

# Water History

## America's Formative Watersheds: Chesapeake, Delaware, and Hudson

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<b>Abstract:</b>	<p>This perspective explores the discovery, decline, and recovery of the Chesapeake, Delaware, and Hudson river basins as America's formative watersheds. These historic river basins were the place where America was founded and now these populous Mid-Atlantic watersheds cover just 2% of the contiguous United States yet provide drinking water to over 10% of the nation's population. These multistate river basins are managed with varying emphasis on governance ranging from voluntary Federal-driven agreements in the Chesapeake Bay, a compulsory Federal-state basin compact for the Delaware River, and grassroots riverkeeper advocacy along the Hudson River. America was born along these historic East Coast waters and after a precipitous decline these rivers and bays are alive once again.</p>
<b>Response to Reviewers:</b>	<p>In accordance with the reviewer's comments I have included more discussion about the context of these mid-Atlantic river basins and include the literature about rivers and history, for instance the seminal Rivers of America series edited by Constance Skinner during the Great Depression.</p>

## America's Formative Watersheds: Chesapeake, Delaware, and Hudson

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**Biography:** Gerald J. Kauffman is Director of the University of Delaware Water Resources Center and holds faculty appointments in the School of Public Policy and Administration, Department of Civil and Environmental Engineering, and Department of Geography. He is a co-founder of the Interdisciplinary Graduate Water Science and Policy program and serves on the Undergraduate Environmental Academic Affairs Council that oversees environmental studies majors at the University of Delaware.

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### Rivers and America

When Constance Lindsay Skinner conceived the seminal Rivers of America series of books during the Great Depression, she was earnest in her conviction that "rivers ... have, a powerful influence on the temperament and imagination of mankind" (Mink 2006). Decades before the environmental movement and Silent Spring in the 1960s and Earth Day in the 1970s, Rivers of America helped the public understand their natural world and landscape in a way that was personal and identifiable. Rivers provided an identity for people because they live, work, fish, and boat along their home waterways. People may not have thought about the environmental movement back then but they wanted to understand the nature of their rivers. The Rivers of America series covered 65 rivers between 1937 and 1974 including books about the Hudson by Carl Carmer in 1939, The Delaware by Harry Emerson Wildes in 1940, and the Susquehanna by Carl Carmer in 1955.

Rivers have influenced America "... from the beginnings of the Republic to today" (Doyle 2018). As a source of hydropower for manufacturing and navigation to transport goods, rivers served a central role in the founding and expansion of the United States. When the Europeans settled along the Atlantic seaboard in the 17<sup>th</sup> Century they built farms on the flat, fertile Coastal Plain where the mild tidal streams were navigable by sailing vessels. They moved inland from the coast and established villages along the Fall Line, the geological boundary of river navigation where streams in the hilly, rocky Piedmont flow down to tidewater on the flat sandy Coastal Plain, a source of mill power and navigation. The combination of mill power along the steep streams to support the Colonial economy and navigation on flat tidewater made the Fall Line a most fortuitous place to build the cities of New York along the Hudson, Philadelphia along the Delaware, and Baltimore on the Chesapeake.

Rivers have been said to connect and divide societies (Schonach 2017) and perhaps nowhere is this more so than in the colonial mid-Atlantic watersheds where America was formed. The Delaware and its neighbors to the north and south, the Hudson and Chesapeake, are river basins "unsurpassed" for their "significance in the history of the American people" (Anderson and Bovaird 1960). This historic perspective provides a synthesis of the discovery, decline, and recovery of the Chesapeake, Delaware, and Hudson river basins, the place where the United States was born. (Figure 1).

### America's Formative Watersheds

Linked by hydrology at the crossroads of American history, the river basins of the Chesapeake, Delaware, and Hudson stretch 500 miles along the Atlantic seaboard in the most populous watershed in the United States (Figure 2). Four centuries ago, Henry Hudson and Captain John Smith first explored these estuaries in the New World looking for gold and furs to send back to their sponsors in the Old World. The original colonies of America were founded along the Atlantic seaboard near the mouths of these rivers and two-thirds of the market crops then were raised within 5 miles of navigable waterways. These large river basins cultivated the American colonies along the Mid-Atlantic seaboard "at the

intersections of rivers and the coast” (Doyle 2012). The American Revolutionary War and the Civil War were fought along its rivers. John F. Kennedy, Richard M. Nixon, and Barack H. Obama adopted Federal programs to protect its rivers and watersheds.

While sharing similar geography and climate, these contiguous Mid-Atlantic basins have contrasting qualities and characteristics (Table 1). All or parts of nine of the original 13 colonies lie with the basin boundaries. The Chesapeake, Delaware, and Hudson basins cover just 2 percent of the contiguous United States yet are home to 10 percent of the nation’s population; the nation’s first-, fifth-, and seventh-largest metropolitan economies; the National Capitol; and six state capitals. The Hudson and Delaware basins cover a similar area (approximately 13,000 mi<sup>2</sup>) but the Chesapeake watershed is four times as large (64,000 mi<sup>2</sup>) which suggests the challenges of governing the nation’s largest estuary are correspondingly complex. The Chesapeake is home to 16 million people or twice that of either the Hudson and Delaware basins but the Chesapeake’s population density (250 people/mi<sup>2</sup>) is less than the Delaware (590 people/mi<sup>2</sup>) or Hudson (900 people/mi<sup>2</sup>) which suggests less pressure per unit area from human pollution sources and water withdrawals. The river basins’ three largest cities - New York, Philadelphia, and Baltimore - now hold over 11 million people (Figure 3).

While each river is over 300 miles long (large as East Coast rivers go), the Chesapeake/Susquehanna, Delaware, and Hudson are just the 42<sup>nd</sup>, 55<sup>th</sup>, and 85<sup>th</sup> longest rivers in the United States. The Chesapeake is the longest estuary in the U.S. (194 miles) and the Hudson (152 miles) and Delaware estuaries (96 miles) are the nation’s 3<sup>rd</sup> and 5<sup>th</sup> longest navigable tidal rivers. All three estuaries are drowned river systems that evolved from rising sea levels that began about 20,000 years ago during the end of the last ice age. The Hudson Estuary is the only fjord in the continental U.S. as it was carved by glaciers about 26,000 years ago while the unglaciated Chesapeake and Delaware estuaries lie south of the glacial terminal moraine deposited at the end of the last Ice Age.

The Hudson recirculates more rapidly as the ratio of watershed to estuary surface area (55:1) is three times higher than the Delaware and Chesapeake ratios (18:1) as reported by Roman et al. (2000). Measured by annual discharge, the Chesapeake (70,000 cfs) is recirculated at a greater rate than the other two basins (14,000-15,000 cfs). In the Delaware and Chesapeake basins, ocean recirculation rates are similar as the bay mouths measure 11 to 13 miles wide, much longer than the mile-wide mouth of the Hudson at the Verrazano Narrows Bridge.

Land use proportions are similar as the urban I-95 corridor cuts through the downstream reaches of each basin while agriculture and forests increase north to the headwaters. The Delaware Basin is covered by almost twice as much urban land (14%) compared to the Chesapeake and Hudson basins (8% urban). The three basins are covered by similar proportions of agriculture (22%-26%) and forests (55%-60%).

## **The Chesapeake**

While gazing at the Potomac River from the White House, President John F. Kennedy may have thought about the Chesapeake Bay when he reportedly said that anyone who can solve the problems of water are worthy of two Nobel prizes - one for peace and one for science. The political complexity of governing this vast 64,000 square mile Chesapeake Bay watershed over six states and the District of Columbia is a major challenge in cleaning up the bay (Horton 2003).

Known by the indigenous Algonquian people as the “village at a big river”, the *Chesepiooc*, is the largest of 130 estuaries in the U.S. and stretches from Havre de Grace, Maryland at the mouth of the Susquehanna River to Virginia Beach, Virginia at the Atlantic Ocean (Ernest 2003). The 4,480 square mile bay is long (194 miles), narrow (3 to 30 miles wide), and shallow (average depth 21 feet) and holds over 15 trillion gallons of water (Chesapeake Bay Program 2017). The bay shoreline (12,000 miles) is longer than the mainland Pacific Coast of the U.S. The bay is flushed with 50% saltwater from the Atlantic Ocean and 50% freshwater from the Susquehanna, Potomac, and Rappahannock rivers and other streams. The Coriolis effect from the Earth’s rotation causes a clockwise tidal cycle where cleaner ocean water washes north up the Western Shore of the bay and more turbid river runoff flows south along the Eastern Shore.

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4 The 64,000 square mile Chesapeake watershed extends 400 miles from Cooperstown, NY (home of  
5 the Major League Baseball Hall of Fame) to the Atlantic Ocean and drains parts of six states and the  
6 District of Columbia. In 2010, 16 million people lived in the bay watershed or double the population  
7 recorded in 1950. Every year, 200,000 people move to the bay to work in the Washington, Baltimore,  
8 Richmond, and Harrisburg metro areas (Chesapeake Bay Program 2017). While the Chesapeake  
9 watershed holds 5% of the U.S. population and is rapidly urbanizing near the big I-95 highway corridor  
10 cities, overall land use is still rural with 60% forest, 9% wetlands/water, 22% agriculture, and 9%  
11 urban/suburban land.  
12

13 A 2004 study indicates the socioeconomic value of the Chesapeake Bay watershed is worth \$1 trillion  
14 from fishery, recreation, tourism, and agriculture benefits (Chesapeake Bay Watershed Blue Ribbon  
15 Finance Panel, 2003). The bay has valuable blue crab, eastern oyster, clam, and striped bass fisheries that  
16 are threatened by low oxygen dead zones and loss of submerged grasses. Fishery moratoriums have  
17 successfully increased blue crab and striped bass abundance lately while overfishing and pollution  
18 continues to depress oyster and clam shellfisheries.  
19

20 About 10,000 years ago, the glaciers melted and rising sea levels drowned the Susquehanna River  
21 valley and created the Chesapeake Bay. Approximately 3,000 years ago, the indigenous Algonquin tribe  
22 established villages near the bay and hunted with bow and arrow. By 1570, the Native American  
23 population was 24,000 when Father Segnra and eight Spanish Jesuits were among the first Europeans to  
24 discover the Chesapeake Bay.  
25

26 In May 1607 Captain John Smith sailed into the bay to assume an appointment by King James as a  
27 governor of Jamestown and noted the “clear rivers and brooks” which fed a “faire bay” (Horton 2003). In  
28 June 1608, the 27 year- old Smith explored the Chesapeake on a "two to three tons burden" boat to  
29 discover gold and look for the settlers from the Lost Colony of Roanoke.” Smith wrote that oysters "lay  
30 as thick as stones" and sturgeon were so plentiful “than could be devoured by dog or man." and "of fish  
31 we were best acquainted with sturgeon, grampus, porpoise, seals, stingrays ... brits, mullets, white  
32 salmon, trouts, soles, perch of three sorts." In 1683, Chief Machaloha deeded English Quaker William  
33 Penn the land between the Delaware and Susquehanna rivers where only 2,500 Native Americans  
34 remained.  
35

36 In August 1777, Admiral Richard Howe sailed a 270-ship British fleet up the Chesapeake Bay and  
37 landed at Head of Elk, Maryland. and invaded the college town of New-ark, Delaware on a roundabout  
38 campaign to capture Philadelphia. On September 5, 1781, French Admiral de Grasse defeated the Royal  
39 Navy in the Battle of the Chesapeake Bay and 44 days later Lord Cornwallis and 7,000 men surrendered  
40 to George Washington at Yorktown, Virginia near the mouth of the bay thus ending the eight-year  
41 American War for Independence.  
42

43 In 1785, Virginia and Maryland signed a compact that gave ships unimpeded passage through the  
44 Chesapeake Bay and interstate fishing rights in the Potomac River. At Monticello, Thomas Jefferson  
45 urged neighbors to plow contours to prevent soil erosion and somehow found the time to invent the mold  
46 board plow, a device that eased cultivation but increased soil erosion in the Piedmont where the muddy  
47 James River flowed “like a torrent of blood” (Paul 2001).  
48

49 In August 1814, the British sailed up the Potomac and burned down Washington, D.C. as President  
50 James Madison fled to Virginia and Dolly Madison saved her possessions in the Presidential mansion  
51 where British officers ate the supper prepared for the President. The British marched to capture  
52 Baltimore on September 13, 1814 but Fort McHenry withstood the bombardment and an inspired Francis  
53 Scott Key wrote the “The Star Spangled Banner”.  
54

55 In 1829, Irish laborers dug the sea level Chesapeake & Delaware Canal along the narrow 12-mile  
56 waist of Delaware that connected the Chesapeake and Delaware bays and the Delmarva Peninsula became  
57 an “island”.  
58

59 In July 1861 at Manassas, Virginia, Confederate forces under Stonewall Jackson halted Union troops  
60 at the First Battle of Bull Run, a tributary to the Potomac. In December 1862, the Confederate Army  
61 killed 12,000 Union soldiers at Fredericksburg along the Rappahannock near George Washington’s  
62 birthplace. During July 1-3, 1963 at Gettysburg, Pa., the Union halted Robert E. Lee’s advance on  
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4 Harrisburg and Philadelphia at the “high water mark” of the Confederacy. On April 9, 1865, the South  
5 surrendered to the North at Appomattox Court House near the headwaters of the James River. Five days  
6 later Abraham Lincoln was shot at Fords Theatre in Washington, D. C. and his assassin John Wilkes  
7 Booth was later captured trying to swim across the Potomac River from Maryland to Virginia.

8  
9 In 1880, 20 million bushels of oysters were harvested by 7,600 oyster boats berthed in Maryland and  
10 Virginia. By 1890, 70% of the forests between Washington and Baltimore were cut down and the  
11 Joppatowne port near Baltimore was closed in 1897 due to siltation from the deforested watershed (Paul  
12 2001).

13 In 1924, the Governors of Maryland and Virginia held the first joint meeting to manage the  
14 Chesapeake blue crab fishery (Ernst 2003). In 1933, the U. S. Bureau of Fisheries held a regional  
15 Chesapeake Bay conference in Baltimore that recommended an interstate, bay-wide crab fishery  
16 management plan. In 1937, 30 boxcars a day full of oysters left Baltimore for Chicago (Paul 2001).

17 During the 1950s, bay water quality was good in places as Maryland’s Bernie Fowler saw his white  
18 sneakers wading 6 feet deep in the Patuxent River. In the late 1950’s, Chesapeake oysters were  
19 decimated by MSX and Dermo disease. In 1965, Lyndon Baines Johnson declared in his State of the  
20 Union address that the Potomac River will be a “model of beauty and recreation” for the nation (Ernst  
21 2005). Congress passed the River and Harbor Act and funded a \$15 million Corps of Engineers study to  
22 assess water needs of the Chesapeake Bay through 2020. During the ‘60s, environmental activists formed  
23 the Chesapeake Bay Foundation.

24 In 1970, Richard Milhous Nixon and the Governors of New York, Pennsylvania, and Maryland signed  
25 the Susquehanna River Basin Compact to jointly manage the upper half of the Chesapeake Bay  
26 watershed. In 1972, Congress overturned Nixon’s veto and passed the Federal Water Pollution Control  
27 Act amendments (Clean Water Act) that imposed fishable and swimmable goals for the cleanup of the  
28 waters of the United States. In the same year, activists formed the Alliance for the Chesapeake Bay to  
29 instill public input into bay policy debates.

30 In 1980, the Maryland, Virginia, and D. C legislatures formed the Chesapeake Bay Commission. In  
31 1983, Maryland, Pennsylvania, Virginia, D.C., and EPA signed the voluntary Chesapeake Bay Agreement  
32 as the first estuary restoration program in the U.S. Maryland imposed a moratorium on striped bass  
33 fishing in 1985 and banned phosphate detergent followed by D.C. in 1986, Virginia in 1988, and  
34 Pennsylvania in 1990. The states, D.C., and EPA signed the 1987 Chesapeake Bay Agreement setting  
35 40% nitrogen and phosphorus reduction goals by 2000. In 1988, Maryland State Senator Fowler waded  
36 into the muddy Patuxent River and barely saw his sneakers just a foot deep. In 1997, *Pfiesteria piscicida*  
37 toxins caused by high nutrient loads and warm water temperatures caused blooms, fish kills, and rashes  
38 on bay watermen.

39 During 2000, the Clinton Administration signed the Chesapeake Bay Agreement that set goals to  
40 reduce nutrient and sediment loads by 40% to remove the bay from the EPA impaired waters list by 2010.  
41 Maryland watermen brought in just 20 million pounds of blue crabs, the lowest harvest on record. On the  
42 400<sup>th</sup> anniversary of the circumnavigation of the bay, President G. W. Bush signed the Captain John  
43 Smith Chesapeake National Historic Trail Act as the nation’s first water-based National Historic Trail. In  
44 2008, Maryland and Virginia enacted emergency harvest regulations to reverse sharp declines in blue crab  
45 abundance. The U.S. Commerce Department declared the Chesapeake Bay blue crab fishery a disaster  
46 and issued payments to watermen to replace lost crab income. The Atlantic States Fisheries Commission  
47 imposed a 40-year moratorium on sturgeon fishing in the Chesapeake (and Delaware and Hudson) as  
48 these basins once were the largest sources of caviar which were shipped for consumption to Russia.

49 In May 2009 President Barrack Obama issued Executive Order 13508 directing Federal agencies to  
50 restore the Chesapeake as a national treasure. In 2010, EPA Administrator Lisa Jackson issued watershed  
51 Total Maximum Daily Loads (TMDLs) ordering states to develop biannual milestones to reduce  
52 pollutants 40% by 2017 and 100% by 2025 to restore the bay to fishable and swimmable Clean Water Act  
53 standards. In December 2010, the EPA approved state Chesapeake Bay watershed improvement plans  
54 (WIP’s) that ushered in a new era of Federal/state cooperation in restoring the USA’s largest estuary.

## The Delaware

The Delaware is the longest undammed river east of the Mississippi, extending 342 miles from the Catskill Mountains near Hancock, NY to the mouth of the Delaware Bay at Cape May. The river is fed by 216 tributaries, the largest being the Schuylkill and Lehigh Rivers in Pennsylvania. The basin contains 13,539 square miles, draining parts of Pennsylvania (51%), New Jersey (23%), New York (18%), and Delaware (8%). About 8 million people live in the Delaware Basin and 16 million people (5% of the nation's population) rely on the river for drinking water (such as New York City and Philadelphia), but the watershed drains only 0.4% of the coterminous United States. New York City draws 50% of its drinking water from three reservoirs located in the Catskill Mountains in the headwaters of the Delaware River. The river is the largest freshwater port in the world (\$19 billion in annual economic activity) yet sustains a recovering shad and striped bass fishery.

About 2,600 years ago, the Lenni Lenape lived in the Delaware Valley, a land they called *Lenapehoking*. In August 1609, Englishman Henry Hudson discovered the Delaware Bay after the *Half Moon* got stuck on a sand bar off Cape May, during his quest for the Dutch East India Company for an inner trade route to Asia. Hudson called the bay *Zuyt* or "South River" and observed that "he that will thoroughly discover this great bay must have a small pinnacle that will draw but four to five feet of water, to sound before him (Kauffman 2010)."

In 1610, British Captain Samuel Argall sailed to the bay and named it for Lord De La Warre, the Governor of Jamestown (Brandt 1981). The native Lenni Lenape called the river *Pautaxat*, *Mariskitton*, *Makerishkisen*, or *Whittuck*. During the 1630s, the Delaware teemed with fish as Dutchman De Vries observed that a single net caught enough perch to feed thirty men and Captain Young wrote back to Europe "of fish here is plenty, but especially sturgeon". In 1682, William Penn landed on the *Welcome* and founded Philadelphia and wrote about six-inch oysters too big to be eaten whole and large sturgeon that played in the river all summer.

As America's first environmentalist, Benjamin Franklin petitioned the Pennsylvania General Assembly in 1739 to remove the fetid tanneries and slaughterhouses near his Market Street print shop and wrote in the Pennsylvania Gazette that Dock Creek was choked with: "hair, horns, guts and skins" and fish "soon floated belly up." In 1769, Franklin led a Philadelphia committee to regulate water pollution between the Schuylkill and Delaware.

On July 4<sup>th</sup>, 1776, the Founding Fathers signed the Declaration of Independence near the banks of the Delaware in Philadelphia, the largest city in America at the time and the 3<sup>rd</sup> largest port in the British Empire after London and Liverpool. On Christmas Day 1776, George Washington crossed the icy Delaware River from Pennsylvania to New Jersey and defeated the Hessians at Trenton, a watershed moment in the American Revolutionary War. In 1778, spring runs of American shad, celebrated as America's founding fish by Pulitzer Prize-winning Princeton author John McPhee, reportedly swam up the Schuylkill from the Delaware River and fed General Washington's starving troops at Valley Forge.

Concerned about polluted drinking water, in 1790 Ben Franklin willed funds to Philadelphia to build the first municipal water system in the U.S (York 2007). In 1801, Philadelphia built the first municipal water system in the United States and later opened a water works on the Schuylkill near the Philadelphia Art Museum. In 1885, Engineer D. Barber from the Philadelphia Water Department meticulously recorded that the Pullman Palace Car Co. built privies for 250 men that emptied into a brook entering the Schuylkill and the J & P Baltz brewery leaked 60 gallons a minute of spoiled beer into the river. The Philadelphia Inquirer wrote in 1897 about a Philadelphia councilman who mistakenly thought the drinking water in his glass was lemonade. In 1904, contaminated drinking water in Philadelphia caused 44 typhoid cases prompting boil water alerts.

In 1880, 1,400 sailing vessels took over 20 million pounds of oysters from the Delaware Bay. In 1886, hotels in Gloucester, New Jersey served 10,000 planked shad dinners. In 1896, 4 million pounds of shad were caught in the Delaware with a value of \$400,000. At the turn of the century, the American shad fishery in the Delaware crashed as 3 million pounds were harvested in 1905, down from 16 million pounds in 1900. The collapse of the American sturgeon fishery left Caviar, New Jersey a ghost town.

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4 During World War I, ship builders dumped untreated sewage into the “American Clyde”. During the  
5 “Roaring Twenties”, the Schuylkill was so dirty Philadelphians joked that “people emerged from their  
6 tubs blacker than they had entered them (Kauffman 2010).” Only 200,000 oily shad were caught in the  
7 river. In 1930, Philadelphia discharged sewage in layers 12 feet thick that unveiled sulfur fumes that  
8 drove sailors to sleep in port rather than in their berths.

9  
10 In 1927, the first interstate compact between the Federal government, New York, New Jersey, and  
11 Pennsylvania was proposed to develop a Delaware River reservoir plan but was never adopted. The three  
12 states later created the Interstate Commission on the Delaware River Basin (INCodel) in 1936 as the  
13 first serious watershed plan to clean up pollution.

14 During the Second World War, INCodel called the tidal Delaware River below Trenton “one of the  
15 most grossly polluted areas in the United States.” Shad were unable to swim past the zero oxygen barrier  
16 at Philadelphia to their ancestral upriver spawning grounds. Dumping continued unabated as defense  
17 industries along the river churned around the clock to meet the war effort. Navy pilots flying a mile  
18 overhead were instructed to ignore the sulfur stench from the Delaware River. President Roosevelt  
19 ordered an investigation in 1941 to determine if pollution was hampering the U. S. war effort. The  
20 Schuylkill was so choked with acid mine wastes at the Philadelphia Navy Yard that the British Admiralty  
21 gave officers on HMS Nelson extra allowances to replace gold braid tarnished by the corrosive river  
22 gases.

23  
24 In 1946, pollution from war industries resulted in a U.S. Fish and Wildlife Service report that recorded  
25 all-time worse anoxia from shore to shore. After World War II, the Delaware was a dead river as summer  
26 oxygen hovered at less than 1 mg/l over a 20-mile section from Philadelphia to Marcus Hook. In 1949,  
27 only 38,000 pounds of shad were caught which led to a Pennsylvania law to preserve the shad from  
28 extinction. In 1952, ichthyologist Edward Raney lamented that the Delaware as an “outstanding example  
29 of destruction of (striped) bass habitat by industrial and domestic pollution.”

30  
31 With the war over, INCodel revived its wastewater control program and by 1954 Philadelphia,  
32 Camden, and Wilmington constructed new sewage treatment plants. In 1954, the Supreme Court issued  
33 an amended decree that permitted New York City to withdraw 800 mgd from the Delaware Basin  
34 headwaters in the Catskills provided the City released sufficient water from its reservoirs to benefit  
35 downstream states. In 1955, Hurricanes Connie and Diane hammered the Delaware Basin causing killer  
36 floods that left 99 people dead and caused \$150,000,000 in damages and left an “oily film of silt... and a  
37 terrible stench – an aroma of feces and rotting flesh”. The hurricanes also washed toxic sediments  
38 downstream and temporarily purified the Delaware as shad came back to the river by the late 1950s.

39 In 1961, John F. Kennedy, Jr. signed the Delaware River Basin Compact as the first Federal/state  
40 water accord that appointed five commissioners (the governors of Del., NJ, NY, and Pa. and a  
41 Presidential appointee) to clean up water pollution and address flooding. Congress approved the DRBC  
42 compact noting: “The establishment of a single agency to coordinate federal interests in the Delaware  
43 River Basin is as much importance as the joining together of the four states and the resultant coordination  
44 of the various state activities. In brief, there is one river, one basin, all water resources are functionally  
45 inter-related, and each one is dependent on the other (DRBC 1961).”

46  
47 In 1963, Dr. Harmic of the Delaware Fish and Game Commission remarked “the future outlook for the  
48 shad in the Delaware presents a rather gloomy picture” (Kauffman 2010). By 1966, the Delaware River  
49 Basin suffered through a multi-year drought of record, the driest spell in 100 years as dissolved oxygen  
50 between Wilmington and Philadelphia reached zero during the summer. In 1968, DRBC issued waste  
51 load allocations to 90 Delaware River dischargers to standards more stringent than later required by the  
52 Clean Water Act. Secretary of the Interior Stewart Udall who originally advised JFK to oppose the  
53 DRBC due to unconstitutionality stated: “Only the Delaware among the nation’s river basins is moving  
54 into high gear in its program to combat water pollution” (DRBC 2017).

55  
56 During the 1970s, the Delaware River was still polluted as American shad landings were down to  
57 500,000 pounds; 30 times lower than late 19<sup>th</sup> century levels. Ichthyologist M. E. Chittendon concluded  
58 that “gross pollution of tidal freshwater had extirpated the striped bass from its historical chief spawning  
59 and nursery areas in the Delaware River.” and later asserted that due to water quality concerns and threat  
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of a Tocks Island dam at the Delaware Water Gap the “extirpation of the remnant (shad) runs is a distinct possibility” (Kauffman 2010).

During the 1980s, dissolved oxygen levels in the Delaware were rising as Trenton, Philadelphia, Camden, and Wilmington tapped over \$1.5 billion in EPA Clean Water Act funds to construct new wastewater plants that treated over 700 mgd of sewage. The DRBC reported that dissolved oxygen improved from 2 mg/l in 1968 to 5 mg/l by 1987. By 1988, DRBC historian Richard Albert called the Delaware Estuary cleanup “one of the premier water quality success stories in the United States” as water quality was better than any time in a century due to wastewater treatment, reforestation, agriculture conservation, and acid mine drainage cleanup programs.

By the 1990s, striped bass and American shad returned in large numbers and a revived Delaware Bay recreational fishery was worth \$25 million per year. In 1993, fisheries biologists found increased American shad, striped bass, and white perch landings statistically correlated with improved water quality in the Delaware. Dissolved oxygen in the Delaware at Philadelphia improved from 1 mg/l in 1958 to 5 mg/l by 1995. In 1996, over 90% of the Delaware Estuary met the fishable and swimmable goals of the Federal Clean Water Act. William D. Ruckelshaus, Nixon’s first Administrator of EPA remarked: “Looking back, the DRBC was the vanguard in the Johnny-come-lately march to manage water resources on a watershed basis.

By 2000, the Philadelphia Water Department reported “the Delaware River is a much healthier river now than it was over the past century. In 2003, the Lehigh River, the second largest tributary to the Delaware, was “cleaner than it had been in the last 150 years” mainly due to acid mine cleanup programs (Kauffman 2010). In 2005, 200,000 shad were caught at Lambertville, NJ. Delaware recreational anglers landed 20,000 striped bass weighing 250,000 pounds.

During 2010, the Delaware continued its revival with an abundant \$7 million blue crab shellfishery. For the first time in 50 years, Delaware fisheries biologists caught a 7-inch juvenile Atlantic sturgeon in the river near Wilmington. Over 50 bald eagle pairs returned to cleaner Delaware waters, even nesting in South Philadelphia in 2007. Delaware and New Jersey planted 500,000 shells for oyster restoration in the bay. By 2011, Congress designated 300 river miles in the Delaware Basin to the National Wild and Scenic River system.

## **The Hudson**

In a foreword to the “The Riverkeeper” by John Cronin and Robert F. Kennedy Jr. (1997), Vice President Al Gore wrote: “During the 1960s, the Hudson River was polluted, so polluted that some considered it to be dead ... the Hudson has shown a remarkable resilience in bouncing back from years of neglect.”

The Hudson River flows from Lake Tear in the Clouds from 4,293 feet Mount Marcy in the Adirondacks down past Albany and West Point to New York Harbor at the tip of Manhattan. While the 315-mile long Hudson is just the 85<sup>th</sup> largest river in the U.S., the Hudson Fjord is one of the nation’s longest estuaries, navigable to ocean-going shipping for 150 miles inland to the head of tide at Troy, New York (Henshaw 2011). The 13,000 square mile Hudson Basin drains parts of New York, New Jersey, Massachusetts, and Vermont and three mountain ranges, the Berkshires, Catskills, and Adirondacks. Cutting through the Appalachians, the Hudson is the only river in the U.S. with sea level passage through a major mountain range (Suszkowski and D’Elia 2006).

Known as “America’s Rhine”, the Iroquois called it *Muh-he-kun-ne-tuk* and the Lenape called it *Muhheakantuck* or “the river that flows both ways” (Suszkowski and D’Elia 2006). Henry Hudson named it *Mauritius*, the “River of Mountains”. The Dutch called it the North River (the Delaware was the South River). During the 19<sup>th</sup> century, the rugged valley and 1,300 ft Storm King Mountain inspired the Hudson River School, an American style of pastoral landscape painting popularized by artists Thomas Cole, Frederic Edwin Church, and Albert Bierstadt. The romantic river provided the muse for authors Washington Irving (*Rip Van Winkle*), James Fennimore Cooper (*Last of the Mohicans*), and Hermann Melville (*Moby Dick*).

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4 The Hudson River, though still impaired, is recovering. Mercury levels in fish fillets have declined  
5 along the Hudson from the Adirondacks to New York City. Dissolved oxygen levels have improved near  
6 the City due to sewage treatment improvements that began in the 30s (NYDEP 2002).

7 About 10,000 years ago, the Wisconsin glaciers retreated north and the rising sea filled the incised  
8 valley creating the Hudson River, a drowned river system. Off the coast, the ancient riverbed follows the  
9 Hudson Canyon far out from New York Harbor to the edge of the Continental Shelf and good blue fin  
10 tuna fishing.

11 In 1524, Italian mariner Giovanni Da Verrazano was the first European to sail through the narrows  
12 between Staten Island and Long Island into New York Harbor. In August 1609, Englishman Henry  
13 Hudson sailed the “*Half Moon*” up the Hudson and noted the river “abounds in trees of every description”  
14 (Suszkowski and D’Elia 2006). After sailing 10 days with the tide for 100 miles through the Appalachian  
15 Gap, Hudson was on the way to find an inner passage to Asia but his quest was cut short by the  
16 impassable falls above Albany at Troy. Hudson did not succeed in his original mission to find an inner  
17 trade route for the Dutch East India Company but he claimed the valley and its rich fur trade for the  
18 Dutch, a reign that lasted half a century with cultural influences that last to this day.

19 In 1664, the English took over the colony of Manhattan Island from the Dutch. A Dutch minister  
20 visited Albany in 1679 and wrote that clear water flowed over the falls at Albany (Suszkowski and D’Elia  
21 2006). By 1730, much of the land along the eastern bank of the Hudson was cleared by logging and  
22 agriculture.

23 In August 1776, the British landed 22,000 men on Long Island and defeated the Americans at  
24 Brooklyn Heights. Only a miraculous nighttime evacuation by boat to Manhattan prevented a total rout  
25 of Washington’s forces during the largest battle of the war. In September the British under General Howe  
26 captured New York City. In October 1777, the British under General Burgoyne headed south from  
27 Canada through Lake Champlain with plans to capture Albany and advance down the Hudson River to  
28 New York City. An 8,000-man army under General Gates defeated the British at Saratoga, the first major  
29 American victory of the war.

30 In 1807, Robert Fulton captained his steam boat from New York City to Albany, signaling a new era  
31 of transportation but with this progress brought an appetite for burning wood for steam that consumed  
32 whole forests along the Hudson. By 1925, Governor DeWitt Clinton completed the Erie Canal that  
33 connected the Hudson with points west to the Great Lakes and made New York City a hub of commerce  
34 and finance. In 1829, the Delaware and Hudson Canal across New Jersey connected the Hudson to the  
35 Pennsylvania coal fields, Canadian fur trade, and agriculture of the Midwest.

36 In 1855, New York State passed the Harbor Commission Act that regulated navigation. Harpers  
37 Weekly published an 1870s cartoon about “Father Hudson” who complained about the dirty river. In  
38 1885, New York protected the Adirondack Park as “forever wild” in a constitutional amendment that  
39 protected the Hudson headwaters from the political whims of Governors and legislatures. In 1890, the  
40 New York Times called the New York City sewerage system an “abomination” due to rampant sludge  
41 dumping in New York Harbor (Suszkowski and D’Elia 2006).

42 In 1906, New York State formed the Metropolitan Sewerage Commission to reduce raw sewage  
43 dumping into the Hudson River and New York Harbor. A year later, George Soper, a sanitary engineer  
44 for the NYC Health Department, tracked down the source of an epidemic to cook “Typhoid Mary”.

45 In 1931, New York City developed a financing plan and began construction of a new sewerage system  
46 as one of the great public works jobs projects during the Great Depression (Suszkowski and D’Elia 2006).  
47 In 1936, New Jersey, New York, and Connecticut adopted the Tri-State Compact and formed the  
48 Interstate Sanitation Commission to develop water quality standards and build sewage treatment plants  
49 along the Hudson River and New York Harbor.

50 During the 1960s, the New York Times condemned the Hudson as an open sewer. In 1964, New York  
51 City finished the Delaware Aqueduct that transported drinking water 100 miles from the pristine  
52 Delaware Basin headwaters in the Catskills to the impaired Hudson Basin. In 1966, New York  
53 Congressman Ottinger pushed legislation for a Hudson River Scenic Riverway Compact but the  
54 congressional deadline expired in 1974. Governor Rockefeller established a state Hudson River Valley  
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Commission but it lost support (Suszkowski and D'Elia 2006). Folksinger Pete Seeger founded the Hudson River Sloop Clearwater in 1966 that provided river awareness and later helped to force General Electric to clean up PCB contamination (Cronin and Kennedy 1997).

During the 1970s, the Rockefeller Foundation funded the Hudson River Basin project that recommended strengthening environmental management institutions but the recommendations were never implemented. The U.S. Army Corps of Engineers commissioned a 1976 Hudson River Level B study that assessed water conditions through 2000 but these recommendations were never implemented (Suszkowski and D'Elia 2006).

In 1976, the New York State Department of Environmental Conservation issued a report that closed the Hudson's commercial fisheries due to PCB contamination in fish tissue. In 1977, General Electric plants at Ft. Edwards and Hudson Falls, New York released 1.3 million pounds of PCBs, a carcinogen, into the river. By 1983, EPA declared 200 miles of the Hudson River from New York City to north of Albany as a Federal Superfund site (Suszkowski and D'Elia 2006). In 2002, EPA issued a decision calling for dredging and removal of over 2.5 million cubic yards of PCB sediment from a 40-mile reach of the Hudson. In 2009, GE began dredging PCBs from the Hudson.

In 1962, Consolidated Edison proposed a pump storage power plant at Storm King Mountain. The Hudson River Fishermen's Association (now Hudson Riverkeeper) challenged the proposal with a final settlement in 1980. As part of the settlement, ConEd provided a \$12 million endowment for environmental policy and science research at the Hudson River Foundation, a one of a kind financing mechanism for a US non profit (Cronin and Kennedy 1997).

During the 1970s, the City of New York proposed to rebuild the 4-mile West Side Highway (Westway project) and create 200 acres of landfill in Manhattan. The City filed a U.S. Army Corps of Engineers Section 404 Clean Water Act Wetland Permit and an Environment Impact Assessment under the 1969 National Environmental Policy Act. The EIA field studies found the highway would impact 25% of the juvenile striped bass population in a wintering area along the Hudson River. The Corps of Engineers approved the permit with a January 1985 finding that the striped bass in the Hudson would not be negatively impacted. The Sierra Club challenged the Corps in court and the court overturned the permit in August 1985 (Cronin and Kennedy 1997).

In 1982, the 750-foot tanker "Palm Beach" was caught flushing out its oil tanks and refilling with Hudson River water to transport to an Exxon oil refinery in arid Aruba. Exxon was fined and required to transmit \$41.5 million to the state and \$0.5 million to the Hudson River Fisherman's Association (now Hudson Riverkeeper).

During 1987, Robert F. Kennedy Jr. set up the Pace University environmental law clinic as the first legal arm of the Hudson Riverkeeper. RFK Jr. sued Hudson River polluters based on the public trust doctrine of U.S. water law (the people own the river) that is embedded in modern environmental statutes such the Clean Water Act, Clean Air Act, Endangered Species Act, and National Environmental Policy Act. The ConEd Storm King Mountain project during the 60s was a landmark legal battle over the right to a clean environment that was largely responsible for passage of NEPA by Congress in 1969. In 1995, RFK Jr. and Hudson Riverkeeper were involved when New York Governor Pataki, Mayor Guiliani, and EPA announced an agreement to implement a watershed plan to protect the reservoirs that deliver over a billion gallons of water daily to New York City.

In 1988, Congress designated the Hudson River Estuary Program and New York/New Jersey Harbor Estuary Program as estuaries of national significance as part of the National Estuarine Research Reserve System funded by the National Oceanic and Atmospheric Administration. In 1987, New York State passed the Hudson River Estuary Management Act to protect the estuary from Troy Dam to NY Harbor. During 1991, the State of New York designated the Hudson River Greenway with a mission of preserving scenic, historic, and cultural resources of Hudson Valley. By 1993, the Hudson River Foundation funded research on a declining Atlantic sturgeon population that led to moratoriums on commercial fishing by New York and New Jersey (Suszkowski and D'Elia 2006).

## Discussion

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5 While sharing similar hydrology and history, each of these contiguous, multistate basins is managed  
6 with varying emphasis on governance ranging from voluntary Federal-driven agreements in the  
7 Chesapeake Bay, a compulsory Federal-state basin compact for the Delaware River, and grassroots  
8 riverkeeper advocacy on the Hudson River.  
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10 **Chesapeake:** The Chesapeake Bay cleanup is driven by a voluntary Federal-state partnership coupled  
11 with a river basin commission in the headwaters. The EPA hosts and funds the Chesapeake Bay Program  
12 through the Clean Water Act and National Estuary Program. The voluntary Chesapeake Bay Agreement  
13 was signed by the watershed states (Delaware, Maryland, New York, Pennsylvania, Virginia, and West  
14 Virginia), District of Columbia, and EPA. In the upper half of the basin, the bay's two largest tributaries  
15 are governed by the Susquehanna River Basin Commission (between Maryland, New York,  
16 Pennsylvania, and United States) and Interstate Commission for the Potomac River Basin (between  
17 Maryland, Pennsylvania, Virginia, and United States). The bay has a long history of activism influenced  
18 by a blend of nonprofits such as the Chesapeake Bay Alliance and Chesapeake Bay Foundation. If the  
19 density of capital cities in a watershed is a measure of political will toward restoration, then the  
20 Chesapeake ought to have a good chance of recovery as the basin includes the capitals of Maryland,  
21 Virginia, and Pennsylvania and the seat of Federal power along the banks of the Potomac.  
22

23 **Delaware:** The Delaware is the only basin governed entirely by compulsory interstate compact by a  
24 single coordinating entity. In 1961, JFK signed the Delaware River Basin Commission compact as the  
25 first Federal-state watershed accord to govern a basin as a single administrative agency. The DRBC  
26 governs by comity (one seat, one vote through a principle of reciprocal courtesy between the  
27 governments) by five commissioners representing the Governors of Delaware, New Jersey, New York,  
28 and Pennsylvania and President of the United States. The Partnership for the Delaware Estuary provides  
29 a science-based approach to the tidal Delaware as one of the 28 congressionally designated estuaries in  
30 the National Estuary Program. Over 300 river miles in the Delaware Basin are protected by the National  
31 Park Service through the National Wild and Scenic Rivers Act.  
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33 **Hudson:** The Hudson Basin is protected by effective and committed nonprofit environmental groups  
34 such as the Hudson River Fisherman's Association, Hudson Riverkeeper, and Hudson River Greenway  
35 that grew out of the social activism of the turbulent 60's. Pete Seeger's Clearwater Sloop continues to  
36 reflect public attention on the health of the Hudson. The states never adopted the concept of an interstate  
37 Hudson Basin compact during the 1930s and 1960s. Today, a semi-formal interstate basin approach (up  
38 to the head of tide at Albany) is provided by the Hudson River Estuary Program and the Interstate  
39 Sanitation Commission between New York, New Jersey, and Connecticut.  
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## 42 **Concluding Remarks**

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44 The discovery, decline, and recovery of the Chesapeake, Delaware, and Hudson rivers basins is the  
45 story of America's formative watersheds. The era of discovery began when the first Europeans explored  
46 the pristine Atlantic Coast of the New World at the turn of the 17<sup>th</sup> Century and continued through  
47 colonization and American victory after the Revolutionary War. The era of environmental decline and  
48 degradation of the rivers and bays began around the turn of the 19<sup>th</sup> century with expansion and  
49 industrialization, the strife of the Civil War, water-borne epidemics, the First World War, and the Great  
50 Depression. Recovery of the waterways began in earnest after the Second World War when the United  
51 States began to turn its attention to domestic concerns with environmental regulation and Federal Clean  
52 Water Act programs during the 1960s and 70s. River basin governance structures have evolved that  
53 range from voluntary Federal-driven agreements in the Chesapeake Bay, a compulsory Federal-state basin  
54 compact for the Delaware River, and grassroots riverkeeper advocacy on the Hudson River. The birth  
55 and expansion of the American Republic was influenced by these historic Mid-Atlantic watersheds and  
56 after a precipitous decline these rivers are alive once again.  
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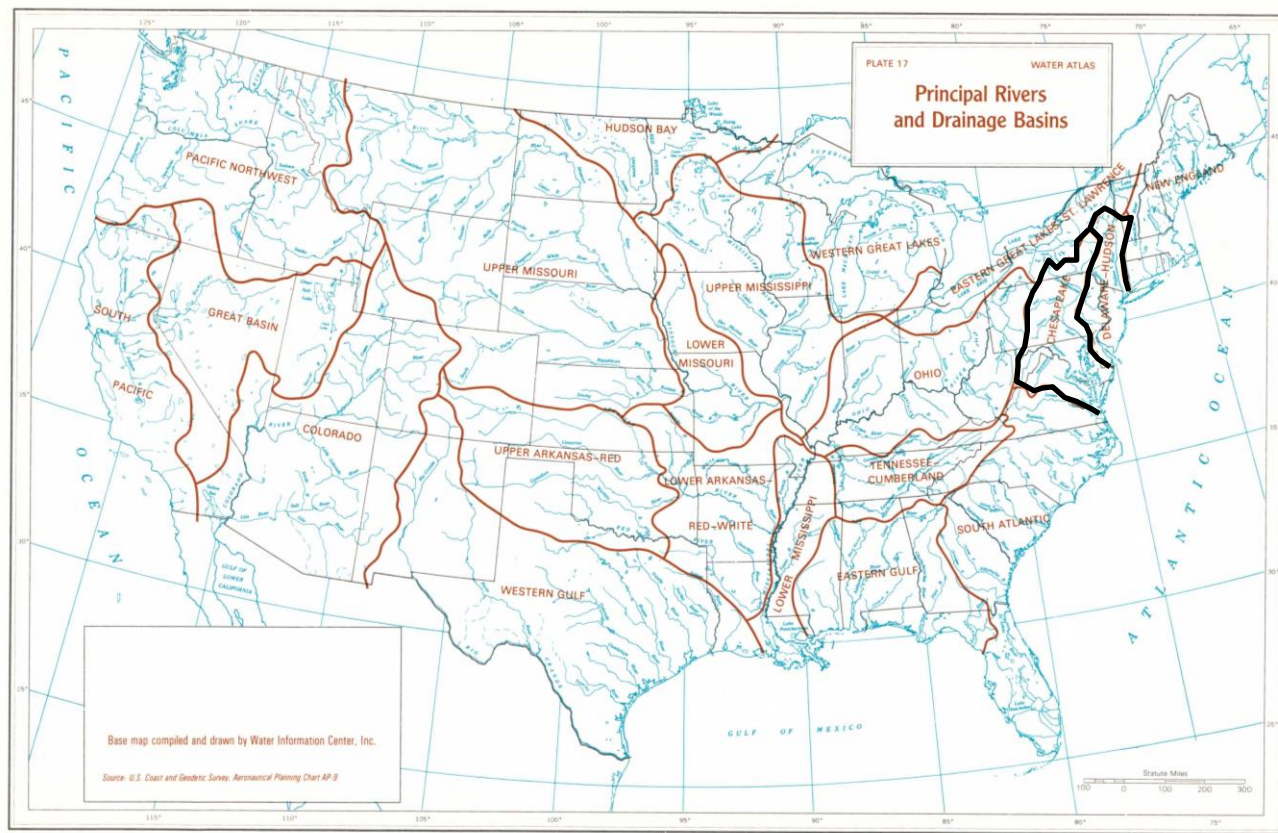
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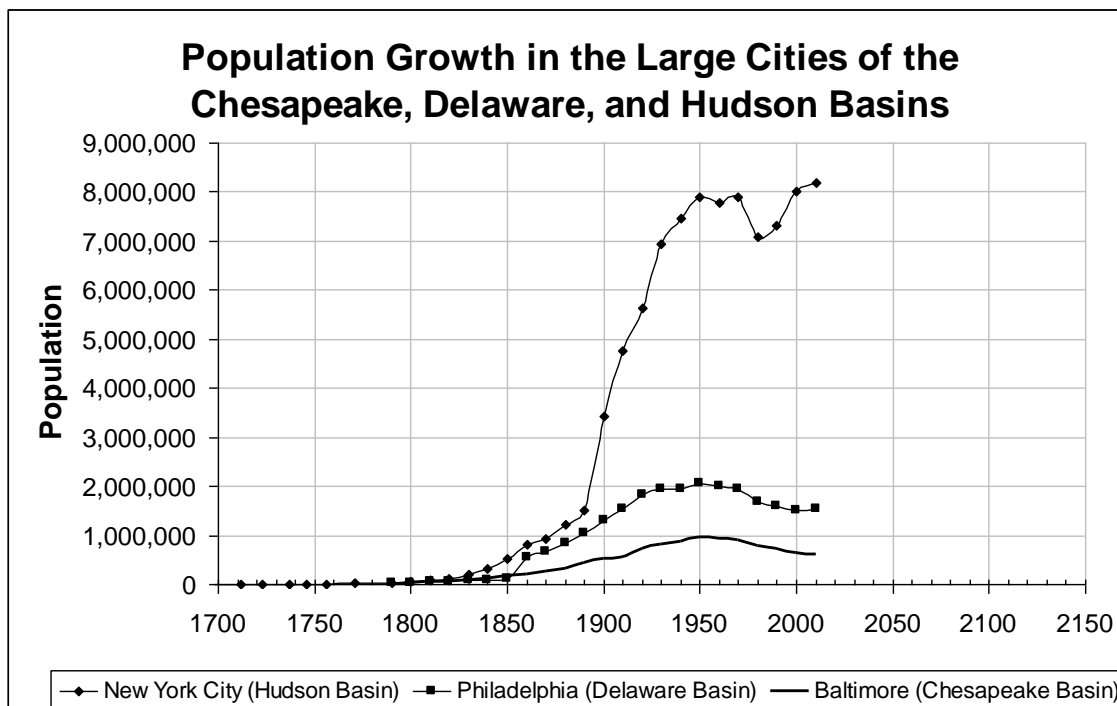


**Figure 1.** Principal Rivers and Drainage Basins of the United States including the Chesapeake Bay and Delaware/Hudson Rivers (Geraghty et al. 1973)





**Figure 2.** Historic map of the Chesapeake, Delaware, and Hudson basins



**Figure 3.** Population growth in the large cities of the Chesapeake, Delaware, and Hudson basins (U.S. Census)



**Table 1.** Comparative qualities of the Chesapeake, Delaware, and Hudson basins

Quality	Chesapeake	Delaware	Hudson
Founded	1570 Father Segura	1609 Henry Hudson	1524 Giovanni Da Verrazano
Basin Area (mi <sup>2</sup> )	64,000	13,600	13,400
River Length <sup>1</sup> (mi)	449	342	317
Population (million)	16	8	12
Metropolitan Economy (Rank)	5th	7th	1st
States	DE, MD, PA, NY, VA, WV, D.C.	DE, NJ, NY, PA	NY, NJ, CN, MA, VT
Major Cities	Baltimore	Philadelphia	New York City
Capitals	Washington, D.C Annapolis, MD Richmond, VA Harrisburg, PA	Trenton, NJ Dover, DE	Albany, NY
Agriculture	22%	26%	25%
Wooded	58%	55%	60%
Luminaries	Captain John Smith Thomas Jefferson Richard Nixon, Barack Obama	William Penn Ben Franklin George Washington, John F. Kennedy	Henry Hudson, Robert F. Kennedy, Jr.,
Governance	Chesapeake Bay Program, Susquehanna River Basin Interstate Comm. Potomac, Chesapeake Bay Foundation, Chesapeake Bay Commission	Del. River Basin Commission Partnership for Del. Estuary Delaware River Keeper	Hudson Riverkeeper, Hudson River Estuary Prog. Hudson River Greenway Interstate Sanitation Comm.