LAND USE AND THE CHESAPEAKE BAY REPORT CARD

This is the second year that a geographically detailed and integrated assessment of Chesapeake Bay health has been produced. The report card aims to inform citizens on the progress Chesapeake Bay is making toward becoming a healthy ecosystem. This year's report card shows that the health of the Bay improved slightly in 2007 when compared to 2006. While the overall health of the Bay and most regions of the Bay improved, the health of some regions of the Bay declined. This newsletter also explores some of the long-term changes in report card scores, making a connection between the scores and influencing factors such as land use and nutrient loads.

BAY SLIGHTLY HEALTHIER IN 2007 COMPARED TO 2006

Overall health was slightly better in 2007 compared to 2006, increasing from a score of 39%* to 42%, which is rated moderate-poor (Figure 1). This small improvement was largely due to improved water clarity, phytoplankton community, and aquatic grasses scores, leading to reporting region scores that were higher in 2007 than in 2006. However, these improvements did not occur everywhere, with some regions of the Bay having decreased health, such as the York River, Patuxent River, and Lower Eastern Shore. The most improved regions in 2007 were the Upper Western Shore and Choptank River. Improvements in these regions resulted in the Upper Western Shore becoming the top-ranked region in 2007, with a score of 65% or "B," and the Choptank River increasing from 21 (second worst) in 2006 to 37 in 2007. Improved scores in 2007 may in part be due to summer drought conditions, which resulted in less nutrients and sediments entering the Bay at a critical time of the year. While restoration efforts continued in earnest during 2007, it will only be possible to determine if they are having an effect through continued monitoring and assessment.

*A slightly revised score from the report last year due to an updated, more comprehensive assessment of some indicators. Last year's reported BHI score was 37%.
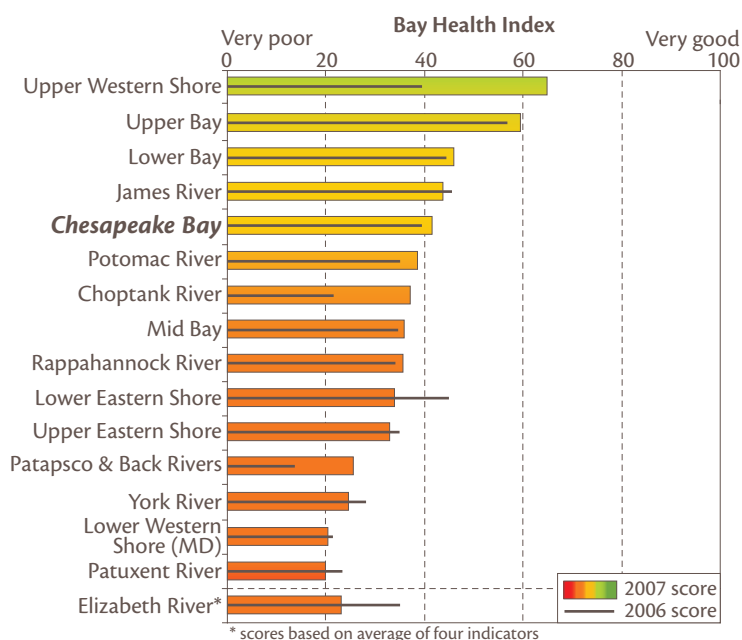

Figure 1: Comparison of Bay Health Index scores for 15 regions of the Bay in 2006 and 2007. See Figure 5 for map of regions.

TWO DECADES OF BAY HEALTH ASSESSMENTS

The Bay Health Index (BHI) allows us for the first time to have an integrated view of the health of the Bay over the past 18 years (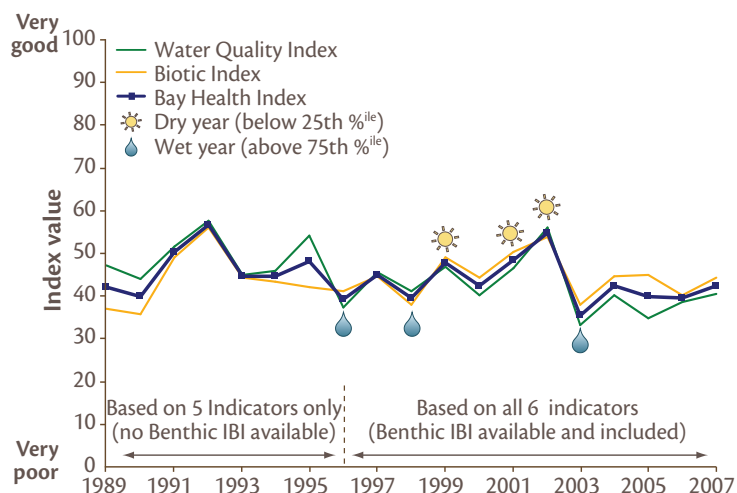Figure 2). This long-term view of overall Bay health illustrates how similarly the water quality (dissolved oxygen, water clarity, and chlorophyll *a*) and biotic indicators (aquatic grasses, Benthic and Phytoplankton Index of Biotic Integrity) respond at a Baywide scale from year to year. This similarity illustrates the connection between the Bay's water quality and biological responses. For example, a period of high nutrient loads (e.g., during a wet year) leads to poor dissolved oxygen, which results in poor benthic conditions. These degraded conditions then contribute to an overall poor score.

Throughout the 18-year period, the BHI is only about half way to the goal, which shows that we need to improve our efforts to restore the Bay. The other noticeable feature in the 18-year assessment is the variability of Bay health scores, and how this inter-annual variation corresponds to changes in rainfall or river discharge. During wet years the Bay's health deteriorates and during dry years it improves. This is particularly noticeable in the 2000 to 2003 period when successive dry years resulted in one of the highest BHI scores, 54, but the wet condition of 2003 resulted in a rapid decrease to one of the lowest on record, 35.

Figure 2: Time series of the Bay Health Index, Water Quality Index, and Biotic Index from 1989 to 2007. Data: Chesapeake Bay Program and UMCES.

LINKING LAND USE TO BAY HEALTH

The Bay Health Index (BHI) provides a broad-level approach to assess the connection between land use and Bay condition. Land use within each of the watersheds (see opposite page for the different watersheds) is compared with the health of the adjacent waterway (Figure 3). In general, the higher the proportion of agricultural and developed land relative to forested land, the lower the BHI. This approach does not account for pollutants from other sources, such as coastal erosion or transport from adjacent waterways, but the strong correlation suggests that watershed activities in each region highly influence the BHI of the corresponding waterway.

This relationship provides a useful framework from which the effects of land use change and best management practice (BMP) implementation can be viewed. Theoretically, if land use (% development and agriculture) stays the same, and the implementation of urban and agricultural best management practices is increased, then the health of the Bay will improve (Figure 3). Conversely, if BMPs were to decrease, then we can expect the health of the Bay to deteriorate. Additionally, if BMPs stay the same and land use (area % development and agriculture) changes, then the health of the Bay will also respond.

This is an oversimplification of these relationships, but still serves as a good conceptual framework. An example of this oversimplification can be seen when looking at the effects of land use change from agriculture to developed land. Developed land (including urban run-off and partial treatment of human waste) within the Chesapeake watershed generates on average a total of 14.8 pounds of nitrogen per acre compared with the average agricultural rate of 11.7[1]. Based on these numbers, a shift toward developed land at the expense of agricultural land will lead to increased nutrient loads *unless* urban BMPs can keep up with land use change — a factor not captured by the relationship shown.
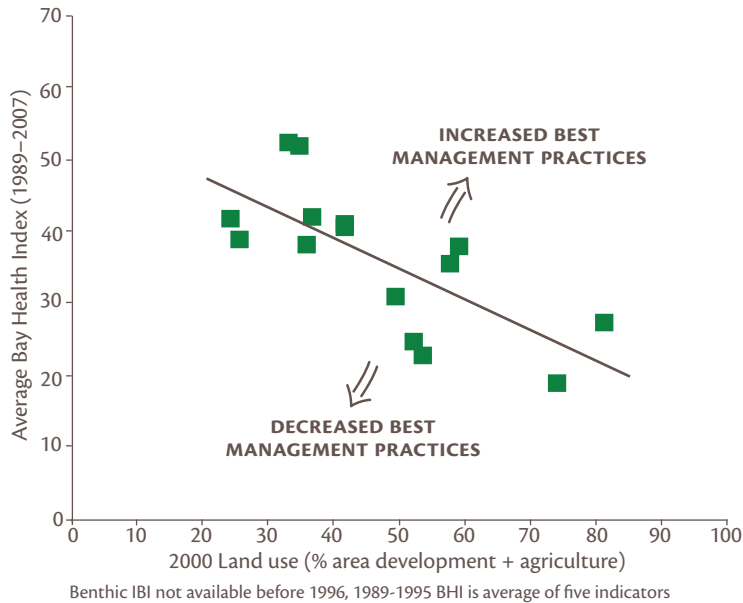

Forest

Agriculture

Industry

Urban/suburban development

Four different types of land use around the Chesapeake Bay watershed.

Ben Longstaff and Jane Thomas

Benthic IBI not available before 1996, 1989-1995 BHI is average of five indicators

Figure 3: The average Bay Health Index decreases with increasing conversion of forested lands to agriculture and urban development.

RELATIVE SOURCES OF NITROGEN AND PHOSPHORUS TO CHESAPEAKE BAY

One of the challenges of categorizing nutrient and sediment loads by the land use type is that it may not show the relative or initial source of a pollutant. An important example used to highlight this distinction is atmospheric nitrogen deposition. Atmospheric deposition accounts for an estimated 22% of watershed nitrogen loads to the Bay, but this is not evident when estimating loads on a land use basis, as presented in the map displayed (opposite page).

Knowing the relative sources of the pollutant is especially important when targeting restoration efforts. For instance, efforts toward reducing automobile emissions, which contribute significantly to nitrogen pollution, are not categorized under land use best management practices, but are needed as part of restoration.

NITROGEN

Municipal and industrial wastewater — 20%
Agriculture (manure and fertilizer) — 42%
Urban and suburban lands — 16%
Atmospheric deposition — 22%

PHOSPHORUS

Urban and suburban lands — 32%
Agriculture (manure and fertilizer) — 46%
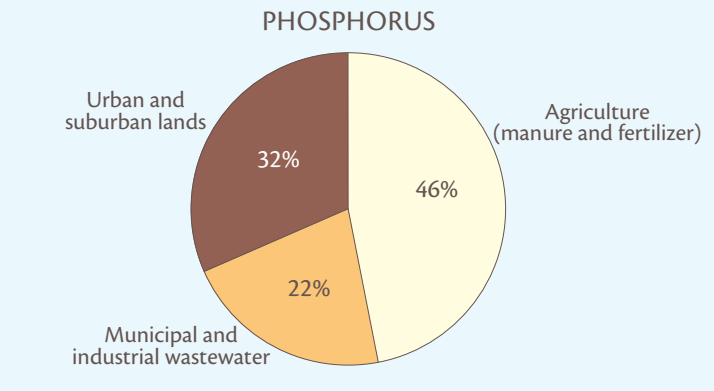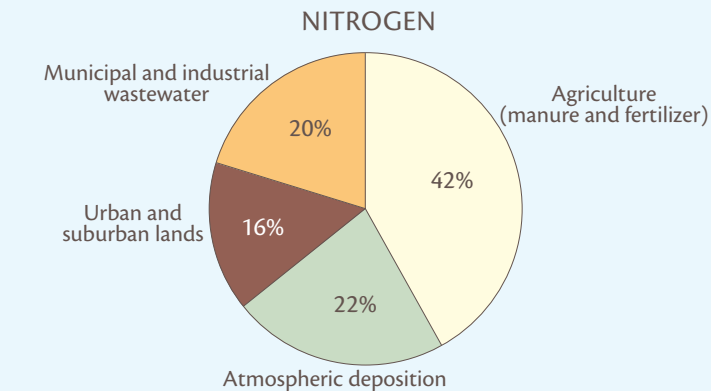Municipal and industrial wastewater — 22%

Figure 4. Relative sources of nitrogen and phosphorus to Chesapeake Bay. Data: Chesapeake Bay Program Watershed Model, Phase 4.3. See back page for details of model inputs.

GETTING TO THE SOURCE OF THE PROBLEM

It is well understood that excessive nitrogen, phosphorus, and sediments are major causes of Chesapeake Bay's poor health condition. To help reduce the amount of these pollutants entering the Bay, it is important to determine their sources, so that restoration efforts can be targeted for maximum effect. One of the tools used to estimate pollutant sources and loads and the effectiveness of best management practices (BMPs) is the Chesapeake Bay Watershed Model. This model estimates loads for a variety of land use types, based on factors such as BMP assumptions, average hydrology, vegetation cover, and point source nutrient loads.

A simple assessment of the modeled nitrogen load estimates (Table 1) illustrates that the largest contributors are the Susquehanna, Potomac, and James Rivers, mainly due to the fact that these rivers have the largest watersheds. The main sources of nitrogen within each of the regions vary significantly (Figure 5). Agriculture is estimated to be the main source of nitrogen in the Eastern Shore regions, while point sources (wastewater) are the main factors in the James River and Patapsco and Back Rivers regions. The different primary nitrogen sources and the Bay health scores highlight the need for targeted implementation of best management practices. While the figure below provides a modeled estimate of nitrogen into each of the report card regions, it does not account for mixing or transport of nutrients from one region (e.g., the mainstem Bay) to another (e.g., a tributary such as the Patuxent River).

Table 1. Estimated total nitrogen loads for 13 watersheds/regions in the Chesapeake Bay Watershed. Data: Chesapeake Bay Watershed Model, Phase 4.3. See back page for details of model inputs.

| | | NITROGEN LOADS PER YEAR | |
WATERSHEDS	AREA (mil acres)	Total (mil lbs)	Per acre (mil lbs acre⁻¹)
1. Susquehanna River	17.60	115.6	6.6
2. Potomac River	9.08	52.7	5.8
3. Rappahannock River	1.64	7.2	4.4
4. James River	6.33	30.9	4.9
5. Upper Western Shore	0.42	3.0	7.0
6. Patapsco and Back Rivers	0.41	10.4	25.3
7. Lower Western Shore	0.17	1.7	9.8
8. Patuxent River	0.56	3.5	6.2
9. York River	1.66	6.1	3.7
10. Elizabeth River	0.11	3.1	27.9
11. Upper Eastern Shore	0.69	7.0	10.1
12. Choptank River	0.49	4.0	8.2
13. Lower Eastern Shore	1.31	10.3	7.9

Modeled estimates of total nitrogen (millions lbs yr⁻¹)

- Septic systems
- Point sources
- Urban
- Other
- Forest
- Agriculture

Bay health scale
100%
80
60
40
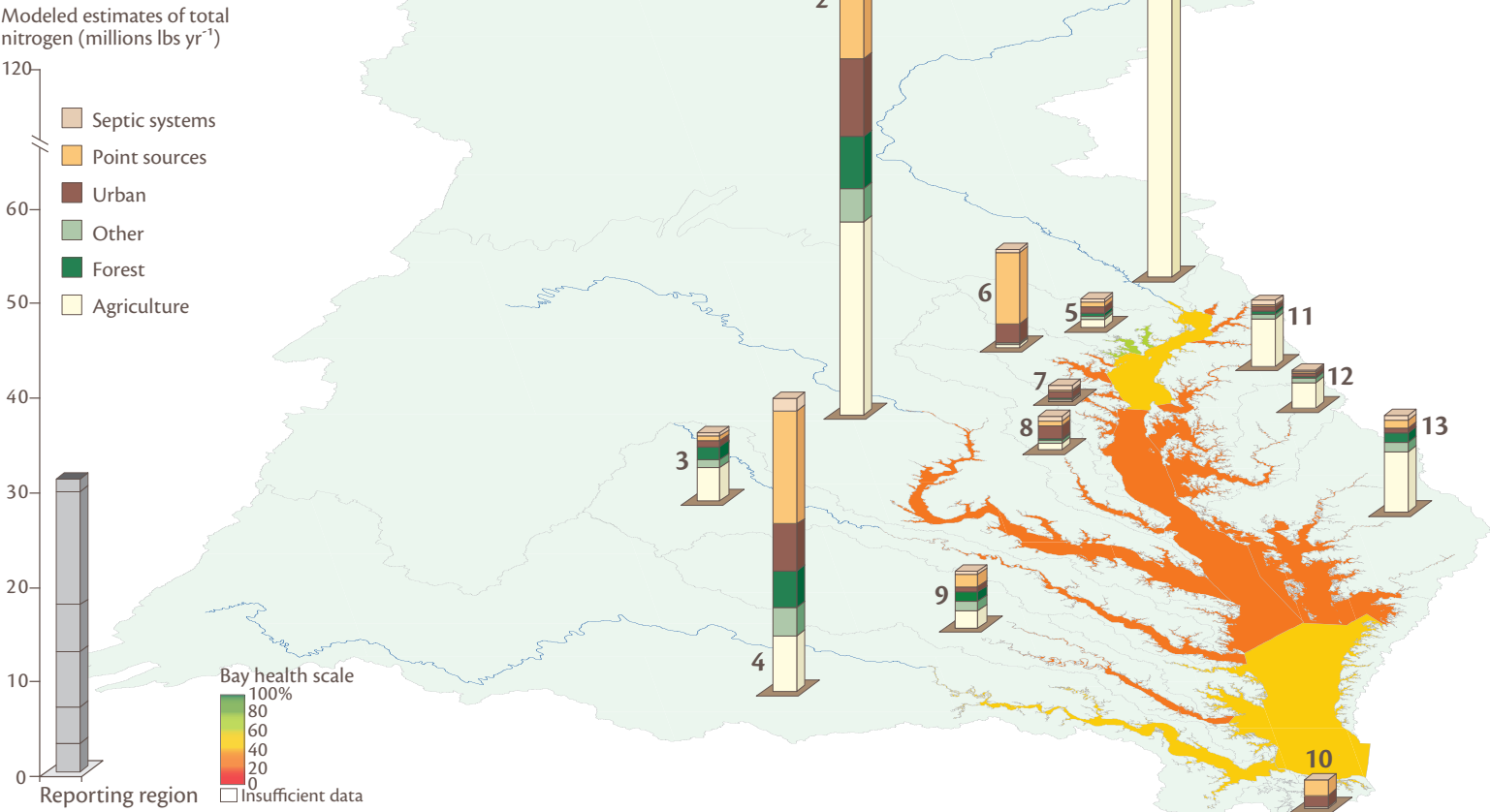20
0

Reporting region   Insufficient data

Figure 5. Estimated total nitrogen loads for 13 watersheds/regions in the Chesapeake Bay Watershed and the 2007 Bay Health Index for the 15 reporting regions. Data: Chesapeake Bay Program Watershed Model, Phase 4.3. See back page for details of model inputs.

BEST MANAGEMENT PRACTICES AROUND THE BAY

There are literally hundreds of Best Management Practices (BMPs) that target reduction of nutrient and sediment loads to Chesapeake Bay. These may be as simple as individuals fertilizing their lawn during the recommended time of the year (fall), to large and expensive engineering exercises such as upgrading municipal wastewater treatment plants. Here are some of the most important and some of the new BMPs being undertaken in agriculture and urban areas.
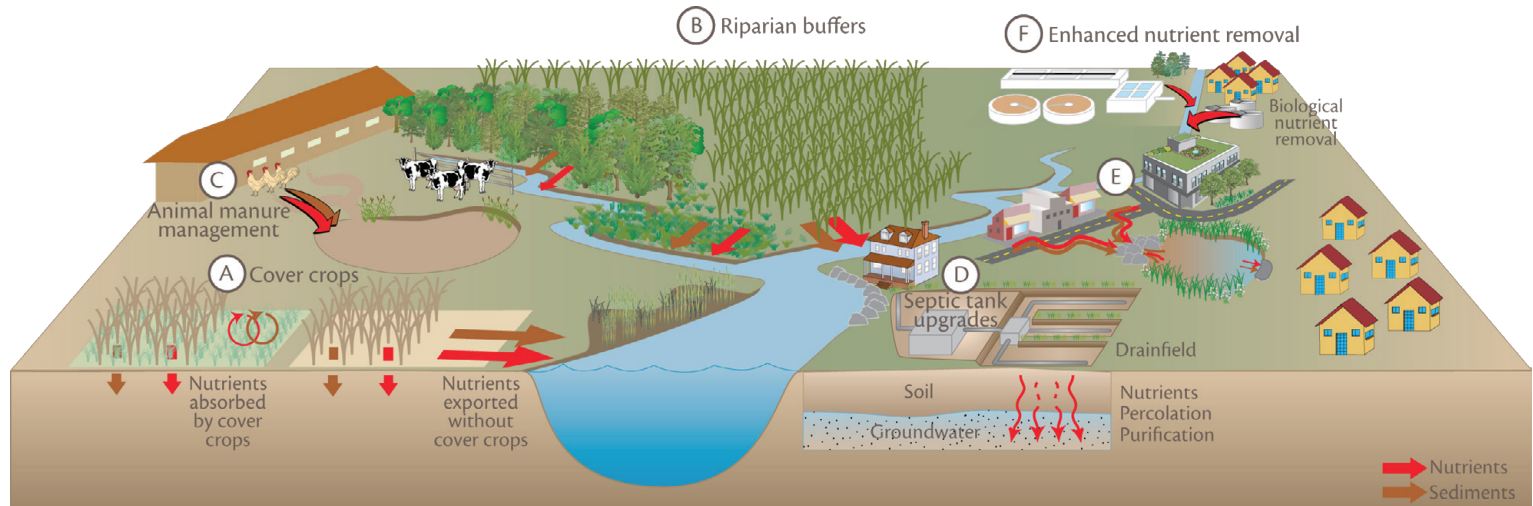
AGRICULTURAL BMPs

A. Cover crops – Non-harvested cereal cover crop specifically planted in fall for nutrient removal. Cereal cover crops reduce erosion and the leaching of nutrients to groundwater by maintaining a vegetative cover on cropland and holding nutrients within the root zone during the non-growing cash crop season (winter).

B. Riparian buffers – Up to 100-foot-wide buffer of grass, non-woody, or woody (forest) vegetation between crop and waterway. A 100-foot-wide strip of grass buffer can reduce sediment significantly. Fencing to exclude farm animals, although not a riparian buffer, can help slow the erosion of streamside soil.

C. Animal manure management – Animal farming uses directed flows to better contain waste products from animal houses. Lagoons, ponds, steel or concrete tanks, and storage sheds are used for the treatment and/or storage of wastes.

URBAN BMPs

D. Septic upgrades – Septic denitrification represents the replacement of traditional septic systems with more advanced systems that have additional nitrogen removal capabilities. Septic connections/hookups represent the replacement of traditional septic systems with connection to and treatment at wastewater treatment plants.

E. Stormwater management control – Includes rain gardens (which direct flow from impervious surfaces to a vegetated area before the water reaches the storm drain), green roofs (which use the rainwater hitting the roof to feed plants), and riparian buffers. Filtering practices capture and temporarily store the water quality volume and pass it through a filter of sand, organic matter, and vegetation, promoting pollutant treatment and recharge.

F. Enhanced nutrient removal – Wastewater treatment plants are being upgraded to enhanced nutrient removal, which uses the most efficient removal process available, before the water is discharged into local waterways.