The History and Science of Managing the Hudson River

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INTRODUCTION

Each year, many decisions are made that involve the utilization and conservation of Hudson River natural resources, or involve projects that impact those resources. Collectively these decisions constitute the *management* of the Hudson River. Regardless of the magnitude and scope of the project or action, each decision exhibits the same common characteristics: it is made by a governmental body in the face of some degree of uncertainty, contention and public expense. While some management activities are carried out by private organizations, all actions or projects invariably result from government sponsorship and a regulatory or legal decision to proceed. Decisions are made at various governmental levels, from municipal to federal, and the consequences of these actions can affect river resources at local or regional geographic scales.

For nearly four centuries humans have been affecting river resources, with the most profound human influences occurring during the last 150 years. Responding to economic and social needs of a growing population, commercial navigation channels were dredged, dams were constructed, industries blossomed, forests were cleared for agriculture and wetlands were filled to create new land. By the end of the 19th century, the Erie Canal was completed, navigation channels throughout the Hudson River were dredged, dikes were built along the banks of the Hudson to increase the "rise of the tide at Albany and Troy" (Klawonn, 1977), the population within the watershed had risen to over 3 million (Hetling et al, 2003), and vast amounts of raw sewage from that growing population were discharged to the river. Changes to the biological, chemical, and physical makeup of the Hudson caused by human intervention escalated during the 20th century leading to pioneering programs in New York State, such as Governor Nelson Rockefeller's Pure Waters Bond Act of 1965, and of important pieces of federal environmental legislation from 1969 through 1972.

Today more than ever, there is a tremendous awareness of all the Hudson River has to offer. Besides the ongoing use of resources for human use, there is a growing appreciation that the river is part of the fabric and culture of the region. As its mysteries are unlocked through scientific observation and personal contact, the river's ecosystem is increasingly being celebrated and embraced as a friendly and valued neighbor. Fortunately, great strides have been made over the past 30 years to

clean up and restore the river, but much remains to be done. Goals have been established through several government initiatives to preserve that relationship. But are these goals realistic and will they be achieved? Have we learned important lessons from the past? Are there mechanisms in place or contemplated for the future to effectively *manage* the river? How do we enhance our understanding of the river and use that knowledge to make the best decisions possible?

HISTORY OF ENVIRONMENTAL MANAGEMENT

Major Environmental Concerns and Jurisdictions

The intricate matrix of governmental institutions, nongovernmental organizations and multiple and multidisciplinary issues involved greatly complicates environmental management in the U.S. The U.S. Constitution vests considerable authority and responsibility at the state level, and only in cases where what happens in one state affects another or has national implications does the federal government readily exercise major authority. Of course, since many environmental policy issues clearly transcend state borders, such as air and water pollution, they do appropriately fall under federal jurisdiction. However, inasmuch as land use is now regarded to be an important determinant of environmental quality at a larger scale, many have advocated stronger land-use planning legislation. Others view this as inconsistent with state sovereignty, New York State's strong tradition of home rule and traditional American values of individual property ownership. Some threatened private interests have strongly opposed any authority seeking to regulate their lands, such as for example, by invoking the "takings clause" of the 5th Amendment in the courts.

In the early days of the Union, scant attention was paid to environmental legislation or regulation. Promoting economic and political well-being were the principal concerns. With time, states started to take an interest in stewardship of resources and began to evince concern for pollution and land-use issues. As it became more obvious to Congress that environmental issues often transit state boundaries, an increasing federal role developed, but even today, the federal government has shown reluctance to involve itself in issues of land-use planning and management, which many believe lie at the core of environmental stewardship. Thus, until recently, the federal role in non-point source pollution management and regulation of non-tidal wetlands has very much remained within the purview of an individual state, and the different states, in turn, vest differing levels of authority to state

and municipal agencies.

As will be discussed below, one of the earliest environmental concerns in New York State related to land-use, and even there, the matter required the State to establish its own authority over local entities by legislation creating the Adirondack Park. The history of home rule is well established in New York, and accordingly, land use is very much relegated to local authority (Kleppel, 2002; Nolon, 1999) leading to a patchwork approach to management of the landscape.

One might conveniently divide the major environmental concerns into the following groupings:

1. *Point and non-point source pollution*. Nutrients, sewage solids and toxic wastes from publicly-owned sewerage facilities and industries now come under state and federal controls. Runoff from the land, atmospheric deposition, both of nutrients and toxic compounds have largely been local and state concerns until the most recent reauthorization of the Clean Water Act.
2. *Disposal of solid wastes and dredged material*. Solid wastes from households and industry, sludge from sewage treatment plants, and sediments dredged from harbors and rivers must all be disposed of. A variety of federal and state laws pertain.
3. *Land-use*. To the extent that land-use affects nonpoint pollution, land use falls under the previous grouping and the pertinent federal and state legislation. To the extent that land-use affects the ecological communities on them and their biological integrity, it has generally been left up to the local planning and zoning boards in New York to exercise primary authority.
4. *Recovery of polluted areas*. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, PL 96-510, enacted in 1980*)*, commonly known as "Superfund," was enacted by Congress in 1980 to eliminate the health and environmental threats posed by hazardous waste sites. This law is highly pertinent to contaminated areas in the Hudson River Valley.
5. *Resource use*. The planning, implementation and regulation of projects and activities, including navigation, fisheries, biodiversity, water supply, power generation and a wide variety array of commercial and recreational uses. Both state and federal authority pertain.

Hudson River Environmental History

Although a complete environmental history of the Hudson River and surrounding areas is well beyond consideration in this paper, we provide here an overview of key issues and events that have had particular bearing on either the management of the river or in a larger sense, on environmental policy in the U.S. We divide this history into two major periods, the first being prior to the 1960's when issues for the Hudson and its watershed focused legislative and managerial action primarily at the state level, and the second being from the late 1960's to the present, when the Hudson figured heavily in changing the course of environmental management at the national level. Table 1 summarizes environmental concerns and issues, institutional drivers and economic drivers of management and policy.

Early history: Before the 1960's

While the most vexing environmental problems we now face, such as the clean up of toxic materials, are clearly rooted in post-Industrial Age technological developments, early colonial activities nonetheless began to have profound effects on the landscape and these, in turn, affected the Hudson River itself. In 1609, as he navigated up the river that is now his namesake, Captain Henry Hudson was impressed with the extensive, dense forest he saw along the entire route, and he noted in his log that it "abounds in trees of every description" (Boyle, 1969). Farming settlements were established on both sides of the River after 1630 (Howe, 2002). Within 100 years, much of the land from the River's eastern bank to the Atlantic Ocean would be substantially cleared (e.g. Foster et al. 1998) to provide fuel for winter heat, lumber for the construction of dwellings, farm buildings and ships, and open land suitable for cultivation. Within the next 100 years, an expansion westward would extend similar effects through the Mohawk Valley, and by 1825 the completion of the Erie Canal would further accelerate westward development. Shortly thereafter, deforestation occurred even in remote mountainous areas of the Hudson's watershed (Stanne et al. 1996).

One of the earliest New World developments of commerce and industry focused squarely on technical improvements in transportation, which has historically been one of the most important uses of the Hudson River proper and the land along its banks. Under the able leadership of Governor

DeWitt Clinton, the construction of the Erie Canal (1817-1825) was among the most ambitious public works programs ever undertaken and completed. The canal opened the primary trade route to the Great Lakes and Midwest and lead to the rapid development of New York City as the nation's center of commerce and finance. Along with the Delaware and Hudson Canal, constructed from 1825-1829 to the south, the Erie Canal provided coastal access to the coal fields in Pennsylvania and Ohio; to the fur trade of Canada and Upstate New York; to vast lumber resources for building and fuel; for tannins used to cure leather; to sand, gravel and stone used in the construction industry; and to the rich agricultural resources in the Midwest. The period from 1825-1860 saw substantial regional expansion as the Troy and Albany region contributed to the rapid increase in northeastern manufacturing and transportation (Howe, 2002). In the westward direction, the finest European manufactured products would now make frontier life more bearable for early settlers. Accordingly, it is not surprising that in the earliest days, the governmental role that related to the environment was aimed squarely at enhancing commerce, such as by ensuring that the waterways were passable and navigable.

The visionary inventor-entrepreneur Robert Fulton recognized that steam could be harnessed to propel commercial traffic in reliable, scheduled service, and his steamer, the *Clermont*, took its maiden voyage from New York City to Albany in 1807. The importance of Fulton's steam-powered service cannot be underestimated: not only did it accelerate trade and commerce, but it also created a new demand for fuel to power steam engines, which proliferated rapidly throughout the ensuing Industrial Revolution. In the early days, the source of fuel was invariably wood, and the need for wood fuel along with a demand for tannins obtained from hemlock trees led, in turn, to increase logging pressures throughout the Hudson's watershed (McMartin, 1992). This demand continued to intensify with the development of the railroad, and by the 1860's, the combination of logging for fuel and construction had taken a noticeable toll on the forest resources of the Adirondack and Catskill mountains (Terrie, 1994).

Deforestation in the late 19th century continued until a public outcry from a variety of strange bedfellows led to one of the first major environmental protections in the U.S. In Terrie's (1994, p. 83) words, "The key authors of the Adirondack conservation story were journalists, wealthy businessmen, cut-and-run loggers, government officials, aristocratic hunters and anglers trying to protect their sport,

and transportation interests worried about water levels in the Hudson River." The culminating event was the adoption of state constitutional protection of the Adirondack Park in 1894 as "forever wild," which has made it nearly invulnerable to the whimsy of a governor and legislature.

While science was not the determining factor in the development of environmental legislation to protect the Hudson's watershed, scientific information and advice played an essential role in framing the issues and raising awareness of them. George Perkins Marsh's historic book, *Man and nature; or, Physical geography as modified by human action* (1864), led to a more widespread understanding that mountain forests control runoff, erosion, sediment input and regional microclimate. Verplanck Colvin, who for three decades surveyed the length and breadth of the Adirondacks, reported back trenchantly to the legislature about the steady demise of forested areas. His persistence raised awareness of the immensity of the problem in the halls of power in Albany. Great men of learning of the time, Harvard Professor C.S. Sargent and Dr. F. B. Hough, through their testimony and own publications, gave further credence to the concerns raised by Marsh, Colvin and others.

Irrespective of the voices calling for environmental protection per se, natural resource management efforts during this period were dominated by economic interests (Johnson, 2000), and the Hudson River and watershed continued to experience significant change as a result of economic development and population growth. Public works projects (e.g., navigation channels, hydroelectric power plants, flood control projects, etc.) were designed and constructed to meet economic needs, with little or no consideration of the impacts these activities on river resources, other than navigation. At the turn of the century, the principal objectives for government regulations associated with the lower Hudson River and New York Harbor included: the prevention of the dumping of solid materials into navigation channels by the federal government; the management of a quarantine by New York State to limit the spread of infectious diseases from vessel passengers; and New York City's prevention of "local nuisances along the shore." (Metropolitan Sewerage Commission, 1910)

By the turn of the 19th century, the Port of New York was the busiest and most important in the country (Klawonn, 1977). A vast network of navigation channels and berthing facilities were created in the lower Hudson River and New York Harbor. Disposal of sediments dredged from the construction and maintenance of these channels was problematic. Much of the dredged material was

dumped in sites in the entrance channels to the harbor, creating new navigation hazards. In addition, the lower river and harbor were convenient dumping grounds for street sweepings and construction debris. Because these practices were seriously affecting navigation by clogging shipping channels, the federal 1888 Supervisor of the Harbor Act was enacted to prevent the discharge of solid materials into the harbor and its tributaries. The Act established dumping grounds for dredged material and other materials in areas offshore of the entrance to the estuary. To further prevent hazards, Section 13 (the Refuse Act) of the Rivers and Harbors Act of 1899 was enacted by the U.S. Congress to prevent the discharge of any refuse matter that might impede or obstruct navigation.

By the 1870's landfilling along the banks of the lower Hudson River was a widespread concern. As the Manhattan and New Jersey shorelines grew closer together, changes in sediment deposition patterns followed. While natural depositional patterns caused sediments to accumulate on the New Jersey side of the river, it was believed by some that shoaling had increased by the "artificial" scour produced by the narrowing of the river (Klawonn, 1977). The first federal water legislation was enacted by Congress in 1886 as the River and Harbor Act. Eventually harbor lines were established to guide the placement of bulkheads and piers, and a permit program was established under the amended Rivers and Harbor Act of 1899 to review the placement of materials into navigable waterways which extended beyond the harbor lines, with the U.S. Army Corps of Engineers as the responsible federal agency. These new authorities brought a halt to significant incursions of new land into the lower Hudson River; however, they had little effect on the massive filling of wetlands and mudflats in other areas of the lower estuary (Squires, 1992).

While federal government interest was primarily vested in protecting navigation with good reason, the states and New York City focused attention on public health issues affecting the harbor. The *New York Times* (1890) called the New York City's sewerage system an "abomination" and warned that deposits of sewage sludge accumulating in New York Harbor are "far from being innocuous to the health of the people." The early pollution of the harbor is graphically summarized by Waldman (1999), who terms it "ecological strangulation." In 1903, the New York Bay Commission was created by a special act of the New York State Legislature. The Commission found the harbor to be seriously polluted and recommended that a metropolitan sewerage district be established to deal

with the sewage problem. Following up on the Bay Pollution Commission's recommendations, the New York State Legislature passed the New York Bay Pollution Act of 1906, directing the City of New York to create the Metropolitan Sewerage Commission to devise ways of correcting the sewage problem.

The Commission did a remarkable and comprehensive job of investigating conditions in New York Harbor, which they found to be "more polluted than public health and welfare should allow" (Metropolitan Sewerage Commission, 1910). The results of the Commission's work are contained in several large volumes, published between 1906 and 1914, and include: detailed scientific and engineering investigations; opinions of prominent scientists, engineers and public health officials; and a plan for a new sewerage system for New York City. Its results paved the way for vast improvements to the water quality of the lower Hudson River.

When a problem transcends state boundaries, it falls under federal jurisdiction. However, if there are no federal programs designed to address the issue, states form alliances or compacts with one another to seek solutions. Because interstate alliances and compacts could unduly encroach upon federal authority and violate federal laws, the U.S. Constitution (Article 1, Section 10, Clause 3) requires that states gain Congressional approval before entering into such agreements. Of the 36 interstate compacts authorized by Congress prior to 1921, virtually all were established to resolve rudimentary issues, such as the settlement boundary disputes (Mountjoy, 2003).

Compacts can, however, provide states the freedom to find creative solutions to complex problems of mutual concern, and put the development of those solutions in the hands of the people who are most familiar with the issues (Sundeen and Runyon, 1998). In fact, important and powerful interstate agencies have been created through compacts. The first, and probably the most famous, is the Port Authority of New York and New Jersey, which was established in 1921 to improve port management in the country's largest port. The shoreline and bottom of New York Harbor have been reshaped by port interests, much of which by the Port Authority, as the need for deeper channels and greater wharf space grew throughout the 20th century. After the Port Authority was established, more than 150 other compacts were formed throughout the country over the next 75 years. Their purposes ranged from conservation and resource management to civil defense (Mountjoy, 2003).

In the 1930's, the New York metropolitan region had moved ahead with plans for the abatement of sewage-related problems, with partnerships forming not only between the states of New York and New Jersey, but with the state of Connecticut as well. Because the federal government had little to offer, and because the expertise and funding for developing engineering solutions were at the regional level, a Tri-State Compact was formed. In 1936, the Interstate Sanitation Commission, authorized by the compact, held its first meeting (Interstate Sanitation Commission, 1937). It was given many responsibilities, including developing water quality classifications for the Sanitation District (which generally includes the lower Hudson River, New York Harbor and Long Island Sound), inspection of sewage treatment facilities, enforcement of non-compliance with the compact, technical planning and monitoring. The Commission's work over the years focused attention on the problems created by inadequate sewage disposal systems on New York Harbor and is given large credit for keeping capital improvement projects on track.

From the 1930's through 1968, modest changes were made to the overall management structure affecting the Hudson River Estuary to include the consideration of factors other than public health and navigation. The federal government was gradually assuming more responsibilities in environmental management through new legislation and regulation revision. The Anadromous Fish Conservation Act (PL 89-304) was enacted in 1965 (Limburg et al., this volume), the Corps of Engineers' regulatory program was revised to include a "public interest review" of proposed actions instead of just a review of the project's effects on navigation, the Federal Water Pollution Control Act and Amendments (1948, 1956, 1965) were enacted which stressed the need for water quality standards and sewage treatment upgrades, and the Pure Waters Program was established in New York State (Brosnan et al., this volume). During this period the federal role in water pollution control was purely advisory, and administered through the Public Health Service (O'Connor, 1990).

A Case Study in Early Management: The New York City Sewerage System

In 1906, the Metropolitan Sewerage Commission was given three objectives (Metropolitan Sewerage Commission, 1910):

- *First. To establish the facts attending the discharge of sewage;*
- *Second. To Determine the extent to which these conditions were injurious to the public health; and,*
- *Third. To ascertain the way in which it would be necessary to improve to improve the conditions of disposal in order to meet the reasonable requirements of the present and future.*

The Metropolitan Sewerage Commission did a superb job of collecting data about New York Harbor, consulting with known experts in science, medicine and engineering, recommending remedial actions, and documenting its findings. A monitoring program, started by the Metropolitan Sewerage Commission in 1909, which continues today as the New York Harbor Survey, documented that conditions in the harbor were steadily deteriorating. The Commission's work provided new insights about the harbor, dispelled rumors and perceptions regarding public health issues, and provided solid, credible information about the harmful effects of sewage discharges. The scientific information was unambiguous about the need for improvements to the sewerage systems emptying into the lower estuary.

Under the terms of the Bay Pollution Act of 1906, five persons were appointed by the Mayor of New York to serve as members of the Metropolitan Sewerage Commission. One its original members, George A. Soper, became president in 1908. Soper, a sanitary engineer working for the New York City Health Department, gained considerable recognition in 1906 by tracking down the source of a typhoid epidemic to one Mary Mallon, a cook who became commonly known as "Typhoid Mary." Soper made medical history by being the first person ever to document that typhoid could be spread by a healthy carrier. While Mallon showed no signs of the disease herself, she is attributed with having caused at least thirty-three cases of typhoid and three deaths. Soper pursued Mallon liked a dogged detetective, not once, but twice. Mallon was incarcerated for two years in a hospital on North Brother Island in the Upper East River after initially being diagnosed as a carrier of Typhoid. She was released with a promise of not working as a cook, but four years later Soper discovered she was responsible for new epidemics at a New Jersey sanitorium and at Sloane Maternity Hospital in Manhattan where she was employed once again as a cook. Mallon was again incarcerated in a North Brother Island hospital, but this time for the rest of her life (Bourdain, 2003).

Soper and his Commission colleagues were passionate about their work and were convinced that conditions in the harbor were a public health threat. Their reports received considerable press attention and sparked interest in the business community. There was little debate about the validity of the Commission's technical conclusions, but there was considerable debate about the best and fastest ways to improve the sewerage system and clean up the harbor.

In 1910, the Commission made its first set of findings public which included a detailed description of the terrible water quality conditions in the harbor, a general design for a new sewerage system and recommendations for public policy changes to deal with the growing sewage problems. It strongly endorsed a joint and permanent sewerage commission to be created by the states of New York and New Jersey. Clearly both New York and New Jersey contributed to the problem and both would need to part of the solution. However, tension between the states existed over the proposed construction of an outfall pipe by the Passaic Valley Sewerage Commission in Upper New York Bay. The new pipeline would divert vast amounts of sewage from being discharged into the Passaic River in northern New Jersey to a point on the New York/New Jersey border within the Harbor. The State of New York vigorously opposed the plan and battled New Jersey in court for nearly twenty years. This battle not only inhibited the creation of an interstate commission but also caused New Jersey to boycott participation in proceedings of the Metropolitan Sewerage Commission.

Even though the State Legislature had asked the Commission for its opinion about sewage disposal policies, the Commission recommendation of an interstate commission brought criticism from the *New York Times*. In an editorial titled, *Cleansing the Harbor* (*New York Times*, 1910), the *Times* supported swift action to rid the Harbor of "the menace of pollution," but chastised the commission for overstepping its technical responsibilities and delving into public policy. The editors commented that, "We would rather have their plans as engineers than lawmakers, for the reason that they have repute as sanitarians, but not as legislators. They now recommend an inter-state sewerage commission, regardless of the ill-success of similar undertakings hitherto." The *Times* also stated that, "If we are to wait until New Jersey persuades New York, or vice versa, the interval promises to be protracted."

One influential business group, the Merchant's Association, became a strong advocate for

sewerage improvements. The Association, like the *New York Times*, supported the technical conclusions of the Commission, but had other ideas concerning the most expedient approach to getting some action. It advocated enlisting the services of the federal government to require a "standard of purity" and let "all abutters and defilers" conform to that standard (*New York Times*, 1910). If water quality standards were set, New York City and other municipalities surrounding the harbor would be forced to make improvements.

The Association pressured New York City officials for many years to take action, advocating that nothing was more important than the City's health and that a healthy harbor was in the best interest of the business community. Its frustration culminated in 1923 with the release to the *New York Times* of correspondence with Mayor Hylan that demonstrated his refusal to devote attention to the sewage disposal problem (*New York Times*, 1923). The Mayor's position was that, "When the immediate and necessary problems are overcome, one of which is transit, it will then be time enough to take up the question to which you refer." Before leaving office in 1926, Mayor Hylan did devote considerable attention to transit issues, creating the city-owned, Independent Subway line (the IND), which opened after he left office, but did little to further the cause of sewage abatement.

From the time of the Commission's release of its final report in 1914, until actual construction of a new sewerage system began in New York City, nearly thirty years had expired. The delays in implementation can be linked to poor regional cooperation, a lack of protection standards, the aftermath of the First World War, changing social issues, funding limitations and political indifference. None of the policy strategies recommended by the Commission and others to speed up the process took hold during this period. But with continued pressure from the business and engineering communities, and the fallout from a typhoid epidemic linked to contaminated shellfish, a joint legislative committee of the States of New York, New Jersey and Connecticut was formed in 1924 to form a new Sanitary Committee to revisit the sewage problem and recommend solutions. After exhaustive study, the Committee's issued its final report in 1927 that recommended immediate adoption of a comprehensive plan of sewage disposal in greater New York. This proved to be the spark that finally ignited action on the part of New York City (Interstate Sanitation Commission 1937).

Though the Metropolitan Sewerage Commission had long since retired, George Soper, still persisted in touting the accomplishments of the Commission and lobbying for the implementation of the Commission's recommendations. He remarked in 1929 that, *"The sewage problem is not a problem at all. This subject was exhaustively studied and solution worked out fifteen years ago…. A commission should at once be established or an existing one designated to go ahead with construction of the works."* (Soper, 1929). In 1931, New York City announced that it had finally developed a financing plan for the sewerage improvements (NY Times, 1931) and construction of a new system, patterned on many of the recommendations of the Metropolitan Sewerage Commission, commenced. Also in 1931, the Tri-State Treaty Commission was created, which led to the eventual created of the Interstate Sanitation Commission. Soper's wishes finally came true. His comprehensive plan, though scaled back considerably, was being instituted and he finally got an interstate commission, which he said *promises to offer the best solution which has thus far been proposed.* (Soper, 1931).

The New York City sewerage story highlights several important challenges to developing regional management strategies for the Hudson River. They include: the development of sound and credible technical information to characterize the problem and to reduce the uncertainties in forecasting the benefits (or consequences) of taking action; the formation of partnerships that include all appropriate decision makers for the geographic scope of the problem and its causes; the inclusion of specific goals to be met; the active participation of user groups and stakeholders; the development of political support; and the creation of funding strategies for both planning and implementation.

A New Era: 1960's - 1980's

A growing public concern over the environment prompted dramatic new federal action in the late 1960's and early 1970's, much of it motivated by events affecting the Hudson River. The National Environmental Policy Act (NEPA, PL 91-190) enacted in 1969 forced federal agencies to write environmental impact statements before proceeding with management decisions deemed to be "significant." The Federal Water Pollution Control Act of 1972 (PL 92-500, in subsequent authorizations referred to as the "Clean Water Act"), proclaiming *it is the national goal that the discharge of all pollutants waters into navigable waters be eliminated by 1985,* was the most

comprehensive water pollution control legislation ever enacted. It was a major transition point from its timid predecessors to the much more comprehensive legislation embodied by the various authorizations of the Clean Water Act that followed. The Act authorized huge federal expenditures to for sewage treatment construction grants, institutionalized a permit program for industrial dischargers (including power plants), required states to make regular evaluations of water quality, required secondary treatment for all municipal wastes, established environmental criteria for dredged material disposal, regulated the filling of wetlands, and provided new direction for water quality standards and criteria with the goal of creating "fishable, swimmable waters."

An avalanche of new programs and organizations cascaded into the environmental management structure at the state and municipal levels. The U.S. Environmental Protection Agency, the New York Department of Environmental Conservation, the New Jersey Department of Environmental Protection and the New York City Department of Environmental Protection were created, and other federal and state agencies were revamped, all designed to address the new and growing environmental mandates that the public was demanding. In addition, states developed legislation to complement the recently enacted federal legislation. For example, to provide for the Environmental Impact Statements at the state level – in essence, the New York State counterpart to NEPA's similar provisions – the State Environmental Quality Review Act (SEQRA) took effect in November, 1978. The overall management structure that emerged was one of strong federal controls initially, with gradual delegation of responsibilities to the states over time as the state programs matured.

Legions of environmental managers were now hard at work correcting environmental problems. Some of their successes are chronicled in Brosnan et al. in this volume and Steinberg et al. (2004). While much of the day-to-day activities of these managers went unnoticed by the public, some key regulatory actions proved to be lightening rods for environmental activism and public debate. Westway and the Hudson River Power Case, discussed below, are two examples of controversial regulatory proceedings that focused regional and national attention on Hudson River environmental issues.

Prompted by the growing awareness of environmental issues in the Hudson River brought

about by the Power Case, Congressman Richard Ottinger, along with several other prominent Democrats in the U.S. Congress, supported legislation for a Hudson River Scenic Riverway. The bill was passed in 1966 and authorized the establishment of an interstate compact to enhance public recreation on the Hudson and its shores and preserve the historic, scenic and natural resources of the river corridor. While providing a tool necessary to support regional cooperation and management of the Hudson River, the new legislation also provided a means of attacking Republican Governor Nelson Rockefeller and his environmental policies. Not to be outdone by the Democrats and seeking to keep issues under State control, Rockefeller established his own state run entity, the Hudson River Valley Commission, and pushed through the Pure Waters Bond Act aimed at cleaning up sewage throughout the state, with an emphasis on the Hudson River. In addition, Rockefeller stalled efforts to negotiate an interstate agreement with New Jersey for many years and the Congressional deadline for ratifying a compact expired in 1974 (Dunwell, 1991).

Rockefeller's HRVC was composed of influential New Yorkers, but had limited powers and was described by Robert Boyle (1979) as a "bad joke." It compiled information about the Hudson's resources and conducted site plan reviews of large projects. Though it did not have the power to stop projects, it could delay them by holding extensive hearings. It was successful in redesigning projects to reduce their scenic impacts and facilitating the creation of new parks like Hudson Highlands State Park (Dunwell, 1991). After a period of time it lost its momentum and local support, and eventually was dissolved.

With vanishing of hope for an interstate compact and the limited authority of the HRVC, the Rockefeller Foundation stepped forward in 1973 and funded a three-year study of environmental problems and institutional issues called the Hudson River Basin Project. This impressive effort, which produced over 4,000 pages of memoranda, working documents, and reports after consulting with approximately 125 people, is synthesized in a two-volume report published in 1979. The Project found that even though important new programs of environmental protection were emerging from new federal and state legislation, responsibility for administering them was assigned to single-purpose agencies and departments. Single-purpose units were found to have fundamental weaknesses because of limitations in mandate, mission, expertise and funding. The need to strengthen environmental

management institutions was identified as the most important problem to be tackled in the Hudson River Basin (Richardson and Tauber, 1979). The overall project unfortunately turned out to be a purely academic exercise. It had no official connection to any individual or agency of the executive or legislative branch within New York State government, nor did it enlist the support of outside organizations to lobby for changes of the present system. Consequently, the Project had little effect on changing policy related to the Hudson River.

A few years later in 1976, another planning effort was initiated to comprehensively analyze the resources of the Hudson River Basin, this time by New York State with federal funding. The Hudson River Level B Study assessed the basin's existing conditions and projected water and related land needs and problems to the year 2000. It provided a series of recommendations, including the creation of *new management structure with a unified approach to conservation and development of land and water* (New York State Department of Environmental Conservation, 1979). The recommendations from the Level B Study suffered the same fate, however, as the Hudson River Basin Project. Though sponsored by government, the project was purely a planning exercise and had no effect on changing existing policies.

Westway

Westway was a project developed in the early 1970's to rebuild the crumbling West Side Highway and create over 200 acres of developable land and parks in Manhattan. A new highway was to be sunk in a landfill created in the Hudson River that extended over four miles, and at a cost of approximately $2 billion. Since the project was designed to be part of the federal interstate highway system, the federal government would pay 90 percent of the bill. A state or local highway would have been cheaper, but would have received a much smaller percentage of federal funds for construction. Having the federal government contribute so generously to build an interstate roadway and create new real estate in the nation's largest city was very appealing to business interests and to City and State elected officials who strongly supported Westway. The project also had its share of detractors, from people concerned about impacts to their neighborhoods to those concerned about effects to the river. Because fill would be placed into the Hudson to create the landfill, the project sponsors were required to obtain a permit from the U.S. Army Corps of Engineers (Corps). The Corps' permit review process

provided a forum for individuals, groups and agencies to voice support or opposition to the plan. While there were many issues debated in the Westway case, the one that resulted in the project's demise was the potential impact of the proposed landfill on the population of striped bass in the Hudson River.

The aquatic environment that the landfill would displace was originally characterized by the project sponsors as being biologically impoverished. This assessment was based upon very little field information. Federal actions, like the Westway permit review by the Corps of Engineers, trigger impact assessments in accordance with the National Environmental Policy Act of 1969 (NEPA), and require scientific counsel (Limburg, et. al 1986). As more information was collected so the Corps could complete its environmental assessment, and as that information was reviewed by other agencies and groups, the project area was found to be inhabited by far more organisms than previously thought. Juvenile striped bass were observed in the inter-pier areas of the project site during winter months, prompting scientists to hypothesize that the Westway area was an important wintering area for these young fish. The Corps rejected that hypothesis and issued a permit 1981. The decision was challenged in court and the permit was vacated.

The Court allowed the project sponsors, the New York State Department of Transportation, to reapply for a landfill permit, but the Corps was required to prepare a supplemental environmental impact statement (SEIS) addressing specifically the impact of Westway on Hudson River fishery resources. In that regard, the Corps was ordered to consult with the National Marine Fisheries Service, the U.S. Fish and Wildlife Service, and the U.S. Environmental Protection Agency, and after such consultation, arrange for any additional studies necessary to evaluate the importance of the Westway area to fisheries. After consulting with the agencies and other fisheries experts, the Corps decided to undertake a limited study of the relative abundance of juvenile striped during the winter of 1983-1984.

Despite criticism that the study was too short in duration, it was able to demonstrate statistically that a relatively large fraction of the population of juvenile fish could be found in the Westway area of the Hudson River. The Corps' SEIS estimated, according to a most probable worst case analysis, that Westway could displace one-quarter of the juvenile striped bass population (New

York District, Corps of Engineers, 1985). But what would become of displaced fish if the project were built? And if these fish perished, would the overall population of striped bass be adversely affected? All of the experts consulted agreed that it was impossible to design a study to determine the answer to those questions. The population dynamics of striped bass would have to be better understood through longer term research before accurate impact predictions could be made.

For Westway's permit decision, the answers would have to come from expert opinion and qualitative judgments. That decision rested on whether the Corps believed that the construction of Westway would harm Hudson River striped bass and result in a finding of *unacceptable adverse impact,* and whether there were any practicable alternatives to the project that would less impacts to the aquatic environment, the criteria used in determining whether projects are in compliance with Section 404 of the Clean Water Act. The Corps concluded that displaced fish would likely survive and that Westway would not cause a *significant adverse impact* to the Hudson and Coastal striped bass stocks. Consequently the Corps approved a permit in January 1985.

The permit was immediately challenged in court, and Corps representatives had great difficulty explaining to Judge Thomas Griesa how they reached their decision. The final SEIS used language in describing aquatic impacts that was dramatically different from language in the final SEIS. The term "significant," which has both a regulatory and statistical meaning, was freely and loosely used in the draft SEIS to describe impacts. The draft document was distributed for public comment without receiving careful scrutiny by the Corps. The final version of the SEIS sought to clarify the use of the term "significant," incorporate new information, and address the comments received by agencies and the public. The Court believed that there were substantive changes made to the final SEIS that could not be explained by the record or by the Corps witnesses. In addition, the scientific expert that the Corps' relied on most heavily in constructing its striped bass assessment gave baffling testimony and could not satisfactorily defend his theories. This caused Judge Griesa to remark in his opinion that the "testimony is a collection of assertions so irresponsible that it is shocking that the Government ever tendered him as a witness." The Court found that the Corps' decision to grant the permit was arbitrary and violated NEPA and the Clean Water Act (Sierra Club vs. United States Army Corps of Engineers, 81 Civ. 3000 Opinion, August 7, 1985).

The Westway saga had a chilling effect on any future plans for large-scale filling of the Hudson River. An unwritten new regulatory commandment of *"Thou shall not fill"* propagated throughout the region. In addition, the Westway case not only highlighted the need to obtain appropriate scientific information and expertise prior to decisionmaking, but also demonstrated the limitations in our understandings of fundamental ecosystem processes, making impact assessment very difficult, especially in cases where there are potential population-level effects.

Hudson River Power Case and Hudson River Foundation

The Hudson River Power Case, involving the permitting of several power plants in the mid-Hudson River, has focused considerable attention to human impacts on fisheries resources and led ultimately to the formation of a foundation to conduct environmental research. The conflicts between the power-generating industry—which uses Hudson River water to run steam turbines and cool them—and those concerned with the conservation of natural resources proved to be an enormously important milestone in environmental policy development for the Hudson, and indeed the nation itself.

In 1962, the electric power generating company, Consolidated Edison (Con Ed), proposed construction of a "pumped storage generating plant" drawing water from the River at historic and beautiful Storm King Mountain in the Hudson Highlands. An enormous outcry ensued and soon thereafter the "Scenic Hudson Preservation Conference[a] was formed and later, the Hudson River Fishermen's Association[b]. The Second Circuit Court's decision in the case, *Scenic Hudson Preservation Conference v. Federal Power Commission* (1965) set an important precedent for environmental law in the United States by affording citizens' groups legal standing to sue over environmental and esthetic issues[c]. From the perspective of the present paper, though, the nearly protracted legal battle that preceded the final settlement in 1980 with Con Ed led to the widespread recognition that *the fundamental environmental information needed to make many management decisions was simply not available*, nor was any public agency adequately prepared to fund necessary studies.

[a] Now known as Scenic Hudson.
[b] Now known as Riverkeeper.
[c] Before only those with a direct economic interest could be construed to be an "injured party" in cases before the courts.

Under the terms of the "Hudson River Settlement Agreement," which also pertains to thermal pollution problems associated with the Indian Point Nuclear Power Plant and two other plants, the Storm King project was abandoned and steps were taken to reduce fish mortality, particularly during spawning times. Of particular significance is the recognition of the need for better scientific information that was articulated and promoted very passionately and cogently by environmental activist Robert Boyle (1969). Accordingly, the utilities also agreed to conduct biological monitoring that still continues today and to provide a $12 million endowment for a new foundation for independent environmental research on the Hudson River. Thus, the Hudson now has an institutional resource that no other river or estuary we are aware of anywhere has, the Hudson River Foundation (HRF). HRF, a private not-for-profit organization, sponsors research in the natural sciences and public policy, and promotes efforts to improve management policies through the integration of science. Since 1983, the Foundation has funded approximately 460 individual projects totaling approximately $30 million, contributing to more than 60% of the research conducted about the Hudson River since that time.

In addition to its contributions to the broader understanding of the ecological function of the River, the HRF is generally regarded to have made important research contributions regarding the operation of power plants and the potential effects they have on the populations of several species of Hudson River fish. The continuing need for regulatory action argues for the need to incorporate cutting-edge, unbiased, and credible scientific information into environmental decision making. As in the Westway matter, current science may not be able to make significant reductions in uncertainties with respect to important impacts, particularly in cases where population-level effects are possible. Clearly, more focused and sustained research on fundamental ecosystem processes will be needed, as will be better ways to enable managers to incorporate the results of basic research into their policies and decisions.

PCBs in the Upper Hudson River

Among the most vexing and persistent challenges to the Hudson River science and

management relate to the PCB's[d] that have accumulated in the river north of the Troy Dam. From 1947 to 1977 General Electric (GE) plants at Fort Edwards and Hudson Falls, NY, released an estimated 590,000 kg (1.3 million pounds) of PCB's into the river, and although GE stopped using PCB's after 1977, some PCB's have since leached from its plant sites.

In the ensuing years–almost three decades have passed since the legal actions first began–this problem has motivated one of the highest profile and most vitriolic environmental debates in the US, pitting environmentalists, who have sought to have PCB-contaminated sediments removed from the river, against GE and its supporters.

As growing awareness of toxic organics developed in the decade after the publication of Rachael Carson's *Silent Spring* (1962), attention began to be focused on the health risks of PCB's. Studies soon linked PCB's to developmental and neurological disorders, as well as cancer, reduced diseased resistance and reproductive problems not only in humans, but also in animal populations in the vicinity of the Hudson.

Monitoring and science have played critical roles in dealing with the Upper Hudson PCB problem, and several numerical models exist to predict the distribution and mobility of PCB's in the freshwater and estuarine parts of the River. Baker (this volume) summarizes the science behind several of the key factors involved in the decision to dredge PCBs from the Upper Hudson River. Finally, in February 2002, the U.S. Environmental Protection Agency issued a record of decision calling for targeted environmental dredging and removal of approximately two million cubic meters of PCB-contaminated sediment from a 65-km (40-mile) stretch of the Upper Hudson.

The Present Management Structure

The Hudson River management structure, once only afforded protections related to navigation and public health, now has a broad range of programs that seek to conserve and protect the aquatic ecosystem and a wide variety of human uses. These initiatives are administered by no fewer than nine

[d]PCBs - polychlorinated biphenyls – are very stable organic compounds with chlorine atoms in a variety of configurations

federal agencies, five state agencies, three regional authorities, and countless municipalities. While there is much to celebrate about these programs, Adler (1995) points out that it is difficult to imagine a political system as complicated and as fragmented as that use for protecting and managing water resources in the United States.

Harbor Estuary Program and Hudson River Estuary Program. In the late 1980's new federal and state legislation significantly changed the management structure for the Hudson River Estuary. At the federal level, the Clean Water Act was amended in 1987 to include the establishment of a National Estuary Program (NEP), patterned after the successful operations of the Chesapeake Bay Program. The governors of New York and New Jersey successfully petitioned the U.S. Environmental Protection Agency to include the Hudson River Estuary (also known as the "New York/New Jersey Harbor Estuary") as *an estuary of national significance.* Inclusion of the New York/New Jersey Harbor Estuary Program (HEP) into the NEP in 1988 provided an excellent opportunity to take stock of the current environment conditions and to develop plans to correct unacceptable conditions found in the lower estuary. Though the Harbor Estuary encompasses all of the tidal waters of New York Harbor and its tributaries, including the Hudson River to the federal lock and dam in Troy, the HEP has focused its attention on a *core area* that includes the harbor, its direct tributaries and the Hudson River north to the vicinity of Piermont Marsh (km 40 - Milepoint 25).

The overall goal of HEP is *to establish and maintain a healthy and productive ecosystem with full beneficial uses* by first characterizing the environmental conditions in the estuary, developing a comprehensive plan that recommends actions to improve conditions, implementing those actions and monitoring the health of the estuary to determine the effectiveness of the actions taken. A "Comprehensive Conservation and Management Plan" (CCMP) was adopted in 1996 and the program is now in its implementation phase.

In 1987, the New York legislature enacted the Hudson River Estuary Management Act which declared that it is the policy of the State of New York to *preserve, protect and, where possible, restore and enhance the natural resources, the species, the habitat and the commercial and recreational values of the Hudson River Estuary.* The Act established an *estuarine district* from the Troy lock and

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that are used as insulators in transformers and other industrial applications

dam to the Verrazano-Narrows in New York Harbor, and required the development of a Hudson River estuary management program by the New York State Department of Environmental Conservation (DEC) for the district in consultation with an advisory committee which included representatives of commercial fishing, sportsmen, research, conservation, and recreation.

Both management programs have similar challenges that relate to institutional, financial and technical constraints. These challenges must be overcome if there is any hope of achieving the lofty goals established by both programs. Management responsibilities are fragmented and spread among several layers of government and among different political jurisdictions. Overlapping responsibilities of agencies can lead to conflicts in protection objectives and inefficiencies in resource allocations. The management of complex, important issues is often artificially fragmented within an agency's structure. Some issues may require that two or more different divisions or bureaus within agencies be involved. Lack of coordination and confusion of responsibilities can lead to a dilution of effort. Probably the most important problem, however, is the existence of gaps in authority to deal with complex problems over geographically broad areas, leading to serious problems in program implementation and funding.

An important function that HEP and HREMP provides is coordination. Both programs provide a structured way for agencies, organizations and individuals to communicate with one another on an ongoing basis. While coordination alone does not ensure that individual organizations will agree to take on expanded responsibilities or that collaborations will be formed, the role that HEP and HREMP play cannot be underestimated in facilitating the creation of new partnerships to achieve the goals that all have agreed upon. Both programs have a sustainable, long term component missing from previous efforts to provide direction toward comprehensive management. They each had a planning phase, and now have an implementation and action phase that is supported by annual funding for essential program functions.

HEP has characterized problems of the estuary and recommended actions to solve those problems in a comprehensive planning document endorsed by the governors of New York and New Jersey and the administrator of EPA. An implementation phase is now in place where resources are

being sought to fund the recommended actions. Lindblom (1995) has cautioned that some comprehensive planning models, i.e., ones that seek clear objectives and require explicit evaluations of all potential decisions before proceeding, are attractive for use in solving complex problems, but rarely can be used by policy and decision makers and when used, prove to be unproductive. He states that an intense comprehensive analysis "assumes intellectual capacities and sources that men simply do not posses." Successful solutions and policies to complex problems have generally evolved through step-by-step, incremental planning and execution.

Both estuary programs have no choice but to approach the countless goals and objectives in their respective management plans in increment ways. Moreover, the development and application of technically sound tools, like mathematical models, have been given high priority by both programs to help forecast future conditions in the estuary in light of management actions that may be taken.

The Chesapeake Bay Program is generally considered the premier estuarine management program in the U.S., achieving success in developing and implementing regional solutions to restore Chesapeake Bay. Much of that success can be linked to the establishment of incremental goals and targets that prescribe what people concerned about the Bay want, and when they want it by. The acceptance and endorsement of these targets by elected officials has led to the allocation of resources to implement the solutions needed to reach those targets. An important aspect of the target setting is that it forces the management structure to assess scientifically how the targets can best be reached and whether they can be reached in the time frames contemplated. Both HEP and HREMP have embarked on similar approaches to the one adopted for the Chesapeake, and at the writing of this chapter, have target-oriented plans awaiting final endorsement by state and federal officials.

The new estuary management structure that has emerged in recent years through the work of HEP and HREMP has had to deal with the gaps and constraints of existing authorities. Smith (2002) in an analysis of estuary management in Australia found that traditional management responsibilities emanating from legislation and regulation, which he terms *de jure*, often evolves into *de facto* responsibilities because of external pressures exerted on management authorities. Pressures for change from environmental organizations and champions of certain issues, a lack of response to these pressures from agencies, and new knowledge from scientific researchers have forced officials and

agencies to assume expanded management roles. New attention to emerging issues has created *de facto* management structures which are more responsive to estuarine problems; however, they are inherently unstable. The *de facto* structure requires continued pressures from external sources to keep its priority at a high level and to generate a continued supply of resources.

Within the HEP structure, two major initiatives have emerged which follow the *de facto* management scenario described above. Concern for greater habitat protection and restoration has been strongly expressed at public meetings convened by HEP, and through members of the Habitat Work Group of HEP. Many organizations including national and local environmental groups, watershed associations, civic organizations and resource management agencies serve on the Work Group. In 2001, the Work Group identified 88 sites for restoration and 60 sites for acquisition surrounding the lower estuary. (Habitat Work Group, 2001) Since thousands of acres of wetland and aquatic areas have been filled or altered over the years to create new land for an expanding metropolis, HEP is now devoted to saving the remaining important habitat areas and working to restore those sites that have been physically or chemically altered. Since there were no agencies with *de jure* responsibilities to conduct restoration or purchase sites, creative ways had to found to move the habitat initiative forward. Groups and individuals, working with the *blueprint* created by the Habitat Work Group, have administratively and legislatively committed approximately $100 million to support the habitat efforts.

Another major *de facto* effort is the Contamination Assessment and Reduction Project (CARP). In the early 1990's dredging activities in New York Harbor came to halt because of environmental concerns over the disposal of dredged sediments at an ocean dump site. Without dredging, ships that carry international cargo and oil products could not safely navigate the waters of the harbor. Their exclusion would be devastating to the regional economy.

Several workshops sponsored by EPA, called the "Dredged Material Forum," were convened to discuss the dredging dilemma among a variety of port stakeholders, including federal, state and local government agencies, labor unions, regional port officials, environmental organizations, engineering consultants and scientists. While workshop participants were deeply divided on many

issues, all agreed that the region needed to address dredging and disposal issues in a more comprehensive way. In particular, new disposal strategies for contaminated sediments needed to be researched and implemented as soon as possible. Also, since contaminants were at the heart of the crisis, a plan should be developed to reduce or eliminate the sources of contaminants that were causing the sediments to be deemed too contaminated for ocean disposal. A work group was established to develop a plan and present its recommendations to the Policy Committee of HEP for inclusion into HEP's comprehensive plan.

The primary management objectives were: (1) to identify sources of contaminants that needed to be reduced or eliminated in order to render future dredged material "clean" (as defined in applicable guidelines and criteria); (2) to define what actions will be the most effective in abating the sources; and (3) to determine how long it will take for freshly deposited sediments to achieve "clean" status.

The work group (co-chaired by the first author of this paper) made several findings. First, addressing the management questions required that a comprehensive technical analysis be made to understand the linkages between inputs of contaminants to the estuary and their ultimate fate in water, sediment and biota. Second, since it was important to forecast future conditions in light of potential contaminant reductions, a mathematical modeling framework would have to be developed. Third, new data would have to be collected to quantify ambient contaminant concentrations and develop credible loading estimates for specific contaminant sources. Even though contaminants like PCBs, dioxins, and PAHs were routinely tested in connection with dredged material management, there was very little complementary testing of these chemicals in other media by government agencies or regulated parties. Lastly, the Work Group found that specific government authority (i.e., *de jure* management responsibility) for taking action to reduce contaminants that were violating dredged material criteria was nonexistent. A new management framework would have to be devised to deal with the issue.

The workgroup recommended that a technical assessment of contaminant inputs in relationship to criteria violations be conducted which included a comprehensive monitoring program coupled with modeling. The results would be used to drive regulatory programs (e.g., Total Maximum Daily Loads (TMDLs), Superfund, Natural Resource Damage Assessments, etc.) to reduce the same contaminants that were problematic to dredging. These recommendations were endorsed by the HEP Policy

Committee and were incorporated into the Comprehensive Conservation and Management Plan for HEP.

The collective actions to be undertaken has become a new management effort (i.e., de *facto* management) termed the Contamination Assessment and Reduction Project (CARP). A management committee guides the progress of CARP and is composed of representatives from the Hudson River Foundation, the Port Authority of New York and New Jersey, NJ Dept. of Environmental Protection, NJ Maritime Resources, NY Dept. of Environmental Conservation, the Empire State Development Corporation, Environmental Defense, the U.S. Environmental Protection Agency, and the Corps of Engineers. To the present, funding for CARP totals approximately $27 million. The majority of that amount emanates from the Port Authority through a bi-state dredging agreement endorsed by the governors of New York and New Jersey.

CARP is perhaps the largest contaminant assessment effort ever undertaken in the U.S. in terms of its analytical program. Over one million individual contaminant analyses have been performed. The utilization of these data in an *ad hoc* management framework is truly remarkable and demonstrates the benefits of having cooperative arrangements, like HEP, in place to bring different parties together to tackle new management challenges.

Hudson River Greenway. Designed to complement the HEP, the Hudson River Greenway Act (1991) established a "cooperative program of the Hudson River Valley Greenway [to promote] the state's commitment to the preservation, enhancement and development of the world-renowned scenic, natural, historic, cultural and recreational resources of the Hudson River Valley while continuing to emphasize economic development activities and remaining consistent with the tradition of municipal home rule." The legislation established two entities, the Hudson River Valley Greenway Communities Council and the Greenway Conservancy for the Hudson River Valley, Inc. The role of the Council is "to intervene in proceedings before [state agencies], to identify scenic areas appropriate to be designated by the [Department of Environmental Conservation] and to help develop and implement a comprehensive program to protect the beauty of the region in scenic highway corridors." The role of the Council is "to encourage individuals, corporations, associations, organizations and public agencies

to preserve and enhance the natural scenic beauty and heritage of the Hudson River valley and the lands, water, exemplary natural communities, aesthetic and cultural resources of the Hudson River Valley, as well as manage and conserve the fish, wildlife and endangered plant and animal species, and to increase public access to the waters of the Hudson River." Entities such as the Conservancy and the Council have potentially very strong roles in mitigating the complexity of different agency jurisdictions in New York State.

COLLECTING SCIENTIFIC INFORMATION

Scientific information about environmental conditions and understanding of ecosystem processes are essential for management of the river's resources. Programs that mandate the protection of aquatic resources generally proceed through a two-step process: a *characterization phase* that involves the collection of new information describing the problem or particular portion of the system that requires protection, and an *interpretation phase* that places the information in the context of the present understanding of natural processes. Moreover, for impact assessment, managers must evaluate how the proposed human action will affect those processes.

Government agencies and regulated parties routinely spend considerable funds in the characterization phase, collecting and managing technical data about the river and estuary. Between 1990 and 2000, approximately $117 million were directed to data collection in connection with monitoring programs, impact assessments, and resource inventories (Figure 1). State and federal agencies funded about 64% of that amount. New York City spent nearly $19 million, half of which was devoted to its Annual Harbor Survey that started in 1909 with the Metropolitan Sewerage Commission.

Managers generally rely on existing scientific literature and experience of their technical staffs for current understandings of ecosystem processes. They sometimes discover that there are serious deficiencies in the understanding of these processes, however, rarely do managers sponsor research to fill needed gaps in that understanding. Many are constrained within their institutional authority to even consider research as management tool. Regulatory programs typically limit most assessments to narrowly defined short-term objectives. After digesting years of scientific and legal debate in

connection with the Hudson River Power Case, Barnthouse et al. (1988) concluded that long-term monitoring and research were clearly needed to improve future assessments, but these efforts require funding and management independent of the regulatory process. Since settlement of the power case in the early 1980's, more than $41 million has been invested in research about the river and estuary. (Figure 2). Only very modest funding was provided by management agencies. More than half of the research funding emanated from the Hudson River Foundation.

Broader planning programs like HEP and HREMP have recognized the importance of new research being incorporated into their planning and implementation efforts. In fact, one of the first initiatives of HREMP was to outline a science program that would support better and more effective management of the Hudson River Estuary. After several meetings with both managers and the research community, a *Science/Management Paradigm* was developed (Schubel, 1992). The elements of the paradigm include research, modeling, monitoring, synthesis, education, outreach, and partnerships between scientists and resource managers. It recognizes that managers need information, not simply data, to make decisions. Data may be derived from monitoring programs, research projects, or both, depending on the nature of the problem being addressed. Data collected through research and monitoring efforts can then be interpreted and synthesized into information that can be used in decision making. To sustain the paradigm, scientists, managers, and the public should form ongoing partnerships, and an education program should be established to enhance public understanding. The paradigm was envisioned to be funded through a large endowment of approximately $100 million.

Inasmuch as securing an endowment of $100 million was highly unlikely, it soon became apparent that the "paradigm" was unrealistic as originally contemplated. Developing a single comprehensive research and monitoring program to address the many problems plaguing the Hudson was far too ambitious (Suszkowski and Schubel, 1994). However, the paradigm did provide a model whose components deserved further examination and application on a smaller scale, and the Hudson River Foundation subsequently used these concepts to develop a special research initiative concerning Atlantic sturgeon.

In the late 1980's, shad fishermen in the river observed that they were capturing fewer small sturgeon as incidental catches in their gill nets, which was corroborated by other fish surveys conducted in the river. Although the reasons for this remained unknown, it was starkly evident that there would be fewer sturgeon available to commercial fishermen in future years. At the same time, commercial fishing for the Atlantic sturgeon stock had increased dramatically, particularly in ocean waters offshore of New Jersey (Waldman et al. 1996).

In response to a growing recognition that the Atlantic sturgeon population of the Hudson River might be in trouble, the Hudson River Foundation convened a workshop, inviting noted sturgeon research scientists and fishery managers to discuss potential courses of action. The workshop concluded that key scientific information was lacking about the reproductive condition of the fish, the size of the Hudson River population, and movement patterns of the sturgeon. This information was deemed critical to the management of the stock.

After establishing sturgeon as a *special interest area* in the Foundation's 1993 call for proposals, several research projects were funded to ascertain the health of the stock at an initial investment of approximately $700,000. The research soon confirmed the hypotheses that there were dwindling numbers of Atlantic sturgeon and that the overall Hudson River population was very small. The reproductive condition of the sturgeon was found to be healthy, and was not a cause of the stock's decline. Modeling analyses performed by New York State biologists, working in concert with the Foundation-sponsored investigators and using their research findings, demonstrated that the sturgeon stock could not withstand a fishing pressure sufficient for an economically viable fishery.

A moratorium on the harvesting of Hudson River Atlantic sturgeon was enacted in New York based upon the research and modeling. A subsequent moratorium was also enacted in New Jersey following legislative hearings in which the results of the Foundation's sponsored research were presented. Commercial fishing will be unlikely to resume for several decades while sturgeon stock rebuild itself to a sustainable population. In the meantime, New York State is supporting a monitoring program to complement the Foundation's research by watching the progress in sturgeon recruitment. This monitoring will be the important ingredient to successful management of this species in the future.

Managing Scientific Research

The authors of this chapter together have over 50 years of experience working in and with federal, state and local agencies having environmental research and management functions. For over a decade, each of us has also had a close association with the Hudson River Foundation (described above). The senior author has served as Science Director who has managed over $25 million in research grants, and the junior author as a proposal reviewer, review panelist and board member serving on the program committee.

During the two decades of its existence, there has quite naturally been considerable discussion of how to direct the Hudson River Foundation's funding to the most meritorious and important projects headed by the best qualified principal investigators. Regardless of the context, management of research funding is a challenge: for corporate R&D managers, for federal and state management offices, for federal basic science agencies and for foundations and non-governmental organizations the desire is to direct funding for the most efficacious purpose. No perfect formula exists for the best mix of research topics, and irrespective of this, philosophical differences abound as to what the highest purpose is. Environmental activists might argue that research must be directly relevant to the problems of the day and thus provide immediate feedback for management actions. In contrast, many scientists might argue that fundamental research should have the largest role, and that only by understanding the environment in depth will we be able to manage it.

HRF has migrated to several principles in managing scientific research over the years. In 1999, it clarified its mission as making science integral to decision making with regard to the Hudson River and its watershed and to support competent stewardship. This purpose is being pursued in large part through support of quality scientific research relevant to public policy. The most important aspect of selecting projects of the highest quality is the reliance on a peer review process with the following important characteristics: use of outside mail reviews and inside panel discussions; avoidance of conflict of interest, real or perceived; use of interdisciplinary evaluation; evaluation of prior results; involvement of scientists from many institutions, including outside of the region; evaluation of

proposal significance; and availability of multiyear funding, when feasible.

HRF further believes that investments in environmental research should be distributed in ways to best address short and long term issues. This "portfolio approach" is akin to what financial managers might recommend to investors, i.e., instead of making all investments in a single category, one should diversify one's holdings. Thus, HRF seeks to have a flexible blend of research projects, addressing scientific and public policy questions that may or may not have time constraints associated with them, but nonetheless relate to important areas in need of scientific inquiry. The categories considered are as follows:

- Long-term or fundamental importance, i.e. what is believed to be necessary in order to understand basic ecological function and thus of potential long-range bearing on management approaches. This is often referred to as "basic" research that is intended to advance the state of knowledge where the possible applications of the results of the research are many years away. Example: studies of lower food web processes in the tidal freshwater portion of the river.
- Near-term importance, i.e. what is anticipated will have important bearing on an environmental issue in the next 5-10 years. This may have both "basic" and "applied" components. Example: studies of the fate, transport and potential effects of toxic chemicals.
- Immediate importance of high priority, i.e., what needs to be known now for a compelling environmental problem of present interest. This typically is what is often referred to as "applied" research. This research is intended to provide needed information for issues facing the Hudson over the near term, say in the next several years. Example: studies in connection with the decline of Atlantic sturgeon.

Managing its grants program as a "portfolio" and making its programs as responsive to public policy issues as possible, makes it incumbent upon HRF to understand the pressing management problems and issues facing the Hudson River and the role that science can play in developing solutions to them. This requires active participation by HRF staff in management deliberations, particularly those of HEP and HREMP. We note that a major disconnect exists between organizations that need

scientific information for management and organizations, like HRF, that fund research. As pointed out in the discussion of the Science/Management Paradigm, most complex environmental problems require some combination of research, monitoring and modeling to formulate solutions. Determining which combination of technical tools is appropriate to solve the problem is crucial, and this process can greatly benefit from the participation of research organizations and scientists who are currently engaged in research or have recently completed studies of the river. Establishment of collaborations and partnerships is perhaps the greatest challenge to resolving complex environmental issues in the future that cross political and administrative boundaries, and where the need for scientific information to reduce the uncertainty in decision making is critical.

Conclusions

For almost four centuries, the human activities have profoundly affected the Hudson River, its estuary and its watershed. Our brief review of the history of human activities and their relationship to the Hudson system, its science and its management leads us to the following major conclusions:

- The Hudson River cannot simply be viewed as a river isolated from the rest of the environment. Indeed, the crucial role of the watershed that feeds fresh water to the River and the Atlantic Ocean that provides salt water to the estuary and powers its tides are important considerations in the Hudson system's ecological functioning and health.
- Economic issues have been at the root of most environmental management decisions. Indeed, it was not until a landmark decision in 1965 regarding power generation on the River that issues related to natural resources and esthetics had any legal standing in environmental litigation.
- While the overall management structure for the river and estuary has dramatically changed over the last 100 years, successes in conquering regional problems have shared the same characteristics: the development of sound technical information to understand the problem and its potential solution; the formation of appropriate partnerships that include all appropriate decision makers; pressure from stakeholders and concerned individuals outside the management agencies for specific outcomes; the acquisition of funds appropriate to the

task; and an institutional structure to implement the solution.

- Science *per se* rarely motivates managerial actions. However, science that is appropriately available to managers when needed is often essential to making the most effective managerial decisions. Science and environmental management may at times seem incompatible, but without proper incorporation of scientific information into decision making, serious errors will result.
- For solving complex environmental problems, it is not enough to collect environmental data by means of monitoring or other survey programs alone. Process-oriented information must also be obtained from research and modeling, either mathematical or conceptual. For there to be real hope for such scientific results to be useful to managers, synthetic and interpretive value must be added.
- Land use is a key issue affecting all parts of the Hudson ecosystem's components. Regulating land use is an aspect of environmental management that is challenging to implement due to a patchwork of regulations in different jurisdictions, the strong tradition of home rule in New York State and U.S. Constitutional protections of the rights of individual land owners.
- The role of the federal government has gradually increased particularly in the latter part of the last century due to recognition of the interconnectedness of different factors affecting the environment. This has had beneficial results regarding environmental management, but has also complicated the role of government in this activity.
- Although prior to the 1960s primary responsibilities for management of the Hudson, its estuary and its watershed fell to just a few agencies, there is now a complex maze of government agencies at the federal, state and local levels whose jurisdictions and purview often overlap. To effect successful environmental management of the Hudson system, substantial interagency interaction and coordination is necessary. Mechanisms that foster interagency and cooperation are important. Of greatest importance is collaboration on issues where gaps in authority and responsibility are preventing regional solutions from being developed and implemented.
- New management structures (i.e., *de facto* management responsibilities) have emerged to deal with problems that cross political and institutional boundaries, and for which no single entity has full responsibility to resolve. Programs like CARP and habitat restoration efforts

demonstrate that external pressures on existing management agencies can generate new collaborations, new funding strategies and bridge gaps in existing authorities.

- Both HEP and HREMP provide excellent forums to set goals for the future of the river and estuary, and provide a starting place and *umbrella* for new management structures to develop and take on the tasks necessary to achieve the goals.
- There is a "disconnect" between the institutions that fund research and the management agencies that use the information that the funded research generates. With growing demands for watershed planning, habitat restoration, contaminant reduction, and biodiversity protection, agencies will require better understandings of ecosystem processes in order to formulate credible and predictive management strategies. Consequently more research, modeling and synthesis will be required than ever before. If the present model of sponsoring research continues, new sources of funding will be required and stronger ties between management agencies and research organizations will have to be forged.
- The Hudson River Foundation has been an important source of funding for scientific research. Much of this research has had bearing, directly and indirectly on issues related to the management of the Hudson's resources, and accordingly has been sought and used by management agencies. Nonetheless, one of the great challenges of managers of research is to find ways to "translate" the results of research to practical application and to keep managers and policymakers informed of the latest scientific information that bears on their responsibilities.

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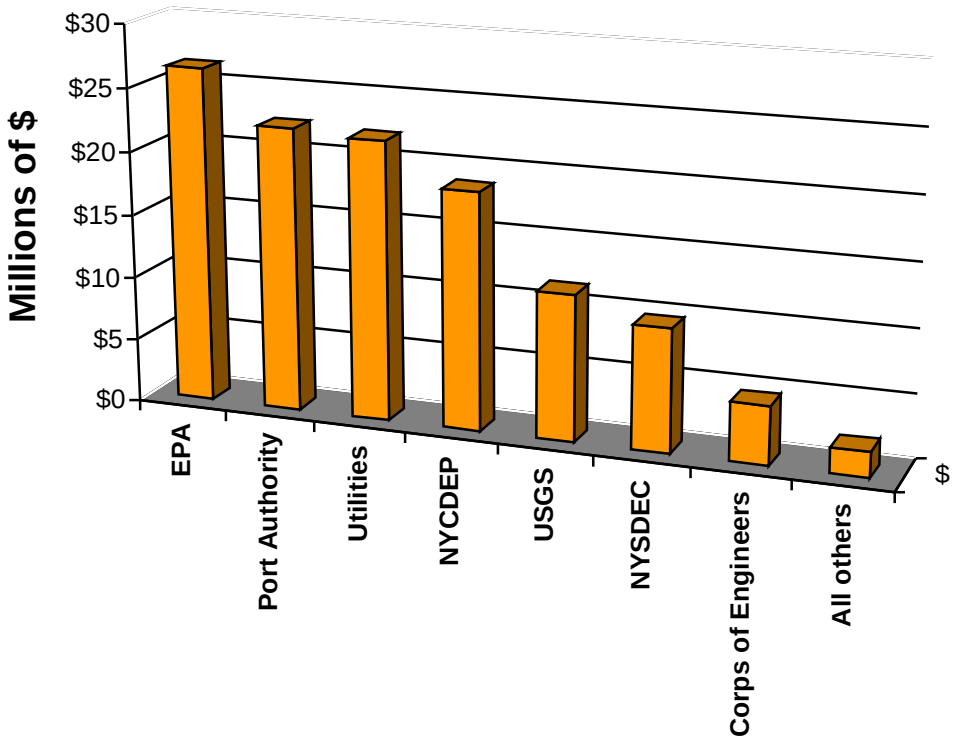

Figure 1: Annual support for monitoring, impact assessment and resource inventories by funding source: 1990 through 2000. (The data contained in this figure and Figure 2 were obtained from 39 individuals representing 25 different organizations. In addition, data from the National Science Foundation was obtained from its website.)

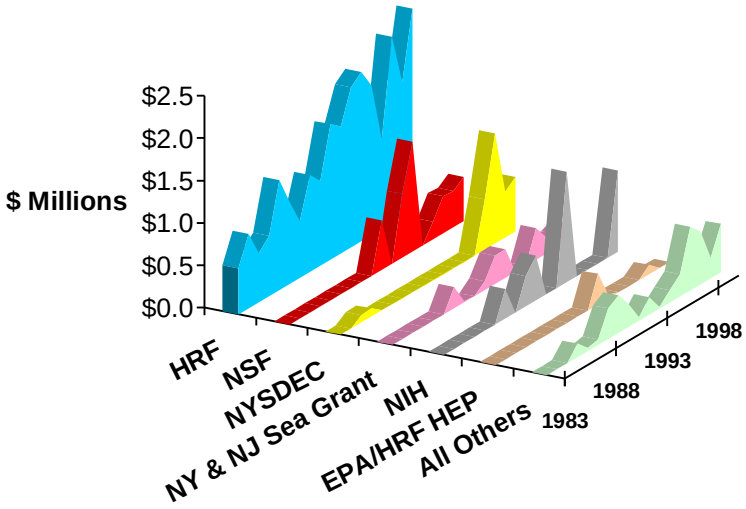

Figure 2: Annual support for research by funding source: 1983 through 2000

Table 1: Environmental concerns and issues, institutional and economic drivers, and enabling legislation related to management of the Hudson River

Time Period	**Environmental Concerns & Issues**	**Major Institutional Drivers**	**Major Economic Drivers**	**Enabling Legislation**
17th and 18th Centuries	♦ Colonial clearing forest	♦ Colonial rule	♦ Agricultural production	
1st half of 19th Century	♦ Forest clearing ♦ Pre-industrial era & transportation	♦ New York State & City commercial interests	♦ Agricultural production ♦ Lumbering ♦ Commerce and trade	♦ Federal navigation projects ♦ 1855 Harbor Commission – NYS
2nd half of 19th Century	♦ Forest clearing ♦ Industrialization & development of transportation	♦ New York State & City business interests ♦ State government	♦ Commerce and trade ♦ Lumbering ♦ Industrial development	♦ Federal navigation projects ♦ 1885 Adirondacks Forest Preserve - NYS ♦ Federal 1888 Supervisor of the Harbor Act ♦ Federal 1899 River & Harbor Act
1st half of 20th Century	♦ Industrialization, urban development public health ♦ Declining water quality in river, estuary and harbor	♦ New York State & City business interests ♦ State government ♦ Major corporate interests	♦ Commerce and trade ♦ Industrial development	♦ Federal navigation projects ♦ 1903 NY Bay Pollution Commission –NYS ♦ 1906 Metropolitan Sewerage Commission –NYS ♦ 1936 Tri-State Compact – NY, NJ & CT ♦ 1948 Federal Water Pollution Control Act
1960s - 1970s	♦ Environmental impact (e.g. power generation) ♦ Storm King proposal ♦ Sewage treatment ♦ Industrial wastes ♦ Fisheries management ♦ Endangered species ♦ Dredge spoil disposal	♦ New York State & City business interests ♦ State government ♦ Major corporate interests ♦ Federal government ♦ NGO's	♦ Commerce and trade ♦ Industrial development ♦ Power generation	♦ Federal navigation projects ♦ 1965 Pure Waters Bond Act –NYS ♦ Federal 1965 Anadromous Fish Conservation Act ♦ Federal 1973 Endangered Species Act ♦ 1969 National Environmental Policy Act ♦ 1972 Clean Water Act ♦ Federal 1972 Marine Protection, Research and Sanctuaries Act (*Ocean Dumping Act)* ♦ Federal 1972 Coastal Zone Management Act

Table 2: Agencies with management responsibilities

Level	Agency	Responsibilities
Federal	National Oceanic and Atmospheric Administration (National Marine Fisheries Service & National Ocean Survey)	- Review & comment on permits - Endangered species - Nautical Charts - Natural Resource Damage Assessment (NRDA)
	U.S. Coast Guard	- Pollution response - Homeland Security - Boater safety
	U.S. Environmental Protection Agency	- Clean Water Act oversight & enforcement - National Estuary Program (HEP) - Superfund - Review & comment on permits
	U.S. Geological Survey	- Collect data tributary flow & sediment data
	U.S. Department of the Interior (National Park Service & Fish and Wildlife Service)	- Manage park facilities - Review & comment to permits - Habitat inventories
	U.S. Army Corps of Engineers	- Navigation projects - Regulation of activities in waterways - Flood & beach erosion control - Dredged material management - Floating drift collection
	U.S. Food and Drug Administration	- Seafood quality standards
State	New Jersey Department of Environmental Protection	- Clean Water Act delegated programs - Coastal & waterfront permitting - Navigation & coastal protection - Monitoring & research - Enforcement - Seafood consumption advisories - Fisheries management - NRDA
	New Jersey Department of Health	- Assists in beach water quality monitoring - Certifies shellfish handling
	New York State Department of Environmental Conservation	- Hudson R. Estuary Management Program - Clean Water Act delegated programs - Fisheries management - Enforcement - State Environmental Quality Review Act - NRDA - Monitoring
	New York State Department of Health	- Seafood consumption advisories - Beach water quality
	New York State Department of State	- Coastal zone management
Municipal	New York City Department of Environmental Protection	- Construction & operation of treatment plants - NY Harbor Survey - Floating drift collection
	New York City Department of Health	- Beach water quality monitoring
	New York City Department of Parks – Natural Resources Group	- Park and natural area management - Habitat restoration
Regional	Port Authority of NY & NJ	- Operate port facilities
	Interstate Environmental Commission	- Water quality monitoring - Enforcement
	Hackensack Meadowlands Commission	- Manage wetlands and open space - Monitoring and education