water resource protection.

Key actions and activities to implement this strategy will include acquiring public information on current forest cover in the Basin, developing and implementing a weighting system for the criterion above, mapping the results, and seeking researchers and practitioners' input at key stages to test and refine results. Forest health is assessed best on an individual property basis, making this difficult to perform remotely on a large scale. However, this problem might be solved by surveying a select number of sites and extrapolating to a larger area, or using four-color aerial imagery (or other new technology) to analyze key characteristics.

These activities could be undertaken through a collaboration of partners, or one partner or professional engaged as a contractor. The PDE will take the lead to explore these implementation options and work with the partners. Fortunately, there are a number of efforts underway currently in and around the watershed that can inform this work. Some potentially helpful resources include:

- ▷ New one-meter resolution land cover data Shippensburg University and the University of Vermont are generating that could be compared to older land cover data to analyze forest loss
- ▷ New research on forest resilience by the OSI, The Nature Conservancy, National Wildlife Federation, and the U.S. Department of Agriculture (USDA)
- ▷ Data the Academy of Natural Sciences and OSI generate/use to fulfill their respective roles in the Delaware River Watershed Initiative
- ▷ Data from other areas/agencies, such as the Chesapeake Conservancy's Innovation Center and conservation data from NASA
- ▷ Prioritization methodologies used in subset areas of the Basin, such as the Hopewell Big Wood Partnership, the SAN Priority Lands, Pinchot Institute for Conservation & Common Waters Partnership, and the DRWI clusters

The United States Geological Survey National Geospatial Program is the Federal Steward for the National Hydrography Dataset (NHD) and the Watershed Boundary Dataset (WBD), and is working on Quality Level 2 digital elevation models derived from lidar in conjunction with the NHD and WBD for updated land cover mapping

Another approach that should be considered is using existing information to assess tipping points for forest losses. The Center for Watershed Protection makes information available on thresholds that indicate when a watershed begins to deteriorate based on a given area's impervious coverage. OSI also provides information for sub-watersheds in the Delaware River Basin (impervious cover rates, number of protected acres, type of land). By combining the OSI model and the Center for Watershed Protection's impervious cover model as a baseline, areas approaching a tipping point for water quality could be identified and designated as high-priority areas.

The watershed is home to a number of conservation organizations with long histories and rich experience in forest protection and stewardship, many of which are involved in the efforts above. Each of these organizations offers potential information and/or partnerships that can be explored and used to implement this strategy. In the meantime, a variety of resources can be promoted and used to prioritize forested areas,

including PDE's Regional Restoration Initiative and The Nature Conservancy's DRBC Initiative, both of which highlight forested riparian areas' importance (See the Regional Restoration Initiative Blueprint Report and the Delaware River Basin Conservation Initiative, respectively, for more information).

Once a baseline is established successfully, it will be used to shape next-generation strategies to improve condition-related effects, including connectivity, resilience, and contribution to water resources protection. The major external constraints that could affect this strategy's success are the quality and comparability of public information over the extensive geography, and PDE's limited capacity to expand its geography and expertise. To address this constraint, this strategy's geography should be limited to those areas where data and partners are sufficient for successful implementation, at least in the short-term. Climate change's effects could make forest health data obsolete eventually, depending on the current dominant species' vulnerability, and should be considered when identifying priorities for resilience.

Performance Measures & Key Deliverables

- Inventory baseline forest acreage and conditions for water quality.
- Identify strategies and begin measuring connectivity between forest patches compared to baselines.
- Assess likely changes from baseline in forest acreage and conditions attributable to climate change and other factors, and furnish recommendations to increase resiliency .
- Track baseline products and projects for forests.

Costs and Funding

- **Estimated Cost Range:** $
- **Possible Funding Sources:** State and foundation grants (Pennsylvania Department of Conservation and Natural Resources, New Jersey Department of Environmental Protection, William Penn Foundation), Federal Farm Bill programs (Conservation Reserve Enhancement Program)

Purpose

Establishing clear baselines will inform decisions on the allocation of forest protection and stewardship resources, including grant funding and organizational priorities.

Core Partners

Partnership for the Delaware Estuary, States (DE, NJ, PA)

Key Partners

Delaware River Watershed Initiative partners, Schuylkill Action Network, United States Department of Agriculture - Forest Service, United States Fish and Wildlife Service

Contributing Partners

Academia, Pinchot Institute for Conservation & Common Waters Partnership, National Oceanic and Atmospheric Administration, United States Army Corps of Engineers, United States Geological Survey National Geospatial Program

Timeframe

With sufficient resources, the process of establishing a baseline could be accomplished in a year or two. However, building the support and partnerships needed, and using results to inform next-generation strategies will require additional time, making this likely to be a 5+ year project, assuming sufficient resources

STRATEGY H2.2: Promote stewardship practices by local partners for the health and sustainability of forests for water quality

Description

Actions to improve existing forests' health and resilience are critical to prevent future losses and maximize the values they provide, particularly for water quality. Important forests include those along riparian areas, in headwaters, and in contiguous blocks. Forests today are threatened not only by fragmentation and conversion to other land uses (e.g., agriculture, development), but by invasive pests and plants, deer overabundance, lack of regeneration, storm damage, and climate change. Past timber harvesting practices have left some forests degraded and of little economic value. Stands of forest that contain only one type of tree are more vulnerable to disturbances that diminish their ecological function further, but still provide other natural benefits.

Green Lane Reservoir riparian buffer planting in Montgomery County, PA. | Credit: SAN

Intervention may be necessary, even on protected lands, to help diversify the age and species present in forest tracts, or encourage regeneration where forest cover is inadequate. Improving riparian forests' connectivity and health is particularly important because of the direct role they play in supporting water quality and regulating flows. Baseflows during summer and drought periods are of particular concern in the Basin, and forest management should be investigated as a strategy to increase groundwater recharge.

The majority of forestland in the Basin's headwaters areas is owned privately, but the largest tracts of intact forests are under public ownership and management. The fragmentation of ownership makes it more difficult to achieve watershed- or landscape-scale goals. Accordingly, tracking progress on this goal, as well as partnering with state and federal agencies, is critical in implementing this strategy.

Specific activities include:

- **Promote forest stewardship and management by adopting and implementing forest stewardship/management plans.** To improve forest health, plans can include actions such as thinning, timber stand improvement, invasive species removal, deer fencing or control, pest control, planting, and erosion control on forest roads/trails, etc. Plans also can include strategic reforestation in priority areas, and integrating climate adaptation strategies/recommendations into management activities, which also helps improve professionals' knowledge base.
- **Promote, develop, and implement riparian corridor management plans.** Riparian corridor management plans can include buffer planting, vegetation management, and fencing to protect and improve stream corridors and adjacent floodplains and wetlands. Plans also can include restoring streambank and stream habitat to restore natural functions in priority areas, and restoring forested floodplains' connectivity and functionality.
- **Encourage and support research.** Research can be used to develop new tactics to increase forest resilience and optimize provision of ecosystem services, including water filtration/infiltration to support adequate baseflows and mitigate heavy precipitation events, especially through the lens of climate change.
- **Support continued funding, use, and targeted expansion of cost-share and incentive programs.** Current examples of cost-share and incentive programs include those available through the USDA Farm Bill, NRCS Environmental Quality Incentives Program, Conservation Stewardship Program, Conservation Reserve Enhancement Program, etc.), and state farmland and forest assessment and tax relief programs. Both conducting outreach to help people learn about and use these existing programs to complete projects, and exploring opportunities to create new incentives are important.
- **Work with partners such as NRCS and USFWS to restore and enhance forested habitat.** Two programs in the USFWS could help restore and enhance forests: The Partners for Fish and Wildlife Program focuses on private land, and the USFWS Coastal Program focuses on the coastal areas, both private and public.

Through their Forestry and other land-holding agencies or divisions, the states (DE, NJ, PA), are primary implementers of this strategy because of their direct ownership and management of forested lands and programs to provide technical assistance to forest landowners. Federal programs through the USDA and USFWS that provide financial support and/or technical assistance to forested land owners support these activities as well. Actions that PDE and other organizations can take to support this strategy include promoting the importance of these state, federal, and local programs and efforts, providing opportunities for collaboration, sharing information and lessons learned across entities, and researching ways to track progress to tell the story of the Estuary's recovery.

Changing trends in land use and the housing market are external constraints with uncertain effects on stewardship and owners' ability/desire to maintain forested lands. Climate change is another external factor that would affect stewardship. Warming temperatures and changing rain patterns could impose stress on native species to the benefit of invasive species, making management to improve forest health even more challenging. Forests also play an important role in helping communities adapt to changes, such as rising temperatures and greater volumes of stormwater. Adapting stewardship practices to changing conditions and new science and needs will be important, yet challenging.

Performance Measures and Key Deliverables

- Increase the number of forest landowners and acres in stewardship management plans and restoration activities.
- Maintain/increase funding for forest cost-share and incentive programs.
- Track number and results of forest restoration, management, and research projects.

Costs and Funding

- **Estimated Cost Range:** $$$$
- **Possible Funding Sources:** State forestry program budgets, foundation grants (National Fish and Wildlife Foundation, William Penn Foundation)

Leipsic, DE | Credit: Vincent Fiorelli

Purpose

Increase the amount of forestland under stewardship and active forest management to help maintain existing water quality, regulate stream flows, and strengthen resilience.

Core Partners

Partnership for the Delaware Estuary, States (DE, NJ, PA)

Key Partners

Delaware River Watershed Initiative partners, United States Department of Agriculture - Forest Service and Natural Resource Conservation Service, United States Fish and Wildlife Service

Contributing Partners

Pinchot Institute for Conservation and Common Waters Partnership, National Association of State Foresters, Penn State University Center for Private Forests, forest land owners

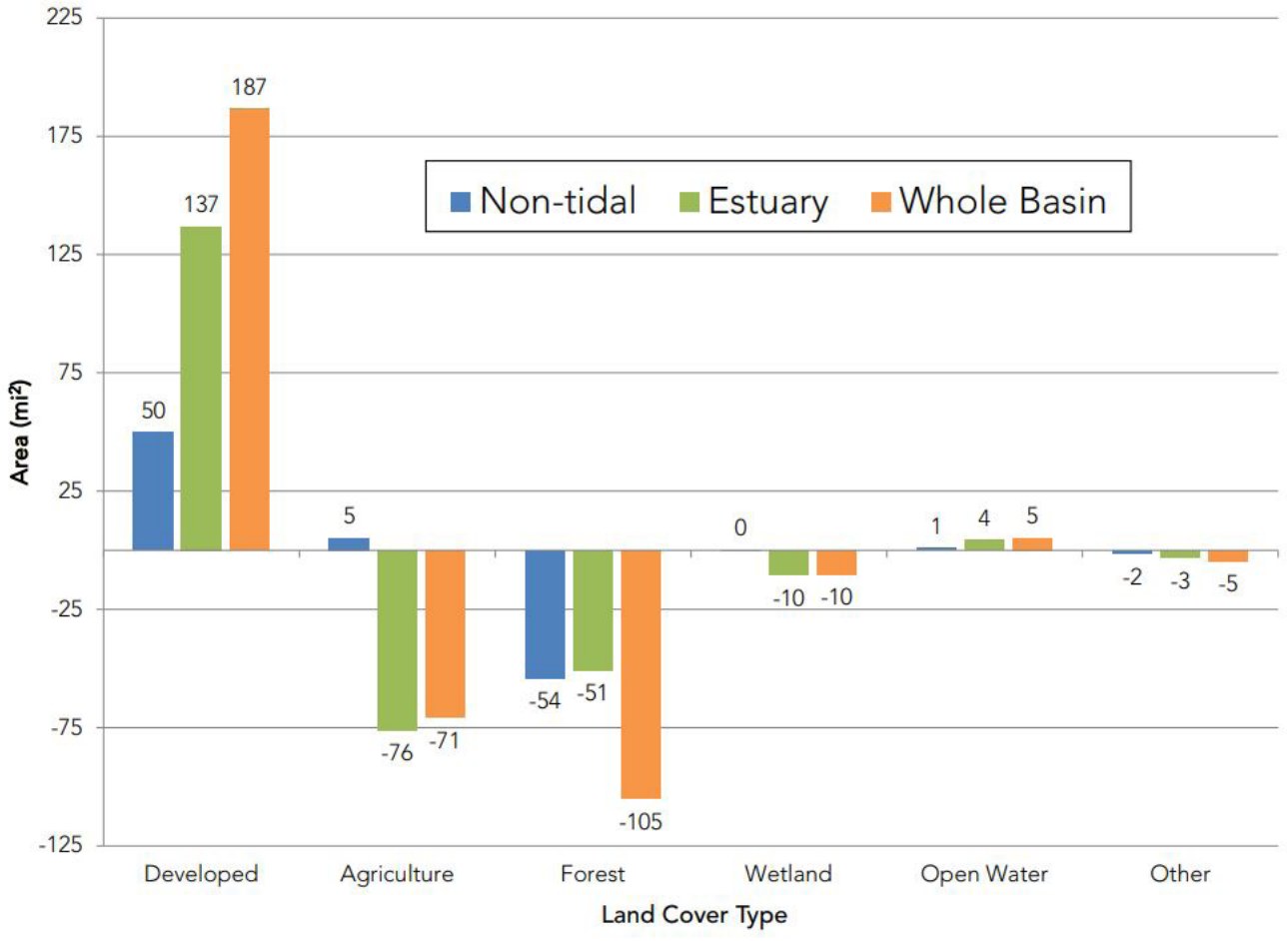
Timeframe

Ongoing

STRATEGY H2.3: Protect and manage high-value and threatened forests for water quality

Description

Maintaining forested land in the Delaware River Basin through protection and/or sound management is critical to maintain the quantity and quality of water flowing into the Delaware Estuary. Thus, increasing the amount of protected forestland in the Delaware River Basin, and ensuring that protection efforts focus on forests that provide significant water quality and quantity benefits is critical. Forest land cover dominates the upper and central regions of the Delaware River watershed, while the lower and bay regions have higher percentages of agricultural, developed, and wetland land cover. Protecting forests within and along key tributaries to the Estuary, including the Schuylkill, Maurice, Brandywine, and main stem Delaware River, is critical to the Estuary's health overall.



This graph from the 2017 TREB shows the change in land cover type in different parts of the Delaware River Basin between 1996 and 2010, showing that Forest is the land cover type with the greatest acreage lost (See TREB 2017 Chapter 1, Section 1.3 Land Cover Change for more information).

To ensure that protection efforts are maximized for their benefits to the Estuary, this strategy focuses on increasing high-value forests' protection for water filtration and that of large unfragmented forested areas, particularly those at high risk for conversion. Studies have shown that forested headwaters, floodplains, and areas along streams and rivers are among the most important to protect surface water quality, while for coastal habitats and cost effectiveness, protecting large and/or threatened forested patches are among the most important. In some areas of the watershed, newer and/or more specific studies and prioritization models can provide additional guidance, and should be used as they become available.

To slow the rate of forest conversion and increase the amount of forestland protected, a comprehensive set of activities is needed, including:

- **Promoting increased land acquisition and stewardship.** Nearly 15% of the land area of the Basin is protected through conservation easement or ownership, and a variety of organizations and agencies protect and manage forested land for conservation purposes. All three states in the basin (DE, NJ, PA) have active land protection programs that include forest protection among their priorities and resources for conservation easement or fee acquisition. All three states also have agencies that hold and manage forested lands for conservation and recreation purposes. Further, the Basin has a host of very successful private land trusts that protect, own, and manage forested lands. Continuation and expansion of these efforts with a focus on priority forested lands is critical.
- **Provide education and outreach on forests.** While government entities own most of the forested lands in the Basin, there are still numerous large parcels owned and/or managed privately. These include lands individuals, farmers, companies, and recreational clubs own that potentially are subject to conversion to other non-forested uses. Education and outreach to these landowners to increase awareness of forests' value and options for permanent protection will help minimize conversion over time. Education and outreach to local municipalities on forests, land use planning, and municipal land protection and stewardship's value also will help minimize conversion over time.
- **Explore and develop economic incentives.** Protecting land permanently is expensive. Economic incentives, such as tax incentives for the permanent protection of forestland, can help ease this financial burden and accelerate protection and hence, they should be developed and/or supported. Land protection funding programs often do not cover various miscellaneous costs associated with permanent land protection (e.g., surveys, legal costs), so finding ways to provide even a small amount of support for these costs can create a meaningful incentive. Partners have efforts underway to explore opportunities to use carbon markets and/or state-wide initiatives for tax benefits as incentives for forest land protection that should be encouraged/supported.
- **Address and protect smaller parcels of forested areas that belong to private landowners.** It is necessary to protect private landowners' forested areas to address fragmentation and aging landowner challenges. Partners have efforts underway to test methods to motivate these landowners to think of conservation routinely before selling their conservation lands that should be encouraged and promoted.

The states (DE, NJ, PA) and conservation program partners implement this strategy primarily, because of their programs, expertise, and funding capacity. Federal programs, such as the Land and Water Conservation Fund, USDA Forest Legacy Program, the Highlands Conservation Act, the North American Wetlands Conservation Act, and work by the Federal Emergency Management Agency (FEMA) and state floodplain management offices on forested floodplain and buffer protection also support and/or supplement state (and private) activities. Further, local municipalities and conservation districts play key roles by providing information and technical assistance to landowners. Actions the PDE and others can take to support this strategy include promoting the importance of these state, federal, and local land protection programs and efforts and their continued/expanded funding; providing opportunities to collaborate and share information and lessons learned, and researching ways to track progress to tell the story of the Estuary's recovery. The DELEP potentially would collaborate with partners involved in the DRWI.

If development trends in the Delaware River Basin increase to pre-2008 levels, we can expect to see increased conversion of critical forestlands and an increase in the cost of land per acre, which will make protection efforts more challenging and expensive. Further, there is mixed support

for preserving forests in rural areas that can create constraints; perceptions often cited are about lands being removed from tax rolls and losing land use control if lands are preserved permanently. Creating, supporting, and promoting programs that help offset these effects could help address these constraints. Climate change will affect forests in a variety of ways, including potentially changing the mix of forests' species and their vulnerability to pests and invasive species. Accordingly, protection priorities should be reevaluated periodically to adapt to these changes.

Performance Measures and Key Deliverables

- Place an additional 50,000 acres of forests under permanent protection by 2025 with examples that preserve or enhance forest connectivity in each state.
- Develop new partnerships to encourage economic incentives and opportunities for forest stewardship for landowners.
- Track number and results of landowner outreach forest protection projects.

Costs and Funding

- **Estimated Cost Range:** $$$$$$
- **Possible Funding Sources:** Federal grants (Land and Water Conservation Fund, Forest Legacy), municipal open space funding, private foundations and land trusts

Bombay Hook National Wildlife Refuge, Smyrna | Credit: Norma Worley

Purpose

To maintain water quality and quantity in the Delaware Estuary through forestlands protection.

Core Partners

Partnership for the Delaware Estuary, States (DE, NJ, PA)

Key Partners

Delaware River Watershed Initiative partners, Non-Governmental Organization land trust community, United States Department of Agriculture - Forest Service and Natural Resource Conservation Service, United States Fish and Wildlife Service

Contributing Partners

Forest landowners

Timeframe

10 years

HEALTHY HABITATS GOAL 3:

INCREASE AND IMPROVE FISH AND SHELLFISH HABITAT

The Delaware Estuary is home to a host of fish, shellfish, and other wildlife, including some that are important for clean waters and strong communities. Some species, such as oysters and mussels, grow into reef habitats that are vital for other organisms, and also filter vast quantities of water for food, a process that helps clean the water. Key shellfish species include oysters and ribbed mussels in the Bay, and beds of freshwater mussels in rivers, streams, and ponds. The horseshoe

Intertidal oyster beds at the Mispillion Harbor in Milford, DE. | Credit: PDE

crab is another ecologically significant species that is an important bottom feeder and helps many bird species by laying its eggs on beaches. Horseshoe crab eggs feed millions of shorebirds that stop in the Delaware Bay in their annual migration. Iconic fish, including sturgeon and shad, once fed the people and economy of the New World, and required healthy estuary waters to live and spawn. Thus, robust populations of these fish and shellfish signify a healthy Delaware Estuary.

Most ecologically significant fish and shellfish species in the Delaware Estuary have a rich and event-filled history. For example, oysters are sensitive to water pollution and salinity, and their populations have declined dramatically since the 1950s because of the introduction of foreign diseases that do not affect humans, but are lethal to oysters. Today, oyster populations have rebounded to some extent thanks to sound management, sustainable fishing practices, development of some disease resistance, and restoration investments such as shell planting. At the same time, current populations of freshwater mussels are depressed significantly. In fact, freshwater mussels are now the most imperiled group of animals locally and nationally because of dams, degraded water quality, and other factors. Many groups are now working together to protect the most endangered species, and restore their range and abundance. Ribbed mussels are another key bivalve that is most abundant in coastal marshes around the Delaware Bay, where they help strengthen the edge of the marsh and filter large amounts of pollutants. However, ribbed mussels face a different challenge—their habitat is washing away because of erosion.

Although Delaware Bay is home to the largest breeding population of horseshoe crabs in the world, they have been over-harvested at times in the past for use as fertilizer, tools, and fish bait, and past declines in the horseshoe crab population have corresponded with declines in shorebird populations. Today, the Bay's horseshoe crab population appears to be stable and likely to rebound further thanks to harvest restrictions, but still remains low compared to historic levels.

Similar to oysters and horseshoe crabs, shad and sturgeon supported robust fisheries historically, but populations in the Delaware Estuary plummeted because of pollution and over-harvesting. A 1998 moratorium on Atlantic sturgeon fishing did not increase the population, and thus, they were listed as an endangered species in 2012. In 2016, The National Marine Fisheries Service issued designations of critical habitat protections for the Atlantic sturgeon to help increase population levels.

Despite past declines, water quality has improved dramatically in recent decades, together with dam removals and other habitat investments, which appear to be helping many of these fish and shellfish begin to recover. For example, several fish species are beginning to reproduce again in the urban Delaware Estuary. As a result of dam removal projects, shad now can migrate to many historic streams that were blocked previously. Planting shells in Delaware Bay to provide settlement surfaces for larval oysters has helped stem the loss of historic fishing reefs. Although Hurricane Sandy decimated some of the most important horseshoe crab spawning beaches around Delaware Bay, the restoration community's rapid restoration effort helped reverse those declines. The periodic presence of juvenile Atlantic sturgeon and reproduction on the part of some native mussel species within the urban corridor of the Delaware River suggest that dwindling populations of even those species have the potential to be restored with continued assistance.

Fish and shellfish provide diverse social, economic, and ecological benefits, and a healthy Delaware Estuary depends on their well-being and abundance. The current status of most of these species is considerably depressed compared to historic conditions, but careful management and restoration efforts have helped stem their declines, and in some cases, have begun to rebuild the stocks. This demonstrates that environmental investments are effective and lead to quantifiable improvements. Continued investments will be needed, especially considering the emerging constraints that are discussed for each strategy below.

HOW WE WILL MEASURE SUCCESS:

- Improve shellfish habitat and abundance and oyster productivity
- Improve habitat for fish and crabs
- Increase and improve fish/shellfish restoration projects

Bombay Hook National Wildlife Refuge, Smyrna | Credit: Benjamin Andersen

STRATEGY H3.1: Inventory, map, protect, and enhance habitat critical for fish and crabs

Description

The Delaware Estuary consists of many different types of aquatic habitats that support fish and crabs, ranging from small headwater streams to large rivers, tidal tributaries, and the open Delaware Bay. Bottom conditions vary from rocky riffles to sandy and muddy areas. Diverse fish and crab species often depend on specific bottom features, and are more abundant and healthier in some areas compared to others. For example, blue crabs are abundant in tidal habitats containing submerged grasses, while horseshoe crabs require unimpeded access to sandy beaches to lay their eggs. Atlantic sturgeon need oxygen-rich hard bottoms to lay their eggs. Many other fish depend on tidal marshes or structurally complex reef habitats either to forage or reproduce. In addition, many fish need to move into different habitats at different life stages, and dams and culverts, for example, impair connectivity between habitats frequently.

Understanding and mapping these critical habitats is important so that these benthic (bottom) areas can be protected and restored. Pairing these maps with climate change and watershed development forecasts guides efforts to enhance fish and crab populations' health in strategic places, thus providing optimal use of precious restoration resources.

Major components of this strategy include:

- **Assess benthic habitat throughout the Estuary.** Benthic organisms often are surveyed to assess bottom habitats' ecological health because their abundance and species diversity varies between degraded and undisturbed sites. Benthic surveys also examine physical conditions and detect the presence of unhealthy chemical compounds. A benthic survey of more than 230 locations was conducted in the Delaware Estuary in 2008, and augmented earlier studies since the 1950s. Acoustic surveys also have helped map benthic habitat types in some regions. However, some gaps in coverage of past benthic and acoustic surveys still need to be addressed. To track changes in conditions, these surveys also should be repeated at 5- to 10-year intervals. Integration and

Dam removal on White Clay Creek in Newark, DE. | Credit: White Clay Watershed Association

cross-comparison of historic and recent benthic survey datasets also are needed. New technology should help reduce costs and increase coverage for future benthic habitat assessments. The EPA currently is funding a RARE project that involves benthic submerged aquatic vegetation surveys in the Delaware Estuary.

- **Restoring fish passage.** Many fish species need to swim up or downriver to reproduce and complete their life cycle, such as American shad, alewife, American eel, and blueback herring. Dams, culverts, and tidal restrictions impede diadromous fish' passage and resident species' dispersal. Removing impediments to fish is an effective tactic to increase their habitat and boost their population health. The Delaware Estuary has a very high concentration of fish passage impediments, and strategic coordination among management agencies and fish biologists can help prioritize efforts to improve fish passage. Most blockages are in feeder tributaries to the Estuary. Partners, including American Rivers and NOAA, could help secure funding for these projects.
- **Supporting shad propagation.** American and hickory shad are anadromous species native to the Basin and are popular sport fish. Historic shad-spawning ground has been lost because tributaries to the Delaware, including the Lehigh and Schuylkill Rivers, have been dammed. Funding is needed to continue monitoring shad populations and enhance them through protection of spawning habitat and fish passage. Support for shad propagation and restocking also would expedite recolonization to historic tributaries once fish passage is restored. The PWD and the Pennsylvania Fish & Boat Commission have efforts underway to develop a shad hatchery, which will improve shad propagation greatly.
- **Creating and sustaining reef habitats.** Complex bottom habitats, such as reefs of oysters and sabellid worms, are important fish habitat. Therefore, investments in natural and artificial reefs and research on successful designs can increase and improve many fish and shellfish species' habitats. These habitats also support a diverse reef community, including reef fish (e.g., sea bass, spadefish). DNREC started an artificial reef building program in 1995 that should be sustained and/or expanded. Recycling oyster and other shells also is needed to restore reefs, as placement of clean shells promotes fastest recruitment of reef organisms, such as oysters, and the lack of availability of clean shells has hampered reef restoration (See Strategy H3.2 for more information on current oyster shell recycling projects).
- **Promoting research on spawning and nursery areas for fish, including sturgeon.** In 2012, the National Marine Fisheries Service declared Atlantic sturgeon in the New York Bight region (includes the Delaware Estuary) an endangered population. NOAA Fisheries also has designated the Delaware River, including the full bank width of the main stem river within the upriver and downriver boundaries, as critical habitat for the Atlantic sturgeon. Atlantic sturgeon spawning does not occur annually, and there is concern that suboptimal dissolved oxygen levels in the summer could be affecting sturgeon larvae's survival. More research is needed to identify and improve ecologically significant fish species, such as Atlantic sturgeon's, habitat and water quality requirements. The timing of disturbance activities (e.g., dredging, shipping) should continue to be adjusted to avoid impacts to spawning and from ship strikes.

Different organizations and agencies play leading roles in each of these efforts. State and federal wildlife agencies and fisheries management agencies are taking the lead to identify and take actions to improve habitat for sturgeon and other fish. State fisheries management agencies in Delaware and New Jersey have taken the lead in acoustic surveys and creating and sustaining reef habitat. Both the Pennsylvania Fish & Boat Commission and PWD have played leading roles in fish passage

and shad propagation, and work with a variety of other partners, including American Rivers and the University of Delaware. PDE played a significant role in benthic habitat assessment working with the University of Delaware, the DRBC, and the EPA. To maximize fish and crab populations' habitat improvements, these and other partners will continue to coordinate and share information about surveys, monitoring, research, and restoration activities via the biennial Delaware Estuary Science and Environmental Summit, workshops, technical and management workgroups, and online media. Because many fish and shellfish species are vulnerable to rising temperature, storminess, sea level, and salinity, investments in critical fish and crab habitat should be strategic in considering future sustainability.

Climate change and the watershed's continued development could have large effects on this strategy that could include, but are not limited to, an increase in storminess that could degrade or destroy sensitive fish and crab habitats directly, such as beds of submerged vegetation, tidal marshes, horseshoe crabs' spawning beaches, or nearshore reefs. Warmer water holds less dissolved oxygen, which could constrain access to key habitats at critical times, such as happened in the urbanized portion of the Delaware Estuary in earlier decades. Fish and crab species that are adapted uniquely to freshwater tidal conditions likely will have less habitat because of increasing salinity associated with rising sea levels. However, rising sea levels and decreasing winter temperatures could expand certain fish and crab species' habitat niches and growing seasons. Indirect effects, such as the changing availability of prey organisms or water quality, also could constrain biological fish and crab habitats, such as oyster reefs and submerged grass beds.

Performance Measures and Key Deliverables

- Complete a baseline benthic map of vegetated and hard-bottom reef habitats throughout the tidal Estuary and develop a strategy to update benthic maps periodically.
- Make progress in restoring fish passage by alleviating at least one obstruction per state.
- Develop a sustained propagation and restocking program for shad.
- Track the number and results of restoration, enhancement, and mapping projects for fish/crab habitat.

Costs and Funding

- **Estimated Cost Range:** $$$$
- **Possible Funding Source:** Federal, state, private grants (National Fish and Wildlife Foundation, American Rivers)

Purpose

To increase and improve aquatic habitats so they can support healthier and more abundant fish and crabs.

Core Partners

Delaware River Basin Commission, Partnership for the Delaware Estuary, Philadelphia Water Department, States (DE, NJ, PA)

Key Partners

American Rivers, Fisheries management agencies, National Oceanic and Atmospheric Administration, United States Fish and Wildlife Service, University of Delaware Water Resources Center, other Science and Technical Advisory Committee member organizations

Contributing Partners

Atlantic Coastal Fish Habitat Partnership, National Fish and Wildlife Foundation, United States Department of Agriculture

Timeframe

Mapping of critical bottom habitats and sharing results to use in strategic planning to prioritize projects and management actions can be implemented now or in the short-term. A repeat of the 2008 benthic survey also is needed soon. Investments in vital habitats, such as dam removal, is ongoing and contingent on funding.

STRATEGY H3.2: Restore oyster beds and productivity in and around the Delaware Bay

Description

Historically, the eastern oyster's commercial importance has driven efforts to restore oyster beds and productivity within the Delaware Bay. Although oyster populations are well below their historic numbers, the population has been relatively stable recently and harvesting wild oysters is considered a sustainable fishery thanks to proactive shellfish bed management and investments in shell planting.

In addition to their historical and contemporary commercial importance, oysters also are valued highly for their ecological benefits. Oysters are considered "ecological engineers" that increase habitat complexity, stabilize

Aggressive shell planting from 2005 to 2009 by the Delaware Bay Oyster Restoration Task Force brought oyster populations in Delaware Bay back from the brink of collapse and demonstrated a $40 to $1 return on investment of federal dollars based on dockside value. | Credit: PDE

sediments, and help sustain water quality, thus providing many benefits to people and fish and wildlife alike.

Recent advances in oyster aquaculture, living shorelines, shell recycling, and public awareness provide additional opportunities and interest that supports oyster restoration in Delaware Bay. Many partners are involved in this strategy to promote and restore Delaware Bay oysters, ranging from state governments (DE, NJ) to non-governmental organizations. Key activities are presented below with descriptions of their current status and future goals:

- **Support oyster management.** Delaware Bay oysters' current management is achieved through a collaborative effort involving resource managers, academia, and shellfish harvesters. Harvests and restoration planning are guided by monitoring trends in oyster population abundance and demographics carefully. This approach sets Delaware Bay apart from many oyster fisheries, and is the reason that many consider it sustainable. Continuation of this successful oyster management approach, including monitoring, is important to sustain oyster populations. The Rutgers Haskin Shellfish Research Laboratory plays a leading role in managing and studying Delaware Bay oysters and works with the New Jersey Shellfish Council, NJDEP, and DNREC.
- **Promote shell planting.** The planting of cured shells at the right time of the year is a method proven to enhance the natural recruitment of oysters on productive beds greatly. Aggressive shell planting from 2005 through 2009 demonstrated its effectiveness and showed that a $1 investment in shell planting could result in up to a $40 return on dockside value. This cost-effective restoration strategy is credited with saving the oyster industry in Delaware Bay, and currently is performed primarily on a volunteer basis by oystermen using "cultch funds"—the voluntary tax put on oyster harvests to support restoration efforts. More aggressive shell planting is needed and has great potential to enhance both commercial and ecological benefits. Increased shell recycling would help resupply shells on which young oysters grow. The NJDEP and DNREC play leading roles in shell planting, working closely with the industry through the NJ Shellfish Council, and with partners in the Delaware Bay Oyster Restoration Task Force.
- **Support oyster aquaculture's expansion.** To complement wild oyster harvests and meet the growing demand for seafood products, interest in oyster aquaculture has been increasing. When oyster aquaculture operations are situated and scaled appropriately, they have the potential to promote diverse economic and ecological benefits. Unlike some forms of fish aquaculture, farms of bivalves such as oysters may enhance water quality because they are filter-feeders. Although more research is needed, nearshore oyster aquaculture also has the potential to buffer waves and potentially help address shoreline protection needs. Mixed-use conflicts can arise with some forms of oyster aquaculture; however, careful and strategic planning has the potential to resolve temporal and spatial resource conflicts. Where appropriate, oyster aquaculture may be expanded to support local economies, enhance ecological goals, and help alleviate fishing pressure on wild oyster stocks. Oyster aquaculture also helps stabilize the supply of oyster seed needed for other restoration projects, depending on state regulations (DE, NJ). Rutgers, NJDEP, and the NJ Shellfish Council play leading roles in oyster aquaculture in NJ, and there is growing interest in aquaculture in Delaware as well, where DNREC has begun a new program for the Inland Bays.
- **Incorporate oysters into living shorelines.** Living shorelines represent an ecologically beneficial alternative to traditional armoring methods to stabilize shorelines and promote coastal resilience to flooding. Many types of living shorelines, such as new hybrid designs, incorporate oysters and other bivalve shellfish in their designs. Oysters

are particularly useful because they cement together to hard surfaces, which promotes structural integrity, while also benefiting water quality and other fish and wildlife. By expanding oyster populations, these reefs created in the bay perpetuate oysters that potentially serve as broodstock directly. With warming temperatures and reduced winter kill, oyster populations also are expanding their colonization of Delaware Bay's intertidal areas, presenting new opportunities to achieve oyster restoration via living shorelines. PDE plays a leading role in developing living shorelines as a viable restoration option, incorporating and enhancing oysters and working closely with the Rutgers Haskin Shellfish Laboratory, The Nature Conservancy, and state (DE, NJ) and federal agency partners.

- **Provide outreach on oysters.** Oyster outreach efforts promote awareness of both this vital resource's commercial and ecological value. Outreach efforts, such as shell recycling initiatives, vary from in-school lessons and curricula to outreach at local restaurants and markets where oysters are sold. This increased awareness of Delaware Bay oysters' importance helps sustain the interest and support needed for oyster restoration. In particular, shell recycling links oyster restoration with consumers directly, but also acts as a supply of oyster shells for restoration projects and potential shell planting. Current regulations prevent residential oyster growing (e.g., oyster gardening), but future outreach may include such activities as opportunities arise. PDE led a major marketing and outreach campaign to promote Delaware Bay Oysters as part of 2005-2009 shell planting efforts, and continues to promote the oysters' success story and the positive effect they have had because of shell planting as a central theme of its public outreach. In 2015, PDE started the Delaware Estuary Shell Recycling program with the dual goals of returning shells to the Bay and raising awareness about oysters' benefits. The Rutgers Haskin Shellfish Research Laboratory also has played a leading role in oyster outreach; they established PORTS (Promoting Oyster Restoration Through Schools), a program that engages schools and volunteers in learning about and creating oyster reefs.

The partners identified above are committed to continuing and increasing these efforts to restore oyster habitat and productivity throughout the Delaware Bay.

Oyster reefs consist of living organisms, and therefore, are dynamic systems subject to environmental factors such as temperature, salinity, food conditions, and disease pressure. As climate changes lead to changes in these environmental conditions, oyster restoration efforts will need to be managed adaptively to maximize oyster population health in the Delaware Estuary. Extreme weather events, rising sea levels and salinity, and possibly ocean acidification represent sources of vulnerability for many estuarine resources, including oysters. On the other hand, oysters may benefit from a longer growing season and expansion of their range from subtidal

into intertidal areas along shorelines, as well as potential colonization and population expansion within tributary systems that are widening and deepening. Additional constraints on oyster restoration include management policies and mixed-use constraints. In some areas, oyster restoration is restricted currently to waters that are classified as open to harvest, as a measure to protect human health from oysters potentially poached from impaired waters. In other areas, permits for oyster restoration projects can be acquired only if the sites were populated with oysters historically, which neglects shifting species ranges associated with changing salinity and other factors. Continued sound management of oyster populations, sustained monitoring, and new scientific and outreach tools, will help inform policy decisions and promote adaptive management of the diverse opportunities and constraints associated with oyster restoration and aquaculture. Some major agencies are hesitant to fund restoration in a system that is harvested actively, which poses an additional constraint on shell planting. Educating these agencies about harvests' sustainability in the Delaware Bay system, finding ways to use temporary sanctuaries or other tools to address harvesting concerns, and seeking creative new funding/financing options are needed to address this constraint.

Performance Measures and Key Deliverables

- Sustain effective research, monitoring, and management of oyster reefs, including studies of the ecosystem services oysters provide.
- Secure at least $1 million annually by 2022 to support shell planting that boosts oyster recruitment and productivity.
- Produce and distribute materials promoting oyster restoration and shell recycling (restaurants, volunteers).
- Track the number and results of restoration, enhancement, and outreach projects to measure the number of oysters in the Estuary annually.

Costs and Funding

- **Estimated Cost Range:** $$$$
- **Possible Funding Sources:** Federal (U.S. Army Corps of Engineers, National Oceanic and Atmospheric Administration), state and private sector grants, industry clutch tax, state budgets (PA, NJ)

Purpose

To restore and expand oyster populations using scientific management and restoration capacity through innovative techniques.

Core Partners

Partnership for the Delaware Estuary, States (DE, NJ)

Key Partners

Delaware Bay Oyster Restoration Task Force, New Jersey Shellfish Council, Shell recycling partners, The Nature Conservancy

Contributing Partners

Bayshore Center at Bivalve, local governments, seafood-related organizations

Timeframe

Ongoing

STRATEGY H3.3: Inventory, restore, and manage mussel populations

Description

A variety of mussels inhabit the Delaware Estuary. Freshwater mussels are important bivalves that live in the large freshwater portion of the Delaware Estuary, and ribbed mussels occupy intertidal habitats along the estuary's fringing marshes. These filter-feeding bivalves improve water quality, diversity, and habitat for other fish and animals in each of their niches. Studies of their current distribution, population density, and ways to manage and restore populations are needed to sustain and increase their populations. Specific activities are broken down by mussel group below:

Survey for tidewater mucket (*leptodea ochracea*, a freshwater mussel) on the Delaware River, in collaboration with the Academy of Natural Science at Drexel University and the Western Pennsylvania Conservancy. | Credit: PDE

Freshwater Mussels

Key activities to inventory, restore, and manage all native freshwater mussels are diverse and include a myriad of methods related to their life history.

- **Conduct freshwater mussel surveys**. Surveys are critical to fill data gaps and provide valuable data either on where to conserve or restore mussels best. As very little is known about different mussel species' unique habitat needs and water quality requirements, research can fill information gaps that would facilitate understanding why they no longer exist in many areas, and perhaps guide mussel restoration. The PDE has completed surveys on approximately 10% of freshwater streams in the watershed, working with the Academy of Natural Sciences at Drexel University and other partners. Completing surveys on the remaining streams is a priority.
- **Promote freshwater mussels' habitat restoration.** Habitat restoration can enhance conditions so that mussels can recolonize or be reintroduced to thrive in areas degraded previously. Dams and other blockages impede fish hosts from traveling upstream, thus blocking

mussels from dispersing properly to upstream habitats. These structures' removal can increase larvae's transport to these underused stream reaches. However, even in areas where fish blockages are removed, mussels might be slow to, or never return to, the historic waterway. To restore populations to these areas, PDE has been working with the Academy of Natural Sciences at Drexel University and a variety of local partners to transplant mussels in streams and ponds successfully. Efforts are underway currently to create a regional hatchery network to produce juvenile mussels for stocking, and explore the possibility of creating mussel "farms" for nutrient removal.

- **Conduct scientific studies on freshwater mussels.** Additional scientific studies are needed to assess the ecosystem services natural and restored mussel beds furnish, and understand the threats to them better (e.g., shell erosion). These studies, in combination with freshwater mussel surveys, can help quantify ecosystem services the existing populations of freshwater mussels provide, as well as the potential services that a more robust population would provide.

PDE will play a leading role in implementing these actions for freshwater mussels, all of which are elements of its Freshwater Mussel Restoration Program and the new Mussels for Clean Water Initiative. However, these efforts' success will rely heavily on partners' contributions, including those of the Academy of Natural Sciences of Drexel University and the PWD.

Ribbed Mussels

Ribbed mussels thrive along fringing marsh shorelines in brackish waters, and salt marshes are more resilient to erosion in areas where ribbed mussels thrive. Key activities include:

- **Conduct ribbed mussel surveys.** Large-scale surveys of ribbed mussels are needed to provide data on where they occur and their status in different parts of the estuary (particularly within tidal creeks). These could be paired with monitoring their preferred salt marsh habitat to assess erosion, the primary threat to their habitat.
- **Conduct marsh restoration projects.** Restoration projects, including living shorelines, are needed to sustain areas where mussels can continue to flourish. Hatchery propagation of ribbed mussels is still a new technology that has yet to be standardized, but should be considered to supply seed needed for restoration purposes, such as in living shoreline projects. PDE has worked with Rutgers Haskin Shellfish Research Laboratory to develop tactics to restore ribbed mussels.
- **Support research and outreach on ribbed mussels.** Ribbed mussels have not been studied well because they are not used commercially, but emerging research suggests that they provide valuable ecosystem services such as shoreline protection and water filtration, and therefore, warrant a management plan. Building support for the inclusion of ribbed mussels in future management decisions may require new outreach efforts.

PDE also will play a lead role in implementing these actions on ribbed mussels, with opportunities through the DELSI, Mid-Atlantic Wetland Assessment and Monitoring Program, and by working closely with Rutgers Haskin Shellfish Research Laboratory and others.

Because mussels are sessile, or immobile organisms, generally, they are subject to environmental effects and shifts that may arise. These include environmental changes in precipitation, temperature, salinity regimes, flood zones, and stormwater inputs, as well as large-scale changes, including rising sea levels and ocean acidification. It is unclear currently in what ways mollusks will respond to ocean acidification. Rising sea levels may adjust the habitat available for mussels by shifting shorelines and associated subtidal and intertidal zones. Anthropogenic factors, such as development and their associated effects (e.g., increased

runoff, forest buffer loss) can affect mussel populations adversely throughout the Estuary. Accidental damage to mussel populations also may occur (e.g., oil spill, bridge constructions). Currently, freshwater mussel populations are managed predominantly via conservation-minded heritage programs with state and federal government programs. The focus of state and federal attention on freshwater mussels is imperiled species protection; whereas, the main goal of shellfish conservation and restoration through this strategy is preserving and enhancing ecosystem services that support cleaner water and more resilient coastlines, which are furnished by both common and rare species. This different focus can impose a constraint on awareness and funding support. In contrast to freshwater mussels and oysters, ribbed mussels are not managed because they are not imperiled and are not used commercially. Despite their sizeable ecosystem services and their loss because of habitat erosion, this strategy could be constrained by limited support and lack of awareness about why investments in ribbed mussel populations are worthwhile.

Performance Measures & Key Deliverables

- Increase survey coverage, both scientific and volunteer, annually to assess native freshwater mussels' status.
- Conduct research and produce one report annually to demonstrate tactics to enhance freshwater and ribbed mussel populations and associated ecosystem services.
- Increase populations of native freshwater mussels annually by enhancing their habitat and expanding propagation and reseeding programs.
- Perform at least one project annually to sustain or enhance ribbed mussel populations, such as via hatchery propagation or use in living shorelines.
- Track the number and results of surveys, research, and restoration projects related to both freshwater and saltwater mussels.

Costs and Funding

- **Estimated Cost Range:** $$$$ - $$$$$
- **Possible Sources:** State revolving fund programs (PennVest), state, federal, local grants, mitigation funds, private businesses, water utilities, philanthropic sources

Longwood Gardens. | Credit: PDE

Purpose

Conserve and restore mussel populations to improve water quality, diversity, and resilience in marshes and waterways.

Core Partners

Partnership for the Delaware Estuary, Philadelphia Water Department, States (DE, NJ, PA)

Key Partners

Aquatic Research and Restoration Center partners, National Fish and Wildlife Foundation, United States Fish and Wildlife Service, William Penn Foundation, local partners

Contributing Partners

Delaware Center for the Inland Bays, Delaware State University, The Nature Conservancy, Rutgers University

Timeframe

Activities are ongoing

STRATEGY H3.4: Protect and restore horseshoe crabs and their habitat

Description

Horseshoe crabs can be found all along the eastern coast of southern North America, from the Yucatan Peninsula in Mexico to northern Maine. The Delaware Estuary is unique even among these groups, in that it is regarded widely to have one of the world's largest populations of spawning horseshoe crabs. Horseshoe crabs are an important part of the marine ecosystem. Their eggs are considered essential food for several shorebird species in the Delaware Bay, which is the second largest migratory staging area for shorebirds in North America. A blood cell extract from the Atlantic horseshoe crab, Limulus amebocyte lysate (LAL) is used to create a test to ensure that medical supplies, such as flu shots and pacemakers, are safe to use. In addition, research on horseshoe crabs has provided valuable insights into the optic nerve, and may help identify cancer treatments. LAL also can detect traces of bacterial presence in medicines and is tested by pharmaceutical companies. Clearly, protecting and restoring horseshoe crabs benefit humans, shorebirds, and the Delaware Bay.

Horseshoe crabs during summer spawning season at Slaughter Beach, DE. | Credit: Stacy Small-Lorenz

Horseshoe crabs also are useful as an environmental indicator of estuary conditions. Therefore, protecting and restoring horseshoe crabs and their spawning habitat is among DELEP's important priorities. Many other species of fish and wildlife need these same habitats, and efforts to protect and restore horseshoe crab habitats benefit the overall goal of

increasing and improving fish and shellfish habitat. Key activities include:

- **Restoring critical habitats, including sandy beaches and intertidal flats.** Generally, juvenile horseshoe crabs spend their first and second summers on the intertidal flats, usually near breeding beaches. As they mature, they move into deeper water, eventually into areas up to several miles offshore. Each spring, adult horseshoe crabs migrate from deep bay waters and the Atlantic continental shelf to spawn on intertidal sandy beaches. They are believed to prefer beaches within estuaries, such as the Delaware Bay, because they are low-energy environments protected from wind and waves, and thus reduce the risks of stranding during spawning events. Spawning occurs from April through July generally, with the peak spawning activity on the evenings of new- and full-moon high tides in May and June.

Horseshoe crab sanctuary signs for Money Island and Gandy's Beach in NJ, created and installed by PDE, ERDG, and 302 Stories. | Credit: Ariane Muller

- **Conduct research on horseshoe crabs.** Horseshoe crab larvae feed on a variety of small polychaetas and nematodes, while juveniles and adults feed largely on a variety of mollusks. Accordingly, research on these food sources and their habitats should be explored. Management of horseshoe crab harvesting coupled with voluntary measures on the part of the bait and biomedical industries can be expected to allow spawning populations of horseshoe crabs in Delaware Bay to increase over time. However, because of past over-harvests, and the length of time needed for horseshoe crabs to reach maturity (8-12 years), populations have not yet shown significant increases in spawning densities relative to what were believed to be historical levels. Shorebirds depend on eggs that wave action exhumes and high densities of spawning horseshoe crabs are still at low levels. Thus, it is unclear whether current levels of surface eggs are sufficiently high to support shorebirds during typical weather conditions. Horseshoe crab eggs also are an essential food source for shorebirds, including the red knot, during their migration, when they use the Delaware Bay as a stopping ground during their migration. Continuing to study horseshoe crab populations will provide a better

understanding of their behavior and life histories, which in turn, provides a better understanding of which habitats to restore and protect.

- **Conduct surveys and monitor horseshoe crabs.** Surveys are conducted to help understand populations and set regulations. The Spawning Survey redesigned in 1999 is an important survey conducted under the direction of the Atlantic States Marine Fisheries Commission's (ASMFC) Interstate Fishery Management Plan for Horseshoe Crab, together with state agencies. The survey provides an index of spawning activity at the Bay-wide scale. It is important to recognize that this survey gives an estimate of density and should not be used to estimate population size. Instead, it provides a useful measure of spawning crabs' relative abundance or density and trends in spawning density.
- **Provide adaptive management for horseshoe crabs.** The ASMFC has implemented an adaptive management framework to help set harvest regulations that uses the best information available to link shorebird and horseshoe crab models in a way that predicts harvests' effects on both horseshoe crab and red knot populations. By projecting these effects into the future and optimizing the results, the framework recommends harvest levels that will allow both species to recover. Two monitoring programs are key elements of this, and the ASMFC has facilitated their establishment. One is the horseshoe crab trawl survey, and the other is the Delaware Bay Shorebird Monitoring Program. These estimate the size of the horseshoe crab and red knot populations, respectively, which is used to determine the appropriate annual harvest recommendations. Continuing these annual surveys will increase knowledge about horseshoe crab spawning behavior, and allow prioritization of horseshoe crab habitats that may require protection.
- **Support funding for horseshoe crab monitoring.** The Horseshoe Crab Trawl Survey and the Shorebird Monitoring Program at Delaware Bay are critical to the Adaptive Resource Management Framework, which incorporates both shorebird and horseshoe crab abundance levels to set horseshoe crab harvest levels for the Delaware Bay. It is a high priority to ensure funding for these two monitoring programs to increase understanding and reduce uncertainty about the way these two populations interact. The results will help make more informed recommendations for horseshoe crab harvesting, which will affect their populations directly.
- **Provide education, outreach, and volunteer stewardship on horseshoe crabs.** Horseshoe crabs provide a compelling story and a variety of opportunities to involve the public in the Delaware Estuary, especially in the role of citizen scientists. Hundreds of volunteers are recruited annually in spawning surveys the USFWS, NJDEP, DNREC, and a variety of conservation organizations, coordinate. Volunteers also are critical to the Shorebird Monitoring Program on both sides of the bay. The "Just Flip 'Em" and "ReTURN the Favor" programs ERDG and Manomet lead, respectively, encourage local residents to rescue crabs that have become stranded properly. ERDG's Horseshoe Crab Beach Sanctuary program allows these communities to be horseshoe crabs' designated stewards, and provides signage and recognition. PDE developed a horseshoe crab plush toy with an educational tag that offers information about them and the Delaware Estuary. These opportunities, together with dozens of educational programs DNREC and other partners run annually, tell the story of horseshoe crabs and shorebirds and build public stewardship—not just for these amazing creatures, but for the Delaware Estuary as well.

A wide variety of organizations and agencies is active in horseshoe crab protection and management in the Delaware Estuary. The USFWS, NJDEP, and DNREC, as well as a variety of conservation organization partners, including ERDG, Manomet, and the American Littoral Society, will continue to take the lead to implement elements of this strategy as described

above. Telling the story of horseshoe crabs with the plush toy, through educational programs and materials, with supporting signage for sanctuary communities, and by promoting volunteer opportunities, will remain priorities for PDE and a variety of partners for the foreseeable future.

In 2012, Hurricane Sandy affected horseshoe crab spawning beaches' abundance and condition significantly. Thanks to significant post-Sandy funding and the conservation community's rapid mobilization, many of these sandy beaches were restored promptly in time for the subsequent spawning event. This demonstrates that one constraint on the management of horseshoe crab habitat will be the frequency and intensity of severe storms, which can counteract efforts to improve and sustain spawning beaches. Other potential constraints that could materialize include rising temperatures, acidic conditions, and changes in subtidal benthic habitats. Although horseshoe crabs live in a complex environment, they have survived for millions of years, which could make them rather resilient to external influences. It is impossible to predict fully the way horseshoe crabs and their associated ecological linkages will respond to a changing environment. To assess these changes best, it is crucial to continue tracking changes and manage investments in horseshoe crab habitat and associated research adaptively.

Performance Measures & Key Deliverables

- Sustain annual spawning and trawl surveys of horseshoe crabs and annual shorebird surveys with volunteers.
- Sustain or increase participation in sanctuaries, volunteer flipping activities, and distribution of educational materials (including plush horseshoe crab).
- Increase the number of beach restoration projects to provide high-quality horseshoe crab spawning and shorebird foraging and nesting habitat.
- Conduct research and expand monitoring to understand the habitat needs of juvenile horseshoe crabs.
- Track the number and results of surveys, research, and restoration projects related to horseshoe crabs to increase protection and monitoring/research.

Costs and Funding

Estimated Cost Range: $$$$

Possible Funding Sources: State, municipal, non-profit partners for monitoring, state and federal grants for restoration (National Fish and Wildlife Foundation, U.S. Fish and Wildlife Service)

Purpose

To protect and restore horseshoe crabs because of the unique role they play and story they tell about the Delaware Estuary.

Core Partners

States (NJ, DE)

Key Partners

Atlantic States Marine Fisheries Commission, American Littoral Society, Ecological Research & Development Group, National Fish and Wildlife Foundation, United States Fish and Wildlife Service, Western Hemisphere Shorebird Reserve Network, The Wetlands Institute

Contributing Partners

Academia, Non-Governmental Organizations, bay beach communities

Timeframe

Ongoing through annual horseshoe crab spawning, trawl, and shorebird surveys

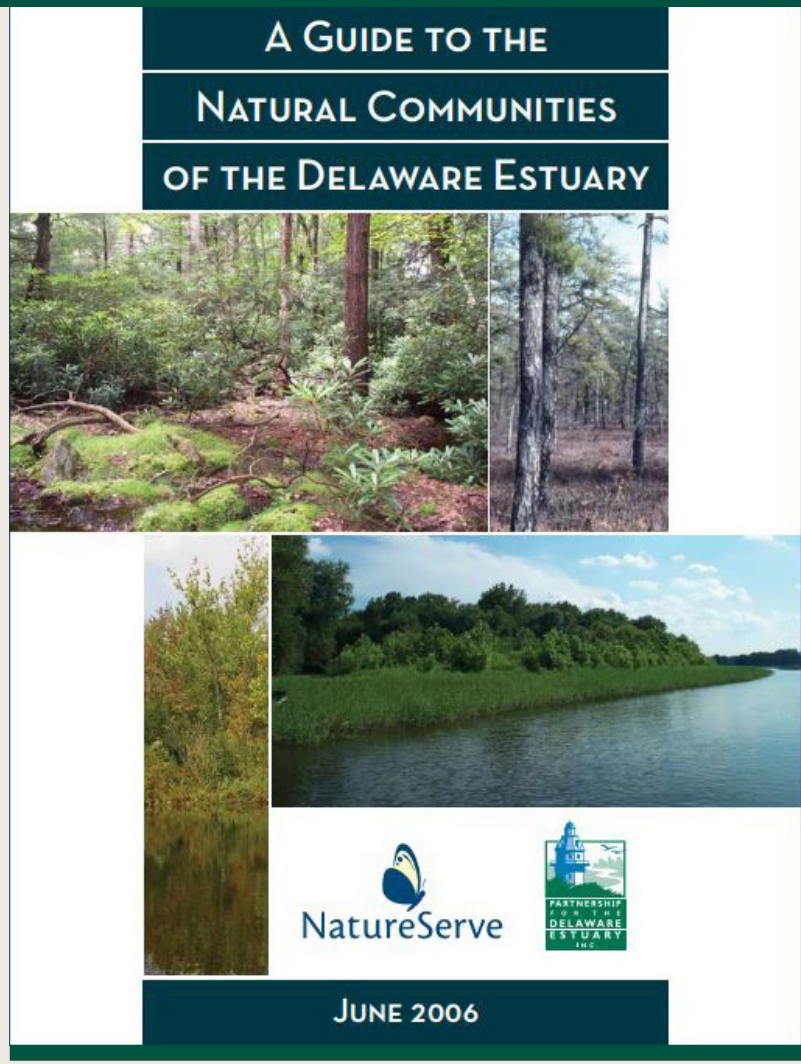
STRATEGY H3.5: Manage and improve populations of rare, endangered, or otherwise important native species in the Delaware Estuary

Description

In a region the size of the Delaware Estuary, there are millions of species of plants and animals listed as those of conservation concern, and numerous agencies and organizations are devoted to their management. Species management plans (SMP) are integral to the success of improving the Delaware Estuary's ecological integrity. Designed to enhance survivorship of imperiled (rare or endangered) species or limit invasive species' adverse effects, SMPs outline specific practices that cater best to species-specific management goals. This also allows agencies or states (DE, NJ, PA) to coordinate efforts efficiently. Although state agencies create their own SMPs generally, for species within the Delaware Estuary, agencies often collaborate to ensure continuity of long-term goals. By engaging a variety of partners, this strategy seeks to conserve species by refining and supporting existing SMPs, helping create new plans for new species management issues as they arise, and implementing the conservation actions these plans recommend.

In particular, SMPs will be used to:

- **Assess and manage cumulative effects.** Where there are cumulative effects of concern to the Delaware Estuary's health (those the combined results of past, current, and future activities cause), SMPs for imperiled or otherwise important species (such as those of economic or ecological importance) may be refined or redeveloped by focusing on those species or a suite of species (e.g., fishes, nektonic animals, bivalves, wading birds, crustaceans) to ensure improvements Estuary-wide. Cumulative effect inventories also may include multi-agency strategies to eliminate key threats to imperiled species' recovery, such as advocating dam removal for anadromous fish or supporting pesticide BMPs to limit chemical exposure.
- **Manage invasive species.** Invasive species that threaten the Delaware Estuary's ecological integrity affect many species. By reviewing SMPs, partners in the DELEP can identify those invasive species that present the greatest risks and work with partners to control, as well as prevent, their effects. Consistent and collaborative efforts to manage invasive species is important to ensure efforts' long-term success. Furthermore, multi-agency contingency plans for invasive species are important to respond swiftly



A Guide to the Natural Communities of the Delaware Estuary, **which describes 35 ecological systems and 185 natural communities known to occur in the region.**

when problematic species known already, but not yet naturalized across the Delaware Estuary, are detected, including the zebra mussel (*Dreissena polymorpha*).

- **Promote native species and communities.** SMPs also help identify the habitats multiple species use and suggest the most strategically important habitat to protect and restore to preserve native plants and animals' diversity in the Delaware Estuary. Information from SMPs, as well as resources such as the Natural Vegetation Communities System PDE developed in 2007, can and should be used not only by managers to shape priorities, but by interested members of the public (gardeners, naturalists) to raise awareness and build stewardship for native species. SMPs also can be translated for those with limited English proficiency.

State and federal agencies, including the NJDEP, PADEP/ Pennsylvania Department of Conservation and Natural Resources, DNREC, and the USFWS, are this strategy's lead implementers. PDE and others can play a supportive role by helping identify SMPs' needs, and advocating for their continued use.

Such external constraints as climatic variability, environmental accidents (e.g., oil spills), disease, funding, and political attitudes affect SMPs' success and the collaboration among agencies on which this strategy focuses significantly. To mitigate certain constraints, when updating existing, or creating new SMPs, management plans should acknowledge and prepare for certain changes, such as rising sea levels, ocean acidification, climate change, or increased developmental or economic pressures. Contingency plans might be outlined for each SMP with respect to environmental accidents and disease, should the need for action arise. Most likely, the best way to deal with funding availability and political attitudes is to make SMPs and outreach materials consistent to inform various audiences better about key species' importance and the detriments of certain conditions (e.g., dams, pollution) to the Delaware Estuary's health overall.

Performance Measures and Key Deliverables

- Use SMPs to assess the cumulative effects of impingement/entrainment on ecologically important native species.
- Develop contingency plan for zebra mussels.
- Work with partners to identify and reduce habitat acres affected by invasive species annually in each state.
- Perform annual outreach to increase stewardship and landowners' use of native species.
- Track the number and results of species-related projects.

Costs and Funding

Estimated Cost Range: $$$

Possible Funding Sources: Agency operating funds, state, federal, and private grants (e.g., iMapInvasives)

Purpose

To work collaboratively to improve the management of key species in the Estuary.

Core Partners

Partnership for the Delaware Estuary, Philadelphia Water Department, States (DE, NJ, PA)

Key Partners

National Fish and Wildlife Foundation, United States Fish and Wildlife Service

Contributing Partners

Delaware Invasive Species Council, United States Coast Guard Ballast Water Management System, fisheries management organizations, private sector

Timeframe

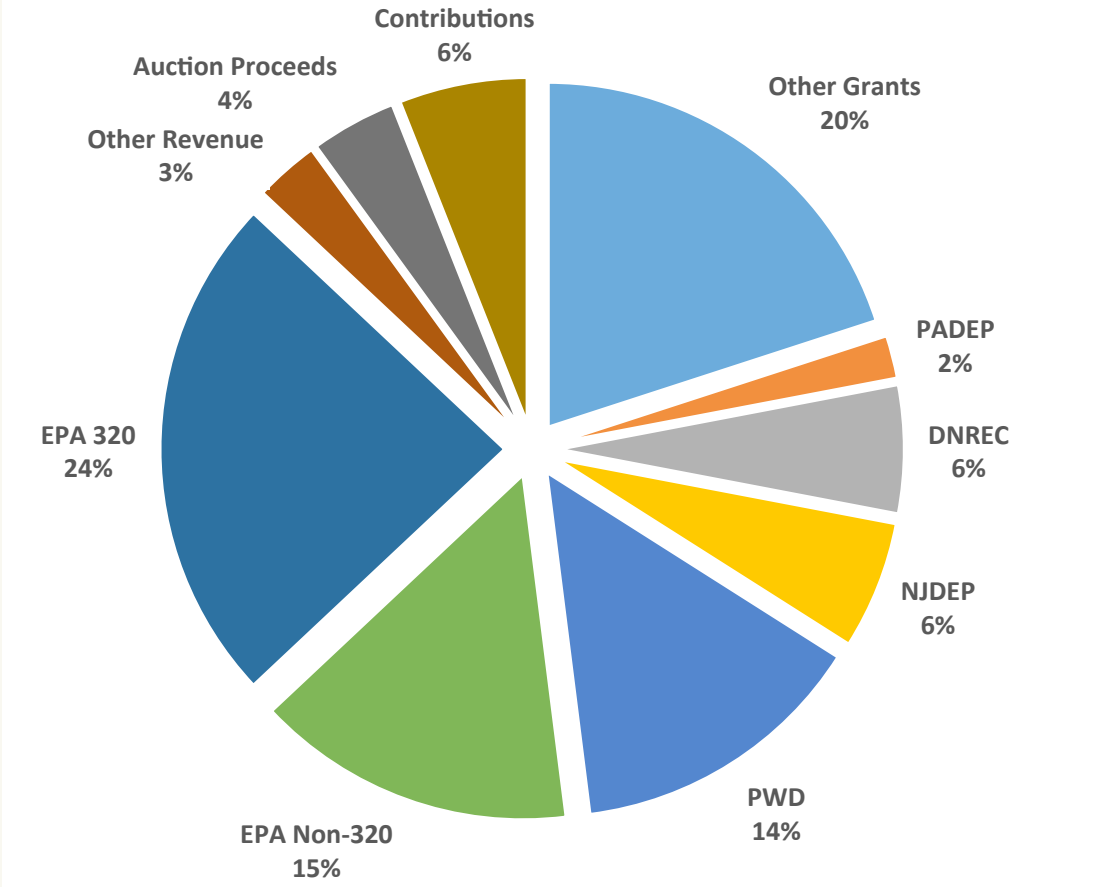
Ongoing

Finance Strategy

Implementing the revised CCMP will require funding through diverse resources and partners. This includes maintaining funding from current sources of support, developing new funding sources, and identifying new partners. The effect on the Estuary's health is limited primarily by the total amount of funding that is dedicated to the efforts outlined in this plan.

Current Funding/Support

- Currently, funding to support CCMP implementation derives from a variety of sources, including the National Estuary Program through the EPA. There are 28 NEPs, each of which receives the same basic level of funding (with occasional opportunities to compete for additional funds). Over the past 10 years, this base funding has remained relatively stable at approximately $600,000 annually for each program. Agency partners consistently have provided the match required for the NEP funds to PDE in the form of in-kind services to support CCMP activities for a total NEP investment of approximately $1.2 million annually.



Example of PDE Total Revenue by Source (Budgeted 2017)

Not including the match required for NEP funds, PDE normally raises two to three times the NEP funding amount annually from other sources for its annual budget of $2.5–$3 million, as shown in this pie chart. A portion of these funds ($62,000–$85,000 annually) has come from the State of Delaware through the DNREC budget to help support PDE's core operations and activities in Delaware. Nearly all other non-NEP sources of support to PDE from government agencies derive from competitive grant programs and contracts. These sources include other federal funds, such as grants through other EPA programs, and grants from other federal agencies for specific projects and programs. Typically, they also include grants and contracts from the PWD and other local governments, and grants from state programs, such as the Coastal Zone Management and Nonpoint Source (319) grants for specific activities that meet those grant programs' requirements. In total, government grants and contracts typically account for the vast majority of PDE's annual budget.

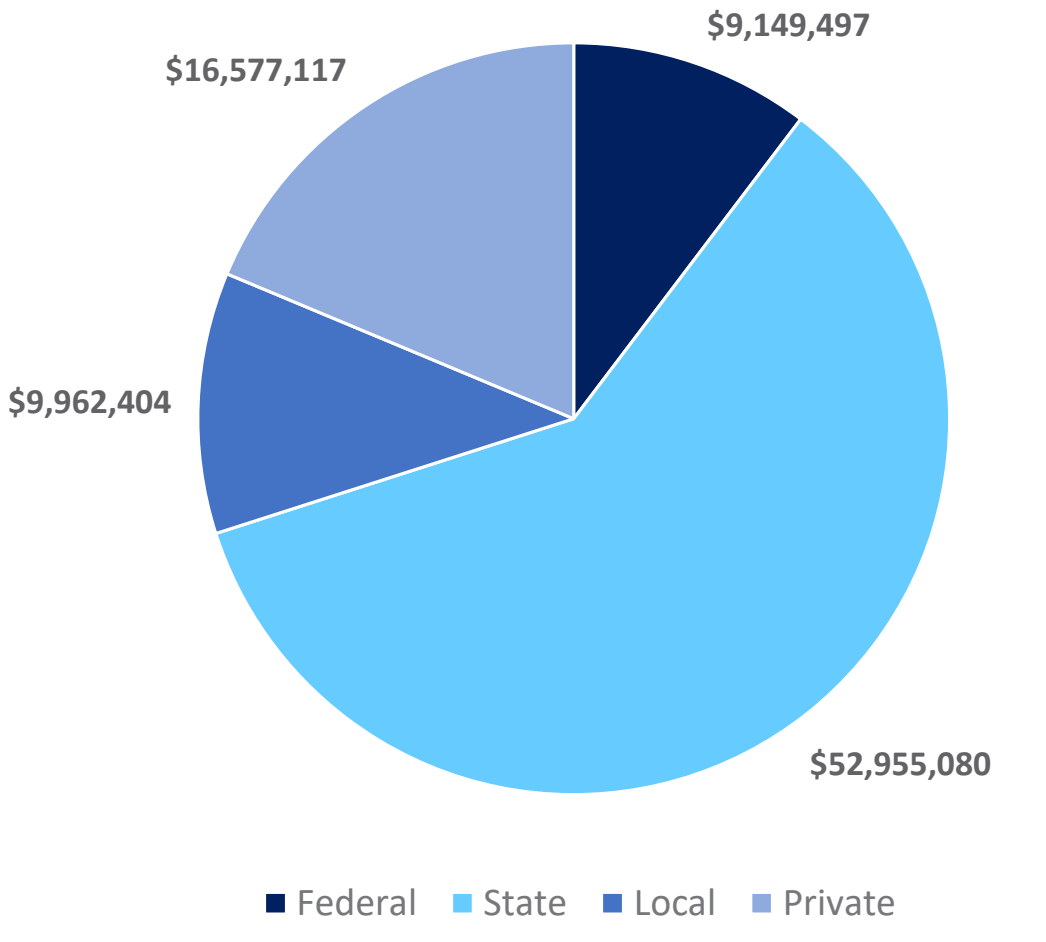
The remaining amount of PDE's budget derives largely from private-sector funding, much of which comes from such foundations as the William Penn Foundation, the

Geraldine R. Dodge Foundation, and the Welfare Foundation. Corporate grants, sponsorships, and donations also are part of this private-sector funding, as are individual donations. In 2008, PDE developed a Fundraising Plan that focused on involving its Board of Directors to raise private-sector funding; PDE continues to implement and update this plan.

Several major initiatives in the watershed support CCMP implementation. In the past 10 years, PDE and Core Partners have leveraged an average of $8.9 million annually from NEP-awarded funding. Much of this leveraging comes from Core Partners through grant-making, land acquisition, and restoration and management programs, accounting for the vast majority of the 44,000 acres of habitat restoration the DELEP achieved during the past 10 years.

A number of other major initiatives in the watershed have resulted in substantial funding:

- The William Penn Foundation's Delaware River Watershed Initiative
- The DuPont Company's Clear into the Future grant program
- National Fish and Wildlife Foundation (NFWF) grants. Today, NFWF administers a grants program for restoration projects using funds from the William Penn Foundation, as well as a new (2018) grant program for the USFWS as a result of the Delaware River Basin Conservation Act passed in 2016
- EPA Wetland Program Development funding programs
- Research and monitoring programs, supported by a combination of state, federal, and regional funding. The DRBC, working with the states, leads water quality and quantity monitoring and research, using funds allocated by state, federal, and DRBC budgets

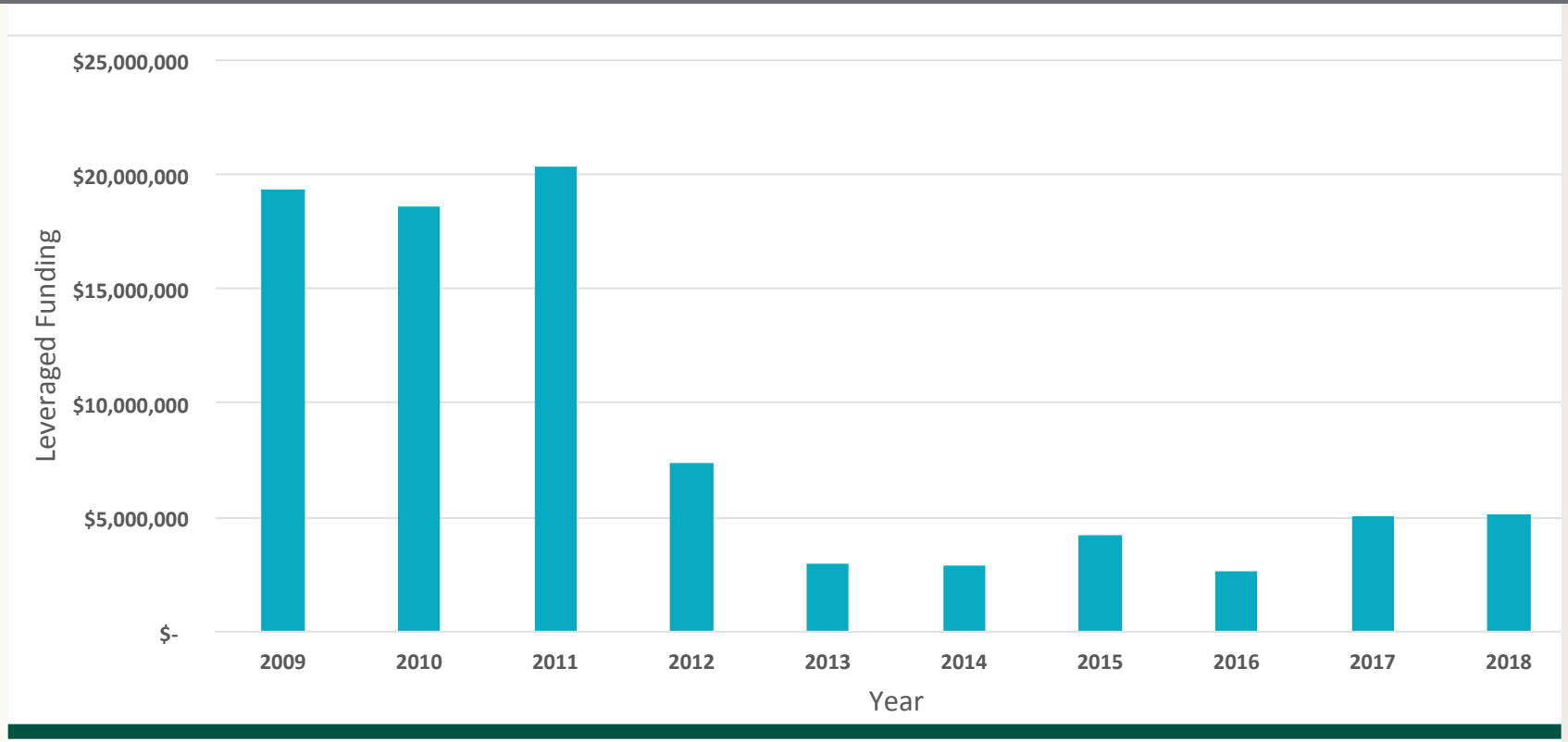


Total DELEP Leveraging by Source (2009 to 2018)

Resource Needs

Despite the current level of funding, more resources are needed to accomplish the activities in this CCMP. Many current activities need to continue over many years to have a measurable effect on the Estuary. In addition, new activities are needed to address emerging threats, to expand the geography and scope of sub-watershed

collaborations, and to form and sustain new partnerships. An estimate of the total cost to implement this CCMP over 10 years is $613 million. To obtain this level of support, current sources of funding must be continued, and new sources added. This seems like an insurmountable challenge, but funding levels for other large American water bodies like the Great Lakes and Chesapeake Bay indicate that it is feasible.



DELEP Leveraged Funding by Year as reported to NEPORT (2009 to 2018)

More reliable (ideally, dedicated) sources of funding also are needed, particularly for science and monitoring. The vast majority of funds available to support CCMP implementation currently are one-time competitive grants, suitable for small, short-term projects, which are insufficient to support large-scale, multi-year projects needed to make a significant difference to the Delaware Estuary. The current level of funding cannot support the rigorous, ongoing monitoring needed to track changes that support sound scientific solutions to such challenging problems as climate change adaptation. Opportunities for multi-million, multi-year funding required for large ongoing undertakings are rare, temporary, and highly competitive.

More resources to involve people also are needed in the watershed. Building support from, and stewardship on the part of, the people who use and benefit from the Estuary's resources is a major need the CCMP reflects. Cultivating this support and stewardship takes many years and significant resources, but is critical to ensure that any improvements achieved today will be sustained in the future. The few resources available to perform this work are increasingly difficult to access because of more grant restrictions and increased expectations of measuring success with environmental outcomes.

Key Activities & Priorities

The following key activities will be pursued:

- **Sustain and increase funding through the National Estuary Program,** including funds from EPA and the match from Core Partners. An important element of this strategy is PDE's continued outreach to federal legislators about DELEP's activities, results, and needs, and continued funding from Core Partners to match NEP funds (including if/when they increase)
- **Sustain and increase funding from major state, federal, and foundation sources** to support DELEP's work on projects and programs that implement strategies in the CCMP. Grant writing and management to secure funds for projects and programs that implement CCMP strategies are important
- **Diversify funding to increase private-sector investment**. The CCMP cannot be implemented with government support alone. In recent years, PDE has increased efforts to secure grants and other types of support from private foundations, companies, and individuals successfully, and will continue to accelerate these efforts
- **Lead or participate in collaborative efforts to develop new and increased funding sources** at the state and regional level, such as:
  - Continue to develop and advance the USFWS's Delaware River Basin Restoration Program created by the Delaware River Basin Conservation Act.
  - Identify and take advantage of opportunities to raise the profile of the Delaware River Watershed in other state, national, and regional funding programs
  - Continue to participate in educational campaigns designed to increase dedicated funding for clean water projects and programs at the state and regional levels (e.g., the Clean Water, Clear Choices campaign in Delaware)
- **Advance the concept of a Trust or Fund for the Delaware River and Bay.** In 2008, PDE set forth a vision for the Delaware Estuary Science and Restoration Trust as part of the 2008 Regional Restoration Blueprint. Since then, PDE has worked with its partners to advance that vision in a number of ways: through the Alliance for Comprehensive Ecosystem Solutions (currently on hold), the Delaware River Basin Conservation Act, and the Innovative Financing Strategy Financing Panel of the University of Maryland Environmental Finance Center (funded by the William Penn Foundation). Each of these efforts has contributed new funding/financing tools or resources to the toolbox successfully. However, there remains a need for the type of comprehensive Trust or Fund envisioned, and PDE will continue to seek opportunities to work with partners to advance that vision
- **Sustain and increase PDE's capacity to accept and manage NEP funds e**ffectively and strategically. Important elements of this activity include providing appropriately-sized physical and information management infrastructures needed to support the NEP program office activities and management conference

The SC and Core Partners that form it are responsible for ensuring that DELEP is funded adequately. As the recipient of NEP funds, PDE plays a leading role in supporting DELEP, and is responsible for the use and management of those funds and confirming that associated requirements are met. The USEPA plays a leading role in administering those funds to PDE, in accordance with NEP guidance. PDE also plays a leading role in securing and managing funds from other sources, and as a non-profit 501(c)(3) organization, can solicit and accept donations and grants from other entities. Other Core Partners play critical roles by providing the match for NEP dollars required, and administering grant programs that provide others' funding for projects and programs that implement CCMP strategies. Other donors, foundations, and grant sources also play important roles in this strategy.

This Finance Strategy's success relies on a variety of factors beyond the NEP's control, including federal and state budgets and priorities and the economic and political conditions that influence them. This strategy's success also relies on additional partners than the Core Partners to help sustain and increase funding. Climate change is likely to increase the costs associated with many CCMP activities over time, and increase the need for funding accordingly. Conducting outreach to legislative offices and seeking collaboration with other potential funding partners are activities that PDE will undertake to address and minimize the risks associated with these constraints.

Performance Measures & Key Deliverables

This finance strategy's ultimate measure of success is increased funding to implement the CCMP, which is measured (at least in part) by dollars leveraged that Core Partners report annually through the GPRA process. With respect to PDE grant-writing, key deliverables reported in the annual Work Plan include the number of grants and grant dollars secured, and the grant-writing success rate. Other important deliverables reported that indicate success in this strategy include an increasing organizational budget over time, annual work plans approved by the EIC, and annual audits that ensure best financial practices. Every five years, PDE works with the EPA on a performance evaluation to assess DELEP's effectiveness over time, and confirm PDE's ability to continue receiving NEP funds. PDE's next scheduled performance evaluation is in 2019.

Costs and Funding

The costs associated with this Finance Strategy include staff time for grant development, writing, and management, which NEP dollars can (and have) funded in part, as well as staff time and expenses to raise funds and advocate for funding, which NEP dollars cannot fund (at PDE, these are funded largely by the unrestricted dollars raised through these activities). Current PDE costs for these activities are approximately $250,000 annually.

The Core Partners will continue to provide NEP matching funds (currently $600,000 annually) in addition to the cost of staff required to administer and manage the NEP roles and grant programs within these agencies, which is considerable, difficult to estimate, and an additional cost of this Strategy.

Timeframe

The NEP work planning/funding cycle is annual (based on funding Congress appropriates annually), with leveraging data collected annually, and performance evaluations conducted every five years. In 2015, Congress reauthorized the NEP for five years and will need to reauthorize it in or around 2020. Other funding cycles vary widely across sources, with some agencies following the federal fiscal year and others the state fiscal year. Some grants are made annually, while others are for shorter or longer periods, and many also follow some sort of an annual cycle, at least for reporting.

2015 Christina River Watershed Cleanup, Wilmington DE | Credit PDE

Monitoring Approach

The following section is a brief, high-level description of the approach that will be taken to track and detect changes and/or improvements in the Delaware Estuary and its watershed, and progress in implementing the revised CCMP, and the way those outcomes and results are related. It describes the framework that will be used to track implementation progress, the activities DELEP partners will undertake to assess progress in meeting objectives, and the way tracking short-term activities/actions relates to longer-term monitoring used for State of the Estuary reporting. A table at the end of this section summarizes the measures that will be used to track success (which are related directly to the objectives expressed in prior sections.)

The table includes examples of some of the types of monitoring programs underway to compare results to objectives in the revised CCMP. An actual inventory or assessment of DELEP partners' monitoring that identifies what data are being collected for which parameters, the parties responsible, frequency of collecting/reporting, and the way data are stored, shared, and used is not included here. Compilation of that information, and subsequent assessment of gaps and the way to fill them, is a significant undertaking that will be completed after, then made an addendum to, this revised CCMP. The monitoring workshop that will be the primary avenue through which to complete that additional work is part of the "Future Monitoring Approach" described in the final part of this section (see workshop results in the CCMP Monitoring Workshop Report).

Objectives

The CCMP's objectives are articulated in the "How We Will Measure Success" sections for each set of strategies. To track progress in implementing the CCMP to meet these objectives, the Management Conference has developed a multi-tiered tracking/reporting system summarized in table Summary of Proposed CCMP Measures at the end of this section. A brief description of the multiple tiers within this system are as follows:

- **Outputs.** Outputs are the deliverables produced directly by activities described in the CCMP. For example, an outcome might be a public outreach workshop, a research dataset, or trees planted for restoration. Outcomes (see below) generally are immediate results, cost-effective, and can be observed and measured in the short term
- **Outcomes.** Outcomes are the results outputs produce. For example, an outcome might be workshop participants' improved understanding of outreach, the findings or knowledge gained from research, or the water filtering services trees planted for restoration provide. Some outcomes can be measured in the short term; others take longer or are not cost-effective to measure, and therefore, need to be estimated
- **Impacts.** Impacts are the lasting results outputs and their outcomes produced. For example, an impact might be pollution-reducing behavior as the result of an outreach workshop, reduced pollution attributable to using a new tool or practice developed in research, or water quality improvements in a stream resulting from trees planted for restoration. Impacts can be measured only with significant investment and by monitoring and tracking conditions over time. Further, it can be challenging, if not impossible, to isolate and measure some outputs/outcomes' the impacts precisely

For each suite of strategies, the Management Conference has identified ways to measure outputs, outcomes, and impacts using the tools and resources available or anticipated. A brief explanation of what and the way the tools/resources will be used includes the following:

Annual Work Plan and GPRA Reporting

Outcomes and outputs will be measured by building on the NEP data collection and reporting mechanisms already in place.

- **NEP Work Plan.** For PDE-led activities, this reporting includes the annual work planning process. Annually, the PDE proposes outputs/deliverables to the EPA that the Management Conference has vetted in the form of a Work Plan. Twice annually, PDE prepares and reports its accomplishments on these deliverables to EPA using the data and parameters established in the Work Plan, with copies provided to the Management Conference (Board and EIC)

- **Annual Compilation of Partners' Habitat and Leveraging Data.** This process includes the annual data collection and reporting for GPRA using NEPORT (the National Estuary Program Online Reporting Tool). Each summer, PDE collects and compiles data from Core Partners and their agencies that have been entered into spreadsheets PDE provided on dollars leveraged and habitat acres protected/restored. PDE compiles and submits the data to the EPA for review and approval using NEPORT-compliant spreadsheets. Through this process, PDE collects some of the data identified in Table RevCCMPMeasures routinely; to collect other data, some modifications to the data collection process and spreadsheet tool are needed (and planned)

Scientists prepare to collect a sample from the bottom of Delaware Bay as part of the Delaware Estuary Benthic Inventory project in 2008. | Credit PDE

Data needed to report outcomes and outputs will be collected and reported through the following key activities:

- Submission of annual Work Plans and accomplishment reports in accordance with EPA guidelines
- Collection and compilation of GPRA information in accordance with EPA requirements
- Modification of the GPRA collection process to incorporate new parameters and translation of information collected on project type and scale into estimates of outcomes

PDE will be responsible for collecting, compiling, and reporting information to track output and outcomes annually as the CCMP describes. The Core Partners will be responsible for collecting this information from their agencies and reporting it to PDE in accordance with the process developed together, including timelines PDE established. The Core Partners also will consider the EPA's timelines for GPRA and Work Plans when reporting information to PDE.

Regional Monitoring and State of the Estuary Reporting

To measure impacts, PDE will rely on the network of regional monitoring that informs State of the Estuary reporting every 4-5 years. The monitoring network includes programs and studies that address diverse objectives spanning regulatory, assessment, scientific, and educational sectors. For example, water monitoring programs track whether water quality standards are being met. State and federal agencies track changes in certain fish and shellfish species' populations to manage recreational and commercial harvests sustainably. Monitoring forests and wetlands' health and extent helps prioritize conservation and restoration activities. To understand the environmental conditions better, professional and citizen scientists perform a great deal of monitoring.

PDE coordinates the collection of such disparate datasets and reports more than 50 indicators' status and trends to develop a comprehensive summary of the Estuary system's ecological health and function, thereby determining whether CCMP strategies are having lasting effects on specific indicators. The table on the following page (Example Monitoring Porgrams–Delaware Estuary) lists examples of monitoring programs that yield data for State of the Estuary reporting and which actions will help assess CCMP implementation's lasting effects in the Delaware Estuary.

Collecting and compiling datasets from these and other monitoring programs is a collaborative effort in which PDE's STAC works closely with the DRBC's MACC. During the MACC meetings, which occur in the fall, participants describe their monitoring programs' structure and status and look for opportunities to collaborate and cooperate in existing monitoring programs. During the STAC-MACC meetings, which occur in the spring, participants work to strengthen ties among monitoring programs, resource management initiatives, and CCMP activities.

As part of this CCMP revision process, the STAC and MACC worked together to produce an updated Technical Report for the Delaware Estuary and Basin. Completed in late 2017, the information from this report helped inform the strategies in this revised CCMP. It also identified more detailed research and monitoring needs in the "Future Actions and Needs" subsections for each indicator.

Future Monitoring Approach

The approach to monitoring in the Delaware Estuary has evolved significantly since the original CCMP was published. The RIMS envisioned in the original CCMP never was realized fully because it required considerable manpower and resources to develop and maintain such a system for the large and complex Delaware Estuary.

Rather than a comprehensive monitoring system, the Management Conference decided to adapt and evolve monitoring programs to address specific aquatic resource management needs, such as assessment compared to water quality standards, evaluating status and trends, and examining ecological function and health. Over time, the STAC and MACC have developed successful processes to work together to coordinate efforts and share monitoring results for the Delaware Estuary through two key activities. In addition to continuing the first two activities below, PDE and DRBC also will collaborate on the third new activity:

1. **Annual joint meetings of the STAC/ MACC** to share results of activities monitored, and coordinate monitoring plans for the upcoming year, which are then shared with the EIC. These meetings also are used to identify emerging needs and opportunities for collaboration, thus strengthening ties among monitoring programs, water resource management initiatives, and the CCMP
2. **Collaboration on State of the Estuary reporting every 4-5 years.** Led by the STAC and MACC, PDE identifies and collects indicator datasets from diverse monitoring and research programs. Subject matter experts then serve as authors of chapters of a TREB, including subjects on Watersheds and Landscapes, Water Quantity, Water Quality, Sediment, Aquatic Habitats, Living Resources, Climate Change, and Restoration. By analyzing these datasets, TREB authors help prioritize current and future monitoring. TREB chapters serve as the basis for a more public-oriented State of the Estuary Report

Example Monitoring Programs–Delaware Estuary

NAME	CCMP STRATEGY	SAMPLING ACTIVITY AND LOCATION	EXAMPLE METRICS
Delaware Estuary Water Quality Monitoring Program (DRBC Boat Run)	W1	Surface water samples from main channel	▶ Dissolved and Particulate Nutrients ▶ Chlorophyll-a ▶ Silica, metals ▶ Organic compounds
Continuous Water Quality Monitors (USGS, PWD)	W1	Surface water sensors at tidal and non-tidal stations	▶ DO, temperature, pH, conductivity ▶ Chlorophyll ▶ Precipitation and photosynthetically active radiation (Schuylkill)
Oyster Population Stock Assessment (Rutgers)	H3	Samples from Delaware Bay seed beds	▶ Abundance ▶ Size demographics ▶ Condition index ▶ Recruitment
Mid-Atlantic Coastal Wetland Assessment (PDE, ANSDU, State of DE)	H1	Surveys and samples at stations in tidal Wetlands	▶ Surface elevation ▶ Dissolved nutrients ▶ Sediment chemistry ▶ Vegetation and fauna robustness ▶ Condition
Freshwater Mussel Recovery Program (PDE, PWD, ANSDU)	H3	Freshwater tidal and non-tidal bottom areas' surveys and samples	▶ Baseline survey areas expanded annually ▶ Survival and growth of extant and restored populations at >11 sentinel sites

3. **Monitoring Workshops every 4-5 years.** Following production of each State of the Estuary report (every 4-5 years), key partners engaged in environmental monitoring will be convened to create/update an inventory of critical monitoring in the region. The first of these workshops will take place in 2018 and will focus on measures needed to track CCMP outcomes and impacts, as well as monitoring needs identified in the 2017 TREB report, and the effects of CCMP implementation over time. This monitoring also will provide an opportunity to explore and use linkages with the new monitoring and research being undertaken for the DRWI. The resulting inventory and list of monitoring priorities will be treated as a monitoring plan that can serve as a tool to frame annual joint STAC/MACC coordination meetings in the future. Once the plan is prepared in 2018, it will be linked as a reference to this revised CCMP.

Monitoring changes in surface elevation helps scientists understand if these tidal marshes are keeping pace with sea level rise. | Credit PDE

Summary of Proposed CCMP Measures

Clean Water Measures	Output (annual)	Outcome (annual)	Impact (every 5 yrs)	Measures
Nutrients (W1)				
Implementation of projects	X			# projects/programs
Nutrients prevented/reduced from projects		X		estimates based on project type, scale
Behavior changed		X		partners and/or people reached
Improved dissolved oxygen			X	DO status/trends in SOE Living resource status/trends in SOE N, P status/trends in SOE
Increased ecosystem health			X	
Decreased nutrients in mainstem and tributaries			X	
Other Pollutants (W2)				
Implementation of projects	X			# projects/programs
Pollutants reduced from projects		X		estimates based on project type, scale
Behavior changed		X		partners and/or people reached
Reduced fish consumption advisories			X	track/report in SOE Contaminants status/trends in SOE PCB status/trends in SOE
Reduced discharges of contaminants			X	
Reduced PCBs from point and non-point sources			X	
Flow (W3)				
Implementation of projects	X			# projects/programs
Water conserved/infiltrated by projects		X		estimates based on project type, scale
Behavior changed		X		partners and/or people reached
Achieve and maintain flow			X	flow status/trends in SOE
Develop/meet flow targets for fish, shellfish, wetlands		X		flow status/trends in SOE
Improve water efficiency through conservation			X	Water use/consumption status/trends in SO

Table continues next page

Summary of Proposed CCMP Measures cont'd

Strong Communities Measures	Output (annual)	Outcome (annual)	Impact (every 5 yrs)	Measures
Resilience & Access (C1)				
Implementation of projects	X			# projects/programs
Improvements resulting from projects		X		estimates based on project type, scale
Behavior changed		X		partners and/or people reached
Increase access to River, sustain/enhance to Bay			X	access points status/trends in SOE
Increase protected land for community benefits			X	protected land status/trends in SOE protected land status/trends in SOE
Public Awareness & Stakeholder Engagement (C2)				
Implementation of projects	X			# projects/programs
Results of projects (envir & engagement)	X			estimates based on project type, scale
People reached / info provided		X		partners and/or people reached
Engagement of key stakeholders		X		$ leveraged reported
Improved public awareness			X	polling/focus groups - add to SOE

Table continues next page



Cape May, NJ | Credit: Krista Scheirer

Summary of Proposed CCMP Measures cont'd

Healthy Habitats Measures	Output (annual)	Outcome (annual)	Impact (every 5 yrs)	Measures
Wetlands (H1)				
Implementation of projects	X			# projects/programs
Improvements in conditions, functions		X		estimates based on project type, scale
Increased protected/restored wetland acres		X		wetland habitat acres reported
Minimize loss of wetlands			X	wetlands status/trends in SOE
Improve wetlands conditions			X	wetlands status/trends in SOE
Forests (H2)				
Implementation of projects	X			# projects/programs
Increase protected/restored forest acres		X		forest habitat acres reported (including management plans)
Improve forest management, baseline		X		estimates based on project type, scale
Minimize loss of forest cover			X	Forest status/trends in SOE
Fish & Shellfish (H3)				
Implementation of projects	X			# projects/programs
Improvements in habitat, populations, baseline		X		estimates based on project type, scale
Volunteer engagement		X		partners and/or people reached
Improvement in habitat, populations			X	Fish/Shellfish status/trends in SOE

Color Key
Reported in Government Performance and Results Act (GPRA) annually
projects/programs
State of the Estuary Report
partners/people
Estimated through project scale/type

Benjamin Franklin Bridge, Delaware River, Philadelphia, PA | Credit: Kerri Yandrich

Glossary of Terms

Acoustic surveys: A research method to map the bottom of waterways using sound waves.

Adaptive management: Adapting and applying lessons learned to natural resources management.

Ambient water: Average water quality conditions in waterbodies, such as rivers, streams, lakes, and bays.

Anadromous [fish]: Fish that migrate from salt water to fresh water to reproduce.

Anthropogenic effects: Humans' effects on the natural world.

Aquaculture: The process of breeding and raising aquatic organisms, such as shellfish and fish.

Aquifer: An underground sediment layer that can store and move water through the ground.

Baseline conditions: An environmental condition monitored before a program or project is implemented (i.e., monitoring chemical, physical, or biological conditions before a restoration project is implemented).

Benthic: Referring to the bottom of a waterbody.

Best management practice (BMP): A practice that is effective and practical in preventing or reducing water pollution.

Bioaccumulate: The buildup of a contaminant in an organism's tissues attributable to breathing, drinking, and/or eating contaminants.

Brackish: A mix of fresh and salt water.

Brownfield: A former industrial or commercial property the redevelopment of which a hazardous substance may affect.

Bulkheads: A manmade hard structure, like a wall, that divides the land and a waterway and has been used traditionally to protect shorelines and stop coastal erosion.

Climate change: A change in the earth's climate and usual weather patterns associated with an increase in global average temperature and carbon dioxide in the atmosphere.

Resilience: The ability to recover or adapt after a disaster occurs.

Combined sewer systems: Sewers that collect rainwater/stormwater runoff and sewage in the same pipe. Most often, the flow is transported to a sewage treatment plant, treated, and then discharged into a waterway. However, during a heavy storm, the combined stormwater and wastewater can overwhelm the system's capacity and overflow into waterways untreated.

Connectivity: Land parcels' proximity, particularly related to preserving lands. Conservation: The act of preserving, protecting, or restoring natural resources.

Delaware Estuary: The portion of the Delaware River and Bay that tides influence. The Delaware Estuary extends from Cape May, NJ and Lewes, DE, to Trenton, NJ.

Delaware River Basin: The land area and streams that drain to the Delaware River. This area covers parts of four states: Delaware, New Jersey, Pennsylvania, and New York.

Diadromous: Fish that spend parts of their life cycles in both fresh and salt water.

Dredging: The act of removing sediment from a river bottom with a dredge and disposing it elsewhere.

Ecological: Living organisms and their interactions with one another and their environment.

Ecosystem: Plants, animals, and other organisms that live together in their surrounding environment.

Ecosystem services: Benefits to humans and nature that an ecosystem provides. Ecosystem services sometimes can be associated with monetary values.

Emerging contaminants: Pharmaceuticals, chemicals, plastics, or other forms of pollution that are not understood fully or regulated because of insufficient knowledge of the way they can enter the environment or their effects.

Environmental justice: Equal treatment and meaningful involvement of all people, regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies, as defined by the U.S. Environmental Protection Agency.

Estuary: Area of a river that is tidal and where fresh and salt waters mix together.

Eutrophication: Condition in which waterways have too many nutrients from land runoff and suffer from low dissolved oxygen and possible algal blooms.

Floodplain: Low-lying land bordering a river or stream that is susceptible to flooding.

Goals: Central actions in the Delaware Estuary that this document seeks to accomplish.

Green infrastructure: A suite of tactics that use natural systems to solve water management problems, including runoff, erosion, and/or local waterways' pollution. Examples of green infrastructure that combat urban stormwater runoff include pervious pavement, rain gardens, green roofs, and tree trenches, while living shorelines and wetlands are types of green infrastructure that can clean water and protect coastal communities.

Headwater: A tributary close to or forming part of the river's source of water.

Hybrid: Term referring to a type of living shoreline that incorporates both nature-based and traditional hard infrastructure in the design.

Hydrophobic: Matter that repels water.

Impervious: Surface, such as a road or walkway, that water cannot penetrate.

continued

Infiltration: Water filtering into the ground and replenishing groundwater systems such as aquifers.

Invasive species: A type of plant, animal, or organism that is not native to a specific area that sometimes can spread rapidly and damage existing ecosystems.

Living shorelines: A method of shoreline stabilization that uses natural materials, such as coconut fiber logs, oyster shells, and native plants, to provide shoreline protection and other ecosystem services.

Management Conference: The Core Partners of the Delaware Estuary Program Management Conference include representatives of the Delaware Department of Natural Resources and Environmental Control (DNREC), the New Jersey Department of Environmental Protection (NJDEP), the Pennsylvania Department of Environmental Protection (PADEP), Regions 2 and 3 of the US Environmental Protection Agency (EPAR2, EPAR3) the City of Philadelphia's Water Department (PWD), and the Board of Directors of the Partnership for the Delaware Estuary (PDE).

Mitigation Projects: Projects completed to offset planned damage natural resources, such as wetlands, streams, etc., suffer.

Municipal Separate Storm Sewer System (MS4): A piping system that conveys only stormwater (not combined sewer) to waterways (not a wastewater treatment plant), that is owned by a municipal public entity (state, city, town, village, etc.). Under the National Pollutant Discharge Elimination System program (NPDES), some MS4 communities are regulated to minimize effects from stormwater pollution.

Native species: Species that are found naturally and thrive in a specific ecosystem.

Nature-based: Practices that incorporate and enhance nature and natural features to address concerns such as flooding, pollution, etc., while helping maintain and improve ecological function and resiliency of important habitats.

Nonpoint source pollution: Pollution that derives from different sources over a large area, rather than from one identifiable location. For example, nonpoint source pollution can include sediment from farms, fertilizers from yards, and pet waste runoff, among others.

Nutrient loading: The amount of nutrients entering a waterbody over a certain period.

Ocean acidification: The condition in which the ocean water's pH decreases and becomes more acidic because more carbon dioxide (CO_2) enters the ocean as a result of climate change. This can result in harmful changes to coral reefs and other calcifying species in the oceans.

Point source pollution: Pollution derived from a single, definite source, such as waste water treatment plants, outfalls, etc.

Pollutant loading: The amount of pollutant or substance entering a waterbody over a certain period. Propagation (fish): Helping fish reproduce with parent stock through natural processes (such as a fish hatchery).

Propagation (fish): Helping fish reproduce with parent stock through natural processes (such as a fish hatchery).

Remediation: Removing chemicals, pollution, and/or contaminates to rectify environmental damage and in some cases promote redevelopment.

Riparian: Referring to the area or habitat that is situated along the riverbank or next to a river. Salt-water intrusion: The process of salt water creeping inland gradually as a result of rising sea levels, overuse of groundwater, etc.

Salt-water intrusion: The process of salt water creeping inland gradually as a result of rising sea levels, overuse of groundwater, etc.

Shell planting: Placing oyster shells in waterways to increase oyster habitat on which populations grow. Spawning: Related to an organism's reproduction, such as releasing eggs.

Spawning: Related to an organism's reproduction, such as releasing eggs.

Steering Committee: Committee comprised of agency leaders that work together to provide the policy and financial framework needed to set and achieve goals for the Delaware Estuary as part of the National Estuary Program.

Stormwater runoff: Water generated by storms in the form of rain or snow that flows over land or impervious surfaces and enters streams rather than infiltrating into the ground. Stormwater runoff often carries nutrients and sediments from the land and therefore, is a type of nonpoint source pollution.

Strategy: The plan of action that DELEP and other partners will take to reach the revised CCMP's common goals and objectives.

Superfund site: A site or area contaminated by hazardous waste that the U.S. Environmental Protection Agency has selected for remediation.

Sustainable: Population or resource is used in a way that is not damaging or depleting.

Total Maximum Daily Load: The regulated amount of a pollutant that is permitted to enter an impaired waterway to comply with water quality standards.

Tributary: A waterway that drains to a larger stream or river.

Underserved communities: A community with environmental justice concerns and/or vulnerable populations, including minority, low income, rural, tribal, and indigenous populations, as defined by the U.S. Environmental Protection Agency.

Water quality: The chemical, physical, and biological components of water; implies whether a stream or river is sufficiently healthy to support humans, plants, and animals.

Watershed: Area of the land that drains to a single water body, also referred to as a drainage basin or catchment.

Wetlands: Land that is saturated with water constantly or seasonally and can include marshes (tidal or non- tidal), bogs, and swamps.

Working waterfront: Areas where high economic value and high ecological value intersect. These areas are important because of the recreation and tourism opportunities they offer, as well as existing or potential fisheries or industries dependent on the Estuary.

Acronyms and Abbreviations

ANJEC	Association of New Jersey Environmental Commission
ASMFC	Atlantic States Marine Fisheries Commission
AWWA	American Water Works Association
BMP	Best Management Practices
CCMP	Comprehensive Conservation and Management Plan
COC	Contaminants of Emerging Concern
DELEP	Delaware Estuary Program
DELSI	Delaware Estuary Living Shoreline Initiative
DNREC	Delaware Department of Natural Resources and Environmental Control
DRBC	Delaware River Basin Commission
DRBOSAC	Delaware River and Bay Oil Spill Advisory Committee
DRWI	Delaware River Watershed Initiative
DVRPC	Delaware Valley Regional Planning Commission
EIC	Estuary Implementation Committee
EPA	U.S. Environmental Protection Agency
ERDG	Ecological Research & Development Group
FEMA	Federal Emergency Management Agency
GI	Green Infrastructure
GPRA	Government Performance and Results Act
IAPMO	International Association of Plumbing and Mechanical Officials
IWA	International Water Association
MACC	Monitoring Advisory and Coordination Committee
MACWA	Mid-Atlantic Coastal Wetland Assessment
MCL	Maximum Contaminant Levels
MS4	Municipal Separate Storm Sewer System
NEP	National Estuary Program
NEPORT	National Estuary Program Reporting Tool
NFWF	National Fish and Wildlife Foundation
NJDEP	New Jersey Department of Environmental Protection
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
OSI	Open Space Institute
PADEP	Pennsylvania Department of Environmental Protection
PCB	Polychlorinated Biphenyl
PDE	Partnership for the Delaware Estuary
PFAS	Perfluorinated and Polyfluorinated Alkyl Substances
PMP	Pollutant Minimization Plan
POTW	Publicly-owned Treatment Works
PPCP	Pharmaceutical and Personal Care Products
PWD	Philadelphia Water Department
RARE	Regionally Applied Research Effort
RCRA	Resource Conservation and Recovery Act
RIMS	Regional Information Management System
RRI	Regional Restoration Initiative
RSM	Regional Sediment Management
RSMIW	Regional Sediment Management Implementation Workgroup
RSMP	Regional Sediment Management Plan
SAN	Schuylkill Action Network
SC	Steering Committee
SMP	Species Management Plan
STAC	Science and Technology Advisory Committee
STEM	Science, Technology, Engineering, and Math
TMDL	Total Maximum Daily Load
TREB	Technical Report for the Delaware Estuary and River Basin
TSCA	Toxic Substances Control Act
TSS	Total Suspended Solids
UPC	Uniform Plumbing Code
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WATAR	Watershed Approach to Toxics Assessment and Restoration

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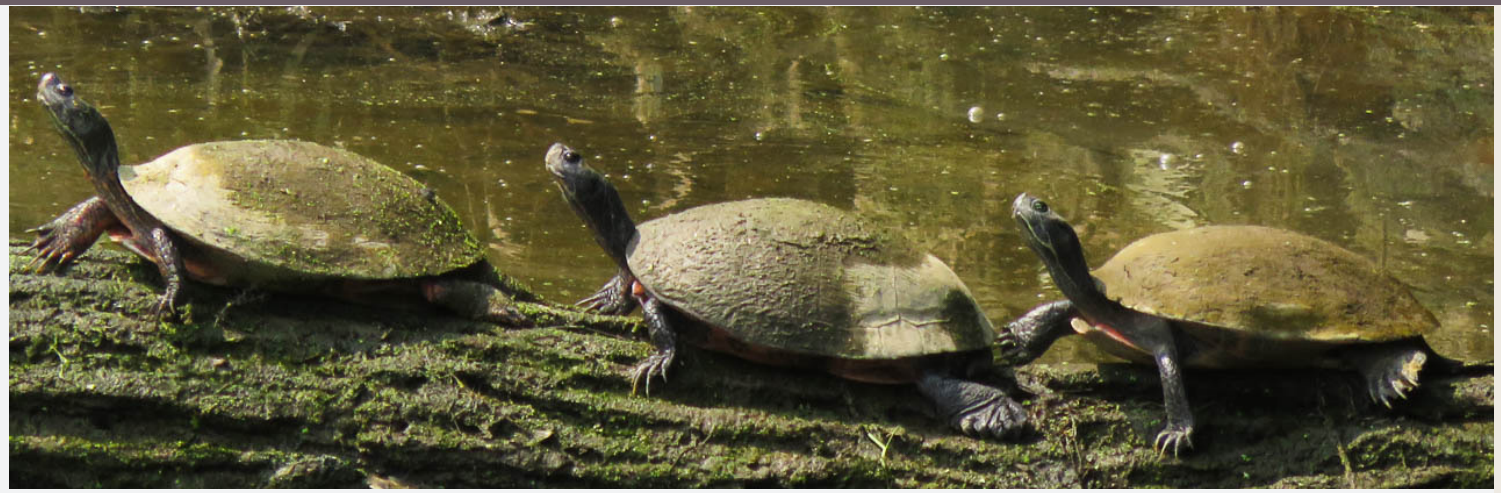
Supporting Documents

CCMP Index of Actions

Climate Change and the Delaware Estuary: Three Case Studies in Vulnerability Assessment and Adaptation Planning – Partnership for the Delaware Estuary

Climate Vulnerability Assessment Report

Contaminants of Emerging Concern in the Tidal Delaware River, Pilot Monitoring Survey 2007 to 2009 – Delaware River Basin Commission



Silver Lake, Middletown, DE | Credit: Wil Scott

Delaware Estuary: Discover its Secrets: A Management Plan for the Delaware Estuary 1996 CCMP – Delaware Estuary Program

Delaware River and Bay Oil Spill Advisory Committee Report – DRBOSAC

DELEP Partner Agreement 2014

Economic Value of the Delaware Estuary Watershed – Institute for Public Administration, University of Delaware

NEP DELEP Frequently Asked Questions

Phase 2 Stakeholder Engagement Summary Report

Regional Restoration Blueprint Report – Partnership for the Delaware Estuary

Revised CCMP Public Comment Period Summary Report State of the Delaware River Basin Report 2013 – Delaware River Basin Commission

State of the Delaware River Basin Report 2008 – Delaware River Basin Commission

State of the Delaware Estuary 2012 – Partnership for the Delaware Estuary.

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State of the Delaware Estuary 2002 – Partnership for the Delaware Estuary

Technical Report for the Delaware Estuary and Basin 2017 – Partnership for the Delaware Estuary