Issue 21

RESTORING ESTUARIES: *CHESAPEAKE BAY*

Key Questions

- What are the sources and the impacts of pollution on Chesapeake Bay and its watershed?
- What is the status of remediation efforts?
- What actions are being taken to reduce the environmental impact of population growth there?
- What is the long-term prognosis for Chesapeake Bay?

Background

The Chesapeake Bay formed about 8,000 years ago as rising sea level drowned the mouth of the Susquehanna River. It is the nation's largest and most productive estuary.[1] There are three interconnected parts of Chesapeake Bay: the Bay proper, the Bay's watershed[2] (Figure 21-1), and the Bay's airshed[3] (Figure 21-2).

The watershed's 64,000 mi^2 area includes parts of six states, the District of Columbia, and 1653 local governments. The watershed had a population around 17 million at the end of 2012, growing at around 1.2 percent per year.[4] Surveys have shown that most residents of the Bay's watershed do not even realize that they live within the watershed. To increase public awareness, in 1997 the states in the watershed put watershed boundary signs along major highways.

The airshed measures 418,000 square miles, or roughly six and a half times the size of the Bay's watershed.

Question 21-1: What is the doubling time (see "Using Math in Environmental Issues," pages 6–8) of the watershed's population?

[1] An estuary is a coastal embayment where freshwater from rivers and groundwater mixes with salt water.
[2] The watershed is the area drained by streams that feed the Bay.
[3] The Bay's airshed is the geographic area that is the source of any airborne pollutants that can affect the Bay.
[4] www.census.gov.

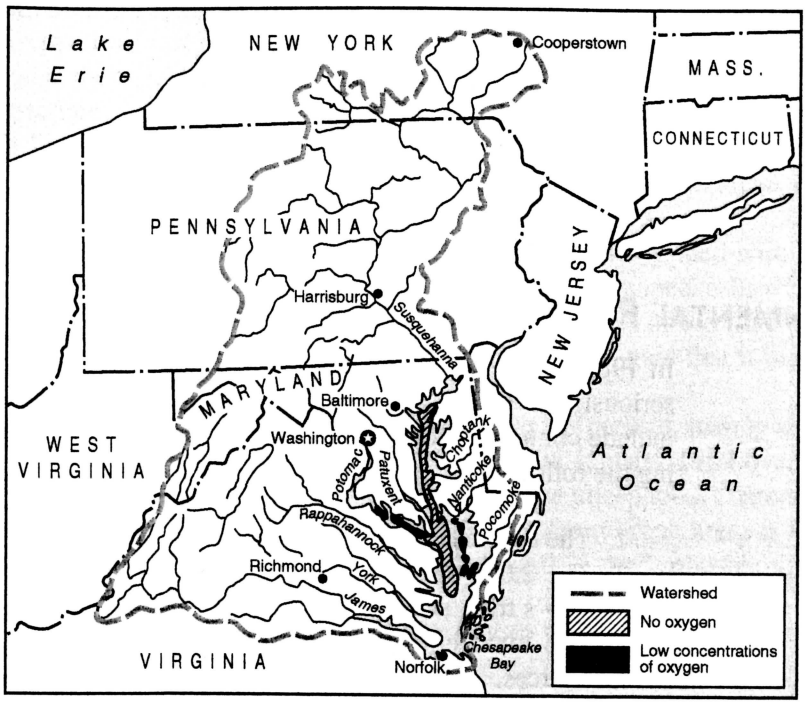

FIGURE 21-1 Chesapeake Bay and its watershed. (From Blatt, H. 1997. *Our Geologic Environment.* Upper Saddle River, NJ: Prentice Hall. Courtesy of Harvey Blatt.)

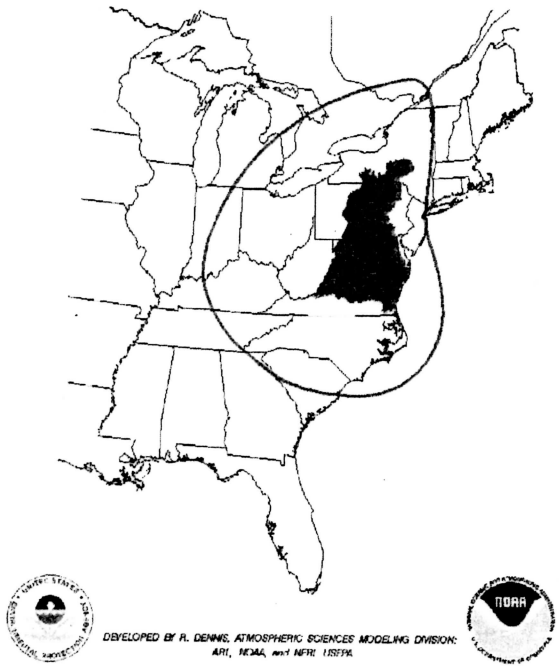

FIGURE 21-2 Chesapeake Bay's airshed. (NOAA)

Question 21-2: How many states and Canadian Provinces are included in the Bay's airshed?

ENVIRONMENTAL RESEARCH ON CHESAPEAKE BAY

In 1983, the U.S. Environmental Protection Agency (EPA) concluded that the Bay was seriously threatened by *nutrient enrichment.* Nutrients are essential for plant growth and include compounds of nitrogen and phosphorus. The EPA also expressed concern regarding the following:[5]

1. The overharvesting of oysters, crabs, and fish,
2. The 2,000 dams and other obstructions to fish passage that had been built on the Bay's tributaries over three centuries, and
3. The toxic emissions entering the Bay, mainly from industrial and commercial sources.

By 1991, the Bay's once thriving oyster population had collapsed. However, a ban on rockfish (striped bass) harvesting allowed that species to begin recovery. This recovery, however, created another problem: the decline of prey species. Bay anchovies are suffering from overpredation due to the increase in the numbers of striped bass, which are feeding heavily on the bay anchovy. Why? Because populations of Atlantic menhaden, the striper's main prey, have been reduced due to pollution, dams, and overfishing. As you can see, a *change in one part of an ecosystem can have unexpected changes throughout.*

The Bay's average depth is only 7 meters (21').

Question 21-3: Calculate the volume of Chesapeake Bay. The Bay's surface area is roughly 11,000 km^2, and the average depth is 7 meters. Express your answer in cubic kilometers, cubic meters, and liters.

Because the Bay is so shallow, it can support luxuriant bottom vegetation, mainly grasses. Bottom grasses, also called submerged aquatic vegetation (SAV) are one key to a healthy Chesapeake Bay. The grasses provide oxygen for the water, food for some Bay organisms, attachment spots for a myriad of tiny organisms, and hiding places for juvenile fish, crab larvae, and many other small animals. These grasses also promote water clarity by trapping sediment particles. Bay grasses had covered most of the Bay's shallow bottom until the 1950s, but by 1983 their area had been reduced by 90 percent. The decline of Bay grasses was caused largely by nutrient enrichment. Excess nutrients allow floating microscopic algae to flourish, blocking sunlight to the bottom grasses. The surface algae grow rapidly, quickly deplete the nutrients, die, and fall to the bottom. There, their decay

[5] McConnell, R.L. 1995. The human population carrying capacity of the Chesapeake Bay watershed: A preliminary analysis. *Population and Environment, 16* (4): 335–351.

depletes the water of oxygen, resulting in hypoxic (low oxygen) or anoxic (no oxygen) conditions (refer back to Figure 21-1). Since most bottom-dwelling animals cannot live without oxygen, they die or leave, and the bottom, now devoid of plant cover and depleted of oxygen, becomes a veritable desert.

Without Bay grasses to replenish the depleted oxygen, the bottom becomes inhospitable to most animal life. Cyanobacteria and diatoms may replace green algae, for example (for details, see Cooper and Brush[6]).

In 1987, the states of Maryland, Virginia, and Pennsylvania joined with the District of Columbia and a number of federal agencies to form the Chesapeake Bay Commission (CBC) to coordinate Bay restoration and protection efforts. One of the CBC's first goals was a 40 percent reduction in phosphorus by the year 2000, a goal that it was unable to meet.

However, by 1992 phosphorus had been reduced by 16 percent, mainly as a result of a ban on phosphate-bearing detergents that took effect in January 1989 over the heated objection of detergent manufacturers. In 1992, the average phosphorus content in the Bay was 0.03 mg/L. A representative value for streams that drain urban areas is 0.075 mg/L phosphorus, and those that drain farmland contain about 0.15 mg/L phosphorus.

Question 21-4: How much phosphorus was dissolved in the Bay as of 1992? Express your answer in kilograms.

By 2006, despite nearly three decades of study and restoration plans, the Bay was described as an "ecological disaster area" by the Chesapeake Bay Ecological Foundation (CBEF).[7] They reported bacteria levels in the Bay in 2006 to be among the highest measured in any estuarine environment. Zooplankton, the food base for many fish species, were becoming scarce in the Bay's main stem during the summer growing season, in part because comb jellyfish, a major predator of zooplankton and fish larvae, had drastically proliferated.

Potentially dangerous explosions in certain algal populations, called "blooms," are becoming more common in the Bay. Not only are these blooms toxic to many forms of marine life, but they also lower the Bay's already low dissolved oxygen (when they die and decompose) and block sunlight, further restricting the growth of underwater grasses. For example, the Chesapeake Bay Foundation (CBF) reports that

> a 2008 study by the U.S. Geological Survey looked at *Mycroscystis [algal]* blooms around the Bay and found that almost a third of the blooms contained toxins in levels sufficient to make the water unsafe for children to swim in. . . . Due to increased research, since 1996 the number of harmful algal species identified in the Bay has grown from 12 to 34.[8]

The CBF identifies sewage, emissions from coal-fired power plants and motor vehicles, agricultural runoff from farms and concentrated poultry and hog operations, growth in impervious surfaces (roads, parking lots, etc.), and silt from sprawl development as among the reasons for the Bay's decline. By 2011, impervious surfaces covered 1.1 million acres of the Bay's watershed, and were expanding faster than population growth.

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[6] Cooper, S.R., & G.S. Brush. 1991. Long-term history of Chesapeake Bay anoxia. *Science, 254:* 992–996.
[7] Chesapeake Bay Ecological Foundation, www.chesbay.org.
[8] Chesapeake Bay Foundation, www.cbf.org.

Question 21-5: Based on the area of the watershed we gave you earlier, what percentage of the entire watershed was impervious surface as of 2011?

THE IMPACT OF SEWAGE ON CHESAPEAKE BAY

The CBF estimated the sewage flow from all sources in the Chesapeake Bay's watershed to be 1.5 billion gallons a day in 2003. Improperly treated sewage is a major source of nitrogen and phosphorus.

Question 21-6: Based on this rate of sewage flow, how long would it take for Chesapeake Bay to fill up with treated sewage, assuming the sewage wasn't flushed to the ocean?

Question 21-7: A 1995 study of the Cameron Run Watershed in Fairfax County, Virginia, found that the amount of phosphorus discharged by urban streams had been significantly underestimated. Researchers found the phosphorus content in these streams to be 2.5 times greater than land-use models had assumed. Discuss the implications for Bay protection in the light of the rapid urbanization of the region.[9]

AIR POLLUTION AND CHESAPEAKE BAY

Between 20 percent and 35 percent of nitrogen in Chesapeake Bay is from air pollution. A third of this air pollution is from cars, power plants, and farm fields in the watershed itself, but as much as two-thirds is from power plant emissions in Ohio, Kentucky, Michigan, and other states as far away as Alabama[10] (see Figure 21-2). This is apparently due to three factors:

1. Prevailing winds from the southwest, northwest, and west,
2. The lack of control of nitrogen pollution emissions on the part of midwestern coal-burning utilities,

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[9] Fairfax County, VA: Cameron Run Watershed Mgmt. Plan, http://www.fairfaxcounty.gov/dpwes/watersheds/cameronrun_docs.htm.

[10] EPA orders twenty-two states to reduce nitrogen oxide emissions. *Washington Post,* October 11, 1997.

3. Smokestacks from the plants that spew pollution high enough into the atmosphere to be carried over 800 kilometers before settling out.

To address water and air pollution problems in the Bay's watershed and throughout the eastern United States, the EPA ordered twenty-two states in an arc from Massachusetts to Missouri to reduce pollutants, including nitrogen (in the form of oxides of nitrogen), or lose federal highway funds.[11] The states most heavily affected and the percentage of nitrogen oxide reductions required are West Virginia (44%), Ohio (43%), Missouri (43%), Indiana (42%), Kentucky (40%), Illinois (38%), Alabama (36%), Wisconsin (35%), Tennessee (35%), and Georgia (35%).

Question 21-8: To what extent should the people in these states be held accountable for air pollution carried beyond their boundaries? Include your reasons and explain them.

These nitrogen oxides contribute to acid precipitation. For example by 2006 parts of the Chesapeake Bay watershed had the most acidic rainfall of any area in the United States, according to the U.S. Geological Survey. Air pollution from excessive nitrogen oxides has been implicated in respiratory problems, especially in children and elderly people. Many allergists and environmental scientists say our health-care system is unfairly burdened by costs to treat persons affected by air pollution from coal-burning power plants and motor vehicles. (You will find a similar observation dealing with turfgrass in Issue 14.) Some believe these costs should be paid in the form of higher electric rates by those who choose coal-fired power plants and who decline to control emissions from these plants.

Question 21-9: Do you agree that the extra costs imposed by using coal to generate electricity should be borne by the consumers of the power? Explain your reasons.

PFIESTERIA AND MANURE

Some of the largest industrial-scale poultry raising facilities in North America are found within the Chesapeake Bay watershed. On Maryland's Eastern Shore, poultry outnumber people 1000 to 1. And poultry produce 150% more solid waste than humans, per unit area. Moreover, poultry produce 24 times more waste than hogs. An outbreak of a mysterious alga of the genus *Pfiesteria* killed tens of thousands of fish in tributaries of Chesapeake Bay in 1997. The outbreak seemed to be limited to streams that drained areas of Maryland with industrial-sized chicken farms. These farms spread up to 800,000 tons of nutrient-enriched chicken manure each year on fields, some immediately adjacent to streams, far in excess of the nutrients the soil can absorb. The federal government and Maryland proposed

[11] Ibid.

to stop the leaching of nutrients from the manure into the streams by paying the chicken growers to leave unplowed grass and, preferably, vegetated buffer strips along streams that drained through their land. The plants would absorb some of the nutrients in runoff, preventing them from contaminating the Bay. The initial cost was reported to be around $250 million.[12]

Question 21-10: To what extent does this $250 million represent a subsidy for chicken production and consumption? Explain your reasoning.

Question 21-11: To what extent, or under what circumstances, do you think government officials have the right to tell farmers and growers what to do with their own land? This involves a key constitutional issue. You can find out more about it by searching the Internet using the phrase "takings clause."

CHESAPEAKE 2010 AND BAY REMEDIATION

The year 2010 saw "winds of change" in the Chesapeake Bay Watershed, according to the Chesapeake Bay Foundation.

As of 2010:

- A measure of Bay health reached 45% of that estimated for the Bay in the 1600s.
- After decades of decline, the Bay's iconic blue crab population "surged 60%."
- Settlement of a lawsuit required EPA to put the states of the watershed on a strict "pollution diet."
- Phosphorus loading decreased from 25 million pounds (1985) to 20 million pounds, with a goal of 15 million pounds by 2025.
- Sediment load decreased from 11 billion pounds (1985) to eight billion pounds.
- Nitrogen load decreased from 325 million pounds (1985) to 250 million pounds.
- A "Manure to Energy Summit" was held in 2011 to support plans to turn manure into energy.
- However, two-thirds of Bay waters failed to meet minimum oxygen standards in 2011, so the health of the Bay declined from "C–" to "D+", mainly due to excessive heat and the impact of intense storms.[13]

[12] MD Dept Natural Res., http://www.dnr.state.md.us/bay/cblife/algae/dino/pfiesteria/pubs.html.

[13] For details go to www.chesapeakebay.net/pubs/snapc2k.pdf.

Future Challenges

The Chesapeake Bay Program identified numerous challenges to Bay protection that must be addressed in the decades ahead. Among them are

- Invasive species, brought into the Bay in the ballast water of ocean-going cargo vessels (see Issue 22)
- Recovery of the Bay's oyster population, which had virtually disappeared by 1991
- Protection of forest and agricultural land from sprawl development (see Issues 24 and 25)
- Further removal of nitrogen and phosphorus from sewage (upgrading of all sewage plants in the Watershed could remove 20% of the N from Bay waters)
- Opening thousands of miles of tributaries to fish passage by breaching dams or building fish ladders
- Protecting the blue crab, a symbol of Chesapeake Bay threatened by overharvesting and pollution
- Dealing with material dredged from harbors (Baltimore especially) and shipping channels, which may be contaminated with toxic materials, but which, even if uncontaminated, could smother bottom-dwelling organisms

Here is a summary of the Bay's status from the president of the Chesapeake Bay Foundation, William C. Baker: "Despite progress on many fronts, the Bay's health has stalled at a dangerously low level."

Question 21-12: Explain why a healthy Chesapeake Bay is an important component of sustainability for the Chesapeake Bay watershed.

Question 21-13: Summarize the major points of this Issue.

FOR FURTHER THOUGHT

Question 21-14: In addition to sewage, sources of phosphorus in Chesapeake Bay include sediment runoff, agricultural runoff, and animal waste from vast chicken and pig farms. Research and discuss any or all of the following questions.

1. How does sediment contribute phosphorus?
2. What is the effect of construction activity on sediment runoff and thus on phosphorus?
3. Why is agricultural runoff other than manure a major source of phosphorus?
4. How might phosphorus from sediment and agricultural runoff be minimized?
5. What can be done about animal waste?