The Chesapeake Bay

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1. *Overview*

The Chesapeake Bay is the largest of more than 100 estuaries in the United States and the third largest in the world. It is located on the east coast of the U.S., stretching about 322 km from Havre de Grace, Maryland to Virginia Beach, Virginia. The Bay's width varies between around 6.4 km near Aberdeen in Maryland to 19.3 km near Cape Charles Virginia. The surface area of the Bay and its tidal tributaries is more than 11,600 km^2 with more than 18,000 km of shoreline. Its average depth is 6.4 m and its deepest point is 53 m and it holds more than 74 km^3 of water.

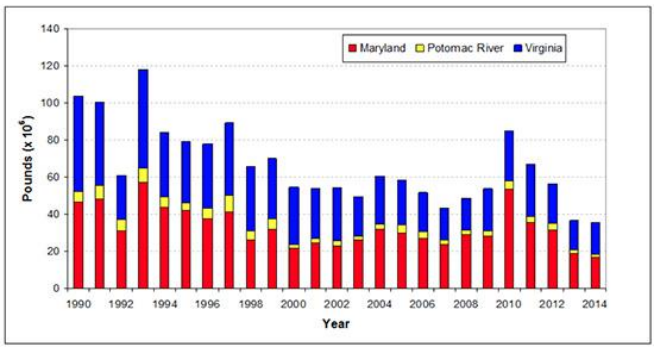
The Bay watershed stretches 843 km from Cooperstown, New York, to Norfolk, Virginia and drains a land area of 166,000 km^2. The Chesapeake Bay's land-to-water area ratio is 14:1, the largest of any coastal water body in the world, which is why our actions on land have such a big impact on the Bay's health. Over 18 million people live in the Chesapeake Bay Watershed, with 10 million living near the coast.

The Bay receives about half of its water volume from the Atlantic Ocean. The rest drains into the Bay from many streams and rivers in a catchment area that includes parts of six states New York Pennsylvania, Delaware, Maryland, Virginia, West Virginia, and all of the District of Columbia. Three rivers, the Susquehanna Potomac and James collectively provide more than 80% of the Bay's fresh water source, with the Susquehanna being the largest river accounting for about 50% of the total fresh water inflow.

The Bay was created approximately 18,000 years ago by the melting of glaciers that resulted in the network of streams and rivers that are flowing into the Bay. As sea level rose, it submerged the Susquehanna River Valley and by around 3,000 years ago had formed the Chesapeake Bay as we know it today.[1]

The Chesapeake Bay region enjoys a rather moderate mid-latitude climate with an average temperature of around 11°C and monthly precipitation of about 87 mm.[2] The Chesapeake Bay also has a moderating effect on the area keeping summer and winter temperatures from reaching extremes.

More than 3,600 species of plants and animals depend upon the Bay for survival. This vibrant ecosystem supports several major fisheries on the East Coast of the U.S. The Bay produces about 250,000 tons of seafood per year. More than 800 thousand tons of blue crabs have been harvested from the Bay since 1990, but the harvest has been steadily declining, and at 17,500 tons in 2014 was the lowest ever recorded.[3] The Bay is also a major



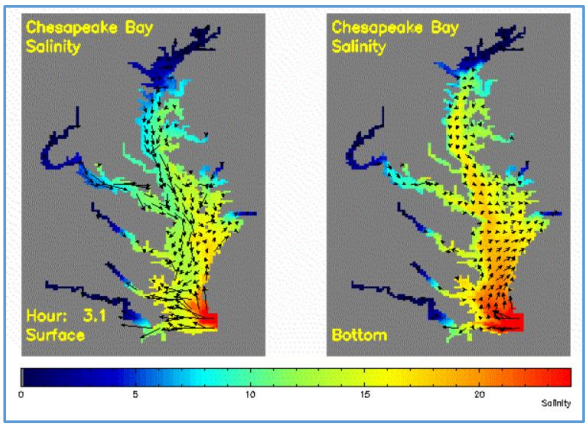
East Coast spawning ground for many species, including seventy to ninety percent of all striped bass, which sustains a very popular recreational and commercial fishery up and down the East Coast of the U.S.

2. Water Quality of Chesapeake Bay

About half of the water in the Bay comes from the Atlantic Ocean, causing the Bay's salinity to gradually increase from the north to south. Salinity ranges from freshwater at the Bay's head to water of oceanic salinity at the Bay's mouth and the water in the bay is brackish -- a mixture of salt and fresh water. Salinity also fluctuates widely between seasons and years due to the changes in fresh water volume flowing in from its rivers.

Circulation of the Bay's water is primarily driven by the interaction of fresh and salt water. The salty water from the sea, surface warming by the sun and river flow into the Bay from its watershed combine to create two layers of water in the Bay with distinct characteristics: 1) a top layer with warmer, lighter, fresh water flowing toward the ocean; and, 2) a bottom layer with saltier, denser water flowing into the Bay. This phenomenon, called stratification, varies seasonally and with changes in rainfall. Rapid vertical mixing of the two layers usually occurs in the autumn, exchanging nutrients and oxygen between the two layers.[4]

The figure below illustrates the salinity distribution in the surface and bottom waters of the Bay.[5] This two layer system forms a very effective trap for pollutants entering the Bay from its rivers. As the river flow enters the



wide Bay, it slows down and pollutants settle out only to be carried back up into the Bay by the landward flowing bottom waters.

The two-layer flow system is also the main cause of the "dead zone" in Chesapeake Bay that is created when excessive nutrient runoff from the watershed fuels algae blooms in the Bay and its tributaries. As the algae die and settle into the bottom waters, the process of decay consumes oxygen in the deeper water. Because of the density stratification caused by warm, fresh water on the surface and cooler, salty water on the bottom, the deeper water is not reoxygenated and becomes inhospitable to most marine life – "dead".[6]

Due to the combination of nutrient and sediment pollution from the watershed and the circulation and stratification of the Bay, much of the Bay does not meet water quality standards established by the States of Maryland and Virginia and the District of Columbia, as required by the federal Clean Water Act. The U.S. Environmental Protection Agency reports that 80% of of the waters of the Bay and its tributaries are at least partially impaired (i.e. do not meet water quality standards) by toxic contaminants, like mecury and PCBs. All of the Bay and its tidal tributaries are also impaired by nitrogen, phosphorus and sediment.[7]

3. The Restoration of Chesapeake Bay

The restoration of water quality in Chesapeake Bay began with the passage of the 1972 amendments to the Federal Water Pollution Control Act, which became known as the "Clean Water Act". The objective of the Clean Water Act *"is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters."* The Act established the regulatory programs to control pollutant discharges and gave the U.S. EPA the authority to work with the states to implement those programs. The Act established the national discharge permit program to control pollution from industrial and municipal wastewater, the construction grants program to finance municipal wastewater treatment systems and required states to establish planning processes to control pollution from other more diffuse sources, referred to collectively as nonpoint source pollution.[8]

Due to growing concerns about the decline in Chesapeake Bay water quality and the health of aquatic life, in the late 1970s, the U.S. Congress appropriated $27 million for a five-year study to analyze the Bay's decline. The study, published in 1983, identified excess nutrient pollution as the main cause of the Bay's degradation. That same

year, Maryland, Virginia, Pennsylvania and the District of Columbia, the federal government, represented by the US Environmental Protection Agency, and the Chesapeake Bay Commission, a multi-state legislative body, signed the first Chesapeake Bay Agreement. With this simple, one page agreement, the parties agreed that the Chesapeake Bay was threatened by pollution from a variety of sources and resolved to work together to correct the identified problems in order to restore and maintain the Bay.[9]

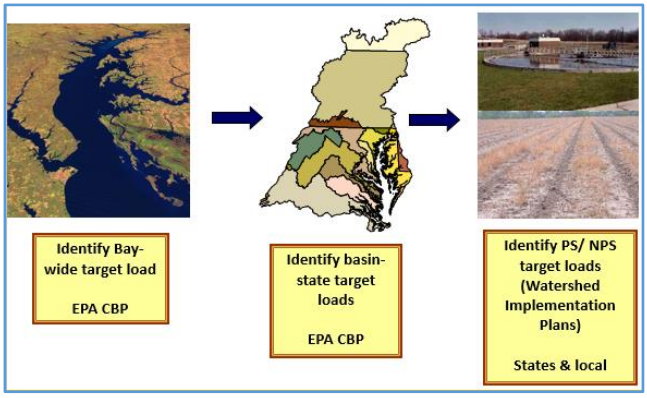
Between 1983 and 2000, when the Bay agreement was updated, it had grown to include a wide range of commitments for living resource, vital habitat and water quality protection and restoration, sound land use management, citizen stewardship and community engagement. Vital habitat protection and restoration includes not only the Bay and its tidal tributaries, but also the land and thousands of streams, rivers and wetland areas that make up the Bay's watershed. It also includes a commitment to work with local governments, community groups and watershed organizations to develop and implement watershed management plans for the purposes of improving habitat and water quality, stream flow and water supplies.

In 2014, the Chesapeake agreement was reaffirmed and became the Chesapeake Bay Watershed Agreement, which builds upon the prior agreements' broad scope and the jurisdiction's efforts to restore and protect the entire watershed, with the vision statement: *"The Chesapeake Bay Program partners envision an environmentally and economically sustainable Chesapeake Bay watershed with clean water, abundant life, conserved lands and access to the water, a vibrant cultural heritage and a diversity of engaged citizens and stakeholders."*[10]

As the 2014 Chesapeake Bay vision statement clearly articulates, the restoration of the Bay requires much more than pollution control alone. The living resources that make up the ecosystem and the lands that make up the watershed must also be restored and protected. And all of it must support the needs and culture of the human population that depends upon and sustains the Bay and its watershed.

4. The Chesapeake Bay TMD

Clean water is the first part of the vision and provides a critical foundation for the restoration. The mechanism for ensuring clean water is obtained that was established by the federal Clean Water Act is the Total Maximum Daily Load (TMDL).[11] The TMDL was developed using the extensive monitoring, scientific studies and computer modeling systems established by the Chesapeake Bay Program beginning with its creation in 1983.[12] The water quality and hydrodynamic models of the Bay and associated scientific information were used to determine how much reduction in nitrogen, phosphorus and sediment would be needed to meet water quality standards in the Bay. The atmospheric deposition, land use practice and watershed models were then



used to determine a 'pollution budget' for nitrogen, phosphorus and sediment and sets load caps for all pollution sources in the portions of six Bay states and the District of Columbia that drain to the Bay and its tidal tributaries. The TMDL was developed by EPA with the agreement and support of all of the Bay Program jurisdiction and was adopted on December 31, 2010. It requires that all pollution control measures needed to fully restore the Bay and its tidal rivers are in place by 2025.

In order to ensure that the pollution reduction goals set in the TMDL are achieved by the jurisdictions, EPA required each jurisdiction to develop a Watershed Implementation Plan (WIP) with 2-year "Milestone" goals. The WIP describes the programs and policies that the jurisdiction either already has or will put in place to achieve the necessary pollutant load reductions. The 2-year Milestone Goals define the short-term actions each jurisdiction will take over each two year period to evaluate progress and make adjustments to improve its WIP in order to stay on track to achieve the goals. The WIPs describe the actions being taken by the federal government and the jurisdictions in detail, including: cutting air emissions of NOx from power plants and mobile sources, conserving and restoring forests and

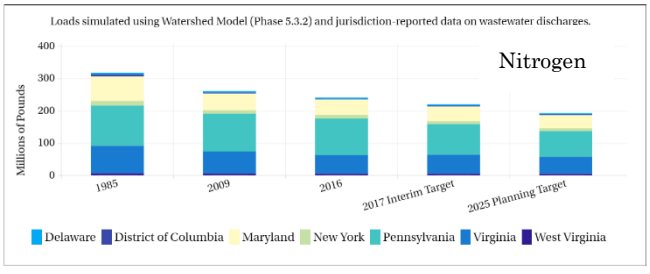
wetlands, upgrading wastewater treatment plants, improving agricultural practices to reduce manure and fertilizer applications, control erosion and runoff, controlling urban runoff and upgrading onsite sewage disposal (septic) systems in rural areas. The WIPs must also include provisions for tracking progress and making further reductions if necessary to offset the pollution impacts of increasing population and associated new development.[13]

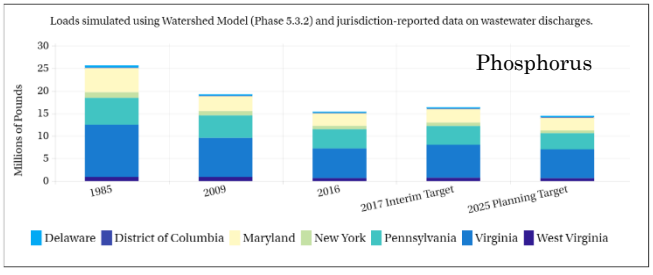
EPA annually evaluates the jurisdictions' progress in WIP implementation and publishes detailed results of its review on line along with a simple "stoplight" chart so the public and other jurisdictions can clearly see where they or other jurisdictions are doing well or falling behind. EPA takes appropriate action in each case to enhance its oversight of the jurisdiction's programs or take "backstop" actions to strengthen jurisdiction's pollution control programs.[14]

5. Progress

The jurisdictions have made significant progress in reducing nitrogen loading to the Bay by 24%. This is about 62% of the way to the 2025 TMDL goal of 39% reduction in nitrogen. Even more progress has been made toward the phosphorus goal, with a 40% reduction achieved, which is 91% of the way toward the ultimate 2025 goal of 44%.

One of many encouraging indications that the pollution reduction efforts are having a strong beneficial impact on the Bay and its tributaries can be seen in the recovery of submerged aquatic vegetation (SAV) in the Bay. The authors of a study published in March 2018 report that *"...since 1984, SAV has regained 17,000 ha to achieve its highest cover in almost half a century. Our study empirically demonstrates that nutrient reductions and biodiversity conservation are effective strategies to aid the successful recovery of degraded systems at regional scales, a finding which is highly relevant to the utility of environmental management programs worldwide."*[15]





6. Future Challenges

The number of people living in the Chesapeake Bay watershed has more than doubled since 1950. Since the Chesapeake Bay Program began intensively monitoring water quality in 1985, the population in the watershed has increased 34% and by 2016 reached 18.1 million people. The economy of the Bay region is strong, attracting many domestic and international migrants that are expected to swell population of the watershed to 20 million by 2030.[16] Continued population growth increases the demand for land development, sewage flows, septic systems and stormwater runoff, which together detract from ongoing Bay pollution control efforts. More people also require more agricultural production and further increases the pollutant loading impacts on the watershed and the Bay. In order to maintain our restoration progress, pollution control efforts will have to be further increased in all these sectors. This requires more innovation and more expensive pollution contol measures, since the traditional and less expensive methods are already being fully employed.

Climate Change also presents multiple challenges, including increasing temperatures, sea level rise and more intense storm events, all of which have major impacts on the physical, chemical and biological integrity of our waters and pose risks to public health, affecting all of us living in the Bay Watershed. Bay waters have risen about one foot in the last 100 years, and

are expected to rise another 1.3 to 5.2 feet (0.4 to 1.6 m) over the next 100 years. The rate of sea level rise in the Bay is faster than many other parts of the world because at the same time the levels are rising due to warming temperatures and melting ice, the land around the Bay is subsiding due to geologic processes and groundwater withdrawals for water supply. As water levels rise, coastal flooding and erosion increases and salt water intrudes into ground water aquifers that many people rely on for their drinking water. Marshes and wetlands are lost to erosion and innundation, reducing valuable coastal habitat that traps pollution entering the Bay and provides food and shelter to fish, shellfish and birds.

Average air temperatures have risen in the northeastern United States almost 2° Fahrenheit (1.1° C) in the last 100 years and are projected to increase another 4.5° to 10° F (2.5° to 5.5° C) in the region by the 2080s.[17] Surface water temperature in the Chesapeake Bay is increasing as well, even more rapidly than air temperature.[18] These rising air and water temperatures pose wide ranging impacts to the human population and the ecosystem of the Bay.

Of immediate concern for human populations living in the watershed is the increased flooding that is already occuring in the region due to more frequent and intense storm events. Analysis of historical data indicates that since 1958 in the Northeastern U.S. there has been a 70 percent increase in the amount of rainfall measured during heavy precipitation events—more than any other region in the nation.[19] This not only causes severe flooding, loss of life and property damage, but it also causes more pollution to be carried into the Bay and its tributaries, making water quality restoration even more difficult.

7. Conclusion

The Chesapeake Bay Region faces many of the same pressures as the rest of the world's coastal waterways. Because the Bay is long and narrow, with a very large watershed and a circulatory system that tends to trap pollutants, it presents a very difficult restoration challenge. But the Bay has also been the focus of one of the longest-running and most comprehensive restoration efforts in the world. There are many facets to the restoration. The most recent watershed agreement, signed in 2014, has 10 major goals in 5 categories: abundant life; clean water, climate change, conserved lands and engaged communities. The restoration goals are wide-ranging, from sustainable fisheries and vital habitats, to clean water and healthy watersheds, to public access and environmental literacy.

Ensuring achievement of these goals is an ongoing, adaptive management process. Right now in 2018, the Bay Program is conducting a reevaluation of the pollutant reduction goals needed to meet water quality standards for the Bay and its tributaries (called the TMDL Mid-point Assessment). The reevaluation is being guided by the latest scientific, monitoring and computer modeling information available to ensure that the restoration goals are accurate, that the effects of climate change and other factors are being properly accounted for and that the jurisdiction's WIPs are on track to achieve the specified goals. The reevaluation will result in refinements to the goals and WIPs to ensure the ultimate objectives of the restoration will be achieved in the face of any new challenges identified for the Program.[20]

The Chesapeake Bay restoration efforts have been successful so far, but we have learned that it will take a concerted, ongoing effort by all parties working throughout the watershed to sustain our progress and achieve the vision of the 2014 Bay Agreement:

"The Chesapeake Bay Program partners envision an environmentally and economically sustainable Chesapeake Bay watershed with clean water, abundant life, conserved lands and access to the water, a vibrant cultural heritage and a diversity of engaged citizens and stakeholders."[21]

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