Delaware River

STATE OF THE BASIN REPORT

2008

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A generous grant from the William Penn Foundation supported collaboration among the Water Resource Research Institutes that made this report possible.

The *State of the Delaware River Basin Report 2008* is available in electronic form at www.drbc.net.
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Message from the Executive Director


DELAWARE RIVER NEAR HANCOCK NY, D. SOETE

The water resources of the Delaware River Basin are vital to the long term health of our citizens and the stability of our economy. These resources supply our drinking water, support our industries, transport our products, provide habitat to a wide array of living resources and contribute to overall quality of life. Management of these resources is a complex task involving all levels of government, public-private partnerships, and a multitude of laws, regulations, and competing interests.

Policy makers and citizens alike often ask me if the health of the system is "getting better." My answer is both "Yes" and "No". While we have made great strides in water quality improvement, we still have a long way to go in many respects. To truly assess issues of ecosystem health and sustainable use, we need to answer a series of questions spanning multiple dimensions of resource management. Examples include:

How clean are the water resources of the Delaware River, its tributaries and Bay?

Do we have enough water for drinking and commerce? Is it safe to drink?

Are our waters "swimmable"?

Are fish abundant and safe to eat? How are other living resources faring?

Is critical habitat being protected?

Are years of management and stewardship yielding good results?

Are we prepared to meet the issues we might face in the future?

Responding to these questions requires environmental managers to set goals for the protection and improvement of resources, to efficiently assess issues and trends, and to monitor the success of implemented management strategies—all of which require high-quality data, scientific information, and an effective feedback system. You can't manage what you don't measure.

This State of the Basin Report 2008 is designed to serve as a benchmark of current conditions and a point of reference for gauging progress toward management goals. It also provides a platform for measuring and reporting future progress in water resource management, and a guide for adjusting monitoring and assessment programs. Finally, it is intended to communicate our understanding of the health of the Basin, to increase public involvement in Delaware River Basin and Estuary Program activities, and to build consensus on a broad array of actions that can be taken to continue to improve water quality, water availability, and enhance the living resources of the Delaware River Basin.

Carol R. Collier
December 2008

Acknowledgments

The Delaware River Basin Commission staff are grateful to the following organizations that helped assemble and assess information for this report:

- Delaware Water Resources Agency, Institute for Public Administration, University of Delaware
- Pennsylvania Centers for Water Resources Research Watershed Stewardship, Pennsylvania State University
- New Jersey Water Resource Research Institute, Rutgers, the State University of New Jersey
- New York State Water Resources Research Center, Cornell University
- Partnership for the Delaware Estuary
- New Jersey Water Science Center, US Geological Survey
- US Environmental Protection Agency, Regions II and III

In addition to DRBC publications and in-house data, major sources of information for this report include USEPA Storet, USGS NWIS, and an array of environmental quality information from NJDEP, PADEP, DE DNREC, NYDEC, US Fish and Wildlife Service, US Forest Service, and the Nature Conservancy. In 1998, as part of the National Water Quality Assessment Program (NAWQA), the US Geological Survey undertook a four year study (1998–2002) of water quality issues in the Delaware River Basin. This Report draws on some of the results of that study.[1] The introduction to Category II: Water Quality relies significantly on Richard C. Albert's seminal article on the history of water resource management in the basin.[2] Much of the background and conditions reported in Category III: Living Resources was published in the State of the Delaware Estuary 2008.[3] References to DRBC's 1981 Level B Study have been used where appropriate to bridge the past and present. A Technical Summary of data underpinning this Report has been published separately by the Water Resources Agency at the University of Delaware.[4]

DRBC staff are also grateful to the many members of state agencies and the Science and Technical Advisory Committee of the Partnership for the Delaware Estuary for their review and contributions to this report.

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In addition to identifying desired environmental end states, the *Water Resources Plan for the Delaware River Basin* includes goals for the development of partnerships; the exchange of data, information and technology; and the improvement of coordination and cooperation among basin institutions, agencies and organizations. The *State of the Basin Report 2008*, product of a extensive collaborative effort, fulfills those goals.

1 Fischer et al. *Water Quality in the Delaware River Basin, Pennsylvania, New York, and Delaware, 1998-2001*. Circular 1227. Reston VA: USGS, 2004.

2 Albert, R.C. "The Historical Context of Water Quality Management for the Delaware Estuary", *Estuaries* 11 no. 2 (1988): 99-107.

3 Partnership for the Delaware Estuary. "State of the Delaware Estuary 2008", Report no. 08-01. *Estuary News* 18 no.3 (Summer 2008).

4 Kauffman, G. et al. *Technical Summary: State of the Delaware Basin Report*. Water Resources Agency, Institute for Public Administration, University of Delaware. Newark DE: July 2008.

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The Basin ~ Then and Now

Then ~… the activities of man vastly affect the behavior of water and ecology of the Delaware River Basin. The Estuary and Bay have been dredged to accommodate deeper draft ships, thereby altering the tidal prism; dredge spoil has been deposited on lowlands previously available to accept flood flows; people have settled where supplies of fresh water are periodically inadequate; waste products have been discharged into the stream system without regard to effect on aquatic habitat; much of the watershed land use has been modified by agriculture and urbanization, altering the erosion, surface runoff, and the delicate balance between land and water in the rivers, bays and marshes; major ground water reservoirs have been pumped to a point where water now flows from surface streams to the aquifer instead of from the aquifer to the streams; and surface storage reservoirs have been constructed to conserve water during periods of high flow for release during periods of low flow to meet the ever-increasing demands of man.

The Final Report & Environmental Impact Statement
of the Level B Study, May 1981
Delaware River Basin Commission

How clean are the water resources of the Delaware River, its tributaries and Bay?

Do we have enough water for drinking and for commerce? Is it safe to drink?

Are our waters 'swimmable'?

Are fish abundant and safe to eat? How are other living resources faring?

Is critical habitat being protected? Are our years of management and stewardship yielding good results?

Are we prepared to meet the issues we might face in the future?

Starting in 1976, a comprehensive study was conducted to identify and resolve water resource problems in the Basin. The resulting *"Level B Study"* issued in 1981 by the Delaware River Basin Commission (DRBC) reported the findings of that study, including resource conditions and recommendations for management. Since then, many excellent specialized studies have been published on a variety of water resource issues, but the *Level B Study* remains the last comprehensive assessment of the Basin – including water supply, water quality and flow management issues – published in one volume.

The *Final Report and Environmental Impact Statement* is commonly referred to as the *Level B Study*, since it conformed to guidelines established by the now defunct US Water Resource Council for a study of its magnitude, or Level B.

In 1999, a process was begun to develop a new and unifying vision for water resource management. The *Water Resources Plan for the Delaware River Basin* (Basin Plan), unveiled in 2004, presents a direction for integrated water resource management, acknowledging the connection between land and water and valuing aquatic habitat protection in the course of ensuring adequate flows and supplies for human needs. In accepting the new Basin Plan, the Governors directed the preparation of a periodic environmental condition report. This *Delaware River: State of the Basin Report 2008* fulfills that mandate.

In 1980 when the Level B Study was under development, the population of the basin was slightly greater than 7 million; the Clean Water Act was not yet a decade old; and industrial and municipal wastewater did not receive the level of treatment that it does today. There are now more than half a million additional people living in the River Basin and 25 years of advanced water treatment and remediation technology have been applied to water resource problems.

Have conditions improved? Has the *imbalance* noted in the 1981 Study been restored in the intervening 25 years? As we will see, the answer is both yes, and no. There have been improvements in resource condition, especially water quality, because of important changes in management policies. For example, required improvements in wastewater treatment have raised the levels of dissolved oxygen and restored shad runs to the River. However, the presence of toxic compounds and our ever-increasing ability to detect them in more minute quantities still leads to consumption advisories for many fish species in spite of site clean ups and cleaner water. Nutrients are holding steady, but concerns about pharmaceuticals and other compounds are growing. A trio of floods ravaged portions of the Basin in 2004, 2005 and 2006, re-focusing interest in flood mitigation. And international panels are preparing reports on


Hawk's Nest, NY

30-50 Million years ago The Delaware River and valley are formed.

1610 Delaware Bay is named in honor of Lord De La Warre (Thomas West), governor of Jamestown.

1769 The Delaware River at Philadelphia is described as a "mess" by a visiting Englishman.

1776 The Declaration of Independence is signed in Philadelphia. George Washington crosses the Delaware River above Trenton, NJ on Christmas Eve.

1790 John Fitch operates the 1st successful steamboat on the Delaware River.

1799 1st government pollution survey notes contamination entering the river from ships and sewers.

1801 Philadelphia's water department is the first in America to supply an entire city with drinking water; Fairmount Water Works on the Schuylkill River serve as a model for other American water delivery systems.

1931 The US Supreme Court grants NYC the right to withdraw 440 mgd from two reservoirs to be built on the headwater tributaries of the Delaware.

1936 The states of NJ, NY, and PA create the Interstate Commission on the Delaware River Basin to clean up pollution. DE joins three years later in 1939.

1954 US Supreme Court amends 1931 decree to increase NYC diversion to 800 mgd, specify flows at Montague NY, and approve 3rd reservoir.

1961 The Delaware River Basin Commission is formed, 1st interstate-federal agreement for comprehensive river basin management.

a changing climate, predicting more rapid changes that challenge our planning and management.

Based on 25 additional years of investigation and assessment, we know more about many issues, from toxic compounds to the effects of landscape changes, than we did in 1981. Yet our knowledge remains incomplete. We are still learning about the relationships among the natural elements of the system – such as soil, geology, slope, rainfall, temperature and chemistry – and of the effects of human influence on parts of this complex system. Changes occur even as we examine and calculate.

This *State of the Basin Report 2008* offers a view of conditions of the Basin's landscapes and waters based on available information on a set of discrete indicators.

Indicators

An *indicator* is a measure of condition; an environmental indicator is a measurement, value or statistic that provides an approximate gauge of the state of the environment and may help evaluate the effectiveness of an environmental management program. Ideally, an indicator is relevant, sensitive to change, easy to measure with low measurement error, and cost effective. For this report, indicators were chosen in part because information on them was readily available.

For each indicator, we include a **Description** and a statement of **Desired Condition** linked to a goal from the 2004 *Water Resources Plan for the Delaware River Basin* (BP), an Action item from the 1997 *Comprehensive Conservation Management Plan for the Delaware Estuary* (CCMP), and, when appropriate, to regulatory standards. There is also a report of condition **Status** and, if relevant, of historic or recent **Trends**. A **status bar** resembling a horizontal thermometer with a red-to-green color gradient accompanies each indicator, where green represents a good condition, and red an unfavorable condition. The placement of an icon indicates the condition status along the continuum, and its style reflects a stable, improving or worsening trend.

Concluding each indicator page is a statement of **Actions and Needs**, advising on improvements or changes that should be considered to enhance reporting capabilities and environmental conditions.

Reporting

Indicators are assembled into four categories:

- Category I: Hydrology
- Category II: Water Quality
- Category III: Living Resources
- Category IV: Landscape

The *State of the Basin Report 2008* offers a view of conditions of the Basin's landscapes and waters based on available information. It serves as a benchmark of current conditions, as a companion to the 1981 *Level B Study,* and as a point of reference for gauging progress towards the goals of the 2004 *Water Resources Plan for the Delaware River Basin*.

Each category section begins with an introduction and event timeline, and ends with a special feature on emerging issues to suggest ideas for future reporting. The final section of the Report summarizes conditions and recommendations.

The *State of the Basin Report 2008* is designed to serve as a benchmark of current conditions, and as a point of reference for gauging progress towards management goals. It also provides a platform for measuring and reporting future progress in water resource management, and a guide for adjusting monitoring and assessment programs.

1970
1st US Earth Day celebrated; the federal Environmental Protection Agency is established.

1972
FWPCA amendments establish construction grant program and permit discharge process for discharges; subsequently known as the Clean Water Act.

1978
Sections of the upper and middle Delaware River are added to the National Wild and Scenic Rivers System.

1981
Good Faith Agreement advances equitable allocation of basin waters.

1990s
Striped bass and American shad return to the Delaware River in large numbers.

2000
Sections of the lower Delaware River are added to the National Wild and Scenic Rivers System.

Welcome to the Delaware River Basin

Introduction

Basin Overview

Welcome to the Delaware River Basin

Lying in the densely populated corridor of the northeastern US, the 13,600 square mile Delaware River basin stretches approximately 330 miles from headwaters in New York State to its confluence with the Atlantic Ocean. The basin includes approximately 12,800 square miles of Bay and over 2,000 tributaries, including many that are rivers in their own right. The Delaware River's condition is very much a product of the cumulative flows from its many tributaries, which in turn take their character from the underlying geology, topography, microclimates and land uses of their watersheds.

The northernmost tributaries to the Delaware River originate in the forested western slopes of the Catskill Mountains that reach elevations of up to 4,000 feet. The East and West Branches meet at Hancock NY where the Delaware River officially begins. The River descends about 800 feet on its journey to the sea.

Political Setting

The drainage area encompasses extensive landscapes in New York, New Jersey, Pennsylvania and Delaware and 8 square miles in Maryland, which are not included in this Report. All or portions of 42 counties and 838 municipalities within four states contribute to and benefit from the resources of the Delaware River Basin. Water resources are also exported to cities in NJ and NY outside of the Basin boundary. While the states retain autonomy, the Delaware River Basin is unique in governance. It is the only river basin with both an interstate-federal Commission and a national estuary program in place. The 1961 Compact establishing the Delaware River Basin Commission (DRBC) was the first federal-interstate agreement for basin-scale water resources management. The DRBC pre-dates the first Earth Day, the establishment of the Environmental Protection Agency and the passage of the Clean Water Act. The national significance of the Delaware Estuary was acknowledged in 1988 when it became part of the National Estuary Program.

How old is the Delaware River?

It is thought that the formation of the Delaware River valley began during cycles of erosion and uplift approximately 30 to 50 million years ago. From Port Jervis to the Water Gap, the Delaware follows a strike (or valley) eroded in shales and limestones. The S-shaped curve at Wallpack Bend is a meander of a tributary stream eroded in this time period. From the Water Gap to Trenton the Delaware flows in a southeast course and this is thought to be the original flow direction of the River.

Below Trenton the River closely follows its contact with the bedrock formations of the Piedmont. Why and how the Delaware River was diverted in a right-angle turn at Trenton by softer sediments—when it had eroded through the harder strata of diabase, argillite, sandstone and shale up stream—is not in accord with normal river development and remains somewhat of a mystery. One possible explanation is that the ancestral Delaware flowed southeastward through its entire length across NJ, as did the ancestral Schuylkill River. Both rivers eventually became the product of stream capture by smaller streams flowing parallel to the southwest strike and created the existing context of the Delaware River and Bay.

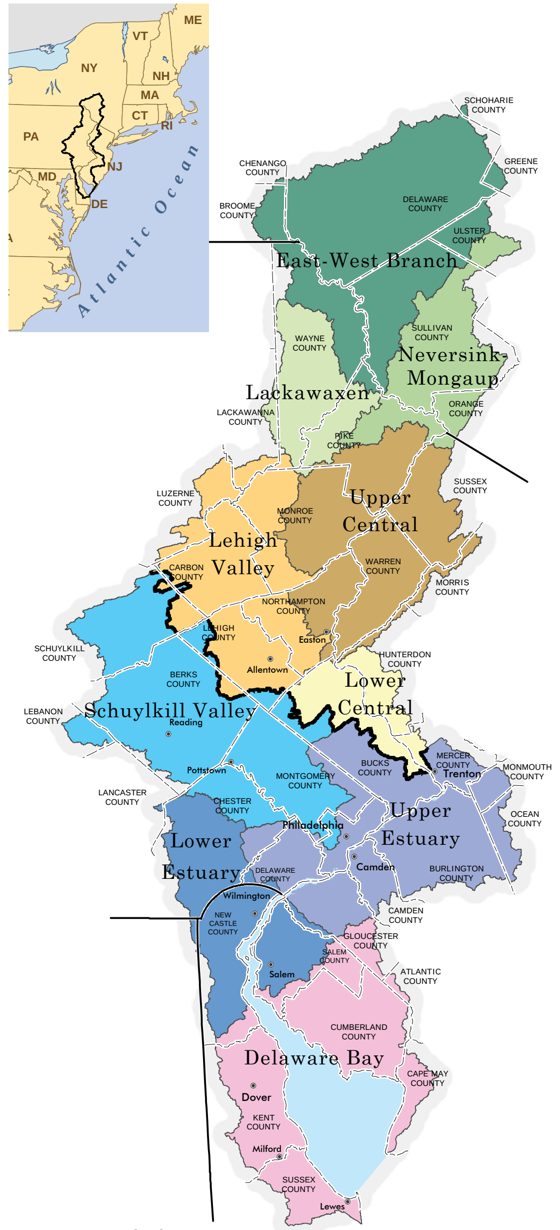


Fig. A.1. Watershed Regions.

What's in a name?

The Delaware River Basin straddles two very different hydrologic provinces corresponding to major physiographic divisions: the Appalachian Highlands and the Atlantic Coastal Plain (Figure 1.1 on the next page). The *fall line* is the natural division between these provinces, running southwest to northeast along the western edge of the River and crossing it near Trenton NJ. Above the fall line freshwater riverine conditions exist. Below the fall line the River is subject to tidal influences and, with increased proximity to the Bay, estuarine conditions exist.

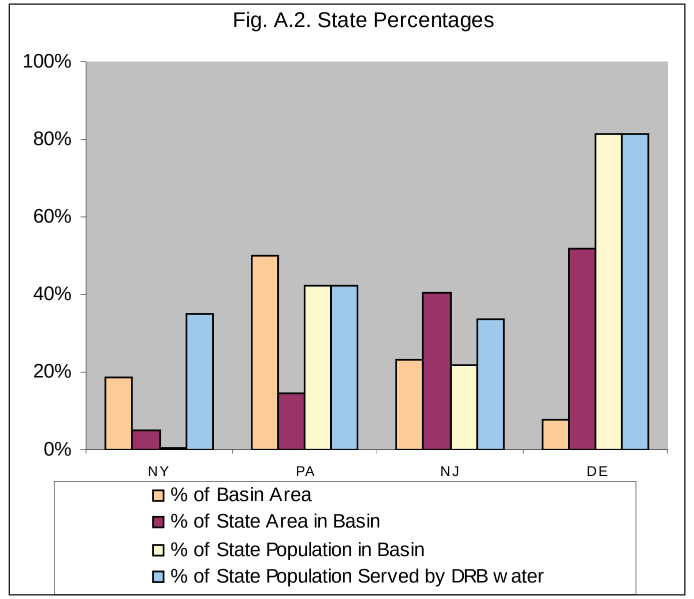
This report honors the Basin as a whole system of functioning parts, and the majority of reporting is on the basin scale. There is also reporting on the regional scale, referencing four regions of the basin. In the context of this Report:

- The **Upper Region** covers the Delaware River headwaters and contributing watersheds to just below Port Jervis NY.
- The **Central Region** is the remaining freshwater river and contributing watersheds between the Upper Region and Trenton NJ.
- The **Lower Region** is the area of tidal flux from Trenton to the head of the Bay and all contributing watersheds.
- The **Bay Region** includes the Bay and the surrounding watersheds.

Combined, the Lower and Bay Regions may also be referred to as the Estuary Region. It is the same area that is included in the National Estuary Program.

Within each region watersheds are grouped together based on the segment of river or bay to which they drain, irrespective of political divisions. For example, in the Upper Region, the Neversink and Mongaup watershed in New York are grouped together with smaller tributaries in Pennsylvania because they all flow into the same stretch of Delaware.

The Delaware River Basin is defined by its natural physical characteristics and by the legacies of hundreds of years of human settlement and use. The basin has been traversed by canals and rail lines and, today, an extensive network of roads link population centers within the basin to one another and to major metropolitan centers; New York City, for example, is within a two hour drive of Philadelphia. The natural landscapes of the Delaware that have attracted artists and vacationers for generations are today under increasing pressure to accommodate an expanding population. Conditions within the Basin therefore reflect historic and current circumstances both within the basin and beyond it.



Water resources are also exported outside of the Basin boundaries to cities in NJ and NY.

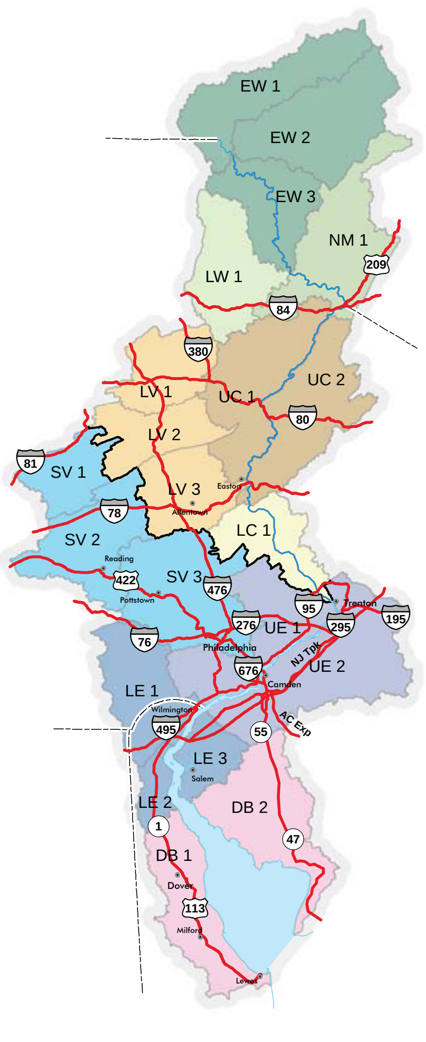


Fig. A.3. Location of Watersheds

Upper Region	EW • East & West Branch; LW • Lackawaxen; NM • Neversink & Mongaup
Central Region	UC • Upper Central watersheds; LV • Lehigh Valley; LC • Lower Central
Lower Region	SV • Schuylkill Valley; UE • Upper Estuary; LE • Lower Estuary
Bay Region	DB1 • Bay watersheds in DE; DB2 • Bay watersheds in NJ

Category I

Basin Hydrology

THEN ~ The physical behavior of the Delaware River water system can be compared to a single pool being utilized for many purposes. If water is evaporated (at any location), the dynamics of the system change; water stored during periods of high runoff affects the degree to which sea salts are repulsed toward the ocean; the withdrawal of ground water, even if returned via waste treatment facilities to surface streams, alters the time / flow relationship of runoff in the Basin, and the absorptive / replenishment capacity of the natural underground reservoirs.

Level B Study, May 1981, p 9
DRBC

As in 1981, the physical behavior of the Delaware River system can still be compared to that of a single pool. Changes in one region can affect circumstances in another. The replenishment of both surface and ground waters is linked to weather and precipitation, soil and geology, human use and transport.

Natural Flows

Compared to many other river systems, the Delaware Basin is blessed with a relative abundance of water, realizing over 45 inches of rainfall on average in a year. In a natural system flows are variable, but unmanaged, and dependent on precipitation and ground water base flows. Flow regimes, tracked as a hydrograph of flow volumes over time, reflect the effect of precipitation on streams. Flows on the River are the cumulative effects of flow from the tributaries; the Schuylkill and Lehigh Rivers are the two greatest contributors to Delaware River flows. Generally, the contribution of each tributary is proportional to the land area it drains—its watershed—but the magnitude of flows is also determined by the geology and soils of the watershed. Note the variability of base flows among the physiographic provinces as well as the difference within the provinces during drought conditions as illustrated in Table 1.1.

Hydrographic Regions of the Basin

The Delaware River Basin lies in two significantly different hydrologic regions which correspond to the two major physiographic divisions in the northeastern US: 1) the Appalachian Highlands 2) the Atlantic Coastal Plain. While physiographic provinces do not follow watershed boundaries, they do help define the character of watersheds and influence flows and water quality.

1) The Appalachian Highlands are made predominantly of consolidated sedimentary rock. Surface water is in high-energy streams and rivers, many of which have been dammed for energy production and water supply. In general, consolidated rocks store and transmit much less water than the sediments of the Coastal Plain and ground water is found in fractures and fissures, or in glacial deposits in some valleys. The Appalachian Highlands includes four provinces each of which has distinctive geology, landforms, and hydrologic characteristics. Two major tributaries, the Lehigh (Central Region) and Schuylkill (Estuary Region) Rivers, flow through all or most of the provinces of the Appalachian Highlands, which include four primary provinces:

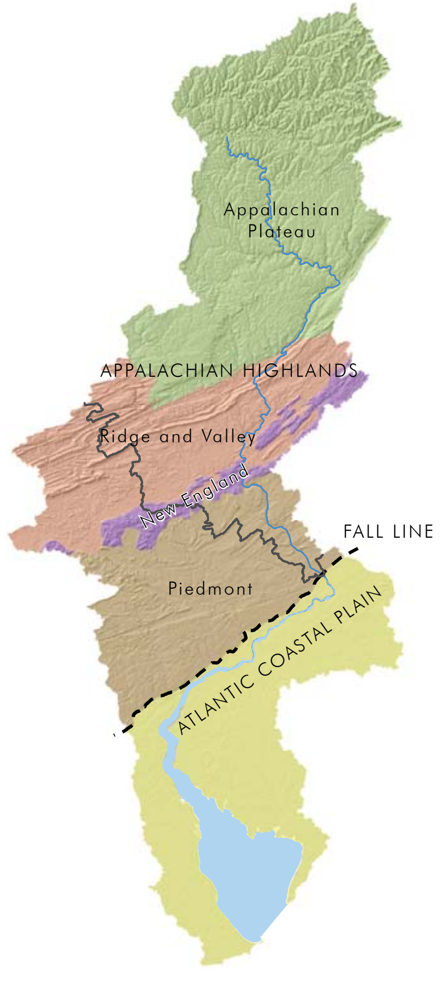


Fig. 1.1. Hydrographic Regions of the Delaware Basin.

Hydrologic Terms:
mgd = million gallons per day
cfs = cubic feet per second
ppm = parts per million

Table 1.1 Baseflow Values

Baseflow Values by Geology in gallons per day per mi²		
Physiographic Province	Normal*	Drought**
Appalachian Plateau	758,000	463,000
Catskill	727,000	478,000
Ridge & Valley	752,000	477,000
New England	671,000	373,000
Piedmont Uplands	539,000	291,000
Piedmont Lowlands	358,000	218,000
Atlantic Coastal Plain	738,000	450,000

* 1 in 2 year low flow ** 1 in 25 year low flow

- **Appalachian plateau.** The 1,000-to-4,000-foot-high uplands of this province form the Catskill & Pocono Mountains where rivers have carved deep and narrow valleys through gently folded shales and sandstone. Hydroelectric dams are interspersed throughout the province and New York City has a trio of reservoirs here for water supply. The Upper Region watersheds are almost exclusively within this province; and the Lehigh system originates in this province. The highest baseflow yields are found in the Appalachian plateau where, even in times of drought, baseflows may exceed those found in some piedmont streams under normal conditions (Table 1.1). Water is abundant here, especially in glaciated valley aquifers, which are also vulnerable to pollution. The landform, especially in the northern reaches, is amenable to damming to create reservoirs for power generation and water supply. In general, the large reservoirs in this region serve distant populations, such as those of New York City, and local communities rely on ground water from wells. While encompassing one third of the basin, only about 3% of the population lives in the Appalachian Plateau. The natural beauty, availability of water, and access to distant employment centers is increasing development here.

- **Ridge and Valley.** The northern section of this province is a series of long, narrow forested mountain ridges oriented southwest to northeast characterized by extreme topographic relief; distances from ridge top to valley bottom can reach 1200 feet. Developed land and agriculture dominate the valleys. Bedrock is principally sandstone and shale. Localized anthracite (coal) deposits have provided the resource for anthracite mining, a source of water quality impairment in the central portion of the Lehigh River (Central Region) and upper reaches of the Schuylkill River (uppermost region of the Estuary watersheds in Pennsylvania). At the southern end of the province is the Great Valley, a broad lowland with rolling hills and good agricultural soils overlaying a productive, but vulnerable carbonate aquifer. About 20% of the basin lies in this province and about 14% of the population lives here. Baseflows in the streams of the Valley and Ridge province provide yields comparable to the Appalachian plateau.

1841
The "Bridges Freshet" sends ice choked floodwaters down the Delaware sweeping away 9 bridges and becomes the "landmark" deluge of the 19th century.

1931
US Supreme Court authorizes NYC to construct 2 reservoirs and divert 440 mgd for water supply; specifies flows at Port Jervis NY and Trenton NJ.

1954
US Supreme Court amends 1931 decree to increase NYC diversion to 800 mgd, specify flows at Montague NY, and approve 3rd reservoir at Cannonsville.

1955
NYC's Pepacton and Neversink Reservoirs go on line; Cannonsville added in 1964.

1961-67
Basin experiences record drought.

1962
DRBC approves its first Comprehensive Plan, which includes a dozen multi-purpose reservoir projects, including Tocks Island, a giant impoundment planned for the Delaware River main stem.

1971
Construction of Beltzville Reservoir is completed; Blue Marsh under construction.

1975
DRBC commissioners defer construction of the Tocks Island Dam project.

1976
Flood plain mapping completed for 119 basin municipalities to qualify for federal flood insurance.

1977
DRBC regulations restrict development in the 100-year flood plain and prohibit development in the floodway.

A major test of any water management plan is to determine whether it is compatible with the hydrologic cycle and related natural systems of the Basin – patterns of precipitation, streamflow, dependence on surface and ground water, ground water recharge and storage.

Level B Study, May 1981

- **New England.** Underlain by hard rock, this province is one of extensively forested hills and ridges drained by a network of steep, rocky streams. Less than 5% of the basin has this type of landscape and less that 3% of the population lives here. Known as the Reading Prong in PA and the Highlands in NJ, this province has been declared a landscape of national significance for its forested habitats and biodiversity. In 2006 New Jersey enacted legislation to protect the Highlands as an area of statewide significance, especially for water resources. The USDA Forest Service has characterized the attributes of the Pennsylvania portion of this province which cuts through the Lehigh (Central) and Schuylkill (Estuary) watersheds in Pennsylvania and the Central watersheds in New Jersey.

- **Piedmont.** Extensive branching streams, rolling hills and prime agricultural soils cover low yielding sedimentary and crystalline rock in the Piedmont. Less than 20% of the land area of the Basin lies in the Piedmont, but nearly 50% of the population lives here. Surface water is the source for nearly 90% of potable water supply. The Piedmont is the southern-most extension of the Appalachian Highlands hydrologic region, ending at the fall line where the Atlantic Coastal Plain begins.

2) The Atlantic Coastal Plain, in great contrast to the consolidated sedimentary rock of the Appalachian Highlands, is a great wedge of unconsolidated sediment. Alternating layers of layers of sand, clay and gravel extend southeast from the fall line, thickening as they slope under Delaware Bay and the Atlantic Ocean. The coastal plain occupies the southern quarter of the basin and lies completely within the Estuary (Lower and Bay) Region. Great amounts of water are stored in these deposits which transmit water much more readily than the consolidated rocks of the other provinces. While ground water is widely available in the coastal plain, it may also be directly vulnerable to contamination. More than 33% of the basin's population lives in the Coastal Plain and ground water supplies are stressed in some areas.

More About Flow

Flows in all provinces vary seasonally, and are also affected by diversions and withdrawals of water for human uses, movement of water and wastewater within and among watersheds, and development that alters runoff and recharge patterns. Both high flows and low flows are important. High flows are associated with seasonal conditions in spring, as well as precipitation events and flooding. Low flows are associated with seasonal conditions of early autumn and can be exacerbated by diversions and withdrawals for human use. Low flows are also important because we use our waterways to assimilate waste water, and without minimum flows water quality problems can develop.

Flow Management

Although the Delaware River does not have a dam on its main stem, the flows of the River can be moderated to some extent through coordinated management of flows of reservoirs on the tributaries. A 1954 Supreme Court decree and subsequent modifications sanctioned the NYC reservoirs and the exports of up to 800 mgd of water to NYC and 100 mgd to New Jersey through the Delaware & Raritan canal. Conditions of the decree also require the maintenance of minimum flows at Montague NY (1,750 cfs) and at Trenton NJ (3,000 cfs). In periods of low flow, this is accomplished through the cooperative management of New York City's water supply reservoirs in NY, several multipurpose reservoirs in PA, and a privately-owned reservoir in NJ.

Permanent storage capacity in tributary reservoirs totals over 410 billion gallons; 68% of this storage is held in the three New York City water supply reservoirs in the Upper Basin. Of the 24 reservoirs in the Basin, nine are dedicated for water supply, two generate hydropower, three are solely for flood loss reduction, one is strictly for flow augmentation. Nine are dual or multi-purpose, providing water for a combination of water supply, flow augmentation, and flood loss reduction. Enhancement of fish and wildlife habitat and recreational opportunities are additional benefits of many of these reservoirs.

Since the Delaware River is subject to tidal influence as far north as Trenton NJ, one purpose of the 3,000 cfs flow target at Trenton has historically been to maintain the salt line—where salt concentration is 180 parts per million (ppm)—at River Mile (RM) 98, safely downstream of intakes for public supply.

Reporting

Hydrologic indicators included in this report are:

- Flows at Trenton NJ
- Salt line location
- Water use
- Water supply sources
- Areas of ground water stress
- Floods and flood damage

Each indicator supplies a look at one piece of the complex hydrologic puzzle. A feature on predicted changes to climatic conditions and the challenges they pose to water resource management concludes this section.

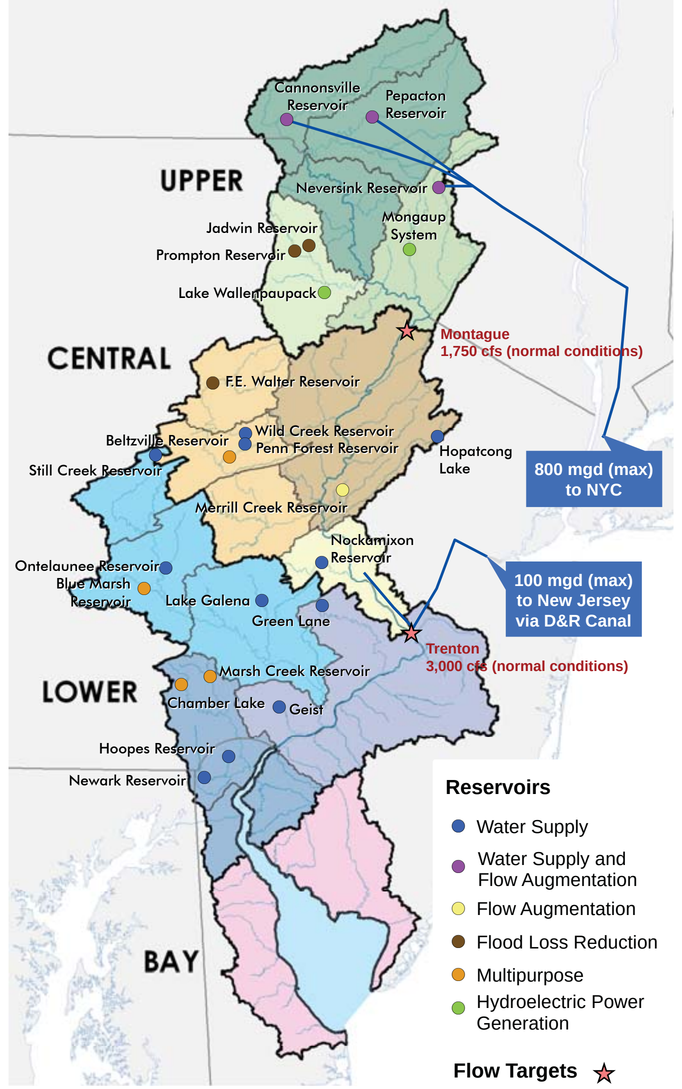


Fig. 1.2. Reservoirs of the Delaware River Basin.

1981 DRBC releases Level B Study; water conservation and reservoir enlargement are key recommendations.

1983 "Good Faith" Agreement redefines state appropriations and establishes drought operating plan for basin reservoirs.

1985 DRBC adopts basin-wide well registration program as integral component of ground water management.

1985 Construction begins on Merrill Creek Reservoir, designed to provide make-up water for riverbank electric generating plants during low flow conditions.

1986 DRBC adopts regulations requiring the source metering of large water withdrawals.

1999 DRBC amends Southeastern PA Ground Water Protected Area regulations, placing withdrawal limits on 62 additional watersheds.

1999 Hurricane Floyd delivers 6 to 10 inches of rain in 18 hours to the lower basin; tributary flooding causes extensive damage to roads and bridges and casualties among motorists.

2001 Tropical Storm Allison generates 10 or more inches of rain in 24 hours causing loss of life and property damage in PA counties.

2001 Basinwide drought emergency declared for only the 3rd time since 1980; combined storage in NYC's Delaware reservoirs drops to a record-low 23% of capacity by Dec 15, 2001. 2002 sets new drought of record for DE.

2003 In the wake of Hurricane Isabel, a series of storms drop 2-3 inches of rain on saturated areas of the basin; flash floods affect towns in PA and DE.

2004-2006 Excessive rainfall in the basin is primary reason for 3 major flood events in 18 months. The worst flooding since 1955 causes evacuations, bridge and road closures, and millions of dollars in damages.

Indicator • Flows at Trenton

Indicator Description

Maintenance of average daily flows and minimum low flows at Trenton, NJ are vital for the protection of drinking water uses and maintenance of fresh water flows to the estuary for living resource health.

Desired Condition

Maintenance of minimum flows at Trenton, NJ (2,500 – 3,000 cfs based on drought status) to protect public water supplies from salt water intrusion (BP Goal 1.3; CCMP Action W6).

Status and Trend

Good: Flow target maintained 95% of the time.

Reservoirs provide a means of maintaining minimum flows at target gages. During the period from 1980 to the construction of the last large reservoir in the Basin in 2007, the 3,000 cfs normal flow target at Trenton NJ has been maintained 95% of the time compared to 87.5% of the time for the period prior to reservoir construction (1913–1949). Occasions when the flow target is not met may be due to reductions in watershed baseflow, the multi-day travel time to Trenton from the reservoirs in the Upper and Central Basin and the uncertainty of precipitation forecasts. The data used to develop the following graphs only include the flows measured at Trenton.

Figure 1.3 presents the mean annual flow at Trenton from 1913–2007, including the drought of record in the 1960s. Note that mean annual flows in 1996 and 2003 exceeded those of any other year in the 84-year historic record.

A flow duration curve shows the probability of a specific flow, being exceeded. The flow duration curves for average daily flow at Trenton NJ (Fig. 1.4) show the increase in high, medium, and low flow conditions in recent years. The higher flows at the left of the graph occur only 0.1% of the time, where the lower flows on the right of the graph are almost always exceeded. Both curves represent similar management practices since the records used are post-reservoir construction. The blue curve represents 1980–2002 and the red curve represents 2003–2007.

Comparison of the two flow duration curves shows the flows that occurred from 2003–2007 are greater than flow from the 1980–2002 for the same exceedence probability. Therefore, flows were higher and less reservoir releases were needed to meet the Trenton target in recent years.

The largest differences are seen at the 0.1% and 50% to 80% probabilities. This indicates that the highest flows between 2003 and 2007 were 80% higher than the highest flows between 1980 and 2002. Normal flows (those likely to happen 25 and 75 percent of the time) are approximately 45% to 63% larger in recent years than during the years 1980–2002. Low flows (those exceeded 95–99.9 % of time) can be managed more easily with reservoirs than high flows. The two curves are closer together at low flow values, but the low flows of recent years are still 14%–27% larger than those of 1980 –2002.

A review of precipitation records for the post reservoir time period shows the median precipitation during the 2003–2007 period was 22 percent greater than during 1980–2002 time period (Fig. 1.5). Greater flow from increased precipitation has implications for water resource management issues in the Delaware River Basin. Streams that are less dependent on ground-water contributions are more sensitive to increases in precipitation.

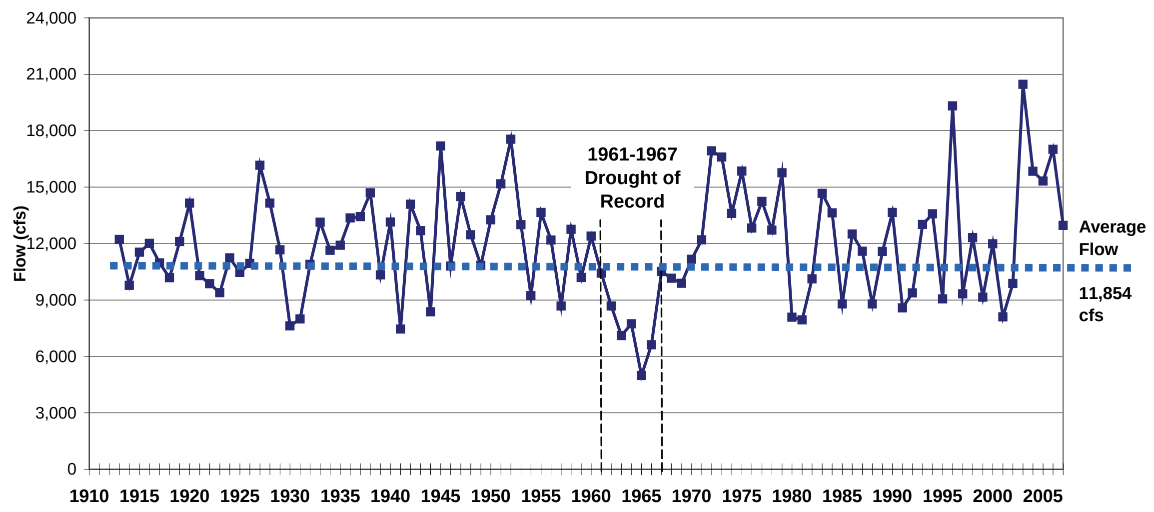


Fig. 1.3 Mean Annual Flow at Trenton NJ. USGS gage #01463500

Climate experts are predicting greater climate extremes, including warmer, wetter weather patterns and more severe droughts. Wetter weather would lead to increases in the probability and duration of reservoirs being at full capacity due to increased runoff and reduced discharges to meet instream needs and minimum flow targets at Montague and Trenton. More severe droughts would require more storage in the basin to meet water demands.

Actions and Needs

- Reservoir management, including the potential development of multi-purpose reservoirs for flood control and water supply, will be an integral part of adaptive responses to maintain minimum flows during changing climatic conditions.
- Stormwater management and other land-based strategies are also necessary to maintain normal flow patterns.

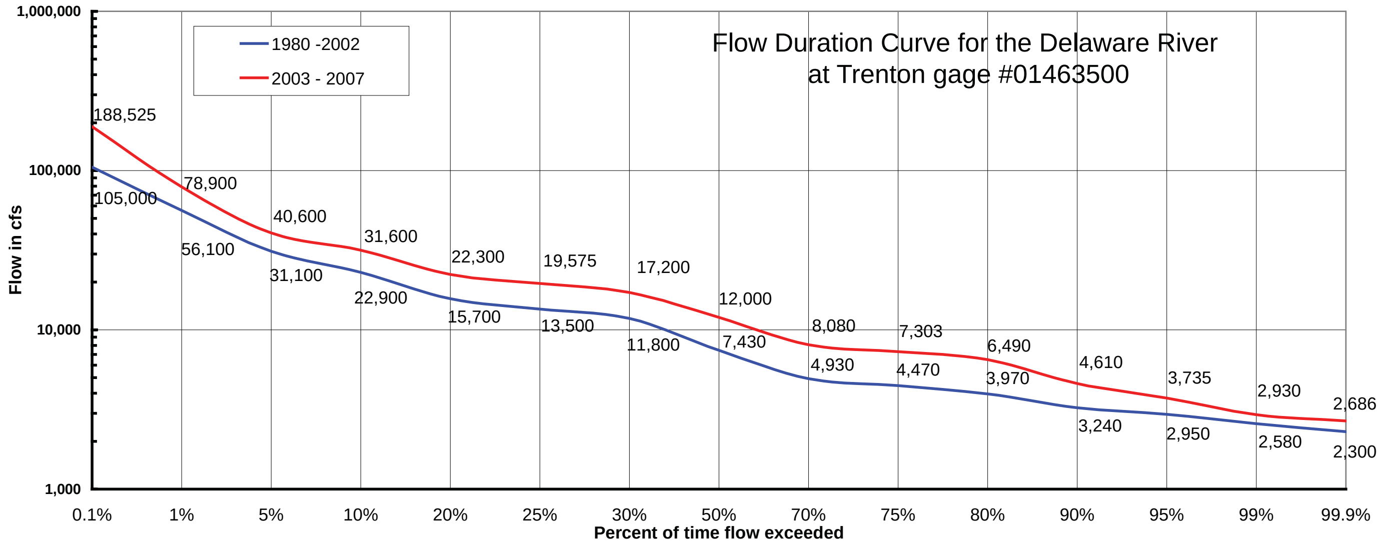


Fig. 1.4 Flow Duration Curves for Trenton NJ comparing two time periods: 1980–2002 and 2003–2007 indicates that recent flows (2003–2007) are higher than historical flows (1980–2002)

A flow duration curve is a cumulative frequency curve showing the percentage of time specified flows are equaled or exceeded.

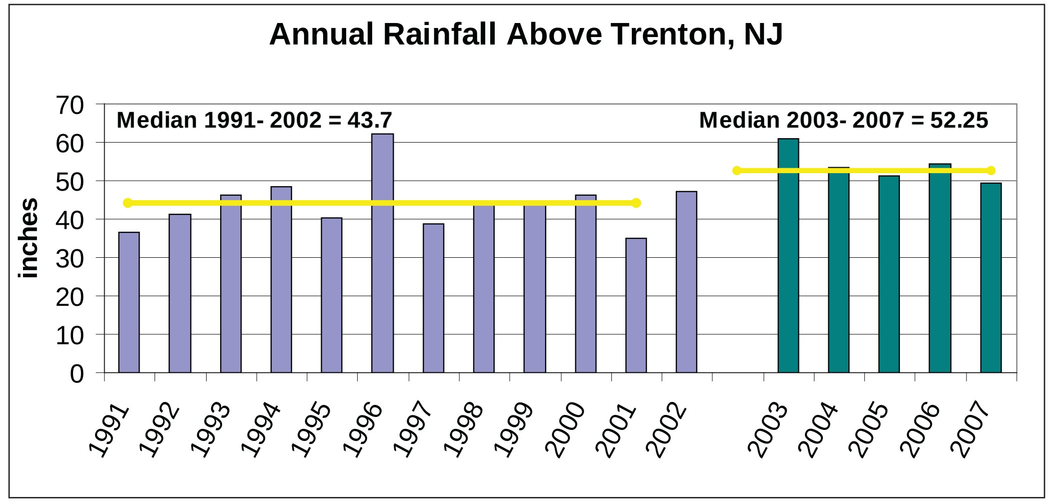


Fig. 1.5 Annual Rainfall Above Trenton, NJ. The median of annual total rainfall above Trenton, NJ was 22% greater during the years 2003–2007 than it was in 1991–2002. Precipitation data from the National Weather Service.

Indicator • Salt Line Location

Indicator Description

The salt line is an estimation of where the seven-day average chloride concentration equals 250 ppm along the tidal Delaware River. The salt line location plays an important role in the Delaware River Basin water quality and drought management programs because upstream migration of brackish water from the Delaware Bay during low-flow and drought conditions could increase sodium chloride concentrations in public water supplies, presenting a public health concern.

Desired Condition

Ensure an adequate and reliable supply of suitable quality of water to satisfy public needs (BP Goal 1.3; CCMP Action W6).

Status

Very good: Drinking water intakes in the tidal River are effectively protected.

The salt line naturally advances and retreats with each tidal cycle and with seasonal variations in freshwater flow. For most of the year, the location of the salt line is between the Commodore Barry Bridge (RM 82) and Reedy Island (RM 54). During droughts and periods of very low flow, a management program directs releases from upsteam reservoirs to augment flows and meet a daily flow target of 3,000 cfs at Trenton NJ. The program has worked well. Since 1970 low flows that once occurred 10% of the time now occur only 1% of the time. The salt line has been successfully repelled below drinking water intakes, protecting drinking water supplies in the most urban area of the Basin.

Actions and Needs

- Investigation of additional sources of chlorides, such as from road salts and runoff, is warranted.
- Documented sea level rise and increasing variability in flow from climatic change may create additional challenges for management of the salt line in the future.

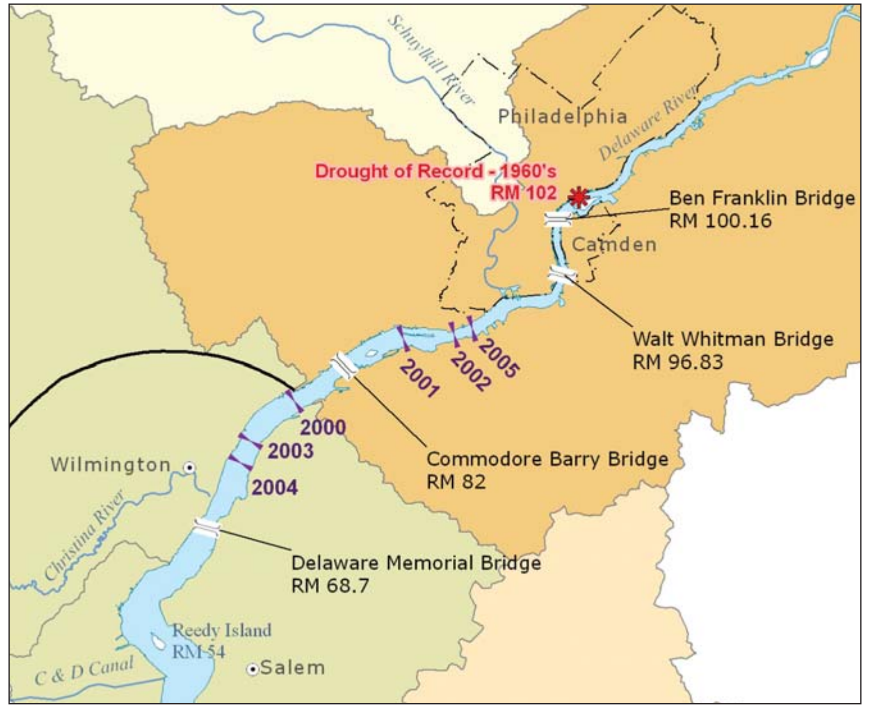


Fig. 1.6. Map of Historic Salt Line Locations.

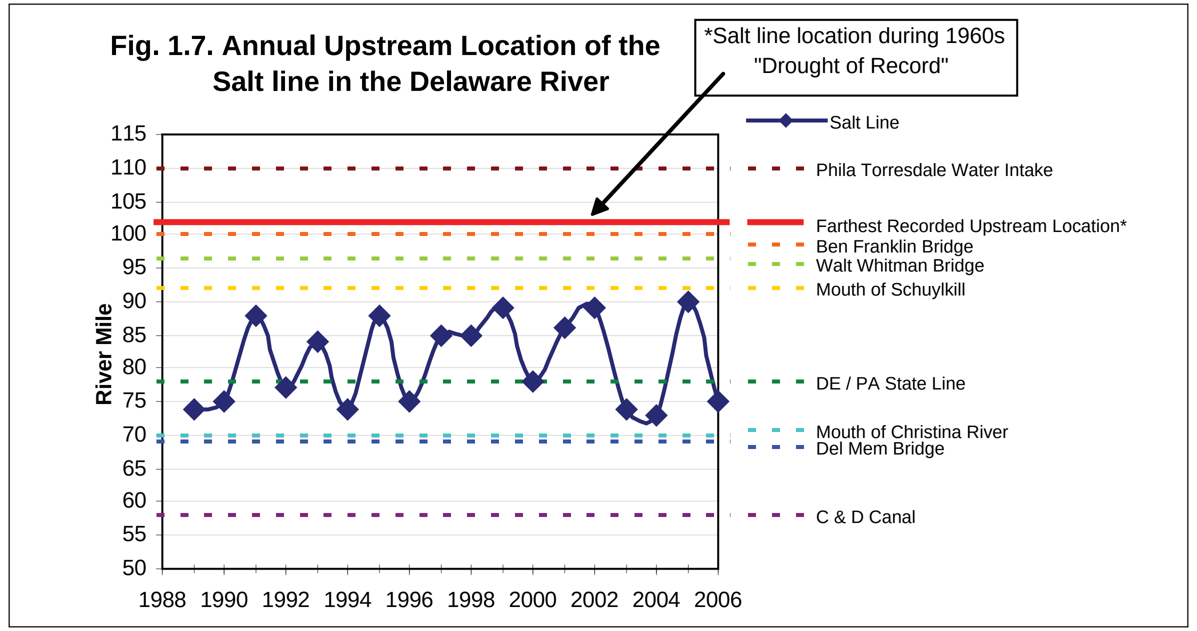


Fig. 1.7. Annual Upstream Location of the Salt line in the Delaware River

Indicator • Water Use Efficiency

Indicator Description

In managing water resources it is desirable to have some measure of water supply efficiency, that is, where water use may be higher or lower in relative terms. This efficiency is measured through *Per Capita* and Consumptive Use.

Per Capita Use normalizes total water use for a given population. *Per capita* water use has been calculated as follows:

$$\frac{\text{Domestic (residential) well use + Public Water Supply}}{\text{Population}}$$

Water use from other sectors has not been included in the calculation in order to allow for a more meaningful comparison. However, public water supply may include some commercial and industrial use.

Consumptive Use measures water that is not returned to the watershed and ultimately lost, via evaporation or transfer, to immediate use within the water resource system. It is calculated both as a volume and as a percentage of total water withdrawals, the data reflect water use by all water use sectors.

Desired Condition

Decreasing or stabilized rate of water use per capita to balance demands on limited water resources (BP Goal 1.1) and the use of water conservation techniques by water utilities (CCMP Action W3).

Status

Fair: Average per capita use is 133 gallons per capita per day (gpcd) and ranges from 90 to 190 gpcd.

Regional differences among the subbasins are shown in Figure 1.8. The Schuylkill Valley subbasin shows the highest *per capita* use with a value close to 200 gpcd.

The basin average for consumptive loss in public water distribution systems is approximately 10%. In terms of absolute consumptive use the Upper Estuary has the highest, as many power generating and industrial facilities are located along the Delaware River in this subbasin (Fig. 1.9). When expressed as a percentage of water withdrawals, however, consumptive use is relatively low in this subbasin. The Delaware Bayshore watersheds have the highest percentage of consumptive use (nearly 30%) relative to total withdrawals (about 45 mgd), which is a function of the significant amount of agricultural activity in this region.

Actions and Needs

- Better tracking of water transfers—how water is moved in pipelines from one location to another—would provide for more accurate and comparable estimates of water use efficiency. New Jersey DEP has developed and populated a water tracking model which may be applicable for use in other portions of the basin.
- Improved measurement and reporting of residential water use separately from other uses—such as commercial and industrial—within a public water system would provide a better idea of per capita water use efficiency. Pennsylvania DEP currently collects data in this manner. Achieving this across the basin would permit more realistic comparisons of *per capita* use.

> There are problems in comparing water use at large scales and among different development types. Differing socio-economic and demographic characteristics can result in vastly different water use patterns. For example, largely suburban watersheds may have a greater per capita consumption than highly urbanized watersheds due to lawn irrigation and household size. And where power generation or agricultural uses dominate water use, consumptive use is also noticeably greater. As long as these limitations are acknowledged, such indicators of water use can be used for general comparison.

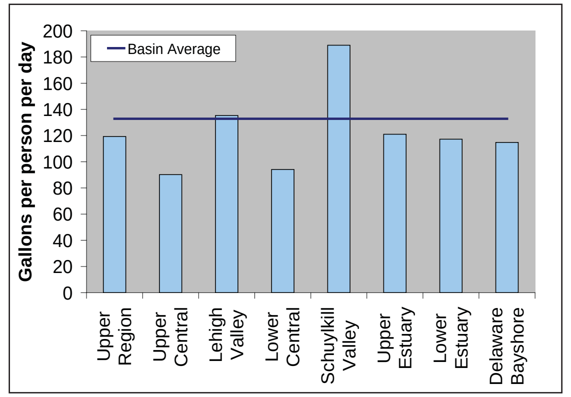


Fig. 1.8. Regional Per Capita Water Use.

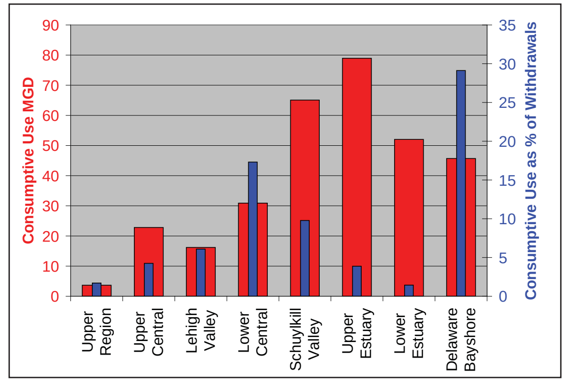


Fig. 1.9. Regional Consumptive Water Use.

Indicator • Water Use

Indicator Description

How water is used for potable supply and commerce is one indicator of the necessity and value of water to society. Accurate and comprehensive water use information enables the proper assessment, planning and management of water resources.

As reporting of water use improves, so does our accounting and our understanding of the need for water among various use sectors. The data set used in this analysis reflects water withdrawals and use in 2003.

Desired Condition

An adequate and reliable supply of suitable quality water to sustain human and ecological needs (BP Goals 1.2, 1.3, 1.4).

Status

Good: Human needs are being met; ecosystem needs are being investigated for consideration in management options.

The dominant use sectors, in the basin and regionally, are shown in Figures 1.10 and 1.11.

Nearly 15 million people rely on water from the Delaware basin for their daily water needs. On average over 8.7 billion gallons of Delaware basin water are put to use each day. These numbers include an average of 736 million gallons of water exported for populations in New York City and northeastern New Jersey, which account for approximately 8% of the total amount of water withdrawals.

A system of reservoirs in the Upper basin store water for export to New York City and make compensating releases to maintain water temperatures and flows for wildlife and downstream uses. New Jersey exports water from the basin via the Delaware and Raritan canal.

Uses related to power generation dominate both basin and regional water use patterns. However, which sectors use the water may not be as important as whether or not the water is ultimately returned to the system. For example, hydroelectric power generation is a dominant use in the Upper and Central region, accounting for 68% of water use (617 mgd). Hydroelectric power generation is non-consumptive and therefore the water is available for use downstream.

In contrast, thermoelectric power generation dominates both the basin and the Lower and Bay Region statistics at nearly 80% of total withdrawals (5,682 mgd). While it has a low consumptive loss rate (1.6%) the sheer volume of water used ensures a substantial water loss to the hydrologic system through evaporation. These plants are generally placed where water supply needs can be met with a less significant hydrologic impact. In addition, Merrill Creek reservoir in New Jersey was built by a consortium to offset power-related consumptive loss in the basin. When necessary, this reservoir can release flows to protect drinking water supplies.

Overall, 90% of all water withdrawn from the Delaware basin is diverted from surface water flows. Potable water in the basin is supplied from surface water diversions (64%) and ground water withdrawals (36%). Nearly 90% of all potable supply for commercial and residential use is through public water supply systems; only 10% is from domestic (household) wells. The basin average for consumptive loss in public water distribution systems is approximately 10%.

Our knowledge of the volumes of water used for irrigation is sparse and numbers reported here are based in part on estimates. Although the amount of water withdrawn for agricultural water use is relatively small (63 mgd basin-wide), the highly consumptive nature of irrigation means that this sector accounts for nearly 1/5 of the total consumptive water use.

Fig. 1.10. Daily Water Withdrawals, Exports and Consumptive Use in the Delaware River Basin

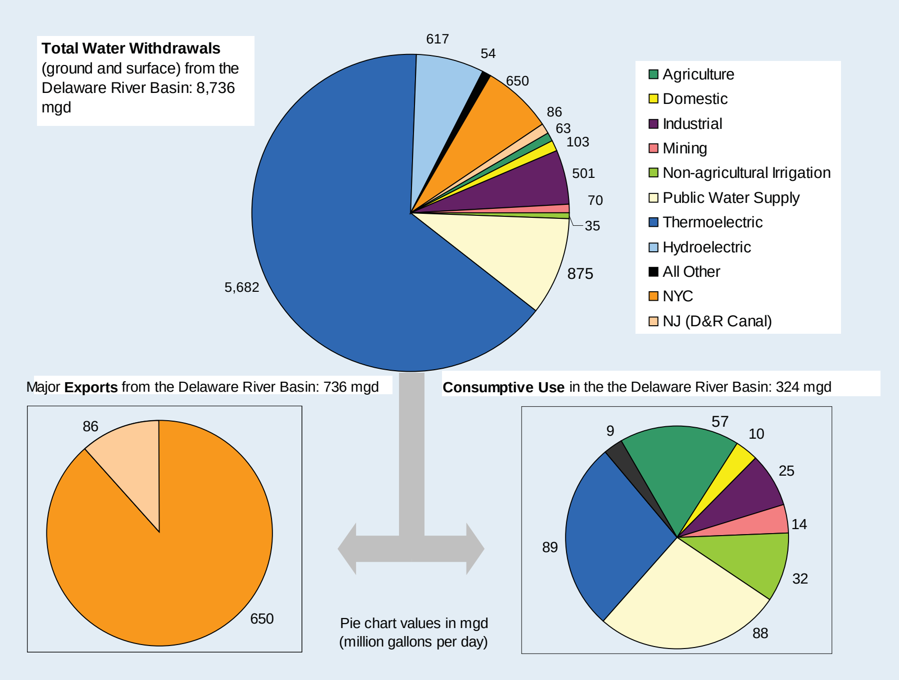


Table 1.2. Water Use Facts	
Values - based on 2003 water use records	
Population using Delaware basin	Approximately 15 million people
Water exported out of basin	736,000,000 gallons per day • 8% of total withdrawals • 45% of regional withdrawals
Water withdrawn for use in the Basin	8,000,000,000 gallons per day
Basin per capita water use	133 gallons per day per person
Dominant in-Basin uses	• 65% Thermoelectric power generation • 10% Public water supply • 7% Hydropower • 6% Industrial
Dominant uses in Upper and Central Regions	• 68% Hydroelectric power • 16% Public supply • 5% Domestic wells
Dominant uses in Lower and Bay Regions	• 79% Thermoelectric power generation • 10% Public water supply • 7% Industrial

Trends

Thermoelectric power generation, and the water demands for this sector, have shown a steady increase in recent decades and are projected to continue to increase.

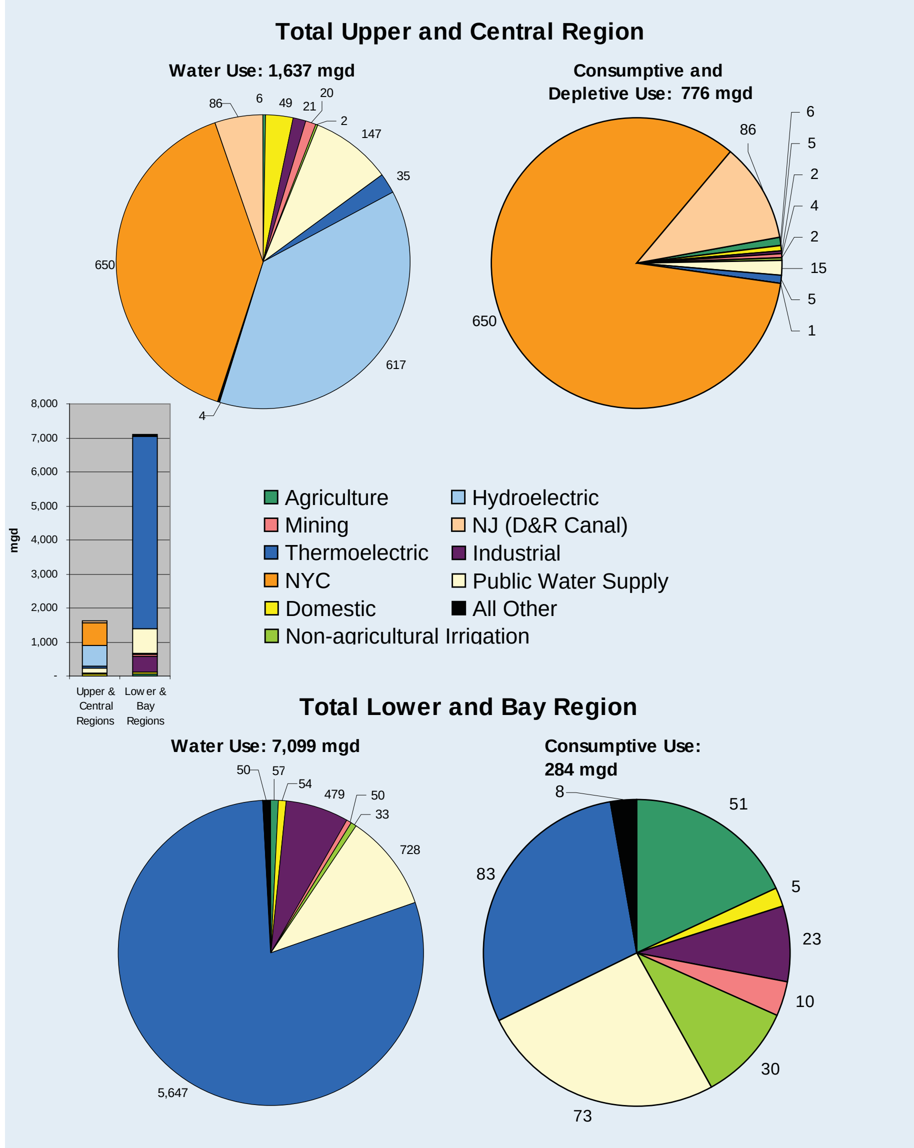
The data suggest that in the past decade, basin-wide water use has remained fairly constant. An increase in population has been offset by a decline in industrial water use and benefits attributable to conservation. Reliable data on agricultural use are generally not available, a situation that hampers efforts to plan for reliable supplies for all sectors.

Actions and Needs

The key challenge is to manage supply to a growing population while ensuring adequate instream flows to satisfy ecological needs.

- Population growth hotspots, especially in the Pocono and select bayshore watersheds, compel attention. Additional demand may compete with the need to maintain seasonal flows for aquatic life needs.
- In groundwater-dependent areas where surface water is not an immediate option, additional planning for alternative sources, such as aquifer storage and recovery or beneficial reuse may be in order.
- A better understanding of irrigation water use, especially for agriculture is needed in order to improve planning and management.
- A study of the potential growth in water demand for the thermoelectric sector is required due to the impact that large power generating facilities can have on water resources. Water needs for other energy production (e.g. drilling) also needs investigation.
- Advances in quantifying the instream needs of aquatic ecosystems are necessary for achieving the desired water supply goals.

Fig. 1.11. Regional Water Withdrawals, Exports, and Consumptive Use



Indicator • Water Supply Sources

Indicator Description

Water for drinking, industrial uses, irrigation and power supply can come from surface sources, such as rivers, streams and reservoirs, or from sources in the ground (aquifers). The ability to draw from a mix of sources increases reliability, especially during times of drought. Knowledge about water supply sources is important in planning for growth, for water supply and waste water collection, treatment and discharge, and for maintaining hydrologic integrity in watersheds.

Desired Condition

An adequate and reliable supply of suitable quality water to sustain human and ecological needs, and to maintain hydrologic integrity (BP Goals 1.1, 1.2, 1.3, and 3.1).

Status

Good: Multiple potable supply sources available in many, but not all, regions of the basin; some source protections in place.

> The ability to draw from a mix of sources increases reliability, especially during times of drought.

The source of potable supply varies across the basin. As illustrated in Figure 1.12, 64% of potable water in the Basin is supplied from surface water sources and 36% from ground water, a portion of which is domestic supply. Domestic supply refers to private household wells; reliance on domestic wells varies greatly across the Basin.

The Upper region is particularly dependent on ground water (nearly 80%) and domestic wells specifically (43%). Supply sources may vary within a region as well. Note that while 70% of the Estuary region relies on surface water to meet demand, the Bayshore region is totally dependent on ground water, 22% of which is from domestic wells.

Trend

Interconnections among public supply systems and the ability to use both ground and surface water to meet demand (conjunctive use) are measures of supply sustainability. Supplies need to be protected from depletive withdrawals and from quality impairments that could impact the long term viability of the source. Source water protection can be accomplished in several ways and is especially important in areas dependent on ground water as a sole source of supply.

Cannonsville Reservoir

Sole Source Aquifer designation is one tool to protect drinking water supplies in areas with few or no alternative sources to the ground water resource, and where if contamination occurred, using an alternative source would be extremely expensive. EPA defines a sole source aquifer as one which supplies at least fifty percent (50%) of the drinking water consumed in the area overlying the aquifer. The designation protects an area's ground water resource by requiring EPA review of all proposed projects within the designated area that will receive federal financial assistance to ensure they do not endanger the ground water source.

The larger high-yielding aquifer systems in New Jersey have been designated as Sole Source Aquifers, since they are the sole source of drinking water for communities in that area. In addition to the aquifers, the designation includes review of projects in a stream flow source zone which lies

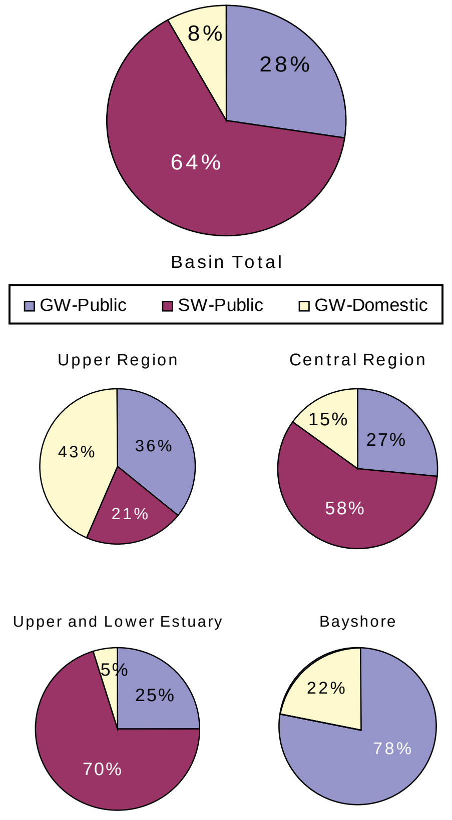


Fig. 1.12. Sources of Potable Supply

within two miles of the Delaware River in counties in NJ (Mercer, Hunterdon, Sussex and Warren), DE (New Castle); PA (Delaware, Philadelphia, Bucks, Monroe, Northampton, Pike and Wayne) and NY (Delaware, Orange and Sullivan).

State-designed **Wellhead Protection** (WHP) Programs offer local options to protect community supply wells, often through specialized zoning and development ordinances. All four basin states have adopted WHP programs in compliance with a federal mandate and may require some degree of protection as part of ancillary permitting processes. Delaware, as part of its Source Water Protection Plan, enacted a law in 2001 requiring large municipalities and counties to recognize WHP Areas in their Comprehensive Land Use Plans and to enact ordinances to protect WHPAs by December 2007. Pennsylvania, New Jersey and New York have voluntary WHP programs. Although a WHP program may recognize clusters of domestic wells as worthy of protection, state programs do not require it.

Actions and Needs

- Additional supply sustainability indicators should be identified; measures of system interconnection and source water protection should be considered.

> *The sole source aquifer determination for New Jersey's Coastal Plain Aquifer was made in part because more than 3 million coastal plain residents depend on this ground water to serve 75% or more of their drinking water needs.*

- Additional information on the adoption of wellhead protection programs should be collected and reported.
- Further efforts for protection of locally significant ground water supplies, especially areas served by community wells and domestic well clusters, should be encouraged and supported.

Buckingham Twp. PA, public community supply well and water tower. The township owns the land surrounding this and other wellheads, effectively protecting the public water supply.

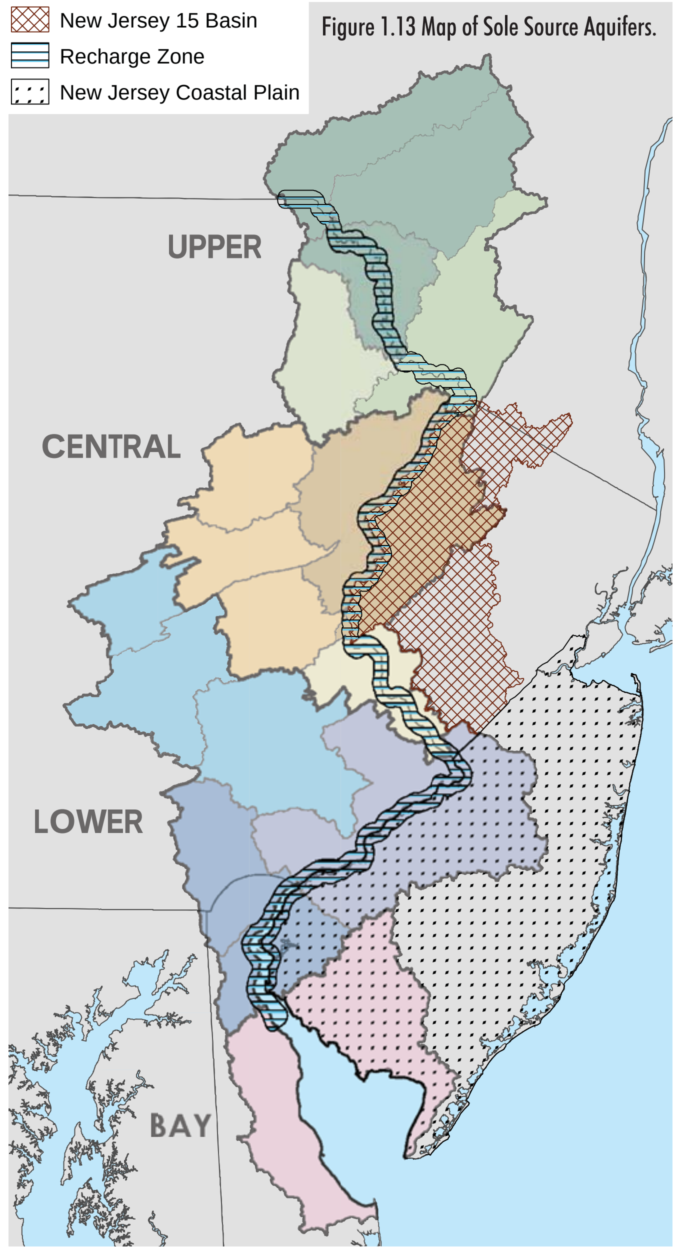


Figure 1.13 Map of Sole Source Aquifers.

Indicator • Areas of Ground Water Stress

THEN ~ Ground-water overdraft, or "mining", is a common practice in the western drylands, but is not likely to become a widespread practice in the Coastal Plain of the Delaware River region.

USGS Professional Paper No. 381, 1964

NOW ~ Some watersheds in the Coastal Plain and Piedmont hydrologic provinces have experienced ground water overdraft conditions and require special management.

Indicator Description

Stress on a water resource system can occur when withdrawals exceed natural recharge. Withdrawal of ground water by wells is a stress superimposed on a previously balanced ground water system. The response of an aquifer to pumping stresses may result in an increase in recharge to the aquifer, a decrease in the natural discharge to streams, a loss of storage within the aquifer, or a combination of these effects, and impacts may extend beyond the limits of the aquifer being monitored.

Two major areas within the watersheds of the Upper Estuary region show stress and are recognized as critical or protected areas: the Ground Water Protected Area in southeastern Pennsylvania, and Critical Area No. 2 in south-central New Jersey which overlays the Potomac-Raritan-Magothy (PRM) Aquifer (see Figure 1.14). New or expanded withdrawals in both of these critical areas are prohibited or limited and managed subject to specific regulations which serve to allocate the resource on the basis of a sustainable long-term yield.

Desired Condition

An adequate and reliable supply of suitable quality water to sustain human and ecological needs (BP Goal 1) and decreased reliance on Triassic and PRM aquifers (CCMP Actions W1-W3).

Status

Fair: Conjunctive use and regional alternatives to local supplies are easing the stress in these two areas, but additional problem areas are emerging.

South Eastern PA Ground Water Protected Area (SEPA-GWPA). Reductions in total annual ground water withdrawals have been observed since numerical withdrawal limits were established for the GWPA. Between 1990 and 2003 total annual ground water withdrawals within the GWPA were reduced by approximately 2.5 billion gallons (6.8 mgd). However, while the GWPA has improved overall through reduced ground water withdrawals, there are still subbasins withdrawing ground water volumes that exceed the potentially stressed level. In the Warminster Subbasin, Little Neshaminy Creek (A), Newtown Creek (B), and Schuylkill-Trout Creek (C) are all withdrawing ground water in annual volumes that exceed the potentially stressed level (Figure 1.15).

New Jersey Critical Area 2. In 1996, implementation of Critical Area #2 by NJ resulted in a reduction in the use of the PRM aquifer system. Many of these municipalities are now served by surface water diverted from the Delaware River near Delran, NJ. As a consequence of conjunctive use of ground and surface water, aquifer water levels have increased and appear to be stabilizing in most parts of Critical Area #2. An example is shown in the hydrograph from USGS Elm Tree 3 observation well (Fig. 1.16), over 700 feet deep in the Middle PRM aquifer in Camden County NJ.

Additional Problem Areas in the Lower Estuary and Bay Region. The PRM aquifer system extends under the Delaware River, through Delaware and into portions of Maryland. A 2007 draft report from the USACE on a ground water model developed for northern New Castle County DE concluded that ground water withdrawals in Delaware are diminishing stream base flows and forming cones of depression. The impact of these withdrawals extends into Maryland and New Jersey. Delaware has developed a program to provide surface water for northern New Castle County (see box).

Base flow declines are also a concern in the Salem-Gloucester area and the Maurice River basin of southern New Jersey. New and expanded allocations are being denied or restricted to limit adverse impacts on the aquifers and protect stream flows.

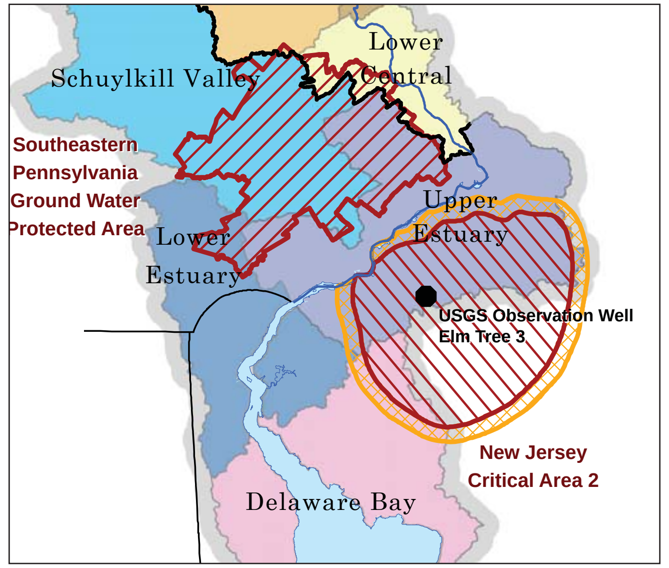


Fig. 1.14. Areas of ground water stress.

Trends

Since the creation of the protected areas, conjunctive use projects and regional alternatives have provided a measure of sustainability. However, depletive use in areas beyond these critical areas is emerging as a problem.

Actions and Needs

- Comprehensive information on stream flow and ground water conditions in the PA-GWPA would enhance the ongoing analysis of this region.
- A detailed study of projected demand, outstanding allocations and water availability are a necessary part of ongoing regional, state and basin-wide water supply planning efforts.

New Castle County, DE

Delaware has responded to seven drought events in 25 years. Adaptive management resulted in a plan and facilities to "drought-proof" the state. In addition to an iron removal plant built in 2003 to treat ground water, a 300-million-gallon reservoir was built to augment supply from the White Clay Creek and make the City of Newark self-sufficient. The DE Water Supply Coordinating Council assembled an additional 2 billion gallons of water supply since 1999.

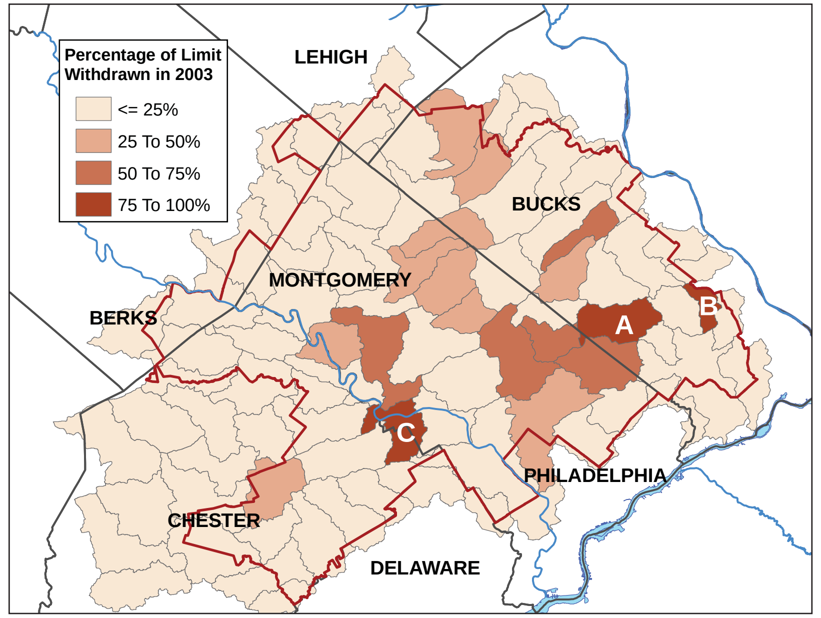


Fig. 1.15. Percentages of subbasin ground water withdrawal limits reached in 2003 in PA-GWPA. Mining withdrawals are not included. The withdrawal limit is defined as the 1-year-in-25 average annual baseflow rate as determined by the USGS for each subbasin.

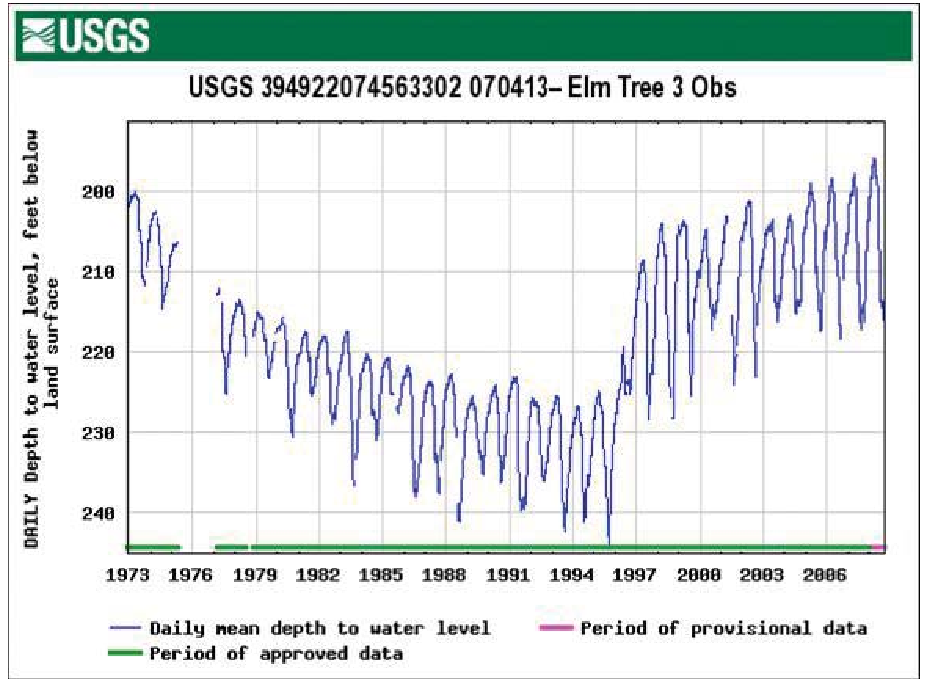


Figure 1.16 illustrates how water levels at a USGS observation well in NJ Critical Area 2 have rebounded.

Indicator • Flood Damage

For more information on the Interstate Task Force and a complete list of recommendations, visit: www.state.nj.us/drbc/Flood_Website/taskforce.

Indicator Description

Flood insurance claims data have been collected and used as an indicator of flood damage since the start of the Federal Emergency Management Agency (FEMA)'s National Flood Insurance Program (NFIP) over 30 years ago. NFIP provides federally-backed flood insurance in communities that adopt and enforce floodplain management ordinances to help reduce future flood losses.

Repetitive loss is a useful indicator of flooding as a recurring economic and environmental problem. Repetitive loss is applicable to a property that endures two or more losses of at least $1,000 for each loss. The two losses must be within ten years of each other and be at least 10 days apart.

While insurance claims can provide a general picture of flood damage, within the basin they reflect only a fraction of the total cost of property damage caused by flooding. In addition to residential and commercial properties whose owners choose not to purchase flood insurance, much of our constructed infrastructure – including roads, bridges, canals and utility lines – suffer damages that are not captured by this indicator or by insurance program records.

Desired Condition

Prevention of flood-induced loss of life and property, and protection of floodplain ecology (Basin Plan Goal 2.1).

Status

Poor: Increased property loss and repetitive claims in recent years.

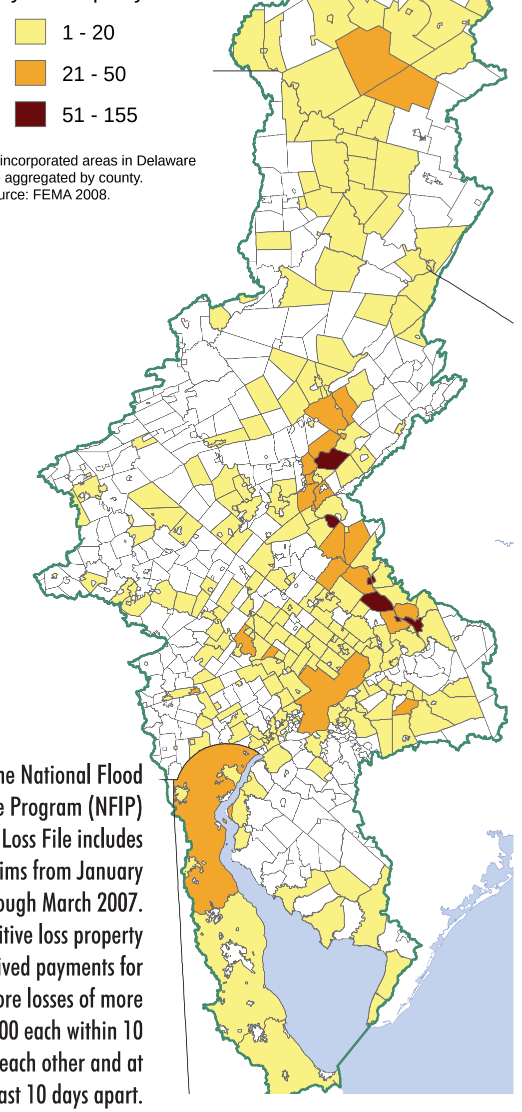
Approximately 1,372 square miles, or 11% of the basin, is located in the 100 year floodplain, or in areas that have a 1 in 100 chance at any time of being flooded. Nearly 20,000 flood insurance claim reimbursements totaling almost $473 million have been awarded in the Delaware Basin since the late 1970s.

Prior to 2004, FEMA reported a total of 317 repetitive loss properties in the basin. Since then, three mainstem floods in 2004, 2005 and 2006 caused the addition of 1949 properties to this list. As of the end of January 2008, nearly $235 million has been paid out to 2,266 repetitive loss properties. The counties with the highest concentrations of repetitive loss properties are Bucks, Montgomery and Northampton PA, and Warren, Hunterdon and Mercer NJ. New Castle County DE ranks 5th in terms of the cost of repetitive losses (Table 1.3, Fig. 1.17).

Table 1.3. Repetitive Claims 1978 - 2008

County	Watersheds	No. of Properties	Repetitive Loss in $Millions
Bucks PA	Delaware River & Neshaminy Creek	590	$ 76.0
Montgomery PA	Schuylkill River & Perkiomen Creek	252	$ 26.8
Northampton PA	Delaware River & Lehigh River	193	$ 25.9
Warren NJ	Delaware, Pequest & Paulinskill Rivers	192	$ 19.8
New Castle DE	Red Clay & White Clay Creeks, Christina River	51	$ 12.9
Hunterdon NJ	Delaware River	155	$ 12.7
Mercer NJ	Delaware River & Assunpink Creek	191	$ 11.2

Fig. 1.17
Total Number of Repetitive Loss Properties by Municipality*



*Unincorporated areas in Delaware are aggregated by county.
Source: FEMA 2008.

The National Flood Insurance Program (NFIP) Repetitive Loss File includes flood claims from January 1978 through March 2007. A repetitive loss property has received payments for two or more losses of more than $1,000 each within 10 years of each other and at least 10 days apart.

It is estimated that a quarter of a million people are at risk because they live within a 100 year flood plain. Ongoing work by FEMA and the Army Corps of Engineers will evaluate the definition and impact of a 1:100 year flood event to more accurately identify at-risk properties.

Trends

The density of claims reflects population density, the degree of development in floodplains, the number of policy holders, and flooding frequency. The vast majority (86%) of the repetitive loss properties were added as a result of three major flood events between 2004 and 2006.

Typically, several factors contribute to flood events in the Basin including:

- antecedent soil moisture – how wet soils are before the storm event
- the duration and intensity of the storm event
- the number of storm events that contributed to precipitation within a given period of time
- the extent of the precipitation, i.e. how large an area was affected by the storm;
- snow pack , since snow melted by rain can contribute to flooding.

PHOTO: J. SPOTWOOD, DRBC, JUNE 29, 2006 YARDLEY PA

Figure 1.18 illustrates some of these factors. It compares the observed total monthly precipitation for recent years (2003–2006) to a historically wetter year (1996) and to average annual precipitation for 1971–2000; record flood events are highlighted.

A record amount of rain fell on the basin in October 2005, but it did not result in mainstem flooding due to antecedent hydrologic conditions: below normal precipitaion in the preceeding five months resulted in very low stream flow, soil moisture, ground water levels and reservoir storage. Conversely, the September 2004 flood event was preceded by two months of above-average rainfall which compromised the ability of soils to absorb additional rainfall.

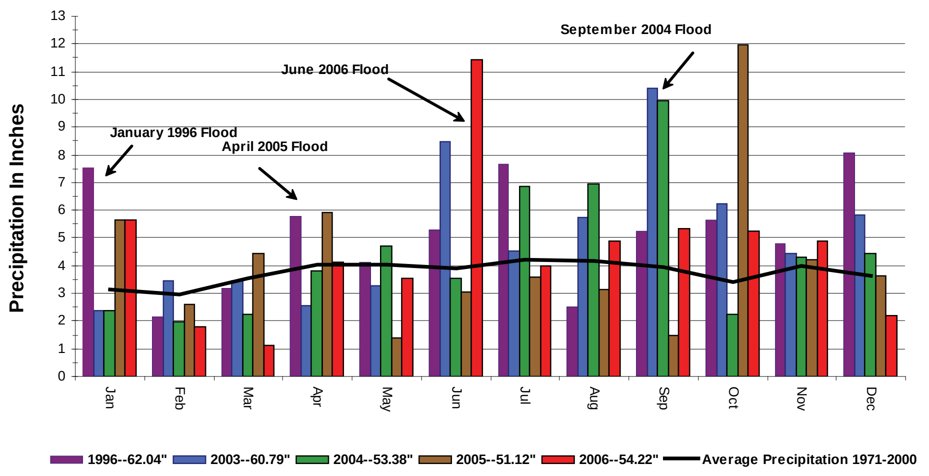
The April 2005 flood also illustrates the importance of antecedent conditions, including a prior rain event in March and the contribution of a melting snow pack. Total rainfall in June 2006 included an especially heavy rain (up to 18") over a 4-day period across the Lehigh, Schuylkill and Upper Basin.

In 2008, the Delaware River Basin Interstate Flood Mitigation Task Force (Task Force) developed a set of 45 concensus recomendations that address a wide variety of actions to improve conditions in the basin, including flood map modernization, improved regulations, and integrated watershed and floodplain management. The Task Force report is available at www.drbc.net.

Actions and Needs

- Additional indicators are needed to capture the ecological functioning and value of floodplains and to reflect the total cost of recurring flood damages to communities.
- Adopt policies to ensure that public funds do not support projects that create a further flood risk.
- Adequately fund planning and mitigation actions; flood prone communities often find that available funds are not sufficient for either acquisition or elevation of buildings that are repeatedly flooded.
- Evaluate the precipitation observing station and stream gage networks in the Basin to support improvements in flash flood forecasting capabilities.

Fig. 1.18. Observed Precipitation Above Trenton, NJ



Climate Change

Note: There is a wealth of information on climate change, some specific to the mid-Atlantic region. A copious number of sources were examined for this assessment, and while we refrain from mentioning them all, a few are worth noting, including: the Consortium for Atlantic Regional Assessment (CARA) and the Northeast Climate Impacts Assessment (NECIA). Since the products of these initiatives are generally available on the web, we have chosen to avoid the distraction of footnotes. Readers are encouraged to investigate.

Measuring climatic change impacts

There is general, but not unanimous, agreement that global temperatures are warming, sea level is rising, and the planet's climate is undergoing a possibly significant change. While the causes, the rate of change, and the degree of climate modification we can expect may be in debate, change from recent historic conditions is already occurring, and adapting to additional change will present a considerable challenge to water resource management.

Precipitation Patterns: Status and Trend

Temperature and precipitation are linked in the global climate system. Because warmer air holds more water vapor, atmospheric moisture will increase as surface temperatures increase, generating the potential for more frequent storms and precipitation. Storm intensity may also increase, as storms, especially hurricanes, are fueled as they pass over warmer waters.

Recent years have been some of the wettest on record and NJ precipitation records indicate an increase of 3.3 inches since 1970. The seven wettest calendar years of the last 113 years have all occurred since 1972, and October 2005 was the wettest on record in New Jersey (11.98 inches). It is unclear whether the long term trend is for continued increases in precipitation, but changes are expected in seasonal precipitation patterns and the severity and frequency of storm events. In contrast, the decade of the 1960s was the driest on record and even amid the wet conditions of recent decades there have been several times when water supplies approached dangerously low levels and drought emergencies were declared in the basin.

Wetter winters. Winter precipitation in the Northeast is forecast to increase by 20%-30% by the end of the century, and this is expected to be in the form of rain rather than snow. Figure 1.19 illustrates the predicted change to snowfall patterns. Rains, especially warm rains, on top of existing snow cover will accelerate snowmelt. Spring

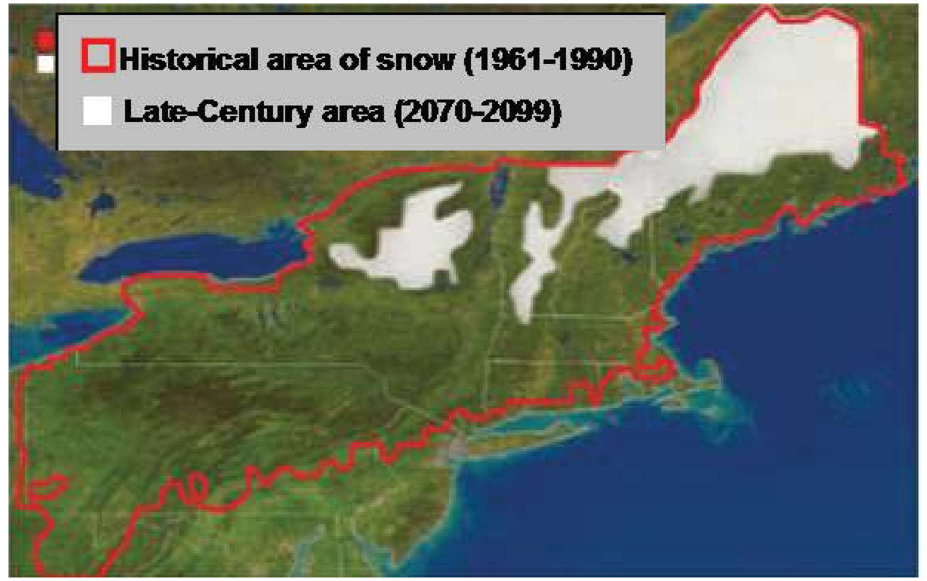
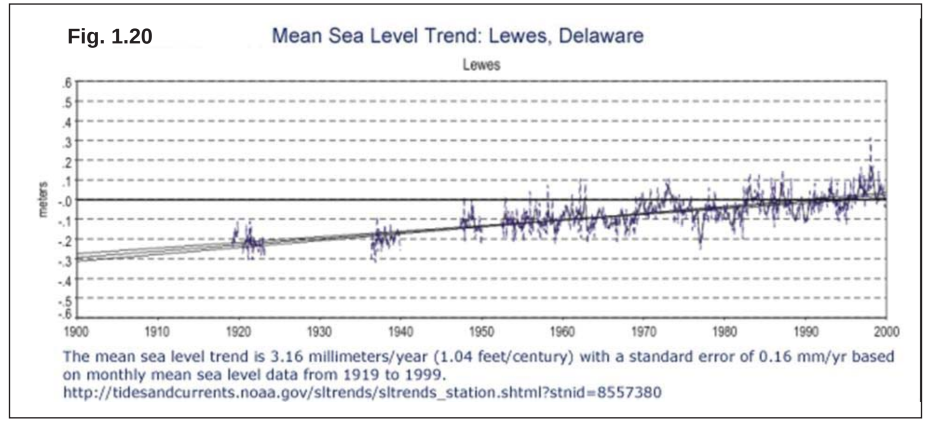


Fig. 1.19 The Changing Face of Winter. The area that typically sees at least a dusting of snow on the ground for at least 30 days during the winter may change by the end of the century under a higher emissions scenario. This suggests that without any reductions in greenhouse gas emissions, the Delaware River Basin may not have any substantial snowpack by the end of the century. From *Confronting Climate Change in the U.S. Northeast*, 2007 Northeast Climate Impacts Assessment.



peak flows, which are now occurring about 7 to 14 days earlier than the long-term average, are expected to be occurring even earlier by the end of the century. While summer precipitation is not predicted to change dramatically, higher air and water temperatures could increase evaporation and reduce summer and autumn stream flows.

Increased droughts. Drought can be classified as short-term (1-3 months), medium-term (3-6 months) or long term (more thatn 6 months) duration. The northeastern US typically experiences short-term droughts about once every 2-3 years and medium droughts once every 15 years in inland regions, but not at all in some coastal areas. In the Delaware basin, the most recent major drought lasted from 1961–1967, and is considered the basin *drought of record* for planning purposes. Dry conditions have triggered regional drought watches and warnings several times since the 1960s, notably in 1980-81, 1985, 1995, and 1999. More recently, portions of the basin experienced drought conditions in 2001–2002; Delaware has adopted 2002 as its planning drought of record. Under the more extreme climate change scenarios, droughts are expected to become more frequent, with short-term droughts potentially affecting areas of the Catrskills and Adirondacks as often as once every year.

Precipitation: Impacts on Water Resources

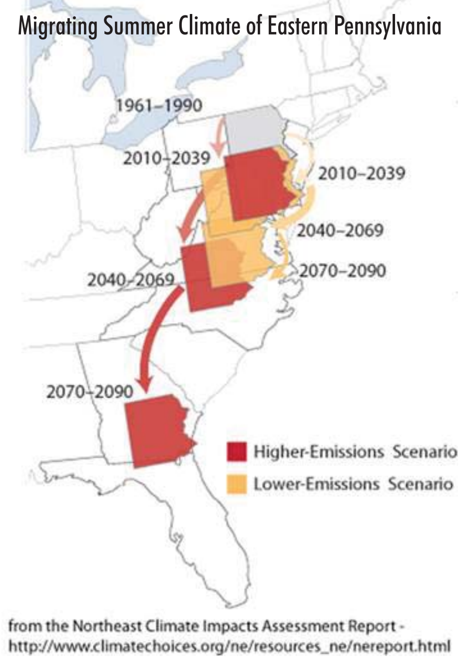
Water supply. Shorter, wetter winters with reduced snowfall and earlier peak flows will affect the water management system of the basin. Snowpack is depended upon for spring flows to reservoirs and for recharge of ground water to ensure stream base flows through the summer months. Without this natural attenuation, additional storage may be necessary. An increase in the frequency of drought would further stress the region's water supplies and challenge current storage capacities.

More frequent, flashier storms will have an impact on water quality. Runoff carries non-point source pollution and sediment loadings, and additional pollutants would be added as overburdened storm and wastewater systems add untreated flows to rivers and streams.

Instream flows. Both reduction in flow and increases in extreme precipitation events pose threats to aquatic communities and to water quality. Extended periods of low flow may mean a reduction of the assimilative capacity of streams and the likelihood of increases in pollutant concentrations. Prolonged periods of low flow will also challenge our ability to maintain freshwater flows into the estuary. Fresh water flow helps repel the upstream incursion of salinity toward drinking water intakes and maintain a salinity gradient hospitable to aquatic life in the estuary.

Fig. 1.21. Aerial Photo of Maurice River Cove comparing 2001 shoreline to that of 1890. Photo courtesy of J. Gebert, U.S. Army Corps of Engineers, Philadelphia District

Fig. 1.22. Summers in eastern Pennsylvania could feel like the current climate of Georgia by the end of the century, based on the heat index, which takes humidity and wind into account to measure how hot it actually feels.



Flooding. In the near term, increased storm severity in late winter/early spring will also exacerbate flood risk as heavy rains and intense storms during that time are naturally compounded by snowmelt. In the longer term, snow will be replaced by rain, and winter flooding could be more common. In tidal areas, more severe storms could bring higher waves and storm surges, increasing coastal flooding and beach erosion.

More intense precipitation events are likely to cause increased frequency and magnitude of floods. Areas of the basin already at risk for flooding may find that risk increased and risk areas may be expanded, with commensurate increases in damages to individual properties and to community infrastructure.

Sea Level Rise: Status and Trends

The effects of sea level rise are especially important to Lower and Bay Regions of the basin. With its limited topography and generally low elevation, the coastal plain province is particularly vulnerable to increases in sea level. Many coastal areas are undergoing subsidence which exacerbates the effects of a rising sea elevation.

The trend in mean sea level at Lewes, DE from 1919 through 1999 (Fig. 1.20) shows an increase of 0.124 inches/year, the equivalent to one inch every eight years. The rate of increase at Philadelphia from 1900 through 1999 was 0.108 inches/year; or about one inch every nine years. Projections for sea level rise in the northeast US range from eight inches to three feet by the end of the century. Rising sea level is principally due to the expansion of the seas as temperatures increase. The rate at which the world's polar ice sheets melt could exacerbate the rate of sea level rise.

Sea Level Rise: Impacts on Water Resources

Increased salinity. It is projected that salinity will increase as a result of increasing temperatures and the incursion of saltwater into fresh as sea level rises. Increased salinity could threaten water supplies for public, industrial, and agricultural use in the tidal watersheds. In the Delaware estuary, freshwater flows from the river and streams naturally buffer against salinity incursions into fresh water. Sea level rise coupled with intermittent decreasing fresh water flows could compromise freshwater intakes and wells in aquifers vulnerable to salt water intrusion. Some coastal areas have already experienced salt water intrusion as a result of overdraft. For example, several wells in the lower Cape May peninsula have been abandoned due to salt water intrusion from overuse of the aquifer, and many homes and businesses are now dependent on desalinated well water; the process is costly. Communities with drinking water intakes along the River could be at risk, including Philadelphia, a city of 1.5 million people.

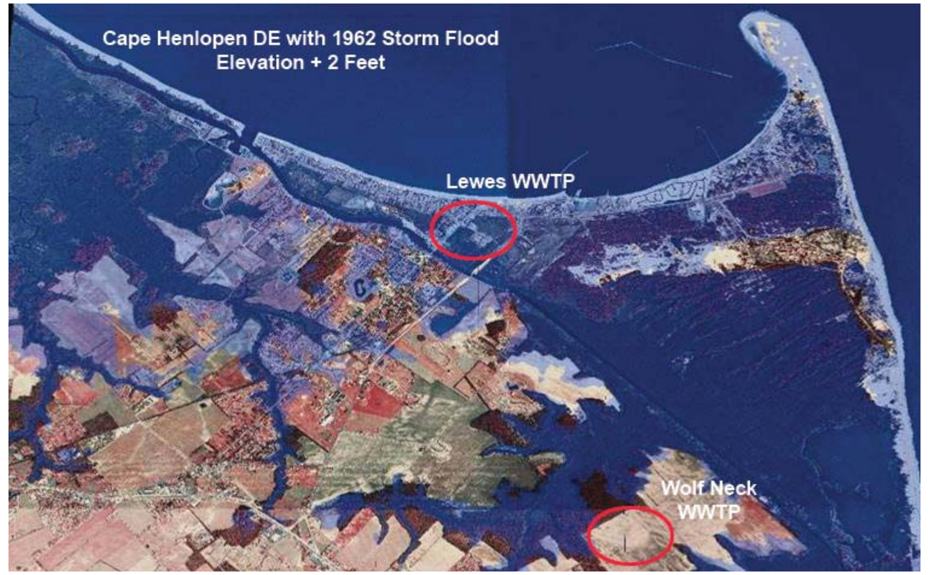


Fig. 1.23. Wastewater treatment plants in the area of Cape Henlopen DE are vulnerable to sea level rise. Using the 1962 storm flood elevation, this image shows that Lewes WWTP would be flooded and the facility at Wolf Neck would be nearly surrounded by water. Courtesy of David B. Carter, Coastal States Organization Climate Change Workgroup Co-Chair & Delaware Coastal Program Manager.

Erosion, flooding and habitat loss. Sea level rise is slowly inundating low lying areas along coastlines, causing significant erosion of beaches. In Salem County NJ, some bay beaches are currently fully submerged at high tide, and further sea level rise could eliminate them at low tide. Over time, a measurable loss of wetlands is predicted, especially where existing tidal marshes are caught between a rising bay and the hard, immovable edges of development. Wetland loss puts human settlements at risk. Wetlands buffer wind and tidal energy; their loss means that buildings and infrastructure take more insults form coastal storms. Figure 1.21 illustrates how erosion and sea level rise has altered the coastline of Cumberland County, NJ since 1890.

Loss of beaches and loss of wetlands means loss of habitat and breeding sites for many species. See for example horseshoe crabs and red knots as indicator species in the Living Resources section of this Report. Impacts to economically important finfish and shellfish species, such as oysters and weakfish, could be dramatic, with repercussions for recreation and employment in the region.

Infrastructure considerations. Rising sea level will cause problems for infrastructure in coastal areas. Roads and bridge approaches in low lying areas will first become vulnerable to flooding during storm events, and eventually be permanently inundated. Storm sewers in coastal areas will carry seawater onto town streets, rather than conveying stormwater away. Several coastal towns have experienced this already. Sea level rise will also render lower bridges too low for the safe passage of boats underneath. Costs to replace infrastructure can be expected to be many millions of dollars.

Wastewater treatment plants are at risk as is drinking water infrastructure. If water supplies are threatened, intakes and treatment plants may have to be relocated and alternative potable water supplies secured.

Temperature: Status and Trend

Temperatures in the northeastern US have increased by about 1.8°F since 1899. Since 1970 the region has warmed at a rate of 0.5°F per decade, with winter temperatures warming at the more rapid rate of 1.3°F per decade. We have experienced more days where temperatures surpassed 90°F and 100°F, fewer days with temperatures below 32°F, and more rain than snow in winter months with a commensurate decrease in snowpack. Earlier spring snowmelt and vegetation blooms have also been documented across the region.

Some predictions indicate that by 2040–2069 mean annual temperatures for the Delaware River basin will range between 2.5°F and 8.7°F warmer than experienced between 1971 and 2000. While the range of estimates depends on the degree to which greenhouse gas emissions are curbed or increased, northeast temperatures are expected to rise 2.5°F to 4°F in winter and 1.5°F to 3.5°F in summer regardless of any emissions reduction, simply because of residual concentrations of greenhouse gases in the atmosphere.

Temperature impacts on water resources

Increased ambient air temperatures will increase water temperature, compromising its ability to hold dissolved oxygen in suspension – a critical condition for aquatic life. Temperature also affects the ability of water to assimilate some pollutants and may cause violations of water quality criteria. Areas that are densely populated with significant areas of rooftops, roadways, parking lots and heat-generating emissions are vulnerable to even greater localized temperature increases and exacerbated impacts on water resources.

The current mix, distribution, and abundance of forests are likely to be altered by rising temperatures. Evergreen forests, because they require colder temperature regimes, will be especially vulnerable to replacement by deciduous species better adapted to warmer weather. Warmer temperatures tend to encourage parasites and diseases that attack vulnerable species; warmer temperatures may play a role in the proliferation of woody adelgid that attack hemlock forests. Major changes to forest cover can be expected to affect water resources.

There are numerous other impacts expected with increased temperatures, including human health effects from heat stress, worsening air quality, and infectious diseases; economic shortfalls from the loss of winter recreation and tourism; increased energy demand for cooling; and impacts on agricultural production, plant and animal life cycles and survival connected to disruption of seasonal phasing.

Actions and Needs

Adapting to changing conditions will be most successful if managers are well informed.

- More localized studies and accurate models are needed to better understand how climate change will affect regions of the basin.
- Close examination of the sufficiency and sustainability of existing water supply infrastructure is needed; current and future planning initiatives must address the reality of a changing climate.
- To predict the effects of sea level rise on wetlands, improved mapping and knowledge of land use at wetlands margins is necessary. The true extent of bulkheads, dikes and other barriers to wetland movement is necessary for the realistic development of policy alternatives.
- Expanded ground water monitoring may be warranted to ensure tracking of salt water intrusion.

Several state and local initiatives are currently investigating the effects of climate change on the basin. The New York City Department of Environmental Protection is involved in studies that examine the effects of climate change on the quality and sustainability of its water supply, and the Partnership for the Delaware Estuary was recently awarded a grant from the EPA to look at how climate change, specifically sea level rise, will affect the estuary. DRBC has filed a research plan with EPA to assess the consequences of climate change on dissolved oxygen, water supply intakes and oyster populations in the estuary. EPA is actively supporting efforts to identify and reduce vulnerability to climate variability and change.

Category II

Water Quality

Major Influences on Stream and River Quality ~

- *Runoff and point-source discharges from agricultural and urban areas*
- *Persistent contaminants associated with past human activities: mining, industry, urban development and agriculture*
- *Impoundments and diversions of water*

Major influences on Ground Water Quality ~

- *Use of pesticides, nutrients and VOCs in urban and agricultural areas*
- *Physical properties of soils and aquifers, and chemical properties of contaminants*
- *Naturally occurring radon and arsenic*

2004 USGS Circular #1227

Water Quality

The quality of our water resources is integrally linked to the long-term availability of water that is clean and safe for drinking and recreation, and also suitable for industry, irrigation and habitat for fish and wildlife. The quality of the River is dependent on the landscapes draining the watersheds and streams that join to form it, including all direct and indirect discharges to water bodies.

When Henry Hudson discovered the Delaware River system in 1609, water quality was presumably pristine. However, by the early 18th century water pollution was a recognized problem, especially the contamination of springs, wells and streams that served as local sources of drinking water. The first pollution survey, conducted in 1799, noted a variety of sources in the Philadelphia harbor area, including ships, wharves, polluted wetlands, and various urban activities. Tanneries and slaughterhouses were already recognized sources of water quality problems.

Providing Clean Water

Making the connection between polluted water and disease, such as typhoid, provided the impetus for constructing public supply pipelines, for segregating human waste from water supply, and subsequently for filtering source water. Concern for water-borne diseases led Benjamin Franklin to leave money to Philadelphia specifically for developing a municipal water system, which the City did, drawing first water from the Schuylkill (1801) and then the Delaware River (1850). Typhoid outbreaks in the 1860s prompted debates and discussion that eventually resulted in the construction of the world's largest sand filtration plants in 1899. By 1915 most cities in the basin had a safe water supply, drawing from either new wells or filtered surface water.

Intense development and use of the River system, waves of population, industrial expansion, and even the increased use enabled by the provision of pubic water supply all contributed to further pollution and degradation of water quality. While water-related diseases had been controlled, other problems were surfacing. By the early 20th century the Delaware was experiencing the collapse of major fisheries, including the historic shad fishery, partly as a result of pollution and low oxygen in the River.

Surveys in 1929 and 1937 indicated that the entire estuary from Trenton to Wilmington was "substantially" polluted with a zone of "gross" pollution in the Philadelphia-Camden area. While pollution was an evident problem, serious efforts to control it at the source did not occur until 1936 with the creation of the Interstate Commission on the Delaware River (INCODEL). This advisory commission was formed to augment and coordinate state efforts and its highest priority was the cleanup of stream pollution.

Pollution Control

Until INCODEL, wastewater added to the Delaware system was discharged without treatment, with the exception of Trenton and a one small plant in Philadelphia which had primary treatment. Through INCODEL, a basin-wide program was implemented and the first set of interstate water quality standards adopted in the 1939–1945 period. War-time action slowed the implementation of the new water quality program and added to the pollution problems in the estuary as industrial and port-related activity increased. However, as a result of the INCODEL program, new sewage treatment plants were built throughout the basin in the post-war period. By the end of the 1950s, 75% of the basin communities, including the major cities responsible for 60% of the sewage discharges, had adequate sewage treatment.

During this time problems from coal mining and processing were also tackled. Desilting basins were constructed and 30–40 tons of coal silt were dredged from the Schuylkill under one of the first non-agricultural nonpoint pollution control programs in the nation. As a result of these efforts, water quality improved even in the most grossly polluted portion of the estuary. Dissolved oxygen levels rose; the river was no longer anoxic.

Comprehensive management

Remnants of hurricanes Connie and Diane caused major flooding in 1955 and indirectly instigated a new generation of management as the Army Corps of Engineers initiated its first comprehensive river basin planning effort. One product was a pioneering study of water pollution control and the development of one of the first water quality models for an estuary. Another result was the establishment of the Delaware River Basin Commission (DRBC) in 1961. Expanding on the advisory powers of INCODEL, DRBC was created by concurrent federal and state legislation and is accorded broad responsibility. This responsibility includes regulatory authority in all facets of water resource management, including water supply and water quality.

In 1967 DRBC adopted higher water quality standards for dissolved oxygen, and new bacteria standards for recreational use. To meet the criteria, some 90 municipal and industrial dischargers were given waste load allocations in 1968 as part of a prescient administrative program that served as a prototype nationally for complex water pollution control problems. In 1972, the Federal Water Pollution Control Act amendments required discharge permits, provided construction funds, added enforcement, and other incentives to ensure implementation of water pollution control efforts. This generation of efforts, which ended in 1987, resulted in the construction of many municipal and wastewater treatment facilities, decreased discharges of oxygen-demanding waste, and long-lasting improvements in dissolved oxygen levels that have benefited fish populations, especially the American shad.

In 1992 DRBC adopted an anti-degradation program designed to protect the high water quality of the portions of the River that had been designated as part of the national Wild and Scenic River system. The Special Protection Water (SPW) program, initially applied to 121 miles between Hancock NY and the Delaware Water Gap, was expanded in 2008 to include the Lower Delaware Scenic and Recreational River. The protection of existing water quality is now the policy for all 197 miles of the non-tidal Delaware River.

Emerging issues

Technological advances in computers, telemetry, satellite imagery, and detection have enabled impressive strides in instantaneous monitoring, source tracking, water quality modeling, and pollutant detection. Our understanding of the functional pathways of contaminants and the potential harm to individuals and populations is vastly expanded, and our grasp on the full range of potential pollutants is tightening.

Some of the major water quality concerns of the past still resonate in

1799 1st government pollution survey notes contamination entering the river from ships and sewers.

1832 Cholera caused by contaminated drinking water kills over 100 people in Philadelphia.

1936 90% of all gas sold in the USA contains tetraethyl lead.

1950 The urban reach of the Delaware River is noted as one of the most polluted stretches of river in the world with essentially zero oxygen during summer.

1967 DRBC adopts a waste load allocation program with the states and starts pollution abatement programs.

1970 1st US Earth Day celebrated; US EPA established; NEPA adopted.

1971 US EPA gives notice of proposed phase-out of leaded gasoline.

1972 FWPCA amendments establish construction grant program for wastewater treatment and permit process for discharges.

1980s Basin states impose numerical P limits at WWTPs through tertiary treatment. By late 1980s, over $1.5 B spent on improving wastewater treatment along the Delaware River and tributaries between Wilmington and Trenton.

1992 DRBC adopts Special Protection Waters regulations to preserve the high water quality of the upper and middle Delaware Scenic River reaches.

1994 In accord with federal mandate, industry ends manufacture of phosphate laundry detergent.

1994 US blood lead levels (a proxy for lead in the environment) declined by 78 percent from 1978 to 1991.

the early 21st century. Public health is still a focus. The concentration of toxic substances, notably mercury and PCBs, in some species of fish is responsible for consumption advisories in all of the basin states. Water borne diseases are far less a threat than they once were, but the viruses too small to be captured by typical treatment processes remain a potential peril.

Dissolved oxygen (DO) remains a parameter of concern. In 1973 US EPA suggested that fishable water quality standards were unattainable in portions of the Delaware, but assessments since have shown that improvements in dissolved oxygen concentrations are possible, and actual. Rebounding fish populations are further proof. The most recent monitoring in the estuary region, however, indicates that progress may be slowly eroding and new initiatives may be necessary to maintain and improve DO levels.

Several toxic substances, such as metals and PCBs, are being addressed through discharge requirements, state and federal site remediation programs, TMDLs and pollution minimization plans. The elimination of phosphorus from detergents contributed to improvements in DO, but nutrient reduction criteria—and strategies to address them—remain elusive as we continue to grapple with contributions from point and nonpoint sources, and the spectre of increasing wet-weather loadings and temperatures under changing climatic conditions.

New substances are emerging as compounds of concern, including pharmaceuticals and constituents in personal care products and manufacturing processes. Improvements in our ability to measure smaller and smaller amounts of compounds in water samples has enhanced water quality assessments and research on public and ecological health effects. In addition to neurological impairment and cancer, our concerns extend to the potential for multi-generational and reproductive effects of new compounds on humans and wildlife.

R. LIMBECK, DRBC

Stream monitoring for macroinvertebrates.

Reporting

Water quality indicators included in this report are:

- Nutrients : Nitrogen & Phosphorus
- Dissolved oxygen
- Water clarity
- Metals: Copper
- Toxic compounds: Pesticides and PCBs
- Trends in tributary water quality
- Support of designated uses
- Fish consumption advisories

A feature on contaminants of emerging concern closes this section.

1995
Most of the 99 major dischargers to the Delaware are in compliance with DRBC water quality standards.

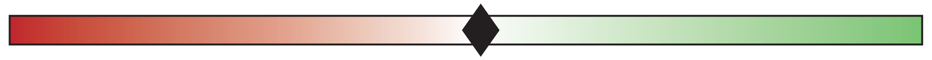
1996
DRBC adopts regulations governing the discharge of toxic pollutants from wastewater treatment plants to the tidal Delaware River. Numerous toxic substances, some carcinogenic, are covered under the new rules.

2003
On behalf of NJ, PA, and DE, and based on work conducted by DRBC, USEPA establishes total maximum daily loads (TMDLs or "pollution budgets") for the tidal Delaware River to address the presence of PCBs.

2006
Water quality in the Delaware River continues to improve; mean annual oxygen level at Philadelphia measures 6 mg/l, up from 2 mg/l in 1967.

2008
Lower Delaware from Water Gap to Trenton included in Special Protection Waters Program.

Indicator • Nutrients



Indicator Description

Nutrients, such as Total Nitrogen (TN) and Total Phosphorus (TP) are critical to the growth of aquatic life. An overabundance of nutrients can lead to excessive plant and algal growth, causing major impairments to ecological health and specific water quality problems such as low Dissolved Oxygen (DO). Whether or not a water body exhibits the negative effects of high nutrient levels can be controlled by many other factors: water clarity; temperature; the availability of trace nutrients like silica; and the species of organisms living in the water body. Because of this, water quality criteria for nutrients can be very different from stream to stream. The states and DRBC are currently working to determine what concentrations of TN and TP will protect the aquatic resources in the Delaware River Basin, and the appropriate water quality criteria to protect these resources.

Desired Condition

Although specific criteria have not been set, nutrients are managed to support aquatic life and DO criteria (BP Goal 1.2, CCMP Action W12).

Status

Fair: Concentrations are high compared to other estuaries, but do not seem to be causing harmful effects, such as eutrophication.

Levels of TN in the Delaware River and estuary tend to be roughly 10 to 20 times higher than levels of TP. Concentrations of TN and TP are lowest in the headwaters of the Delaware River and increase downstream. Nutrient concentrations peak near the midpoint of the estuary and then decrease again toward the mouth of the Bay (Fig. 2.1). Since the current concentrations of nutrients have not resulted in the typical symptoms of excessive nutrients, it is difficult to determine whether the current concentrations are at a level that warrants regulatory control. However, measurements of low DO concentrations raise concerns about nutrients or other pollutants in those areas (See the discussion of DO on the next page.)

Trends

Data from a station in the Delaware River near the Philadelphia Airport show a very large decrease in phosphorus was achieved by 1985; a similar, but much smaller decrease in nitrogen was achieved by 1990 (Fig. 2.2). Although nutrient levels are still very high today compared to other estuaries, the concentrations are stable and there do not appear to be obvious problems.

Actions and Needs

- States and DRBC should continue efforts to define the relationships between nutrients, water clarity, algal growth, DO, and ecological health and determine nutrient levels that will protect water resources and prevent the harmful effects on aquatic communities.

Fig. 2.3 Nutrient Monitoring Sites

Fig. 2.1 Nutrient Concentrations by River Mile

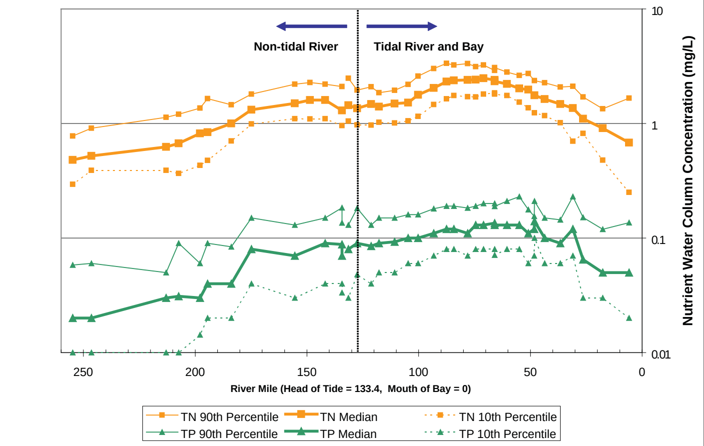
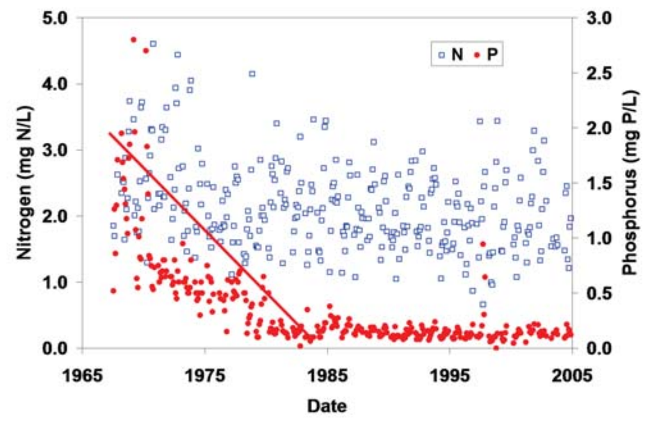


Fig. 2.2 Delaware Estuary Nutrient Trends



Indicator • Dissolved Oxygen

Indicator Description

Dissolved oxygen (DO) in surface water is one of the most basic and important measures of the health of a waterbody, affecting a wide array of aquatic plants and animals. Low DO has both chronic (long term) and acute (immediate) impacts, ranging from shifts in biological communities to fish kills and disruption of fish migration. Oxygen enters water at the water surface and through photosynthesis of aquatic plants and algae. Plants and animals also respire, utilizing some of this oxygen. DO can become too low to support healthy aquatic communities when concentrations of oxygen-demanding pollutants are too high and/or when high concentrations of nutrients like nitrogen and phosphorus cause excessive plant growth. When the excess plants die and decompose, they use DO in the water.

Desired Condition

Dissolved oxygen levels should meet standards supportive of aquatic life (BP Goal 1.3, CCMP Action W12). State criteria apply to watershed tributaries, and range from 4.0 to 7.0 mg/L. DRBC criteria apply to shared waters of the river and estuary and vary by Water Quality Zone, from 3.5 to 6.0 mg/L.

Status

Good: DRBC and state DO standards are generally being met; upper basin DO is better than lower basin.

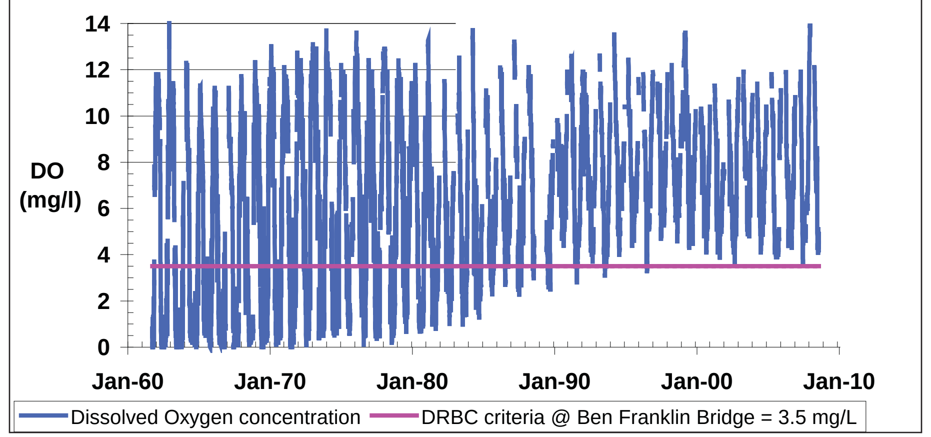
Minimum DO criteria are routinely being met in the tributaries and most of the mainstem River (Fig. 2.6). Five year medians at selected stations along the river remain above their respective state standard, although within the last five years some stations in the Lower and Bay regions have shown a decrease in DO concentrations according to an analysis by Delaware's Water Resources Agency (see Table 2.2 for *Trends in Tributary Water Quality*).

Currently, DO concentrations in the non-tidal river and in the upper portion of the estuary routinely meet DRBC's minimum criteria. However, in the lower estuary near Reedy Island where the DO standard is more stringent, DO criteria violations are a common summertime occurrence and Delaware has listed this segment of the River for TMDL development by 2019. Although the cause for these violations is not clear at this time, DRBC and other agencies are working to better understand all the factors, including nutrient loadings, which may be contributing to the DO criteria violations.

Trends

With the water quality improvements to waste treatment in the mid-1980s, the Delaware River and tributaries have been able to maintain DO concentrations that support aquatic life and meet state and DRBC criteria. Figure 2.4 illustrates the increase in dissolved oxygen concentration at the Ben Franklin Bridge since the 1960s. The noticeable change during the 1980s were the direct result of discharge regulations and waste treatment enhancements. Before this time much of the tidal river below Trenton frequently violated minimum DO criteria. Figure 2.5 shows the number of days criteria has been violated at stations with continuous gages since 1970. Improvements in DO concentrations in the mainstem river have supported the return of shad and other important fisheries to the basin. As previously noted, the number of criteria violation days has recently increased at the Reedy Island Station, requiring vigilance and research to determine the cause.

Fig. 2.4 Dissolved Oxygen
Delaware River at Ben Franklin Bridge, Philadelphia
USGS 01467200



Actions and Needs

- Because DO tends to be higher in the daytime (when aquatic plants are photosynthesizing) and lower at night, its important to measure DO around the clock with continuous monitoring stations, to be sure that DO levels are not unhealthy.
- Without continuous monitoring on the tributaries, data reflect intermittent sampling, and only median values can be compared to the criterion, which is usually a minimum value to protect aquatic resources.

SOURCE: US DEPARTMENT OF AGRICULTURE

Dissolved oxygen, our most fundamental indicator of water quality conditions, is critical for aquatic life.

Fig. 2.5 Comparison of DO Violation Days from 1970 through 2007 at 5 Delaware River Continuous Monitoring Sites

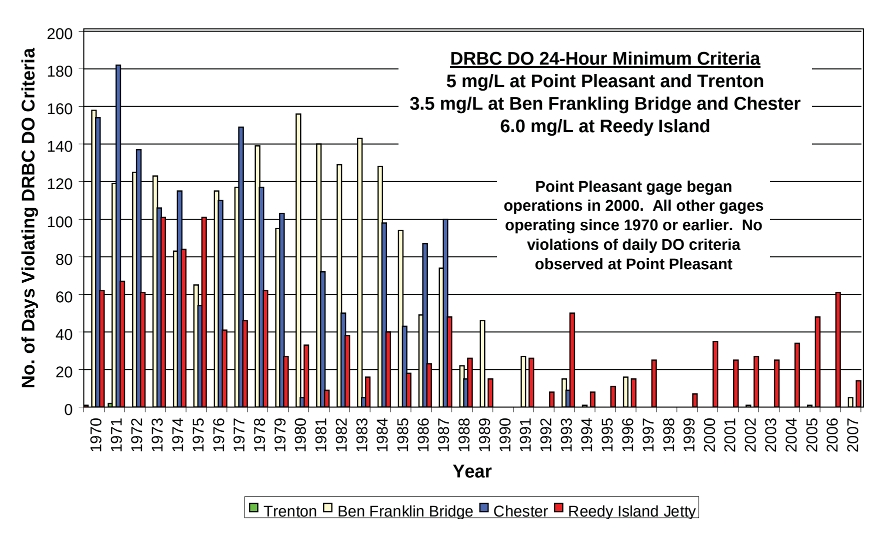
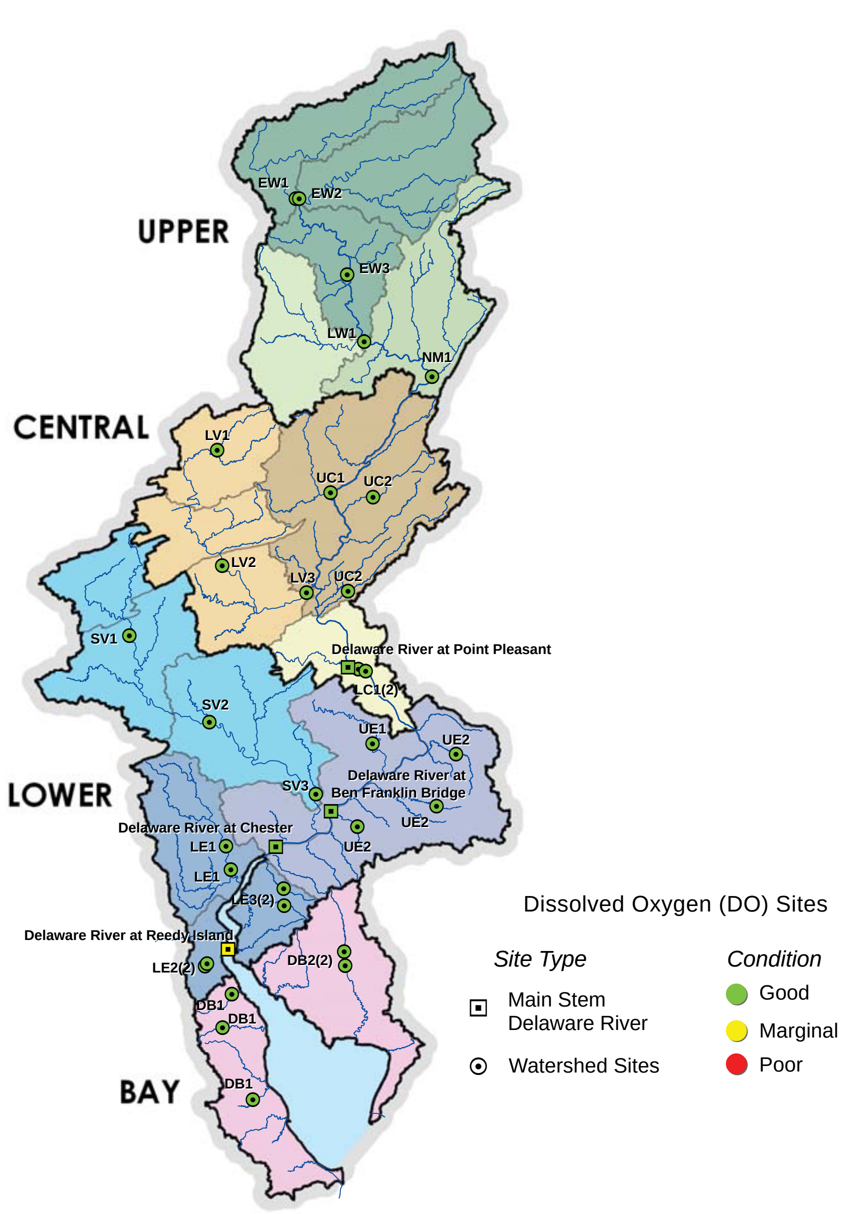


Fig. 2.6 DO Condition at Selected Sites



Indicator • Water Clarity

Water Clarity

- Total Suspended Solid (TSS)
- Turbidity
- Chlorophyll-a

Indicator Description

Total Suspended Solids (TSS), turbidity, and chlorophyll-a are three distinct but related indicators that all pertain to the amount of particulates suspended in the water that influence water clarity. TSS is a measure of the total amount of particulate solids per unit volume of water. These solids include living, non-living, organic, and inorganic particles. Turbidity is an optical property of water where particles and colloidal matter from living and non-living sources cause light to scatter, rather than pass through the water column. Excessive turbidity can impair bottom plants by filtering out sunlight needed for photosynthesis. Finally, chlorophyll-a is a photosynthetic pigment found in plants such as phytoplankton. When measured in surface water, chlorophyll a provides an indication of how much phytoplankton is in the water.

Suspended particulates are important for river and estuarine ecology because they provide sediments to help tidal marshes keep pace with sea level rise, and some suspended particles such as phytoplankton are important foods for animals such as mussels and oysters. In disturbed systems, however, suspended solids and phytoplankton often become overly concentrated and out of balance with natural processes. Therefore, these three measurements provide some indication of both the ecological status and overall health of the river system, especially as it relates to eutrophication (over fertilization).

Most estuaries have an area of elevated turbidity and solids, known as an estuary turbidity maximum (ETM). The ETM is a natural consequence of the chemical and hydraulic mixing of fresh and salt water. The Delaware ETM is centered near river mile 60 in the estuary, but its location can change depending on tides and fresh water flows from upstream.

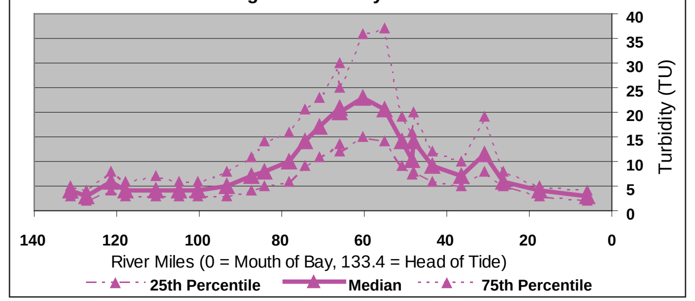


Fig. 2.8 Turbidity Profile

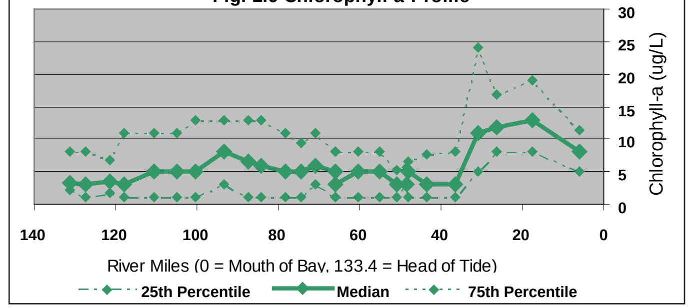


Fig. 2.9 Chlorophyll-a Profile

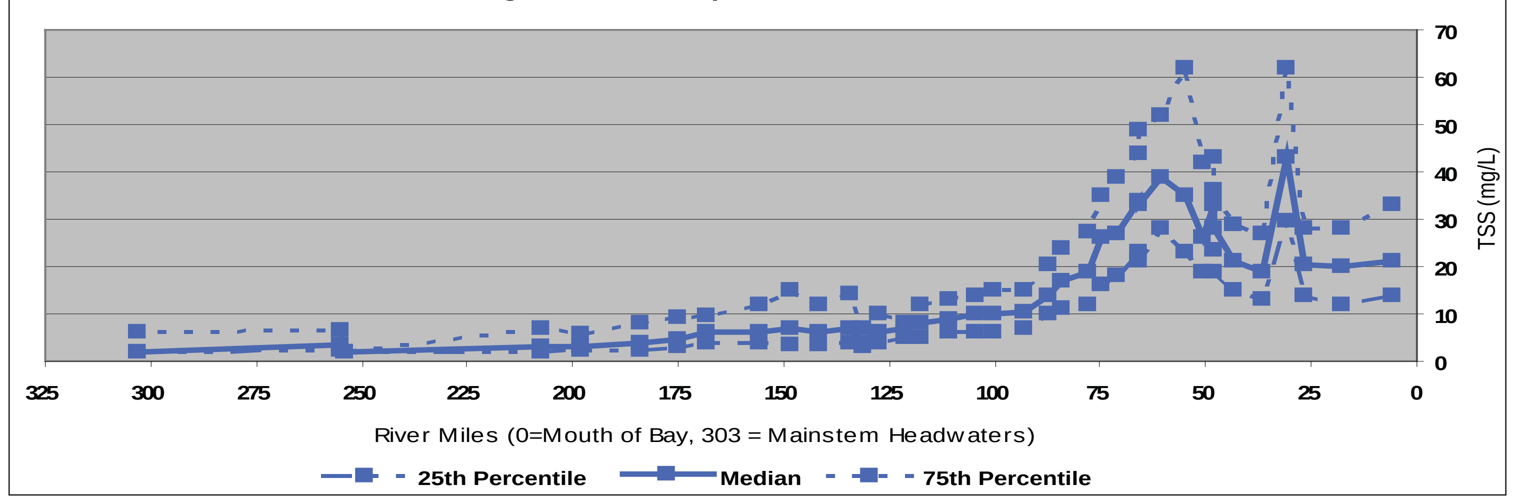


Fig 2.7 TSS - Suspended Soilds Profile

Desired condition

Protection of aquatic life (BP Goals 1.2, 1.3, and 1.4; CCMP Action W12).

Since clarity is affected by a number of chemical and physical conditions, setting criteria is difficult. Both too little and too great a concentration of suspended solids are problematic for aquatic systems, and the range is also dependent on the physical and chemical attributes of each system. Delaware, New York and Pennsylvania do not have water quality standards for TSS in streams; New Jersey has set a maximum TSS level of 40 mg/l for warm water streams and 20 mg/l for cold water streams. The DRBC has adopted a TSS maximum of 150 mg/l for the tidal Delaware River. Negative effects from suspended solids and nutrients usually result in impacts to dissolved oxygen.

Status

Good: Naturally turbid estuary; non-tidal river is generally clear except after storm events.

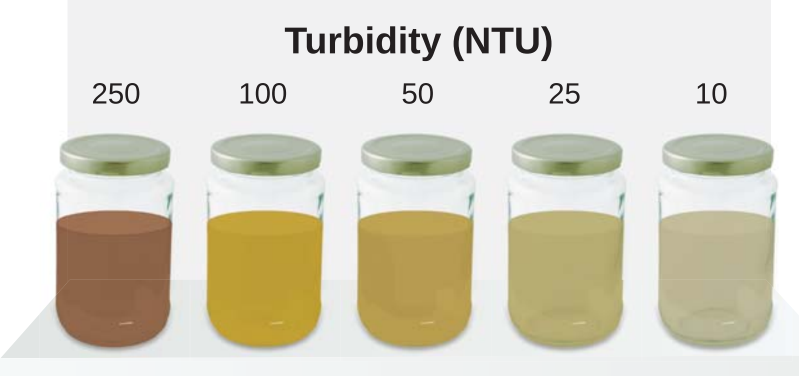
In the Delaware River system, TSS values range from 1 or 2 mg/L to more than 60 mg/L (Fig. 2.7). Turbidity is typically between 1 and 40 turbidity units, well below the maximum 150 unit criteria (Fig. 2.8). Chlorophyll-a concentrations usually range from below detectable levels to 30 ug/L (Fig. 2.9). In some estuaries, efforts to control eutrophication include surface water standards for chlorophyll-a, as a measure of the effectiveness of efforts to control excess nutrients. Currently, DRBC does not have criteria for either TSS or chlorophyll-a in surface water, but could consider developing criteria as part of a broader nutrient strategy.

Trends

Because TSS, turbidity, and chlorophyll-a concentrations change with location, tidal and freshwater flows, temperature and season, identifying specific trends in concentrations is very difficult. Overall, these indicators appear to be stable throughout the period from 1990 through 2005.

Actions and Needs

- The regional science and management community will need to continue efforts to define relationships among nutrient concentrations and forms, water clarity, and phytoplankton.
- A better understanding is needed regarding the importance of sediment supply for habitats such as tidal marshes and how this can be assured through regional sediment budget management.
- Ongoing efforts to both understand and monitor suspended solids will help identify the most appropriate measures for ensuring good water quality in the Delaware River and estuary.



BASED ON: HTTP://WWW.WATER.NCSU.EDU/WATERSHEDS/INFO/TURBID.HTML

Turbidity, the amount of suspended material in water, is measured in nephelometric turbidity units (NTUs).

CATEGORY II • WATER QUALITY

WATER QUALITY

WATER QUALITY

Indicator • Copper

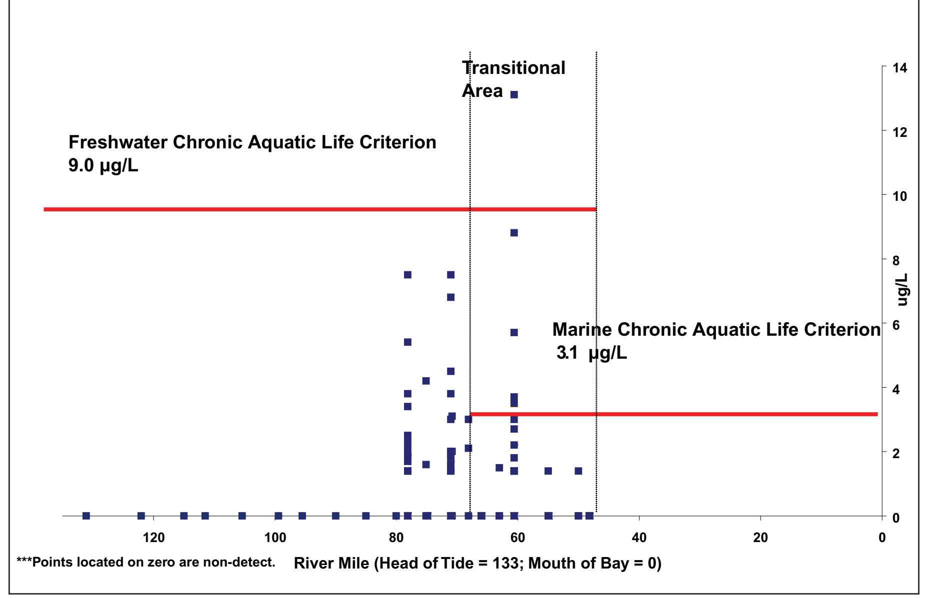
Indicator Description

Copper is a naturally occurring trace element found in surface waters and essential to virtually all plants and animals. However, even at low concentrations dissolved copper can be toxic to aquatic life. Sources of dissolved copper contributing to concentrations in water and sediment include metal finishing, leather processing, fungicides and pesticides.

Desired Condition

Concentrations in water and sediment that do not pose a threat to aquatic life (BP Goal 1.3; CCMP Actions T1-T5).

Fig 2.10 Dissolved Copper 2004 to 2006



Status

Fair: Dissolved copper concentrations are below or near water quality criteria.

Figure 2.10 shows concentrations of copper at sites in the tidal Delaware River (Fig. 2.11). Assessment in estuarine areas transitioning from fresh to marine waters is complicated by the impact of ions on the toxicity of copper to aquatic life. DRBC has aquatic life objectives for dissolved copper similar to the following EPA criteria:

Fresh water, chronic: 9 ug/L,
Fresh water, acute: 13 ug/L
Marine waters, chronic: 3.1 ug/L
Marine waters, acute: 4.8 ug/L

However, DRBC's fresh water criteria are based on water hardness in the Delaware River.

Trends

Dissolved copper concentrations have remained steady.

Actions and Needs

- Increased monitoring of copper and other metals is necessary for improved assessment capability, especially river miles 48 to 68.
- Coordination of monitoring among agencies should assure the use of state of the art methods and procedures as well as harmonization of assessment methodologies.
- The Biotic Ligand Model (BLM), developed to improve the predictions of metal bioavailability and toxicity, is currently recommended for use in fresh water. Its usefulness for monitoring and assessment in the basin, including estuarine and marine waters, is being investigated.

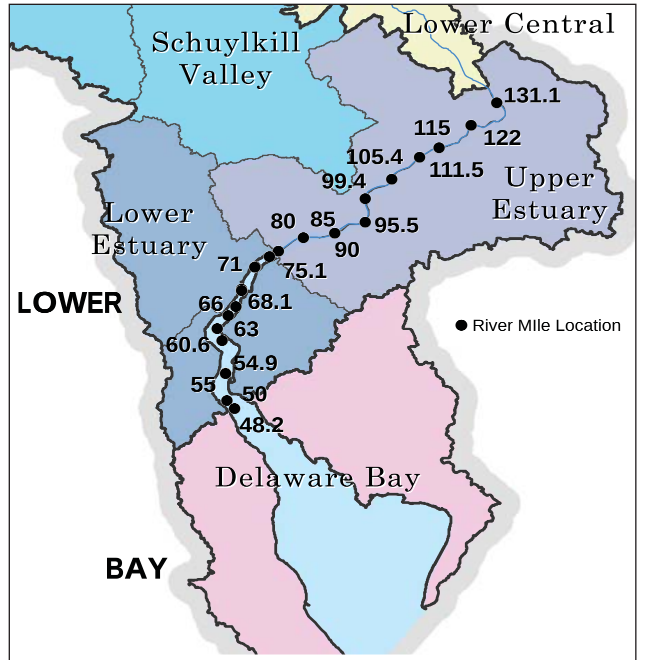


Fig. 2.11 Copper Monitoring Sites

Indicator • Fish Consumption Advisories

Indicator Description

Fish consumption advisories are issued by each state to inform the public when locally-caught fish are not safe to be eaten due to known levels of contamination. The advisories recommend either limiting or avoiding consumption of certain fish from specific water bodies. The two most common pollutants to cause advisories in the Delaware River Basin are mercury and polychlorinated bipheynls (PCBs), which both bioaccumulate in the aquatic ecosystem. Eating fish that contain these harmful substances is the principal way to be exposed to these chemicals. Therefore, fish consumption advisories are an important tool to help protect public health and to identify areas where further management of pollution may be needed.

Desired Condition

Finfish and shellfish that are safe to eat; a systematic and coordinated approach to assessing and communicating the results of fish and shellfish contaminant data. (BP Objective 4.1.D; CCMP Action T6).

Status

Poor: There are fish consumption advisories for waterbodies in all four Basin states and on the main stem of the Delaware River (Fig. 2.12).

The amount of contaminants fish accumulate depends on the species, size, age, sex, and feeding area of the fish. Generally, older and larger individual fish have accumulated the most contaminants, although in some cases contaminants are shed each time the fish spawn. Since fish accumulate many contaminants in their fatty tissues, certain species with higher oil content can pose more risk than others when both inhabit polluted areas.

The American eel and carp caught throughout the main stem of the Delaware should not be eaten at all and no fish should be consumed from upper Zone 5. Contaminants found in Delaware River basin fish tissue causing consumption advisories include: PCBs, Mercury, Dioxin, Chlorinated Pesticides, Dioxin/Furans, Dieldrin, DDT, Chlordane, and Toxaphene.

It is important to use caution when comparing fish advisories across state lines or in shared waters. Fish consumption advisories are based on risk assessments, and each state may use different methods to evaluate the risk of eating contaminated fish. Therefore, the number of meals recommended for each type of fish may vary even for the same levels of contamination. Inconsistencies also exist in the way the basin states list their advisories to the public.

For more information about fish consumption advisories, including specific locations, meal limits and individual fish species, search for "fish consumption" at these web sites:

- www.depweb.state.pa.us/watersupply
- www.state.nj.us/dep/dsr/njmainfish.htm
- www.fw.delaware.gov/Fisheries
- www.dec.ny.gov

Actions and Needs

- Provision of clear and consistent information to the public based on more uniform assessment methods.

The term *Bioaccumulation* refers to the uptake and retention of a chemical by an organism from all surrounding media (e.g., water, food, sediment).

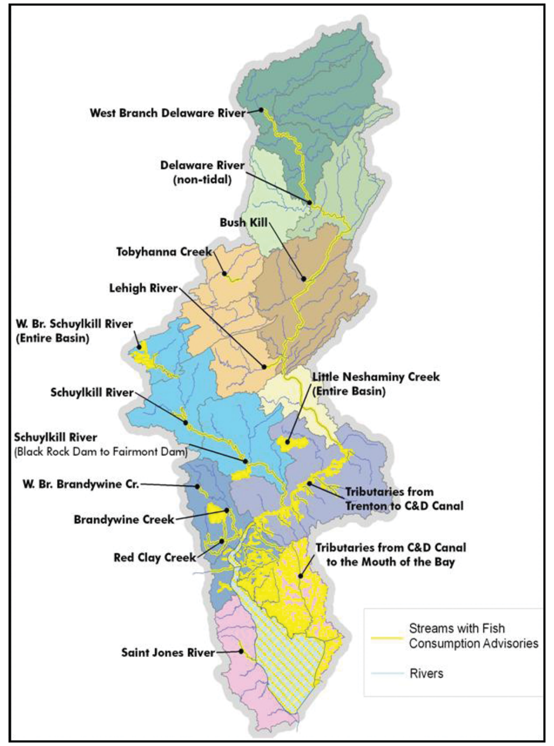


Figure 2.12. The map shows waterways where advisories are currently in place. Recommendations may range from one 8 oz. meal per week of one type of fish to no consumption of any fish.

Indicator • Pesticides

Indicator description

Atrazine and metolachlor are among the pesticides most frequently detected in ground water and surface water by the USGS's NAWQA Program and the USEPA's National Survey of Pesticides in Drinking Water. Both are designed to persist in soil for several months during the growing season for continuous weed control. However, both pesticides are water soluble, allowing the toxins to mobilize and pollute streams and ground water.

Atrazine is registered with the EPA as a Restricted Use Pesticide; it is classified as toxic to aquatic life, especially aquatic plants. It is a known human carcinogen, ground water contaminant, and a suspected endocrine disruptor. Atrazine is used primarily to control weeds on agricultural fields for crops such as corn and evergreen tree farms—especially for conservation tillage or "no-till" farming—and along highways for non-selective vegetation control.

Metolachlor is of low toxicity to humans but slightly to moderately toxic to some aquatic life. It is classified as a possible human carcinogen based on studies in rats and it may also cause developmental impairment. Metolachlor is primarily used for weed control in the production of corn, soybean, and woody ornamentals. It is sometimes used in formulations with other pesticides such as atrazine, cyanazine, and fluometuron.

Desired condition

Detection in ground and surface water supplies at concentrations below limits suspected of causing heath effects on humans and wildlife (BP Goals 1.2, 1.3; CCMP Actions T1-T5).

The EPA recommended level for Atrazine is 3 µg/L (ppb) and the World Health Organization (WHO) guidance is 2 ppb. EPA does not currently have a recommended concentration for for Metolachlor, but WHO guidance is 10 ppb.

Status

Fair: Pesticides prevalent, but in low concentrations.

The percentage of sampling sites with detected concentrations of atrazine was higher than that of metolachlor for both surface and ground water, indicating that atrazine contamination is more prevalent than metolachlor (Figs 2.13, 2.14). In the basin, atrazine was detected in 95% and Metolachlor in 81% in surface waters sampled. In ground water, atrazine was detected in 40% of samples, and metolachlor in 31% of samples.

The median concentration of atrazine at basin sampling sites was almost 0.05 ug/L for urban watersheds and 0.12 ug/L for agricultural watersheds. Surface water concentrations are highest in runoff from agricultural fields, especially following major runoff events occurring within a few weeks of application. Ground water concentrations are expected to be highest in areas with a long history of agricultural land use, especially corn crops, and where surface and ground water systems are connected sufficiently to allow infiltration.

Concentratiotns of atrazine and metolachlor generally were lowest in the northern part of the basin above the confluence with the Lehigh (Table 2.1). All median concentrations were below the drinking water standards. However, atrazine and metolachlor break down into degradation products that are detected as frequently or more frequently than parent compounds, an issue that demands further investigation about environmental and human health impacts.

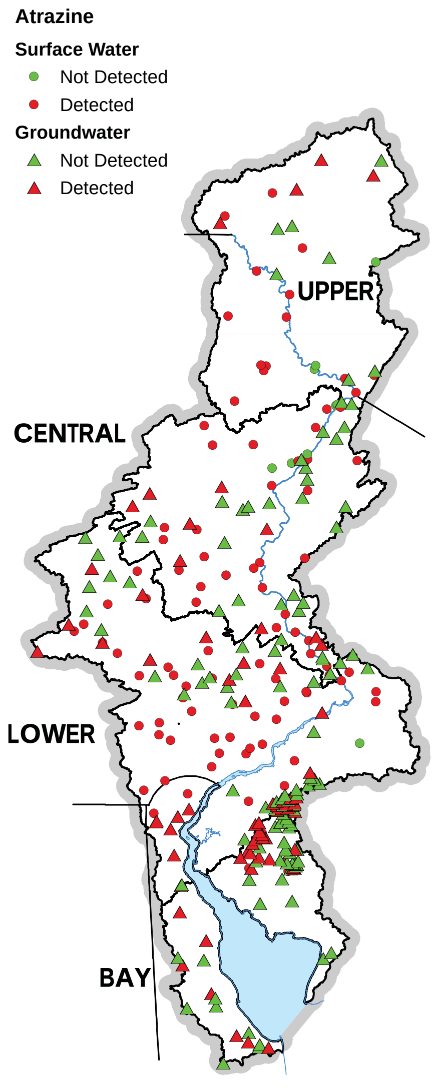


Figure 2.13. Atrazine detections in the Delaware River Basin. The USGS NAWQA studies found concentrations of Atrazine above the detection limit in 95% of Surface water stations and 40% of ground water stations.

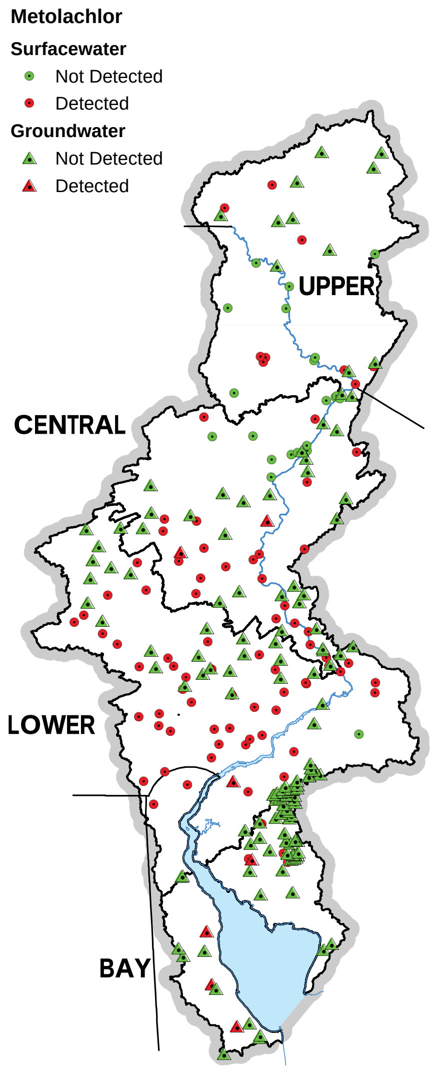


Figure 2.14. Metolachlor detections in the Delaware River Basin. The USGS NAWQA studies found concentrations of Metolachlor above the detection limit in 81% of Surface water stations and 31% of ground water stations.

Trends

It is difficult to determine trends over time in atrazine and metolachlor concentrations. The USGS National Water Quality Assessment (NAWQA) program provided a baseline assessment of these pesticides based on five years of data (1998–2001). NAWQA monitoring is continuing at selected sites as part of a specialized national program to assess pesticides, but currently there is not a program to specifically address pesticides in basin waters.

Actions and Needs

- Surface and ground water concentrations should be matched with levels of atrazine and metolachlor application; areas of concern should be identified and monitoring efforts stratified to capture conditions and trends in these areas.
- Periodic sampling is needed to determine trends in concentrations of atrazine, metolachlor, and their degradation products in ground and surface waters across the basin.
- Additional research is needed to determine the affect of these and other pesticides and their degradates on the aquatic environment, and the synergistic effects of multiple pesticides on humans and aquatic organisms.

Table 2.1 Atrazine and Metolachlor Concentrations

Subwatersheds	Median Atrazine ug/l	Median Metolachlor ug/l
Upper Region (NY and PA)		
EW1 West Branch (Cannonsville)	*0.020	*0.020
EW2 East Branch (Pepacton)	*0.002	*0.003
EW3 Mainstem (above Narrowsburg)	0.006	<0.001
LW1 Lackawaxen	0.005	0.002
NM1 Neversink-Mongaup	0.001	0.001
Central Region (PA and NJ)		
UC1 Pennsylvania tributaries	0.001	<0.001
UC2 New Jersey tributaries	0.011	0.006
LV1 Lehigh River above Lehighton	*0.004	*0.001
LV2 Lehigh River above Jim Thorpe	0.080	0.026
LV3 Lehigh River above Easton	0.233	0.054
LC1 Lower Central (above Trenton)	0.063	0.025
Lower Region (PA, NJ and DE)		
SV1 Schuylkill River above Reading	ND	ND
SV2 Schuylkill R . above Valley Forge	0.111	0.021
SV3 Schuylkill River above Phila.	0.047	0.025
UE1 Pennsylvania piedmont	0.030	0.022
UE2 New Jersey coastal plan	0.008	0.027
LE1 Christina River	0.158	0.045
LE2 C and D Canal, DE	ND	ND
LE3 Salem River, NJ	ND	ND
Bay Region (NJ and DE)		
DB1 DE Bayshore watersheds	ND	ND
DB2 NJ coastal plain	0.013	0.092
ND= no data * median based on 2 or fewer samples		

Table 2.1. Concentrations of atrazine and metolachlor generally were lowest in the northern part of the basin, above the confluence of the Lehigh River. USGS 2001.

For More Information:
Detailed information on atrazine, metolachlor and other pesticides found in water supplies can be found by reading "Pesticide compounds in streamwater in the Delaware River Basin, December 1998-August 2001" by Hickman, et al
located at: http://pubs.er.usgs.gov/usgspubs/sir/sir20045105

Indicator • Toxics

Indicator description

Polychlorinated biphenyls (PCBs) are toxic compounds shown to cause cancer in animals and serious non-cancer health effects to the immune, reproductive, nervous, and endocrine systems. Studies provide supportive evidence for potential carcinogenic and non-carcinogenic effects in humans as well. PCBs persist in the environment for long periods of time because they bond strongly to soil and sediments and bioaccumulate (See p. 37 for a definition) in fish and wildlife.

Invented in 1927, PCBs are mixtures of synthetic organic chemicals with the same basic chemical structure and similar physical properties ranging from oily liquids to waxy solids. Due to their non-flammability, chemical stability, high boiling point and electrical insulating properties, PCBs were used in hundreds of industrial and commercial applications including electrical, heat transfer, and hydraulic equipment; as plasticizers in paints, plastics and rubber products; in pigments, dyes and carbonless copy paper and many other applications. Based on the evidence that PCBs are persistent in the environment and can cause harmful health effects, the Toxic Substances Control Act (TSCA) of 1976 prohibited the manufacture, processing, and distribution of PCBs.

Desired Condition

PCB concentrations in water, sediment and fish tissue that are designed to protect human health and the environment (BP Goals 1.2, 1.3; CCMP Actions T1-T5). These include the following numeric criteria:

- drinking water: 500 ppt (EPA)
- ambient water for aquatic life protection: 14 ppt chronic (EPA)
- ambient water to protect wildlife: .074 ppt (EPA-Great Lakes Initiative)
- ambient water for human health protection: .016 ppt (DRBC-proposed)

Status

Poor: PCBs persist in the Basin's water, sediment and fish tissue.

Extensive analysis of the sources and fate of PCBs has been studied by DRBC as part of the development of the Total Maximum Daily Load (TMDL) for Zones 2-6. As illustrated in Figure 2.15, the current sources of PCBs to the tidal river are non-point sources accounting for 25% of loadings and point sources contributing 18%. The non-tidal river above Trenton, the Schuylkill River and other tributaries to the tidal river contribute about 34.5%.

Contaminated sites contributed 11% of total loading. The Delaware Toxics Reduction Program (DelTRiP) is a multi-agency effort to identify, track, prioritize, and report the status of contaminated sites that contribute or potentially contribute to toxics within the basin. The program, started in 2004 through a grant from EPA, is currently focused on PCB contamination. According to the January 2008 report, 128 sites have completed remediation for PCBs and 81 sites are in some stage of remediation including 28 of unknown status (Figure 2.16). Future DelTRiP reports will update this information with a focus on sites of unknown status.

Trends

Despite the ban on PCB manufacture in 1979, PCBs still persist in landfills, streambeds, terrestrial sediments, and some closed electrical systems. They remain a ubiquitous legacy pollutant in much of the basin, but concentrations vary greatly, and there is evidence that concentrations in fish tissue is decreasing (Figure 2.17).

The goal of the TMDL for the tidal Delaware River is to reduce PCB loadings and eliminate consumption advisories based on this contaminant. The first stage is a non-numeric approach, all point sources are required to conduct monitoring and 42 dischargers are required to submit a Pollution Minimization Plan (PMP). This plan identifies all known and potential sources of PCBs on their property, and outlines a procedure to find all unknown sources and implement strategies for minimizing and preventing releases from all identified sources. The permittees must also document measured progress in this effort in an annual report to DRBC.

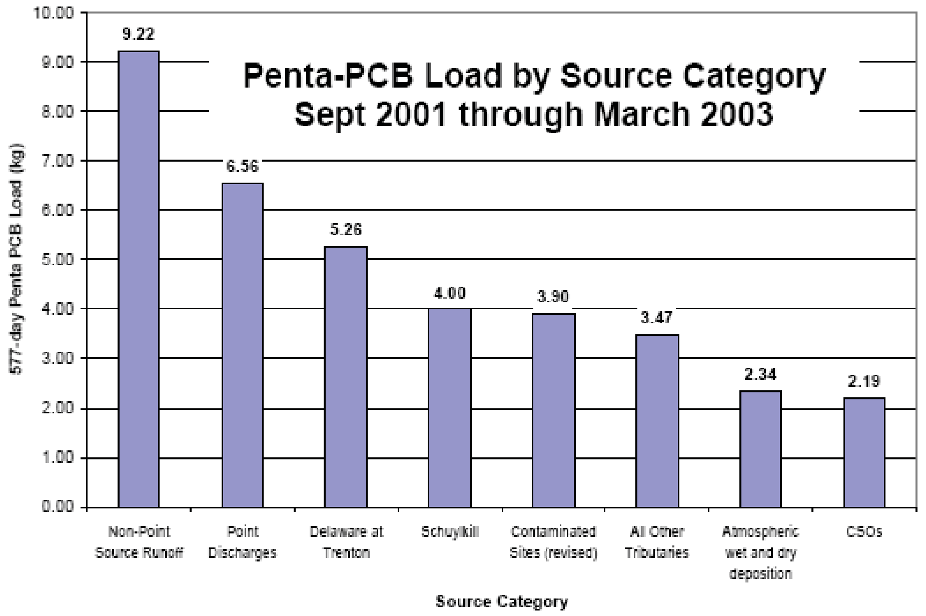
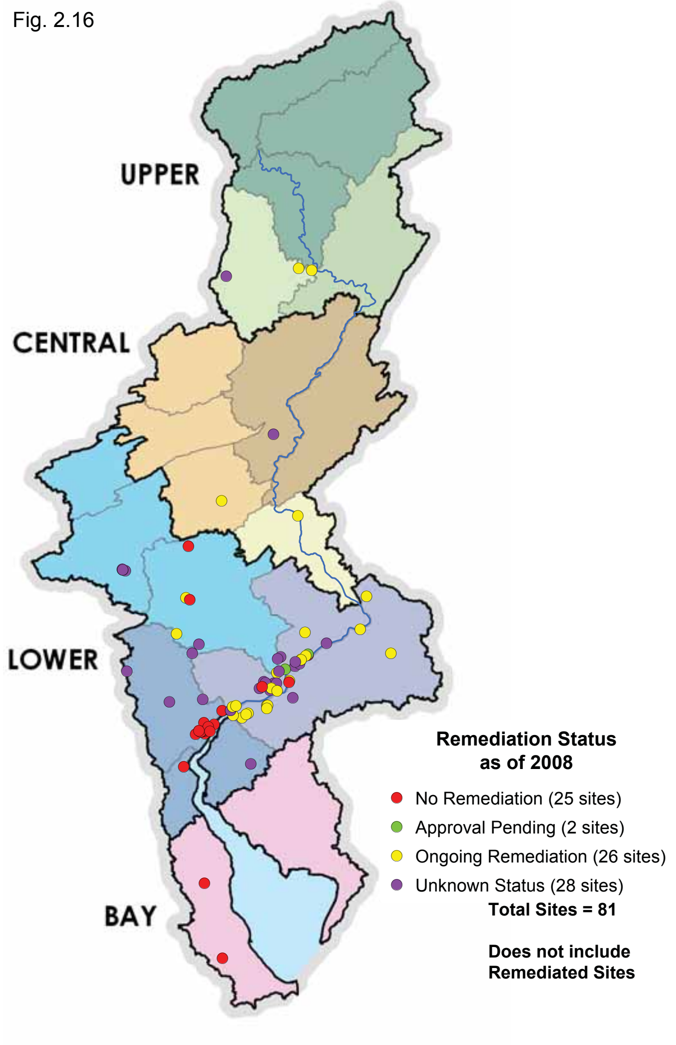


Figure 2.15. Non-point and point source sources contribute more PCBs to the tidal portion of the river more than any other. The non-tidal Delaware and the Schuylkill River also have high loadings of PCBs. Data collected September 2001–March 2003.

Fig. 2.16



SOURCE: DRBC

The Lower Schuylkill is a major contributor of PCBs in the Delaware Estuary. This photo taken in 1999 at Bartram's Gardens shows the heavy industrial area along the Schuylkill just above its confluence with the Delaware.

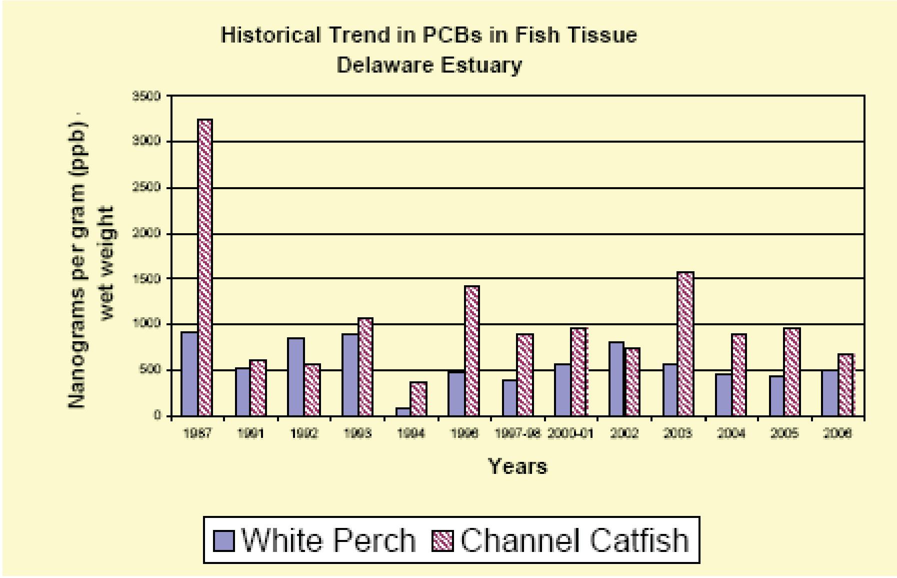


Figure 2.17. PCBs are still found in fish tissue in the Delaware Estuary but concentrations appear to be diminishing.

Actions and Needs

- Continued monitoring and source identification is needed for PCBs in the Delaware River Basin.
- Removal and containment should be done as sources of PCBs are found.
- Revised water quality criterion for PCBs and regulations addressing the long-term attainment of this criterion. A second stage of the TMDL program will be implemented and completed by December 2009.

Indicator • Support of Designated Use: Tributaries

Indicator Description

This indicator reports conditions on tributaries relative to their designated uses. Each state independently identifies uses for each waterbody, for example, drinking water supply, contact recreation (swimming), and aquatic life support (fishing), and specifies scientific criteria to support that use.

Biennial assessments are mandated by the federal Clean Water Act (CWA). Waterbodies that are not attaining water quality standards are included on a "List of Water Quality Limited Waters" or "303(d) List" and reported to US EPA to satisfy section 303(d) of the CWA. States must prioritize 303(d)-listed waterbodies for TMDL analyses and identify those high priority waterbodies for which they anticipate establishing TMDLs in the subsequent two year cycle.

Desired Condition

All streams meet standards set to support their designated uses per the federal Clean Water Act (BP Goals 1.2, 1.3, 1.4; CCMP Action W12).

Status

Fair: Approximately 37% of basin stream miles do not meet required conditions. The presence of fish consumption advisories is a major factor in 303(d) listings in the basin. Not all waters of the basin have been assessed.

Trends

Figure 2.18 is a composite of data across four biennial reporting cycles (2002 through 2008). The ability to geographically report on each state analysis is dependent on the availability of geographic information suitable for mapping and on final condition assessment information. Differences in assessment and reporting methodologies among the basin states complicate attempts to assemble and compare results, as do periodic changes instituted by the states. For example, in 2006 NJ changed its reporting units from stream segments to watershed units.

Actions and Needs

- Better cartographic representation of impaired waters information in all four states.
- Assessment information relevant to chemical, physical and biological conditions.
- Comparable reporting of summary statistics.

A TMDL (Total Maximum Daily Load) is the sum of the allowable amount of a single pollutant from all contributing point and nonpoint sources. It includes a margin of safety and seasonal variation in water quality.

Fig. 2.18
303d Listed Streams and Watersheds

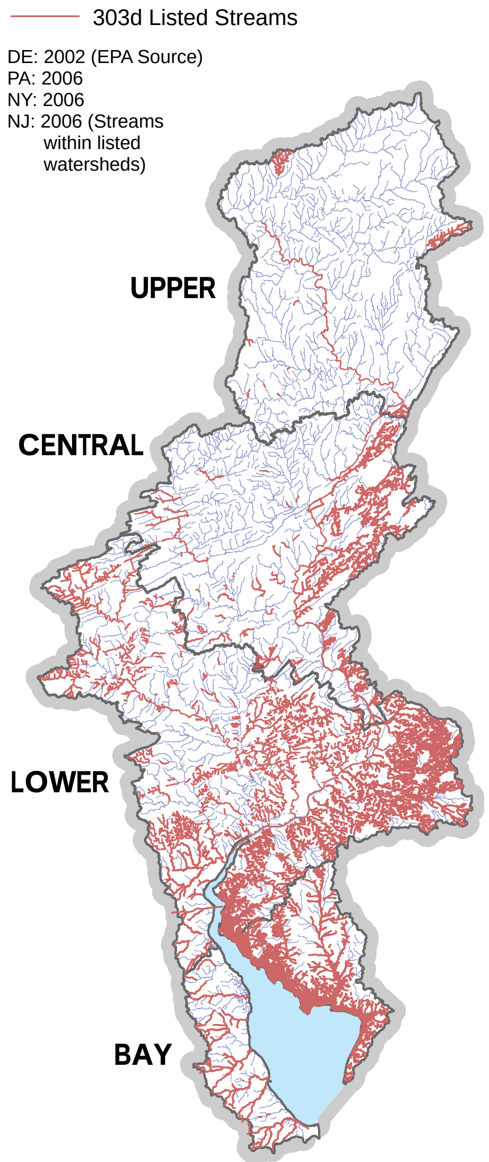


Table 2.2 Unattaining 303(d) Listed Streams

State	Data Year	Total Tributary Miles	Total 303(d) Stream Miles	Stream Miles w/Consum. Advisories	% of Total	% of Total w/o Consum. Advisories
DE Total	2002	2,480	569		23%	
NJ Total	2006	6,975	5,786		83%	
NJ Consum. Advisories				3,597		31%
NY Total	2006	4,197	81		2%	
PA Total	2006	10,578	2,512		24%	
PA Consum. Advisories				658		18%
TOTAL		24,230	8,948	4,255	37%	19%

Indicator • Trends in Tributary Water Quality

Lower and Bay | Upper & Central

Indicator Description

This indicator reports trends in conditions on representative freshwater tributaries relative to four water quality parameters that effect living resources: dissolved oxygen (DO), nitrogen (N), phosphorus (P) and total suspended solids (TSS). The assessment was developed by the Water Resources Agency at the University of Delaware with assistance from Penn State, Cornell and Rutgers and is based on water quality data from the EPA STORET, USGS NWS and state water quality information systems.

Five year median values for each parameter were compared to targets:

- DO: applicable state criteria.
- N: 1.0, 2.0, and 3.0 mg/L (DE low, moderate and high TMDL targets)
- P: 0.1 mg/L (NJ criterion)
- TSS: 40 mg/L for warm water and 20 mg/L for cold water (trout) streams (NJ criteria).

Although many years of data are available, 1990 was selected as the beginning year for trend analysis to exclude water quality improvements related to the waste water infrastructure investments of the 1980s.

Desired Condition

Improving or constant conditions in streams, where water quality meets or is better than criteria (BP Goals 1.2, 1.3, 1.4; CCMP Action W12).

Status and Trends

Upper and Central Regions: Good

DO levels are very good and show increases at 6 of 9 watershed stations. P is below 0.1mg/L and has improved or remained constant, except at the lower Lehigh station (LV3) where it is slightly elevated, but improving. Water quality in the lower Lehigh appears to be degrading since 1990 with respect to N and TSS (Table 2.3).

Lower and Bay Regions: Fair

DO, while good to fair, is decreasing at 6 of 11 stations. N, while constant, is higher than the moderate target (2.0 mg/L) at half the stations, and phosphorus is constant but above 0.1 mg/L at 8 of 11 stations. TSS is high, but improving, on the Smyrna River (LE2) (Table 2.3).

Actions and Needs

- More consistent monitoring is needed: at least one station in each region had insufficient periods of record for one or more parameters.
- Metals data were generally not sufficiently robust to assess because of changes in detection capability or incomplete records.
- This initial look should be expanded to include additional watershed stations.

Fig. 2.19
Selected Tributary Water Quality Stations

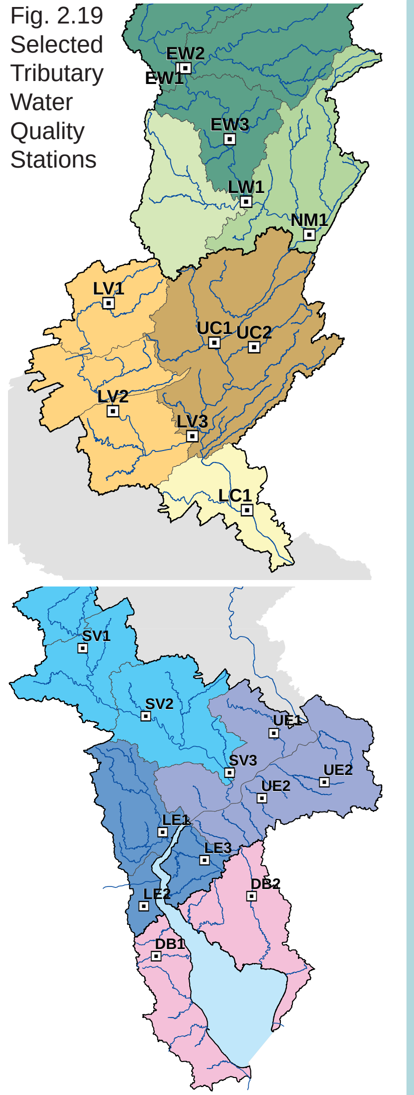


Table 2.3 Trends in Water Quality of Selected Tributary Streams

Upper and Central Region Stations	DO (mg/l)	N (mg/l)	P (mg/l)	TSS (mg/l)
	SHORT	TERM	SINCE	1990
EW1 West Br. Delaware R. Hancock, NY	10.4 ●	0.4 ●	0.01 ▲	6 ●
EW2 East Br. Delaware R. Hancock, NY	9.9 ●	0.2 ●	0.01 ●	5 ●
EW3 Hancock - Narrowsburg, NY	Insufficient Data			
LW1 Lackawaxen R. at Lackawaxen, PA	12.6 ▲	0.2 ●	0.02 ▲	6 ●
NM1 Delaware River at Pt. Jervis, NY	10.7 ▲	0.2 ●	0.02 ●	5 ●
UC1 Brodhead Cr at Del. Water Gap, PA	12.0 ▲	0.5 ●	0.05 ▲	2 ●
UC2 Paulins Kill at Blairstown, NJ	10.0 ●	1.0	0.02 ●	7 ●
LV1 Lehigh River at Stoddartsville, PA	11.5 ▲	0.2 ●	0.01 ▲	4 ●
LV2 Lehigh River at Walnutport, PA	12.1 ▲	0.7 ●	0.02 ▲	8 ▼
LV3 Lehigh River at Glendon, PA	11.2 ▲	2.1 ▼	0.11 ▲	9 ▼
LC1 Wichechocke Creek at Stockton, NJ	Insufficient Data			

Lower and Bay Region Stations	DO (mg/l)	N (mg/l)	P (mg/l)	TSS
SV1 Schuylkill River at Berne, PA	10.5 ▼	1.0 ▲	0.02 ▲	6 ▼
SV2 Schuylkill River at Pottstown, PA	10.1 ●	3.0 ●	0.12 ▲	8 ●
SV3 Schuylkill R. at Philadelphia, PA	10.8 ▲	3.2 ●	0.23 ▲	2 ▲
UE1 Neshaminy Cr. at Langhorne, PA	10.7 ●	2.3 ●	0.18 ▲	6 ●
UE2 N. Br. Rancocas at Pemberton, NJ	7.1 ▼	I.D.	0.05 ●	I.D.
UE2 Cooper River at Haddonfield, NJ	7.2 ▼	1.0 ●	0.23 ●	19 ●
LE1 Brandywine R. above Wilmington, DE	9.9 ▲	2.5 ●	0.12 ●	9 ●
LE2 Smyrna River at Route 9 bridge, DE	6.1 ▼	0.6 ●	0.21 ●	86 ▲
LE3 Salem River at Woodstown, NJ	9.5 ▲	3.7	0.15 ●	17 ●
DB1 Leipsic River at Route 13, DE	7.9 ▼	0.1 ▲	0.23 ●	20 ●
DB2 Maurice River at Norma, NJ	8.2 ▼	2.0	0.01 ●	3 ●

Legend
Green numbers = Good
Blue numbers = Fair
Red numbers = Poor
▲ = Improving
● = Constant
▼ = Degrading

Indicator • Support of Designated Use: River and Bay

Indicator Description

This indicator reports whether or not the water quality of the River is supportive of its designated uses, including: drinking water, aquatic life, recreation, and consumption of fish and shellfish, although not all uses are designated for all ten water quality zones. This assessment is conducted every two years in accordance with USEPA requirements. A full explanation of the assessment can be found in the 2008 Delaware River and Bay Integrated List—Water Quality Assessment available at www.drbc.net.

Desired Condition

Water quality that meets the criteria designed to ensure support of designated water uses per the federal Clean Water Act (BP Goals 1.2, 1.3, 1.4; CCMP Action W12).

Status

Fair: Ranges from poor (fish consumption and aquatic life) to good (drinking water and recreation).

The assessment involves comparing key water quality parameters by river assessment units (water quality management Zones) with applicable water quality criteria adopted by DRBC to support the designated use(s). The non-tidal assessment units include Zones 1A, 1B, 1C, 1D, and 1E and the designated uses assessed include aquatic life, drinking water, primary recreation, and fish consumption. Zones 2, 3, 4, and 5 make up the tidal portion of the River and fish consumption, aquatic life, and recreation apply to all the tidal zones. Drinking water use is only applicable to Zones 2 and 3 of the tidal river. Delaware Bay is Zone 6 and its designated uses include aquatic life, primary recreation, fish consumption, and shellfish consumption.

The final assessments for 2008 by zone and designated use are listed in Table 2.4 and shown in Figure 2.20.

Integrated Assessment Summary

Aquatic life is supported in zones 3 and 6. In Zones 1A and 1E, pH does not meet criteria; and Zones 2 and 4 do not meet temperature criteria. Additionally, in Zone 5 approximately 17% of the samples assessed for DO did not meet the 24-hour average criteria.

Drinking water use is supported in all designated zones.

Primary contact recreation is supported in all applicable zones, except Zone 4 below RM 81.8 where there are insufficient data.

Fish consumption is not supported in any zone, based upon the assessment methodology used. This means that an advisory has been issued by a State with a recommendation to limit consumption of at least one species of fish. In most instances, the contaminants are PCBs and mercury. New York did not issue any fish advisories for the Delaware River, however fish advisories due to mercury are listed for the reservoirs feeding the Delaware River. Recently compiled toxics data from fish tissue collected in 2004 and 2005 also support fish advisories in the tidal river. PCBs remain the primary cancer risk driver, followed by dioxin and dioxin-like chemicals. Mercury levels in striped bass are moderately elevated and contribute to non-cancer health risks.

Shellfishing support varies within Zone 6 based on periodic pathogen exceedences.

Actions and Needs

- Examination of DO issues, including assessment of current monitoring and adequacy of existing criteria in the tidal river.
- Implementation of the PCB Total Maximum Daily Load (TMDL) for Zones 3, 4, 5 and 6.
- Review and assessment of the adequacy of current water quality criteria.
- Additional real-time monitoring is an identified need that can only enhance our ability to assess and report water quality conditions.

Table 2.4 2008 Integrated Listing Category for the Delaware River by DRBC Water Quality Management Zones

Zone	Aquatic Life	Drinking Water	Recreation	Fish Consumption	Shellfishing	Final 2008 Assessment Category	Final 2006 Assessment Category
1A	NS	S	S	NS	NA	5	5
1B	ID	S	S	NS	NA	5	5
1C	ID	S	S	NS	NA	5	5
1D	ID	S	S	NS	NA	5	5
1E	NS	S	S	NS	NA	5	5
2	NS	S	S	NS	NA	5	5
3	S	S	S	NS	NA	4A	5
4	NS	NA	ID (below RM 81.8)/S	NS	NA	5	5
5	NS	NA	S	NS	NA	4A	5
6	S	NA	S	NS	S/SS/NS/ID	4A	5

S: The assessment unit supports the designated use.
SS: The assessment unit supports the designated use, but with special conditions.
NS: The assessment does not support the designated use.
NA: DRBC WQR does not contain applicable criteria for a parameter in the AU.
ID: Insufficient or unreliable data is present.
4A: A TMDL to address a specific segment/pollutant combination has been approved or established.
5: Available data and/or information indicate that at least one designated use is not being supported or is threatened, and a TMDL is needed.

Fig. 2.20 Support of Designated Uses: Delaware River and Bay

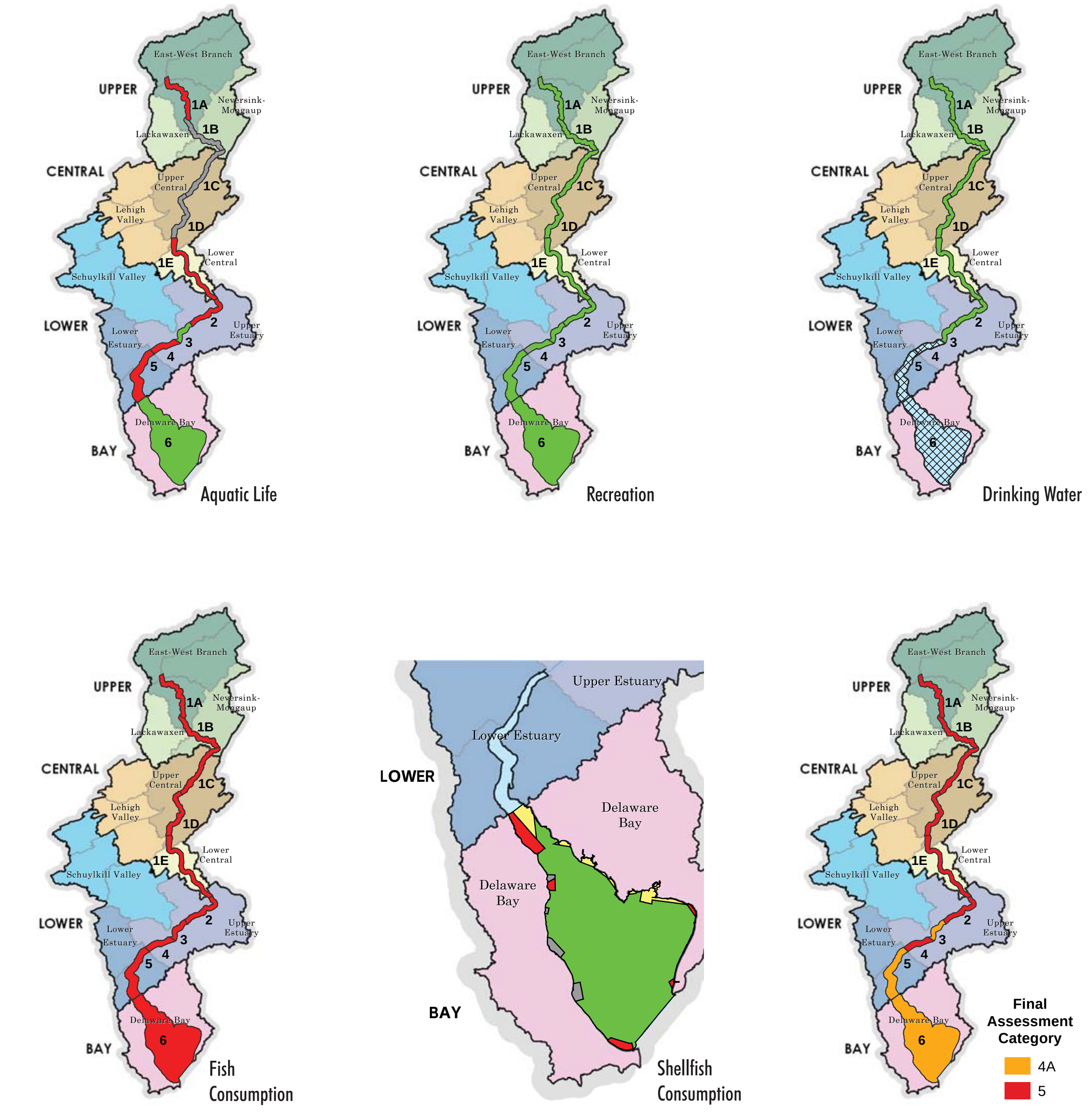
Upper Region
EW • East and West Branch watersheds
LW • Lackawaxen watershed
NM • Neversink and Mongaup watersheds

Central Region
UC • Upper Central watersheds
LV • Lehigh Valley
LC • Lower Central watersheds

Lower Region
SV • Schuylkill Valley
UE • Upper Estuary watersheds
LE • Lower Estuary watersheds

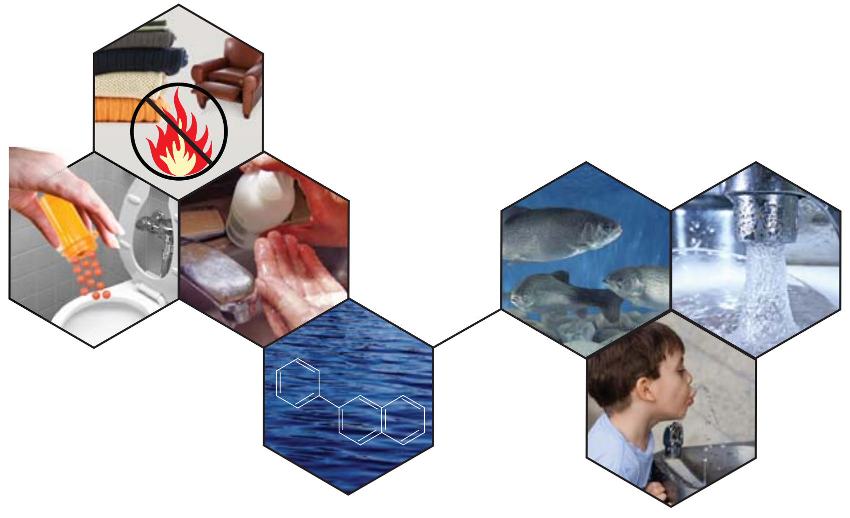
Bay Region
DB1 – Bay watersheds in DE
DB2 – Bay watersheds in NJ

Supporting
Supporting, but with Special Conditions
Not Supporting
Insufficient Data
Not Assessed



Feature • Water Quality

Contaminants of Emerging Concern



Description

Contaminants of emerging concern are chemicals that are not regulated through water quality programs, but are of interest to scientists because of their persistence, bioaccumulation, and potential for toxicity to aquatic life and humans. Although their fate and transport are not fully understood, and a consensus has not yet been reached concerning their toxicity, these substances are believed to have the potential to cause adverse impacts on human health or the environment, including causing cancer and reproductive effects. Contaminants of emerging concern include pharmaceuticals, personal care products, flame retardants, insecticides, plasticizers, and resistant pathogens (bacteria and viruses).

Status

Significant work is being conducted to study emerging contaminants in the Delaware River Basin. Polybrominated diphenyl ethers (PBDE) are manufactured flame retardants used in everyday items, from computer casings to carpet pads to foam cushions in chairs and couches. In the environment PBDEs accumulate in the fatty lipid tissue of humans and animals. Figure 2.21 shows the relative concentrations among 18 tissue samples of eel from six sites in the Delaware River. Concentrations are measured in nanograms (10^{-9}, parts per trillion or ppt) of PBDE per gram of tissue.

In 2007, DRBC conducted a pilot survey in the tidal Delaware River, sampling and analyzing ambient waters for pharmaceuticals and personal care products (PPCP), perfluorinated compounds (PFC), hormones and sterols, nonyl phenols, and polybrominated diphenyl ethers (PBDE).

- Twenty-one out of 54 PPCP compounds were detected.
- Aquatic ecotoxicity data, primarily based on individual compounds and single species tests, are readily available for only 16 out of the 21 PPCP compounds which limits the assessment of risk to aquatic life.
- PFCs were measured in concentrations that exceed benchmarks for water quality.
- Nonyl phenol levels did not exceed current EPA water quality criteria.
- PBDE were measured in pg/L to ng/L concentrations with distributions similar to those observed in other North American locations.
- Natural and synthetic hormones were reported in ng/L levels. Concurrent, short-term chronic toxicity tests for survival, growth, and reproduction in the ambient water samples did not indicate toxicity for species and endpoints measured.

How small is…

A nanogram is
10^{-9} or 1/1,000,000,000
or one trillionth of a gram
ppt = part per trillion = ng/Liter

A picogram is
10^{-12} or 1/1,000,000,000,000 or
one billionth of a gram
ppb = parts per billion = pg/Liter

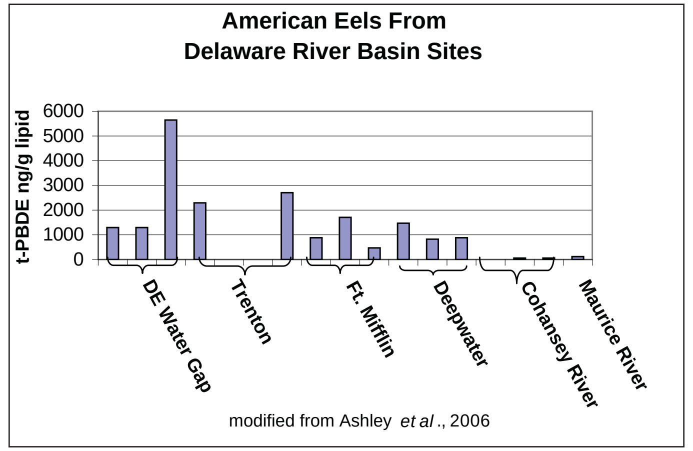


Fig. 2.21. American Eel PBDE concentration

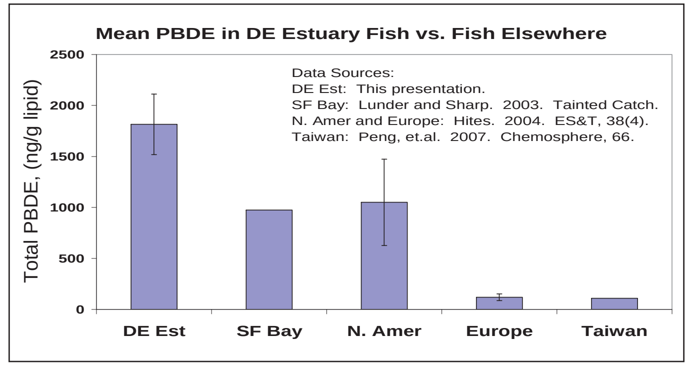


Fig. 2.22. PBDE in DE Estuary Fish

Trends

The levels of PBDEs in people's bodies are reported to be doubling every 2 to 5 years, and are 40 times higher in North America than on other continents. A comparison of PBDE concentration in fish from the Delaware Estuary and fish found in other locations is illustrated in Fig. 2.22. These data suggest that PBDE concentrations are significantly higher in fish from the Delaware than from other parts of North America, and orders of magnitude greater than those from Europe and Taiwan. The effect levels and human health implications of these compounds have yet to be established.

Actions and Needs

- Systematic monitoring is needed to understand how and where these substances are being released into the environment, what is happening to them once they enter the environment, and the risk they pose to humans and to our ecosystem.
- Assessment of ecotoxicity from emerging contaminants in the tidal Delaware River would be further informed by estrogenicity screening, biomarker measurements and population (sex ratio) surveys.

Learn more about contaminants of emerging concern at these web links.

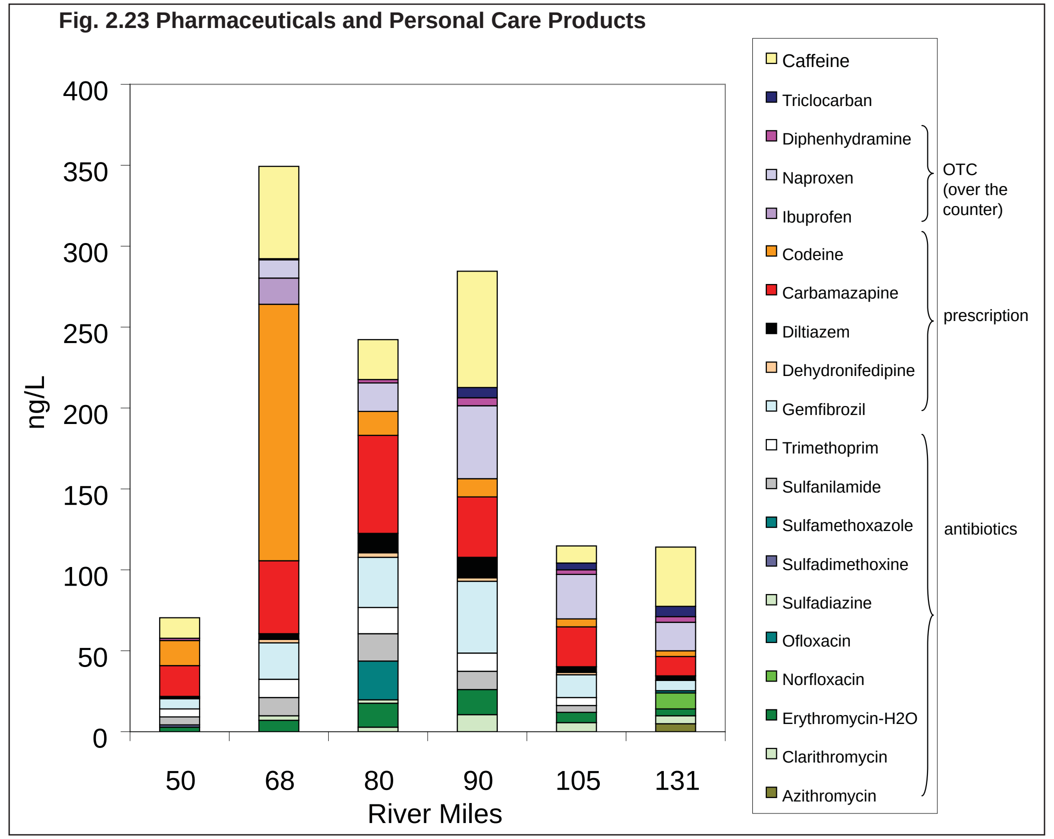
Delaware River Basin Commission Emerging Contaminants
http://www.state.nj.us/drbc/emc.htm

United States Environmental Protection Agency (USEPA) Pharmaceuticals and Personal Care Products
http://www.epa.gov/ppcp/

United States Geological Survey (USGS) Emerging Contaminants in the Environment
http://toxics.usgs.gov/regional/emc/

Proper Disposal of Prescription Drugs Consumer Guidance (White House Office of National Drug Control Policy)
http://www.whitehousedrugpolicy.gov/drugfact/factsht/proper_disposal.html

Teleosis Institute List of National Pharmaceutical Take-Back Programs and Resources
http://www.teleosis.org/gpp-national.php



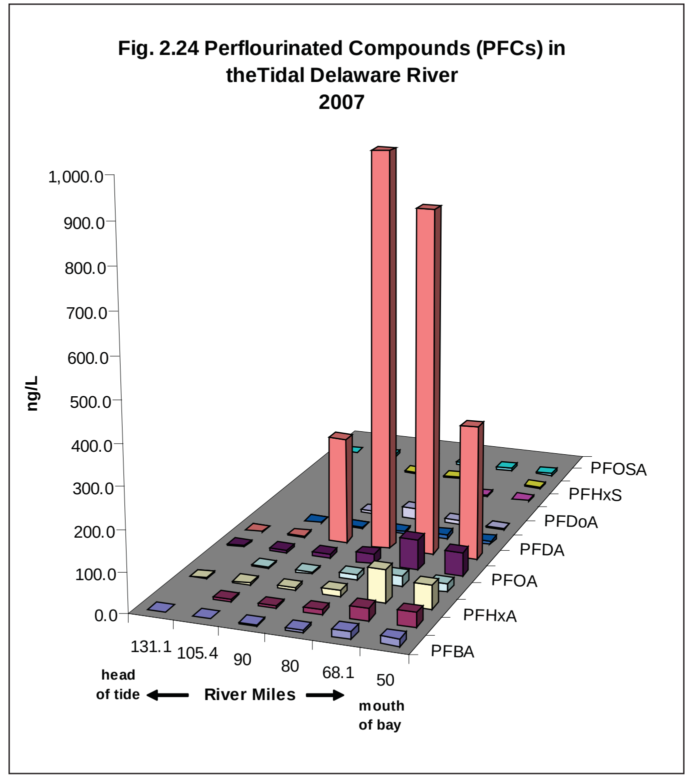


Fig. 2.24. Results of a 2007 DRBC study show concentrations in nanograpms per liter of perflourinated compounds (PFCs) by river mile.

Category III

Living Resources

THEN – "The extensive commercial fishery of the 19th century in the Delaware River and Bay declined in the 1920s, due to deterioration of water quality and over-harvesting. Fishery conditions have improved in the last several years. An objective now must be to maintain and continue the improvement, with traces of toxic substances."

Level B Study, May 1981, p 19
DRBC

Now

The past history of the river's anoxic (zero dissolved oxygen) zone, the introduction of water quality regulations, and subsequent improvements in water quality is recounted the Water Quality section of this report. The success of years of management and change is most dramatically evident in the restoration of living resources, especially fin fish populations and most notably shad.

Water quality criteria for the support of aquatic life have been adopted for a number of parameters, and are being considered for more. All of the waters of the basin are designated for the support of aquatic life. The key water parameter of concern has been dissolved oxygen (DO) because it is necessary for nearly every aquatic resource and is essential for overall ecosystem health. Aside from water quality, there are many other aspects affecting living resource condition. These include, but are not limited to, flows, temperature, natural predation, harvesting by humans, disease, and habitat loss.

Context and Linkage

As food and as habitat, healthy aquatic resources are linked to terrestrial and avian populations. The story of living resources in the basin is one of food webs, competition, interconnections, and water. Clean water is a requisite for fish and shellfish, which are principal foods for birds and mammals. Shellfish are filter feeders and help to absorb nutrients that can result in low DO levels that impair fish survival.

One example of an interconnection is the horseshoe crab and red knot. Horseshoe crabs, a key crustacean of Delaware Bay, lay eggs on bayshore beaches at exactly the right time for them to nourish migrating red knots on their annual journey to nesting grounds in the arctic. Without sufficient food, many birds cannot complete the trip and species survival may be in jeopardy. The infringement of rising sea levels and human settlement on bay beaches, the commercial harvesting of crabs, the earlier onset of spring with changes in global climate, and other unknown impacts beyond the basin all have the potential to affect the success of migrating red knot populations.

Table 3.1. **Environmental Factors Highly Related to Impairment of Aquatic Communities Along An Urban Land-Use Gradient.**
Green shading indicates factors that were more favorable to healthy aquatic communities and red shading indicates factors that were less favorable.
[NS= No statistically significant effect on aquatic community]

Watershed Characteristic	Fish	Aquatic invertebrates	Algae
Area of forest and wetlands	NS	Positive	NS
Ability to maintain base flow	NS	Positive	NS
Percentage of cobble substrate	Positive	Positive	NS
Median sulfate concentration	NS	Positive	Positive
Median total phosphorus concentration	Negative	NS	Positive
Mean annual flood	Negative	Negative	Negative
Flashiness of streamflow	Negative	NS	NS
Impervious area, road area only	Negative	Negative	Negative
Impervious area, nonroad area only	NS	Negative	NS
Population density	Negative	Negative	Negative
Total urban area in 1986	Negative	NS	NS
Urban area growth from 1986 to 1995	NS	Negative	NS
Commercial and industrial area in 1986	NS	Negative	Negative
Total point-source flow	NS	Negative	NS

Source: Ayers, M , J Kennen, P Stackelberg 2000. *Water Quality in Long Island-New Jersey Coastal Drainages 1996-98*. USGS Circular 1201. http:/nj.usgs.gov/nawqa/linj.ntml.

Not all links among living resources are this dramatic or international. Aquatic invertebrates, like freshwater mussels, are or become sedentary species and therefore are excellent indicators of local water quality and watershed condition. Aquatic invertebrates are especially sensitive to landscape changes related to development (Table 3.1).

Getting Personal

The health of living resources is not just important to maintaining the natural ecology of basin and estuary. Humans are an integral part of the web, linked by economic, recreational, and health interests. Fishing, for example, is both a commercial and recreational enterprise, highly valued throughout the basin. World-class trout fishing in the cold waters of the basin is an economically important enterprise that lures thousands of fisherfolk each year. The importance of oysters, crabs and other species of the Bay have been the foundation of commercial enterprises – harvesting, canning and shipping – for many generations. Threats to the living resource base may also be threats to the survival of basin and bayshore towns.

Monitoring living resources is important not only for ecosystem condition assessment, but also for understanding threats to human health and wellbeing. Toxic substances and diseases in water and sediment can be accumulated in fish tissue and shellfish. When consumed, that burden is passed on to other animals, including humans. As our knowledge of living resources improves, so may our ability to protect human health. (See *Fish Consumption* in the Water Quality section.)

Reporting

More than any other category of indicators, living resources are the most problematic to measure and report. Living resources tend to move about, change size and form, alternate food preferences, alter habits, and even their habitat, as they pass through their life cycles. Determining which species to evaluate in a community, what parameter to measure, and how to account for the effects of natural and imposed stressors is daunting. Moreover, although a wealth of information may exist; centralized clearinghouses for the information generally do not.

This section on living resources reports the condition status and observed trends for only a few of the thousands of species that call the basin home for all or part of the year. Some were chosen for their economic benefits, others were chosen because of their ecological significance, several are critical species that need to be protected from extirpation or extinction, and some were chosen for their ability to be monitored and serve as a representative indicator of other living resources.

Living resource indicators included in this report are:

- Benthic macroinvertebrates
- Freshwater mussels
- Oysters
- Horseshoe crabs
- Birds: Red knot, Louisiana water thrush, and American bald eagle
- Finfish: Weakfish and Striped bass, Atlantic sturgeon, American shad, and Brook trout.

A feature on invasive species concludes the Living Resource section.

1896 Nearly 20 million pounds of American shad, celebrated as America's founding fish by author John McPhee, are caught in the Delaware River.

1910 The value of the NJ oyster harvest in Delaware Bay exceeds the state's wheat harvest by $1 million.

1914 Area of leased oyster grounds at 30,000 acres, up from 12,000 acres in 1900.

1940s Shad and herring, unable to migrate through zero oxygen barrier at Philadelphia, cannot swim to upriver spawning grounds.

Late 1950s MSX disease devastates oyster stocks in the Delaware Bay.

1981 Sole surviving commercial shad fishery on the non-tidal river nets 6,392 shad—the biggest catch since 1896.

1987 Over 56,000 shad, worth about $1.6 M recreational dollars are landed in 9 weeks between Hancock NY and Yardley PA.

1987 New Jersey and Delaware Shellfish Councils close Delaware Bay oyster seed beds to dredging.

1989 Landing of a 53 lb. 13 oz. striped bass from the Delaware River near Chester breaks PA record.

1991 The economic value of recreational fishing in Delaware Bay is estimated at $25 million per year.

1995 Over a half million shad swim up the Delaware to spawn.

1996 Over 90 percent of the Delaware Estuary meets fishable and swimmable goals of the Clean Water Act.

1998 Striped bass fishery declared "Restored" by ASMFC.

1999 Red knot listed as "threatened" by NJ.

2007 DE and ASFMC limit harvesting of male horseshoe crabs.

2008 NJ bans harvesting of all horseshoe crabs.

Indicator • Benthic Macroinvertebrates

Indicator Description

Benthic macroinvertebrates—mainly insects but also snails, worms, crayfish, and other fauna without back bones—are considered one of the nation's top biological indicators of environmental conditions in freshwater systems. In a pristine stream, aquatic invertebrates are typically diverse and abundant, consisting of many species from a wide variety of invertebrate groups. Because most invertebrates have limited movement, they typically spend their life in a short segment of stream and thus reflect the local conditions. In addition, many species live in the stream for a year or more, long enough to experience the full range of environmental conditions at a site but short enough so that they reflect the present and recent conditions.

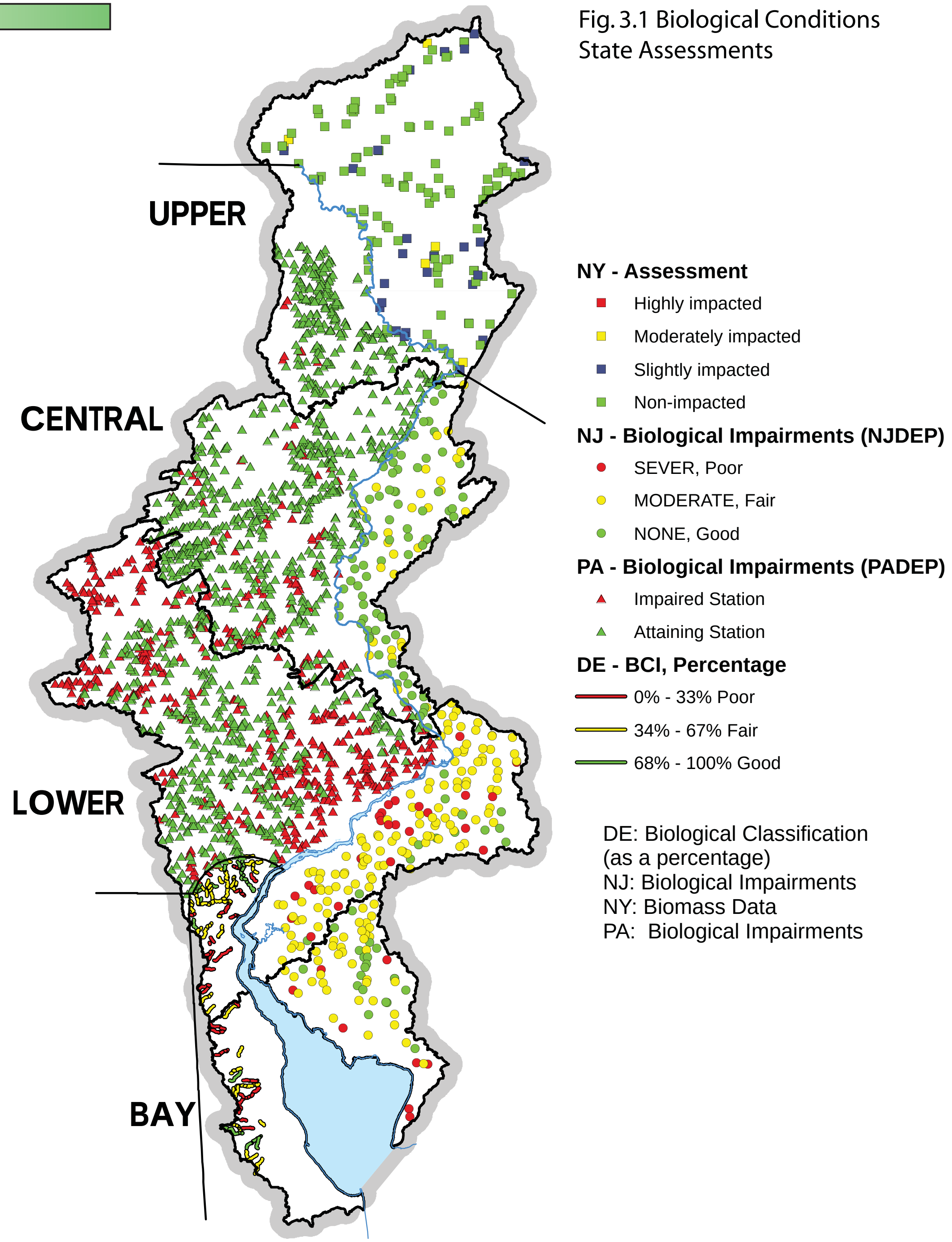
Among the invertebrates most commonly encountered in streams are species of mayflies, caddisflies, stoneflies, and true flies. Many of the midges (true fly family *Chironomidae*) can tolerate high levels of pollution and low dissolved oxygen, whereas the mayflies (e.g., *Drunella, Epeorus*), caddisflies (e.g. *Rhyacophila*) and stoneflies (e.g., *Acroneuria, Paragnetina*) typically require clean water and suitable habitats. Scientists continue to learn more about these species, and their requirements and sensitivities to environmental pollutants. Taken together with information from longer-lived invertebrates such as crayfish and freshwater mussels, the invertebrate fauna can tell us a lot about conditions at the base of the food chain.

Many government agencies center their stream assessment programs around collections of aquatic invertebrates. It is relatively easy and inexpensive to collect these aquatic invertebrates, and many statistical tools exist for converting data from an aquatic invertebrate sample into recognizable elements of ecological health.

Desired Condition

Diverse and abundant species of aquatic invertebrates indicative of high water quality (BP 1.2, 2.3; CCMP Action H5).

Fig. 3.1 Biological Conditions State Assessments



Status

Fair: Ranges from poor to very good; all regions show impacts.

Based on macroinvertebrate diversity, water quality and environmental conditions vary widely across the watershed. The most broadly impaired waters are in the urbanized area of the Lower Region, and in watersheds with a legacy of mining activity. Some level of impairment is found in almost all watershed regions. The best condition is represented in the uppermost portion of the basin where population density is low and a greater proportion of land remains in natural landscapes.

Trends

Trend data are not uniformly available. The frequency of macroinvertebrate sampling in the basin ranges from one to 5 years and may or may not include recurrent sampling. Differences among streams (temperature, flow regimes, chemistry and physical attributes) make application of a single index inappropriate. For example, a species index for the low-gradient and low-pH waters of the New Jersey Pinelands is very different from that of the coldwater streams of northeastern PA and NY. Furthermore, the basin states have developed dissimilar scoring systems that confound the comparison of conditions.

Scientific studies suggest that macroinvertebrate condition can be expected to decline in watersheds with greater point source flows, urban development, population and greater areas of impervious cover – especially associated with roads. Watersheds with greater areas of forests and wetlands, more cobble substrate, and maintained base flows have heathier macroinvertebrate communities (Table 3.1). Thus, watersheds that are undergoing development are at risk of degraded conditions for macroinvertebrates. Riparian corridor and wetland restoration efforts should improve macroinvertebrate health.

Actions and Needs

- Macroinvertebrate studies for the entire Delaware River Basin need to be conducted on a regular basis to facilitate trend analyses.
- In addition, the four states should consider standardized methods for reporting macroinvertebrate data to enable interstate comparisons and watershed-based reporting like that attempted here.
- Integration between estuarine and freshwater biological monitoring programs would facilitate a watershed approach to ecosystem monitoring.

Rhyacophila (*Rhyacophilidae*) caddisfly. Free-living predatory caddisfly are a strong indicator of clean water and a healthy aquatic ecosystem.

Chironomidae midges. Although varying in their tolerance to pollution, midge larvae are a vital component of all aquatic ecosystems yet can become dominant as water quality and ecological condition deteriorate.

Mayfly nymph (*Attenella*). Mayflies constitute one of the most important groups of bottom-dwelling animals in streams, rivers and lakes.

Mayfly adult. Mayflies are routinely used for monitoring water quality because their presence and diversity can be valuable indicators of the health of their aquatic environment. Many mayfly species are among the most sensitive to pollution.

LIVING RESOURCES

Indicator • Freshwater Mussels

Indicator Description

Freshwater mussels are filter feeding bivalve mollusks that live in lakes, rivers, and streams. Unlike marine species, freshwater mussels grow more slowly, live longer (50 years or more), and have complicated reproduction strategies dependent on fish hosts. Because of their long and complex life-cycle, freshwater mussels provide different environmental information than benthic macroinvertebrates, which are good indicators for shorter-term changes in conditions. The health, reproductive status, population abundance, and species diversity of the mussel assemblage represents an excellent indicator of watershed conditions over long time scales. Unfortunately, they also lay claim to being the most imperiled taxonomic group in the nation.

Desired Condition

Water quality and flow conditions to support diverse aquatic communities (BP 1.2, 2.3; CCMP Action H5).

Status

Very poor: More than 75% of species have special conservation status.

North America has the world's greatest diversity of native freshwater mussels (more than 300 species); however, more than 75 percent have special conservation status. The leading causes of mussel decline are habitat and water quality degradation. For example, dams that block fish passage can affect reproduction, gene flow, and prevent re-colonization from adjacent tributaries following disturbance. Of the 12 or more native species in the Delaware basin, even the most common mussel is irregular in abundance and may not be successfully reproducing across much of its range. See Table 3.2.

Trend

The most recent comprehensive mussel survey in the region was conducted in Pennsylvania between 1909 and 1919. Even at that early date, dams and poor water quality may have diminished mussel communities. Nevertheless, the study provides a benchmark for gauging mussel status over nearly one hundred years. State surveys and recent anecdotal information suggest that all native mussel species in the region are impaired to some degree, with most being severely depressed or extirpated altogether.

Actions and Needs

- Additional monitoring is needed to assess species presence and the health of freshwater mussel populations across the Delaware River Basin.
- Improved coordination and data sharing among state and regional agencies, environmental groups and researchers would facilitate condition assessment.
- Standardized terminology would be helpful for comparing assessments.

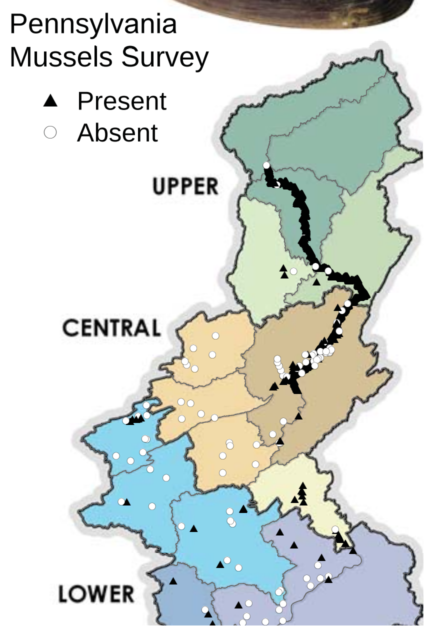


Fig. 3.2. Presence of Freshwater Mussels. From stream and snorkel surveys 1998-2004, The Nature Conservancy.

Table: 3.2 Freshwater Mussels - State Conservation Status

Common Name	Scientific Name	State Conservation Status			
		DE	NJ	PA	NY
Dwarf Wedgemussel	*Alasmidonta heterodon*	Endangered	Endangered	Critically Imperiled	Endangered
Triangle Floater	*Alasmidonta undulata*	Extirpated	Threatened	Vulnerable	Common
Brook Floater	*Alasmidonta varicose*	Endangered	Endangered	Imperiled	Endangered
Alewife Floater	*Anodonta implicata*	Extremely Rare	Not Listed*	Vulnerable	Uncommon; not protected
Eastern Elliptio	*Elliptio complanata*	Common	Common	Secure	Abundant
Yellow Lampmussel	*Lampsilis cariosa*	Endangered	Threatened	Vulnerable	Rare; not protected
Eastern Lampmussel	*Lampsilis radiata*	Endangered	Threatened	Imperiled	Common
Green Floater	*Lasmigona subviridis*	Not Listed*	Endangered	Imperiled	Threatened
Tidewater Mucket	*Leptodea ochracea*	Endangered	Threatened	Critically Imperiled	Rare; not protected
Eastern Pondmussel	*Ligumia nasuta*	Endangered	Threatened	Critically Imperiled	Uncommon; not protected
Eastern Pearlshell	*Margaritifera margaritifera*	Not Listed*	Not Listed*	Critically Imperiled	Rare; not protected
Eastern Floater	*Pyganodon cataracta*	Not Listed*	Not Listed*	Secure	Abundant
Squawfoot	*Strophitus undulatus*	Extremely Rare	Special Concern	Apparently Secure	Common to Abundant

*These mussels may never have been found in that state.

Indicator • Oysters - *Crassostrea virginica*

Indicator Description

American oysters are a nutritious food and an important fishery in the Delaware Bay. In 1887, about 1,400 sailing vessels harvested approximately 1.5 million bushels, or 22 million pounds of oysters. Today, harvests deliver about 100,000 bushels with a dockside value of $3 to $5 million, but efforts are under way to boost those numbers.

Oysters also provide important ecosystem services by creating reef habitats for fish and other organisms, filtering water, recycling nutrients, and stabilizing sediments. However, these filter-feeders can be sensitive to degraded water conditions. Like other bivalve mollusks, oysters are world-renowned as excellent "bioindicators" of environmental conditions.

Desired Condition

Water quality and habitat conditions to support oyster communities (BP 2.3, CCMP Action H5.8).

Status

Poor: Populations are low but carefully managed and stabilizing.

Although only a fraction of their historic size, today's oyster populations are carefully managed to maintain and increase abundance through the interplay of harvest, oyster disease mortality, and recruitment. Fortunately, oysters in Delaware Bay have developed some resistance to MSX disease, which devastated the population from 1957 to 1986. However, Dermo disease has been a persistent problem since 1990, especially in the lower bay's high-salinity waters. After an unprecedented seven years of low "recruitment" by juvenile oysters (a.k.a., spat), 2007 marked a return to average levels (Fig. 3.3).

Trends

Oyster abundance was not accurately assessed before the 1950s, but landings data suggest that populations are a fraction of their historic size in the 19th and early 20th centuries. Seed bed data indicate that current abundance is 39 percent of the 1953 to 2007 long-term average and 78 percent of the 1989 to 2007 (short-term) average. While recruitment in 2007 was 54 percent of the long-term average, it represents 135 percent of the short-term average. In fact, populations in Upper Delaware Bay remain relatively robust. Therefore, it is likely the oyster population will continue to support commercial harvests. Oyster population health and recruitment are presently monitored at seed beds by Delaware's Department of Natural Resources (DNREC) and Haskin Shellfish Lab of Rutgers University (Fig. 3.4).

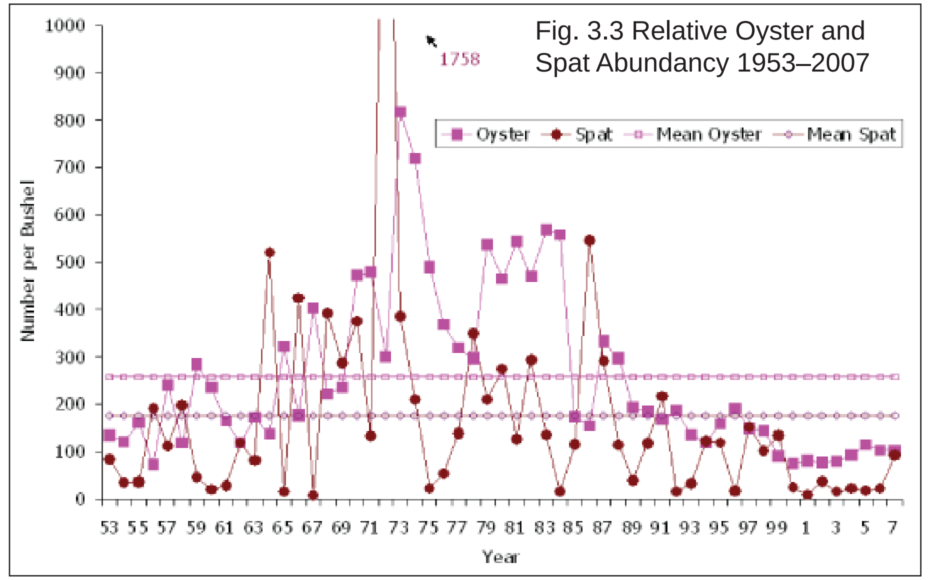
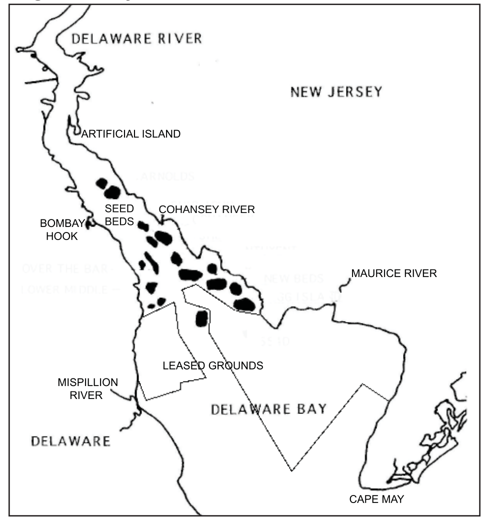


Fig. 3.3 Relative Oyster and Spat Abundancy 1953–2007

Actions and Needs

- A more comprehensive monitoring program to provide additional information about fresh water flow requirements, along with continued study of both oyster biology and food supplies.
- Attention should be paid to the effects of human activity and climate change on oyster habitat and life cycle.
- Shell-planting activities are crucial to maintaining and enhancing the oyster resource.

Fig. 3.4 Oyster Seed Bed Locations



Indicator • Horseshoe Crabs - *Limulus polyphemus*

Indicator Description

Delaware Bay is the principal breeding location for horseshoe crabs on the east coast. More closely related to spiders than crabs, they have seen few physical changes in the past 350 million years. The arthropod's hard, curved shell defends a soft underbelly and protects a body able to survive for up to a year without eating. Economically viable, they are used as bait by watermen and their blue blood has important pharmaceutical uses for testing medications and biomedical devices. Horseshoe crabs are also the State of Delaware's official marine animal.

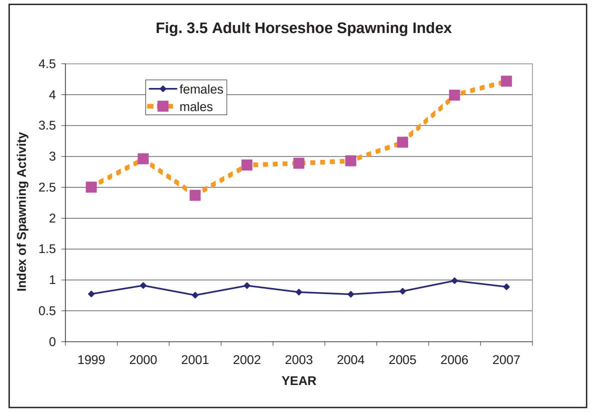
The horseshoe crab's greatest importance, however, is ecological. Their sheer abundance makes them an important consumer along the bottom where they prey on marine worms, bivalves and other fauna. Their eggs, deposited on beaches, are a critical food source for migrating shorebirds, including the red knot, listed as a *threatened* species by NJ (see facing page). Horseshoe crabs also appear to be an important part of the diet of sea turtles and many other animals. The Delaware estuary's signature commercial and ecological resource is the horseshoe crab, and the health of this population is one of our region's most important environmental indicators.

Desired Condition

Water quality and habitat conditions to support horseshoe crab populations (BP 1.2, 2.3; CCMP Action H5)

Status

Fair: Breeding populations are reduced but show improvement.



Source: *State of the Delaware Estuary 2008*, PDE.

The horseshoe crab population appears to be stable, but greatly reduced in number from historic levels. However, current population levels are not high enough to support historic levels of shorebirds during the spring stopover. There are indications that management actions to limit harvests combined with voluntary reductions in bait use by watermen are allowing the population to increase. Because horseshoe crabs are long-lived and do not reproduce until at least 8-to-12 years old, it can take a decade or more for management actions to result in a measurable increase in the spawning population.

Trends

Little data are available for measuring trends prior to 1990, but the population probably declined in the early 1900s due to overharvest and then increased through the 1970s. Bait overharvest led to another decline in the 1990s, followed by stability and recovery in the late 1990s and early 2000s. Baywide female spawning activity has remained stable since 1999, whereas male spawning activity has significantly increased for the same period (Fig. 3.5). Since males mature earlier, this increase in males may signal an increase in females to come. New Jersey currently has a harvest moratorium; Delaware allows only limited harvests of males.

Actions and Needs

- Continued monitoring and management are needed to benefit horseshoe crab populations.
- Habitat restoration projects would also benefit horseshoe crab spawning and could potentially increase the number of eggs available for shorebirds.

Fig. 3.6. Almost 30 beaches are included in the Delaware Bay Horseshoe Crab Spawning Survey, which is undertaken annually. Radio transmitters aid in this research by monitoring beaches throughout the Delaware Bay and signals often overlap. Source: *State of the Delaware Estuary 2008*, PDE.

Indicator • Red Knot (*Calidris canutus rufa*)

Indicator description

The red knot (*Calidris canutus rufa*) is one of many species of migratory shorebird that relies on the resources of the Delaware estuary for rest and nutrition to complete its spring flight. Listed as a "Species of High Concern" in the *US Shorebird Conservation Plan*, the red knot is of special interest because its survival is linked to the health of the horseshoe crabs populations of Delaware Bay. In 1999, NJ listed the red knot as a "threatened" species.

Desired Condition

Sufficient habitat and forage for migrating shorebirds along the Atlantic flyway to support robust and diverse populations, (BP 1.2, 2.3; CCMP Action H5).

Status and Trend

Very poor: Populations may be crashing.

The Delaware Estuary is the largest stop-over for shorebirds in the Atlantic flyway and is the second largest staging site in North America. Close to a million migratory shorebirds converge on the Delaware Bay to feed and build energy reserves prior to completing their migrations. The red knots are perhaps the best know migratory shorebirds, described by the National Audubon Society as champion, long-distance migrants.

Aerial surveys conducted in Delaware Bay and South America, along with counts in Canada, show that shorebird populations, particularly the red knot, have declined over the past 30 years (Fig. 3.7). In the 1980s for example, up to 100,000 red knots descended on Delaware Bay, but in 2006 they numbered less than 13,500. At the current rate of decline, biologists fear that the red knot could become extinct by the end of this decade.

Factors affecting shore bird survival include delayed migration, die-offs in other parts of their ranges, habitat suitability, and abundance of food at critical stopover points. While there is uncertainty concerning the risk each factor is contributing, the most important factor related to Delaware Bay is food supply, since weight gain at stopover points affects breeding success and survival. In the 1990s the horseshoe crab spawning population declined due to over-harvesting, which in turn reduced the Bay's available egg supply for migrating shorebirds. Current surface densities of horseshoe crab eggs may be insufficient to support the recovery of migrant shorebirds.

In addition to harvesting, horseshoe crab populations are adversely affected by sea level rise and coastal development, both of which infringe on the sandy shore environments essential for egg laying. See the *Horseshoe Crab* and *Coastal Wetland Buffer* indicators for more information.

Since 2000, horseshoe crab harvest restrictions have been imposed, a sanctuary has been established, and watermen have reduced their use of horseshoe crabs as bait. The success of these measures may take years to measure. It takes 9 to 12 years for horseshoe crabs to reach spawning age and for measurable changes to be seen in the abundance of eggs for the red knots in the spring.

Actions and Needs

- Continued vigilance in monitoring red knot populations and efforts to increase the abundance of horseshoe crab breeding populations and egg densities.

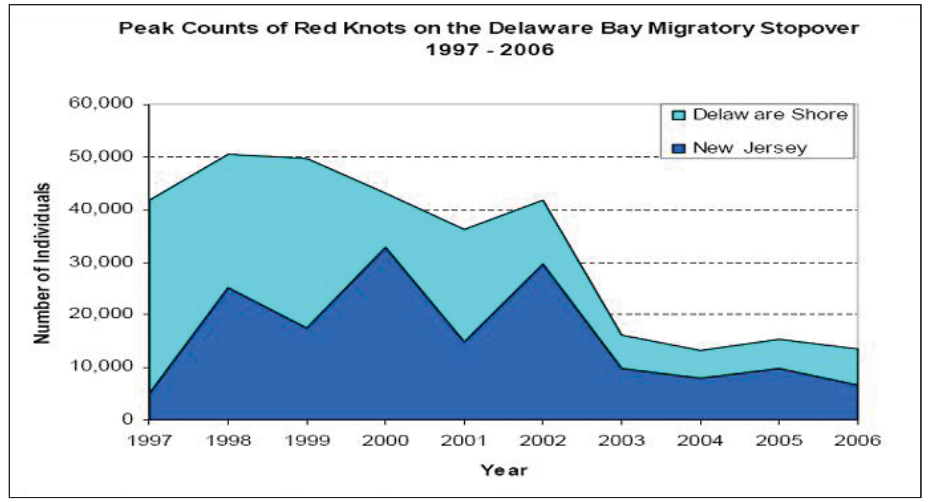


Fig. 3.7. The number of red knots (Calidris canutus rufa) migrating to the Delaware Bay declined during the period 1997 to 2006. Source: *State of the Delaware Estuary 2008*, PDE.

Indicator • Louisiana Waterthrush - *Seiurus motacilla*

Indicator description
The Louisiana waterthrush, *Seiurus motacilla*, is the only obligate headwater riparian songbird in the Delaware River Basin and the eastern United States. It is a biological indicator both of riparian songbird population and fresh water wetland habitat condition, correlating to healthy land and water environments throughout the Basin. It is a widespread species with breeding populations recorded in nearly all of the hydrologic regions in the basin Data are compiled semi-annually as part of a national Breeding Bird Survey (BBS).

Desired Condition
Robust breeding communities of songbirds indicating adequate habitat of suitable quality for forage and propagation (BP 1.2, 2.3, CCMP Action H5).

Status
Fair: Very sensitive to polluted waters and loss of forested riparian habitat.

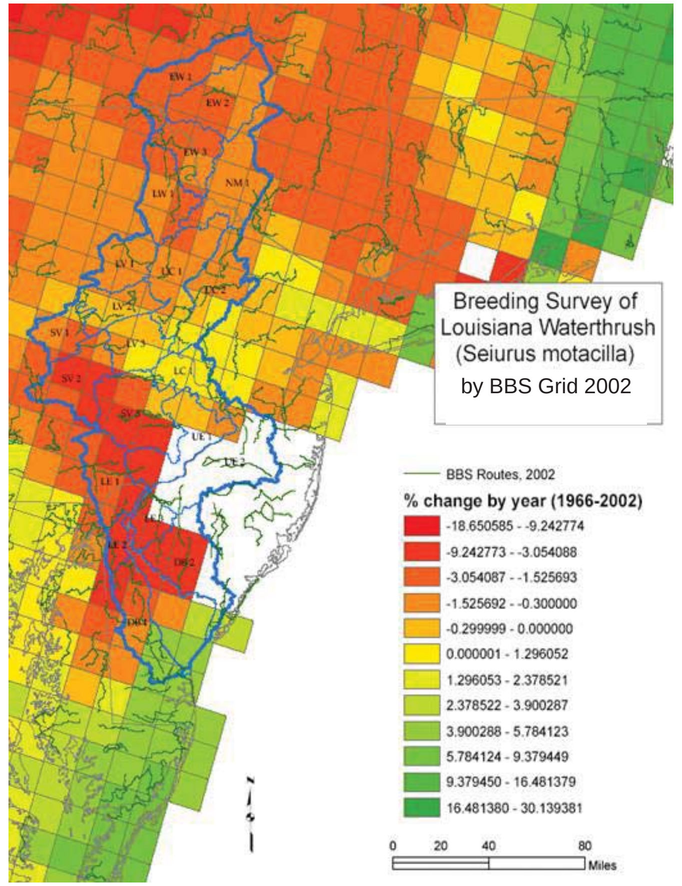
The status of songbirds generally can be examined by assessing the breeding abundance of the Louisiana waterthrush, which correlates positively with riparian tree density and continuity. However, breeding success, in terms of nest density, is very closely tied to the bird's reliance on aquatic macroinvertebrates. A paired watershed study of pristine watersheds and polluted watersheds impacted by acid atmospheric deposition and abandoned mine drainage in Pennsylvania, more than double the number of nests per kilometer of streams were found in unpolluted streams versus acidified streams with much lower abundance and diversity of macroinvertebrates.

Trend
As of 2002, the abundance of Louisiana water thrush appears to be decreasing in much of the Basin (Fig. 3.8). Changes seem to coincide with development patterns and change. Decreases are greatest in the more heavily developed bayshore, estuary and Schuylkill valley watersheds, while the less developed reaches of the southern bayshore and lower central basin show modest increases.

Actions and Needs
- Maintaining natural vegetative cover and tree canopy on riparian headwaters is critical for the Louisiana waterthrush and many other riparian species, including amphibians and reptiles.
- Measurements of riparian and wetland habitat integrity would enhance assessment and reporting.
- Identification, tracking and assessment of additional species related to the water-related habitats of the basin, especially amphibians, is recommended.

SOURCE: C. CONRAD, FLICKER 2007

Fig. 3.8 Louisiana Waterthrush Breeding Survey



Indicator • Bald Eagle - *Haliaeetus leucocephalus*

Indicator description
The bald eagle (*Haliaeetus leucocephalus*) is the only eagle unique to North America. Fish are an important food source for all bald eagles.

Desired Condition
Continued protection and expansion of bald eagle nesting and foraging habitat, and continued monitoring programs.

Status
Good and generally improving.

Bald eagle populations are currently in good condition in the Delaware Basin watersheds. Sightings along the non-tidal Delaware River have generally increased annually since 1998. In 2007, a pair of bald eagles established a nest near the confluence of the Schuylkill and Delaware Rivers at the Navy Yard in south Philadelphia, which may be the first nesting pair within the city limits since Colonial times. Since the main diet of the eagles are fish, it is thought that the birds are returning in nests near the Delaware River in greater numbers due to a greater abundance of fish and cleaner water.

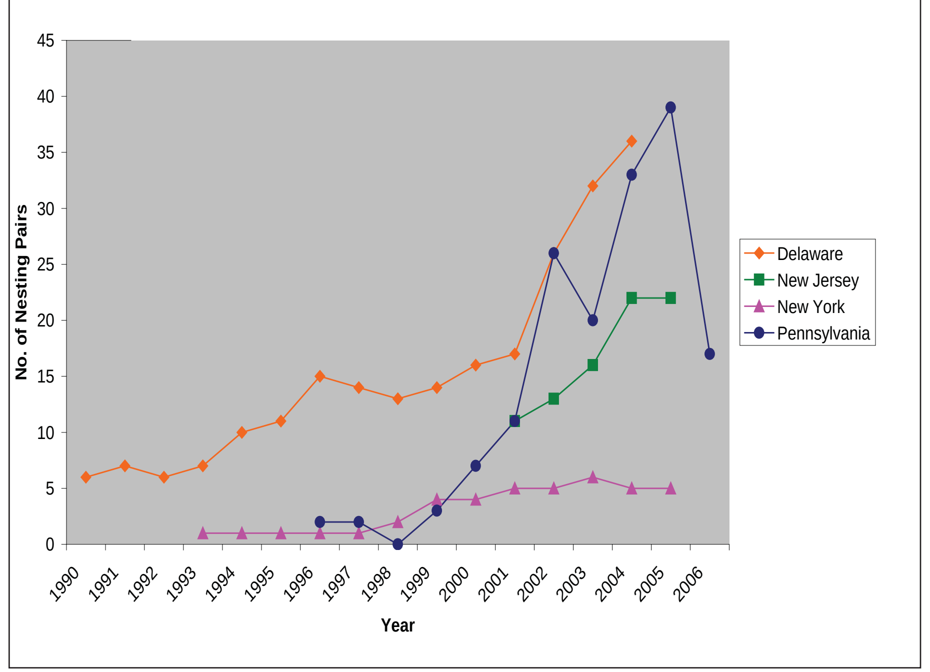
The return of the bald eagle to Delaware basin watersheds is an astonishing success story. Bald eagle nests have increased significantly. In 2004 for example, 96 nests were spotted in the basin, up from 44 in 2001.

Trend
The Bald Eagle Protection Act of 1940 prohibited shooting or otherwise harming the birds in the US, but this protection did not prevent damage from pesticides that harm their eggs. By the 1960s only about 400 breeding pairs of bald eagles remained in the lower 48 states and they were declared an endangered species in 1967. The banning of DDT in 1972 and other measures launched an amazing comeback for eagles, and by 1995 their status was upgraded from endangered to threatened. Today, with more than 6,000 breeding pairs, the US Fish and Wildlife Service proposes to remove eagles from the nation's Endangered Species list later in 2007.

Actions and Needs
- Continued vigilance to monitor water quality, especially emerging contaminants with the capacity to disrupt reproduction cycles in living resources.
- Continued monitoring of eagles and other mammals dependent on aquatic resources and associated habitat in order to determine population health and protect it from reversals.

SOURCE: PENNSYLVANIA GAME COMMISSION

Fig. 3.9 Population of Bald Eagle Nesting Pairs in Delaware River Basin



Source: Technical Summary of the State of the Delaware River Basin, Water Resources Agency, University of Delaware 2008.

Indicator • Striped bass and Weakfish - *Morone saxatilis* and *Cynoscion regalis*

Weakfish | Striped bass

Indicator Description

As a premiere sport fish and a top predator in the aquatic food web, striped bass is economically and ecologically important in the Delaware basin. Striped bass is a large anadromous species of finfish that live mostly in the ocean and bay but spawn in freshwater. Found throughout the tidal ecosystem from spring to fall, striped bass are much sought after as game fish. Weakfish, a smaller finfish and the state fish of Delaware, show a more compressed range, spawning in the lower reaches of the Bay and migrating nearer offshore. Both species are important economic and recreational species.

Desired Condition

Water quality and habitat conditions to support healthy and diverse finfish populations (BP 1.2, 2.3; CCMP Action H5).

Status

Good: Striped bass restored.
Fair: Weakfish declining.

Substantial populations of striped bass indicate a true success story in fishery restoration credited to water quality improvements and constraints on striped bass harvests until 1998. Water quality improvements also benefited weakfish, whose numbers increased and peaked in 1996. A decline in abundance of both species in the last decade requires additional investigation.

Trends

Striped bass were nearly eliminated from the Delaware estuary by the 1960s. Low dissolved oxygen levels in the River created a barrier that prevented fish from migrating to their spawning grounds. Weakfish which generally stay further south in the river were not as affected by this, although their population numbers were also depressed. A further dramatic decline in stripers in the late 1970s led to harvest moratoria in 1985–89 followed by harvest restrictions until 1995.

Survival of weakfish and striped bass increased with improved water quality, and reduced harvesting of stripers meant that more adults were present to spawn. In 1998 the Atlantic States Marine Fisheries Commission officially declared the striped bass fishery “restored.”


SOURCE: PHILADELPHIA WATER DEPARTMENT

In contrast, weakfish populations have declined in recent years following improved abundance between 1994 and 2002. The decrease may be related to the increase in striped bass and perhaps predation of weakfish by stripers.

The age structure of populations as well as physical variations in temperature and salinity affect spawning stock. Entrainment and impingement in large water intake structures affect larval and juvenile populations and also is a factor in population survival.

Actions and Needs

- A more detailed investigation of the dynamic interactions among finfish population would help in the prediction of future status and trends, and may suggest management options.
- The emergence of an apparent bottleneck to yearling survival for striped bass is worthy of investigation, as is the cumulative impact of entrainment and impingement on fish populations.

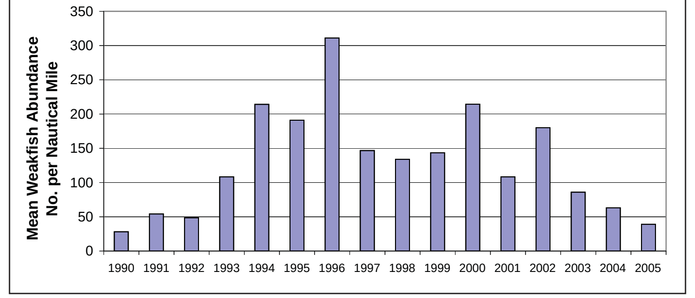


Fig. 3.10 Mean Weakfish Abundance 1990-2005 Delaware Estuary

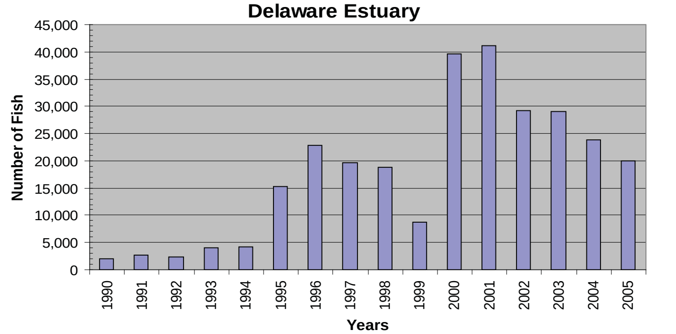


Fig. 3.11 Delaware Recreational Striped Bass Harvest Delaware Estuary

Indicator • Atlantic Sturgeon - *Acipenser oxyrhynus*

Indicator Description

The shortnose and Atlantic sturgeon are long-lived species that spend at least part of their life cycle in the Delaware Estuary. The shortnose is currently a federal endangered species, but the Atlantic sturgeon may be even more imperiled. The Atlantic sturgeon is an ancient fish that, when abundant, can represent an important bottom consumer in large eastern rivers.

Desired Condition

Water quality and habitat conditions to support diverse fish populations (BP 1.2, 2.3; CCMP Action H5).

Status

Poor and getting worse.

The population of shortnose sturgeon in the Delaware Estuary currently appears stable at about 13,000 fish, despite being listed as an endangered species. Today’s numbers of Atlantic sturgeon, on the other hand, are estimated to be less than 1,000 and probably less than 100 across the Estuary. The Atlantic sturgeon is on the endangered species list in Delaware and it may be a good candidate for federal listing.

Trends

The Delaware estuary was once the hub of American sturgeon fishery, having the largest population of Atlantic sturgeon in the world. Record harvests and virtual elimination of spawning and nursery habitat, combined with poor water quality and low reproduction, likely caused the population collapse during the late 1800s.

Nearly fished to extinction over a century ago, they have not yet rebounded despite increasing management attention and harvest restrictions. In 1991, a seven-foot size minimum was adopted, and by 1998 a complete harvest moratorium was imposed. As recently as 1986 an adult female sturgeon was valued at $3,000 per fish for its caviar.

Scientists have stepped up studies of sturgeon population dynamics and ecology. Telemetry indicates that sturgeon use main channel habitats; large alterations such as dredging may have changed salinity and bottom habitats causing sturgeon to now spawn further upstream from their historic reaches. This, coupled with boat strikes and by-catch by large mesh gill nets are thought to be impeding their recovery.

Actions and Needs

- A better understanding of sturgeon habitat requirements and improvements in reporting.
- A better understanding of the impacts of human actions on sturgeon populations and habitat to inform management strategies.

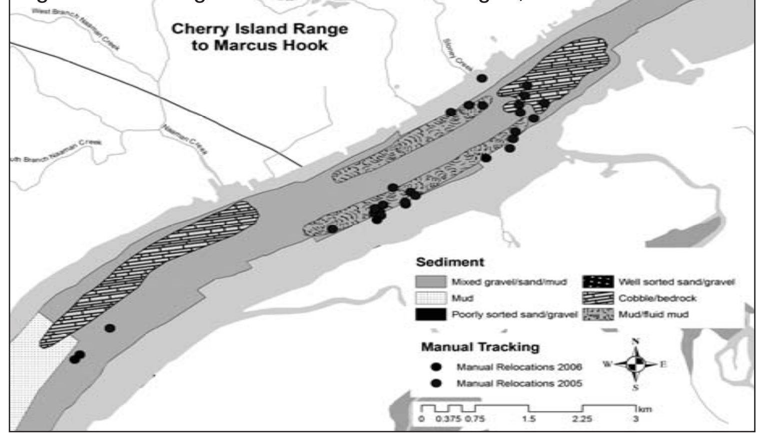
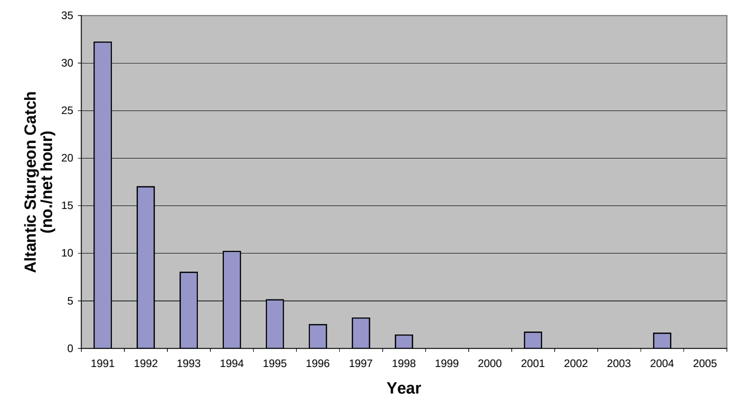
Fig. 3.12 Tracking Locations of Atlantic Sturgen, 2006


Fig. 3.13 Annual Catch Rates of Atlantic Sturgeon Collected in the Delaware River


Indicator • Shad - *Alosa sapidissima*

Indicator Description

The American shad is the largest North American member of the herring family. The shad is an anadromous fish that migrates each spring to the Delaware Estuary watershed to spawn. Between 1880 and 1890 fishermen in the Delaware River caught 10 to 20 million pounds of shad annually. Around 1910, shad numbers began to decline rapidly, and populations were so low by 1920 that shad fisheries were no long a viable industry. Overfishing, dammed spawning tributaries, and degraded water quality, such as low dissolved oxygen levels, were the principal factors in the shad's decline. As a once abundant fish that travels between tidal and non-tidal areas of the watershed (Fig. 3.15), shad represent a valuable indicator of environmental conditions in the Delaware Estuary and Basin.

Desired Condition

Water quality and habitat conditions to support healthy and diverse finfish populations (BP 1.2, 2.3; CCMP Action H5).

Status

Fair: Stable since improvements in dissolved oxygen and tributary fish passage, but recent reductions evident.

Today, the Delaware River supports a viable commercial and shad sport fishery, but harvests are small compared to historic benchmarks. In 1896 over 14 million pounds of shad were caught, having a value of $10 million in 2006. Although current populations cannot sustain that level of harvest, the economic value of today's recreational fishery is nearing levels reported more than 100 years ago. In 1996, for example, the economic value of the shad sport fishery in the Delaware was estimated at $3.2 million.

Trends

Once blocked by a lack of oxygen, shad now move more freely through the tidal freshwater zone during spawning runs. Sewage facility upgrades improved water quality and increased dissolved oxygen, which helped shad return to the Delaware. Still, shad abundance is low, even compared with numbers from the 1990s. Pennsylvania leads the nation in removing obsolete dams, and fish ladders are being installed in many areas of the basin. These efforts have reopened approximately 165 stream miles for shad migration.

Actions and Needs

Increases in the shad population in the Delaware Basin should continue if water quality and fish passage are continually maintained or improved (e.g., by removing dams and installing fish ladders). Habitat conditions in spawning reaches of tributaries must also be maintained and monitored.

Fig. 3.14. Shad Migration Routes

S. OWENS, DRBC; BASE MAPS: NATIONAL ATLAS OF THE US HTTP://NATIONALATLAS.GOV

Fig. 3.15 Number of Juvenile Shad Collected along the Delaware River 1979-2005

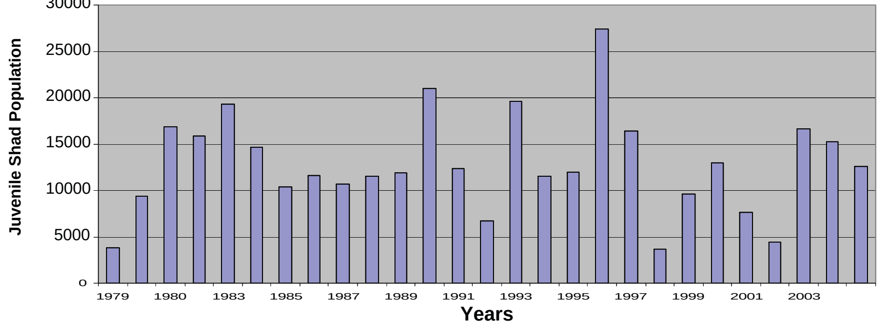
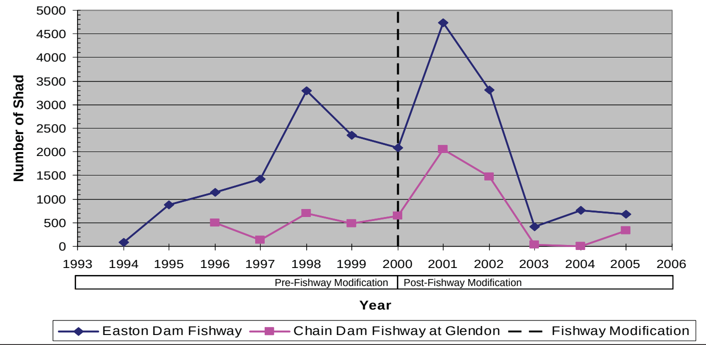


Fig. 3.16 Shad Monitoring along the Lehigh River



Indicator • Brook Trout - *Salvelinus fontinalis*

Indicator Description

Brook trout (*Salvelinus fontinalis*) are the only trout species native to streams in the Delaware River Basin. The brook trout thrives in cold water streams with heavily forested watersheds and low densities of human population; trout are extremely sensitive to temperature increases. As a once-abundant, native species that is relatively intolerant of degraded conditions, brook trout represent ideal biological indicators in the cold water streams of the Basin, particularly in headwater areas. It is also a fishery of significant economic importance for ecotourism. States often designate streams in part by their support of trout propagation or maintenance of adult populations.

Desired Condition

Sustained populations of native fish species (BP 1.2, 2.3, CCMP Action H5).

Status

Poor: Native trout populations have been extirpated or severely reduced in most of the basin's watersheds.

Former brook trout habitat has been virtually eliminated in urban corridors and greatly reduced in most of the rest of the basin. Temperature fluctuations from poor stormwater management practices, inadequacy of food sources, and changes in flow regimes may all have a role in reducing the extent and quality of trout habitat. Few areas remain that can support native brook trout, except those cold water streams that remain unaffected by development.

Trends

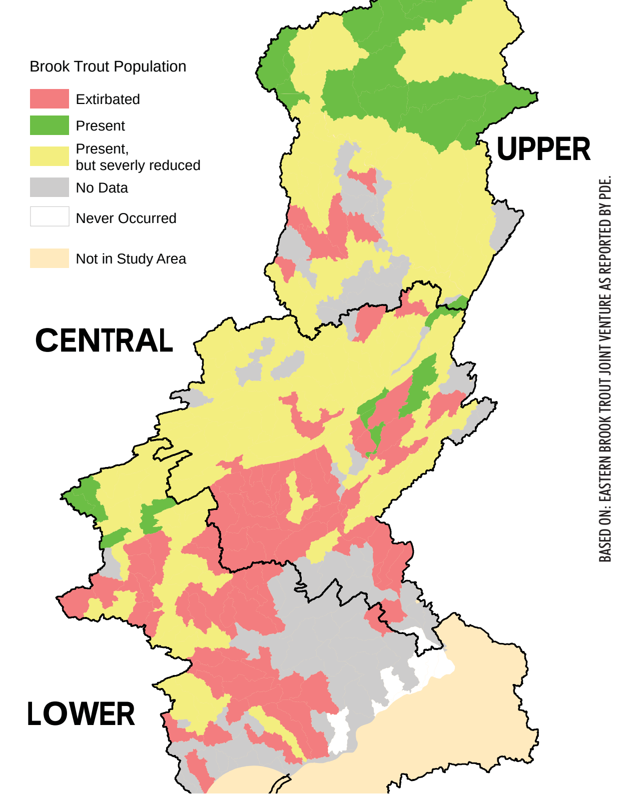
While actual brook trout population data and trends were not available for this report, a habitat-based analysis of their former and present range suggests that this native species has been either extirpated or severely reduced across most of its former range across the basin. Brook trout populations are in decline because of changes to water quality and temperature caused by acid deposition, deforestation, and other watershed changes caused by human development that increase sediment loads in spawning areas or otherwise impair water quality and trout habitat. Increasing temperatures and reduction in the timing and amount of snowmelt related to climate change may also be a factor.

The effects of continued land use change in the basin is likely to spur further declines, although restoration projects may help brook trout survive and perhaps even increase in suitable areas, such as spring-fed creeks in headwaters.

Actions and Needs

- Conservation, restoration and management attention is needed, particularly in headwater areas, to safeguard and possibly reclaim the habitat and water quality necessary to sustain naturally-reproducing populations of brook trout.
- Efforts should be made to improve the monitoring and reporting of brook trout populations as harbingers of human-induced environmental degradation and climate change impacts.

Fig. 3.17 Brook Trout Conditions in Watersheds



BASED ON: EASTERN BROOK TROUT JOINT VENTURE AS REPORTED BY PDE

Feature • Living Resources

Invasive Species

Description

Invasive species are those introduced from outside of an ecosystem with characteristics that allow them to dominate and limit the diversity of species within an invaded area. Invasive species can be plants or animals, terrestrial or aquatic. They gain advantage over native species by their capacity to reproduce, grow or expand their range faster than their native counterparts. A lack of natural predators or diseases often gives invasive species an advantage over local native species. Similarly, changes in temperature, precipitation, flow and chemistry can also exacerbate the establishment and success of invasives. While usually non-native, some native species can become invasive, especially in disturbed areas; an example is poison ivy (*Toxicodendron radicans*) that appears to be spreading and becoming more virulent in response to increased atmospheric carbon dioxide and global warming.

Invasive species causing the greatest impacts on water resources are directly associated with waterways and their adjacent riparian landscapes. In terms of potential loss of native biodiversity and ecological function, riparian zones are probably the landscape most vulnerable to severe impact by invasive species. As the margin or overlap between aquatic and terrestrial ecosystems, riparian zones have evolved a natural balance of richness, resilience and complexity that keeps any single species from becoming overly dominant. Invasive species can dangerously affect this balance. Furthermore, a watercourse provides the ideal conduit for the spread of invasive species by water, wind, and animals.

Desired Condition

The maintenance of healthy and biologically diverse riparian and aquatic ecosystems, and the implementation of invasive species detection and management plans (BP 2.3.E, CCMP Action H6).

Status

There are very few locations remaining in the Delaware River Basin that are undisturbed or sufficiently resilient to resist the establishment of invasive species. The Mid-Atlantic Exotic Pest Plant Council currently identifies 275 species of invasive plants in this region. The scale of economic and ecological damage is already significant; estimates of ecological damage and control costs top $137 billion/year nationwide. Table 3.3 shows a few of the many non-native invasive species that are established in or threatening forests, waterways, and riparian areas of the Delaware River Basin.

Trends

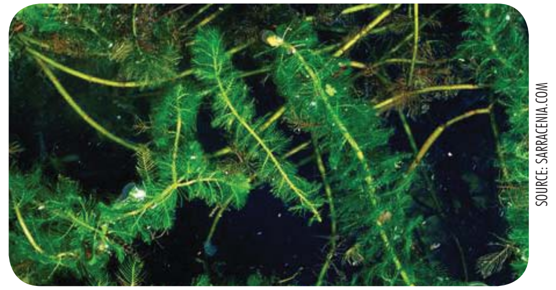
With increased global trade, the rate of species introductions in the US is high (Figure 3.19). The news is not all bad, however, as government agencies and other organizations have poured resources into planning and action. All Delaware Basin states have invasive species councils, rapid response teams are in action, and volunteers are very active in monitoring and control.

Actions and Needs

Where waterways and riparian lands are undisturbed, prevention of invasive species establishment is critical. Where invasive species have become established, the greatest practical effort should be made to eradicate those that pose the greatest risk to aquatic and riparian communities. Establishing appropriate metrics to track progress would be advantageous.

General actions for agencies and Institutions include:

- Prevention of additional introductions
- Early detection and eradication of new pests
- Control and management of established problem species
- Protection and recovery of native species and ecosystems
- Improved education of the general public regarding their role in invasive species introduction and control.



Eurasian water-milfoil, *Myriophyllum spicatum*, infests the Lehigh and Lower Delaware Rivers.

Table 3.3 Invasive Species of Concern

Common Name	Scientific Name
FOREST	
Hemlock Woolly Adelgid	*Adelges tsugae*
Gypsy Moth	*Lymantria dispar*
Chestnut Blight	*Cryphonectria parasitica*
Dutch Elm Disease	*Ophiostoma ulmi*
AQUATIC	
Northern Snakehead	*Channa argus*
Flathead Catfish	*Pylodictus olivarus*
Common Carp	*Cyprinus carpio*
Chinese Mitten Crab	*Eriocheir sinensis*
Zebra Mussel	*Dreissena polymorpha*
Rusty Crayfish	*Orconectes rusticus*
Asiatic Clam	*Corbicula fluminea*
Rock Snot	*Didymosphenia geminata*
Eurasian Water-Milfoil	*Myriophyllum spicatum*
Curly Pondweed	*Potamogeton crispus*
Water Chestnut	*Trapa natans*
Hydrilla	*Hydrilla verticillata*
Yellow Floating Heart	*Nymphoides peltata*
RIPARIAN PLANTS	
Japanese Knotweed	*Fallopia japonica*
Purple Loosestrife	*Lythrum salicarium*
Poison Hemlock	*Conium maculatum*
Lesser Celandine	*Ranunculus ficaria*
Dames Rocket	*Hesperis matronalis*
Mile-a-Minute Weed	*Persicaria perfoliata*
Porcelainberry	*Ampelopsis brevipedunculata*
Japanese Hops	*Humulus japonicus*
Multiflora Rose	*Rosa multiflora*
Oriental Bittersweet	*Celastrus orbiculatus*
Burning Bush	*Euonymus alatus*
Amur Honeysuckle	*Lonicera maackii*
Reed Canary Grass	*Phalaris arundinacea*
Common Reed	*Phragmites australis*
Japanese Stiltgrass	*Microstegium vimineum*
Princess Tree	*Paulownia fomentosa*
Tree-of-Heaven	*Ailanthus altissima*

To learn more about invasive species:

Pennsylvania Field Guide: Common Invasive Plants in Riparian Areas. Alliance for Chesapeake Bay, Harrisburg PA 2004.

Economic and Ecological Costs Associated with Aquatic Invasive Species by D. Pimentel in Symposium Proceedings: Aquatic Invaders of the Delaware Estuary, May 20, 2003. Edited by L H Ziska, R C Sicher, K George & J E Mohan. Penn State University 2007.

America's Least Wanted: Alien Species Invasions of U.S. Ecosystems edited by B A Stein and S R Flack. The Nature Conservancy, Arlington VA 1996.

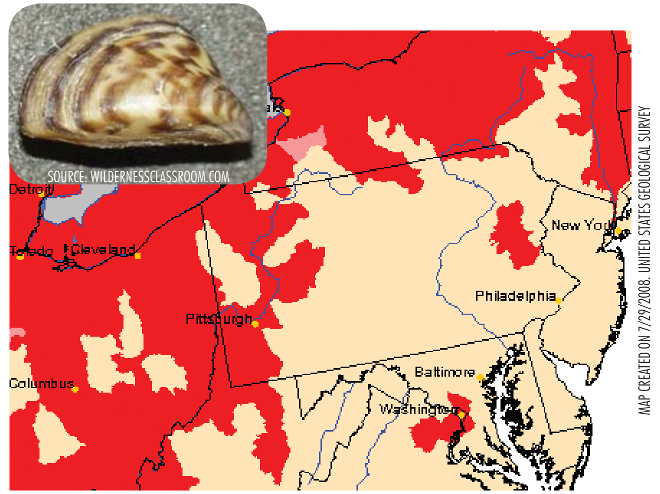


Fig. 3.18. Zebra Mussel Locations. The USGS reports that zebra mussels have been found in many areas surrounding the Basin. The areas in red on the map are hydrologic units (HUC 8s) where zebra mussels have established populations, competing with native mussel species. At this time, the only reported occurrence of zebra mussels in the Delaware River Basin is in Dutch Springs Reservoir, just north of Bethlehem, PA in Northampton County. The Lehigh River Watershed is of greatest risk of zebra mussels, where the reservoir is located, but precautions must be taken to ensure the invasive species is not introduced to any part of the basin.

Purple loosestrife, *Lythrum salicarium*, might be pretty but it competes with native plants for habitat all along the Delaware River.

Japanese knotweed (*Fallopia japonica*) is a large, herbaceous perennial plant, native to eastern Asia. In the US the species is very successful and has been classified as invasive. Tolerant of a wide range of temperature, soil types, pH and salinity, it readily colonizes riparian zones and sensitive wetlands, driving out native species. Its root system (rhizomes) can extend nearly 10 feet deep and 23 feet horizontally, making it difficult to eradicate and possibly exacerbating erosion along stream banks. Its flowers are valued as a nectar source by some beekeepers, and its young stems are edible.

STATE OF THE DELAWARE RIVER BASIN REPORT 2008

Category IV
Landscape

THEN – The Delaware River Basin drainage area encompasses 12,765 square miles, draining 1% of the land area of the United States. These lands are varied in both terrain and use, from rolling farmland and forest, to marshes and fishing villages along the Bay . . . at the time of discovery by Europeans [it] comprised an ever evolving system, accepting and discharging into the Atlantic Ocean the fresh water and silts from mountains and plains . . .[and] aquifers were fully and generally discharged to surface streams. In this dynamic system, the activities of man were nearly inconsequential . . . Today, the activities of man vastly affect the behavior of water and the ecology of the Basin.

Level B Study, May 1981, p 8
Delaware River Basin Commission

USGS reports that the total area of forests and wetlands has a positive effect on aquatic invertebrates, while urban area growth, impervious cover, population density and total point source flow (discharges to waterways) often has a negative effect.

Today

The activities of man continue to affect the behavior of water and the basin ecology, but a desire to minimize those effects has been embedded in environmental management programs for several decades. Water quality success stories based on regulating discharges are by now legendary, illustrated by the return of shad populations to the Delaware River. Other successes are included in the timeline in the Water Quality section of this report. Today, the landscape is the next frontier in water resource management.

Landscapes and Water Resources

Natural landscapes and human alteration of that landscape – measured as land cover and land use – play a crucial role in water resource condition. Human use of land and changes to its physical state can be major factors in the alteration of ecological processes at both local and global scales. Many if not most physical and chemical changes in waterway systems are linked to land use, although some of the linkages are complex and difficult to quantify. USGS has found significant relationships between landscape condition and the health of aquatic communities (Table 3.1.). The 2003 Final Report of the New Jersey Comparative Risk Project identified landscape change as "lying at the heart of many environmental problems," and when compared to an array of known or perceived threats, land use change, in the view of the experts, "produced by a wide margin the largest negative ecological and socio-economic impacts" including: habitat loss and fragmentation; permanent ecosystem destruction; increases in stormwater flows and flooding; skewed employment patterns and property values detrimental to older communities; traffic congestion; and public health impacts. (Final Report of the NJ Comparative Risk Project, March 2003, pp 17–18).

Historic Land Use

The pre-industrial basin landscape was predominantly woods and wetlands, with expanses of farmland and nodes of human settlement. Decades of development and harvesting resulted in filled wetlands and a decrease of forests, so that by 1930, forests and wetlands had been reduced to 32% and 3% of the landscape, respectively.

Conservation efforts, shift in raw material needs for production and better understanding of the services that wetlands and forests provide have to some extent reversed the old trends. By the mid-1990s forested land had nearly doubled from its 1930 level, basin land in agricultural use had been reduced by more than half, and wetlands had slightly increased. The National Wetland Inventory Status and Trends report attributes recent increases to the creation of ponds which do not provide the same function as vegetated wetlands.

Between 1930 and 1996, urbanized land nearly quintupled from 3% of the basin to 14%.

Landscape Change

Assessing changes to the landscape —how we use and manage it, how much remains in a "natural" state—is a requisite for setting baselines for comparison, for identifying watersheds or areas of immediate concern, and for anticipating effects on water resources. Unfortunately, while we possess the technical ability to interpret data from satellite and aerial images, the financial ability and political will to do this at geographic scales and reference periods that would be most appropriate for water resource management has been inadequate. An explanation of the issues related to compiling information for this Report accompanies an assessment of needs and recommendations at the end of this section.

Reporting

Indicators of landscape condition included in this report are:

- Population change
- Population density
- Land use 2001
- Land use change 1995–2001
- Land consumption
- Natural landscapes: forests, wetlands and wetland buffers

A feature on *Natural Capital*, the economic value of ecological goods and services, completes this section.

Land Use Category*	Examples of Uses/ Activities included in category	Potential Impacts	Land Use Trend
Developed	Low, medium and high intensity residential, commercial & industrial uses; transportation, communication & utilities; athletic fields, parks.	• Water use • Hydrology: Increased flashiness@ of stream flows • Increased pollutant loadings to streams	↑
Agriculture	Cropland, orchards, vineyards, pasture, livestock operations	• Water use (crop dependent) • Increased nutrients • Increased sediment & erosion • Increased pesticides, fungicides	↓
Forest	Deciduous, evergreen and mixed forests	• Provides carbon & nutrient uptake • Improves air quality • Provides habitat • Moderates temperature	↓
Wetlands & Water	All wetland types (not differentiated)	• Carbon and nutrient uptake • Provides habitat • Provides flood protection	↔
Other	Barren land, mining, etc	Impacts vary	↔

* Note: Land use trend derived from NOAA-CSC change analysis 1996-2001. Categories were combined into five major types to extract a coarse change analysis for the basin.

@ Flashiness means higher peak runoff and shorter periods of peak discharge.

↔ Nominal change; within range of analytical accuracy

Table 4.1: Potential Impacts of Land Use on Water Resources

1682 William Penn establishes Philadelphia.

1700 Population of Philadelphia reaches 5,000.

1790 John Fitch's 1st successful steamboat operation connects Philadelphia and Trenton.

1832 Opening of the Delaware (PA) and D&R (NJ) Canals.

1871 Philadelphia's City Hall – world's tallest masonry structure and largest municipal office building in US.

1880s Ship building is a major industry in the basin.

1908 Steel for 1st skyscraper produced at Bethlehem PA.

1909 W. Wright first to take aerial photos of landscape.

1920 Basin population 4 million

1930s D&R canal used to carry drinking water from the Delaware to meet needs of northeastern NJ

1940 Delaware Canal becomes part of the PA State Park system.

1954-55 Zero oxygen conditions from shore to shore for 20 miles of the Delaware River.

1972 US space station provides 1st land use imagery. *Landsat 1* launched to generate multispectral image of land use and land cover.

1980 Superfund (CERCLA) enacted by Congress.

1993 EPA orders US Steel to clean up contamination at Fairless Hills PA.

1995 Bethlehem Steel closes after 100 years of iron making.

2000 Basin population nears 7.8 million.

Indicator • Population Growth and Distribution

Not Rated

Indicator Description

Population growth is an indictor of potential stress on water resources and natural landscapes. People create demand for water and wastewater provision, buildings, roadways, and parking, all of which increase the potential for impairments to water quality and aquatic resources.

For this report US Census tracts were aligned with 236 watershed units for analysis, and the watersheds aggregated into the basin reporting regions. Results are also reported by political units, e.g., counties and municipalities.

Desired Condition

Accommodate growth while protecting and enhancing water resources (BP 3.4, CCMP Actions L1-18).

Status

Basin population grew 6% between 1990 and 2000.

The population of the basin was 7.76 million in 2000, an increase of 436,354 (6%) over 1990. There was greater growth in the first half of the decade than the latter half (Table 4.2). Basin population is expected to approach 9 million by 2030 (Fig. 4.1). For comparison, the 2000 populations of New York City and the State of New Jersey were 8.0 and 8.4 million, respectively.

Population is unevenly distributed across the basin (Fig. 4.2). The vast majority (78%) of residents live in the Lower Region and nearly half (3.7

Table 4.2 Population Change

	Population	Change
1990	7,322,320	
1995	7,591,690	269,370
2000	7,758,675	166,984
Total Increase		436,354

Fig. 4.1 Delaware River Basin Population

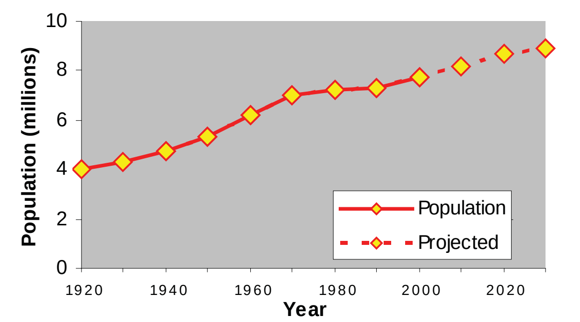


Fig. 4.1. By 2030 the Basin population is expected to approach 9 million.

Fig. 4.2 Percent Change in Total Population 1990–2000

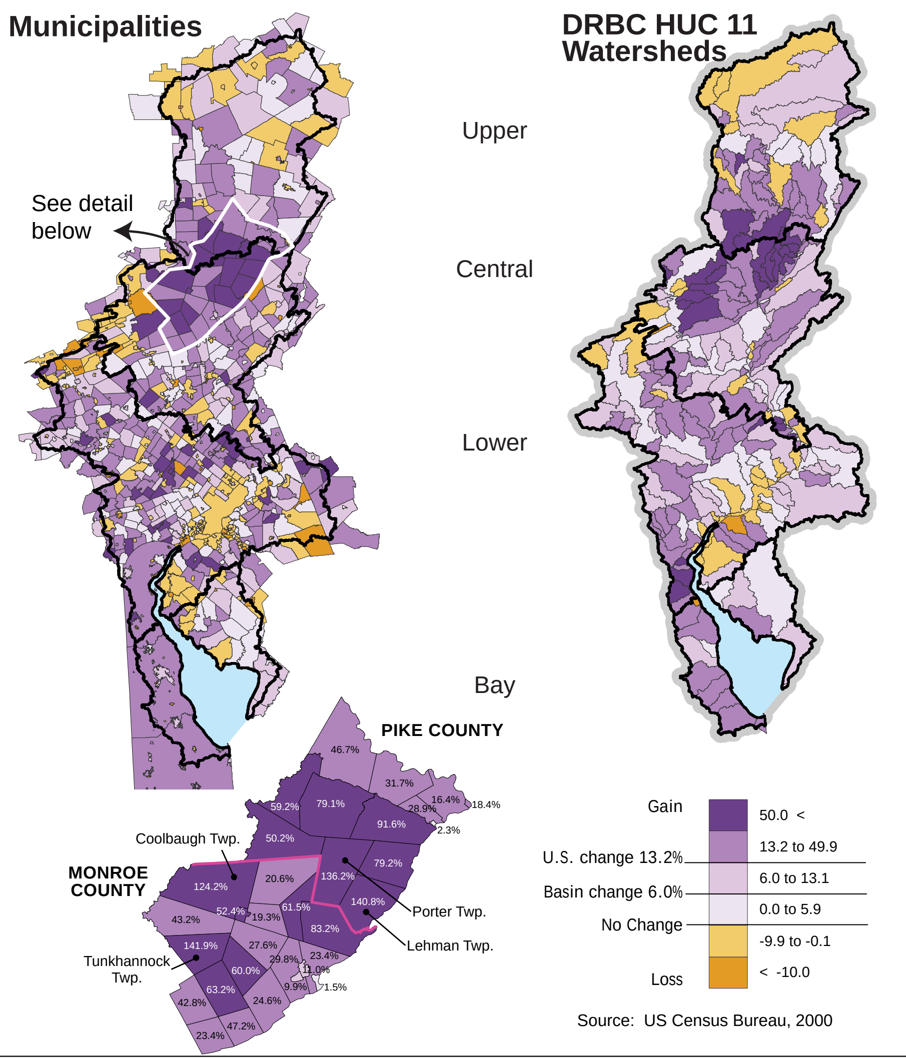


Fig. 4.3 Basin Population 2000

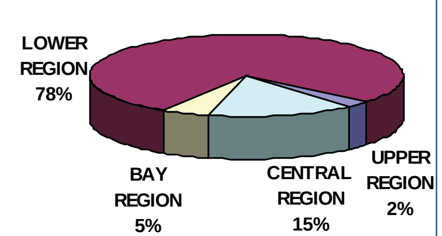
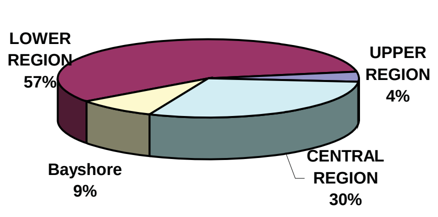


Fig. 4.4 Contribution to Population Change 1990-2000



million) reside in the Upper Estuary watersheds which include the greater Philadelphia metropolitan area.

Population growth also has an uneven pattern. Not surprisingly, the Lower region still accounts for most of the increase, but the Central Region, especially the Upper Central Watersheds, experienced a significant increase, accounting for 30% of the basin's population growth. See Figures 4.3 and 4.4.

Across the 236 watersheds:

- The greatest population increase occurred in the Neshaminy Creek PA watershed which added more than 23,000 new residents between 1990 and 2000. The Christina River watershed (Lower Estuary) ranked second, adding just over 20,000 in the same time period.
- The greatest percentage increases occurred in the Upper Central region, where the 600 square mile Lackawaxen watershed added 10,000 new residents, a 25% increase (Fig. 4.5).
- Pike and Monroe Counties, straddling the divide between the Upper and the Central regions, are the fastest growing counties in Pennsylvania. Not surprisingly, watersheds that include Pike and Monroe counties accounted for 77% of the population increase in the watersheds of the Central and Upper regions.
- Eight of the ten most densely developed watersheds, located in the Philadelphia metropolitan area, lost a combined total of more than 66,000 people between 1990 and 2000.

Trends

In the eighty years between 1920 and 2000, the population of the Delaware River Basin has nearly doubled. While population continues to increase in general across the basin, older communities, most notably the City of Philadelphia, continue to experience population loss. And while established areas—portions of the Schuylkill watershed, for example—continue to grow, new development is making inroads into areas once sparsely developed, such as the Lackawaxen watershed (Fig. 4.6 and 4.7).

Recent population estimates for 2006 show a continued decline in Philadelphia, as well as in Schuylkill County PA, Delaware County NY, and Cape May County NJ. The reasons for the decline in each of these areas vary significantly.

Continued increases are evident in the Central (Pocono) region: Pike and Monroe counties in PA, Sussex in NJ. With the exception of Cape May County NJ, areas within the Bayshore Region are also developing rapidly as indicated by substantial increases in the Delaware counties of Kent and Sussex, and Cumberland County NJ.

In summary, some sparsely developed watersheds are undergoing substantial growth and some established urban areas are being slowly abandoned. This trend has substantial implications for water resource management, including landscape alteration, construction and maintenance of new infrastructure systems, and abandonment or inefficient use of existing infrastructure.

> Identifying watersheds with substantial population change highlights where changes in landscape function and water quality might be expected to occur, and where preventive management measures could be employed to mitigate impacts.

Fig. 4.5 Population Distribution & Change

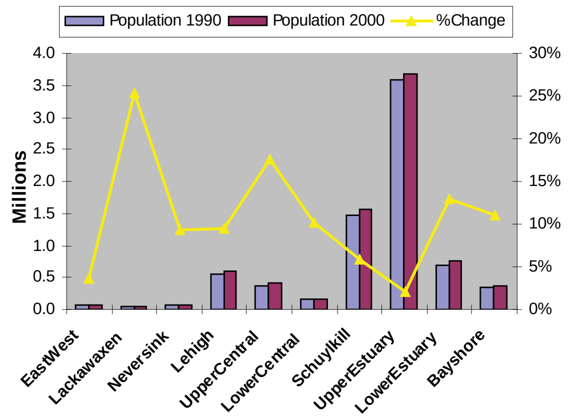


Fig. 4.6 Recent Population Change Selected Counties ~ Upper and Central Regions

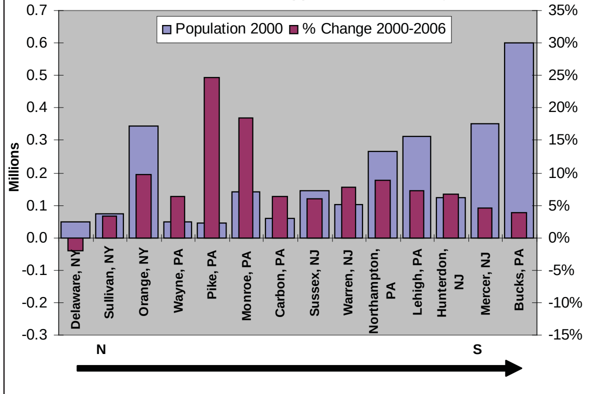
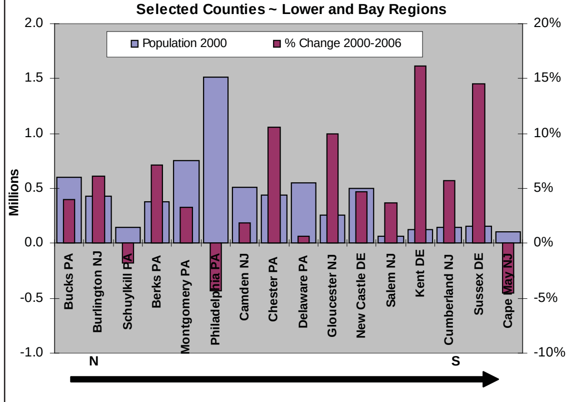


Fig. 4.7 Recent Population Change Selected Counties ~ Lower and Bay Regions



Indicator • Population Density

Not Rated

Indicator Description

Population density is an indicator of potential stress on water resources and natural landscapes and can be used as a surrogate for impervious cover, which has emerged as an important indicator of potential water quality impairment. Studies have correlated population density and impervious road area with negative impacts to water quality, fish and aquatic invertebrate communities, algae and changes to stream flow.

However, while density can indicate a potential for harm, in most instances building communities in compact form is more desirable than spreading lower density development and road networks throughout a watershed or region.

Desired Condition

Accommodate growth while protecting and enhancing water resources (BP 3.4, CCMP Actions L1-18)

Status

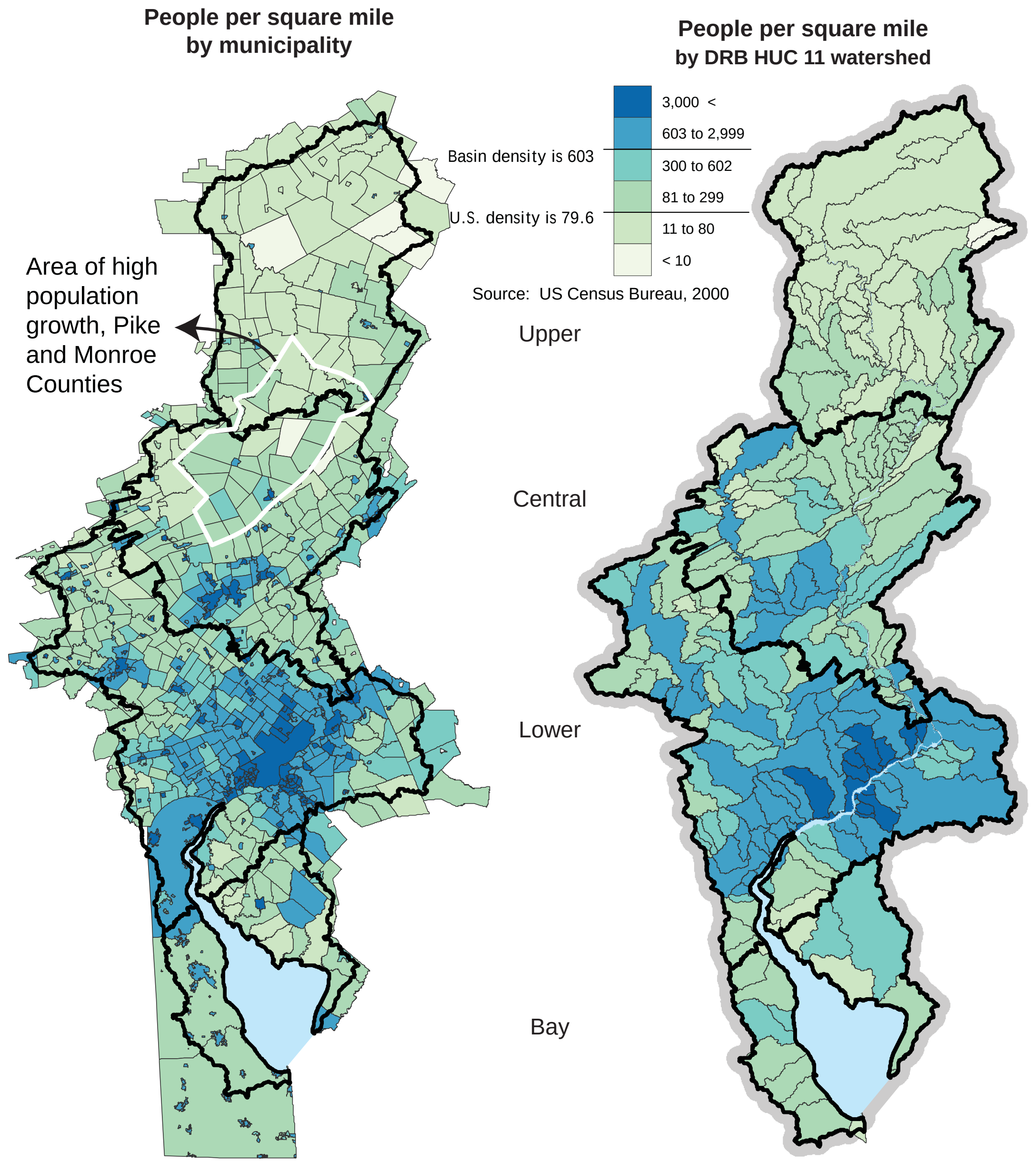
Density continues to increase in the basin, and averages 603 people/sq. mile.

In 2000, the average basin density was 603 persons per square mile (p/mi²) or about 1 person/acre. Population density varies dramatically across the Basin and among watersheds (Fig. 4.8). Population density in the Upper and Central regions is about 204 p/mi², while the Estuary density approaches 1,050 p/mi². The US census classifies densities greater than 1,000 p/mi² as *urban*.

Generally, density is lowest in the uppermost watersheds of the Basin (ranging from 30 to 100 p/mi²), increasing with proximity to the River and its confluence with major tributaries. After peaking at the greater Philadelphia metropolitan area (>2,000 p/mi²), density decreases again in the more southern watersheds of the Lower and Bay regions.

Headwater streams are especially vulnerable to impacts. Historically, these areas have remained sparsely developed due to distance from other population centers, poor accessibility and problematic terrain. In the last decade, high housing costs within and beyond the basin have fueled a sharp increase of new housing

Fig. 4.8 Population Density



and seasonal home conversions in the headwaters of the Upper Central and Lackawaxen watersheds on the Appalachian plateau. Compare the relative increase in population with population density for municipalities in Pike and Monroe (PA) counties in the inserts in Figures 4.2 and 4.8.

Differences in development patterns and population changes within watershed units can be seen by comparing the municipal and watershed density maps.

Trends

As population is increasing, density is also generally increasing. The greatest percentage increase was in the Lackawaxen (25%), the Upper Central (18%) and the Lower Estuary watersheds (13%). However, some watersheds, especially those with older urban communities, lost population.

For example, the ten most densely populated watersheds are located in the Upper Estuary around Philadelphia. Between 1990 and 2000, eight of these lost population; in those watersheds alone population declined by nearly 60,000 which may indicate an aging population and reduction in household size. Population losses can also indicate abandonment of existing housing and eventual disuse of the existing capacity of support infrastructure such as transportation, water supply and waste treatment systems.

During the same decade, slightly more than 63,000 people were added to the population of the watersheds in the Upper Central region—including areas of Pike and Monroe County PA—where developed land increased by more than 80,000 acres at the rate of ~1.3 ac/person. More than 74,000 acres of forested watershed land was converted for development and agriculture.

Actions and Needs

- Attention to where and how we develop could greatly aid in preventing or limiting negative effects on water resources. More densely developed communities offer many cultural, health and economic benefits, and the downside of imperviousness can be offset by smarter development and land management.
- Improving stormwater management practices—to capture rain water onsite and to eliminate combining storm flow with sanitary sewer flows—and adding vegetation to cityscapes can mitigate many of the negative impacts of existing communities on water resources. New development can be designed and built to meet Low Impact Design (LID) standards.

Learn about LID at http://www.lowimpactdevelopment.org/

There is a critical need to understand the relationship between land cover and water quality and quantity, and population growth and development within the Delaware River watershed.

-Delaware River Watershed Source Water Protection Plan
Philadelphia Water Department (PWSID#1510001)
June 2007

Fig. 4.9 Average Basin Density

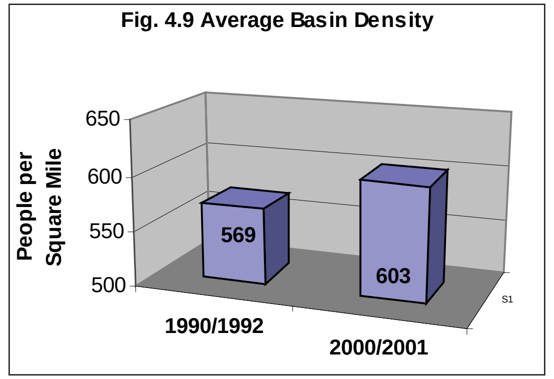


Fig. 4.10 Regional Population Density

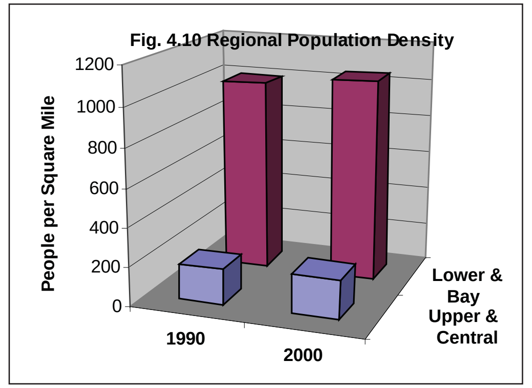
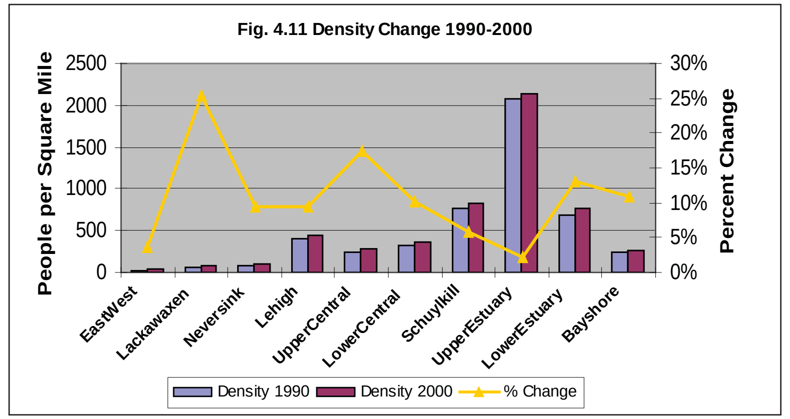


Fig. 4.11 Density Change 1990-2000



Indicator • Land Use 2001

Not Rated

The 2003 Final Report of the New Jersey Comparative Risk Project identified land use change as lying at the heart of many environmental problems, producing by a wide margin the largest negative ecological and social impacts.

Indicator Description

Land use plays a crucial role in water resource condition. The alteration of the landscape for human use can be a major factor in the alteration of ecological processes at local and global scales. Most physical and chemical changes to waterway systems are linked to land use and landscape change, although many of those links are complex and therefore difficult to evaluate and quantify. Potential impacts to water resources are shown in Table 4.1.

Desired Condition

Maintenance of the integrity and function of high value water resource landscapes and habitat for species diversity (BP Goal 3.2, CCMP Actions L1-18).

Status

As of 2001, 55% of the basin landscape was dominated by forest cover, 26% was in agricultural use, and developed land accounted for nearly 15% (Fig. 4.12).

Wetlands, a crucial landscape for water resources and biodiversity, are represented as only 4% of the landscape. This figure may under-represent the full extent of wetlands across the basin, especially isolated wetlands or wetland systems under forest canopy which are abundant in the watersheds of the Upper and Central Regions, but counted as forest in this assessment. Tidal wetlands, a dominant feature of the coastal fringes of watersheds in the Lower and Bay Regions, are more accurately captured.

Land use differs remarkably among the watersheds of the basin (Fig. 4.13). In the Upper and Central Region watersheds, forest cover dominates. The watersheds of the Lower Region have a higher percentage of developed land, while agriculture and wetlands are the more dominant features of the Bay Region.

Development has historically occurred at river confluence points, and the development at the confluence of the Lehigh (LV3) and the Schuylkill (SV3, UE1) with the Delaware River are very visible on Figure 4.14.

The concentration of human development and uses, such as ports and industry, in the Lower Region watersheds is related to water quality problems in this portion of the River. See the timeline in the Water Quality section of this report for an historical perspective.

Fig. 4.12 Basin Land Use 2001

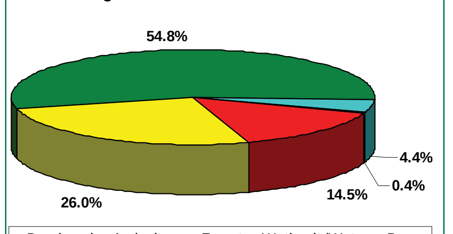
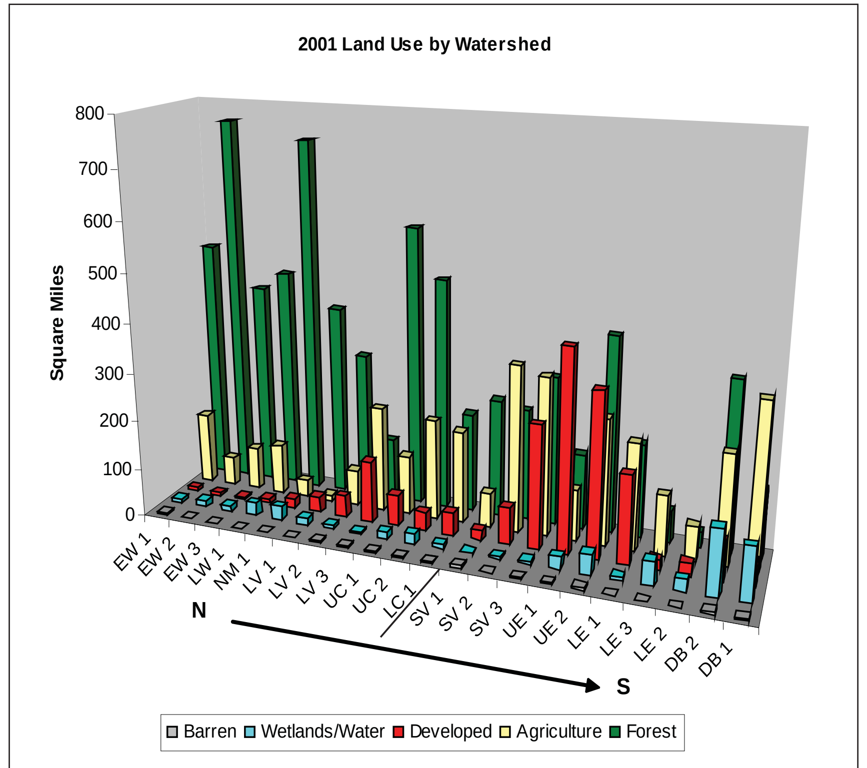


Fig. 4.13 Watershed Land Use 2001



Watersheds

Upper Region	EW • East & West Branch; LW • Lackawaxen; NM • Neversink & Mongaup
Central Region	UC • Upper Central watersheds; LV • Lehigh Valley; LC • Lower Central
Lower Region	SV • Schuylkill Valley; UE • Upper Estuary; LE • Lower Estuary
Bay Region	DB1 • Bay watersheds in DE; DB2 • Bay watersheds in NJ

Fig. 4.13. There is an obvious land use gradient from upstream to downstream through the watershed. Forested land decreases and agricultural and landscapes generally increase from north to south. Developed land is concentrated in the watersheds of the Lower Region. The relative dominance of the coastal wetlands in the Bay Region is also visible.

Trends

Based on a land use change analysis from NOAA's Center for Coastal Services, about 70 square miles of basin land was developed between 1996 and 2001. The change analysis also revealed a 48 square mile loss of forested land and 18 square mile loss of agricultural land. The wetlands and water category lost about 3.5 sq mile. Table 4.3 shows the change in acres and square miles.

The conversion of landscapes to development occurred at a rate of 25 to 35 acres per day, or an average of 132 football fields each week. Figure 4.15 illustrates landscape conversion as a daily average.

Naturally, land use change has not occurred uniformly across the basin. Between 1996 an 2001, more development occurred in the watersheds of the Lehigh and Central regions than in other watersheds. The high loss of forested land in the Lehigh is especially noteworthy (Fig. 4.16).

Although forested lands have increased since the 1930s, recent data show a decline in forested landscapes as well as wetlands. A more detailed assessment of changes to these landscape types follows, but improved mapping and assessment of changes to these landscape types follows.

Actions and Needs

- More refined landscape assessments, preferably orthophoto, should be coordinated for the basin on a time frame coincident with the decadal and mid-decade census.

Table 4.3 Landscape Change 1996-2001

Land Use	Change in Sq Mi	Change in Acres
Developed	70.75	45,283
Agriculture	- 18.41	- 11,781
Forest	- 48.29	- 30,909
Wetlands/Water	- 3.48	- 2,230
Barren	- 1.21	- 772

Source: NOAA Center for Coastal Services

Fig. 4.14 Map of Basin Land Use 2001

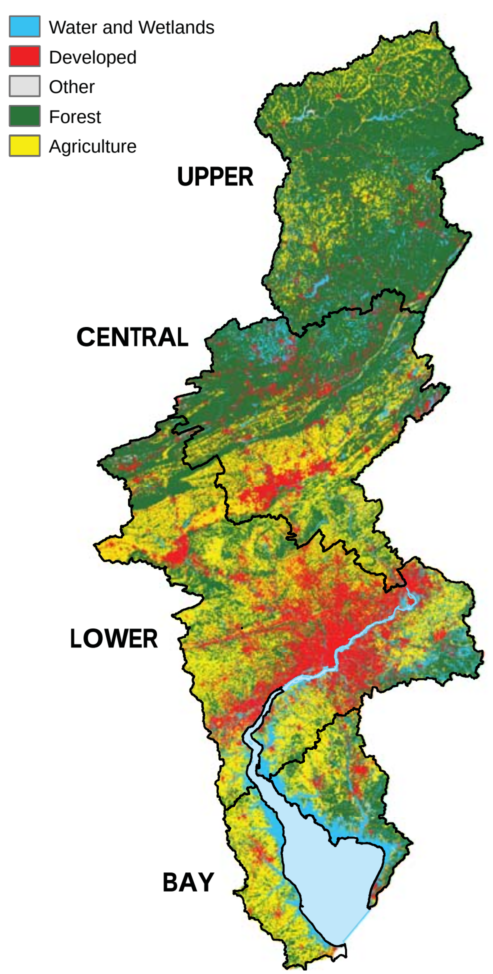


Fig. 4.15 Land Use Change per Day 1996-2001

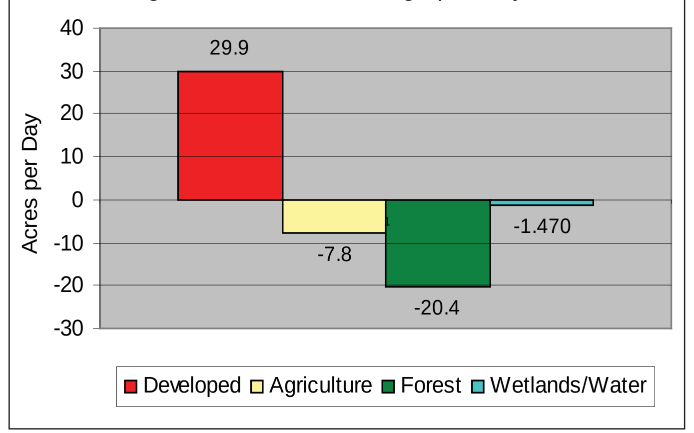
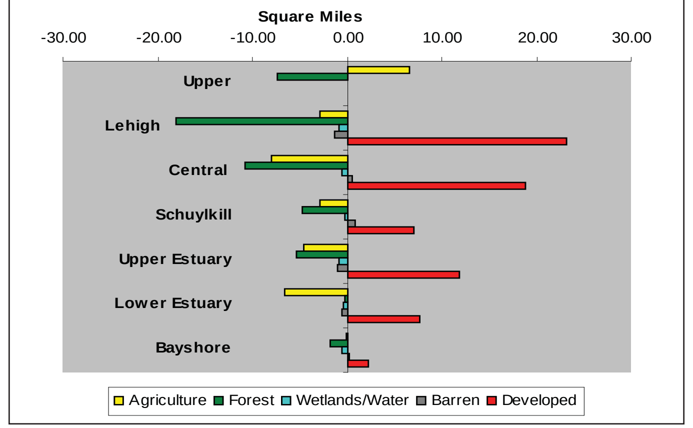


Fig. 4.16 Regional Land Use Change 1996-2001



Indicator • Land Consumption

Land Consumption
The amount of land that is developed per person is a measure of land use efficiency. An increase in land consumption indicates that more acres of land are being developed or altered for each additional person.

Desired Condition
A decreasing or stabilized rate of land developed per capita and protection of landscapes necessary to water resources through efforts to redevelop areas with existing infrastructure (BP Goal 3.4, CCMP Action L16).

Status
Poor: *Per capita* amount of land being developed is increasing.

In 1995, the population of the basin was 7,591,690 and developed land covered approximately 1,790 square miles or 1.44 million acres. On a *per capita* basis, each person represented 0.151 acres of developed land. In 2001, this *per capita* figure had risen to 0.153 acres. Although apparently small, it indicates that the rate of land conversion in relation to changes in population has increased even within a very short 5-year time frame.

In 1995 the cumulative result of historic land development was 0.151 acres of developed land per person. Between 1995 and 2000, the basin's population increased by 166,980 people. Developed land increased by nearly 71 square miles (45,280 acres) in roughly the same time period (1996–2001). The land consumption ratio for this five year period was 0.271 acres per person, nearly double the historic average (Fig. 4.17).

Trend
While coarse, this analysis is revealing: we are developing land at a far greater rate than we have historically. The proliferation of large-lot subdivisions —large homes on several acres—bear witness to this trend.

Rising fuel and construction costs, however, may act as the economic brakes that turn this trend around. Efforts to redevelop housing in urban areas, where social and cultural amenities, utilities and transportation networks are well established, are underway in many cities, fueled by changing demographics and demand.

Actions and Needs
- Analysis of land consumption requires accurate information about land use and population change in representative time periods. Currently, census and land use data are not collected within the same time periods and questions of accuracy in both data sets confound use of the data at smaller scales.
- Understanding how we use land is essential for increasing our efficient use of the landscape and for protecting the landscape functions that support water resources. Additional efforts to link landscape use and change to resource condition and to identify performance standards for land use management are necessary for comprehensive water resource protection.

How big is ...
43,560 square feet = 1 acre
640 acres = 1 square mile
1.32 acres = 1 football field

Between 1996 and 2002, land was developed at an average rate of about 19 football fields per day. Nearly 70% of all land conversion took place on previously forested landscapes.

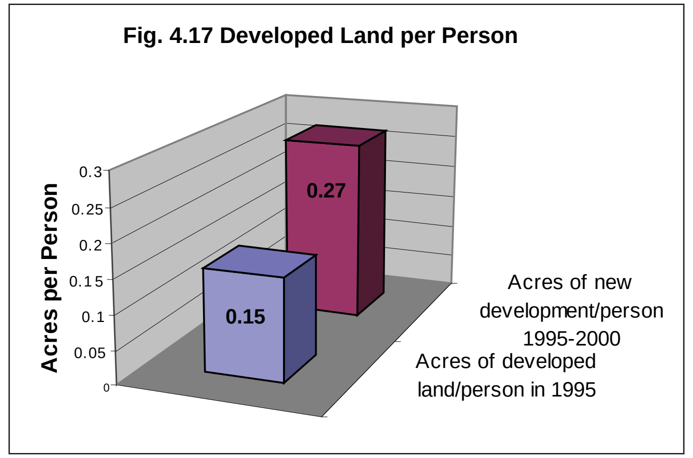


Fig. 4.17 New development of land is occurring at nearly twice the historic ratio.

Indicator • Dams

Indicator Description
Dams are structures built across a water course to impede the flow of water. Historically, dams were built to impound water for irrigation and drinking water supply, for power production, and to create recreational lakes and ponds. These structures pose some harm to ecosystems by causing genetic isolation among sub-populations of resident aquatic life, contributing to anoxic (de-oxygenated) conditions, and inhibiting the migration of spawning fish.

Desired Condition
Restoration of fish access to spawning grounds and ecological connectivity within tributary streams and rivers. Maintaining and enhancing stream flows and ecological health and diversity are primary goals for basin waters (BP Goal 1.2; CCMP Action H5.7)).

Status
Poor: 1550 dams remain on tributaries of the Delaware, blocking fish passage and disrupting the natural hydrology.

The Delaware River is the longest undammed river east of the Mississippi, but approximately 1,550 tributary dams impede stream flow and fish passage. All but a few hundred of these dams were built since 1900. Most are old and many have exceeded their design life, adding concerns about public safety to those of ecosystem health.

It is becoming a common practice to install fish passages to aid the movement of migratory fish up and down stream. Since 1991, the construction of fish ladders has opened up approximately 165 miles of streams in the Lower and Bay Regions to fish migration (PDE 2008). Unfortunately, figures on the total number of stream miles opened to fish passage across the basin are not readily available.

Trend
There is growing interest in dam removal for both ecological and public safety benefits. Several advocacy groups are leading efforts for fish passage construction and dam removal. Pennsylvania reports to be leading the nation in dam removal. The Natural Resources Conservation Service (NRCS) is actively involved in dam evaluation and removal in the basin.

Dam removal is not without controversy. Dams capture sediment which frequently harbors legacy pollutants from upstream farming and industrial activity. Disturbing and disposing of these sediments adds some ecological risk and considerable financial costs to dam removal projects. Re-establishing natural stream corridor conditions—including flow, flood plain function and vegetation—can be a complicated undertaking.

Actions and Needs
- Accurate information about dams and the potential for remediative actions, such as feasibility for dam removal or for the installation of fish ladders, is necessary for continued monitoring and reporting of this indicator.
- Identification and prioritization of restoration projects on a watershed basis could increase efficiency in planning projects and securing resources.
- While the establishment of fish passage is a sound indicator for fish migration, it is only one measure of the health of aquatic communities. Additional indicators for aquatic and riparian community health and for stream corridor integrity and function should be developed.

Anadromous **fish such as shad and sturgeon live in the ocean and return to the fresh water of their birth to spawn.**

Catadromous **fish, notably the American eel, spend most of their lives in fresh water and migrate to the sea to breed.**

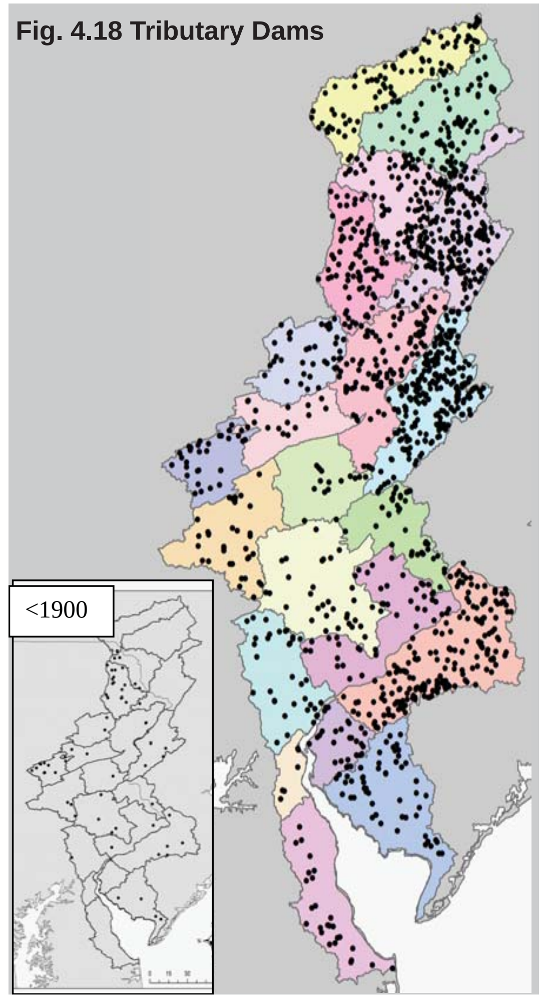


Fig. 4.18. Current location of dams within the basin compared to the location of dams built before 1900 (inset) showing their proliferation in the 20th century.

Indicator • Forests

Indicator Description

Forested landscapes are those with a high percentage of tree canopy and an absence of agriculture and development. Forested land is of prime importance to water resources, playing an important role in temperature moderation, nutrient transfer, oxygen generation, maintenance of soil health, and protection of natural hydrology.

Vegetated riparian corridors, especially forested edges of headwater streams, are important to water resource quality and aquatic ecosystems. For example, forested corridors significantly reduce nitrogen, phosphorus and sediment loadings to streams in proportion to their width; 100 foot stream buffers can reduce loadings by 80%–90%.

Desired Condition

Maintenance of forested landscapes of value to water resources and wildlife (BP 3.2; CCMP Actions L4,L6).

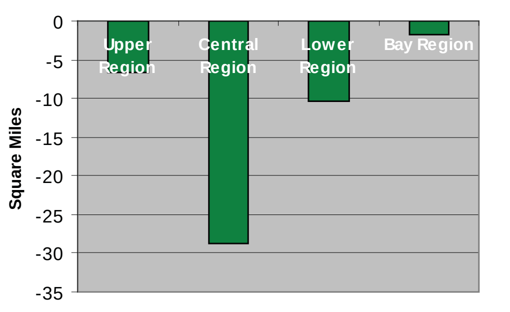
Status

Fair: The basin is losing forested land important to water resources.

While still the predominant land cover in the basin, forested land decreased by nearly 50 square miles between 1996 and 2001. Forest was lost in every region of the basin, but the greatest loss was in the Central Region (Fig. 4.19) where the Lehigh Valley and Delaware drainage watersheds of Pennsylvania are undergoing substantial population growth.

Of the 6,263 square miles remaining, approximately 782 (11%) are protected under state or federal ownership, i.e., part of federal and state forests, forest preserves and gamelands (Fig. 4.21). Forested land accounts for 88% of state and federal landholdings in these categories.

Fig. 4.19 Change in Forested Land 1996-2001



Trend

As a result of re-growth following decades of timber harvesting and clearing of land for agriculture, the amount of forested land increased between the 1930s and the mid-1990s. More recent information, however, shows that forested landscapes are being lost at the rate of more than 6,000 acres per year. In more graphic terms, that is in excess of 12 football fields per day or about one 1.32 acre football field every 2 hours.

As additional forest is converted for development or cultivation, the percentage of protected land will increase even though no additional land is being preserved. Other methods of protection, such as easements, land trusts and forest management plans, can be effective means of ensuring the landscape function of forested land. The extent of such private efforts is not accounted for in this assessment.

Stroud Water Research Center estimates that full restoration of riparian forest buffers would significantly reduce stream pollution levels even without changes to point and non-point discharges, and the PA Campaign for Clean Water has recommended that all streams be afforded a minimum 100 foot forested buffer. New Jersey recently improved protection of high quality streams by increasing regulatory control of disturbance within 150 feet.

> The rate of forest loss in the Delaware basin exceeds 12 football fields per day.
> ~
> One football field-sized swath of forest is cleared every 2 hours.

Fig. 4.20 Map of Basin Forests

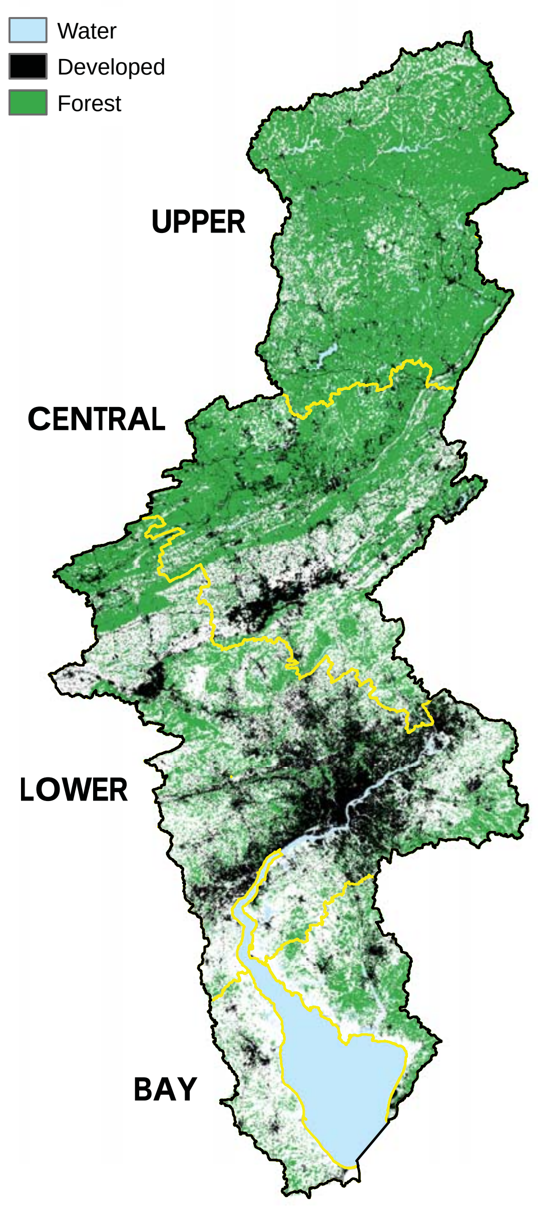
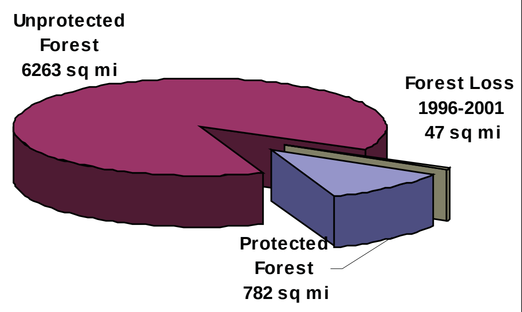


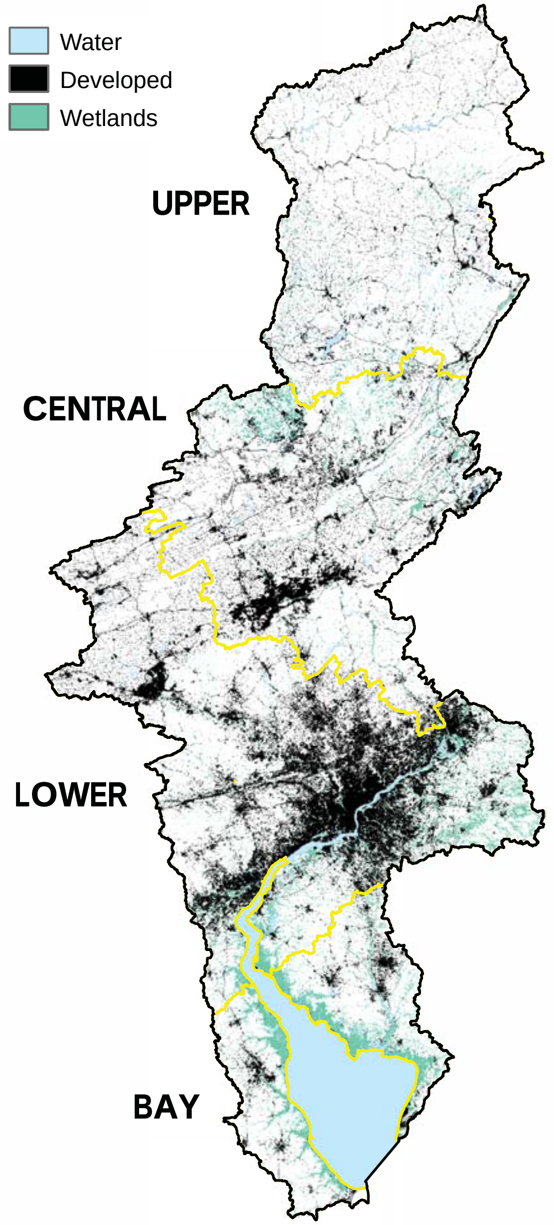
Fig. 4.21 Forested Land 2001



Actions and Needs

- Forest status, including the extent and function of forested land by region, should be assessed and reported on a regular basis, preferably synchronized to census and development information.
- Assessments of riparian buffers should include active river areas—inclusive of all lands which a river interacts in dynamic processes—and be incorporated into future condition status reports.
- Improve the mapping, assessment and tracking of forested wetlands.

Fig. 4.22. Map of Basin Wetlands



Indicator • Wetlands

R. LIMBECK, DRBC

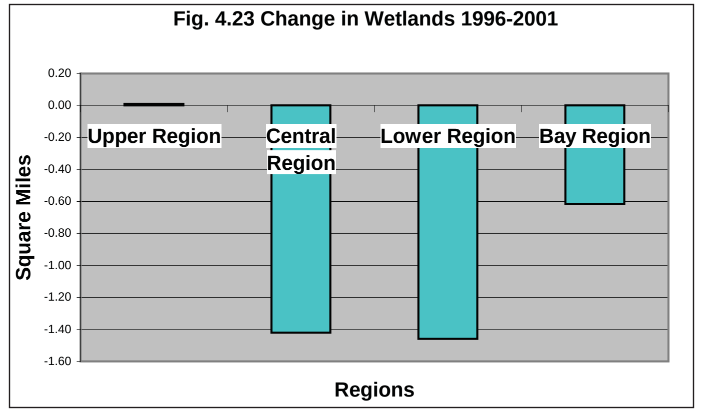
Tannersville Bog located along Cranberry Creek, Monroe County PA, is the southernmost low-altitude boreal bog in the eastern US.

Indicator Description

Wetlands are lands that attain a sufficient degree of saturation to affect soil chemistry and maintain a specialized assemblage of wetland-related plant species. The value of wetlands is substantial. Their unique biogeochemical properties filter sediments and pollutants from runoff, and process carbon and nitrogen. During storms, wetlands buffer the effects of wind and precipitation, a function especially important in riparian and coastal areas for flood and erosion protection. Wetlands also furnish essential spawning, foraging, and nesting habitat for finfish and shellfish, birds, and other wildlife, including those important to local economies.

Desired Condition

There is a federal policy to attain "no net loss" of wetlands and wetland function. State and federal programs are in place to protect wetlands (BP Goal 3.2, CCMP Actions H4, H7).



Status

Fair: Rate of loss has slowed, but continues. Assessments of functional integrity are needed.

The NOAA assessment of changes to land cover between 1996 and 2001 (NOAA 2008) shows approximately 3.5 square miles (2,300 acres) of wetland loss. While the net change for the basin was small, these changes are concentrated principally in five watersheds: the headwaters of the Lehigh (LV1), the Pennsylvania watersheds of the Central Region (UC1), the New Jersey and Delaware watersheds of the Lower Region (UE2, LE2) and the watersheds of the Bayshore Region (DB1, DB2). Not surprisingly, these same areas also experienced significant population increases in the last decade ranging from 13% to 50%, and all more than twice the basin average of 6%.

All of the watersheds with tidal wetlands showed a loss, except the Lower Estuary watersheds of New Jersey (LE3). Marsh restoration efforts, undertaken in the past decade to offset ecological impacts of power generation, may be responsible for the small increase in that area.

In spite of protection and restoration efforts, *de minimis* changes are accumulating into measurable losses of wetland landscapes.

Trends

The extent and integrity of wetlands in the Delaware River basin and estuary has been under human assault for over 300 years. In the estuary perhaps 50 percent of the natural marshes have been lost to development, conversion, or degradation. Losses have been most severe in the urban corridor where perhaps only five percent of pre-settlement of freshwater tidal marsh remains.

In 2005 New Jersey reported that the annual rate of wetland conversion appears to have slowed since the state Freshwater Wetlands laws went into effect in 1988; the loss between 1995 and 2000, based on satellite imagery and aerial photography, is half of that seen from 1986 to 1995 (New Jersey's Environment 2005: Trends, NJDEP). Too little information on wetlands conversion is available to determine definitively how the rate of change is progressing across the basin, and less is known about the degree of impairment to wetland functions. Wetlands remain vulnerable to both human landscape conversion and, in the case of tidal wetlands, to changes in sea level.

Actions and Needs

- Coordinated monitoring and assessment programs are needed to track the extent and condition of fresh water and tidal wetlands on a regular basis.
- Additional attention should be paid to freshwater wetlands in forested areas, which are poorly mapped since they are often hidden under forest canopy.

New Jersey's Environment 2005: Trends is available at http://www.state.nj.us/dep/dsr/trends2005/.

Indicator • Tidal Wetland Buffers

Upper estuary — Lower estuary and bay

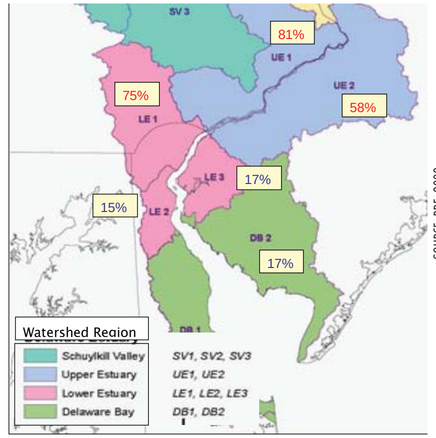
PDE 2008

Development is seen encroaching on the tidal wetland buffers at John Heinz National Wildlife Refuge, PA's largest remaining freshwater tidal marsh. Freshwater tidal wetlands are one of the most diverse types of marsh in the Delaware estuary, and they are nationally rare.

Indicator Description

A wetland buffer refers to the area immediately landward of a tidal wetland. Buffers that remain in a natural, undeveloped state provide the opportunity for wetland migration in response to changing hydrologic conditions. This is especially important for tidal wetlands where the inability to migrate can mean a loss of this vital landscape feature.

Buffers are an important indicator of the future conditions of tidal wetlands, which play a unique role in the reproductive cycle of many aquatic and avian species, and in the recycling of nutrients, especially carbon.



SOURCE: PDE, 2008.

Fig. 4.24. Wetland Buffers. The percentages in each watershed region denote the proportion of land that is unavailable for marsh encroachment due to development in the one-kilometer buffer just inland of tidal marshes. Based in 1992 NLCD.

Desired Condition

Protection of tidal wetlands and their ability to migrate in response to changing conditions (BP Goal 3.2 ; CCMP Actions H4, H7).

Status

Poor: Upper estuary
Fair: Lower estuary and bay.

The Delaware River has one of the largest freshwater tidal prisms in the world extending approximately from Trenton NJ to Wilmington DE. The gradual transition from fresh to salt water allows for freshwater tidal wetlands in the upper estuary, brackish marshes in the middle estuary, and salt marshes surrounding Delaware Bay. Together, these wetland types form a nearly continuous perimeter fringing the tidal system.

Land use within 1,000 meters of tidal wetlands was analyzed using 2001 land use (PDE 2008). The results indicate that the majority of buffer land in the Upper Estuary watersheds (UE1, UE2) is developed and unavailable for the development and migration of the freshwater wetlands characteristic of this portion of the tidal river.

In the Lower Estuary Region, more land is available to accommodate landward advancement of wetlands, except in LE1. Land also remains available in the Bayshore watersheds, although recent population and development trends indicate that much of this land may be in jeopardy from conversion for cultivation or development.

Trends

The good news is that land remains available along the bayshore for the migration of tidal wetlands (Fig. 4.24). Historically, the production of salt hay and the development of dikes to keep out the tides were common practice in these areas. Recent restoration efforts, especially on the eastern bayshore, have restored these lands to the tidal regime of the Bay and enabled wetland migration and survival. The more problematic news is that most buffer area is unavailable to the establishment and migration of freshwater and brackish wetlands in the Lower and Upper Estuary Region.

Human population continues to expand into coastal watersheds. According to a New Jersey report, new development encroaches within 50 feet of 1000 acres of wetlands each year, and within 300 feet of more than 6000 acres of wetland each year (New Jersey's Environment 2005: Trends, NJDEP 2005). This leaves little room for wetland adaptation to changing conditions.

An acceleration of sea level rise adds additional stress, as it quickens the pace of migration necessary to ensure tidal wetland survival. There is also evidence that land subsidence may be magnifying the effects of climate-related sea level rise in some coastal areas.

Actions and Needs

- An analysis of wetland buffers should be completed often enough to be useful for targeting areas for preservation.
- Policies discouraging development and redevelopment in wetland buffer areas, and restoration strategies to facilitate the landward transgression of marshes should be developed.

Feature • Landscape

Valuing Natural Landscapes

Natural Capital Project

In 2002, the New Jersey Department of Environmental Protection (NJDEP) began a multi-year study of the economic value of the state's "natural capital." The project is based on the recognition that the various components of the natural environment provide long-term streams of benefits to individuals and to society as a whole and can therefore be viewed as capital assets or, in the aggregate, as "natural capital".

Many of the benefits provided by natural capital come from ecological systems (ecosystems) such as forests, wetlands, and lakes, and include both goods (products) and services provided by both biotic (living) systems, and abiotic (non-living) systems. Goods are tangible commodities such as mineral deposits, fish and timber. Services are process-related outcomes, such as climate regulation, nutrient cycling and crop pollination. See tables for examples of the types of ecosystem goods and services that the New Jersey team considered during the valuation process.

The goods and services of natural capital provide economic value to us as individuals and as a society. The on-going benefits are usually expressed in terms of dollars per year; as with any capital asset, the value of natural capital equals the present value of the related benefit stream. In deriving estimates for those values, the study used several approaches, including value transfer, hedonic analysis, spatial modeling, and market value analysis. The full reports is available from NJDEP at www. state.nj.us/dep/dsr/naturalcap/.

Results

As economic assets, ecosystems provide substantial benefits over time. Values are reported in 2004 dollars.

- New Jersey's ecosystem assets are worth at least $26 Billion per year in goods and services.
- Present value of these New Jersey resources is estimated to be at least $850 billion.
- In general, areas containing wetlands, estuaries, tidal bays, and beaches have the highest ecosystem service values on a per acre basis.
- Different spatial patterns of land use affect ecosystem service levels; Landscape modeling shows that the size and location of ecosystems relative to each other significantly affects their level of ecoservice production. For example, forests located close to an estuary zone contribute more to estuary water quality than forests located further away. For the water quality index, the difference can be as large as 40%.
- Within the overall total, natural goods in the aggregate have an economic value of over $1 billion annually and a present value in the tens of billions of dollars.
- Estimating sustainable harvest or extraction levels for goods is a major challenge,

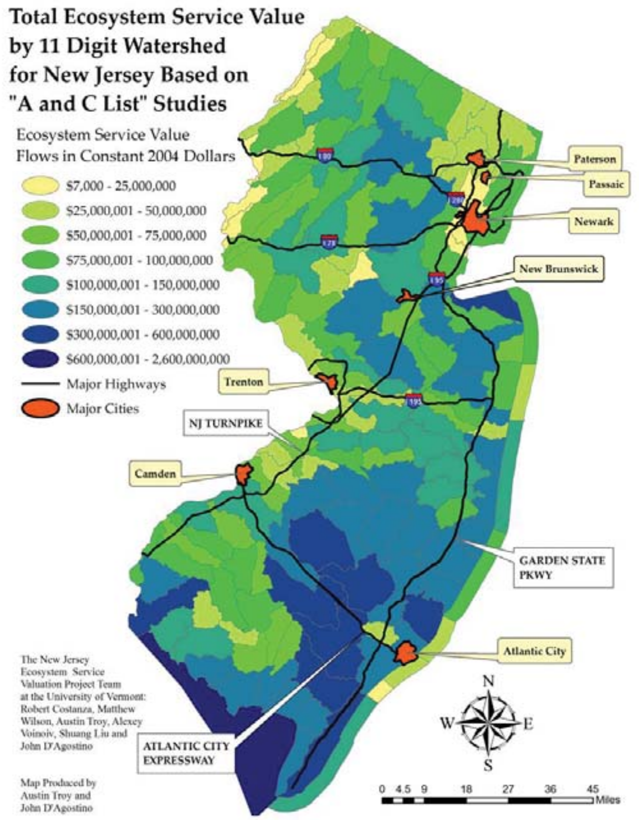


Fig. 4.25. NJ Watershed Ecosystem Service Value.

Table 4.4 Present Value 2004 of New Jersey's Natural Capital (excluding ecotourism)

Ecosystem	Area	NATURAL GOODS & SERVICES			
	(Acres)	$MM/yr	$/ac/yr	PV $Bn	PV $/ac
Freshwater wetland[1]	814,479	$9,612	$11,802	$320.4	$393,394
Marine[2]	755,535	$6,550	$8,670	$218.3	$288,987
Farmland	673,464	$4,242	$6,229	$141.4	$209,982
Forest land[3]	1,465,668	$2,512	$1,714	$83.7	$57,136
Saltwater wetland	190,520	$1,194	$6,269	$39.8	$208,973
Barren land	51,796	$587	$11,337	$19.6	$377,893
Urban[4]	1,483,496	$439	$296	$14.6	$9,869
Beach/dune	7,837	$330	$42,149	$11.0	$1,404,969
Open fresh water	86,232	$145	$1,686	$4.8	$56,208
Riparian buffer	15,146	$53	$3,500	$1.8	$116,681
Total or Avg.	**5,544,173**	**$25,664**	**$4,630**	**$855.4**	**$154,317**

[1] Forested & unforested freshwater wetlands
[2] Estuary/tidal bay and coastal shelf
[3] includes wooded farmland
[4] Urban impervious and green space

and the amount of natural goods provided is subject to change as land use patterns, climate, and other factors change in response to societal land use decisions and wider environmental trends such as global warming.

Actions and Needs

With the release of the natural capital report in April of 2007, the NJ project entered a second phase focusing on disseminating the report's findings as widely as possible and developing ways to help state and local officials, planners, and citizen groups use the study's findings when making decisions on master plans, zoning, and permitting. Economic analyses such as those described above should not be the sole criterion for environmental protection, but such analyses can shed light on the trade-offs we face in making land use decisions and can suggest which land use alternatives will result in the most favorable outcomes for society as a whole.

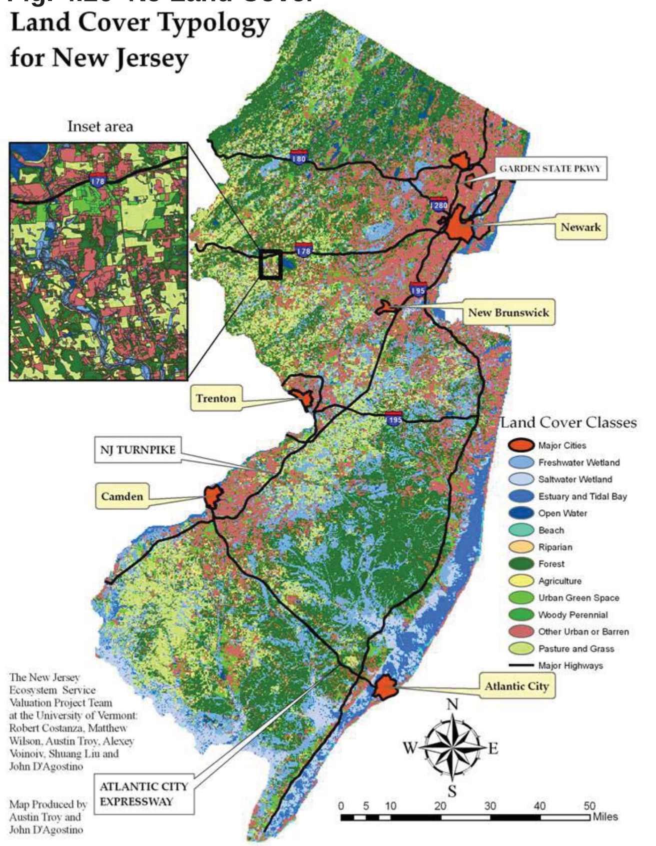
Delaware River Basin ~ Forest Capital
Present Value of Forests: $258 B
Lost Forest Capital (1995–2001): $ 1.7 B

The Delaware River Basin is blessed with visually breathtaking and functionally valuable natural resources. While significant gaps exist in the valuation literature, it is clear that natural systems have substantial economic value and maintenance of these systems in a healthy functioning state can help avoid costly expenditures on artificial replacements such as water treatment plants and flood control infrastructure.

Applying the present value of goods and services derived from the NJ study to the landscapes of the basin yields a coarse estimate of the value of its goods and services. For example, in 2001 forests covered over 7,000 square miles of the basin and, at a present value of $57,136 per acre, were worth nearly $258 billion. Between 1995 and 2001, the basin lost 47 square miles of forest with a natural capital value of $1.7 billion in goods and services. This is a very conservative estimate since it does not include an economic valuation of several services that forests provide, including long-term carbon storage, dampening of stormwater runoff and peak stream flows, and the removal of pollutants such as carbon monoxide, sulfur and nitrogen dioxides, ozone, and particulates from the air. Including such services could conservatively add more than $6,000 to the value of an acre or an additional $36.9 billion to the value of the basin's forests.

More detailed analyses to fully cover the services of landscapes found in the basin, especially those that are shared by the basin at large, such as the Delaware River and Bay, would give a fuller picture of the economic value of the basin's natural capital. Valuing our natural resource base is a necessary step to improving decisions that impact ecosystem function, and to preserving those functions for their long-term value to society.

Fig. 4.26 NJ Land Cover



Examples of Ecosystem Goods and Services

Ecosystem Goods

- Farm products, fiber and food
- Commercial fish
- Raw water
- Saw timber
- Fuel wood
- Game animals, fur
- Minerals

Ecosystem Services

- Climate regulation
- Soil creation
- Habitat
- Flood mitigation
- Pollination
- Air quality
- Water quality
- Nutrient cycling
- Recreational and aesthetic experiences
- Other functions that would require money to replace

Summary of Conditions and Recommendations

The *State of the Basin Report 2008* offers a view of the condition of the waters and landscapes of the Delaware River Basin. Based on available information, it serves as a benchmark of current conditions, as a companion to the 1981 *Level B Study*, and as a point of reference for gauging progress towards the goals of the 2004 *Water Resources Plan for the Delaware River Basin.* In accordance with the 2001 Commission directive, condition reporting should be repeated in 5-year cycles following this initial 2008 baseline report.

An indicator is a measure of condition; an environmental indicator is a measure, value or statistic that provides an approximate gauge of the state of the environment and may help to evaluate the effectiveness of an environmental management program or policy.

In all, 37 indicators representing hydrology, water quality, living resources and landscape conditions have been reviewed in this report. Pertinent data, trend analysis, qualitative information, and professional judgment were brought to bear to assign graphic and narrative representation of condition for each individual indicator. Three landscape indicators—land use, population and population density—were reported, but not classified or rated. Although of supreme importance as stressors or causes of changes to water-related resources, they are essential statements of fact that do not warrant a rating.

To summarize each assessment, a simple categorical measure of condition was used; each indicator was assigned a rating of *Good*, *Fair* or *Poor*. The results are shown by indicator category in Table S.1.

Table S.1
Condition Summary by Category

Category	Good	Fair	Poor
Hydrology	4	2	1
Water Quality	3	5	2
Living Resources	2	5	5
Landscape	0	2	3
Total	**9**	**14**	**11**

Summary of Water Resource Status: Fair

Based on overall ratings of 34 of the 37 indicators, the condition of the basin's water-related resources is *Fair.* Variation exists within and among the indicator categories, and suggests where additional effort should be focused.

Hydrology. Hydrologic indicators are overall in good shape. We are meeting the flow targets that are the foci of management efforts, meeting human demand for water, using resources with some degree of efficiency, and making headway in water use and protection, and working to improve flood losses. The potential for increased climatic variation may challenge adaptive management efforts in the future.

Water Quality. Metrics indicate that water quality overall is *Fair.* Dissolved oxygen, nutrients and clarity appear to be good and generally meeting criteria in the tributaries and the river mainstem. However, toxics remain a problem. Lack of criteria for some parameters make evaluation problematic, and deficiencies in monitoring hinder robust assessments of others, especially DO and nutrients.

Living Resources. This category includes species of concern that are affected by changes in water quality and hydrology, e.g., the "endpoints" of changing biological, chemical and physical conditions in waterways and water-related landscapes. The overall condition assessment for this category is *Fair* with a significant number of indicators having a *Poor* rating. Selection of additional indicators may be advised for subsequent reports to include additional species that are of ecological or economic importance.

Landscapes. Indicators in the landscape category include factors that contribute to impacts in the other three categories. Improvements in data quality, availability and timeliness are essential for improved reporting. The functional linkages between landscape change and other indicators are not always well quantified nor well represented through indicators. Additional metrics to help bridge this gap should be considered for the next report.

Summary of Issues and Recommendations

Several issues related to indicator selection, monitoring and assessment were identified during the development of this Report.

Monitoring Needs.

Gaps in the approach to basin-wide monitoring and assessment are evident and an excellent summary can be found in the Final Report of the Delaware River Basin National Water Quality Monitoring Network Pilot Study prepared in February 2008.and available at: http://acwi.gov/monitoring/network/pilots/NWQMN-DRB-Pilot_Final%20Report_02-07-08.pdf

Several items specifically related to monitoring and reporting are summarized below.

- **Enhance continuous monitoring of water quality.** Continuous monitoring of some water quality parameters—particularly DO, pH and temperature—is necessary for accurate condition assessment. DO, our most fundamental indicator of water body condition is most appropriately assessed this way, since intermittent samples do not capture diurnal changes, especially pre-dawn sags in DO concentrations. Spot measurements may lead to a false sense that criteria are being met, even when they are not.

- **Link monitoring to water quality concerns and criteria.** Each parameter of concern should be reviewed to determine its appropriate monitoring frequency. Intermittent data sets were available for several metals and compounds of interest, but breaks in data, changes or differences in detection capabilities, or differences in the specific chemical form of the parameter of concern rendered the data sets unusable. Some parameters should be monitored routinely, while others may be monitored once every several years to determine that concentrations remain below that of concern. Coordination is necessary to ensure that agencies monitor within similar time frames and for similar chemical forms.

- **Enhance capacity for landscape change analysis.** Land use/land cover data were among the most problematic to obtain and use since no single intra-basin organization coordinates or assembles timely land use and land cover data for the entire basin. USGS National Land Cover Data (NLCD) is inappropriately coarse for delineation and assessment of land use change at any intra-regional (watershed) scale, and the change product comparing 1992 and 2001 (2008) contained too many discrepancies with state photogrammetric-based assessments to be used with any confidence. The change product from NOAA's Coastal Services Center (2008) comparing 1996 and 2001 is used for this report even though it only covers five years of change, and omits a small but important portion of the basin in the fast-developing Appalachian plateau region. Note that both data provide less than up-to-date information. Furthermore, state photogrammetric data sets lack sufficient conformity to join and analyze. There is a significant gap that needs to be filled for adequate landscape change assessment.

- **Link landscape and population assessment.** Landscape change and population reporting should be synchronized to provide a more robust assessment of development patterns and potential impacts to water resources.

- **Increase data accessibility and mapping capability.** While significant progress has been made to improve the retrieval of water data, some water-availability data still reside on local management systems that are difficult or impossible to obtain electronically. Monitoring and assessment data should include a geographic coding to allow them to be spatially represented.

- **Indicator Selection.** Indicator selection was primarily based on data availability and completeness. As a result several indicators originally identified as desirable, including many metals, were not included. Additional indicators should be considered for future reporting.

- **Evaluate water quality and hydrologic indicators.** The use of additional chemical or flow indicators may be advisable. Temperature and pH are two additional indicators to consider. Coordination of state data collection would greatly enhance tributary evaluation. For example, variations in the form of nitrogen collected (NO2, NO3, TN, TKN) hampered analysis and comparison.

- **Appraise indicators for relevancy** to management goals. Programmatic goals and objectives of the Water Resources Plan for the Delaware River Basin (Basin Plan) and the Comprehensive Conservation Management Plan (CCMP) for the Delaware Estuary should be reviewed to inform the selection of additional appropriate indicators.

A reductionist approach—deconstructing a system into its component parts and assessing each individually—may be an efficient means of reporting metrics, but, as the US General Services Administration acknowledged in Sustainable Development and Society (2004), the reductionist approach is inconsistent with the concept and principles of sustainability.

While the 2008 State of the Basin report has laid a foundation, many improvements are needed to enable an assessment of the basin system as a sum of inter-related parts and functions. The challenge for the subsequent State of the Basin report (2013) will be to select, appraise, and reassemble information on the health and function of the systems that contribute to the overall well being of the Delaware River Basin.

Table S.2 Delaware River Basin Indicator Rating 2008

Legend: ○ = GOOD ◐ = FAIR ● = POOR **NR** = Not Rated

Category	Indicator	Rating	Present Condition / Trend	Recommendations
Category I: Hydrology	Flows at Trenton	○	Good; stable Flow target maintained 95% of the time	• Improve reservoir and stormwater management • Evaluate instream flow needs for River and estuary
Category I: Hydrology	Salt Line Location	○	Very good; fluctuations within acceptable range Drinking water intakes effectively protected	• Investigate effects of other chloride sources and sea level rise scenarios • Manage for climate change impacts
Category I: Hydrology	Water Use Efficiency	◐	Fair Per capita use ranges from 90 to 190 gal. per capita per day	• Improve reporting and utilize conservation technologies
Category I: Hydrology	Water Use	○	Good Human needs being met; instream needs being studied	• More information needed on agricultural demand and instream needs
Category I: Hydrology	Water Supply Sources	○	Good; stable Multiple potable supply sources available in many areas	• Employ conjunctive use and expand source water protection for sustainable supply • Evaluate and execute long term supply alternatives
Category I: Hydrology	Areas of Ground Water Stress	◐	Fair; stabilizing with conjunctive use New problem areas identified	• Continue conjunctive use and demand management • Assess effectiveness of SEPA-GWPA program
Category I: Hydrology	Flood Damage	●	Poor; increasing repetitive claims in recent years	• Improve floodplain mapping and management • Evaluate potential climate change impacts.
Category II: Water Quality	Nutrients	◐	Fair; stable Concentrations high compared to other systems, but harmful effects not evident	• Establish criteria to protect aquatic life
Category II: Water Quality	Dissolved Oxygen	○	Good; stable DRBC and state DO standards being met; upper basin DO is better than lower basin	• Continuous monitoring of DO needed throughout basin
Category II: Water Quality	Water Clarity	○	Good Naturally turbid estuary; non-tidal river generally clear except after storm events.	• Improve monitoring of suspended solids; add turbidity probes to automatic monitors • Define relationship among nutrients, water clarity and phytoplankton and sediment budgets
Category II: Water Quality	Copper	◐	Fair Dissolved copper below but near water quality criteria.	• Additional monitoring / modeling required to improve assessment, especially River Zone 5
Category II: Water Quality	Fish Consumption	●	Poor Advisories for at least one species on many tributaries and River for mercury and/or PCBs.	• Implement TMDLs for targeted toxics • Monitor additional toxic compounds in water and fish tissue; identify sources
Category II: Water Quality	Toxics: Pesticides	◐	Fair Presence throughout basin, esp. historic agricultural use areas; atrazine concentrations below drinking water standard	• Regular sampling protocols needed • Additional research needed to determine effects levels and set criteria for pesticides
Category II: Water Quality	Toxics: PCBs	●	Poor; possibly improving PCBs persist in water, sediments and fish tissue, esp. in the tidal river/estuary.	• Continue monitoring, source identification and removal; Revise and implement TMDLs
Category II: Water Quality	Support of Designated Use: Tributaries	◐	Fair 37% of assessed tributary miles do not support designated uses	• Assessment information should include chemical, physical and biological conditions • Standardize cartographic representation
Category II: Water Quality	Tributary Water Quality Trends (DO, N, P, TSS)	○	Good: stable in Upper & Central watersheds; some declines in Lower and Bay watersheds	• Consider additional or different constituents for next report • Criteria needed for Nitrogen and Total Suspended Sediment
Category II: Water Quality	Support of Designated Use: Delaware River	◐	Fair; conditions range from poor to good depending on use designation	• Add data collection for missing reaches • Review current quality criteria for DO • Investigate nutrients, temperature, pH • Restore impaired waters

Table S.2 Delaware River Basin Indicator Rating 2008

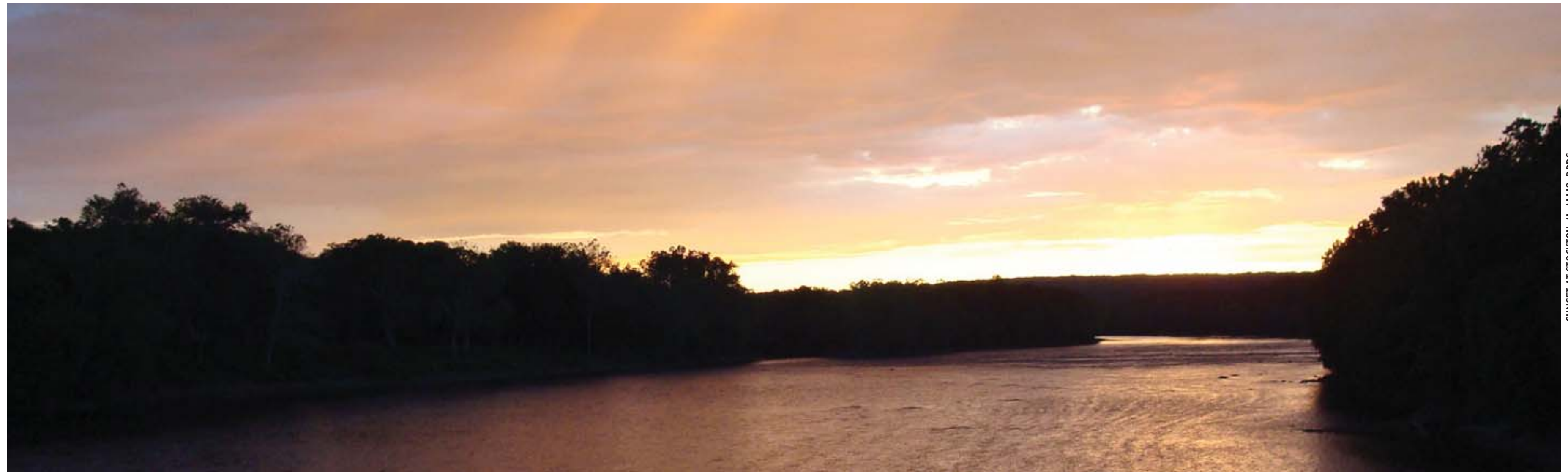
Legend: ○ = GOOD ◐ = FAIR ● = POOR **NR** = Not Rated

Category	Indicator	Rating	Present Condition / Trend	Recommendations
Category III: Living Resources	Benthic Macroinvertebrates	◐	Fair; conditions range from poor to very good All regions show impacts	• Additional data collection • Standardize reporting indices
Category III: Living Resources	Freshwater Mussels	●	Very poor More than 75% have special conservation status due to habitat and water quality degradation	• Proactive monitoring to fill data gaps • Improve coordination between researchers and water managers
Category III: Living Resources	Oysters	●	Poor; recent trend positive Populations are low but seed beds are being carefully managed	• Comprehensive monitoring • Continue restoration efforts • Establish flow needs
Category III: Living Resources	Horseshoe Crabs	◐	Fair; reduced breeding populations are improving Egg densities affect shore birds	• Continue / improve management to re-build populations
Category III: Living Resources	Red Knot	●	Very poor; populations may be crashing Vulnerable to loss of food source and climate impacts	• Continue moratorium/limitations on horseshoe crab harvest
Category III: Living Resources	Louisiana Waterthrush	◐	Fair Sensitive to polluted waters and loss of forested riparian habitat	• More data needed to determine trends • Additional obligate riparian species (e.g., amphibians) indicators needed
Category III: Living Resources	Bald Eagle	○	Good; generally improving	• Continue monitoring of eagles and increase monitoring of water quality, especially emerging contaminants
Category III: Living Resources	Striped Bass	○	Good; restored, but stability uncertain	• Ecological studies to determine dynamic interactions with weakfish and other species
Category III: Living Resources	Weakfish	◐	Fair; recent declines	• Ecological studies of predation & dynamic interaction with other species, especially Striped Bass
Category III: Living Resources	Atlantic Sturgeon	●	Poor; declining	• Study sturgeon population dynamics and continue moratoria and other protections
Category III: Living Resources	Shad	◐	Fair; improved with DO and fish passage, but recent declines evident	• Monitor habitat conditions in spawning areas • Maintain good water quality and fish passage
Category III: Living Resources	Brook Trout	●	Poor Population extirpated or severely reduced in many watersheds	• Data on status and trends needed • Conservation, restoration, and flow management actions needed
Category IV: Landscape	Population Growth and Distribution	NR	Basin population 7.8 million, up 6% (1990-2000)	• Synchronize land use and population change assessments • Employ technologies and LID techniques to minimize effects on water resources
Category IV: Landscape	Population Density	NR	Basin average is 603 p/mi^2 Ranges from <10 to >2,000 p/mi^2.	• Track population & land use change simultaneously • Employ techniques to mitigate impact of density on water resources
Category IV: Landscape	Land Use 2001	NR	Developed area increased by 71 mi^2 in 5 years at expense of forest and agricultural land	• Improve basin-wide monitoring of land use change; increase frequency and synchronize with census
Category IV: Landscape	Land Consumption	●	Poor; *Per capita* rate of developed land has increased	• Current and accurate data on population, land cover, and development trends for more efficient use of land and water resources
Category IV: Landscape	Dams	●	Poor 1550 tributary dams disrupt natural hydrology and fish passage	• Monitoring needed before and after dam removal to detect effects • Inventory and prioritization for restoration
Category IV: Landscape	Forests	◐	Fair; decreasing by size of 1 football field every two hours 48 mi^2 of forest lost in 5 years	• More accurate estimates of forested landscapes are needed to protect water resources • Forests need to be protected to sustain water resources
Category IV: Landscape	Wetlands	◐	Fair Losses occurring at a slower rate; assessment of functional integrity needed	• Improve mapping of forested wetlands • Coordinate monitoring & assessment to track extent and condition of freshwater and tidal wetlands
Category IV: Landscape	Tidal Wetland Buffers	●	Poor in Upper Estuary Fair in Lower Estuary and Bay regions	• Analysis needed to target areas for protection and restoration
	State of the Basin	◐	Fair	• Enhance monitoring, evaluation and reporting capacity • Apply integrated sustainability principles and metrics

Illustrations

Acronyms

Ac	Acre; equal to 43,560 square feet
ASMFC	Atlantic States Marine Fisheries Commission
BBS	Breeding Bird Survey
BMPs	Best Management Practices
BOD	Biological Oxygen Demand
BP	Water Resources Plan for the Delaware River Basin, 2004 (Basin Plan)
CCMP	Comprehensive Conservation and Management Plan for the Delaware Estuary
cfs	Cubic feet per second
CO²	Carbon dioxide
CWA	Clean Water Act
D&R Canal	Delaware and Raritan Canal
DDT	Dichloro Diphenyl Trichloroethane
DE	Delaware
DNREC	Delaware Department of Natural Resources and Environmental Control
DRBC	Delaware River Basin Commission
DO	Dissolved Oxygen
EPA	United States Environmental Protection Agency
ETM	Estuary Turbidity Maximum
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
GW	Ground water
gpcd	Gallons per capita per day
HUC	Hydrologic Unit Code, used to identify watersheds
ID	Insufficient data
INCODEL	Interstate Commission on the Delaware River
KRA	Key Result Area from the 2004 Basin Plan
LID	Low Impact Development
mgd	Million gallons per day
mg/L	Milligrams per liter
Mi	Mile
MI^2	Square mile; about 640 acres
MSX	Multinucleated Sphere Unknown; oyster disease
N	Nitrogen
NFIP	National Flood Insurance Program
ng/L	Nanograms per liter
NJ	New Jersey
NJDEP	New Jersey Department of Environmental Protection
NLCD	National Land Cover Dataset
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollution Discharge Elimination System
NPS	National Park Service
NY	New York
NYC	New York City
NWI	National Wetlands Inventory
Obs	Observation well
P	Phosphorous
P/mi^2	Persons per square mile
PA	Pennsylvania
PADEP	Pennsylvania Department of Environmental Protection
PA-GWPA	Southeastern PA Groundwater Protected Area
PAH	Polycyclic aromatic hydrocarbon
PBDE	Polybrominated Diphenyl Ethers
PCB	Polychlorinated Biphenyls
PDE	Partnership for the Delaware Estuary
PFC	Perfluorinated Compounds
PPCP	Pharmaceuticals and Personal care Products
PRM	Potomac-Raritan Magothy aquifer system
ppm	Parts per million
ppt	Parts per trillion
RM	River Mile
SOTB	State of the Basin
STP	Sewage Treatment Plants
SW	Surface Water
TCE	Trichloroethylene
TN	Total Nitrogen
TP	Total Phosphorous
TSS	Total Suspended Solids
TMDL	Total Maximum Daily Load
TU	Turbidity Unit
ug/L	Micrograms per liter
USACE	United States Army Corp. of Engineers
USDA	United States Department of Agriculture
USGS	United States Geological Survey
VOCs	Volatile Organic Compounds
WHP	Wellhead Protection
WWTP	Wastewater Treatment Plants



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STATE OF THE DELAWARE RIVER BASIN REPORT 2008

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Printed on recycled paper with soy inks.