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U.S. Fish & Wildlife Service

The Hackensack Meadowlands Initiative

Preliminary Conservation Planning

U.S. Fish & Wildlife Service

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Preliminary Conservation Planning for the Hackensack Meadowlands Hudson and Bergen Counties, New Jersey

Prepared by:

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Satellite image of the Hackensack Meadowlands District (boundaries in red) and the surrounding metropolitan region.

The Hackensack Meadowlands Initiative

The Hackensack Meadowlands is the largest brackish estuarine complex in the New York – New Jersey Harbor Estuary and among the largest in the northeastern United States. The Meadowlands supports remarkable biodiversity. Using the Meadowlands are more than 275 species of plants, 115 species of invertebrates, 45 species of fish, 25 species of amphibians and reptiles, 332 species of birds, 24 species of mammals, and approximately 25 State-listed species, and 42 species considered rare or uncommon in the urban core. Yet, over the last 150 years, industry and development have filled in well over half of the area's original 21,000 acres, polluting its lands and waters. Invasive exotic species, environmental contaminants, and water quality are major issues confronting the successful restoration of the Meadowlands.

In 2001, the U.S. Fish and Wildlife Service (Service) established the *Hackensack Meadowlands Initiative* to promote and support the remediation, restoration, and long-term protection of the Meadowlands ecosystem. Over the next few years, the *Initiative* evolved as the Service partnered with other federal and State agencies in various efforts, such as stakeholder workshops and a scientific symposium focused on the Meadowlands. The partners in the Service's *Initiative* now include the U.S. Army Corps of Engineers' New York District, U.S. Environmental Protection Agency's Region 2, National Park Service, National Marine Fisheries Service, New Jersey Meadowlands Commission, and New Jersey Division of Fish and Wildlife. The *Initiative* seeks to build communication and collaboration among stakeholders and, even more importantly, to develop and implement comprehensive measures to clean up, restore, and protect this extensively degraded, coastal ecosystem. The *Initiative* partners are already engaged in numerous clean-up, restoration, and related projects throughout the Meadowlands.

In response to Congressional direction, the Service has developed this document, titled *The Hackensack Meadowlands Initiative: Preliminary Conservation Planning*, to promote successful clean-up and restoration projects and to encourage the critical and much-needed support of other regional activities (*e.g.*, water-supply, sewage-treatment, and flood-control planning). Successfully cleaning up and restoring the Meadowlands and integrating those actions with other regional planning will not only help protect the region's fish and wildlife but will also provide recreational and educational opportunities for the 20 million residents in the surrounding metropolitan area.

This planning document is submitted to our partner agencies to provide a framework for the restoration and protection of the Meadowlands ecosystem. The document represents the findings, recommendations, and conclusions of the Service; it identifies key issues, important fish and wildlife resources, and critical data gaps, and proposes a common vision to guide all future restoration efforts. The Service provides the document as a springboard for addressing key issues and finding the common ground that will be critical to restoring the Meadowlands ecosystem and protecting its fish and wildlife resources. Working together, guided by a common vision, we can restore the Meadowlands ecosystem.

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is working with others to conserve, protect and enhance fish, wildlife, plants and their habitats for the continuing benefit of the American people.

The U.S. Fish and Wildlife Service is the principal federal agency responsible for conserving, protecting and enhancing fish, wildlife and plants and their habitats for the continuing benefit of the American people. The agency manages the 96-million-acre National Wildlife Refuge System, which encompasses 547 national wildlife refuges, thousands of small wetlands and other special management areas. The Service also operates 70 national fish hatcheries, 64 fishery resources offices, 9 fish health centers, 7 fish technology centers, and 81 ecological services field stations. The agency enforces federal wildlife laws, administers the Endangered Species Act, manages migratory bird populations, restores nationally significant fisheries, conserves and restores wildlife habitat such as wetlands, and helps foreign and Native American tribal governments with their conservation efforts. It also oversees the *Federal Assistance* program, which distributes hundreds of millions of dollars in excise taxes on fishing and hunting equipment to state fish and wildlife agencies.

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DEDICATION AND ACKNOWLEDGMENTS

This plan is dedicated to Clifford Grant Day, who retired as this report was being completed. Cliff began his long, successful career with the U.S. Fish and Wildlife Service as a biologist working out of a trailer in the E.B. Forsythe National Wildlife Refuge. In 1987, following a special 2-year assignment in Washington, he was appointed Supervisor of the New Jersey Field Office, where he worked diligently for more than 20 years to protect fish and wildlife throughout New Jersey. As everyone who knew him can attest, Cliff's passion was the protection of the Hackensack Meadowlands. He recognized its importance and envisioned its revitalization long before it was a popular stance. Without his tireless efforts over many years, the Meadowlands would have been greatly diminished and its future would not be so assured.

This report was prepared pursuant to Congressional directives, including P.L. 109-54 (see H.R. 109-80) for Fiscal Year 2006, for advancing restoration and long-term protection of the Hackensack Meadowlands ecosystem. The U.S. Fish and Wildlife Service (Service) thanks Congressman Steven R. Rothman (NJ 9th District) for his continued interest and support of Service programs and his commitment to restoring and protecting the Meadowlands.

This planning report was prepared primarily by Stanton Hales, John Staples, and Clifford Day of the Service's New Jersey Field Office (NJFO). All NJFO staff contributed to this product. In particular, Brian Marsh and Timothy Kubiak contributed to the environmental contaminants sections; Carlo Popolizio provided botanical information; Wendy Walsh, Ronald Popowski, and Timothy Kubiak reviewed the draft; James Cramer and Gene Nieminen provided editorial comment, graphics assistance, and other support. Unless referenced otherwise, the photography in this report is by Gene Nieminen. Ralph Tiner, Herbert Bergquist, and John Swords (National Wetlands Inventory, Northeast Regional Office) provided information and maps used in the land-use sections. Sarah Bevilacqua, Joseph Dowhan (retired), Susan Essig, Robert Foley, Andrew Milliken, Ralph Tiner (Northeast Regional Office), and Donald Henne (Southern New England-New York Bight Coastal Ecosystems Program) provided review and critique of the draft manuscript.

Development of the *Hackensack Meadowlands Initiative* would not have been possible without the support of Mamie Parker and Marvin Moriarty, former and current Regional Directors, respectively, of the Service's Northeast Region. The Service is also appreciative of Lynn Dwyer and the National Fish and Wildlife Foundation for their assistance and support of the *Initiative*.

Personnel at other federal agencies contributed to this report. In particular, the Service thanks James Cannon, Leonard Houston, George Nieves, William Shadel, and Bryce Wisemiller (U.S. Army Corps of Engineers, New York District), Mario Paula and Marianne Thiesing (U.S. Environmental Protection Agency, Region II), Carl Alderson and Craig Woolcott (National Oceanic and Atmospheric Administration, Restoration Center), Karen Greene (National Marine Fisheries Service, Habitat Conservation Division), Timothy Wilson (U.S. Geological Survey, N.J. Water Science Center), and Michael Erwin (U.S. Geological Survey, Patuxent Wildlife Research Center).

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Appreciation is also extended to U.S. Senator Frank Lautenberg and Governor Jon Corzine for their continuing support of the *Hackensack Meadowlands Initiative*. Their respective staff, especially Lisa Plevin of Senator Lautenberg's office and Mada Liebman of U.S. Senator (now Governor) Jon Corzine's office have supported the *Initiative* since its inception.

The Service thanks the many nongovernmental organizations active in environmental issues in the Meadowlands. The Service especially thanks William Sheehan and Hugh Carola (Hackensack Riverkeeper, Inc.), Tina Schvejda (Meadowlands Conservation Trust), Dennis Schvejda (Sierra Club), Mark Becker (Bergen Save-the-Watershed-Action-Network), Andrew Willner and Gregory Remaud (New York-New Jersey Baykeeper), Erik Kiviat (Hudsonia, Inc.), Dennis Suskowski (Hudson River Foundation), Craig Kessler (Ducks Unlimited, Inc.), Emile DeVito (New Jersey Conservation Foundation), and Richard Kane (retired), David Mizrahi, and Eric Stiles (New Jersey Audubon Society).

Numerous biologists and others familiar with the Meadowlands, its biota, history, restoration, and other topics contributed information important to the development of this report. The Service apologizes for any inadvertent omissions or other errors to those who gave so much of their time, knowledge, and experience in support of this preliminary conservation planning effort.

EXECUTIVE SUMMARY

The *Hackensack Meadowlands Initiative: Preliminary Conservation Planning* (Plan) was prepared by the U.S. Fish and Wildlife Service (Service) to provide a foundation for enhancement and restoration of the Hackensack Meadowlands in Hudson and Bergen Counties, New Jersey and to promote a vision for the Meadowlands. The Service's vision includes: (1) a more natural estuarine ecosystem with healthy fish and wildlife resources; (2) a cleaner environment (progressive reduction in acute and chronic contaminant effects); (3) diverse wetland and associated communities that sustain local and regional populations of native species, including federal trust fish and wildlife resources; and (4) public commitment to and diverse social benefits from the Meadowlands. To attain this vision, the Service's overall goal for the Meadowlands is to sustain and safeguard the Meadowlands ecosystem, including its fish and wildlife resources. This goal will be achieved through conservation partnerships to remediate, enhance, restore, manage, and protect the Meadowlands ecosystem. The Plan also identifies key principles, drawn from federal policies and other guidance, to guide and carry out habitat restoration activities. The Plan provides a historical overview of the region, describes the ecosystem and its biodiversity, identifies priority threats to the Meadowlands, and recommends objectives and future conservation actions.

The Plan is formulated pursuant to Congressional direction (P.L. 109-54; see H.R. 109-80) to provide assistance to the federal effort to restore and protect the Meadowlands ecosystem. Recommendations and conclusions in this Plan are based on available information from federal, State, and other sources, and were offered to agencies prior to the release of this report for their review and concurrence and for incorporation in ongoing or future restoration efforts (*e.g.*, U.S. Army Corps of Engineers- and New Jersey Meadowlands Commission-funded Hackensack Meadowlands Environmental Restoration). Some of the Service's recommendations focus on actions of specific agencies or groups; however, most recommendations are directed toward all stakeholders in the Meadowlands, including: (1) federal, State, and local government agencies operating pursuant to existing authorities, (2) non-governmental organizations, and (3) the public. Implementation of these recommendations extends beyond the authorities and capabilities of any single stakeholder and exceeds financial and other resources presently committed to restoring the Meadowlands.

The Hackensack Meadowlands is the largest brackish estuarine complex in the New York-New Jersey Harbor and among the largest in the northeastern United States. When Europeans arrived, the area comprised more than 21,000 acres of waterways and wetlands, including a substantial portion (roughly one-third) forested with Atlantic white-cedar. Since then, the Meadowlands has been subject to nearly 400 years of resource extraction, habitat loss, alteration, and degradation. The Meadowlands is heavily contaminated with PCBs, dioxins, and other contaminants from Superfund sites along the Hackensack and adjoining rivers. Included among its contaminant "hot-spots" is possibly the worst mercury-contaminated wetland in North America (Berry's Creek). Flows in the Hackensack and adjoining rivers also have been dammed and diverted to supply municipal drinking water in the heavily urbanized region. Secondary sewage effluent now comprises the largest source of freshwater in the Meadowlands, and contributes to

numerous impairments in water quality throughout the Hackensack River watershed. Today, approximately 5,800 acres of estuarine wetlands remain in the Meadowlands' 8,400-acre complex of wetlands and waterways. These remaining wetlands reflect extensive landscape and hydrologic alterations (*e.g.*, fragmentation, extensive development of adjoining upland buffers), and are dominated by invasive species, especially a non-native form of common reed, which has spread throughout the Meadowlands.

Despite these problems, the Meadowlands remains an oasis of biodiversity in one of the largest and most heavily populated metropolitan areas in the northeastern United States. The Meadowlands has been documented as home to more than 275 species of plants, 115 species of invertebrates, 45 species of fish, 25 species of amphibians and reptiles, 332 species of birds, and 24 species of mammals. Many taxa have not been well studied; some historical populations no longer exist. Among the species that occur in the Meadowlands are approximately 90 species of special conservation status, including species identified as federally listed (endangered or threatened), State-listed (endangered or threatened), "of special concern," or managed.

Several agencies and non-governmental organizations have begun efforts to acquire wetlands, restore specific sites, and manage certain fish and wildlife resources. Such activities are moving environmental restoration forward; however, problems encountered (*e.g.*, *Phragmites* reinvasion, contaminants) make clear the need for, and importance of, improved collaboration, comprehensive planning, and adaptive management to remediate, enhance, and restore the Meadowlands ecosystem and protect its biodiversity. Development of a comprehensive remediation and restoration plan is critical to address the substantial, complex, and inter-related problems confronting the Meadowlands ecosystem. Detailed investigations of the movements, diets, and reproduction of fish and wildlife species in the Meadowlands and broader research efforts throughout the region are needed to guide remediation and restoration on contaminated sites. Otherwise, restoration activities may create "attractive nuisances" for fish and wildlife by increasing availability of contaminants and subsequent accumulation in fish and wildlife using restored wetlands. Also, implementation of existing water-quality criteria and development of such criteria for additional contaminants are necessary to address the impaired functioning of the Meadowlands ecosystem and the health of its fish and wildlife and people. Protecting wetlands and adjoining upland buffers throughout the entire Hackensack River watershed is critical to address impairments to water quality and to provide habitats for sustaining fish and wildlife throughout the region.

Important collaborative efforts for all stakeholders include developing a protocol to guide removal of the invasive form of common reed from heavily contaminated sites and identifying the desired long-term recovery goals (*e.g.*, vegetative communities) to be achieved through restoration. Concerted remediation, restoration, management, and planning efforts provide an opportunity for stakeholders to reverse and rectify historical, adverse land-use impacts on the Meadowlands ecosystem and its biota. Stakeholders must also explore designation of the Meadowlands as a type of marine/estuarine protected area to promote and provide comprehensive long-term protection.

The Meadowlands represents a valuable natural resource within driving distance to 20 million people in the greater NY-NJ metropolitan area. Therefore, the restoration and protection of the Meadowlands must also provide for compatible recreational uses (*e.g.*, fishing, hunting, wildlife photography), while sustaining and safeguarding fish and wildlife. Restoration efforts must also contribute to a new public image for the Meadowlands as an important ecological area worthy of protection and preservation. Expansion of formal and informal educational programs, demonstration projects and other public exhibits, and a unified outreach program are essential to nurture and sustain the public's strong support for restoring the Meadowlands.

Because restoration activities will likely require a substantial and lengthy commitment at all levels of government, the Service recently established the *Hackensack Meadowlands Initiative* to provide a venue open to all agencies and organizations for communication and coordination regarding any issues that potentially affect the restoration of the Meadowlands ecosystem. To lead this *Initiative*, the Service encourages federal and State agencies to improve current restoration efforts in the Meadowlands by developing an interagency memorandum of agreement that formalizes establishment of an oversight committee known as a principals' group. The principals' group would develop a collaborative process to ensure that coordination on restoration and related objectives is being accomplished. The group would provide federal and State agencies with an organized forum to discuss policy and fiscal matters, to better coordinate existing staff and funding, and to promote the recovery of the entire ecosystem.

In providing this Plan, the Service seeks to increase its efficiency and effectiveness on a landscape level. This Plan is consistent with the Service's current emphases of ensuring greater voluntary compliance with environmental laws and regulations, developing conservation partnerships, and increasing its influence with individuals and organizations that can help accomplish goals on a landscape level. The Service's current overall goals include restoring habitats, remediating environmental contaminants, controlling invasive species, and protecting native fish and wildlife populations long-term.

This planning document represents the findings, recommendations, and conclusions of the Service, and is submitted to our partner agencies to provide a baseline and framework for the restoration and protection of the Meadowlands ecosystem. The Service provides the Plan to facilitate addressing the key issues and finding the common ground to restore and protect the Meadowlands ecosystem and its fish and wildlife resources. We thank *Initiative* partners for their review and comments on earlier drafts, and invite all partners to support this conservation planning effort.

The U.S. Fish and Wildlife Service requests that no part of this document be taken out of context and thus, that the document be distributed only in its entirety. This document is intended for conservation planning purposes only and does not constitute an endorsement by the U.S. Fish and Wildlife Service or the U.S. Department of the Interior for a formal land-use plan or project or to establish a National Wildlife Refuge in the Hackensack Meadowlands.

Questions, comments, and suggestions related to this document are encouraged and should be directed to:

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I. The Hackensack Meadowlands Initiative

Mallards (*Anas platyrhynchos*) in flight.

I. The Hackensack Meadowlands Initiative

A view of Manhattan from New Jersey (upper); mallards in flight (lower).

Just 7 miles west of Manhattan, the Hackensack Meadowlands represents one of the largest brackish estuarine complexes in the northeastern United States. The Meadowlands ecosystem attracts and variously supports a remarkable diversity and abundance of fish and wildlife, including federal trust resources such as migratory birds (*e.g.*, mallard ducks [*Anas platyrhynchos*] above, and bufflehead [*Bucephala albeola*] on facing page). As one of the largest contiguous areas of open space remaining in the urban Northeast, the Meadowlands has become increasingly important for fish and wildlife species throughout the region.

The U.S. Fish and Wildlife Service has established the *Hackensack Meadowlands Initiative* as a collaboration of federal, State, and local stakeholders to address the problems created by past land use of the Meadowlands and to provide long-term protection for its biodiversity. Working together with partners, the Service envisions a more natural Meadowlands ecosystem, a progressively cleaner environment that sustains healthy species, diverse biological communities comprised predominantly of native fishes and wildlife, and a natural environment that will provide social, recreational, educational and other benefits. Public support that will improve the quality of life for people throughout the urban area is needed to realize this vision.

A view of the Sawmill Creek Wildlife Management Area.

Bufflehead (*Bucephala albeola*) in flight.

I. THE HACKENSACK MEADOWLANDS INITIATIVE

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Bufflehead in flight.

I. THE HACKENSACK MEADOWLANDS INITIATIVE

The Mission of the U.S. Fish and Wildlife Service (Service) is to *work with others to conserve, protect and enhance fish, wildlife, and plants and their habitats for the continuing benefit of the American people*. In partial fulfillment of this Mission, the Service has worked in close collaboration with other federal and State agencies, non-governmental organizations, and the public to protect the Hackensack Meadowlands from further degradation. The challenge now is to develop effective partnerships to protect, remediate[1], enhance[2], restore[3], and manage the Meadowlands. Thus, the Service developed *The Hackensack Meadowlands Initiative* (*Initiative*) as a collaborative effort among federal, State, and local stakeholders to coordinate the remediation, enhancement, restoration, and long-term protection of this ecosystem (Figure 1).

The Service presents this document titled *The Hackensack Meadowlands Initiative: Preliminary Conservation Planning* (Plan) to our *Initiative* partners and other stakeholders to provide a framework for restoring and protecting the Meadowlands ecosystem. As documented in the following pages, the Meadowlands has endured centuries of misuse yet still supports substantial fish and wildlife resources. Cleaning up and restoring its wetlands and adjoining uplands will not only help improve the health of fish and wildlife, but will also provide unparalleled opportunities for education and recreation and a better quality of life for people in the region. The Service provides the document to identify critical issues and work toward the common ground to advance restoration and long-term protection of the Meadowlands ecosystem. The purpose of the Plan is twofold: to provide a technical foundation for the restoration of the Meadowlands ecosystem, including its fish and wildlife resources; and to promote the Service's vision for the Meadowlands. The Service's vision for the Meadowlands includes providing for:

(1) a more natural[4] estuarine ecosystem with healthy fish and wildlife resources;

(2) a cleaner environment (progressive reduction in acute and chronic contaminant effects);

(3) diverse wetland and associated communities that sustain local and regional populations of native species, including federal trust fish and wildlife resources; and

(4) public commitment to and diverse social benefits from the Meadowlands.

---

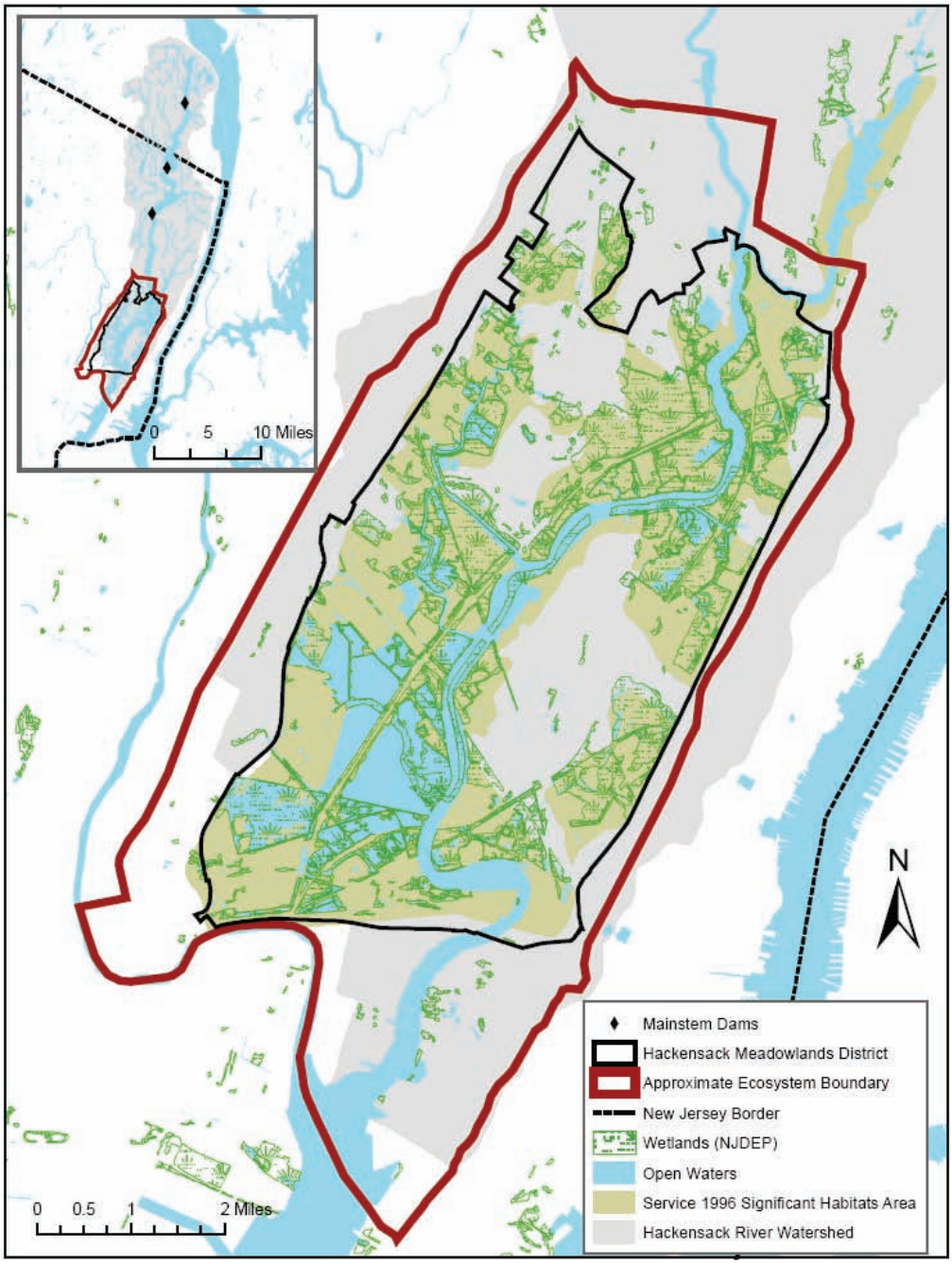
[1] Remediate- to correct or treat pollution, usually by actions that stabilize, contain, entomb, neutralize, remove, or destroy the hazardous material in accordance with specific federal or State regulations. (See the Glossary for additional detail on this and other definitions.)

[2] Enhance- to manipulate the physical, chemical, or biological characteristics of a site for a specific purpose (*e.g.*, invasive species control) or to improve a specific function (*e.g.*, marsh production, habitats for target species).

[3] Restore- to return historical functions and/or conditions (not necessarily functions or conditions that existed prior to human disturbance) to a former or degraded wetland by manipulating its physical, chemical, or biological features.

[4] Natural- as used here, indicating an ecosystem in which diverse conditions (*e.g.*, nutrient concentrations, water quality) and functions (*e.g.*, biogeochemistry, biodiversity) do not reflect extensive human activities or disturbance.

Figure 1. The Hackensack Meadowlands ecosystem. As used throughout this document, the Hackensack Meadowlands ecosystem refers to the open waters (includes both subtidal and intertidal areas), wetlands, former wetlands, and upland buffers along the lower Hackensack River and its tidal tributaries. Though ecosystems lack precise boundaries, this ecosystem roughly corresponds to the area outlined in red below. Note that this area is larger than the State-designated Hackensack Meadowlands District, shown outlined in black, and mostly lies within the Hackensack River watershed, shown in gray in the inset in the upper left.



With this Plan, the Service makes clear that protecting the Meadowlands ecosystem is an essential part of fulfilling the Service's Mission in the northeastern United States.

A. INTRODUCTION

The Hackensack Meadowlands is the largest brackish estuarine complex in the New York-New Jersey (NY-NJ) Harbor and among the largest in the northeastern United States (Tiner *et al.*, 2002). While changes have occurred throughout the 400 years since European colonization and settlement in the Northeast, it is during the past century that most of the Meadowlands has been extensively developed, lost, and seriously degraded, resulting in fragmentation of and functional impairments to the remaining habitats for fish and wildlife. Exotic species, both aquatic and terrestrial, have also proliferated and spread throughout the Meadowlands, further altering its ecosystem functioning and diminishing its biodiversity and value to fish and wildlife. Nonetheless, the Meadowlands remains one of the largest contiguous areas of open space in the urban Northeast that is available to wildlife. The remediation, enhancement, restoration, and protection of its wetlands and adjoining uplands are increasingly important to fish and wildlife resources at local, regional, and larger scales, and thus have become the primary focus of the HMI. Furthermore, *restoration of the Meadowlands to a healthy, productive ecosystem can improve the quality of life for 20 million people in the NY-NJ Harbor area*. These improvements to the quality of life include direct benefits such as the appreciation of land values, recreation, and non-consumptive uses (*e.g.*, wildlife observation, education) of wildlife by the public and indirect benefits resulting from various ecosystem functions, including flood control and improvements to water quality.

Public attitudes toward the Hackensack Meadowlands have changed considerably over the past 45 years. In 1960, the Meadowlands Regional Development Agency (1961) was formed by 14 municipal governments with the charter of "reclaiming" and developing the Meadowlands. Hundreds of acres of the wetlands were filled each year for residential and industrial development, transportation corridors, and other rights-of-way, while land unsuitable for such development had other uses. By 1969, open landfills for garbage occupied nearly 10 percent of the Meadowlands and had greatly degraded the area (Hackensack Meadowlands Development Commission, 1978). Acknowledging a mounting waste-management problem and growing environmental concerns (*e.g.*, poor air and water quality), the State of New Jersey established the Hackensack Meadowlands Development Commission (HMDC) to develop the area, accommodate the disposal of garbage, and protect the "balance of nature."

Beginning with the 1973 decision to prohibit dumping of out-of-state garbage, waste disposal in the Hackensack Meadowlands District (HMD) was gradually reduced. Nonetheless, filling of hundreds of acres of wetlands continued each year through the mid-1980s. Although the filling of wetlands later slowed, pressure to continue filling wetlands for development in the Meadowlands remained strong until the late 1990s. With increasingly vocal public opposition to the filling of wetlands, development, and further encroachment into the Meadowlands, along with a greater public awareness of its considerable fish and wildlife resources, development activities in the Meadowlands began to stall between 2000 and 2001. Recognizing the change in public attitudes and the need to reassess its development mandate, the State of New Jersey

renamed the HMDC in 2001 as the New Jersey Meadowlands Commission (NJMC) to emphasize a renewed commitment to environmental protection.

The Service has long faced challenges in its efforts to protect the Hackensack Meadowlands. In the past, the Service primarily worked within federal statutory authorities (Section D below) to protect fish and wildlife resources in the Meadowlands, largely through review of proposals for activities affecting wetlands under Section 404 of the Clean Water Act (CWA; 33 U.S.C. 1344 *et seq.*) and Section 10 of the Rivers and Harbors Appropriations Act of 1899 (33 U.S.C. 403 *et seq.*). Application of such authorities, although moderately successful, repeatedly placed the Service in a controversial role as an "opponent" to those groups that continued to promote plans to develop the Meadowlands. Now, with broad government and public support for protecting and restoring the Meadowlands, the Service is not only changing but also expanding its role to influence land-use planning. The challenge now is to foster collaboration that will build effective partnerships to remediate, enhance, restore, and ultimately protect the Meadowlands ecosystem.

B. PRELIMINARY CONSERVATION PLANNING: GOAL, OBJECTIVES, AND PRINCIPLES

1. Goal and Objectives

To attain its vision for the Meadowlands, the Service's overall *goal* for the Meadowlands is to sustain and safeguard the Meadowlands ecosystem, including its fish and wildlife resources. This goal will be achieved through conservation partnerships to remediate, enhance, restore, manage, and protect the Meadowlands ecosystem. The broad, major *objectives*[5] of the Service's Plan are to work with its partners to:

(1) promote, and where appropriate, lead efforts for land acquisition, remediation, enhancement, restoration, and management of the Hackensack Meadowlands;

(2) increase scientific understanding to better define successful remediation and restoration and to enhance ecosystem functions and natural dynamic processes, especially through activities that remediate contaminated sites and improve water quality;

(3) establish diverse, native wetland and upland vegetative communities, to include greater acreage and diversity of forest, shrub, grassland, and wetland cover types to support biodiversity at local, regional, and larger scales; and

(4) increase responsible use of, public awareness of, and education about the Meadowlands, including its flora and fauna.

[5] Objective- used here in a broad sense, as a component of a goal. Most objectives identified here are general; more specific (*i.e.*, measurable) objectives will be established by technical stakeholder groups.

This Plan is not a technical blueprint for clean-up and restoration of individual parcels within the Meadowlands, but it provides an initial framework for remediation, enhancement, restoration, and protection based upon the best available information in restoration ecology, ecotoxicology, conservation biology, wildlife management, and related technical disciplines. In many cases, the Plan identifies data gaps where the best available information is insufficient to address the complex problems in the Meadowlands. The Plan does not provide immediate solutions to obvious (*e.g.*, environmental contaminants) or even subtle (*e.g.*, habitat fragmentation) problems that have grown increasingly worse in the Meadowlands over many decades, but does identify critical fish and wildlife resources, prioritizes concerns, and initiates development of common objectives and relevant tasks. Another intent of the Plan is to make its readers aware that *despite serious environmental impacts, the Meadowlands still provides critical ecosystem functions (e.g., biogeochemical cycling of nutrients, flood storage) and supports a remarkable and tenacious biodiversity (e.g., 75 percent of New Jersey's avifaunal species and over 25 State-listed species).* With additional enhancement and other conservation actions, the ecosystem functions provided by the Meadowlands and the value of its habitats to wildlife can be increased.

This Plan presents a technical foundation to inspire and influence future land-use decisions that will sustain and safeguard the Meadowlands ecosystem. Drawing extensively on the Service's and other stakeholder's efforts and products, this Plan identifies the benefits and challenges of restoring the Meadowlands. The remainder of this chapter (Section I) introduces the Service's restoration principles, authorities, responsibilities, and past involvement in the Meadowlands. Section II describes the human use history of the Meadowlands, whereas Section III describes the natural history and identifies important fish and wildlife resources of the Meadowlands. Sections IV through VI identify major technical challenges to restoration; Sections VII through IX present acquisition, restoration, protection, management, and social objectives; and Section X addresses planning and coordination issues. Section XI provides an organized compilation of the recommendations identified in the preceding sections; and finally, Section XII presents the Service's conclusions.

Throughout this Plan, the Service has identified important data gaps and critical issues. The need for additional information to guide decision-making regarding remediation and other activities is a constant theme throughout the Plan. Remediation, enhancement, and restoration can be structured to achieve many different objectives and goals in the Meadowlands. The challenge to achieve *successful* remediation, enhancement, restoration, and ultimately, the protection of the Meadowlands and its fish and wildlife resources is formidable. These actions require a deliberative and iterative approach based on sound information, including numerous kinds and types of information from sites in the Meadowlands, and in some cases, the surrounding region. Whether restoring vegetative cover types, managing regional water supplies and hydrology, addressing impairments to overall water quality, remediating contaminated sites and nearby wetlands, controlling invasive species, or improving the health of species chronically contaminated, collaboratively defined success metrics or performance measures for these activities must be established for comparison with information acquired from regular monitoring of sites throughout the Meadowlands to guide and improve subsequent actions. How all stakeholders work together to address these challenges will be critical. While it is unrealistic to propose that all of the problems of the Meadowlands can be completely eliminated by

remediation, enhancement, and restoration, thoughtful planning, careful implementation, and sound science-based management can improve the Meadowlands for fish, wildlife, and people.

Many dedicated groups and individuals have worked tirelessly to stop further encroachment and degradation of the Meadowlands; this Plan should make clear that the vital work to save the Meadowlands and its biodiversity has just begun and will require substantial effort by many stakeholders.

2. Restoration Principles

Any recommendations, technical assistance, planning, and other actions that the Service promotes and undertakes to achieve its vision, goal, and objectives for the Meadowlands will conform to federal guidance on estuarine restoration. The following restoration principles were drawn from: (1) the *Final Estuary Habitat Restoration Strategy Prepared by the Estuary Habitat Restoration Council* (*Federal Register*, Vol. 67, No. 232, December 3, 2002), which included representatives from the Service, U.S. Army Corps of Engineers (Corps), National Oceanic and Atmospheric Administration (NOAA), U.S. Environmental Protection Agency (EPA), and U.S. Department of Agriculture; (2) the *Principles for the Ecological Restoration of Aquatic Resources* (U.S. Environmental Protection Agency, 2000); and (3) the *National Wetlands Inventory: A Strategy for the 21st Century* (U.S. Fish and Wildlife Service, 2002a). Each principle is integral to the Service's vision, goal, and objectives for the Meadowlands.

(1) Address and prevent ongoing causes of degradation first; eliminate and remediate ongoing stresses, (including their cumulative, indirect impacts) within and surrounding the ecosystem.

(2) Preserve and protect existing resources to provide the biotic diversity and other natural resources (*e.g.*, water) needed for the recovery of impaired systems.

(3) Understand a watershed's past, assess its current conditions and trends, and anticipate future changes (*e.g.*, development, sea level rise) to improve water quality and restore hydrologic structure and function.

(4) Restore ecosystem structure (*e.g.*, habitat, populations) to re-establish ecosystem function, integrity, and sustainability.

(5) Employ a multi-disciplinary team representing federal, State, and municipal agencies, academia, private organizations, and others to develop site-specific remediation and restoration plans that include the following components:

   a. clear priorities and measurable goals;
   b. monitoring before, during, and after projects;
   c. reference sites to gauge restoration success; and
   d. preferential use of passive techniques (e.g., re-establish natural hydrology to promote re-vegetation by native plants), natural bioengineering (*e.g.*, integrating

plants and other living materials into structures), and adaptive management (*e.g.*, integrating experimental design and monitoring into restoration projects).

(6) Integrate good science with sound decision-making, emphasize collaborative problem-solving by meaningful involvement of appropriate public and private stakeholders, and reflect community values and perspectives.

C. MEADOWLANDS ECOSYTEM RESTORATION PRINCIPALS' GROUP

The Meadowlands has endured several centuries of indifference, neglect, and abuse. As will become evident with the information presented in this Plan, the challenges in the Meadowlands confronting stakeholders are complex, costly to address, and will not be solved overnight. Remediating, enhancing, restoring, and protecting the Meadowlands will require substantial commitments by stakeholder groups, considerable financial investments from federal, State, and regional government agencies, and unwavering public support. Careful planning and coordination of the major commitments and diverse component activities will be essential to achieving a successful, comprehensive restoration of the Meadowlands. In recognition of the critical importance of this coordination and the substantial long-term commitments that will be required by federal, State, and regional agencies, a central interagency group, currently referred to as the principals' group, is forming to address and provide for the overall planning and coordination. Furthermore, many issues not under the purview of the Service and other federal or State partner agencies have substantive potential to adversely impact the restoration of the Meadowlands and the sustainability of its biota. The principals' group provides a venue for communicating and coordinating those concerns under the purview authority of other agencies.

D. FEDERAL AUTHORITIES AND SERVICE RESPONSIBILITIES IN THE MEADOWLANDS

1. Key Federal Laws, Executive Orders, and Policies for Service Activities

A number of federal resource laws, executive orders, management plans, and policies provide the capability or guidance for the Service's involvement in the Meadowlands. Most authorities are situational, and apply only to federally funded or authorized activities, to federal lands, or to federally involved remediation and planning activities, and include the following:

- Fish and Wildlife Coordination Act (FWCA; 48 Stat. 401, as amended; 16 U.S.C. 661 *et seq.)*;

- Endangered Species Act of 1973 (ESA; 87 Stat. 884, as amended; 16 U.S.C. 1531 *et seq.*);

- Migratory Bird Treaty Act of 1918 (MBTA; 40 Stat. 755, as amended; 16 U.S.C. 703-712);

- Federal Water Pollution Control Act of 1972 (Clean Water Act of 1977 [CWA]; 33 U.S.C. 1251 *et seq.*), including the National Estuary Program;

- Rivers and Harbors Appropriation Act of 1899 (30 Stat. 1151, as amended; 33 U.S.C. 403 *et seq.*);

- National Environmental Policy Act of 1969 (NEPA; 83 Stat. 852; 42 U.S.C. 4321 *et seq.*);

- Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA; P.L. 96-510; 26 U.S.C. 4611-4682; as amended by the Superfund Amendment and Reauthorization Act of 1986, P.L. 99-499; 42 U.S.C. 9601 *et seq.*);

- Resource Conservation and Recovery Act of 1976 (RCRA; P.L. 94-580; 42 U.S.C. 6901-6992; 90 Stat. 2795, as amended);

- Emergency Wetlands Resources Act of 1986 (EWRA; P.L. 99-645);

- North American Wetlands Conservation Act of 1989 (NAWCA; 103 Stat. 1968; 16 U.S.C. 4401-4412; P.L. 101-233, including the North American Waterfowl Management Plan) and the Neotropical Bird Conservation Act of 2000;

- Coastal Wetlands Planning, Protection and Restoration Act of 1990 (104 Stat. 4779; 16 U.S.C. 3951 3956 *et seq.*);

- Magnuson-Stevens Fishery Conservation and Management Act of 1976 (P.L. 94-265; 16 U.S.C. 1801-1882; 90 Stat. 331; as amended);

- Coastal Zone Management Act of 1972 (CZMA; P.L. 92-583; 86 Stat. 1280; 16 U.S.C. 1451-1464; as amended) and the Coastal Zone Management Improvement Act of 1980 (P.L. 96-464; as amended);

- Department of Transportation Act of 1966 (Policy on lands, wildlife and waterfowl refuges, and historic sites, 49 U.S.C. 303);

- U.S. Fish and Wildlife Service Mitigation Policy (*Federal Register*, Vol. 46, No. 15, January 23, 1981);

- Executive Order 11988 on Floodplain Management (*Federal Register*, Vol. 42, No. 26971, May 24, 1977);

- Executive Order 11990 on Protection of Wetlands (*Federal Register*, Vol. 42, No. 26961, May 24, 1977);

- Executive Order 13112 on Invasive Species (*Federal Register*, Vol. 64, No. 25, February 3, 1999); and

- Executive Order 13186 on Migratory Birds (*Federal Register*, Vol. 66, No. 11, January 17, 2001).

Not all of the above are primary Service authorities; however, coordination with the Service may be necessary to fulfill authorities of other agencies. Thus, a brief description summarizing the above legal authorities, policies, and executive orders is provided in Appendix A. These and other operating authorities primarily determine the Service's responsibilities in the Meadowlands, which are identified below.

2. Service Trust Responsibilities

The Service and NOAA are charged with the protection of federal trust resources and, in some cases, the habitats that support trust resources. In the Hackensack Meadowlands, the Service is primarily responsible for:

- all terrestrial and freshwater species that are (1) federally listed as endangered or threatened, (2) candidates for listing, or (3) listed under the Convention on International Trade in Endangered Species;

- migratory birds, especially neotropical migrant landbirds, colonial nesting waterbirds, shorebirds, seabirds, waterfowl, and raptors;

- certain interjurisdictional fishes (*e.g.*, striped bass [*Morone saxatilis*]) and other migratory fishes; and

- impacts from Superfund sites and invasive and exotic species on native fish and wildlife populations.

The NOAA, primarily through the National Marine Fisheries Service (NMFS) Office of Protected Resources and the NMFS Office of Habitat Conservation, is charged with protection and conservation of coastal and marine resources (National Oceanic and Atmospheric Administration, 2004a; 2004b), including the following in the Hackensack Meadowlands:

- endangered and threatened marine species (*e.g.*, shortnose sturgeon, *Acipenser brevirostrum*);

- managed fishery resources (*e.g.*, winter flounder [*Pseudopleuronectes americanus*]);

- diadromous species (*e.g.*, American shad [*Alosa sapidissima*] and American eel [*Anguilla rostrata*]);

- marine mammals (*e.g.*, dolphins and seals); and

- habitats that support those species (*e.g.*, Essential Fish Habitat for managed species).

Additional information about Service responsibilities is provided below.

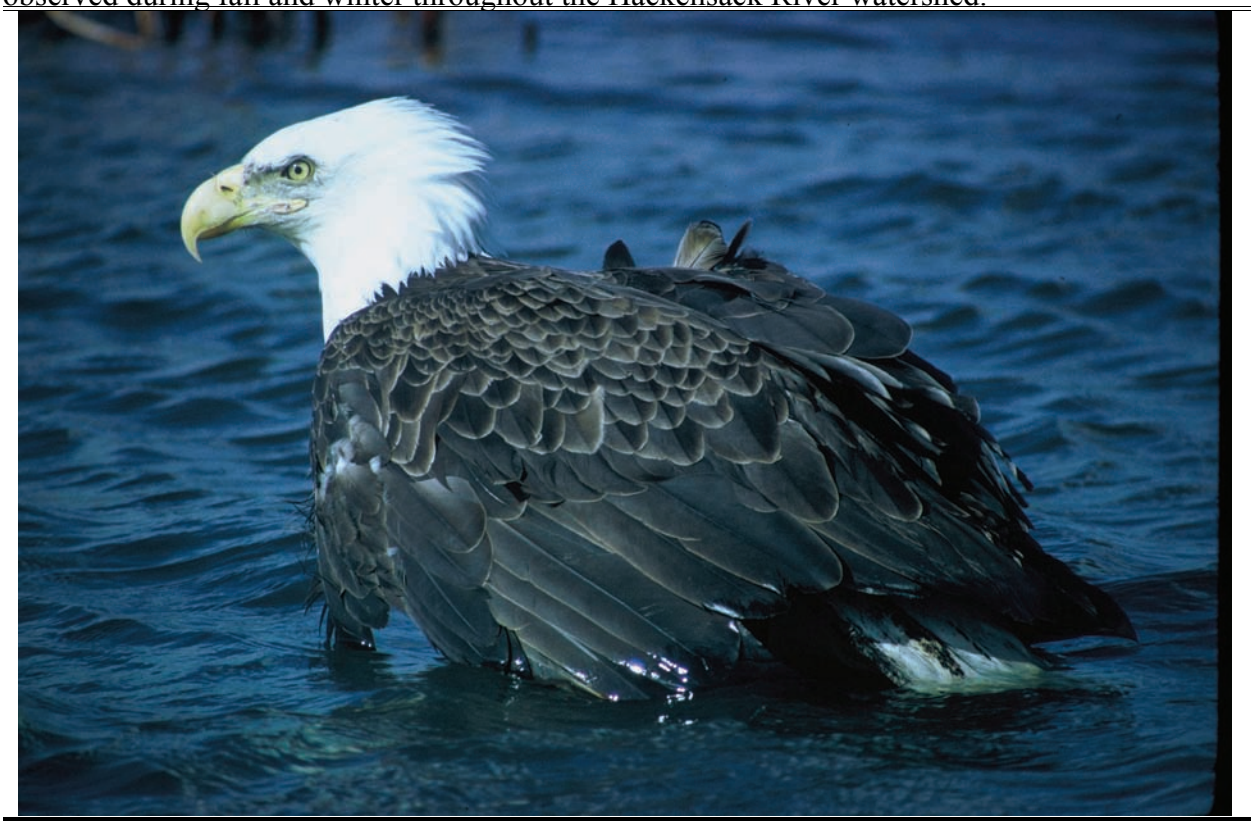
a. <u>Federally Listed Species</u>

Federally listed species include species designated as endangered or threatened by the Secretary of Interior in accordance with the ESA (see Appendix A). Endangered species are defined as

those species in danger of extinction throughout all or a significant portion of their range, whereas threatened species are those that are likely to become endangered within the foreseeable future throughout all or a significant portion of their range.

The Hackensack Meadowlands is increasingly used for migrating, foraging, and overwintering by the federally listed (threatened) bald eagle (*Haliaeetus leucocephalus*; Figure 2). Overwintering bald eagles are increasing throughout New Jersey and the Hudson-Raritan estuary (Walsh *et al*., 1999; Smith *et al*., 2003), including the Meadowlands (Kiviat and MacDonald, 2002). Bald eagles have been observed along the Hackensack River and other large bodies of water in the region, where they roost and forage. A bald eagle that drowned subsequent to a mid-air collision was recovered in October 2000 from the Hackensack River (Ralston, 2000).

Figure 2. Bald eagle (*Haliaeetus leucocephalus*): A federally listed species that is increasingly observed during fall and winter throughout the Hackensack River watershed.



During the 1900s, the Meadowlands and the Hackensack River watershed (HRW) were home to other federally listed species, including shortnose sturgeon, dwarf wedgemussel (*Alasmidonta heterodon*), bog turtle (*Clemmys muhlenbergii*), peregrine falcon (*Falco peregrinus*; formerly listed), and Indiana bat (*Myotis sodalis*). However, with the exception of peregrine falcon, now nesting on bridges and other tall structures within the Meadowlands area, none of the above species has been found recently within the HMD.

In August 1999, the Service removed (de-listed) the peregrine falcon from the list of endangered and threatened species, ending all protections provided to the species under the ESA. However,

section 4(g)(1) of the ESA requires implementation of a monitoring program for a minimum of 5 years. The Service has decided to monitor the peregrine falcon for 13 years in order to provide data that will reflect the status of at least two generations of peregrines. If it becomes evident during this period that the peregrine is not maintaining its recovered status, the species could be re-listed under the ESA. The peregrine will continue to be protected by the MBTA, which prohibits the taking, killing, possession, transportation, and importation of migratory birds, their eggs, parts, and nests except when specifically authorized by the Department of the Interior.

b. Migratory Birds

The Meadowlands is located in the Atlantic Flyway at the juncture of three physiographic areas (Southern New England, Mid-Atlantic Coastal Plain, and Mid-Atlantic Piedmont; Figure 3) and within the hub of several major bird migration routes connecting the eastern Great Lakes, Hudson River Valley, New England, and the coast (Figure 4). The Meadowlands provides increasingly vital migratory stopover and breeding habitats for nearly 40 percent of the migratory bird species that occur in the eastern United States. Approximately 76 percent of the 445 species observed in New Jersey use the Meadowlands as nesting habitat or as a stopover for resting and feeding along historic migration corridors between the Atlantic Ocean and interior regions of the Hudson Valley and the Great Lakes (Dunne *et al.*, 1989; Kane and Githens, 1997). Nearly all of the 65 bird species nesting in the Meadowlands are migratory (Kane *et al.*, 1991). Nearly all migratory birds in the United States are protected under the auspices of the MBTA (see Appendix A). Addressing the loss and degradation of migratory bird habitat and strengthening regional and other partnerships to achieve bird conservation are two of the top three current priorities of the Service's Migratory Bird Program (U.S. Fish and Wildlife Service, 2004a).

c. Interjurisdictional Fisheries

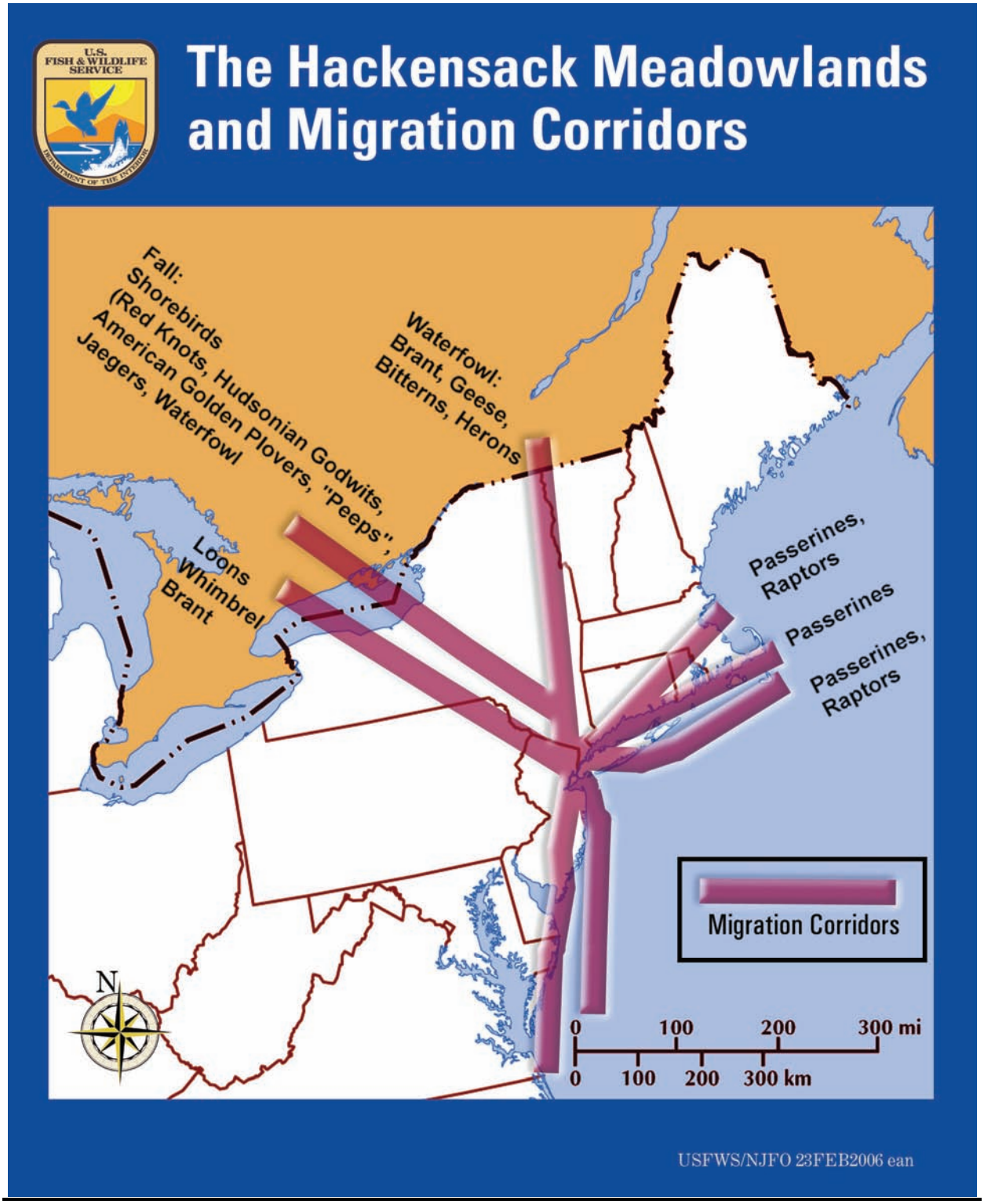
Interjurisdictional fisheries pertain to fishes that traverse state boundaries (*e.g.*, striped bass). In coastal waters, organizations such as the Atlantic States Marine Fisheries Commission were created by Congress to address interstate fisheries issues. Through the Fish and Wildlife Management assistance program, the Service works across state borders to provide a national perspective as well as technical support and coordination services to interstate fisheries commissions. Specifically, the Service participates in stock assessments, research, habitat evaluation and management, and information sharing. With respect to fish species, the Service's focus is on federal trust species, which in this case include species that cross state and national borders or are federally listed under the ESA. Programs that benefit interjurisdictional or listed species benefit other aquatic resources as well. With the Service as a partner, interstate commissions and other interjurisdictional organizations can develop programs for large-scale restoration, conservation, and management of aquatic resources. Development of such programs has the potential to expand the Service's fisheries activities in the HRW. The Service's fisheries program has historically included mussels (*e.g.*, triangle floater [*Alasmidonta undulata*], dwarf wedgemussel; Figure 5) and fishes (*e.g.*, shortnose sturgeon) that are now federally or State listed (New Jersey Department of Environmental Protection, 2004a). Migratory fishes are also protected under the Magnuson-Stevens Fishery Conservation and Management Act, which is administered by the NMFS (see Appendix A).

d. Superfund National Priorities List Sites (Impacts to Native Fish and Wildlife Populations)

The Superfund Program, administered by the EPA under the CERCLA (see Appendix A), seeks to remediate sites where toxic and hazardous wastes have been deposited or spilled. The National Priorities List (NPL) identifies sites that warrant further investigation to assess the nature and extent of the public health and environmental risks associated with the site and to determine what CERCLA-financed remedial action(s), if any, may be appropriate (*Federal Register*, Volume 54, No. 223, November 21, 1989; EPA Rules and Regulations, National

Figure 3. A map of Bird Conservation Regions developed by the North American Bird Conservation Initiative. The juncture of three bird conservation regions (#28: Appalachian Mountains; #29: Piedmont; and #30: New England-Mid Atlantic Coast) near the Hackensack Meadowlands contributes to its diversity of migratory birds. Different management plans for Bird Species of Conservation Concern have been developed for these conservation regions by the Service and its partners.

Figure 4. Major bird migration routes through the Hackensack Meadowlands. New Jersey's latitude, geography, and habitat suitability make it a critical area for bird migration.



Priorities List for Uncontrolled Hazardous Waste Sites; 40 CFR Part 300). Via involvement with the EPA's Biological Technical Assistance Group, the Service's Division of Environmental Quality provides technical assistance in the form of information, data, and guidance to the EPA to ensure that site remediation protects federal trust fish and wildlife resources. The responsibilities of the Service and EPA are often complementary and provide for the protection of human health and safety, and of fish and wildlife resources. The EPA primarily addresses human health and safety and generally does not address off-site contamination of natural resources (*e.g.*, wetland sediments); however, EPA actions do provide some indirect benefits to fish and wildlife resources. The Service's priorities include both on and off-site contaminant impacts and concentrate on the protection of fish, wildlife, and their habitats within contaminated areas. Under CERCLA, the Service also has a role as a trustee for natural resources and thus is authorized to assess and recover damages for injury to, destruction of, or loss of natural resources. Compensation for injuries is accomplished through the Department of the Interior's Natural Resources Damage Assessment and Restoration Program.

Figure 5. Federally and State-listed freshwater mussel species that have historically occurred in the Hackensack River watershed. The dwarf wedgemussel (*Alasmidonta heterodon*, upper photos) is federally and State-listed as endangered. The triangle floater (*Alasmidonta undulata,* lower photos) is State-listed as endangered.

Photos courtesy of the North Carolina Wildlife Resources Commission

e. Invasive Species (Impacts to Native Fish and Wildlife Populations)

Human activities have introduced exotic (*i.e.*, non-native) species into many ecosystems throughout the U.S. and other parts of the world. Under suitable conditions, some exotic species proliferate and spread rapidly, displacing and destroying dominant and highly valued native species. Such *invasive* species often cause considerable destruction to natural ecosystems, communities, and native species and may have diverse adverse impacts upon human health and the economy. For example, the invasive form of common reed (*Phragmites australis* Haplotype M) has displaced other typical marsh plants (*e.g.*, saltmarsh bulrush [*Scirpus robustus]*; Marks *et al.*, 1994; Meyerson *et al.*, 2000) and created a monoculture (Saltonstall, 2002; Figure 6) that differs substantially from the native communities that once characterized the Meadowlands.

The Service is one of many federal and state agencies regionally and nationally working to reduce the spread and impacts of exotic species on native fish and wildlife populations. Increasingly, the Service's activities are being planned and coordinated through the Invasive Species Council (*e.g.*, development of the Chesapeake Bay-wide Management Plan to control common reed; Chesapeake Bay *Phragmites australis* Working Group, 2003). The Service implements programs on and off Service lands to: (a) prevent species introductions (*e.g.*, law enforcement, NWR management, public education), (b) provide biological, chemical and mechanical control of species already introduced (*e.g.*, *Galerucella* beetles for purple loosestrife; glyphosate application for common reed), and (c) restore disturbed and degraded habitats to prevent future introduction and proliferation of exotic species (see U.S. Fish and Wildlife Service, 2004b for an overview of Service concerns and activities regarding invasive species in New Jersey). The Service's *Partners for Fish and Wildlife* program includes habitat restoration efforts to control the spread of invasive species. The National Wildlife Refuge System Improvement Act (P.L. 105-57; 111 Stat. 1253) provides the Service with the authority to control invasive species on NWR lands, whereas the 1981 amendments of the Lacey Act (95 Stat. 1073; 16 U.S.C. 3371-3378) empower the Service to block pathways of invasive species into the United States.

E. SPECIFIC SERVICE ACTIVITIES IN THE MEADOWLANDS

1. Federal Permit Review Program

Pursuant to the FWCA, the Service coordinates with other federal agencies regarding water and associated land resource projects that require a federal license or permit or are under review for federal funding. The federal authorities that apply to activities in the tidal waters and wetlands of the Hackensack Meadowlands are Section 10 of the Rivers and Harbors Appropriation Act of 1899 and Section 404 of the CWA of 1977 (33 U.S.C. 1344 *et seq*.; see Appendix A).

2. Special Area Management Plan and Related Activities

In 1972, the recently formed HMDC introduced its first Master Plan, which called for filling nearly half of the wetlands in the Meadowlands District for development. The Master Plan was not in compliance with the CWA, which happened to be passed that year. Conflicts arose

Figure 6. Two plant species with different population trajectories in the Meadowlands. Saltmarsh bulrush (*Scirpus maritimus*, upper photo), is uncommon throughout the Meadowlands and is State-listed as endangered. Common reed (*Phragmites australis*, a monotypic stand on lower left; diagram of stalk, flower, seed head, and rhizome on lower right) is an invasive species that has spread throughout the Meadowlands.

frequently between land-use planners within the Meadowlands District and various agencies (including the Service) that reviewed permit applications for projects in wetlands. Coordination among federal and State agencies, project sponsors, and the public grew increasingly controversial with each federal permit application requiring wetlands fill. Compounding the controversy was the fact that these proposed projects were non water-dependent, suggesting that upland alternatives were available. Water dependency is specifically emphasized in the CWA Section 404(b)(1) Guidelines (40 CFR 230), which provide the guidance for evaluating and granting CWA Section 404 permits.

a. Advanced Identification

In 1987, the Corps' New York District, EPA's Region II, and the NJMC began a joint study (the "Advanced Identification" or AVID) to guide the use of dredged and other fill material in the Meadowlands. The Service's New Jersey Field Office (NJFO) and other agencies later participated in the study. Using a modified Wetland Evaluation Technique (Adamus *et al.*, 1987), the AVID assigned 7,622 acres of the District's wetlands to one of three categories: generally unsuitable for fill (88 percent, 6,823 ac), potentially suitable for fill (2 to 3 percent, 122 ac), and indeterminate (9 percent, 677 ac; U.S. Environmental Protection Agency, 1992). Although the AVID provided a useful tool for regulatory decision-making, increasing development pressures continued to exacerbate the inconsistencies between the Master Plan and the CWA. The AVID was conducted in part as a prelude to developing a Special Area Management Plan (SAMP) for the Hackensack Meadowlands.

b. Special Area Management Plan

Pursuant to satisfying a former desideratum for development in the Meadowlands and in an effort to rectify perceived inconsistencies with the federal Section 10/404 permit program, the HMDC included the formulation of a SAMP under a Memorandum of Agreement (MOA) between the Corps, EPA, and NOAA in the 1988 revision of its Master Plan. The Service declined to sign the MOA because the agreement would have restricted the Service's ability to participate effectively in evaluating the impacts of wetland loss on fish and wildlife resources. The Coastal Zone Management Improvement Act of 1980 defines a SAMP as a "comprehensive plan providing for natural resource protection and reasonable coastal-dependent economic growth, containing a detailed and comprehensive statement of policies, standards and criteria to guide public and private uses of lands and waters; and mechanisms for timely implementation in specific geographical areas within the coastal zone."

The SAMP's sponsors prepared a draft Environmental Impact Statement (EIS), which eventually addressed seven different land-use scenarios and their impacts. Initially, the SAMP promoted the filling of nearly 1,200 acres of wetlands; later versions reduced the filling to 850 acres and then to approximately 480 acres. Throughout those different versions of the SAMP, the Service continually expressed serious concerns about the extensive filling of wetlands, which was inconsistent with the AVID determinations as well as the intent of the CWA. In its final (1999) proposed form, the SAMP would have "streamlined" federal and State permitting processes, but would have endorsed further degradation and fragmentation of the remaining habitats of the

Hackensack Meadowlands, though to a lesser extent than proposed in earlier versions of the SAMP. The SAMP was abandoned by its sponsors in 2001. A final EIS was never produced.

c. Wildlife Management Plan for the Hackensack Meadowlands

Prior to the abandonment of the SAMP, the Service's review of the SAMP draft EIS cited lack of an inclusive plan to manage fish and wildlife resources. Thus, the SAMP sponsors and the Service agreed to develop an interagency plan, with the Service as lead agency. Although generic and simplified, the resulting *Wildlife Management Plan* (U.S. Fish and Wildlife Service *et al.*, 2000) identified the priority fish and wildlife resources and the diversity of vegetative and aquatic communities that occur in the Hackensack Meadowlands. Some goals and objectives that were identified in the WMP (*e.g.*, retain large contiguous blocks of vegetated areas, eliminate barriers to the movement of fish and wildlife) were clearly inconsistent with land-use activities promoted by the SAMP (*e.g.*, 10 major filling projects that would have further fragmented the Meadowlands). The WMP also emphasized the diverse commitment needed for long-term protection and management of the Meadowlands ecosystem and its priority resources.

3. Meadowlands Interagency Mitigation Advisory Committee

The Meadowlands Interagency Mitigation Advisory Committee (MIMAC) was established by the Interagency Compensatory Wetland Mitigation Agreement for the Hackensack Meadowlands District in August 1997 as an outgrowth of the aforementioned Meadowlands SAMP. Membership of the MIMAC is comprised of the Service, EPA, Corps, NMFS, New Jersey Department of Environmental Protection (NJDEP), and NJMC. The original 1997 agreement identified important wetlands functions, stated the MIMAC's intended compliance with federal and State authorities and policies (*e.g.*, CZMA, CWA Section 404, New Jersey Water Pollution Control Act [N.J.S.A. 58:10A-1 *et seq*.]), established the duties and responsibilities of the MIMAC members, and provided general guidelines and application requirements for the location, development, and use of wetland mitigation sites and banks. The MIMAC was established to ensure appropriate use of any mitigation bank by approving the use of a mitigation bank only when it had been demonstrated that "…there is no practicable alternative to construction in a wetland and all practicable measures to avoid and minimize impacts to wetlands have been incorporated in the project."

The MIMAC members have worked collaboratively over the years to improve assessment of Meadowlands wetlands and consistency in their mitigation requirements. The MIMAC initiated and participated in developing a *Guidebook for Hydrogeomorphic Assessment of Tidal Fringe Wetlands in the Meadowlands* (Louis Berger Group, Inc., 2004a) to provide a standardized method for assessing the hydrologic, biogeochemical, plant habitat, and animal habitat functions of wetlands in the Meadowlands. The Service is an active member of the MIMAC.

4. New York-New Jersey Harbor Estuary Program

Congress established the National Estuary Program in the CWA's 1987 amendments (33 U.S.C. Section 1330, as amended; P.L. 107-303) to develop comprehensive management plans for estuaries of national significance that are threatened by development, pollution, or overuse. In

1988, the NY-NJ Harbor Estuary, which includes the Meadowlands, was designated an "Estuary of National Significance" and the NY-NJ Harbor Estuary Program (HEP; Harbor Estuary Program, 2005a) was established as one of 28 National Estuary Programs (U.S. Environmental Protection Agency, 2004a). The resulting Comprehensive Conservation and Management Plan (CCMP), developed as a product of the HEP, was intended to serve as a blueprint for managing the Harbor Estuary and the New York Bight (Harbor Estuary Program, 1996). The CCMP includes many components: (1) a monitoring plan; (2) intermediate actions and long-term strategies designed to protect, restore, and enhance fish and wildlife habitats; (3) guidance for developing strategies to prevent pollution and reduce inputs of toxins, pathogens, excess nutrients, and floatable debris into the Harbor Estuary; (4) a mechanism to address changes to the dredge material management plans for the NY-NJ Harbor; (5) policy, management, and implementation components; and (6) an estimate of costs for CCMP activities (Harbor Estuary Program, 1996). Information exchange and coordination between the HEP and the NJMC was limited initially but has increased in the last few years.

5. Significant Habitats and Habitat Complexes of the New York Bight Watershed

The Service's Southern New England-New York Bight Coastal Ecosystems Program, in cooperation with the Harbor Estuary Program, produced *Significant Habitats and Habitat Complexes of the New York Bight Watershed* (U.S. Fish and Wildlife Service, 1996a), an extensive ecological assessment focused on identification and description of essential habitats of terrestrial, coastal, and marine species inhabiting the New York Bight watershed, a region which includes the Hackensack Meadowlands. Species distributions and other information, together with background information on the region's geology, hydrology, physiography, and land use were graphically integrated to portray species occurrences in relation to landscape and other features. These analyses of species distributions within the New York Bight resulted in identification of 35 "Regionally Significant Habitat Complexes," including the Hackensack Meadowlands. Fish and wildlife resources, together with general threats and conservation considerations, were then addressed for each complex. This comprehensive assessment was intended to guide ecologically sound land-use decisions and land protection efforts, and emphasized the need for specific conservation measures to protect and restore the identified habitat complexes and their fish and wildlife resources. It was one of the first federal reports to document the extraordinary significance of the Meadowlands to fish and wildlife resources in the Northeast and the threats to its continued existence and function, and to promote its long-term protection and management.

6. Stakeholder Work Sessions (2000-2005) and the Meadowlands Symposium (2003)

During 2000 and 2001, three stakeholder work sessions were conducted by the Service to build stakeholder partnerships and develop strategies to protect and restore habitats in the Meadowlands. The first session (October 17, 2000), hosted by the Service's Northeast Regional Director, was requested by a number of major conservation groups to address options for protection of the Meadowlands, including the Service's interests in and the feasibility of establishing a National Wildlife Refuge. During the second work session (May 23, 2001), representatives of 20 non-governmental organizations (NGOs), the New Jersey Division of Fish and Wildlife (NJDFW), and the Service identified several action items: (1) forming a

subcommittee to investigate development of a conservation trust to receive and retain funds for land acquisition, (2) identifying priority sites to preserve via purchase or conservation easement, (3) promoting legislation that will set aside brownfields as open space, and (4) addressing contaminated site remediation. The third session (October 31, 2001) included Congressional, federal and State agency, National Fish and Wildlife Foundation (NFWF), and NGO representatives. The purpose of this session was to foster collaboration for acquisition, restoration, and management, and strengthen partnerships. A summary of the three stakeholder work sessions is presented in the NJFO's Hackensack Meadowlands Issue of *Field Notes* (U.S. Fish and Wildlife Service, 2002b). A fourth session (June 13, 2005) was co-sponsored by the Service, Corps, NJMC, NJDFW, and the NFWF. The following objectives, established for the fourth session, were achieved: (1) update participants regarding on-the-ground activities as well as conservation planning efforts by various stakeholders; (2) introduce the Service's technical-assistance efforts, including preliminary conservation planning, for the Meadowlands; (3) discuss opportunities and strategies for integrating fish and wildlife conservation into long-term planning and (4) promote the remediation, restoration, protection, and management of the Meadowlands ecosystem.

The Meadowlands Symposium, held on October 9-10, 2003 at the NJMC facilities in Lyndhurst, was a scientific meeting focused exclusively on the Meadowlands and sponsored by Hudsonia, Ltd. (a regional NGO), the Meadowlands Environmental Research Institute (MERI), the Corps, and the Service. Proceedings from this conference have been published online (Brooklyn Botanic Garden, 2004a).

7. A Vision Plan for Fish and Wildlife Resources of the Hackensack Meadowlands (2002)

The NJDFW and the Service (2002) jointly developed a *Vision Plan* for the fish and wildlife resources of the Hackensack Meadowlands (see Appendix B). This plan listed six goals (*e.g.*, improve conditions for all native plant, fish, and wildlife species) and six tasks (*e.g.*, prioritize sites and begin protecting lands either through fee title or conservation easements) to be accomplished. The *Vision Plan* represented an important initial collaboration of the NJDFW and the Service on the restoration and future management of the Hackensack Meadowlands.

8. Ecological Vision Plan for the New York-New Jersey Harbor Estuary (2003)

The Service's Hudson River-New York Bight Ecosystem Team, a regional coordination effort, elucidated its vision for the entire Harbor Estuary in its *Ecological Vision Plan* (U.S. Fish and Wildlife Service, 2003a): *a healthy, functioning ecosystem that can sustain diverse and viable populations of indigenous plant and animal species to produce maximum benefits for federal trust fish and wildlife resources and ultimately the public.* For the six major aquatic complexes previously identified (U.S. Fish and Wildlife Service, 1996a) in the NY-NJ Harbor Estuary, the *Ecological Vision Plan* identified the major fish and wildlife populations and their habitats; threats and conservation concerns; and conservation goals, objectives, and strategies.

9. Federal Project Planning, Including the Hackensack Meadowlands Ecosystem Restoration Study

Pursuant to the FWCA, the Service coordinates with other federal agencies regarding potential impacts of proposed federal projects to fish and wildlife resources and their supporting ecosystems. For example, the Service has provided recommendations to the Corps on how to avoid and minimize adverse impacts of various harbor dredging projects to fish and wildlife resources (*e.g.*, U.S. Fish and Wildlife Service, 2003b).

Currently, the Service is advising the Corps on its Hackensack Meadowlands Ecosystem Restoration Study, which is one component of the Hudson Raritan Estuary (HRE) Restoration project (U.S. Army Corps of Engineers, 2003a; 2004a). By providing a source of federal funds and serving as the nexus for the participation of other federal agencies, the Corps project is envisioned to be one of, if not the principal, restoration efforts in the Hackensack Meadowlands. The project's local sponsor is the NJMC, which is already involved in restoration of other sites within the Meadowlands. The Reconnaissance Phase for the HRE Restoration project, including the Meadowlands, began in January 2000; the Project Management Plan for the Meadowlands Restoration was completed in April 2003 (U.S. Army Corps of Engineers, 2003a). Due to budget limitations, the Feasibility Study currently includes detailed plans for restoration of only one site and preliminary planning for three additional high-priority sites. To date, at the Corps' request, the Service (2005a; 2005b) has provided the Corps with reports that include recommendations for remediation and restoration of specific sites or for the Meadowlands overall.

10. Designation of the Hackensack Meadowlands as a Regional Resource Priority

The Hackensack Meadowlands has been designated as a "Regional Resource Priority" in the Service's Northeast Region. A Regional Resource Priority distinguishes a resource issue and locale that has regional importance for sustaining and safeguarding federal trust fish and wildlife resources. The Service's Northeast Regional Director designated the Meadowlands a Regional Resource Priority in August 2004 after touring the Meadowlands and meeting with other Service personnel, State biologists, and other stakeholder representatives. Designation of the Meadowlands as a Regional Resource Priority indicates that the Service's Northeast Region has recognized the regional significance of the Hackensack Meadowlands and will undertake all reasonable measures to facilitate the protection of the Meadowlands ecosystem. The designation also emphasizes a long-term commitment to protect the Meadowlands and elevates opportunities to fund monitoring, assessment, management, and other actions; however, the designation does not allocate specific funding for the Meadowlands.

F. PROLOGUE

The Service has a long history of involvement in the Meadowlands, as well as a commitment to protect this area's fish and wildlife resources. As will be illustrated in the following section, while efforts to protect the Meadowlands go back several decades, the Meadowlands has an even longer history of human use, misuse, and abuse. Perhaps more than any other locale in New

Jersey, the Meadowlands is the harbinger of the Nation's environmental challenges—a bellwether that if we do not take care of our resources now, we will pay even greater costs, financially and socially, in the future. In his book on the Meadowlands, John Quinn (1997) stated it eloquently:

> And so, here it is, in these urban fields of sun and grass, that the probable environmental future of humankind—in all its overwhelming ugliness, yet stark and haunting beauty—may be glimpsed . . . .

The Service accepts the many challenges of the Meadowlands as an opportunity to fulfill its Mission of *working with others to conserve, protect and enhance fish, wildlife, and plants and their habitats for the continuing benefit of the American people*. The Hackensack Meadowlands, though not without difficult challenges, offers a unique opportunity for all stakeholders, fish and wildlife resources, and the American people.

II. Human Use History

Detail from *Our Vanishing Game Birds* (see next page).

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DIKING AND DRAINING THE NEW JERSEY MEADOWS.

OUR VANISHING GAME-BIRDS.—SHOOTING RAIL ON THE HACKENSACK MEADOWS, NEW JERSEY.—SEE PAGE 36.

Titled *Our Vanishing Game Birds—Shooting Rail on the Hackensack Meadows, New Jersey*, this illustration highlights one problem of over-hunting recognized more than a hundred years ago (Frank Leslie's Monthly, 1885).

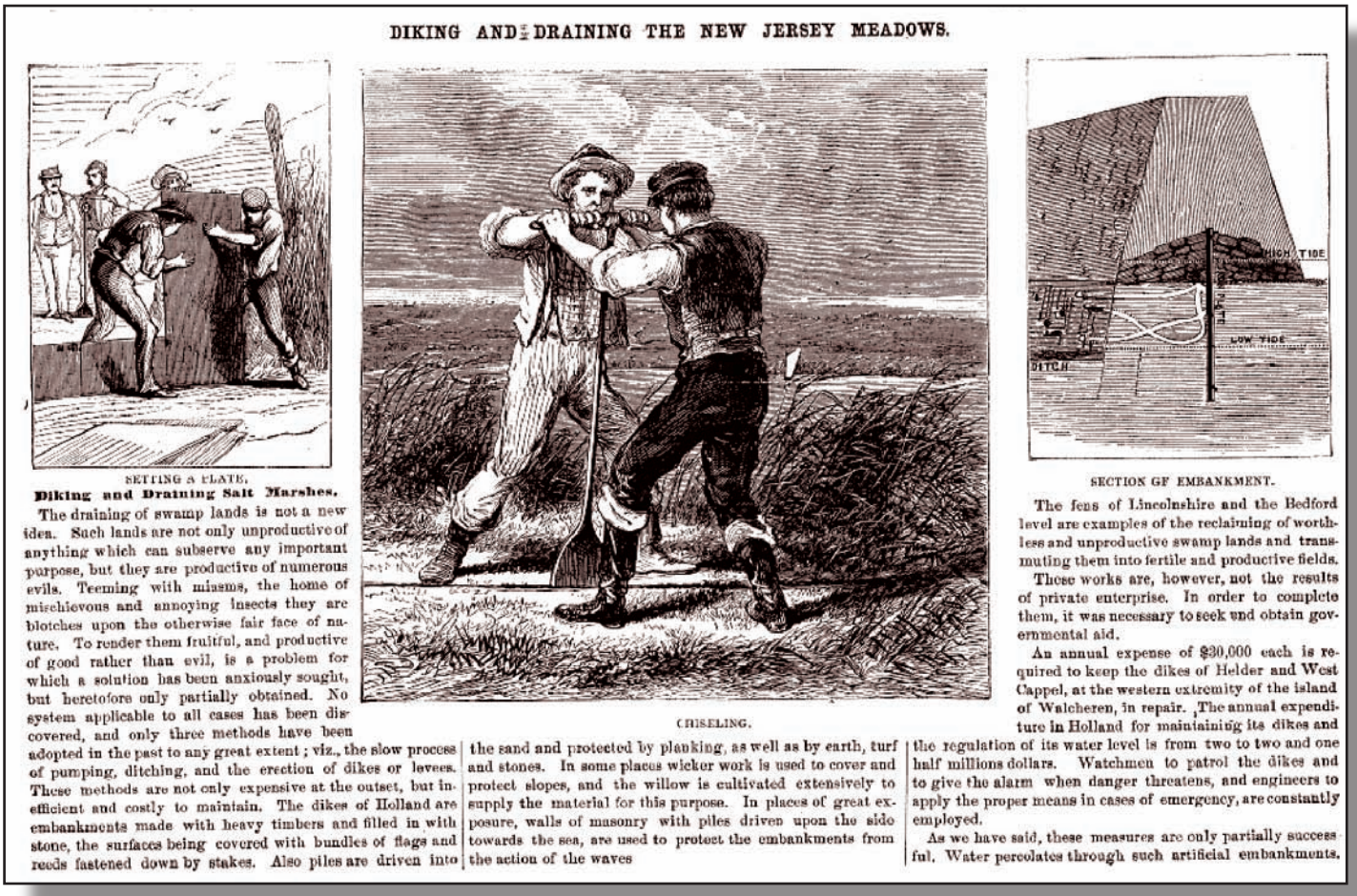
Five species of rail still occur in the Meadowlands but remain at risk from contamination and habitat loss.

II. Human Use History

These lithographs (left/below) and accompanying captions (*Scientific American*, 1868; *Frank Leslie's Monthly*, 1885) illustrate how failure to understand the ecological value of wetlands has contributed to human destruction and exploitation of crucial natural resources. The article in *Scientific American* features the labors of the Iron Dike & Land Reclamation Company, founded by Samuel N. Pike, a real estate developer and distiller who had just completed building New York's Grand Opera House. Pike made use of inventor Spencer B. Driggs' designs for "driving iron plates into the soil and joining them end to end, thus presenting an unbroken and impenetrable iron wall, which may be extended to any required length, and the durability of which is unquestionable." For some reason, however, the land thus reclaimed grew lush stalks but not a single ear of corn.

Unfortunately, this and other lessons we should have learned were lost on several generations of Americans, who continued to dike, drain, ditch, fill, and otherwise misuse the Meadowlands ecosystem. It was not until a century later that we began to see wetlands as intrinsically valuable for humans as well as fish and wildlife. The many years of abuse have exacted a significant toll. Restoration will take considerable resources, years of planning, and decades of hard work to return the Meadowlands to a cleaner, more natural ecosystem that sustains diverse communities of healthy, native species.

History is a great teacher. As the coastal population in the United States continues to grow, the Meadowlands, perhaps more than any other urban area, is a harbinger of the Nation's environmental problems. We must learn from the history of the Meadowlands to address its many challenges; more importantly, we must share our solutions to the Meadowlands' problems to improve the future for fish, wildlife, and people everywhere.



DIKING AND DRAINING THE NEW JERSEY MEADOWS.

SETTING A PLATE.

Diking and Draining Salt Marshes.

The draining of swamp lands is not a new idea. Such lands are not only unproductive of anything which can subserve any important purpose, but they are productive of numerous evils. Teeming with miasms, the home of mischievous and annoying insects they are blotches upon the otherwise fair face of nature. To render them fruitful, and productive of good rather than evil, is a problem for which a solution has been anxiously sought, but heretofore only partially obtained. No system applicable to all cases has been discovered, and only three methods have been adopted in the past to any great extent; viz., the slow process of pumping, ditching, and the erection of dikes or levees. These methods are not only expensive at the outset, but inefficient and costly to maintain. The dikes of Holland are embankments made with heavy timbers and filled in with stone, the surfaces being covered with bundles of flags and reeds fastened down by stakes. Also piles are driven into the sand and protected by planking, as well as by earth, turf and stones. In some places wicker work is used to cover and protect slopes, and the willow is cultivated extensively to supply the material for this purpose. In places of great exposure, walls of masonry with piles driven upon the side towards the sea, are used to protect the embankments from the action of the waves

CHISELING.

SECTION OF EMBANKMENT.

The fens of Lincolnshire and the Bedford level are examples of the reclaiming of worthless and unproductive swamp lands and transmuting them into fertile and productive fields.

These works are, however, not the results of private enterprise. In order to complete them, it was necessary to seek and obtain governmental aid.

An annual expense of $30,000 each is required to keep the dikes of Helder and West Cappel, at the western extremity of the island of Walcheren, in repair. The annual expenditure in Holland for maintaining its dikes and the regulation of its water level is from two to two and one half millions dollars. Watchmen to patrol the dikes and to give the alarm when danger threatens, and engineers to apply the proper means in cases of emergency, are constantly employed.

As we have said, these measures are only partially successful. Water percolates through such artificial embankments.

II. HUMAN USE HISTORY

A. NATIVE AMERICAN HISTORY AND SETTLEMENT

B. EUROPEAN IMMIGRATION, SETTLEMENT, AND RESOURCE EXTRACTION

C. EARLY LANDSCAPE MODIFICATION

D. LARGE-SCALE ENVIRONMENTAL MODIFICATION

E. ENVIRONMENTAL DEGRADATION

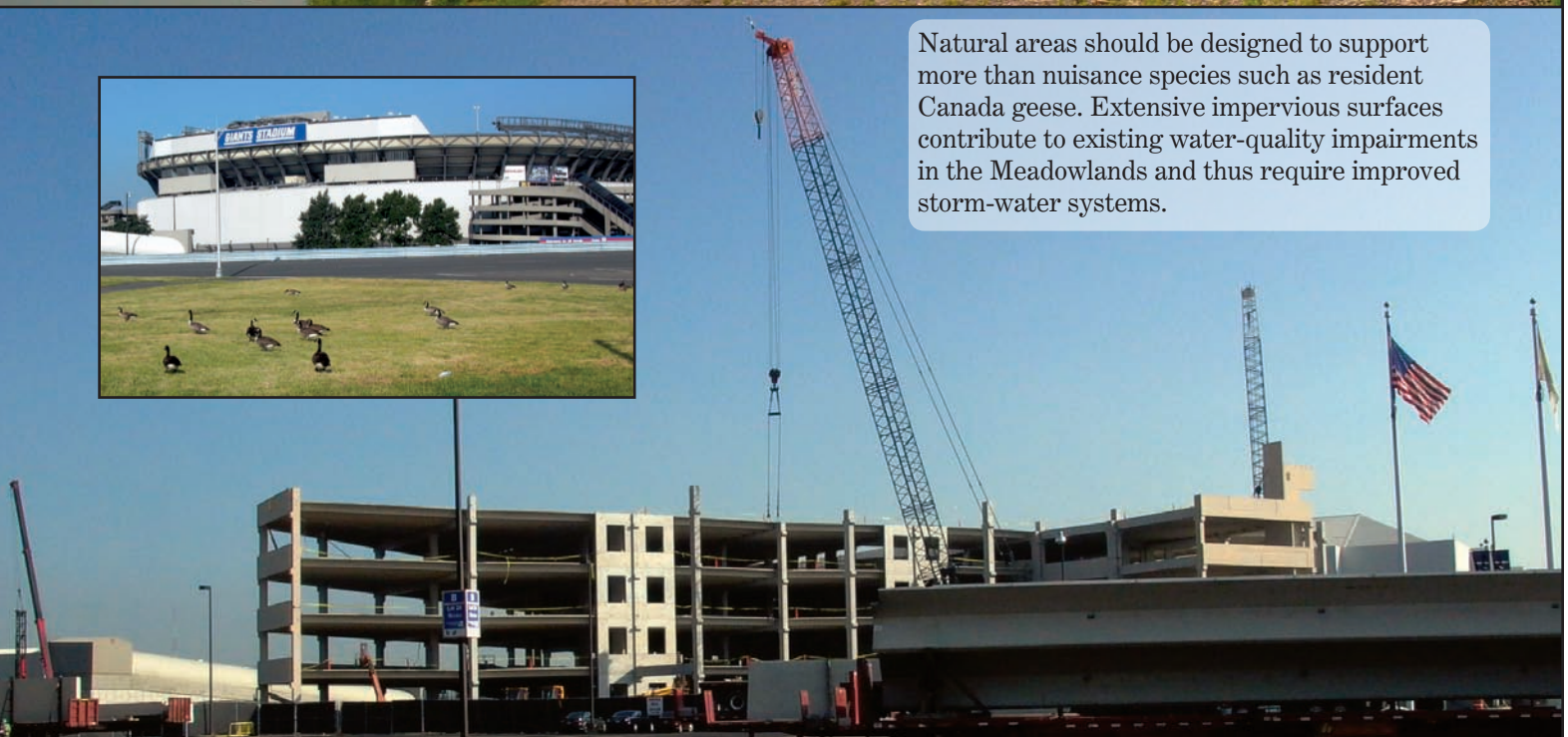
F. LAND-USE PLANNING (Late 1960s to Present)

G. DEVELOPMENT AND ENVIRONMENTAL ALTERATION (1970s to Present)

H. STEWARDSHIP AND FUTURE PLANNING

I. SUMMARY

Future redevelopment projects must better address the ecosystem functions of wetlands and the needs of fish, wildlife, and people. Development projects in the Hackensack Meadowlands must be set back from wetlands and waterbodies by vegetated buffers to provide fish and wildlife habitat.



Natural areas should be designed to support more than nuisance species such as resident Canada geese. Extensive impervious surfaces contribute to existing water-quality impairments in the Meadowlands and thus require improved storm-water systems.

II. HUMAN USE HISTORY

The history of human use of the Meadowlands is similar to that of many areas in the United States and the world. Human use history in the Meadowlands begins with a small population of indigenous people living off the land, shifts imperceptibly during initial European settlement, changes more radically as more of the ecosystem's natural resources are extracted or modified by the growing colonial population, then plunges into a period of wholesale modification of an environment that increasingly cannot support the human population (Marshall, 2004). The history of human use becomes an embarrassment as the environment is degraded with refuse and industrial waste from the sprawling human population. Neglect and degradation of the environment continues until enough citizens and public officials recognize that the environment that previously supported the human population in so many ways will likely fail to support a desirable quality of life without direct intervention to remediate and restore the land.

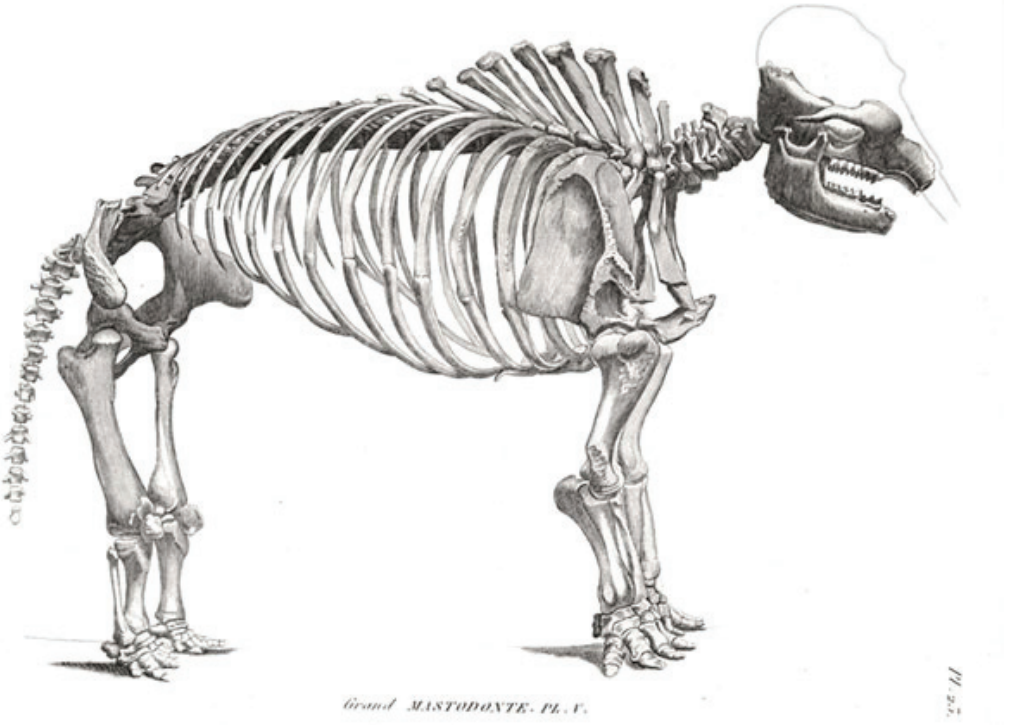
This history of human use in the Meadowlands mandates the purpose for preliminary conservation planning and hence this document: making the Meadowlands a better place for fish, wildlife, and people. History is a great teacher. We must learn from the history of land use in the Meadowlands and share it, not only to prevent past mistakes from being repeated, but to improve the quality of life for future generations.

A. NATIVE AMERICAN HISTORY AND SETTLEMENT

Artifact trails provide evidence that humans first migrated into the northeastern United States along the Allegheny and Ohio valleys, the Susquehanna and Delaware valleys, and the Hudson valley (Kraft, 2001). Radiocarbon dating of archaeological sites in the Delaware and Hudson valleys in Pennsylvania and New York indicates that occupancy of the northeastern United States probably began between 12,580 and 10,190 years ago (Kraft, 1986). Early immigrants undoubtedly consisted of small, nomadic bands of hunter-gatherers that occupied areas seasonally to take advantage of different resources. Just when and where humans first arrived in the HRW is unknown.

At the time of early occupancy by indigenous peoples, the flora and fauna of the HRW were much different from what they are today. The present Meadowlands area was dominated by species of far northern forests and extensively covered with black ash (*Fraxinus nigra*), alder (*Alnus* sp.), tamarack (*Larix laricina*), and black spruce (*Picea mariana*); the animal fauna likely included American mastodon (*Mammut americanus*, Figure 7), mammoth (*Elephas primigenius*), stag moose (also known as moose-elk, *Cervalces scotti*), caribou (*Rangifer tarandus*), and giant beaver (*Castoroides ohioensis*), which have been reported from other sites in the region (Parris, 1983; Laub *et al.*, 1996; Speiss *et al.*, 1998). Most of those species became extinct over 10,000 years ago, but the cause(s) of the extinctions of those animals (*e.g.*, climate change, human hunting) is much debated (Martin and Wright, 1967; Dunn, 1990). Historical information and other data (*e.g.*, soot layers) suggest that fire became a regular part of the landscape once these early human occupants arrived, and may have been used as a tool in hunting certain animals (Delcourt and Delcourt, 1988; MacCleery, 2004).

Figure 7. Living in the Hackensack Meadowlands during prehistoric times. American mastodon (upper diagram) lived in the Hackensack Meadowlands when humans first immigrated into the region. The diagram below was made of one of the first American mastodon (*Mammut americanus*) skeletons that was ever excavated in North America. The specimen was excavated from the Hudson valley by Charles Willson Peale with the support of Thomas Jefferson (Academy of Natural Sciences in Philadelphia, 2004) and is now on display in Germany. A specimen excavated from the Hackensack Meadowlands is being prepared for display at the Bergen Museum of Art and Science. A fishing-net sinker and a projectile point crafted by native people who inhabited the Meadowlands are shown in the lower photos (artifacts from the Bergen Museum of Art and Science).



By approximately 1,000 A.D., at least three independent cultural-linguistic groups (recognized now as the Munsee, Unalachitgo, and Unami) were established in *Lenapehoking*, the land of the Lenape, an area encompassing present-day New Jersey and portions of nearby states (Kraft, 2001). About that time (the late Woodland period, from 1,000-1,600 A.D.), agriculture (*e.g.*, corn, beans, tobacco) had contributed to establishment of native settlements in the northeastern United States (Hart and Scarry, 1999; Kraft, 2001). Diverse pottery, sometimes decorated, and more sophisticated hunting and fishing implements (stone projectile points and weighted fishing nets) also had appeared (Stewart, 1998; Kraft, 2001; Figure 7). Except for a few year-round settlements, the landscape was little affected or modified by the native groups living in the region.

B. EUROPEAN IMMIGRATION, SETTLEMENT, AND RESOURCE EXTRACTION

In 1524, the Florentine navigator Giovanni da Verrazano and the crew of the French caravel *Dauphine* became the first Europeans to visit Lenapehoking. The area characterized what is presently referred to as true wilderness, indigenous people living in a subsistence mode on the landscape, with large predators and other wildlife. Through the early 1600s, relatively little contact occurred between the native tribes and European explorers in Lenapehoking. By this time, a number of distinct Lenape groups were established, including groups identified as the Carnasees, Esopus, Navasinks, Raritans, Tappans, Kitchtaewanks, Warranawankongs, Wiechquaeskecks, and Hackensacks (Kraft, 1986). These tribes interacted variously with the European groups they encountered, benefiting in some ways (*e.g.*, commerce, especially fur trading) and not in others (*e.g.*, alcohol, infectious diseases). Differences in marriage and family responsibilities, spiritual beliefs, and governance contributed to barriers between native and European cultures. European concepts of land ownership and stewardship also differed from those of native cultures; conflicts continually arose among native and European groups, especially the Dutch who taxed and continually displaced native tribes (Kraft, 1986). Some colonial leaders (*e.g.*, William Penn, Philip Carteret) and Quaker and Presbyterian missionaries treated native groups well, but other colonial leaders' hatred for native peoples was widely recognized (Kraft, 2001).

On February 25, 1643, after several years of increasingly frequent hostilities, more than 80 Hackensack men, women, and children were killed by Dutch settlers (*i.e.*, the Pavonia massacre) under the command of Willem Kieft. On that same night, 40 other natives also were massacred by the Dutch on Manhattan (Corlear's Hook); additional captives from that and subsequent skirmishes were often sold into slavery. Native groups fought back but were generally not well-armed and suffered considerable losses. Over the next hundred years, native peoples increasingly suffered both from armed conflicts and diseases, especially smallpox, which may have killed as many as 90 percent of some native groups during numerous epidemics (*e.g.*, 1654, 1663, 1677, 1688, 1694) originating in European settlements (Kraft, 2001). Census data from 1726 and 1745 clearly reveal the decline in the native population throughout the region. Two regional treaties (Crosswicks and Easton in 1758) eventually ended the hostilities and formalized relocation of native groups (Kraft, 2001). By 1798, all Lenape bands in the region had been relocated to Brotherton, an American Indian reservation established in southern New Jersey (presently Indian Mills, Burlington County), or forced westward to Pennsylvania, and areas now

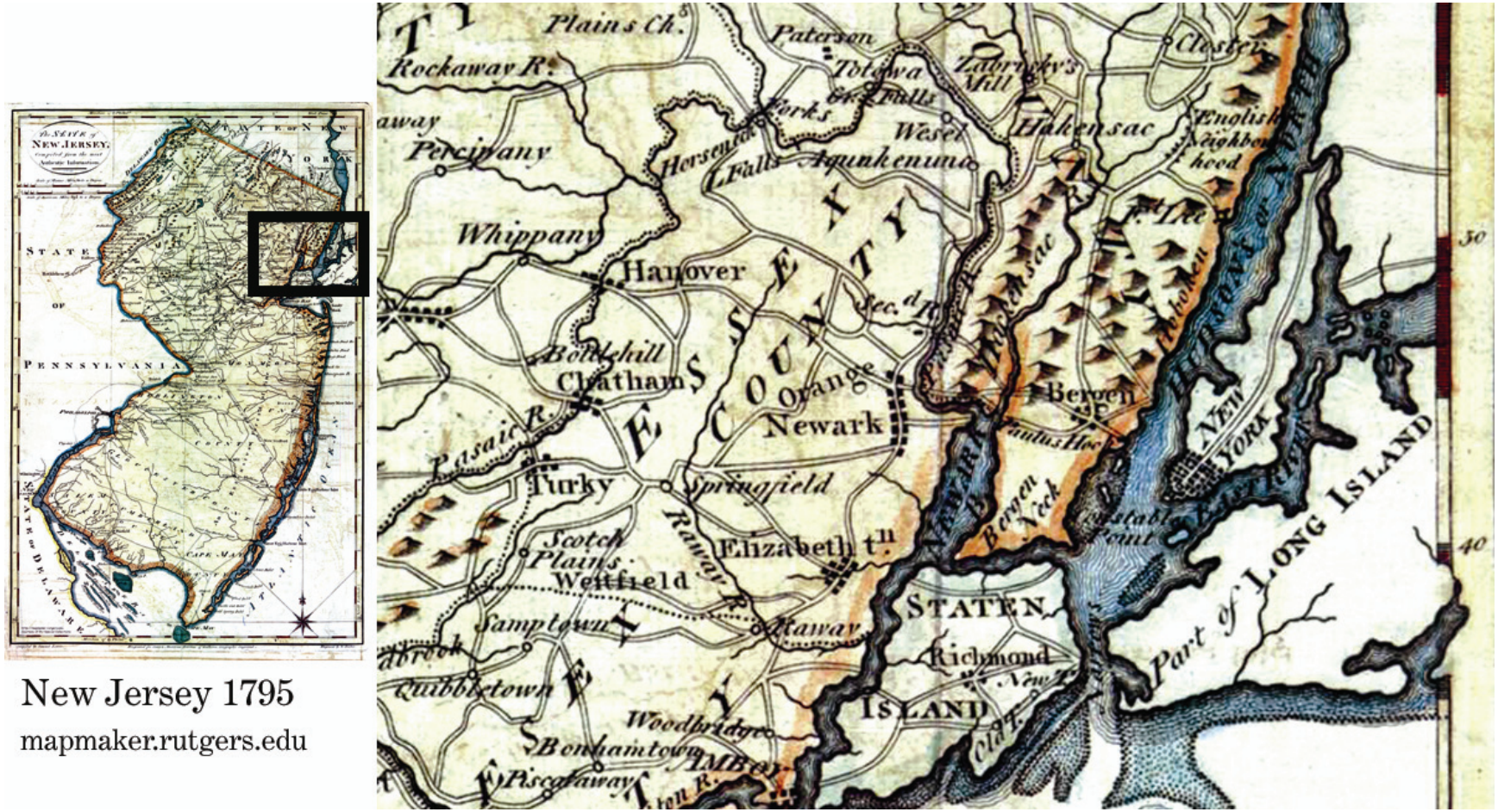
known as Ohio and Oklahoma (Kraft, 2001). After the presence of indigenous people was erased, settlers increased their focus on resource extraction and exploitation of the Meadowlands.

From 1650 to 1800, the Hackensack region had relatively few European inhabitants, with most settlers scattered among a few towns (*e.g.*, Bergen, Hobuc) or large farms (*e.g.*, John Berry's plantation). Some changes to the natural landscape in the region began with those European settlements, as the region's Dutch and other settlers extensively harvested the region's resources (*e.g.*, timber, game) and burned off the forests and marshes regularly in spring or fall. In the 1700s, salt marshes were considered valuable property, and local laws (74 different statutes from 1697-1783; Quinn, 1997) were established to protect and maintain marshes for salt hay (*Spartina patens*) harvest. Dutch settlers are believed the first to attempt to drain low marsh areas to improve their use for agriculture, as salt hay had many uses in addition to winter fodder for livestock (*e.g.*, roof thatching, improving traction on winter roads, and packing material for produce, glass, and paper). Maps from the mid-to-late 1700s (*e.g.*, Figure 8) show a few communities connected by several roads, some of which clearly traverse the Meadowlands from east to west or north to south. Through the late 1700s, the area's natural character was little impacted by human use of the landscape; however, by the end of that century, most of the Atlantic white-cedar (*Chamaecyparis thyoides*) and other forests had been harvested of their old-growth trees. In addition, marshes and remaining woodland areas were being regularly burned to clear land for various purposes (*e.g.*, agriculture, livestock) to accommodate the growing population.

C. EARLY LANDSCAPE MODIFICATION

In the 1800s, the steadily increasing scale of human activities (*e.g.*, wetlands "reclamation" and major transportation efforts) clearly began to result in substantial changes to the Meadowlands. In 1816, John, Robert, and Samuel Swartout began diking and ditching marshes, eventually "reclaiming" 1,300 acres for growing grains, vegetables, hemp (*Cannabis* spp.), and flax (*Linum* spp.), and supporting a herd of 80 to 90 dairy cattle (*Bos taurus*). Though a major storm in 1820 that breached their dikes and flooded the area ended that business venture, maps in the mid 1800s show an expanding network of roadways and railroads replacing some of the early roadways. In the late 1860s, Spencer Driggs and Samuel Pike installed a canal and levee system to convert 5,000 acres of wetlands into farmland. This was the largest agriculture project ever enacted in the Meadowlands; however, the levee system never worked as anticipated and no crops were ever harvested. Despite these difficulties, the human population in the region continued to grow steadily, as indicated by the growing number of towns, roadways, and railroads in late 19th-century maps (Figure 9). The harvest of the area's Atlantic white-cedar and other forests also continued, with less than six percent of the Meadowlands remaining as forest in the 1890s (Vermeule, 1897). With increasing use and occupation of the Meadowlands came increasing concern about the abundance of mosquitoes.

Figure 8. An early map of New Jersey. In this 1795 map, colonists from Europe have established few settlements in the region, yet roads connecting those communities already cross the Meadowlands.



D. LARGE-SCALE ENVIRONMENTAL MODIFICATION

Railroads began to traverse the Meadowlands in the 1830s; this required extensive ditching, diking and filling of wetlands, and also made substantial use of available timber resources (*i.e.*, mostly Atlantic white-cedar). Logs were driven into the Meadowlands' deep muds (deposits 30 feet thick in some places, Figure 9) to support the rail bed. The Meadowlands' hydrology or ecology was not considered in locating these railways, and creek basins within the Meadowlands were increasingly fragmented and isolated by railway and roadway construction (Figure 9). The ditching and diking of marshes, initially begun for agriculture and farming and later for mosquito control (discussed below), made travel across the Meadowlands more pleasant and served to increase demand for rail service, which fueled further regional population growth and industrialization.

Quinn (1997) labeled mosquitoes "the single most important force in the historical coevolution of European humankind and the Meadowlands." In the 1860s, ditching and diking of the Meadowlands to "control" mosquitoes and to make the "land" more suitable for development became important activities. Kearny, Kingsland, and Berry's Creek marshes on the western side of the Hackensack and Ridgefield and Cromakill marshes along Bellman's and Cromakill Creeks on the eastern side of the Hackensack River were all ditched extensively by hand over the next 30 years. Diking of the lower Hackensack along Kearny and Kingsland marshes was also accomplished entirely by hand in this period (Figure 9).

Shortly after the turn of the century, ditching of the Meadowlands became increasingly mechanized with the development of the Eaton plow, which had separate power plant and ditching equipment, and the later Reilly ditching plow, which was essentially a small tractor (Quinn, 1997). Various mosquito extermination organizations, created by the New Jersey General Health Act in 1904, began extensive marsh-ditching and draining activities. The New Jersey Agricultural Experiment Station joined in the efforts in 1906. By 1924, the Bergen County Mosquito Commission alone is reported to have had one million feet of drainage ditches through salt marshes and over 500,000 feet of upland ditches. The New Jersey Agricultural Experiment Station developed a "swamp tractor" that increased the efficiency of ditching (reducing the cost in 1930 to less than one cent per foot) and shredded the excavated marsh material prior to broadcasting it over the surface of the marsh (Quinn, 1997). By 1945, most salt marsh along the Hackensack River and Newark Bay had been ditched and diked. Common reed became well established in the northern sections of the Meadowlands; bundles and layers of reed were incorporated into dikes throughout the Meadowlands to make them stronger (Headlee, 1945). By 1950, more than 17,000 acres of marshes were ditched and diked for mosquito control in the Meadowlands alone (Quinn, 1997).

About the time of increased mechanized ditching, providing sufficient water supplies for the growing human population became a concern. In 1905, Woodcliff Lake was formed by an earthfill dam on Pascack Brook just north of Hillsdale in Bergen County. In 1907, the New Jersey Water Supply Commission became the first State agency authorized to conduct planning, construction, and operation of surface water projects. The following year, the Commission completed studies for four reservoirs on the upper Passaic River. In 1916, the State established the North Jersey District Water Supply Commission to develop and regulate the public water

Figure 9. The Geological Survey of New Jersey's 1896 Map of the Hackensack Meadows. This map identifies then-existing stands of Atlantic white-cedar and other woody vegetation, the types (peats, blue muds) and thicknesses of sedimentary deposits, natural creeks, dikes, and man-made ditches. Some wetlands are already fragmented extensively by roads and railroads.

supply in twelve counties: Sussex, Warren, Hunterdon, Morris, Passaic, Somerset, Middlesex, Union, Essex, Hudson, Bergen, and Monmouth. In 1922, a hollow concrete dam was constructed on the Hackensack River at Oradell to create a much larger reservoir. It is unclear if construction of this dam was a component of the State-wide plan to divert and store surface waters in reservoirs; however, this dam and reservoir were to have major adverse effects on upstream and downstream areas, including the Meadowlands, which changed from a tidal palustrine to a predominantly estuarine ecosystem (see Section IV.A).

As growth and sprawl of the region's human population increased the demand for municipal water supplies, additional large reservoirs were constructed in upper portions of the HRW. DeForest Lake, currently the largest reservoir in the HRW, was formed after construction of an earthfill dam in 1956 on the main stem of the upper Hackensack River north of West Nyack in Rockland County, New York. Lake Tappan formed after construction of another earthfill dam in 1966 on the main stem of the river north of Old Tappan in Bergen County, New Jersey. The Woodcliff Lake dam was modified in 1984 to increase that reservoir's capacity. Within a few years, the total storage capacity of these reservoirs (13.9 billion gals) was insufficient to provide the water supply for the region, and additional hydrologic alterations were made to supply the region with additional water (see Sections II.G and III.D).

E. ENVIRONMENTAL DEGRADATION

Early in the 20th Century, Meadowlands communities became steadily industrialized, and pollution began to limit recreational and other opportunities on the Hackensack River. By 1900, sewage and pollution already had begun to affect recreation throughout the Hackensack Meadowlands (Iannuzzi *et al.*, 2002). Continued widespread abuse of waters and wetlands throughout the New York harbor area eventually fostered the public perception that the wetlands needed reclaiming (Quinn, 1997). Thus, several large-scale plans were proposed for the Meadowlands and other port areas around New York Harbor. Early plans for the Meadowlands during the mid-1920s included two canals: one connecting the Hackensack River near New Milford to the Hudson River near Piermont, New York, and a second connecting the Hackensack River near Hackensack straight to Newark Bay (Quinn, 1997). The proposed canals were never built. By the mid-1920s, the Hackensack River had become so polluted that several local boards of health had prohibited bathing in the river (Robichaud and Buell, 1973).

Following the establishment of the Meadowlands Reclamation Commission by the New Jersey State Legislature, other plans in the region materialized and contributed to the continuing destruction of the Meadowlands. Several roads (*e.g.*, Lincoln Highway, realigned later as U.S. Rt. 1) soon traversed the Meadowlands in the 1920s (Patrick and Wilson, 2002). The Newark marshes on the west side of Newark Bay and the most southerly portion of the Meadowlands were filled with more than 6 feet of sand pumped out of Newark Bay to establish land for a Newark airport in 1928. Featuring the world's first hard-surface landing strip (*i.e.*, asphalt) at any commercial airport, the Newark Airport quickly became the busiest airport in the world. This success directly resulted in the construction of the Pulaski Skyway connecting Newark to Jersey City in 1932, and led to further wetland filling in the Meadowlands for transportation and

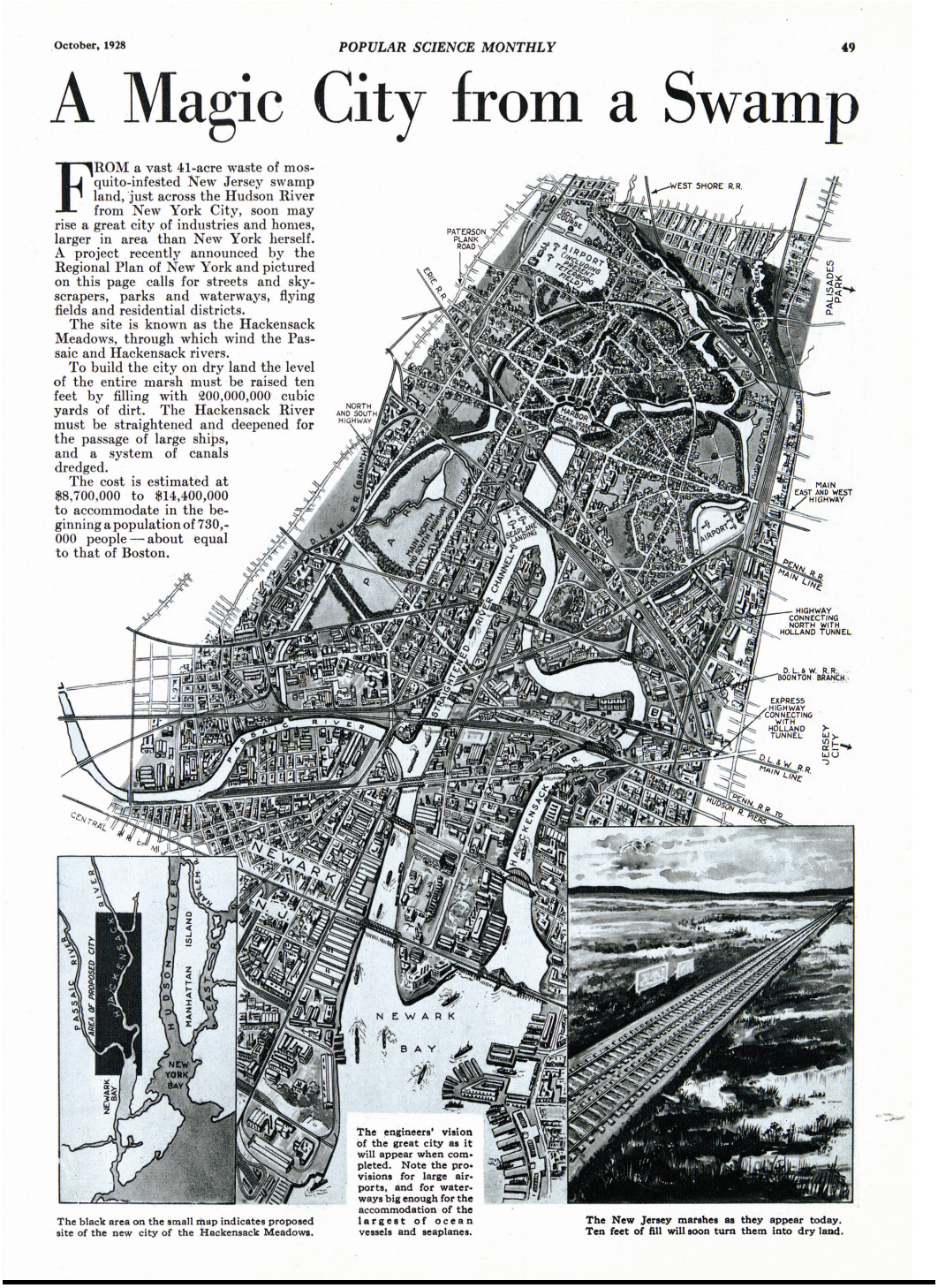
other commercial projects. In the 1930s large tracts of these drained salt marshes were already being overrun by common reed and other invasive species.

Some of these projects were components of various land-use plans for the Meadowlands; however, not all projects or plans were successfully completed. For example, Charles Dyer Norton, together with other influential businessmen, formed the Committee on the Regional Plan in 1922. Incorporating under the name Regional Plan Association (RPA) in 1929, this group developed the nation's first comprehensive, long-range metropolitan plan, the *Regional Plan for New York and Its Environs*. The RPA's first *Regional Plan* proposed filling a "vast 41-acre waste of mosquito-infested New Jersey swampland" with 200 million cubic yards of dirt, dredging and straightening the Hackensack River, and building a city larger than New York was at the time (Popular Science Monthly, 1928). The proposed city would be complete with skyscrapers, seaplane ports, residential neighborhoods, and parks (Figure 10). Despite the influence of the RPA through Frederick Delano (President Franklin D. Roosevelt's uncle and RPA President) and others (*e.g.*, master builders Austin Tobin [then Director of the Port Authority of NY-NJ] and Robert Moses [creator of the Triborough Bridge and Tunnel Authority]), the arrival of the Great Depression undoubtedly terminated the proposed plan for the Meadowlands. As a result, area-wide planning was not a significant component of many projects and activities that soon proliferated in the Meadowlands.

In addition to the draining and diking, vast expanses of land began to be used as dumping grounds for municipal and industrial waste. Landfill dumping began with the intention of turning "unproductive swampland" into tracts of developable land. Land bought or leased from local governments was excavated. Garbage was then dumped into the low areas, sometimes burned at the end of each day to save space, and periodically covered with soil. There were no environmental regulations concerning any aspect of this disposal method. Occasionally, mint-fragrant deodorizers were sprayed over the dumps when the odor became unbearable, though fire was more often employed to eliminate malodorous materials not consumed by invasive scavengers (*e.g.*, Norway rat [*Rattus norvegicus*], German cockroach [*Blattella germanica*]). Dumping in Meadowlands landfills rapidly developed into several commercial enterprises (*e.g.*, trucking, landfill disposal) in the 1940s, and even included disposal of building rubble from London, England that was used as ship ballast during World War II (Sullivan, 1998).

Following World War II, the State of New Jersey recognized that roads in the region were inadequate to accommodate the tremendous increase in traffic volume that had occurred, especially in the corridor between New York and Philadelphia. To address this problem, the New Jersey Turnpike Authority was created by the State legislature in 1948; construction of the New Jersey Turnpike (NJT) from the Delaware Memorial Bridge to the George Washington Bridge began in 1949. The final leg of the initial six-lane roadway, the eastern spur through the Meadowlands, was completed in January 1952. The NJT was one of the first "modern" highways, employing design criteria (*e.g.*, lane width, 3 percent maximum grades, acceleration and deceleration lanes, minimum shoulder widths) that are still used today. While these criteria provided for safety and a high rate of speed, the NJT and similar highways occupy more area with a more extensive "ecological" footprint than other roadways in the United States (Forman and Alexander, 1998). Although the roadway was projected to accommodate increased traffic volume until the mid-1970s, the NJT was widened in 1955 (a third, and for some segments, a

Figure 10. A "Magic City from a Swamp," which appeared in the October 1928 issue of *Popular Science Monthly*. Note the projects (*e.g.*, waterways, parks) that would have required extensive dredging and filling activities to achieve this vision of the Meadowlands.



October, 1928 POPULAR SCIENCE MONTHLY 49

A Magic City from a Swamp

FROM a vast 41-acre waste of mosquito-infested New Jersey swamp land, just across the Hudson River from New York City, soon may rise a great city of industries and homes, larger in area than New York herself. A project recently announced by the Regional Plan of New York and pictured on this page calls for streets and skyscrapers, parks and waterways, flying fields and residential districts.

The site is known as the Hackensack Meadows, through which wind the Passaic and Hackensack rivers.

To build the city on dry land the level of the entire marsh must be raised ten feet by filling with 200,000,000 cubic yards of dirt. The Hackensack River must be straightened and deepened for the passage of large ships, and a system of canals dredged.

The cost is estimated at $8,700,000 to $14,400,000 to accommodate in the beginning a population of 730,000 people — about equal to that of Boston.

The black area on the small map indicates proposed site of the new city of the Hackensack Meadows.

The engineers' vision of the great city as it will appear when completed. Note the provisions for large airports, and for waterways big enough for the accommodation of the largest of ocean vessels and seaplanes.

The New Jersey marshes as they appear today. Ten feet of fill will soon turn them into dry land.

fourth lane was added each way) and again in 1966 (six lanes each way throughout). Eventually, a western spur was completed in 1971 that bisected the Meadowlands. Though the NJT's western spur was noted to have some positive impacts on certain fauna for several years following the roadway's construction (*e.g.*, ducks, muskrat [*Ondatra zibethicus*]; Hackensack Meadowlands Development Commission, 1975), more recent studies indicate profound changes (*e.g.*, reduced hydrologic flow) in the wetlands that were cut off from the Hackensack River by the NJT's western spur (Tiner *et al.*, 2005).

Dumping continued virtually uncontrolled throughout the 1950s and most of the 1960s, and turned the Meadowlands into the world's largest landfill at the time (Sullivan, 1998). The amount of garbage that was dumped in the Meadowlands each day, about 10,000 tons, would fill an average-sized football stadium. As they filled with household garbage, most dumps were molded slowly into large hills. Many garbage hills were burned regularly to save space or control wind-strewn debris; others burned accidentally. Methane gas from the decaying refuse and other flammable debris fueled the fires, some of which burned uncontrollably for years (*e.g.*, the Giant stadium-site fire). During the height of the dumping in the 1960s, the Meadowlands received 40 percent of the State of New Jersey's solid waste stream and another 10,000 tons per day from New York City. More than 200 dumps occupied approximately 2,500 acres within the Meadowlands. The garbage and other waste discarded at these sites increasingly degraded ecological processes in the Meadowlands. The air was filled with smoke, the stench of decay, and millions of cubic feet of landfill methane. Landfill leachates and other toxic materials poured into the Hackensack River and its tributaries, combined with heated effluents from power plants and industrial discharges, and made extensive anoxic zones and widespread fish kills a recurring event. At the same time, the landfills' growing hills increasingly dominated the landscape.

F. LAND-USE PLANNING (Late 1960s to Present)

By the late 1960s, many recognized that environmental degradation in the Meadowlands was impacting the quality of human life and compromising the region's ecology and economy; however, residents of the Meadowlands' diverse communities differed as to their preferred solutions. Under increasing political pressure to act, the State legislature created the HMDC in 1969 with three mandates in its governance of the newly designated HMD: manage solid waste, provide for economic development, and protect the environment. Through regional land-use planning, zoning authority, and revenue sharing, the HMDC moved to address the garbage problem. The HMDC took numerous steps to close illegal dumps, prohibit most dumping of out-of-state waste, and more tightly regulate other dumping. Eventually, the HMDC formulated plans to close most dumps and address their diverse impacts to the land, water, and air. Most dumping was halted in the 1970s, but a small number of dumps remained open to accommodate household garbage generated within the HMD. The legacy of the Meadowlands dumping, 2,500 acres of refuse-filled marshes, still impacts the region's landscape (Iannuzzi *et al.*, 2002).

Over the next 30 years, the HMDC directly or indirectly participated in other plans and activities that affected the Meadowlands' environment (Table 1; New Jersey Meadowlands Commission, 2004a). Perhaps most importantly, the HMDC increasingly regulated waste disposal within the

Table 1. Timeline of activities of the Hackensack Meadowlands Development Commission / New Jersey Meadowlands Commission in the Hackensack Meadowlands District (1969 to date).

1969	The Hackensack Meadowlands Development Commission (HMDC) is established by the Hackensack Meadowlands Reclamation and Development Act (N.J.S.A. 13:17-1 *et seq.*) and begins operations (*e.g.*, waste management and land-use planning).
1970	The HMDC formulates its first comprehensive land-use plan for the Hackensack Meadowlands District (HMD). This plan imposes certain environmental controls and standards and leads to denial of applications for additional landfills in Lyndhurst and Kearny. Adopted prior to the Clean Water Act (Federal Water Pollution Control Act; see Appendix 1), this plan also calls for the filling and development of more than 2,000 acres of wetlands.
1971	The New Jersey Sports and Exposition Authority (NJSEA) is established to operate sports and entertainment facilities in the Meadowlands.
1973	The HMDC adopts regulations banning disposal of all out-of-state solid waste in HMD landfills.
1974	The HMDC establishes the first tax sharing formula for the HMD.
1975	The New Jersey Department of Environmental Protection (NJDEP) establishes the Sawmill Creek Wildlife Management Area.
1976	Passage of the Solid Waste Management Act (N.J.S.A 13:1E-20) establishes the HMD as the State's 22nd Solid Waste District and further regulates solid-waste disposal. The NJSEA opens the Meadowlands Stadium for football and the Meadowlands Racetrack for horseracing.
1977	The HMDC and the NJDEP begin their first study of contamination in the Hackensack Meadowlands.
1979	The HMDC begins negotiating with local governments (*e.g.*, Morris and Union County) to end solid-waste disposal from sources outside of the HMD.
1981	The HMDC begins construction of the Meadowlands Environmental Center with Green Acres funding ($1 million) from the NJDEP. The NJSEA opens the Meadowlands Arena (now Continental Airlines Arena) for professional basketball and hockey.
1982	The HMDC begins a feasibility study to extract methane from landfills.
1984	The HMDC negotiates and signs an agreement to end disposal of solid waste from Passaic County in the HMD.
1985	The HMDC begins closure of several landfills in Kearny and North Arlington, and protects the Kearny Freshwater with zoning amendments.
1986	The HMDC, the U.S. Army Corps of Engineers, New York District (Corps), and the U.S. Environmental Protection Agency, Region II (EPA) initiate the "Basis for the Advanced Identification of Wetlands" (AVID), a study to identify wetlands in the Hackensack Meadowlands that are suitable for filling. Leachate collection begins at the Kearny 1-A Landfill.
1987	The HMDC closes the Kearny 1-C Landfill and ends disposal of solid waste from Essex and Passaic Counties in HMD landfills.
1988	Prior to the publication of the AVID results, the New Jersey Department of Community Affairs, on behalf of the HMDC, proposes to the Corps and the EPA that a Special Area Management Plan (SAMP) be considered for the HMD. The goal of the SAMP is to "streamline" the federal permitting process to accommodate economic development in the HMD.

1989 The HMDC completes closure of the Kearny 1-A Landfill, establishes a recycling program for HMD municipalities, and undertakes its first inventory of the HMD's historic and cultural resources.

1991 The HMDC opens its methane recovery plant, the nation's second largest, dedicates the Marshland Discovery Trail and the Losen Slote Creek Park, and establishes the Environmental Improvement Program Trust for remediation.

1992 The EPA, Corps, and HMDC publish the findings of their joint AVID study (also conducted with the U.S. Fish and Wildlife Service (Service), National Marine Fisheries Service, and NJDEP): the AVID designates less than 2 percent of wetlands in the HMD as suitable for filling activities.

1993 The HMDC signs an agreement with Conrail to accept mitigation funding for wetlands enhancement.

1994 The HMDC revises its inventory of cultural and historic resources, and begins wetlands enhancement and its first redevelopment study.

1995 The Draft Environmental Impact Statement for the SAMP is published by the EPA and the Corps on behalf of its partners. The HMDC expands its landfill-gas recovery, environmental education, and wetlands enhancement programs.

1995 The HMDC proposes establishment of a Meadowlands Conservation Trust, and acquires two wetlands enhancement sites (Mill Creek and Riverbend Marshes). The HMDC participates in discussions regarding a mitigation bank in the HMD.

1997 The HMDC ends all household solid-waste disposal in the HMD, establishes an Open-Space Policy, and continues expanding its landfill-gas recovery and environmental education programs.

1998 The HMDC establishes the Meadowlands Environmental Research Institute and begins operating: (1) New Jersey's largest leachate-collection system around several HMDC-owned landfills (1-A and 1-E), and (2) two electric-generating stations using landfill gas. The HMDC also receives federal grants to develop a hydrologic model and revise the HMD's flood control.

2001 The HMDC withdraws its local sponsorship of the SAMP; the State of New Jersey enacts legislation renaming the HMDC as the New Jersey Meadowlands Commission (NJMC) to reflect its commitment to the restoration and protection of the environment in the HMD.

2002 The NJMC, the Corps, and the Service begin the Hackensack Meadowlands Environmental Restoration Project, a component of the Hudson-Raritan Estuary Restoration.

2003 The NJMC proposes a revised Master Plan, announces the Encap Redevelopment Project to close and remediate 6 landfills and provide extensive open-space in the form of golf courses and adjoining areas, and reorganizes the Meadowlands Environment Center in partnership with Ramapo College. The NJMC, the Corps, the Service, and Hudsonia, Ltd. co-sponsor The Meadowlands Symposium, a scientific meeting focused on research in the Meadowlands.

2004 The NJMC adopts its revised Master Plan.

2005 The NJMC, Corps, NJDFW, NFWF, and Service co-sponsor the 4th Stakeholders Work Session for the Hackensack Meadowlands. The NJMC initiates a 3-year study by the NJDEP, the New Jersey Audubon Society, and Ducks Unlimited, Inc. to assess the HMD's fish and wildlife resources and develop a wildlife management plan.

HMD. The HMDC formulated its first comprehensive land-use plan in 1970. This plan imposed certain environmental controls and standards and led to denial of applications for additional landfills in Lyndhurst and Kearny (New Jersey Meadowlands Commission, 2004a). However, adopted prior to significant federal and State legislation, this plan also called for the filling and development of more than 2,000 acres of wetlands. The HMDC adopted regulations banning disposal of all out-of-state solid waste in 1973 and the HMD's first tax sharing formula in 1974. In 1977, the HMDC and the NJDEP began their first study of contamination in the Hackensack Meadowlands. Two years later, the HMDC began restricting disposal of solid waste from in-state communities outside of the HMD.

Activities by the HMDC affecting the environment slowly grew more diverse during the 1980s. Wetlands filling in the HMD continued but was increasingly opposed by other government-agencies and the public. The HMDC began construction of the Meadowlands Environmental Center and extraction of methane from landfills in 1981 and 1982. The HMDC further restricted disposal of solid waste from in-state sources through the mid-1980s and began closure of large landfills in North Arlington and Kearny a few years later. The NJMC undertook its first inventory of the HMD's historic and cultural resources in the late 1980s.

In 1986, the HMDC, the Corps, and the EPA initiated the AVID study to identify wetlands in the Hackensack Meadowlands that were suitable for filling. The NMFS, Service, and NJDEP also participated in the AVID, which designated slightly less than 2 percent of the Meadowlands (only 122 acres) as suitable for filling activities (U.S. Environmental Protection Agency, 1992). Thus in 1988, prior to publication of the AVID results, the New Jersey Department of Community Affairs, on behalf of the HMDC, proposed that the Corps and the EPA consider a SAMP for the Hackensack Meadowlands District. The goal of the SAMP was to "streamline" the federal permitting process regulating activities in wetlands to accommodate economic development in the HMD. As initially conceived, the SAMP ignored the AVID findings that only 122 wetland acres were suitable for filling, and promoted filling more than 1,200 acres of wetlands for non- water-dependent development. Subsequent revisions to the SAMP reduced the acreage of fill. The HMDC withdrew its local sponsorship of the SAMP in 2001, and soon thereafter, work on the SAMP was discontinued. A short time later, the HMDC changed its name to the New Jersey Meadowlands Commission.

G. DEVELOPMENT AND ENVIRONMENTAL ALTERATION (1970s to Present)

Two years after the HMDC's establishment in 1969, the New Jersey Sports and Exposition Authority (NJSEA) was established in part to build a racetrack and football stadium in the Meadowlands. The Meadowlands Stadium, home initially to the New York Giants, opened in 1976 on the site of one of the largest Meadowlands landfills, where a fire had burned uncontrollably for years. The Meadowlands Arena, now known as the Continental Airlines Arena, was opened 5 years later on an adjoining site as a home for the region's professional basketball and hockey teams. Due to these and other large projects, the landscape in the HRW became increasingly suburban and urban (Hasse and Lathrop, 2001; 2003).

Although the population throughout much of the region declined from the 1970s through the mid-1990s (CensusScope, 2005), natural vegetative cover was declining and becoming increasingly fragmented as suburban sprawl spread throughout the HRW and into the adjoining Passaic River watershed. The increased demand for water in these watersheds was satisfied by extensive alteration of the hydrology of several rivers in northern New Jersey. In the mid-1970s, the North Jersey District Water Supply Commission (a State government agency) and the Hackensack Water Company (privately owned) established a partnership to build the 29.6-billion-gallon Wanaque Reservoir on the Wanaque River, a Passaic River tributary. A few years later, the partnership completed another dam upstream of the Wanaque Reservoir to form the Monksville Reservoir. Both reservoirs in the Passaic River watershed are connected by 102-inch aqueducts to the Oradell Reservoir to allow for regular diversions of water from the Passaic River reservoirs into the Oradell Reservoir. The storage capacity of Woodcliff Lake on the upper Hackensack River basin also was increased by construction of a new dam. Other aqueducts were constructed to transfer water from the Saddle River in the Passaic River watershed and Sparkill Creek in the Hudson River watershed. While satisfying the demand of local municipalities for water, the reservoirs cause additional losses of riparian areas and further fragmentation of riverine habitats in the upper watershed. The increased water supply also promoted additional development throughout the upper Passaic and Hackensack watersheds. Though outside the Meadowlands, development of the landscape and subsequent hydrologic alterations throughout the watershed have long contributed to: (1) further isolation of the Meadowlands, (2) additional deterioration in water quality and other adverse hydrologic impacts on the Meadowlands, and (3) greater vulnerability of the Meadowlands to other disturbances, such as invasive species.

Although original enabling legislation granted the HMDC broad powers for brownfield redevelopment, the HMDC did not undertake its first redevelopment project until 1994. The HMDC adopted an Open Space Plan in 1997. Since that time, several other redevelopment projects (*e.g.*, Vincent Place in Teterboro, 16th Street in North Bergen) have been initiated. One of the latest redevelopment projects in the HMD, the Encap Project, will convert six common reed-covered landfills into golf courses and a mix of other land uses, including open space (New Jersey Meadowlands Commission, 2005a). The NJMC is pursuing redevelopment of several other brownfields within the HMD. More recently, a new retail-entertainment complex, known as Xanadu, has received federal and State permits to redevelop a portion of the NJSEA site. As has occurred with other projects in the HMD, upland grasslands and wetlands are being converted to other uses for this project. Most recently, the State has proposed limited gambling (*i.e.*, slot machines) at the Meadowlands Racetrack; the NJSEA has announced possible modifications to and/or an expansion of the Meadowlands Stadium and a minor league baseball stadium as part of the Xanadu project. At this writing, the Service has not received detailed information regarding the proposed activities; therefore, any potential environmental impacts of these projects are unknown.

H. STEWARDSHIP AND FUTURE PLANNING

By the late 1990s, public attitudes toward the Meadowlands had changed considerably. Many NGOs were vocal in their opposition to what is now considered an unacceptable use (*e.g.*,

wetlands filling for non-water-dependent projects) of the Meadowlands and became increasingly effective in engaging government agencies regarding protection of the Meadowlands. Government agencies also became active. The Service's (1996a) Southern New England – New York Bight Coastal Ecosystems Program completed a comprehensive study, *Significant Habitats and Habitat Complexes of the New York Bight*, which identified the importance of the Meadowlands' open space to fish and wildlife populations and further promoted protective efforts. In response to NGO advocacy and a Congressional inquiry, the Service's Northeast Regional Land Acquisition Review Committee requested a briefing on the feasibility of establishing a National Wildlife Refuge in the Meadowlands. In reply, the NJFO prepared a 1999 presentation entitled *The Hackensack Meadowlands National Wildlife Refuge: A Proposal for a New Refuge Establishment*. At the time, the Northeast Regional Office decided not to pursue establishment of the Meadowlands as part of the refuge system, largely due to contaminant concerns and other higher-priority land acquisitions. However, the Service continued to pursue partnering in stewardship efforts.

The next few years represented a turning point in the focus of activities regarding the Meadowlands. Beginning in 1999, several of New Jersey's Congressional members as well as the Secretary of Interior toured the Meadowlands. In 2000, the Corps initiated the Reconnaissance Phase for the Hudson-Raritan Estuary Restoration Project: the Meadowlands was identified as one of several potential restoration areas that warranted priority consideration. Later that year, the Service and other agencies co-authored a *Wildlife Management Plan for the Hackensack Meadowlands* (U.S. Fish and Wildlife Service *et al.*, 2000). Although intended as a document to supplement the SAMP, which was still being developed at the time, the management plan advocated protection of large, undeveloped wetland tracts. In response to the NGO constituency, the Service also hosted the first of several stakeholder work sessions later that year. In May 2001, the second stakeholder session included the NJDFW and addressed expectations of the NGOs, the NJDFW, and the Service. Later that year the SAMP was discontinued and a third stakeholders work session, attended by representatives from NGOs, government agencies, and elected officials, was held. Stakeholders reached a consensus that environmental restoration and protection were their shared objectives for the Meadowlands.

With strong support from local organizations, federal and State agencies expanded their activities to protect the Meadowlands. The Corps, NJMC, and the Service initiated their joint planning (*i.e.*, the Project Management Plan) for the Meadowlands as a component of the HRE Ecosystem Restoration Project in spring 2002. The NJFO and the NJDFW hosted the Service's Director and District Congressman Steve Rothman (NJ 9th) on a Meadowlands tour in August 2002. In the fall, the Service's Northeast Regional Directorate Team toured the Meadowlands. In December 2002, the NJFO promoted the Hackensack Meadowlands via 18 articles authored by various stakeholders in its newsletter *Field Notes*. Also in 2002, the Service and the NJDFW developed a *Vision Plan* for the Meadowlands (Appendix 2). The Service's National Wetlands Inventory (Tiner *et al.*, 2002) published *Wetland Status and Trends for the Hackensack Meadowlands* to identify cumulative losses of wetlands and other land-use trends within the HMD. In 2003, the Service, Corps, Meadowlands Environmental Research Institute (MERI), and Hudsonia, Ltd. (a local NGO) sponsored *The Meadowlands Symposium*, a research symposium to showcase scientific research in the Meadowlands. Eight papers from the symposium were published in the online journal of the Brooklyn Botanic Garden (2004a), *Urban Habitats*. Also in 2003, the

NJMC's Meadowlands Environmental Center began re-organization through a partnership with Ramapo College. In 2004, the Service declared the Meadowlands a "Regional Resource Priority." In June 2005, the Service, Corps, NJDFW, NJMC, and NFWF co-sponsored the fourth stakeholders' work session to update stakeholders regarding ongoing restoration, planning, and other activities (*e.g.*, outreach, research). All of these activities increased the public visibility of the Meadowlands and promoted additional and ongoing efforts to protect and restore the Meadowlands.

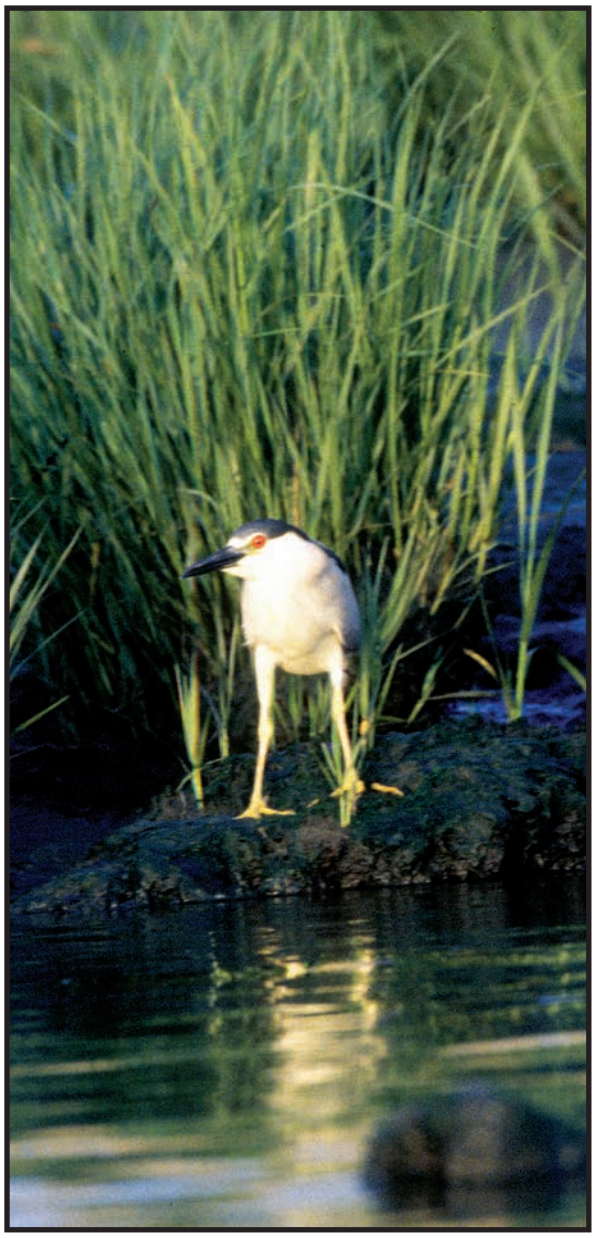
Presentations at the June 2005 stakeholders' work session identified several restoration efforts that are currently underway or in planning stages. The Service, Corps, and NJMC are partners in the Feasibility Study that is currently focused on the restoration of the 53-acre Anderson Creek Marsh (*e.g.*, U.S. Army Corps of Engineers, 2004b). These same three partners are not only planning the restoration of that site but also investigating restoration (and the potential need for prior remediation) of other sites (*e.g.*, ENSR, International, 2004; U.S. Fish and Wildlife Service, 2005a). Additionally, the NJMC (2004b) has received funding from the EPA to investigate use of *in situ* barrier materials for capping the heavily contaminated Kearny Marsh site. The NJDFW has been funded by the NJMC (2004c) to develop a detailed wildlife management plan for the HMD; this plan will take the form of a wildlife action plan and focus on protection of State-listed species inhabiting the Meadowlands. During the June 2005 stakeholders' works session, the Service presented an overview of four ongoing Meadowlands activities: (1) *The Hackensack Meadowlands Initiative: Preliminary Conservation Planning* (this effort), (2) an overview of its contaminant concerns as a partner in the Feasibility Study (U.S. Fish and Wildlife Service, 2005b), (3) updating and expanding its wetlands status and trends assessment for the entire HRW (Tiner and Bergquist, 2005), and (4) outreach and education. The presentations at the work session identified many different efforts to move forward the restoration of the Meadowlands and made clear the need for regular collaboration among stakeholders, especially those federal and State agencies partnered in diverse efforts to remediate and restore numerous sites throughout the Meadowlands.

I. SUMMARY

Humans have lived in the Meadowlands for roughly 10,000-12,000 years. For most of that time, the human population, comprised of ancestral Lenape groups, had minimal impacts upon the landscape and largely subsisted off the area's abundant natural resources, including wildlife species that no longer exist today. Upon the arrival of European colonists, exploitation of the natural resources of the Meadowlands increased, slowly at first, and then rapidly as the colonial population expanded, displaced the native Lenape from their settlements, and spread across the landscape. About 200 years ago, as the region's timber resources were harvested, humans began large-scale modification of the Meadowlands. Wetlands were ditched and diked for agricultural and other purposes (*e.g.*, mosquito eradication) and altered to improve transportation throughout the region. Landscape alterations promoted further development and contributed to a faster growing human population. Around the turn of the century, the natural water supply in the Meadowlands watershed was no longer adequate to meet human demands. As a result, the landscape of several watersheds (*e.g.*, adjacent Passaic River basin) was increasingly altered to store water, thus disrupting natural hydrology. Flow alterations hastened further changes in the

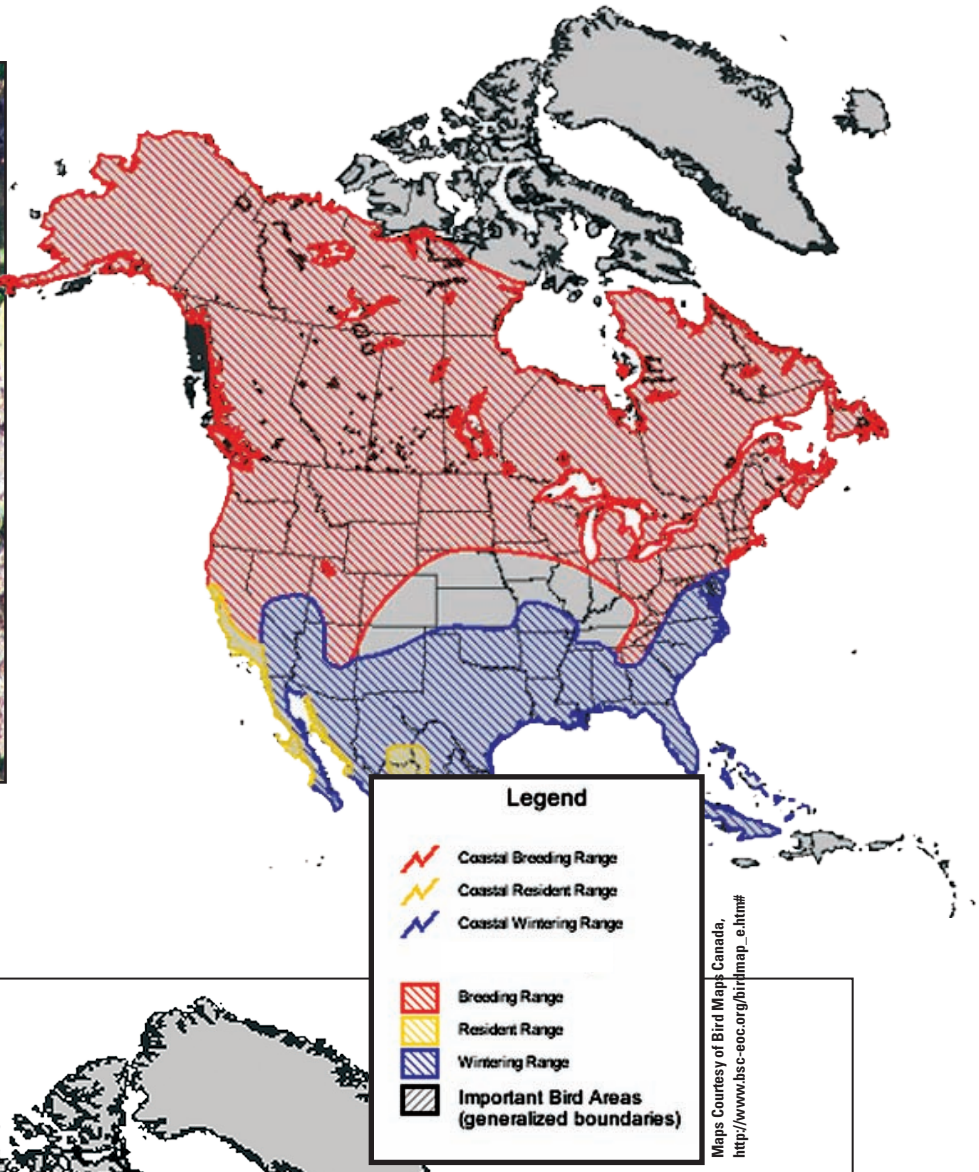
landscape, and dramatically changed the Meadowlands from a tidal palustrine to a predominantly estuarine ecosystem (see Section V). With further population growth, waters and wetlands in the Meadowlands became increasingly neglected and degraded. Much of the wetlands were used as landfills, and human refuse and industrial contamination became widespread. As the environmental consequences were slowly recognized, the need to address them became apparent. However, short-term needs outweighed concerns as the human population continued to alter the landscape and hydrology throughout the HRW. Since the turn of this century, diverse stakeholders, including NGOs and State and federal agencies, have joined together in efforts to protect and restore the Meadowlands. These organizations and agencies now have many ongoing projects addressing restoration of specific sites, management of fish and wildlife resources, and public outreach and education. Such activities are moving environmental restoration forward but make clear the need for, and importance of, more and improved stakeholder collaboration in future efforts to restore the Meadowlands and protect its fish and wildlife populations.

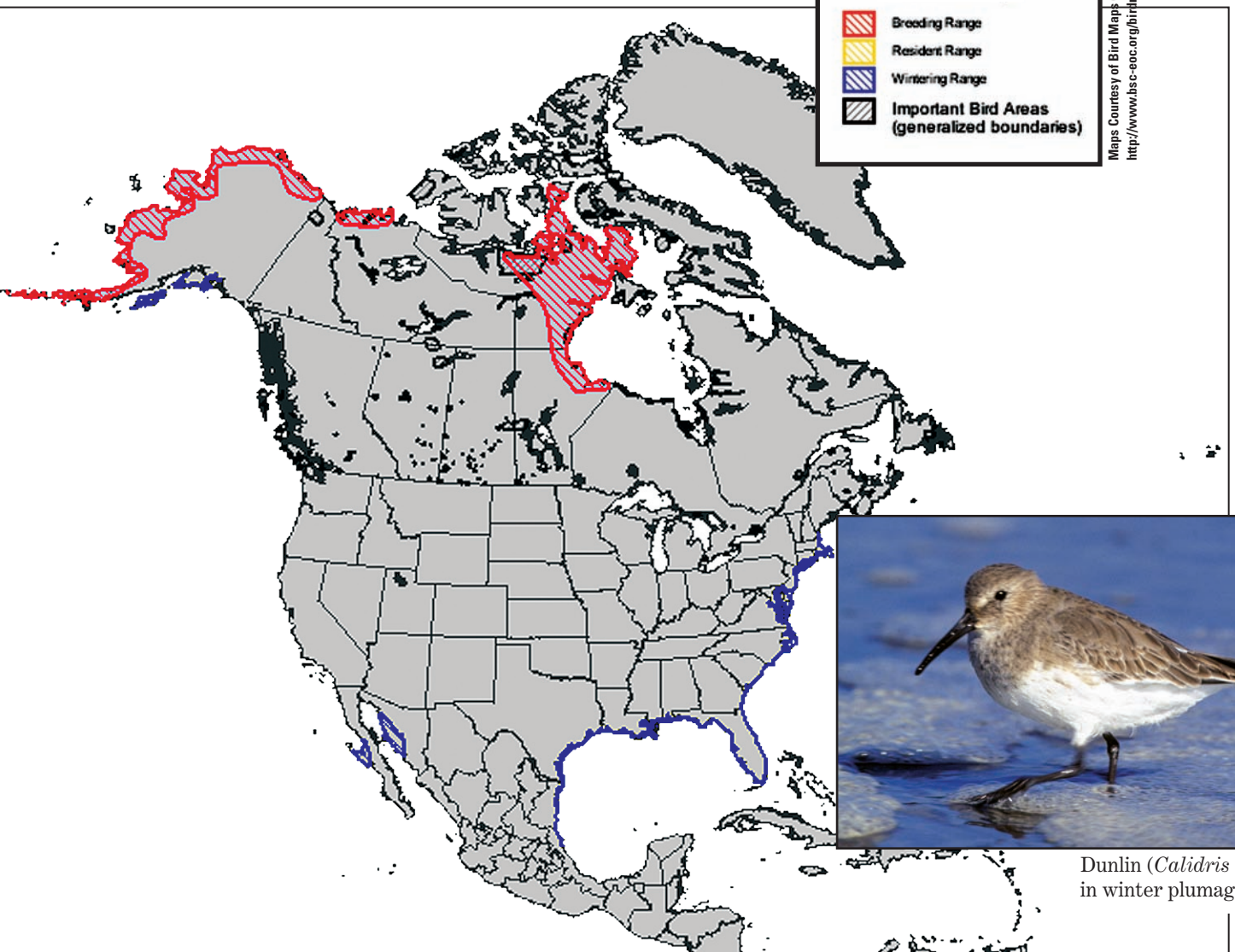
III. Natural History



A black-crowned night heron (*Nycticorax nycticorax*).

Savannah sparrow
(*Passerculus sandwichensis*)





Dunlin (*Calidris alpina*)
in winter plumage.

III. Natural History

The Meadowlands is used by numerous species of fish and wildlife. The most visible animals in the Meadowlands are birds. Approximately 40 percent of the 800 or more species of migratory birds in North America use the Meadowlands as breeding or wintering habitat or as a "stopover" in which to feed and rest during their spring and fall migrations. Eliminating or degrading even one such migratory stopover may adversely affect populations that range from such faraway places as northern Alaska and Argentina.

The two bird species on the left illustrate the diversity of birds and the connections of the Meadowlands to other places in the Americas. Small numbers of savannah sparrow (*Passerculus sandwichensis*), State-listed as threatened, nest in several different habitats in the Meadowlands (grassy fields, marsh edges) and feed on upland and wetland prey (insects, crustaceans, small mollusks). Large numbers of dunlin (*Calidris alpina*) migrate through the Meadowlands during spring and fall. Dunlin can be seen foraging on mud flats with their long bills, which they use to feed on small crustaceans, mollusks, and worms living in the mud.

These species also illustrate the importance of remediating and restoring the Meadowlands. For example, removing invasive plant species along marsh edges and enhancing upland grasslands will benefit savannah sparrow, as well as other riparian and grassland species. Remediation and restoration of wetlands and adjoining uplands, together with other comprehensive actions improving water quality throughout the region, will help prevent certain contaminants from bioaccumulating in invertebrate animals upon which dunlin and other animals feed.

A Mill Creek marsh restoration site.

III. NATURAL HISTORY

A. REGIONAL PHYSIOGRAPHY AND GEOLOGY

B. GLACIATION, LAKE HACKENSACK, AND THE MEADOWLANDS

C. THE COLONIAL LANDSCAPE AND ATLANTIC WHITE-CEDAR

D. THE HACKENSACK RIVER AND MEADOWLANDS ENVIRONMENT

1. **Hydrology**
   a. The Hackensack River Watershed
   b. The Brunswick Aquifer and Groundwater
2. **Soils and Sediments**
3. **Land Use and Landscape Cover**

E. WETLANDS OF THE HACKENSACK MEADOWLANDS

1. **Introduction**
2. **Estuarine Wetlands**
   a. A Natural Restoration Site
   b. Restored Sites
   c. The Pilot Site of the Hackensack Meadowlands Environmental Restoration
   d. Potential Restoration Sites Currently with Minimal Concerns
   e. Potential Restoration Sites Currently with Moderate Concerns
   f. Potential Restoration Sites Currently with Substantial Concerns
3. **Palustrine Wetlands**
4. **Riverine and Lacustrine Wetlands**

F. SIGNIFICANT BIOTA

1. **Federally Listed Species**
   a. Bald Eagle
   b. Dwarf Wedgemussel
   c. Shortnose Sturgeon
   d. Bog Turtle
2. **State-Listed Species**
3. **Special-Concern Species**

G. SUMMARY

Shortnose sturgeon (*Acipenser brevirostrum*).

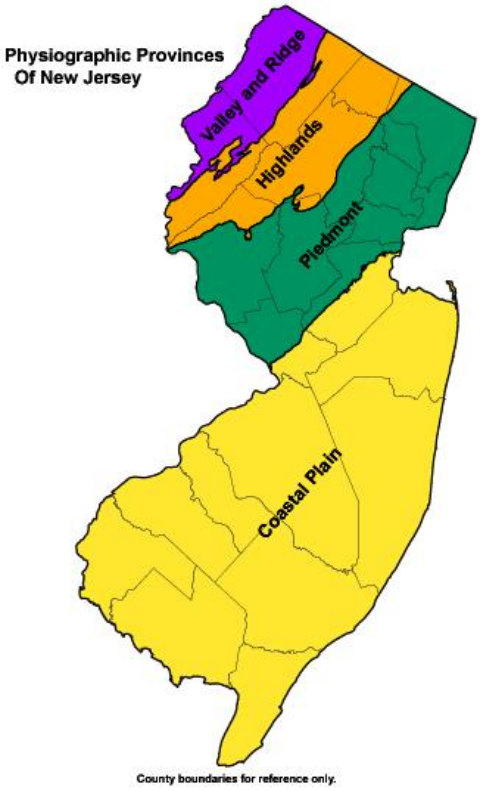
Atlantic sturgeon (*Acipenser oxyrhynchus*).

III. NATURAL HISTORY

A. REGIONAL PHYSIOGRAPHY AND GEOLOGY

The Hackensack Meadowlands is located in the narrow (16 to 30 miles wide), northernmost section of the *Piedmont Province*, one of 25 major physiographic provinces in the United States (Figure 11). The Piedmont Province is a transitional geologic region, which lies between the Precambrian (formed approximately 900 million to 1.2 billion years ago) Appalachian region of New Jersey (the Highlands) to the northwest and the Tertiary (formed about 10 million years ago) to Cretaceous (formed up to 90 million years ago) areas of the Coastal Plain to the southeast (U.S. Fish and Wildlife Service, 1996a).

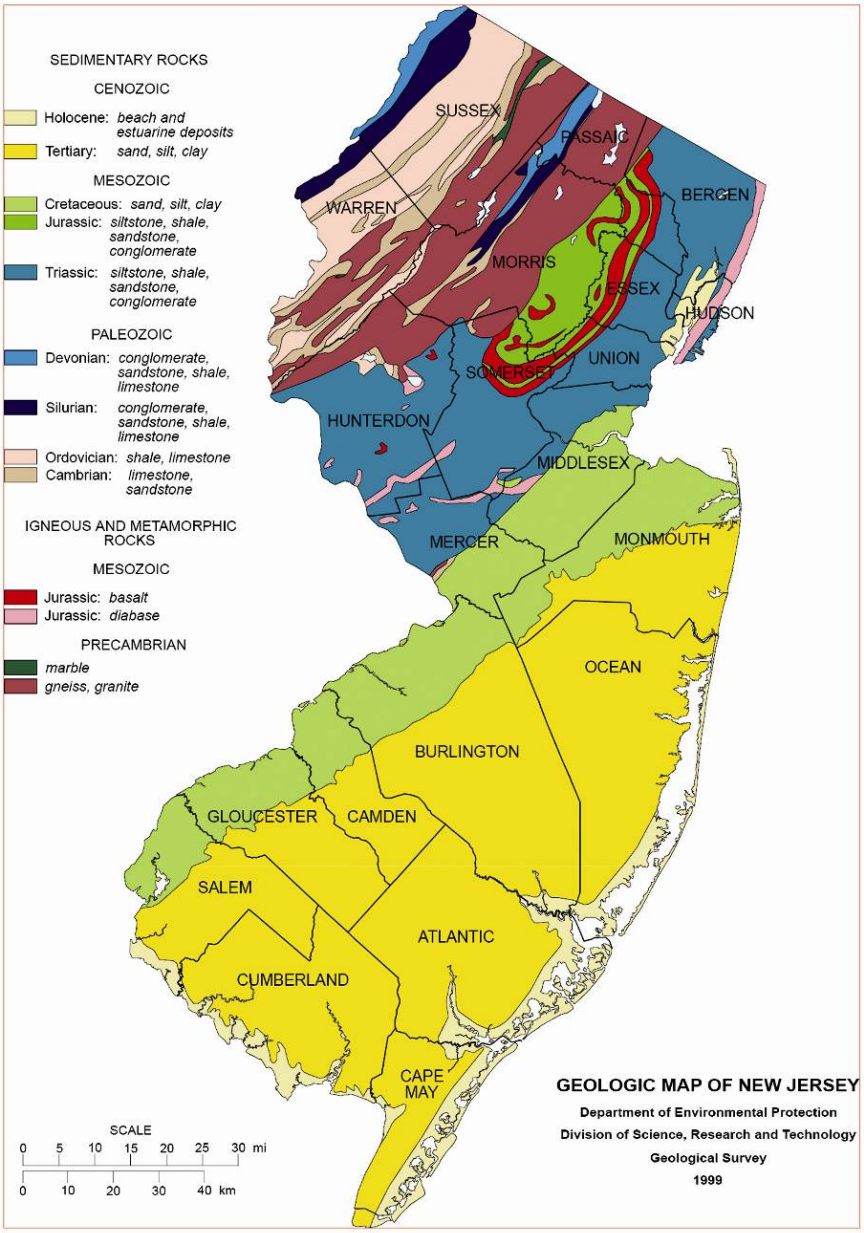
Figure 11. Physiographic provinces of New Jersey. The Hackensack Meadowlands District occurs entirely within the Piedmont Province, one of 25 major physiographic provinces in the United States. Figure courtesy of New Jersey Department of Environmental Protection (2004b).



The Piedmont is divided into upland and lowland sections throughout its range from the Hudson River to Alabama; however, only the lowland section occurs extensively in New Jersey. The *Piedmont Lowlands* consists of several continuous formations of Triassic sedimentary rocks (*e.g.*, reddish shales and sandstones of the Brunswick formation) that stretch from the Hudson River southward into Virginia (Figure 12). The *Northern (Triassic) Lowlands*, extending from the Palisades along the Hudson River in New York southward to the Schuylkill River in

Pennsylvania, is a relatively low-lying formation of broad valleys and low hills that slopes gently in a southeastward direction from its highest elevations of about 400 feet (122 meters) above sea level in northeastern New Jersey to sea level at Newark Bay (U.S. Fish and Wildlife Service, 1996a).

Figure 12. Geologic map of New Jersey. Rocks throughout most of the Hackensack River watershed are largely shales and sandstones of Triassic origin, whereas the HMD area (in yellow) is comprised mostly of younger (Holocene) glacial and estuarine deposits.



The Northern Lowlands is interrupted by ridges of hard igneous rock (traprock), including the Watchung Mountain ranges of New Jersey and the Palisades Sill along the west bank of the Hudson River (Figure 12). Two offshoots of the Palisades, known locally as Snake Hill and Little Snake Hill, stand out prominently in the Hackensack Meadowlands. Traprock deposits of Snake Hill have been mined extensively for building materials; traprock deposits on both hills also contain distinctive minerals that are prized by collectors (*e.g.*, petersite, natrolite; Peacor and Dunn, 1982; Anthony *et al.*, 1995; Figure 13).

Figure 13. Petersite (left photo) and natrolite (right photo) mineral deposits from traprock outcroppings (Snake Hill and Little Snake Hill) in the Hackensack Meadowlands.

B. GLACIATION, LAKE HACKENSACK, AND THE MEADOWLANDS

Glaciers and the continental ice sheet during the four major glacial advances (glacial stages) of the *Pleistocene Epoch* have shaped the modern landscape of the northern portion of the Piedmont Province. The last glacial period, the *Wisconsin glaciation*, began between 70,000 and 100,000 years ago. The Wisconsin glacier eventually became the largest glacier in North America, extended farther south than other Pleistocene glaciers, and caused the crust of the continent to sag, depressing the land east and north of New York City and elevating the coast south of its harbor (U.S. Fish and Wildlife Service, 1996a). During the maximum period and extent of the Wisconsin glaciation, much of the earth's surface water was frozen in an ice sheet. Sea level was roughly 350 to 400 ft (107 to 122 m) lower and temperatures in the region were approximately 18°F cooler than at present. Between 15,000 and 12,000 years ago, this glacier formed the massive Harbor Hill terminal moraine that extended from Long Island west across Staten Island to Perth Amboy and formed the southern boundary for Glacial Lake Hackensack (U.S. Fish and Wildlife Service, 1996a).

As the earth's climate began to warm, the Wisconsin glacier left pockets of glacial deposits as it began to retreat (Figure 14). Meltwaters trapped by these deposits slowly formed and expanded Lake Hackensack and other nearby glacial lakes (*e.g.*, Lake Passaic; Figure 15). The broad, shallow lake filled with additional glacial deposits in some places and became interspersed with pockets of sedge meadows and other vegetation (*e.g.*, *Sphagnum*, *Typha*) until about 10,000 years ago, when the terminal moraine was breached near Staten Island (U.S. Fish and Wildlife Service, 1996a). As Lake Hackensack slowly drained from 10,000 to 8,000 years ago, the lake bottom accumulated varved (layered) clays, and then experienced hydrologic and related changes (*e.g.*, sea-level rise, crustal rebound). Vegetation in the initially formed meadows underwent successional changes, with woody vegetation (*e.g.*, alder and birch swamps, then tamarack [*Larix laricina*] and black spruce [*Picea mariana*] forests) contributing to a more diverse coastal landscape (U.S. Fish and Wildlife Service, 1996a). The taiga-like, black-spruce forest and other woody communities persisted on some sites within the Meadowlands as late as the early 1800s (Schmid, 1987). Glacial Lake Passaic experienced similar changes about the same time, and eventually became occupied by Great Swamp, Great Piece Meadows, Little Piece Meadows, Long Meadows, Black Meadows, Troy Meadows, Hatfield Swamp, Lee Meadows, and Bog and Vly Meadows. With the gradual post-Pleistocene sea level rise, the initial freshwater marsh of the Hackensack Meadowlands was gradually invaded by increasing amounts of seawater, tidal influences, and salt-tolerant vegetation (*e.g.*, species of *Spartina* cordgrasses).

Figure 14. Generalized glacial sediments in New Jersey. Wisconsin glacial deposits are widespread in northern New Jersey and have contributed to formation of glacial lakes in the region. Figure courtesy of New Jersey Department of Environmental Protection.

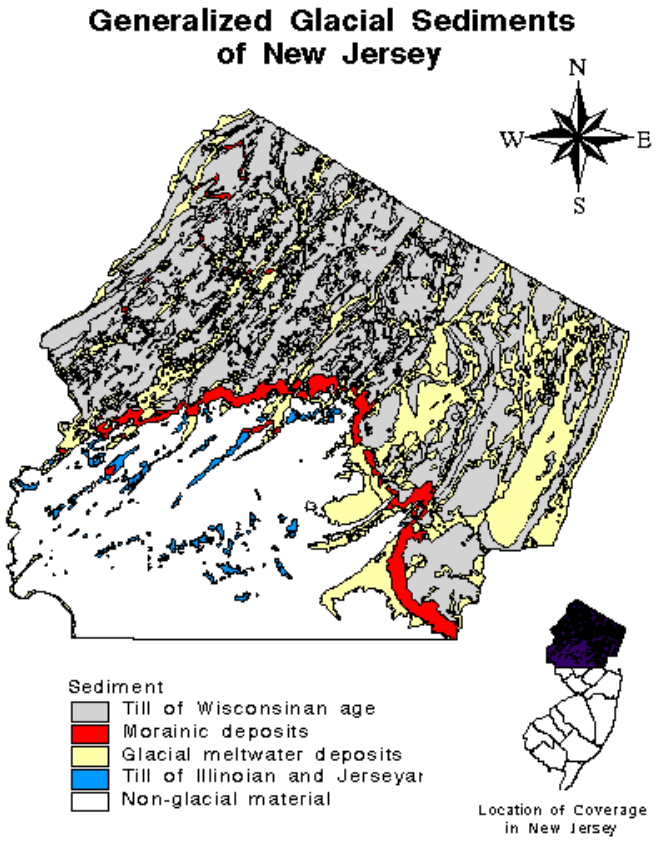
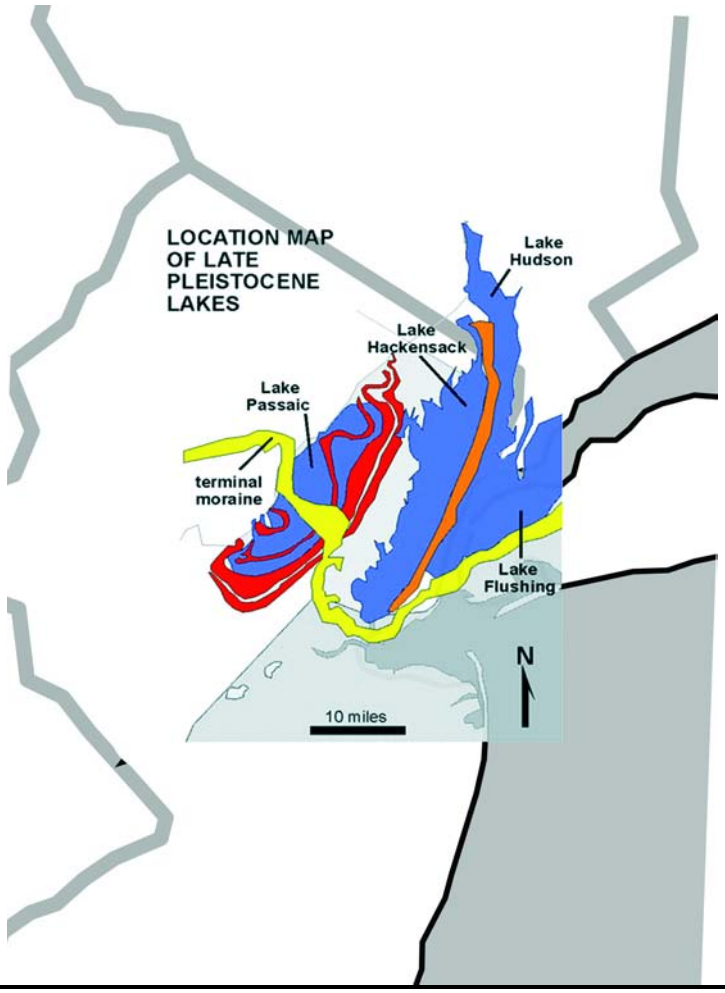


Figure 15. Glacial lakes (shown in blue) formed in New Jersey (Lake Passaic and Lake Hackensack) and New York (Lake Hudson and Lake Flushing) as the Wisconsin glacier retreated. The ridges of the Watchung Mountains and the cliffs of the Palisades are indicated by red and orange, respectively.



C. THE COLONIAL LANDSCAPE AND ATLANTIC WHITE-CEDAR

Extensive forests of Atlantic white-cedar (*Chamaecyparis thyoides*) have sometimes been portrayed as the dominant prehistoric and colonial component of the Hackensack Meadowlands (Figure 16). However, Atlantic white-cedar, though common in other freshwater wetlands throughout the eastern United States and southern New Jersey (Laderman, 1987), did not become a substantial component of the Meadowlands flora until the 1400s and probably was never as extensive as generally portrayed (Schmid, 1987). When Europeans arrived in the 1600s, the Hackensack Meadowlands was predominantly a freshwater tidal river system with diverse, forested swamps and bogs in headwater areas, large forested tracts of Atlantic white-cedar, and

Figure 16. Aerial (upper) and ground (lower) photos of Atlantic white-cedar forest. These illustrate the vegetation that occurred in the Hackensack Meadowlands from 1400-1900, but no longer occurs in the Meadowlands due to logging and damming of the Hackensack River.

diverse freshwater and brackish meadows in its lower reaches. When Europeans began colonizing the area in the 1700s, Atlantic white-cedar apparently occupied about one-third of the Meadowlands (Torrey *et al.*, 1819 and Vermeule, 1897, as cited in Schmid, 1987). Whether the cedar forest was expanding or declining at that time is uncertain (Sipple, 1972); however, the white-cedar forest was reduced by harvesting and burning from the 1700s through the early 1900s. Heusser (1949) reported only six Atlantic white-cedar trees alive in the Meadowlands; the species does not occur anywhere in the Meadowlands today. Rot-resistant stumps of Atlantic white-cedar along Berry's Creek Canal, Mill Creek, and other locales within the Meadowlands are all that remains of the stands that once covered thousands of acres.

D. THE HACKENSACK RIVER AND MEADOWLANDS ENVIRONMENT

Most of the region, including uplands, wetlands, and the river, has been disturbed extensively by human activities during the last several hundred years. As discussed in Section II, wetlands in the Meadowlands were diked for farming, ditched for mosquito control, and filled to create uplands (Quinn, 1997; Sullivan, 1998). The hydrology, soils and sediments, and land use of the Hackensack River watershed (HRW) are described below.

1. Hydrology

a. The Hackensack River Watershed

The Hackensack River extends 34 miles (54.4 kilometers) from Haverstraw, New York to its confluence with Newark Bay; the watershed covers 202 square miles (523.2 square kilometers; Figure 17). More than half (58 percent) of the watershed occurs in Bergen County; approximately one-third (32 percent) of the watershed occurs in Rockland County, New York, and the remainder (10 percent) occurs in Hudson County, New Jersey. The watershed includes 19 hydrologic sub-basins (see Section V.A), and is divided by the Oradell Dam into two major portions (Figure 17): (1) the lower watershed, which is comprised of all tidally influenced areas, primarily the Meadowlands; and (2) the upper watershed, which is not tidally influenced and is less developed, especially in New York. Pascack Brook and Overpeck Creek are the major upper and lower tributaries of the river, respectively.

Including storm-flow conditions, historical water flows over the Oradell Dam in the Hackensack River averaged more than 58 million gallons per day (mgd; approximately 90 cubic feet per second [cfs]) from 1922 to the present, but only 41 mgd (approximately 63.4 cfs) during the past 25 years (U.S. Geological Survey, 2003) due to increasing withdrawals to provide drinking water. To meet the region's demand for water, four water-storage reservoirs were created by constructing several dams along the Hackensack River (Figure 17). The reservoirs hold nearly 14 billion gallons (gal) of water and cover more than 6,000 acres (ac; Table 2; U.S. Geological Survey, 2003). To maintain these water-storage reservoirs, the main flow of the river is managed by local water companies (primarily United Water New Jersey) in accordance with agreements and regulations in New York and New Jersey. The river flow is managed using a series of interbasin connections through which water is pumped from other sources into the watershed, largely but not always directly into the Oradell Reservoir. On average, approximately 35 to 45

Figure 17. Major water bodies of the Hackensack River watershed (including its four large water-storage reservoirs), and the lower Passaic and Hudson Rivers. Oradell Dam divides the Hackensack River in upper (non-tidal) and lower (tidal) portions. The Meadowlands, located in the lower portion, is affected by activities in the upper and lower portions of the watershed.

Table 2. Name, location, drainage area, volume, and year of construction of water storage reservoirs in the Hackensack River watershed.

Reservoir (location)	Drainage (square miles)	Volume (gallons)	Year built
De Forest Lake (Nyack, New York)	27.5	5,670,000,000	1956
Lake Tappan near (North Tappan, New Jersey)	49.0	3,853,000,000	1966
Woodcliff Lake (Hillsdale, New Jersey)	19.4	871,000,000	1905, 1984
Oradell Reservoir (Oradell, New Jersey)	113	3,507,000,000	1922

mgd (approximately 54.1 to 69.6 cfs) are pumped into the Oradell Reservoir from the Pompton River, the Wanaque Reservoir, or the Saddle River (all in the Passaic River basin; U.S. Geological Survey, 2003). Depending on rainfall, reservoir levels, and other conditions, water companies may also use well water or pump water from Sparkill Creek (Hudson River basin) into the Oradell Reservoir.

The total daily demand for water within the watershed (110 mgd, largely due to usage in Bergen and Hudson Counties; United Water New Jersey, 2004) has resulted in tremendous reductions in the Hackensack River's daily flow. The current NJDEP Bureau of Water Allocation's Water Diversion Permit (No. 5111) requires minimum flows of 8.3 mgd (approximately 12.8 cfs) at Oradell Dam. During the past few years, only minimum flows in the Hackensack River have been maintained during summer; however, meeting even those minimum flow requirements has not always been possible during drought conditions (Sullivan, pers. comm., 2004). Thus, requests for additional diversions of water from the Passaic River watershed into the upper Hackensack River appear inevitable, and emphasize the need for planning that integrates water supplies, re-use, and conservation.

As a result of the Oradell Dam, only the Lower Hackensack River (the portion below the dam) is under tidal influence. The tidal range at Hackensack, New Jersey averaged 6.0 feet in 2001 and 2002 (U.S. Geological Survey, 2003). Tidal transport of materials, including some contaminants, from Newark Bay up to the Oradell Dam (see Section IV.B; Wilson, pers. comm., 2004) emphasizes the need to adopt a watershed-wide (and perhaps regional) approach to any management plan for the Meadowlands. Only three small creeks (Hirshfield Brook, Van Saun Mill Brook, and French Brook) drain into the tidal freshwater stretch of the Hackensack River. Overpeck Creek, the Hackensack's largest tributary, discharges into the mainstem of the Hackensack River just above the northern border of the HMD. The flow of Overpeck Creek is restricted by a dam and a tide gate; the majority of tributaries of the Hackensack River that lie within the HMD are restricted by tide gates or culverts (New Jersey Meadowlands Commission, 2004d).

Approximately three-fourths of water used within the HRW eventually returns to the Hackensack River as sewage effluent processed by a county or municipal sewage treatment plant (STP; Table 3). Sewage is processed at one of three major STPs within the HMD; approximately 85 mgd of secondary-treated effluent is discharged primarily into the Hackensack River, but also into Mill and Chromakill Creeks along the northern border of the HMD. The STPs of a few municipalities receiving water from Hackensack sources (*e.g.*, West Nyack, Palisades, Edgewater) discharge their treated waste into the Hudson River. Some wastewaters and other materials generated within the HRW are transferred to facilities of the Passaic Valley Sewerage Commissioners (PVSC) for treatment and discharge into the Hudson River (*i.e.*, Upper Bay).

In addition to its freshwater and sewage-effluent inputs, the Hackensack River estuary receives considerable tidal flows of brackish water from Newark Bay (mean tidal discharge = 1,200 cubic meters per second; Najarian Associates, 1990; DiLorenzo *et al.*, 2004). The high average ratio of tidal to freshwater flows (more than 100:1; DiLorenzo *et al.*, 2004) contribute to a relatively well-mixed estuarine system. The tidal flows distribute dissolved and suspended materials, including contaminants, from Newark Bay throughout the Hackensack River as far upriver as the Oradell Dam (Wilson, pers. comm., 2004).

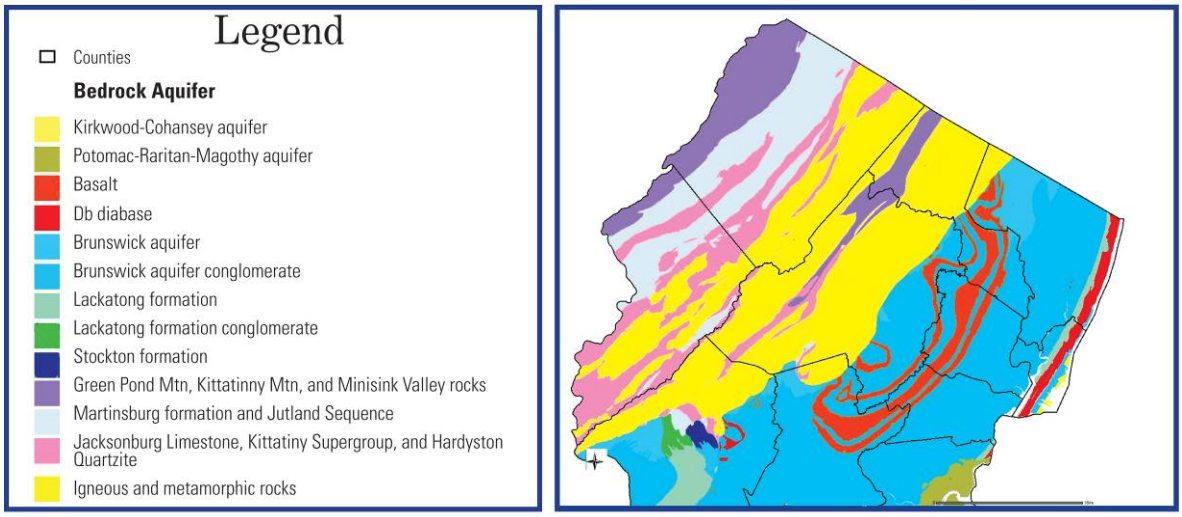
Table 3. Name, location, receiving body, treatment, and capacity of sewage treatment plants discharging into the Hackensack River watershed. Capacity of sewage treatment plants is expressed in millions of gallons per day (mgd).

Facility (location)	Receiving Water Body	Treatment	Capacity (mgd)
Bergen County Utilities Authority (Little Ferry)	Hackensack River	Secondary	109
North Bergen Municipal Utilities (North Bergen)	Cromakill Creek	Secondary	18
Secaucus Municipal Utilities Authority (Secaucus)	Mill Creek	Secondary	5
Passaic Valley Sewerage Commissioners (Newark)	Upper Bay	Secondary	330

b. The Brunswick Aquifer and Groundwater

The Brunswick Aquifer underlies much of the HRW, including the HMD (Figure 18; New Jersey Department of Environmental Protection, 2004b), but its utility as a source of freshwater is limited by underlying rock layers and other factors (*e.g.*, contaminants) to the upper reaches of the watershed (*e.g.*, Ridgewood, Rockland County, New York). Movements of groundwater into the aquifer depend upon the underlying rock layers and generally parallel surface waters throughout the HRW (U.S. Environmental Protection Agency, 2003a). Much of the watershed's groundwater enters surface water streams at lower elevations; thus, surface waters are used to provide the water supply for most of the watershed.

Figure 18. Map of aquifers in northern and central New Jersey. The Brunswick Aquifer (medium blue color) underlies nearly the entire Hackensack River watershed (HRW), including the Meadowlands. Because of the regional geology and contaminants, groundwaters of the Brunswick aquifer in the HRW are of limited utility as a source of drinking water. Figure courtesy of the New Jersey Department of Environmental Protection.



2. Soils and Sediments

Most soils throughout the HRW are unconsolidated Pleistocene glacial deposits roughly 10,000 to 80,000 years old. Soft, red shales, coarse-grained sandstones, and other conglomerates usually underlie the glacial deposits but can be found at the surface occasionally. Boonton, Dunellen, and Haledon are among the most common soil types identified throughout the watershed; several hydric soil types (*e.g.*, sulfahemists, sulfaquents) also cover extensive areas within the watershed (Natural Resources Conservation Service, 2004). Some common soils in the watershed have low pH (*e.g.*, Boonton, pH = 4.1) and bind heavy metals poorly (Lee *et al.*, 1996).

Due to the long history of human use and landscape modification, most surface soil in the HRW (especially in the HMD) can only be identified as "urban land" (Natural Resources Conservation Service, 2004; New Jersey Meadowlands Commission, 2004d). Urban land is a miscellaneous soil classification that reflects development (*e.g.*, buildings, roads, landfills, dredge-and-fill activities). Thus, the origins and characteristics used to determine naturally occurring soil types are unidentifiable in urban land.

Though sometimes described as soils, tidal marsh deposits are more accurately identified as sediments and are composed of fine silts and clays with considerable organic content, usually less than 30 percent (Adam, 1990). Because these sediments are inundated by tidal waters, aerobic decomposition is hindered by the saturated conditions. Thus, anaerobic processes (*e.g.*, fermentation, sulfate reduction; Adam, 1990), which are important components of biogeochemical processes and also affect contaminant availability (Section IV.B), predominate. As a result, marsh sediments in the Hackensack Meadowlands accumulate considerable amounts of partially decayed organic matter and are referred to as peat. The peat is widespread throughout the HMD and even occurs within urban land, much of which is historical fill on wetlands; in general, peat increases in thickness from the outer edges of the Meadowlands towards the Hackensack River's mainstem.

3. Land Use and Landscape Cover

The Hackensack Meadowlands is not only the largest brackish estuary within the New York Bight, it is also the largest undeveloped area within the State's Hackensack and Pascack Water Management Area (Figure 19), which roughly approximates the New Jersey portion of the HRW. The dominant land cover within the Water Management Area is primarily urban and suburban (roughly 70 percent; New Jersey Department of Environmental Protection, 2004c). Forest (10 percent), water (10 percent), and wetlands (7.5 percent) are the most extensive naturally occurring landscape cover types within the entire Water Management Area (Figure 19 and Table 4; New Jersey Department of Environmental Protection, 2004c). Urban and suburban land use within the HMD is less extensive (57 percent) than in the entire HRW and in many other coastal watersheds (Pew Oceans Commission, 2004). This difference results in part from the extensive wetlands (30 percent; 5,784 ac) and open water (10 percent; 1,870 ac) within the HMD. Other extensive land uses/cover types within the HMD include altered lands (primarily closed landfills; approximately 7 percent; 1,450 ac), recreation areas (approximately 4 percent), and vacant lands (approximately 2 percent; *e.g.*, cemeteries). Land use within the HMD and the HRW has resulted in extensive changes in landscape cover and adverse impacts to fish and wildlife populations; thus, additional detail and concerns about land use are presented in Section V.

Figure 19. Map of land use and landcover for the Hackensack and Pascack Watershed Management Area in New Jersey. This image emphasizes the limited acreage and fragmentation of open water, wetlands, and forested cover throughout the region. Image courtesy of New Jersey Department of Environmental Protection.

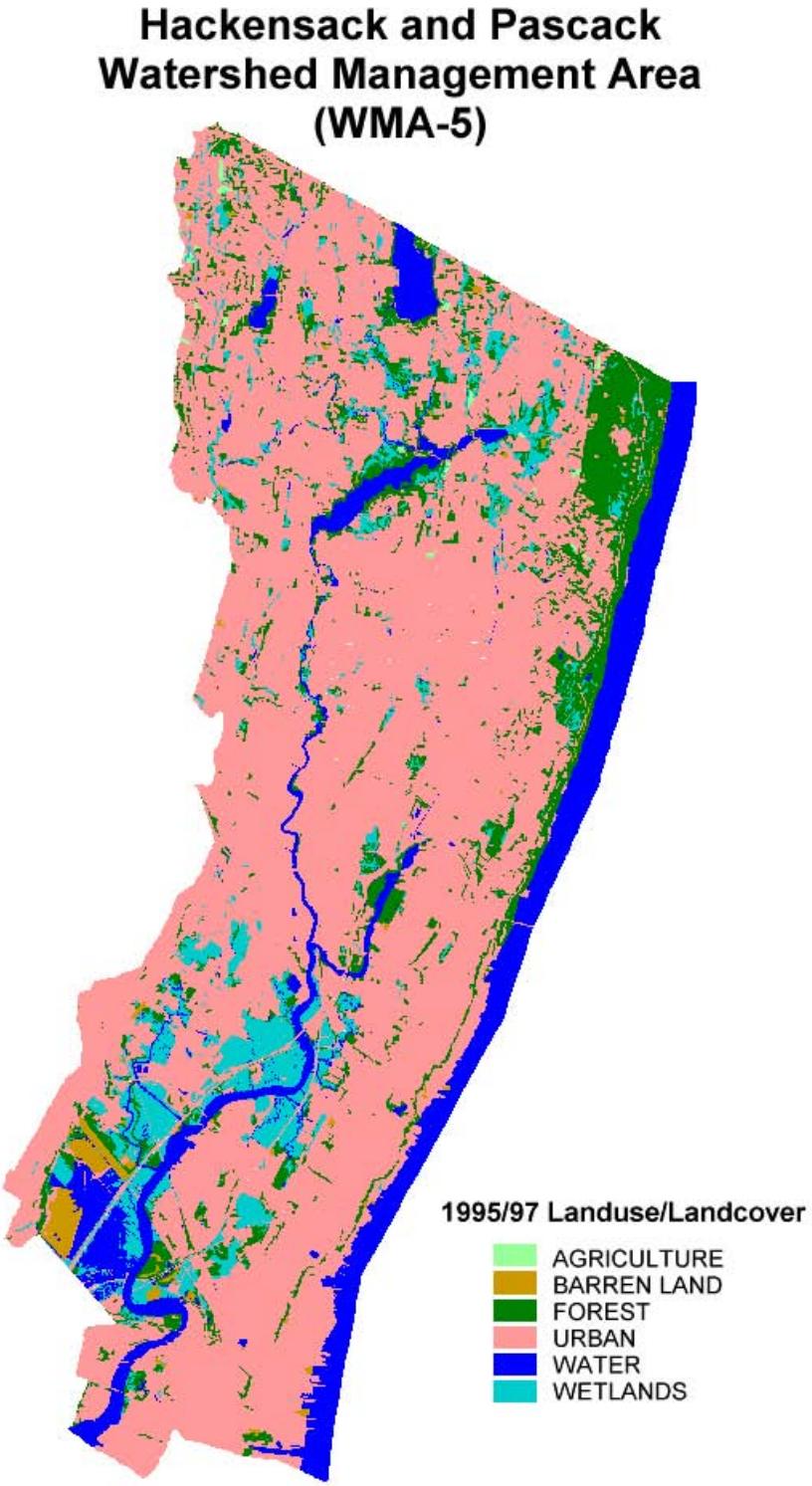


Table 4. Summary of land use and landscape cover for the Hackensack Meadowlands District (HMD) and the Hackensack and Pascack Water Management Area (HPWMA). The boundary of the HPWMA extends beyond the Hackensack River watershed (HRW) in New Jersey, but does not include any portions of the HRW in New York. Data for the HMD are taken primarily from the NJMC (2004d) Master Plan, and data for the HPWMA are taken from the New Jersey Department of Environmental Protection (2004b).

Cover/Land Use	HMD acreage	percent of the HMD	HPWMA acreage	percent of the HPWMA
Water	1,870	9.6	10,560	10.0
Wetlands	5,784	29.5	7,920	7.5
Forest	258	1.3	10,560	10.0
Agricultural	0	0	211	0.2
Recreational	757	3.9	2,429	2.3
Urban / Suburban	10,816	55.7	73,920	70.0

E. WETLANDS OF THE HACKENSACK MEADOWLANDS

1. Introduction

Wetlands are among the most productive and "valuable" ecosystems in the world (Mitsch and Gosselink, 1993). Wetlands have provided important backdrops for the evolution of life onto land by many different groups (*e.g.*, plants, arthropods, amphibians), and played critical roles in the production and preservation of much of the fossil fuels upon which humans now depend. Globally, wetlands provide diverse landscapes that support considerable biodiversity, from lower to higher forms of life (bacteria, fungi, algae, vascular plants, and animals). Wetlands, especially tidal marshes, are also among the most productive ecosystems in the world, annually producing up to 35 tons of plant material per acre (80 metric tons per hectare; Mitsch and Gosselink, 1993). The high production and "nursery" habitats provided by wetlands sustain fishes, shellfishes, and other wildlife (*e.g.*, Teal, 1962; Boesch and Turner, 1984; Kiviat, 1989; Valiela, 1991; Beck *et al.*, 2001). In addition, wetlands uniquely combine chemical transformation and transport processes in the biogeochemical cycling of carbon, nitrogen, phosphorus, sulfur, iron, and manganese (Nixon, 1981; Mitsch and Gosselink, 1993). Finally, wetlands and estuaries are recognized as among the most "valuable" ecosystems in the world, with economic estimates of the services that they provide ($5,983 and $9,240 per acre per year, respectively) far exceeding those estimates of forests, grasslands, and other natural terrestrial ecosystems ($392, $94, and $325 per acre per year, respectively; Costanza *et al.*, 1997).

While efforts to attach an economic or dollar value to the ecosystem services provided by wetlands are sometimes viewed as controversial (*e.g.*, Costanza *et al.*, 1997), many services provided by wetlands are well recognized as important to the public. Wetlands also contribute to

both public and private benefits. In addition to the important ecological features and roles identified above, wetland ecosystems filter and purify water, retain storm waters and moderate floods, recharge ground water, trap sediments and contaminants, and cycle nutrients and other materials (*e.g.*, National Research Council, 1995; Daily *et al.*, 1997). Wetlands are also valued for social, recreational, and aesthetic reasons (*e.g.*, Hoehn *et al.*, 2002; Boyer and Polasky, 2004).

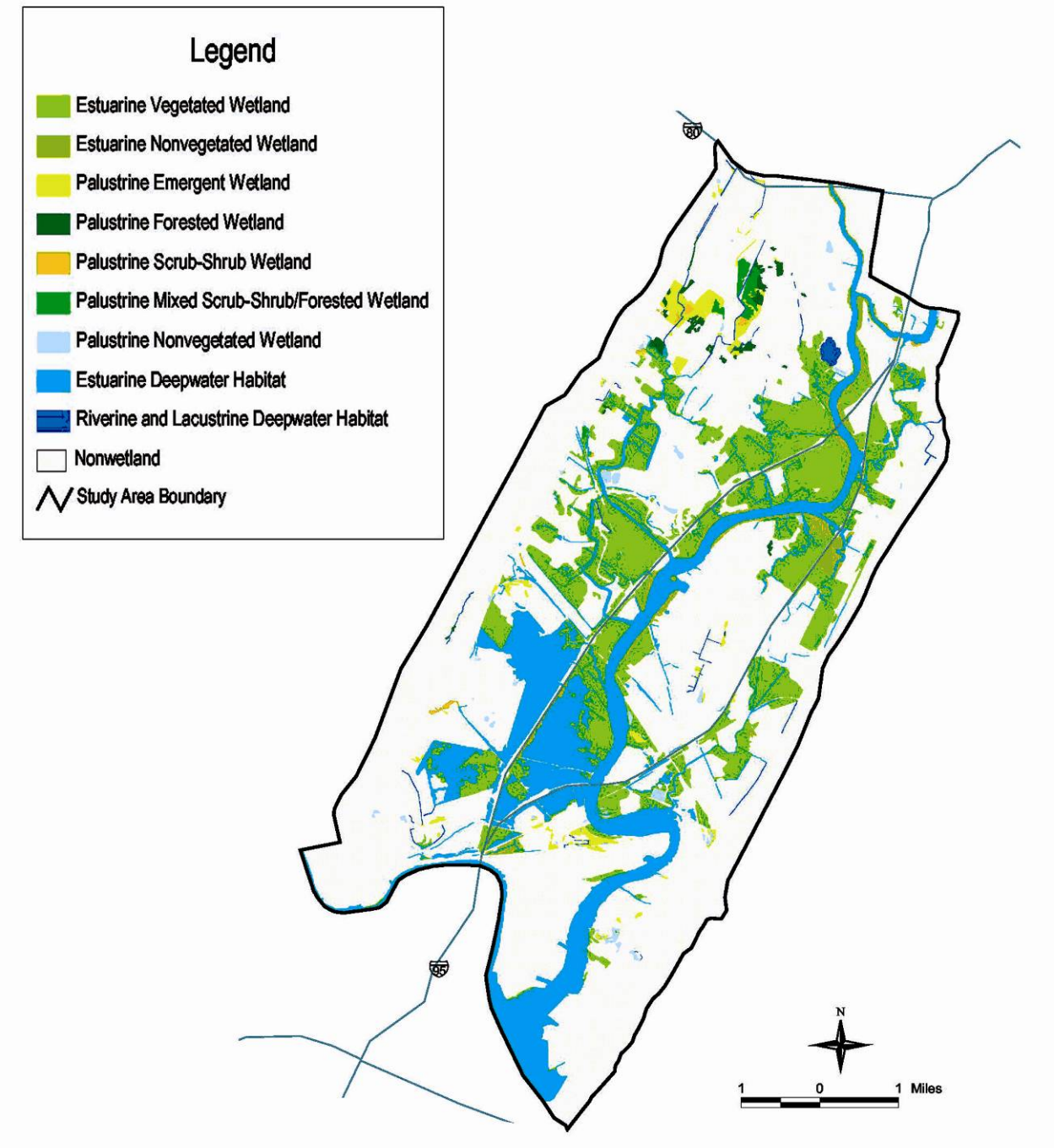
As in other estuaries, the wetlands in the Hackensack Meadowlands have been dynamic during its relatively brief (approximately 10,000-year) geologic history, particularly as global temperatures have warmed following the retreat of the glaciers. The Meadowlands' estuarine (*i.e.*, brackish water) and palustrine (*i.e.*, mostly freshwater) wetlands have changed extensively to reflect the increasing presence of salt water from natural causes, mainly post-glacial sea level rise, and, during the past 100 years, from anthropogenic causes. Due to the gradual reduction in freshwater flow of the Hackensack River (Section D1) since the construction of the Oradell and other dams, estuarine wetlands (2002 area approximately 5,300 ac) are now the most common and widely distributed wetland type within the HMD (Figure 20; Tiner *et al.*, 2005). Approximately 75 percent of the estuarine wetlands in the HMD are characterized further by the presence of emergent vegetation. Estuarine wetlands lacking vegetation (*i.e.*, areas with unconsolidated shores and substrates, mostly intertidal mudflats) have increased and have become the second most common wetland type in the Meadowlands (Tiner *et al.*, 2005). Palustrine wetlands, approximately one-third to one-half of the Meadowlands in colonial times, comprised less than 10 percent of the Meadowlands (approximately 540 ac [219 hectares, ha] in 2002 (Tiner *et al.*, 2005).

The Meadowlands clearly remains a changing landscape; understanding the dynamics and causes is important to planning the remediation, restoration, and management of the Meadowlands' resources into the future. For example, changes in vegetative community structure during wetland succession may be affected by continued sea-level rise and watershed alterations (*e.g.*, surface and groundwater use). Additional details about wetland types and sites are provided in the sections below.

2. Estuarine Wetlands

Available information (*e.g.*, Tiner *et al.*, 2002) indicates that approximately 90 percent of estuarine wetlands in the Meadowlands, which represent the majority of wetlands in the HMD, are dominated by the invasive form of common reed, Haplotype M (Saltonstall, 2002). Only one unrestored estuarine wetland site within the HMD is not dominated by common reed. That site, the Sawmill Creek Wildlife Management Area (jointly managed by the NJDEP and the NJMC), provides an indication of the potential for marsh restoration within the HMD. To illustrate several points, all other wetland sites in the HMD are grouped in the discussion below by their restoration history (*e.g.*, restored) or the Service's (2005b) concerns regarding restoration. The Service has identified preliminary categories of concern (minimal, moderate, or substantial), which are based on available, though in some cases, limited information regarding environmental contamination. Thus, these preliminary concern categories should be revised as additional contaminant information becomes available.

Figure 20. Wetlands classification map of the HMD from Tiner *et al.*, 2002. Major wetland classifications include estuarine (vegetated, non-vegetated and deepwater), palustrine (emergent, forested, scrub-shrub, mixed, or non-vegetated), and riverine and lacustrine deepwater. Identification and mapping of these habitats for the Hackensack River watershed outside of the HMD has recently been completed (Tiner and Bergquist, 2005). Approximately 200 acres of wetlands shown in this 1995 map have since been filled.



a. A Natural Restoration Site

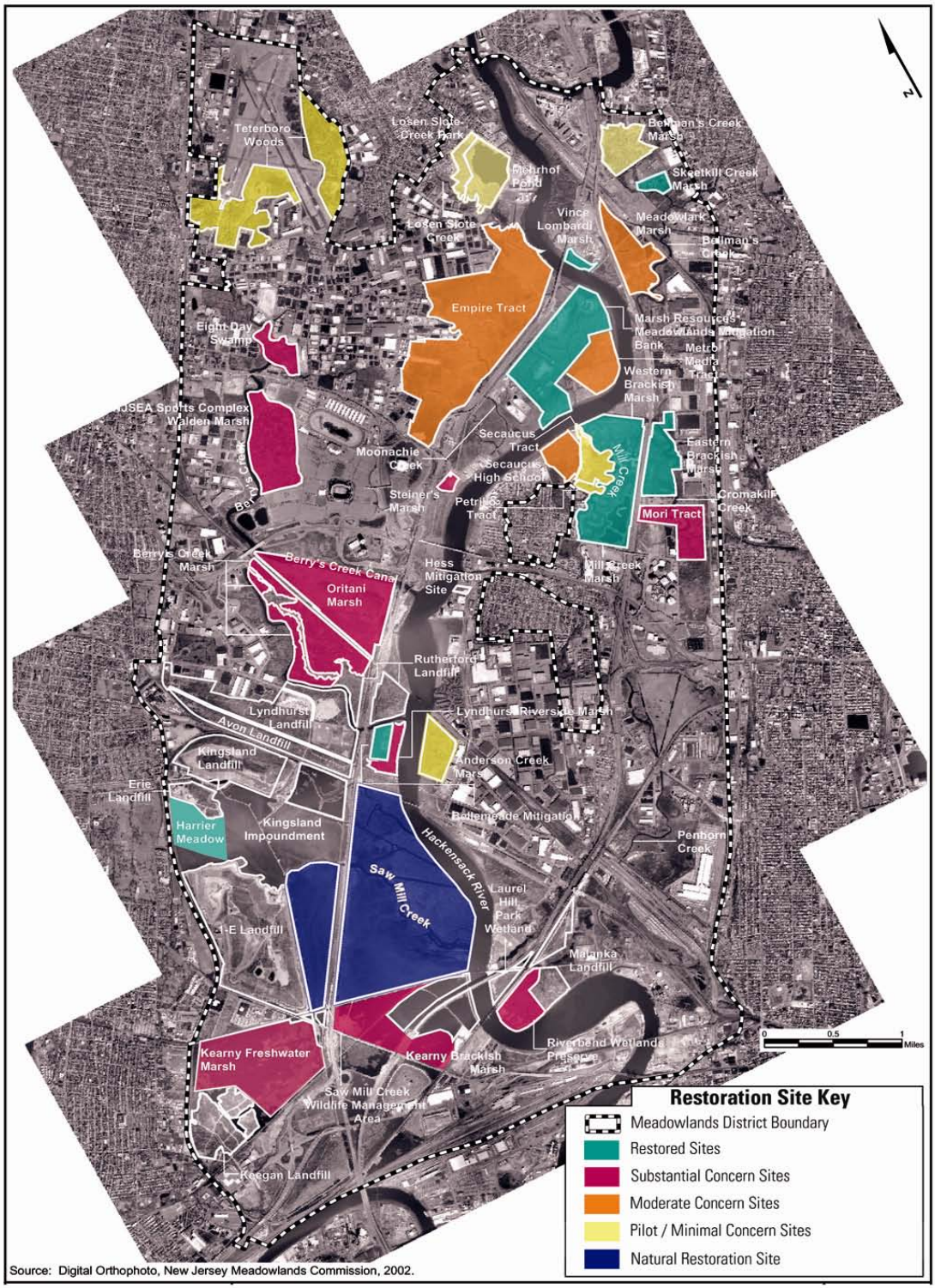
The 878-acre Sawmill Creek Wildlife Management Area is the largest single wetland landholding in the HMD (Figure 21; U.S. Army Corps of Engineers, 2003a). The site is owned by the State of New Jersey; the NJMC and NJDEP have an open-ended agreement for the NJMC to be the principal manager of the site. The New Jersey Division of Fish and Wildlife also plays an active role in the management of Sawmill Creek. The Sawmill Creek area near the Hackensack River was diked for mosquito control early in the 20th century. Cut off from tidal flows, the marsh slowly changed as it was colonized by common reed; subsequently, its biodiversity declined.

In 1950, a northeaster destroyed the Sawmill Creek dikes and reopened the marsh to tidal flooding from the Hackensack River. As a result of the increased tidal flow from this "natural restoration" event, common reed at this site was weakened and eventually died off in low marshes as smooth cordgrass began to spread into the Sawmill Creek area. Seeds of cordgrasses were also likely brought in with the re-established tidal flooding. The recovery of smooth cordgrass may be attributed to the relatively high salinity at this site (14 to 18 parts per thousand [ppt]); higher salinities (more than 17 to 18 ppt) are known to promote re-establishment of cordgrasses and retard growth of common reed (*e.g.*, Wijte and Gallagher, 1996; Chambers *et al.*, 1998; Rice *et al.*, 2000).

With its tidal flow restored, the Sawmill Creek Wildlife Management Area today (Figure 22) is comprised of comparatively diverse landscapes and has higher biodiversity than most wetlands of the immediate region. Low marsh areas are dominated by smooth cordgrass and other brackish marsh vegetation. High marsh areas, including the old embankments, are still dominated by common reed because of their higher elevation and less frequent tidal flooding. A large, contiguous mudflat occurs just north of the New Jersey Transit rail line that forms the marsh's southern border near the water's edge; the mudflat is dotted with islands of smooth cordgrass. Wildlife using this area extensively include striped bass (*Morone saxatilis*), fiddler crabs (*Uca* spp.), diamondback terrapin (*Malaclemys terrapin*), great blue heron (*Ardea herodias*), gadwall (*Anas strepera*), common moorhen (*Gallinula chloropus*), and least bittern (*Ardea exilis*). Several State-listed species (*e.g.*, least tern [*Sterna antillarum*], black skimmer [*Rynchops niger*], black-crowned night heron [*Nycticorax nycticorax*], and osprey [*Pandion haliaetus*]) are also common there (Kiviat and McDonald, 2002).

In many ways, the Sawmill Creek Wildlife Management Area serves as a reference area and a "model" for what restoration projects in some portions of the Meadowlands may accomplish. Wetlands biologists and wildlife managers sometimes refer to this condition of approximately equal proportions of open water and wetland vegetation as a "hemi-marsh," which can be highly productive for wetland-dependent birds such as waterfowl and long-legged waders (*e.g.*, Environment Canada, 2005). However, salinity at this site is higher than in most of the HMD; thus, it may not be possible to duplicate the success of this natural restoration throughout the Meadowlands, where lower salinities (less than 15 parts per thousand) provide more favorable conditions for growth of common reed (Roman *et al.*, 1984; Burdick *et al.*, 1997). Additional studies of contaminant distribution, availability, and bioaccumulation on this site are

Figure 21. Location of wetland restoration sites in the HMD. Sites are categorized as: (1) natural, (2) restored, (3) first and minimal contaminant concern, (4) moderate contaminant concern, or (5) substantial contaminant concern. Not all sites in these categories are shown here.



Source: Digital Orthophoto, New Jersey Meadowlands Commission, 2002.

Figure 22. The Sawmill Creek Wildlife Management Area. The upper photo shows the entrance to Sawmill Creek, and the lower photo shows a closer view of its cord-grass marshes.

recommended as their findings would be invaluable to guide decision-making regarding restoration of other sites in the Meadowlands.

b. Restored Sites

To date, a total of 10 sites have undergone restoration in the HMD (Table 5 and Figure 21): the sites range in size and age from the largest and most recently restored site (the 206-acre Marsh Resources Inc., Meadowlands Mitigation Bank [MRI], restored in 1999) to the smallest site (the 3-acre Hess Mitigation Site) and the earliest restored sites (the Vince Lombardi Marsh and Eastern/Western Brackish Marshes, all restored in 1989). Most of these restoration sites are located along the main stem of the Hackensack River or major creeks in the upper half of the HMD. Prior to restoration of these sites, common reed occurred in dense, monotypic stands on all of these sites. Depending upon their elevation, size, location, and other factors, individual sites were restored using different methodologies to variously include high marsh, low marsh, upland, and open water. Restoration of the MRI site illustrates some of the benefits and challenges of marsh restoration in the HMD.

The 206-acre MRI site (Figure 23) was restored as a private wetland mitigation bank to compensate for permitted wetland fill impacts that occur within the service area, primarily the HMD. Prior to restoration, dredged material placed on the site restricted tidal inundation; thus, the site was dominated by common reed. As part of the restoration, dredged material was excavated to create low- and high-marsh areas and tidal channels; excavated material was used to create islands; and finally, native vegetation was planted within the marsh and upland areas. During the 5 years of monitoring and assessment required by the Department of Army permit, it was noted that levels of some contaminants (*e.g.*, mostly heavy metals, but also hydrocarbons including polychlorinated biphenyls [PCBs]) exceeded soil criteria found in the NJDEP (1998) guidelines (Louis Berger Group, Inc., 2000).

Currently, low-marsh areas are dominated by smooth cordgrass, dwarf spike rush (*Eleocharis parvula*), and marsh fleabane (*Pluchea purpurascens*); high-marsh areas are dominated by saltmarsh hay (*Spartina patens*), spikegrass (*Distichlis spicata*), and groundsel tree (*Baccharis halimifolia*); and finally, upland islands support several tree species (groundsel tree, black locust [*Robinia pseudoacacia*], gray birch [*Betula populifolia*] and swamp white oak [*Quercus bicolor*]), dense thickets of shrubs (*e.g.*, northern bayberry [*Myrica pennsylvanica*], marsh elder [*Iva frutescens*]), and numerous herbaceous plants (*e.g.*, smartweeds [*Polygonum* spp.], switch grasses [*Panicum* spp.], goldenrods [*Solidago* spp.], fireweed [*Erechtites hieracifolia*]; Louis Berger Group, Inc., 2004b; Figure 23). The dominance of the vegetative cover of this marsh is atypical for a brackish marsh in the region; however, the site has uncommonly high vegetative diversity for the HMD and is used extensively by migratory birds (Louis Berger Group, 2002). It is not known if contaminant availability on-site contributed to the development of the atypical vegetative community; for example, germination of spike rush has been reported to be less affected by hydrocarbon contamination than germination of some other wetland plants (*e.g.*, Vavrek and Campbell, 2002). Bioaccumulation of certain contaminants (*e.g.*, mercury, PCBs) also may have increased as a result of the restoration, for example, from the physical disruption of the soil.

Table 5. Ownership, size, year restored, wetland habitat type(s), dominant vegetation, and extent of re-invasion of restored sites by common reed.

Site Name / Owner	Size (acres)	Year restored	Wetland habitat type(s) / Dominant vegetation	Common reed reinvasion?
Bellmeade Marsh / NJMC	21	1992	High marsh / inland saltgrass Low marsh / smooth cordgrass	Yes, in both high and low marsh
Eastern Brackish Marsh / NJMC	77	1989	High marsh: smooth cordgrass, saltmarsh fleabane Low marsh / mudflats	Yes, in high marsh
Harrier Meadows / NJMC	76	1998	High marsh / salt marsh hay, purple loosestrife, black rush	Yes, in high marsh
Hess Mitigation Marsh / Amerada Hess	3	1996	Low marsh / smooth cordgrass	Yes, in low marsh
MRI Marshes / Marsh Resources, Inc.	206	1999-to date	High marsh / salt marsh hay, inland saltgrass, salt marsh hemp Low marsh / smooth cordgrass, dwarf spikerush	Common reed present in high marsh areas and being treated
Mill Creek Marsh / NJMC	128	1999	Low marsh / salt marsh hemp, marsh fleabane, smooth cordgrass	Yes, in low marsh; dominant elsewhere
Secaucus High School Marsh / Town of Secaucus; leased to NJMC	38	2005-to date	Common reed treated with glyphosate in fall; mowing / re-treatment underway	Not applicable
Skeetkill Creek Marsh / NJMC	16	1999	High marsh / bulrush, rose mallow Low marsh / dwarf spikerush marsh fleabane	Yes, in both high and low marsh
Vince Lombardi Marsh / N.J. Transit Authority	10	1989	Low marsh / smooth cordgrass	Yes, in low marsh
Western Brackish Marsh / NJMC	75	1989	High marsh / salt marsh hay, salt marsh fleabane Low marsh / smooth cordgrass	Yes, in high marsh

Figure 23. The Marsh Resources, Inc. Meadowlands Mitigation Bank Site.

To some extent, nearly all restoration sites to date can be considered a success in that they currently exhibit greater diversity in the species composition of their plant communities in comparison to their previous (unrestored) condition. The three native species planted on most sites (smooth cordgrass, saltmarsh hay, and spikegrass) are abundant and established, and have partially replaced the dense monotypic stands of common reed that typically provide limited value as wildlife habitat. However, common reed has reinvaded and become re-established as a dominant plant on every restoration site, except for the MRI site, which is the most recent restoration site in the HMD. In accordance with applicable permit conditions, monitoring and assessment of all restored sites has not been required beyond 5 years. Subsequently, monitoring and assessment of most, though not all, of these restored sites do not regularly occur; thus, the current status and progress of most sites are not well known. In addition, the availability and effects of contaminants on any of the restoration projects within the Meadowlands are unknown.

c. The First Site of the Hackensack Meadowlands Environmental Restoration

The 52-acre Anderson Creek Marsh (Figure 24) located south of the Bergen Transit Rail Line is the first site that will be restored by the Corps, NJMC, and the Service as part of the Hudson-Raritan Estuary HMER (U.S. Army Corps of Engineers, 2004a). The site was chosen because of its size, physiography, ownership (by the NJMC, the HMER's local sponsor), absence of industrial use, and the low contaminant concentrations identified in preliminary (albeit limited) surveys. Recent Corps (2004b) sampling of sediments for HMER planning indicates high concentrations of certain contaminants such as mercury in some areas on the site. Mosquito ditches and a non-functioning tidegate are present in the marsh and creek, respectively. The site is predominantly covered by dense stands of common reed, with some small mudflats and areas of open water. One small patch of smooth cordgrass persists on the site. A baseline survey (TAMS Consultants, Inc., 1985) reported that typical aquatic biota (*e.g.*, mummichog [*Fundulus heteroclitus*], juvenile blue crab [*Callinectes sapidus*]), diamondback terrapin, red-winged blackbird [*Agelaius phoeniceus*], marsh wren [*Cistothorus palustris*], muskrat [*Ondatra zibethicus*], and raccoon [*Procyon lotor*]) use the site.

Although the Anderson Creek Marsh does not have a history of industrial or municipal uses, it is bordered by commercial properties to the east and north and is across the Hackensack River from Berry's Creek, which continues to discharge mercury into the river. Anderson Creek Marsh does not appear to contain large deposits of fill other than a berm along its northern and eastern sides that supports rail lines. According to preliminary restoration designs (which, as is typical of plans for sites where contamination is suspected, is being modified as a result of the high mercury and other contaminant concentrations documented in recent sampling; U.S. Army Corps of Engineers, 2004b), this berm will not be disturbed during restoration and thus may provide a barrier between the marsh and adjoining industrial properties. The currently preferred alternative restoration plan (U.S. Army Corps of Engineers, 2003a; New Jersey Meadowlands Commission, 2004e;) would regrade (*i.e.*, lower) the site to increase tidal flow and promote change in the vegetative cover from common reed to cordgrass, create a more extensive creek network, and surround the entire site with a moat to prevent recolonization of the site by common reed. However, recent contaminant surveys (U.S Army Corps of Engineers, 2004b), performed as per Corps regulations and policies (*i.e.*, ER 1165-2-1132) and to address Service (2005b) concerns, revealed concentrations of mercury (up to 43 ppm) in sediments on certain portions of the site

Figure 24. The Anderson Creek Marsh, the first site to be restored by the Corps, NJMC, and Service in the Meadowlands.

that are more than 60 times higher than the effects range-median (ERM[1]) sediment concentration for mercury (0.71 ppm). Because this is the first site of the HMER and comprehensive monitoring and assessment has not been undertaken on any restoration site in the Meadowlands, the preliminary restoration plans for the Anderson Creek Marsh may be reconsidered

While the level of contamination of this site is a concern to the Service, this site nonetheless presents a valuable opportunity to address most of the major challenges to the restoration of the Meadowlands, including interagency coordination, contaminants, and invasive species (U.S. Fish and Wildlife Service, 2005b). The high contaminant concentrations emphasize the need to gather relevant information (*e.g.*, contaminant distribution, bioaccumulation) before, during, and after restoration projects to guide subsequent restoration efforts and to ensure the greatest success on other sites. Because this is the first site of the HMER, the State and federal partners must thoroughly consider and discuss all of the different issues regarding its restoration.

d. Potential Restoration Sites Currently with Minimal Concerns

Sites within the HMD where the Service's (2005b) contaminant and other concerns currently are minimal include Bellman's Creek Marsh, the Secaucus Tract, and other neighboring properties (Table 6 and Figure 21). These potential restoration sites are identified as having minimal restoration concerns primarily due to each site's: (1) history indicating a lack of on-site contamination, and (2) relative isolation from other, known sources of contamination. Nearly all of these sites are situated in the northern half of the HMD. Because of their proximity to other current or future restoration sites, the Bellman's Creek and Secaucus Tract sites have the potential, when restoration is completed, to contribute to the creation of large, contiguous marsh areas. Limited information is available regarding the flora or fauna of these sites; therefore, information for Bellman's Creek is provided as an example of such properties.

The 62-acre Bellman's Creek Marsh, owned by PSE&G, lies between Bellman's Creek and the New Jersey Turnpike (Eastern Spur) in the northern portion of the HMD. The site consists of a mixture of marsh dominated by common reed, uplands with woody species, and mudflats. The site contains several small berms and is used for utilities. One STP discharges effluent near Bellman's Creek. This STP effluent increases nutrient concentrations and decreases salinity in the creek, factors which promote the growth of common reed. The creek also passes through several culverts that restrict tidal flow and contribute to flooding of low-lying properties along Bellman's Creek. These hydrologic concerns need to be studied in detail and addressed in all phases of the restoration process. Available information on water quality and conventional pollutants did not identify any extensive, industrial contamination (Mattson *et al.*, 1971; Hackensack Meadowlands Development Commission, 1980). Limited information is available regarding the flora or fauna of this site (U.S. Army Corps of Engineers, 2004a).

[1] ERM - the median contaminant concentration in sediments at which adverse biological effects on benthic invertebrates have been observed in previous studies. The ERM indicates a correlation, not a causal relationship. Although not used as regulatory standards, ERMs have proven useful in assessing potential adverse impacts on fish and wildlife.

Table 6. Ownership, size, wetland habitat type(s), dominant vegetation, and special issues of the first restoration of the Hackensack Meadowlands Ecosystem Restoration project (*i.e.*, Anderson Creek Marsh) and restoration sites currently identified by the Service (2005b) as having minimal contaminant concerns.

Site Name / Owner	Size (acres)	Wetland habitat type(s)	Dominant vegetation	Special issues
Anderson Creek Marsh / NJMC	52	Tidal emergent	Common reed	Tide gate
Secaucus Tract / Town of Secaucus	42	Tidal emergent	Common reed	Public boat launch
Bellman's Creek Marsh / Public Service Enterprise Group	62	Tidal emergent, mudflats, wooded upland	Common reed	Utility use
Teterboro Woods / Port Authority NY-NJ	258	Palustrine forest, scrub-shrub, emergent	Deciduous forest, several invasive species	Adjacent to airport, restricted access
Losen Slote Creek Park / Borough of Little Ferry	26	Freshwater riverine, palustrine	Remnant forest, various meadows	Diverse public uses
Mehrhof Pond / Bergen County Utilities Authority	77	Palustrine, upland, open water	Remnant forest, native meadows	Adjacent to STP, restricted access

e. Potential Restoration Sites Currently with Moderate Concerns

At present, the Service (2005b) supports the restoration of all wetland sites in the HMD. Nonetheless, the Service has "moderate" concerns regarding restoration of a number of sites within the HMD due to: (1) limited information available regarding contamination of these sites, (2) need for extensive on-site surveys for contamination because of the presence of nearby contaminated sites, (3) likely need for remedial activities as a component of the restoration design, and (4) other on-site concerns (*e.g.*, presence of radio towers, flood-control structures) that create additional challenges for restoration. Foremost among the sites with moderate concerns are the Richard P. Kane Natural Area, Metro Media Tract, Meadowlark Marsh, and Secaucus High School Marsh (Table 7 and Figure 21). Information from two sites is presented here as representative of this category.

The 74-acre Metro Media Tract (Figure 25) is a deed-restricted mitigation site that surrounds the Metro Media Broadcast facility, including its four unguyed radio towers. The site is mostly undeveloped, dominated by common reed due to restricted tidal flows, and adjoins the MRI Mitigation Bank, where replacement of common reed with cordgrass has been a primary focus of restoration for several years. The HMER (U.S. Army Corps of Engineers, 2003a) identified the Metro Media Site for its restoration potential. However, unguyed radio towers present on the site, though presenting a reduced collision risk (in comparison to guyed towers) to migratory birds, require maintenance roads, ancillary infrastructure, and copper radials and grounding straps. All of these requisite components have potential adverse impacts on fish and wildlife and present additional recurrent complications (*e.g.*, contamination, pathways for re-invasion by exotic species). Additional radio towers also have been proposed for the site in the past year. This site previously had been acquired and deed-restricted by the State to provide compensatory mitigation for wetland impacts near Teterboro Airport as a condition of a federal permit. Available contaminant data (Celebrano, 1995) do not indicate any major industrial contamination on this site. Stakeholders are unaware of any surveys of the flora or fauna of this site (U.S. Army Corps of Engineers, 2004a).

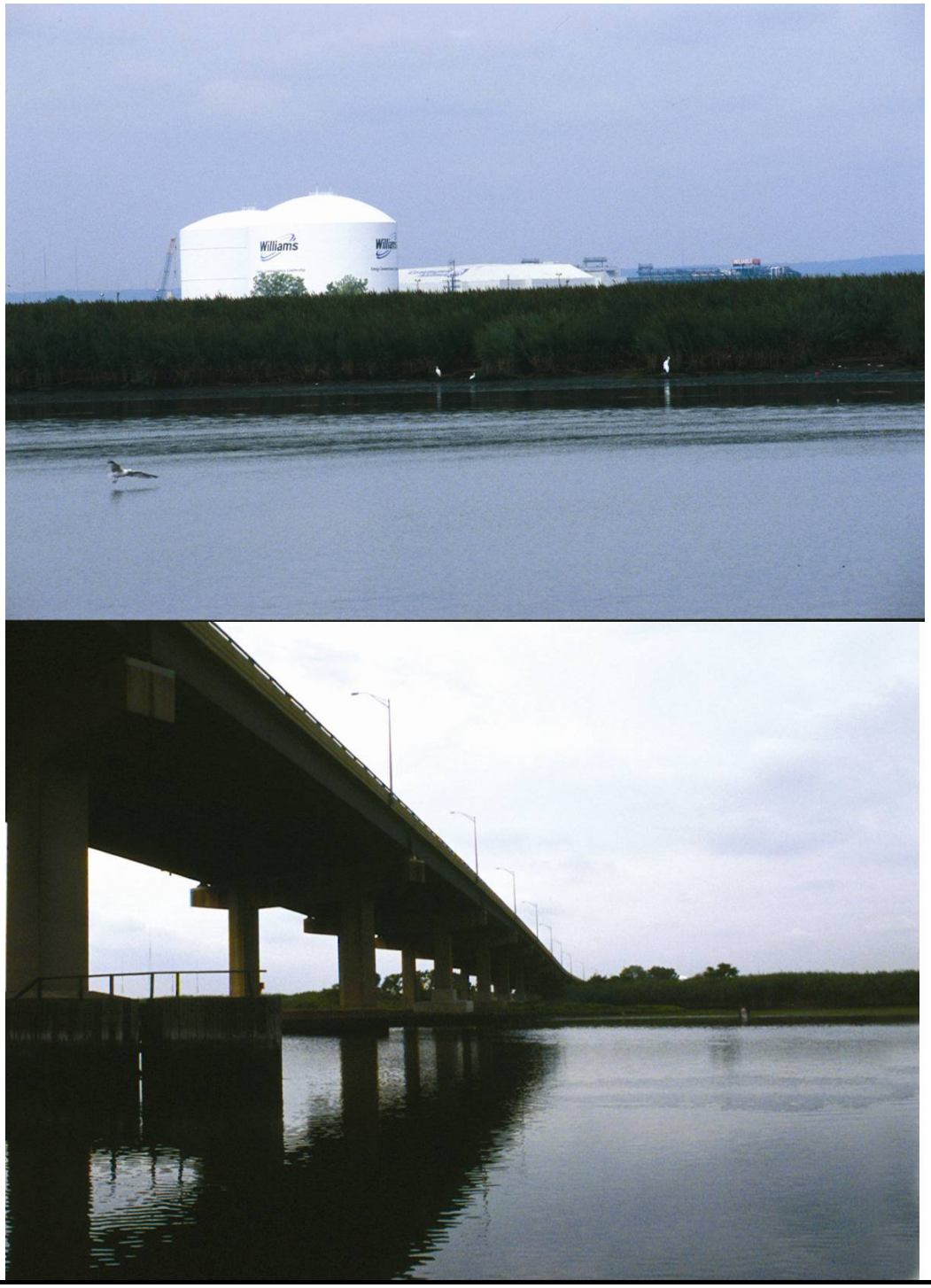
The 587-acre former Empire Tract, recently acquired and subsequently renamed the Richard P. Kane Natural Area by the Meadowlands Conservation Trust, comprises the second largest public landholding in the HMD (Figure 26). A small portion of the Kane Natural Area lies along the Hackensack River east of the western spur of the New Jersey Turnpike, but most of the Kane Natural Area lies west of the western spur. Because of its large size, strategic location in the core of the Meadowlands, connectivity to other marsh preservation areas, and comparatively high biodiversity, this site should be a high priority for restoration and protection. Also referred to as the Carlstadt-Moonachie marshes, the Kane site includes a diked freshwater marsh, extensive tidal marshes dominated by common reed, small patches of high marsh wetlands, and about 20 acres of upland habitat, which generally have limited vegetative cover and are scattered throughout the wetlands. The site is poorly drained by several creeks (Bashes, Moonachie, and Doctor's Creeks) that are restricted by culverts or tidegates. Sensitive fern (*Onoclea sensibilis*) and blue vervain (*Verbena hastata*) co-exist with the reed in some areas (New Jersey Turnpike Authority, 1986; as cited in Kiviat and MacDonald, 2002). Previous studies of conventional pollutants (Paulus *et al.*, 2000) and water quality (*e.g.*, Mattson *et al.*, 1971) have not provided any evidence of extensive industrial contamination.

Table 7. Ownership, size, wetland habitat type(s), dominant vegetation, and special issues of restoration sites currently identified by the Service (2005b) as having moderate contaminant concerns.

Site Name / Owner	Size (acres)	Wetland habitat types	Dominant vegetation	Special issues
Empire Tract / Meadowlands Conservation Trust	587	Tidal emergent, uplands	Common reed	Tide gates, culverts, illicit access
Metro Media Tract / NJMC	74	Tidal emergent	Common reed	Radio towers and ancillary structures
Secaucus High School / Town of Secaucus; leased to NJMC	43	Tidal emergent	Common reed	Tide gates, culverts, stormwater basins
Meadowlark Marsh / NJMC	90	Tidal emergent, uplands, open water	Common reed	Extensive berms

Figure 25. The MetroMedia Marsh has four radio towers: three can be seen in the lower photo.

Figure 26. The Meadowlands Conservation Trust's Richard P. Kane Natural Area, formerly known as the Empire Tract. This site adjoins the Marsh Resources Inc.'s Mitigation Bank.



The Richard P. Kane Natural Area has considerable potential for restoration. The site's large size makes it one of the few sites in the Meadowlands that can support species that have large area requirements, such as northern harrier [*Circus cyaneus*]. Avifaunal use of the tract is reportedly high: more than 115 species (*e.g.*, common yellowthroat [*Geothlypis trichas*], song sparrow [*Melospiza melodia*], swamp sparrow [*Ammodramus palustris*], American goldfinch [*Carduelis tristis*], yellow warbler [*Dendroica petechia*], gray catbird [*Dumetella carolinensis*], and the State-listed yellow-crowned night heron [*Nyctanassa violacea*], northern harrier, and least tern) have been reported to use the site (TAMS Consultants, Inc., 1998; Kiviat and McDonald, 2002). The plant diversity of some marshes on the Kane site is high for the Meadowlands; also, reptile and mammal use of the entire site is reportedly high (Kiviat and McDonald, 2002).

f. Potential Restoration Sites Currently with Substantial Concerns

This category contains a number of different properties that are known to contain, or show indications of, serious environmental contamination and includes at least one of the worst contaminated wetland sites in the United States (Table 8 and Figure 21). Most of these sites can be grouped into two general areas within the HMD, those near Berry's Creek and those in the Riverbend area; however, additional sites for which the Service has substantial concerns (*e.g.*, Lyndhurst Riverside, Steiner's, Kearny Brackish Marsh, Mori tract) are located in other areas throughout the HMD. While the Service supports restoration of these sites, contaminants must be evaluated and remediated prior to initiating other habitat improvements to avoid increasing wildlife exposure to heavy metals and other toxic compounds, especially those that bioaccumulate.

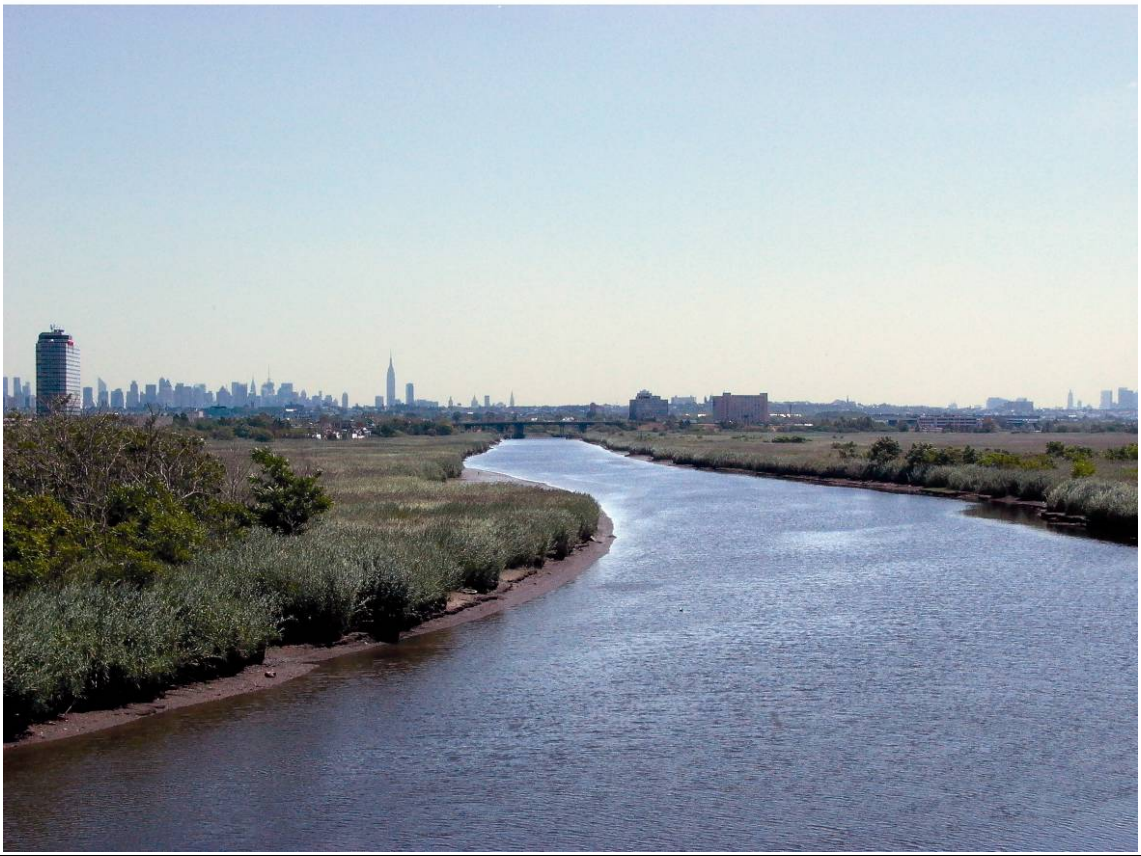
One area of particular concern is the Berry's Creek/Berry's Creek Canal area (Figure 27), where three Superfund Sites are located (*i.e.*, the Ventron-Velsicol, Universal Oil Products, and Scientific Chemical Processing Superfund sites; U.S. Environmental Protection Agency, 2004b; 2004c; 2004d). Berry's Creek is located on the western side of the Hackensack River, running along the NJSEA Sports Complex Walden Marsh, Berry's Creek Marsh, Lyndhurst Landfill, Rutherford Landfill, Bellemeade Mitigation site, and Lyndhurst Riverside Marsh. The creek flows through East Rutherford into Rutherford, then along the boundary of Rutherford and Lyndhurst out to the Hackensack River in Bergen County. Berry's Creek Canal is located to the east of the Hackensack River along the northern boundary of Oritani Marsh in East Rutherford, Bergen County. Berry's Creek and Berry's Creek Canal converge just south of the Route 3 Bridge. The canal flows unimpeded, while the creek flows through two degraded culverts located under the Rutherford Landfill haul road and the New Jersey Transit Bergen Line.

The Berry's Creek/Berry's Creek Canal area is considered among the worst mercury-contaminated sites in the United States. From as early as 1943, F.W. Berk and Co. and later the Wood-Ridge Chemical Corporation (Velsicol Corporation) released effluents containing mercury into the creek upstream of the canal. Studies have estimated that as much as 1 to 2 kilograms of mercury per day were released from the chemical plant until it ceased operation in 1974. More than 144 metric tons of mercury waste were discarded and have contaminated soils, sediments, surface water, and groundwater in the Berry's Creek area (U.S. Environmental

Table 8. Ownership, size, wetland habitat type(s), dominant vegetation, and special issues of restoration sites currently identified by the Service (2005b) as having substantial contaminant concerns.

Site Name / Owner	Size (acres)	Wetland habitat types	Dominant vegetation	Special issues
Berry's Creek Marsh / NJMC	168	Tidal emergent, open water, mudflat	Common reed	Mercury and other known contaminants
Oritani Marsh / NJMC	224	Tidal emergent, upland, open water	Common reed, other invasive species	Filling, several known contaminants
Lyndhurst Riverside / NJMC	31	Tidal emergent	Common reed	Adjacent to landfills, filling
Steiner's Marsh / Tomu Construction Co.	8	Upland, tidal emergent	Smooth cordgrass	Filling, commercial use, service roadway
Mori Tract / Eugene Mori	77	Tidal emergent, upland	Common reed, other invasive species	Adjacent to STP
Riverbend Wetlands Preserve / NJMC	58	Tidal emergent, open water	Common reed, native high marsh	Adjacent to landfill, known contaminants
Kearny Freshwater Marsh / NJMC	311	Lacustrine, emergent	Common reed, purple loosestrife, duckweed	Known contaminants, adjacent to landfill
Kearny Brackish Marsh / NJMC	155	Open water, mud flat	Common reed	Known contaminants, adjacent to landfill,

Figure 27. Various marsh sites along the Berry's Creek/Berry Creek Canal. Stumps of Atlantic white-cedar are present along the canal.



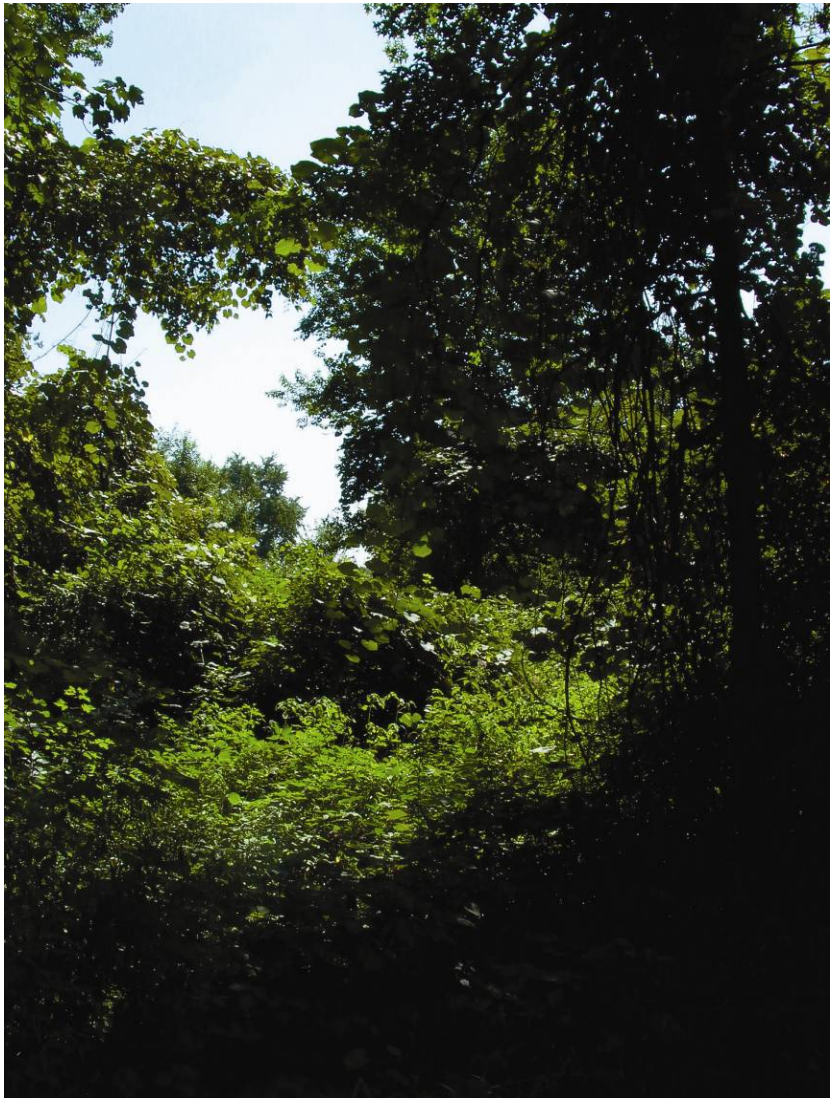
Protection Agency, 2004a). There are several sites along this creek that, because of contamination, present substantial concerns for restoration. More than 20 tons of mercury waste is believed to be buried at the nearby Walden Marsh site. Less than 1 mile away, the Berry's Creek Marsh and the Oritani Marsh have been identified as potential restoration sites by the Corps (2003a). All three sites are known to have extensive contamination from mercury (U.S. Environmental Protection Agency, 2004b; 2004c; 2004d). The invertebrate and other aquatic communities of these sites reflect impacts by mercury (*e.g.*, altered species abundance and community composition, increased resistance and bioaccumulation; Schaeffer *et al.*, 2003; Weis and Weis, 2003a; Yuan *et al.*, 2006) and possibly other contaminants (*e.g.*, hydrocarbons, Galluzzi, 1981; Barrett *et al*. 2003; Barrett and McBrien, 2004). Although generally supportive of restoring all wetland sites in the Meadowlands, the Service advocates caution in the remediation and restoration of Berry's Creek and other sites with substantial contamination. The Service recommends that none of the sites in the Berry's Creek Study area should be restored until mercury contamination is addressed within the entire Berry's Creek sub-basin. Stakeholders must fully understand the issues, alternatives, feasibilities, and risks present in remediating and restoring these wetlands.

The Service (2005b) has substantial contaminant concerns that must be addressed before restoring several marshes and adjoining sites in the Riverbend area along the Hackensack River in the southernmost portion of the HMD. These marshes are likely contaminated from nearby landfills and other sites (Table 8 and Figure 21). At least one of the sites in this area, the undeveloped 57-acre Riverbend Wetlands Preserve, is considered a priority site for restoration and preservation as a component of the HMER (U.S. Army Corps of Engineers, 2003a). This site currently supports three major cover types: (1) native high saltmarsh vegetation (mostly saltmarsh hay), (2) open water, and (3) dense monoculture stands of common reed. Because of the presence of native high saltmarsh vegetation, this area is used as a reference site (*e.g.*, Bart and Hartman, 2000). However, the area is likely contaminated by leachate from the Malanka Landfill immediately adjacent to the site (*e.g.*, Torlucci, 1982; in which metal levels exceed the Long *et al.* [1995] sediment criteria). In addition, the Riverbend Wetlands Preserve lies close to the mouth of the Hackensack River near known sources of dioxin (*i.e.*, Diamond Alkali Superfund Site on the Passaic River, the Standard Chlorine State Remediation Site in Kearny, and the historically contaminated sediments and waters of Newark Bay; U.S. Environmental Protection Agency, 2004e; 2004f), which has been re-distributed by tidal currents throughout the Hackensack River channel (Wilson, pers. comm., 2004). In conclusion, much more work needs to be done investigating the methods, alternatives, feasibility, and priority of heavily contaminated restoration sites.

3. Palustrine Wetlands

Several remnant forest and freshwater communities are all that remain of the once extensive forested and other freshwater communities that were present in the 1600s. Of the 8,400 acres of wetlands and adjoining undeveloped uplands within the HMD today, only a few woodlands (totaling approximately 200 ac) remain (Tiner *et al.*, 2002). Most of this forested acreage consists of palustrine wetlands located on two tracts of deciduous forests immediately southeast and southwest of Teterboro Airport (Figure 28). Because both tracts adjoin runways and other facilities of the Teterboro Airport, access to the sites has been necessarily restricted for

Figure 28. Views of two forested areas in Teterboro Woods. The flora of Teterboro Woods includes several invasive species: note the presence of purple loosestrife in the foreground in the photo on the right.



more than 50 years. Until recently, the only available information regarding the flora and fauna was limited to cursory, and in some cases, one-day surveys.

A cursory survey of a few sites in Teterboro Woods was made in February 2004 by Service and NJMC biologists. Tree and shrub species typical of northern and southern deciduous forests were observed (Figure 28), including red maple (*Acer rubrum*), sweetgum (*Liquidambar styraciflua*), blackgum (*Nyssa sylvatica*), poplars (*Populus* spp.), various oaks (*e.g.*, *Quercus palustris*), overcup oak (*Quercus lyrata*), arrowwood (*Viburnum dentatum*), pussy willow (*Salix discolor*), and common elderberry (*Sambucus canadensis*). Due to the time of year, only a few herbaceous species typical of the region were observed. The Louis Berger Group (2006) recently documented approximately 75 herbaceous and 50 woody plant species on portions of the site that may be modified for improvements to the airport's security system. During preliminary survey of amphibians in June 2004, NJMC biologists did not observe or collect any amphibian specimens (Feltes, pers. comm., 2004). During a preliminary survey of birds in spring 2003, NJMC biologists observed a number of species uncommon in the Meadowlands (*e.g.*, lesser nighthawk [*Chordeiles acutipennis*], wood thrush [*Hylocichla mustelina*], black-throated green warbler [*Dendroica virens*], black-throated blue warbler [*Dendroica caerulescens*], Swainson's thrush [*Catharus ustulatus*], and northern oriole [*Icterus galbula*]; Spendiff, pers. comm., 2004). The Service has initiated a more thorough floristic survey of the Teterboro Woods to identify its plant species (including invasive species) and provide recommendations for needed monitoring and enhancement activities, such as invasive-species control.

Small remnants of hardwood forest occupy the rock outcrop of Laurel Hill in Secaucus, in Schmidt's Woods in Secaucus, and on other smaller sites. At least some of these sites are used by State-listed and other species (*e.g.*, American woodcock [*Scolopax minor*]; Spendiff, pers. comm., 2004). Because these sites have lengthy and diverse histories of use and reflect many kinds of disturbance (*e.g.*, mining, filling), efforts should be made to assess the biological value and ecological integrity of these sites, and if warranted, to protect and manage their remaining natural habitats for fish and wildlife.

4. Riverine and Lacustrine Wetlands

The only riverine wetlands remaining in the HMD are small remnants (less than 7 acres) dominated by non-persistent vegetation that adjoins a coastal plain lowland forest at the Losen Slote Creek Park, the late-1700s site of John Berry's Plantation. Dominant tree species at the palustrine wetland site include red maple, grey birch, gum species, black cherry (*Prunus serotina*), and several oak species (*e.g.*, pin oak, scarlet oak [*Quercus coccinea]*). American chestnut (*Castanea dentata*), American elm (*Ulmus americana*), several poplar species, and a few non-native species (*e.g.*, European ash [*Sorbus aucuparia*], European buckthorn [*Rhamnus frangula*]) were reported at the site in 1991 (Dicker and Anderson, 1991). Common understory shrubs and herbs include purple chokeberry (*Aronia prunifolia*), sweet pepperbush (*Clethra alnifolia*), swamp (or bristly) dewberry (*Rubus hispidus*), steeplebush (*Spiraea tomentosa*), fetterbush (or swamp doghobble, *Leucothoe racemosa*), and southern arrowwood (Dicker and Anderson, 1991).

Two lacustrine (lake and pond) wetlands, also with non-persistent vegetation, are present on opposite sides of the HMD and differ in their current suitability for restoration. Mehrhof Pond, adjacent to the Bergen County Utility Authority's (BCUA) treatment plant on the Hackensack River, currently presents only minimal concerns and appears to have potential for restoration (Table 6 and Figure 21). On the other extreme, one of the most contaminated sites within the Meadowlands presenting substantial concerns for restoration is the Kearny Freshwater Marsh (Table 8 and Figures 21 and 29; Langan Engineering and Environmental Services, Inc., 1999). Remediation of this site is likely to be complex and costly; the NJMC is currently exploring use of an *in situ* capping technology (Aquablok™, New Waste Concepts, Inc., Perrysburg, Ohio) with an EPA grant. These two sites are described below.

Mehrhof Pond is a 77-acre site consisting of a freshwater pond surrounded by native grasslands, wet meadow areas, and forested, palustrine wetlands (U.S. Army Corps of Engineers, 2003a). The Service and other stakeholders are unaware of any studies regarding the flora and fauna of this site (U.S. Army Corps of Engineers, 2004a). The pond was formerly a clay pit that was mined by a brick manufacturing company until the 1940s. This site is now owned by the BCUA, which operates a restricted-access nature preserve along one edge in conjunction with the NJMC. There is no evidence of contamination of this site, and its restricted access has reduced the likelihood of recent contamination.

Figure 29. Kearny Freshwater Marsh. This marsh has been recognized for its biodiversity, which appears to be declining as water levels rise due to leachates from an adjoining landfill.

The 310-acre Kearny Freshwater Marsh (Figure 29) is an impounded wetland recognized by the New Jersey Natural Heritage Program as a Priority Site for Biodiversity with a biodiversity rank

of B4 (moderate biodiversity significance). This marsh was once densely vegetated with common reed. Rising water levels partly due to blocked culverts, runoff, and leachates from the adjacent Keegan Landfill have created large, contaminated freshwater ponds that are interspersed with common reed, duckweeds (*Lemna* spp.), purple loosestrife (*Lythrum salicaria*), marsh-fleabane, rose mallow (*Hibiscus moscheutos*), water shield (*Brasenia schreberi*), arrow arum (*Peltandra virginica*), white water-lily (*Nymphaea odorata*), mild waterpepper (*Polygonum hydropiperoides*), pickerelweed (*Pontederia cordata*), broadleaf cattail (*Typha latifolia*), and spatterdock (*Nuphar* spp.; Kiviat and McDonald, 2002). This area currently offers important foraging grounds for waterfowl and wading birds, as well as breeding habitats for marsh and water birds (Kane, 2001). Because of the heavy contamination, the site may now be functioning as an attractive nuisance, that is, attracting fish and wildlife but contributing to their accumulation of certain contaminants that cause subtle, yet pernicious and debilitating, chronic effects. To what extent this site is now, or may in the future, function as an attractive nuisance requires intensive study. Remediation of environmental contaminants will be an important component of a suitable restoration plan (U.S. Fish and Wildlife Service, 2005b). Substrate and bioperturbation problems of *in situ* barriers (*see* Hull *et al.*, 1999; Rutgers Environmental Research Clinic, 2005) suggest methodological modifications (*e.g.*, layering; Lampert, 2006) and additional studies are needed prior to application of such barriers to sites in the Meadowlands.

F. SIGNIFICANT BIOTA

1. Federally Listed Species

Discussed below are all federally listed (endangered or threatened) species included in federal or State databases in the HRW. The only federally listed species presently known to occur in the HMD or elsewhere in the HRW is the bald eagle. One federally listed species, the shortnose sturgeon, has been reported historically to occur throughout the Hudson River and the New York Harbor (Smith 1897). Two other federally listed species (the dwarf wedgemussel and the bog turtle) have been reported to occur historically in the upper HRW but have not been reported there for many years (U.S. Fish and Wildlife Service, 1993; 2001a).

Each federally listed species account includes an introduction to the biology of the species, the species' current or former distribution in the HMD and the HRW, the threats to the species, and the potential for restoration. There are currently no candidate species (species under consideration by the Service for federal listing) in the watershed.

a. <u>Bald Eagle</u>

One of the largest (average wingspan of 6.5 to 8.0 feet; average weight of 8 to 14 pounds), most distinctive raptors, the federally listed (threatened) bald eagle occurs throughout most of North America (Figure 30). The bald eagle feeds primarily on fish, waterfowl, gulls, and carrion, though it will prey on other small animals. Bald eagles usually pair for life and often use the same nest site repeatedly. Initial nest platforms average 5 feet across but may reach more than 10 feet across and weigh more than 4,000 pounds (U.S. Fish and Wildlife Service, 2004c).

The bald eagle represents one of the success stories of the ESA and has been proposed for "de-listing." Observations of bald eagles are increasingly frequent in the Meadowlands (Kiviat and MacDonald, 2002), the HRW, and New Jersey (Walsh *et al*., 1999; Smith *et al.*, 2003). Within the HMD, bald eagles have been observed foraging in the Mill Creek area and roosting in Harrier Meadows and the Teterboro Woods (Spendiff, pers. comm., 2004).

Figure 30. Bald eagle, a federally protected species. The bald eagle is an increasingly frequent site in the skies over the Meadowlands.

With the recovery of this species in New Jersey (from 1 pair in the early 1970s to nearly 50 nesting pairs in 2005), bald eagles are now foraging and otherwise using areas (such as the Meadowlands) of smaller patches of suitable habitat and in sites closer to human development, where they may be vulnerable to various threats. For example, the carcass of an immature bald eagle was recovered in late October 2000 in the Hackensack River approximately 4 miles downstream from Mill Creek and turned over to the Service's Division of Law Enforcement personnel. An autopsy revealed that the eagle had been seriously injured in a mid-air collision and subsequently drowned (Ralston, 2000). This event has substantiated Service concerns regarding the adverse impacts on raptors, waterfowl, and other migratory birds from power lines, communication towers, and other structures increasingly being located in the HMD, especially in wetlands.

Of greater potential concern to the bald eagle in the Meadowlands are contaminants. The primary factor in the original listing of the bald eagle as endangered in 1967 was the dramatic decline of its population(s) as a result of the adverse effects of dichloro-diphenyl-trichloroethane (DDT) and its metabolic by-products on bald eagle reproduction (*e.g.*, U.S. Fish and Wildlife Service, 2004c). Prior to their closure years ago, several large facilities that historically manufactured and discharged considerable qualities of DDT and related contaminants into the surrounding wetlands and waterways were located along the Hackensack and Passaic Rivers. Sediment samples in areas adjoining those former manufacturing facilities are known to have high levels of DDT (nearly 1 percent; Wilson, pers. comm., 2004). The presence of such bioaccumulative contaminants raises concerns about restoration actions that may attract not only the bald eagle as its population expands, but other species that are sensitive to DDT, its byproducts, and other bioaccumulative contaminants.

b. Dwarf Wedgemussel

The federally listed (endangered) dwarf wedgemussel is a small (up to 1.5 inches in length) freshwater bivalve that lives buried in aquatic sediment, where it feeds by filtering small organisms (*e.g.*, algae) with its gills from the water (Figure 31). Unlike many mollusks that are hermaphroditic (*i.e.*, individuals function as both sexes during their life), males and females of this species are sexually dimorphic (*i.e.*, sexes have distinctive shapes). The female has an enlarged shell that enables her pouch-like gills to retain fertilized eggs for many months, before releasing free-swimming larvae the following spring. These larvae, known as glochidia, must soon attach to the gills of certain species of benthic fishes (*e.g.*, sculpins [*Cottus* spp.], some darters [*Etheostoma* spp. or *Percina* spp.]) or they will die. Glochidia do not receive any nutrition from the fish but use the fish as a means of dispersal before dropping off of the fish when they metamorphose into juvenile mussels.

Although there are few freshwater areas within the HMD, there are historical records of dwarf wedgemussel having occurred in the HRW (*e.g.*, U.S. Fish and Wildlife Service, 1993). Some areas of the HRW, including streams upriver of the Oradell and other dams, have not been thoroughly surveyed in recent years for this and other rare freshwater mollusks. The dwarf

Figure 31. Dwarf wedgemussel, a federally listed (endangered) species, which previously occurred at various locales in the Hackensack River watershed. Presently, dwarf wedgemussel is not known to occur anywhere in the watershed.

wedgemussel inhabits rivers and streams with muddy sand, sand, and gravel substrates. The species requires areas with a slow to moderate current, little silt deposition, and well-oxygenated, unpolluted water. Many species of freshwater mussels, including the dwarf wedgemussel, are sensitive to heavy metals and other compounds associated with industrial pollution (Havlik and Marking, 1987).

The dramatic decline of dwarf wedgemussel, as well as the small size and extent of most of the remaining populations in other river systems, suggest that any remaining population in the HRW would be highly vulnerable to extirpation (U.S. Fish and Wildlife Service, 1993). The Recovery Plan for the dwarf wedgemussel includes expanding the current recognized distribution of this species from 7 rivers where it is now abundant to 13 rivers representative of the former range. Thus, the Hackensack River remains one of a small number of rivers, ranging from the James River in Virginia to the Merrimack River in Massachusetts, that provide habitats potentially important to the recovery of this species (U.S. Fish and Wildlife Service, 1993).

c. Shortnose Sturgeon

Shortnose sturgeon, the smallest sturgeon species (maximum length of 4.5 feet; maximum weight of 50 pounds), was federally listed as endangered in 1973 (Figure 32). Sturgeons are primitive fishes, with skeletons of cartilage and a connection between their gut and their swim bladder that partially functions as an accessory respiratory structure (*i.e.*, lung). Sturgeons are anadromous, and migrate every few years from coastal waters upstream into freshwaters to spawn. They feed on benthic invertebrates (*e.g.*, clams, worms, crabs), and are long-lived (life span of 50 to 67 years; National Marine Fisheries Service, 1998; Van Winkle *et al.*, 2002).

Figure 32. Shortnose sturgeon, a federally listed (endangered) species. This species is now known to occur only in major river systems along the east coast of North America from the St. Johns River in Florida to the St. Johns River in New Brunswick, Canada. The species occurred previously throughout the Hudson River and portions of the Hudson-Raritan estuary (HRE); within the HRE, shortnose sturgeon are now reported to occur only in the Hudson River.

The shortnose sturgeon historically occurred from Florida to New Brunswick, Canada, possibly including the Hackensack River, but now is documented in only 16 river systems and their adjoining estuarine and coastal waters (Smith, 1897; Kynard, 1997). The Hudson-Raritan estuary is home to one of the largest (abundance reported to be several tens of thousands; National Marine Fisheries Service, 1998) of the 16 recognized populations of this species (Kynard, 1997). Despite this nearby population, the present-day range of shortnose sturgeon

does not appear to include the Hackensack River. Construction of dams, other habitat alterations, and commercial exploitation from colonial times until the 1950s are believed to be the major factors contributing to the decline of sturgeon throughout most of its range. This species' long life span and benthic-predator feeding habits that places it in close proximity to sediments also predisposes it to the effects of bioaccumulation of contaminants, another likely cause of the decline of this species in some areas (NatureServe, 2004).

Both habitat restoration and restocking are believed to be important to the recovery of this species in some areas from which it was previously extirpated (National Marine Fisheries Service, 1998). Given their proximity to the large Hudson-Raritan population and the extensive movements of adults, shortnose sturgeon from that population may eventually expand back into the Hackensack Meadowlands with further improvements in water quality throughout the estuary. Regular sampling for this species using appropriate gear and methods commenced in 1999 but has not detected shortnose sturgeon in the HMD (Bragin *et al.*, 2005). Waters outside the HMD in the Hackensack River have not been adequately surveyed for shortnose sturgeon. Remediation and restoration of aquatic habitats of the HRW adequate to support shortnose sturgeon would not appear to be a reasonable goal of any comprehensive restoration planning for the Hackensack River watershed at this time.

d. Bog Turtle

The bog turtle (Figure 33) has very specialized habitat requirements, living its entire life in sphagnum bogs, calcareous fens, marshy/sedge-tussock meadows, spring seeps, wet cow pastures, or shrub swamps that support an abundance of grassy or mossy cover. Bog turtles move little where they occur (average home range is approximately 0.59-3.2 ac [0.24-1.3 ha]) while using a variety of wetland microhabitats for foraging, nesting, basking, and hibernating (Bury, 1979; Chase *et al.*, 1989; Carter *et al.*, 1999). This is one of only a few turtle species known to bury itself in both summer and winter. One of North America's smallest turtles, bog turtle females generally lay only 3 to 5 eggs per year in one nest.

Federally listed as threatened in 1997, the bog turtle is believed extirpated from the HRW in Bergen County (U.S. Fish and Wildlife Service, 2001a). Illegal collecting for the pet trade may have contributed to the loss of the species from this and other watersheds (Bourg, 1992). The HRW lies within the Hudson/Housatonic Recovery Unit for the bog turtle and contains many areas that are believed to provide suitable habitat (U.S. Fish and Wildlife Service, 2001a); however, most suitable habitat in the HRW is imperiled by suburban sprawl and other land-use activities. Within the Hudson/Housatonic Recovery Unit for this species, only calcareous fens fed by groundwater appear to support stable populations (U.S. Fish and Wildlife Service, 2001a). Thus, wetland restoration within the HRW to support bog turtle is not currently a component for the recovery plan of this species (U.S. Fish and Wildlife Service, 2001a).

Figure 33. Bog turtle, a federally listed (threatened) species. The bog turtle occurs in upper portions of the Hackensack River watershed, but no longer occurs in the Meadowlands.

2. State-Listed Species

A total of 39 species (9 plants, 1 insect, 1 mollusk, 1 fish, 1 reptile, and 25 bird species; Tables 9 and 10) that are State-listed as being endangered or threatened in New Jersey (New Jersey Department of Environmental Protection, 2004a) occur in the HRW; the majority of these species are thought to occur within the HMD. Unfortunately, the distribution and abundance of State-listed species (especially plants) within the HMD generally is poorly known due to a lack of regular monitoring of the extensively disturbed, degraded, and restricted-access sites. The State-listing of plant species (Table 9; Figure 34) is based on summaries of information, collections, and historical occurrences reported to the State's Natural Heritage Program. Unfortunately, definitive information on the current presence, absence, or status of these species is often lacking (New Jersey Department of Environmental Protection, 2004a). Certain groups of State-listed animals (*e.g.*, insects, clams; Table 9; Figure 35) are also poorly known in the

HMD and surrounding region. The best-known group (birds) has been the subject of previous surveys (*e.g.*, Kane *et al.*, 1991; Kane and Githens, 1997); additional surveys by the New Jersey Audubon Society are ongoing. Other than surveys of bird distributions, most aspects of the biology of bird species have not been extensively studied in the Meadowlands. Some bird species of State-status (Table 10; Figure 36) are known to nest in and make extensive use of Meadowlands' habitats (*e.g.*, yellow-crowned night herons in Schmidt's Woods; Spendiff, pers. comm., 2004). Understanding the biology and management needs of birds is complicated by the

Table 9. Common and scientific names of State-listed (E = endangered and T = threatened) plants, insects, mollusks, fishes, and reptiles reported in the Hackensack Meadowlands District (HMD) or the Hackensack River watershed (HRW).

Common name	Scientific name	Locale	New Jersey Status
Plants			
Saltmarsh bulrush	*Scirpus maritimus*	HMD	E
Seaside arrowgrass	*Triglochin maritimum*	HMD	E
Cyperus-like sedge	*Carex pseudocyperus*	HMD	E
Torrey's mountain mint	*Pycnanthemum torrei*	HRW	E
Barton's St. John's wort	*Hypericum adpressum*	HRW	E
Wafer-ash	*Ptelea trifoliata*	HMD	E
Smooth rattlesnake root	*Prenanthes racemosa*	HMD	E
Canada hawkweed	*Hieracium kalmii*	HMD	E
Dog fennel thoroughwort	*Eupatorium capillifolium*	HMD	E
Insects			
Appalachian grizzled skipper	*Pyrgus wyandot*	HRW	E
Mollusks			
Triangle floater	*Alasmidonta undulata*	HRW	T
Fishes			
Shortnose sturgeon	*Acipenser brevirostrum*	HRW	E
Reptiles			
Wood turtle	*Clemmys insculpta*	HMD	T

Figure 34. State-listed plants (clockwise from top left: saltmarsh bulrush, Torrey's mountain mint, seaside arrowgrass, cyperus-like sedge, smooth rattlesnake root, dog fennel thoroughwort, Canada hawkweed, and wafer ash) reported to occur in the HMD.

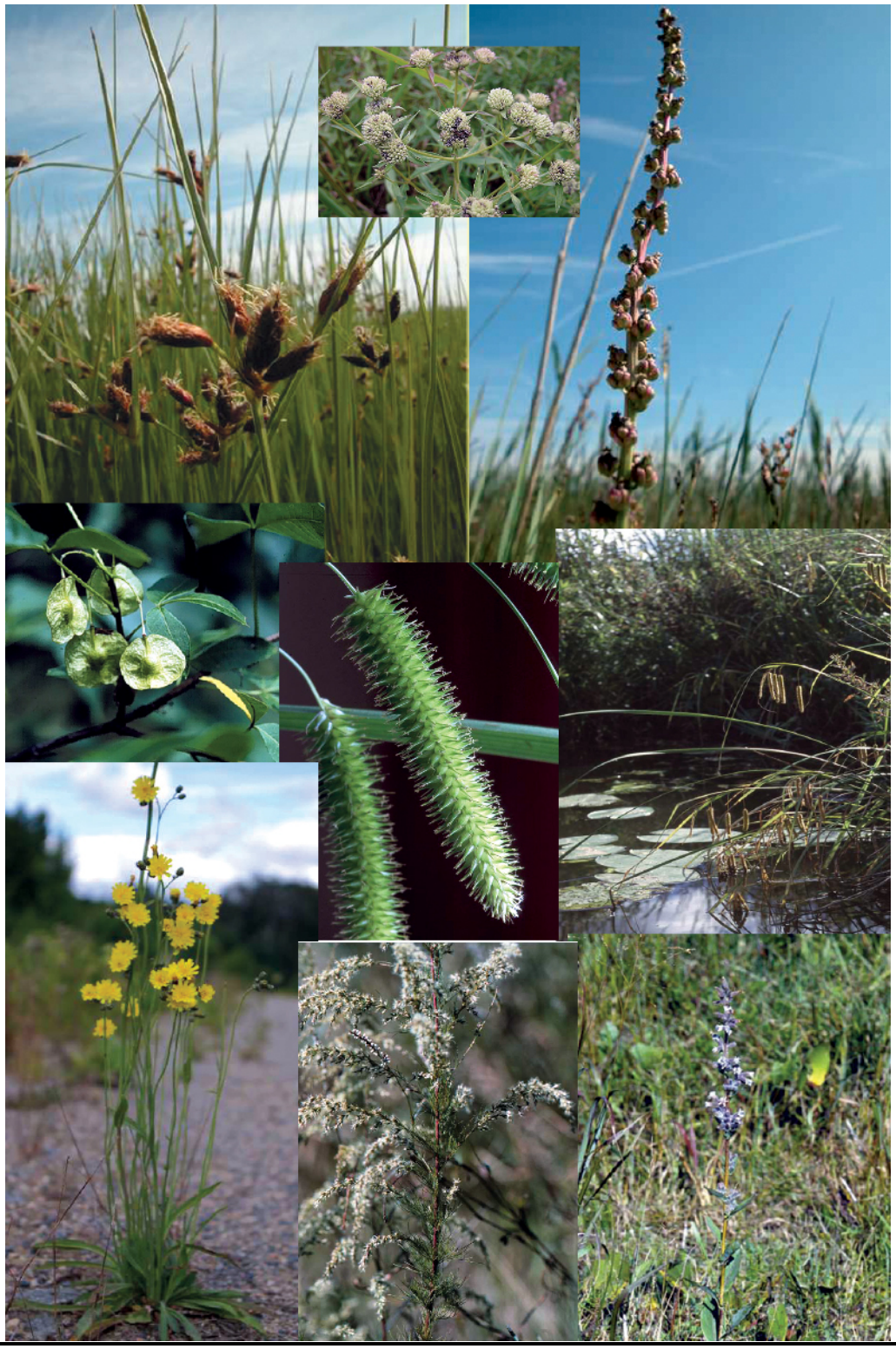


Figure 35. Animal species other than birds reported to occur in the HMD that are State-listed or "of special concern." Clockwise from top left: Appalachian grizzled skipper, creeper, wood turtle, northern spring salamander, northern diamondback terrapin, Fowler's toad, spotted turtle, marbled salamander, and triangle floater.

Table 10. State-listed bird species in the Hackensack Meadowlands District (HMD). The common and scientific names, HMD breeding status (NB = non-breeding, BR = breeding), seasonality (year-round or seasonal), and status (endangered = E and threatened = T) are provided.

Common name	Scientific name	Breeding Status	Seasonality	New Jersey Status
Bald eagle	*Haliaeetus leucocephalus*	NB	Year-round	T
Osprey	*Pandion haliaetus*	BR	Seasonal	T
Peregrine falcon	*Falco peregrinus*	BR	Seasonal	E
Northern goshawk	*Accipiter gentiles*	NB	Seasonal	E
Northern harrier	*Circus cyaneus*	BR	Year-round	E
Red-shouldered hawk	*Buteo lineatus*	NB	Seasonal	T
Cooper's hawk	*Accipiter cooperii*	NB	Seasonal	T
Short-eared owl	*Asio flammeus*	NB	Seasonal	E
Long-eared owl	*Asio otus*	NB	Seasonal	T
Barred owl	*Strix varia*	NB	Year-round	T
American bittern	*Botaurus lentiginosus*	BR	Year-round	E
Bl.-crwnd. night heron	*Nycticorax nycticorax*	BR	Year-round	T
Yl.-crwnd. night heron	*Nyctanassa violacea*	BR	Seasonal	T
Pied-billed grebe	*Podilymbus podiceps*	BR	Year-round	E
Upland sandpiper	*Bartramia longicauda*	BR	Seasonal	E
Roseate tern	*Sterna dougallii*	NB	Seasonal	E
Least tern	*Sterna antillarum*	NB	Seasonal	E
Black skimmer	*Rynchops niger*	NB	Seasonal	T
Red knot	*Calidris canutus*	NB	Seasonal	T
Red-headed woodpecker	*Melanerpes erythrocephalus*	NB	Seasonal	T
Sedge wren	*Cistothorus platensis*	NB	Seasonal	E
Loggerhead shrike	*Lanius ludovicianus*	NB	Seasonal	E
Bobolink	*Dolichonyx oryzivorus*	NB	Seasonal	T
Vesper sparrow	*Pooecetes gramineus*	NB	Seasonal	E
Savannah sparrow	*Passerculus sandwichensis*	BR	Seasonal	T

occurrence of breeding and non-breeding (transitory or migratory) populations of some species (Table 10). Thus, the NJMC (2004c) recently funded a proposal from the NJDEP's Endangered and Nongame Species Program to develop a wildlife plan to address this lack of information and focus research and other collaborative efforts on establishing and addressing the habitat needs of State-listed species in the HMD. Determining whether populations of State-listed species in the HMD are self-sustaining is a primary concern and a high priority for further studies.

Figure 36. State-listed birds that breed in the HMD. Clockwise from upper left: osprey, peregrine falcon, pied-billed grebe, savannah sparrow, upland sandpiper, American bittern, black-crowned night heron, northern harrier, and yellow-crowned night heron (center).

3. Special-Concern Species

Various criteria (*e.g.*, evidence of decline, recognized species vulnerability) are used to identify federal or State-listed species of Special Concern. The large number of species in these categories that occur in the Meadowlands provides additional evidence of the importance of its habitats. In most cases, additional study of these species is warranted, especially with regard to their distributions within the HRW outside of the HMD.

The Service (2002c) identified Bird Species of Conservation Concern for the Nation and smaller designated regions. Of the twenty-nine of these species known to occur in the Meadowlands, nine bird species have been reported to breed there (Kane *et al.*, 1991; Table 11; Figure 37).

Table 11. Service-listed (2002b) "Birds of Conservation Concern" occurring in the Hackensack Meadowlands District (HMD). These species may be listed for the NABCI Mid-Atlantic/New England Region (R30), the northeastern United States (R5), or the Nation (N).

Common name	Scientific name	HMD Breeding Status	Service BCC Status
Peregrine falcon	*Falco peregrinus*	BR	R30, R5, N
Northern harrier	*Circus cyaneus*	BR	N
Short-eared owl	*Asio flammeus*	NB	R30, R5, N
Common tern	*Sterna hirundo*	BR	R30, R5, N
Least tern	*Sterna antillarum*	NB	R30, R5, N
Black skimmer	*Rynchops niger*	NB	R30, R5, N
Little blue heron	*Egretta caerulea*	BR	N
Yellow rail	*Coturnicops noveboracensis*	NB	R30, R5, N
Red knot	*Calidris canutus*	NB	R30, R5, N
Hudsonian godwit	*Limosa haemastica*	NB	R30, R5, N
Marbled godwit	*Limosa fedoa*	NB	R30, R5, N
Solitary sandpiper	*Tringa solitaria*	NB	N
Upland sandpiper	*Bartramia longicauda*	BR	R30, R5, N
Buff-breasted sandpiper	*Tryngites subruficollis*	NB	R30, R5, N
Wilson's phalarope	*Phalaropus tricolor*	NB	N
Whimbrel	*Numenius phaeopus*	NB	R30, R5, N
Black-billed cuckoo	*Coccyzus erythropthalmus*	NB	N
Red-headed woodpecker	*Melanerpes erythrocephalus*	NB	R30, R5, N
Sedge wren	*Cistothorus platensis*	NB	R30, R5, N
Marsh wren	*Cistothorus palustris*	BR	R30
Wood thrush	*Hylocichla mustelina*	BR	R30, R5, N
Loggerhead shrike	*Lanius ludovicianus*	NB	R5, N
Bay-breasted warbler	*Dendroica castanea*	NB	R5
Prairie warbler	*Dendroica discolor*	NB	R30, R5, N
Blue-winged warbler	*Vermivora pinus*	NB	R30
Canada warbler	*Wilsonia canadensis*	NB	R30, R5, N
Dickcissel	*Spiza americana*	NB	N
Sharp-tailed sparrow	*Ammodramus caudacutus*	BR	R30, R5, N
Seaside sparrow	*Ammodramus maritimus*	BR	R30, R5, N

Figure 37. Service (2002b) "Birds of Special Concern" that breed in the HMD. Clockwise from top left: northern harrier, seaside sparrow, peregrine falcon, common tern, sharp-tailed sparrow, upland sandpiper, marsh wren, wood thrush, and little blue heron.

The ENSP (New Jersey Department of Environmental Protection, 2004d) has designated 34 other species (Table 12; Figure 38) that occur in the HRW as "Species of Special Concern." This designation applies to: (1) species that warrant attention because of evidence of their decline and their vulnerability to environmental degradation or habitat modification and (2) species meeting those criteria for which little information exists (New Jersey Department of Environmental Protection, 2004d). The distribution and biology of nearly all of these species is poorly known within the HRW, including the HMD. Determining whether populations of these species in the HMD are self-sustaining is also a major concern and a priority for further studies.

G. SUMMARY

The Meadowlands' natural history has been marked by significant change for more than 10,000 years with the retreat of the Wisconsin glacier, the formation of a glacial lake, the breaching of the lake's terminal moraine and subsequent drainage of surface waters, the arrival of Paleolithic people, the development of indigenous Lenape culture, and colonization by European immigrants. However, during the past 350 years, the Meadowlands and its biota changed radically through human exploitation and land-use activities that became increasingly destructive with the continued growth of the region's human population. Slowly at first, but then more perceptibly, the ecosystem's hydrology was altered; its natural habitats were diminished and fragmented; its animal and plant communities were invaded by exotic species brought from other continents; and finally, its air, water, and land were degraded by contaminants and other anthropogenic conditions.

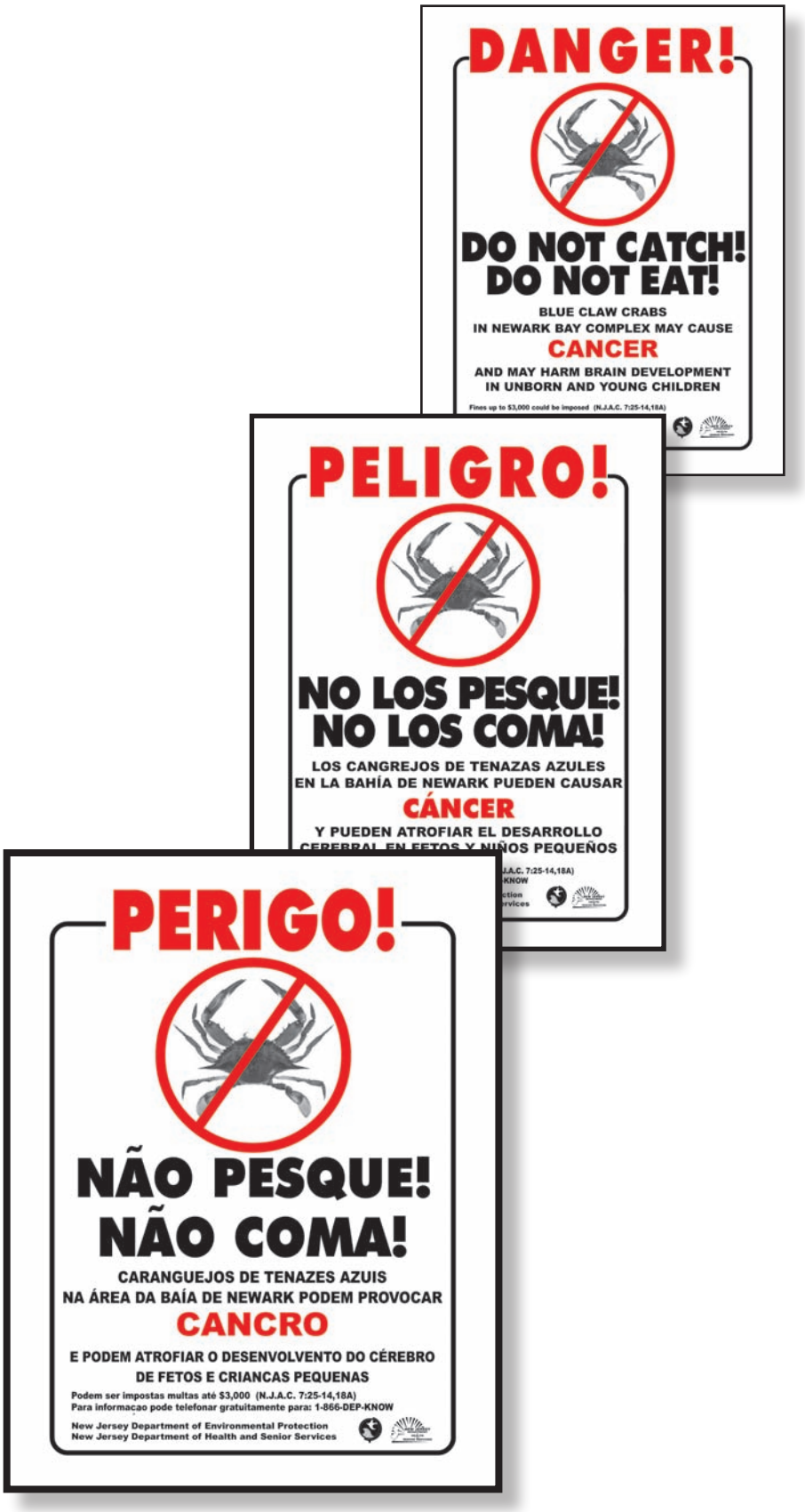
Despite considerable loss, alteration, and degradation of its natural lands and waters, the Meadowlands remains one of the largest and most productive brackish estuarine habitat complexes in the northeastern United States. Whether because of its size, position in the landscape, or because it is the only remaining habitat of its type in the region, or a combination of all of these, the Meadowlands continues to support considerable biodiversity (more than 700 species), including numerous migratory bird species, many State-listed species, and other species that are managed or of special conservation concern. As coastal areas, especially wetlands, in New England and middle-Atlantic States continue to be increasingly modified for human use, the Meadowlands becomes even more critical as an environmental oasis for the region's biodiversity. Thus, remediation, restoration, and long-term management of the Meadowlands ecosystem are vital to sustain and safeguard its remaining biodiversity. Because the ranges of species using the Meadowlands extend across North and South America, restoration efforts will have far-reaching benefits beyond the immediate region.

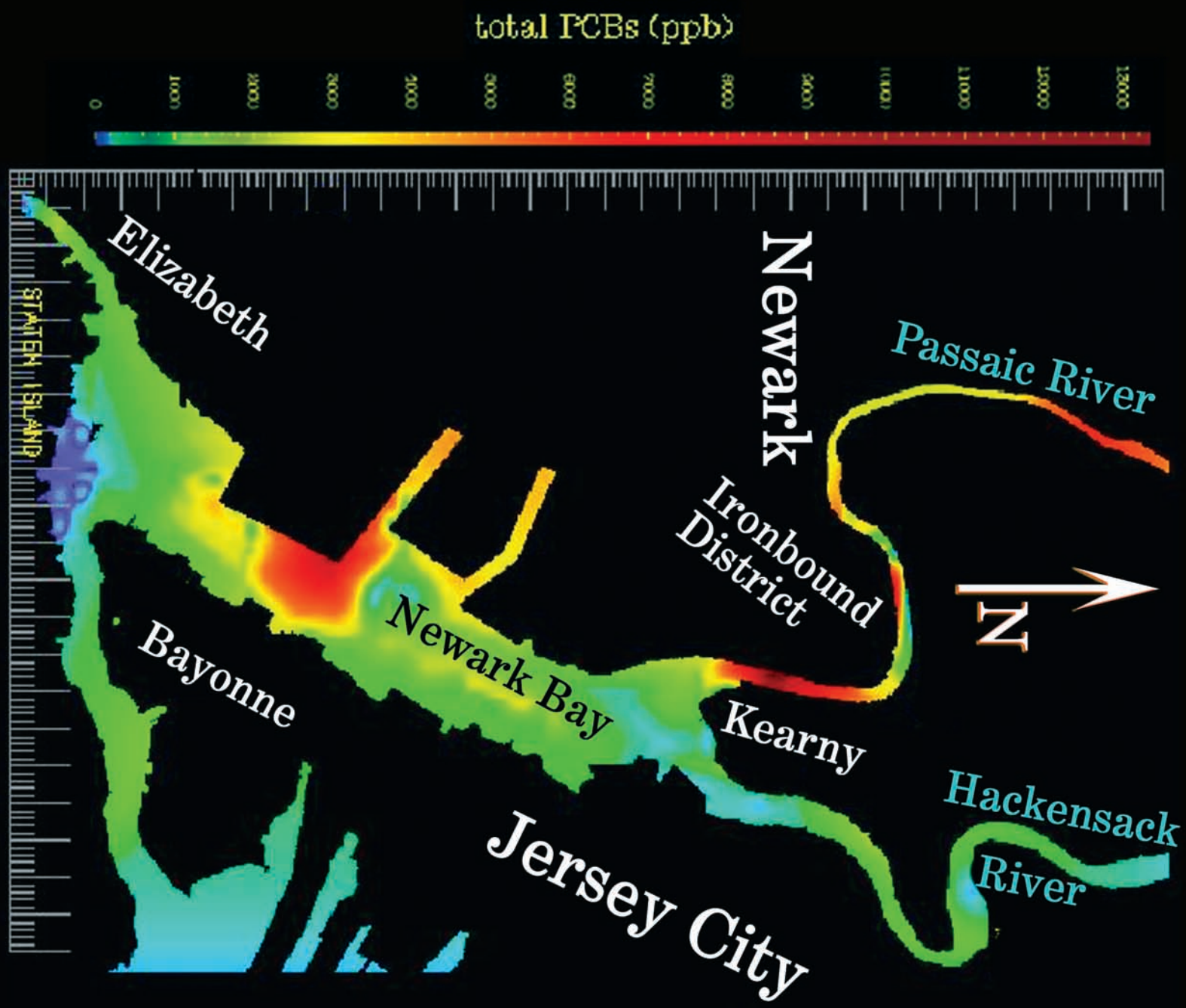
Table 12. State-listed Species of Special Concern occurring in the Hackensack Meadowlands District (HMD) or the Hackensack River watershed (HRW). An * indicates bird species that breed in the HMD.

Common name	Scientific name	Distribution
Creeper (mussel)	*Strophitus undulatus*	HRW (?)
Marbled salamander	*Ambystoma opacum*	HRW/HMD
Jefferson's salamander	*Ambystoma jeffersonianum*	HRW/HMD
Northern spring salamander	*Gyrinophilus porphyriticus porphyriticus*	HRW/HMD
Fowlers's toad	*Bufo woodhousii fowleri*	HRW/HMD
Spotted turtle	*Clemmys guttata*	HRW/HMD
Eastern box turtle	*Terrapene carolina carolina*	HRW/HMD
Northern diamondback terrapin	*Malaclemys terrapin terrapin*	HRW/HMD
Least bittern*	*Ixobrychus exilis*	HMD
Tricolor heron	*Egretta tricolor*	HMD
Little blue heron	*Egretta caerulea*	HMD
Great blue heron	*Ardea herodias*	HRW/HMD
King rail	*Rallus elegans*	HMD
Whimbrel	*Numenius phaeopus*	HMD
Spotted sandpiper*	*Actitis macularia*	HRW/HMD
Sanderling	*Calidris alba*	HMD
Common tern	*Sterna hirundo*	HMD
Black tern	*Chlidonias niger*	HMD
Caspian tern	*Sterna caspia*	HMD
Sharp-shinned hawk	*Accipiter striatus*	HMD
Broad-winged hawk	*Buteo platypterus*	HRW/HMD
American kestrel*	*Falco sparverius*	HRW/HMD
Common barn owl*	*Tyto alba*	HRW/HMD
Common nighthawk	*Chordeiles minor*	HRW/HMD
Least flycatcher	*Empidonax minimus*	HMD
Horned lark*	*Eremophila alpestris*	HMD
Cliff swallow	*Petrochelidon pyrrhonota*	HMD
Winter wren	*Troglodytes troglodytes*	HRW/HMD
Veery	*Catharus fuscescens*	HRW/HMD
Gray-cheeked thrush	*Catharus minimus*	HMD
Solitary vireo*	*Vireo solitarius*	HMD
Northern parula	*Parula americana*	HMD
Black-throated green warbler	*Dendroica virens*	HMD
Eastern meadowlark	*Sturnella magna*	HMD

Figure 38. Avian "Species of Special Concern" breeding in the HMD. Clockwise from top left: barn owl, solitary vireo, American kestrel, spotted sandpiper, horned lark, and least bittern.

IV. Hydrology and Contaminants




total PCBs (ppb)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000
STATEN ISLAND
Elizabeth
Newark
Passaic River
Ironbound District
N
Newark Bay
Bayonne
Kearny
Hackensack River
Jersey City

IV. Hydrology and Contaminants

The Hackensack and Passaic Rivers and Newark Bay have much in common; they share contaminants carried in diverted river flows and by tidal currents. More than 50 million gallons of water are diverted daily from the Passaic River through Pascack Brook into the upper Hackensack River; even larger diversions are being considered to meet public needs. A change in the hydrology of these waterbodies and land-use activities in upper portions of their watersheds can change the distribution and availability of contaminants.

Hot spots of contaminants in the Passaic River and Newark Bay (see the map on the left) are potential sources of contaminants in the Meadowlands because of tidal currents. Contaminants from the Passaic River and even the Hudson River have been found in sediments in the Hackensack River as far upstream as the Oradell Dam. Certain fishes in the Hackensack River are contaminated with PCBs and dioxins from the Hudson and Passaic Rivers. Contamination may be exacerbated by endocrine disruptors and nutrients discharged in sewage effluent, which now comprises roughly 80 percent of the Hackensack's "freshwater" flow.

Storm surge, flooding, and even modest sea level rise also have the potential to increase scouring of contaminated sediments in any of these water bodies and redistribute contamination. Thus, remediation and restoration must address water quality and supply issues and must be coordinated throughout the region. Otherwise, restoration may contribute to "attractive nuisances," which further imperil fish and wildlife resources.

The sewage treatment plant above is discharging its effluent into Mill Creek, where several marsh areas are being restored. High nutrient concentrations, hypoxia, and impairments to water quality occur in Mill Creek.

The map on the left indicates the concentration of PCBs in the sediments of the Newark Bay and adjacent rivers. A red color indicates extremely high levels of PCBs; blue indicates a zero level (map modified from U.S. Enviromental Protection Agency *et al*., 1999). Recent studies suggest PCBs from several sources have contaminated the Hackensack River up to Oradell Dam.

IV. HYDROLOGY AND CONTAMINANTS

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D. SUMMARY

More freshwater enters the Meadowlands through sewage treatment plants than flows over the Oradell Dam.

IV. HYDROLOGY AND CONTAMINANTS

A. INTRODUCTION

The long history of land and water use by the large human population in the HRW, often without regard to the biological values of the area, has resulted in extensive, cumulative, adverse impacts to the Meadowlands, including reductions and losses of fish and wildlife populations. Dams, diverted and regulated river flows, groundwater extraction, sewage effluents, industrial contamination, non-point source run-off, and urban/suburban land and water use in the surrounding watersheds have contaminated and disturbed the Meadowlands ecosystem and more severely impaired its functioning. The Hudson Raritan Estuary (HRE), including the Hackensack Meadowlands, was recognized for many years as one of the three most polluted estuaries in the United States (*e.g.*, U.S. Department of the Interior, 1994). In recent years, considerable improvements have been made in water quality throughout most of the HRE and have been attributed in part to improved sewage treatment (*e.g.*, Brosnan and O'Shea, 1996; Steinberg *et al.*, 2004). However, in comparison with the HRE, water quality in the Meadowlands ecosystem remains impaired for many criteria (*e.g.*, mercury, fecal coliform) and has not shown similar improvements (Keller *et al.*, 1990; DiLorenzo *et al.*, 2004). In 2001, American Rivers listed the Hackensack River as one of the most "endangered" rivers in the United States.

Despite increased government and public concern about hydrologic, contaminant, and related issues (*e.g.*, sea level rise as discussed below), adverse effects will likely worsen as the region's human population increases and urbanization of the landscape continues. Much of the information needed to guide the remediation and restoration of the Meadowlands is not currently available on a site-specific or species-specific basis. Improved coordination is needed among federal and State agencies to identify information gaps, design suitable monitoring and assessment programs, and develop comprehensive solutions. Long-term protection of the public's natural resources in the Meadowlands requires strengthened institutional, scientific, and legal tools to monitor, assess, and manage the hydrology and remediate contamination of the Hackensack and surrounding rivers of the NY-NJ Harbor estuary (*e.g.*, Pringle, 2000).

Habitat restoration planning and projects are occurring in the Meadowlands to counter decades of abuse. Habitat restoration is increasingly recognized and supported by the general public. The challenge to achieve successful protection and restoration of the Meadowlands is formidable and requires a deliberative and iterative approach that can define restoration success. There must be collaboratively defined success metrics or performance measures for all activities, including: restoring physical habitat and vegetative cover, managing hydrology and water supply, improving water quality, remediating contaminated sites and sediments, improving contaminant-related species health, and controlling invasive species. How all stakeholders embrace these challenges and work cooperatively to define successful restoration and management will be critical. For instance, the degree of successful wildlife restoration will be directly proportional in many cases to remediation of contaminated sites and sediments. Also, restoration success must be clearly defined. To ensure successful restoration and healthy fish and wildlife, performance metrics currently being developed collaboratively for the HMER must be comprehensive (*i.e.*, they must include reproduction of key species, appropriate tissue criteria, and other measures).

B. HYDROLOGIC CHANGES

1. Dams, Reservoirs, and Flow Diversions

Beginning in 1922 with the construction of the Oradell Dam, several large reservoirs were created along the Hackensack River to provide a regional water supply for the growing suburban/urban population. Dams have caused profound changes to the Meadowlands and the entire HRW: they eliminated extensive areas of riverine habitats, altered and fragmented the remaining riverine habitats, and created several large reservoirs. The dams also changed the river's hydrology (*e.g.*, flow volume, seasonality, and pulsing), geomorphology (*e.g.*, channel location, depth, and width), temperature (*e.g.*, greater seasonal and daily ranges), and chemistry (*e.g.*, salinity and nutrient ions). Moreover, the dams and changes to the landscape undoubtedly altered ecosystem functions (Table 13; *e.g.*, eutrophication[1] from nutrient loading, sediment trapping) and especially disrupted ecosystem processes that occur as water and materials flow down the river (*e.g.*, Vannote *et al.*, 1980; Ward and Stanford, 1983; Junk *et al.*, 1989). Studies in other systems indicate that dams and consequent landscape changes probably resulted in decreased or changed diversity (*e.g.*, local extirpation of species or shifting of guilds[2] — warm water fish in reservoirs, cold water fish in streams below the dam) of nearly all major taxa, including algae, plants, invertebrates, and fishes (*e.g.*, Paul and Meyer, 2001).

The effects of dams and reservoirs (descriptions of individual reservoirs are included in Section III) on the Hackensack Meadowlands and its estuarine biota have not been well studied. Construction of the Oradell Dam caused a drop in the local water table and oxygenation of deeper soils, which resulted in subsequent peat decomposition, ground subsidence, and saltwater penetration into the Hackensack Meadowlands (Sipple, 1972). Water regime is critical to the survival and growth of Atlantic white-cedar (Golet and Lowry, 1987); therefore, construction of the dam and subsequent flow reduction hastened the demise of remaining stands of Atlantic white-cedar (and has made it impractical, if not impossible, to return the Hackensack Meadowlands to its previous condition, as an ecosystem forested extensively by Atlantic white-cedar). Populations of freshwater fishes and invertebrates were further fragmented by construction of additional dams on the upper Hackensack to create water-storage reservoirs and by diversions of Passaic and Hudson River flows into storage reservoirs within the HRW (see Section III). These hydrologic alterations likely contributed to losses of certain fauna from the watershed (*e.g.*, freshwater mollusks). The diversion of flows from the Passaic and the Hudson Rivers into the HRW also has increased certain risks to fishes and wildlife. For example, the diversion of flows may disperse invasive species (*e.g.*, zebra mussel), contaminants, and pathogens.

The flow of the Hackensack River has been increasingly altered and managed to meet public demand for drinking water; however, ecosystem maintenance and the needs of fish and wildlife are not included in present-day water management within the watershed. The base flow of the

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[1] Eutrophication- the process whereby water bodies receive excess nutrients that stimulate excessive plant growth leading to low oxygen concentrations, which cause mortality of other aquatic organisms.

[2] Guild- a group of species that exploit an environmental resource similarly.

Table 13. Ecosystem functions and services provided by wetlands (from Daily *et al.*, 1997).

Modify/regulate the hydrologic cycle and local climate

- Transfer water from ground into the atmosphere, and thus affect local precipitation and temperature

Modify/regulate surface and groundwater water quantity

- Reduce peak flood flows and volumes through surface and groundwater storage
- Increase drought flows through surface and groundwater storage
- Recharge groundwater aquifers

Modify/improve water quality

- Assimilate biodegradable waste products and nutrients
- Trap and detoxify contaminants
- Trap nutrients and sediments

Modify/improve air quality

- Modify global carbon cycle (usually carbon dioxide sinks)
- Modify global nitrogen cycle (transform various forms of nitrogen)
- Modify global phosphorus, sulfur, and other biogeochemical cycles (modifies forms of nutrients and other materials)

Transport/secure materials

- Transport nutrients and sediments
- Trap nutrients and sediments
- Protect shorelines

Support primary and secondary production

- Support growth of plants, including food plants and timber
- Support growth of animals, including invertebrates, fishes, and birds

Maintain biodiversity

- Provide critical/essential habitat for bacteria, fungi, plants and animals

Hackensack River at the Oradell Dam from 1922-2002 averaged 58.4 mgd (U.S. Geological Survey, 2003). Recent flows have been much lower than the average due to below-average precipitation (New Jersey State Climatologist, 2005); for example, the daily flow just below Oradell Dam from July 2000 to July 2003 was only 26.7 mgd (T. Wilson, pers. comm. 2004). Only 8.3 mgd is required currently by the NJDEP Bureau of Water Allocation's Water Diversion Permit (No. 5111); however, minimum flows to comply with that permit condition have not always been met during dry periods. Thus, flows from the Passaic and Hudson Rivers have been diverted into reservoirs on the Hackensack River to address acute and long-term water supply needs in the region (New Jersey Department of Environmental Protection, 1996; U.S. Geological Survey, 2003). Improved conservation and water-reuse programs are needed to meet long-term water supply needs (New Jersey Department of Environmental Protection, 1996).

In addition, in-stream flow maintenance goals for ecosystem protection (*i.e.*, fish and wildlife) must also be developed (New Jersey Department of Environmental Protection, 1996; U.S. Geological Survey, 2005a). The long-term protection of the Hackensack Meadowlands and its biotic resources must be considered in planning future water projects.

Increasing water withdrawal from reservoirs to support the region's human population has steadily reduced the daily flow of the Hackensack River, and increased the volume of "water" being returned to the river in the form of sewage effluent. Unlike most of the NY-NJ Harbor estuary, where sewage effluent comprises approximately 15 percent of the freshwater input (Tetra Tech, Inc. and Andrew Stoddard and Associates, 2000), sewage effluent from STPs comprises more than 75 percent of the "freshwater" input into the HRW under normal (*i.e.*, non-storm) conditions. Under normal conditions, the largest freshwater input to the Meadowlands is the sewage effluent discharged by the Bergen County Utilities Authority sewage treatment plant (BCUA STP), which averaged approximately 75 mgd from July 2000 to July 2003 (Wilson, pers. comm., 2004). The permitted treatment capacity of the BCUA STP is 109 mgd (New Jersey Meadowlands Commission, 2004d). Thus, pollutants, nutrients, and other materials are concentrated within the Meadowlands as a whole and even more so within certain portions of the Meadowlands (*e.g.*, Mill Creek). High nutrient inputs lead to excessive algal and bacterial growth, which may cause hypoxic (low-oxygen) and anoxic (no oxygen) conditions and initiate a "cascade" of complex changes (*e.g.*, altered biogeochemical cycling) that adversely affect biological communities (*e.g.*, nuisance algal blooms, impaired benthic communities, loss of shellfish resources, fish kills; Cowardin *et al.*, 1979; Adam, 1990; Mitsch and Gosselink, 1993; Kemp *et al.*, 1997). Contaminant and nutrient problems may also be exacerbated by other users of Hackensack water that discharge directly into the river. For example, PSEG's Hudson Generating Station in Jersey City continues to use Hackensack River water (as much 913.8 mgd but an average of only 474 mgd; Versar, Inc., 1989; Furnari, pers. comm., 2005) for cooling. In contrast, the PSEG Bergen Generating Station in Ridgefield now recycles waste water for cooling. Previously, the daily intake of river water by the Bergen facility exceeded 650 million gallons (Versar, Inc., 1989). These thermal (and other industrial) dischargers represent an additional stressor to aquatic fish and wildlife resources in the Hackensack River, especially in summer when oxygen concentrations are already low.

Dams on the Hackensack River have long impeded the migration of anadromous fishes throughout the watershed and fragmented populations of freshwater fishes and invertebrates. The Oradell Dam, located roughly mid-way on the Hackensack River mainstem, blocks upstream passage of American shad, alewife (*Alosa pseudoharengus*), and blueback herring (*Alosa aestivalis*), and possibly other species (Zich, 1977; New Jersey Department of Environmental Protection, 2000). Installation of a fishway at the Oradell Dam is being considered by certain stakeholders. Installing a fishway may help restore spawning runs of native fishes, provided that suitable habitat for spawning and the support of early life history stages (eggs, larvae, and juveniles) is present above the dam. However, installation of a fishway may also introduce contaminants in migrating fishes into those upstream habitats and affect other species, such as piscivorous[3] birds (*e.g.*, ospreys, bald eagles) that are sensitive to bioaccumulation of certain contaminants (*e.g.*, endocrine disruptors; see Section C.6. below).

[3] Piscivorous- fish eating.

The status of federal authorizations for dams on the Hackensack River is presently unknown. The Rivers and Harbors Appropriations Act of 1899, which requires a federal permit from the Corps for any structure placed in navigable waters, predates the construction of the dams that created the water storage reservoirs in the HRW. Planning that provides consideration for anadromous fish spawning would be apparent in the design of the dam. Prior to passage of the Federal Power Act (16 U.S.C. 791-828c, as amended) in 1920, the Secretary of Commerce had primary responsibility for fish passage facilities at federally licensed projects pursuant to the Dam Act of 1906 (P.L. No. 262, 34 Stat. 386, Sec. 3). The Act states: "The persons owning or operating any such dams shall maintain, at their expense . . . such fishways as the Secretary of Commerce and Labor shall prescribe." The status of the authorization of all dams in the HRW needs to be verified in order to determine the legal requirements for providing fish passage at these structures.

2. Flooding, Stormwater, and Tidegates

The frequency of and extent to which wetlands are flooded (inundated) are two of the most important factors determining the physical environment and the biological communities living in wetlands (Cowardin *et al.*, 1979; Middleton, 2002). Wetlands modify the quality and quantity of flood and storm waters moving through them. Flood events can structure fish and other aquatic communities (*e.g.*, Grossman *et al.*, 1982) and eliminate exotic species from aquatic ecosystems (*e.g.*, Minckley and Meffe, 1987).

In addition to storm events, the frequency and extent of flooding in urban watersheds may increase due to certain land uses and other human activities that modify how precipitation is stored and runs off the land. For example, buildings, parking lots, roads, and other transportation infrastructure create a network of impervious surfaces that do not absorb or process precipitation; thus, in urban areas, less water is stored on and in vegetation, surface depressions, and in soils. A 1-acre parking lot releases 16 times more stormwater runoff than a 1-acre meadow (Schueler, 1994). Landscape alterations that are implemented to protect human life and property from flooding (*e.g.*, filling, bulkheads, tidegates) also change the natural movement and processing of precipitation. Removing vegetation, grading and hardening land surfaces and riverbanks, and constructing drainage networks increase flooding frequency, velocity, total volume, and peak discharge (Butler and Davies, 2000). Urban landscapes also introduce pollutants and exacerbate wastewater treatment (Butler and Davies, 2000; Center for Watershed Protection, 2003).

The effects of land use changes noted above are more severe in the Meadowlands due to its physiography. Nearly all of the acreage within the HMD now classified or used as uplands was formerly wetlands (Tiner *et al.*, 2002), and filling has reduced the flood-storage detention and retention capacity of remaining wetlands. Flooding during severe weather is a common occurrence in the HMD and other portions of the watershed (Table 14). Though flooding in the HRW historically has been neither as frequent nor as severe as in the nearby Passaic River watershed (*e.g.*, U.S. Army Corps of Engineers, 2002a; 2005a), flooding of these former wetlands has occurred repeatedly within every municipality in the HMD and is viewed by residents and local governments as a significant problem (*e.g.*, New Jersey Meadowlands Commission, 2004f; 2004g). For example, Little Ferry, Teterboro, and Rutherford were damaged substantially by flooding from Tropical Storm Floyd in 1999 with damage and cleanup

costs estimated in the multimillions of dollars (Carola, 1999). Most of these flood-prone areas lie within the 100-year flood zone (Federal Emergency Management Agency, 1995). Several municipalities in the HMD (*e.g.*, Kearny, Jersey City) have been among the national leaders in properties for which the National Flood Insurance Program (NFIP) has repeatedly paid claims (Conrad *et al.*, 1998). For example, in Kearny, one building flooded 34 times in 12 years for which the building's owners have received nearly $4 million from the NFIP (Johnson, 1998). Thus, it is clear that greater consideration and development of programs employing non-structural means of flood control are needed. Moreover, those upland areas for which repeated flood-damage claims have been made should be reclaimed as floodplain and wetlands.

Table 14. Flood-prone areas in various municipalities of the Hackensack Meadowlands District. Sources of information for these flood-prone areas are also provided.

Municipality	Flood-prone Areas	Information Source(s)
Carlstadt	Berry's Creek/ Patterson Plank Road area	New Jersey Meadowlands Commission, 2004d
East Rutherford	Berry's Creek/ Patterson Plank Road area	New Jersey Meadowlands Commission, 2004d
Hackensack	Green Street, Newman Avenue	Rethage, 2004
Jersey City	Downtown area	U.S. Department of Housing and Urban Development, 2005
Kearny	Various	Johnson, 1998; Skelly, 2002; New Jersey Meadowlands Commission, 2005b
Little Ferry	along Losen Slote	Federal Emergency Management Agency, 1999
Moonachie	Moonachie Avenue, Grand Street	New Jersey Meadowlands Commission, 2004f; 2005b
North Bergen	along Bellman's Creek (*e.g.*, 91st Street, West Side Avenue)	New Jersey Meadowlands Commission, 2005b
Rutherford	Rt. 17	Borough of Rutherford, 2004; New Jersey Meadowlands Commission, 2005b
Secaucus	Mill Ridge Road, Penhorn Road	New Jersey Meadowlands Commission, 2004f; 2005b

Nearly all modifications that have been made historically (*e.g.*, drainage pipes, ditches, retention basins) to address specific flooding problems have some adverse impacts on fish and wildlife. Until recently, the urban problems of storm runoff, drainage, and flooding were addressed by transferring large quantities of water downstream as quickly as possible. This approach required putting large volumes of stormwater into the sewage treatment system (*i.e.*, a combined sewerage system) or building a separate system of storm drains. While these approaches provide a solution at the source, each system creates problems downstream due to increases in volume, flow, erosion, and pollution. In the Meadowlands, the former approach is still used in numerous locations, resulting in the need for 32 combined sewer overflows (CSOs) to discharge the excess volume of runoff generated by large storms (New Jersey Meadowlands Commission, 2004d). In CSOs, this excess volume of stormwater is mixed with wastewater. As a result, excessive volumes of water are delivered rapidly to the wetlands, causing even greater contamination of wetlands and waterways during storm events. While separate stormwater systems do not discharge sewerage waste, they do contribute contaminated runoff to waterways and aquatic systems. Stormwater runoff has been identified as a major source of certain contaminants and materials (*e.g.*, coliform bacteria, oil, and grease) into the NY-NJ Harbor estuary (Harbor Estuary Program, 1996).

The State of New Jersey has begun implementing new regulations (Stormwater Regulations; N.J.A.C. 7:8) designed to address the shortcomings of traditional stormwater approaches. The new regulations require an integrated approach that includes local disposal of stormwaters (*e.g.*, infiltration devices, vegetated surfaces), inlet and pollution controls on runoff (*e.g.*, temporary storage to delay runoff, screening to reduce floatable debris), and other measures (*e.g.*, larger wetland buffers). The NJMC is in the process of developing its own rules within the HMD for consistency with the State regulations. The Service recommends that the NJMC work with federal and other State agencies to develop and implement rules that not only provide protection for human life and property but also reduce adverse impacts to fish and wildlife resources, especially through practices that will reduce physical and chemical impacts on waters and wetlands from storm runoff.

In 2006, several large development projects in the Meadowlands are ongoing, just beginning, or in planning stages (*e.g.*, EnCap, Xanadu, new sports stadium). Based upon the total acreage and extent of impervious surfaces potentially included in these projects, comprehensive storm-water control programs should be developed that employ best management practices, including use of low-impact solutions, sufficient water storage capacity, and water treatment designed to address contaminants on-site. In addition, planning of all large projects should include acquisition of open-space, floodplain reclamation, and wetlands creation elsewhere in the watershed to augment existing flood storage.

Finally, to reduce flooding throughout the HMD, 30 flood control structures such as tidegates and culverts are located along the Hackensack River and its tributaries (U.S. Army Engineer Research and Development Center *et al.*, 2000). One or more tidegates are located in at least eight tributaries of the Hackensack River (New Jersey Meadowlands Commission, 2004d) and are planned for additional tributaries (*e.g.*, Sack Creek, which, though confined to culverts for much of its length, drains wetland areas in Secaucus). Remnants of former or non-functioning tidegates are visible in several other tributaries (*e.g.*, Mill Creek, Penhorn Creek). Used in

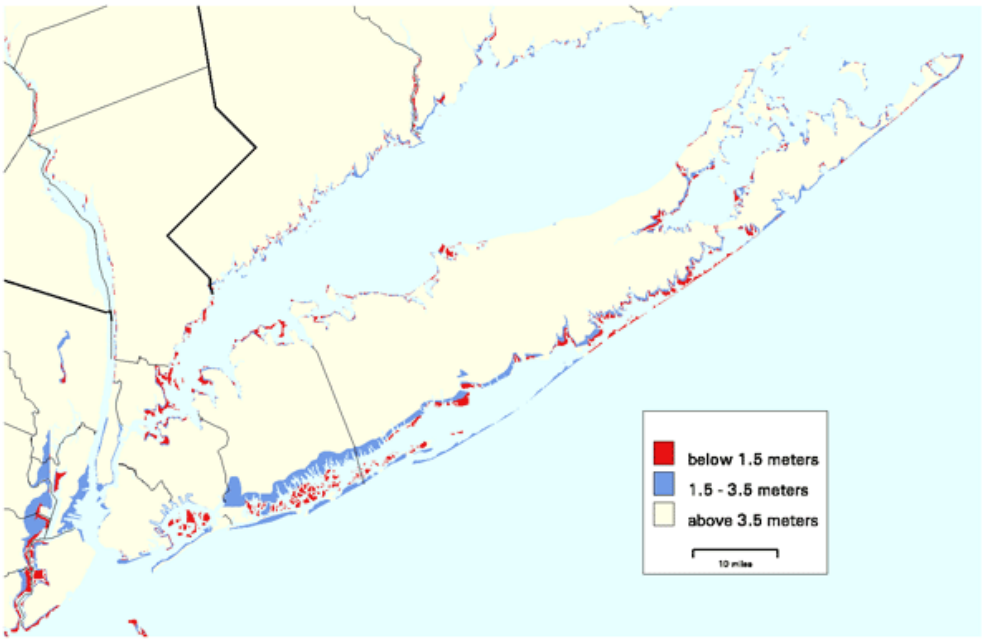
concert with other coastal modifications (*e.g.*, levees, pump stations), tidegates can be effective in reducing and preventing flooding if properly designed, located, and maintained. Nevertheless, poorly designed or maintained tidegates have diverse impacts on wildlife (Giannico and Souder, 2004) and have facilitated the spread of invasive species in coastal wetlands of the northeastern United States (Roman *et al.*, 1984). Thus, evaluation of all flood control structures should be undertaken and former and non-functioning tidegates removed to improve tidal flow. Careful consideration should also be given to the need, design, maintenance, and potential adverse impacts of tidegates on fish and wildlife, especially on nearby restoration efforts.

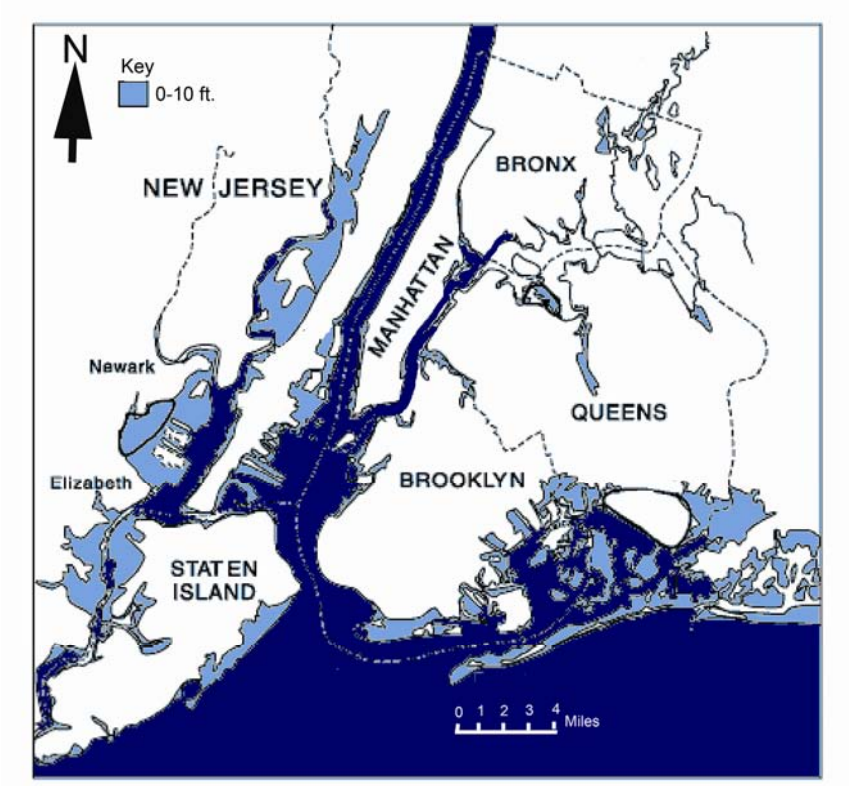
3. Sea Level Rise

Recent natural tragedies around the globe have heightened public concern about the vulnerability of coastal communities and renewed interest in understanding sea level rise (SLR) and its modifiers. Global sea level change is, in part, an indicator and integrator of global climate change; however, the complex linkages between global climate change and SLR are just beginning to be recognized and remain poorly understood (Douglas *et al.*, 2001; Church *et al.*, 2001). Two processes directly increase *global* SLR: (1) an increase in the mass of the oceans due to the addition of waters from land sources (the eustatic, or true, water-rise component of SLR) and (2) an increase in the volume of the water as the oceans warm (the steric component of SLR). Measuring these SLR components individually and collectively has been plagued with difficulties (Cabanes *et al.*, 2001; Meier and Wahr, 2002; Munk, 2002). Nonetheless, there is general agreement that global sea level has risen 10 to 20 cm throughout much of the past century and that global SLR will continue at similar or higher rates as global warming progresses (Intergovernmental Panel on Climate Change, 2001; Meier and Wahr, 2002) and lowland subsidence increases.

Though the predicted 10 to 20 cm (approximately 1 to 1½ feet) of global SLR seems small, certain low-lying coastal areas will experience additional relative SLR (SLR that incorporates eustatic, steric, and other regional/local factors) due to movements of tectonic plates. Some areas are also more vulnerable to adverse effects from SLR due to other local factors such as subsidence (Titus and Narayanan, 1995; Intergovernmental Panel on Climate Change, 2001; Munk, 2002). During the past century, the mid-Atlantic coast of the U.S. (New Jersey to Virginia), including the New York Harbor area, is among those areas that has experienced the greatest relative SLR (Figure 39; National Ocean Service, 2002), a trend that is expected to continue. The vulnerability of coastal environments also is affected by coastal geomorphology and other risk factors (Table 15; Thieler and Hammar-Klose, 1999). For example, sandy barrier islands and salt marshes are more vulnerable to SLR and "drowning" than coasts comprised of rocky cliffs; and areas with low tidal amplitudes are at greater risk than areas with large tidal amplitudes. Except for its comparatively sheltered, upstream location within the New York Harbor estuary, the Meadowlands fits into several high-risk categories due to its low elevation, flat topography, and other factors (see Table 15; Thieler and Hammar-Klose, 1999).

Figure 39. Areas at risk from sea level rise in the New York-New Jersey metropolitan region. The upper figure (from Titus and Richman, 2001) shows relative risk of sea level rise in the metropolitan region. The lower figure (from Gornitz, 2000) shows the risk of flooding of low-lying areas in the New York City area, including the Hackensack Meadowlands, from increased storm surge.





Wetlands are among the coastal areas most vulnerable to SLR (Table 15). Sea level rise is predicted to: (1) increase tidal flooding and coastal erosion of low-lying areas, and (2) contribute to a higher frequency and greater magnitude of storm surges throughout much of the NY- NJ Harbor and coastal New Jersey (Sorensen *et al.*, 1984; Zhang *et al.*, 1997; Gornitz *et al.*, 2001). Sea level rise during the past century may already be affecting some NY-NJ Harbor wetlands, such as Jamaica Bay, which is already experiencing considerable loss of low marsh wetlands (more than 38 percent of area lost since 1974; Hartig *et al.*, 2002). Considerable losses of the exterior and interior portions of marshes have also occurred at sites in mid-Atlantic and southern New England States (Erwin *et al.*, 2004). In nearly every case, formerly vegetated wetlands are being converted to open water as they are inundated by rising ocean water. In southern New England, increasingly flooded and stressed high marsh areas also are being overgrown by "landward-migrating" low-marsh vegetation, primarily smooth cordgrass (Donnelly and Bertness, 2001). Monitoring of the Coastal Virginia Long-Term Ecological site indicates that most high-marsh vegetation is not accumulating inorganic and organic materials at rates sufficient to keep pace with SLR, whereas low marsh vegetation is keeping pace with SLR (Hayden *et al.*, 2003). A considerable portion of marshes in the Meadowlands (*i.e.*, the Sawmill Creek Wildlife Management Area) was converted to open water in 1950 as a result of a single storm event; this suggests that wetlands in the Meadowlands are at risk to storm events with continued SLR.

Losses of, and changes in, marsh landscapes have considerable implications for ecosystem functions and for fish and wildlife resources in the Meadowlands. First, many bird species breeding in the Meadowlands' wetlands (*e.g.*, common moorhen, least bittern) would suffer loss of breeding habitat. Erwin *et al*. (2004) has raised additional concerns about potential marsh losses on waterfowl and other bird species that forage in marshes. Marsh losses also will likely result in increases in contaminants, decreases in sediment accretion and water quality, and changes in community composition (Poff and Hart, 2002).

The above observations have several implications for restoration activities planned or underway on several sites; SLR will clearly affect the type(s) of natural communities we can expect to become established in the Meadowlands. First, additional tidal flow resulting from modest SLR may have both beneficial and adverse impacts on restoration that are difficult to predict without additional information (*e.g.*, more precise elevation information through LIDAR [light detection and ranging], site-specific sedimentation/erosion rates, predicted future current velocities). For example, additional salt-water intrusion into the Meadowlands may facilitate establishment of smooth cordgrass in certain areas (*e.g.*, mesohaline [5 ppt < salinity < 18 ppt] areas where salinities favor growth of common reed) of the HMD. Second, high marsh comprised primarily of salt marsh hay, a rare vegetation throughout the Meadowlands that is valued at several current restoration sites (*e.g.*, Marsh Resources Inc., Mitigation Bank), appears vulnerable to even modest SLR. Third, the vegetative responses to dynamic conditions related to SLR are likely to be "constrained" by the hardened condition of banks throughout the HMD and the HRW. Urban areas and upland areas along the edge of the wetlands, where most shorelines are hardened, are likely to experience greater marsh losses than undeveloped areas, where shoreline movement is less constrained (Galbraith *et al*., 2002). With increasing SLR, the "drowning" of wetlands may have some beneficial short-term effects (*e.g.*, increased production with conversion of high

marsh to low marsh; Kana *et al.*, 1988), but will ultimately result in net losses of vegetated wetlands and increases of permanently flooded, shallow-water areas. Finally, by increasing the tidal prism (the volume of water that moves in and out of an estuary with each tide), SLR increases tidal currents and scour of sediments in certain areas within the Meadowlands and thereby increases the resuspension and availability of contaminants throughout the Meadowlands and adjoining water bodies.

Table 15. Geomorphic and other risk categories (Thieler and Hammar-Klose, 1999) affecting coastal vulnerability to sea level rise. The risk level(s) of wetlands and adjoining properties in the Meadowlands for each risk variable is denoted by shading. (> = more than; < = less than)

			RISK LEVEL		
VARIABLE	Very low	Low	Moderate	High	Very high
Geomorphology	Rocky cliffs and fiords	Indented coasts and moderate cliffs			
Shoreline change (± meters per year)	Rapid accretion (> +2.0)				Rapid erosion (< - 2.0)
Coastal slope (percent)					
Sea level rise (millimeters per year)	Low, < 1.8	1.8 - 2.5	Moderate, 2.5 - 2.9		
Mean tidal range (meters)	> 6.0	4.1 - 6.0	2.0 - 4.0		< 1.0
Mean wave height (meters)		0.55 - 0.85	0.85 - 1.05	1.05 - 1.25	> 1.25

C. CONTAMINANTS AND WATER QUALITY

1. Introduction

The Meadowlands and surrounding area have been a center of industrial activity for more than 200 years. For decades, manufacturing plants, refineries, energy facilities, and landfills discharged or otherwise disposed of their waste and hazardous materials directly into the river or

adjacent wetlands. Many sites became contaminated with numerous pollutants, many of them quite toxic, including mercury, other heavy metals, dioxins, polychlorinated biphenyls (PCBs), pesticides, and other hydrocarbons. Containing most of the historic Hackensack Meadowlands, the HMD includes seven Superfund sites[4] in or within 2 miles of its borders, two power plants, three public STPs, and roughly 2,500 acres of landfills (Table 16, Figure 40). Each of these components of the Meadowlands' landscape has resulted in substantial impacts upon the environment. Two of the Superfund sites (*e.g.*, Ventron-Velsicol NPL site on Berry's Creek, U.S. Environmental Protection Agency, 2004a; Diamond Alkali, U.S. Environmental Protection Agency, 2004e) have been identified as among the worst contaminated sites in the United States, and have extensively degraded nearby wetlands and subtidal regions of the Hackensack River.

Table 16. Survey of Superfund National Priority List sites in the Hackensack Meadowlands District and in adjoining waterbodies. These and other industrial sites have contributed to contamination of wetlands and waterbodies in the HMD.

Site Name/Location	Site Status	Major contaminants
Hackensack Meadowlands District		
Ventron-Velsicol/ Woodridge, Bergen County	Superfund NPL	mercury
Universal Oil Products/ East Rutherford, Bergen County	Superfund NPL	VOCs[5], PCBs[6], PAHs[7], lead
Scientific Chemical Processing/ Carlstadt, Bergen County	Superfund NPL	VOCs, phenol, PAHs, heavy metals
PJP Landfill/ Jersey City, Hudson	Superfund NPL	chromium, lead, VOCs, pesticides, phenols
Syncon Resins/ Kearny, Hudson County	Superfund NPL	DDT[8], aldrin, PCBs, VOCs, heavy metals
Standard Chlorine Chemical Co., Inc. Kearny, Hudson County	Proposed for Superfund NPL	naphthalene, dioxin, PCBs, VOCs, chromium
Passaic River/Newark Bay		
Diamond Alkali Co. Newark, Essex County	Superfund NPL	Dioxin, PCBs, VOCs, DDT, PAHs

[4] Superfund site- any federal priority listed site in the United States that has been contaminated by hazardous waste and identified by the EPA as a candidate for cleanup because it poses a risk to human health and the environment
[5] VOC = Volatile organic compound
[6] PCB = Polychlorinated biphenyl
[7] PAH = Polycyclic aromatic hydrocarbon
[8] DDT = Dichloro-diphenyl-trichloroethane

Figure 40. Map of the Hackensack Meadowlands District (HMD) modified from the U.S. Army Corps of Engineers (2004). The location of major landfills (green outline) and Superfund sites (yellow star) is shown. Some landfills are being remediated and redeveloped, whereas others are to be remediated and capped and used to provide open space. The future use of most Superfund sites is currently undecided.

In addition, the HMD is subject to more than 50 active industrial discharges, combined sewer overflow (CSO) discharges, and tidally transported contamination from Newark Bay and the lower Passaic River. Tidal and riverine currents introduce additional contaminants from sources outside the Meadowlands (*e.g.*, PCBs from the NY-NJ Harbor estuary, pesticides and dioxin from the Passaic River, and leachates from landfills along Overpeck Creek). Certain contaminants (*e.g.*, PCBs) are dispersed broadly throughout the HMD; however, heavy metals and other contaminants may accumulate in subbasins and certain areas such as turbidity maximum zones (areas of intense settlement of suspended particulate matter; Williams *et al.*, 1994; Nedwell *et al.*, 1999; Feng *et al.*, 2002).

Historical and current uses of the Hackensack Meadowlands and its watershed have created a spatial mosaic of environmental contaminants throughout tidal waters and wetlands characterized by excessive nutrient concentrations, dissolved and suspended contaminants, abundant microbes, and summer hypoxia. The interactive effects of these chronic and acute stressors on fish and wildlife are largely unknown, but have contributed to historical declines of fish and wildlife diversity in the Meadowlands and its watershed. Identifying and describing all contaminants of potential concern, all contaminated sites within the HMD, or all of the associated adverse impacts on fish and wildlife resources are beyond the scope of this document. Rather, this section of the Plan identifies two basic concerns: the Meadowlands' potential to function as a wildlife "population sink," and the potential for contaminants to broadly compromise the restoration. This section also identifies and describes four specific categories of pollutants and related concerns: (1) mercury and other heavy metals, (2) hydrocarbon contaminants, (3) novel contaminants, and (4) eutrophication and hypoxia.

2. Population Sinks

Historical declines in fish and wildlife populations may be difficult to recognize because of complex movement patterns of animals (Holt, 1985; Pulliam, 1988). For example, individuals may regularly occur and breed in "sink" habitats, where (within-habitat) reproduction is insufficient to balance local mortality. Nevertheless, populations may persist in such sink habitats, maintained by immigration of individuals from nearby higher-quality "source" habitats, where reproduction exceeds local mortality. Sink habitats increasingly are being attributed to anthropogenic causes, including habitat fragmentation, invasive species, and contaminants for diverse taxa (*e.g.*, insects, fishes, amphibians, reptiles, birds, and mammals; Dias, 1996; Pulliam, 1996). Recent laboratory and field studies indicate that certain contaminants, invasive species, and other anthropogenic factors contribute to establishment of sink habitats (*e.g.*, Rowe *et al.*, 2001; Borgman and Rodewald, 2004). Localized and regional movements of individuals among different sites (habitats or areas) within the region have not been characterized for most species in the Meadowlands. For instance, animals that feed in the Meadowlands may accumulate contaminants, then migrate and reproduce outside of the Meadowlands (or the region) in productive source habitats. Movements of contaminated animals to source habitats have the potential for long-term adverse impacts to the entire population.

Conservation and management based on species abundance in sink habitats may lead to tragic results, including local extirpation of a species (Pulliam, 1988). Recognizing source and sink populations requires habitat-specific information on birth, death, and movement rates (*e.g.*,

Pulliam and Danielson, 1991; Howe *et al.*, 1991). With the possible exception of certain species that are closely monitored throughout the region (*e.g.*, peregrine falcon), such information is not known and has not been reported for any population in the Meadowlands. Most of the biological information being collected in the Meadowlands (*e.g.*, abundance data, species presence-absence) is inadequate to distinguish between sink and source habitats. Furthermore, abundance or density measures may actually provide misleading information about habitat quality or value (*e.g.*, Van Horne, 1983; Vickery *et al.*, 1992); large numbers or high densities may reflect production in and emigration from other habitats. Thus, reproductive success of species must be compared among habitats, regions, and years to understand local population trends (*e.g.*, Murphy, 2001). Without habitat-specific information on reproductive success, restoration and management may place uncommon and rare species at increased risk of extirpation locally or regionally, especially in fragmented landscapes (Collier and Powell, 1998; Cornutt *et al.*, 2000; Donovan and Lamberson, 2001), and/or may result in failure of efforts to re-introduce populations of locally extirpated species (*i.e.*, species that occurred formerly in the Meadowlands).

Available information raises serious concerns that contaminants may have "created" sink habitats for certain invertebrates and fishes in the Meadowlands. For example, dioxins, furans, and PCBs accumulate in, alter gonadal and embryonic development of, and reduce larval survival of certain bivalve mollusks (*e.g.*, softshell clam [*Mya arenaria*] and American oyster [*Crassostrea virginica*]; Gardinelli *et al.*, 2004; Wintermyer and Cooper, 2003; Butler *et al.*, 2004). Mummichogs in marshes contaminated by heavy metals have significantly lower prey capture rates than mummichogs inhabiting clean reference sites (Smith and Weis, 1997). Moreover, fish from clean sites housed in tanks with contaminated sediments showed significant declines in prey capture rates and significant increases in vulnerability to predation by blue crabs (Smith and Weis, 1997; Weis *et al.*, 1999a). In addition, mummichogs from contaminated marshes have exhibited: (1) decreases in reproductive success when exposed to additional pesticides (Weis *et al.*, 1999b); (2) development of resistance to toxicity of chlorinated aromatic hydrocarbons (Prince and Cooper, 1995a; 1995b) and methyl mercury (Weis and Weis, 1989); and (3) physiological (*e.g.*, poor fin regeneration) and reproductive (*e.g.*, a reduced salinity range for fertilization) impairments associated with resistance to toxicity (Bush and Weis, 1983; Weis and Weis, 1987). Such findings raise additional questions about assessing contaminant risks and the potential impacts of contaminants to higher trophic levels by toxicity-resistant species, which have implications for restoration planning in the Meadowlands (Clotfelter *et al.*, 2004; Wirgin and Waldman, 2004). For example, evolution of pollution-tolerant mummichog has raised concerns regarding the potential for increased bioaccumulation of certain contaminants (*e.g.*, mercury, PCBs) in higher predators such as piscivorous fishes and birds (Wirgin and Waldman, 2004).

The pervasiveness of contaminants in the Meadowlands may contribute to "sink habitats" for species that use terrestrial habitats for most of their lives or that use the Meadowlands solely as foraging habitat. For example, trace-metal contaminants known to impair development, growth, reproduction, and survival of amphibians (*e.g.*, Rowe *et al.*, 1996; Raimondo *et al.*, 1998; Hopkins *et al.*, 2000; Baud and Beck, 2005) have been shown to create sink habitats for certain amphibian species in other regions (Rowe *et al.*, 2001). For example, in sites contaminated with metal-laden coal ash, tadpoles of southern toad (*Bufo terrestris*) usually died prior to their

metamorphosis; as a result, the adult population contained few recent metamorphs and was reliant on adult recruits from other sites (Rowe *et al.*, 2001). Bioaccumulation of contaminants in certain birds (*e.g.*, American kestrel, *Falco sparverius*) may result in smaller eggs, smaller clutches, delayed clutches, and other adverse effects on reproduction and survival; moreover, some adverse effects may extend for several generations beyond the exposed generation (*e.g.*, Fernie *et al.*, 2000a; 2000b; 2001a; 2001b). Those same contaminants also impair the immune systems and potentially increase the susceptibility of kestrels to environmental stressors (*e.g.*, Smits *et al.*, 2002; Love *et al.*, 2003). These findings further emphasize the need for detailed studies on behavior (especially movements) and reproduction of select species within different vertebrate groups (*e.g.*, fishes, birds) to determine to what extent the Meadowlands may function as sink habitat and to guide and ensure the success of subsequent restoration decisions.

3. Contaminant Effects on Restoration

Sampling of wetland sites throughout the Meadowlands, including potential restoration sites, has identified several contaminants at levels associated with substantial adverse effects on fish and wildlife. Most recently, a Screening-Level Ecological Risk Assessment (SLERA) conducted for the NJMC (ENSR, International, 2004) identified seven heavy metals, two pesticides, and two other hydrocarbon compounds (Table 17) as Contaminants of Potential Concern (COPCs) at potential restoration sites. In a review of wetland contamination from one or more Superfund sites located in the Berry's Creek Study Area, (U.S. Army Corps of Engineers and U.S. Environmental Protection Agency, 2004), eight heavy metals, PCBs, dioxins, furans, and other hydrocarbons were identified as COPCs (Table 17). The Berry's Creek Study Area is among the worst mercury contaminated sites in North America (U.S. Environmental Protection Agency, 2004a). The NJDEP (2002a) previously identified the Hackensack River and several of its tributaries as impaired for a number of persistent toxic contaminants (Table 17) and other water quality parameters (*e.g.*, dissolved oxygen, total phosphorus, fecal coliform bacteria).

Comprehensive assessments of contaminant distribution, bioavailability, and effects (including bioaccumulation) on fish and wildlife have not been determined before, during, and after restoration. To date, only limited contaminant information has been collected from sites recently restored in the Meadowlands (*e.g.*, Louis Berger Group, Inc., 2000). As a result, the effects of restoration activities (*e.g.*, sediment removal, marsh contouring, ditching) on contaminant availability and accumulation are largely unknown; thus, adverse effects of any contamination on subsequent restoration success remain unknown. For example, the MRI Mitigation Bank site experienced low planting success and has been colonized extensively by volunteer species (Louis Berger Group, Inc., 2000; 2004b). Potential causes of the poor survival of plantings and of atypical plant communities on restoration sites, such as increased contaminant availability, should be evaluated to guide restoration of other sites. Therefore, restoration projects must include comprehensive assessments of contaminant availability and effects to prevent adverse impacts on fish and wildlife (and human) health. Failure to address contaminants in Meadowlands restoration efforts has the potential to: (1) adversely affect results (*e.g.*, inhibit re-vegetation by target species); (2) negatively affect the health of fish and wildlife in the Meadowlands and the region, possibly contributing to a species' local extirpation; (3) contribute to continued advisories on consuming fish and shellfish (New Jersey Department of Health and

Senior Services, 1998) or establish new advisories on other wildlife, such as waterfowl; and (4) adversely affect future human use of the Meadowlands.

Table 17. Contaminants of Potential Concern (COPCs) identified by three different Screening Level Ecological Risk Assessments conducted in the Hackensack Meadowlands.

	Screening Level Ecological Risk Assessments (Year)		
COPC by category	ENSR, Intl. (2004)	Corps/EPA (2004)	NJDEP (2002)
Heavy Metals			
Arsenic	X	X	X
Cadmium[9]			
Chromium	X	X	X
Copper	X	X	X
Lead	X	X	X
Mercury	X	X	X
Selenium		X	
Zinc	X	X	
Pesticides			
Chlordane	X		
DDT/DDE[10]	X		
Other Hydrocarbons			
PCBs[11]	X	X	X
PCDDs[12]		X	X
PCDFs[13]	X	X	X
PAHs[14]	X	X	

Stakeholders continue to learn about the distribution of contaminants in the Meadowlands; however, site- and species-specific information sufficient for a comprehensive risk assessment to guide restoration plans is not yet available. Screening level assessments (*i.e.*, SLERAs, see above) have identified contaminants of concern on some but not all potential restoration sites in the HMD. The Service (2005b) has ranked potential restoration sites into three general

[9] Although toxic and present throughout NY-NJ Harbor, cadmium is slowly "washing out" of the harbor in the dissolved phase, which is less available to fish and wildlife, and is generally decreasing in sediments harbor-wide (Boehme and Panero, 2003; Steinberg *et al.*, 2004).
[10] DDT/DDE = Dichloro-diphenyl-trichloroethane and its breakdown product
[11] PCB = Polychlorinated biphenyl
[12] PCDD = Polychlorinated dibenzodioxin (dioxin)
[13] PCDF = Polychlorinated dibenzofuran (furan)
[14] PAH = Polycyclic aromatic hydrocarbon

categories (Minimal, Moderate, and Substantial Concerns) based on available contaminant information. Contaminant data are generally lacking or do not provide sufficient depth of sediment profiles to identify potential contaminant "hotspots" at some of the potential restoration sites (U.S. Fish and Wildlife Service, 2005b). Because restoration activities on one site have the potential to increase contaminant exposure and availability on another site, an overall picture of the suitability of different sites for restoration is needed. A SLERA should be conducted for all potential restoration sites to evaluate their suitability for restoration, potential risks, and courses of action. Priority target groups (*e.g.*, species), stressor responses, exposure estimates, and contaminant effects (U.S. Environmental Protection Agency, 2005a) have not been identified or determined to characterize the overall risk of activities on any potential restoration site. Contaminant issues must be addressed consistently for all restoration projects. Equally important, contaminant guidelines protective of fish and wildlife (*e.g.*, Buchanan *et al.*, 2001) must become standards to guide restoration activities in the Meadowlands.

Contaminant problems in the Meadowlands are pervasive, technically complex, and potentially costly to address. Presently, unremediated contamination of several priority restoration sites and adjoining areas in the Hackensack Meadowlands (*e.g.*, Oritani Marsh and other sites near Berry's Creek; U.S. Army Corps of Engineers, 2003a) creates the potential for restoration activities to increase exposure of fish and wildlife (and people) to additional contaminants. In addition, STPs, CSOs, and stormwater have been identified as substantial contributors of certain contaminants (*e.g.*, mercury [de Cerreño *et al.*, 2002], PCBs [Panero *et al.*, 2005]). Such observations suggest that improved sewage treatment and stormwater management are as important to restoration as on-site remediation. Finally, future land-use planning (*e.g.*, drinking water supply, sewage treatment, flood control, transportation) must recognize and accommodate ecosystem functions, native species, and increasing human use of the Meadowlands if it is to protect the Meadowlands ecosystem and sustain its fish and wildlife resources.

4. Mercury and Other Heavy Metals

a. Introduction to Heavy Metal Contamination

As a group, heavy metals (*e.g.*, arsenic, chromium, lead, mercury, zinc; Table 18) potentially represent the most significant challenges to achieving successful restoration of the Meadowlands: such metals are difficult to assess, and restoration activities can increase their availability and adverse effects on fish and wildlife. Heavy metals originate from transportation, energy, waste disposal, and industrial sources and may be highly localized or widespread in their distribution. For example, surface sediments in many marshes contain concentrations of mercury and zinc sufficiently high to cause adverse impacts to wetland communities in the Meadowlands; however, deeper sediments generally contain those and additional metals (chromium and cadmium) at toxic concentrations (ENSR International, 2004). Due to their high concentration in deep sediments, heavy metals potentially complicate restoration at several sites, such as the Kearny Freshwater Marsh (Langan Engineering and Environmental Services, Inc., 1999) and especially the marshes along Berry's Creek and Canal (*e.g.*, Oritani Marsh; Barrett and McBrien, 2004), where construction and earth-moving activities may bring up and expose buried sediments and exacerbate air, water, and soil contamination. For example, portions of the Secaucus High School Mitigation Marsh are heavily contaminated (TAMS Consultants, Inc.,

2001); appropriate monitoring of contaminant accumulation and effects needs to be conducted during and after the site's restoration.

Table 18. Summary of effects of heavy metals (other than mercury) on fish and wildlife.

Metal	Effects and Affected Taxa	References
Arsenic	Toxic to plants; highly toxic to fish Mutagen and teratogen Interactive with other metals, bioaccumulative	National Research Council, 1997 Hamilton and Hoffman, 2003
Cadmium	Altered behavior and physiology; reduced growth and reproduction in fish and wildlife Highly toxic to fish and wildlife Teratogen and carcinogen; probable mutagen	Eisler, 1987
Chromium	Reduced growth and chlorosis in plants at high concentrations Sublethal and lethal effects vary widely in fish and wildlife Mutagen, teratogen, and carcinogen Interactive with other metals	Eisler, 1987 Chandra and Kulshreshtha, 2004
Copper	Toxic to algae and plants; highly toxic to invertebrates, fishes, and amphibians Reduced growth and fecundity in birds Developmental and other effects in birds and mammals	U.S. Environmental Protection Agency (EPA), 2005b
Lead	Low toxicity to plants Reduced growth and impaired flight in birds Reduced growth, altered behavior and reproductive failure in mammals Toxic to fish, birds, and mammals Interactive with other metals, bioaccumulative	Pattee and Pain, 2003
Selenium	Reduced growth of algae Reduced growth and reproduction in aquatic animals; possible mutagen Interactive with other metals Bioaccumulative	Ohlendorf, 2003 EPA, 2005b
Zinc	Toxic to plants Reduced growth, reproduction, and survival in aquatic animals Carcinogenic, teratogenic, and mutagenic Diverse effects on reproduction and physiology in birds and mammals	Eisler, 1987 EPA, 2005b

Heavy metals cause both acute and chronic toxicity, and some bioaccumulate and biomagnify in upper trophic level species, such as predatory fishes and fish-eating birds and mammals (Table 18; Eisler, 1987). Metal contamination in the Meadowlands (and other wetlands) is difficult to assess because complex, interacting processes affect metal forms, properties, toxicity, and bioavailability. Such processes include microbial transformation (in biogeochemical cycles), sediment-water interactions, plant uptake, and subsequent animal bioaccumulation (Gambrell, 1994). Minor changes in the chemical environment (*e.g.*, pH, salinity, sulfide and oxygen concentrations) during restoration can alter a metal's form, distribution, toxicity, and bioavailability; thus, restoration may increase the adverse effects of contaminants on fish and wildlife resources (Gambrell, 1994). For example, copper, nickel, and zinc bind to small particles (*e.g.*, silts and clays) and are less available under anaerobic conditions (Lau and Chu, 1999). Metals bound to particulates may be available to deposit feeders and filter feeders, some of which may be affected by relatively low metal concentrations (Millward *et al.*, 2001). Because physicochemical and other conditions in estuaries are dynamic, accurate prediction of the behavior and toxicity of metals may not be a function of their total abundance.

b. Effects of Mercury

Mercury is the contaminant that presents the most problems for the restoration of the Hackensack Meadowlands. No known form or compound of mercury has any documented beneficial function in living organisms; thus, any substantial sink of mercury in the environment is potentially a source of contamination to fish and wildlife (Eisler, 1987). Organic mercury is a potent neurotoxin. In living organisms, organic mercury can pass through the blood-brain and placental barriers, be transferred to eggs and developing embryos, pass through individual cell membranes, and cause disruptions at the cellular and nuclear level (Eisler, 1987; Heinz, 1996; Wolfe *et al.*, 1998; Wiener *et al.*, 2003). Organic mercury causes diverse, subtle, sublethal effects (*e.g.*, altered activity patterns and behaviors, poor condition, neural lesions) that broadly impair survival and reproductive success in fishes, birds, and mammals (Eisler, 1987; Heinz, 1996; Wolfe *et al.*, 1998; Wiener *et al.*, 2003). Studies establishing definitive causal carcinogenic, mutagenic (causing a mutation, a change in the base sequence of a cell's DNA), and teratogenic (causing a non-heritable mutation or malformation in the developing embryo or fetus when a pregnant female is exposed to that substance) relationships for all forms of mercury have not been conducted (Agency for Toxic Substances and Disease Registry, 2005a). However, mercuric chloride and methylmercury are considered possible carcinogens in humans (U.S. Environmental Protection Agency, 2005b), and methylmercury has been reported to be a mutagen and teratogen in studies of animals (Costa *et al.*, 1991; Agency for Toxic Substances and Disease Registry, 2005a). Though not well studied, mercury's adverse effects may also be synergistic with other contaminants (Beckvar *et al.*, 1996). Mercury bioaccumulation has been associated with the decline of federally listed species, including a subspecies of clapper rail (*Rallus longirostris obsoletus*; Schwarzbach *et al.*, 1996). Eggshells of an eastern U.S. population of clapper rail with high mercury concentrations have exhibited egg-shell thinning and anomalous eggshell microstructure (Rodriguez-Navarro *et al.*, 2002).

Mercury contamination of aquatic environments became widely recognized as a serious human-health problem in the late 1950s, when 1,800 people near Minimata, Japan died, or suffered

congenital birth defects, cerebral palsy, or other serious neurological impairments from eating seafood contaminated with mercury (Eisler, 1987). This incident was one of several tragedies that focused attention on understanding the mercury cycle and sources of mercury pollution, and prompted government efforts in the early 1970s to identify and reduce mercury contamination of aquatic environments in the United States. Mercury was the first contaminant chosen for study in the NY-NJ Harbor estuary by the Harbor Consortium of the New York Academy of Sciences (de Cerreño *et al.*, 2002).

c. Distribution of Mercury in the Meadowlands

Much of the concern about mercury contamination in the U.S. and especially in New Jersey and other northeastern states results from mercury in: (1) emissions from power plants and waste incinerators, and (2) waste generated by health-care facilities, including hospitals (New Jersey Department of Environmental Protection, 2000). Localized mercury contamination also results from the use of many products containing mercury that are discarded in household garbage (*e.g.*, disinfectants, paints, detonators, barometers, thermometers, batteries, switches, and lamps). While mercury emissions from power plants and incinerators have contaminated most aquatic sites from atmospheric deposition throughout New Jersey, local industrial activities have resulted in unparalleled levels of mercury contamination within the Hackensack Meadowlands (de Cerreño *et al.*, 2002; New Jersey Department of Environmental Protection, 2002b).

The Meadowlands is heavily contaminated by mercury from the Ventron-Velsicol site (New Jersey Department of Environmental Protection, 2002b; U.S. Environmental Protection Agency, 2004a). The 38-acre Ventron-Velsicol site on Berry's Creek (Figure 40) was occupied from 1929 until 1974 by the largest producer of intermediate inorganic mercury compounds and processor of contaminated mercury materials in the U.S., and is recognized as among the world's most severely mercury-contaminated aquatic sites (New Jersey Department of Environmental Protection, 2002b; U.S. Environmental Protection Agency, 2004a). Most contamination at the production site (estimates range from 30 to 289 tons) was composed of the liquid, elemental (inorganic) form; nonetheless, recent mercury concentrations in surface (13,800 µg/g) and subsurface (123,000 µg/g) soils remain acutely toxic (New Jersey Department of Environmental Protection, 2002b). In addition to contaminating the production site, the Ventron-Velsicol plant discharged 0.9 to 1.8 kg of mercury per day into Berry's Creek (Lipsky *et al.*, 1980). Mercury concentrations in surface (0 to 2 cm) sediments have been reported as high as 11,100 µg/g in Berry's Creek (New Jersey Department of Environmental Protection, 2002b); moreover, mercury concentrations in subsurface sediments to at least 6 feet in depth exceed sediment guidelines (U.S. Army Corps of Engineers and U.S. Environmental Protection Agency, 2004).

Mercury continues to disperse from the Ventron-Velsicol site to nearby waters and wetlands through erosion, ground-water transport, volatilization, and biological transformation and uptake (New Jersey Department of Environmental Protection, 2002b; U.S. Army Corps of Engineers and U.S. Environmental Protection Agency, 2004). Mercury concentrations in ground (8.2 µg/L) and surface (15.6-17.6 µg/L) waters adjacent to the site, including Berry's Creek, exceed the acute and chronic water quality criteria for mercury (Exponent Environmental Group, 1998; New Jersey Department of Environmental Protection, 2002b) and far exceed (more than 30,000 times) the State's draft water quality criterion (530 pg/L) to protect fish and wildlife (Buchanan *et al.*,

2001). Mercury concentrations in Hackensack River sediments (average = 99.9 ng/L ± 94.4 ng/l) are the highest in the entire HRE. The highest mercury concentrations (190.8 ng/L ± 130.8 ng/L) were measured in river sediments between Routes 46 and 80, well upstream of the confluence of the river and Berry's Creek. Pecchioli *et al.* (2003) hypothesized that the mercury concentrations in upper tidal areas of the Hackensack River are higher than areas near the mouth of the river because mercury-contaminated sediments are being resuspended, distributed with flood tidal currents, and redeposited in mid-river areas without being flushed from the river.

d. Forms and Availability of Mercury

While most mercury released at the Ventron-Velsicol site was in elemental or inorganic forms with relatively low toxicity, mercury is readily transformed in aquatic ecosystems into the organic form methylmercury, which is highly toxic to plants, fish, wildlife, and humans (Watras and Huckabee, 1994). The majority of mercury found in living organisms is methylmercury (Wolfe *et al.*, 1998). Methylmercury production is especially high in productive wetland ecosystems, both freshwater (Zillioux *et al.*, 1993) and estuarine (Compeau and Bartha, 1985; Davis *et al.*, 2003); therefore, understanding methylmercury production in the Meadowlands is necessary for evaluating appropriate remediation and restoration activities of mercury-contaminated sites.

Sulfate-reducing bacteria are the most important producers of methylmercury in freshwater and saltwater ecosystems (King *et al.*, 2000). Mercury methylation is highest at the interface of the aerobic and anaerobic layers of sediment, where sulfate-reducing bacteria are most abundant (Bloom and Lasorsa, 1999; Langer *et al.*, 2001). Methylmercury diffuses into the water and is distributed by currents; thus, high methylmercury production in any wetland, such as Berry's Creek, acts as a source for other wetlands (Langer *et al.*, 2001). Methylation of mercury in aquatic systems varies with environmental features (Table 19, from Davis *et al.*, 2003) and also depends on mercury loadings, microbial activity and species, nutrient content, redox condition, suspended sediment load, and sedimentation rates (Compeau and Bartha, 1985; Berman and Bartha, 1986; Jackson, 1986; King *et al.*, 2000). Modifiers of methylation are potentially affected by restoration activities; therefore, restoration of sites with high mercury concentrations has the potential to increase mercury methylation and bioavailability.

A major concern regarding any increase in the availability of methymercury is its subsequent accumulation and biomagnification. Methylmercury is moderately lipophilic (soluble in fats) and hydrophilic (soluble in water), properties that facilitate its availability to organisms, especially animals. These properties also ensure the increasing accumulation, or biomagnification, of mercury from one trophic level to the next. Eventually, biomagnification results in higher, more toxic doses of mercury in higher trophic level animals, such as piscivorous birds (*e.g.*, herons, raptors) and humans. For example, total mercury concentrations in water of less than 1 part per trillion may result in mercury concentrations in fish in excess of 1 ppm (Zillioux *et al.*, 1993). Mercury also can bioaccumulate from the environment into plants, especially aquatic species (Zillioux *et al.*, 1993; Heller and Weber, 1998). Mercury concentrations as high as 13 ppm (dry weight) have been found in the wetland vegetation near Berry's Creek (Ludwig, 1988).

Table 19. Factors identified by Davis *et al.* (2003) that influence mercury methylation and affect the spatial availability of mercury in wetlands.

Variable	Relationship
Oxygen	Creates aerobic conditions that decreases methylation of mercury by sulfate-reducing bacteria (which require anaerobic conditions).
pH	Low pH increases methylation; more likely in wetlands with high organic content
Sulfate	In low sulfate waters, increased sulfate increases methylation. In high sulfate waters (*e.g.*, estuaries), increased sulfate increases demethylation. Increased sulfide decreases methylation.
Dissolved organic carbon (DOC)	High DOC in the water column may indicate high organic loading leading to high bacterial activity and anoxic sediments. Complexation of Hg forms by DOC may increase dissolved concentrations without appreciably increasing biological uptake.
Temperature	Up to 35-40ºC, increasing temperatures increases bacterial activity (*e.g.*, methylation).
Salinity	Bacterial and algal mercury uptake reduced by complexation with chloride (*i.e.*, formation of $HgCl_2$, MeHgCl); chloride is the major component of salinity.

e. Criteria for Mercury

Mercury concentrations in water, sediment, and the biota that have been examined in the Meadowlands far exceed most environmental guidelines. Mercury concentrations in tissues of certain common marsh invertebrates (*e.g.*, grass shrimp, mud snails) inhabiting Berry's Creek often exceed 1 µg/g (Lipsky *et al.*, 1980; ERM-Southeast Inc., 1985), which is high for low trophic level species. In its review of published and unpublished data from Berry's Creek sites, NJDEP (2002) reported mercury concentrations of 0.01 to 0.79 µg/g in mummichog, which feed predominantly on invertebrates, and 0.30 to 1.90 µg/g in white perch (*Morone americana*), which feed more extensively on fishes. These tissue concentrations are sufficiently high to be lethal to sensitive fishes (Eisler, 1987). ENSR, International (2004), in a screening-level environmental risk assessment, reported a mercury hazard quotient of 1,190 for great blue heron in the Meadowlands (*i.e.*, the levels are 1,190 times too high to be protective for this species). Finally, mercury guidelines protective of fish and wildlife developed by the State, EPA, and the Service (Buchanan *et al.*, 2001) have not been adopted as binding regulatory standards in accordance with the Service's (1996b, 1998) Biological Opinion. Such criteria would help guide

restoration activities in the Meadowlands as well as support efforts to clean up the other waters and wetlands in New Jersey.

In summary, mercury is the contaminant of greatest potential concern to fish and wildlife and to the restoration of the Hackensack Meadowlands. Considerable effort is needed to assess mercury's distribution, dispersal, availability, and effects on fish and wildlife in the Meadowlands. Assessing bioavailability of mercury deserves a high priority when considering restoration of any site in the Meadowlands. In addition, water and sediment criteria protective of wildlife should be established and considered in planning restoration sites to prevent creation of attractive nuisances (*i.e.*, sink habitats or sites with preferred vegetative communities but high mercury availability). Lastly, sites that are most heavily contaminated by mercury should be restored only when its site-specific availability and effects on fish and wildlife are known.

5. Hydrocarbon Contaminants

a. Introduction

Hydrocarbon contaminants (*e.g.*, various crude and refined petroleum products, pesticides, PCBs, dioxins, furans, and polycyclic aromatic hydrocarbons [PAHs]) became a worldwide problem in the early 20th Century when ocean transport of crude oil began and developments in chemical engineering led to increased production of synthetic hydrocarbon compounds. Although some hydrocarbons enter the environment through natural processes, certain hydrocarbons (*e.g.*, PAHs) enter the environment from human activities such as petroleum spills, CSOs, landfills, and disposal. Other hydrocarbons, such as pesticides, were dispersed intentionally or discarded accidentally during manufacturing and use. Hydrocarbon pollutants differ in their general properties, bioavailability, and toxicity (Table 20; Albers, 2003; Rice *et al.*, 2003). Because most hydrocarbon contaminants are hydrophobic and have low solubility in water, they bind to particles in water and subsequently accumulate in sediments. Certain hydrocarbon contaminants may be absorbed from the environment but ingestion is the most common route of exposure for animals (Meador *et al.*, 1995). Certain hydrocarbons are metabolized and excreted, whereas others are stored in lipid-rich tissues (Albers, 2003; Rice *et al.*, 2003). Nearly all hydrocarbon contaminants have adverse effects on fish and wildlife and human health. For example, PAHs may cause tumors (Chang *et al.*, 1998), decreased egg viability (Hose *et al.*, 1981), and suppressed immunity (Arkoosh *et al.*, 1994) in fishes. Young-of-the-year bluefish in the Hackensack River show a five-fold increase in DNA adduct formation (*i.e.*, a chemically induced gene mutation, often a precursor to a cancerous tumor) compared to the same fish from a cleaner estuary in southern New Jersey (Samson and Deshpande, 2003).

Hydrocarbon contaminants are widespread in sediments of the Meadowlands and elsewhere in the NY-NJ Harbor estuary (Gunster *et al.*, 1993a; 1993b; Crawford *et al.*, 1995; Dimou *et al.*, 2003; Steinberg *et al.*, 2004). Inputs of certain hydrocarbon contaminants have decreased throughout the NY-NJ Harbor estuary as a result of bans on their production and use; however, concentrations of most of the above-identified hydrocarbon contaminant groups remain sufficiently high to cause adverse effects to fish and wildlife resources (Huntley *et al.*, 1995; Steinberg *et al.*, 2004). For example, hydrocarbons such as PAHs are nearly ubiquitous in urban areas as a result of the extensive area of asphalt surfaces (Mahler *et al.*, 2005).

Bioaccumulation of certain hydrocarbon contaminants (*e.g.*, pesticides) is generally high in ecosystems such as the Meadowlands, where exposures can occur frequently (Meador *et al.*, 1995). Hydrocarbon contaminants differ in their potential to bioaccumulate within each trophic level (Corner *et al.*, 1976; Whittle *et al.*, 1977; Clements *et al.*, 1994). The forms and toxicities of hydrocarbon contaminants, unlike those of metals, generally will not change during restoration. Additionally, the concentrations of certain hydrocarbons (*e.g.*, PAHs) may decrease with restoration activities due to biodegradation (Eijsackers *et al.*, 2001). Concentrations of all hydrocarbon contaminants and changes in their bioavailability should be addressed in restoration planning.

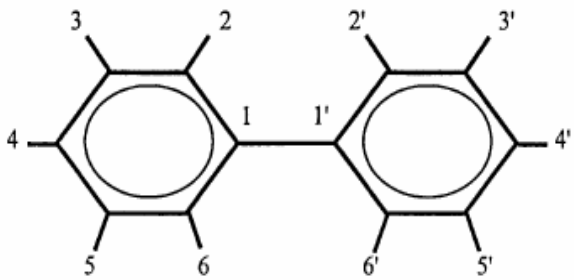
Table 20. Survey of effects of selected hydrocarbon contaminants on fish and wildlife. Selected contaminants are those reported frequently at Superfund and other contaminated sites in the Meadowlands. Information on PCBs, dioxins, and furans is presented in the text.

Hydrocarbon	Effects and Affected Taxa	References
Organochlorine pesticides		
Aldrin/dieldrin	Toxic to aquatic plants Highly toxic to invertebrates, fishes, birds, and mammals Carcinogenic; endocrine disrupting Bioaccumulative	Briggs *et al.*, 1992 Agency for Toxic Substances and Disease Registry (ATSDR), 2006a
Chlordane	Highly toxic to invertebrates and fishes Toxic to birds and mammals Carcinogenic; Endocrine disrupting Bioaccumulative	Eisler, 1987 Briggs *et al.*, 1992 ATSDR, 2006b
DDT/DDE	Decreased growth of algae Highly toxic to invertebrates and fishes Toxic to amphibians, reptiles, birds, and mammals; diverse non-lethal effects Carcinogenic and mutagenic Endocrine disrupting Bioaccumulative	Briggs *et al.*, 1992 ATSDR, 2006c
PAHs	Diverse, poorly known non-lethal effects Altered metamorphosis and reduced reproduction in invertebrates Toxic to aquatic invertebrates and fishes Adverse effects on reproduction, immunity, and development in mammals Highly carcinogenic to all animals	Eisler, 1987 EPA, 2005b ATSDR, 2006d

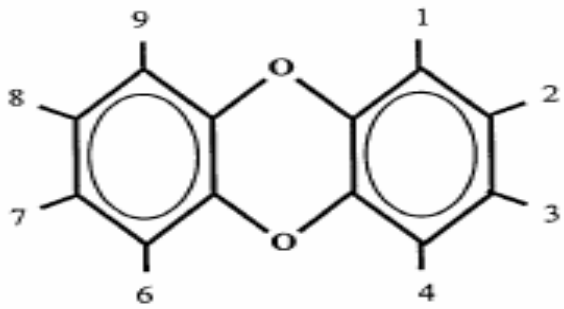
The hydrocarbons of greatest potential concern for fish and wildlife and for restoration of the Meadowlands are the polyhalogenated organic contaminants, which include three major groups: (1) PCBs, (2) dioxins (polychlorinated dibenzodioxins or PCDDs), and (3) dibenzofurans (polychlorinated dibenzofurans, furans, or PCDFs). All three groups share a common chemical "backbone" of two benzene rings, but differ in the connection between the benzene rings (Figure 41). Changing the number and location of the chlorine atoms that are substituted along the backbone (Figure 41) potentially results in a maximum of 209 PCB compounds, 75 dioxin compounds, and 135 furan compounds. In general, each compound (or congener) has distinct properties; however, congeners of PCBs, dioxins, and furans that have the same number and location of chlorine atoms may share pathways, modes of action, and effects (Rice *et al.*, 2003).

Figure 41. Chemical structure of three classes of polyhalogenated organic contaminants: PCBs, dioxins, and furans. PCBs may be halogenated at any carbon numbered 2 to 6 or 2′ to 6′, whereas dioxins and furans can be halogenated at carbons 1 to 4 and 6 to 9.

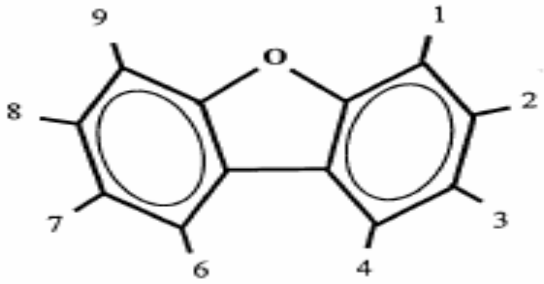
PCBs



Dioxins



Furans



b. Polychlorinated Biphenyls

Depending on their degree of chlorination, PCBs range in consistency from heavy oils to sticky resins to waxy crystals. All PCB congeners are inert, hydrophobic, and stable across a wide range of temperatures. They resist oxidation and other chemical aging processes, and do not conduct electricity. First produced commercially in 1927 in Alabama, PCBs became widely used in electrical equipment (*e.g.*, transformers, insulators, capacitors, circuit breakers), hydraulic systems (*e.g.*, compressors, vacuum pumps), coating materials (*e.g.*, paints, plastics, adhesives, wood preservatives), pesticides, and pressure-sensitive copying paper. Commercial PCB formulations, sold under the trade-name Aroclor in the U.S. by Monsanto, were produced as mixtures of different PCB compounds.

Jensen (1966) first reported PCBs in fishes and birds in Sweden, and expressed concern about bioaccumulation. Two years later, more than 1,600 people in Yusho, Japan became ill after eating PCB-contaminated rice oil. Many people exhibited acute or chronic effects, including liver cancer, and other skin, immune, reproductive, nervous, and gastrointestinal disorders (Masuda, 1994; Panero *et al.*, 2005). Shortly after a similar incident occurred in Taiwan, other countries began to prohibit manufacturing, sale, and use of PCBs. In the U.S., PCB production voluntarily ceased in the mid-1970s and was subsequently prohibited in 1977 with passage of the Toxic Substances Control Act of 1976 (P.L. 94-469; 90 Stat. 1686; 15 U.S.C. 2601-2671). Continuing concern about the effects, persistence, and mobilization of PCBs led to their inclusion as one of 12 Persistent Organic Pollutants that were banned in 2001 by international treaty (Stockholm Convention on Persistent Organic Pollutants).

Exposure to PCBs has resulted in acute toxicity and death of fish and wildlife; however, chronic exposures and effects are more commonly reported (Hoffman *et al.*, 1996). Fishes with chronic exposure to PCBs exhibit immune system suppression (Zelikoff, 1994), enzyme modulation (Otto *et al.*, 1997), histopathological lesions (Teh *et al.*, 1997), liver tumors (Barron *et al.*, 1999), and reproductive and developmental impairments (Niimi, 1996). PCBs in Great Lakes fish are believed to adversely affect reproduction of bald eagle, other fish-eating birds, mink (*Mustela vison*), and river otter (*Lutra canadensis*; Wren, 1991; Giesy *et al.*, 1994). Also, reproductive failure, liver damage, immunosuppression, and wasting syndrome in wildlife have been attributed to chronic exposure to PCBs (Hoffman *et al.*, 1996). Improved recognition of the modes of action of specific congeners has resulted in identification of twelve PCBs as dioxin-like (Van den Berg *et al.,* 1998). Thus, toxicities of these congeners, such as PCB 77 and 126, is expressed in a widely accepted (but not regulatory) protocol as Toxic Equivalency (TEQ), in which the toxicity of these compounds is determined relative to 2,3,7,8-tetrachlorodibenzo-*p*-dioxin, the most potent and prototypical dioxin congener (Rice *et al.*, 2003).

PCBs are common in the water, sediment, and biota of the NY-NJ Harbor estuary, including Newark Bay and the Hackensack River (Achman *et al*., 1996; Skinner *et al*., 1997; Adams *et al.*, 1998; Durell and Lizotte, 1998; Feng *et al*., 1998; Litten, 2003; Monosson *et al*., 2003; Fernandez *et al.*, 2004). Nearly 30 years after the ban on their production, PCBs continue to enter the NY-NJ Harbor estuary (including the Hackensack River) through riverine and other inputs (Totten, 2004). For many years, General Electric's Fort Edward and Hudson Falls

facilities discharged 500,000 to 1.1 million pounds into the Hudson River (U.S. Environmental Protection Agency, 2004g). These two facilities were considered the primary sources of PCBs to the estuary. Atmospheric input, CSOs, and stormwater runoff collectively are now thought to contribute nearly as much total PCB-contamination as the Hudson River inputs; landfills may also contribute substantial quantities of PCBs (Totten, 2004). Based on the information currently available, Newark Bay and portions of the Hackensack River (upriver potentially as far as Snake Hill) appear to have among the highest sediment burdens of total PCBs in the entire NY-NJ Harbor estuary. Of greater concern, PCBs in certain fishes collected in the Hackensack River near Snake Hill have PCB concentrations as high as in the same species collected in the Hudson River (Fernandez *et al.*, 2004).

Low molecular-weight PCB congeners (*e.g.*, PCB 11) have not been considered in contaminant assessments for the NY-NJ Harbor estuary, in part due to the lack of congener-specific data and other information on their toxicity (Totten, 2004). New methods providing congener-specific information, such as EPA (1999) Draft Method 1668A, have stimulated interest in all congeners that are present in the environment and their effects on fish and wildlife. For example, a hydroxylated form of PCB 35 is known to disrupt the actions of certain thyroid and sex hormones (Lans *et al.*, 1993; Kester *et al.*, 2000). Available information regarding PCB 11 also raises concern. Preliminary surveys found PCB 11 constituted greater than 90 percent of the total PCBs in the treated-sewage discharge of the Passaic Valley Sewerage Commissioners' treatment facilities. Though comprising only hundredths of a percent of commercial PCB formulations (*i.e.*, Rushneck, 2004), PCB 11 may be the most abundant congener in the NY-NJ Harbor estuary (*e.g.*, Litten *et al.*, 2002). This congener's relatively high solubility in comparison to other PCB congeners may increase its dispersion and availability in the water column. This congener may be neuroactive *in vitro* (Kodavanti and Tilson, 1997), and, like other light-weight congeners, may be associated with DNA-adduct formation (McLean *et al.*, 1992; Oakley *et al.*, 1996; Schilderman *et al.*, 1999; Pereg *et al.*, 2002). Finally, available information on hydroxylation of PCBs raises concerns about the potential endocrine-disrupting effects of PCB 11 (Lans *et al.*, 1993; Darnerud *et al.*, 1996; Andersson *et al.*, 1999; Kester *et al.*, 2000).

Many aromatic compounds, including PCBs, are hydroxylated (the addition of a hydroxyl group [-OH] to a molecule) in all vertebrate species to increase their polarity and thus facilitate their excretion. However, hydroxylated PCBs often remain in tissues at concentrations similar to heavy, persistent PCBs (Klasson-Wehler *et al.*, 1998; Sinjari *et al.*, 1998; Hovander *et al.*, 2002). Hydroxylated PCBs resemble hormones (chemical messengers produced by different organs such as the ovary and thyroid) that have diverse roles in metabolism, development, and reproduction. For example, hydroxylated PCBs have an affinity for (*i.e.*, may bind with) certain female-hormone receptors (*e.g.*, estrogen receptors; Korach *et al.*, 1988; Andersson *et al.*, 1999) and certain enzymes that deactivate female hormones (*e.g.*, sulfotransferase; Kester *et al.*, 2000). Thus, these hydroxylated PCBs have considerable potential to interfere with sexual differentiation and cause abnormal growth and development of reproductive structures and products (Bergeron *et al.*, 1994; Kester *et al.*, 2000).

In addition, hydroxylated PCBs resemble thyroid hormones (*e.g.*, thyroxin and triiodothyronine) and have an affinity for several molecules affecting thyroid metabolism such as transthyretin, a

transport protein (Lans *et al.*, 1993). Perhaps not coincidentally, mummichogs in the NY-NJ Harbor estuary show evidence of adverse effects on thyroid tissue and thyroid hormone levels (Zhou *et al.*, 1999), which may be due to high concentrations of PCBs. The State of New York is reported to have taken steps to identify sources and reduce manufacturing and discharge of PCB 11 into the NY-NJ Harbor; the Passaic Valley Sewerage Commissioners are also reported to be taking steps to identify sources of PCB 11 to its STP (Panero *et al.*, 2005). While definitive evidence does not exist that hydroxylated PCB 11 is adversely affecting fish and wildlife health, PCBs should be monitored in a manner that can identify and detect all PCB congeners and their metabolites to assess their potential adverse effects on fish and wildlife resources.

c. Dioxins and Furans

Polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans are two related classes of aromatic compounds that share certain structural similarities to PCBs (Figure 41) and are persistent in the environment. As with PCBs, congeners of dioxins and furans are hydrophobic and lipophilic, giving them low solubility in water and high affinity for organic particles. In contrast to PCBs, these two classes of compounds have no commercial uses but are formed and are released into the environment as by-products of: (1) chlorine bleaching of pulp and paper, (2) chemical manufacturing of chlorophenols (*e.g.*, pesticides) and other chemicals (*e.g.*, PCBs, polyvinyl chloride [PVC] plastics), and (3) combustion from municipal waste incinerators (Rice *et al.*, 2003).

Seventeen dioxins and furans are considered highly toxic to vertebrate wildlife and pose a significant risk to human health (Grassman *et al.*, 1998; GPA Clearinghouse, 2001). There is no clear consensus on the toxicity of other congeners (Rice *et al.*, 2003). Because congeners differ in their toxicity, their potency is expressed in Toxic Equivalents to 2,3,7,8-tetrachloro-dibenzo-*p*-dioxin (TCDD), the most potent, hazardous and well-studied dioxin (Rice *et al.*, 2003). Specific effects of dioxins documented in laboratory mammals and humans include wasting, immunotoxicity, endocrine disruption, reproductive and developmental abnormalities, cancer, and death (*e.g.*, Peterson *et al.*, 1993; Pohjanvirula and Tumost, 1994). Similar adverse effects have been reported for fishes and birds (*e.g.*, Spitsbergen *et al.*, 1991; Walker *et al.*, 1991; Heid *et al.*, 2001). A recent National Institute of Health study also indicates that dioxin-like congeners are additive in their ability to induce cancerous and precancerous conditions in controlled experiments (Walker *et al.*, 2005).

Invertebrate animals lack an aryl hydrocarbon receptor that binds to coplanar dioxins, furans, and PCBs, and are generally less sensitive than vertebrate animals to dioxin and dioxin-like compounds (Powell-Coffman *et al.*, 1998; Butler *et al.*, 2001). However, recent work indicates that certain invertebrates are adversely affected by low concentrations of dioxin. Butler *et al.* (2004) reported that a mechanism independent of the aryl-hydrocarbon receptor was responsible for alteration of gametogenesis (*i.e.*, gamete formation) in softshell clam (*Mya arenaria*). Wintermyer and Cooper (2003) also found eastern oyster (*Crassostrea virginica*) reproduction may be impaired at dioxin tissue concentrations as low as 2 pg/g, well below concentrations known to occur in bivalves in Newark Bay (Brown *et al.*, 1994). If dioxins and related compounds adversely affect invertebrates, timely remediation is needed of sites heavily contaminated by dioxin. Additional research investigating the effects and exposures of dioxins,

dioxin-like compounds, and related hybrid compounds (*e.g.*, polybrominated/chlorinated diphenyl ethers, dioxins, and furans) on invertebrates, fishes, and wildlife is necessary to guide remediation and restoration of the Meadowlands (Litten *et al.*, 2003).

Dioxins and furans are common throughout the HRE due to their inadvertent production during industrial processes. In particular, the manufacture of chlorophenols has resulted in considerable contamination of Newark Bay and the Meadowlands with both dioxins and furans. The Kolker Chemical Works' Diamond Alkali plant (ID No. NJD980528996; U.S. Environmental Protection Agency, 2004f) on the Passaic River produced 15 million tons of 2,4,5-trichlorophenoxyacetic acid (2,4,5-T; a chlorophenol herbicide) and 50,000 tons of dichloro-diphenyl-trichloroethane (DDT, a widely used organochlorine pesticide). Some of these products, including impurities in their manufacture (*e.g.*, the most potent and hazardous dioxin congener [2,3,7,8-tetrachloro-dibenzo-*p*-dioxin]), were discarded into the lower Passaic River (Wahrman, 2000). The Diamond Alkali plant is recognized as the single largest contributor of dioxin to Newark Bay and its tributaries, including the Hackensack River. In addition to the Diamond Alkali site, the Standard Chlorine State Remediation Site (NJDEP Bureau of Case Management No. NJD002175057, proposed EPA Superfund Site ID No. NJD002175057) is a potential source of substantial dioxin and certain other contaminants (*e.g.*, benzene, chlorobenzene, di- and tri-chlorobenzenes, naphthalene, PCBs) to the Hackensack River and nearby wetlands (U.S. Environmental Protection Agency, 2004g). Dioxin (2,3,7,8-TCDD) has been found on-site and in nearby river sediments (96.1 ng/kg; U.S. Environmental Protection Agency, 2004f).

Recent sampling has revealed that dioxin congener profiles in the Hackensack River upriver to the Oradell Dam are identical to those in the Passaic River and are attributed to the Diamond Alkali Superfund Site (Wilson, pers. comm., 2004). Transport of Passaic River dioxins upstream in the Hackensack River is likely due to transport of sediment-associated contaminants in (tidal) flood currents along the bottom. Such transport of dioxin would suggest that other contaminants in the Passaic and in lower portions of the Hackensack have also been distributed throughout the tidal regions of the HRW. Because concentrations of PCBs, dioxins, and furans may vary in their depth distribution within sediments (Wilson, pers. comm., 2004), typical restoration activities (*e.g.*, excavation of fill materials to increase tidal flow) may increase the exposure of fish and wildlife to these compounds. Thus, the Service recommends assessment of the specific depths of different contaminants to guide restoration and to prevent exposure of buried contaminants to fish and wildlife. Where heavy contamination is present, remediation of buried, contaminated sediments must precede restoration. Finally, PCB and DDT guidelines protective of fish and wildlife developed by the State, EPA, and the Service (Buchanan *et al.*, 2001) were not adopted as binding regulatory standards: adoption of such criteria would help guide restoration activities in the Meadowlands as well as support efforts to clean up other waters and wetlands in New Jersey.

6. Novel Contaminants

Over 40 years ago, Rachel Carson's (1962) *Silent Spring* warned about the dangerous consequences to fish and wildlife resulting from pesticide use. Later examples of such consequences included eggshell thinning in peregrine falcon from bioaccumulation of DDT (Hickey and Anderson, 1968). More recently, the production, use, and disposal of a broad

variety of synthetic chemicals used in industry, agriculture, medicine, and everyday life are creating concern regarding adverse ecological and human health effects (U.S. Geological Survey, 2005b). Many of these products, including over-the-counter medications, have been widely used and generally considered safe for many years. However, recent studies have revealed that many such chemicals, including detergent metabolites, steroid hormones, caffeine, antimicrobial disinfectants, antibiotics, fire retardants, and plastic by-products (Table 21), have increasingly entered, and in some cases, accumulated, and become widespread in aquatic systems (Kolpin *et al.*, 2002). Collectively referred to as "novel" or "emerging contaminants," most of these chemicals are not monitored routinely. Although their effects on fish, wildlife, and human health are largely unknown, their potential effects, properties, and exposure raise concerns for the health of fish and wildlife.

Much of the concern regarding novel contaminants arises from their potential actions as endocrine disruptors. Endocrine disruptors are exogenous (produced outside the body) chemical substances or mixtures that alter the structure or function of the endocrine system; they cause adverse effects at the level of the organism, its progeny, populations, or subpopulations (U.S. Environmental Protection Agency, 1998). Known endocrine disruptors include many chemical groups with diverse uses in agriculture, industry, medicine, and the home, including various pesticides (*e.g.*, DDT, kepone, lindane, methoxyclor); certain PCB-, dioxin-, and furan-congeners; various cadmium, mercury, lead, and organo-tin compounds; alkylphenols, other non-biodegradable detergents, and anti-oxidants; certain styrene dimers and trimers and other plastics; laboratory animal, pet-food, and soy products (Colburn and Clement, 1992; Colburn *et al.*, 1996). Recognized endocrine disruptors are structurally diverse and have different mechanisms of action that may depend on the "timing" of exposure (*e.g.*, life history stage, degree of reproductive maturity, season) and may not be detected for many years (Gillesby and Zacharewski, 1998). For example, alkyl phenol detergents and their degradation products are toxic to algae and invertebrates, may cause development of an ovotestis instead of a typical ovary or testis in fishes (*e.g.*, Gray and Metcalf, 1997), disrupt metamorphosis in aquatic invertebrates and fishes (Servos, 1999), and may be persistent in the environment (McGuire, 1999). Tributyltin, widely used in marine anti-fouling paints, persists in estuarine sediments, bioaccumulates in estuarine invertebrate taxa that are forage for other wildlife (Pereira *et al.*, 1999), and causes malformation of reproductive organs in mollusks (Schulte-Oehlmann *et al.*, 2000). Other novel endocrine disruptors may include new pesticides, fungicides, flame retardants, polyhalogenated surfactants and paraffins, and certain pharmaceuticals (*e.g.*, Brown *et al.*, 2004). The diverse effects of novel contaminants on growth, development, and reproduction may result in extirpation of local populations (Colburn *et al.*, 1996).

Several studies have identified a number of adverse contaminant effects that are not attributable to any specific compound. For example, effluent from STPs in urbanized estuaries causes slower growth, increased mortality, abnormal gonad development and secondary sexual characteristics, and lower reproductive success of fishes (Kime, 1998; Matthiessen, 2003). Antibiotic resistance has been shown to increase in bacteria exposed to pharmaceuticals and other contaminants in waste streams in industrialized areas (Roane and Kellogg, 1996; Goñi-Urizza *et al.*, 2000). Genes that code for antibiotic resistance are carried on the same genetic components (*i.e.*, plastids) that confer metal resistance (Wireman *et al.*, 1997). Thus, elevated exposures to metals

Table 21. Novel and organic wastewater contaminants (by chemical use) and their effects.

Antibiotics	Known/probable effects
Erythromycin	Antibiotic resistance
Lincomycin	Antibiotic resistance
Sulfamethoxazole	Antibiotic resistance
Trimethoprim	Antibiotic resistance
Disinfectants/detergents and metabolites	
Triclosan	Antibiotic resistance
Methyl phenol (cresol)	Endocrine disruption
Alkyl-, methyl-, nonyl- and octyl-phenols and ethoxylates	Endocrine disruption
Flame retardants	
Polybrominated diphenyl ethers (PBDEs)/metabolites	Endocrine disruption
Tris (2-chloroethyl) phosphate	Endocrine disruption
Fungicides/herbicides//pesticides/repellants	
Carbaryl	Toxic
N,N-diethyl-meta-toluamide (DEET)	Toxic
Diazinon	Toxic
Dichlorobenzene	Toxic
Phamaceuticals/byproducts	
Acetaminophen	Toxic
Caffeine	Toxic/stimulant
Cotinine (nicotine metabolite)	Toxic/stimulant
Dimethylxanthine	Stimulant
Methyl benzotriazole	Toxic
Solvents/resins/plasticizers	
Bis phenol A	Endocrine disruption
Dichlorobenzene	Toxic
Ethanol butoxy-phosphate	Toxic
Phthalic anhydride	Toxic
Tetrachloroethylene	Toxic
Steroids	
Cholesterol	
Coprostanol	
Estrogens (estriol, estradiol)	Endocrine disruption
Progesterones	Endocrine disruption
Androgens (testosterone)	Endocrine disruption
Other	
Fluoranthene	Toxic
Pyrene	Toxic

is somehow contributing to development of antibiotic resistance in those bacteria. Brominated flame retardants such as polybrominated diphenyl ethers are also a concern (Birnbaum and Staskal, 2004). These flame retardants and related contaminants such as polybrominated dioxins, polybrominated furans, and their chlorinated and brominated hybrids are common in the NY-NJ Harbor (Litten *et al.*, 2003), persistent in the environment, and appear to bioaccumulate and biomagnify in fish and other wildlife (Eljarrat *et al.*, 2004; Morris *et al.*, 2004). These flame retardants also appear to impair neurodevelopment and actions of thyroid hormones (U.S. Geological Survey, 2004). Finally, certain antidepressants (*e.g.*, fluoxetine, sertraline) have been detected in all tested tissues (including muscle) of several fishes inhabiting river systems receiving considerable discharges of effluent from STPs (Brooks *et al.*, 2005). Though the concentrations in muscle were too low to have therapeutic effects if consumed by humans, fishes exposed to such chemicals exhibit altered reproductive and other behaviors (*e.g.*, Perreault *et al.*, 2003).

Given the large human population of this urban region, fish and wildlife (and humans) will likely be exposed to endocrine disruptors and other "novel" contaminants from human waste streams and other sources. Failing to account for the amounts, fates, or adverse effects of synthetic materials will likely perpetuate the *status quo* of the Meadowlands as an extensively degraded environment or, under worse circumstances, exacerbate its current contaminant problems. The above-referenced and other studies have established the need to: (1) identify compounds in waste streams, (2) determine the distribution, transport, and availability of such compounds in the environment, (3) assess ecological effects and impacts on fish and wildlife (and human) health, and (4) if necessary, develop corrective measures that are protective of fish and wildlife (and human) health (Kolpin *et al.*, 2002; U.S. Geological Survey, 2005b). Designing sewage-treatment systems to eliminate or reduce all of these materials in human waste-streams may not be feasible or cost-effective at this time; however, these and other compounds should be monitored to determine the extent of contaminant problems. New compounds are being produced every year; therefore, the Service recommends periodically revising the list of synthetic materials being monitored and updating sampling protocols to improve detection of existing and novel contaminants.

7. Eutrophication, Nutrients, and Hypoxia

Tidal marsh ecosystems are widely considered among the most productive ecosystems in the world (Mitsch and Gosselink, 1993). For example, marshes in the northeastern U.S. may produce annually as much as 4,500 metric tons of plant material per hectare (4,500 g m^{-2} yr^{-1}; Valiela *et al.*, 1976). Nitrogen, phosphorus, and other nutrients are essential for growth and reproduction of producers (*e.g.*, marsh grasses, phytoplankton, and benthic algae) in tidal marsh ecosystems. Nitrogen has long been thought to be the primary limiting nutrient of production in coastal ecosystems, including tidal marshes (*e.g.*, Ryther and Dunstan, 1971; Valiela and Teal, 1974; Smart and Barko, 1980). However, prolonged periods of excess nutrients may lead to unsustainable primary production and eutrophication (a highly increased rate of supply of organic matter, which leads to rapid "aging" and impaired functioning of an ecosystem; Nixon, 1995). Although eutrophication may result from natural causes, the major factor along the industrialized east coast of the U.S. has been an intensified supply of nutrients to estuaries as a

consequence of the accelerated development of cities, farms, and industries in the watersheds (Bricker *et al.*, 1999; National Research Council, 2000).

Effects of nutrient over-enrichment are diverse and largely detrimental (U.S. Environmental Protection Agency, 2003b). During eutrophication in estuaries, primary producers respond to excessive nutrients by increasing their growth and production. Consumers and decomposers also increase production, but may be unable to keep pace with the increased primary production. Biological needs for dissolved oxygen eventually exceed the available oxygen supply (especially in summer when water temperatures are high), and result in hypoxia[15], which has numerous adverse effects on aquatic wildlife (as discussed below). Eutrophication frequently results in impoverished biological communities dominated by nuisance (food-web disrupting) or toxic species (Burkholder *et al.*, 1995; Paerl *et al.*, 2003). Eutrophication also alters certain ecosystem functions (*e.g.*, decreased nitrogen fixation, Valiela and Teal, 1974; microbial sulfate reduction, Hargrave, 2003). Hypoxia and certain associated conditions (*e.g.*, altered hydrogen sulfide concentrations and oxidation-reduction potentials) associated with eutrophication may also exacerbate other environmental stressors by changing form and availability of contaminants (National Oceanic and Atmospheric Administration, 2005a). In addition, toxic trace elements such as arsenic, copper, and cadmium may have complex effects on primary and secondary production in eutrophic systems (Wiegner *et al.*, 2003). Such effects have included a reduction in primary production in experimental studies (Wiegner *et al.*, 2003). Effects of trace elements in the Meadowlands, with its diverse sources of contamination, remain unknown.

Water quality in the Hackensack River estuary, Newark Bay, and the adjoining Passaic River estuary (the Passaic River watershed is 11 times larger than that of the Hackensack) has been highly degraded for many years (Squibb *et al.*, 1991) by excessive contamination and eutrophication (Crawford *et al.*, 1995; Steinberg *et al.*, 2004). Because contaminants and hypoxia cause adverse impacts on fish and wildlife (see below), poor water quality in the Hackensack River estuary and the adjoining waterways represents a considerable challenge to the restoration of the Meadowlands and its aquatic resources. Despite substantial improvements in sewage treatment throughout the Meadowlands and the rest of the NY-NJ Harbor estuary in the 1970s and 1980s, no significant overall improvements in water quality in the Meadowlands were reported for the period 1971-1988 (Keller *et al.*, 1990). This lack of improvement may have resulted from the comparatively poor flushing of the Meadowlands in comparison to other portions of the HRE, which appear better flushed by freshwater flows (Steinberg *et al.*, 2004).

Although reported to be somewhat improved from the 1970s and 1980s, water quality within the HMD continues to show evidence of eutrophication. For example, average ammonium concentrations from 1993 to 2004 have remained high (*e.g.*, > 12 mg/L) in some portions of the HMD (*e.g.*, Cromakill Creek, where secondary sewage effluent is discharged from a STP; New Jersey Meadowlands Commission, 2005c). The continuous discharge of high concentrations of ammonium in the sewage effluent of the Bergen County Utility Authority's STP (the single largest source of freshwater into the Hackensack River estuary) results in consistently high ammonium concentrations in the vicinity of the discharges and tidal transport of ammonium to upriver and downriver portions of the estuary (DiLorenzo *et al.*, 2004). Though ammonium is subsequently dispersed and converted to less toxic forms of nitrogen (nitrites and nitrates) by

[15] Hypoxia- low oxygen concentration; in water, usually defined to indicate oxygen concentrations less than 2 ppm.

nitrification (DiLorenzo *et al.*, 2004), studies (*e.g.*, Valiela and Teal, 1979; Valiela, 1991) suggest that considerable quantities of nitrogen are likely accumulating in the sediment in portions of the HMD. Some forms of nitrogen may be present periodically in concentrations known to be toxic to some species of plants (*e.g.*, Van Katwijk *et al.*, 1997); also, high concentrations of different forms of nitrogen may affect plant community composition by facilitating the spread of invasive plant species (*e.g.*, Trémolières, 2004). The accumulating reservoirs of various forms of nitrogen may be contributing to the trapping of contaminants in the Meadowlands. Finally, DiLorenzo *et al*. (2004) noted that seasonal water sampling activities in the HMD, such as those performed by the NJMC for the past 10 years, are inadequate to detect weak trends (*e.g.*, improvements) in water quality. Thus, comparison of numerous water quality criteria in the Meadowlands for symptoms of eutrophication (*e.g.*, fecal coliform, other nutrients) may be of limited utility, except when improvements or deteriorations are exceptionally pronounced (DiLorenzo *et al.*, 2004).

Comparison of dissolved oxygen concentrations from 1971-1988 with seasonal water quality data provided by the NJMC (2005b) does suggest some improvements in water quality, yet indicates that hypoxia continues to occur in the Meadowlands during the summer growing season when water temperatures are warm. Oxygen concentrations in the Hackensack River and its tributaries regularly fall below the NJDEP's water quality criterion (4.0 mg/L; N.J.A.C. 7:9B) and EPA's (2003c) protective minimum oxygen concentration (2.3 mg/L) for adult fishes. Even periodic hypoxia may affect the normal behavior, growth, and reproduction of many estuarine organisms (Diaz and Rosenberg, 1995; Diaz, 2001). For example, juveniles of several common estuarine fishes that are commercially important (*e.g.*, winter flounder, black sea bass) experience reduced growth rates and may die even when exposed to hypoxia for a few days (Bejda *et al.,* 1992; Hales and Able, 1995). Aquatic invertebrates such as polychaetes and other benthic infaunal taxa are generally more sensitive to oxygen concentrations than fishes (Diaz and Rosenberg, 1995).

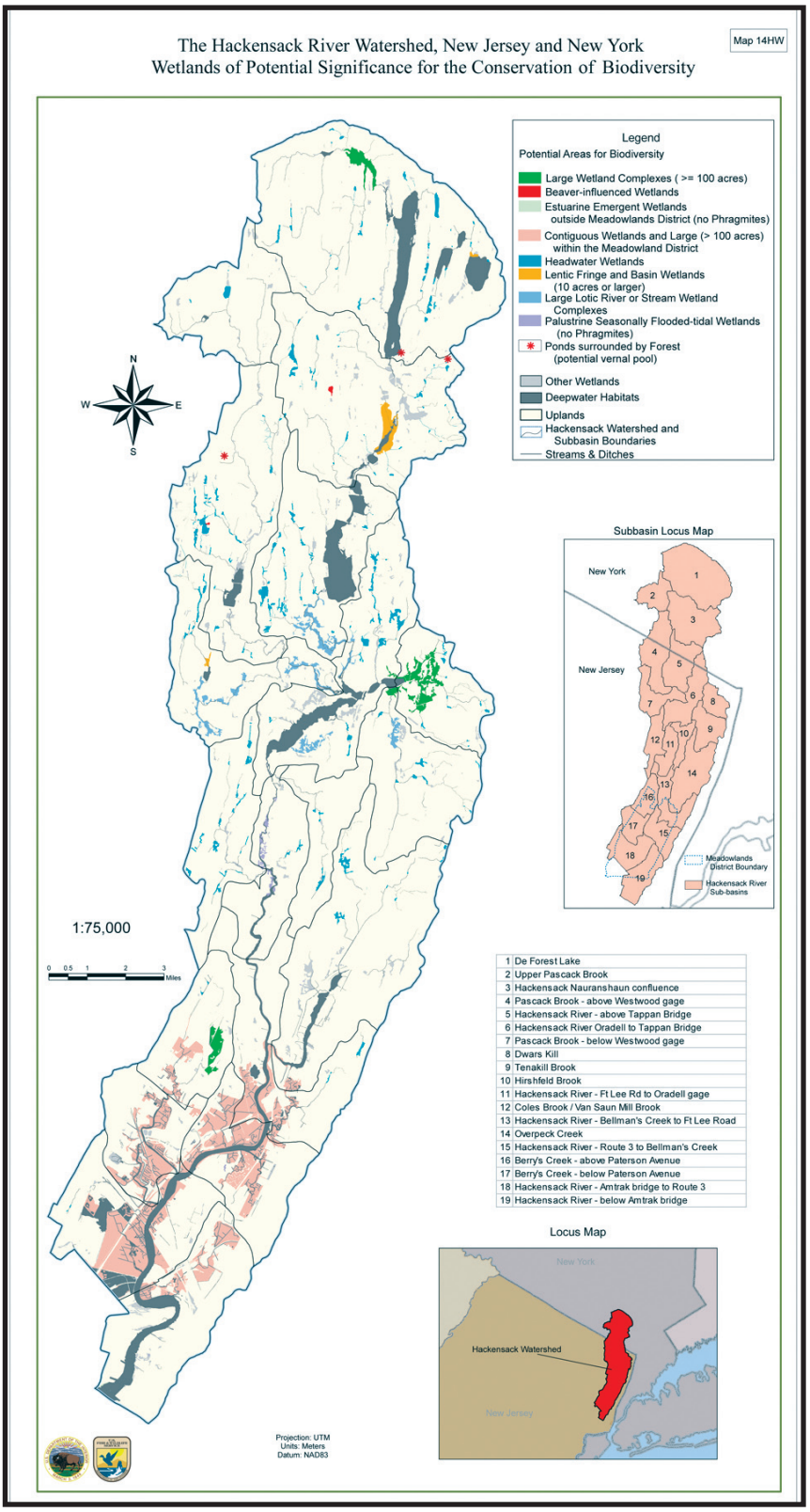
D. SUMMARY

Land and water use by the large human population has resulted in extensive cumulative impacts to the Meadowlands over time, including losses of fish and wildlife populations. Hydrologic alterations to the HRW to satisfy the public need for potable water include construction of several dams and water storage reservoirs, diversions of water from other watersheds, controlled river flows, and groundwater extraction. These alterations have resulted in a substantial reduction in the freshwater flow throughout the HRW. Consequently, secondary treated sewage effluent is now the largest source of "freshwater" in the Hackensack River. Sewage effluents, together with CSOs, non-point source run-off, landfill leachates, pollutants from industrial sites, and contaminants transported by tides have created a mosaic of heavily contaminated sediments washed by waters with excessive nutrient concentrations, abundant microbes, and hypoxic water. As a result, water quality in the Hackensack River remains broadly impaired for many criteria (*e.g.*, mercury, fecal coliform bacteria) in comparison with water quality throughout the rest of the HRE.

Historic declines in fish and wildlife populations are difficult to recognize because of largely unknown, yet potentially complex movement patterns in animals. Because of these movement patterns, populations may persist in contaminated and other "sink" habitats, in which local reproduction is insufficient to balance local mortality. Historic losses of certain taxa from the Meadowlands (*e.g.*, aquatic invertebrates, amphibians, fishes) raise serious concerns about the potential functioning of wetlands in the Meadowlands as sink habitats. Several contaminants that originated from multiple sources or dispersed from localized "hotspots" have become widely distributed in the Meadowlands, and have considerable potential to adversely affect fish and wildlife. For example, Berry's Creek, which adjoins three of the seven Superfund sites in the Meadowlands, may be the most heavily contaminated mercury site in the nation. Mercury and the other contaminants of greatest concern in the Meadowlands (*i.e.*, PCBs, dioxins, certain hydrocarbons) are not only toxic to many species, but bioaccumulate and are endocrine disruptors that have adverse effects on growth, survival, and reproduction of animals. Restoration activities (*i.e.*, regrading marsh elevation and planting native vegetation) may create "attractive nuisances" by increasing the availability of those contaminants and their subsequent bioaccumulation in fish and wildlife populations that use restored wetlands. Finally, the legacy of contamination in the Meadowlands will continue and may likely worsen with increasing demand and reuse of the region's water resources, unless a program to monitor and address novel contamination is developed and implemented.

Poor water quality and environmental contaminants potentially limit the recovery of the aquatic fauna and dependent species in the Meadowlands. The reduced flow of the Hackensack River combined with the high nutrient concentrations in sewage effluents that dominate the freshwater inputs have created a system that is stressed, as evidenced by the hypoxia that occurs during the summer growing season, for most fishes and invertebrates. Heavily contaminated wetlands along Berry's Creek and possibly other contaminant hotspots also represent a considerable challenge to restoration. Burgeoning human population and industry will continue to increase water consumption; thus, water quality degradation will continue and may worsen with increasing demand and reuse of the region's water resources. The Service recommends improvements to sewage treatment and the flows of the Hackensack and Passaic Rivers to improve the health of fish and wildlife throughout the region. Development of a comprehensive program to monitor and assess contaminants is essential to guide remediation and restoration of the Meadowlands. In addition, the Service recommends that a priority task of government agencies and stakeholders be development of a plan to remediate and restore wetlands along Berry's Creek and beyond without creating an attractive nuisance to fish and wildlife populations. Remediation and restoration activities, combined with comprehensive improvements in water quality, will eventually increase opportunities for appropriate recreational and other uses (see Sections VIII and IX) of the Meadowlands and improve the quality of life for area residents. A strategy for water conservation, including the monitoring, management, and restoration of water resources, is necessary to ensure that future water quality and quantity needs will be met for fish, wildlife, and people.

V. Wetland and Upland Land Use



Map from Tiner and Bergquist (2005).

A contaminated site along the Hackensack River.

An abandoned industrial site on the Hackensack River.

An abandoned tide-gate on Mill Creek.

A river view of Snake Hill and the Pulaski Skyway.

Marshes along the Berry's Creek Canal.

V. Wetland and Upland Land Use

Wetlands and uplands along Mill Creek.

Along Overpeck Creek, garbage bags and other debris from a covered landfill slowly erode into the Hackensack River. At another site, a foul-smelling, yellowed stratum of chromium stretches along the shoreline, lying under the shell of the factory that once refined the metal. Powerlines, roads, railroads, and highways crisscross the Meadowlands. A dam blocks flows on Overpeck Creek; the much larger Oradell Dam drastically increases the extent of tidal inundation, sharply differentiating the nature of wetlands on the upper and lower Hackensack. Docks jut into waters, and bulkheads turn shorelines into rigid, artificial barriers. Diking and dredging scar the landscape. All of these features bear witness to past land-use decisions, many of which filled wetlands and fragmented and degraded fish and wildlife habitat. In the process, more than 70 percent of the wetlands that comprised the Hackensack Meadowlands before European colonization have been destroyed.

Thoughtful land use and management are crucial to reversing this destructive trend and restoring wildlife habitat functions in the Meadowlands. Even now, palustrine wetlands and their adjoining uplands along the Upper Hackensack improve water quality and help sustain biodiversity. In fact, even in the degraded Meadowlands, uplands provide important habitat for fish and wildlife. Fishes and invertebrates use overhanging banks as cover; birds and mammals feed, nest in, and migrate along riparian habitats by the water's edge. Uplands also "buffer" wetlands by moderating stormwater flows, retaining stormwater run-off, and trapping sediments laden with contaminants and nutrients. Thus, future land-use planning in the Meadowlands must address the use of remaining open space—both uplands and wetlands.

V. WETLAND AND UPLAND LAND USE

A. INTRODUCTION

B. HISTORICAL WETLAND CHANGES

1. Historical Wetland Losses
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1. Upland Landscape Cover and Land Use
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E. SUMMARY

Forests once covered extensive areas of the Hackensack Meadowlands and the watershed. Only a few hundred acres remain.

V. WETLAND AND UPLAND LAND USE

A. INTRODUCTION

Throughout the history of the United States, coastal areas have been home to more than half of the country's population (Beach, 2002). Historic use of the Meadowlands and adjoining uplands in this densely populated area has resulted in substantial losses of wetlands and uplands, altered and fragmented remaining natural habitats, and disrupted the Meadowlands ecosystem and diminished its capacity to sustain fish and wildlife populations. Presently, nearly all uplands within the HMD and most uplands within the HRW are developed (Balzano *et al.*, 2002; New Jersey Meadowlands Commission, 2004d). The population of coastal areas will continue to grow in New Jersey and throughout the world (U.S. Census Bureau, 2005a; United Nations, 2005). Remaining natural habitats within coastal urban areas are of increasing importance to preserving biodiversity as well as the quality of human life (Crooks and Turner, 1999; Crane and Kinzig, 2005). A comprehensive assessment of urban land-use effects and integration of urban land-use into protection, restoration, and management of natural resources are widely lacking in coastal areas (Beach, 2002; Crane and Kinzig, 2005). Moreover, addressing these informational and management needs is vital to protecting, conserving, and enhancing fish and wildlife habitats in the Meadowlands.

The Service's National Wetlands Inventory (NWI) has recently documented the status and trends of wetlands in the Meadowlands from the 1890s to the mid-1990s (Tiner *et al.*, 2002); some of that information is summarized below (Section B). Using imagery provided by the NJMC and the State of New Jersey, the NWI has updated and improved an earlier status and trends effort by: (1) providing a more detailed (by USGS subbasin) analysis of wetlands within the HMD (Tiner *et al.*, 2005); (2) expanding wetlands interpretation and analyses to the entire HRW (Tiner and Bergquist, 2005); and (3) assessing remotely-sensed vegetative-cover and disturbance indicators (*e.g.*, roadway extent within hydrologic subbasins; Tiner, 2004) to evaluate wetlands more thoroughly within the HMD and the watershed (Tiner and Bergquist, 2005). Those findings (Tiner and Bergquist, 2005; Tiner *et al.*, 2005) are summarized below to provide an overview of: (1) historic wetland losses and alterations throughout the watershed; (2) the current status of remaining wetlands, including their types, fragmentation, disturbance, and functioning; and (3) adjoining upland land use, including vegetative buffers and corridors. The NWI reports clearly document the extensive losses of wetlands that have occurred throughout the HRW; moreover, the substantial losses of wetlands and alterations to the landscape establish the need for a comprehensive assessment of the cumulative adverse impacts to the watershed and especially to the Meadowlands. The full text and figures of those reports (Tiner and Bergquist, 2005; Tiner *et al.*, 2005) will be available on the Service's website at www.fws.gov.

The human population in New Jersey and in the HRW is expected to grow substantially in the next 25 years (U.S. Census Bureau, 2005a; 2005b). Therefore, remaining natural areas within the watershed, and especially its wetlands, remain at risk to direct impacts from development and to indirect and cumulative adverse impacts from surrounding land-use activities. For these reasons, stakeholders and decision-makers must better understand the Meadowlands ecosystem, its values to society and the natural world, and the interactions among its waterbodies, wetlands, and uplands (including developed areas). Using such landscape information, stakeholders can

effectively address and mitigate the adverse impacts of land-use activities through restoration and other land-use planning. For example, the NJDEP's Landscape project (Niles *et al.*, 2004) is using landscape information to identify and manage natural areas to protect the State's biodiversity. Elsewhere in the Northeast, the USGS and the Service (2005) are using landscape information to assess responses of the marsh surface to different vegetative cover types to address potential impacts of SLR on the Blackwater NWR in Maryland. Landscape-scale planning is considered by many conservation biologists as among the most effective mechanisms to protect biodiversity and ecosystems vulnerable to human threats (*e.g.*, Dramstad *et al.*, 1996; Noss *et al.*, 1997; Peck, 1998) and is increasingly used by the Service to protect habitat for fish and wildlife (*e.g.*, the North American Waterfowl Management Plan). Thus, developing a comprehensive understanding of the Meadowlands landscape and land use is critical to (1) formulating effective plans to improve water quality and sustain biodiversity, (2) promoting a more positive image of this long-neglected urban area, and (3) educating the public on the value of its fish and wildlife resources.

B. HISTORICAL WETLAND CHANGES

1. Historical Wetland Losses

Just 150 years ago, the Hackensack Meadowlands was comprised of more than 21,000 acres of waterways and wetlands. Since that time, wetland losses from the Meadowlands have shrunk and fragmented its once vast open spaces into a checkerboard of industrialized and commercial sites, transportation corridors, and small oases of degraded, semi-natural wetlands. From 1889 to 1995, more than 70 percent of the total wetlands in the HMD (20,045 acres, which included most but not all wetlands in the Hackensack Meadowlands) were destroyed by human activities (Figure 42; Tiner *et al.*, 2002). Details regarding the exact location, timing, and acreage of wetland losses from the 1890s to the 1950s are poorly known; however, the overall rate of wetlands loss during that time was approximately 102 acres per year (Table 22; Tiner *et al.*, 2002). Most of the losses during that 60-year period were due to filling activities; however, nearly 1,400 acres of wetlands were converted to open water habitats when historic marsh dikes near Sawmill Creek were breached by a storm in 1950 (Figure 42). Sea level rise has been implicated as a contributing factor in the conversion of other Mid-Atlantic wetlands, including those in NWRs, to deepwater habitats (Tiner, 2005) and may be a factor in the Meadowlands as well. In addition, land-use activities and landscape alterations (*e.g.*, dam construction, dredging) may disrupt sediment transport to estuaries, decrease vertical accretion of marshes, and result in conversion of wetlands to deepwater habitats (*e.g.*, French and Burningham, 2003). The interaction of local land uses and SLR has the potential to compromise restoration efforts and illustrates the importance of the Service's recommendations throughout this document to better understand the effects of human activities on many natural processes (*e.g.*, sediment transport, marsh accretion rates) throughout the Meadowlands. Additional information about SLR is provided in Section IV.B.

The temporal pattern of wetland losses in the HMD (Table 22; Tiner *et al.*, 2002) paralleled national trends during the past century (Dahl, 1990; Dahl and Johnson, 1991; Dahl, 2000). The rate of wetland losses in the Meadowlands more than doubled from the mid-1950s to the mid-

1960s (231 acres per year), and increased further from the mid-1960s through the mid-1970s (304 acres per year). Fortunately, wetland loss rates in the following 10 years decreased due to implementation of the Clean Water Act, which provides regulation of water development projects and specifically seeks to protect wetlands; nonetheless, rates of marsh loss remained fairly high (208 acres per year). From the mid-1980s through the mid-1990s, the rate of wetland losses declined substantially (20 acres per year). Wetland losses in the Meadowlands since the mid-1990s have been comprised mostly of small parcels (*i.e.*, less than 2 acres), although there have been a few notable exceptions of large, publicly and privately owned wetlands that were filled (*e.g.*, a 24.3-acre wetland adjacent to the Teterboro Airport, a 53.5-acre wetland along Penhorn Creek). Although the rate of wetlands loss has decreased dramatically in the past twenty years, the Service nonetheless remains concerned about the contribution to cumulative adverse impacts from wetlands losses that have occurred since implementation of the CWA.

Table 22. Annual wetland loss rates from 1889 to 1995 for the Meadowlands ecosystem (Tiner *et al.*, 2002). The average annual rate of wetland loss has decreased since the early 1990s.

Time Period	Total Wetland Losses (acres)	Annual Wetland Loss Rate (acres per year)
1889-1953/54	6,626	102
1953/54-1966	2,769	231
1966-1976	3,043	304
1976-1984/85	1,868	208
1984/85-1995	198	20

The chronology of wetland losses within present-day individual subbasins of the HRW is not well known. These subbasins are portions of the larger watershed units that reflect fragmentation and isolation by roads and railroad beds in the HMD and by dams elsewhere in the watershed (Figure 43; Tiner and Bergquist, 2005; Tiner *et al.*, 2005). In other words, they are basins within basins and were artificially created through development practices. Nearly all subbasins in the HMD have lost most of their wetland acreage (Table 23; Figure 43). More than 1,000 acres in each of the HMD subbasins were filled (Table 23) once primarily for agriculture, and are now used for transportation, industrial, commercial, residential, and other purposes. The Hackensack River subbasin between the Amtrak Bridge and Rt. 3 has lost roughly 7,765 acres. Moreover, nearly 40 percent of wetlands (approximately 2,400 acres) have been lost from Hackensack River subbasins outside of the HMD (Table 23). Most wetland losses in the upper watershed have occurred in subbasins: (1) along the main stem of the Hackensack River (*e.g.*, Hackensack-Nauranshaun Confluence), (2) along Pascack Brook (*e.g.*, Upper Pascack Brook), and (3) where dams were constructed to create water storage reservoirs (*e.g.*, De Forest Lake).

Figure 42. Changes in the landscape: a time sequence of wetlands losses for the Hackensack Meadowlands (from Tiner *et al.*, 2002). Note the extensive filling of wetlands (light green) to create uplands (off-white). A major storm breached a man-made dike in 1950; as a result, an extensive area of marshes along Sawmill Creek in the lower western portion of the Meadowlands were converted into open water (shown in blue) from the mid-1950s through the early 1960s.

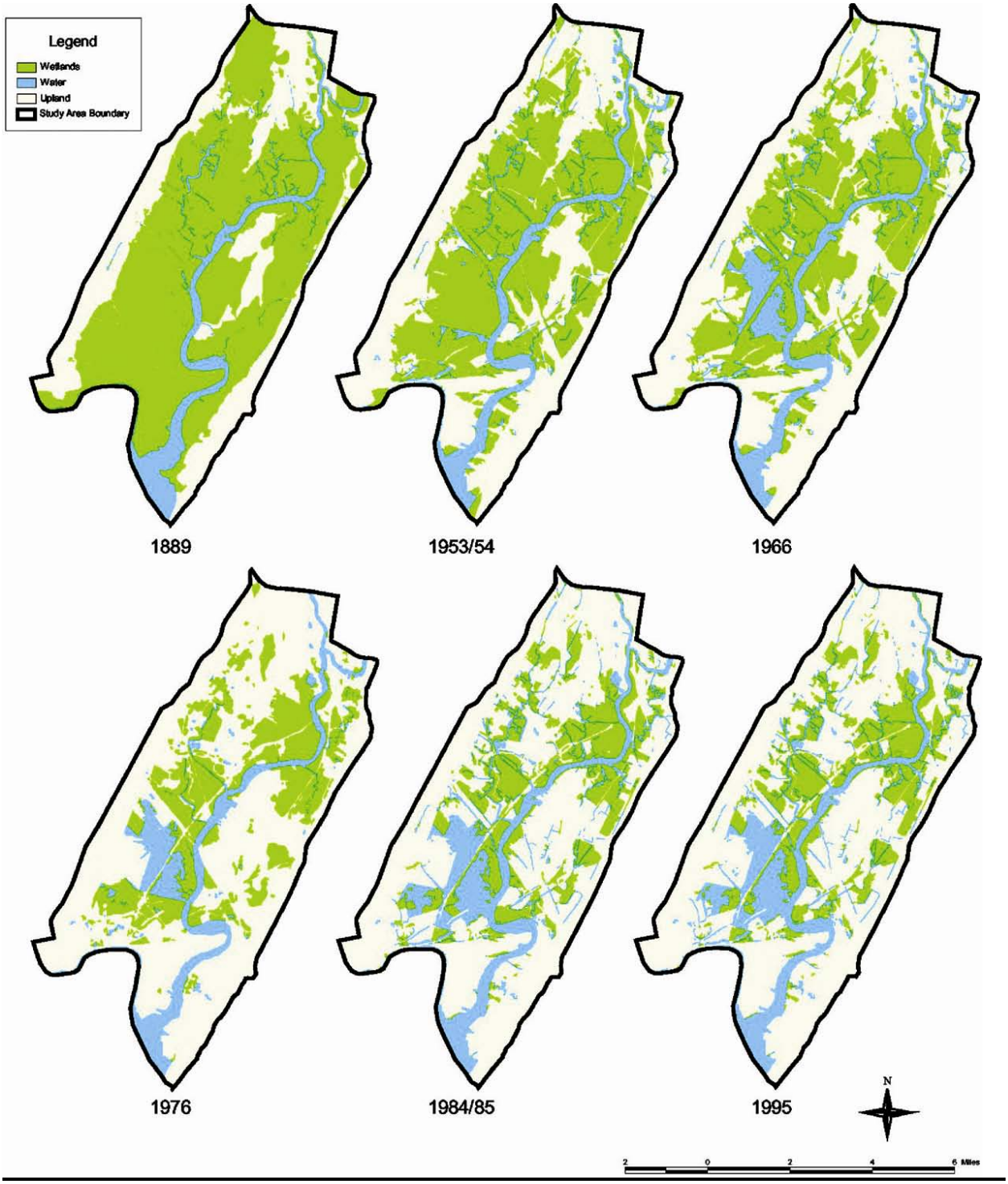
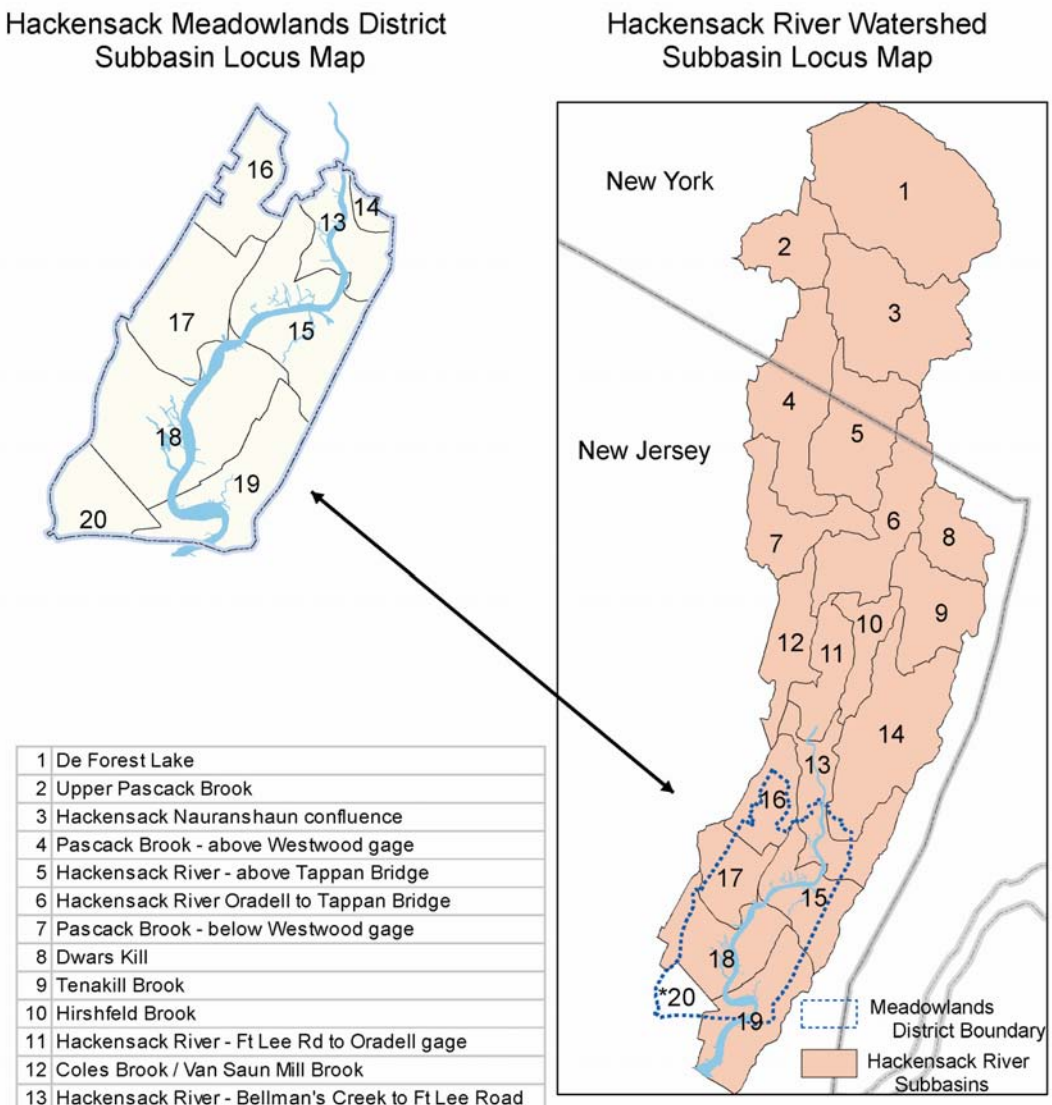


Figure 43. Hydrologic subbasins within the Hackensack Meadowlands District (HMD) and the HRW (from Tiner and Bergquist, 2005). These subbasins are subdivisions of watersheds in the USGS hierarchy of hydrologic units. Subbasins are geographic areas representing part or all of a surface drainage area, a combination of drainage areas, or a distinct hydrologic feature (Seaber *et al.*, 1987). Portions of several subbasins in the HMD extend beyond the HMD's boundaries. Subbasin #20 (Passaic River Lower) is part of the Passaic River watershed.



1	De Forest Lake
2	Upper Pascack Brook
3	Hackensack Nauranshaun confluence
4	Pascack Brook - above Westwood gage
5	Hackensack River - above Tappan Bridge
6	Hackensack River Oradell to Tappan Bridge
7	Pascack Brook - below Westwood gage
8	Dwars Kill
9	Tenakill Brook
10	Hirshfeld Brook
11	Hackensack River - Ft Lee Rd to Oradell gage
12	Coles Brook / Van Saun Mill Brook
13	Hackensack River - Bellman's Creek to Ft Lee Road
14	Overpeck Creek
15	Hackensack River - Route 3 to Bellman's Creek
16	Berry's Creek - above Paterson Avenue
17	Berry's Creek - below Paterson Avenue
18	Hackensack River - Amtrak bridge to Route 3
19	Hackensack River - below Amtrak bridge
20	Passaic River Lower - Newark Bay to 4th St Bridge

2. Historical Wetland Alterations

In addition to the cumulative wetland losses discussed above, wetland alterations have occurred throughout the HRW. Beginning in the 1800s, wetlands were extensively diked and ditched, primarily for farming and mosquito control (Section II.C). During that time, the Hackensack River initially comprised a tidal freshwater ecosystem with extensive palustrine (swamp) wetlands (approximately 6,000 to 10,000 acres) forested by Atlantic white-cedar (Figure 44). Beginning in the 1900s, wetlands throughout the watershed began to experience changes and losses with the construction of dams along the Hackensack River (Section IV.B.). With freshwater flows in the Hackensack River decreased by dams, especially at Oradell, tidal currents upstream in the HRW subsequently increased the salinity of these once fresh- or low-salinity waters and contributed to the extensive development of latter-day estuarine wetlands in the subbasins that now comprise the HMD (Table 23).

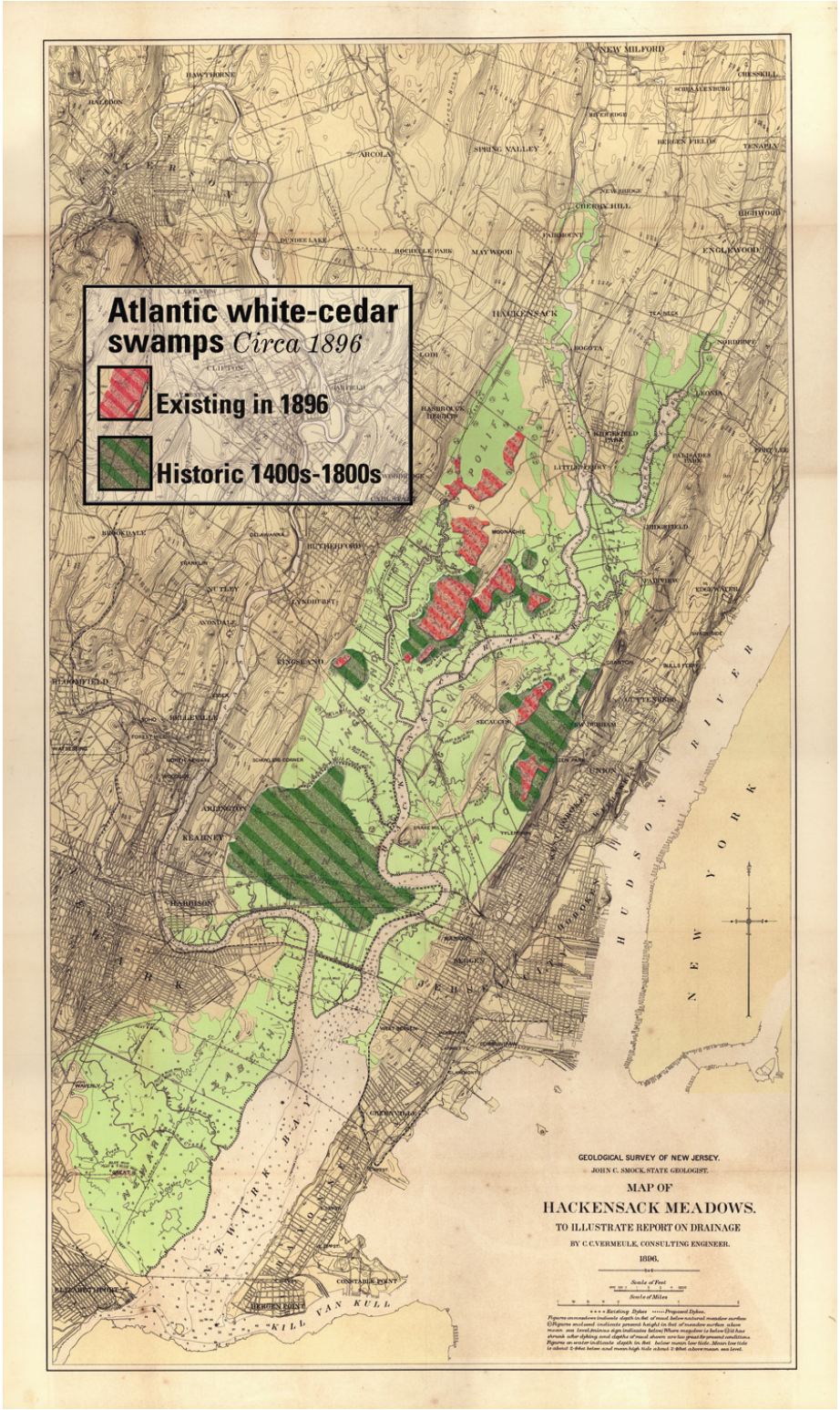
Although the rate of wetland losses in the Meadowlands has decreased substantially since 1985, owing to regulatory overview and protection, changes in remaining wetlands appear to be increasing as a result of several factors, some of which are unknown. Estuarine wetlands with unconsolidated shores (an NWI wetland type represented primarily by mudflats in the HMD; Tiner *et al.*, 2005) totaled approximately 400 acres in 1995 but increased to more than 1,187 acres in 2002. Some increase of unconsolidated shore acreage undoubtedly has resulted from: (1) restoration activities (*i.e.*, excavation and regrading of the marsh surface to eradicate common reed and create mudflats as habitat; *e.g.*, Skeetkill and Mill Creek marshes; U.S. Army Corps of Engineers, 2004a); and (2) dredging. In addition, an increase in acreage may also be the result of a methodological artifact in which the use of boundaries for the wetland areas in current analyses were different from those used in analyses in 1995 (Tiner *et al.*, 2002) and 2002 (Tiner and Bergquist, 2005; Tiner *et al.*, 2005). However, these explanations appear inadequate to account for the majority of increases in the extent of unconsolidated shores. Increases in the extent of unconsolidated shores and wetlands in other Mid-Atlantic coastal estuaries (*e.g.*, Delaware's Nanticoke River estuary; Tiner, 2005; Blackwater NWR, U.S. Geological Survey and U.S. Fish and Wildlife Service, 2005) have been attributed to SLR, which may be a factor in the HMD. (See Sections B [above] and IV.B for additional concerns and information about SLR.) To understand these wetland changes, wetland elevation in the Meadowlands should be closely monitored with the use of surface elevation tables (*e.g.*, Cahoon and Lynch, 2005) and investigated regarding their causes (*e.g.*, dredging, controlled river flows, and other processes affecting sediment transport in the estuary). Significant wetland changes ongoing in the Meadowlands necessitate comprehensive assessments of their cumulative adverse impacts and their interaction with other factors (*e.g.*, SLR). Such assessments are critical to guide long-term land-use decisions, especially those regarding remediation and restoration.

Wetland alterations in subbasins in upper portions of the HRW are not as extensive as in lower subbasins; however, construction of the Oradell and other dams to create water storage reservoirs clearly resulted in alterations to lotic (flowing water) wetlands above the dams. Extensive stretches of riverine wetlands were converted to open water, and remaining lotic sites (*i.e.*, streams, adjoining wetlands, riparian areas) were fragmented by dams, water storage reservoirs,

Table 23. Historic wetland losses of subbasins of the Hackensack Meadowlands District and in the Hackensack River watershed (from Tiner and Bergquist, 2005 and Tiner *et al.*, 2005). The location of subbasins and the ID number are shown in Figure 43. Note that wetlands losses are extensive throughout all subbasins. Subbasin 20 in the HMD is part of the Passaic River watershed.

Hackensack River Watershed Subbasin (Subbasin ID)	Historic Wetland Acreage	Estuarine/ Palustrine Acreage	Current Wetland Acreage	Lost Wetland Acreage	Current Percent of Watershed
Hackensack Meadowlands District					
Berry's Creek above Paterson Ave. (16)	1,495	83.8 / 379.5	463.3	1,032	4.8
Berry's Creek below Paterson Ave. (17)	2,717	909.3 / 42.1	951.4	1,766	9.9
Hackensack River, Amtrak Bridge to Rt. 3 (18)	9,244	1,431 / 47.9	1,479.2	7,765	15.3
Overpeck Creek (14)	867	162.6 / 149.5	312.1	555	3.2
Hackensack River, Bellman's Creek to Ft. Lee Rd. (13)	904	651.7 / 55.6	707.3	197	7.3
Hackensack River, Rt. 3 to Bellman's Creek (15)	3,637	1,445 / 9.6	1,455.2	2,182	15.1
Hackensack River below Amtrak Bridge (19)	2,419	563.1 / 89.9	653.0	1,766	6.8
Lower Passaic River (20)	1,912	216.4 / 51.4	267.8	1,645	0.0
Elsewhere in the HRW					
Coles Brook/Van Saun Mill Brook (12)	149	-- / 123.7	123.7	25	1.3
De Forest Lake (1)	1,297	-- / 506.0	506.0	791	5.2
Dwars Kill (8)	583	-- / 408.0	408.0	175	4.2
Hackensack-Nauranshaun Confluence (3)	1,104	-- / 596.4	596.4	508	6.2
Hackensack River, Ft. Lee to Oradell Gage (11)	118	-- / 118.0	118.0	0	1.2
Hackensack River, above Tappan Zee Bridge (5)	536	-- / 397.4	397.4	139	4.1
Hackensack River, Oradell to Tappan Zee Bridge (6)	699	-- / 510.6	510.6	188	5.3
Hirshfeld Brook (10)	41	-- / 30.0	30.0	11	0.3
Pascack Brook above Westwood Gage (4)	511	-- / 301.7	301.7	209	3.1
Pascack Brook below Westwood Gage (7)	402	-- / 337.6	337.6	64	3.5
Tenakill Brook (9)	204	-- / 202.3	202.3	2	2.1
Upper Pascack Brook (2)	402	-- / 96.4	96.4	306	1.0

Figure 44. Geological Survey of New Jersey's 1896 Map of the Hackensack Meadows, colored to show change in distribution of Atlantic white-cedar from the 1400s (striped green) to 1896 (striped red). Other vegetation, mostly grasses, is shown in light green.



and other land-use changes. Small lotic areas are vulnerable to hydrologic changes (*e.g.*, water temperature, sedimentation) and degradation in water quality due to other land-use changes, especially changes that create impervious surfaces (*e.g.*, Limberg and Schmidt, 1990; McMahon and Cuffney, 2000; Paul and Meyer, 2001). Wetlands may become degraded by poor water quality when impervious cover in the watershed exceeds 10 percent or more (*e.g.*, Garie and McIntosh, 1986; Limberg and Schmidt, 1990); however, urban land-use and runoff / impervious cover effects are variable and site-specific (Pitt, 2003). Headwater and other low-order streams are often critical to ecosystem functioning and water quality downstream (*e.g.*, McMahon and Cuffney, 2000; Paul and Meyer, 2001). Thus, the Service recommends that stakeholders with applicable authorities: (1) acquire and protect remaining lotic wetlands throughout the Hackensack watershed, including those in New York; (2) restore lotic wetlands, especially where contaminated or where restored wetlands will re-connect fragmented lotic wetlands; and (3) protect, restore, and create vegetated riparian areas adjoining lotic wetlands. The Service's recommendation expands upon a recommendation in a previous DOI (1994) report to Congress on the impact of federal programs on wetlands. In the report, the DOI cited the economic value of wetlands and recommended acquisition of "critically important and vulnerable wetland complexes" in northeastern New Jersey, which include those in the HRW, largely for the purpose of flood control. The DOI (1994) recommended direct purchase or cost sharing with the State or local municipalities.

C. CURRENT WETLAND STATUS

Despite extensive historical losses, substantial wetland acreage remains throughout the HRW, especially within the HMD. Approximately 9,650 acres of wetlands occur in the HRW (Figure 45; Tiner and Bergquist, 2005), of which approximately 60 percent (5,844 acres) occur in the HMD (Tiner *et al.*, 2005). However, wetland types present today within the HMD reflect the increasing influence of salt water in the watershed below the Oradell Dam since it was built in 1922. Wetlands in the HMD are predominantly estuarine, whereas wetlands in other portions of the HRW upstream are predominantly palustrine (Table 23; Tiner and Bergquist, 2005; Tiner *et al.*, 2005). This distribution of wetland types underscores the anthropogenic changes to the Meadowlands ecosystem and the importance of carefully considering the goals and objectives of any efforts to enhance and restore wetlands in different subbasins. The value of ecosystem functions provided by all wetlands throughout the HRW also emphasizes the importance of acquiring and protecting these remaining wetlands. The DOI (1994) recommended purchasing wetlands throughout northern New Jersey for flood control, and emphasized the value of wetlands as a non-structural means of flood control.

1. Wetland Types, Landscape Positions, and Landforms in the HMD

Wetland types now present in the HMD, in comparison with conditions throughout most of the 1900s, reflect the increased presence of saltwater within the Hackensack River due to both decreased upstream flow as a result of dams, increased water usage, and possibly SLR. The HMD now contains approximately 5,300 acres of estuarine wetlands (Figure 46). Estuarine wetlands with emergent vegetation (4,100 acres; approximately 70 percent) and

Figure 45. Wetlands (9,650 acres) and deepwater habitats classified by National Wetlands Inventory types in the Hackensack River watershed (from Tiner and Bergquist, 2005).

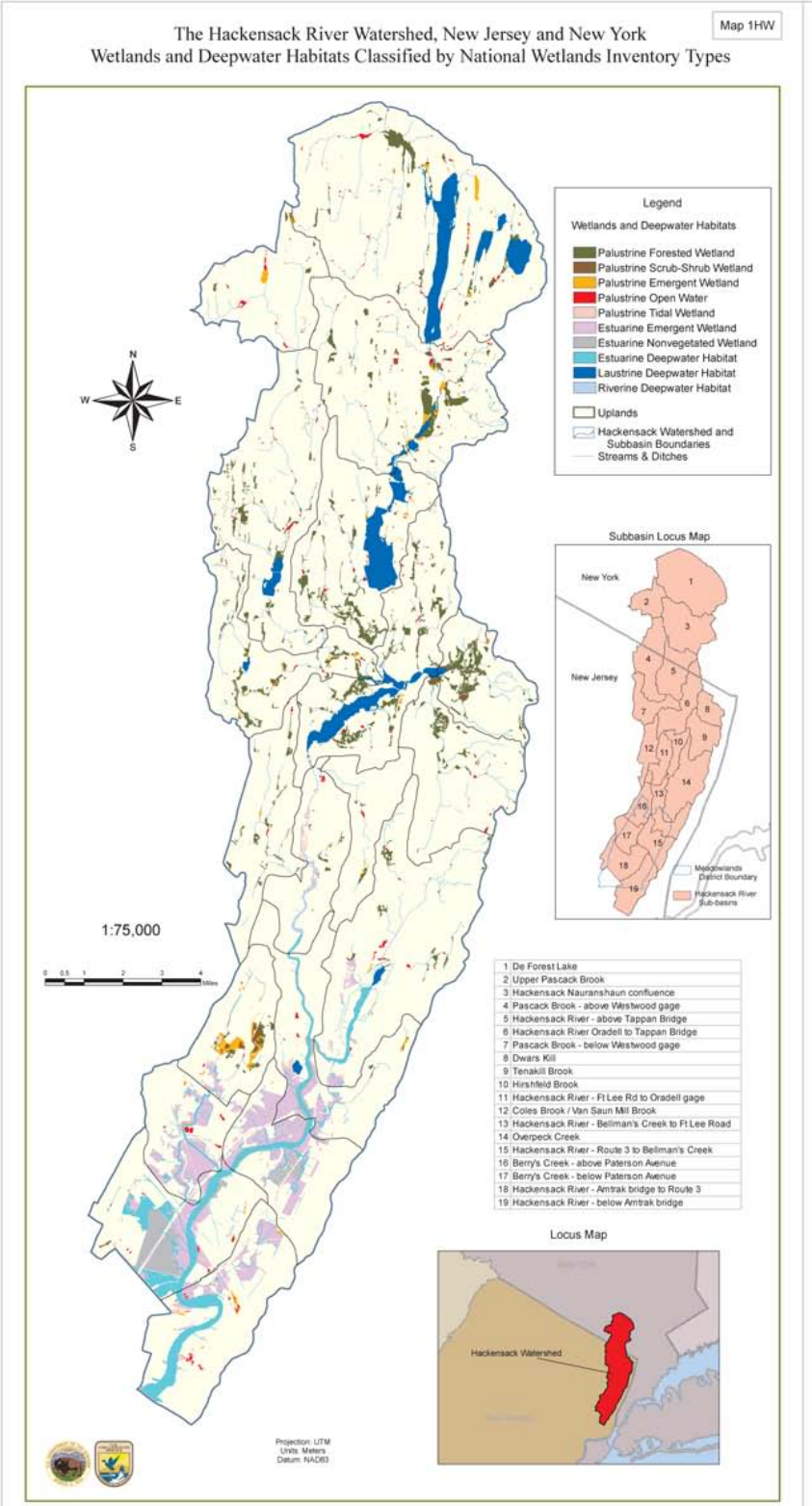


Figure 46. Wetlands (5,844 acres) and deepwater habitats classified by National Wetlands Inventory types in the Hackensack Meadowlands District (HMD; from Tiner *et al.*, 2005). Vegetated (4,100 acres) and non-vegetated (1,200 acres) estuarine wetlands are the most common types in the HMD.

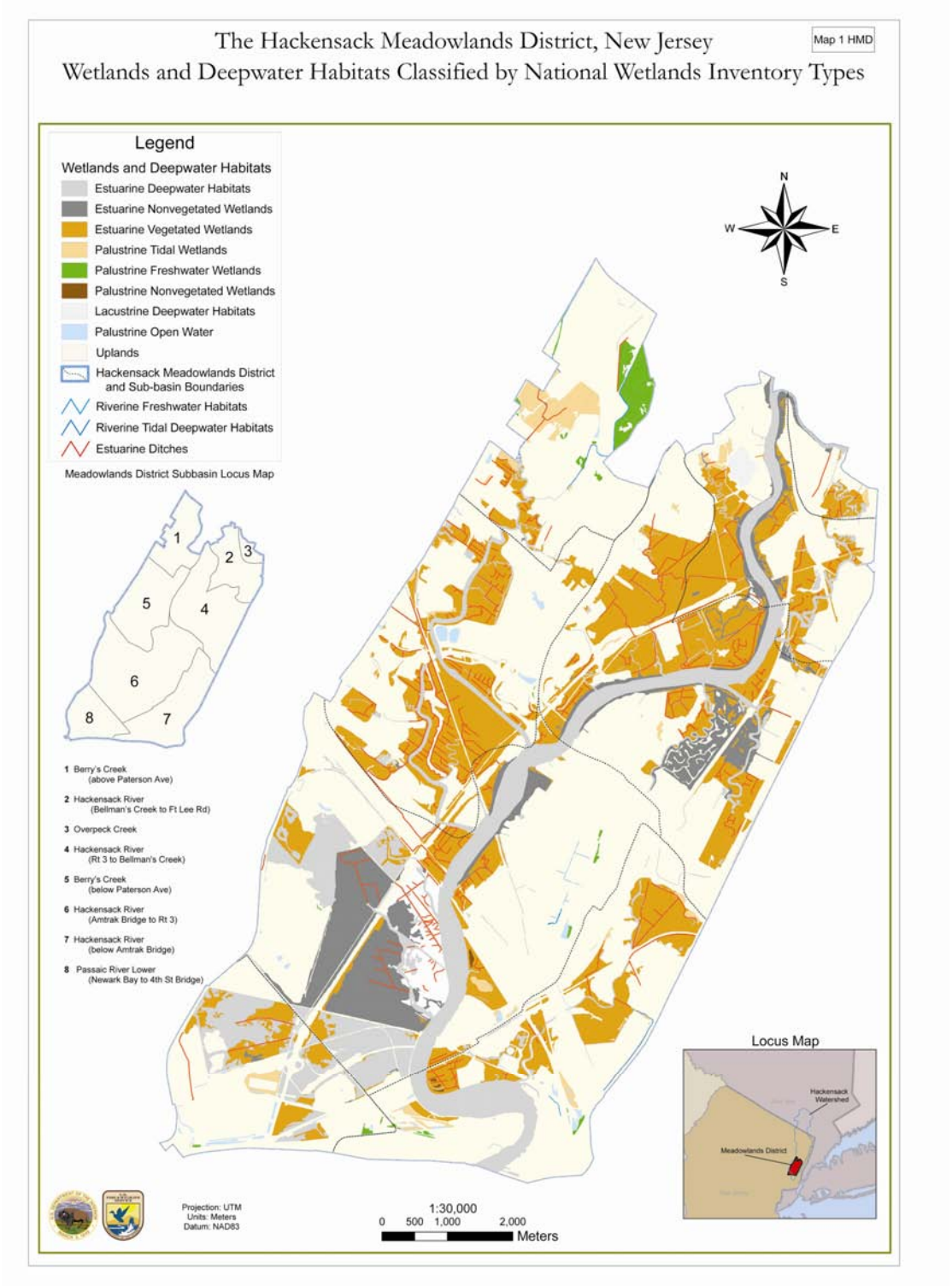


Table 24. Acreage of wetlands by National Wetland Inventory types in subbasins (ID numbers as in Figure 43) of the Hackensack Meadowlands District (from Tiner and Bergquist, 2005 and Tiner *et al.*, 2005). Note that estuarine wetlands with emergent vegetation are the most common wetland type; estuarine wetlands with unconsolidated shores are increasing.

Hackensack Meadowlands District Subbasin (ID number)	Estuarine Wetland Acreage		Palustrine Wetland Acreage			Total Wetland Acreage
	Emergent vegetated	Other vegetated/ unconsolidated	Emergent vegetated	Forest/ scrub	Uncon-solidated	
Berry's Creek above Paterson Ave. (16)	81.2	2.5	160.4	144.9	3.4	392.4
Berry's Creek below Paterson Ave. (17)	908.5	1.1	7.1	4.9	26.3	947.9
Hackensack River Amtrak Bridge to Rt. 3 (18)	655.9	776.1	20.3	0.4	16.3	1,469.0
Overpeck Creek (14)	51.3	8.3	0.4	4.5	0.2	64.7
Hackensack River, Bellman's Creek to Ft. Lee Rd. (13)	522.7	103.7	5.7	18.6	0.7	651.4
Hackensack River Rt. 3 to Bellman's Creek (15)	1,155.3	291.0	4.2	3.9	1.5	1,455.9
Hackensack River below Amtrak Bridge (19)	529.9	0.4	47.5	---	18.2	596.0
Lower Passaic River (20)	210.9	5.5	29.3	---	22.1	267.8
Total acreage	4,115.7	1,188.6	274.9	177.2	88.7	5,845.1

unconsolidated substrates (*e.g.*, tidal mudflats; 1,200 acres; approximately 20 percent) are now the predominant wetland types in the HMD (Figure 46, Table 24). Palustrine (tidal and non-tidal freshwater) wetlands are now restricted almost entirely to the upper Berry's Creek subbasin. Palustrine wetlands now comprise only 9 percent (approximately 540 acres) of wetlands in the HMD.

Wetland landscape positions (relationship to the adjoining waterbody [*e.g.*, lotic, lentic]) and landforms (*i.e.*, wetland form or shape [*e.g.*, flat, slope]) present in the HMD (Tiner, 2003) reflect extensive landscape and hydrologic alterations. Because of alterations in the flow of the Hackensack River and subsequent ecosystem changes, nearly all HMD wetlands are classified as estuarine (5,445 acres; Figure 47). Within the HMD, lotic (156 acres), lentic (89 acres), and terrene (154 acres) wetlands remain primarily in upper subbasins (*e.g.*, upper Berry's Creek; Figure 47; Tiner *et al.*, 2005). Filling and other activities have altered the present-day landforms of the HMD's wetlands (Tiner *et al.*, 2005). Presently, the HMD's wetlands are comprised almost entirely of: (1) fringe wetlands (*i.e.*, estuarine landforms with unrestricted flows) along the main stem of the Hackensack River (57 percent), and (2) basin wetlands (*i.e.*, estuarine landforms with restricted tidal flows) isolated by the New Jersey Turnpike and other major roadways (43 percent; Figure 48; Tiner and Bergquist, 2005).

The current distribution of wetland types and their vegetation within different subbasins have four important implications for remediating and restoring the Meadowlands. First, the two subbasins that straddle the Hackensack River (Rt. 3 to Bellman's Creek, and the Amtrak Bridge to Rt. 3; Figure 43) collectively comprise slightly more than half (54 percent) of the HMD's estuarine wetlands. Wetlands within those subbasins are relatively large in comparison to wetlands in other subbasins in the HMD (*e.g.*, the Hackensack River subbasin below the Amtrak Bridge, which includes several isolated wetlands along Penhorn Creek; Figure 43). Second, reestablishing large contiguous wetlands is an important goal for sustaining and managing fish and wildlife resources in the Meadowlands (U.S. Fish and Wildlife Service *et al.*, 2000). A large contiguous natural landscape of high quality habitats for fish and wildlife could be created by remediating and restoring the Lower Berry's Creek subbasin (Figure 43), which includes 909 acres of wetlands (17 percent of HMD wetlands) that currently separate the two large subbasins described above. Third, the upper subbasins of the HMD (*e.g.*, Berry's Creek above Paterson Avenue, Hackensack River-Bellman's Creek to Ft. Lee Rd.; Figure 43) are comprised of more diverse wetland types than lower subbasins (Figure 47; Table 24); preserving the existing native biodiversity is one of the restoration principles for the Meadowlands (See Section I.B.). Finally, the Service has fewer concerns about the potential adverse impacts of environmental contaminants in upriver portions of the HMD (Section III.C.3).

2. Wetland Types, Landscape Positions, and Landforms Outside the HMD in the Hackensack River Watershed

Although reduced from historical times, several thousand acres of wetlands (Table 25; Figure 48) remain upriver of the HMD in upper portions of the HRW. Except for approximately 100 acres of estuarine wetlands located north of the HMD along Overpeck Creek, all other wetlands

Figure 47. Wetlands and deepwater habitats in the Hackensack Meadowlands District (HMD) classified by landscape position (from Tiner *et al.*, 2005). Freshwater habitats and lotic and terrene wetlands occur mostly in upper portions of the HMD.

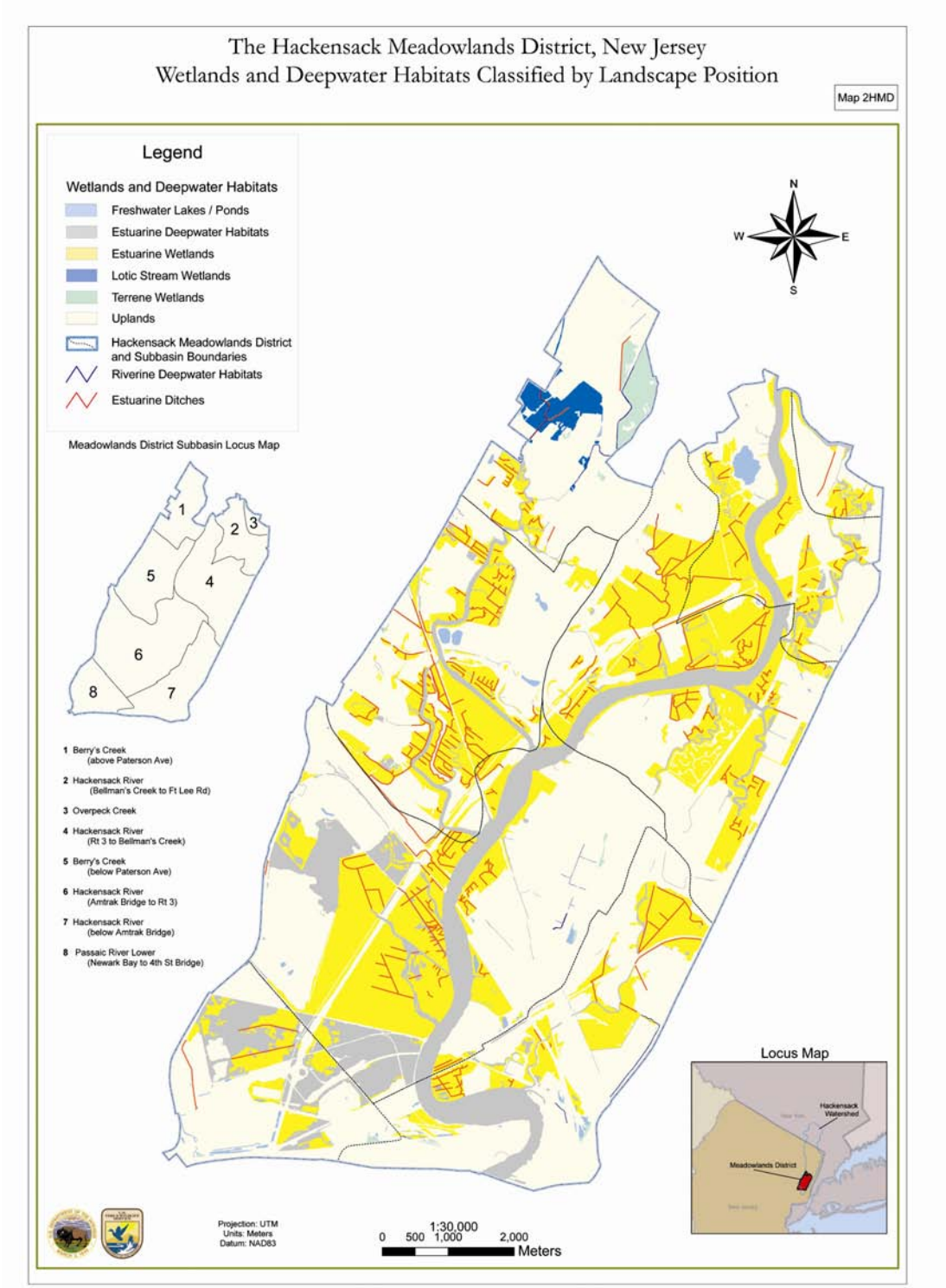
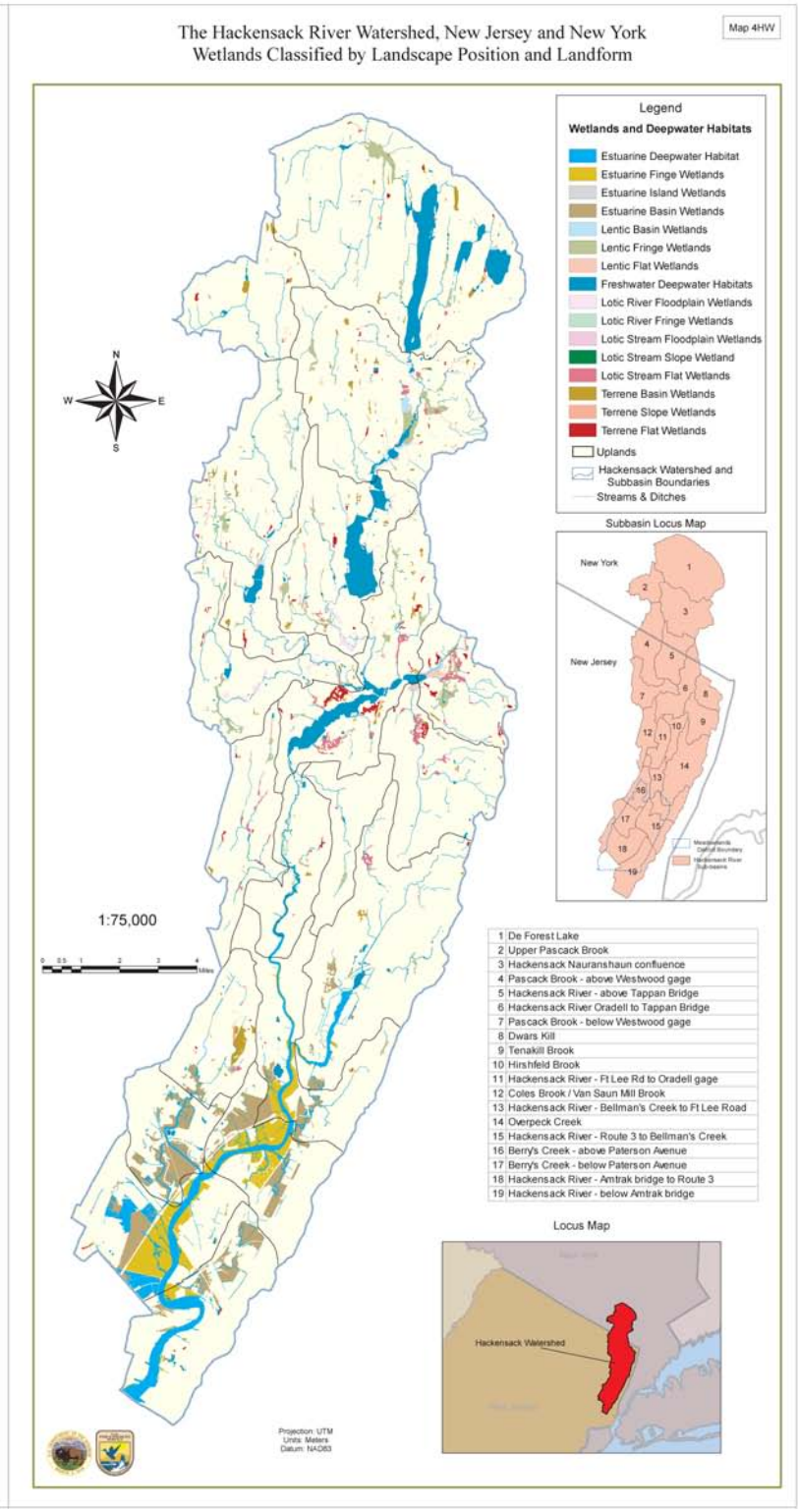


Figure 48. Hackensack River watershed wetlands classified by landscape position and landform (from Tiner and Bergquist, 2005). Note the thin upland roadbed that separates fringe and basin wetlands in the HMD.



upriver of the HMD in the HRW are palustrine (Table 25). Overall, palustrine wetlands are numerous and widely distributed throughout the upper HRW; however, in comparison to wetlands in the HMD, wetlands are smaller and less contiguous with one another in the upper watershed. Extensive palustrine wetlands are located only in certain subbasins along the upper Hackensack River (from Oradell Dam to Tappan Zee Bridge [488 acres], above the Tappan Zee Bridge [370 acres]) and along Pascack Brook (above [277 acres] and below [321 acres] Westwood Gage). Increasing the connectivity among the many small wetland areas in the upper HRW (many of which were connected previously) potentially improves: (1) water quality downstream in lower, estuarine portions of the watershed (*e.g.*, Lin and Kuo, 2003), and (2) certain ecosystem functions, such as the suitability of the wetlands to provide habitats for fish and wildlife species (*e.g.*, U.S. Fish and Wildlife Service, 1980; 1981; Brinson, 1993). Therefore, the Service recommends that, before such areas are acquired or considered for restoration, these small wetlands be assessed for fish and wildlife resources, historical connectivity, contaminants, and overall condition, potential for restoration, and water quality. An assessment will provide an essential planning step by regional and local stakeholders and decision-makers prior to acquiring and protecting these wetlands and adjoining upland sites in the upper HRW. Efforts to identify which sites to acquire, protect, and restore can be as important as efforts to identify how much area to protect (Huxel and Hastings, 1999), especially when fish and wildlife populations are supported by minimal and fragmented areas (Fahrig, 1997). Land-use activities that affect run-off and input of certain materials (*e.g.*, nutrients, contaminants) in upper portions of watersheds may significantly affect water quality of (*e.g.*, Jordan *et al.*, 1991, Mallin *et al.*, 1999), and aquatic communities in (*e.g.*, Fry, 1999), lower portions of watersheds including estuaries.

Two subbasins comprising nearly 1,000 acres of palustrine wetlands, the De Forest Lake and Hackensack-Nauranshaun confluence subbasins (Subbasins 1 and 3, respectively, in Figure 43), are located entirely in New York. Substantial palustrine wetland acreage in these subbasins is contiguous, and potentially provides habitats for species that require extensive area or are sensitive to disturbance (*e.g.*, forest-interior nesting bird species). Thus, the Service considers the acquisition and protection of these wetlands a high priority. Because upper portions of the HRW lie outside of New Jersey and the operating authorities of some stakeholders, the Service recommends that Meadowlands stakeholders include government agencies (*e.g.*, New York Department of Environmental Conservation) and NGOs (*e.g.*, the Sierra Club's Eastern New York Chapter) operating in New York to evaluate the necessity and feasibility of habitat restoration, acquisition, and protection of these wetlands. Land acquisition priorities should be based on such assessments throughout the watershed.

The greater variety of wetland landscape positions and landforms in upper portions of the Hackensack River (Figure 48; Tiner and Bergquist, 2005) generally reflects less extensive landscape alteration and land-use of the upper watershed (Section V.D below). Substantial acreage of lentic (449 acres), lotic (riverine, 466 acres; stream, 1,611 acres), and terrene (843 acres) wetlands is present throughout the upper watershed (Table 25; Figure 48; Tiner and Bergquist, 2005). Most lentic wetlands occur in subbasins located: (1) in the most northern portion the watershed, (2) along Pascack Brook, and (3) east of the Oradell Reservoir. As

Table 25. Acreage of wetlands by National Wetland Inventory type and landscape position in subbasins (ID number as in Figure 43) in the Hackensack River watershed that are located outside of the Hackensack Meadowlands District (from Tiner and Bergquist, 2005 and Tiner *et al.*, 2005).

Hackensack River Watershed Subbasin (ID number)	Estuarine Acreage	Lentic Acreage	Lotic River Acreage	Lotic Stream Acreage	Terrene Acreage	Total Wetland Acreage
Coles Brook/Van Saun Mill Brook (12)	--	--	3.9	92.6	19.8	116.3
De Forest Lake (1)	--	45.1	--	280.0	114.0	439.1
Dwars Kill (8)	--	84.8	--	240.8	77.3	402.9
Hackensack-Nauranshaun Confluence (3)	--	211.5	23.9	204.2	120.2	559.8
Hackensack River;						
Ft. Lee to Oradell Gage (11)	1.0	--	79.8	13.5	15.4	109.7
above Tappan Zee Bridge (5)	--	5.8	148.2	145.2	71.0	370.2
Oradell to Tappan Zee Bridge (6)	--	3.3	31.4	248.3	205.8	488.8
Hirshfeld Brook (10)	--	--	--	26.3	--	26.3
Pascack Brook above Westwood Gage (4)	--	27.6	36.7	132.7	80.4	277.4
Pascack Brook below Westwood Gage (7)	--	41.8	129.6	123.4	26.2	321.0
Tenakill Brook (9)	--	28.6	11.6	102.7	43.9	186.8
Upper Pascack Brook (2)	--	--	0.6	1.3	68.9	70.8
Total acreage	1.0	448.5	465.7	1,611	842.9	3,369

expected, lotic riverine wetlands occur in subbasins located along the Hackensack River (Ft. Lee to Oradell, Oradell to Tappan Zee Bridge, and above Tappan Zee Bridge) and the Pascack Brook (above and below Westwood Gage), whereas lotic stream wetlands occur within most subbasins in the upper watershed. For most wetland types in the upper watershed, basin (located in a distinct depression) and flat (located in a relatively level landscape) wetlands are the most common wetland landforms in the upper HRW (Tiner and Bergquist, 2005). These wetlands, like others in northeastern New Jersey, likely remain under considerable threat from development (U.S. Department of the Interior, 1994; New Jersey Meadowlands Commission, 2004d); thus, the Service reiterates the recommendation to acquire and protect remaining wetlands in accordance with a prioritized acquisition/restoration plan for the watershed developed by the principals' group.

3. Fragmentation

Fragmentation, any disruption in the continuity within an ecosystem, is recognized as a primary concern in conservation biology (Lord and Norton, 1990; Meffe and Carroll, 1997). An example is the breaking up of a large intact area, such as a forest or wetland, into smaller areas, which fragments habitats for individual species. Such habitat fragmentation is widely recognized as a threat to biodiversity (Wilcox and Murphy 1985; Lord and Norton, 1990). Fragmentation may exacerbate the problem of habitat loss: as large continuous parcels are disrupted by roads, power lines, culverts, or stands of non-native vegetation, remaining areas become too small (area or scale effect), too distant (isolation effect), and too influenced by habitat discontinuities (edge effect) to support viable populations or even individuals of some species (Fagan *et al.*, 1999; Franklin *et al.*, 2002). Basically, habitat suitability for some species is decreased by fragmentation even without any other changes. For example, predatory animals requiring large areas of contiguous habitat may be sensitive to discontinuities in or the arrangement or shape of a habitat (Fahrig, 2003). Movements among isolated habitat islands may be greatly reduced (*e.g.*, amphibians, Lehtinen *et al.*, 1999), even for species able to traverse considerable distances (*e.g.*, certain migratory bird species; Belisle and St. Clair, 2001). Dispersal of propagules (*e.g.*, plant seeds; Soons *et al.*, 2004) and colonization of isolated habitat "islands" (including restored sites; *e.g.*, Huxel and Hastings, 1999) may also be affected. Interactions of species with predators, competitors, and parasites also may change along the edges of different habitats (*e.g.*, Bolen and Robinson, 2003; Patten and Bolger, 2003). The conservation community has been as concerned for the potential adverse effects of fragmentation in the Meadowlands as for the actual loss and deterioration of quality of habitats, and has emphasized the importance of protecting, restoring, and maintaining large blocks of wetlands and other open space to provide habitats for fish and wildlife (U.S. Fish and Wildlife Service *et al.*, 2000).

Certain effects of fragmentation can be especially pronounced in suburban and urban areas (Fahrig, 2003). First, fragmentation in developed landscapes changes physical features of remaining habitats. For example, fragmentation increases solar radiation reaching the ground, which contributes to lower soil moisture and other conditions (*e.g.*, low soil fertility, increased soil erosion) that increase tree death in urban areas (Soulé, 1991). Second, invasive species are more likely to invade and adversely affect fragmented and other disturbed systems (Marvier *et al.*, 2004; With, 2004). Third, though not generally considered invasive species, domestic dogs (*Canis familiaris*) and cats (*Felis silvestris*) that roam free in urban areas also have adverse

impacts on wildlife (Crooks and Soulé, 1999). Domestic cats especially kill considerable numbers of birds and other wildlife (*e.g.*, Coleman and Temple, 1996; Lepczyk *et al.*, 2003). Finally, fragmentation exacerbates certain human disturbance problems, such as unauthorized use of off-trail areas and accidental fires, which may further degrade wildlife habitats (*e.g.*, Watts, 2000).

The Tiner and Bergquist (2005) preliminary assessments indicate that fragmentation due to roadways is a greater problem in the HMD than elsewhere in the HRW. Numerous roadways and railways cross the Meadowlands; some roadways and railways are elevated along much of their length, whereas others have been built atop causeways that completely sever surface water flows. Indices of habitat fragmentation due to roadways (Table 26) indicate that, on average, nearly twice as much area is occupied by roadways in each subbasin of the HMD (Index average = 0.76) compared to other subbasins in the HRW (Index average = 0.41; Table 26).

Certain wildlife species recognized as most susceptible to fragmentation are disappearing from the HMD. For example, northern harrier, a State-listed species that has large territorial requirements (MacWhirter and Bildstein, 1996; Temeles, 1989), has disappeared along Penhorn Creek, where filling has reduced and fragmented remaining wetlands. Two other State-listed species occurring in the Meadowlands (savannah sparrow and bobolink) are sensitive to fragmentation (Swanson, 1996). For example, bobolink breed in grasslands as small as 5 to 10 acres but have higher nest densities and reproductive success in larger fields (Jones and Vickery, 1997). The NJDEP, NJMC, and other stakeholders should consider potential fragmentation effects in developing a wildlife management plan for the HMD (Section X.E). Government agencies (during regulatory and zoning [permit] processes) and other stakeholders should also consider the need for, and alternatives to, any proposed projects that would further fragment remaining wetlands in the Meadowlands. In addition, stakeholders should seek diverse and innovative means of addressing the historic fragmentation of the Meadowlands and its impacts to fish and wildlife resources. For example, long-range planning for future transportation (and other public) projects should consider ways to reverse and rectify the impacts of previous public projects that initially fragmented and altered the hydrology of wetlands. One stated intent of Executive Order 13274 ("Environmental Stewardship and Transportation Infrastructure Project Reviews") is for federal agencies to promote environmental stewardship in the Nation's transportation system and to "advance environmental stewardship through cooperative actions with project sponsors to promote protection and enhancement of the natural and human environment in the planning, development, operation, and maintenance of transportation facilities and services." Without addressing and rectifying the historical fragmentation impacts on the Meadowlands, functional restoration will be difficult if not impossible to achieve.

4. Other Wetland Disturbances

Many types of human disturbance to wetlands in the HMD are commonly recognized; however, relatively few efforts have been made to assess certain other types of disturbance and their adverse effects on different wetlands within the Meadowlands. For example, most small

Table 26. Three different measures of habitat disturbance for subbasins in the Hackensack Meadowlands District (HMD) and elsewhere in the Hackensack River watershed (HRW; from Tiner and Bergquist, 2005 and Tiner *et al.*, 2005). The Habitat-Fragmentation by Roadway Index (I_{HFR}) indicates the area in a subbasin relative to Secaucus, New Jersey, a "built-out" urban city in which 6 percent of the land area is occupied by roadways. The Channelized-Stream Length Index (I_{CSL} = sum of channelized stream lengths / sum of total stream lengths) is a measure of stream alteration, whereas the Index of Wetlands Disturbance (I_{WD} = is the area of disturbed [*e.g.*, diked, ditched] wetlands / total area of wetlands) indicates the percentage of the wetland area in which the land is disturbed or the local hydrology has been altered. High indices reflect greater alteration of wetlands; note that nearly all indices indicate greater alteration of wetlands in the HMD in comparison to the HRW.

HMD Subbasin (ID number)	Wetland Acreage	I_{HFR}	I_{CSL}	I_{WD}
Berry's Creek above Paterson Ave. (16)	392	0.61	1.00	0.61
Berry's Creek below Paterson Ave. (17)	948	0.72	--	0.87
Hackensack River, Amtrak Bridge to Rt. 3 (18)	1,469	0.56	1.00	0.55
Overpeck Creek (14)	65	0.69	0.56	0.36
Hackensack River, Bellman's Creek to Ft. Lee Rd. (13)	651	0.77	0.88	0.72
Hackensack River, Rt. 3 to Bellman's Creek (15)	1,456	0.91	--	0.69
Hackensack River, below Amtrak Bridge (19)	596	0.82	1.00	0.77
Lower Passaic River (20)	268	1.00	--	0.99
	HMD averages	0.76	0.89	0.70
HRW Subbasin (ID number)				
Coles Brook/Van Saun Mill Brook (12)	149	0.58	0.13	0.10
De Forest Lake (1)	1,297	0.34	0.29	0.66
Dwars Kill (8)	583	0.26	0.09	0.07
Hackensack-Nauranshaun Confluence (3)	1,104	0.58	0.29	0.41
Hackensack River, Ft. Lee to Oradell Gage (11)	118	0.54	0.03	0.10
Hackensack River, above Tappan Zee Bridge (5)	536	0.26	0.19	0.72
Hackensack River, Oradell to Tappan Zee Bridge (6)	699	0.31	0.24	0.63
Hirshfeld Brook (10)	41	0.54	0.36	0.12
Pascack Brook above Westwood Gage (4)	511	0.41	0.09	0.41
Pascack Brook below Westwood Gage (7)	402	0.36	0.45	0.18
Tenakill Brook (9)	204	0.38	0.43	0.45
Upper Pascack Brook (2)	402	0.40	0.67	0.34
	HRW averages	0.41	0.27	0.35

waterways (*e.g.*, 63 percent of the total length of streams) in the HMD have been altered by channelization and dredging; however, stream channelization is more extensive in some subbasins (*e.g.*, lower Berry's Creek) than in others (*e.g.*, Overpeck Creek; Table 26; Tiner and Bergquist, 2005). Also, water flow on more than 60 percent of the wetland area within the HMD has been disrupted as a result of diking, ditching, and filling (Table 26; Tiner and Bergquist, 2005). Assessments of disturbance across the landscape must be expanded to include factors such as the extent of impervious cover, and roadway and traffic effects (Spellerberg, 2002) when planning any remediation and restoration activities in the Meadowlands (Louis Berger Group Inc., 2004a; Tiner and Bergquist, 2005).

Some disturbances to wetlands in the Meadowlands are widespread but have never been carefully evaluated for their actual or potential effects, especially cumulative adverse impacts, on fish and wildlife resources. For example, a number of communication towers and power lines have been located in wetlands in the Meadowlands. Some of these structures have the potential to cause substantial mortality of migratory birds through electrocution and collision with guywires and the towers themselves, especially during the periods of peak migration (Shire *et al.*, 2000; Edison Electric Institute and U.S. Fish and Wildlife Service, 2005). However, neither individual nor cumulative impacts of these structures in the HMD have been adequately assessed. Tidegates, bulkheads, and other flood control structures have been placed in many creeks within the HMD to prevent flooding (Section IV.B). Such structures have adverse impacts on fish and wildlife resources, such as facilitating spread of invasive species (Roman *et al.*, 1984) or reducing occurrence of rare species (Chapman, 2003; Giannico and Souder, 2004); however, cumulative effects of flood control structures have not been assessed in the HMD. The Service is committed to improving assessment, and reducing adverse impacts of, communication towers, wind turbines, and certain other features of the built environment (*e.g.*, roads) on fish and wildlife populations (*e.g.*, Interim Guidance on Avoiding and Minimizing Wildlife Impacts from Wind Turbines, *Federal Register*, July 10, 2003, Volume 68, Number 132). Regional stakeholders and decision-makers should pursue assessment of cumulative impacts of the above-mentioned structures on fish and wildlife resources in the Meadowlands and seek to identify creative and feasible means to mitigate any current and future impacts.

5. Wetlands Functioning in the HMD and the Hackensack River Watershed

Preliminary assessments indicate that wetlands remaining in the HMD provide many commonly recognized wetland functions (Tiner and Bergquist, 2005). For example, the estuarine wetlands that occur throughout the HMD have considerable potential to provide coastal storm surge detention (Figure 49) and nutrient transformation (Figure 50). In addition, different habitats within those estuarine wetlands are also critical for sustaining the Meadowlands biodiversity, such as waterfowl and waterbirds (Figure 51), though these habitats will require further assessment and consideration of contaminant loads. Tiner and Bergquist's (2005) preliminary assessments are based on studies from other ecosystems and do not incorporate the potential adverse effects of environmental contaminants. Thus, in some ways, these assessments represent the potential for the Meadowlands to sustain fish and wildlife subsequent to determining whether appropriate remediation and restoration are feasible. In any case, additional study is clearly needed to assess cumulative adverse impacts resulting from land use and other human activities throughout the HRW in addition to contaminant and hydrological obstacles.

Figure 49. Wetlands of potential significance for coastal storm surge detention in the Hackensack River watershed (from Tiner and Bergquist, 2005). Note that wetlands with high potential are located almost entirely in the Hackensack Meadowlands District.

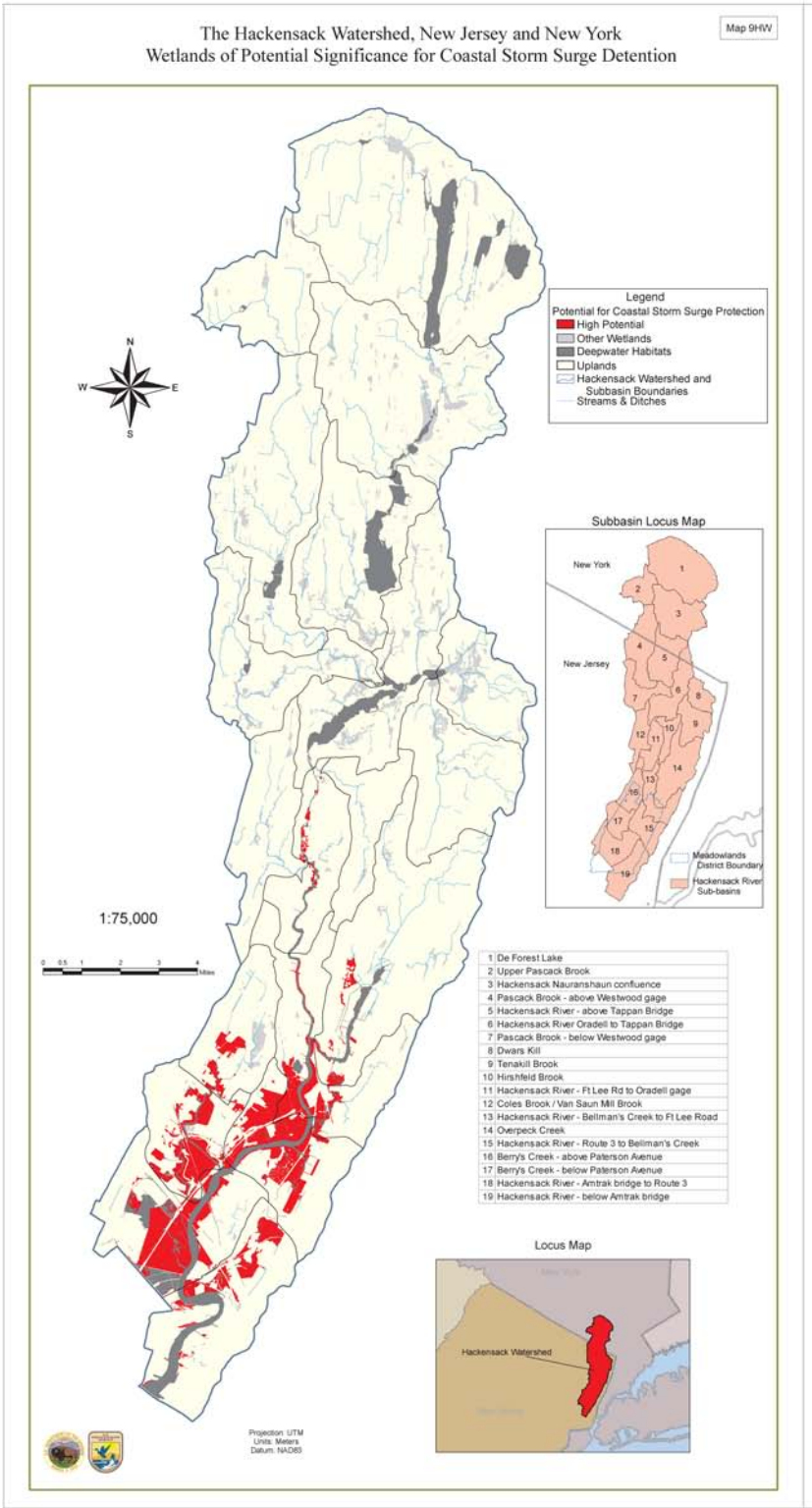


Figure 50. Wetlands of potential significance for nutrient transformation in the Hackensack River watershed (from Tiner and Bergquist, 2005). Estuarine and palustrine wetlands throughout the watershed have the potential to transform nutrients and improve water quality.

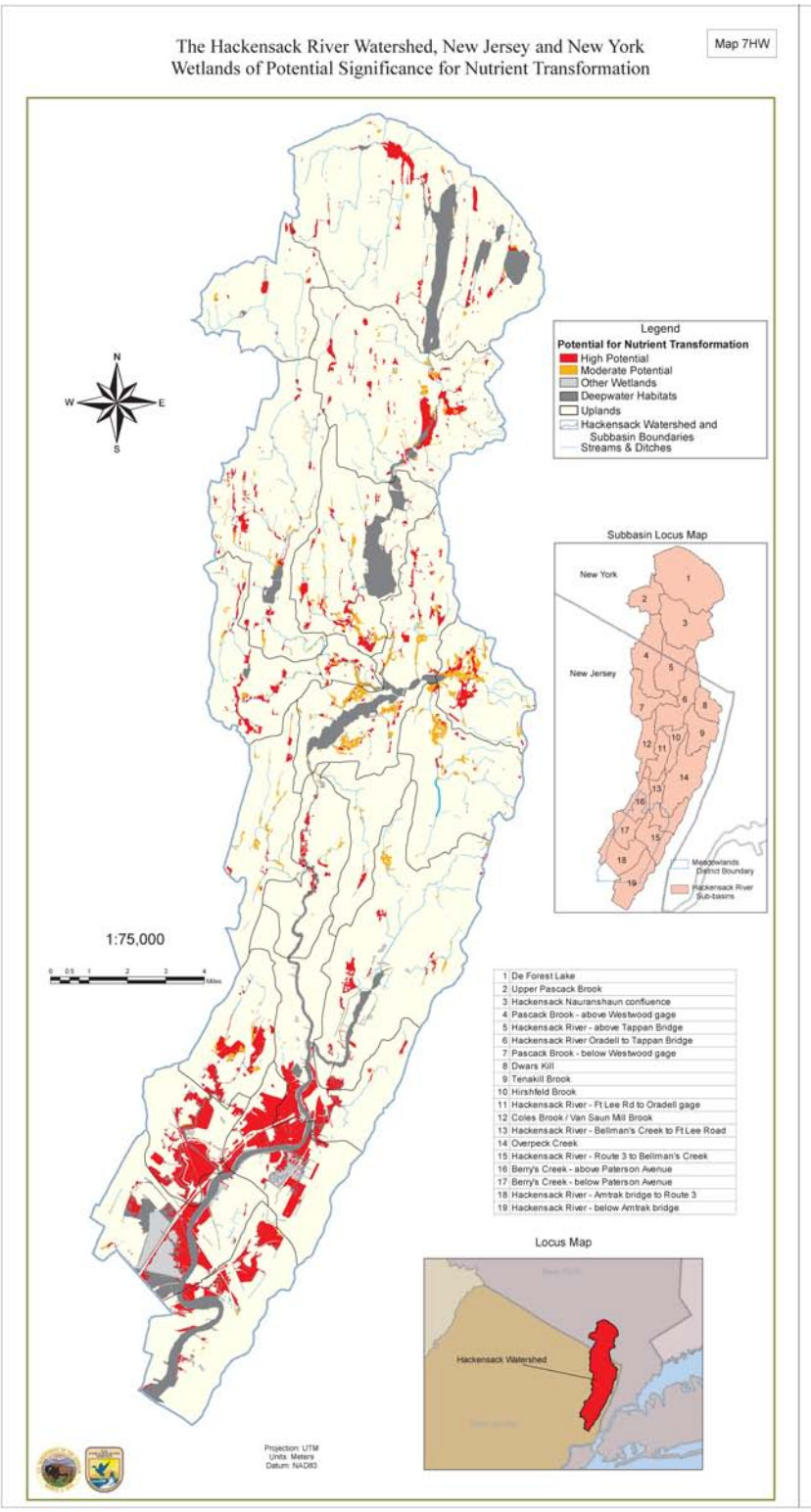
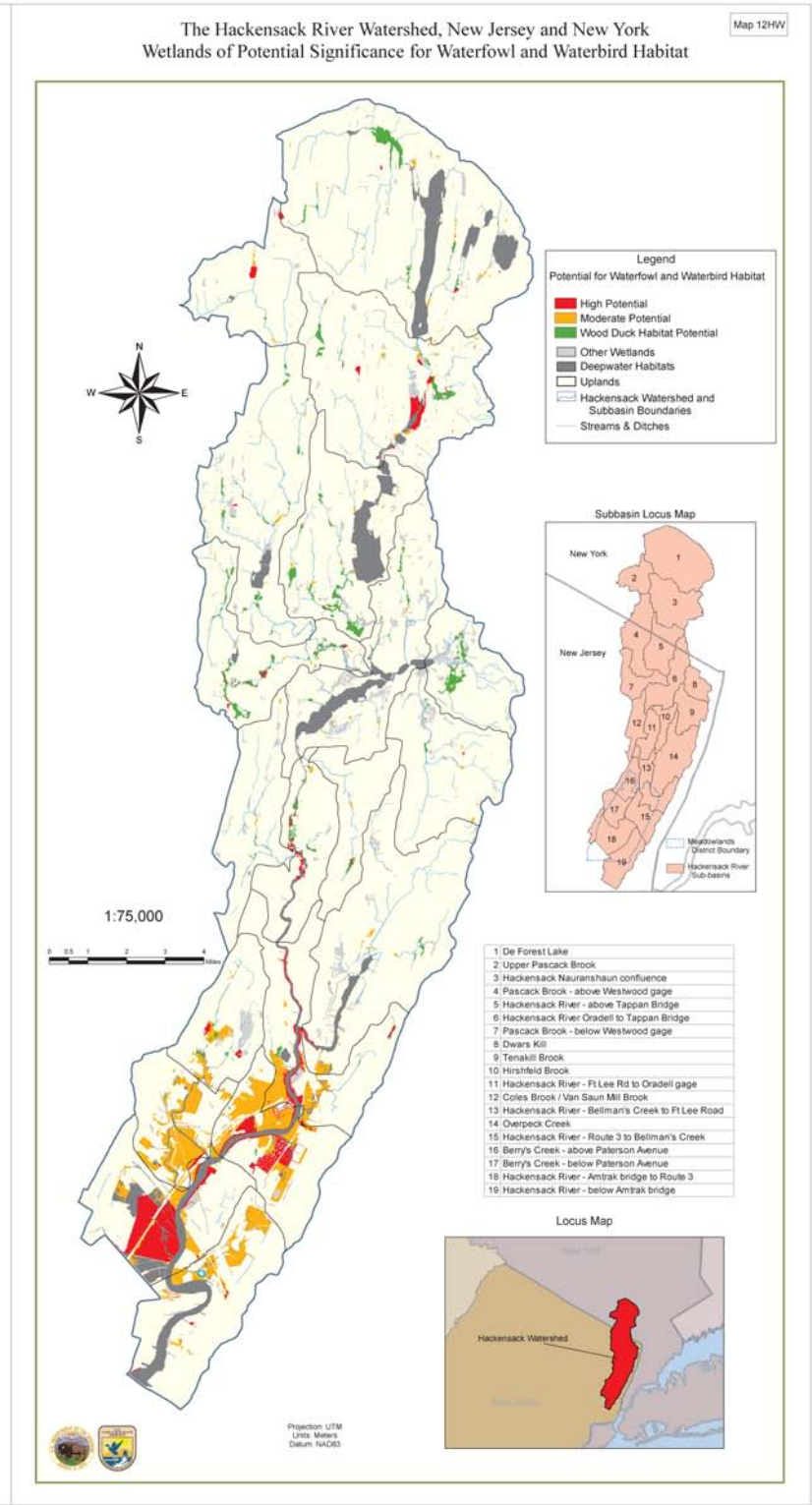


Figure 51. Wetlands of potential significance for waterfowl and waterbirds in the Hackensack River watershed (from Tiner and Bergquist, 2005). Certain estuarine, lotic riverine, and lotic stream habitats have high or moderate potential to support waterfowl and waterbirds.



In summary, preliminary assessments indicate that the extensive palustrine wetlands that occur throughout the HRW are important to restoring the Meadowlands and to sustaining its fish and wildlife resources. For example, palustrine wetlands throughout the HRW appear to be important sites for nutrient transformation (Figure 50; Tiner and Bergquist, 2005) and thus improve water quality in lower portions of the watershed. Palustrine wetlands also maintain stream flows in upper portions of the watershed (Figure 52); maintenance of stream flows is important for water quality and sustaining the biodiversity in the upper portions of the watershed (Figure 53). Preliminary assessments indicate that wetlands in upper portions of the watershed are less disturbed than those in the Meadowlands and are located within a less-developed upland landscape (Tiner and Bergquist, 2005). The quality of wetlands in the upper watershed must be protected because water quality and biodiversity in the entire watershed depend, in part, on them. Stakeholders need to expand their efforts to evaluate and protect land and water use in the upper HRW as part of any overall strategic restoration effort for the Meadowlands.

D. UPLAND LANDSCAPE COVER, LAND USE, BUFFERS, AND CORRIDORS

1. Upland Landscape Cover and Land Use

Landscape cover throughout the HRW and the HMD has been altered extensively to accommodate human activities and land uses that are typical of the heavily populated northeastern United States. Approximately 70 percent of the Hackensack-Pascack watershed (Figure 54) that lies within the State of New Jersey has been developed for human use and is defined as "urban" (New Jersey Department of Environmental Protection, 2004b; Tiner and Bergquist, 2005). As defined by NJDEP (2004c), the urban land-use classification includes land primarily developed for industrial, commercial, residential, utility, and transportation uses. Agricultural and certain barren lands (*e.g.*, landfills, recently cleared areas) occupy less than 1 percent of the HRW within the State of New Jersey. Natural landscape types remaining within the entire watershed include forests (13.6 percent), open water (2.6 percent), and wetlands (4.7 percent; Table 27; New Jersey Department of Environmental Protection, 2004c). Extensive alteration of the landscape emphasizes the importance of comprehensive efforts to preserve open space remaining throughout the watershed for fish and wildlife and other functions.

The natural vegetative cover on nearly all uplands in the HMD has been altered to accommodate past and present human land uses (Figure 55). Except for landfills, recreation areas, some vacant and transitional lands, and a few other areas (*e.g.*, open area around Teterboro airport runways), most upland areas within the HMD are developed for transportation, industrial, utilities, government, commercial, residential, communication, or other purposes (Table 27; New Jersey Meadowlands Commission, 2004d). Until recently, common reed, other grasses, and scrub-shrub vegetation covered more than 1,400 acres of closed landfills; however, approximately 45 percent of that land cover has been cleared to accommodate landfill remediation and closure, and subsequent redevelopment (*i.e.*, EnCap's Meadowlands Golf Project). Fewer than 100 acres of forested uplands occur throughout the HMD. Despite the extensive alteration of natural landscape cover within the HMD, urban and other human land-uses within the HMD occupy a less extensive area percentage-wise in the HMD (59 percent; 11,457 acres) than in the entire HRW and in many other coastal watersheds (Pew Oceans Commission, 2004). Again, although

greatly reduced from its historical dimensions, the extensive acreage of remaining wetlands and waterways within the HMD as compared to the remainder of the watershed underscores the importance of restoring and protecting its aquatic and adjoining terrestrial habitats.

Table 27. Acreage and percent of upland landscape cover and land use in the Hackensack Meadowlands District (HMD) and that portion of the Hackensack River watershed (HRW) in New Jersey. Because information sources include the NJMC, NJDEP, and the Service (*i.e.*, Tiner and Bergquist, 2005 and Tiner *et al.*, 2005), acreage totals may vary slightly from other estimates for the HMD. Percentages pertain to the respective area (HMD or HRW). Dashes (--) indicate the cover type was not reported.

	HMD		HRW	
Landscape Cover or Land Use	Acres	Percent	Acres	Percent
Open water	1,870	9.6	2,397	2.6
NWI wetlands	5,784	29.7	4,402	4.7
Forested uplands	92	0.5	12,778	13.6
Herbaceous/shrub	282	1.4	--	--
Agricultural	0	0.0	230	0.2
Altered and vacant lands	1,800	9.2	1,200	1.3
Recreational lands	757	3.9	--	--
Urban	8,900	45.7	72,935	77.6
Total	19,485		93,942	

Figure 52. Wetlands of potential significance for streamflow maintenance in the Hackensack River watershed (from Tiner and Bergquist, 2005). These headwater areas contribute to improved water quality in lower portions of the watershed.

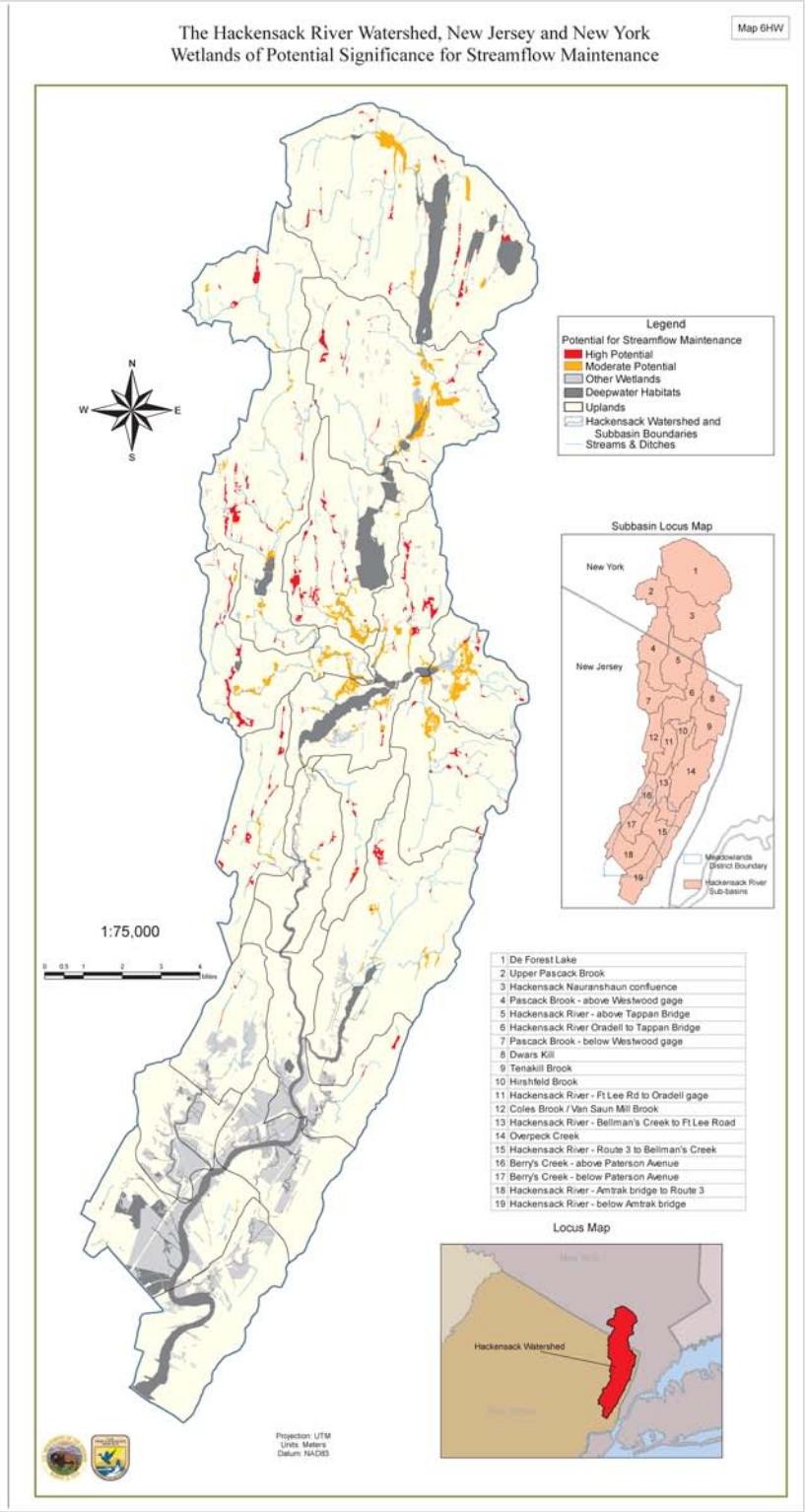


Figure 53. Wetlands of potential significance for sustaining biodiversity in the Hackensack River watershed (from Tiner and Bergquist, 2005). Estuarine and palustrine wetlands throughout the watershed help sustain the biodiversity of the Meadowlands and the region.

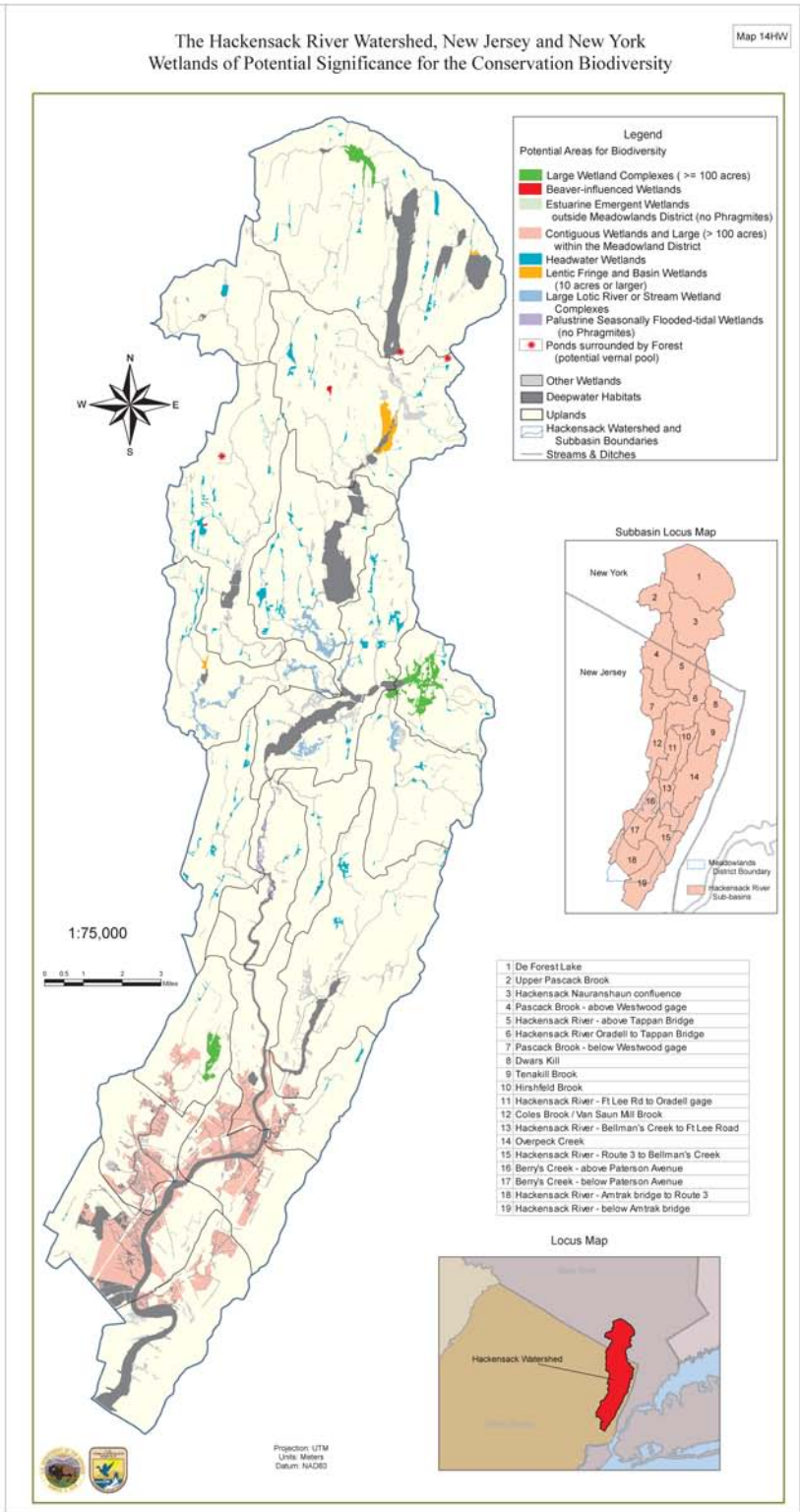


Figure 54. The extent of natural (upland and wetland) habitat in the Hackensack River watershed (from Tiner and Bergquist, 2005). The Hackensack Meadowlands District includes the most extensive area of natural habitat remaining in the entire watershed.

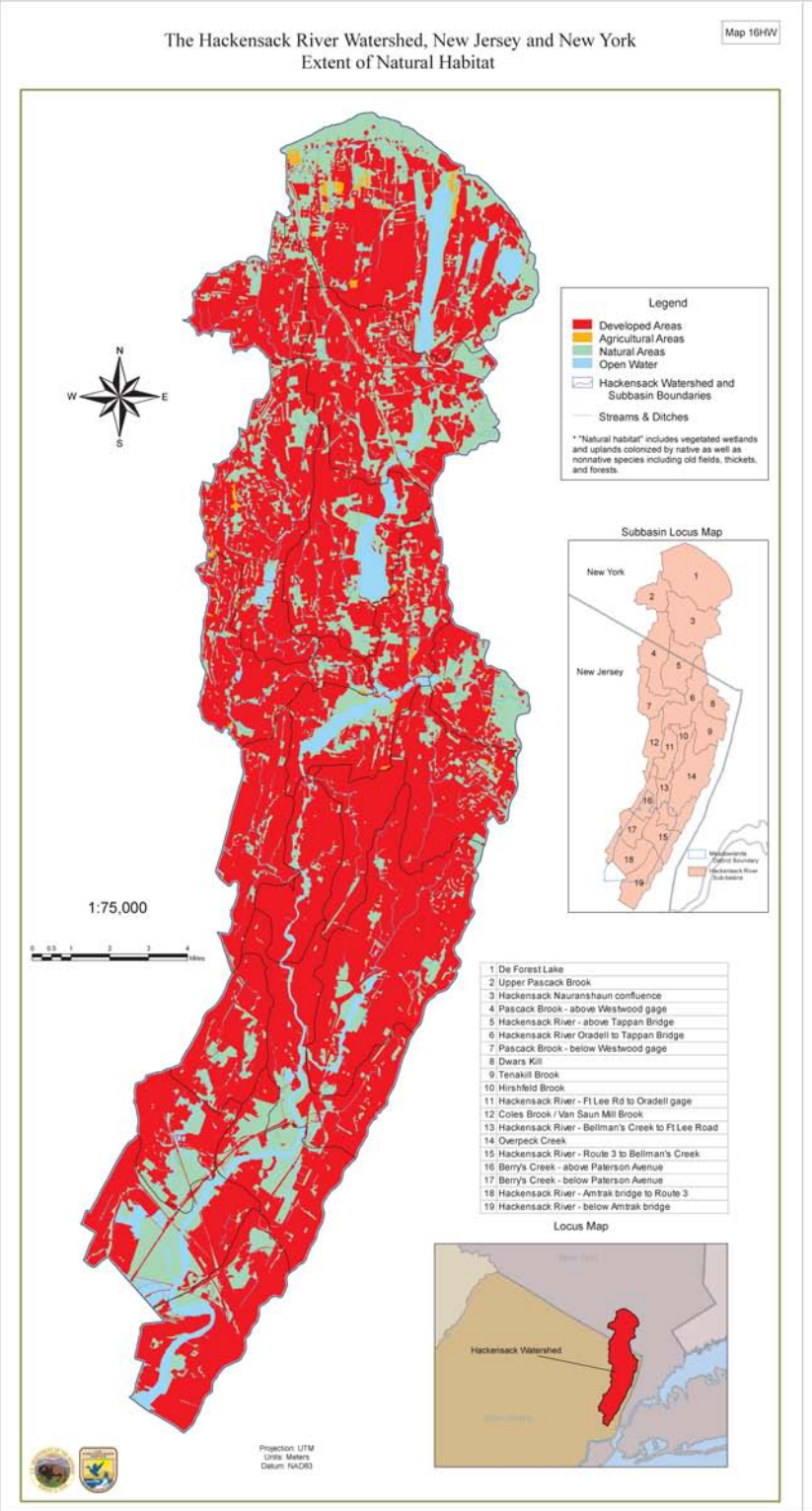
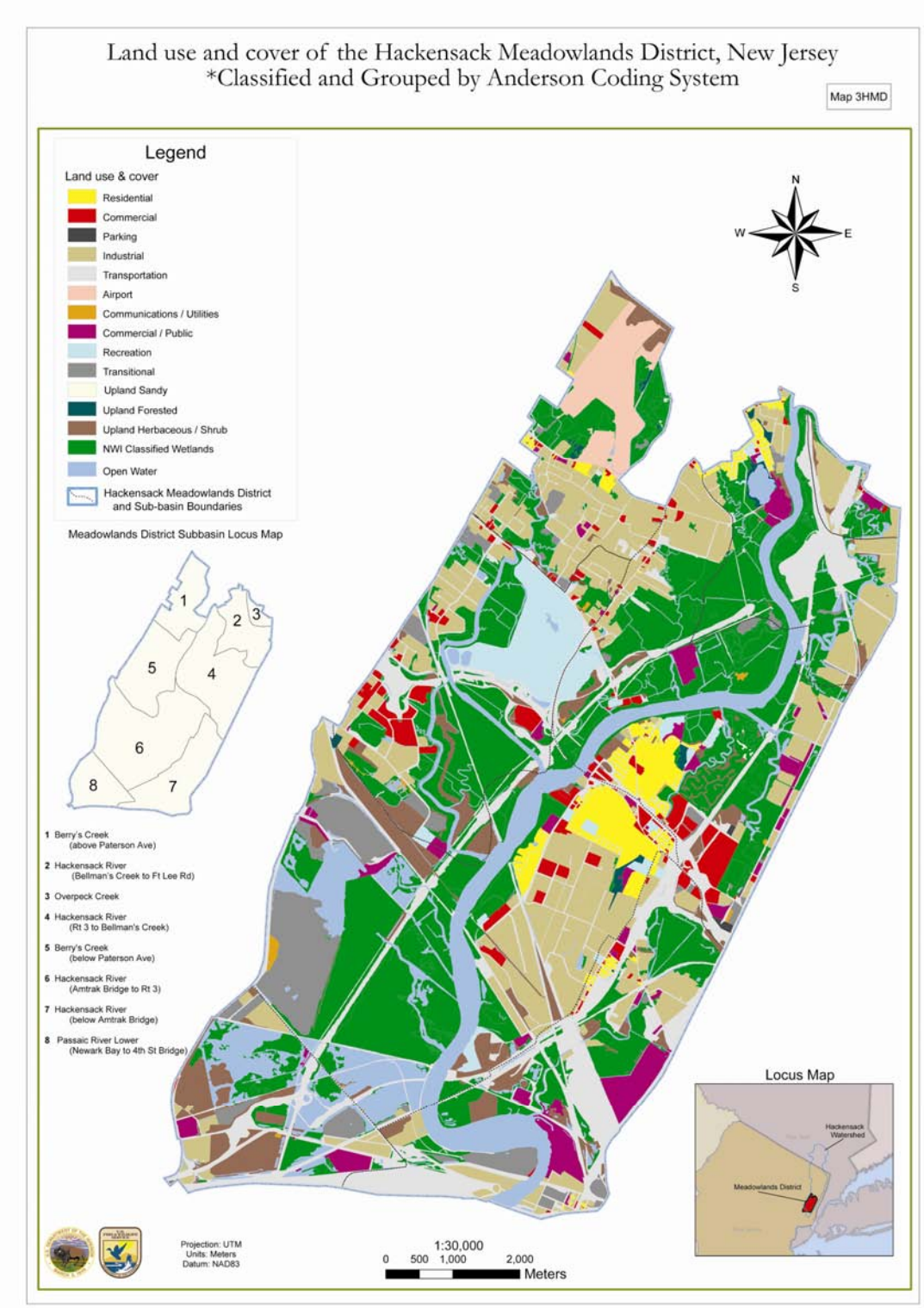


Figure 55. Land use and landscape cover in the Hackensack Meadowlands District (HMD; from Tiner *et al.*, 2005). Uplands in the HMD are extensively developed; however, its remaining wetlands and waterways are among the largest open areas in the northeastern United States.



2. Upland and Riparian Buffers

The term *buffer* is most often applied to areas that separate natural lands from lands modified for human activities, such as agriculture; however, *buffer* is used in this document to describe all lands that adjoin wetlands or waterways. Buffers include vegetated upland and transitional riparian areas (see below) that protect wetlands from disturbances and adjacent land uses and support ecosystem functions of wetlands (*e.g.*, Bren, 1993; Castelle *et al.*, 1994; Leavitt, 1998; Wenger, 1999; Fischer and Fischenich, 2000). Buffers provide or support many ecosystem functions by: (1) trapping sediment and controlling erosion, (2) storing and moderating the flow of storm and flood waters, (3) processing certain nutrients (*e.g.*, nitrates) and contaminants (*e.g.*, heavy metals), and (4) providing habitats for aquatic and terrestrial organisms (*e.g.*, Naiman *et al.*, 1993; Schueler, 1994; Weller *et al.*, 1998). In addition, buffers offer recreational and educational opportunities and improve aesthetics, and may increase property values (Wenger, 1999). Riparian areas[1] are increasingly recognized as dynamic, functionally unique components of wetland buffers (*e.g.*, Naiman and Descamps, 1997). Riparian areas typically comprise a small percentage of the landscape, harbor a disproportionately high number of wildlife species, perform disparate ecological functions when compared to most upland cover types (*e.g.*, biogeochemical cycling), and have become a major focus in the restoration and management of landscapes (Knopf *et al.*, 1988; Naiman and Descamps, 1997; Allan, 2004).

The extent to which riparian and other buffer areas affect wetland functioning and biodiversity varies with buffer and wetland characteristics (*e.g.*, Castelle *et al.*, 1994; Weller *et al.*, 1998). Buffer width and extent, wetland hydraulics, the vegetative community, and other features affect the retention and discharge of sediment and nutrients into wetlands. For example, buffer widths between 5 and 50 m are often identified as critical to maintaining water quality (*e.g.*, Lynch *et al.*, 1985; Lowrance, 1992); however, buffer widths between 100 and 500 m are identified as critical to sustaining biodiversity (*e.g.*, Keller *et al.*, 1993; Whittaker and Montevecchi, 1999; Fischer and Fischenich, 2000). Thus, the Service recommends that restoration planning include identification of buffer widths and other features necessary to protect water quality and provide habitats for key species (*e.g.*, amphibians, reptiles such as diamondback terrapin, migratory birds, and mammals such as muskrat) in the Meadowlands ecosystem and throughout the HRW.

Preliminary assessments employing 100-m-wide buffers indicate that buffers throughout the watershed, and especially in the HMD, are in poor condition (Tiner and Bergquist, 2005; Tiner *et al.*, 2005). Approximately 35 percent of the wetland-buffer area throughout the HRW is vegetated; however, only 13 percent of the wetland-buffer area in the HMD is vegetated (Figure 56; Table 28). (For perspective, the extent of buffers in subbasins of the Nanticoke River, Delaware watershed, which is considered heavily impacted by agricultural activities, averages approximately 40 percent [Tiner, 2004]). Buffers around wetlands in all subbasins throughout the HMD have little vegetation; most buffer areas in the HMD are developed (Figure 56). Transitional lands (mostly landfill) also occupy a considerable portion of the wetland buffers; this indicates the importance of remediating and restoring transitional areas to prevent further degradation of water quality and provide habitat for fish and wildlife. Vegetation covers roughly 35 percent of the 100-m-wide corridor along each side of non-tidal rivers and streams throughout

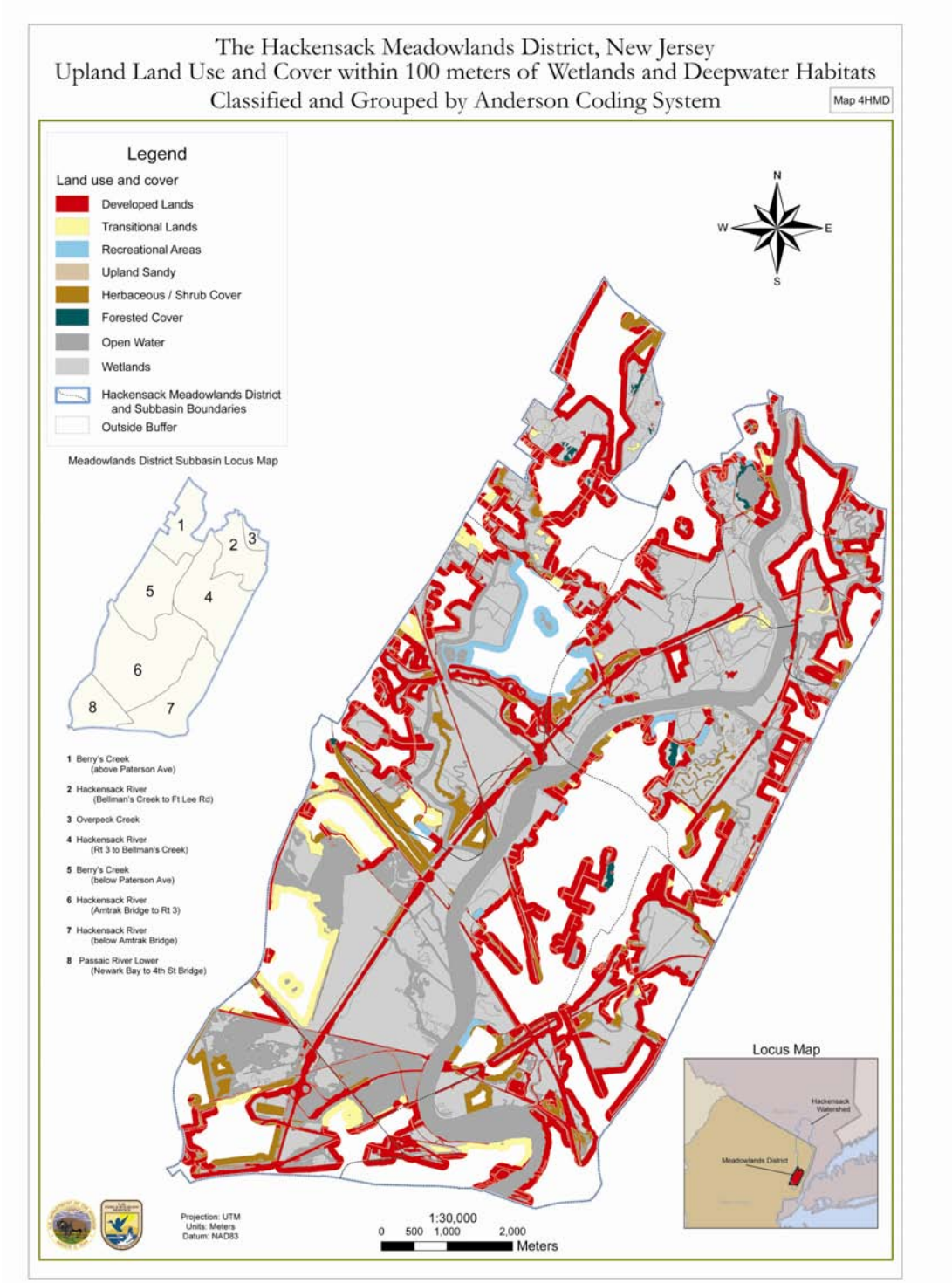
[1] Riparian areas- vegetated areas adjacent to streams, rivers, lakes, reservoirs, and other inland aquatic systems that affect or are affected by the presence of water

the HRW; however, few basins in the HMD have such non-tidal buffers (Table 28). In addition to wetland buffers, the extent of buffers around ponds and lakes is greater in the watershed (37 percent) than in the HMD (16 percent). The only extensively vegetated pond/lake buffer in the HMD occurs around Mehrhof Pond; this high-quality buffer contributes to the high Pond and Lake Buffer Index for the Hackensack River subbasin from Bellman's Creek to Fort Lee Road (Table 28). The poor condition of all buffers undoubtedly contributes to poor water quality and other adverse impacts upon biodiversity in the HMD.

Table 28. Wetland, river and stream, and pond and lake buffers for subbasins (ID number as per Figure 43) in the Hackensack Meadowlands District (HMD) and elsewhere in the Hackensack River watershed (HRW; from Tiner and Bergquist, 2005 and Tiner *et al.*, 2005). Indices of: (1) vegetated wetland buffers (I_{VWB} = area of 100-m buffer around wetlands that is vegetated / total area of the 100-m buffer around wetlands), (2) of river and stream buffers (I_{RSC} = area of 100-m buffer around rivers and streams that is vegetated / area of the 100m-buffer around rivers and streams), and (3) of pond and lake buffers (I_{PLB} = area of 100-m wide buffer around ponds and lakes that is vegetated / total area of the 100-m buffer around ponds and lakes). The low indices reflect the limited extent of vegetation in most buffer areas, and suggest impaired ecosystem functioning and reduced capacity to support biodiversity throughout the watershed.

Hackensack Meadowlands District (Subbasin ID number)	I_{VWB}	I_{RSC}	I_{PLB}
Berry's Creek above Paterson Ave. (16)	0.13	0.46	0.04
Berry's Creek below Paterson Ave. (17)	0.14	--	0.06
Hackensack River, Amtrak Bridge to Rt. 3 (18)	0.18	--	0.03
Overpeck Creek (14)	0.03	--	0.00
Hackensack River, Bellman's Creek to Ft. Lee Rd. (13)	0.07	0.48	0.48
Hackensack River, Rt. 3 to Bellman's Creek (15)	0.12	--	0.08
Hackensack River below Amtrak Bridge (19)	0.15	0.11	0.26
Lower Passaic River (20)	0.24	--	0.33
HMD averages	0.13	0.35	0.16
Hackensack River Watershed (Subbasin ID number)			
Coles Brook/Van Saun Mill Brook (12)	0.11	0.18	0.15
De Forest Lake (1)	0.51	0.44	0.56
Dwars Kill (8)	0.56	0.64	0.68
Hackensack-Nauranshaun Confluence (3)	0.47	0.41	0.56
Hackensack River, Ft. Lee to Oradell Gage (11)	0.11	0.33	0.07
Hackensack River, above Tappan Zee Bridge (5)	0.61	0.45	0.45
Hackensack River, Oradell to Tappan Zee Bridge (6)	0.50	0.47	0.54
Hirshfeld Brook (10)	0.11	0.12	0.08
Pascack Brook above Westwood Gage (4)	0.26	0.41	0.39
Pascack Brook below Westwood Gage (7)	0.19	0.35	0.27
Tenakill Brook (9)	0.29	0.27	0.33
Upper Pascack Brook (2)	0.49	0.08	0.36
HRW averages	0.35	0.35	0.37

Figure 56. Wetland buffers in the Hackensack Meadowlands District (HMD; from Tiner *et al.*, 2005). Land-use activities in the 100-m-wide area surrounding wetlands were characterized for the entire HMD and for each hydrologic subbasin. Only 13 percent of the buffer areas surrounding the HMD's wetlands are vegetated; the poor condition of buffers likely contributes to poor water quality, impaired ecosystem functions, and low biodiversity.



Buffer requirements throughout much of New Jersey have recently changed as part of the State's new stormwater regulations (*i.e.*, Phase II New Jersey Pollutant Discharge Elimination System Stormwater Regulation Program Rules [N.J.A.C. 7:14A] and the Stormwater Management Rules [N.J.A.C. 7:8]) to increase buffer width (up to 300 feet in certain areas) to provide better protection of wetlands and waterways, especially where water quality is good. Within the HMD, the buffer requirements are established by the NJMC's Zoning Regulations. Because land-use and runoff effects on water quality vary considerably (Pitt, 2003), the Service recommends that the NJMC evaluate the effects of its buffer requirements on water quality and modify the regulations as needed to reduce impairments to water quality in the Hackensack River and its tributaries (See Section IV.B for additional information about stormwater effects.).

3. Upland Corridors

Landscape connectivity generally enhances population sustainability for many species (*e.g.*, Meffe and Carroll, 1997; Primack, 2002). Certain human land-use activities (*e.g.*, wetland filling, transportation development, urbanization) are recognized as severing connectivity between wetland and upland landscapes. As a result, retaining, enhancing, and creating habitat corridors have been widely advocated as means of sustaining biodiversity, and consequently, as important to conservation planning (*e.g.*, Fahrig and Merriam, 1994; Beier and Noss, 1998; Rosenberg *et al.*, 1998). However, demonstrating the utility of corridors has been difficult due to experimental and statistical problems (Beier and Noss, 1998). For example, connecting two areas with a corridor may be no more effective than simply increasing the size of one of the areas. In addition, corridors may: (1) promote the spread of pathogens and invasive species, (2) increase mortality; and (3) have high acquisition costs in comparison with acquisition costs of other natural areas (*e.g.*, Hobbs, 1992; Simberloff *et al.*, 1992; Haddad *et al.*, 2000; Levey *et al.*, 2005). Also, unless distinct travel corridors have been closely identified and observed, there is no assurance that such corridors will actually be used.

Despite the potential problems noted above, corridors are increasingly recognized as useful for conservation of invertebrate, amphibian, reptile, bird, and mammal species, including species inhabiting wetlands and adjoining riparian areas (*e.g.*, Dunning *et al.*, 1995; DeGraaf and Yamasaki, 1999; Marsh and Trenham, 2001; Martin, 2002; Gibbons, 2003; Levey *et al.*, 2005). For example, the entire Meadowlands is important for birds migrating along the Atlantic flyway (Dunne *et al.*, 1989); moreover, most open space, including forested, grassland (mostly landfill), and wetland habitats in the Meadowlands are important refugia to migrating birds (Kane and Githens, 1997). Animal behavior (*e.g.*, predator or edge responses), corridor features (*e.g.*, width, quality), and landscape structure (*e.g.*, the mix of habitats surrounding the corridor) clearly affect corridor use by different animal species (*e.g.*, Lima and Zollner, 1996; Fagan *et al.*, 1999; Nathan *et al.*, 2003). For example, some animals may not enter narrow corridors, whereas animals may not progress far in wide corridors due to cross-directional movements (*e.g.*, Andraesson *et al.*, 1996).

To date, the extent to which open space in the Meadowlands ecosystem or the HRW is connected has not been thoroughly investigated. Wetlands in the HMD are more contiguous than wetlands in upper portions of the HRW; however, some forested and other upland open space (*e.g.*, active agricultural lands) is located in the upper Hackensack River watershed. Stakeholders should

explore acquisition, protection, and restoration of those areas that potentially serve as corridors (*i.e.*, improve connectivity in remaining open space) to sustain biodiversity in the Meadowlands, based upon actual observations of movements in certain areas and similar kinds of sites. Commitments need to be made to monitor such corridors closely for effectiveness as well as potential problems and to utilize adaptive management accordingly. The Service also recommends that initial stakeholder efforts regarding the potential use of corridors focus on landscape structures, corridor features, and the behavior and habitat requirements of rare and priority species (*e.g.*, State-listed birds, Service Birds of Conservation Concern).

E. SUMMARY

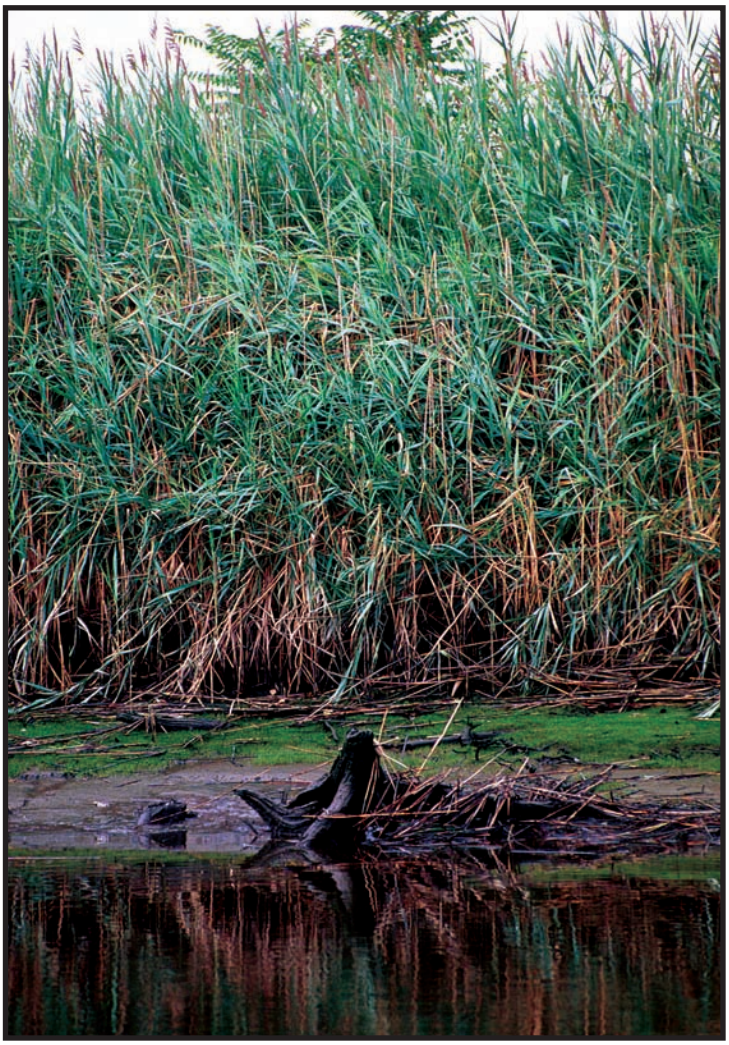
Historical human uses of the Meadowlands, other wetlands in HRW, and adjoining uplands in this densely populated area have resulted in substantial losses of wetlands and uplands, altered and fragmented remaining natural landscape, and disrupted the Meadowlands ecosystem and its capacity to sustain fish and wildlife populations. More than 70 percent of the total wetlands that once existed in the HMD (20,045 acres, which included most but not all wetlands in the Hackensack Meadowlands) have been destroyed by human activities, mostly filling. Approximately 40 percent of wetlands elsewhere in the watershed also have been lost to filling and other activities such as construction of water-storage reservoirs. Wetland types in the Meadowlands have changed extensively over the past 100 years, and continue to change as a result of increasing saltwater intrusion and other factors in the lower Hackensack River.

Currently, approximately 9,650 acres of wetlands remain in the HRW. There is a pronounced difference in the types, condition, functioning, and risks to wetlands in the HMD and the upper HRW. Wetlands in the HMD are primarily estuarine, and fairly homogeneous in their NWI inventory type and vegetative cover (predominantly common reed). Many wetlands in the HMD are relatively large and contiguous in comparison with wetlands elsewhere in the watershed. The lower Berry's Creek subbasin, which is heavily contaminated, lies between the two subbasins that contain the most extensive wetland acreage in the HMD. Wetlands in the upper watershed are almost entirely palustrine and generally small and not contiguous, yet they represent more diverse NWI wetland types (*e.g.*, lentic, lotic, terrene).

Estuarine wetlands in the HMD are extensively fragmented by roads and other rights-of-way and have been highly disturbed by human activities such as ditching and diking that have adversely impacted the land and the flows of tidal and fresh water. As a result, wetlands in the HMD are impaired for certain (*e.g.*, streamflow maintenance) but not all wetland functions. Estuarine wetlands also appear at risk of conversion to deepwater habitats due to SLR and other factors such as dredging and restoration. As a result of their type, size, and isolation, palustrine wetlands in the upper watershed remain vulnerable to adverse impacts from surrounding land-use changes and at increasing risk of development. Nonetheless, palustrine wetlands in the upper watershed help maintain and improve water quality and sustain biodiversity in the lower watershed. Thus, Meadowlands stakeholders must focus greater attention than has been given in the past to protecting wetlands and adjoining uplands in the upper HRW. Such efforts should include partnerships with agencies and NGOs in New York.

Landscape cover throughout the HRW and the HMD has been altered extensively to accommodate human land uses that are typical of the heavily populated northeastern United States. Natural upland areas that serve as buffers around wetlands and water bodies are in poor condition throughout the HRW, and especially distressed within the HMD. The Meadowlands is recognized as a corridor for migratory birds; however, natural lands throughout the watershed are heavily fragmented and poorly connected. Better assessment and an improved understanding of fragmentation-, buffer-, and corridor-effects appear essential to sustaining the fish and wildlife resources of the Meadowlands. Concerted restoration and planning efforts provide an opportunity for stakeholders to reverse and rectify historic, adverse land-use impacts on the Meadowlands ecosystem and its biodiversity.

VI. Invasive and Exotic Species



A stand of common reed (*Phragmites australis*), Haplotype M.

VI. Invasive and Exotic Species

During the last century, a nonnative form of common reed (Haplotype M shown along the bottom) that thrives in disturbed wetlands has spread throughout the Meadowlands and much of North America. Common reed is tolerant of certain contaminants and can stabilize sediments in heavily contaminated wetlands. However, Haplotype M grows into vast stands that choke out other plant life and reduce animal diversity and production. Also, Haplotype M is difficult to eradicate and is re-invading restoration sites. Thus, when and where to eradicate common reed must be evaluated on a site-specific basis for enhancing and restoring the Meadowlands.

Common reed is not the only invasive species that is widespread in the Meadowlands: new exotic species arrive in the New York-New Jersey Harbor on an almost daily basis. Most exotic species do not survive for long, but those that do compete with or prey upon native life forms. Purple loosestrife (*Lythrum salicaria*, upper right), Japanese knotweed (*Polygonum cuspidatum*, upper left), and tree-of heaven (*Ailanthus altissima* middle insert) are spreading at many sites. Several invasive mollusks and other animals have also spread throughout the Meadowlands' waterways, though their impacts are unknown. Because invasive species, including disease-causing agents, may change biological communities and ecosystem processes, restoring the Meadowlands will not be successful unless monitoring and control programs are developed in the Meadowlands and the entire New York-New Jersey Harbor.

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VI. INVASIVE AND EXOTIC SPECIES

A. INTRODUCTION

B. COMMON REED (*Phragmites australis*)
- **1. Haplotype M: Characteristics and Biology**
- **2. Effects on Wetlands**
- **3. Interaction of Haplotype M with Environmental Contaminants**
- **4. Control**

C. PURPLE LOOSESTRIFE (*Lythrum salicaria*)
- **1. Biology and Effects on Wetlands**
- **2. Control**

D. JAPANESE KNOTWEED (*Polygonum cuspidatum = Fallopia japonica*)
- **1. Biology and Effects on Wetlands**
- **2. Control**

E. TREE-OF-HEAVEN (*Ailanthus altissima*)
- **1. Biology and Effects on Wetlands**
- **2. Control**

F. OTHER INVASIVE PLANTS, MARINE SPECIES, AND PATHOGENS

G. SUMMARY

Extensive monoculture stands of common reed such as that shown here can stabilize eroding areas of contaminated sediments. However, such stands provide minimal habitats for native fish and wildlife populations.

VI. INVASIVE AND EXOTIC SPECIES

A. INTRODUCTION

One of the first features of the Meadowlands that a person will notice while driving by on the New Jersey Turnpike, visiting Giants Stadium, or flying into Newark Airport is the vast sea of the giant, grass-like reed known as *Phragmites*. The form of *Phragmites* that dominates the Meadowlands is an invasive species that is not native to the United States. The species has spread over the Meadowlands in recent history to form a monoculture that has degraded the habitat suitability for many native plant and animal species and reduced the overall biological diversity of the Meadowlands. This invasive plant has been the primary subject and target of restoration activities in the Meadowlands.

At the 1994 national meeting of the Ecological Society of America, it was proclaimed that the earth was entering a new geologic/biologic period, "the Homogocene Age," in which natural borders are lacking and the planet's biota is increasingly homogenized with the potential for dramatic and far-reaching changes on the earth. Since that pronouncement, scientists in diverse disciplines (*e.g.*, epidemiology, agriculture) and organizations with broad scopes (*e.g.*, United Nations) are becoming increasingly aware of and concerned about the impacts of invasive species on the biology of natural systems and on the people of the earth (Myers and Knoll, 2000; United Nations Earthwatch, 2003).

Invasive species have diverse and well-documented impacts on native species, communities, and ecosystems (Drake *et al.*, 1989). For example, introduction of a single invasive species can have a wide variety of effects including:

(1) the displacement of one or more native species (*e.g.*, purple loosestrife displacing native wetland plant species; Gaudet and Keddy, 1988);

(2) reduced abundance of wildlife species dependent on displaced native species (*e.g.*, native butterflies that pollinate or obtain nectar from introduced plant species may have larvae that are entirely dependent on a single native plant species; Kearns *et al*., 1998);

(3) altered habitats (*e.g.*, purple loosestrife overgrows grassy nesting habitat of some shorebirds and waterfowl; Faanes, 1979); and

(4) disrupted community and ecosystem ecology (*e.g.*, European earthworms [*e.g.*, *Lumbricus terrestris*] altering fern, decomposer, and forest communities; Frelich and Holdsworth, 2002; Groffman *et al*., 2004).

As a result of their diverse actions on species, communities, and ecosystems, invasive species may directly or indirectly result in considerable economic and other costs that far exceed the costs of treatment or control (Simberloff, 1996; Connelly, 2003; Pimentel, 2004). For example, 80 introduced fishes are causing about $3 billion dollars in losses annually to commercial and sport fisheries in the northeastern U.S. alone. European starlings (*Sturnus vulgaris*) are

responsible for nearly $1 billion annually in crop losses nationwide. Compounding the costs of eradicating or managing invasive species are research and educational costs.

Recognizing the threats to native flora and fauna in the United States, President Clinton issued an Executive Order in February 1999 (E.O. 13112) establishing an Invasive Species Council and directing federal agencies to identify, prevent, and mitigate the adverse environmental effects of invasive species. Despite local efforts to publicize invasive-species problems and educate the public (*e.g.*, the Service's 2004 Issue of *Field Notes* titled "Invasion! In Your Back Yard?"), the scope of the invasive-species problems in the Meadowlands and the surrounding urban area is not sufficiently recognized or publicized, and concerted efforts to address the problems to date are just beginning. In 2004, the Governor of New Jersey signed an executive order forming an Invasive Species Council at the State-level, charged with submitting an Invasive Species Management Plan for the State in 2006. The NJDEP has also issued a new policy directive prohibiting the planting of non-native species on State lands (Policy Directive 2004-02, New Jersey Department of Environmental Protection, 2004e). However, non-native species are often included in recommended planting lists for landscaping within the HMD, and nurseries within the HMD and surrounding areas still market a number of invasive species (*e.g.*, purple loosestrife). Such inconsistencies have helped create public indifference toward invasive species. Certain particularly noxious, recent invaders of wetlands in New Jersey and elsewhere in the northeastern U.S. (*e.g.*, giant hogweed [*Heracleum mantegazzianum*]) may contribute to a change in the public's perception of invasive species, but more comprehensive efforts, including education, are needed to address the many problems of invasive species in the NY-NJ Harbor area, including the Meadowlands.

While the number of invasive species occurring in the Meadowlands is not known, it has been estimated that 20,000 of the 50,000 exotic species introduced into the U.S. were first introduced into the northeastern United States (Pimentel, 2004). Many species now known nationwide were introduced first within the NY-NJ Harbor region. Some of the best-known examples include purple loosestrife (Torrey *et al.*, 1819), carp (*Cyprinus carpio*; DeKay, 1842); European starlings (Adeney, 2001), and disease-causing agents (West Nile virus [*flavivirus*]; Animal and Plant Health Inspection Service, 2004). Although some of the above species were purposely introduced, traditional colonial shipping (*e.g.*, dumping dry ballast material in marsh areas) and agricultural practices (*e.g.*, landscape clearing and burning) are thought to have promoted introduction and establishment of an untold number of exotic insect and plant species. Later shipping practices such as using water as ballast introduced the larvae of freshwater and marine invaders (*e.g.*, zebra mussel [*Dreissena polymorpha*], Great Lakes Science Center, 2000; Japanese shore crab [*Hemigrapsus sanguineus*], McDermott, 1991) and probably some infectious diseases (*e.g.*, cholera [*Vibrio cholera*]; DePaulo *et al*., 1992; Ruiz *et al.*, 2000). Considerable attention is now paid to transportation practices to address dispersal and transport of exotic species (*e.g.*, National Ballast Information Clearinghouse, which collects, analyzes, and interprets data on the ballast water management practices of commercial ships that operate in the waters of the United States; Smithsonian Environmental Research Center and the U.S. Coast Guard, 2005). Despite such efforts, disturbed urban systems adjacent to shipping and other transportation centers will remain at considerable risk from existing and novel invasive species.

Without effective biological or other environmental controls to limit their abundance as occurs with native species, several invasive species have spread throughout the Meadowlands and significantly diminished the habitat values of the area for many native species. The invasive species discussed below are among the most abundant invasive species in wetlands within the HMD; each of these presents significant, complex, and potentially costly challenges for restoration of the Meadowlands. Given the continuing status of the NY - NJ Harbor estuary as one of the world's busiest shipping centers, a comprehensive effort to assess, evaluate, control, and manage these and other invasive species (and identify and respond to "new" exotic species) is needed.

B. COMMON REED (*Phragmites australis*)

At the present time, common reed (Figure 57) is the most significant invasive species affecting the restoration of not only the Meadowlands but also marshes throughout much of eastern North America (Chesapeake Bay *Phragmites australis* Working Group, 2003). During the past century, common reed has become one of the most abundant and widely distributed plants throughout the world (Den Hartog *et al.*, 1989). In North America, the invasive form of common reed has become more abundant in areas where the native form has occurred for several thousand years and spread into areas where common reed did not previously occur (Chambers *et al.*, 1999; Orson, 1999). During this century, common reed has been replacing the dominant plant species (*e.g.*, *Spartina* species in saltmarshes and *Typha* species in freshwater marshes) along the Atlantic coast at rates of 1 to 6 percent per year (Chambers *et al*., 1999; Warren *et al.*, 2002). Common reed appears to have become well established throughout most of the Meadowlands by the early 1930s (Sipple, 1972) as a result of conditions favorable to the species. Salinities throughout most of the Meadowlands (0 to 15 ppt; New Jersey Meadowlands Commission, 2005c) are ideal for growth of common reed (Saltonstall, 2003a).

1. Haplotype M: Characteristics and Biology

Recent molecular research has established that a competitively superior, non-native lineage of *Phragmites australis*, referred to as Haplotype M, is responsible for the widespread invasion of this species throughout wetlands and adjacent lands in eastern North America, including the Hackensack Meadowlands (Saltonstall, 2002; 2003b). Haplotype M denotes a specific set of closely linked genes occurring in the invasive form, now recognized to differ from native Mid-Atlantic haplotypes (strains) in several characters including stem color, root growth, and rhizome growth (Saltonstall and the IAN Group, 2003; Meadows and Saltonstall, 2004; Saltonstall, 2004). The attachment of leaf sheaths is considered the most reliable character to distinguish Haplotype M from native Mid-Atlantic strains (Meadows and Saltonstall, 2004). Haplotype M is the only strain that has been reported recently in the Meadowlands, though native strains undoubtedly occurred there previously (Waksman *et al.*, 1943; Orson *et al*., 1987), and may still persist in some locales, especially in the HRW outside of the HMD.

Haplotype M was most likely brought to northeastern North America from Europe during the 19th Century. During most of that century, ships' ballast largely consisted of dry materials that were readily available in coastal areas (*e.g.*, coastal rocks and earthy debris). Common reed has

been documented as growing in the U.S. where ships' ballasts were regularly dumped or used to fill marshes for railroad and shipping facilities (Saltonstall, 2002). Recent genetic analysis of museum materials has indicated that Haplotype M was present at a number of sites but uncommon in the U.S. prior to 1910 (Saltonstall, 2002); however, by 1940 it was present in nearly all sampling locations. Presently, Haplotype M is the most abundant plant in the Meadowlands, where it forms dense monotypic stands (Saltonstall, 2002). The spread of Haplotype M in the Meadowlands and elsewhere is largely due to human activities, including historical disturbances, such as the clearing or burning of vegetation, and more recent stresses such as pollution, alteration of the natural hydrologic regime, dredging, filling, eutrophication, and decreased oxygen levels in water (Roman *et al.*, 1984; Marks *et al.*, 1994).

Haplotype M is a successful colonizer of disturbed aquatic and adjacent upland areas due to a unique combination of adaptive features. Unlike many other plants, its seeds germinate readily on oxygenized, disturbed soils (Witje and Gallagher, 1996). Its colonies expand by rhizomes in aquatic sediments and by rhizomes and stolons in sandy soils; growth of rhizomes may exceed

Figure 57. Monotypic stand of the invasive form of common reed (Haplotype M) growing along Berry's Creek Canal. The Oritani Marsh along Berry's Creek is one of many common-reed dominated marshes in the Hackensack Meadowlands.

10 m in a single growing season (Ailstock, 2000; Chesapeake Bay *Phragmites australis* Working Group, 2003). Haplotype M is an aggressive form that outcompetes other strains of common reed across a wide range of salinity and nutrient conditions (*i.e.*, low or high concentrations singly or in combination; Saltonstall, 2004). Haplotype M is more efficient in gas exchange and mineral uptake than other emergent marsh plants and is more tolerant of low oxygen levels and acidic sediments, characteristics that enable it to survive in habitat unsuitable for other emergent marsh plants (Bart and Hartman, 2000). Common reed also possesses several adaptations that inhibit the growth of other plant species: (a) it attains greater heights, thus shading other emergent marsh plants; (b) it grows more densely than most other emergent plant species, thus reducing available space for other species; and (c) its colonies generate dense thatch layers that inhibit germination and growth of other species (Haslam, 1971; 1972; Ailstock, 2000).

2. Effects on Wetlands

Invasion of marshes by Haplotype M is increasingly recognized as capable of affecting entire ecosystems; however, many of the changes are subtle and at some sites do not always represent an ecological disaster (*e.g.*, Weis and Weis, 2003b). For example, certain ecosystem functions provided by common reed and smooth cordgrass (*e.g.*, sediment trapping, litter decomposition) may be comparable, but common reed's tolerance of high levels of heavy metals enables the plant to grow in and stabilize contaminated substrates (*e.g.*, Weis and Weis, 2003b). However, even subtle differences between the invasive and native haplotypes may have substantial effects on certain features of biological communities and ecosystem functioning. Marshes dominated by common reed have somewhat different seasonal temperature cycles, freezing earlier in fall and thawing later in spring than other marshes (Saltonstall, 2003a); thus, invasion of marshes by common reed may cause changes in the seasonality of primary and secondary production of Atlantic coast marshes. Dense stands of common reed result in: (1) decreases in topographic relief (*i.e.*, reduced microhabitat availability), abundance of standing water habitats, soil salinity, light levels, and benthic algal production, and (2) increases in detritus loading, depth to the water table, and soil aeration (Weinstein and Balleto, 1999; Windham and Lathrop, 1999; Wainwright *et al.*, 2000). Common reed thus changes the structure of the marsh, which facilitates its continuing invasion. As it spreads throughout the marsh, common reed alters the hydrology of marshes and tidal creeks. For example, common reed-dominated marshes tend to accrete sediment and organic material more rapidly than other marshes, resulting in the filling of creeks and tidal channels and reduced water flow over the marsh surface (*e.g.*, Weinstein and Balleto, 1999). During this reed-induced transformation of the marsh, the accumulation of detritus and other debris may degrade the aquatic habitat for many species. Species affected by this transformation include habitat generalists (*i.e.*, species such as benthic invertebrates [Angradi *et al.*, 2001] and larval fishes [Able and Hagan, 2003] that may use many marsh structures, features, or vegetation as habitat, and thus range widely over the marsh surface) and habitat specialists (*i.e.,* species such as willets [*Catoptrophorus semipalmatus*] and seaside sparrow [*Ammodramus maritimus*] that require very specific features, structures or vegetation for habitat, and thus are more restricted in their distribution within a marsh; Benoit and Askins, 1999). Common reed also ties up nutrients in its biomass, including its litter; nutrients are not released as quickly by litter of common reed as by litter of other common native vegetation in North American marshes (*e.g.*, salt hay grass; Windham, 2001). This trait can provide beneficial effects on polluted sites by reducing the bioavailability of environmental contaminants (see

discussion below). Microbial growth on common reed litter may be slow in comparison to microbial growth on litter of other plants (Findlay *et al.*, 2002).

The aggressive and pervasive growth of common reed has reduced plant diversity within the Meadowlands; however, a detailed understanding of the effects of common reed on the Meadowlands is lacking. The factors affecting the growth of common reed and its re-invasion of sites from which it has been eradicated (Table 5) must be understood better to restore the Meadowlands successfully. This species is known to have reduced plant diversity in many freshwater and estuarine marshes (Fell *et al.*, 1998; Chambers *et al.*, 1999; Meyerson *et al.*, 1999; Windham and Lathrop, 1999) and shifted plant community composition to tall-grass species (Saltonstall, 2003a). Typical estuarine landscape components (*e.g.*, high marsh communities) appear to be disappearing from the Meadowlands and other marshes along the Atlantic coast, though invasion by common reed appears only partially responsible (Bertness *et al.*, 2002). Common reed is reinvading nearly every site in the Hackensack Meadowlands that has been "restored" by removal of common reed and replacement with cordgrass (T. Doss, pers. comm., 2004). The only exception is the Marsh Resources Inc., Mitigation Bank site, which is the most recent site in which common reed was replaced with other vegetation. Thus, it may only be a matter of time before common reed reinvades this site. Because common reed is widely distributed on uplands (*e.g.*, especially on ditches, landfills, brownfields), numerous stands of common reed that potentially serve as sources for reinvasion of wetlands restoration sites occur throughout the Meadowlands. Reinvasion of estuarine restoration sites has occurred in other Mid-Atlantic states (*e.g.*, Virginia; Havens *et al.*, 1997). Currently, State and federal agencies have limited jurisdiction and resources to address management and control of common reed in the HMD. For example, current federal permits typically require only 5 years of monitoring of mitigation sites; longer periods of monitoring and control (10 years or longer), as are being considered elsewhere (Chesapeake Bay *Phragmites australis* Working Group, 2003), would be beneficial in the Meadowlands.

Though used by some wildlife, dense stands of Haplotype M are recognized generally as reducing native species diversity and providing poor-quality habitat for most wildlife (Cross and Fleming, 1989). Fewer than half of the bird species reproducing in the Meadowlands will nest in common reed (*e.g.*, red-winged blackbird, marsh wren, swamp sparrow; Kane, 2001); however, additional species may forage or rest in stands of common reed on migration stopovers. The usage of common reed by birds in the Hackensack Meadowlands may be due to the high value of common reed as shelter (*i.e.*, a refuge from predation or harsh weather) or simply due to the lack of other suitable vegetation to provide birds with food and cover. Large monotypic stands of common reed generally contribute to declines in overall avian species richness and marsh usage in most other estuaries (Roman *et al.*, 1984; Marks *et al*., 1994; Benoit and Askins, 1999). Wildlife use of *Phragmites* edges, mixed stands, and patches is higher than use of large, dense stands of common reed (Kiviat *et al.*, 2002).

The majority of studies of fishes and invertebrates suggest that the nursery value of common reed marshes is inferior to that of marshes dominated by native plant species. Invertebrate community structure has been observed to change following invasion by common reed (*e.g.*, Talley and Levin, 2001). Studies in the Hackensack Meadowlands suggest the epifaunal community of smooth cordgrass is more diverse and abundant than the community of common

reed (Robertson and Weis, 2002). This may be due to the poor food quality of live leaves and litter of common reed for many common invertebrates (*e.g.*, gammarid amphipods, Agnew *et al.*, 2003). Common reed-dominated marshes in the Meadowlands and elsewhere in New Jersey (Able and Hagan, 2000; 2003; Raichel *et al.*, 2003) had substantially lower abundances of larval and juvenile mummichog than cordgrass-dominated marshes. Mummichog is widely recognized as one of the most important and pollution-tolerant fish species inhabiting the Meadowlands and other marshes. Able and Hagan's (2003) results suggest that *Phragmites* marshes produce less overall biomass of fish and wildlife than native estuarine marsh communities. Studies in other areas have made similar observations comparing use of cordgrass- and common reed-dominated marshes by larval and juvenile fishes, the most abundant life-history stages inhabiting estuaries (Fell *et al.*, 1998).

3. Interaction of Haplotype M with Environmental Contaminants

Long recognized for its tolerance of various pollutants (*e.g.*, heavy metals, hydrocarbons), common reed was at one time widely planted to limit adverse environmental effects in contaminated sites (Mulamoottil *et al.*, 1999) and to improve water quality in constructed wetlands and restoration sites in this and other countries (*e.g.*, Botch and Light, 1994; Brooks and Agate, 2001). Even today, one widely perceived benefit of common reed in the Meadowlands is its ability to stabilize wetlands and other areas (*e.g.*, landfills) that have highly contaminated sediments, which can be toxic to native plant species. Dense stands of common reed limit the spread of certain contaminants and reduce their adverse biological impacts upon ecosystems by:

(1) restricting sediment mobility (Leonard *et al.*, 2002);

(2) trapping new organic and inorganic matter, which may sequester additional contaminants (Rooth *et al.*, 2003);

(3) incorporating contaminants into various living tissues and its litter (*e.g.*, Ye *et al.*, 1997; Windham *et al.*, 2003); and

(4) facilitating bioremediation of contaminants (Tischer and Hüber, 2002).

Although common reed may serve well in "localizing" certain contaminants, common reed may also affect a wetland's capacity to serve as a "sink" or "source" of contaminants (Weis and Weis, 2004). For example, common reed appears to process and excrete certain contaminants (*e.g.*, lead) into the water at slower rates than cordgrass species (*e.g.*, Windham *et al.*, 2001a; 2001b). Common reed also sequesters more of those same contaminants below ground than other plant species (*e.g.*, Windham *et al.*, 2001a; 2001b). Finally, stem litter of common reed initially (during the first 2 years) breaks down and releases heavy metals (lead, copper, and zinc) more slowly but subsequently decomposes and releases metals at rates similar to decomposing litter of smooth cordgrass (*e.g.*, Windham *et al.*, 2004). Studies conducted in the Meadowlands and elsewhere suggest that restoration activities replacing common reed with other plant species potentially affect the distribution and abundance of contaminants. However, because of differing results, studies to date indicate the need to base decisions on site-specific information. The

effects of replacing common reed with cordgrass on contaminant fates (*e.g.*, their distribution and accumulation in the biota) in the Meadowlands are largely unknown. Thus, replacing common reed on heavily contaminated sites is not advisable until the availability, bioaccumulation, biomagnifications, and effects of contaminants are better understood.

4. Control

Control of common reed presents a considerable challenge to the overall restoration of the Hackensack Meadowlands, most of which provides ideal salinity (0-15 ppt) and nutrient (*e.g.*, high nitrates and ammonium; New Jersey Meadowlands Commission, 2005c) conditions for growth of Haplotype M. High salinity, sulfide, and prolonged flooding are known to restrict the invasion and spread of common reed (*e.g.*, Osgood *et al.*, 2002); as a result, excavation of tidal marshes to improve tidal flooding and increase salinities has been a common feature of most restoration projects in the Meadowlands to control proliferation of Haplotype M. However, common reed has a propensity to re-invade restoration sites from which it has been eradicated. Another consideration is that opening sites to increased tidal flow and exchange where contaminant remediation has been achieved may exacerbate contaminant loading.

Widely employed methods to eradicate and/or control common reed include chemical treatments, mechanical treatments, and combination (mechanical and chemical) treatments. The most efficient eradication method to date is aerial or broadcast spraying with a glyphosate-based herbicide; other methods of application of glyphosate (*e.g.*, wipe-on or injection) may be more effective but are labor-intensive and costly. Because glyphosate is a broad-spectrum herbicide (*i.e.*, kills other plant species) and is toxic to invertebrates, mechanical methods (disking, burning) are sometimes preferred for small sites or for preventing damage to other vegetation. Glyphosate has been used to eradicate common reed from most restoration sites in the Meadowlands (*e.g.*, Marsh Restoration Inc., Mitigation Bank; Louis Berger Group, Inc., 2000). Irrespective of the method used, repeated treatment is often required. Removal or eradication by herbicides is rarely 100 percent effective, nor is it long-term. Treated areas generally require additional applications. Thus, programs to monitor the treatment success and reinvasion of sites by common reed are recommended (Chesapeake Bay *Phragmites australis* Working Group, 2003), and plans for repeated treatments need to be taken into account.

The Service has extensive experience in restoring *Phragmites*-dominated wetlands in New Jersey. The Service's *Partners for Fish and Wildlife* Program has demonstrated on-the-ground success in restoring wetlands sites on a number of private lands invaded by common reed. From 1999 to the present, common reed occurred on and was eradicated from approximately 80 percent of the 5,500 wetland acres in New Jersey restored by this program; other invasive species (*e.g.*, purple loosestrife, see below) occurred on and were eradicated from the remaining acreage that was restored. Similarly, the Service's *Coastal* Program, which focuses exclusively on coastal watersheds, restored more than 2,100 acres of wetlands in the state on private and public lands from 1997 to 2004. The Service's experience in successfully eradicating common reed from other restoration sites in New Jersey will prove beneficial in future efforts to restore marshes in the Meadowlands, particularly on those sites where contamination has been remediated.

Research into biological control of common reed is underway in the United States and elsewhere and offers some promise for the future. Approximately 30 arthropods in North America are reported to attack common reed; however, the majority of these species appear to have been introduced also, at least some of them along with Haplotype M (Tewksbury *et al.*, 2002). Native herbivorous (plant-eating) insects of common reed include one gall midge (*Calamomyia phragmites*), and the larvae of certain skippers (*Ochlodes yuma, Poanes viator*) and dolichopodid flies (*Thrypticus* spp.); however, these native insects apparently target only native strains (haplotypes) of common reed (Tewksbury *et al.*, 2002). Thus, most research into biological control of common reed has focused on the exotic pests of common reed already introduced into the United States (Blossey *et al.*, 2003). Some of these pest species (*e.g.*, an eastern European gall midge, *Lasioptera hungarica*, and several gall flies in the genus *Lipara*) appear to feed solely on common reed. Also, more than 100 other pest species of common reed occur outside the United States (Tewksbury *et al.,* 2002). The potential of some of these species to provide biological control of Haplotype M is being evaluated in laboratory experiments conducted by Cornell University and the University of Rhode Island. If any of these species is effective in controlling Haplotype M, additional research will be needed to establish that these species do not feed on native haplotypes of common reed or on other native plant species (*e.g.*, other marsh grasses). Some non-native herbivore species of common reed appear to be spreading along waterways from the NY-NJ Harbor area (Blossey *et al.*, 2003). To date, it is not known if these non-native insects are capable of providing effective biological control of Haplotype M in the Meadowlands. Regardless of the control mechanisms and restoration activities that are implemented, common reed is likely to remain one of the major vegetative cover types in the Meadowlands for a long time to come. Some have questioned whether it is actually feasible or desirable to eradicate *Phragmites* from the Meadowlands entirely, but without its removal, restoration will never truly be achieved and the potential diversity of plant and animal communities will be diminished.

C. PURPLE LOOSESTRIFE (*Lythrum salicaria*)

Purple loosestrife (Figure 58) has occurred in New Jersey for nearly 200 years (Torrey *et al.*, 1819); during the past 10 to 20 years, it has invaded freshwater marshes, wet fields, and drainage ditches throughout much of the state. The spread of purple loosestrife throughout most states has been facilitated by its widespread use for landscaping and honey production (Thompson *et al.*, 1987). Despite its recognition as a problem invasive species, purple loosestrife remains widely available at nurseries throughout New Jersey, including some within the HRW. Because its numerous seeds are readily dispersed, established landscape plants serve as source populations for introduction of the species into new locales and reintroduction into wetlands from which it has been eradicated. In the HRW, purple loosestrife has established populations on several freshwater wetland sites (*e.g.*, Kearny Marsh, Teterboro Woods, Losen Slote, Harrier Meadows), public parks (*e.g.*, Laurel Hill Park, New Bridge Landing, Johnson Park), and many privately owned properties. The infestation of purple loosestrife is also conspicuous in the adjacent Passaic River basin, especially in the glacial Lake Passaic central wetlands.

Figure 58. Purple loosestrife growing in Teterboro Woods; a close-up of the flowers in the inset. Purple loosestrife flowers are attractive to butterflies and other pollinators; the plant's attractiveness has facilitated its use for ornamental and landscape plantings.

1. Biology and Effects on Wetlands

Like many invasive plant species, purple loosestrife exhibits tremendous seed production (more than one million per plant; Welling and Becker, 1990) and may form a monoculture under some growing conditions (Thompson *et al.*, 1987). Purple loosestrife is known to displace native wetlands plant species (*e.g.*, Gaudet and Keddy, 1988), including plant species that provide forage for waterfowl (*e.g.*, *Potamogeton* spp., *Utricularia vulgaris*, *Lemna minor*; *e.g.*, Haramis and Thompson, 1985). Stands of purple loosestrife may also alter hydrology and nutrient cycling (Emery and Perry, 1996; Dixon and Johnson, 1999) and the distribution and abundance of native invertebrates (*e.g.*, Gardner *et al.*, 2001). The species may adversely affect use of wetlands by certain wildlife (*e.g.*, waterfowl, Faanes, 1979; bog turtle, New Jersey Department of Environmental Protection, 2003). Purple loosestrife-dominated wetlands have been reported to support higher bird densities but lower bird diversity than other vegetative communities (Whitt *et al.*, 1999).

2. Control

Since 1997, the New Jersey Department of Agriculture, Beneficial Insect Rearing Laboratory has reared and released two beneficial insects (*Galerucella pusilla* and *Galerucella calmariensis*) that feed upon the leaves of purple loosestrife. These insects have been highly effective in controlling purple loosestrife on some loosestrife-dominated sites in New Jersey but have required repeated releases (of approximately 10,000 beetles per acre) for several years in order to generate sufficient beetle populations and densities to achieve control of loosestrife on other sites (Scudder *et al*., 2002). These beetles have been used successfully in the HMD to control purple loosestrife at the NJMC's Harrier Meadows marsh restoration site and in the Great Swamp NWR approximately 20 miles west of the Meadowlands.

Some researchers (*e.g.*, Hager and McCoy, 1998) are not convinced that the adverse impacts of purple loosestrife on plant communities and wildlife are sufficient to justify releasing non-native insects. Other researchers (*e.g.*, Galatowitsch *et al.*, 1999) have recognized the absence of herbivory as the major contributor to the explosive growth of purple loosestrife in North America. Although purple loosestrife may not always form dense, monotypic stands everywhere under all conditions (*e.g.*, in southeastern New York wetlands; Morrison, 2002), the potential for dense stands of purple loosestrife to alter wetland ecosystems and promote succession toward terrestrial habitats suggests that its abundance should be closely monitored to avoid extensive control efforts.

D. JAPANESE KNOTWEED (*Polygonum cuspidatum = Fallopia japonica)*

Japanese knotweed (Figure 59), a member of the buckwheat family (Polygonaceae), is believed to have been introduced as an ornamental plant to the United States through the United Kingdom's Royal Botanical Gardens, which began distributing the plant in 1855 (Mehrhoff *et al.*, 2003). In addition to its use as an ornamental plant (especially for landscape screening), Japanese knotweed was originally used in this and other countries for erosion control. It was

reported as naturalized in Atlantic Highlands, New Jersey and in several northeastern cities (*e.g.*, Philadelphia, Schenectady) in the mid 1890s. Information was being published on how to eradicate this plant in gardens by 1938 (Mehrhoff *et al.*, 2003). This species is now widespread in the United States in a variety of disturbed habitats (*e.g.*, abandoned fields, roadsides, utility rights-of-way) and thrives in riparian and wetland areas in at least 36 states (National Park Service, 2005). Japanese knotweed is widespread at a number of wetlands sites throughout the Meadowlands (*e.g.*, Kearny Marsh, Teterboro Airport, Harrier Meadow) and also occurs extensively throughout many other freshwater wetlands and riparian areas within the HRW (*e.g.*, Laurel Hill Park, Overpeck County Park, Teaneck Creek Conservancy, Schmidt's Woods).

Figure 59. A close-up of a thicket of Japanese knotweed, showing its leaves and flowers. Note the location of the leaves on alternating sides of each stem.

Photo courtesy of Rutgers University

1. Biology and Effects on Wetlands

Comparatively little information is available on the biology of this plant in the United States; however, information is available on this plant in Europe and especially in the United Kingdom, where Japanese knotweed has been banned from planting or growing outdoors since 1981 (Shaw and Seiger, 2002). Once established, populations are persistent and spread downstream. This species spreads quickly to form dense thickets that exclude native plant species, reduce native herbivorous insect populations, and provide little value as wildlife habitat (Holzner, 1982; Beerling and Dawah, 1993). Japanese knotweed survives floods and rapidly colonizes scoured shores and islands but does not provide year-round erosion control in riparian areas as do other native species because it dies back in winter (Child *et al.*, 1992). Slow rates of decomposition of its leaves and stalks relative to native riparian species (Seiger, 1997) result in considerable standing biomass that may create a fire hazard (Ahrens, 1975). In urban areas, Japanese knotweed has been reported to grow through sidewalks and building foundations (Japanese Knotweed Alliance, 2005).

2. Control

Much debated until recently, the common invasive form of Japanese knotweed is now identified as *Fallopia japonica*, a relative of other exotic species (*e.g.*, *Polygonum* and *Reynoutria* spp.; Shaw and Seiger, 2002). Japanese knotweed may hybridize with the related species (*e.g.*, hybrids with other *Polygonum* and *Fallopia* species are already known) and create additional invasive forms (Japanese Knotweed Alliance, 2005). Herbicide treatment on a watershed basis is effective but usually only when repeated for several years (Shaw and Seiger, 2002); research into biological control with insects and other agents (*e.g.*, fungi) are ongoing in the United Kingdom but have shown limited promise to date. Given the abundance of Japanese knotweed in the Meadowlands and its adverse impacts elsewhere, a management program to consider eradication and control measures for this species should be established immediately.

E. TREE-OF-HEAVEN (*Ailanthus altissima*)

A native of China, tree-of-heaven (Figure 60) was reportedly first brought to North America from England by William Hamilton, a Pennsylvania gardener, for ornamental purposes in 1784. Commercially distributed in the east as early as 1840, the species was spread throughout the U.S. and especially to the West Coast by Asians, who used the plant for medicinal purposes (Hu, 1979). Its tolerance to air pollution contributed to its being planted throughout some metropolitan areas in the United States, though it has also been used as an indicator species for ozone pollution (Gravano *et al.*, 2003). All parts of this plant exhibit a strong odor, likened to cat urine or rotting peanuts; this property has given rise to one local name, stinking sumac. Tree-of-heaven is common in a number of different habitats throughout the New York Bight, including abandoned fields and lots, roadsides, and coastal dunes. This species is possibly the most common tree of disturbed uplands and wetland/upland borders in the Meadowlands (Spendiff, 2004).

Figure 60. Tree-of-heaven. A tree in full flower in summer (upper photo) and a close-up of the upper and lower surface of the leaflets (lower photo). Small glandular notches occur on the underside of leaflets in summer.

Photos courtesy of the University of Georgia Bugwood Network

1. Biology and Effects on Wetlands

A member of the mostly tropical quassia family (the Simaroubaceae), tree-of-heaven grows rapidly, seeds prolifically, and forms dense thickets that displace native plant species. This species thrives on poor soils and is tolerant of many air pollutants, sulfide, and mercury (Kozlowski, 2002; Mehrhoff *et al.*, 2003). This species' ability to spread from metropolitan areas and displace native plants may also result in part through its production of allelopathic chemicals that have non-selective, post-emergent herbicidal properties similar to glyphosate or paraquat (De Feo *et al.*, 2003; Ferguson and Rathinasabapathi, 2003).

This species has not only been recognized for a variety of adverse impacts on native plants, but for other diverse impacts in urban areas (*e.g.*, root growth clogging sewer lines, growing into building foundations). Although the tree is reportedly unpalatable to native herbivores and only its seeds are consumed (Mehrhoff *et al.*, 2003; Howard, 2004), Spendiff (2004) reports it is variously used by some insects and other arthropods, and its wood is easily excavated by cavity-nesting birds. Eastern cottonwood (*Populus deltoides*), grey birch, native sumacs (*Rhus* spp.), and box elder (*Acer negundo*) are native species that have likely been displaced by tree-of-heaven. The species is prohibited or listed as a noxious invasive or weed in 43 states (U.S. Department of Agriculture, 2005); however, despite threats to native species, *Ailanthus* seeds are still readily available in nurseries and seed catalogs in the United States. Because of its tolerance of polluted air and barren soils, tree-of-heaven may also be of some benefit in highly urbanized landscapes where native tree species are unable to grow and thus provide some habitat requirements such as roosting or nesting sites for migratory birds.

2. Control

Although controlled with several herbicides that can be applied in different ways, this species is reported to re-sprout from root or stem fragments. Effective control thus requires careful and repeated herbicide treatments and girdling (National Park Service, 2003). Natural control methods appear limited: fungi that kill tree-of-heaven (*e.g.*, *Verticillium* spp., *Fusarium oxysporum*; National Park Service, 2003; Connecticut Agricultural Experiment Station, 2005) also kill many native tree species.

F. OTHER INVASIVE PLANTS, MARINE SPECIES, AND PATHOGENS

Many invasive species are a familiar component of the region's urban landscape and are no longer widely recognized as non-native. Thus, problems caused by invasive species have not been fully recognized and have been considered a lower priority for resolution than other issues throughout the NY-NJ Harbor estuary. For example, comprehensive sampling of aquatic and wetland habitats throughout the NY-NJ Harbor estuary for invasive species did not begin until 2003 (U.S. Environmental Protection Agency, 2003d). Thus, except for well-recognized and conspicuous species such as common reed that may dominate a landscape, the distribution and abundance of invasive plant and animal species in the Meadowlands and elsewhere in NY-NJ Harbor estuary are not well known. Available information suggests that invasive species,

including pathogens, are probably more abundant and widespread than is generally recognized, and their impacts are unknown.

There are approximately 2,200 species of plants in New Jersey, of which roughly 1,300 are believed to be non-native (Snyder and Kaufman, 2004), originating mostly from Europe or Asia. Most were introduced as ornamental plants or for specific purposes (*e.g.*, food, fiber, medicine). New Jersey has approximately the same number of non-native plant species as New York, California, Florida, Pennsylvania, and Massachusetts, five of the states among the highest in reported totals of non-native plant species (Williams and Meffe, 1998). The large number of non-native plant species in these states is due to their long history as commerce and transportation centers. Historically, the single most significant mechanism for introducing non-native plants (and animals) in the northeastern U.S. has been the dumping of foreign ballast soils and ballast waters at seaports (Snyder and Kaufman, 2004).

The problems presented by invasive plant species to restoring the Meadowlands are likely to increase. In addition to the four invasive plant species discussed in this report, the NJMC has begun efforts to control other invasive plant species, including mile-a-minute (*Polygonum perfoliatum*), Amur peppervine (*Ampelopsis brevipedunculata*), and hedge false bindweed (*Calystegia sepium*, also known as wild morning glory). A preliminary list of native and non-indigenous plants species occurring in the Hackensack Meadowlands and the surrounding watershed is being generated by the Service from unpublished sources (*e.g.*, field-trip reports by the Torrey Botanical Society [Brooklyn Botanic Garden, 2004b] and collection records of the Brooklyn Botanical Society) and field surveys to assist in determining the magnitude of the invasive plant problem in both the Meadowlands and the surrounding watershed.

Many invasive animals, especially terrestrial species, are accepted as common components of the urban landscape in the New York metropolitan area. Nonetheless, efforts should be made to identify all terrestrial invasive animal species and determine their impact upon native fish and wildlife populations, especially upon federally and State-listed species for which recovery plans are being implemented and for other species of concern. For example, the common street pigeon or rock dove (*Columba livia*, a European species) in urban areas may contribute to bioaccumulation of certain contaminants in peregrine falcon (*e.g.*, DeMent *et al.*, 1986), and its excrement is estimated to harbor over 50 diseases. Also, invasive bird species may differ in their susceptibility to recently-introduced diseases of wildlife and humans such as West Nile virus, and facilitate the spread of the virus among wildlife and humans (see below; *e.g.*, Male, 2003). Exotic earthworms, likely brought in ballast soils, are being increasingly recognized for their adverse impacts on North American forest ecosystems (*e.g.*, altered carbon, nitrogen, and phosphorus cycles, which stress certain trees; Groffman *et al.*, 2004). Thus, the impacts of exotic and invasive species that have been widely accepted as "naturalized" components of the landscape may have novel, poorly recognized impacts on native fish and wildlife (Rappole *et al.*, 2000; Male, 2003).

Approximately 300 aquatic animal and plant species have been identified as invasive in estuaries and coastal waters of the United States (*e.g.*, Ruiz *et al.*, 2000; Ray, 2005). Several invasive mollusks have been collected in the NJMC's fishery surveys (*e.g.*, dark false mussel [*Congeria leucophaeta*], Baltic macoma clam [*Macoma bathica*]; Kraus and Bragin, 1989; Bragin *et al.*,

2005); however, the total number of invasive species present in the Meadowlands and the HRE is presently unknown. Approximately 200 invasive species are known in Chesapeake Bay (Ruiz *et al.*, 2000) and San Francisco Bay (Cohen and Carleton, 1998). Clearly, additional effort must be made to monitor and assess invasive species in the Meadowlands and where these pose a significant ecological risk; methods for their control should be sought and implemented.

Studies in other areas (*e.g.*, Ray, 2005) indicate that some invasive species have the potential to alter the ecology of the Meadowlands and adversely affect native fish and wildlife populations. Ballast-water released from large ships has introduced non-native meroplanktonic (planktonic as larvae only) and holoplanktonic (planktonic as larvae and adults) species (Lavoie *et al.*, 1999). Invasive copepod species now dominate the zooplankton of many estuaries (Cordell and Morrison, 1996), and estuarine faunas are increasingly dominated or affected by invasive species (Ray, 2005). For example, introduction of the Amur River corbula clam (*Potamocorbula amurensis*) into San Francisco Bay displaced entire benthic assemblages (Carlton *et al.*, 1990) and significantly reduced phytoplankton abundance, which caused a "trophic cascade" affecting the biology of dependent species including zooplankton and fishes (Alpine and Cloern, 1992; Kimmerer *et al.*, 1994; Feyrer *et al.*, 2003). Even with recent development and implementation of ballast water management and programs to reduce the likelihood of introducing invasive species (U.S. Coast Guard, 2005), programs are needed to assess the status of existing exotic and invasive species in the Meadowlands, prioritize species for development of control programs, and monitor and target new exotic species before they spread. Successful eradications of established marine invaders in Australia (a mussel, *Mytilopsis* sp.; Bax *et al.*, 2002) and California (a polychaete worm, *Terebrasabella hetrouncintata*; Culver and Kuris, 1999) have been reported; however, in both instances, invaders were detected during their initial colonization.

Finally, no program addressing impacts of invasive species would be complete without some focus on invasive pathogens, that is, invasive species that cause disease. Some of the most familiar invasive pathogens that have already devastated native plant and animal communities and ecosystems throughout North America were introduced in the New York City area. For example, Chestnut blight (formerly *Endothia parasitica,* now known as *Cryphonectria parasitica*, *e.g.*, Gryzenhout *et al.*, 2005) was introduced into the New York City area shortly before 1900. The blight contributed substantially (along with another invasive fungus, *Phytophthora cinnamomi*, likely introduced in the southeastern United States, Zentmyer, 1988; Schlarbaum *et al.*, 2002) to essentially eliminating native American chestnut trees from more than 9 million acres in North America (American Chestnut Foundation, 2004), where over large regions of its range it had previously constituted over 50 percent of the forest tree biomass. West Nile virus (flavivirus), a causative agent of a type of meningitis and encephalitis in horses and humans, first appeared in the New York City area in 1999 (Lanciotti *et al.*, 1999). West Nile virus is now known to occur in more than 250 species of birds and 18 species of mammals in North America; there is considerable concern about its potential impacts on raptor populations and on other bird species as the virus is spread throughout the Americas (U.S. Geological Survey, 2005c). Other pathogens were first recognized in other port cities (*e.g.*, Dutch elm disease in Cleveland, Ohio; Schlarbaum *et al.*, 2002). Many invasive pathogens are often introduced along with other invasive species (*e.g.*, plants, insects); therefore, it is prudent and cost-effective to identify and intercept invasive species in port areas prior to infestations.

G. SUMMARY

As the movements of goods and people around the globe increase, the opportunities for invasive species to arrive and spread throughout the United States are similarly increasing (Carleton, 2001). Invasion of coastal ecosystems surrounding major urban seaports by exotic species is considered a national problem (National Invasive Species Council, 2001). Agencies participating in the restoration of the Meadowlands and elsewhere in the NY-NJ Harbor estuary have not addressed invasive species in a coordinated manner to date. Harbor-wide efforts must be developed to prevent current and future invasions of non-native species that may have considerable adverse impacts on indigenous fish and wildlife populations in the region. Development of comprehensive and coordinated programs to monitor, assess, and control invasive species are increasingly common in seaports and surrounding urban areas elsewhere in the United States (*e.g.*, Chesapeake Bay, San Francisco Bay). Such programs have done much to inform the public of the problems and costs associated with invasive species. Human activities are the primary cause of invasive-species introductions. Public education, blocking pathways of future introductions, on-the-ground control (including biological, mechanical, and chemical), working with local nurseries to supply native plant materials and seeds, and habitat remediation and restoration are necessary to stop the transport and introductions of exotic and invasive species in the Meadowlands and the surrounding NY-NJ Harbor estuary.

VII. Resource Objectives

Great egret (*Ardea alba*).

VII. Resource Objectives

The Meadowlands' Sawmill Creek, pictured to the left, was established in 1975 as New Jersey's only urban Wildlife Management Area (WMA). Diking for mosquito control in the early 1900s promoted the spread of common reed, and led to further degradation of its marshes. In 1950, a northeaster destroyed the dikes and "restored" tidal flows to the Sawmill Creek marshes. The Sawmill Creek's extensive mudflats and cordgrass-marshes provide diverse habitats used by many animal species. However, the Sawmill Creek WMA also is fragmented by rail and road beds and bordered by the 1-E Landfill (shown in the figure background), which is being capped with dredged material from Newark Bay. Thus, the Sawmill Creek WMA not only provides inspiration for enhancing and restoring marshes, but also illustrates the diverse challenges to restoring the Meadowlands and safeguarding its fish and wildlife resources.

Landfills represent considerable challenges to remediating, enhancing, and restoring the Meadowlands and sustaining its biodiversity. On former wetlands, landfills presently provide extensive and contiguous yet degraded upland habitats for fish and wildlife. Some landfills are being remediated, with portions redeveloped to provide residential and commercial opportunities and extensive acreage transformed into golf courses. Golf courses often provide habitat for resident Canada geese and other, already over-abundant, nuisance species.

Alternatively, certain landfills (such as the 1-E pictured below in back of the Kearny Marsh) and other degraded industrial sites, properly remediated, may be restored to provide diverse upland "buffer" habitats that contribute important ecosystem functions as well as shelter, foraging and nesting habitats for many native species that now struggle to survive in the Meadowlands. The time has come to plan comprehensively and take corrective actions to reverse the pattern of destruction and ensure that the Meadowlands sustains populations of healthy fish and wildlife in the future.

VII. RESOURCE OBJECTIVES

A. ACQUISITION
- 1. Overview
- 2. Objectives

B. PROTECTION
- 1. Overview
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C. ENHANCEMENT AND RESTORATION
- 1. Hydrology
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D. BIODIVERSITY
- 1. Wetland Plants
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- 4. Amphibians
- 5. Reptiles
- 6. Birds
- 7. Mammals

E. SUMMARY

VII. RESOURCE OBJECTIVES

A. ACQUISITION

1. Overview

Since the late 1990s, the NJMC has taken the lead role in acquiring wetlands within the HMD. Currently, the NJMC owns roughly 1,700 wetland acres, leases three other wetland sites totaling 361 acres, and manages an additional 1,600 acres of tidal wetlands, including the NJDFW-owned 878-acre Sawmill Creek Wildlife Management Area. In addition, in 2005 the NJMC supported the Meadowland Conservation Trust's acquisition of the 587-acre Empire Tract, the second largest wetland landholding in the HMD, in the Carlstadt-Moonachie wetlands. Altogether, these acquisitions represent vital steps for ensuring the long-term protection of nearly 3,400 acres of wetlands in the Meadowlands.

Current efforts to acquire additional open space within the HMD continue to be focused primarily on wetlands. The NJMC has identified wetland areas (totaling roughly 620 acres) within the HMD, owned by private individuals, corporations, and other public entities, as potentially suitable for public acquisition and preservation. Local governments (*e.g.*, Hudson County, Town of Secaucus) also are participating in collaborative efforts, such as the HEP's Habitat Work Group, to prioritize land acquisitions (Remaud, 2004). For example, Hudson County recently passed an open-space referendum to establish a trust fund generated through property taxes and has developed an Open Space Plan (Heyer, Gruel, and Associates, 2004) that has identified the County's open-space needs and priorities (*e.g.*, acquisition of riverfront greenway and brownfields, such as the PJP Landfill Superfund site, for public use). The NJMC has received a grant from the EPA to assess brownfield sites in the HMD. Acquisition of adjoining upland areas to provide wetland buffers and other open space is challenging and expensive but is necessary to protect the ecological integrity of the system and to provide habitats for non-wetland plant and animal associations in this densely populated urban area. The NJMC (2004d) has committed the 1-D and 1-A Landfills as restoration areas; however, most landfills in the HMD have been or appear targeted for re-development (*e.g.*, EnCap Golf, Inc.). Most acquisition of upland areas currently appears focused on waterfront parcels that would provide opportunities for public recreation (*e.g.*, landings, marinas).

Stakeholders in the region have taken initial steps to identify and acquire additional wetlands and adjoining uplands outside of the HMD yet within the HRW. The Service's National Wetlands Inventory is currently mapping and identifying wetlands within the HRW. The Meadowlands Conservation Trust is assembling a database of owners of waterfront parcels along the main stem of the Hackensack River. The Teaneck Creek Conservancy established a new 46-acre park in Bergen County that includes forested and other wetland areas, some of which are being restored with State funds (M. Arnold, pers. comm., 2004). The Borough of Oradell has acquired the former Hackensack Water Company site on Van Buskirk Island to protect the historical site and surrounding open space. The Bergen Save the Watershed Action Network (2005) established the Hackensack River Watershed Fund to acquire property in the upper HRW.

2. Objectives

The NJMC has taken and should continue a leadership role in the acquisition of wetlands and adjoining upland sites within the HMD. Federal and State agencies and other stakeholders have supported the NJMC's acquisition efforts indirectly (*e.g.*, identifying acquisition priorities [Remaud, 2004]), and may further assist the NJMC's future acquisition efforts. Wetland and riparian areas outside of the HMD but within the HRW remain under considerable threat of development; for example, development is being proposed on three riparian parcels along the Hackensack River, Lake Tappan, and Cherry Brook in River Vale Township. Thus, the Service recommends that stakeholders *further develop coordinating acquisition efforts outside the HMD throughout the watershed through the MCT*, which has the entire HRW designated as its operational area. In addition, the Service encourages stakeholders to investigate means to expand the funding mechanisms (*e.g.*, the Meadowlands license plate) that currently support the MCT. The acquisition of wetlands offers a community-based solution to the area's need for open space in addition to retaining wetland ecosystem functions in the watershed.

Acquisition of nearly all remaining wetlands in the HMD is a critical objective to restore the Meadowlands ecosystem and protect its fish and wildlife resources. The Service recommends *determining the priority of wetland and upland acquisitions* by size (large tracts preferred), proximity to other natural areas (connectivity to or closer preferred), and biological factors (*e.g.*, high biodiversity, and the presence of federal or State-listed, special-concern, and other "special interest" species preferred). Such spatial and biological factors affect a species' probability of colonization of and survival in different sites (*e.g.*, Hanski and Thomas, 1994). These priorities for site acquisition are also consistent with the Service's operating principles (Section I) to protect existing biodiversity. Urban ecosystems may differ unpredictably from less human-influenced systems in production, predation levels, and trophic dynamics (*e.g.*, Faeth *et al.*, 2005). Thus, acquiring more sites and increasing their connectivity may improve biodiversity in urban areas (Taylor *et al.*, 1993; Bueno *et al.*, 1995). The future outcomes and objectives of such acquisitions are subject to more detailed analyses of environmental contamination, hydrology, and restoration feasibility on a site-by-site basis.

Flood and storm water control projects have been integrated into large restoration programs elsewhere in the United States (*e.g.*, the Everglades, Lower Colorado River, Gulf Coast). The feasibility of integrating such projects into the remediation, enhancement, and restoration of the Meadowlands should be considered. Certain federal programs (*e.g.*, flood control, flood insurance, transportation projects, tax codes and policies, subsidized mortgage rates) and unsuccessful or partial mitigation of wetland impacts have contributed to wetland losses in northeastern New Jersey, including the Meadowlands. In recognition of the adverse impacts of federal programs on wetlands, the U.S. Department of the Interior (1994) recommended a long-term wetland acquisition plan as a primary aspect of a coordinated flood control program for northeastern New Jersey. At that time, no funds were committed to acquiring wetlands as part of the existing Passaic River Flood Control Program. Presently, the Corps is purchasing wetlands, riparian areas, and adjoining upland areas to preserve natural flood detention and retention storage areas in upper portions of the Passaic River watershed (U.S. Army Corps of Engineers, 2005a; 2005b; 2005c). Although not specific to flood control purposes, federal funding currently is committed to the NJMC to acquire wetlands within the HMD for their preservation.

Acquisition of additional wetlands throughout the HRW is justified not only for flood control (consistent with the 1994 DOI report) but also to improve ecosystem functions (*e.g.*, water filtration, nutrient cycling) and support fish and wildlife resources. The Service recommends that *stakeholders in the HRW coordinate activities to acquire substantial wetlands and adjoining areas to address and integrate enhancement, restoration, flood control, and open-space needs*.

Finally, the Service recommends *acquisition of riparian corridors and adjacent uplands and their preservation as open space to support fish and wildlife resources and provide passive recreational opportunities for the public*. Undeveloped riparian and upland sites are rare in the urban core and remain under increasing development pressure. Thus, the feasibility of remediating, enhancing, and restoring landfills and other contaminated industrialized sites should be investigated to reduce adverse impacts of contaminated areas on fish and wildlife resources and on humans. Depending upon the site-specific measures needed for their remediation, enhancement, and restoration, landfill and industrial sites may provide considerable opportunities to implement wildlife management and public use objectives. Because of the high cost of uplands in the urban/suburban area, Meadowlands stakeholders must develop a comprehensive plan that uses all available authorities and means to acquire corridors, buffers, and other upland areas. Acquisition of such areas is necessary for protecting the ecological integrity of the Meadowlands ecosystem and to provide habitats for upland plant and animal communities. Thoughtful public planning and implementation can result in a well-connected system of diverse wetlands, rivers, and ponds that are integrated with and buffered by public facilities, parks, and trails.

B. PROTECTION

1. Overview

Wetlands in the HMD are regulated by local laws (*e.g.*, NJMC's existing zoning regulations for all municipalities within the HMD), certain State laws (*e.g.*, Flood Hazard Control Act [N.J.S.A. 58A:16A-50 *et seq.*]), and federal laws (*e.g.*, CWA; see Appendix A). Uplands in the HMD generally have less protection, especially pursuant to federal regulations. Regulations at each level have limited capacity to protect wetlands; therefore, *all levels of governance have essential regulatory roles and a shared responsibility in protecting the Meadowlands and its fish and wildlife resources.*

Certain wetlands and adjoining uplands in the HMD owned by State agencies (*e.g.*, NJMC, NJDEP, and MCT) are managed pursuant to additional regulations (*e.g.*, Wildlife Management Area regulations, zoning regulations); therefore, not all publicly owned landholdings are similarly protected. For example, the NJMC (2004d) has proposed new zoning regulations in concert with its Master Plan for the HMD. The Master Plan sets aside extensive wetland (and to a lesser extent, upland) acreage for preservation and enhancement, and additional acreage for public recreational use. At this writing, the revised land-use plan and its zoning regulations have not been submitted to NOAA for determination of consistency with the Coastal Zone Management regulations (see Appendix A; K. Herrington, pers. comm., 2005). In the draft zoning regulations, wetlands and other open space remaining in the HMD are identified as

wetlands, preservation areas, conservation areas, restoration areas, and enhancement areas; however, the meaning of different designations and the specific protections conveyed to those areas are unclear. In addition, radio towers and marinas, activities that have considerable potential to adversely impact fish and wildlife populations, are proposed as "special use exceptions" that could be allowed in certain areas. Any proposed changes to existing zoning and other regulations should be carefully evaluated for potential consequences on wetlands, restoration activities, and protection of fish and wildlife. Also, consistency should be ensured between the NJMC's 2004 Master Plan and Zoning Regulations in order to achieve long-term objectives. For example, instead of providing "special use exceptions" to allow communication towers in "preservation wetlands," zoning regulations should seek to reduce adverse impacts on fish and wildlife resources and allow only appropriate public uses of the public resources in those areas.

Miscommunication, inadequate coordination, and lack of consensus among federal and State agencies have adversely affected the protection of wetlands and fish and wildlife resources in the HMD for many years (*e.g.*, U.S. Department of the Interior, 1994). Recent activities (*e.g.*, filling of wetlands along Penhorn Creek in 2004, construction of guyed radio towers in wetlands along Berry's Creek in 2006) reflect a continuing lack of coordination between resource and regulatory agencies that must be addressed for restoration to move forward. Deed restrictions, conservation easements, and compensatory mitigation have not been applied in the HMD consistent with federal guidance in recent years. For example, deed restrictions on several wetland sites in the HMD have been transferred and proposed for transfer to other wetlands to accommodate proposed (non-water-dependent) projects. In addition, some mitigation banking provisions in the HMD are inconsistent with mitigation banking recommendations of the National Research Council (2001). Thus, additional coordination may be needed by federal and State agencies to bring mitigation wetlands and banks into compliance with federal and State policy guidelines and to prevent future losses of wetlands in the Meadowlands.

The NJMC executed an agreement with the NJDFW in 2004 to develop a HMD-wide conservation plan that will follow the format of the statewide Wildlife Action Plan (formerly the Comprehensive Wildlife Conservation Strategy). This State plan will identify and map those wildlife areas in the Meadowlands that warrant the greatest conservation efforts, and lead to establishment of an action plan, monitoring, and periodic review. The State plan will also evaluate and facilitate development of appropriate public access. This plan is being developed in cooperation with Ducks Unlimited, Inc., the New Jersey Audubon Society, and other stakeholders. Among its key benefits, development and implementation of this State plan should improve protection and promote recovery of State-listed species.

2. Objectives

Recent wetland acquisitions by the NJMC are key steps in preventing the continuing loss of wetlands within the HMD. Currently, most wetlands in the HMD are owned by the NJMC, NJDEP, and the MCT. Because the missions of these groups differ, wetlands under the various ownerships may be subject to different uses or potential threats. The Service recommends that the NJMC, NJDEP, and MCT collaborate on the formulation of any plans, policies, or regulations that may be necessary to *provide uniform, consistent protection of wetlands* under

their respective stewardships. The Service also encourages these agencies and other stakeholders to consider the consolidation of wetland landholdings with the most appropriate State agency for long-term management and protection.

Long-term protection of wetlands under private and other ownership in the HMD remains uncertain due to continuing development and other pressures throughout the urban region. First, urbanization of the landscape (*e.g.*, housing, commercial and infrastructure development) far outpaced the growth of the human population in the NY-NJ Harbor area during the past three decades (Diamond and Noonan, 1996; Beach, 2002). In addition, wetlands in the HMD remain at risk because transportation needs in this urban region will continue to drive demand for improved transportation infrastructure (New Jersey Transportation Planning Authority, 2002). Thus, the Service recommends a coordinated effort by stakeholders to *explore diverse federal, State, and other mechanisms to provide long-term protection to the Meadowlands ecosystem*.

The Service recommends that stakeholders *consider formal establishment of an explicitly identified "preserve"* to protect the Meadowlands ecosystem. Long-term protection is a component of the Service's overall goal for the Meadowlands; federal and State agencies have considerable potential to provide long-term protection through several different authorities and administrative mechanisms that may be applicable to the Meadowlands. In response to a Congressional inquiry and appeals from local NGOs in 1999, the Service's Northeast Regional Land Acquisition Review Committee addressed the feasibility of establishing a Hackensack Meadowlands NWR. The Service decided that establishment of a Meadowlands NWR was not the best option due to contaminant concerns, other land-acquisition priorities, and budgetary issues. In addition, the central location of the Meadowlands in such a large urban and suburban area makes it difficult to prioritize needs of fish and wildlife consistent with NWR policy over the likely high demand for outdoor recreation and opportunities.

Other administrative mechanisms pursuant to federal authorities may strengthen the long-term protection of the Meadowlands. For example, the feasibility of incorporating the Meadowlands into, and managing it as a unit of, the Gateway National Recreation Area of the National Park Service could be explored. The National Park Service's mission is "to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations (National Park Service Organic Act, 16 U.S.C. 1)."

Other alternatives might include formal recognition of the Meadowlands as a marine sanctuary pursuant to the Marine Protection, Research and Sanctuaries Act (16 U.S.C. 1431 *et seq.*) or designation of this area as a Marine Protected Area (MPA) based on Executive Order 13158. A MPA is defined as "any marine area that has been reserved by federal, State, tribal, territorial, or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources therein." Different types of MPAs exist; workshops and training for resource managers and stakeholders in MPAs are supported by NOAA's Coastal Services Center. Designating the Meadowlands as a certain type of MPA, such as a National Estuarine Research Reserve (NERR), may provide additional federal funding for research and related activities. Currently, 26 estuarine areas have been designated as NERRs under the provisions of the national Coastal Zone Management Act (16 U.S.C. 1451 *et seq.*). The NERR system includes

the Hudson River NERR in New York, the Jacques Cousteau NERR in New Jersey, and other imperiled ecosystems that do not fit strict definitions of *marine* or *estuarine* (*e.g.*, Old Woman Creek NERR on Lake Erie). Because the primary purpose of the NERR system is research, other legislative protections may be needed. Thus, establishment of the Meadowlands as a National Marine Sanctuary (NMS), another type of MPA, has potential to provide considerable long-term protection of the Meadowlands and its resources. A NMS is defined (15 CFR Part 922) as an area of the marine environment of special national significance due to its resource or human-use values, which is designated as such to ensure its conservation and management. Designation of the Meadowlands as a NMS would require NOAA to establish its own federal permitting process for activities in the Meadowlands, including an independent application and review of activities such as wetland filling that require other federal permits (16 U.S.C. 1435 *et seq.*). Designating the Meadowlands as a NMS would still allow fishing, hunting, other recreational activities, and potentially even commercial resource harvesting. The Service recommends that stakeholders carefully consider all available alternatives for protection pursuant to existing federal authorities.

The Service recommends considering State mechanisms to protect the Meadowlands, but cautions that such actions alone may affect (*i.e.*, restrict) federal opportunities and mechanisms for restoration or other assistance. Otherwise, application of certain State authorities, such as the designation of the Meadowlands as a State Park, may provide suitable, long-term protection. Protection through county and municipal governments would achieve localized (partial) but not comprehensive protection. The Service supports application of authorities or mechanisms that would provide *broad*, long-term protection for the Meadowlands ecosystem and its biodiversity.

The Service recommends *revisiting the interagency MIMAC agreement to improve coordination* (as discussed in Section VII.A.2 above) and to ensure consistency with recent guidance regarding the CWA and with other concerns (*e.g.*, monitoring requirements, long-term stewardship and management) regarding mitigation in the Meadowlands and nationally (as discussed in Section X; National Research Council, 2001). For example, the Service recommends that federal and State regulatory agencies and the MIMAC require upland buffers as a component of compensatory mitigation for projects adversely impacting wetlands in the HMD. The Corps has the authority to require vegetated buffers next to streams and other open waters in keeping with the CWA's goal to restore and maintain the chemical, physical and biological integrity of U.S. waters (National Mitigation Action Plan, 2004). Guidance regarding the assessment and incorporation of upland buffers as components of compensatory mitigation projects is currently available (*e.g.,* Corps *et al.*, 1995; U.S. Army Corps of Engineers, 2001; 2002b). Also, reinvasion by common reed elsewhere has led to recommendations that monitoring of mitigation sites be extended to at least 10 years (*e.g.*, Chesapeake Bay *Phragmites australis* Working Group, 2003); currently, monitoring of mitigation sites in the Meadowlands is typically required only for 5 years. Revisions to the MIMAC agreement to improve coordination, require vegetated buffers, and ensure long-term stewardship would assist federal and State agencies in preventing losses of wetlands and in improving the functioning of wetlands provided as compensatory mitigation. Finally, the MIMAC should investigate varied efforts to improve the functioning of mitigation wetlands and make mitigation projects more consistent with other, ongoing remediation and restoration activities in the HMD.

C. ENHANCEMENT AND RESTORATION

Enhancement and restoration both employ manipulations of physical, chemical, and biological attributes of the environment and differ primarily in the "historical" nature of the outcome achieved on the site. Enhancement does not involve a return to former functions or conditions, whereas restoration specifically seeks the recovery of historical functions and conditions though not necessarily functions or conditions that existed prior to any human disturbance. Estuaries are dynamic ecosystems with different landscape components (*e.g.*, open water, intertidal) that may undergo succession; the Meadowlands is known to have changed considerably over the past 10,000 years. However, without detailed knowledge of the entire history of all sites throughout the Meadowlands, it is difficult to determine whether habitat and other manipulations of a single site are best defined as enhancement or restoration.

To date, approximately 650 acres of wetlands at 10 sites have been or currently are being restored in the HMD (U.S. Army Corps of Engineers, 2004a). Most of these sites were restored as compensatory mitigation for federally permitted projects and have been acquired by the NJMC. To date, approximately 240 acres of wetlands remain under private ownership within the HMD that have been or are being restored as compensatory mitigation for impacts to other wetlands. The Corps' (2004a) MESIC report identifies nearly all other unrestored wetlands in the HMD as potential restoration sites. Although the vegetative cover of the restored sites has usually met regulatory requirements for success (> 85 percent coverage), comprehensive assessments of these sites (*e.g.*, Neckles *et al.*, 2002), including contaminant distributions and bioaccumulation, and the extent to which such sites sustain fish and wildlife populations, have not been conducted.

Except for sites within the HMD, efforts to restore wetlands throughout the HRW are in preliminary stages. The Service recognizes and supports the MCT's and other stakeholders' interests in pursuing restoration of Hackensack wetlands outside the HMD. For example, the Teaneck Creek Conservancy has received funding to restore a small palustrine wetland in the Overpeck Park area. The emphasis of this 46-acre forest restoration project is educational, recreational, and cultural, focusing on the history of the Lenape. The Service encourages major wetland or upland restoration projects outside of the HMD throughout the HRW. For example, several federally supported restoration projects are underway in upper portions of the Passaic River watershed (*e.g.*, Upper Rockaway River Ecosystem Restoration, U.S. Army Corps of Engineers, 2005b).

1. Hydrology

Enhancing and restoring the Meadowlands and protecting its fish and wildlife resources will require the development of a comprehensive program to assess, integrate, and coordinate efforts to address several complex hydrologic issues: (1) water flow, (2) system-wide improvements in water quality (including improved sewage treatment) to reduce nutrient and contaminant inputs, (3) flood control and storm water issues, and (4) SLR. Nearly all biological processes in estuaries are affected by the nature of freshwater inputs; therefore, a better understanding of hydrologic and ecosystem processes in the Meadowlands, including its capacity to process contaminant and nutrient inputs, is essential to improving water quality and promoting

restoration. Enhancement and restoration will not be successful without a thorough assessment of the feasibility of improving hydrologic conditions throughout the ecosystem.

The NJDEP (1996) and DOI (1994) have recognized the vulnerability of the HRW to water supply and related flow problems. Water is currently diverted from the Passaic and Hudson Rivers (and some wells) into the Hackensack River above Oradell Dam (U.S. Geological Survey, 2003); therefore, water supply planning will likely require broad coordination by planners, resource managers, and interdisciplinary researchers focused on several adjoining watersheds (Pringle, 2000). Comprehensive water-supply planning that incorporates the needs of fish and wildlife has not yet been developed in the HRW as in other urban systems with similar environmental problems and high demand for water resources (*e.g.*, San Francisco Bay; CALFED Bay Delta Program, 2002).

Although a return to historic flows throughout the HRW does not appear feasible, *stakeholders should consider means to restore a more natural pattern of flows to the Hackensack River*, such as periodically requiring increased flows over the Oradell Dam. Additional monitoring and expanded flow analyses (*e.g.*, the USGS Water Information System, stream-flow maintenance assessments) in freshwater portions of the Hackensack, Pascack, and Passaic Rivers are recommended to determine any necessary flow modifications. Water conservation and re-use by all water users in the watershed, and especially major users (*e.g.*, Hudson Generating Station, which uses approximately 475 mgd for cooling purposes), may increase and restore natural flows, and merit greater consideration in regional water-supply planning.

Current and continued impairments to water quality throughout the HRW may limit and compromise successful ecosystem restoration. High concentrations of nutrients and trace elements affect autotrophic (*i.e.*, converting light and chemical energy to complex organic molecules) and heterotrophic (*i.e.*, generating energy from complex organic molecules) processes and biological communities in other degraded estuaries (*e.g.*, Sanders *et al.*, 1987; Wiegner *et al.*, 2003). Organic materials and nutrients from internal and external sources also have different fates in other degraded estuaries (Sobczak *et al.*, 2002). In addition, anthropogenic nutrient inputs may lead to hypoxic and anoxic conditions, which may alter the dominant trophic (predator-prey) relationships in degraded estuaries (*e.g.*, Breitburg *et al.*, 1997). Finally, nutrient inputs may shift the overall balance between production and consumption within estuaries (Kemp *et al.*, 1997). Additional research, including development of ecosystem models of key nutrients and contaminants, will be necessary to provide stakeholders an adequate understanding of the processes affecting water quality and the level of waste treatment required to protect living resources within the Meadowlands. Further research and performance standards are also needed to determine if programs of nutrient reduction are effective. Restoring the Meadowlands will require improvements in sewage treatment throughout the watershed.

Factors affecting water quantity, including flood control and storm water management, also may adversely affect restoration. If integrated and combined, such water resource projects may improve restoration success. For example, non-structural flood control and storm water management projects could provide additional riparian areas and storm water detention and retention areas around restoration sites, and contribute to improved water quality and the overall size of the natural area (*e.g.*, Pallone and Todd, 1997). Diversion of water from the Passaic

watershed into the HRW can also affect flood control, storm water management, and restoration (including remediation) in both watersheds. Restoration partners should explore integrating restoration, flood control, and storm water projects to improve water quality and address other water supply issues throughout the Passaic and Hackensack watersheds. Information obtained by the USGS National Water Quality Assessment Program (NAWQA) has been used in managing, planning, and other decision-making (*e.g.*, stream-flow maintenance objectives) for freshwater portions of other coastal watersheds in New Jersey (*e.g.*, Ayers *et al.*, 2000) and is likely to be increasingly needed throughout the northeastern United States (*e.g.*, Pringle, 2000). The NAWQA Program should be expanded to include a number of monitoring stations throughout the Hackensack, Pascack, and Passaic watersheds to address flow and water quality issues in the upper portions of these connected watersheds.

Finally, *additional information on SLR and its modifiers is needed to assist long-term restoration and related planning for the Hackensack Meadowlands watershed, especially in the HMD*. Limited tide-gauge data available for the Hackensack Meadowlands suggest that SLR is occurring at rates comparable to the New York Harbor area (Hobble, pers. comm., 2004). However, additional information on sedimentation rates and relative SLR within the HMD, such as those provided by surface elevation tables (Cahoon and Lynch, 2005), is needed to determine relative SLR more precisely and to establish the vulnerability of marsh areas, especially those with different vegetation (*e.g.*, common reed, smooth cordgrass, saltmarsh hay). The interaction of SLR and other physical and biological factors will strongly affect the outcomes of restoration throughout the Meadowlands.

Scientific consensus regarding SLR has been slow to develop; therefore, policy makers and planners have not fully considered SLR's implications either to coastal communities or to ecosystems. Accommodating and planning for SLR is difficult in urban areas because human modifications to, and the value of, coastal property influence government priorities (Titus *et al.*, 1991; Boesch *et al.*, 2000). For example, highly developed areas will likely be protected from flooding at high costs (*e.g.*, with levees and pumps), whereas other less-developed or natural areas are more likely to be protected at lower costs (*e.g.*, by increased fill heights) or not protected at all (*i.e.*, allowing natural processes to proceed unimpeded). A gradual retreat of development from waterfront areas appears more likely in the Meadowlands than elsewhere in the NY-NJ Harbor. Such an approach would restore a more natural ecosystem with wetlands surrounded by adjoining riparian buffers. Sea level rise should be considered in long-term planning of storm-water storage, certain infrastructural facilities (*e.g.*, new sewage treatment plants), and hazardous waste sites (Flynn *et al.*, 1984; Sorensen *et al.*, 1984). Failure to plan for impacts of even modest SLR could affect the restoration of the Meadowlands by causing: (1) loss or conversion of wetlands, especially high marsh, to open water; (2) redistribution of contaminants, especially contaminants deposited in sub-tidal sediments, in certain erosional areas, or in heavily contaminated sites, such as landfills near wetlands; and (3) damage to sewage treatment plants or other utilities. Furthermore, lack of planning for SLR could result in substantial socioeconomic costs in the region (*e.g.*, storm-related damage to infrastructure, damage to coastal drainage and sewage treatment systems; Titus *et al.*, 1987).

2. Contaminants

Contaminants, both localized and widespread, present a formidable challenge to the restoration of the Meadowlands ecosystem. Despite the Service's substantial concerns about widespread contamination, Service objectives include the *enhancement and restoration not only of wetland sites within the HMD but also of nearby wetlands outside of the HMD* (*e.g.*, along Overpeck Creek). Virtually the entire Meadowlands ecosystem is contaminated by mercury, PCBs, pesticides, and dioxins from several Superfund NPL sites and other sources. Prudent restoration planning for the Meadowlands must include development of a comprehensive risk assessment regarding contaminants throughout the entire HMD and adjoining watersheds that can influence the health of this ecosystem (U.S. Fish and Wildlife Service, 2005b). Additionally, a state-of-the-art monitoring program of known and novel contaminants and their pathways must be instituted in a manner that addresses both risk and ecological health outcomes. Lastly, development and implementation of water quality criteria that protect wildlife from bioaccumulation of certain contaminants (*e.g.*, mercury, PCBs, and DDT; Buchanan *et al.*, 2001) must be integrated with the above activities.

The Service has developed a preliminary ranking of potential restoration sites based on available information and the degree of concern regarding contaminants (U.S. Fish and Wildlife Service, 2005b). Although progress has been made (*e.g.*, ENSR, International, 2004), insufficient information currently exists to assess and characterize contaminant risks in the Meadowlands for fish and wildlife. *Restoration of the Meadowlands cannot be adequately or fully achieved without a more complete knowledge of the distribution, availability, bioaccumulation and effects of contaminants from waste sites and other sources that are responsible for substantial health and ecological risk to fish, wildlife, and people*. On contaminated sites, restoration should not proceed until this assessment is complete. A recent risk assessment conducted in the Meadowlands (ENSR International, 2004) concluded that: (1) predaceous vertebrates exceed hazard quotients for certain contaminants (*e.g.*, mercury) substantially, and (2) "using site-specific factors [contaminant information] may lead to a significantly lesser degree of potential risk." Contaminants have considerable potential to adversely impact not only the successful restoration of the Meadowlands but also the sustainability of fish and wildlife resources within the region. The loadings and fates (pathways, availability, effects) of mercury originating from heavily contaminated sites in the Hackensack and Passaic Rivers have been identified as among the largest contaminant data gaps for the entire New York Harbor (de Cerreño *et al.*, 2002). Thus, development of a comprehensive risk assessment is critical to evaluating and implementing the most appropriate remediation, enhancement, and restoration alternatives.

In addition to contaminants presently impacting restoration, activities associated with restoration have the potential to exacerbate contamination of the Meadowlands ecosystem, that is, to increase contaminant availability and adversely affect fish and wildlife. For example, grading to achieve a desired elevation to re-establish tidal flow or connections may expose buried contaminants, which then become tidally suspended and redistributed. In addition, care must be taken that restoration does not result in population sinks or attractive nuisances, as has happened elsewhere in the United States. Examples include Lake Apopka, Florida, where a public restoration project caused deaths of hundreds to thousands of birds (U.S. Fish and Wildlife Service, 2001b) and the Channel Islands, California, where re-introduction of raptors was

unsuccessful for more than 20 years (National Oceanic and Atmospheric Administration, 2005b). The effects of certain contaminants on a population may extend several generations beyond the generation originally exposed (*e.g.*, PCB effects on kestrels; Fernie *et al.*, 2001a; 2001b). Other research suggests that sink habitats have the potential to affect the long-term status of large populations (Howe *et al.*, 1991).

Removal of all historical contamination throughout the Meadowlands does not appear technically possible, even excluding any economic considerations; moreover, we do not know what percentage of contamination is possible to remove. A comprehensive risk assessment will, however, help identify the extent to which existing and future contaminants can and must be reduced, (*e.g.*, their existing problematic pathways to biota broken) and may possibly assist in restoring other areas within the HRE. For instance, criteria for removal of the invasive common reed from contaminated sites must be addressed during remediation and restoration risk assessments. Additionally, mercury and other contaminants may be broadly dispersed at substantial levels throughout a hydrologic sub-basin (*e.g.*, Berry's Creek and Canal) and beyond, which would justify restoring the entire sub-basin as well as the area to which this contamination has migrated. The incremental site-by-site approach of most current restoration projects in the HMD does not always provide this focus. Also, a determination of vertical sediment/soil contaminants distributions as well as the chemical forms of this distribution, when appropriate, is needed. The propensity of contaminants to bioaccumulate in aquatic and terrestrial species is critical to understanding exposure and effects. This understanding may provide justification for alternative approaches to restoration of specific sites, following remediation where necessary. Remediation should include evaluating the feasibility of contaminant isolation, such as capping sites or portions of sites, instead of contaminated materials being targeted for removal from the HMD.

Due to a large human population and extensive development, the Meadowlands ecosystem will continue to face challenges regarding contamination of waterways and wetlands from both current and future human activities. To address these challenges, restoration partners and natural resource managers must have timely access to precise information regarding anthropogenic inputs into the HRW. Thus, a comprehensive state-of-the-art program for monitoring water, sediment quality, and biotic exposure to contaminants must be developed. Monitoring should include nutrients, micronutrients, novel contaminants (*e.g.*, Kolpin *et al.*, 2002), and bioaccumulation of contaminants in selected taxa (*e.g.*, invertebrates [Penuto *et al.*, 2005], fishes [Kammen *et al.*, 2005; Weis, 2005], amphibians [Bank *et al.*, 2005], birds [Evers *et al.*, 2005]). In addition, coupling and transformation of nutrients and contaminants between the water column and sediment should be monitored, as bioavailability of those materials varies spatially and temporally with different sources (*e.g.*, Seitzinger *et al.*, 2002; Wiegner *et al.*, 2003).

Finally, federal and State agency stakeholders should work together to develop and implement water quality and related criteria (together with other performance measures) that guide restoration decisions and protect wildlife from bioaccumulation of certain contaminants, especially mercury, PCBs, and DDT. Wildlife water quality criteria previously developed for those contaminants (Buchanan *et al.*, 2001) have not been implemented in the State. These criteria and others, such as for dioxin-like compounds that occur throughout the HRE, are necessary to facilitate remediation, restoration or mitigation projects. An interagency and

stakeholder (*i.e.*, public) consensus needs to be reached on what general conditions are acceptable for restoration, what level of contamination is acceptable, and the ramifications of allowing some contamination to linger.

The Service recognizes that examination of contaminants in the Meadowlands will almost always result in "some level of risk," especially from bioaccumulative contaminants such as mercury. Some small risk, especially to sensitive upper-trophic-level species, will likely be unavoidable during and after remediation projects as well as restoration projects. Some level of risk must be an accepted baseline following remediation and restoration in this urban estuary. This residual level of risk emphasizes the need to develop diverse performance measures to define and evaluate the success of remediation, enhancement, and restoration activities. This residual contamination also can be fully accounted for under the purview of CERCLA and other statutory authorities.

3. Ecosystem and Landscape

A major theme yet to be clearly defined is the broader landscape that will result from successful restoration of the Meadowlands. After decades of industrialization, how will the Meadowlands and the surrounding area be restored and protected? What will it look like, and how will it function? Restoring the entire Meadowlands to a tidal riverine ecosystem extensively forested with Atlantic white-cedar (*i.e.*, present from the 1400s to the late 1800s) is clearly unrealistic. One of the Service's primary objectives for the Meadowlands' restoration is establishing a more diverse landscape of mostly estuarine and other wetland communities of native plant, fish, and wildlife species; however, more specific objectives and features of that landscape have not been established. Restoration of the Meadowlands will likely rely primarily on increasing or re-establishing tidal flows over and within marshes, removing and replacing common reed with a few native estuarine and other wetland species, such as smooth cordgrass, bulrushes, and spike grass, depending on the location of the site within the estuary and the distances from tidal creeks and upland drainage. This approach has been widely used in many estuaries in other states for more than 20 years and in marshes in the Meadowlands for nearly 10 years. Studies of vegetation (*e.g.*, LaSalle *et al.*, 1991; Zedler, 1993, Warren *et al.*, 2002), invertebrate and fish communities (*e.g.*, Burdick *et al.*, 1997; Roman *et al.*, 2002), and birds (*e.g.*, Zedler and Callaway, 1999) indicate that recovery of certain species may take 20 years or longer. Such studies also suggest that establishing specific, hard and fast restoration targets may be unrealistic due to a host of physical and biological variables, but that wetlands with community structure and ecological functions similar to natural systems will develop given time and appropriate hydrology, substrate, and propagules (Warren *et al.*, 2002).

Ecosystem restoration began in the 1930s as an effort to repair systems damaged by agriculture; however, restoration of wetland ecosystems, especially degraded ones, is a more recent endeavor (Jordan *et al.*, 1987; Cairns, 1987). Also, changing degraded, dynamic, wetland ecosystems into more desired ecosystems is not a simple and straightforward process (Zedler, 2000; Peterson and Lipcius, 2003). Thus, research into fundamental and applied questions generated from restoration of previous sites in the Meadowlands (and elsewhere) and additional monitoring of ongoing restoration sites are continually needed to guide and improve restoration activities. For example, the invasive species common reed is re-invading older restoration sites in the

Meadowlands from which it was totally removed; thus, additional research is needed to determine why and how best to prevent re-invasion (*e.g.*, Bart and Hartman, 2000; 2002; 2003; Silliman and Bertness, 2003). Removal of common reed from some sites may be an ongoing activity that will be necessary on a continual or periodic basis in the future. A decrease in invasive species and an increase in indigenous species, particularly in the composition of the vegetational community, along with a rich and diverse native fauna and other indicators (*e.g.*, reproductive success), will provide a gauge of successful restoration. Also, restoration of certain sites can enhance specific processes and functions, some of which may favor different taxa (Havens *et al.*, 2002). For example, increasing subtidal habitats may benefit fishes whereas increasing intertidal vegetative (especially shrub) habitats may benefit birds.

Preliminary studies suggest that marsh restoration increases biodiversity within certain taxa (*e.g.*, birds, Siegel *et al.*, 2003), yet comprehensive assessments of restoring specific sites in the Meadowlands are lacking. Monitoring studies suggest that successful restoration generally increases vegetative cover by desired species (*e.g.*, Hartman, 2000; Louis Berger Group, Inc., 2000); however, restoration has not always resulted in vegetative communities consisting predominantly of planted and other typical species, due to secondary colonization by atypical volunteer (not planted) species such as salt marsh water hemp, marsh fleabane, marsh orach, and umbrella sedge (*e.g.*, Louis Berger Group, Inc., 2002a) or other, unknown reasons (Celebrano, 1995). Comprehensive assessment (*e.g.*, to include contaminants, hydrology, primary and secondary production) of different restoration sites in the Meadowlands has not been, but should be, undertaken. Such assessments may justify consideration of atypical restoration designs (*e.g.*, moats, caps, open water) on heavily contaminated sites. With EPA support, the NJMC also is evaluating use of wetlands restoration methods at Secaucus High School Marsh that have not been used previously in the Meadowlands. Monitoring and periodic assessment is also necessary for adaptive management of current restoration projects and design of future projects with changing conditions (*e.g.*, climate, sea level; French McCay and Rowe, 2003).

Finally, an increasing number of studies are identifying the unique features of urban ecosystems (*e.g.*, altered species composition and food webs, enhanced predation; Faeth *et al.*, 2005) and the potential to manage them (*e.g.*, Rudd *et al.*, 2002). For example, eliminating and replacing exotic vegetation throughout an urban landscape may have positive effects on the reproduction and survival of native bird species (Borgmann and Rodewald, 2004). For the purpose of this report, research and management efforts on urban habitats are secondary to restoration efforts in the Meadowlands and are not addressed in detail here. However, with increasing urbanization of the landscape in the HRW and the northeastern United States, there is growing recognition that such efforts will become increasingly important to the long-term protection of many species. For example, long-term transportation planning could address the fragmentation and hydrologic effects resulting from certain roadways (*e.g.*, I-95) in the Meadowlands. Thus, the Service recommends that stakeholders address urban ecology throughout the HRE in project and land-use planning. The consequences of human-induced landscape change must be better recognized by stakeholders in the Meadowlands and addressed collectively through long-range planning of major transportation and other urban redevelopment projects.

D. BIODIVERSITY

As previously discussed in Section III, biological communities of the Meadowlands ecosystem reflect considerable anthropogenic disturbances. In addition, among conspicuous groups of organisms that are comparatively well-studied (*e.g.*, plants, fishes), many species that were historically present within the Meadowlands have been extirpated. Restoring the Meadowlands to a former undisturbed condition (*e.g.*, a tidal riverine ecosystem extensively forested with Atlantic white-cedar, as was present from the 1400s to 1800s) and re-introducing all of its historical fish and wildlife resources are unrealistic. Nonetheless, the Service recommends addressing hydrological, chemical, and other conditions throughout the Meadowlands (and, in part, the surrounding watershed) as major components of a comprehensive remediation, enhancement, and restoration program. Such actions will increase the biodiversity of the Meadowlands and improve its capacity to sustain healthy native fish and wildlife.

1. Wetland Plants

For much of this millennium, the Meadowlands was a brackish to freshwater wetland ecosystem dominated by marshes with diverse vegetation (*e.g.*, threesquare bulrush, black rush, narrowleaf cattail, and cordgrasses) and interspersed with extensive forested stands of Atlantic white-cedar. Undisturbed, the Meadowlands supported extraordinary biodiversity and species richness. Though the idea of returning the Meadowlands to a forested wetland landscape is unrealistic given both natural and anthropogenic hydrologic alterations to the entire watershed, *establishment of a more diverse landscape of native wetland and upland species is essential to supporting the fish and wildlife resources of the Meadowlands and the region*. Thus, the Service's primary objectives for plant communities in the Meadowlands include: (1) increasing the biodiversity of native plant species in wetlands and adjoining uplands, and (2) reducing the vegetative cover by exotic and invasive species throughout the HMD and the entire watershed.

Increasing biodiversity of native species and reducing impacts of invasive and other exotic species are interdependent and are viewed as a "coarse-filter" approach (*sensu* Noss, 1987) for the long-term conservation of fish and wildlife in the region. Re-establishing and increasing the distribution, extent, and diversity of native plant species is critical to long-term support of fish and wildlife resources. For example, native plant pollinators may be adversely impacted by invasive plant species (Shepherd *et al.*, 2003). Heterogeneous (varied or patchy) landscapes of common reed may provide habitat for many birds and mammals (Marks *et al.*, 1994; Meyerson *et al.*, 2000); however, the form of common reed in the Meadowlands (Haplotype M), once established, grows into extensive homogeneous stands that do not provide high-quality habitats supporting diverse, native fish and wildlife communities. Juvenile fishes are less abundant in common reed-dominated marshes, possibly due to higher predation (*e.g.*, Able and Hagan, 2000; 2003), the different epiflora and epifauna living on common reed (Robertson and Weis, 2005), or marsh microtopography (Raichel *et al.*, 2003).

Recent studies of marsh restoration projects in New Jersey (Able *et al.*, 2005) have shown that secondary production of mummichogs (a common forage fish important to the diet of many marsh fishes and wading birds) is significantly lower in common reed marshes than in restored

or natural cordgrass marshes. Secondary production may be considered a proxy for ecosystem functioning (*e.g.*, Peterson and Lipcius, 2003); in addition, mummichogs are the most abundant fish species in marshes in the Meadowlands. Lower secondary production of mummichogs potentially affects many other aspects of marsh ecology, especially for those species, such as piscivorous (*i.e.*, fish eating) wading birds, that directly interact with mummichog. The findings of these studies suggest that restoration projects replacing common reed with native cordgrasses are improving ecosystem functions. Similarity of the findings reported for mummichogs in the Meadowlands (*e.g.*, Raichel *et al.*, 2003) with those in Delaware Bay marshes (Able *et al.*, 2005) suggests that the current approach to marsh restoration (replacement of common reed with cordgrass) should continue. The Service recommends that secondary production of mummichogs in the Meadowlands be determined using methods similar to the Able *et al.* (2005) study to allow a direct comparison of results.

To date, restoration projects have increased vegetative diversity at most sites, though certain wetlands (*e.g.*, the MRI mitigation bank site; Louis Berger, 2004b) are now covered extensively by uncharacteristic species assemblages, and older (~10 years) restoration sites are being re-invaded by common reed. Research to date in the Meadowlands suggests that restored wetlands, including those with plant communities composed of atypical volunteer species, are being used by diverse wildlife (D. Smith, pers. comm., 2004); this observation is consistent with findings in marsh bird communities in other areas (*e.g.*, Chesapeake Bay; DeLuca *et al.*, 2004). The Service recommends that restoration of wetland sites therefore focus on eradication of common reed and its subsequent replacement with other vegetation, including replacement entirely by volunteer species due to the low success of plantings on some wetland sites (*e.g.*, MRI Mitigation Bank, Louis Berger Group, Inc., 2000). Additional research is needed into: (1) biocontrol of common reed, (2) factors affecting re-invasion of restoration sites by common reed, and (3) development of criteria to guide decision-making on removal of common reed from contaminated sites.

The vegetation of large areas in the upper portion of the HMD (*e.g.*, areas around Teterboro Woods, Losen Slote, Mehrhof Pond) is likely the most diverse within the Meadowlands, but has not been adequately surveyed in recent years and merits additional study. The Service's preliminary vegetative survey of the Teterboro Woods has identified more than 73 species in that area alone; other surveys report invasive, uncommon, and State-listed plant species in other wetland areas (Foote and Loveland, 1982; New Jersey Meadowlands Commission, 2004d; Kiviat and MacDonald, 2004). Thus, botanical surveys should be conducted throughout those and additional natural areas (*e.g.*, local parks) as soon as possible to guide future restoration and other land use activities at these oligohaline (low-salinity) and freshwater sites.

For example, NJDFW and the State's Natural Heritage Program should reassess the status of, and consider developing and implementing a management plan for State-listed and other rare native plant species in the Meadowlands. (Funded by the EPA, the NJMC is developing remote sensing techniques to determine vegetation types; such techniques may facilitate rapid identification of areas that have high vegetative diversity.) The NJDFW and Natural Heritage Program should periodically evaluate the need to assess adverse impacts on those plants from white-tailed deer (*Odocoileus virginianus*), which have returned to the Meadowlands. Deer populations are growing nationwide and are difficult to manage and control with traditional approaches (*e.g.*, hunting) for ecological, social, and political reasons (Brown *et al.*, 2000).

Management approaches suitable for nearby refuges or airports in southern New Jersey (*e.g.*, managed hunting, U.S. Fish and Wildlife Service, 1995; 2004d) may be applicable in the urban landscape of the HMD. White-tailed deer are reported to have eliminated more than 150 plant species from one urban park in Ohio (Peek and Stahl, 1997). Deer browsing also has pronounced direct and indirect effects on the distribution and abundance of other wildlife, including birds (*e.g.*, McShea and Rappole, 2000; Rooney and Waller, 2003; Côté *et al.*, 2004).

2. Upland Plants

Vegetated uplands are generally lacking because of extensive development in the Meadowlands; at present, the most extensive vegetated upland areas are closed landfills covered by common reed. Many disturbed upland areas such as roadsides and abandoned industrial sites in the HMD also are vegetated primarily by common reed and other invasive species that provide diminished support for fish and wildlife in comparison to areas vegetated with native species. Although such areas are far from natural in their origin, the closure, remediation, capping, and redevelopment of landfills potentially represents a considerable loss of vegetated open space, albeit primarily common reed. While the Service supports the closure and remediation of landfills, their replacement by golf courses further shrinks the total availability of upland habitats for native fish and wildlife. In addition, that "replacement" landscape may also support nuisance species (*e.g.*, resident Canada goose) that exacerbate problems for restoration of wetland sites throughout the HMD by feeding heavily on young vegetation at recently (within the past few years) restored marshes.

Remediation and restoration of landfills should focus on increasing native vegetation and biodiversity within the HRW. The NJMC (2004d) has committed to preserving the 1-A and 1-D Landfills as open space; the Service recommends that the NJMC commit to restoring extensive areas of additional landfills in the HMD with native upland vegetation, especially native grass and shrub species. Stakeholders should investigate and evaluate the vegetative communities most suitable for landfills in terms of their impacts on water quality and support for fish and wildlife and explore the use of tree species, as is being done on other landfills in the New York Harbor area (*e.g.*, Fresh Kills Landfill, Staten Island, New York; Handel *et al.*, 1997). Planting trees over landfill caps requires considerable volumes of clean fill; restoration partners should examine the scheduling of restoration and dredging projects to accommodate complementary needs (*i.e.*, the disposal and use of clean dredged materials).

In addition, the Service recommends that restoration partners and other Stakeholders increase the extent and quality (*i.e.*, native vegetation) of upland buffers throughout the HMD and the watershed. Upland buffers are increasingly recognized as critical to the functioning of wetlands, including their ability to support fish and wildlife resources. Buffers provide or enhance a number of ecosystem functions, including groundwater exchange, sediment removal and erosion control, moderation of storm water runoff, removal of nutrients and certain contaminants (*e.g.*, metals), moderation of water temperature, and maintenance of habitat and species diversity (Leavitt, 1998; Wenger, 1999; U.S. Army Corps of Engineers *et al.*, 2002). Disturbance of buffers surrounding high marsh habitat (especially the removal of woody vegetation) promotes the spread of common reed throughout New England marshes (Silliman and Bertness, 2003). Increasing the width of buffers decreased both non-point source loading of nutrients and invasion

by exotic species in urban and suburban areas in New York's Hudson River Valley (Kleppel *et al.*, 2004). Increasing buffer width also increases the suitability of riparian areas as habitat for migratory birds (*e.g.*, Whitaker and Montevecchi, 1999).

3. Aquatic Animals (Invertebrates and Fishes)

In support of its overall goal for the Meadowlands, the Service's major objectives for aquatic animals in the Meadowlands are to: (1) increase native invertebrate and fish biodiversity, and (2) reduce the extent of disturbed and impaired aquatic communities, including those dominated by invasive and exotic species. These objectives are dependent on each other, and, to some extent, can be achieved only by improving water quality throughout the entire watershed. Rare species with specific habitat requirements (*e.g.*, gravel beds for spawning sturgeons) or other special requirements (*e.g.*, commensal species needed for freshwater mollusks) may require additional efforts to assist their recovery.

Many diverse phyla of invertebrates (*e.g.*, mollusks, arthropods) are critical components of aquatic ecosystems: they transfer and cycle nutrients, matter, and energy and link all other diverse components of wetland ecosystems (Mitsch and Gosselink, 1993). Invertebrate groups include some of the smallest, most abundant, yet least studied animals within the Meadowlands (Yuhas *et al.*, 2003; Robertson and Weis, 2005). Available information indicates that many of these invertebrates are adversely impacted by poor water quality and contaminants; for example, surveys of benthic macrofaunal and megafaunal invertebrates in the Meadowlands (*e.g.*, New Jersey Turnpike Authority, 1986; Kraus and Bragin, 1989) reported low species diversity with collections typically dominated by only a few common species (*e.g.*, sand shrimp [*Crangon septemspinosa*], grass shrimp [*Palaemonetes pugio*]). While the total abundance of benthic invertebrates in those collections was comparable to invertebrate abundance found in other portions of the HRE and other mid-Atlantic estuaries (Steimle and Caracciolo-Ward, 1989), invasive species (*e.g.*, the polychaete worm *Polydora ligni*, the bivalves *Macoma balthica* and *Congeria leucophaeta*) and pollution-tolerant species (*e.g.*, tubificid worms) frequently have dominated samples and contained few other species. Factors affecting the success of these species and their impacts on contaminant cycling and availability are not well-known.

Available information is scarce but indicates that the invertebrate communities in primarily freshwater portions of the Hackensack River also are imperiled by the extensive hydrologic alterations and poor water quality (especially turbidity) in upper portions of the watershed. The federally endangered dwarf wedge mussel (and perhaps commonly associated State-listed mollusks, the green floater [*Lasmigona subviridis*], yellow lampmussel [*Lampsilis cariosa*], and tidewater mucket [*Leptodea ochracea*]) apparently no longer occur in the HRW. The North American temperate freshwater fauna, especially mussels, appears to be losing species as rapidly as tropical forests (Ricciardi and Rasmussen, 1999). The diversion of water from the Passaic and the Hudson Rivers also increases the likelihood of invasive mollusks (*e.g.*, the zebra mussel) and other exotic species being introduced into freshwater portions of the upper Hackensack River above Oradell Dam. Zebra mussel and other invasive mussel species (*e.g.*, the Asian clam *Corbicula fluminea*, known nationwide; McMahon 1983; Leff *et al.*, 1990) have played a major role in the decline of other freshwater mollusks and are considered a threat to native endangered and threatened mollusk species (*e.g.*, Baker and Levinton 2003; U.S. Fish and Wildlife Service,

2003c). Thus, surveys are needed to assess the Hackensack and Passaic River watersheds' freshwater faunas and their critical limiting factors, and investigate the feasibility of re-establishing populations of rare mollusks (*e.g.*, federally and State-listed species) subsequent to improvements in water quality and storm water control.

Comprehensive surveys of the fishes throughout the HMD (*e.g.*, Kraus and Bragin, 1989; Bragin *et al.*, 2005) suggest that the fish community remains broadly impaired by poor water quality but may be recovering. Some tidal tributaries of the Hackensack River still experience hypoxic conditions periodically throughout the year (Neuman *et al.*, 2004). The 36 to 39 species of fishes identified in the above HMD-wide studies included only 45 to 61 percent of the 51 estuarine fishes reported as commonly occurring in New Jersey estuaries (Able, 1992; Able and Fahay, 1998) and about half of the species reported in the Meadowlands by Smith (1897). Many fishes reported as common throughout New Jersey estuaries (Able, 1992) were represented by 5 or fewer specimens (*e.g.*, Atlantic tomcod [*Microgadus tomcod*], Atlantic croaker [*Micropogonias undulatus*], striped searobin [*Prionotus evolans*], hogchoker [*Trinectes maculatus*], summer flounder [*Paralichthys dentatus*], naked goby [*Gobiosoma bosc*]) in the 480 collections of the most recent 2-year study in the Meadowlands (Bragin *et al.*, 2005). Not surprisingly, most abundant fishes in the recent survey of the Meadowlands (*e.g.*, mummichog, Atlantic silverside [*Menidia menidia*], gizzard shad [*Dorosoma cepedianum*]) are recognized for their tolerance of dynamic physicochemical conditions and pollution in estuaries (*e.g.*, Weis *et al.*, 1999b; Maryland Department of Natural Resources, 2005). Notably, Atlantic and shortnose sturgeons (*Acipenser oxyrhynchus* and *A. brevirostrum*) no longer occur in the HRW, despite the presence of a large population of the latter species in the Hudson River (National Marine Fisheries Service, 2004a). Fish collections in the Meadowlands also have consistently included such exotic fishes as carp (*Cyprinus carpio*) and goldfish (*Carassius auratus*; Kraus and Bragin, 1989; Bragin *et al.*, 2005). The NMFS (2004b) has identified the Meadowlands as Essential Fish Habitat for 8 marine fishes of commercial importance (Table 29), including several popular food fishes such as black sea bass (*Centropristis striata*), bluefish (*Pomatomus saltatrix*), summer flounder (*Paralichthys dentatus*), and winter flounder (*Pseudopleuronectes americanus*). Because certain of these fishes likely experience slower growth rates (and presumably higher mortality) as a result of the chronic and periodic hypoxia and other stressors in the Meadowlands (*e.g.*, Bejda *et al.*, 1992; Hales and Able, 1995), improved water treatment has the potential to promote greater diversity and increased growth and production of fishes in the Meadowlands.

Table 29. Fishes for which the Meadowlands has been identified as providing Essential Fish Habitat (National Marine Fisheries Service, 2004b).

Common name	Scientific name
Butterfish	*Peprilus triacanthus*
Bluefish	*Pomatomus saltatrix*
Red hake	*Urophycis chuss*
Scup	*Stenotomus chrysops*
Black sea bass	*Centropristis striata*
Winter flounder	*Pseudopleuronectes americanus*
Summer flounder	*Paralichthys dentatus*
Windowpane flounder	*Scophthalmus aquosus*

Fishes with different feeding habits and prey are bioaccumulating certain contaminants in the Meadowlands (*e.g.*, Fernandez *et al.*, 2004; Weis, 2005). Such findings indicate: (1) a need for additional studies of contaminant bioaccumulation in the prey and predators of fishes in the Meadowlands, and (2) development of a comprehensive program targeting remediation and restoration of heavily contaminated and other aquatic sites. Young-of-the-year Atlantic tomcod collected in the Hackensack River had higher body burdens of dioxins and furans than tomcod collected anywhere in the HRE; the hepatic concentrations of dioxins and furans far exceed those known to elicit toxicity in tomcod and some other fishes (Fernandez *et al.*, 2004). In addition, although predatory fishes appear to be increasing in the Meadowlands, certain species (*e.g.*, white perch, *Morone americana*) contain high body burdens of mercury and PCBs (Weis, 2005). The Service recommends that bioaccumulation of certain contaminants (*e.g.*, mercury, PCBs) in fishes, their prey, and their predators be identified as a research priority critical to guiding remediation and restoration of the Meadowlands.

4. Amphibians

Amphibians in some areas are sometimes more abundant (*e.g.*, 70,000 per ha [Ovaska *et al.*, 2004]), contribute more biomass to terrestrial ecosystems than most mammals (Burton and Likens, 1975; Beebee, 1996), and are important components of both terrestrial and aquatic food webs and ecosystems (Hairston, 1987). Certain amphibians (*e.g.*, stream salamanders) have been recognized as keystone species[1] in wetland ecosystems (Wilbur, 1997; Kurzava and Morin, 1998; Wyman, 1998). Because they are sensitive to environmental change, many amphibians also are considered sentinel species[2]. Habitat loss, alteration, and fragmentation, contaminants, and illegal collecting are the likely causes of the low amphibian diversity throughout the HMD (Schlauch, 1976; Rouse *et al.*, 1999; Ovaska *et al.*, 2004; Rubbo and Kiesecker, 2005; AmphibiaWeb, 2005). Exotic species, including fungal pathogens (Berger *et al.*, 1998; Daszak *et al.*, 2003) have also been implicated in the extirpation of amphibians from some locales.

Ten species of frogs are the only amphibians that have been reported to occur in freshwater wetlands in the Meadowlands (Hackensack Meadowlands Development Commission, 1987; Kiviat and MacDonald, 2004), although there are unconfirmed reports of one salamander species occurring at one or more upland sites (W. Sheehan, pers. comm., 2005). Most, though not all, frogs that occur in the Meadowlands are common species with stable populations statewide (New Jersey Department of Environmental Protection, 2004f); however, most amphibians have been reported to be declining throughout the New York urban region (U.S. Fish and Wildlife Service, 1996a). Amphibians are not well studied in the Meadowlands; most species were reported by only one study conducted 20 years ago in a single locale. Their current status anywhere in the HMD is unknown. Recent surveys of the Teterboro Woods, which appeared to provide suitable habitats, recorded no amphibians (New Jersey Meadowlands Commission, 2004h).

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[1] Keystone species- a species that strongly affects community composition (biodiversity) and ecosystem processes.

[2] Sentinel species- a species sensitive to environmental change and environmental conditions; the presence of sentinel species indicates a relatively clean, undisturbed ecosystem.

The NJDEP (2004f) previously established the *Herp Atlas Project* to assess and protect amphibians (and reptiles) throughout the State. In support of this and other regional activities (*e.g.*, Amphibian Research and Monitoring Initiative; U.S. Geological Survey, 2005d) to protect amphibian biodiversity, efforts should be made to assess the distribution and abundance of amphibians in the HMD. Surveys of nocturnal calling and vernal pools are needed. Morphological (limb and development) and reproductive (intersex) data also should be gathered to assess contaminant and other environmental influences on the biology of amphibians in the HMD (*e.g.*, Crump *et al.*, 2002). Depending upon results of those surveys, additional steps to protect and sustain amphibians in the HMD (*e.g.*, roadway crossing structures, re-introductions, AmphibiaWeb, 2005) may be necessary, and would contribute to the Service's overall goal of sustaining diverse fish and wildlife resources in the Meadowlands. Forest amphibians may serve as keystone species; thus, the presence of amphibians may be important to re-establishing and sustaining a diverse palustrine community.

5. Reptiles

Reptiles are important predators and scavengers in many ecosystems, and often are recognized as indicator or sentinel species for entire regions. The presence of some reptile species may increase regional biodiversity; thus, certain reptiles (*e.g.*, snakes) serve as keystone species within an ecosystem (Bondavalli and Ulanowicz, 1999). While habitat loss, collecting, pesticides, and other factors have all contributed to the global loss of reptile biodiversity, habitat alteration may have greater adverse impacts on reptiles than on other terrestrial taxa (Gibbons *et al.*, 2000; Howes and Lougheed, 2004). Even subtle changes in microhabitat can directly alter: (1) behavior and site selection (Howes and Lougheed, 2004); (2) microclimatic conditions important for behavioral thermoregulation (Heatwole, 1977); (3) underground conditions of hibernacula (*e.g.*, stability, depth, humidity) that are essential for over-wintering (Rosen, 1991; Prior and Weatherhead, 1996), and (4) reproductive ecology (Shine *et al.*, 2002). Habitat alteration also affects the reproduction of many aquatic turtles, which increasingly must nest in comparatively small, unsuitable sites, closer to the water's edge, that have high nest predation rates (*e.g.*, Kolbe and Janszen, 2002; Baldwin *et al.*, 2004).

Of the 24 species of reptiles that occur in northeastern New Jersey, 15 species have been reported in the Meadowlands (Hackensack Meadowlands Development Commission, 1987; Kiviat and MacDonald, 2004). One reptile species often observed in the Meadowlands, the northern diamondback terrapin (*Malaclemys terrapin*), is reportedly declining throughout the entire state and elsewhere in the region. Historically, carcasses of vehicle-killed female terrapins, which were searching for nest sites, have been frequently observed along major roadways (*e.g.*, I-95) in the HMD in spring and early summer; in addition, nest predation in wetland restoration areas occurs frequently in the HMD (Spendiff, pers. comm., 2004). Roadways, nest predation, and contamination likely represent considerable sources of mortality for diamondback terrapin in the Meadowlands (*e.g.*, Roosenburg and Place, 1994; Wood and Hales, 2001; Gibbs and Shriver, 2002). The status of the mud turtle (*Kinosternon subrubrum*), stinkpot (*Sternotherus odoratus*), five-lined skink (*Eumeces fasciatus*), northern black racer (*Coluber constrictor*), and smooth green snake (*Opheodrys vernalis*) is unknown in the Meadowlands (New Jersey Department of Environmental Protection, 2004g). Several of those species have only been reported from a single site (Hackensack Meadowlands Development

Commission, 1987) and may be extirpated within the Meadowlands. One of the most common turtle species in the Meadowlands, the red-eared slider (*Trachemys scripta*), was introduced from the pet trade (Kiviat and MacDonald, 2004).

The NJDEP (2004g) recently established the *Herp Atlas Project* to assess the distribution and abundance of reptiles (and amphibians) throughout the State. To further this effort, the distribution and abundance of reptiles and their critical habitats (*e.g.*, potential den areas such as Snake Hill and Little Snake Hill, nesting sites of the diamondback terrapin) in the HMD should be determined. Available information suggests that additional protective measures should be considered for terrapins (*e.g.*, roadside fencing to reduce mortality of nesting females) and snakes (*e.g.*, protect known den areas). Creation of nesting areas for diamondback terrapins has been suggested previously as a potential restoration activity in the Meadowlands (U.S. Fish and Wildlife Service, 2004e) and is being undertaken in other mid-Atlantic states (*e.g.*, Maryland). Rearing and release programs are being used elsewhere in New Jersey in part to rebuild terrapin populations (Herlands *et al.*, 2004). Development of such a program in the Meadowlands would provide a valuable educational program, and would additionally support efforts to understand contaminant effects in the Meadowlands (*e.g.*, as has been done with studies of the mummichog in polluted and non-polluted wetlands; Weis and Weis, 1989; Khan and Weis, 1993).

6. Birds

Birds are among the most conspicuous components of ecosystems throughout North America and the world, and exhibit diverse feeding (*e.g.*, granivory, carnivory) and reproductive behavior, including nest parasitism[3]. Their endothermy[4] and ability to fly have enabled birds to exploit resources at spatial scales that exceed most other groups of animals and contributed to the evolution of lengthy spring and fall migrations between distant nesting and wintering grounds. Birds also are recognized as keystone species in some ecosystems (*e.g.*, Payton *et al.*, 2002).

Birds are increasingly viewed as imperiled worldwide, including North America (Rich *et al.*, 2004). Approximately 40 percent (more than 330 species) of the 800+ species of migratory birds on the Atlantic flyway use the Meadowlands as breeding habitat or as a "stopover" in which to feed and rest during their spring and fall migrations (Kane *et al.*, 1991; Kane and Githens, 1997). This diversity includes year-round resident species that breed in the Meadowlands, migrant species that pass through the Meadowlands in spring or fall, and a small group of species that overwinter there during their non-reproductive season. Because birds in the Meadowlands are diverse, occasionally abundant, generate considerable public interest, and are a federal trust resource responsibility, migratory birds provide a strong justification for the protection and restoration of the Meadowlands.

A preliminary study (Siegel *et al.*, 2003) indicates that restoration has the potential to increase the diversity of birds that use the Meadowlands for breeding. Avian species richness increased

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[3] Nest parasitism- where an individual of one species (e.g., cowbird [*Molothrus ater*]), places its eggs in the nest of another species (*e.g.*, eastern Meadowlark).

[4] Endothermy- the ability to generate heat and metabolically regulate internal body temperature; animals (*e.g.*, mammals) with this capacity are sometimes referred to as "warm-blooded."

during the years following the restoration of the Harrier Meadow. Pre-restoration bird communities were similar throughout Harrier Meadow marshes and showed little inter-annual variation; in addition, unrestored portions of the Harrier Meadow marshes had similar bird communities pre- and post-restoration. In contrast, restored portions showed considerable changes in the bird community composition and guild structure (landbirds, waders, waterfowl, raptors, gulls/terns, and shorebirds). The greatest change in bird community composition occurred during the first post-restoration year as increased habitat heterogeneity attracted more bird species; however, bird diversity continued to increase in succeeding years. This preliminary information is encouraging, but also indicates the need for additional site information (*e.g.*, contaminant monitoring) to evaluate the potential for Harrier Meadow and other restored sites to function as attractive nuisances and population sinks.

Thus, Service-recommended actions to support and maintain avian biodiversity include remediating contaminated sites and improving water quality to increase habitat quantity and quality. These actions are critical to providing for the long-term protection and support of birds residing in and migrating through the Meadowlands. Remediating contaminated sites and improving water quality have beneficial effects on all fish and wildlife resources in the Meadowlands, including birds. Because of their food preferences and trophic position, piscivorous and insectivorous birds are especially vulnerable to bioaccumulation and biomagnification of contaminants such as mercury (Evers *et al.*, 2005). However, while the presence of different species of birds in the Meadowlands is well-recognized, most aspects of the biology of birds in the Meadowlands are poorly known. Acquiring additional information about (1) contaminant impacts on select bird species (*e.g.*, belted kingfisher, *Ammodramus* and *Melospiza* sparrow species, red-winged blackbirds, herons, and rails), (2) urban landscape impacts (*e.g.*, buildings, radio towers, automobiles) on birds, and (3) habitat-specific life history is critical to providing for the long-term protection of avian species that reside in or migrate through the Meadowlands.

In addition to actions that will protect and sustain all bird species, the Service recommends considering actions to support rare bird species, including federally listed and State-listed species, and other declining or vulnerable species on various special concern or watch lists (Tables 8, 9, and 10). For example, the federally listed (threatened) bald eagle has been increasingly observed in the Meadowlands during fall, winter, and spring. However, the bald eagle neither nests nor is regularly seen at many sites; perhaps few foraging perches and roost sites are available. Prior to providing (or supporting applications to provide) any artificial perch or roost structures to encourage the re-establishment of bald eagle or other bird species in the Meadowlands, the Service must consider potential impacts from the "built landscape," as one bald eagle is known to have died from a mid-air collision in the Meadowlands. Available information regarding State-listed bird species is limited, but indicates that breeding populations of most of those species in the Meadowlands are small and limited to few sites. The status and needs of rare bird species breeding in the Meadowlands should be assessed; depending upon the results of such species and needs assessments, programs should be implemented to protect those species and species groups and educate the public regarding their biology, needs, and threats. The source and extent of potential contaminants and their availability and effects must be evaluated when considering establishment of programs to support listed and other rare species (*e.g.*, State's Wildlife Action Plan).

7. Mammals

Because of their size, abundance, endothermic physiology, and other features of their biology, mammals often have major impacts on many ecosystems, including wetlands. Because of their endothermy, mammals must consume larger amounts of food than ectothermic[5] animals and strongly influence the transfer of materials and energy through wetland and upland ecosystems. For example, herbivorous mammals may increase or decrease plant diversity, physically alter the landscape, and redistribute nitrogen and other nutrients through their waste (Huntly, 1991; Rooney and Waller, 2003). Small predaceous mammals such as bats, shrews, and moles are important predators of insects and other invertebrates (Chapman and Feldhammer, 1992). Small mammals also are important prey items for a number of other animals, including reptiles, birds, and certain mammals (*e.g.*, red fox [*Vulpes vulpes*]). Just through these predator-prey relationships, small mammals may directly influence population levels of other animals, such as insect pests (*e.g.*, gypsy moth [*Porthetria dispar*]; Jones *et al.*, 1998; Schauber *et al.*, 2004), disease vectors (*e.g.*, deer tick [*Ixodes scapularis*]; Giardina *et al.*, 2000; Goodwin *et al.*, 2001), and raptors (*e.g.*, sharp-shinned hawk [*Accipiter striatus*], Schmidt and Ostfeld, 2003). Mammals also may modify the physical environment in ways that create habitat for other animal species, and thus are recognized as keystone species of certain ecosystems.

Approximately 24 mammal species have been reported in the Meadowlands (Hackensack Meadowlands Development Commission, 1987; Kiviat and MacDonald, 2004). Most mammal species common in uplands and wetlands of the Meadowlands are recognized for their tolerance of urban environments but have not been well-studied in such areas (Kiviat and MacDonald, 2004). These species include the eastern cottontail (*Sylvilagus floridanus*), white-footed mouse (*Peromyscus leucopus*), meadow vole (*Microtus pennsylvanicus*), common muskrat (*Ondatra zibethicus*), and the four introduced species known to have feral populations in the Meadowlands (house mouse [*Mus musculus*], Norway rat [*Rattus norvegicus*], dog [*Canis familiaris*], and cat [*Felis domesticus*]). Populations of house mice and Norway rat have likely declined with landfill closures (Kiviat and MacDonald, 2004); however, feral cats remain likely to have adverse impacts on wildlife populations in the Meadowlands. Muskrats have been identified as a probable keystone species in the Meadowlands (Kiviat and MacDonald, 2004). White-tailed deer (K. Spendiff and R. Feltes, pers. comm., 2004) and coyote (*Canis latrans*; K. Spendiff and B. Mohn, pers. comm., 2004) have been reported recently in the Meadowlands. As the deer population grows in the Meadowlands, so will the need to manage this species.

The Service seeks to sustain or increase the biodiversity of all taxa, including mammals; however, it is unclear to what extent the Meadowlands may be capable of supporting additional mammalian species. For example, the Meadowlands lies along the edge of the range of foraging habitat of the Indiana bat, a federally listed (endangered) species; however, suitable roosting habitat (*i.e.*, trees with loose bark in summer and caves or mines during winter; U.S. Fish and Wildlife Service, 1999) does not occur in the Meadowlands.

[5] Ectothermic- when environmental temperature primarily influences body temperature, sometimes referred to as "cold-blooded"

One mammal species that may deserve consideration for establishment in the Meadowlands is the State-listed (endangered) Allegheny woodrat (*Neotoma magister*), which also is listed as threatened by the State of Pennsylvania (Pennsylvania Game Commission, 2005) and endangered by the State of New York, where it is believed extirpated (New York State Department of Environmental Conservation, 2003). The last remaining population in New Jersey occurs in Bergen County along the Palisades (New Jersey Department of Environmental Protection, 2005a). The presence of other populations, even isolated ones in the Meadowlands, would improve the long-term survival of the species in the region. Efforts to establish populations in other areas of apparently suitable habitat have been unsuccessful (M. Valent, pers. comm., 2005). It is unclear if the rock outcrops in the HMD (*e.g.*, Snake Hill, Little Snake Hill) provide sufficient habitat or if raccoon roundworm (*Baylisascaris procyonis*), a common parasite of northern raccoon (*Procyon lotor*) responsible for the extirpation of Allegheny woodrat in neighboring states, is prevalent in the area.

Reducing adverse impacts of non-native mammal species in this urban area is another Service objective. To accomplish this objective, the Service recommends: (1) monitoring and assessing the status of introduced or feral mammal populations, (2) monitoring pathogens and disease vectors of selected mammal populations, and (3) educating the public regarding non-native mammal species, such as the domestic cat. Management plans and accompanying public education programs are needed to address the adverse impacts of those species.

E. SUMMARY

Considerable progress has been made during the past few years by the NJMC and the MCT in acquiring wetlands in the HMD; however, acquisition of wetlands elsewhere in the HRW and of upland open space throughout the watershed has progressed slowly. This may result from a lack of information on the distribution, composition, and value to fish and wildlife of such wetland and upland habitats. Acquisition of remaining wetlands and other open space throughout the HMD and the watershed is critical to safeguarding and sustaining the Meadowlands and its biodiversity.

All levels of government (federal, State, and local) have important roles in protecting the Meadowlands ecosystem and its fish and wildlife resources. Implementation of current laws and regulations pertaining to wetlands has been inconsistent and resulted in lapses in the protection of wetlands and fish and wildlife resources throughout the HMD. Federal, State, and local laws and regulations should be reviewed to ensure consistency and improve protection for fish and wildlife resources. Stakeholders should pursue designation of the Meadowlands as a marine protected area to promote and provide comprehensive long-term protection.

Restoration activities in the Meadowlands to date appear promising; current activities have shown the potential for restoration to reduce and in some areas eradicate common reed and promote increases in native biodiversity. Efforts to restore the Meadowlands and protect its fish and wildlife populations must include a comprehensive program to integrate and address hydrologic (*e.g.*, river flow, stormwater control, SLR) and contaminant concerns (*e.g.*, industrial contamination, landfills, sewage treatment). Similarly, the impacts of the urban landscape upon

fish and wildlife populations must be addressed. Many of the historical adverse impacts on fish and wildlife populations can be reversed through: (1) restoration, (2) adaptive management based on monitoring of existing restoration projects, and (3) incorporating urban ecology in future project planning throughout the HRE. In some instances, active management and manipulation of fish and wildlife populations and their habitats likely will be necessary.

Establishment of diverse vegetative communities comprised of native species is a major Service objective for the Meadowlands. Plant diversity in wetlands and uplands can be improved substantially by eradicating common reed, planting desired species, allowing re-colonization by native species, monitoring on-site vegetation, and treating common reed that re-invades sites before it becomes re-established. Although restoring the Meadowlands to its former condition (*i.e.*, forested extensively by Atlantic white-cedar) is unrealistic given the watershed's current hydrology, increasing the extent, diversity, and native composition of its wetlands is vital to sustaining and safeguarding the region's fish and wildlife resources. Increasing the extent and quality of upland buffer areas also will promote the recovery of wetland vegetation and the functioning of restored wetlands, as well as provide upland habitat for other species such as migratory birds. An increase in upland vegetative diversity will also better sustain animal diversity in uplands and adjoining wetlands.

The Meadowlands retains considerable biodiversity despite the extirpation of species that historically occurred there, a testament in part to the resiliency and adaptiveness of many species. Available information, though limited for many taxonomic groups, indicates that aquatic and terrestrial communities of invertebrates, fishes, amphibians, reptiles, birds, and mammals remain imperiled by water quality, contamination, and other stressors (*e.g.*, invasive species). Populations of many species of these groups have been identified as keystone species; thus, programs targeting the re-establishment of populations of those species may further assist the recovery of biodiversity and restoration of the Meadowlands ecosystem.

VIII. Research and Education

Organizers, presenters, and attendees.

Buckeye (*Junonia coenia*) forage on white thoroughwort (*Eupatorium album L.*).

Thomas G. Barnes Ph.D.
http://plants.usda.gov

VIII. Research and Education

Restoration of wetlands at the Marsh Resources Inc.'s (MRI) Meadowlands Mitigation Bank began in 1999. Like much of the Meadowlands, this site was covered with common reed. Restoration involved several steps: (1) treating existing stands of common reed with herbicide, (2) removing remaining wrack and other debris, (3) excavating, dredging, and regrading the site to improve tidal flow throughout creeks, low marsh, and high marsh networks, and (4) planting and seeding with smooth cordgrass, salt meadow hay, and spike grass. More than 200 acres at the MRI site have now been restored.

Some restored portions of the MRI site presently have atypical vegetative communities—wetlands dominated by native species such as salt marsh water hemp, marsh fleabane, dwarf spike rush, and uplands characterized by deer tongue grass, smartweeds, goldenrods, and late-flowering thoroughwort. Such unplanted "volunteer" species typically do not dominate tidal marshes in the region, yet the MRI site is used by diverse fish and wildlife species. Restoring the MRI site has raised many interesting questions regarding the volunteer species and their value to fish and wildlife populations. Understanding the factors that enabled these species to colonize this site may help us enhance and restore other sites.

Scientists are not alone in needing more information to understand the Meadowlands responsibly. Every one of the 20 million residents of the New York metropolitan area has the potential to effect change (both positive or negative) in the entire estuary. Thus, public education is absolutely crucial to restoration efforts. Area residents must be encouraged to take pride in the Meadowlands, appreciate its value, advocate restoration, and seek active participation in recovery efforts. Public action today will benefit future generations.

The Marsh Resources, Inc. Meadowlands Mitigation Bank (1999).

VIII. RESEARCH AND EDUCATION

A. PRIORITY RESEARCH OBJECTIVES

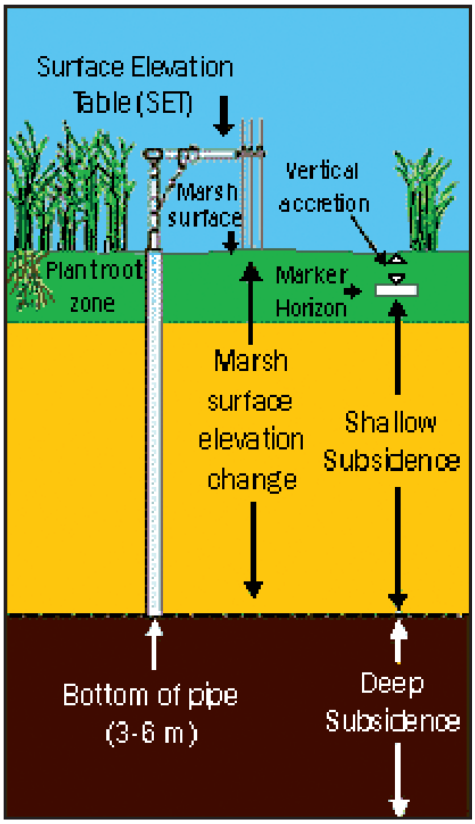
1. **Expanded Capability, Collaboration, Access, and Communication**
2. **Environmental Contaminants, Water Quality, and Hydrology**
3. **Urban Land Use and Ecology**
4. **Invasive and Exotic Species**

B. PRIORITY PUBLIC EDUCATIONAL OBJECTIVES

1. **Outreach Program**
2. **Formal and Informal Educational Programs**
3. **Demonstration Projects and Exhibits**
   a. Atlantic White-Cedar
   b. Mastodon
   c. Bioremediation
   d. The Old Landfill Legacy: Leachates and Methane Gas
   e. The New Landfill Legacy: Golf Courses and Resident Canada Geese
   f. Prevention and Biological Control of Invasive Species
   g. Sea Level Rise and Global Change
   h. Native Peoples: Subsistence on Fish and Wildlife Resources
   i. The Watershed: Connecting the Landscape and the Hackensack River

C. SUMMARY

Networks of surface elevation tables such as the one shown here can be used to monitor sea level rise on different restoration sites.



VIII. RESEARCH AND EDUCATION

Research and education are vital to Service and other stakeholder efforts to restore the Meadowlands and protect its fish and wildlife. To date, however, research activities conducted in the Meadowlands have been largely associated with site-specific regulatory matters. Remediating, enhancing, and restoring the Meadowlands will require additional, comprehensive, long-term monitoring, assessment, and research programs. Comprehensive research programs will be needed in several different areas of concern, such as contaminants, invasive species, and landscape effects, to provide the technical information needed for successful remediation, enhancement, and restoration. Unfortunately, the Service, and to some extent, other stakeholders are currently limited in their capacity to generate and provide needed information to remediate, enhance, and restore the Meadowlands ecosystem and provide for the long-term protection of its fish and wildlife.

Research can address broad and specific concerns; however, varied and effective educational programs are also needed to foster public appreciation for the Meadowlands and an awareness of the numerous challenges to its remediation and restoration. Public concerns drive public policy; thus, an educated, informed, and involved public can be effective in holding regulatory agencies and officials accountable for making informed decisions, solving existing problems, and preventing future problems.

In many ways the Hackensack Meadowlands serves as the harbinger of the Nation's environmental challenges. Research and education developed to address the environmental challenges of remediating, enhancing, and restoring the Meadowlands may help prevent or solve similar environmental problems elsewhere.

A. PRIORITY RESEARCH OBJECTIVES

1. Expanded Capability, Collaboration, Access, and Communication

The Meadowlands is located in one of the busiest commercial port complexes in North America, in what has long been considered one of the most contaminated waterways in the United States (National Oceanic and Atmospheric Administration, 1991a). As a result, fish and wildlife resources in the Meadowlands will continue to face a wide array of chemical and biological challenges (*e.g.*, chemical spills, invasive species). Thus, scientific research in many disciplines will be critical to guiding remediation, enhancement, and restoration in the Meadowlands.

The Service acknowledges the contributions of the Meadowlands Environmental Research Institute (MERI) to improving our understanding of the Meadowlands environment. Since its inception in 1998, MERI has initiated research projects to address the HMD's environmental problems (*e.g.*, Kearny Marsh), collaborated with scientists at academic institutions in the region, developed support facilities (*e.g.*, the GIS Laboratory, MERI Library), and raised the profile of research in the Meadowlands through outreach and other professional activities (*e.g.*, co-sponsoring *The Meadowlands Symposium*).

Nonetheless, substantial additional monitoring, assessment, and other research efforts are needed to guide remediation, enhancement, and restoration. The necessary efforts exceed the capabilities, areas of expertise, and other resources presently available within *any* single stakeholder agency or organization. Such efforts also include certain legislative responsibilities (*e.g.*, water quality assessment, restoration monitoring) of different agencies as designated by federal or State law. Thus, monitoring, assessment, and research capacities of all stakeholder agencies (including the Service), educational institutions, and NGOs must be expanded to provide scientific, technological, and other information essential to the remediation, enhancement, and restoration of the Meadowlands. Addressing these research and information needs will likely require: (1) expanding formal and informal partnerships among federal and State agencies currently working in the Meadowlands and the NY-NJ Harbor (*e.g.*, Service, EPA, NMFS, NJMC, and NJDFW), and (2) involving additional federal and State entities (*e.g.*, USGS, NMFS Sandy Hook Laboratory, the Rutgers University Institute for Marine and Coastal Science, New Jersey Marine Science Consortium) and private organizations (*e.g.*, American Museum of Natural History Center for Biodiversity and Conservation) that can provide critical areas of expertise.

These expanded research activities must focus especially on three major environmental concerns: (1) environmental contaminants, water quality, and hydrology, (2) urban land use and ecology, and (3) invasive and exotic species. In support of these research objectives, it will also be necessary to increase our overall understanding of the biodiversity and ecology of the Meadowlands, expand and enhance routine monitoring and assessment of water quality and contaminants, and continually explore and expand use of innovative technologies.

The research (and educational) objectives discussed here cannot be achieved without access to sites throughout the HMD and the HRW. While existing waterways provide access to the interior of the Meadowlands, public docks and facilities for recreational access (discussed in detail in Section IX) can also provide access for research and educational purposes. Thus, improving public access to the Meadowlands, including its waterways, must be a high priority in regional planning.

Finally, results from these research activities must also be effectively communicated to Meadowlands stakeholders and the public. Regular communication among research collaborators and the principals' group (discussed in Section I.C) is essential for sound decision-making regarding the remediation, enhancement, and restoration of the Meadowlands ecosystem and for science-based management of its fish and wildlife resources. As public demand for all coastal resources continues to increase, restoration and long-term management of coastal ecosystems will increasingly rely on effectively communicating and integrating information across disciplines and institutions (*e.g.*, Crooks and Turner, 1999).

2. Environmental Contaminants, Water Quality, and Hydrology

Water is the key to nearly all biological processes and the biodiversity of estuaries; thus, water-related issues, including contaminants, will increasingly affect decision-making regarding the remediation, enhancement, restoration, and long-term protection of ecosystems such as the

Meadowlands in the northeastern United States (Pringle, 2000). One of the major obstacles to advancing the remediation and restoration of the Meadowlands is the lack of a comprehensive research program to address contaminant distributions and fates (including bioaccumulation) and the effects of contaminants and water quality on fish, wildlife, and indirectly, human health.

Contaminant and related studies conducted to date in the Meadowlands, including those directed through other regional contaminant centers (*e.g.*, the EPA Center for Hazardous Substances in Urban Environments, NOAA Center for Coastal Monitoring and Assessment), do not provide sufficient information on a site- or species-specific basis to guide decision-making for remediation, enhancement, and restoration. Therefore, environmental contaminants, water quality, and hydrology must comprise a major research emphasis to move restoration forward. Research activities of the contaminants and water quality program should address: (1) contaminant distributions, sources, availability, bioaccumulation, effects, and risk assessments; (2) nutrients, eutrophication, hypoxia, and sewage treatment; and (3) other hydrologic issues such as river flow, flooding, ground water, and SLR. These activities should be coordinated with contaminant programs throughout the entire HRE and New York Bight (*e.g.*, the New York Academy of Science Harbor Consortium, the EPA Harbor Estuary Program's Contaminant Assessment and Reduction Program [CARP]).

The Service and other stakeholders should expand collaborative research and monitoring activities to better understand the Meadowlands ecosystem and its watershed. In particular, increasing efforts to monitor and assess ground- and surface- (including reservoir) water quality, including contaminants and nutrients, and the bioaccumulation of contaminants in the flora and fauna of the Meadowlands and surrounding region are essential. These data should be integrated into and synthesized with other information being collected throughout the NY-NJ Harbor estuary. Moreover, water, sediment, and biotic information in the Meadowlands (*e.g.*, continuous and seasonal water quality information) does not appear thoroughly integrated into data sets (*e.g.*, Regional Data Depot; Harbor Estuary Program, 2005b) used in NY-NJ Harbor-wide evaluations and models of contamination and water quality. Additional collaboration among stakeholders regarding water quality and contaminant issues in the Meadowlands is also needed. For example, considerable progress has been made on understanding nutrient cycling processes in individual estuaries; however, generalizing those results, especially to systems as heavily contaminated and unstudied as those in the Meadowlands, is not yet possible (Nedwell *et al.*, 1999; Sobczak *et al.*, 2002). Over time, establishment of a comprehensive and coordinated research program of water quality, contaminants, and biogeochemical cycling would: (1) improve our understanding of the Meadowlands ecosystem and watershed, (2) help guide and evaluate remediation and restoration activities, (3) prevent future degradation of the Meadowlands, and (4) facilitate development and application of new technologies (*e.g.*, ground penetrating radars, high-frequency electromagnetic sounding, radar tomography; Lane, 2003).

Since the 1980s, considerable funding has been expended to improve the delivery of drinking water to urban areas, including suburban/urban counties within the Hackensack and Passaic River watersheds. Substantial commitments also must be made by all levels of government to address additional hydrologic issues, including water flow, water conservation and reuse, and wastewater treatment.

3. Urban Land Use and Ecology

Land use is the principal anthropogenic factor of ecosystem alteration. Sometime this decade, more people will be living in urban areas than in rural areas worldwide (Global Rural Urban Mapping Project, 2005). The suburban/urban landscape has become the most common landscape in coastal areas of the northeastern and middle Atlantic states. Nationwide, 70 million acres of forested and agricultural lands are projected to be converted into urban and other developed landscapes in the next 25 years (U.S. Global Change Research Program, 2003). At current rates of landscape change, New Jersey is projected to be "built-out" around 2040 (Hasse and Lathrop, 2001). The suburban/urban landscape is becoming more common, but many complex effects of this landscape on the earth's ecosystems and biodiversity (*e.g.*, hydrologic cycle, carbon sequestration) are just beginning to be recognized (Pickett *et al.*, 1997; Collins *et al.*, 2000; Luck *et al.*, 2001). In addition to a focus on water and contaminant issues, the Service recommends an expanded research effort on suburban/urban ecology, including ecosystem, landscape, and other issues (*e.g.*, transportation) that affect the long-term protection of fish and wildlife resources.

For example, habitat connectivity has been an objective in the restoration of natural areas, but its effectiveness in supporting wildlife, especially in suburban and urban areas, and in promoting other biological processes (*e.g.*, seed dispersal, succession, disease transmission, invasive species pathways) is not well understood (*e.g.*, Beier and Noss, 1998; Levey *et al.*, 2005). Certain corridor networks may be more effective than others in connecting habitats and supporting wildlife, especially migratory species (*e.g.*, Rudd *et al.*, 2002). Connectivity among urban landscapes may also be disrupted by buildings and landscaping with exotic species that create zones of high mortality for adult and immature birds (Klem, 1990; Meffe and Carroll, 1997; Borgmann and Rodewald, 2004). These and similar studies may have important implications for the restoration and protection of certain wetlands and natural areas in the HMD. For example, Berry's Creek marshes are situated directly between the two Hackensack sub-basins with the greatest acreage of emergent wetlands (see Section V); thus, remediating and restoring the Berry's Creek marshes would provide a large contiguous area of high-quality habitat, widely recognized as important for certain fish and wildlife populations (*e.g.*, tidal marsh birds; Benoit and Askins, 2002). Providing corridors and other connections (*e.g.*, habitat patches) may also be critical for species inhabiting isolated marshes along Penhorn Creek and other wetlands east of the Hackensack River. Research is therefore needed to identify features of effective corridors and improve connections among those wetlands.

The importance of and need for ecological research programs that address urbanization is increasingly recognized: urban ecology centers have been established on the West Coast (*e.g.*, San Francisco Bay, Seattle), the Midwest (Detroit, St. Paul-Minneapolis), and elsewhere. For example, the National Park Service established a Center for Urban Ecology to provide "science, service, and partnerships" to understand, protect, and restore natural resources in the Washington, D.C. metropolitan area. Several institutions in the NY-NJ metropolitan region, such as Rutgers University's Center for Urban Restoration Ecology, Columbia University's Center for Sustainable Urban Development, and New Jersey Institute of Technology's Center for Hazardous Substances in Urban Environments, also have developed programs focusing on urban environmental issues (*e.g.*, landfills, land use planning, hazardous waste remediation). The GIS

Laboratory of NJMC's MERI and The Institute for Meadowlands Studies (jointly established with Rutgers University's Center for Urban Policy Research in 2005) may also provide focal opportunities to develop collaborative research activities. Collaboration of Meadowlands stakeholders and USGS researchers familiar with diverse USGS data resources and cutting-edge technologies would also prove useful (*e.g.*, assessing alternative energy technologies [Aerotecture, Ltd. (2005) and McKenzie Bay, Ltd. (2005) turbines]).

4. Invasive and Exotic Species

Most wetlands in the Meadowlands are dominated by a single invasive species, common reed; many other exotic and invasive species occur in aquatic and terrestrial communities in the HRW. The Service recommends developing a harbor-wide program on exotic and invasive species as a third research focus. The role of this program would be to: (1) assess exotic and invasive species throughout the HMD, (2) address invasive species issues relating to restoration (*e.g.*, contaminant criteria for removing common reed, re-invasion of restoration sites), and (3) facilitate collaboration with other stakeholders in the urban area to manage, control, eradicate, and prevent invasions by exotic species.

Impacts from invasive species are increasingly recognized as globally important (Lowe *et al.*, 2000). Comprehensive long-term research programs have been established in other estuaries, including the Chesapeake Bay (Smithsonian Environmental Research Center) and San Francisco Bay (San Francisco Estuary Institute). In the Meadowlands, research, control, management and other activities should be coordinated with the federal interagency Invasive Species Council and the Department of Interior's related Advisory Committee, pursuant to Executive Order 13112 of February 3, 1999 on Invasive Species and other pertinent authorities (*e.g.,* NEPA, Lacey Act).

B. PRIORITY PUBLIC EDUCATIONAL OBJECTIVES

1. Outreach Program

As noted throughout this report, in recent years a diverse group of stakeholders comprised of federal and State agencies and NGOs has raised awareness of the need to restore and protect the Meadowlands ecosystem and its fish and wildlife resources. Other stakeholders, notably the NJMC and the Hackensack Riverkeeper, are currently engaged in a variety of public outreach efforts. An even greater commitment by stakeholders with additional public support will be needed to remediate, enhance, restore, and protect the entire Meadowlands ecosystem and its resources. Stakeholders have disparate interests, different responsibilities, and sometimes conflicting goals; nonetheless, the Service recommends that stakeholders collaborate to develop a unified outreach program to generate and maintain public support for the remediation and restoration of the Meadowlands. A unified outreach program will send a clear and consistent message to the public and elected officials and is more likely to gain support.

The unified outreach program should inform the public about the Meadowlands and needed or ongoing restoration efforts. In doing so, stakeholders will gain *broad* public support for restoration and long-term protection of the Meadowlands. Components of the outreach program

must share a common focus, but the outreach program should be evaluated periodically and modified as restoration proceeds. The outreach program must address high-profile issues effectively. For example, outreach must use different media (*e.g.*, television, radio, web, print), government agencies, educational institutions, and NGOs to inform the ethnically diverse people in the urban area. Meadowlands stakeholders should consider establishing a restoration web site to which key stakeholders are connected and may contribute. The Service and other stakeholders interested in developing the unified outreach program should consider evaluating and building upon previous outreach efforts by the Service (*e.g.*, Hackensack Meadowlands Issue of *Field Notes*) and other stakeholders (*e.g.*, the NJMC informal education programs such as "Wonderful Weeds," the Corps' HMER Fact Sheets, the Hackensack Riverkeeper's Meadowlands video). The Service also recommends exploring and developing new outreach efforts, such as public television and radio programming, a "coffee-table" book of the Meadowlands, and presentations to local civic and other groups.

Meadowlands stakeholders must also work together to overcome language barriers in the area. To maximize the effectiveness of public education, the Service and its partners need to communicate key messages in Spanish, Portuguese, Chinese, and Russian, all of which are primary languages for sizable minority populations in the Meadowlands area and used by providers of local government services. Despite warnings, consumption of contaminated fishes and shellfishes from the Hackensack River and the surrounding area remains substantial; thus, advisories and other outreach efforts in the languages noted above would be beneficial to protecting public health (Burger *et al.*, 1999; Chess *et al.*, 2005).

Slogans used in various outreach efforts (*e.g.*, the Hackensack Riverkeeper's "Work to Save the Meadowlands, Not Pave the Meadowlands") and the New Jersey motor vehicle license plate "The Meadowlands" have successfully focused the public's attention on protective efforts in the Meadowlands. Other slogans could be developed to unify public support for the present challenge of remediating and restoring the Meadowlands. Such slogans could be used on bumper-stickers, t-shirts, and other materials to gather public support.

2. Formal and Informal Educational Programs

It would appear necessary if not vital to expand educational programs, resources, and facilities not only within the Meadowland but throughout the watershed in order to protect the region's fish and wildlife resources. The Service acknowledges the NJMC's past commitment to education through its support of programs and activities of the Meadowlands Environment Center; moreover, the Service supports the NJMC's efforts to expand its current facilities and develop more educational programs, some in collaboration with other educational institutions (*e.g.*, Ramapo College) to familiarize the public with the Meadowlands, including its resources, problems, and restoration. The Service recommends that the NJMC collaborate with other resource agencies (including the Service) and the State to develop new programs to increase public awareness of the Meadowlands ecosystem and its fish and wildlife resources.

Educational programs should be developed for children and adults, as well as for communities, and include: (1) formal activities in schools and other settings, and (2) informal programs and other components (*e.g.*, additional web-based and take-home materials). Formal classroom

programs with lessons and activities designed for different age groups have been used successfully by the Service (*e.g.*, the NFWF, the NJFO's collaborative *The Nature of Learning* program) and other federally and State-supported comprehensive restoration programs (*e.g.*, San Francisco Bay Estuary Restoration, Gulf of Mexico Restoration Programs).

While there are any number of existing or potential environmental education programs that could be used or developed for the Meadowlands, two complementary programs for environmental education, the Department of the Interior's *Hands on the Land*, and the NFWF/Service's *The Nature of Learning,* are examples of programs that could serve public schools within the HMD and the HRW. Providing a national network of "field classrooms" on public lands to enhance student learning from kindergarten through high school, *Hands on the Land* also sponsors annual workshops for educators, supplies a range of lesson plans and educational programs, and offers ideas for class projects. *The Nature of Learning* is a 3-year program that partners a Service field station with a school to integrate environmental education into the total curriculum with the intent that the school will be able to retain the environmental component in its curriculum when the program is completed. Over the past decade, the NJFO has maintained this program at four schools in New Jersey. Both *The Nature of Learning* and *Hands on the Land* would encourage local schools to use the Meadowlands and the HRW as a learning environment.

3. Demonstration Projects and Exhibits

As a visually stimulating means of increasing public interest in the Meadowlands, demonstration projects and exhibits could be developed through partnerships with current stakeholders and other organizations to inform the public about the natural history and importance of the Meadowlands, its fish and wildlife resources, remediation, and restoration. The purpose of these projects and exhibits should be to stimulate public interest, encourage community, and inspire involvement in land-use planning at the municipal and county levels. Such demonstration projects and exhibits could focus on diverse topics but emphasize common themes such as the value of conserving and restoring biodiversity in the Meadowlands. Each exhibit would serve as a portal to obtain additional information about the Meadowlands restoration initiative. The demonstration projects would also serve to develop a public appreciation for the uniqueness of the Meadowlands ecosystem and its importance in supporting fish and wildlife at local, regional, national, and international levels. Demonstration projects could be located in support of existing educational programs (*e.g.*, the NJMC's MEC/MERI facility) and exhibits (*e.g.*, Bergen Museum of Science and Art's Hackensack Mastodon exhibit), developed in conjunction with access and facilities that support recreational objectives, and placed in novel venues that attract large segments of the public (*e.g.*, the Xanadu complex, Meadowlands Stadium, Newark Airport, American Museum of Natural History). Examples of potential demonstration projects and exhibits are presented below.

a. <u>Atlantic White-Cedar</u>

Atlantic white-cedar once formed the dominant vegetative cover in the Meadowlands and other parts of New Jersey. Although eradicated from the Meadowlands due to exploitation and to hydrologic and other changes, Atlantic white-cedar was still present in the Meadowlands in the 1940s. The feasibility of establishing one or more stands of Atlantic white-cedar (5-10 acres)

should be investigated at certain locales (*e.g.*, Teterboro Woods and Kearny Freshwater Marsh, once restored). Establishing a few stands would underscore the importance of water resources to biodiversity and serve as a living visual symbol of the commitment of stakeholders to Meadowlands restoration.

b. Mastodon

The natural history of the Meadowlands has continually changed throughout geological and human history. Mastodon roamed the Meadowlands at the retreat of the last great Ice Age, 10,000 or so years ago. A specimen excavated from the upper Berry's Creek drainage is being prepared for display at the Bergen Museum of Science and Art. Museum personnel have expressed interest in partnering with other stakeholders to develop the exhibit (J. Waldron, pers. comm., 2005).

c. Bioremediation

Bioremediation, the use of biological organisms such as plants or microbes to aid in removing or altering hazardous substances, has been explored at several sites in New Jersey (*e.g.*, Launen *et al.*, 2002) and has potential application at sites contaminated by certain hydrocarbons (*e.g.*, PAHs) in the Meadowlands. Small demonstration projects could be set up near the NJMC facilities and at other sites as feasibility studies and to provide relevant examples of the value of biodiversity (*e.g.*, direct-use values such as harvest, indirect-use values such as ecotourism, and option values such as undiscovered medicinal drugs in plants and fungi).

d. The Old Landfill Legacy: Leachates and Methane Gas

Potential demonstration projects could identify specific problems associated with waste streams and how to reduce these problems. For example, two problems of landfill wastes are methane gas and leachates. Two potential sites for demonstration projects are the Meadowlands Stadium, location of one of the Meadowlands' worst landfill fires, and the NJMC facilities, where efforts are being made to collect methane. Such demonstration projects could stress the importance of reducing waste streams, their impacts, and their real (and often hidden) costs.

e. The New Landfill Legacy: Golf Courses and Resident Canada Geese

Remediation and redevelopment of landfills into golf courses generally provide little habitat for fish and wildlife. Golf courses impact water quality in the Meadowlands: they use large volumes of water and receive considerable amounts of nutrients, herbicides, and pesticides that contribute to further water quality impairments in the HRW. In addition, golf courses often provide nesting and foraging habitat for resident Canada geese, which forage extensively on newly established vegetation at restoration sites (K. Spendiff, pers. comm., 2004) and make revegetation very difficult. Although the Service generally encourages most actions that are supportive of waterfowl, populations of resident Canada geese have increased throughout much of the Northeast, where they have become a nuisance species and adversely affect migratory populations of waterfowl in the Meadowlands and elsewhere. Venues for this exhibit might

include public areas where resident Canada geese might occur; such exhibits would remind the public that wildlife species are not domesticated and should not be fed.

f. Prevention and Biological Control of Invasive Species

Demonstration projects could feature exotic species that have invaded locally, the problems associated with them, and biological control efforts. For example, biological control of purple loosestrife at Harrier Meadows in the HMD is being accomplished by NJDEP through propagation and release of several exotic, leaf-eating beetle species. One demonstration might focus on ongoing studies (supported by the Service and other federal agencies) to evaluate the potential of native and exotic species as control agents of common reed.

g. Sea Level Rise and Global Change

Sea level rise is a complex and controversial subject, which is made even more difficult in urban areas owing to more limited options (*e.g.*, insufficient area for rolling easements, reliance on seawalls and bulkheads to protect property) and the high costs of real estate (Titus *et al.*, 1991). Using three-dimensional displays and hands-on models, such a project could clearly show possible consequences of minimal, moderate, and maximum rates of SLR in the Meadowlands and the surrounding urban area.

h. Native Peoples: Subsistence on Fish and Wildlife Resources

The indigenous peoples that lived in the HRW subsisted on fish and wildlife resources for thousands of years. Their cultures coexisted and depended upon a relatively unspoiled environment. The fish and wildlife resources existing in the Meadowlands during this time included large predators, such as grey wolf and eastern cougar, and large populations of shellfishes, fishes, waterfowl, raptors, and other migratory birds. Potential exhibits located at several venues could focus on (1) present-day archeological efforts, (2) accurate depictions of native cultures, and (3) resources used by native cultures.

i. The Watershed: Connecting the Landscape and the Hackensack River

Diverse exhibits and outreach focusing on the entire watershed, such as efforts undertaken by the Chesapeake Bay Program (*e.g.*, signage stenciled onto sewage grates and gutters "This flows into the Meadowlands," commercial radio and television announcements), can be effective tools in addressing point and non-point sources of pollution and protecting potable water supplies and sensitive areas such as wetlands and headwaters. A watershed approach should also emphasize landscape and watershed priorities and pollution prevention strategies to improve water quality for fish, wildlife, and people. Improved watershed management is vital to the future of the Meadowlands.

C. SUMMARY

Research and public education are vital to restoring the Meadowlands and protecting its fish and wildlife resources. Developing additional monitoring, assessment, and research capabilities among federal and State agencies and other stakeholders is essential to move restoration forward. Additional research programs should especially focus on: (1) environmental contaminants, water quality, and hydrology, (2) suburban/urban ecosystems, landscapes, and habitats, and (3) invasive and exotic species. Outreach and education are also critical for sustaining the public's commitment to remediate and restore the Meadowlands. Development of a unified outreach program should build on previous successes of all partners; incorporate various media, including television; communicate key messages in several languages; and utilize access and facilities developed for recreational objectives. Formal and informal educational programs should be developed for adults and children and innovative use made of demonstration projects and exhibits to stimulate public interest and inspire involvement in Meadowlands issues. Continued public support for research and education is vital to future efforts to remediate and restore the Meadowlands and to ensure responsible land use and management of the HRW.

IX. Public Access and Recreation

Schoolchildren and chaperones along the Mill Creek Trail.

Against a Manhattan background, schoolchildren make good use of the NJMC's DeKorte Park facilities.

Successful duck hunters returning from the Sawmill Creek WMA.

A blue crab (*Callinectes sapidus*).

Schoolchildren learning about the Meadowlands NJMC's DeKorte Park.

Laurel Hill County Park boat ramp.

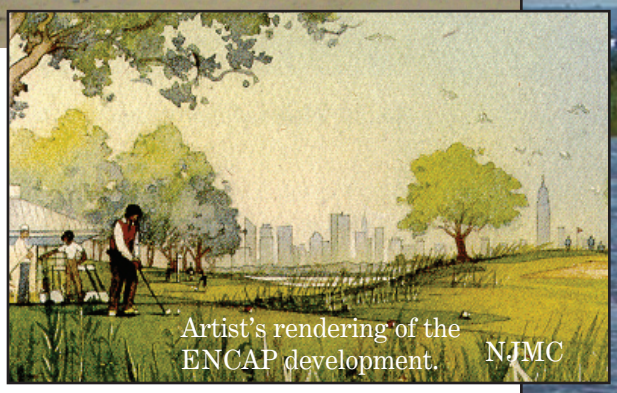
IX. Public Access and Recreation

Located only 7 miles west of Manhattan, the Meadowlands lies within 50 miles of nearly 20 million people. In the Meadowlands, remediation and restoration not only must sustain fish and wildlife resources but also must improve public opportunities for appropriate social and recreational uses. The Service supports public uses such as wildlife observation, photography, fishing, and waterfowl hunting that have minor, if any, adverse impacts on fish and wildlife when properly managed and/or regulated. However, sustaining fish and wildlife resources and improving social and recreational uses, especially in combination, necessitate careful long-term planning.

For example, the State of New Jersey currently prohibits recreational and other harvesting of blue crabs from the Hackensack River due to their bioaccumulation of mercury, PCBs, and dioxins. This prohibition on recreational harvest represents an "impaired use" resulting from the contamination of the Meadowlands ecosystem. Therefore, remediation and restoration must improve the status quo of contamination in the Meadowlands; otherwise, fish and wildlife populations will remain at risk and social and recreational uses of the Meadowlands will remain impaired. Access to, and use of, restoration sites are often critical determinants of the public's evaluation of the success of restoration projects. Thus, restoration that improves social and recreational uses will help strengthen public confidence in, and support for, restoring the Meadowlands.

Laurel Hill County Park.

Photo / Hackensack Riverkeeper



Artist's rendering of the ENCAP development. NJMC

A Hackensack Riverkeeper "eco-tour." Photo / Hackensack Riverkeeper

IX. PUBLIC ACCESS AND RECREATION

A. INTRODUCTION

B. HUMAN USE OBJECTIVES

1. Promoted Uses of Aquatic and Terrestrial Areas
2. Prohibited, Permitted, and/or Managed Uses (Including Zoning)

C. INFRASTRUCTURE OBJECTIVES (IN SUPPORT OF HUMAN USES)

1. Parks, Trails, River Overlooks, and Wildlife Observation Sites
2. Landings, Docks, Fishing Piers, and Shorelines
3. Parking and Special Needs Access

D. REDEVELOPMENT, REMEDIATION, AND RESTORATION OF THE MEADOWLANDS: CREATING A NEW PUBLIC IMAGE

Improving appropriate access to, and use of, wetlands and adjoining areas must be an integral feature of restoring the Meadowlands.

Photo / Hackensack Riverkeeper

IX. PUBLIC ACCESS AND RECREATION

A. INTRODUCTION

A major justification for restoring the Meadowlands ecosystem and protecting its fish and wildlife resources is the Meadowlands' proximity to the more than 20 million Americans residing in the suburban/urban area surrounding the NY-NJ Harbor. *The availability of a large natural area to so many people makes the Meadowlands a very special place.* Remediation, restoration, and protection of the Meadowlands will provide to the public numerous educational, social, and recreational opportunities and other benefits associated with open space that are rare in the urban landscape. Such benefits include learning about the natural world, gathering with others in diverse natural settings, and enjoying recreational activities such as wildlife observation, photography, boating, fishing, and hunting. Remediation and restoration of natural areas also improve the value of nearby suburban and urban property (*e.g.*, Streiner and Loomis, 1995; Udziela and Bennett, 1997), and are recognized as an important component of the revitalization of many downtown areas (Bailey *et al.*, 2005). In particular, public open-space projects and other improvements to waterfronts are recognized often as the centerpiece of redeveloping urban centers and as giving these revitalized areas a unique sense of place (*e.g.*, U.S. Conference of Mayors, 2002; Breen and Rigby, 2004). Thus, although waste and landfills characterized land use and influenced public perceptions of the Meadowlands for many decades, remediation and restoration projects in the Meadowlands that support wildlife and encourage a new landscape have the potential to establish a positive image of living in this densely populated urban and suburban area.

Restoration planners must also recognize that access to and use of restoration areas are important determinants in the *public's* evaluation of the success of restoration projects (*e.g.*, Bauer *et al.*, 2004). Securing and maintaining the public's interest in and commitment to the Meadowlands, demonstrated through the actions of elected officials, is critical to the remediation, restoration, and long-term protection of the Meadowlands ecosystem and its living resources. Because of the Meadowlands' urban location, public uses should be given prominent consideration in planning for remediation and restoration. For example, the Service recommends considering potential public uses in selecting contaminant criteria for remediation of sites. It is unlikely that the public will embrace recreation on, and other public uses of, sites that have been cleaned and/or remediated to marginal (*i.e.*, low) standards that essentially continue the *status quo* of contamination in the Meadowlands.

While the public desires and values many uses of wetlands (*e.g.*, fishing, hunting; Woodward and Wui, 2001; Boyer and Polasky, 2004), certain activities and uses of natural areas have potential to adversely affect fish and wildlife resources. Various government agencies and other groups have established use policies to achieve specific objectives on many other urban park and refuge areas; therefore, the Service recommends that stakeholders establish a human use policy for the Meadowlands with the objectives of: (1) protecting fish and wildlife resources, (2) supporting appropriate activities, and (3) providing public access to the river. (Continued support for law enforcement will be necessary to ensure that increased usage of the Meadowlands does not compromise fish and wildlife resources. In 2006, the NJMC agreed to

provide funding for two new conservation officers in the HMD.) Integrating appropriate human use objectives into remediation and restoration of the Meadowlands will not only improve the quality of life for area residents, but will also act as an antidote to the images and legacies of the Meadowlands' neglect, promote public support for remediation and restoration activities, and help establish a new and positive public image of the Meadowlands.

B. HUMAN USE OBJECTIVES

1. Promoted Uses of Aquatic and Terrestrial Areas

Although the Meadowlands is not part of the NWR system, the Service's nationwide policy for NWRs serves as a good model for human use of the Meadowlands. The NWR's "wildlife first" policy places the needs of wildlife foremost in decision-making regarding human uses and activities, yet also identifies wildlife-dependent activities as priority public uses. The NWR's recommended priority public uses of the Meadowlands include waterfowl hunting, fishing, wildlife observation, photography, environmental education, and environmental interpretation. In all cases these and other uses undergo a strict compatibility determination to ensure that wildlife values are not harmed or compromised. Properly regulated, these uses normally have minor, if any, adverse impacts on fish and wildlife resources. In addition, these public-use activities are currently allowed in the Meadowlands and are consistent with State and federal laws (*e.g.*, waterfowl hunting provisions of the MBTA). Overall, the Service promotes human uses of wetlands that are popular and do not adversely impact indigenous fish and wildlife populations.

The Service's above-recommended priority human uses of the Meadowlands are among the most popular and highly valued recreational activities in the United States, including New Jersey (U.S. Fish and Wildlife and U.S. Census Bureau, 2002; 2003a). Wildlife-watching (1.9 million total participants, defined as observing, feeding, or photographing wildlife as the primary activity) is more popular than hunting (135,000 participants) or fishing (806,000 participants) among New Jersey's residents and visitors (U.S. Fish and Wildlife and U.S. Census Bureau, 2003a). Wildlife observation also results in substantial positive economic impacts in New Jersey, which was ranked 6th nationally for economic benefits generated from wildlife watching (U.S. Fish and Wildlife Service and U.S. Census Bureau, 2003b). For New Jersey residents, the average expenditures of bird watchers ($977 per participant) is comparable to expenditures of anglers ($1,115) and hunters ($1,259; U.S. Fish and Wildlife Service and U.S. Census Bureau, 2002). Surveys of residents near urban wetlands being restored in the northeastern U.S. indicate that the opportunities to view wildlife and other passive recreational activities are the most highly valued recreational uses of urban wetlands (*e.g.*, Casagrande, 1997a).

With the development of appropriate facilities and educational outreach, the Meadowlands could also provide social and recreational opportunities to a geographic region and urban populations that have thus far been difficult to engage. Residents of the northeastern United States are less likely than residents in other parts of the country to visit a federal recreation site (*e.g.*, national park or wildlife refuge) or participate in wildlife watching and other outdoor recreation (U.S. Fish and Wildlife Service and U.S. Census Bureau, 2003c; RoperASW, 2004). Most wildlife

observation occurs within a mile of home (U.S. Fish and Wildlife Service and U.S. Census Bureau, 2002). Providing opportunities for wildlife-watching in an urban/suburban area can afford an outstanding, economical outdoor recreational activity for low-income populations who would otherwise lack access to such sites. Outdoor recreation is also generally recognized by the public to improve family happiness, health, unity, and overall quality of life; moreover, participation in outdoor recreation is positively correlated with appreciation of, and respect for, the natural environment (RoperASW, 2004). Thus, providing social and recreational facilities within the Meadowlands is likely to improve public support for its remediation and restoration.

Currently, most though not all recreational uses of the Meadowlands appear to be infrequent and occur irregularly, though few rigorous surveys have been conducted to assess that perception. Water quality impairments (including unpleasant sights and smells), pollution (especially exposed waste and garbage but also unseen pollution causing seafood-consumption advisories), limited access, lack of aesthetics, limited opportunity to view wildlife, abundant mosquito populations, crime, and limited financial resources potentially affect use of urban wetlands (Casagrande, 1997a; 1997b). Thus, increasing appropriate public uses of the Meadowlands can be a complicated challenge; gender, culture, demographic, and other issues also complicate efforts to encourage public use of wetlands (Page, 1997; Bauer *et al.*, 2004). Although pollution is often identified as the greatest concern of urban residents, improving aesthetics and removing physical and social barriers to access may be equally important for increasing public uses of wetlands (*e.g.*, Casagrande, 1997a). While water quality improvements and restoration activities contributing to the recovery of fish and wildlife may increase public uses of the Meadowlands, studies in other urban areas in the northeastern United States (*e.g.*, Boston, New Haven; Casagrande, 1997b; Bauer *et al.*, 2004) suggest that a strong outreach program is necessary to increase public awareness.

The Service recommends conducting surveys of public uses, values, and perceptions of the Meadowlands as a starting point to develop and implement a social and recreation vision that includes appropriate use policies. Surveys should be undertaken during the initial stages of planning to provide the public and local stakeholders a voice in recreational land-use decisions. Moreover, it is especially important to assess certain risks (*e.g.*, consumption of contaminated seafood and wildlife) and address concerns of low-income and minority populations residing in the diverse communities within the HMD (Executive Order 12898 [Federal Actions to Address Environmental Justice in Minority Population and Low Income Populations]; 59 *Federal Register* 7629; February 16, 1994). These surveys should be designed and conducted by social scientists and survey specialists. Survey information should be communicated to the principals' group and other stakeholders to support appropriate public uses of the Meadowlands while avoiding and minimizing adverse impacts to fish and wildlife resources. Because public uses, values, and perceptions are dynamic, the Service recommends that surveys be undertaken periodically to guide long-term use policies and long-range planning to increase socioeconomic benefits.

2. Prohibited, Permitted, and/or Managed Uses (Including Zoning)

To restore the Meadowlands and protect its federal trust resources, the Service is strongly opposed to activities, particularly if non-water-dependent, that would result in an additional loss

or degradation of wetlands. All proposed projects requiring a federal permit pursuant to the Clean Water Act should be in full compliance with the Section 404(b)(1) Guidelines (40 CFR Part 230). Activities in wetlands that would impair ecological functions and adversely impact fish and wildlife resources should be strongly discouraged. The Service recommends that the NJMC: (1) discuss special use exceptions (*e.g.*, marinas) that are proposed as part of the HMD's new zoning regulations with State and federal resource agencies, and (2) reconsider the need for inclusion of the proposed special use exceptions as part of the zoning regulations to prevent compromising restoration of the Meadowlands and the long-term protection of its fish and wildlife resources.

Most current recreational activities and uses of the Meadowlands should be allowed to continue. State and local government agencies should be encouraged to assess: (1) the need for regulations and restrictions to protect sensitive and declining wildlife species during their reproductive season, and (2) potential risks to human health, such as risks from consumption of wildlife. For example, NJDEP monitors beaches and erects barriers to protect nests of certain shorebirds (*e.g.*, piping plover). The Service recommends similar efforts in the Meadowlands to protect nesting colonies and other aggregations of species that are declining. Of concern are activities such as riding all-terrain vehicles or flying model airplanes that may disturb nesting wildlife in certain areas of the HMD (*e.g.*, Empire Tract, Losen Slote); thus, Meadowlands stakeholders should explore alternative sites to provide these recreational needs elsewhere while protecting fish and wildlife species, especially during their breeding seasons. The Service recommends continuing recreational fishing and hunting in the Meadowlands in accordance with federal and State regulations, although assessing contaminant levels, as done with fishes and shellfishes, should be carried out to protect potential consumers from bioaccumulative effects of certain contaminants (*e.g.*, PCBs, mercury). Expansion of recreational uses and activities also will increase the need for law enforcement personnel (*e.g.*, State Conservation Officers) in the Meadowlands.

Finally, the Service recommends increased research on such issues as air quality to assess potential impacts on human health resulting from general activities (*e.g.*, hiking, boating) in the Meadowlands. Such assessments complement risk assessments for fish and wildlife and would strengthen decision-making regarding public uses, especially in certain areas (*e.g.*, Berry's Creek) of the Meadowlands where volatile contaminants (*e.g.*, PCBs, mercury) may be present in high concentrations. Such assessments might result in recommendations or restrictions regarding human activities and uses of the Meadowlands in addition to the current seafood advisories throughout the entire Newark Bay area. Use advisories and restrictions have been established in other urban parks and refuges (*e.g.*, Boston's Emerald Necklace Park System). Advisories and use restrictions can increase public awareness of impairments and promote support for restoration.

C. INFRASTRUCTURE OBJECTIVES (IN SUPPORT OF HUMAN USES)

Access is a critical component by which the public assesses publicly funded restoration projects in the northeastern United States (*e.g.*, Bauer *et al.*, 2004). The New Jersey Open Space and Outdoor Recreation Plan recommends setting aside at least three percent of developable area for municipal open space. Most communities in the Meadowlands have not preserved the

recommended minimum acreage of open space (*e.g.*, Jersey City, Kearny, North Bergen; Heyer, Gruel, and Associates, 2004). Thus, the Service recommends acquisition of uplands to provide locations for the infrastructure needed to improve access and support appropriate public uses of wetlands. Infrastructure should include land-based facilities such as parks and trails and water-dependent facilities such as landings and fishing areas. Land-based and water-dependent facilities should be integrated together where practical (*i.e.*, where such integration would not adversely impact fish and wildlife resources and uses are compatible). Hudson County has identified many types of recreational facilities which are not available locally but could be integrated into future park projects. Examples include swimming pools, archery ranges, skating rinks, and volleyball and shuffleboard courts (Heyer, Gruel, and Associates, 2004).

Infrastructure to support wetland activities should be planned carefully to support passive recreational activities. Recreational facilities should also be designed to minimize impacts to wetlands and wildlife resources from ancillary support structures such as parking lots. Facilities should also be designed to provide universal access, that is, to provide access to people with special needs. Acquisition of uplands adjoining wetlands not only helps meet the region's open space needs but can improve wetland functions and promote public support for restoring and maintaining the region's biodiversity.

The Service also recommends that local stakeholders, particularly municipalities and counties, explore the availability of federal funding, including funds generated by transportation and other projects, in support of recreational infrastructure. For example, the Recreational Trails Program was established by a provision of the Intermodal Surface Transportation Efficiency Act of 1991 (P.L. 102–240; 23 U.S.C. 100 *et seq*.) and reauthorized in 1998 as part of the Transportation Equity Act for the 21st Century (P.L. 105-178). Eligible projects include: maintenance and restoration of existing recreational trails; development and rehabilitation of trailside and trailhead facilities and trail linkages for recreational trails; purchase and lease of recreational trail construction and maintenance equipment; construction of new recreational trails; and acquisition of easements and fee simple title to property for recreational trails or trail corridors.

1. Parks, Trails, River Overlooks, and Wildlife Observation Sites

The Service recommends development of "passive" recreational facilities such as parks, trails, river overlooks, site-specific boardwalks, and wildlife observation sites throughout the Meadowlands. Moreover, the Service recommends integrating open space throughout the Meadowlands using trails and other corridors. Networks of open space are highly valued by the urban residents (*e.g.*, especially homebuyers (Bailey *et al.*, 2005), enhance some ecosystem services performed by wetlands (*e.g.*, flood storage), and provide additional habitat supporting fish and wildlife. Thus, the Service strongly supports the efforts of local governments to acquire additional open space for passive recreational activities, especially where such acquisitions may help protect environmentally sensitive areas (*e.g.*, wetlands along Penhorn Creek; Remaud, 2004; Heyer, Gruel, and Associates, 2004). In particular, the Service recommends that all local governments and other stakeholders maintain, enhance, and increase the extent of vegetated buffers along waterways and around wetlands. Such areas not only increase biodiversity and enhance wetland function but also provide opportunities for passive recreation (*e.g.*, bird watching, photography).

Multi-use walking, running, and biking trails, especially those parallel along a river, are considered one of the most effective means of providing access to rivers in urban areas (Bailey *et al.*, 2005). Trails integrated into other open-space projects and the surrounding urban landscape have been components of the downtown revitalization of major cities, including Denver, Phoenix, San Antonio, and St. Paul. Thus, the Service supports trail projects in the HMD being developed by the NJMC (2004h) and municipal governments; these projects serve to link many parcels of open space throughout the HMD. These trail projects include small-scale upland and wetland restoration components that, if properly designed, provide wildlife habitat and buffer wetlands, which contribute to the improvement of water quality. Consideration should be given to: (1) extending these trail projects to include all significant open-space areas within the HMD; (2) connecting these trail projects to other trails, green corridors, and open-space areas in the HRW and the region; and (3) acquiring, remediating, and restoring degraded upland areas, such as Superfund Sites, abandoned rail lines, and other brownfield sites, along the trails. The three current trail projects in the HMD include the Meadows Path, the Secaucus Greenway, and the Blue Water Trail.

The Meadows Path, a component of the NJMC's 1983 Master Plan, is a 25.5-mile pedestrian trail planned along the western side of the Hackensack River from Losen Slote Creek Park in Little Ferry to West Hudson Park in Kearny. To date, approximately 5 miles of the Meadows Path has been completed. The Service recommends that the NJMC and local groups work with the Service's *Partners for Fish and Wildlife* Program, and enter into a partnership landowner agreement to restore various sites along the Meadows Path. Because this project has many components in different communities within the HMD, the Meadows Path would provide a number of distinct opportunities for the Service, the NJMC, and local stakeholder groups to work collaboratively in a diversity of on-the-ground restoration projects.

The Secaucus Greenway is a 15-mile waterfront greenway planned through Secaucus and Jersey City on the east side of the Hackensack River. Only two short portions along the Mill Creek Marsh and the Laurel Hill County Park (totaling 3 miles) are currently completed. The Service recommends that local governments: (1) acquire upland areas along the waterfront to complete the Greenway; (2) acquire additional upland areas, including existing open space (*e.g.*, Little Snake Hill) and brownfields, to provide wetland buffers and recreational venues along the river; and (3) integrate the Greenway with other open space and neighborhoods. For example, Hudson County has expressed interest in acquiring the PJP Landfill, following its remediation of this Superfund Site, as a component of the Secaucus Greenway. The Service recommends appropriate public uses of this site (*e.g.*, county park integrating natural and recreational areas), subsequent to appropriate remediation and restoration. Approximately 25 percent of Superfund sites nationwide, including other Superfund sites in New Jersey, have been re-used for ecological and recreational purposes (U.S. Environmental Protection Agency, 2004h).

The Blue Water Trail was completed by the NJMC in 2004 as a canoe trail focused around the Mill Creek Marsh and connected to all other parks within the HMD. This trail features several restoration sites and portions of the State's Sawmill Creek Wildlife Management Area, and includes trail markers and interpretive signage at various points. The Service recommends such low-impact boating uses of the HMD; moreover, the Service recommends that the MCT and

other local stakeholders expand this trail along the Hackensack River above the HMD to other open-space areas and historic or cultural landmarks (*e.g.*, Overpeck County Park, Van Buskirk Island).

2. Landings, Docks, Fishing Piers, and Shorelines

Currently, very few boat landings, docks, and fishing piers are present within the HMD along the Hackensack River. Commercial boat landings provide the primary means of public access to the Hackensack River. Only one public boat landing suitable for all types of recreational boats, at the Laurel Hill County Park, is currently available. A second boat landing is present on Mill Creek but is suitable only for canoes and kayaks. Docks are located alongside the public boat ramp at the Laurel Hill County Park; a fishing area is designated at the Mill Creek Landing, and other areas along the shoreline of the river of the Laurel Hill County Park appear suitable for fishing. Public facilities along the Hackensack River within the HMD appear little used and sufficient to meet existing demand. The Service recommends periodically assessing use of these facilities and considering other sites (*e.g.*, Overpeck Creek, Fairleigh Dickinson University) where additional access points to the river might be developed as demand on existing facilities increases.

The Service recommends establishing a long-range plan for adding facilities, such as another boat landing exclusively for kayaks and canoes to emphasize "low-impact" recreational activities as another future use priority. Although the Service generally supports fishing as a recreational activity elsewhere and in the Meadowlands, the Service recommends caution and continued use of warning signs to prevent additional facilities from contributing to any increased consumption of contaminated fish.

3. Parking and Special Needs Access

Parking and special needs access are critical components in planning for public use of open space. Public parking is available currently at most local parks and other facilities; however, the adequacy of parking is a concern at some sites. The Service recommends matching the parking needs to the capacity of parks and other facilities to prevent them from being overused and degraded. Parking facilities should be safe, secure, and well-maintained, and should employ green-design principles (*e.g.*, parking with pervious surfaces); otherwise, the purpose of the facilities will be compromised and may contribute to negative perceptions of the Meadowlands restoration. Many local communities in Bergen and Hudson Counties have increasing percentages of elderly residents and family households headed by women (New Jersey Meadowlands Commission, 2004d); access, including parking, and safety are important issues regarding use of public facilities for those demographic groups. Parking and other public facilities (*e.g.*, trail kiosks) should include provisions for emergency communications (*e.g.*, panic buttons, closed circuit TV) and ready access by law enforcement.

The Meadowlands is located within one of the densest population centers in the United States; therefore, facilities must be designed to provide access to people with special needs. Universal-design features (*e.g.*, "cuts" in curbs for wheelchairs, ramps in place of steps) should be provided to allow all citizens to engage in recreational and educational activities. Accommodating

different difficulty levels in the trail system is also an important part of universal design. Therefore, the Service recommends that all structures (*e.g.*, gating, trail surfacing and grades, restrooms, curbing, drinking fountains, picnic tables, fishing piers, boardwalks, wildlife observation decks, pedestrian bridges, and drainage structures) must be planned and designed for accessibility.

Some local NGOs, such as the Project for Public Spaces (2005), have incorporated universal design considerations into renovations of other nearby parks (*e.g.*, Liberty State Park, Morningside Park). The Service also recommends that stakeholders request technical assistance from the State's Department of Community Affairs. The Department of Community Affairs administers New Jersey's Access Code through the Barrier Free Subcode of the Uniform Construction Code (N.J.A.C. 5:23-7) and the U.S. Access Board (2005), which not only enforces the Americans with Disabilities Act of 1990 (P.L. 101-336) and related laws but has also become one of the leading sources of information on accessible design. The U.S. Access Board (2005) is currently developing regulations regarding outdoor developed areas. Certain federal-state partnerships (*e.g.*, National Center on Accessibility; National Park Service and Indiana University, 2005) may provide further technical assistance regarding the inclusion of people with disabilities in parks, recreation, and tourism in the Meadowlands.

D. REDEVELOPMENT, REMEDIATION, AND RESTORATION OF THE MEADOWLANDS: CREATING A NEW PUBLIC IMAGE

Social and recreational uses of the Meadowlands have the potential to: (1) provide enjoyment to many Americans, (2) increase local property values and local business opportunities, (3) promote better health and quality of life, and (4) increase an awareness and appreciation of fish and wildlife and the environment. Increased uses of the Meadowlands also have considerable potential to adversely impact fish and wildlife populations; the need for additional law enforcement will increase, as has been observed in other urban settings. Thus, social and recreational opportunities must be carefully considered, planned, and monitored in the remediation and restoration of the Meadowlands.

Redevelopment, remediation, and restoration of different wetland and upland sites in the Meadowlands are gradually moving forward. These different activities represent considerable financial and technical undertakings and reflect substantial efforts and commitments of resources by private groups and government agencies; however, each of these activities currently lack a vital ingredient: all stakeholders *working together for the future* to: (1) change the entire area's image, (2) increase public use, and (3) foster greater awareness of, improve, and protect the environment and its resources. The Meadowlands and its adjoining waterways in the Hackensack watershed have always been a public resource, yet projects focused specifically on redevelopment, remediation, and restoration have not fully embraced the region's resources as a public treasure. To reclaim the Meadowlands ecosystem for future generations of Americans, redevelopment, remediation, and restoration projects must include elements to increase public access, integrate human uses of open space while sustaining and safeguarding fish and wildlife, and perpetuate the new public image of the Meadowlands. The integration of these elements will also help define social and recreational objectives for the Hackensack Meadowlands.

X. Restoration Planning and Coordination

Collaborating on the Meadowlands.

The First Stakeholders Work Session for the Hackensack Meadowlands
I
Secaucus, NJ
October 17, 2000

The Second Stakeholders Work Session for the Hackensack Meadowlands
II
Elizabeth, NJ
May 21, 2001

The Third Stakeholders Work Session for the Hackensack Meadowlands
III
Morristown, NJ
October 31, 2001

The Fourth Stakeholders Work Session for the Hackensack Meadowlands
IV
Lyndhurst, NJ
June 13, 2005

X. Restoration Planning and Coordination

Numerous remediation, enhancement, and restoration projects are now underway or in various planning stages for specific wetland sites in the Meadowlands and adjoining waters. These projects, such as the Hackensack Meadowlands Environmental Restoration and the Lower Passaic River Restoration, are being undertaken pursuant to specific legal authorities (*e.g.*, WRDA, Superfund) for various purposes (*e.g.*, water resource improvement, contaminant remediation) by different agencies (*e.g.*, Corps, NJMC, and EPA) on independent schedules.

Preliminary results of ongoing restoration projects are encouraging; however, these projects are not necessarily coordinated or integrated with other regional planning for water supply, sewage treatment, flood control, and transportation. Also, the funding of some remediation and restoration projects is only sufficient for improvements to small sites. As a result, current efforts will result neither in a successful restoration of the Meadowlands ecosystem overall, nor in the long-term protection of its fish and wildlife.

Thus, stakeholders must continue to work to improve overall coordination, collaborate on the development of a shared vision, and initiate establishment of a unifying authority to restore the entire Meadowlands ecosystem. Additionally, federal and State agencies must establish a principals' group to ensure the broad, long-term commitments and coordination (*e.g.*, restoration, regulatory, and other planning) necessary for comprehensive restoration of the Meadowlands ecosystem.

State and federal wildlife officials tour the Meadowlands.

X. RESTORATION PLANNING AND COORDINATION

A. INTRODUCTION

B. AUTHORITIES AND PURPOSES

1. **Clean Water Act**
2. **Water Resources Development Act**
3. **Comprehensive Environmental Response, Compensation, and Liability Act**
4. **Specifically Authorized Projects and Their Applications to the Meadowlands**

C. PARTNERSHIPS AND OVERSIGHT

D. RESTORATION SCHEDULES

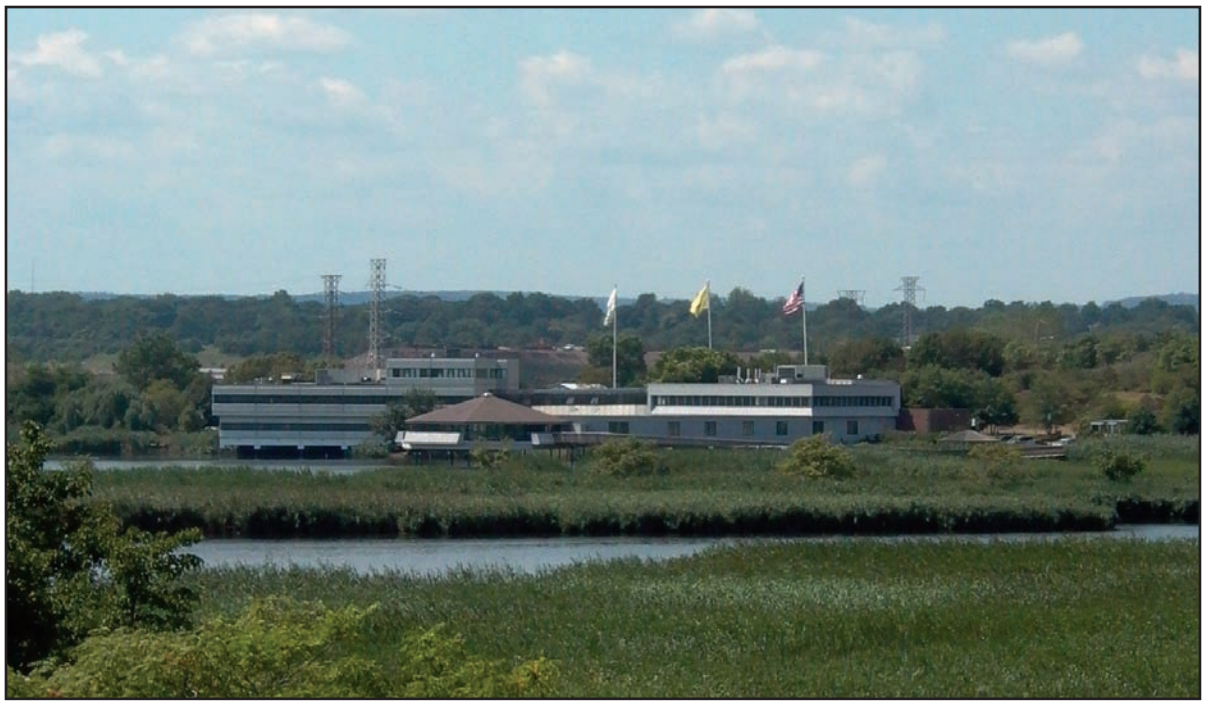
E. BASELINE REMEDIATION AND RESTORATION PLANS

1. **Development of Baseline Remediation Plans**
2. **Current Restoration Planning**
   a. The Harbor Estuary Program's (1996) Comprehensive Conservation and Management Plan
   b. The Corps' HRE Feasibility Study and Comprehensive Restoration Implementation Plan
   c. The Corps' Meadowlands-Comprehensive Restoration Implementation Plan
   d. The NJDEP Coastal Management Program's Coastal Zone Management Plan
   e. The NJMC's 2004 Master Plan for the Hackensack Meadowlands District
   f. The NJDFW's Meadowlands Wildlife Action Plan

F. RESTORATION FUNDING

G. INTERAGENCY AGREEMENTS AND OVERSIGHT COMMITTEES

H. SUMMARY



The New Jersey Meadowlands Commission facilities at DeKorte Park in Lyndhurst, New Jersey.

X. RESTORATION PLANNING AND COORDINATION

A. INTRODUCTION

The past 10 years have seen a remarkable renaissance of environmental activities in the Meadowlands. To some extent, this rebirth has been reflected in the actions of individual stakeholders and the improved relations and interactions among government agencies and NGOs. For example, federal and State agencies that previously held widely different views on land use in the Meadowlands now partner together in efforts to protect natural resources and restore the ecosystem. These agencies must continue to build this partnership and work together to address critical issues related to water quality, contaminants, cumulative land-use effects, and invasive species. Issues at stake present substantial, complex, and costly challenges. In addition to technical or financial obstacles, expanding and improving the collaboration among those agencies and other stakeholders is of equal importance to restoring the Meadowlands.

Ongoing and/or future remediation and restoration activities are being undertaken: (1) pursuant to different authorities, (2) for various purposes (*e.g.*, mitigation, contaminant remediation), and (3) under the direction of different agencies. These differences potentially affect the scheduling, coordination, and costs of restoration, especially at Superfund sites, thereby complicating the restoration of the entire ecosystem and potentially placing fish and wildlife populations at risk. These differences also contribute to inefficiencies in remediating and restoring the Meadowlands. Avoiding such complications and inefficiencies will require a collaborative process to ensure open dialogue of major issues and concerns, and agreed-upon timeframes among restoration partners. Because government agencies have different responsibilities and priorities, restoration of the Meadowlands ecosystem will be most successful if all stakeholders identify and communicate concerns during early planning stages and work cooperatively to resolve outstanding issues.

Establishment of a common vision has been identified by many experienced restoration practitioners as the foundation for all successful restoration programs and a missing ingredient of many unsuccessful restoration programs (National Research Council, 1999; Vigmostad *et al.*, 2005). Once a common vision is established as a guide, supporting goals, specific objectives, restoration alternatives, implementation, success criteria, and monitoring can be developed collaboratively by stakeholders (Diefendorfer *et al.*, 2003). Developing a shared vision for the Meadowlands has been a Service focus in recent years and is also desired by other Meadowlands stakeholders. Though developed for different purposes, the Wildlife Management Plan for the Hackensack Meadowlands (U.S. Fish and Wildlife Service *et al.*, 2000), the Vision Plan (New Jersey Division of Fish and Wildlife and the U.S. Fish and Wildlife Service, 2002), and the NY-NJ Harbor Estuary Ecological Vision Plan (U.S. Fish and Wildlife Service, 2003a) are consistent with this document and emphasize collaborative development of a common vision, goals, and tasks. The NJMC's 2004 Master Plan also outlines a vision for the future of the Meadowlands. The commitment of all Meadowlands stakeholders to a common vision to guide the restoration of the Meadowlands and long-term protection of its natural resources will promote a new image of this long-neglected urban and suburban environment.

B. AUTHORITIES AND PURPOSES

Restoration and other modifications of specific wetland and waterway sites in the Meadowlands have been or are being undertaken according to various federal (*e.g.*, WRDA, CWA) and State (*e.g.*, Freshwater Wetlands Protection Act, Flood Hazard Area Control Act) authorities, which were legislated to accomplish different purposes. To date, the majority of restoration in the Meadowlands has been undertaken as compensatory mitigation for activities in wetlands regulated under the CWA. Because several mitigation projects may have failed over time, these "restorations" may in fact be contributing to continuing net losses of wetland acreage and functions in the Meadowlands. Increasingly, sites in the Meadowlands are being restored pursuant to the WRDA. While some sections of WRDA (*e.g.*, Section 206 [Aquatic Ecosystem Restoration]) appear applicable to a number of sites throughout the Meadowlands, current funding levels for such projects will probably limit WRDA-authorized restorations of the Meadowlands. The present WRDA Section 206 funding limit ($5 million) will likely affect consideration or feasibility of certain project alternatives (such as remediation or hazardous waste disposal), prevent restoration of large sites or several sites within a basin with potential for connectivity, and encourage restoration partners to eliminate certain costs, such as monitoring, that do not provide immediate on-site benefits to restoration. Restoration of certain heavily contaminated sites in the Meadowlands and adjoining water-bodies in accordance with CERCLA also presents special coordination and other challenges due to the spread and pervasiveness of contamination. Irrespective of whether site remediation is performed prior to or concurrent with restoration, contamination may also greatly increase the costs of restoration. Thus, stakeholders should explore development of a specific authority (similar to the Coastal Wetlands Planning, Protection, and Restoration Act for coastal Louisiana [16 U.S.C. 3951-3956] or the CALFED Bay-Delta Authorization Act of 2004 [P.L. 108-361] for the San Francisco Bay watershed) that will amalgamate and better integrate restoration and related efforts of different agencies by combining, parlaying, or directing individual funding sources. Working under such an umbrella authority could hasten and improve clean-up and restoration of the entire system, minimize adverse impacts on fish and wildlife resources, and maximize efficiency and long-term benefits.

1. Clean Water Act

Several sites within the Meadowlands have been restored as compensatory mitigation for off-site impacts to other wetland sites in the Meadowlands from projects authorized pursuant to the CWA; the Service is concerned that such mitigation may be contributing to continued loss of wetland acreage and functions in the Meadowlands, particularly if such projects are not successful in the long term. When restoration is required as compensatory mitigation, federal laws (*e.g.*, CWA), policies, guidelines (*e.g.*, the Service's Mitigation Policy, Section 404[b][1] Guidelines), and other agreements (*e.g.*, the August 29, 1997 MIMAC agreement) are intended to guide the actions and recommendations of regulatory and resource agencies, respectively. The poor success and lack of long-term oversight of compensatory wetland mitigation projects under the Corps' jurisdiction nationwide have received considerable criticism (*e.g.*, U.S. General Accounting Office, 2001; National Research Council, 2001) that has led to improvements such as the National Mitigation Action Plan. Nonetheless, long-term review and management of mitigation sites in the Meadowlands appear lacking. The success of wetland mitigation projects

in the Meadowlands has not been evaluated by the Corps' New York District as it has in other Districts (*e.g.*, New England; U.S. Army Corps of Engineers, 2003b). Strict adherence to the Section 404 permit processes, strong regulatory oversight by the Corps, EPA, and the NJDEP (2005b), rigorous enforcement of permit conditions, and integration of remediation and restoration efforts with regulatory decisions are essential for protecting the Meadowlands (U.S. Department of Interior, 1994). It is the Service's view that under the guidance of the principals' group, the Corps and other MIMAC members should conduct a comprehensive review and evaluation of all past mitigation projects in the Meadowlands, as has been done in other Corps' Districts (*e.g.*, the New England District; U.S. Army Corps of Engineers, 2003b). After the MIMAC's review and evaluation of mitigation projects are completed, the August 29, 1997 interagency agreement that established the MIMAC should be revisited and revised accordingly to promote better communication and incorporation of specific review criteria to ensure compliance with federal regulations and prevent continuing loss of wetland acreage and functions. This should include the development of performance measures to determine project success, using species, habitats, and ecosystem functions.

2. Water Resources Development Act

The Hackensack Meadowlands Ecosystem Restoration (HMER), is being funded and conducted under the Corps' General Investigations Program (*Federal Register*, Volume 69, No. 248, Tuesday, December 28, 2004) as a part of WRDA. The HMER was authorized by a resolution of the Committee on Transportation and Infrastructure of the U.S. House of Representatives, dated April 15, 1999, that amended the Water Resources Development Act of 1986 (16 U.S.C. 2201 *et seq.*), to determine the feasibility of environmental restoration and protection relating to water resources and sediment quality within the New York and New Jersey Port District, including but not limited to creation, enhancement, and restoration of aquatic, wetland, and adjacent upland habitats. Although intended to employ an ecosystem approach with a broad scope consistent with Corps planning guidance (*e.g.*, Planning Guidance Notebook; U.S. Army Corps of Engineers, 2000), authorizations for restoration pursuant to WRDA have not always possessed a clear vision, distinct goals, broad focus, oversight, and, most importantly, a long-term planning process that involves local stakeholders. As a result of current funding limitations, the HMER to date has focused primarily on the restoration of the Anderson Creek Marsh.

In addition to feasibility studies, Section 206 of the WRDA (Aquatic Ecosystem Restoration) also provides the Corps with authority to undertake restoration projects in certain types of aquatic ecosystems (*e.g.*, wetlands, rivers), and has been approved for use on at least one site in the Meadowlands (the 31-acre Lyndhurst Riverside Marsh; U.S. Army Corp of Engineers, 2005d). Under Section 206, each project must be complete within itself and not a part of a larger project. Costs are shared between the federal government (65 percent) and a non-federal sponsor (35 percent); the maximum federal expenditure per project, which includes both planning and construction costs, is only $5 million, a relatively small amount, given the extremely high costs of such activities in the Meadowlands. As a result, Section 206 authority has been considered only for restoration of small sites in the Meadowlands (*e.g.*, the 31-acre Lyndhurst Riverside Marsh); however, restoration planning pursuant to this authority is currently suspended in the Meadowlands due to funding shortfalls (U.S. Army Corp of Engineers, 2005d). Restoration of certain sites in the Meadowlands may be undertaken pursuant to other sections of WRDA: (1)

Section 22, which provides up to $500,000 for planning assistance for development, use, and conservation of water and related land resources; (2) Section 1135, which provides up to $5 million for restoration and to improve the quality of sites that were degraded by previous Corps projects; and (3) Section 204, with an annual appropriations limit of $15 million, for projects that will beneficially use dredged material (from federal navigation and other dredging projects) to protect, restore, and create aquatic and ecologically related habitats. All of these WRDA programs require cost-sharing with non-federal project sponsors. One potential limitation in the use of these authorities for restoring one or more sites in the Meadowlands is the lack of an "umbrella" program or principals' group to ensure a consistent and broad focus over problems or issues (*e.g.*, poor water quality, access) affecting the entire ecosystem.

3. Comprehensive Environmental Response, Compensation, and Liability Act

Seven heavily contaminated sites in the HMD have been identified on the Superfund National Priorities List (NPL) pursuant to CERCLA; some of these sites were identified on the NPL in the early 1980s. These NPL sites (*e.g.*, Diamond Alkali, Ventron/Velsicol) present numerous technical, communication, and coordination challenges for restoration (*e.g.*, U.S. Fish and Wildlife Service, 2005c). For example, although contamination originating from those sites has spread throughout the Meadowlands ecosystem, efforts have been made at various times by responsible parties and government agencies to restrict the geographic extent of the Berry's Creek Study Area (as defined for remediation) to the immediate source areas. Restricting the Berry's Creek Study Area reduces the financial obligations of the responsible parties for remediation and restoration to much smaller sites. However, restricting a study area may perpetuate risks to, and adverse impacts on, fish and wildlife populations from contamination spread beyond a designated study area. Restricting the Berry's Creek Study Area may also result in lost resource uses and the transfer of unrealized remediation and restoration costs to the public.

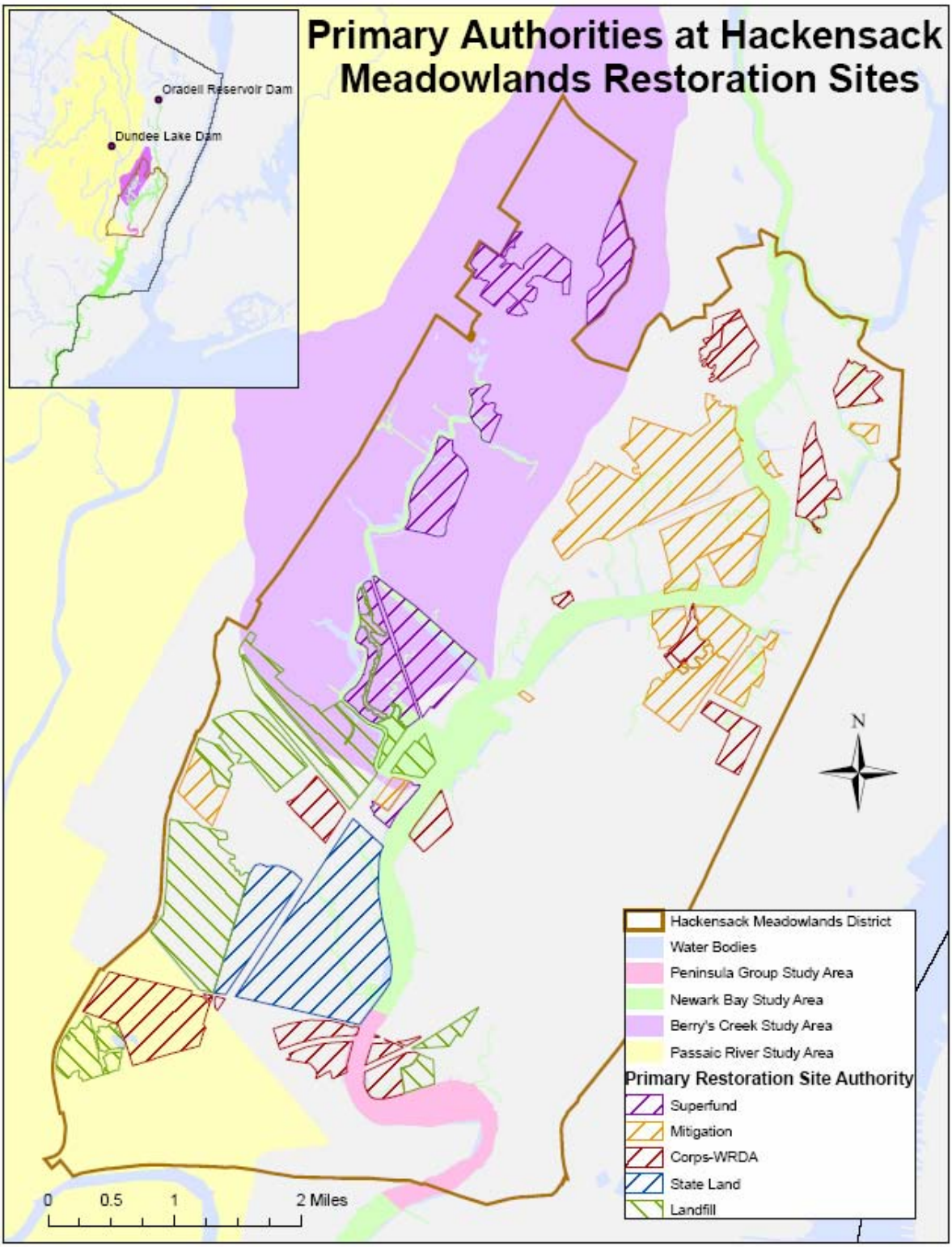
As an example, the designation of study areas in the Passaic River illustrates the potential complexity regarding assessment, remediation, and restoration of Superfund sites in the Meadowlands. The Diamond Alkali Superfund Site, initially designated in 1984, consisted of two upland parcels on Lister Avenue in Newark. However, the EPA defined a 6-mile stretch of the Lower Passaic River as the Passaic River Study Area in 1994. Information gathered within that area led the EPA to expand the Study Area to include the entire Passaic River below the Dundee Dam in 2004 and to include all contaminants and their sources associated with the degradation of the river. Additional studies led the EPA, through an Administrative Order of Consent, to expand the Study Area again to include Newark Bay and its tributaries, including portions of the Hackensack River, the Kill van Kull, and the Arthur Kill (U.S. Fish and Wildlife Service, 2005c). Additional legal challenges (*e.g.*, Natural Resources Defense Council *et al.* vs. U.S. Army Corps of Engineers and Colonel Richard Polo; U.S. Army Corps of Engineers, 2005e) may further delay remediation and restoration activities. Presently, there are four "operable units" of the Passaic River Study Area: (1) the Lister Avenue properties, (2) the 6-mile stretch of the Lower Passiac River, (3) the entire Passaic River below Dundee Dam, and (4) Newark Bay and portions of its tributaries (U.S. Fish and Wildlife Service, 2005c). Contamination originating from the sites undoubtedly extends far beyond the current designated Study Area (see Figure 61) due to tidal actions.

While considerable progress has been made in assessing and addressing contamination from some NPL sites affecting the Meadowlands (*e.g.*, Diamond Alkali, listed in 1984), minimal progress has been made with other sites in the Meadowlands (*e.g.*, Ventron/Velsicol, also listed in 1984) due to budget constraints and other work priorities of federal and State agencies. The importance of coordination issues surrounding NPL sites in the Meadowlands cannot be overemphasized. The Berry's Creek sub-basin includes some of the most heavily contaminated wetlands in North America. Furthermore, the Berry's Creek sub-basin is located between the two sub-basins with the greatest extent of wetlands in the HMD (see discussion in Section V above). The dispersal and availability of mercury originating from this site as a result of natural and restoration activities remains a considerable threat to all wetlands in the system, and has the potential to compromise the success of restoration of other sites throughout the Meadowlands. Thus, specific activities to remediate and restore the Berry's Creek sub-basin, and the sequence of those activities, have serious implications to restoring the entire system. *Timely communication and coordination among federal and State agencies and other stakeholders regarding the Berry's Creek, Diamond Alkali, and possibly other Superfund sites are essential for restoring the Meadowlands.* The EPA and BTAG coordinate individual site remediation; however, as noted above regarding implementation of WRDA projects, a specifically authorized oversight (principals') group is needed. Such a principals' group could work with BTAG to coordinate and implement restoration projects in Berry's Creek together with other remediation and restoration efforts (*e.g.*, MCRIP, Lower Passaic River) to help avoid or minimize adverse impacts and maximize benefits to fish and wildlife populations throughout the Meadowlands.

4. Specifically Authorized Projects and their Applications to the Meadowlands

Current State and federal funding is sufficient for planning the restoration of approximately one relatively small site in the Meadowlands per year. In other parts of the United States where federal actions have been recognized as having contributed to adverse impacts to fish, wildlife, and their habitats (as they have been in the Meadowlands; *e.g.*, U.S. Department of the Interior, 1994), federal laws have been enacted to establish comprehensive restoration projects in those specific areas. For example, the Missouri River Protection and Improvement Act of 2000 and the Missouri River Restoration Act of 2000 (Title VII and IX, respectively, P.L. 106-541) were enacted to improve conservation and water quality and protect recreational, cultural, and other resources in the Missouri River watershed in North and South Dakota, respectively. The Coastal Wetlands Planning, Protection and Restoration Act [16 U.S.C. 3951-3956] established a federal task force to achieve "no net loss" of wetlands through regulatory and other measures (*i.e.*, restoration and other long-term actions) in Louisiana. This task force, composed of regional directors (or their designees) from five federal agencies and the State Governor, provides oversight of a $50 million annual appropriation for restoration projects that is based on a fixed percentage of excise taxes deposited into the Federal Sportfish Restoration Account. In one of the larger restoration projects undertaken by the federal government, the Comprehensive

Figure 61. Mapped areas of primary federal and State regulatory authorities for potential restoration sites and adjoining waterways in the Hackensack Meadowlands District.



Everglades Restoration Act of 2000 (Title VI, P.L. 106-541) was established to restore, preserve, and protect the South Florida ecosystem, including the Everglades, nearby national parks and NWRs, other conservation areas, wetlands, and submerged lands. This Act authorized four "pilot projects," totaling $69 million, to improve water quality (*e.g.*, restore riverine flows through oxbow lakes, control water flow and seepage among in-ground reservoirs, reuse wastewater) and ten "initial restoration projects" totaling $1.1 billion to begin restoring the Everglades ecosystem and the Florida Bay estuary (*e.g.*, several large water-storage reservoirs, stormwater treatment systems, re-establishing hydrologic connections), including $100 million to the Service for monitoring and assessment. These are just a few examples of the level of funding commitment necessary to effect restoration on an ecosystem scale, similar to what is required for the Meadowlands.

In addition to providing a sufficient funding base, authorization of a comprehensive restoration project at the federal level, specific to the Meadowlands, would offer many advantages to the restoration of this heavily contaminated ecosystem. Such an authorization is not meant to compete or be at cross-purposes with other restoration projects in the Meadowlands (*e.g.*, the Corps and NJMC-funded HMER [in which the Service is also a partner]), but to amalgamate and integrate those efforts and provide a broader authority and more stable funding base for additional comprehensive activities (*e.g.*, improving water quality) critical to achieving successful restoration. In addition, this funding would ensure that appropriate resources are available to each agency involved in the restoration effort. Other benefits would include: (1) improved interagency coordination; (2) broad planning scope; (3) thorough analyses; (4) consistent project oversight, including application of contaminant criteria; (5) public outreach and education; (6) long-term monitoring and management; and (7) potential for cost-sharing. Monitoring and other costs (*e.g.*, analyses) potentially slow down restoration of different sites, since they are costly and sometimes perceived as having little or no (immediate) benefit. Also, federal and State agencies have other considerable responsibilities and priorities that do not allow them to focus on any one project unless specific, dedicated resources are made available for that purpose. With a specific authorization, all agencies can actively pursue restoration and related activities (*e.g.*, remediation, assessment, planning) on all potential restoration sites in the most desired sequence (see Section D below).

C. PARTNERSHIPS AND OVERSIGHT

To date, restoration of various sites in the Meadowlands often has been undertaken separately by a number of individual government agencies, NGOs, and businesses. The NJMC has acquired or is undertaking restoration on most of those sites; one notable exception is the MRI Marsh Mitigation Bank site, owned by a publicly traded corporation, in Carlstadt. Several NGOs (*e.g.*, the Hackensack Riverkeeper's Cole's Brook Project in Hackensack, the Teaneck Creek Conservancy Site in Teaneck) are also restoring wetland sites with State or federal funding (*e.g.*, U.S. Environmental Protection Agency, 2005c). Other government agencies potentially have varied responsibilities in restoration projects in the Meadowlands. For example, the Corps and the NJDEP have regulatory oversight for all the above sites (*i.e.*, the NJMC and MRI Marsh Mitigation Bank site), which were restored as compensatory mitigation for activities in wetlands requiring federal and State permits (Figure 61). The EPA has regulatory oversight for the

assessment and remediation of designated Superfund areas pursuant to CERCLA; in some cases, remediation of a site may be necessary prior to any restoration of the site. The Service, NMFS, and the State have primary oversight for restoration of those Superfund (and possibly additional) sites pursuant to NRDAR. The Service's (2004f; 2005d) *Partners for Fish and Wildlife* and *Coastal* programs and NOAA's (2005c) *Community-based Restoration* Program works with certain partners (*e.g.*, private or State-owned lands) for restoration of specific wetland or upland sites and would be available to undertake such projects in the HMD. Similarly, the Service's and NFWF's *Bring Back the Natives* program also offers partnership opportunities with landowners to restore aquatic resources in the Meadowlands.

Coordination of restoration activities may be complicated further by the involvement of different administrative units within an agency. Within the Corps, the Regulatory and Planning Branches may be involved in restoration of different sites within the Meadowlands. Within the EPA, the RCRA Branch, Office of Water, Environmental Review Section, and the interagency BTAG (chaired by the EPA) may be involved in remediation and restoration activities in the Meadowlands. Within the Service, the NJFO and the Southern New England-New York Bight Coastal Ecosystems Program Office have been involved in Meadowlands resource issues. The involvement of different agencies and administrative units within agencies emphasizes the need and importance of communication and coordination among all the restoration partners. Thus, the Service recommends establishment of a technical committee (under the guidance of, and reporting to, the principals' group) to develop and implement a collaborative process to track and coordinate all projects potentially affecting remediation and restoration in the Meadowlands. The principals' group and technical committee would be most effective if created through a specifically authorized project similar to the examples discussed above for the Missouri River, Louisiana Coast, and the Florida Everglades.

D. RESTORATION SCHEDULES

Financial, biological, engineering, administrative, and legal issues pursuant to different federal and State authorities can affect the restoration sequence, both seasonally and longer-term. Despite various factors potentially affecting the scheduling of restoration activities, restoration of all sites should be scheduled to minimize additional adverse impacts on fish and wildlife resources and thus maximize the long-term benefit (*i.e.*, produce a net gain) to these resources. The sequence in which sites are restored and the scheduling of activities on each site should not contribute to creating attractive nuisances that adversely impact fish and wildlife resources; thus, the Service has consistently recommended remediation of contaminated sites prior to restoration. To date, the Service is unaware of efforts by government agencies or other stakeholders to identify issues (*e.g.*, contamination, dredged-material availability) affecting the sequence of restoring certain sites; however, an administrative issue may already be affecting the planning for the first site (Anderson Creek Marsh) to be restored by the HMER. For example, wetland filling required to close, cap, and remediate a landfill (*e.g.*, Keegan Landfill) requires compensatory mitigation according to the CWA. At this writing, the NJMC may "withhold" a portion of the Anderson Creek Marsh from the HMER's restoration to provide suitable mitigation for the wetland impacts associated with the Keegan Landfill closure. If portions of the site are restored

under different authorities, the timing must be coordinated to avoid compromising the overall restoration of the Anderson Creek Marsh.

A principals' group should encourage all stakeholders in the restoration of any site, and especially those with operating authorities governing several sites or any large area within the HMD, to identify potential concerns and timetables pertaining to restoring each site, and to use that information and the characteristics of each site to develop a master timetable for restoring all sites within the HMD. This master timetable should identify all currently planned projects in the HMD, and their potential interactions and impacts to wetland sites and sub-basins. The timetable also should include contingencies and alternatives based upon the specific concerns of each site. Planning and coordination are especially critical for activities at heavily contaminated sites. Coordination at this level would obviously result in cost-sharing and in-kind services to promote specific efforts and outcomes at certain restoration sites.

E. BASELINE REMEDIATION AND RESTORATION PLANS

1. Development of Baseline Remediation Plans

The Service recommends development of a "baseline plan" for remediation of all sites for the entire HMD. This baseline plan would be generated by mapping the concentrations of each contaminant of potential concern for every wetland site and waterway in the Meadowlands. The maps would then be overlaid to generate a contaminant map for the entire HMD. Using currently available information on contaminant depth profiles, this map would be used to:

(1) improve risk assessments and determine the feasibility of restoration;

(2) develop preliminary estimates of the volume and cost of removing all contaminated sediments to specified criteria within different sub-basins;

(3) develop alternative remediation plans based upon projected removal of lesser volumes of contaminated materials, using consistent or other, less stringent, criteria (consistent across sites restored pursuant to different authorities) and other steps to isolate remaining contaminants *in situ* within different sub-basins; and

(4) identify (a) sub-basins where additional contaminant research and study information has the potential to yield the greatest risk and cost benefits, and (b) other remediation and/or contaminant concerns.

Development of this baseline remediation plan would provide the principals' group, other stakeholders, and the public with a better understanding of the magnitude of, and threats presented by, the contamination in the Meadowlands and the funding required for remediation, enhancement, and restoration. The plan would also provide a framework for evaluating alternatives for remediation and restoration to determine which would be the most efficient and cost-effective in the long-term.

2. Current Restoration Planning

The Service has long been committed to the protection of the Meadowlands ecosystem; thus, this planning effort has been built partially upon earlier Service efforts pertaining to the Meadowlands. In particular, this effort benefited from: (1) the Service's (1996a) *Significant Habitats and Habitat Complexes of the New York Bight Watershed*, (2) the *Wildlife Management Plan for the Hackensack Meadowlands* (U.S. Fish and Wildlife Service *et al*., 2000), (3) the *Vision Plan* (New Jersey Division of Fish and Wildlife and the U.S. Fish and Wildlife Service, 2002), and (4) the Service's (2003a) *New York-New Jersey Harbor Estuary Ecological Vision Plan*. Though developed for different purposes and sometimes including input from other agencies, these documents emphasized goals of limiting further encroachment into (*i.e.*, filling of) the Meadowlands, remediating heavily contaminated wetland sites, improving water quality, restoring wetlands, and increasing public access.

Several planning efforts led by other government agencies that address the restoration of the Meadowlands or larger geographic areas that include the Meadowlands have been completed or are underway (Table 30). These planning efforts were initiated by federal or State agencies under different authorities and for different purposes; however, some of these planning efforts identify similar concerns or address the same issues and therefore would benefit greatly from increased communication, coordination, and cooperation among all parties. Planning efforts by other agencies that specifically affect the remediation and restoration of the Meadowlands ecosystem are summarized and presented below.

a. <u>The Harbor Estuary Program's (1996) Comprehensive Conservation and Management Plan</u>

Authorized in 1987 by Section 320 of the Clean Water Act, the HEP received support from federal and State agencies, NGOs, academic institutions, and others in formulating its vision: "to establish and maintain a healthy and productive New York Harbor/Bight ecosystem with full beneficial uses." The CCMP's goals are to: (1) restore and maintain an ecosystem which supports and sustains optimum biodiversity; (2) preserve and restore ecologically important habitat and open space; (3) attain water quality that fully supports bathing and other recreational uses of the estuary; (4) ensure that fish and shellfish in the Hudson Raritan Estuary are safe for unrestricted human consumption; (5) restore and enhance the aesthetic quality of the estuary; (6) actively address emerging issues that impact the estuary; (7) manage and balance the competing uses of the estuary to improve environmental quality; and (8) manage pollutants within the estuary to prevent use impairments outside the estuary. Through several working groups, the HEP is charged with addressing five categories of impairments (habitat loss/degradation, toxics, pathogens, floatables, and nutrients/organic enrichment).

Overall, the HEP and the CCMP have been among the most important groups and planning efforts, respectively, regarding the NY-NJ Harbor. However, exchange of information and technical expertise among the HEP, the Service, and the NJMC has been limited by agency resources and multiple priorities. Moreover, the Service and NJMC have had limited participation in implementing the CCMP in the Meadowlands for similar reasons.

Table 30. Overview of planning efforts by federal and State agencies that pertain to the Hackensack Meadowlands.

Lead agency/ Document Title	Status/Date of issue	Geographic scope	USFWS assistance	Other partners	USFWS concerns
I. U.S. Army Corps of Engineers (Corps)					
A. Hudson Raritan Estuary (HRE) *Feasibility Study* and *Comprehensive Restoration Implementation Plan* (CRIP)	Project Management Plan completed	HRE	None	Port Authority of NY-NJ	Planning priorities and sequence; vision?
B. Miscellaneous port planning *-Dredged Material Management Plan* *-Comprehensive Port Improvement Plan*	 2003 In revision	NY-NJ Harbor	FWCA 2(b) report; other	Port Authority of NY-NJ and others	Adverse dredging and filling impacts (contaminants)
C. Hackensack Meadowlands Ecosystem Restoration *Feasibility Study* and CRIP	In progress	HMD	PARs, other	NJMC and USFWS	Contaminant effects on restoration; vision?
II. U.S. Environmental Protection Agency (EPA)					
A. Harbor Estuary Program's *Comprehensive Conservation and Management Plan*	1996	NY-NJ Harbor	Limited	USFWS; federal and state agencies; others	Limited integration of HMD information
B. *Lower Passaic River Remediation and Ecosystem Restoration Plan*	In progress	Area in HMD	PARs, other	USFWS; federal and state agencies	Contaminant effects on restoration
C. Framework Document, Berry's Creek (Superfund) Study Area	2005	Area in mid-HMD	Technical assistance	USFWS; federal and state agencies; others	Contaminant effects on restoration
III. New Jersey Meadowlands Commission (NJMC)					
A. *Master Plan* and Zoning Regulations	2004; in review	HMD	Technical assistance		Inconsistency with NJDEP regulations
IV. New Jersey Department of Environmental Protection (NJDEP)					
A. Coastal Management Program's *Coastal Zone Management Plan*	1978; in revision	New Jersey	None	NJMC	NJMC coordination; consistency in HMD
B. Derivation of NJ-Specific Wildlife Values as Surface Water Quality Criteria for PCBs, DDT, and Mercury.	Expired in 2003	New Jersey	Co-author	EPA; USFWS	USFWS (1996b, 1998) requires NJDEP/EPA to promulgate the criteria.
C. Division of Fish and Wildlife's *Meadowlands Wildlife Action Plan*	In progress	HMD	None	Ducks Unlimited, Inc. New Jersey Audubon	None known.
D. Hackensack River Study Area Known Contaminated Site Investigation	In progress	Area in lower HMD	Technical assistance		Contaminant effects on restoration

b. The Corps' HRE Feasibility Study and Comprehensive Restoration Implementation Plan

In 2001, the Corps completed a Project Management Plan and executed a Feasibility Cost-Sharing Agreement with the Port Authority of NY-NJ to restore numerous sites throughout the entire HRE. The HRE Feasibility Study and Comprehensive Restoration Implementation Plan were designed by the Corps and its local sponsor (the Port Authority of NY-NJ) as a master plan to guide the restoration of the entire HRE, in part by "spinning-off" local projects, including HRE-Gowanus (NY), HRE-Hackensack Meadowlands (NJ), HRE Lower Passaic (NJ) and HRE-Liberty State Park (NJ). These projects are to focus on: (1) removal of fill and *Phragmites*, (2) restoration of tidal flow to enhance fish and wildlife habitat value and water quality, (3) restoration of shellfish beds, (4) recontouring of bottom sediments in selected harbor areas to restore benthic habitat, (5) removal of impairments to fish migration on tributaries, (6) covering of contaminated sediment hot spots with clean sediments, and (7) identification and implementation of beneficial uses of dredged material for habitat enhancement (U.S. Army Corps of Engineers, 2005f).

The Service supports efforts to restore degraded environments throughout the HRE; however, neither the Service nor most other stakeholders and interested parties have had an opportunity to participate substantially in the development of or review HRE "umbrella guidance" to establish a vision, goals, or objectives for the restoration of the entire HRE. Service concerns are focused on contaminant characterization and risk assessment and the development of water quality and other criteria needed to protect fish and wildlife; other stakeholders have similar and additional interests and concerns beyond the HRE and CCMP.

c. The Corps' Meadowlands-Comprehensive Restoration Implementation Plan

The *Meadowlands Comprehensive Restoration Implementation Plan* (MCRIP), recently released as a draft document, is the most recent and detailed Corps (2005g) planning document regarding the restoration of numerous sites throughout the Hackensack Meadowlands. The MCRIP reportedly addresses two primary water-resource needs: (1) the need for a single Meadowlands-wide analysis of ecosystem restoration opportunities, and (2) the need for initial ecosystem restoration efforts at specific candidate restoration sites. These needs include plans for restoring salt-marsh and benthic habitats, and recommended solutions to: habitat fragmentation, infrastructure encroachments on tidal flow, water-management control structures, and adverse impacts of contaminated sediments, brownfields, and landfills on the Meadowlands ecosystem and its fish and wildlife resources. The overall goal of the Corps' (2005g) MCRIP is "to restore ecological function to the Meadowlands to the extent practicable within the context of the greater HRE." Other Corps (2005g) goals are to: (1) identify historical ecological functions of the Meadowlands; (2) identify impairments to ecological functions of the Meadowlands; (3) identify physical impairments to the Meadowlands; (4) identify quantifiable restoration performance metrics; (5) identify conceptual restoration opportunities; (6) conduct site characterization and selection; (7) evaluate restoration alternatives and functions restored; (8) assess cost/benefit; (9) select restoration opportunities; and (10) monitor and measure performance.

The Service (2005b) supports the Corps' wetland restoration efforts throughout the HMD, and has provided planning aid regarding site evaluation to avoid increasing the bioavailability of

contaminants. Well-designed remedial components must be included in the restoration of contaminated sites. Therefore, the Service's (2005b) recommendations for the MCRIP are to focus on: (1) regional and local contaminant sources that might hinder restoration efforts; (2) water quality throughout the Meadowlands; (3) the use of existing restoration projects for studies and monitoring to develop an understanding of contaminants in the Meadowlands and their impact on restoration; and (4) pursuing restoration projects that will minimize further problems related to contaminants, their redistribution, and their exposure to fish and wildlife. The Service (2005b) also ranked candidate restoration sites in the HMD into three categories: minimal, moderate, and major contaminant concerns (see Section III.E).

d. The NJDEP Coastal Management Program's Coastal Zone Management Plan

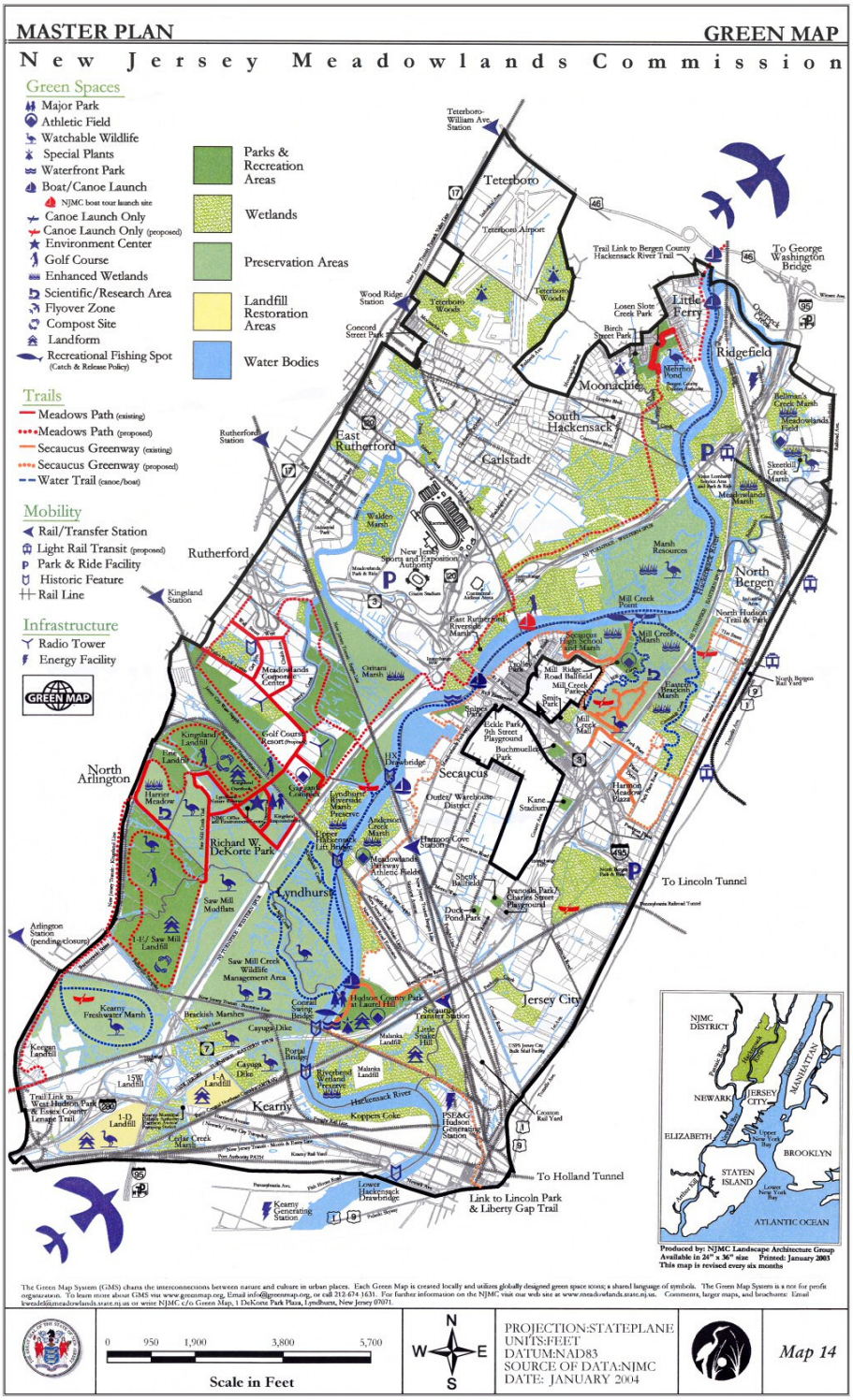
As part of the revision of the State's 1978 *Coastal Zone Management Plan* (CZMP), the NJDEP's Coastal Management Program is undertaking a critical evaluation of the CZMP goals, policies, and implementation strategies prior to revising and submitting an updated plan to the NOAA for approval pursuant to the Coastal Zone Management Act of 1972. The State's CZMP is implemented by the NJDEP's Land Use Regulation Program except in the HMD, where the NJMC is the lead agency. The Service recommends that the roles of, and coordination between, the State agencies (*i.e.*, NJMC and NJDEP) be clearly identified in the revision of the CZMP. In addition, any apparent inconsistencies between the NJMC's 2004 *Master Plan* and zoning regulations and with State wetland laws should be clarified.

e. The NJMC's 2004 Master Plan for the Hackensack Meadowlands District

As the NJMC's primary planning document, the *Master Plan* provides a policy framework to promote the careful balancing of environmental and economic development needs in the HMD. The plan includes an overall vision of a "re-greened Meadowlands and a revitalized urban landscape," to be achieved through: (1) protection, preservation, and enhancement of wetlands culminating in the preservation of 8,400 acres; (2) the thoughtful balancing of planned redevelopment and new development on upland sites; (3) an integrated multi-modal transportation network; and (4) the retention and growth of commercial, industrial, and financial enterprises and jobs. The *Master Plan* is implemented through revised zoning regulations adopted by the NJMC in 2005. The *Master Plan* and the zoning regulations have not been formally submitted to NOAA for consistency determination (K. Herrington, pers. comm., 2005; K. Wall, pers. comm., 2007).

The policies and principles of the *Master Plan* are to be enacted through the NJMC's regulations, including zoning, that are codified at N.J.A.C. 19:3-1.1 *et seq.* The zoning regulations must be consistent with other State regulations to prevent future encroachment into wetlands in the HMD. The NJMC's (2004d) *Master Plan* and zoning regulations would allow marinas and communication towers (as "special use exceptions") in wetlands. The extent of protection provided by land-use designations, such as wetlands, preservation areas, landfill restoration areas, and scientific/research areas on the NJMC's "Green Map" for the HMD (Figure 62), will need clarification. Also, the projected or future use of open space currently represented by landfills on some maps will need to be more clearly defined. The Service is concerned about the potential adverse impacts of special exception uses (*e.g.*, communication towers, marinas)

Figure 62. The New Jersey Meadowlands Commission's (2004d) Green Map for the Hackensack Meadowlands District.



proposed for the environmental conservation zone. The Service encourages the NJDEP and the NJMC to review and clarify procedures for interagency coordination to ensure consistency of State regulations with federal provisions of the Coastal Zone Management Act and to minimize the potential impacts of federally approved, licensed, permitted, or funded projects in the HMD on federal trust fish and wildlife resources.

f. The NJDFW's Meadowlands Wildlife Action Plan

At the request of, and through funding provided by, the NJMC, the NJDFW has agreed to develop a *Meadowlands Wildlife Action Plan*. This plan is separate from and unrelated to the interagency wildlife management plan that was developed during the SAMP (U.S. Fish and Wildlife Service *et al.*, 2000). The *Meadowlands Wildlife Action Plan* being developed by the NJDFW will form one component of the Statewide *Wildlife Action Plan*, which provides the blueprint for statewide protection of wildlife with special conservation needs. The *Wildlife Action Plan* provides planning tools in a geographic information system to assist landowners and others in protecting habitats for species of conservation need. The Wildlife Action Plan relies on a landscape approach, which includes mapping the occurrence of rare species and their habitats. Fish and wildlife species and habitats can then be monitored to assist in the decision-making for remediation and restoration activities. Specifically, the information will be used to guide planning and regulatory decisions, direct management of conservation areas, provide conservation tools to local stakeholders, and guide further open-space acquisitions. The Service supports the efforts of the NJDFW to develop the *Meadowlands Wildlife Action Plan*; moreover, the Service recommends that this effort be expanded to assess rare plant species and develop management plans (*e.g.*, invasive-species control), as needed.

F. RESTORATION FUNDING

To date, private funding has accounted for the sites restored to date within the Meadowlands as compensatory mitigation for authorized projects in wetlands. Presently, estimates of the cost of restoring an acre of wetland in the HMD range from $100,000 to $165,000 per acre (M. Renna, pers. comm., 2004; R. Feltes, pers. comm., 2005). This estimate does not include costs for disposing of any hazardous waste and includes only minimal monitoring and contaminants assessment. Not including acquisition, costs of past HEP (2002) restoration projects throughout the NY-NJ Harbor are estimated to be $466,000 per acre. Costs for wetland restoration ranging from $500,000 to $1.5 million per acre have been reported in other urban areas (*e.g.*, Zentner *et al.*, 2003; U.S. Environmental Protection Agency, 2005d).

Using the above cost estimates based on restoration of previous sites in the Meadowlands, the restoration of all remaining wetland sites in the Meadowlands (other than previously restored sites and the Sawmill Creek Wildlife Management Area) is projected minimally to cost approximately $405 to $648 million (4,050 acres x $100,000 and $165,000 per acre, respectively). Using the HEP estimate, restoration of the Meadowlands increases to $1.89 billion. (The Everglades Restoration Project, as an example, has been allocated at $8 billion.) Other activities associated with restoration, such as site remediation and disposal of hazardous waste, may increase that total estimate substantially (U.S. Environmental Protection Agency,

2005d). This estimate also does not include monitoring, which is currently estimated at approximately 10 to 15 percent of the costs of restoring other sites (*e.g.*, Everglades; U.S. Army Corps of Engineers, 2005h).

Large wetland restoration projects are recognized to have lower costs per acre than small projects (*e.g.*, Imus, 2003); thus, the Service recommends including restoration of adjoining or nearby sites, especially those in the same hydrologic sub-basin (*e.g.*, sites along Berry's Creek), wherever feasible, to reduce the cost and the risk to fish and wildlife. On a per-acre basis, recent Service restoration programs (*e.g.*, *Coastal*, *Partners for Fish and Wildlife* programs) have been reported to be more cost-effective nationwide than those of most other federal agencies. Possible differences in wetlands quality or other factors known to affect the cost of projects need to be addressed (U.S. Office of Management and Budget, 2004). Expanding the role of the Service may provide an effective means of minimizing costs of restoring certain sites (*e.g.*, Teterboro Woods, Mehrhof Pond, Losen Slote Creek) in the Meadowlands.

G. INTERAGENCY AGREEMENTS AND OVERSIGHT COMMITTEES

The Service recommends that federal and State agencies partnered in remediation and restoration activities develop an interagency memorandum of agreement that establishes a principals' group and technical committee to ensure a collaborative process to coordinate and direct activities affecting the restoration of the Hackensack Meadowlands. As noted above, such oversight committees would be most effective if created and supported by an authorized Meadowlands project similar to restoration projects in Louisiana, the Everglades, and other areas. The principals' group for the Meadowlands would be supported by the (staff-level) technical committee. The principals' group would meet several times a year to coordinate on major policy, programmatic, budgetary scheduling, and other issues affecting the restoration of the Meadowlands. The technical committee would address restoration of specific sites and related technical issues, and its function would be similar to that of the MIMAC and other groups (*e.g.*, the HMER Project Delivery Team, which is comprised of the Corps, NJMC, Service, EPA, NMFS, and NJDEP) regarding restoration planning for specific sites. The Service encourages the principals' group to consider carefully the exact structure and expertise of the technical committee, as its purpose is to provide an effective mechanism for obtaining timely and relevant technical support from appropriate agency resources and disseminating critical information within each agency. In addition, the principals' group and technical committee would coordinate on issues that potentially affect the restoration of the entire HMD. For example, consensus water quality criteria protective of wildlife (*e.g.*, Buchanan *et al.*, 2001) were proposed several years ago but were never adopted and implemented by the State of New Jersey. Similarly, the EPA has not taken action to promulgate these criteria. These criteria are needed to strengthen overall Clean Water Act planning and implementation. In the future and for new parameters, a technical committee could derive new parameter criteria, whereas the principals' group would coordinate and promote the adoption and implementation of these criteria among their respective agencies. In addition, the stakeholders could develop goals for plant communities and consistent guidelines (*i.e.*, under what contaminant and physiographic scenarios) and procedures (*i.e.*, chemical or mechanical) for removal of common reed. Incorporating valuable technical expertise from individuals or work groups not currently involved in the MIMAC or the Meadowlands could

help address issues such as contaminant remediation, re-vegetation goals, and *Phragmites* control. Thus, the utility of the interagency memoranda of agreement and the establishment of a formal principals' group would be increased by including representatives with expertise from outside government, such as NGOs, businesses, or universities, into *pro hoc* working groups for addressing designated issues.

Successful restoration of the Meadowlands ecosystem will require a serious, long-term commitment by government agencies and other stakeholders to fund and carry out remediation, enhancement, restoration, and protection. Thus, the principals' group and technical committee must address major, long-term issues affecting the restoration of the Meadowlands ecosystem and long-term protection of its resources. The Service recommends that activities of both oversight groups include, but not be limited to, the development of: (1) a collaborative process to coordinate all restoration and related activities, (2) a collective vision, (3) development of contaminant criteria and comprehensive risk assessments, and (4) performance measures as prerequisites for restoration. In addition, development of a specially authorized Meadowlands project, similar to restoration projects noted in other parts of the country, would ensure a long-term funding plan, authority for federal involvement, interagency coordination, and a means to move the restoration forward. Subsequent tasks should include addressing: (1) water supply, flow, and quality, including improved sewage treatment, and stormwater and flood control, (2) cumulative land-use impacts, and (3) other invasive species. The Service also recommends that any interagency agreement(s) be reviewed and revised periodically, as necessary.

Currently, the MIMAC performs only part of the communication and coordination functions necessary for the protection and restoration of the Meadowlands. While the MIMAC provides regulatory oversight of sites restored as compensatory mitigation, improvements in the MIMAC's coordination and oversight of compensatory mitigation projects are clearly needed to help prevent future wetland losses. Such improvements should include increased attention to contaminant issues (*e.g.*, monitoring, assessment, impacts) that pertain to many wetland sites considered for restoration, especially those within a designated Study Area for any federal (*e.g.*, Superfund sites, pursuant to CERCLA) and possibly other State-managed contaminated sites (*e.g.*, Peninsula Group site, managed currently by NJDEP's Site Remediation Program). The EPA's Superfund Branch (and coordination with the BTAG) should be considered for regular participation in the MIMAC. Thus, the current Interagency Compensatory Wetland Mitigation Agreement for the Hackensack Meadowlands District (dated August 29, 1997) that established the MIMAC should be re-evaluated to ensure: (1) compliance of all remediation and restoration projects with federal and State regulatory requirements, (2) consistency in remediation, restoration, and other activities governed by different authorities, and (3) coordination of remediation and restoration projects with other activities involving restoration or land use in the Meadowlands. Such actions have contributed to improvements in mitigation in other states (*e.g.*, Florida; Florida Office of Program Policy Analysis and Government Accountability, 2000).

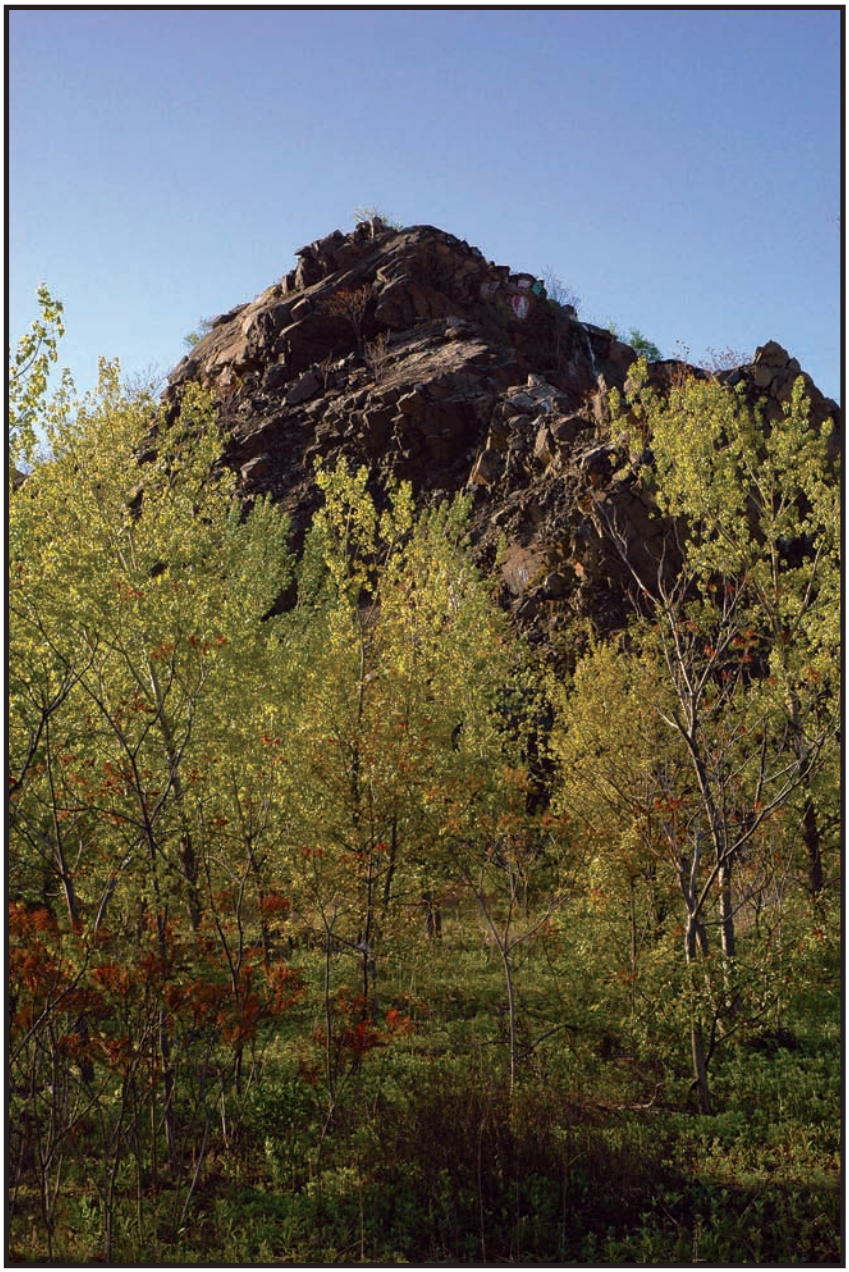
Finally, the principals' group and technical committee should meet annually with other stakeholders in a forum for information exchange (and other specific purposes), such as the Stakeholders' Work Sessions that have been hosted by the Service since October 2000. Additional meetings with smaller workgroups might be conducted to facilitate specific tasks. The commitment of restoration partners to an annual gathering would improve communication,

facilitate coordination on issues important to remediation and restoration (particularly restoration schedules), improve cooperation on projects, and enhance the visibility of efforts to restore the Meadowlands.

H. SUMMARY

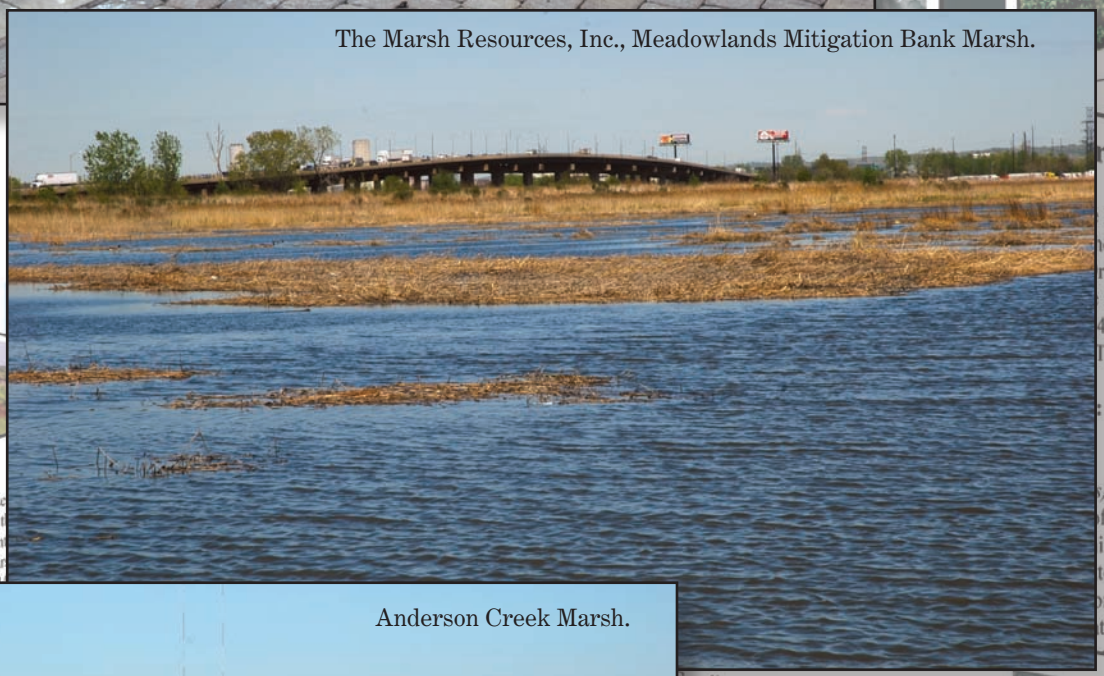
Greater collaboration among federal and State agencies and NGOs is necessary to address the numerous and complex problems and issues regarding the restoration of the Meadowlands and the long-term protection of its fish and wildlife resources. Numerous agencies are involved in restoration of different sites in the Meadowlands; however, these restoration efforts are being undertaken by different agencies independently and pursuant to different authorities for different purposes on different schedules. To date, activities reflect the absence of a shared vision to guide actions by restoration partners, including regulatory and resource agencies. Several land-use planning efforts are underway for different purposes and have the potential to contribute to the restoration and protection of the Meadowlands; however, these efforts would also be improved by the commitment of all agencies to a shared vision and collaborative action. While current funding is sufficient to undertake restoration of small sites, it will not be adequate for comprehensive restoration of the Meadowlands ecosystem. Stakeholders need to explore the development of a specific funding authority for Meadowlands restoration similar to what has been established for other landscape-scale restoration projects in the Missouri River, Florida Everglades, and lower Colorado River. While development of such an authority may take time, all stakeholders, and especially federal and State agencies, could improve current restoration efforts in the Meadowlands by developing a memorandum of agreement that establishes a principals' group and a technical committee to develop a collaborative, consensus-driven process and ensure coordination on regulatory, remediation, and restoration issues. Recent efforts to restore the Meadowlands are encouraging; however, improved collaboration and long-term coordination will be necessary to address the complex problems affecting the Meadowlands ecosystem and its fish and wildlife resources.

XI. Recommendations

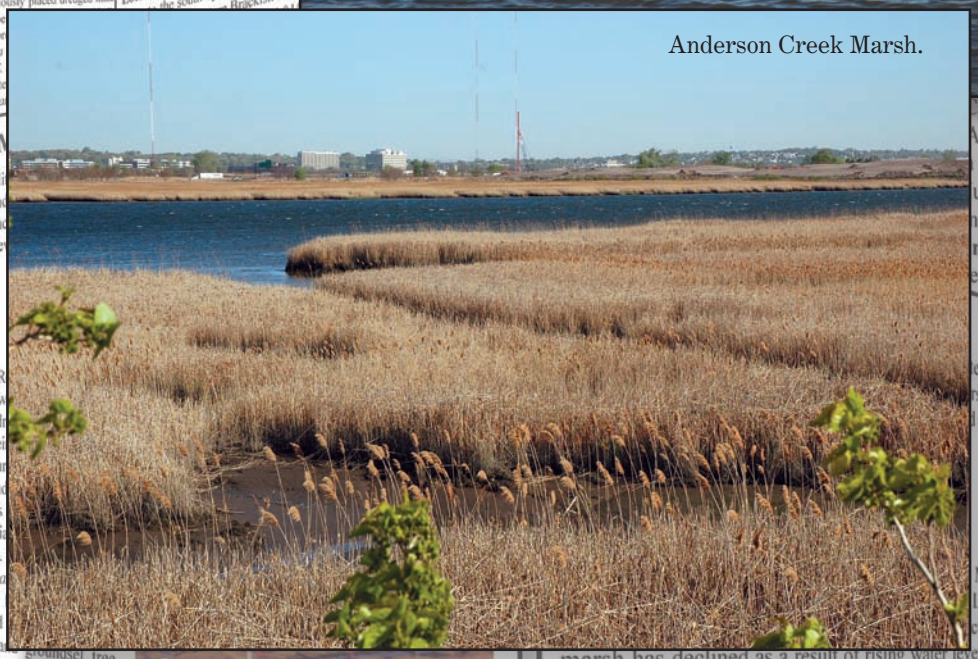


"Snake Hill," now part of Laurel Hill County Park.

The Mill Creek Park Landing.



The Marsh Resources, Inc., Meadowlands Mitigation Bank Marsh.



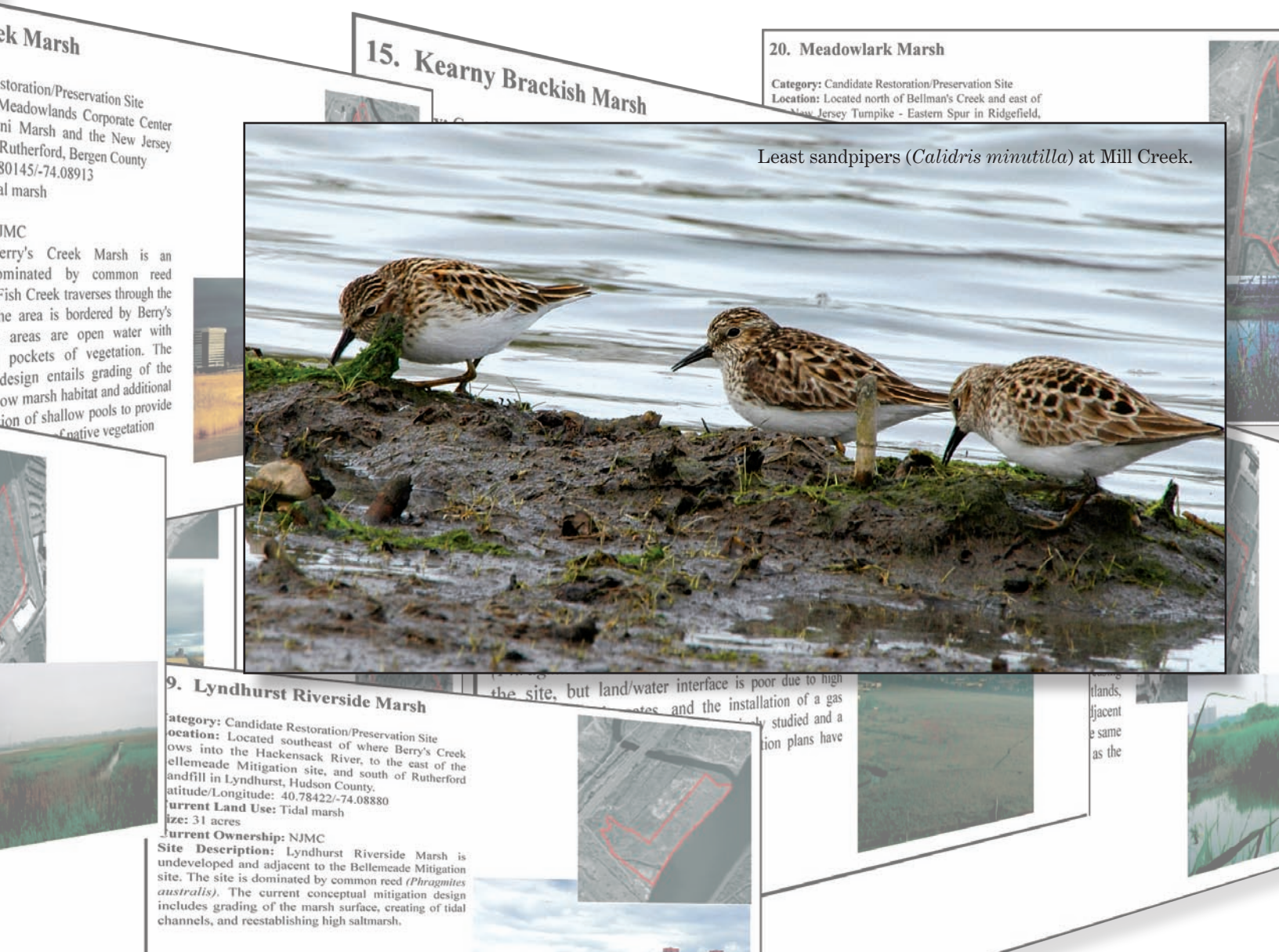
Anderson Creek Marsh.

XI. Recommendations

The Meadowlands has been degraded by centuries of human activities, and is surrounded by an extensively modified landscape that is the home and workplace of one of the largest urban populations in North America. Prompt and decisive actions to restore available wetland sites appear to be tempting remedies for promoting and maintaining public support for investing in the Meadowlands. Nonetheless, remediation and restoration of the Meadowlands will not be accomplished overnight and will require *comprehensive* actions to address complex problems, especially contamination.

At first glance, the following pages filled with recommendations would seem to provide ample justification to restore the Meadowlands quickly and efficiently. These recommendations are based on available information and supportive of the Service's overall goal and major objectives for the Meadowlands. Unfortunately, current information is insufficient to guide the overall remediation and restoration of the Meadowlands efficiently and effectively. Thus, additional monitoring and subsequent analyses are essential to guide prudent decision-making that minimizes risks to fish, wildlife, and people. Decision-making must also be guided by a shared vision to reclaim the Hackensack Meadowlands ecosystem for the American people.

Comprehensive remediation and restoration of the Meadowlands must begin with all stakeholders working together, guided by a common vision.



Least sandpipers (*Calidris minutilla*) at Mill Creek.

XI. RECOMMENDATIONS

A. PROMOTE AND LEAD EFFORTS FOR LAND ACQUISITION, REMEDIATION, ENHANCEMENT, RESTORATION, AND MANAGEMENT

1. **Acquisition**
2. **Remediation**
3. **Enhancement and Restoration**
4. **Management**

B. INCREASE SCIENTIFIC UNDERSTANDING TO BETTER DEFINE SUCCESSFUL REMEDIATION AND RESTORATION AND TO ENHANCE ECOSYSTEM FUNCTIONS AND NATURAL DYNAMIC PROCESSES

C. ESTABLISH DIVERSE, NATIVE WETLAND AND UPLAND COMMUNITIES

D. INCREASE RESPONSIBLE USE OF, PUBLIC AWARENESS OF, AND EDUCATION ABOUT THE MEADOWLANDS

Schoolchildren exploring DeKorte Park.

XI. RECOMMENDATIONS

In providing this Plan, the Service seeks to increase its efficiency and effectiveness on a landscape level. This Plan is consistent with the Service's current emphases of ensuring greater voluntary compliance with environmental laws and regulations, developing conservation partnerships, and increasing its influence with all stakeholders that can help accomplish goals on a landscape level. The Service's current overall goals include restoring habitats, remediating environmental contaminants, controlling invasive species, and protecting fish and wildlife populations long-term.

The overall goal of the Service's *Hackensack Meadowlands Initiative: Preliminary Conservation Planning* is to sustain and safeguard the Meadowlands ecosystem and its fish and wildlife resources. To achieve this goal, the Service will work with its partners to accomplish the following major *objectives*:

(1) promote, and where appropriate, lead efforts for land acquisition, remediation, enhancement, restoration, and management of the Hackensack Meadowlands;

(2) increase scientific understanding to better define successful remediation and restoration and to enhance ecosystem functions and natural dynamic processes, especially through activities that remediate contaminated sites and improve water quality;

(3) establish diverse, native wetland and upland vegetative communities, to include greater acreage and diversity of forest, shrub, grassland, and wetland cover types to support biodiversity at local, regional, and larger scales; and

(4) increase responsible use of, public awareness of, and education about the Meadowlands, including its flora and fauna.

The following recommendations have been taken from the preceding sections and have been organized in support of these four major objectives. These recommendations are consistent with federal regulations, Service policies and objectives, and previous Service recommendations concerning the Meadowlands and the NY-NJ Harbor Estuary; furthermore, they are offered here for consideration and incorporation in ongoing or future restoration efforts (*e.g.*, the Corps- and NJMC-funded Hackensack Meadowlands Ecosystem Restoration [HMER]). Although some recommendations may focus on actions either initiated or under the purview of specific agencies or groups, most recommendations are directed toward the federal, State, and local government stakeholders whose operating authorities would provide the means for involvement and implementation. Support is also needed from nongovernmental organizations (NGOs) and the public. For reference and to assist the reader in understanding the recommendations in their proper context, each recommendation is followed by its text source(s) in parentheses. Implementing many of these recommendations extends beyond the scope of any single stakeholder and exceeds financial and other resources presently committed to restoring the Meadowlands.

Despite the challenges associated with achieving the above objectives, the recommendations emphasize the importance of *all stakeholders working together, guided by a shared vision, to restore the Meadowlands and sustain its biodiversity*. Hopefully, this entire document, including these recommendations, also inspires a respect for the natural environment and its value to society, and establishes the indisputable need for substantial additional information to guide decision-making in the Meadowlands.

A. PROMOTE AND LEAD EFFORTS FOR LAND ACQUISITION, REMEDIATION, ENHANCEMENT, RESTORATION, AND MANAGEMENT

1. Acquisition

- Acquire, enhance, restore, and protect all remaining wetland complexes throughout the Hackensack River watershed (HRW) to: (1) address the historical misuse of the Meadowlands ecosystem, (2) offset the adverse impacts of previous federal programs on wetlands throughout northeastern New Jersey, and (3) sustain the region's fish and wildlife resources (Sections V.B and VII.A).

- Acquire natural upland areas to: (1) increase connectedness among wetlands throughout the HRW; (2) improve their suitability as habitats, and (3) improve water quality (Section V.B).

- Investigate the feasibility of acquiring uplands for conversion to wetlands where appropriate, such as in flood-prone areas (Section V.B).

- Work with agencies and NGOs in New York to acquire, and ensure protection of, palustrine wetland and adjoining upland tracts in New York in the headwaters and the sub-basins of the upper HRW (Sections V.B and V.E).

- Coordinate acquisition of wetlands and uplands outside of the HMD throughout the HRW through the MCT; furthermore, stakeholders should investigate expanding the funding base of the MCT. Stakeholders should coordinate acquisitions with federal and State agencies to make use of all relevant funding authorities (Section VII.A).

- Prioritize wetland and upland acquisitions throughout the HRW based on size (large tracts preferred), proximity to other natural areas (connectivity preferred), biological features (*e.g.*, high biodiversity preferred), and other criteria (Sections V.B and VII.A).

- Acquire, restore, and preserve riparian corridors and adjacent uplands to improve ecosystem functions, support fish and wildlife resources, provide recreational opportunities for the public, and integrate open space into Meadowlands communities (Sections VII.A, IX.B, and IX.C).

- Consider acquisition, remediation, enhancement, and restoration of degraded upland areas (*e.g.*, Superfund Sites, abandoned rail lines, and available brownfield sites) within and along

the periphery of the Meadowlands to support fish and wildlife resources and to replace lost public uses of wetlands and wetland resources (Section IX.C).

2. Remediation

- Conduct a thorough and comprehensive Meadowlands-wide contaminant risk assessment, including the distribution, availability, and bioaccumulation of contaminants, to guide decision-making regarding ongoing or planned remediation, enhancement, and restoration of sites in the Meadowlands (Sections III.E, IV.C, and VII.C).

- Comprehensively address (*e.g.*, assess, remediate) mercury and other contaminants throughout the entire Meadowlands ecosystem to prevent creating attractive nuisances to wildlife (Sections III.E and IV.D).

- Using the Service's priority ranking system for identifying and categorizing sites of concern, remediate heavily contaminated sites, including those where contaminants may be buried, prior to, or possibly concurrent with, enhancement and restoration to avoid increasing wildlife exposure to heavy metals and other toxic (especially bioaccumulative) compounds (Sections III.E and IV.C).

- Evaluate the potential adverse effects of dioxins and related compounds on invertebrates; moreover, if dioxins and related compounds adversely affect invertebrate growth, survival, or reproduction, remediate sites heavily contaminated by dioxin (Section IV.C).

- Investigate the potential adverse effects of, and exposures to, dioxins and related compounds on fish and wildlife to guide remediation, enhancement, and restoration of the Meadowlands (Section IV.C).

- Develop criteria for removal of common reed from contaminated sites (Sections VI.B and VII.C).

- Remediate, enhance, and restore landfills to increase the acreage and diversity of the vegetative landscape (e.g., upland grasslands, shrublands, and forests) within the HRW; consider diverse public uses of these areas and the integration of such public areas into the landscape (Sections VII.B and VII.C).

3. Enhancement and Restoration

- Investigate and evaluate the restoration of the Anderson Creek Marsh (*e.g.*, contaminant effects, success measures) prior to enhancing or restoring subsequent sites of existing (*e.g.*, HMER) or future restoration programs (Section III.E).

- Develop performance measures, success criteria, and other metrics to guide adaptive management and to gauge the overall success of remediation, enhancement, and restoration (Sections IV.A, IV.C, and VII.C).

- Maintain and/or restore existing buffers, and increase the extent of vegetated buffers along waterways and wetlands throughout the HRW (Sections VII.C and IX.C).

- Examine the scheduling of restoration and dredging projects to accommodate complementary needs, such as the disposal and use of clean dredged materials (Section VII.C).

- Consider combining the enhancement and restoration of adjoining or nearby sites, especially those in the same hydrologic sub-basin, to reduce the cost as well as the risk to fish and wildlife (Section IX.B).

- Utilize the Service's expertise in restoration ecology to expand its role in ongoing and other programs (*e.g.*, HMER) to enhance and restore wetlands and uplands, such as by working with the Service's *Partners for Fish and Wildlife, Coastal*, and other programs (Sections IX.C and X.E).

- Coordinate and implement restoration projects throughout the Meadowlands with the EPA's Biological Technical Assistance Group to avoid and minimize potential adverse impacts of contaminants on fish and wildlife populations (Section X.B).

- Focus the Meadowlands Comprehensive Restoration Implementation Plan (MCRIP) on contaminant sources and obstacles that might hinder enhancement and restoration efforts and impact water quality throughout the Meadowlands; plan and pursue projects that will minimize further contaminant redistribution and exposure to fish and wildlife (Section X.E).

4. Management

- Develop and implement stormwater regulations that: (1) employ best management practices, (2) use low-impact solutions, and (3) provide sufficient water storage and water treatment on-site to reduce contaminant inputs in stormwater (Section IV.B).

- Develop comprehensive stormwater and flood-control programs throughout the HRW that: (1) employ non-structural means of flood control, (2) reclaim and restore floodplains, and (3) create and conserve wetlands to augment existing flood storage (Section IV.B).

- Remove former and non-functioning tide gates to improve tidal flow throughout the HMD; carefully assess and consider the need for, and design, maintenance, and potential adverse effects of new/replacement tide gates on fish and wildlife and especially on nearby enhancement and restoration efforts (Section IV.B).

- Combine and integrate the Hackensack and Passaic River watersheds into a single water management program addressing: water flow, inter-basin diversions, reservoir management, water quality, wastewater treatment, sea level rise, and water conservation and reuse to sustain fish and wildlife and meet the long-term water supply needs of the region (Sections IV.B, IV.D, VII.C, VIII.A and X.D).

- Adopt and implement water quality criteria for contaminants (*i.e.*, Buchanan *et al.*, 2001) that were jointly developed by the State and federal government to protect fish and wildlife in New Jersey; develop additional criteria for other contaminants to improve water quality, ecosystem functioning, and fish and wildlife health (Sections IV.C, VII.C, and X.D).

- Conduct a periodic revision of the list of synthetic materials being monitored and update the sampling protocols to improve detection of existing and novel contaminants (Section IV.C).

- Improve sewage treatment in the Hackensack and the Passaic Rivers to improve the health of fish and wildlife and the aquatic ecosystem upon which they depend (Section IV.D).

- Coordinate and integrate the State's *Wildlife Action Plan* for the HMD with comprehensive planning of remediation, enhancement, and restoration activities in the Meadowlands (Section V.C and X.E).

- Evaluate any proposed changes (*e.g.*, allowing radio towers and marinas as special use exceptions in wetlands) to NJMC zoning and other regulations for consistency with the Master Plan and for their potential adverse impacts on wetlands, restoration activities, and fish and wildlife resources (Section VII.B and IX.B).

- Conduct a comprehensive review and evaluation of all federally permitted mitigation projects in the Meadowlands to evaluate the success of these projects and to ensure that all mitigation wetlands and banks are in compliance with federal and State policy guidelines; these actions will help guide future restoration efforts and improve future mitigation (Sections VII.B, X.B and X.G).

- Encourage State land management agencies and landowners to consider: (1) collaborating on the formulation of plans, policies, and regulations to provide uniform, consistent protection of wetlands under their respective stewardships; and (2) transferring their wetland landholdings to the most appropriate State agency for long-term management and protection (Section VII.B).

- Consider diverse mechanisms, including formal establishment of an explicitly identified "preserve" or marine/estuarine protected area pursuant to existing federal authorities, to augment and support long-term protection to the Meadowlands ecosystem (Sections VII.B and VII.E).

- Integrate enhancement, restoration, flood control, and storm water projects to improve water quality and address other water supply issues throughout the Passaic and Hackensack watersheds (Section VII.C).

- Employ surface elevation tables and other technology (*e.g.*, LIDAR) to gather detailed local information on sea level rise and its modifiers to guide both short- and long-term restoration planning (Section VII.C).

- Develop and implement an interagency memorandum of agreement to establish collaborative processes with a principals' group (and supporting technical committee) to ensure: (1) regular and open dialogue on major issues (*e.g.*, a *collective vision* for the Meadowlands), (2) improved organization, management, and coordination of remediation, enhancement, and restoration activities (*e.g.*, risk assessments, contaminant criteria), and (3) development of a master schedule and contingency plan for restoring all sites within the HMD (Sections X.B, X.D, and X.G).

- Investigate establishing a specific federal authority to provide funding to ensure interagency coordination to restore the entire system, minimize adverse impacts on fish and wildlife resources, and maximize long-term benefits (Sections X.B and X.G).

- Include the EPA's Superfund Branch and the Biological Technical Assistance Group as regular participants in the MIMAC (Section X.B).

- Request that the NJMC and the NJDEP review and clarify interagency coordination procedures regarding, and the consistency of, State regulations with regard to federal provisions in the Coastal Zone Management Act that pertain to federally-approved, licensed, permitted, or funded projects in the HMD (Section X.E).

- Develop a memorandum of agreement to establish an interagency principals' group to: (1) coordinate restoration and related activities in the Meadowlands and (2) provide a forum for regular information exchange with stakeholders and the public (Section X.G).

B. INCREASE SCIENTIFIC UNDERSTANDING TO BETTER DEFINE SUCCESSFUL REMEDIATION AND RESTORATION AND TO ENHANCE ECOSYSTEM FUNCTIONS AND NATURAL DYNAMIC PROCESSES

- Monitor contaminant concentrations, distributions, effects, and bioaccumulations before, during, and after each enhancement and restoration project, then evaluate the results on a schedule to facilitate adaptive management and to guide subsequent enhancement and restoration efforts (*e.g.*, MCRIP) on other sites (Sections III.E, IV.C, VII.C, X.D, and X.E).

- Monitor PCBs in a manner that can identify and detect all PCB congeners and their metabolites (*e.g.*, hydroxylated forms) and assess their potential adverse effects on fish and wildlife resources (Section IV.C).

- Expand and integrate physicochemical and biotic monitoring and assessment throughout the Hackensack and Passaic River watersheds to better understand ecosystem processes and functioning and to develop hydrologic goals and objectives regarding water quantity and quality to provide for ecosystem maintenance and protection of biodiversity (Sections IV.B and VII.C).

- Investigate the feasibility of developing and implementing a contaminants program for sewage-treatment plants to: (1) identify and monitor novel compounds and potential

contaminants (*e.g.*, over-the-counter drugs, pharmaceuticals) in effluents from sewage-treatment plants and other waste streams; (2) determine the distribution, transport, and availability of novel compounds and potential contaminants in the environment; (3) assess ecological effects and impacts on fish and wildlife (and human) health; and (4) if necessary, develop corrective measures that are protective of fish and wildlife (and human) health (Section IV.C).

- Investigate the natural hydrograph and determine the feasibility of providing a natural pattern of flows to the Hackensack River, such as by periodically and seasonally allowing increased flows over the Oradell Dam (Sections IV.D and VII.C).

- Substantially expand comprehensive research and related activities in the areas of: (1) environmental contaminants, water quality, and hydrology; (2) suburban and urban ecology; and (3) invasive and exotic species; furthermore, increase the capabilities of stakeholders, especially federal and State agencies, to provide critical information needed to guide-decision making regarding restoration, protection, and related activities (Sections V.A, V.C, VIII.A, and X.G).

- Improve wetland monitoring (*e.g.*, using surface elevation tables) to detect wetland changes (*e.g.*, conversion of wetlands to open water through subsidence or SLR; Section V.B).

- Assess cumulative impacts of processes affecting the hydrology and sediment transport in the HRW (*e.g.*, dredging, controlled river flows) to guide decision-making regarding remediation, enhancement, and restoration (Section V.B).

- Consider the purposes, need for, and alternatives to, any proposed projects that would further fragment remaining wetlands in the Meadowlands during federal, State, and local (permit) authorizations (Section V.C).

- Develop and evaluate innovative alternatives, to reverse and rectify the impacts of previous public projects that fragmented and altered the hydrology of wetlands, in long-range planning for new public transportation and other large projects (*e.g.*, stadiums, redevelopment; Sections V.C, VII.C, and VII.E).

- Assess adverse impacts (including cumulative impacts) of land-use and other human activities (*e.g.*, impervious cover, roadway and traffic effects, communication towers, and other features of the built environment) on fish and wildlife as a guide for enhancement and restoration activities (Section V.C).

- Comprehensively assess buffer features (*e.g.*, width) and consider revisions to buffer regulations to improve water quality and protect habitats for key species throughout the HRW (Section V.C).

- Assess landscape structures, corridor features, and the behavior and habitat requirements of rare and priority species as a guide toward creation and restoration of upland corridors (Section V.D).

- Develop a comprehensive state-of-the-art watershed-wide program for monitoring: (1) nutrients, micronutrients, and contaminants (including novel compounds) in sediment and water and (2) bioaccumulation of contaminants in select taxa (*e.g.*, invertebrates, fishes, and other vertebrates; Section VII.C).

- Collect amphibian morphological and reproductive information (*e.g.*, abnormal limb and development, and intersex data) together with contaminant and other information to evaluate the feasibility of re-establishing populations of some amphibian species at palustrine wetland sites (*e.g.*, Teterboro Woods; Section VII.C).

- Determine to what extent current programs of nutrient and contaminant reduction are working, *i.e.*, having beneficial effects (Section VII.C).

- Assess transformation in, and coupling of, nutrients and contaminants between the water column and sediment to understand the potential availability and effects of those materials on ecosystem processes and fish and wildlife (Section VII.C).

- Expand formal and informal research and other partnerships among federal and State agencies working in the Meadowlands and the NY-NJ Harbor to better understand, enhance, restore, and protect the Meadowlands ecosystem and the HRW (Section VIII.A).

- Develop a plan to assess and reduce potential adverse impacts of communication towers (including their removal) on wildlife, especially migratory birds, in the HMD (Section IX.B).

C. ESTABLISH DIVERSE, NATIVE WETLAND AND UPLAND COMMUNITIES

- Conduct a floristic survey of remnant palustrine wetlands (*e.g.*, Teterboro Woods), local parks, and other open space to recommend procedures for monitoring, enhancement, and management regarding invasive and rare plant species (Sections III.E and VII.C).

- Protect and manage remaining natural areas, especially palustrine wetlands, for State-listed and other rare species, as well as for viable populations of native wildlife species using the Meadowlands for breeding, foraging, and migrating (Section III.E).

- Investigate the potential causes of the poor survival of plantings at restoration sites to improve planting success of future enhancement and restoration efforts (Section IV.C).

- Develop a Meadowlands-wide program to identify, assess, prioritize, and address (*i.e.*, eradicate or control): (1) “new” exotic species before they spread, and (2) invasive species adversely impacting listed, rare, and managed species; coordinate with other agencies to develop a similar NY-NJ Harbor-wide program (Sections VI.A, VI.E, and VI.F).

- Consider revisions to federal and State regulations to require longer periods (10 years or more, as compared to the current 5-year requirement) of monitoring performance of

permitted mitigation sites to prevent re-invasion by common reed or other invasive species (Section VI.B).

- Conduct and support additional research into: (1) biocontrol of common reed, (2) re-invasion of restoration sites by common reed, and (3) effects of common reed on secondary production of fishes (Sections VI.B and VII.C).

- Develop a comprehensive program to assess, evaluate, prioritize, control, and manage currently widespread invasive species (*e.g.*, purple loosestrife, Japanese knotweed; Sections VI.B through VI.E).

- Assess adverse impacts of resident Canada geese and white-tailed deer on the flora of sites being restored and on State-listed and other rare native plant species in the Meadowlands; periodically assess the need to develop management plans for those species (Section VII.C).

- Investigate and evaluate the vegetative communities most suitable for landfills in terms of their impacts on water quality and support for fish and wildlife; consider techniques used on landfills elsewhere (*e.g.*, localized use of thick caps) to promote use of appropriate native tree species to provide forested riparian buffers and increase plant diversity (Section VII.C).

- Survey the freshwater faunas and their habitats in the Hackensack and Passaic River watersheds; also, investigate the feasibility of re-establishing populations of rare mollusks (*e.g.*, federally and State-listed species; Section VII.C).

- Assess the distribution and abundance of amphibians in the HMD and the HRW by surveying nocturnal calling and vernal pools (Section VII.C).

- Assess the distribution and abundance of reptiles and their critical habitats (*e.g.*, potential snake den areas such as Snake Hill and Little Snake Hill, nesting sites of the diamondback terrapin) in the HMD (Section VII.C).

- Consider additional protective measures for terrapins (*e.g.*, roadside fencing to reduce mortality of nesting females) and snakes (*e.g.*, protect known den areas; Section VII.C).

- Assess impacts, including cumulative impacts of the urban landscape (*e.g.*, buildings, radio towers, automobiles) on birds and other wildlife (Sections VII.C and VII.E).

- Gather information on contaminant bioaccumulation and the status, diet, and habitat-specific production (*e.g.*, reproductive success) to guide restoration and manage the long-term protection of avian species that reside and breed in the Meadowlands. Especially consider those bird species that feed extensively in aquatic habitats or on aquatic resources (*e.g.*, belted kingfisher, *Ammodramus* and *Melospiza* sparrow species, red-winged blackbirds, waterfowl, herons, and rails; Section VII.C).

- Establish programs and develop management plans to protect and support rare, including federally listed and State-listed species, and other species on various regional, special concern, or watch lists (Section VII.C).

- Consider the sources, levels, and effects of potential contaminant availability when establishing programs to support listed and other rare species (Section VII.C).

- Regularly monitor and assess the status of introduced mammal populations, their pathogens, and disease vectors to develop needed control or other management plans (Section VII.C).

- Evaluate the feasibility of re-establishing a population of Allegheny woodrat in the Meadowlands (Section VII.C)

D. INCREASE RESPONSIBLE USE OF, PUBLIC AWARENESS OF, AND EDUCATION ABOUT THE MEADOWLANDS

- Promote collaboration among agencies throughout the NY-NJ Harbor estuary on exotic and invasive species, and the means (*e.g.*, public education, on-the-ground control, restoration) to prevent their introduction and reduce their impacts (Section VI.G).

- Educate the public regarding the biology, needs, and threats (*e.g.*, certain human activities, domestic animals) to fish and wildlife in the Meadowlands (Section VII.C).

- Develop a *unified* outreach program to generate and maintain public support for the remediation, enhancement, and restoration of the Meadowlands, including: (1) use of various media [*e.g.*, web-pages, public television, radio programming, a "coffee-table" book]; (2) innovative exhibits and demonstration projects at key venues [*e.g.*, museums, sports facilities]; and (3) communicating key messages in other languages (Sections VIII.A and B).

- Expand development of formal and informal educational programs for children and adults through existing stakeholders (*e.g.*, NJMC's Meadowlands Environment Center; Section VIII.A).

- Improve public access to the Meadowlands, especially its waterways (Section VIII.A).

- Establish a public use policy for the Meadowlands that promotes a broad range of wildlife-related activities (*e.g.*, waterfowl hunting, fishing, wildlife observation, photography, environmental education, and environmental interpretation) that is compatible with the conservation of fish and wildlife resources (Sections IX.A and B).

- Conduct periodic surveys of public uses, values, and perceptions of the Meadowlands to develop a social and recreation vision, conduct long-range planning, and refine human use policies to increase public benefits (Sections VII.B and IX.B).

- Assess certain health risks (*e.g.*, consumption of contaminated seafood and wildlife, other Meadowlands recreational activities such as boating and hiking), and address related

concerns of low-income, minority, and high-risk populations (*e.g.*, children) residing in the HMD (Sections VIII.B and IX.B).

- Identify and develop sites to provide diverse land-based (*e.g.*, bicycle paths, skateboard and ATV parks) and water-dependent recreational opportunities (*e.g.*, fishing piers and boat ramps) in/near the Meadowlands while protecting fish and wildlife species, especially during their breeding seasons (Sections IX.B and C).

- Develop "passive" recreational facilities and greenways (*e.g.*, parks, trails, river overlooks, site-specific boardwalks, and wildlife observation sites) that connect to, and integrate, open-space areas throughout the Hackensack watershed (Section IX.C).

- Establish a long-range plan to monitor and assess public use of, and support facilities (*e.g.*, parking areas) in, the Meadowlands to prevent adverse impacts on fish and wildlife and misuse or destruction of facilities (Section IX.C).

- Include provisions for emergency communications (*e.g.*, panic buttons, closed circuit television) at parking and other public facilities (Section IX.C).

- Incorporate universal access into planning and design of recreational facilities and facility components (*e.g.*, trail surfaces, restrooms, curbing) to be accessible to those with special needs (Section IX.C). Request federal (*i.e.*, U.S. Access Board) and State (*i.e.*, Department of Community Affairs) assistance to provide exemplary access to facilities for those with special needs (Section IX.C).

- Investigate the availability of federal funding, including funds generated by transportation and other projects, in support of recreational infrastructure (Section IX.C).

- Increase public access, integrate human uses of open space, and sustain and safeguard fish and wildlife to perpetuate the new and more favorable public image of the Meadowlands (Section IX.D).

XII. Conclusions

Teaching children at DeKorte Park: helping to ensure their healthy future in the Meadowlands.

Schoolchildren enjoying spring in the Meadowlands.

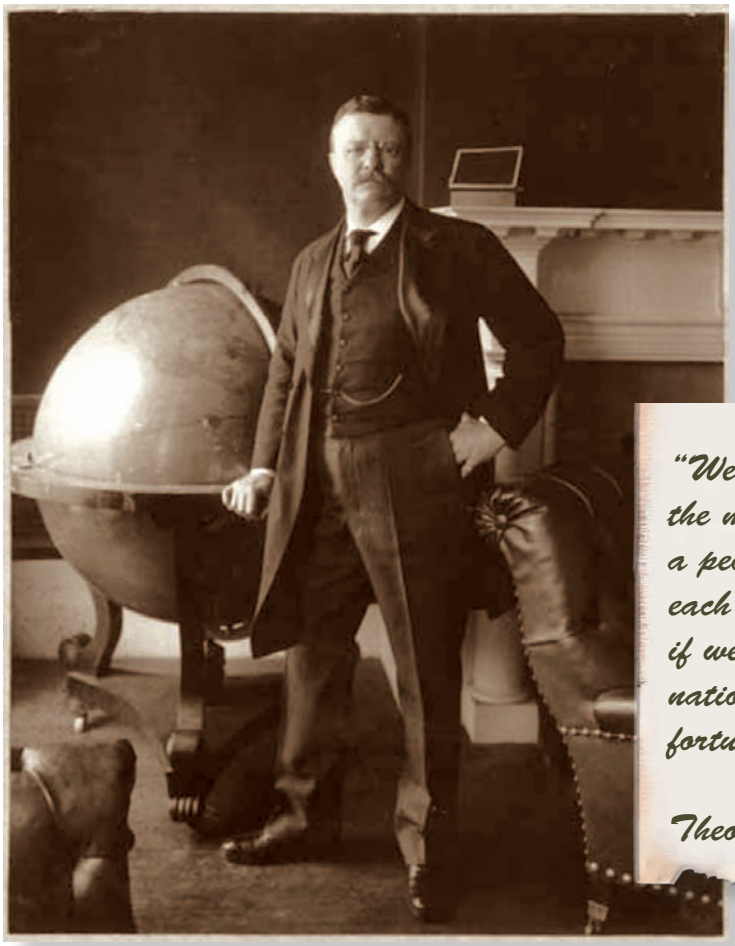
XII. Conclusions

During the past few centuries, the Meadowlands was transformed by human activities—its forests were harvested, its rivers and streams were dammed, its marshes were filled, and its land, water, and air were degraded. The Meadowlands' forests, meadows, waterways, and marshes were replaced by reservoirs, plumbing systems, combined sewer overflows, sewage treatment plants, and a few large pipes discharging into the lower Hackensack River. Untold biodiversity was lost during this transformation; yet surprisingly, considerable biodiversity remained.

Today, the Meadowlands is being transformed again by human activities—landfills and industrial sites are being remediated, invasive species are being controlled to enhance biodiversity, and tidal currents are being restored to diked and ditched marshes. If carefully planned and implemented, remediation, enhancement, and restoration have the potential to revitalize the Meadowlands. For the Meadowlands ecosystem to recover, sustain fish and wildlife resources, and nourish a new image for this long-neglected urban area, Meadowlands stakeholders must embrace a central concept:

> "Everybody (man and organisms) lives downstream from everybody else in an estuary."
> Eugene Odum (1971)

Stakeholders must develop a shared vision, supported by clear goals and objectives, and work together. Such actions require improved coordination among all stakeholders, especially federal, State, and local agencies. Finally, stakeholders must establish a unifying authority to provide comprehensive remediation and restoration if the Meadowlands is to sustain fish, wildlife, and people in the future.



"We have fallen heirs to the most glorious heritage a people ever received, and each one must do his part if we wish to show that the nation is worthy of its good fortune."

Theodore Roosevelt

XII. CONCLUSIONS

A. HUMAN USE HISTORY

B. NATURAL HISTORY

C. HYDROLOGY AND CONTAMINANTS

D. WETLAND AND UPLAND LAND USE

E. INVASIVE AND EXOTIC SPECIES

F. RESOURCE OBJECTIVES

G. RESEARCH AND EDUCATION

H. PUBLIC ACCESS AND RECREATION

I. RESTORATION PLANNING AND COORDINATION

J. SUMMARY

Satellite image of the Hackensack Meadowlands District (boundaries in red) and the surrounding metropolitan region.

XII. CONCLUSIONS

The Service acknowledges and accepts the many challenges of the Meadowlands as an opportunity to fulfill its Mission of *working with others to conserve, protect, and enhance fish, wildlife, and plants and their habitats for the continuing benefit of the American people*. The Hackensack Meadowlands also presents the Service, other stakeholders, and the American people with unparalleled opportunities to shape a new image of this long-neglected urban coastal ecosystem, and to improve the quality of life for the 20 million people living in the surrounding urban area.

The Service has a long history of commitment to the protection of the Meadowlands and its fish and wildlife resources. Building upon the previous efforts of many State, federal, and local agencies, the Service has articulated a vision for the Meadowlands in this *Hackensack Meadowlands Initiative: Preliminary Conservation Planning* as a guide for restoring and protecting the Meadowlands and its biodiversity. The Service's vision for the Meadowlands includes:

(1) a more natural estuarine ecosystem with healthy fish and wildlife resources;

(2) a cleaner environment (progressive reduction in acute and chronic contaminant effects);

(3) diverse wetland and associated communities that sustain local and regional populations of native species, including federal trust fish and wildlife resources; and

(4) public commitment to and diverse social benefits from the Meadowlands.

Restoring and protecting the Meadowlands ecosystem and its biodiversity will require that all stakeholders work together, guided by a common vision.

The Service has presented this planning document to its agency partners in the *Hackensack Meadowlands Initiative*. While it represents the Service's findings, recommendations, and conclusions, the Service presents the Plan to identify the critical issues and to work toward common ground that is critical to advance the restoration of the Meadowlands ecosystem and the long-term protection of its fish and wildlife. Working together and finding common ground to restore the Meadowlands may also be instrumental to broader restoration and protection efforts throughout the New York-New Jersey Harbor.

A. HUMAN USE HISTORY

Understanding the human use and misuse of the Meadowlands is vital to undoing adverse causes and effects and essential in preventing human impacts on this ecosystem from being duplicated continuously in the Meadowlands and elsewhere in the United States. Humans have lived in the Hackensack Meadowlands for 10,000 to 12,000 years. During most of that time the small, native Lenape population had minimal impacts upon the landscape and largely subsisted off the area's abundant natural resources. However, soon after arriving, European colonists in the region

began exploiting the Meadowlands' natural resources and initiated large-scale modification (*e.g.*, ditching and diking) of the Meadowlands for agricultural and other purposes (*e.g.*, transportation and mosquito eradication). With continued population growth and land-use manipulation, the natural water supply became inadequate to supply human demands. The landscape of several watersheds (*e.g.*, adjacent Passaic River basin) was altered and the flows of neighboring rivers were diverted into the Hackensack watershed and stored to provide water. As the human population continued to grow, waters and wetlands and their dependent living resources in the Meadowlands became increasingly neglected and degraded. Degradation of the landscape and waters of the Meadowlands continued for over 200 years. However, since the turn of this century, numerous stakeholders, including NGOs and State and federal agencies, have joined together in an unprecedented manner to protect and restore the Meadowlands. These organizations and agencies have begun several projects to restore specific sites, manage fish and wildlife resources, and educate the public on the value of urban wildlife reserves, nature sanctuaries, and functional wetlands. Such projects are moving environmental restoration forward but make clear the need for, and importance of, *improved collaboration and comprehensive actions (e.g., monitoring, assessment, site remediation, improved water and land use planning) to restore the Meadowlands ecosystem and protect its biodiversity*.

B. NATURAL HISTORY

Notwithstanding the extensive history of misuse of its lands and waters, the Meadowlands remains one of the largest and most productive brackish estuarine wetland complexes in the northeastern United States. The Meadowlands retains and continues to support considerable biodiversity despite the extirpation of many species historically present. It is, in many respects, an urban oasis for many species of plants and animals that find few available or alternative habitats in the highly urbanized, regional landscape. The Meadowlands supports more than 700 species, including more than 330 migratory bird species, and dozens of State-listed and other species that are managed or of special conservation concern. The Meadowlands latitude, geography, and remaining habitats in a sea of urbanization make it a critical stopover area for bird migration. Available information, though limited for many taxonomic groups, indicates that aquatic and terrestrial communities of invertebrates, fishes, amphibians, reptiles, birds, and/or mammals remain imperiled by existing conditions; moreover, the recovery of certain species will be extremely difficult as a result of contaminants and other factors. As coastal areas, especially wetlands, in New England and the middle-Atlantic States are increasingly modified and/or disturbed by human use and activities, the Meadowlands becomes more critical as an environmental oasis for the region's biodiversity. Thus, *development of a comprehensive remediation and restoration plan is critical to address the substantial, complex, and inter-related problems confronting the Meadowlands ecosystem*.

C. HYDROLOGY AND CONTAMINANTS

Historical hydrologic alterations throughout the Hackensack River watershed, despite substantial inputs from nearby watersheds to augment and satisfy the public need for potable water, have greatly reduced the average daily flow of water throughout the Hackensack River and the

watershed, flows which were vital to the biota of the HMD. Secondary treated sewage effluents now comprise the largest source of "freshwater" in the Hackensack River. As a result, water quality in the Hackensack River remains broadly impaired for many criteria (*e.g.*, mercury, fecal coliform bacteria) in comparison with water quality throughout the rest of the Hudson Raritan Estuary, and contributes to hypoxia and other stressors for fishes and invertebrates during summer months. Poor water quality continues to raise serious concerns about the potential functioning of Meadowlands wetlands as "sink" habitats. Such concerns emphasize the need for more *detailed investigations of the movements, diets, and reproduction of fish and wildlife species in the Meadowlands and surrounding region*.

Mercury and the other contaminants of greatest concern in the Meadowlands (*i.e.*, PCBs, dioxins, certain hydrocarbons) are toxic to many species, bioaccumulate in fish and wildlife, and are endocrine disruptors that have adverse effects on growth, survival, and reproduction of animals. Several contaminants that originated from multiple sources or dispersed from localized "hotspots" (*e.g.*, Superfund sites along Berry's Creek, possibly the most heavily contaminated mercury site in the United States) have become widely distributed in the Meadowlands. The successful remediation of contaminants in such areas is needed; otherwise, restoration activities may create "attractive nuisances" by increasing the availability of those contaminants and their subsequent bioaccumulation in fish and wildlife that use restored wetlands. *Implementation of existing water-quality criteria and development of such criteria for additional contaminants is needed to address the impaired functioning of the Meadowlands ecosystem and the health of its fish and wildlife*. Finally, the legacy of contamination in the Meadowlands will continue and may likely worsen with increasing demand and reuse of the region's water resources. *Thus, establishment of a state-of-the-art program on a watershed scale to monitor contaminants (including novel compounds) and to address their effects on restoration is critically needed.*

D. WETLAND AND UPLAND LAND USE

Currently, approximately 9,650 acres of wetlands remain in the Hackensack River watershed, of which 5,445 are located in the HMD. There is a pronounced difference in the types, condition, functioning, and risks to wetlands in the HMD as compared to the upper Hackensack River watershed. The large, tidal estuarine wetland areas in the HMD have been highly disturbed through decades—if not centuries—of human activities such as ditching, diking, and dredging. Stream flows have been diverted through culverts, and wetlands have been extensively fragmented by roads and other rights-of-way. As a result, wetlands in the HMD are impaired for certain (*e.g.*, streamflow maintenance) but not all wetland functions. Estuarine wetlands also appear at risk of conversion to deepwater habitats due to sea level rise and other causes (*e.g.*, lack of sediments above the dam). The diverse, palustrine wetlands in the upper Hackensack River watershed help maintain and improve water quality and sustain biodiversity in the lower watershed. However, as a result of their small size, type (*e.g.*, stream), and isolation, palustrine wetlands in the upper watershed remain vulnerable to adverse impacts from surrounding land-use changes and are at increasing risk of development. Thus, Meadowlands stakeholders must also focus attention on *protecting wetlands and adjoining upland buffers in the upper Hackensack River watershed*. Such efforts should include partnerships with agencies and NGOs in New York State.

Landscape cover types throughout the Hackensack River watershed and the HMD have been altered extensively to accommodate human land uses that are typical of the heavily populated northeastern United States. Natural upland areas that serve as buffers around wetlands and water bodies are in poor condition throughout the Hackensack River watershed, and are especially distressed within the HMD. The Meadowlands is recognized as a migration corridor for birds; however, continued adverse impacts on wetlands and uplands (*e.g.*, habitat loss, fragmentation) and exotic species invasion throughout the watershed may diminish the value of the Meadowlands for migratory birds. Better assessment and an improved understanding of buffer-, fragmentation-, and corridor-effects are needed to implement measures to sustain fish and wildlife resources in the Meadowlands. Concerted restoration and planning efforts provide an opportunity for stakeholders to *reverse and rectify historical, adverse land-use impacts on the Meadowlands ecosystem and its biodiversity*.

E. INVASIVE AND EXOTIC SPECIES

Many invasive and exotic plant and animal species occur in wetlands and uplands throughout the Meadowlands and the surrounding watershed. Restoration will require extensive replacement of invasive species with indigenous plant communities more characteristic of the regional landscape. The spread of the invasive form of common reed (Haplotype M), forming dense, monoculture stands throughout nearly all of the Meadowlands, currently presents both a considerable challenge and a dilemma to restoration. Because the spread of common reed has contributed to the loss of native plant diversity, the eradication of common reed has been a major focus of the restoration efforts undertaken to date in the Meadowlands and elsewhere in the Northeast. However, Haplotype M is difficult to eradicate under the current salinity and nutrient regime present throughout much of the Meadowlands and is re-invading most, especially older, restored sites. On the other hand, Haplotype M also grows well in heavily contaminated sediments, stabilizes erosion from some contaminated aquatic sites, and reduces the bioavailability and subsequent effects of certain contaminants. In other words, Haplotype M may be the most acceptable and resistant plant species on some sites because it is able to thrive under the stressful and toxic soil and water conditions. Revegetation with native species may not be advisable on contaminated sites until such sites are remediated. More research is definitely required not just on control of *Phragmites* but also on propagation of native species.

The Service and other stakeholders must collaborate to develop a protocol that will guide decision-making regarding the removal of Haplotype M from heavily contaminated sites. Additional research is needed regarding the effects of Haplotype M on the Meadowlands ecosystem (*e.g.*, growth, survival, and production of fishes) and biocontrol of Haplotype M. Also, the impacts of other invasive plant species (*e.g.*, purple loosestrife, tree-of-heaven, Japanese knotweed) on the Meadowlands ecosystem and its fish and wildlife resources are not well-known and should be assessed and prioritized (given that funding is presently limited). In addition, agencies participating in the restoration of the Meadowlands and elsewhere in the NY-NJ Harbor estuary to date have not addressed invasive species in a coordinated manner but must do so to prevent future invasions of non-native species that may have considerable adverse impacts on indigenous fish and wildlife populations in the region. Public education on the

effects of invasive species, blocking pathways of future introductions, on-the-ground control, working with local nurseries to supply native plant materials, and successful site remediation and restoration are necessary to stop the transport and introductions of exotic and invasive species in the Meadowlands and the NY-NJ Harbor estuary as well as their pernicious effects on the Meadowlands ecosystem. Furthermore, the Service in conjunction with other stakeholders must *identify the desired long-term recovery goals (e.g., vegetational community structure of the Meadowlands) to be achieved through restoration*. This may require modeling that takes into account known and potential stressors such as sea level rise. Given the extreme contamination of much of the Meadowlands, such a plan will need to critically examine and compare alternative remediation, enhancement, and restoration scenarios.

F. RESOURCE OBJECTIVES

Acquisition and protection of remaining wetlands and other open space throughout the HMD and the watershed are critical to safeguarding and sustaining the Meadowlands and its biodiversity. To be effective, prioritization and acquisition of key sites must be planned and coordinated through a central organization. In addition, federal, State, and local laws and regulations should be reviewed to ensure consistency and improve protection of fish and wildlife resources. Stakeholders should review and consider *designation of the Meadowlands as a marine/estuarine protected area to promote and provide comprehensive long-term protection*.

Efforts to restore the Meadowlands ecosystem and protect its fish and wildlife populations must include a comprehensive interagency program to integrate and address hydrologic (*e.g.*, river flow, stormwater control, SLR) and contaminant concerns (*e.g.*, industrial contamination, landfills, sewage treatment). *Many of the historical adverse impacts on fish and wildlife populations can be reversed and rectified,* or at least improved, through: (1) remediation, (2) enhancement, (3) restoration, (4) adaptive management based on monitoring of existing projects, and (5) incorporating urban ecology in future project planning throughout the HRE. It is clear, however, that many questions must be answered through studies and sampling before restoration can begin seriously on a broad scale.

For the Service and most stakeholders, establishment of diverse vegetative communities comprised of native species is a major objective for the Meadowlands. Taking into account the concerns and obstacles discussed throughout previous sections, plant diversity in many wetlands and uplands can still be improved substantially by eradicating and treating common reed that re-invades sites before it becomes re-established, eradicating other invasive exotic species, allowing re-colonization by native species, and monitoring on-site vegetation. *Increasing the extent and connectivity of upland buffer* areas also will promote the recovery of wetland vegetation and the functioning of restored wetlands and will better sustain animal diversity in uplands and wetlands. The Meadowlands currently supports considerable biodiversity, even with all the stressors it contains. Programs targeting the *recovery or re-establishment of populations of keystone species* may further assist the recovery of biodiversity and restoration of the Meadowlands ecosystem.

G. RESEARCH AND EDUCATION

Efforts to remediate, enhance, and restore the Meadowlands and provide long-term protection for its fish and wildlife resources currently are hampered by numerous information gaps; moreover, federal and State agencies are limited in their capacity to generate essential information. Thus, the Service recommends *development of comprehensive and collaborative research programs to provide the highly technical, informational needs required for remediation, enhancement, and restoration*. Research programs should focus especially on: (1) environmental contaminants, water quality, and hydrology, (2) suburban/urban ecosystems, landscapes, and habitats, and (3) invasive and exotic species. Such programs should be developed primarily within and among current stakeholders, but should also be extended to other regional agencies and organizations with certain capabilities and expertise. Communication of research needs and results among stakeholder groups and the principals' group also is critical to ensure that decision-making regarding the Meadowlands and its resources is based on sound science.

Public concern drives public policy, and a citizenry well-informed of the values of the Meadowlands will be necessary to promote acquisition, remediation, and restoration efforts. Development of a unified public outreach program by all stakeholders is necessary to generate and maintain public support for remediating, enhancing, and restoring the Meadowlands and protecting its fish and wildlife resources. In addition, *development of formal and informal educational programs, demonstration projects, and other public exhibits will help stimulate public interest and inspire involvement in Meadowlands issues.*

H. PUBLIC ACCESS AND RECREATION

Social and recreational uses of the Meadowlands have the potential to provide diverse benefits to people in the urban region, including: (1) providing recreational opportunities, (2) increasing local property values and business opportunities, (3) promoting better health and quality of life, and (4) increasing an awareness and appreciation of fish and wildlife and the environment. Thus, social and recreational uses must be carefully considered, planned in the remediation and restoration of specific sites, and subsequently monitored and assessed to prevent future misuse of the Meadowlands. To preserve the Meadowlands ecosystem for future generations of Americans, redevelopment, remediation, and restoration projects must include projects that *increase public access, integrate human uses of open space while sustaining and safeguarding fish and wildlife, and contribute to a new public image for the Meadowlands*. Some projects are underway but lack a vital ingredient: *all stakeholders working together for the future*.

I. RESTORATION PLANNING AND COORDINATION

Numerous federal and State agencies and others are involved in restoration of different sites in the Meadowlands. However, presently there is no shared vision to guide these restoration efforts consistently. Greater collaboration among federal and State agencies, local governments, and NGOs is necessary to address in a more efficient and effective manner the complex problems and issues regarding the restoration of the Meadowlands and the long-term protection of its fish

and wildlife resources. While current funding is adequate to restore small sites, it does not allow sufficient site investigation prior to restoration or monitoring after restoration to determine what has worked or what is not working. Also, such limited funding is inadequate for improving larger sites that may offer greater wildlife benefits. As a result, the current funding will not provide for a comprehensive restoration of the Meadowlands ecosystem. Therefore, stakeholders must *investigate development of a specific funding authority for the restoration of the Meadowlands*. While development of such an authority may take time, current restoration efforts in the Meadowlands could be greatly improved by developing an interagency memorandum of agreement that establishes a principals' group supported by a technical oversight committee to develop a collaborative process and ensure coordination on acquisition, regulatory, remediation, research, and other restoration issues.

J. SUMMARY

Initial efforts to restore and protect the Meadowlands are encouraging; however, improved stakeholder collaboration, comprehensive water- and land-use planning, and long-term management are necessary to address and rectify the complex problems affecting the Meadowlands ecosystem. The long-neglected wetlands, waterways, and fish and wildlife of the Meadowlands must be recognized as public resources; stakeholders must consistently embrace the Meadowlands as one of the region's unique public treasures. The Service and other stakeholders must *work in a coordinated effort, guided by a common vision, to sustain and safeguard the Meadowlands ecosystem, including its fish and wildlife resources*.

> "We have fallen heirs to the most glorious heritage a people ever received, and each one must do his part if we wish to show that the nation is worthy of its good fortune."
>
> Theodore Roosevelt

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XIV. LIST OF ABBREVIATIONS, ACRONYMS, FOREIGN EXPRESSIONS, AND UNITS OF MEASURE

A. ABBREVIATIONS AND ACRONYMS

ATSDR	Agency for Toxic Substances and Disease Registry
AVID	Advanced Identification of Wetlands
BCUA	Bergen County Utility Authority
BTAG	Biological Technical Assistance Group
CCMP	Comprehensive Conservation Management Plan
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
CFR	Code of Federal Regulations
COPC	Contaminant of potential concern
Corps	U.S. Army Corps of Engineers, New York District
CRIP	Comprehensive Restoration Implementation Plan
CSO	Combined sewer overflow
CWA	Clean Water Act
CZMA	Coastal Zone Management Act
CZMP	Coastal Zone Management Plan
DDT/DDE	dichloro-diphenyl-trichloroethane/dichloro-diphenyl-dichloroethylene
DEET	N,N-diethyl-meta-toluamide
DNA	deoxyribonucleic acid
DOI	Department of the Interior
EIS	Environmental Impact Statement
EO	Executive Order
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
EWRA	Emergency Wetlands Resources Act
FWCA	Fish and Wildlife Coordination Act
HBCD	hexabromocyclododecane
HEP	(New York-New Jersey) Harbor Estuary Program
HMD	Hackensack Meadowlands District
HMDC	Hackensack Meadowlands Development Commission, now NJMC
HMER	Hackensack Meadowlands Ecosystem Restoration
HMI	Hackensack Meadowlands Initiative
HPWMA	Hackensack-Pascack Water Management Area
HRE	Hudson Raritan Estuary
HRW	Hackensack River watershed

ID	identification
Inc.	Incorporated
LIDAR	light detection and ranging
Ltd.	Limited
MBTA	Migratory Bird Treaty Act
MCRIP	Meadowlands Comprehensive Restoration Implementation Plan
MCT	Meadowlands Conservation Trust
MERI	Meadowlands Environmental Research Institute
MIMAC	Meadowlands Interagency Mitigation Advisory Committee
MOA	memorandum of agreement
MPA	marine protected area
MRI	Marsh Resources, Inc.
MOU	memorandum of understanding
NAWCA	North American Wetlands Conservation Act
NAWQA	National Water Quality Assessment Program
NEPA	National Environmental Policy Act of 1969
NFIP	National Flood Insurance Program
NFWF	National Fish and Wildlife Foundation
NGO	non-governmental organization
N.J.A.C.	New Jersey Administrative Code
NJDEP	New Jersey Department of Environmental Protection
NJDFW	New Jersey Division of Fish and Wildlife
NJFO	New Jersey Field Office
NJMC	New Jersey Meadowlands Commission, formerly (pre-2001) HMDC
N.J.S.A.	New Jersey Statutes Annotated
NJSEA	New Jersey Sports and Exposition Authority
NJT	New Jersey Turnpike
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPL	(Superfund) National Priority List
NWI	(Service's) National Wetlands Inventory
NY-NJ	New York-New Jersey
PAH	polycyclic aromatic hydrocarbon
PBDE	polybrominated biphenyl ether
PCB	polychlorinated biphenyl
PCDD	polychlorinated dibenzodioxin
PCDF	polychlorinated dibenzofuran
P.L.	Public Law
Plan	the *Preliminary Conservation Planning* report
PSEG	Public Service Enterprise Group
PVC	polyvinyl chloride

RCRA	Resource Conservation and Recovery Act
RPA	Regional Plan Association
SAMP	Special Area Management Plan
Service	U.S. Fish and Wildlife Service
SLERA	Screening Level Ecological Risk Assessment
SLR	sea level rise
Stat.	United States Statutes at Large
STP	sewage treatment plant
2,4,5-T	2,4,5-trichlorophenoxyacetic acid
TBBPA	tetrabromobisphenol A
TCDD	2,3,7,8-tetrachloro-dibenzo-*p*-dioxin
U.S.C.	United States Code
USGS	U.S. Geological Survey
VOC	volatile organic compound
WMA	Wildlife Management Area
WMP	Wildlife Management Plan
WRDA	Water Resources Development Act

B. ABBREVIATIONS AND MEANINGS OF FOREIGN EXPRESSIONS

A.D.	*anno Domini*	In the year of the Lord
e.g.	*exempli gratia*	for example
et al.	*et alia*	and others
et seq.	*et sequentia*	and the following things
i.e.	*id est*	that is
	in vitro	in glass (not in a living organism [not *in vivo*])

C. SYMBOLS AND UNITS OF MEASURE

ac	acre (=0.405 ha)
cfs	cubic feet per second (=0.646 mgd)
°C	degrees Celsius (=[°F-32]/1.8)
°F	degrees Fahrenheit (=[°C x 1.8] + 32)

ft	feet (=0.30 m)
g	gram (=0.0001 kg, =0.0353 ounces)
gal	gallon (=3.783 liters)
ha	hectare (=2.471 acres)
kg	kilogram (=2.2 pounds)
m	meter (=1.33 feet)
mg	milligram (=0.0001 grams)
mgd	million gallons per day (=1.547 cfs)
ng	nanogram (=0.000000001 grams)
pg	picogram (=0.000000000001 grams)
pH	potential of hydrogen
pph	part per hundred (=percent)
ppm	part per million
ppt	part per thousand
>	is more than
<	is less than
=	equals

XV. GLOSSARY

acute toxicity – the ability of a substance to cause harmful effects soon after a single, short-term exposure or dose.

adaptive management – a systematic process for continually improving practices and policies by learning from the results of existing activities and programs.

ailanthone – allelopathic chemical (see below) produced by plants in the genus *Ailanthus* (*e.g.*, tree-of-heaven [*A. altissimma*]).

allelopathic chemical – chemical produced by a living organism that kills other species, most often employed by species that cannot move to reduce or prevent competition from other species living adjacent to it (*e.g.*, juglone by black walnut [*Juglans nigra*], ailanthone by tree-of-heaven).

anoxia – the condition of no oxygen (adjective = **anoxic**). When occurring in surface waters, oxygen concentrations are less than 1 ppm. Compare with **hypoxia**.

aquatic – of, living in, or referring to, water.

autotrophic – refers to organisms that make complex organic nutritive compounds such as sugars from simple inorganic sources such as carbon dioxide by photosynthesis or other chemical processes. Examples of **autotrophs** include most plants, algae, and some bacteria. Compare with **heterotrophic**.

avian – of, or referring to, birds.

basin wetland – estuarine landform with restricted tidal flows.

benthic – living on or in bottom sediments in freshwater and marine ecosystems.

benthos – all of the organisms living near, on, in, or attached to the bottom substrate(s) of any marine or freshwater ecosystem. Clams, snails, polychaete "bristle" worms, and algae are common representatives of the benthos in the Meadowlands.

bioaccumulation – increase in concentration of a substance, especially contaminants, in living organisms as they take in contaminated air, water, or food because the substance is very slowly metabolized (broken down) or excreted.

bioavailability – the degree to which chemicals, including contaminants, can be taken up by organisms.

biodiversity – the variety of living organisms in some place, which may encompass diversity at several different levels of organization (*e.g.*, individuals that have different genes, populations that have genetically different individuals, species that have genetically distinct populations).

biological community – an association of different species living together within a defined area. A few examples of biological communities within the Meadowlands include the intertidal marsh, grassland, and palustrine forest communities.

bioremediation – the use of biological organisms such as plants or microbes to aid in removing hazardous substances from an area.

buffer – a vegetated upland area that adjoins a wetland or waterbody. Buffers reduce human impacts on, provide, or enhance a number of important aquatic resource functions including stormwater moderation and erosion control, nutrient and metal cycling and removal, and maintenance of diverse habitats for fish and wildlife.

carcinogen – any substance or agent that causes cancer. Examples of known human carcinogens include asbestos and benzene.

carnivore – a consumer of animals. Examples of carnivores in the Meadowlands include raptors (*e.g.*, barn owl [*Tyto alba*]) and certain mammals (*e.g.*, mink [*Mustela vison*]).

channelization – the manipulation of a waterbody to increase the rate of water flow through the waterbody. Manipulation may include deepening, widening, straightening, armoring, or other activities that change the stream cross-section or other aspects of stream channel geometry to increase the rate of water flow through the waterbody. Despite the modifications to increase the rate of water flow, a channelized waterbody remains a water of the United States pursuant to the Clean Water Act. Channelization has many effects, such as increasing scour and erosion, which may have adverse impacts on fish and wildlife.

chronic toxicity – the capacity of a substance to cause long- term adverse health effects in humans, animals, fish, and other organisms after repeated or regular exposure to low doses.

congener – in chemistry, one of the variants or configurations of a chemical's structure. Congeners usually differ in varying degrees in certain chemical and physical properties.

conservation – the careful preservation and protection of something, generally used in this document in reference to biodiversity. Conservation generally requires planned management and related efforts to prevent exploitation, neglect, and/or degradation.

consumer – an organism that ingests other organisms, their parts, and/or their products for energy. Synonym of **heterotroph**. Compare with **producer** and decomposer.

contaminant of potential concern (COPC) – a contaminant identified by a Screening Level Ecological Risk Assessment (SLERA) for a particular site.

corridor – a strip of land that differs from the adjacent lands on either side; corridors usually serve to connect the "like" landscape components at each end of the corridor.

DDT/DDE – dichloro-diphenyl-trichloroethane and its breakdown product, dichloro-diphenyl-dichloroethylene. DDT was among the first organochlorine insecticides to be developed in the 1940s; most uses of DDT were banned in the early 1970s, when it was shown to have substantial adverse effects on non-target species. DDT was manufactured at several plants located in the Hackensack and Passaic River watersheds, and contaminates portions of both watersheds.

decomposer – an organism that breaks down organic matter into inorganic forms to obtain materials and energy. Examples of decomposers include bacteria and fungi.

dibenzofurans – synonym of **furans**.

dioxin – any form of a group of 75 aromatic heterocyclic compounds, consisting of two benzene rings linked together by two oxygen atoms and containing at least one chlorine atom. Dioxins are byproducts of many chemical and combustion processes, especially those involving combustion of man-made materials. Although there are no known natural sources of dioxins, they are ubiquitous in the environment in minute quantities. Ingestion is the most common exposure of fish, wildlife, and humans to dioxin. Dioxin toxicity varies with the number and location of chlorine atoms; its effects include edema, weight loss, reproductive impairment, immune suppression, and hormonal alterations. Dioxins and related compounds are carcinogens.

direct value – the economic value of goods from natural resources, including fish and wildlife species, that are consumed locally or sold in commercial markets.

DNA adduct formation – an alteration in a gene, usually due to its binding with some chemical agent (*e.g.*, pesticide molecule), which often results in growth of a cancerous tumor.

drainage basin – an area draining into, and including, a waterbody; synonym of **watershed**.

ecosystem – the interacting system of biological communities with their physical environment. The Hackensack Meadowlands ecosystem is comprised of the Hackensack Meadowlands and its biological community.

ecosystem integrity – the capability of supporting and maintaining a balanced, integrated, adaptive, community of organisms having species composition, diversity, and functional organization comparable to that of natural systems.

ecosystem sustainability – maintenance of ecosystem processes and functions conditions indefinitely without progressive diminution of valued qualities inside or outside the ecosystem.

ectothermy – the use of environmental or ambient heat to control body temperature. Body temperature of ectothermic animals usually varies widely but may be moderated by the animal's behavior. For example, snakes and lizards may maintain a relatively constant temperature by basking in the sun or seeking underground refugia. Compare with endothemy.

edge effect – an effect of the interface between different cover types, including interfaces between vegetative cover types or other site conditions. Certain species (*e.g.*, cardinal) occur at

such interfaces because of the juxtaposition of different resources (*e.g.*, refuge in shrubs and trees, food in open areas); however, other species (*e.g.*, bobolinks) avoid those areas because of the different physical environment or high incidence of predation that may occur there.

effects range-median (ERM) – represents the median contaminant concentration in sediments at which adverse biological effects on benthic invertebrates have been observed. The ERM is not a regulatory guideline, and indicates a correlation and not a causal relationship. Developed by NOAA, the ERM has proven useful in assessing potential adverse impacts on fish and wildlife. The ERM for dioxin differs only a little from the contaminant level in EPA guidance, which identifies the concentration at which there is a risk to mammals consuming dioxin-contaminated food.

endangered species (federally listed) – a plant or animal species that is in danger of extinction throughout all or a significant portion of its range. Endangered species are listed pursuant to the Endangered Species Act of 1973.

endocrine disruptor – any exogenous chemical substance or mixture that alters the structure or function of the endocrine system and causes adverse effects at the level of the organism, its progeny, populations, or subpopulations, based on scientific principles, data, weight of evidence, and the precautionary principle. Known endocrine disruptors include some PCBs, dioxins, and furans; bisphenol A; the pesticides DDT, DDE, and methoxychlor; and octyl- and nonyl-phenols.

endogenous – produced inside the body. A few examples of endogenous substances include muscle proteins, digestive enzymes, and hormones. Antonym of exogenous.

endothermy – the ability to generate and regulate internal body temperature. Erroneously considered synonymous with warm-blooded. Examples of endotherms include birds, most mammals, and a few fishes (*e.g.*, tunas, billfishes). Compare with ectothermy.

enhancement – a manipulation of the physical, chemical, or biological characteristics of a site for a specific purpose (*e.g.*, invasive species control) or to improve a specific function (*e.g.*, marsh production, flood water retention).

environmental risk assessment – evaluation of scientific information on the hazardous properties of environmental agents (hazard characterization), the dose-response relationship (dose-response assessment), and the extent of the exposure to those agents (exposure assessment). The product of the risk assessment is a statement regarding the probability that populations or individuals so exposed will be harmed and to what degree (risk characterization).

estuary – the mixing zone of freshwater and seawater, which usually occurs in a semi-enclosed coastal area (*e.g.*, embayment or wide mouth of a river). As a result of the mixing, estuaries contain brackish water, which have salinities intermediate between freshwater (0 parts per thousand [ppt] salinity) and seawater (approximately 35 ppt salinity).

eustatic sea level – sea level which changes in response to the volume of water in the ocean.

eutrophication – the process whereby water bodies, such as estuaries, receive excess nutrients that stimulate excessive plant growth leading to low oxygen concentrations (**hypoxia** or **anoxia**), which cause mortality of aquatic organisms.

exogenous – produced outside the body. Examples of exogenous compounds include contaminants and endocrine disruptors. Antonym of **endogenous**.

exotic species – a plant or animal species that is not native to a geographic area or ecosystem. Because they may have no or few biotic controls (*e.g.*, competitors) in the new location, many exotic species have the potential to reproduce prolifically and to replace native species.

fishery – the harvesting of a certain fish species in specific waters.

fishway – any facility, structure, device, measure, or project operation, or any combination thereof, necessary for safe, timely, and effective movement of fish, regardless of life stage, whether upstream or downstream, through, over, or around a manmade obstruction, such as a dam. An example of a fishway is a fish ladder.

floodplain – the relatively flat surfaces adjacent to active stream or river channels, formed by deposition of sediments during floods.

food chain – movement of energy and nutrients from one feeding group of organisms to another within an ecosystem. For example, algae are eaten by krill, which are consumed by whales. Compare with **food web**.

food web – a complex intermeshing of feeding relationships within an ecosystem. Conceptually, a food web may be considered as many interacting food chains. Also, different stages in the life of a species may have different feeding relationships with other species. For example, a larval fish may eat certain algae, the juvenile fish eats copepods, and the adult eats other fishes. Thus, in a food web, each species eats and is eaten by many other species. Compare with **food chain**.

fragmentation – a disruption in the continuity of an ecosystem. An example is the splitting of a large land parcel into smaller parcels by roads. Fragmentation exacerbates the problems of habitat loss, and contributes to additional loss of **biodiversity**.

fringe wetland – an estuarine landform with unrestricted tidal flows.

furans – refers to polychlorinated dibenzofurans, a group of 135 different aromatic heterocyclic compounds, consisting of two benzene rings linked together by one oxygen atom and containing at least one chlorine atom. Like dioxins and PCBs, which are related classes of aromatic heterocyclic compounds and share similar properties, furans form as byproducts of many chemical manufacturing processes.

geology – the science of the origin, history, and structure of the earth, and including the dynamic processes changing the structure.

glochidia – a specialized larval form of some freshwater mollusks that attaches to the gills of specific freshwater fishes. The larva does not derive any nutrition from the gills of the fish, but simply uses the fish as a means of dispersal to another habitat. Example: larva of the federally endangered dwarf wedgemussel (*Alasmidonta heterodon*).

granivore – a grain-eater. Examples include some birds (American goldfinch [*Carduelis tristis*], Northern cardinal [*Cardinalis cardinalis*]) and mammals (*e.g.*, most rodents).

guild – a group of species that exploit an environmental resource similarly. For example, herrings (*Alosa* spp.), bay anchovy (*Anchoa mitchilli*), and silversides (*Menidia* spp.) in the Meadowlands may be considered a guild of planktivorous (plankton-eating) fishes.

guyed – steadied or supported by cables or other attachments. For example, guyed radio towers are supported by a circular array of guy wires attached to the ground. Unguyed (also known as freestanding) radio towers lack guy wires.

habitat – the combination of environmental factors that provides food, water, cover, and space that a living organism needs to survive and reproduce.

haplotype – a set of closely linked genes that tends to be inherited together as a unit, usually due to their linkage (their proximity on a single chromosome). For example, haplotype M of common reed (*Phragmites australis*) gives rise to an invasive phenotype (form).

hazard quotient – the ratio of a single substance exposure level over a specified time period to a reference dose for that substance derived from a similar exposure period.

hazardous substance – a substance which, upon release into the atmosphere, water, sediments, or soil, or which, in direct contact with the skin or other organs, or which is consumed with or without food, cause health risks to humans or animals through absorption, inhalation, or ingestion.

headwater streams – the smallest streams in a watershed, usually including low-order (*i.e.*, first-, second-, and third-order) streams. First-order streams are the smallest distinct streams in a watershed. Second-order streams are formed when two first-order channels combine, third-order streams are formed by the combination of two second-order streams, and so on.

hermaphroditism – the functioning of both sexes during the lifetime of an individual animal. Hermaphroditism occurs in two forms, **simultaneous**, when an individual functions as both sexes at the same time, as in many invertebrates (*e.g.*, earthworms [*Lumbricus* spp.]), or **sequential**, when the genders occur in a sequence (one sex, then the other) as in some fishes (*e.g.*, black sea bass [*Centropristis striata*]).

herbivore – a consumer of plants. Examples in the Meadowlands include many insects (*e.g.*, *Galerucella* beetles, which consume purple loosestrife) and certain mammals (*e.g.*, white-tailed deer [*Odocoileus virginianus*]).

heterogeneous – consisting of different elements or parts. Antonym of homogeneous.

heterotrophic – refers to organisms which acquire and convert forms of organic carbon to obtain energy. Heterotrophic organisms include all animals, fungi, some algae, parasitic plants, and most bacteria. See **consumer**. Compare with **autotrophic**.

homogeneous – consisting of similar elements or parts. Antonym of heterogeneous.

hydric – characterized by, relating to, or requiring an abundance of water

hydrology – the science of the distribution, properties, and circulation of water above, on, and below the earth's surface.

hydrophilic – "water-loving," usually referring to a substance, molecule, or portion of a molecule that has a strong affinity for and readily mixes with water. Hydrophilic substances are polar; examples of hydrophilic substances include sugars, salts, ammonia, and alcohols.

hydrophobic – "water fearing," usually referring to a substance, molecule, or a portion of a molecule that will not mix with or repels water. Most hydrophobic substances are non-polar. Examples of hydrophobic substances include oils and waxes.

hydroxylation – the addition of a hydroxyl group (-OH) to a compound; this addition most often involves the replacement of a hydrogen atom. Hydroxylation represents an oxidation of the molecule and often makes an atom more polar (charge imbalanced) and thus more soluble in water. Hydroxylation in living organisms is usually accomplished by an enzyme known as a hydroxylase. For example, hydroxylation of PCBs makes them more soluble in water and may increase their uptake and excretion.

hypoxia – a low oxygen condition (adjective = hypoxic). When occurring in surface waters, oxygen concentrations are usually between 1 and 2 ppm. Slightly higher oxygen concentrations (up to 3.2 ppm) may be considered hypoxic for invertebrates and other sensitive aquatic organisms. Most aquatic organisms are stressed by hypoxic conditions.

impairment – a diminished capacity of a habitat or ecosystem to support fish and wildlife that results from an environmental alteration. An impaired water body is one in which some chemical or physical component of water quality does not meet some specified federal or State criterion. Water quality in the Hackensack River is impaired, as a result of exceeding numerous water quality criteria (*e.g.*, oxygen concentration).

indirect value – economic values resulting from fish and wildlife resources that are not harvested or damaged during their use. Examples include ecosystem services (stormwater storage, production, and biogeochemical) and recreation.

interjurisdictional fishery – a freshwater, coastal, or marine fish population managed by two or more states, nations, or tribal governments because of the population's geographic distribution or migratory patterns.

invasive species – animal or plant species that colonize and spread, often displacing other species and altering communities. Invasive species are usually, though not always, exotic (non-native) species; two common examples of invasive species in the Meadowlands include common reed (*Phragmites australis*) and Japanese knotweed (*Polygonum cuspidatum*).

isolation effect – in ecology, an effect of distance from something, which usually contributes to a difference in the entity (*e.g.*, wetland, biological population) that is isolated.

keystone species – a species that affects the survival and abundance of many other species in the community in which it lives. Its removal or addition results in a significant shift in the composition and sometimes even the physical structure of the community.

lacustrine – pertaining to a lake or lakes. A synonym of lentic.

landform – the physical form or shape of a wetland. In general, six landform types are recognized: basin, flat, slope, floodplain, island, and fringe.

landscape position – descriptor of the relationship between a wetland and an adjacent waterbody. Four general types are recognized: estuarine (along marine and brackish waters), lotic (along freshwater rivers and streams), lentic (along lakes and reservoirs), and terrene (isolated, surrounded by upland).

lentic- refers to wetlands located along any permanent waterbody with standing water (*e.g.*, lake, pond, reservoir). A synonym of lacustrine.

lipophilic – "fat-loving," usually referring to a substance, molecule, or portion of a molecule that has a strong affinity for and readily mixes with fats. Many lipophilic substances are non-polar. Examples of lipophilic substances include steroid hormones, dioxins, and PCBs.

lotic – refers to wetlands located along any permanent waterbody with running water (*e.g.*, river or stream).

low-order stream – the smallest tributary of a river in a watershed; a headwater stream with no tributaries.

marine protected area (MPA) –- any marine area that is protected by legislation (*e.g.*, National Marine Sanctuaries Act); within an MPA, activities are regulated to protect natural resources, biodiversity, or human livelihoods. The level of protection between MPAs varies with the protecting legislation.

marine transient species – species such as certain fishes (*e.g.*, summer flounder [*Paralichthys dentatus*]) that use various estuarine habitats during their early life history stages and marine and estuarine habitats as adults.

mesohaline – refers to aquatic ecosystems with a salinity between 5 and 18 ppt. Extensive portions of the Meadowlands now experience mesohaline conditions.

mitigation – the steps taken to avoid or minimize adverse impacts on environmental resources or environmental processes. For consistency with federal laws, mitigation is a sequential process that (1) avoids an impact altogether by not taking certain actions or parts of an action; (2) minimizes impacts by limiting the degree or magnitude of the action and its implementation; repairing, rehabilitating, or restoring the affected environment; or reduces the impact over time by preservation and maintenance operations during the life of the action; and finally, (3) compensates for the action's impact by replacing or providing substitute resources or lands.

monitoring – the process of continually checking, observing, recording or testing of some phenomenon, activity, or feature.

monophagous – a pest species with only one species of host plant. One well- known example of a monophagous insect is the boll weevil (*Anthonomus grandis*); all stages in the life history of this beetle feeds only on the bolls of cotton.

mutagen – a substance or agent (*e.g.*, radiation) that causes a mutation, which is a change in the base sequence of a cell's DNA. Mutations can lead to birth defects, miscarriages, or cancer. Benzo-[a]-pyrene, a polycyclic aromatic hydrocarbon (see PAH below), is a potent mutagen.

natural – indicating an ecosystem in which diverse conditions (*e.g.*, nutrient concentrations, water quality) and functions (*e.g.*, biogeochemistry, biodiversity) do not reflect extensive human activities or disturbance.

nekton – community of free-swimming animals. The nekton includes fishes, whales, sea turtles, squid, portunid (swimming) crabs, and other swimming animals.

nest parasitism – an association where one animal (parasite) lays eggs in the nest of another animal (host or foster parent) of the same (conspecific) or different (interspecific) species. Obligate nest parasites have lost the ability to build nests and incubate eggs, and do not rear their own young. Examples of conspecific parasites include bank swallows (*Riparia riparia*) and redhead (*Aythya americana*); obligate nest parasites include brown-headed cowbird (*Molothrus ater*) and yellow-billed cuckoo (*Coccyzus americanus*).

Northern Triassic Lowlands – one formation of the Piedmont Lowlands, which occurs in northern New Jersey and eastern Pennsylvania and is underlain by sedimentary rocks that are 240- 205 million years old.

oligohaline – refers to aquatic ecosystems with a salinity between 0.5 and 5 ppt. Upper portions of the Meadowlands now experience oligohaline conditions throughout much of the year.

omnivore – an animal that consumes plants and animals as food. Examples of omnivores in the Meadowlands include certain birds (*e.g.*, American crow [*Corvus brachyrhynchos*], song

sparrow [*Melospiza melodia*], northern mockingbird [*Mimus polyglottos*]) and mammals (*e.g.*, raccoon [*Procyon lotor*], gray fox [*Urocyon cinereoargenteus*]).

option value – the potential economic value of a species for future use. For example, many plants, fungi, and bacteria produce chemicals that may have value for treating diseases. Pacific yew (*Taxus brevifolia*) was considered a "trash" tree species until it was recognized that yew bark contained a potent anticancer agent known as taxol. Recognition of the mode of action of this chemical led to an entirely new class of anticancer medicines.

palustrine – nontidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens, and all such tidal wetlands where ocean-derived salinities are below 0.5 ppt. This category also includes wetlands lacking such vegetation but with all of the following characteristics: (1) area less than 8 ha; (2) lacking an active wave-formed or bedrock boundary; (3) water depth in the deepest part of the basin less than 2 m (6.6 ft) at low water; and (4) ocean-derived salinities less than 0.5 ppt.

PCDD/PCDF – polychlorinated dibenzodioxin (**dioxin**) / polychlorinated dibenzofuran (**furan**).

pH – the potential of hydrogen, the negative logarithm (to the base 10) of the hydronium ion (H^+) concentration, in moles per liter. It is a numerical measure of acidity (when pH <7) or alkalinity (when pH > 7) on a scale of 1 to 14, with the value of 7.0 being neutral and approximately equal to the hydronium ion concentration of distilled water.

phylum (-a) – the primary taxonomic division within the animal kingdom**.** An example of an animal phylum is the Arthropoda, which consists of all animals having jointed appendages and an exoskeleton (*e.g.*, crabs, spiders, insects).

Piedmont Lowlands – together with the Piedmont Uplands, one of two sections of the Piedmont Physiographic Province. The Hackensack Meadowlands lies entirely within the Piedmont Lowlands.

piscivore – a fish-eating species (adjective = **piscivorous**). Examples in the Meadowlands include certain fishes (*e.g.*, striped bass [*Morone saxatilis*]), birds (*e.g.*, osprey [*Pandion haliaetus*]), and mammals (*e.g.*, harbor seal [*Phoca vitulina*]).

planktivorous – plankton-eating. A common **planktivore** in the Meadowlands is the Atlantic silverside (*Menidia menidia*).

plankton – community of small drifting, floating, or weakly swimming organisms that inhabit the water column. Most species in the plankton have a small body size; examples include copepods, jellyfishes, and the larvae of fishes, crabs, and clams.

Pleistocene Epoch – time period between about 1,650,000 and 10,000 years before present. In general, this is the time period during which humans largely evolved and the Northern Hemisphere was covered extensively by glaciers.

polychlorinated biphenyl (PCB) – any of 209 chlorinated compounds consisting of two benzene rings connected by a single carbon to carbon bond. PCBs were manufactured by Monsanto (U.S. production = 1.25 billion pounds) and used in mixtures as lubricants, heat exchangers, dielectric fluids, and plasticizers due to their relative chemical inertness, low solubility in water, resistance to acids and alkalis, and thermal stability. PCBs are persistent, widely distributed throughout the environment, carcinogenic in animals; nearly all adversely affect the immune, reproductive, nervous, and endocrine systems of fish and wildlife.

polycyclic aromatic hydrocarbons (PAH) – any of a group of approximately 100 aromatic hydrocarbon compounds consisting of two or more fused carbon rings, which are produced by incomplete combustion of organic molecules and also are a component of crude oil. PAHs interfere (1) with cell division and photosynthesis of plants and thus cause various sublethal and lethal effects, and (2) with cellular membrane enzymes and membrane functions in animals, and thus cause mutations, developmental malformation, tumors, and cancers.

polyhaline – refers to aquatic ecosystems with a salinity between 18 and 30 ppt.

primary production – the amount of organic material (biomass) synthesized by living organisms from inorganic material in a given area in a given period, usually expressed as grams of carbon per square meter per year; most primary production results from photosynthesis in plants and algae, though it may result from other processes in bacteria.

producer – an organism that converts inorganic molecules into energy-rich organic molecules that can be used as food. Examples of producers include algae and nearly all plants. Synonym of autotroph. Compare with **consumer** and **decomposer**.

production – the amount of organic material (biomass) produced by living organisms, most often expressed per unit area (or volume) per unit time; usually divided into primary (of producers) and secondary (of consumers) components. Estuaries are recognized widely for having high rates of primary and secondary production.

remediation – activities performed to clean up or treat hazardous waste sites, sometimes including activities to relieve their adverse effects.

restoration – the repair of ecological damage to an ecosystem so that: (1) it is close to the natural condition prior to a disturbance or degradation, and (2) it can function as a normal self-regulating system. Restoration may be accomplished through processes such as re-vegetation and/or the reintroduction of native species.

riparian – of, relating to, or located on or along the banks of a waterbody, usually referring to streams, rivers, lakes.

riverine – wetland and deepwater habitats contained within a channel except those wetlands: (1) dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens, and (2) which have salinities greater than 0.5 ppt.

salinity – the concentration of salt in a solution, such as seawater, commonly and simply measured as the relative weight in parts per hundred (pph or percent [%]) or parts per thousand (ppt). The salinity of seawater is 3.5% or 35 ppt.

sandstone – a sedimentary rock composed largely of coarse, weathered quartz grains (sand) held in a matrix of silt or clay.

scale effect – an effect that changes as a correlate of the size or level of some factor. For example, fragmentation effects change with the size of the area that is fragmented.

Screening Level Ecological Risk Assessment (SLERA) – an initial assessment of a potential hazardous site, as recommended by the EPA. This includes an assessment of: (1) the site and its known or suspected contaminants, (2) potential contaminant fates and transport mechanisms, (3) contaminant ecotoxicity and potentially affected taxa, (4) potential exposure pathways, and (5) selection of endpoints to screen for risk. The Service recommends a SLERA for potential restoration sites in the Hackensack Meadowlands.

sea level rise (SLR) – an increase in apparent height of water in an ocean in relation to some point on land; sea level rise may result from an increase in an ocean's mass (more water in an ocean basin [eustatic sea level rise]), an increase in an ocean's volume (thermal expansion with increasing temperature due to global climate change [steric sea level rise]), or geology (movements, changes in the earth's crust [local sea level rise]).

secondary production – the amount of organic material (biomass) produced in a given area in a given period by consumers, usually expressed as grams of carbon per square meter per year; organic material produced by processing other organic material.

secondary treatment – the second step in most sewage treatment systems in which bacteria consume most (85 to 90 percent) of the organic components of the waste, primarily dissolved substances and suspended solids. Disinfection is the final stage of secondary treatment.

sediment – mineral and organic particles that have been transported by air, water, or ice and deposited on the bottom of an aquatic environment

sentinel species – a species that is a sensitive indicator of chemical, physical, or biological disturbance in the environment. Because they occur in aquatic and terrestrial environments and may absorb materials through gills, lungs, and skin, amphibians are considered sentinel species.

shale – a sedimentary rock composed largely of fine particles of clays, silts, and detritus.

sink habitat – a habitat in which reproduction is insufficient to balance mortality. Populations are unable to persist long-term in sink habitats without immigration of individuals from other productive habitats. See **source habitat.**

soil – the unconsolidated mineral and organic materials on the immediate surface of the earth that serves as a natural medium for the growth of land plants. In contrast to the underlying

source material, soil has been altered by the interactions of climate, topographic relief, and living organisms over time.

source habitat – a habitat in which reproduction exceeds mortality. Populations generally persist long-term in source habitats; individuals in source habitats may also migrate into less-productive habitats nearby. See **sink habitat**.

stakeholder – an individual or organization that has an interest or investment.

steric sea level rise- increase in the sea level due to the thermal expansion of water with increasing temperature, *i.e.*, an increase in the volume but not the mass of the ocean.

Superfund site – any federal priority listed site in the United States that has been contaminated by hazardous waste and identified by the EPA as a candidate for cleanup because it poses a risk to human health or the environment.

surface elevation table – a mechanical leveling device for precisely measuring the relative elevation of wetland sediments or water surface. Surface elevation tables can be used to determine both the influence of a single meteorological event on sediment surface elevation and long-term trends in elevation change. When used with marker horizons (*i.e.*, a layer of feldspar, glitter, or other material sprinkled over the surface), information on both above- and below-ground processes affecting elevation can be obtained. Surface elevation tables can provide information to determine rates of sedimentation, erosion, sea level rise.

sustain – support, maintain, or keep alive continually

sustainable – the maintenance of a condition (such as biodiversity or resource productivity) over time indefinitely.

taxon (taxa) – any group of evolutionarily related organisms. Examples of taxa include species (humans, *Homo sapiens*), genus (all species of *Homo*), family (Hominids, including humans and great apes), class (primates, including hominids and other monkeys), and mammals (primates and other groups such as rodents, carnivores, whales).

teratogen – an agent or substance that may cause a non-heritable mutation or malformation in the developing embryo or fetus when a pregnant female is exposed to that substance. Cadmium and chromium are teratogens in certain wildlife.

terrene – of, or pertaining to, a land area.

terrestrial – in, on, or referring to land (as opposed to water).

threatened species (federally listed) – those species likely to become endangered within the foreseeable future throughout all or a significant portion of their range. Threatened species are listed pursuant to the Endangered Species Act of 1973.

tidal prism – the volume of water that moves in and out of an estuary with each tide.

topography – the detailed arrangement of a portion of the earth's surface and the relations among its man-made and natural features.

traprock – various dark-colored, heavy igneous (volcanic) rocks (*e.g.*, basalt, dolerite, amygdaloid, diorite, and feldspathic-augitic rocks).

trophic dynamics – the biological processes (*e.g.*, predation) whereby energy and matter are passed up through successive levels of food webs.

trust resource (federal) – a resource (*e.g.*, federally listed species, migratory birds) for which the Service (or NOAA) is responsible as defined by legislation, treaty, or other legal authorities.

turbidity maximum zone – a localized area in an estuary where acidic to neutral freshwater mixes with more alkaline seawater and dissolved materials adhere to suspended particulate matter or otherwise settle or "flocculate" out of solution. The turbidity maximum zone moves within the estuary on tidal and seasonal periods. The area bounded by the zone accumulates materials, including contaminants; in some estuaries, it may be a zone of high production.

varved – layered. Many sedimentary deposits of clays, shales and slates are varved.

vegetative cover type – A plant community or group of plant communities having the same primary dominant species and similar physiognomy; an aggregation of plant community types. An example of a vegetative cover type is the low-marsh cover type, comprised mostly of smooth cordgrass (*Spartina alterniflora*) with patches of other plants (mostly grasses, *e.g.*, dwarf spike rush [*Eleocharis parvula*], salt marsh hay [*Spartina patens*], and spikegrass [*Distichlis spicata*]).

watershed – the area of land draining into, and including, the receiving waterbody; synonym of **drainage basin**.

wetlands – transitional areas between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. Wetlands have one or more of the following attributes: (1) the substrate is non-soil and is saturated with water or covered by shallow water at some time during the growing season of each year; (2) the substrate is predominantly undrained hydric soil; and (3) at least periodically, the land supports aquatic plants. Some examples of wetlands include freshwater swamps, saltwater marshes, vernal pools, intertidal mudflats, and portions of lakes, ponds, rivers, and streams.

Wisconsin glaciation – the last of the great glacial periods that occurred from about 11,000 to about 25,000 years ago.

XVI. LIST OF COMMON AND SCIENTIFIC NAMES

Listed below are the scientific and common names of all species identified in the text. The scientific name is usually provided (parenthetically) at the first usage of the common name; subsequently, the common name alone is used throughout the text.

Scientific names are presented in taxonomic groupings to the Order, except for the Monera and Fungi, which are presented only by Phylum. Within Order, scientific names are presented alphabetically. The taxonomies were obtained from the Integrated Taxonomic Information System (U.S. Department of Agriculture *et al.*, 2005), the National Plant Data Center (U.S. Department of Agriculture, 2005), the National Biological Information Infrastructure (U.S. Geological Survey, 2006), and the *Systema Naturae* 2000 (Brands, 2005).

KINGDOM MONERA

Phylum Bacteria

Vibrio cholera	Cholera bacterium

KINGDOM FUNGI

Phylum Ascomycota

Cryphonectria parasitica	Chestnut-blight fungus
Fusarium oxysporum	Fusarium (wilt) fungus

Phylum Oomycota

Phytophthora cinnamomi	Cinnamon fungus

Phylum Imperfecti

Verticillium spp.	Verticillium (wilt) fungus species

KINGDOM PLANTAE

Division Bryophyta

Class Sphagnopsida

Order Sphagnales

Sphagnum spp.	Bog moss species

Division Pteridophyta

Class Filicopsida

Order Polypodiales

Onoclea sensibilis	Sensitive fern

Division Coniferophyta

Class Pinopsida

Order Pinales

Chamaecyparis thyoides	Atlantic white-cedar
Larix laricina	Tamarack
Picea mariana	Black spruce

Order Taxales

Taxus brevifolia	Pacific yew

Division Magnoliophyta

Class Liliopsida

Order Cyperales

Carex pseudocyperus	Cypress-like sedge
Carex spp.	Sedge species
Cyperus spp.	Sedge species
Distichlis spicata	Spikegrass
Eleocharis parvula	Dwarf spike rush
Panicum spp.	Panic grass species
Phragmites australis	Common reed
Scirpus maritimus	Saltmarsh bulrush
Scirpus robustus	Stout bulrush
Spartina alterniflora	Smooth cordgrass
Spartina patens	Salt-marsh hay
Spartina spp.	Cordgrass species
Zea mays	Corn

Order Najadales

Potamogeton spp.	Pondweed species
Triglochin maritimum	Seaside arrowgrass

Order Arales

Lemna minor	Lesser duckweed
Lemna spp.	Duckweed species
Peltandra virginica	Arrow arum

Order Typhales

Typha latifolia	Broadleaf cattail
Typha spp.	Cattail species

Order Liliales

Pontederia cordata	Pickerelweed

Class Magnoliopsida

Order Asterales

Baccharis halimifolia	Groundsel tree
Erechtites hieracifolia	Fireweed
Eupatorium capillifolium	Dog fennel thoroughwort
Hieracium kalmii	Canada hawkweed
Iva frutescens	Saltmarsh elder
Pluchea purpurascens	Saltmarsh fleabane
Prenanthes racemosa	Purple rattlesnake-root
Solidago spp.	Goldenrod species

Order Dipsacales

Sambucus canadensis	Common elderberry
Viburnum dentatum	Arrowwood

Order Lamiales

Pycnanthemum torrei	Torrey's mountain-mint
Verbena hastata	Blue vervain

Order Scrophulariales

Fraxinus nigra	Black ash
Utricularia vulgaris	Common bladderwort

Order Solanales

Nicotiana rustica	Tobacco
Calystegia sepium	Hedge false bindweed

Order Polygonales

Polygonum cuspidatum	Japanese knotweed
Polygonum perfoliatum	Mile-a-minute
Polygonum hydropiperoides	Swamp (or water) smartweed
Polygonum spp.	Smartweed species

Order Theales

Hypericum adpressum	Creeping St. Johnswort

Order Ericales

Clethra alnifolia	Sweet pepperbush
Leucothoe racemosa	Swamp fetterbush

Order Malvales

Hibiscus moscheutos	Rose mallow

Order Salicales

Populus deltoides	Eastern cottonwood
Populus spp.	Poplar species
Salix discolor	Pussy willow

Order Fagales

Alnus sp.	Alder species
Betula populifolia	Gray birch
Betula spp.	Birch species
Castanea dentata	American chestnut
Quercus bicolor	Swamp white oak
Quercus coccinea	Scarlet oak
Quercus lyrata	Overcup oak
Quercus palustris	Pin oak

Order Hamamelidales	
Liquidambar styraciflua	Sweetgum
Order Juglandales	
Juglans nigra	Black walnut
Order Myricales	
Morella (Myrica) pensylvanica	Northern bayberry
Order Urticales	
*Cannabi*s spp.	Hemp
Ulmus americana	American elm
Order Nymphaeales	
Brasenia schreberi	Water shield
Nuphar spp.	Water lily species
Nymphaea odorata	Fragrant water lily
Order Apiales	
Heracleum mantegazzianum	Giant hogweed
Order Cornales	
Nyssa sylvatica	Blackgum
Order Fabales	
Phaseolus vulgaris	Bean
Robinia pseudoacacia	Black locust
Order Myrtales	
Lythrum salicaria	Purple loosestrife
Order Rhamnales	
Rhamnus frangula	European buckthorn
Ampelopsis brevipedunculata	Amur peppervine
Order Rosales	
Aronia prunifolia	Purple chokeberry
Prunus serotina	Black cherry
Rubus hispidus	Swamp dewberry
Sorbus aucuparia	European ash
Spiraea tomentosa	Steeplebush
Order Linales	
Linum spp.	Flax
Order Sapindales	
Acer negundo	Box elder
Acer rubrum	Red maple

Order Sapindales (continued)

Ailanthus altissima	Tree-of-heaven
Ptelea trifoliata	Wafer ash
Rhus spp.	Sumac species

KINGDOM METAZOA

Phylum Nematoda

Class Phasmida

Order Ascaridida

Baylisascaris procyonis	Raccoon roundworm

Phylum Annelida

Class Oligochaeta

Order Haplotaxida

Lumbricus spp.	Earthworm species
Lumbricus terrestris	Common (European) earthworm

Class Polychaeta

Order Spionida

Polydora ligni	Whip mud worm

Order Sabellida

Terebrasabella hetrouncintata	South African shell-boring sabellid

Phylum Arthropoda

Class Arachnida

Order Acarina

Ixodes scapularis	Deer tick

Class Insecta

Order Orthoptera

Blattella germanica	German cockroach

Order Diptera

Calamomyia phragmites	Common-reed gall midge
Lasioptera hungarica	European univoltine gall midge
Lipara spp.	Gall fly species
Thrypticus spp.	Petiole mining fly species

Order Lepidoptera

Lymantria dispar	Gypsy moth
Ochlodes yuma	Yuma skipper
Pyrgus wyandot	Appalachian grizzled skipper
Poanes viator	Broad-winged skipper

Order Coleoptera

Anthonomus grandis	Boll weevil

Order Coleoptera (continued)

Galerucella calmariensis	Black-margined loosestrife beetle
Galerucella pusilla	Golden loosestrife beetle
Galerucella spp.	Loosestrife beetle species

Class Crustacea

Order Decapoda

Callinectes sapidus	Blue crab
Crangon septemspinosa	Sand shrimp
Hemigrapsus sanguineus	Japanese shore crab
Palaemonetes pugio	Grass shrimp
Rhithropanopeus harrisii	Estuarine mud crab
Uca spp.	Fiddler crab species

Phylum Mollusca

Class Bivalvia

Order Myoida

Mya arenaria	Softshell clam

Order Ostreoida

Crassostrea virginica	American oyster

Order Unioida

Alasmidonta heterodon	Dwarf wedge mussel
Alasmidonta undulata	Triangle floater
Lampsilis cariosa	Yellow lampmussel
Lasmigona subviridis	Green floater
Leptodea ochracea	Tidewater mucket
Strophitus undulates	Creeper

Order Veneroida

Corbicula fluminea	Asian (Asiatic) clam
Dreissena polymorpha	Zebra mussel
Macoma bathica	Baltic macoma clam
Mytilopsis leucophaeata	False dark mussel
Mytilopsis sp.	False mussel species
Potamocorbula amurensis	Amur River corbula clam

Phylum Chordata

Class Osteichthyes

Order Acipenseriformes

Acipenser brevirostrum	Shortnose sturgeon
Acipenser oxyrhynchus	Atlantic sturgeon

Order Clupeiformes

Alosa aestivalis	Blueback herring
Alosa pseudoharengus	Alewife

Order Clupeiformes (continued)

Alosa sapidissima	American shad
Alosa spp.	Herring species
Anchoa mitchilli	Bay anchovy
Dorosoma cepedianum	Gizzard shad

Order Anguilliformes

Anguilla rostrata	American eel

Order Cypriniformes

Carassius auratus	Goldfish
Cyprinus carpio	Carp

Order Gadiformes

Microgadus tomcod	Tomcod

Order Atheriniformes

Menidia menidia	Atlantic silverside
Menidia spp.	Silverside species

Order Cyprinodontiformes

Fundulus heteroclitus	Mummichog

Order Scorpaeniformes

Cottus spp.	Sculpin species
Prionotus evolans	Striped searobin

Order Perciformes

Centropristis striata	Black sea bass
Etheostoma spp.	Darter species
Micropogonias undulatus	Atlantic croaker
Morone americana	White perch
Morone saxatilis	Striped bass
Percina spp.	Darter species
Pomatomus saltatrix	Bluefish

Order Gobiiformes

Gobiosoma bosc	Naked goby

Order Pleuronectiformes

Paralichthys dentatus	Summer flounder
Pseudopleuronectes americanus	Winter flounder
Trinectes maculates	Hogchoker

Class Amphibia

Order Urodela

Ambystoma jeffersonianum	Jefferson's salamander
Ambystoma opacum	Marbled salamander

Order Urodela (continued)

Gyrinophilus porphyriticus	Northern spring salamander

Order Anura

Bufo terrestris	Southern toad
Bufo woodhousii fowleri	Fowler's toad

Class Reptilia

Order Chelonia

Clemmys guttata	Spotted turtle
Clemmys insculpta	Wood turtle
Clemmys muhlenbergii	Bog turtle
Kinosternon subrubrum	Eastern mud turtle
Malaclemys terrapin	Diamondback terrapin
Sternotherus odoratus	Stinkpot
Terrapene carolina	Eastern box turtle
Trachemys scripta	Red-eared slider

Order Squamata

Coluber constrictor	Northern black racer
Eumeces fasciatus	Five-lined skink
Opheodrys vernalis	Smooth green snake

Class Aves

Order Podicipediformes

Podilymbus podiceps	Pied-billed grebe

Order Anseriformes

Anas platyrhynchos	Mallard
Anas rubripes	Black duck
Anas strepera	Gadwall
Aythya americana	Redhead
Branta canadensis	Canada goose
Bucephala albeola	Bufflehead

Order Ciconiiformes

Ardea alba	Great egret
Ardea exilis	Least bittern
Ardea herodias	Great blue heron
Botaurus lentiginosus	American bittern
Egretta caerulea	Little blue heron
Egretta tricolor	Tricolor heron
Ixobrychus exilis	Least bittern
Nyctanassa violacea	Yellow-crowned night heron
Nycticorax nycticorax	Black-crowned night heron

Order Falconiformes

Accipiter cooperii	Cooper's hawk
Accipiter gentiles	Northern goshawk
Accipiter striatus	Sharp-shinned hawk
Buteo lineatus	Red-shouldered hawk
Buteo platypterus	Broad-winged hawk
Circus cyaneus	Northern harrier
Falco peregrinus	Peregrine falcon
Falco sparverius	American kestrel
Haliaeetus leucocephalus	Bald eagle
Pandion haliaetus	Osprey

Order Gruiformes

Coturnicops noveboracensis	Yellow rail
Gallinula chloropus	Common moorhen
Rallus elegans	King rail
Rallus longirostris obsoletus	California clapper rail
Rallus spp.	Rail species

Order Charadriiformes

Actitis macularia	Spotted sandpiper
Bartramia longicauda	Upland sandpiper
Calidris alba	Sanderling
Calidris alpina	Dunlin
Calidris canutus	Red knot
Calidris minutilla	Least sandpiper
Catoptrophorus semipalmatus	Willet
Chlidonias niger	Black tern
Limosa fedoa	Marbled godwit
Limosa haemastica	Hudsonian godwit
Numenius phaeopus	Whimbrel
Phalaropus tricolor	Wilson's phalarope
Rynchops niger	Black skimmer
Scolopax minor	American woodcock
Sterna antillarum	Least tern
Sterna caspia	Caspian tern
Sterna dougallii	Roseate tern
Sterna hirundo	Common tern
Tringa arenaria	Sanderling
Tringa solitaria	Solitary sandpiper
Tryngites subruficollis	Buff-breasted sandpiper

Order Columbiformes

Columba livia	Rock dove

Order Cuculiformes

Coccyzus americanus	Yellow-billed cuckoo

Order Cuculiformes (continued)

Coccyzus erythropthalmus	Black-billed cuckoo

Order Strigiformes

Asio flammeus	Short-eared owl
Asio otus	Long-eared owl
Strix varia	Barred owl
Tyto alba	Common barn owl

Order Caprimulgiformes

Chordeiles acutipennis	Lesser nighthawk
Chordeiles minor	Common nighthawk

Order Coraciiformes

Ceryle alcyon	Belted kingfisher

Order Piciformes

Melanerpes erythrocephalus	Red-headed woodpecker

Order Passeriformes

Agelaius phoeniceus	Red-winged blackbird
Ammodramus caudacutus	Sharp-tailed sparrow
Ammodramus maritimus	Seaside sparrow
Ammodramus palustris	Swamp sparrow
Ammodramus spp.	Sparrow species
Cardinalis cardinalis	Northern cardinal
Carduelis tristis	American goldfinch
Catharus fuscescens	Veery
Catharus minimus	Gray-cheeked thrush
Catharus ustulatus	Swainson's thrush
Cistothorus palustris	Marsh wren
Cistothorus platensis	Sedge wren
Corvus brachyrhynchos	American crow
Dendroica caerulescens	Black-throated blue warbler
Dendroica castanea	Buff-breasted warbler
Dendroica discolor	Prairie warbler
Dendroica petechia	Yellow warbler
Dendroica virens	Black-throated green warbler
Dolichonyx oryzivorus	Bobolink
Dumetella carolinensis	Gray catbird
Empidonax minimus	Least flycatcher
Eremophila alpestris	Horned lark
Geothlypis trichas	Common yellowthroat
Hylocichla mustelina	Wood thrush
Icterus galbula	Baltimore oriole
Lanius ludovicianus	Loggerhead shrike
Melospiza melodia	Song sparrow

Order Passeriformes (continued)

Melospiza spp.	Sparrow species
Mimus polyglottos	Northern mockingbird
Molothrus ater	Brown-headed cowbird
Parula americana	Northern parula
Passerculus sandwichensis	Savannah sparrow
Petrochelidon pyrrhonota	Cliff swallow
Pooecetes gramineus	Vesper sparrow
Riparia riparia	Bank swallow
Spiza americana	Dickcissel
Sturnella magna	Eastern meadowlark
Sturnus vulgaris	European starling
Troglodytes tyroglodytes	Winter wren
Vireo solitarius	Solitary vireo
Vermivora pinus	Blue-winged warbler
Wilsonia canadensis	Canada warbler

Class Mammalia

Order Rodentia

Castoroides ohioensis	Giant beaver
Mus musculus	House mouse
Neotoma magister	Allegheny woodrat
Ondatra zibethicus	Muskrat
Rattus norvegicus	Norway rat

Order Chiroptera

Myotis sodalis	Indiana bat

Order Lagomorpha

Sylvilagus floridanus	Eastern cottontail rabbit

Order Proboscidea

Elephas primigenius	Mammoth
Mammut americanus	American mastodon

Order Carnivora

Canis familiaris	Domestic dog
Canis latrans	Coyote
Felis silvestris	Domestic cat
Lutra canadensis	River otter
Mustela vison	Mink
Procyon lotor	Northern raccoon
Urocyon cinereoargenteus	Gray fox
Vulpes vulpes	Red fox

Order Pinnipedia

Phoca vitulina	Harbor seal

Order Artiodactyla

Bos taurus	Domestic cow
Cervalces scotti	Stag-moose
Odocoileus virginianus	White-tailed deer
Rangifer tarandus	Caribou

Order Primata

Homo sapiens	Human (modern)

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XVIII. Epilogue

Mature Atlantic white-cedar (*Chamaecyparis thyoides*).

XVIII. Epilogue

The Atlantic white-cedar forests that once covered much of the Hackensack Meadowlands are gone—a casualty of centuries of logging followed by alteration and degradation of the remaining landscape. Water and land use throughout the Hackensack River watershed not only makes restoration of Atlantic white-cedar forests an unrealistic goal but also threatens remaining fish and wildlife resources. Still, the loss of the Atlantic white-cedars will be instructive if we can learn to value, restore, and protect the Meadowlands ecosystem.

Challenges to the restoration of the Meadowlands include dams, reservoirs, diverted and regulated river flows, nutrient-enriched sewage effluents, widespread and localized contamination, a fragmented landscape, and invasive species. Despite these challenges, the Meadowlands remains an oasis of biological diversity in one of the largest urban centers in the northeastern United States.

Historian Stephen Marshall (2004) has delineated four stages of human ecological modification in the Meadowlands: extraction of natural resources, diversion of water flow, reclamation and development, and degradation. To these stages we now propose to add a final stage—restoration.

Restoring the Meadowlands will require *stakeholders working together with:*

(1) strengthened organizational, scientific, and legal tools;
(2) long-term commitments from federal, State, and municipal governments;
(3) strong public support; and
(4) a shared vision.

Atlantic white-cedar in south Jersey (left and above)

Atlantic white-cedar trees and stumps at low tide off the Mill Creek Nature Trail in Secaucus, NJ.

APPENDIX A

DESCRIPTIONS OF KEY FEDERAL LAWS, EXECUTIVE ORDERS, AND POLICIES RELEVANT TO ACTIVITIES OF THE U.S. FISH AND WILDLIFE SERVICE IN THE HACKENSACK MEADOWLANDS

1. Fish and Wildlife Coordination Act of 1934
2. Endangered Species Act of 1973
3. Migratory Bird Treaty Act of 1918
4. Federal Water Pollution Control Act of 1972 (Clean Water Act of 1977, including the National Estuary Program)
5. Rivers and Harbors Appropriation Act of 1899
6. National Environmental Policy Act of 1969
7. Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (Superfund)
8. Resource Conservation and Recovery Act of 1976
9. Emergency Wetlands Resources Act of 1986
10. North American Wetlands Conservation Act of 1989 (including the North American Waterfowl Management Plan) and the Neotropical Bird Conservation Act of 2000
11. Coastal Wetlands Planning, Protection and Restoration Act of 1990
12. Magnuson-Stevens Fishery Conservation and Management Act of 1976 and the Sustainable Fisheries Act of 1996
13. Coastal Zone Management Act of 1972 and the Coastal Zone Management Improvement Act of 1980
14. Department of Transportation Act of 1966
15. U.S. Fish and Wildlife Service Mitigation Policy
16. Executive Order 11988 on Floodplain Management
17. Executive Order 11990 on Protection of Wetlands
18. Executive Order 13112 on Invasive Species
19. Executive Order 13186 on Migratory Birds
20. Literature Cited

APPENDIX A. DESCRIPTIONS OF KEY FEDERAL LAWS, EXECUTIVE ORDERS, AND POLICIES RELEVANT TO ACTIVITIES OF THE U.S. FISH AND WILDLIFE SERVICE IN THE HACKENSACK MEADOWLANDS.

The following federal resource laws, executive orders, management plans, and policies provide the capability for most U.S. Fish and Wildlife Service (Service) involvement in the Hackensack Meadowlands. See the *Digest of Federal Resource Laws of Interest to the U.S. Fish and Wildlife Service* (U.S. Fish and Wildlife Service, 2003) for more descriptive information of the laws and other materials noted below.

1. Fish and Wildlife Coordination Act of 1934

Included under the auspices of the Fish and Wildlife Coordination Act (FWCA; 48 Stat. 401, as amended; 16 U.S.C. 661 *et seq.*) is the capability for the Service's involvement in evaluating impacts to fish and wildlife from proposed federally funded or permitted water resource and associated land development projects (*i.e.*, projects that divert, control or modify the flow of water in any way). This Act requires federal agencies that construct, license, or permit water resource development projects to consult first with the Service (and the National Marine Fisheries Service [NMFS] in some instances) and the State fish and wildlife agency (in New Jersey, the New Jersey Department of Environmental Protection's Division of Fish and Wildlife) regarding the impacts on fish and wildlife resources and measures to mitigate these impacts. The 1958 amendments to the FWCA require that fish and wildlife resources receive equal consideration to other project features and require full consideration of Service recommendations.

2. Endangered Species Act of 1973

The Endangered Species Act of 1973 (ESA; 87 Stat. 884, as amended; 16 U.S.C. 1531 *et seq.*) is widely regarded as one of the most comprehensive wildlife conservation laws in the world. The Act's major purposes include: (1) conservation of ecosystems upon which threatened and endangered species of fish, wildlife, and plants depend, and (2) recovery of populations of endangered and threatened species. Endangered species face likely extinction throughout all or a significant portion of their range, whereas threatened species may become endangered in the foreseeable future. Under the ESA, the Service has primary responsibility for terrestrial and freshwater species, and the NMFS is primarily responsible for marine fishes, sea turtles, and marine mammals.

The ESA, widely regarded as a complex yet flexible law, includes a number of key provisions. Most importantly, Section 6 encourages states to develop programs to manage federally listed species, whereas Section 7 requires federal agencies to ensure that any action authorized, funded or carried out by them is not likely to jeopardize the continued existence of listed species or modify any designated critical habitat. Section 9 prohibits the "take" of a listed species: "take" is defined to include significant modification or degradation of habitat or disruption of essential activities (*e.g.*, feeding, sheltering, breeding).

3. Migratory Bird Treaty Act of 1918

The Service is authorized by more than 25 primary conventions, treaties, and laws to ensure the conservation of migratory birds and their habitats. Foremost among these laws, the Migratory Bird Treaty Act of 1918 (MBTA; 40 Stat. 755, as amended; 16 U.S.C. 703-712) implements various international treaties and conventions with other countries to protect migratory birds, and establishes a federal prohibition (except when permitted consistent with regulations) to pursue, kill, or possess any migratory bird, or any part, nest, or egg of any such birds. Various provisions in the MBTA identify prohibited actions (*e.g.*, attempt to pursue, barter for, export), penalties (*e.g.*, forfeiture of equipment, fines), and authorizations to establish regulations (*e.g.*, Migratory Bird Hunting [50 CFR Part 20]) for hunting migratory game birds.

The MBTA also prohibits the incidental take of migratory birds. In a significant first step to reduce the 100 million to 1 billion birds estimated to be killed by buildings and other structures (Klem, 1990), the Service's (2004) *Blueprint for the Future of Migratory Birds: Migratory Bird Program Strategic Plan 2004-2014* has identified evaluation of human-caused mortality (*e.g.*, buildings, lighting, landscape fragmentation) as a research priority. The Service currently provides interim technical guidelines to reduce such mortality (*e.g.*, the 4 to 5 million birds killed annually by communication towers; U.S. Fish and Wildlife Service, 2000).

4. Federal Water Pollution Control Act of 1972 (Clean Water Act of 1977, including the National Estuary Program)

In its comprehensive 1977 amendments, the Federal Water Pollution Control Act of 1972 (33 U.S.C. 1251 *et seq.*) was renamed the Clean Water Act (CWA) and strengthened to maintain and restore the chemical, physical and biological integrity of the nation's waters. Primary authority for implementation of the CWA rests with the U.S. Environmental Protection Agency (EPA); however, Section 404 (33 U.S.C. 1344 *et seq.*) generally requires permit authorization from the U.S. Army Corps of Engineers (Corps) for the discharge of dredged or fill material in United States' waters, including tidal areas within the Hackensack Meadowlands District. Section 401 (33 U.S.C. 1341) requires a state water quality certificate for any federally licensed or permitted activity that results in discharge of a pollutant, whereas Section 402 (33 U.S.C. 1342) established the National Pollution Discharge Elimination System with both permit and planning components. The Service coordinates with the Corps and EPA pursuant to the FWCA (see above) on projects requiring a federal permit pursuant to the CWA.

Section 320 (33 U.S.C. 1330) established the National Estuary Program, a consensus-based program to protect and restore the Nation's estuaries. The New York-New Jersey Harbor estuary was among the first estuaries to be designated by this program. Unlike traditional regulatory approaches, the National Estuary Program targets a broad range of issues and partners within local communities to develop and implement Comprehensive Conservation and Management Plans to protect the resources in each designated estuary and its watershed. This program focuses on improving water quality in the estuary and on maintaining ecosystem integrity. This includes not only its chemical, physical and biological parameters, but also its economic, recreational, and aesthetic values. A key component of the program is the building of partnerships of stakeholders

including state and local governments, citizens, industry, academia, environmental groups, and commercial interests.

5. Rivers and Harbors Appropriation Act of 1899

The Rivers and Harbors Appropriations Act of 1899 (30 Stat. 1151, as amended; 33 U.S.C. 403 *et seq.*) governs the placement of structures in navigable waters of the United States. Section 9, administered by the U.S. Coast Guard, regulates the construction of bridges and dams, whereas Section 10, administered by the Corps, regulates construction of any other structure (*e.g.*, pier, bulkhead, jetty) in any port, harbor, canal, navigable river, or other waters of the United States. The Corps may authorize the activities by issuance of a federal permit, but only after coordination with the Service, other federal resource agencies, and state fish and wildlife agencies pursuant to the FWCA (see above) and other applicable authorities.

6. National Environmental Policy Act of 1969

The National Environmental Policy Act of 1969 (NEPA; 83 Stat. 852; 42 U.S.C. 4321 *et seq.*) establishes the fundamental, national charter for protection of the environment. The NEPA is intended to ensure that information about environmental effects of a proposed major federal action and alternative actions are available to agency decision makers and requires that federal agencies present this information in an Environmental Assessment or an Environmental Impact Statement (EIS). An EIS is required for "every recommendation or report on proposals for legislation and other major federal actions significantly affecting the quality of the human environment." A key provision of NEPA is the requirement to consider alternative projects and/or actions. The Service may provide information for use in NEPA documents and also provides review comments on these documents. Through this process, the Service seeks to ensure that: (1) primary, secondary, and cumulative impacts to fish and wildlife resources are adequately described for each alternative that would fulfill the purpose and need for the action; (2) efforts are made to avoid, minimize, and rectify impacts to fish and wildlife resources; and (3) appropriate compensation for unavoidable impacts to fish and wildlife resources is made with the recommended plan.

7. Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (Superfund)

Administered primarily by the EPA, the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (P.L. 96-510; 26 U.S.C. 4611-4682; as amended by the Superfund Amendment and Reauthorization Act of 1986, P.L. 99-499; 42 U.S.C. 9601 *et seq.*) seeks to remediate sites where toxic and hazardous wastes have been deposited or spilled. The original act authorized the collection of taxes (through 1985) on crude oil and petroleum products, certain chemicals, and hazardous wastes, and established liability to the United States Government for damage to natural resources over which the United States has sovereign rights. In the 1986 re-authorization, amendments mandated that: (1) federal officials be designated as trustees for natural resources and assess damages and injury to, as well as destruction of, or loss of, natural resources; (2) stipulated that Superfund monies only be used for natural resource damage claims if all administrative and judicial remedies to recover costs from liable parties have been exhausted; (3) federal facilities are subject to the same cleanup requirements and liability standards as non-

governmental entities; (4) federal trustees be notified of any settlement negotiations regarding damages to natural resources; and (5) established circumstances under which federal trustees may agree not to sue for natural resource damages. The Department of the Interior is a trustee for natural resources, and the Service is responsible for the protection and restoration of trust resources injured by uncontrolled releases of hazardous materials. The Service is responsible for conducting assessments to establish injury and the dollar equivalent of that injury for collection of damages from parties responsible for releasing hazardous materials. Via the EPA's Biological Technical Assistance Group, the Service's Division of Environmental Contaminants also provides technical assistance in the form of information, data, and guidance to the EPA to ensure that site remediation protects federal trust fish and wildlife resources.

8. Resource Conservation and Recovery Act of 1976

The Resource Conservation and Recovery Act of 1976 (P.L. 94-580; 42 U.S.C. 6901-6992; 90 Stat. 2795; as amended) regulates the treatment, transportation, storage, and disposal of solid and hazardous wastes. Key provisions include: (1) the identification and listing of hazardous waste, (2) standards applicable to hazardous waste, (3) requirements for reporting hazardous waste and for permitting storage, transport, and disposal of hazardous waste, (4) management of landfills and other solid waste, (5) management, replacement, and monitoring of underground storage tanks, (6) the applicability of federal, State, and local laws to federal agencies, and (7) citizen suits, judicial review, and enforcement authority.

9. Emergency Wetlands Resources Act of 1986

Congress, recognizing the integral role of wetlands in maintaining the quality of life through material contributions to our food supply, water supply and quality, flood control, fish, wildlife, and plant resources, and thus to the health, safety, recreation, and economic well-being of all citizens of the United States, enacted the Emergency Wetlands Resources Act of 1986 (EWRA; P.L. 99-645) to promote the conservation of wetlands. The EWRA directed the Department of the Interior to develop a national wetlands data base (including maps; *e.g.*, U.S. Fish and Wildlife Service, 2005a), report to Congress on the status and trends of wetlands within the contiguous United States, and develop a National Wetlands Priority Conservation Plan identifying the priority wetlands for acquisition by federal, state, and local agencies using the Land and Water Conservation Fund.

Wetlands reports generated pursuant to EWRA have become important tools in assessing wetlands trends and assessing government policies and management of wetlands. Early wetlands status and trends reports (*e.g.*, Dahl, 1990) documented the extensive losses of wetlands since colonial times and during the first half of the past century. Subsequent reports, generated every 10 years as required by EWRA, not only report trends in wetlands losses, but characterize the kinds and causes of wetlands losses. Wetlands within the Hackensack Meadowlands have been designated as "priority wetlands" by the Service, in accordance with the EWRA. Trends in wetlands losses in the Meadowlands since the mid 1960s (Tiner *et al.*, 2002) largely paralleled trends in wetlands losses for the entire nation (Dahl and Johnson, 1991; Dahl, 2000) until 2003, when nearly 60 acres were filled pursuant to a Corps permit (a 300 percent rate increase in the annual loss compared to the previous decade).

10. North American Wetlands Conservation Act of 1989 (including the North American Waterfowl Management Plan) and the Neotropical Bird Conservation Act of 2000

The North American Wetlands Conservation Act (NAWCA; 103 Stat. 1968; 16 U.S.C. 4401-4412; P.L. 101-233) provides funding and administrative direction for implementation of the North American Waterfowl Management Plan and the Tripartite Agreement on wetlands between Canada, the U.S., and Mexico. The NAWCA established a North American Wetlands Conservation Council, composed of the Service's Director, the Executive Director of the National Fish and Wildlife Foundation, and representatives from state fish and wildlife agencies in each flyway and three non-profit organizations, to make recommendations for NAWCA-funded projects.

The North American Waterfowl Management Plan was established to conserve our continent's remaining wetlands and increase migratory bird populations with NAWCA appropriations. This international effort provides the following funding initiatives: (1) a large matching-grants program, with up to $1 million per project in federal funds, to manage, restore and/or acquire land, through purchase or easement; and (2) a small-grants program, with up to $50,000 per project in federal funds, to encourage new partnerships. Currently, 16 large projects known as Joint Ventures (U.S. Fish and Wildlife Service, 2005b), are funded though this program in the United States and other countries.

The Atlantic Coast Joint Venture initially focused on protecting and restoring habitat for black duck (*Anas rubripes*) and other waterfowl along the east coast (U.S Fish and Wildlife Service, 2005c), but later expanded to include conservation of other bird groups. Its regional plans, developed by different groups of public and private agencies, organizations, and stakeholders, now include a focus on waterbirds (Waterbird Conservation for the Americas, 2005), shorebirds (U.S. Shorebird Conservation Plan, 2005), and neotropical migrant landbirds (Partners in Flight, 2004). The Service's Office of Migratory Bird Management and relevant Regional Offices are partners in these regional planning efforts. The Hackensack Meadowlands is located on the Atlantic Flyway at the juncture of three physiographic areas (Southern New England, Mid-Atlantic Coastal Plain, and Mid-Atlantic Piedmont) for which specific plans are developed.

The Neotropical Migratory Bird Conservation Act of 2000 (P.L. 106-247) provides grants to agencies, international organizations, and individuals for the conservation of neotropical migratory birds that spend the winter season in Latin America and the Carribean and the summer season in North America. The law creates a competitive grants program to be administered by the Secretary of Interior, through the Director of the U.S. Fish and Wildlife Service. The law encourages habitat protection, education, researching, monitoring, and capacity building to provide for the long-term protection of neotropical migratory birds.

11. Coastal Wetlands Planning, Protection and Restoration Act of 1990

The Coastal Wetlands Planning, Protection and Restoration Act of 1990 (16 U.S.C. 3951-3956) supports and funds coastal wetlands restoration and conservation projects. This Act requires the Service to make matching grants of 50 to 75 percent of project costs, under the National Coastal Wetlands Conservation Grants Program, to any coastal state to carry out coastal wetlands conservation projects that will be administered for the long-term conservation of lands, waters, and

dependent fish and wildlife. Nationwide, recent grants have ranged from $10,000 to $1 million. The Act also authorizes the Corps to carry out projects for the protection, restoration, or enhancement of aquatic and associated ecosystems; the Corps must give projects that protect, restore, or create wetlands and coastal ecosystems equal consideration with projects relating to irrigation, navigation, or flood control. To date, National Coastal Wetlands Conservation Grants have been used to acquire property in the NY-NJ Harbor Estuary but not within the Hackensack Meadowlands.

12. Magnuson-Stevens Fishery Conservation and Management Act of 1976 and the Sustainable Fisheries Act of 1996

The Fishery Conservation and Management Act of 1976 (P.L. 94-265; 16 U.S.C. 1801-1882; 90 Stat. 331; as amended) provides for management of fish and other species within the 200-mile Exclusive Economic Zone under plans drawn up by eight Regional Councils comprised of federal and State officials (including the U.S. Fish and Wildlife Service) and reviewed and approved by the Secretary of Commerce. Major amendments to the Act (the Sustainable Fisheries Act, P.L. 104-297) made important changes in federal efforts to conserve and manage marine fishery resources. The Act mandated NMFS' identification of Essential Fish Habitat (EFH) for managed species as well as measures to conserve and enhance the habitat necessary to fish to carry out their life cycles. The Sustainable Fisheries Act requires cooperation among the NMFS, Regional Councils, fishing participants, federal and State agencies, and others in achieving Essential Fish Habitat protection, conservation, and enhancement. Other provisions included requirements of the Regional Councils to: (1) minimize bycatch (the incidental harvest of non-targeted marine species) and its mortality, (2) identify overfished species and actions to rebuild those stocks, and (3) require research on fishery management and conservation and on the economics and social characteristics of fisheries.

13. Coastal Zone Management Act of 1972 and the Coastal Zone Management Improvement Act of 1980

The Coastal Zone Management Act of 1972 (CZMA; P.L. 92-583; 86 Stat. 1280; 16 U.S.C. 1451-1464; as amended) established a voluntary national program within the Department of Commerce's NOAA to encourage coastal states to develop and implement coastal zone management plans. Funds were authorized for cost-sharing grants to states to develop their plans. Subsequent to federal approval of their plans (certification for consistency with the CZMA), grants would be awarded to implement the plans. In order to be eligible for Federal approval, each state's plan is required to: (1) define boundaries of the coastal zone, and (2) identify uses of the area to be regulated by the state, the mechanism (criteria, standards or regulations) for controlling such uses, and broad guidelines for priorities of uses within the coastal zone. Currently, the NJMC's 2004 Master Plan has not been formally submitted to NOAA for certification of consistency with the CZMA.

Subsequent amendments have established additional programs for coastal areas. The Coastal Zone Management Improvement Act of 1980 (P.L. 96-464) established a new system of Resource Management Improvement Grants related to preservation of certain coastal areas, redevelopment of urban waterfronts, and public access to beaches. Subtitle D of the Consolidated Omnibus Budget Reconciliation Act of 1985 (P.L. 99-272) established the National Estuarine Reserve Research System (a state-federal process for designating national reserves) and guidelines for estuarine

research. Consistency provisions of the CZMA were amended as part of the Omnibus Budget Reconciliation Act of 1990 (P.L. 101-508) to require that "any federal activity within or outside of the coastal zone that affects any land or water use or natural resource of the coastal zone" shall be "consistent to the maximum extent practicable with the enforceable policies" of a State's coastal zone management plan. The new law also established a new Enhancement Grants Program for specific areas, including protecting, restoring or enhancing existing coastal wetlands or creating new coastal wetlands and assessing the cumulative effects of coastal development on coastal wetlands and fishery resources. In addition, this statute has established a new Coastal Nonpoint Source Pollution Control Program and increased the financial assistance for land acquisition under the National Estuarine Research Reserve System.

14. Department of Transportation Act of 1966

Amendments to the Department of Transportation Act of 1966 (Policy on lands, wildlife and waterfowl refuges, and historic sites, 49 U.S.C. 303) require special effort to preserve the natural beauty of the countryside and public park and recreation lands, wildlife and waterfowl refuges, and historic sites. Section 4(f) of the Act requires the Secretary of Transportation to cooperate and consult with the Secretaries of Interior and other federal land-management agencies in developing transportation plans and programs that include measures to maintain or enhance the natural beauty of lands crossed by transportation activities or facilities. The Secretary of Transportation may approve a transportation program or project (other than any project for a park road or parkway under 23 U.S.C. 204) requiring the use of publicly owned land of a public park, recreation area, or wildlife and waterfowl refuge of national, State, or local significance only if: (1) there is no prudent and feasible alternative to using that land; and (2) the program or project includes all possible planning to minimize harm to the park, recreation area, wildlife and waterfowl refuge, or historic site resulting from the use.

15. U.S. Fish and Wildlife Service Mitigation Policy

The Service's Mitigation Policy (*Federal Register*, Vol. 46, No. 15, January 23, 1981) establishes guidance for Service personnel to make consistent and predictable recommendations on mitigating adverse impacts of land and water use and development on fish, wildlife, and their habitats. The policy also allows other agencies and the regulated public to anticipate Service recommendations and incorporate mitigative measures into the early stages of project planning. This policy was established in accordance with key federal authorities (*e.g.*, FWCA, NEPA). Most importantly, the Mitigation Policy makes clear the Service's adoption of the NEPA definition of mitigation in the following sequence: (1) avoiding the impacts, (2) minimizing the impacts, (3) rectifying the impacts, (4) eliminating the impacts over time, and (5) compensating for the impacts. This policy also established mitigation goals dependent upon resource quality, with more stringent mitigation recommended for the more valuable and/often uncommon resources. The Service adheres to its Mitigation Policy when commenting on a Public Notice for a regulated activity in the Meadowlands and in its member role with the Meadowlands Interagency Mitigation Advisory Committee.

16. Executive Order 11988 on Floodplain Management

The purpose of Executive Order (EO) 11988, signed May 24, 1977, is to prevent federal agencies from contributing to the "adverse impacts associated with the occupancy and modification of floodplains" and the "direct or indirect support of floodplain development." This EO requires federal agencies to "take action to reduce the risk of flood loss, to minimize the impact of floods on human safety, health and welfare, and to restore and preserve the natural and beneficial values served by floodplains." Before proposing, conducting, supporting or allowing any action in a floodplain, each federal agency must determine if proposed activities will affect the floodplain and evaluate the potential effects of the intended actions on its functions. The EO requires federal agencies "to avoid adverse effects and incompatible development in floodplains." This EO applies to federal agencies that are (1) acquiring, managing, and disposing of federal lands and facilities; (2) providing federally undertaken, financed, or assisted construction and improvements (including restoration projects, such as the Hackensack Meadowlands Environmental Restoration [U.S. Army Corps of Engineers, 2003]); and (3) conducting federal activities and programs affecting land use, including but not limited to water and related land resources planning, regulating, and licensing activities.

17. Executive Order 11990 on Protection of Wetlands

Executive Order 11990 (signed May 24, 1977) requires federal agencies to avoid to the extent possible the long- and short-term adverse impacts associated with the destruction or modification of wetlands and to avoid direct or indirect support of new construction in wetlands wherever there is a practicable alternative. The EO applies to federal agencies that are (1) acquiring, managing, and disposing of federal lands and facilities; (2) providing federally undertaken, financed, or assisted construction and improvements; and (3) conducting federal activities and programs affecting land use, including but not limited to water and related land resources planning, regulating, and licensing activities. The EO does not apply to the issuance by federal agencies of permits, licenses, or allocations to private parties for activities involving wetlands on non-federal property.

18. Executive Order 13112 on Invasive Species

The purposes of this EO (signed February 3, 1999) are to prevent the introduction of invasive species (*e.g.*, common reed; purple loosestrife), provide for their control, and minimize the economic, ecological, and human health impacts of invasive species. Federal agencies whose actions may affect the status of invasive species shall: (1) identify such actions, (2) use relevant programs and authorities to prevent, control, monitor, and research such species, and (3) not authorize, fund, or carry out actions that are likely to cause or promote the introduction or spread of invasive species in the United States or elsewhere. This EO also established a National Invasive Species Council (2004), of which the Secretary of Interior serves as Co-Chair, to provide national leadership regarding invasive species. The Council develops and implements a *National Invasive Species Management Plan* (National Invasive Species Council, 2001) to coordinate complementary, cost-efficient, and effective actions by federal agencies to achieve performance-oriented goals and objectives and specific measures of success regarding invasive species.

19. Executive Order 13186 on Migratory Birds

This EO (signed January 10, 2001) directs each federal agency taking actions that negatively affect migratory birds to develop a Memorandum of Understanding (MOU) with the Service to promote the conservation of migratory bird populations. Although no such MOUs have been completed to date, the EO encourages each federal agency to immediately begin implementing 15 identified categories of conservation measures as appropriate and practicable. Some of these categories of conservation activities include: (1) avoiding and minimizing adverse impacts on migratory bird resources when conducting agency actions; (2) restoring and enhancing the habitat of migratory birds; (3) preventing or abating the pollution or detrimental alteration of the environment for the benefit of migratory birds; (4) designing migratory bird habitat and population conservation principles, measures, and practices, into agency plans and planning processes, and coordinating with other agencies and nonfederal partners in planning efforts; and (5) promoting research and information exchange related to the conservation of migratory bird resources, including coordinated inventorying and monitoring and the collection and assessment of information on environmental contaminants and other physical or biological stressors having potential relevance to migratory bird conservation.

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APPENDIX B

NEW JERSEY DIVISION OF FISH AND WILDLIFE AND U.S. FISH AND WILDLIFE SERVICE (2002) VISION PLAN FOR THE HACKENSACK MEADOWLANDS

A Vision Plan

Presented by
The New Jersey Division of Fish and Wildlife
and the
U.S. Fish & Wildlife Service

The Hackensack Meadowlands is a complex of wetlands, forests, and fields along the lower Hackensack River. This unique area supports an astonishing number of raptors, ducks, geese, wading birds, other migratory birds, fish, reptiles and amphibians. It is an oasis in the midst of one of the most densely populated areas in the United States. This 8,400-acre area is the largest remaining brackish wetland complex in the New York / New Jersey Harbor Estuary.

Unfortunately, however, the Meadowlands has problems. This mixture of land and water so rich in natural resources has been the center of a growing human population for the last 300 years. Consequently, development pressure, pollution, and ignorance have led to the degradation and destruction of this area, which threatens the health and vitality of fish and wildlife. But now there is an opportunity to save and restore the Meadowlands.

Contamination can be eliminated and cleaned up. Fill can be removed and areas restored to wetlands. Tidegates can be removed to restore a more natural hydrology. Lands can be acquired and conservation easements obtained to prevent over-development and provide wildlife habitat and public recreation opportunities. Invasive and exotic species can be controlled and areas restored to natural conditions. Citizens can work together to protect the integrity of the Meadowlands. Saving this unique habitat will require the cooperation and meaningful involvement of all stakeholders—municipal, state and federal agencies, local and national environmental groups, and the people of New Jersey and New York. Taking the right steps now can ensure a future of clean water to our communities, flourishing plant, fish, and wildlife populations, and outdoor recreational opportunities for more than 14 million people.

Any environmental protection plan for the Meadowlands must recognize that government agencies alone cannot achieve sustained environmental improvements. The cumulative effects of the day-to-day decisions made by millions of people who live, work, and play in the Hackensack River watershed can greatly outweigh the environmental benefits of a particular government program. The approach for developing a long-term plan must be to operate both individually and collectively. Instead of simply controlling problems or mitigating the impacts of our actions on the environment, all parties must work to avoid problems from the start to improve the current condition of the Meadowlands. Through our cooperative efforts, each stakeholder and interest group, as well as all levels of government, have an opportunity and an obligation to help find a solution for making the Meadowlands an example of our collective commitment to natural resource stewardship.

Goals for the Meadowlands:
1. Improve conditions for all native plant, fish and wildlife species.
2. Clean up contaminated sites and reduce the effects of pollution on fish and wildlife resources.
3. Acquire, preserve, and restore remaining undeveloped tracts of land to key functioning parts of the Meadowlands ecosystem (*e.g.*, removal or replacement of tide gates with structures that close only on extremely high tides to allow more normal tidal flow and fish passage). Preserve and restore vegetated wetland and upland corridors connecting both small and large tracts that are necessary to connect populations of less mobile species and increase the habitat value of formerly isolated tracts.
4. Control invasive and exotic species.
5. Enhance, restore, and maintain ecosystem integrity, including natural dynamic processes (*e.g.*, successional patterns, natural disturbance regimes, hydrologic processes, nutrient cycles, predator-prey associations).
6. Increase public awareness and education about the Meadowlands and its regional importance through an expanded number of public access points within the Meadowlands, and by encouraging increased but ecologically responsible use of these public facilities.

Tasks to be Accomplished:
1. Develop long-term management options for fish and wildlife species and native plant communities.
2. Build a stakeholder coalition of agencies and citizens to spearhead the protection, restoration and management of the Hackensack Meadowlands. Define roles and responsibilities of groups and move forward on Memoranda of Understandings.
3. Prioritize sites for acquisition and begin protecting lands either through fee title or conservation easements. Seek funding for priority acquisitions. Contact landowners to identify willing sellers.
4. Identify contaminated sites, determine the source and extent of contamination, and estimate the costs of remediation options.
5. Identify sites with restoration potential. Begin collaborating with natural resource agencies, local universities and environmental groups to explore methods and timing.
6. Create opportunities for public use and education targeting urban populations that often have limited outdoor recreation options or experience.

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