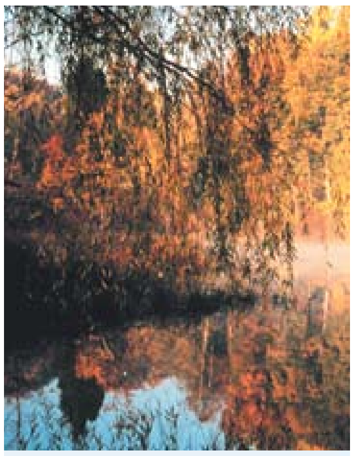
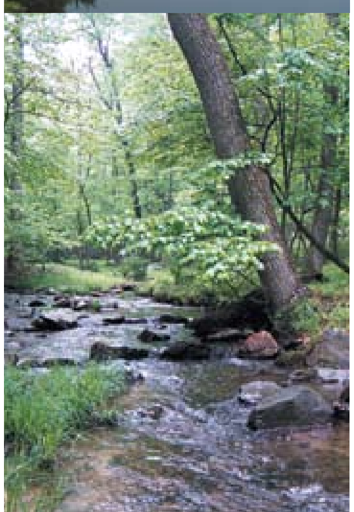
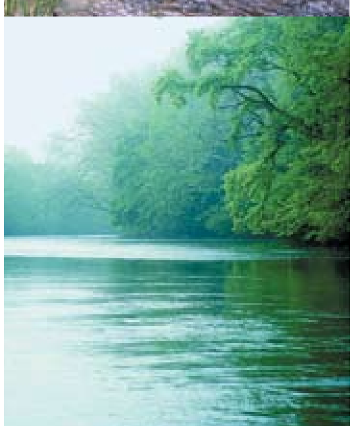



Chapter 4:

The Key to Watershed Function

Key Findings

- Forests act as a living sponge by storing, cleaning, and slowly releasing the majority of the water that maintains stream flow and replenishes groundwater.

- Forests are the most beneficial land use for promoting and maintaining clean water. While forests cover 58% of the Chesapeake Bay watershed, they contribute less than 15% of total nitrogen and 2% of total phosphorus loads to the Bay.

- The health of a watershed is directly tied to the amount of forest and tree canopy cover, the quantity of intact riparian forests, and the health, condition, and distribution of its forested lands.

- Forests protect local waterways by retaining more than 85% of the nitrogen deposited on them from the air. If nitrogen deposition continues to rise, this retention rate could decline to 23% by the end of the century.

- Forestland loss disproportionately increases nutrient pollution to the Bay. Reducing forest area in a watershed by 10% leads to as much as a 40% increase in nitrogen loads to the water.

- Urban and rural forests are critical to reducing stormwater runoff from small storms–storing and filtering up to six times more rainfall than grass and 20 times more than a parking lot.

- Riparian forests are essential for healthy aquatic habitat and water quality, and currently buffer 60% of the streams and rivers in the Bay watershed. To achieve water quality, habitat, and watershed function goals in the Bay watershed, at least 30,000 miles of additional riparian forest buffers will be needed.

- Losses of forestland increase the cost of clean drinking water for more than 10 million residents in the Bay watershed.

- Over 5.5 million acres or 31% of the most valuable forests identified are at high risk to development.

The Living Filter

In 1864, George Perkins Marsh wrote in his landmark book *Man and Nature* that, "with the disappearance of the forest, all is changed."[1] Science has confirmed Marsh's observations that the loss of forestland can have far-reaching implications. As forests are lost and become fragmented by other land uses, the function of watersheds likewise changes—in terms of water yield, timing of runoff, soil erosion, and supply of food to streams. Numerous studies have observed declines in water quality and stream health as watershed forest cover dropped below a range of 65 to 75%.[2]

In general, forests in a watershed improve the water quality and health of the aquatic ecosystem and moderate stream flow. Forest cover in a watershed, however, is neither uniformly distributed nor always concentrated in areas that control pollution most effectively.[3] Although the loss of forests in one area may be offset by gains in other parts of the watershed, the result is not necessarily equal in terms of ecological value or impact on the Bay.

Effects of Land Use

If we assume that regional trends hold true for the Bay watershed, approximately two-thirds of the water that maintains our streams and replenishes our groundwater comes from forested lands.[4] This is especially significant because forests normally yield water of exceptionally high quality. Compared with other land uses, forests also have more steady water yields throughout the year.[5] In watersheds dominated by agricultural or urban land, remaining forests cushion or dilute the impacts of these other land uses, while supporting ecological functions that maintain productive streams.[6]

Lower quality water increasingly flows through the watershed as forests are converted to other uses.[7] Especially on a rainy day, the results become apparent as water rushes off hard surfaces such as roads and parking lots. Even as we spend millions of dollars annually on best management practices to control polluted runoff, nothing yet devised works like an intact forest.

The capacity of forests to absorb and store runoff can be almost 20 times higher than a parking lot and up to six times higher than a turf lawn.[8] A study of the Gwynns Falls watershed in Baltimore, Maryland, indicated that heavily forested areas reduced total runoff by as much as 26% and increased the low-flow volume of streams by up to 13%.[9]

Forests and Water Storage

The flow of streams throughout the year depends in large part on the storage capacity of the watershed. Impervious surfaces stop precipitation from infiltrating into the soil. Instead, the rainwater washes rapidly into stream channels. This increases both erosion in the stream channel and the level of pollutants that are transported from rooftops, lawns, and streets to streams during rain events. This same process, which floods the stream during

Vital Signs of a Healthy Watershed

A healthy watershed can be measured by its ability to:

- Intercept and store rainfall
- Recharge groundwater supplies
- Protect soil loss and erosion
- Sustain and regulate stream flows
- Sequester and recycle nutrients
- Support natural riparian and floodplain functions
- Meet the habitat needs of natural aquatic species

The extent and health of forests will ultimately determine how well a watershed can provide these functions. The critical measures of a watershed's forests include:

- The total amount of forestland or percentage of a watershed that is forested
- The extent to which critical landscapes remain forested (riparian corridors and wetlands, steep slopes, erodible soils, and groundwater recharge areas)
- The health and condition of remaining forests, including their degree of fragmentation
- The nature of ownership and land stewardship

Photo: Mary Hollinger NOAA

rainfall, leaves the stream dry during other times of the year. Rain that would otherwise infiltrate the soil to recharge groundwater has simply washed away, leaving streams without sustenance during drier times.

Because so little overland flow occurs naturally in a forest, almost any conversion to other land uses, especially impervious cover, produces proportionally larger peak flows. Models used to examine the effects of impervious cover have clearly demonstrated the importance of forests. One study looked at a 4% increase in impervious cover on a 100-acre grass watershed. The outcome indicated more than a 50% increase in the magnitude of a two-year flood and a 65% increase in the magnitude of a 100-year flood. Increased flooding was insignificant when the same imperviousness was introduced to a fully forested area. These studies show how well forests can help to moderate the harmful impacts of development. Current research points to both the importance of retaining forests and reducing impervious cover in urbanizing watersheds.[10]

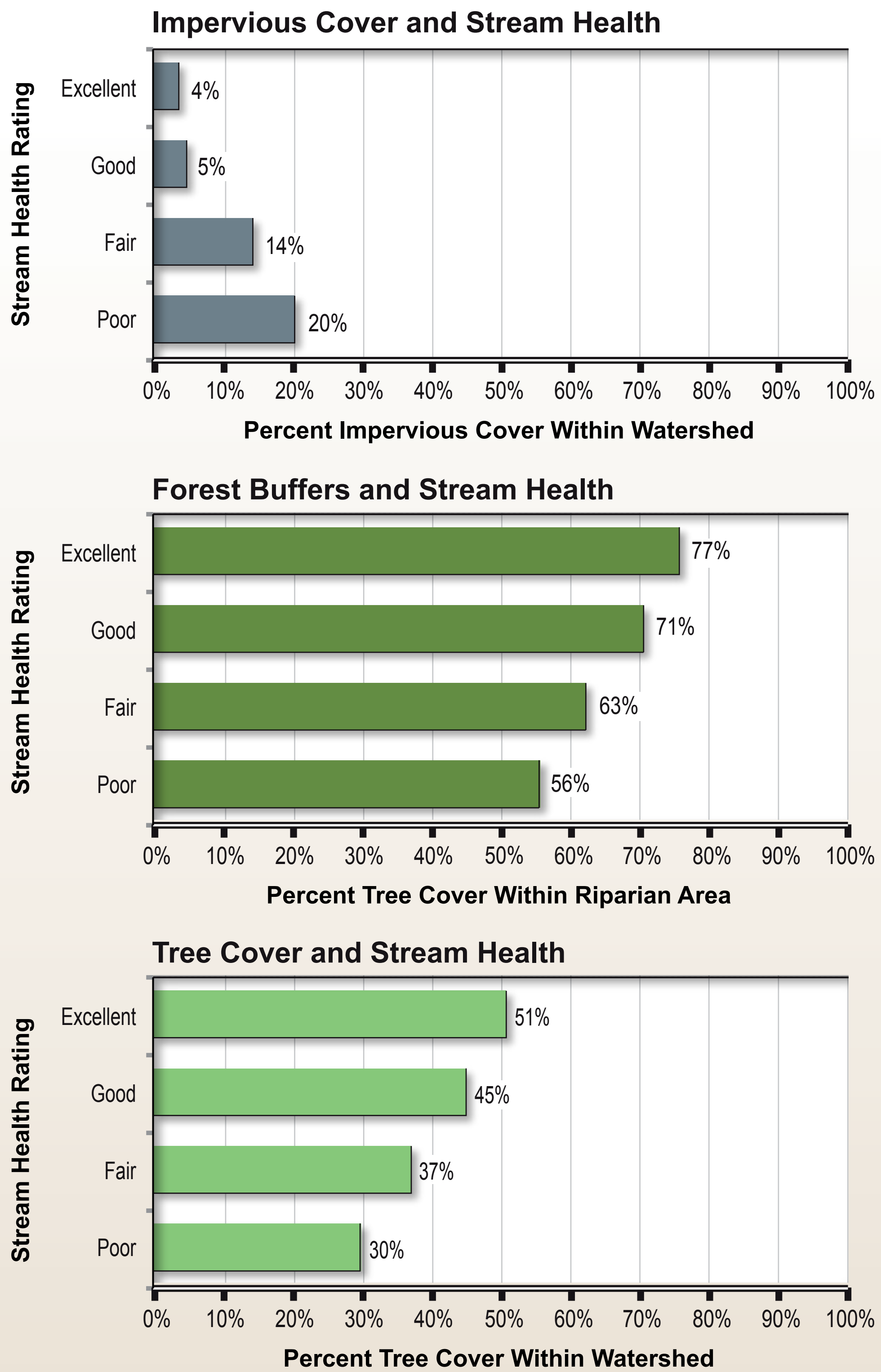
Studies conducted by the Smithsonian Environmental Research Center also tied changes in stream flow and water quality to land use. They found that an increase in agricultural land use and impervious area was a stronger determinant for water quality than the percentage forestland alone.[11,12] There are clearly limits to what forest cover alone can achieve. However, mounting evidence indicates that forest conservation should be a valued component of growth management strategies.

Forests and Stream Health

The conversion of forests to impervious surfaces is particularly damaging to streams and the life within them. In general, negative effects on stream conditions can begin at impervious levels as low as 5% and become dramatic at approximately 25%. This impact is largely due to changes in stream flow, which have pronounced and sometimes devastating effects on stream stability and the aquatic life in the stream.[13]

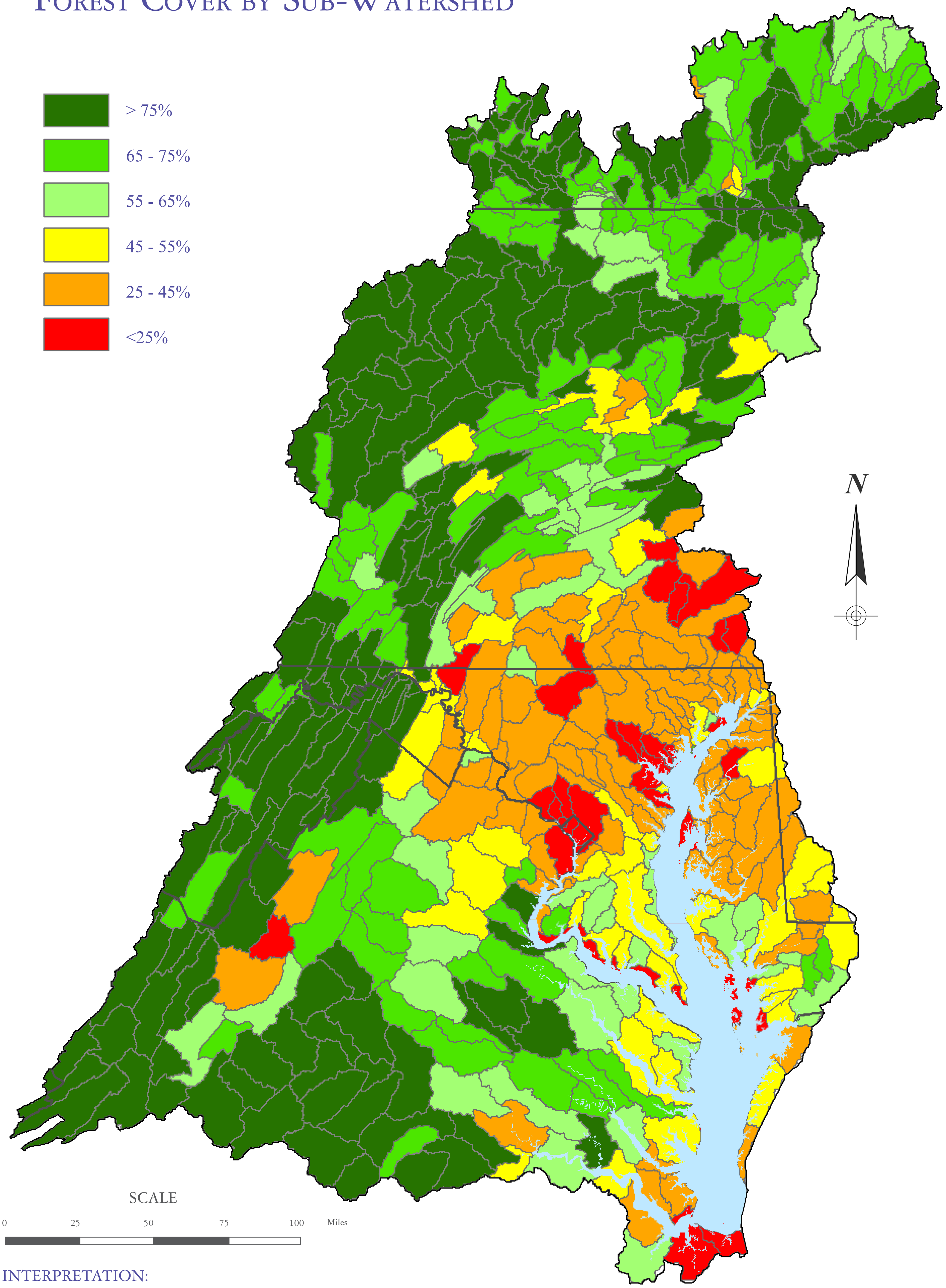
Small watersheds with high percentages of forest and tree cover are more likely to have "excellent to good" stream health than watersheds with higher percentages of impervious cover.[14] In addition, streams with intact riparian forest corridors seem better able to sustain the health of their biological communities, even when forest is lost to impervious cover. A recent study suggests that streams with an "excellent to good" rating for biological integrity would be most commonly achieved in watersheds with less than 10% impervious cover, at least 60% of streams with forested buffers, and greater than 45% forest cover. While other factors play a role, the nature of land use in a watershed, along with the extent and condition of forested stream corridors, greatly affect stream flow and nitrogen, phosphorus, and sediment loadings to streams.[15]

Land Cover and Stream Health



Source: Goetz et al. 2003

Forest Cover by Sub-Watershed



INTERPRETATION:
As forests are lost and become more fragmented by other land uses, the function of watersheds is degraded. In general, watershed health begins to decline as forest cover drops below 65-75% of a watershed.

SOURCE: MA RESAC 2000

Urban Tree Canopy

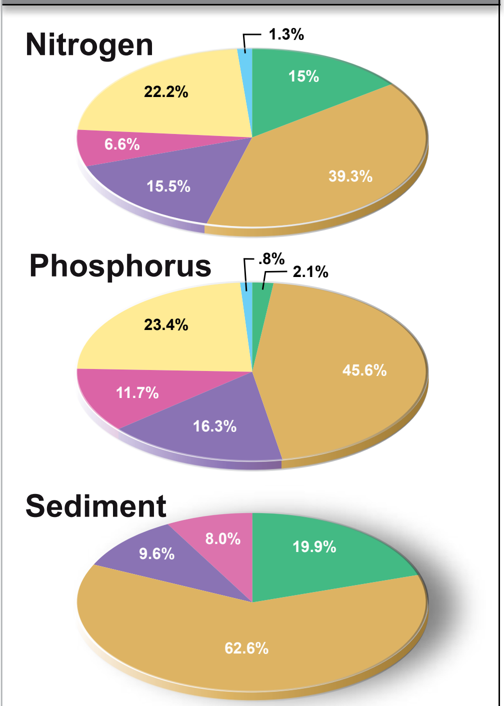
An urban tree canopy is the layer of trees and branches that shade the ground. It is often measured when viewed from above as percent tree canopy cover. A tree canopy that overhangs impervious areas not only cools these surfaces but also captures and holds rainfall, reducing runoff from rainstorms. It is especially effective during small storms, which wash off the majority of pollutants from streets, parking lots, and other developed areas. In already developed areas, the effects of urban tree canopies on storm water runoff and water quality have not been investigated in detail. New hydrologic models, currently under development, should provide significant insight to this area of research.[i]

Water Quality Functions

Nutrients and other pollutants travel to streams through both surface and ground water. Forests act as pumps, taking up water and nutrients through their root system, storing them in the biomass of the tree and releasing moisture into the air. In this way, forests are a long-term nutrient storage reserve. Nutrients are circulated in forest ecosystems through a series of physical, chemical, and biological processes. Each year, this nutrient cycle adds about two tons of leaves and organic debris or "litter" to each acre of the forest floor. The resulting organic layer shields the soil and creates an environment that fosters water infiltration and biological activity. Through a process called "denitrification," bacteria in wet forest soils convert nitrate into a nitrogen gas, which is released into the air instead of being introduced to local streams.

Decades of research have established two fundamental principles. The first is that forests retain nutrients and sediment much more effectively than all other land uses in the Chesapeake Bay watershed. The second principle is that the distribution of forests in a watershed, especially their distance from streams and nutrient sources, determines how well forests keep nutrients and sediments out of rivers, streams, and the Bay itself.[18,19,20]

Nitrogen, Phosphorus, and Sediment Loads to the Chesapeake Bay, 2003



	Nitrogen Million lbs.	Phosphorus Million lbs.	Sediment Million Tons
Forest	41.2	.4	1
Agriculture	108.2	8.8	3.1
Urban	42.7	3.2	.5
Mixed Open	18.2	2.3	.4
Point Source	61.2	4.5	0
Atmosphere	3.5	.2	0
Totals	**275.1**	**19.3**	**5.0**

Source: Chesapeake Bay Program 2003

Development Density and Watershed Imperviousness

Even small amounts of impervious surface can degrade water quality. Because of this, some communities have limited the amount of impervious cover that can be used on a building site. Zoning often limits housing density to one unit per one, two, or even five acres. This approach attempts to minimize hard surfaces and preserve absorbent ones.

However, low building densities can increase imperviousness at the watershed level and lead to worse overall water quality. How does this occur? Low-density development requires more land and infrastructure than would be needed for a similarly sized development in a more compact area.[16] In the Chesapeake Bay watershed, a study compared compact and dispersed developments on similarly sized tracts of land. Compact development consumed one-third as much land as dispersed development and included about half the amount of impervious surfaces. As a result, the compact development pattern had 43% less runoff.[17]

Local governments concerned about the effects of development on water quality and stream health should consider setting goals for forest cover and thresholds for impervious surfaces. With a goal in place, municipalities could achieve a mix of land uses while evaluating the cumulative effects on forest cover and stormwater runoff.[8]

Photo: Howard County, Maryland

[i] For example, RHESSys model (http://geography.sdsu.edu/Research/Projects/RHESSYS/) or the UFORE-Hydromodel (http://www.fs.fed.us/ne/syracuse/Tools/UFORE.htm)

Non-Point Source Pollutant Loadings to the Chesapeake Bay, 2003

River Basin	% Forest Cover	Nitrogen: Load to Bay (percent)	Nitrogen: Load From Forests (lbs/acre/year)	Phosphorous: Load to Bay (percent)	Phosphorous: Load From Forests (lbs/acre/year)	Sediment: Load to Bay (percent)	Sediment: Load From Forests (lbs/acre/year)
Susquehanna	63.0	49.0%	12.7% (2.4)	21.1%	1.0% (<.1)	21.2%	4.1% (<.1)
Potomac	51.7	19.1%	2.7% (1.5)	23.3%	0.5% (<.1)	34.7%	4.0% (<.1)
James	61.6	10.2%	1.9% (1.5)	27.9%	0.8% (<.1)	23.5%	8.6% (<.1)
Eastern Shore MD	44.1	9.9%	0.7% (1.5)	11.4%	0.2% (<.1)	5.6%	0.5% (<.1)
Rappahannock	52.9	3.4%	0.6% (1.2)	5.9%	0.1% (<.1)	6.6%	1.4% (<.1)
York	63.4	3.0%	0.6% (1.1)	4.0%	0.1% (<.1)	2.5%	0.7% (<.1)
Western Shore MD	38.3	3.2%	0.2% (1.1)	3.7%	<.1% (.1)	2.7%	0.3% (<.1)
Patuxent	43.6	1.5%	0.1% (1.1)	1.4%	<.1% (<.1)	2.7%	0.3% (<.1)
Eastern Shore VA	43.1	0.8%	0.1% (1.0)	1.2%	<.1% (<.1)	0.4%	<.1% (.11)
Totals		100%	19.6% (12.4)	100%	2.7% (.30)	100%	19.9% (.43)

Source: Chesapeake Bay Program 2005

Even though forests account for 58% of the land area in the Bay watershed, they contribute only about 15% of the total load of nitrogen and 2% of the phosphorus load to the Bay.[21] Likewise, river basins with the highest percentage of forest cover have the lowest annual sediment yields in the Bay region.[22]

Forestland in the Susquehanna River basin is particularly valuable for the bay. Nearly half of all nitrogen pollution from non-point sources (excludes atmospheric deposition and point sources like sewage treatment plants) originates from this portion of the Bay watershed. As other land uses replace forestland, the amount of nitrogen entering the Bay will likely increase with great effect on water quality.

Nitrogen: A Principal Problem for the Bay

While excess phosphorus is a more serious issue in fresh water streams and lakes, nitrogen has the greatest effect on estuarine systems, like the Bay, that are naturally nitrogen limited. Nitrogen is the most abundant nutrient on earth and is essential to the growth of all living things. It is in the air we breathe and the rocks and soils under our feet. However, it is also at the heart of problems with the Bay's health. Under natural conditions, most nitrogen is tied up as organic nitrogen, mineral soil, or in the air as a gas. But, fertilizers, air pollution, animal waste, sewage treatment, and other land use activities can introduce more inorganic and dissolved forms of nitrogen, including nitrate and ammonium, that are far more water soluble and easily enter local waterways. The release of nitrogen from forests to streams depends on a number of factors including amount of nitrogen deposited through the air, climate change, forest loss, and forest type:

Air Deposition

A quarter of the nitrogen entering the Bay is directly deposited from the air. Nitrogen oxide, formed by fuel combustion, reacts with other substances in the air and falls to earth as rain, fog, snow, or dry particles.[23] When nitrogen oxides and other pollutants interact with water, they form "acid rain" which carries nitrogen back to the surface.

Chesapeake forests generally retain 88% of the nitrogen they receive, making them an efficient buffer for air deposition. In watersheds where forests grow rapidly, biological demand for nitrogen is often sufficient to retain virtually all atmospherically deposited and mineralized nitrogen during the growing season.

However, prolonged exposure to acid rain can make forest soils acidic. This in turn can kill trees, stunt their growth and productivity, and thereby increase pollutant loads to streams. Highly acidic soils can also release aluminum into nearby streams, which can be toxic to plant or animal life. Over the past 20 years, the Bay watershed has received some of the highest amounts of acid rain in the continental United States. Between 1994 and 2001, the average amount of acidic nitrogen deposited on Chesapeake forests fell well within the range that is detrimental to forest ecosystem health.[19,24] Larger amounts of nitrogen deposition occur in higher elevations and the western highlands of the Bay watershed. High nitrogen rates continue to affect Chesapeake forests, particularly because the largest source of nitrogen oxides—automobiles—is expected to increase. Pollutants originating from industries outside of the Bay watershed exacerbate the problem. In fact, roughly half the air pollution deposited in the Bay originates outside of the watershed.[25]

After decades of nitrogen depositon, the soils of many Chesapeake forests store an overabundance of nitrogen. These saturated soils tend to leach nitrogen into waterways. While none of the forested watersheds in the Chesapeake region appear to be at an advanced stage of nitrogen saturation, increasing evidence shows that too much acid rain may be acidifying soils and reducing the degree to which forests will be able to retain nitrogen in the future.[26]

If nitrogen deposition rates stay at current levels, the ability of Chesapeake forests to retain nitrogen could decrease from its current high rate of 88% to only 47%. This change would represent a four-fold increase in nitrogen exported to streams from forests.

Chesapeake Bay Program Water Quality Goals

	Current Nutrient Loads	Chesapeake 2000 Goals	If All Watershed Land Use Was Forest
Nitrogen (million pounds per year)	275	175	60.6
Phosphorus (million pounds per year)	19	13	1.1
Sediment (million tons per year)	5	4	1.5

Source: Chesapeake Bay Program 2005

Water Quality Goals of the Chesapeake Bay Program

The Chesapeake Bay Program has set a goal to reduce current nitrogen and phosphorous loadings to 175 and 12.8 millions of pounds per year respectively by 2010. In addition, sediment loadings are to be lowered to 4.2 million tons. Can the conservation and restoration of forests affect the success of Bay restoration efforts?

If forestland extended across most of the Bay watershed as it did at the time of European settlement, the Chesapeake Bay Program's goals would be surpassed by a wide margin. Of course, restoring this much forestland in the Bay watershed is unrealistic if we are to maintain our economy and communities. However, looking at this baseline provides a view of the water quality changes brought about by human settlement and our use of the watershed. According to the Chesapeake Bay Program watershed model, a forested watershed would produce 1,700% less phosphorus, 450% less nitrogen, and 300% less sediment than current loadings.[21]

If nitrogen deposition from the air is allowed to continue to rise uncontrolled, the retention rate of forests could drop to 23% and the amount of nitrogen in streams would be 13 times higher.

This scenario is particularly troubling for the Bay. When multiplied by the large acreage of forestland in the Bay watershed, even small losses in a forest's ability to retain nitrogen could pose serious challenges to meeting and maintaining nutrient reduction goals—making the connection between air pollution and water quality very real. This is especially true in the high elevation streams of Pennsylvania and New York.[27]

Climate Change

Climate change creates uncertainty for Chesapeake forests. Over the next 30 years, forests may experience decreased growth rates, higher average annual temperatures, less rainfall during the growing season, shifts in species composition, and more disturbances such as hurricanes, fire, or insects. All of these changes may affect nitrogen yields, but the precise changes are unknown.[3]

Forest Loss and Disturbance

Forest conservation, restoration, and management all have great potential to influence the future health of the Bay. Relatively small changes in forest cover, plus or minus 10% can increase or decrease nitrogen loss from forests by 40%.[28] Retaining existing forests, expanding forests in critical areas, and managing forests to improve their growth and nitrogen retention should be an essential part of nutrient reduction strategies for the Bay.

Forests are naturally resilient in the face of disturbances. High winds, fires, hurricanes, and other natural events have shaped the distribution and composition of Chesapeake forests for millennia. Over the past few hundred years, humans have drastically changed the degree and frequency of disturbances. However, not all disturbances are equal in their impacts on forests. After a timber harvest, small to large forests can return to their original function in terms of nutrient retention and sediment production within three to five years, while a forest cleared for farming or construction may not recover for centuries, if it recovers at all.

Forest Type

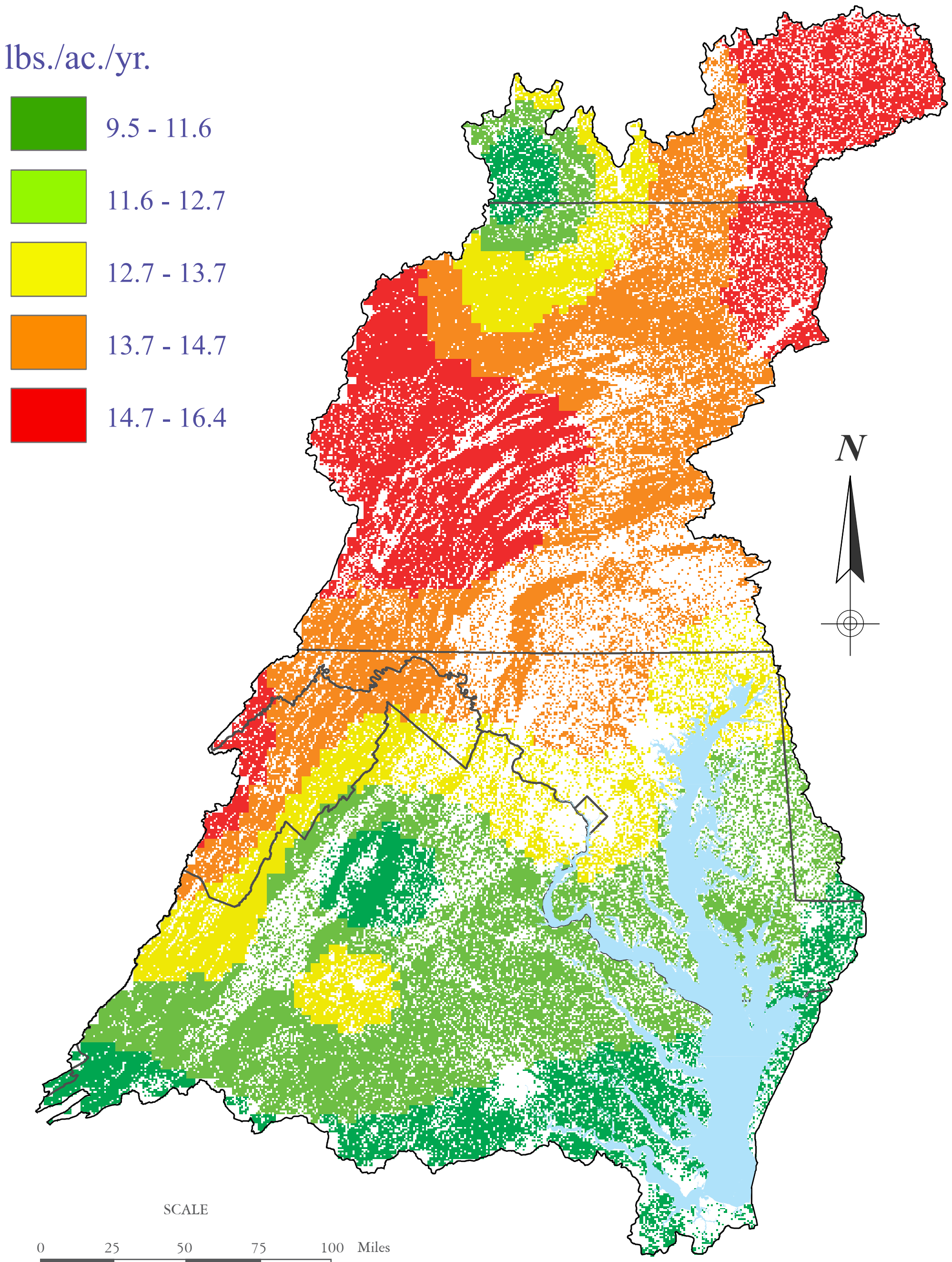
The natural character of Chesapeake forests favors nitrogen retention. An oak/hickory forest, the most abundant forest type in the watershed, retains an average of 90% of atmospheric deposition, while the smallest forest type, spruce/fir, retains 78%.[27] Coniferous forests in general use less nitrogen than deciduous forests; this is determined more by the soils where conifers grow than the nature of the tree itself. There are important exceptions, such as Eastern hemlock forests, which are highly efficient at retaining nitrogen because of their distinct microclimates.[29] Hemlock in the Chesapeake region is experiencing a dramatic decline due to the exotic hemlock wooly adelgid. Hardwood forests are also periodically affected by insect outbreaks, such as the gypsy moth, which can generate pulses of nitrogen output.

Nutrient Export Rates From Mid-Atlantic Forests

Watershed	Air Deposition (lbs./ac./yr.)	Retention (%)	Mean Stream Export (lbs./ac./yr.)
Rhode River, MD[1]	10.53	85	1.58
Baldwin Creek, PA[1]	13.83	87	1.95
Delaware Bay[2]	11.29	86	1.63
Delaware Bay[3]	11.29	77	2.64
Chesapeake Bay[3]	11.52	82	2.03
Chesapeake Bay[4]	11.52	89	1.24
Chesapeake Bay[5]	8.95	88	1.10

1: Gardner et al. 1994 2: Stacey et al. 2000 3: Alexander et al 2000 (SPARROW model)
4: Chesapeake Bay Program 2003 (Watershed model) 5: Pan et al 2004 (PnET-CN)

AIR DEPOSITON OF NITROGEN



INTERPRETATION:
Long-term air deposition of nitrogen in the range of 4 to 18 lbs./ac. is known to be detrimental to forest ecosystem health in the Bay watershed. The entire watershed averaged over 9.5 lbs./ac./yr. from 1994 - 2001 with the highest rates present in the northern and western portions of the Bay watershed.

SOURCE: Coulston et al. 2003

Riparian forests: The Link Between Land and Water

Four centuries ago, when Europeans arrived on the shores of the Chesapeake Bay and explored its watershed, nearly every stream flowed beneath a canopy of trees. The shorelines were rimmed with forests and fallen woody debris.

Humans have been influencing the quality of the forested riparian zones in the Chesapeake Bay watershed for thousands of years. Most Native American settlements were near riparian areas because of the relatively flat land, fishing opportunities, and transportation routes. The drastic decline in forest area over the past 400 years has been mirrored by similar losses of riparian forests. Too many people do not realize the importance of these streamside forests. As they disappear, the quality and productivity of streams, rivers, and the Bay itself have declined, and wildlife habitats have been eliminated.

Riparian forests also serve as the "last line of defense" for streams. While there are other forms of vegetative buffers, forested riparian buffers provide long-term nutrient storage better than either grasses or shrubs. The most common and natural riparian area has a combination of trees, shrubs, and herbaceous vegetation.

Over 200,000 miles of interconnected streams, rivers, and their associated riparian areas serve as the "circulatory system" for the Bay. Although riparian forests comprise only about 5% of the total land area, they are disproportionately important to the healthy function of watersheds. Because of their position in the landscape, riparian forests interact with the flow of surface and groundwater from upland areas and play an important role in filtering runoff, reducing nutrient pollution, and moderating stream temperature.

Conserved and managed as buffers, riparian vegetation can reduce the effects of upslope land-use activities. If they are forested, these buffers can also provide a wealth of ecological benefits for fish and wildlife, both onsite and downstream. The protection and restoration of riparian forests is an essential cornerstone to long-term restoration efforts in the Bay watershed.

Photo: Heather Richards

Functions and Benefits

Moderating Water Temperature

Leafy tree canopies produce shaded streams that maintain cooler, temperatures, especially in small streams. Cooler water reduces stress on fish and other creatures and holds more oxygen, encouraging the growth of diatoms, beneficial algae, and aquatic insects. In addition to more moderate temperatures in warm summer months, stream shading reduces daily temperature fluctuations. Continuity of these shaded streams is also important as a few degrees can have a major effect on water quality and the survival of aquatic organisms. Elevated stream temperatures can also serve to accentuate negative effects of pollutants in the stream.

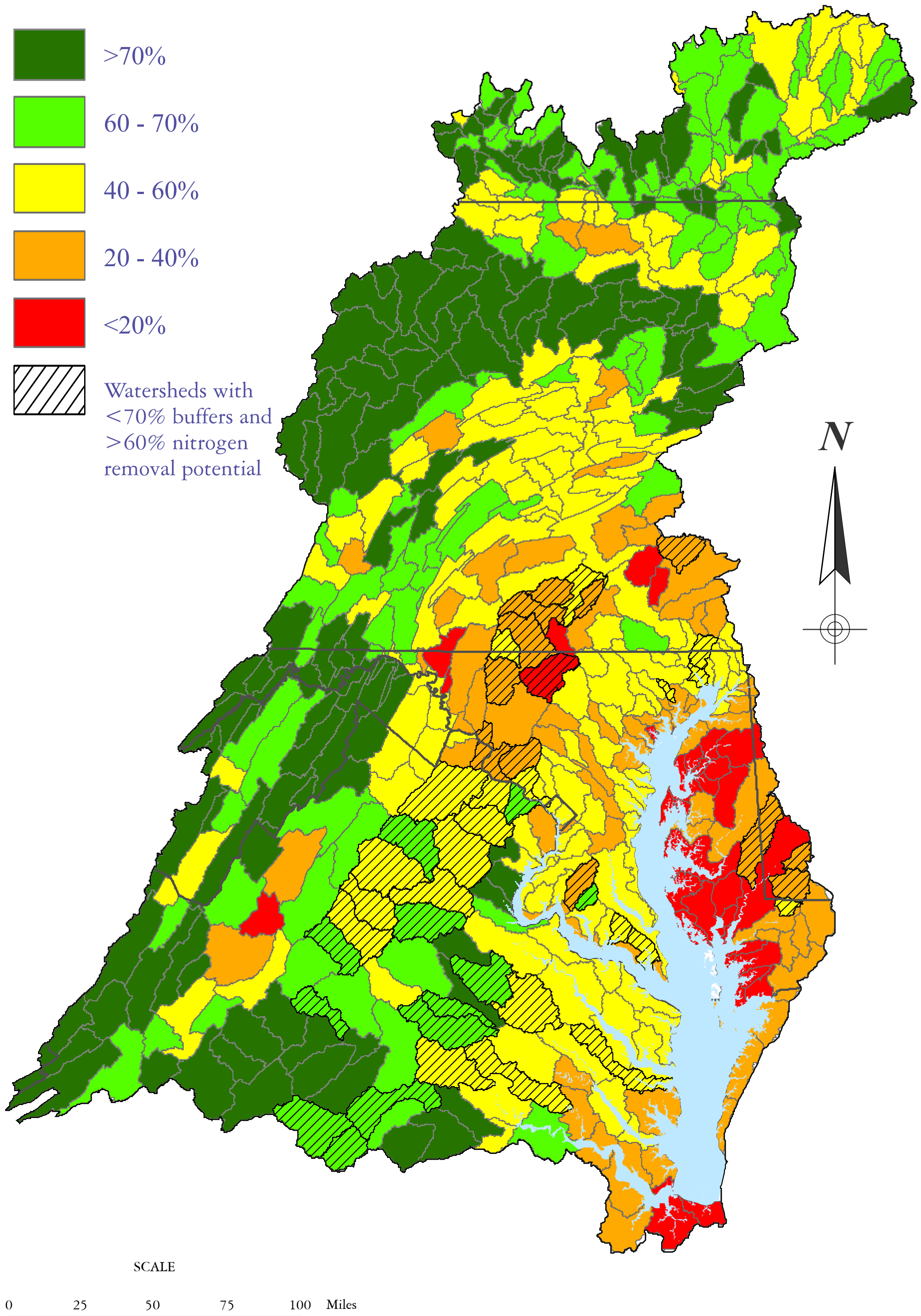
Protecting Stream Banks and Stabilizing Floodplains

Healthy riparian forests help stabilize stream banks and reduce erosion. The network of roots holds soil in place, while both branches and roots help protect banks by reducing stream flow velocity during floods. Floodplain forests can also lessen the effects of flooding downstream by retaining and temporarily storing flood waters.

Riparian Forests

Because of their position in the landscape, riparian forests can serve as buffers between land uses in upland areas and waters that eventually enter the Bay. A riparian forest buffer is defined as: an area of trees, usually accompanied by shrubs and other vegetation, that is adjacent to a body of water and is managed to maintain the integrity of stream channels and shorelines, to reduce the impact of upland sources of pollution by trapping, filtering, and converting sediments, nutrients, and other chemicals, and to supply food, cover, and thermal protection to fish and other wildlife.

Riparian Forest Cover by Sub-watershed



INTERPRETATION: Although riparian forests comprise only 5% of the land area in the Bay watershed, they are disporportionately important to the health of the watershed. For maximum benefits, riparian forests should cover over 70% of a watershed. Riparian forests are not always concentrated in areas that are most effective for reducing water pollution. Those watersheds that have less than 70% riparian forests and are capable of reducing greater than 60% of nitrogen flowing through them represent areas with high restoration value.

SOURCE: Chesapeake Bay Program 2005

Chesapeake Bay Forest Buffer Goals

Since 1996, the Chesapeake Bay Program and its partners have been actively pursuing the restoration and protection of riparian forest buffers in the Bay watershed. Working across state boundaries, this effort has set aggressive restoration goals, developed innovative programs and landowner incentives, conducted training and outreach, and built local community partnerships.

In December 2003, the Chesapeake Bay Executive Council expanded and strengthened the riparian forest buffer goals and defined a long-term vision for forest buffers in the Bay watershed. The new goals were expanded beyond the original directive to include the following:

- Restore at least 10,000 miles of riparian forest buffers by 2010
- Ensure that at least 70% of stream banks and shorelines in the Bay watershed are buffered
- Advance efforts to conserve existing forest buffers
- Work with a minimum of five jurisdictions per state to promote urban forests and increase tree canopy

To reach the long-term goal of 70% coverage in the Bay watershed, over 30,000 miles of new riparian forest buffers must be restored. The Conservation Reserve Enhancement Program (CREP), a federal-state program that provides financial incentives for restoring forest buffers on agricultural lands, has supported much of the current progress. In the future, more innovative and incentive-driven practices will be needed to accomplish the riparian forest buffer goals for the Bay watershed. The maintenance and conservation of current forested buffers is also an integral part of the initiative and will continue to be a focus of those leading the efforts.

Photo: David Winston

Filtering Pollution

The potential of riparian buffers to remove nutrients and sediment has been documented since the late 1970s.[20] While all forests filter sediment and runoff, riparian forests are particularly effective at capturing and transforming nitrogen and other pollutants into less harmful forms, mostly due to the high level of chemical and biological activity in the organic, carbon-rich soil.

Not only do forest buffers prevent non-point source pollutants from entering small streams, they also enhance the in-stream processing of both non-point and point source pollutants, thereby reducing their impact on downstream rivers and estuaries. Fallen woody debris and tree roots slow stream flow, which significantly increases the possibility of pollutant removal. In fact, deforested streams are able to process only one-tenth to half the amount of nitrogen as forested streams. The effectiveness of buffers in reducing in-stream pollutants depends on the width of the buffer, the soils and vegetation, and the contributions of pollutants from upland land use activities.

Buffers also help to prevent common pesticides, such as atrazine, as well as insecticides from reaching streams. Once in the water, degradation of these chemicals has been found to be higher in forested rather than non-forested streams. Although sunlight plays a significant role in pesticide degradation, the increased area of stream bottom, riffles, and woody debris in forested reaches seem able to compensate for lower sunlight.[30]

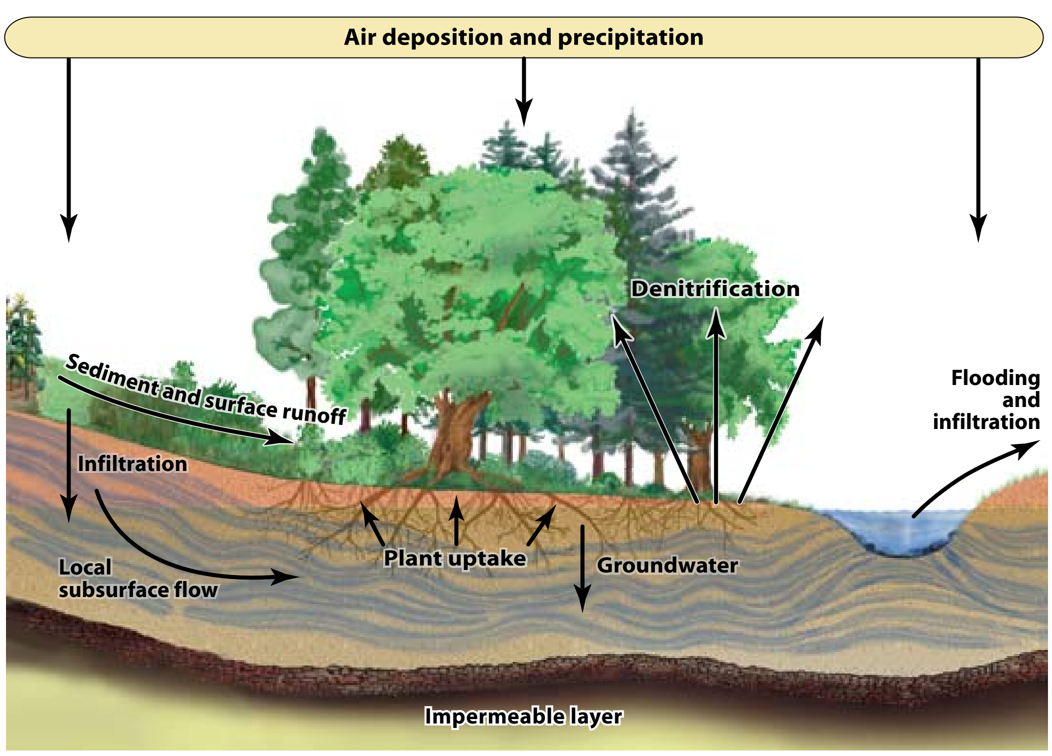
The effectiveness of buffers in some areas can be restricted by watershed and site conditions as well as past land use. For example, urban stream channels often erode as runoff increases, short circuiting the functional interaction between streams and riparian vegetation. Other means of concentrating flow, from stormwater pipes in urban areas to drain tiles on farms, prevent riparian areas from effectively filtering water before it reaches the stream.

Recent attention has also been drawn to legacy sediments in some portions of the watershed where sediment was deposited in the floodplain from soil erosion on farm fields or stored behind historic mill dams. Some of this sediment has been present for hundreds of years. In Lancaster, Pennsylvania alone, for example, there were over 450 mills built between 1700 and 1900—equaling roughly one mill dam for every two miles of stream.[31] Forests that reclaimed these legacy sediments sometimes grew on artificially high banks, 3 to 20 feet above the original floodplain. The roots of these perched forests can be separated from the primary source of nitrogen and have more trouble preventing it from reaching streams.[32]

Sustaining Aquatic Habitats

Mats of fallen leaves form the food base for aquatic insects and beneficial bacteria. Furthermore, as water passes through the forest on its way to a stream, it picks up an enormous variety of useful organic molecules. When that water enters a stream, a special blend of dissolved organic matter is dispersed like tea from a tea bag. Without riparian forests, the aquatic food web is dysfunctional.

Nutrient Flows Through a Riparian Buffer



Status and Trends of Riparian Forest Buffers

Currently, riparian forests buffer nearly 60% of streams in the Bay watershed. West Virginia has the greatest percentage of buffered streams in the watershed, at close to 70%. Most Bay states have approximately 50% of their stream miles bordered by riparian forests of 100 feet in width.[33] However, at smaller scales, developed watersheds are known to have as little as 15% riparian cover along streams.[34]

The overall loss of forested riparian buffers in the Bay watershed has been substantial over the past few hundred years. Forest corridors that were once thousands of feet wide have often been reduced to narrow strips of trees. Forested wetlands or bottomland hardwood forests have been particularly affected by land cover change.

The status and trends of buffers is often controlled by the implementation of riparian buffer ordinances by local jurisdictions. Ordinances are designed to protect streamside forests during the development process and likely have had an influence on retaining riparian forests in urbanizing areas. Individual local governments create and adopt these development regulations. In Virginia, many local buffer ordinances were developed in response to implementation of the Chesapeake Bay Act. In Maryland, an evaluation of the Maryland Critical Area Program found a low rate of loss of resource lands and, therefore, suggested that the Critical Area Criteria are making a difference.[35] The Forest Conservation Act in Maryland is also a landmark development law that requires conservation of forests and mitigation of forest loss within a hierarchy that recommends that riparian forests be the highest priority for protection.

Even where local buffer ordinances exist, development continues to "chip away" at remaining forests along vulnerable streams. Buffers continue to be developed into

Riparian Buffer Research

In 1993, Bern Sweeney of the Stroud Water Research Center suggested "one of the biggest factors contributing to the decline in water and habitat quality in aquatic ecosystems of eastern North America was the removal of forest ecosystems adjacent to the streams and rivers comprising the Atlantic drainage." He and his colleagues have demonstrated this fact and more. Research at Stroud has shown that reforesting riparian areas not only helps keep pollutants out of streams, but also significantly increases a stream's ability to process pollutants already in its waters.[30] Dr. Sweeney offers the following insights on riparian forest buffers and their restoration:

- A combination of native tree species is best. They adapt better to regional conditions, and do a better job of supporting the growth and survival of stream invertebrates, which are the primary food for fish. The leaves from non-native plants are even toxic to some stream organisms.

- Forested streams have a greater abundance and diversity of macroinvertebrates because they provide more benthic habitat area and food supply.

- Forested streams have 200 to 500% more organic matter per unit of channel length than deforested streams. The value of this organic matter is often underestimated or overlooked. A natural stream flowing through a mature forest in the Chesapeake Bay watershed needs an average of approximately 0.75 pounds of leaves for every square yard of stream bottom and at least 8 to10 species of trees to support natural levels of stream life.

- Forested streams tend to be wider and shallower than grassed streams. Increased channel width plays a critical role in nutrient processing by providing significantly greater surface area for biological activity. The stream bottom in a forested area can process 10 to 40 times more in-stream nutrients than a grass-bordered stream. Restoring forests can reduce the transport of nitrogen downstream to large rivers and estuaries.

- Proactive reforestation is usually necessary because foreign invasive plants hinder natural reforestation; intense grazing by deer, rabbits, and voles; and the lack of mature forests nearby to provide a seed source. Without proactive reforestation, aggressive non-native plants can dominate streamsides for more than 40 years following their abandonment from farming.


Photo: Heather Richards

Riparian Buffer on Previously Disturbed Land

recreation sites, storm water retention ponds, lawns, and other land uses.[36]

Drinking Water Supplies

In much of the Bay watershed, there is a direct connection between the forest and the faucet. Forests protect watersheds and drinking water better than any other land cover. They safeguard more than 3,000 surface water sources across the northeastern United States, providing water supply for more than 70 million Americans. While protecting water quality, these lands are often managed for timber, wildlife, recreation, and other purposes that help conserve them as open space.

Approximately 75% of people in the Bay watershed rely on surface water supplies for their clean drinking water. However, the public and policymakers alike often overlook the fact that safe, clean, and cheap water begins with the management and conservation of forested watersheds. Although non-point source pollution from agriculture remains the largest threat to water supplies, pollution related to development is the fastest growing threat.[37] Sprawling development, particularly when it replaces forests and wetlands, greatly increases the impact of pollution by removing natural barriers that filter pollutants and retain water. While droughts were historically the domain of the Western United States water shortages have begun to take center stage in the humid East. In 1998, when the Washington, D.C. area faced an unusually dry summer, local water authorities withdrew nearly 70% of the Potomac River's flow to supply water to area residents.

Many local water supplies that were established in the country, far outside of town centers, are now being rapidly encroached upon by development. Of the watersheds supplying drinking water to Bay communities, 60% are losing forestland. A recent survey of water suppliers conducted by the Trust for Public Lands and the American Water Works Association showed that treatment costs for drinking water go up when the amount of forest goes down.

With the exception of a few rivers, most sources of drinking water in the watershed have already been tapped. There are few, if any, ecologically or economically viable ways to augment most water supplies aside from water conservation, reuse, and greater depletion of groundwater. While water is a renewable natural resource, this geographic limitation should remind us that, for all practical purposes, water supplies are finite and irreplaceable. As a result, source water protection programs are showing renewed focus on forest conservation, ecosystem restoration, and stormwater management in water supply watersheds.[38]

Critical Forests for Water Quality

While all forestland enhances watershed health and water quality, some forests are particularly effective at delivering these benefits. The loss of high priority forests could severely compromise or degrade water quality and watershed functions.[2]

The Chesapeake Bay Program conducted a Resource Lands Assessment to identify these high-value forests in the Bay watershed. The water quality protection model ranked forests by their ability to store precipitation, retain and assimilate nutrients, moderate runoff, protect soils, and maintain important critical landscape functions such as those of riparian areas. Forests that scored high among these physical and biological factors were presumed to best protect water quality.

The following characteristics of soil and vegetation at a particular site as well as the characteristics of the watersheds within which they occur were used as parameters:

<u>Site</u>

- Proximity to water
- Erodible soils
- Forest productivity
- Slope
- Wetland function
- Fragmentation/patch size

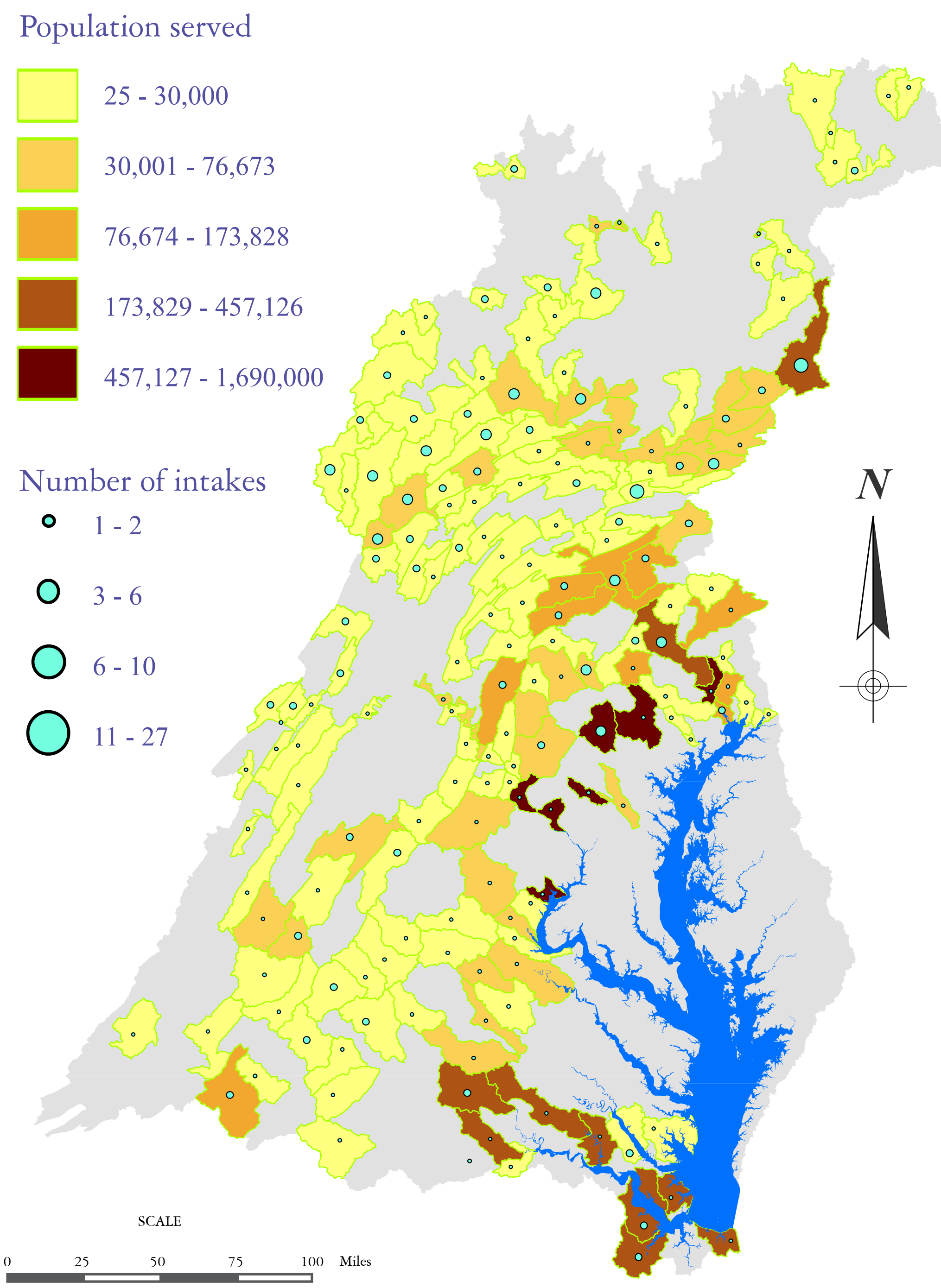
<u>Watershed</u>

- Percent of watershed forested
- Stream density of watershed
- Percent watershed imperviousness
- Current water quality
- Drinking water supply
- Floodplains
- Hydrogeomorphic region

Based on this analysis, regional conservation and restoration efforts to protect water quality should be enhanced in southern and southeastern Virginia, the Appalachian Plateau of western Pennsylvania, the Appalachian ridges, and scattered portions of the Piedmont and Coastal Plain. To determine the value of forests on a smaller scale, communities are encouraged to use the model to rank their local forests.

Based on current development patterns, 31% of the forests that are most valuable for water quality protection are threatened. For more information, see Chapter 7.

Drinking Water Supplies



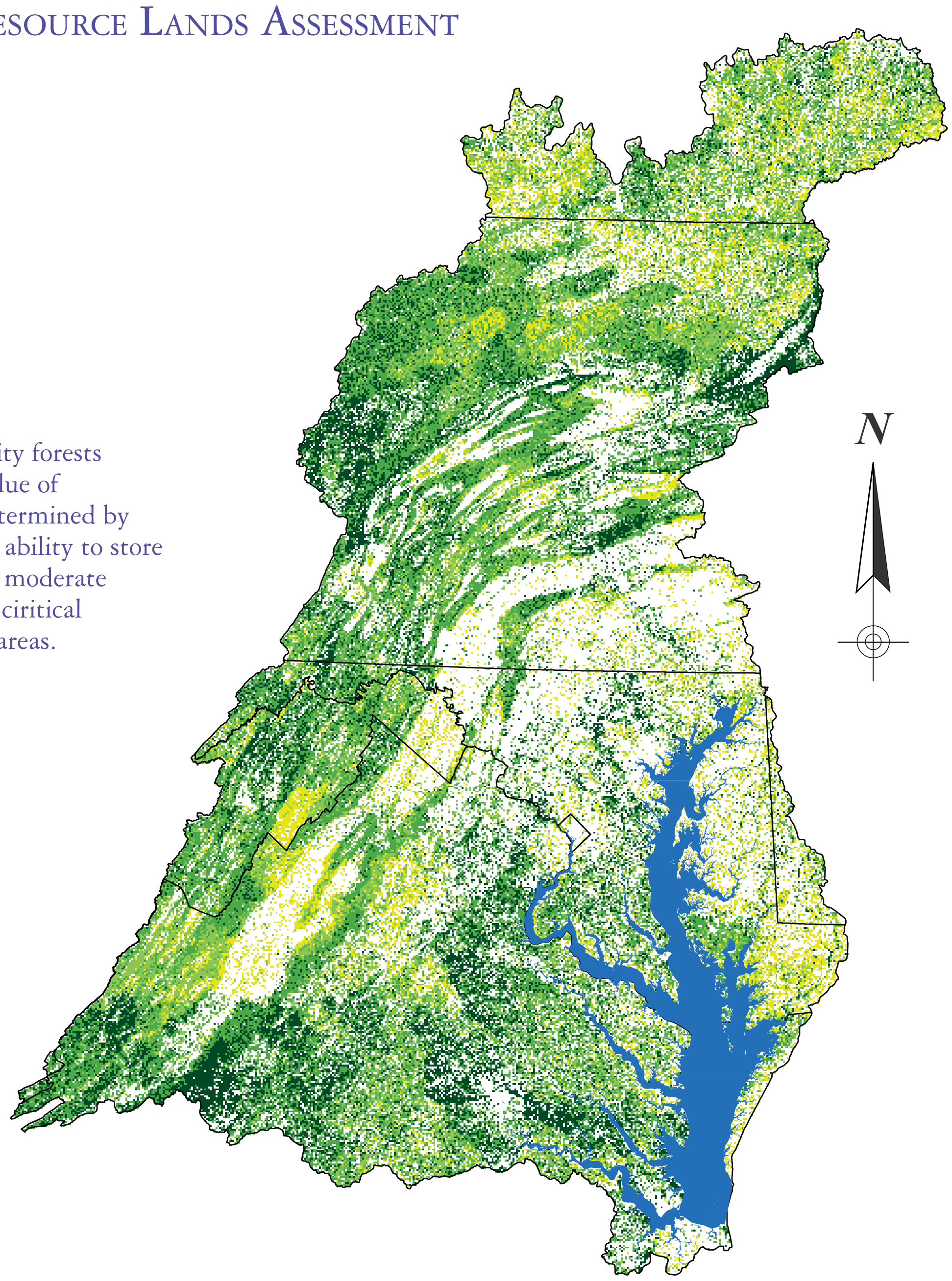
INTERPRETATION: Approximately 75% of people rely on surface water supplies for clean drinking water. Of the watersheds supplying drinking water, 60% are losing forestland. Becaues of this, drinking water quality will likely be degraded and treamtment costs will rise.

SOURCE: Chesapeake Bay Program 2005

Forestland Important to Water Quality

Resource Lands Assessment

- Very high
- High
- Moderate
- Low



INTERPRETATION: The loss of high priority forests could severely degrade water quality. The value of forest-provided water quality benefits was determined by numerous characteristics including the land's ability to store percipitation, retain and assimilate nutrients, moderate runoff, protect soils, and maintain important ciritical landscape functions such as those of riparian areas.

SOURCE: Chesapeake Bay Program 2005

SCALE

0 25 50 75 100 Miles

Indicators for Sustainable Chesapeake Forests

The following indicators can be used to track the ability of forests to maintain watershed function:

- Area and percent of impervious surface by watershed
- Percent of stream and shoreline miles that are buffered by at least 100 feet of forestland by watershed
- Area and percent of forestland by watershed

Chapter in Perspective

Forests and watershed health are closely linked. As forests are lost, less water is stored in our watersheds, less groundwater recharge takes place, and more nutrients are likely to make it to rivers, streams, and the Chesapeake Bay. Yet, most people still take for granted the important benefits provided by forests in discussions about non-point pollution control or stream health. Acre for acre, forests are the most beneficial land use for water quality and every loss of forestland contributes to increased nutrient loading to the Bay. However, forests and their stewardship are not only integral to improving the health of the Bay. They are also critical to the daily lives of every Bay watershed resident. The ability of forests and trees to protect public health and contribute to the overall quality of life in the Bay watershed is discussed in the next chapter, Forests for People.