POTOMAC RIVER WATER QUALITY IN THE METROPOLITAN WASHINGTON REGION - DRAFT

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POTOMAC RIVER WATER QUALITY IN THE WASHINGTON REGION
Prepared by the Water Resources Technical Committee
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The Metropolitan Washington Council of Governments (COG) is an independent, nonprofit association that brings area leaders together to address major regional issues in the District of Columbia, suburban Maryland, and Northern Virginia. COG's membership is comprised of 300 elected officials from 24 local governments, the Maryland and Virginia state legislatures, and U.S. Congress.

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EXECUTIVE SUMMARY

Progress

The Metropolitan Washington Council of Governments' (COG) assessment of water quality in the Potomac River shows that the billions of dollars invested by the region's local governments and utilities on water quality improvements have reduced pollution significantly. COG's assessment, which covers the period from 1985 to 2016 and which focuses on the Potomac River estuary, finds that there have been substantial improvements in water quality. Among the success stories: the amounts of nitrogen and phosphorus contained in the discharge from wastewater plants in metropolitan Washington has declined dramatically since the 1980s and is on track for further reductions. Also, the number and extent of harmful algal blooms in the upper Potomac estuary (the portion of the river affected by tides, it stretches from the river's fall line at Chain Bridge in Washington, D.C., downriver to its confluence with the Chesapeake Bay) has declined significantly. Populations of some of the plants and animals that live in this portion of the river, such as submerged aquatic vegetation and American shad, have grown closer to their historical abundances.

But More To Be Done

But these improvements do not mean that the river has fully recovered. Further efforts are needed for the river to meet the same restoration goals as the Chesapeake Bay as a whole; the river and the bay share the same issues and are subject to the same regulatory framework.

The report, *Potomac River Water Quality in Metropolitan Washington*, presents data collected by various entities and compiled by COG to provide a broad overview of water quality conditions in the Potomac River, particularly the portion that flows through metropolitan Washington. It focuses on both the key water quality parameters – dissolved oxygen, water clarity, and chlorophyll-a -- and the major pollutants -- nitrogen, phosphorus, and sediment -- that are targeted by the Chesapeake Bay Total Maximum Daily Load (TMDL), the main regulatory framework of the Bay restoration effort. Almost all of the data in the report is trend data; that is, it shows the direction of change over time, either positive (improving) or negative (degrading) and it is designed to answer the question: are we making progress in our efforts to improve water quality.

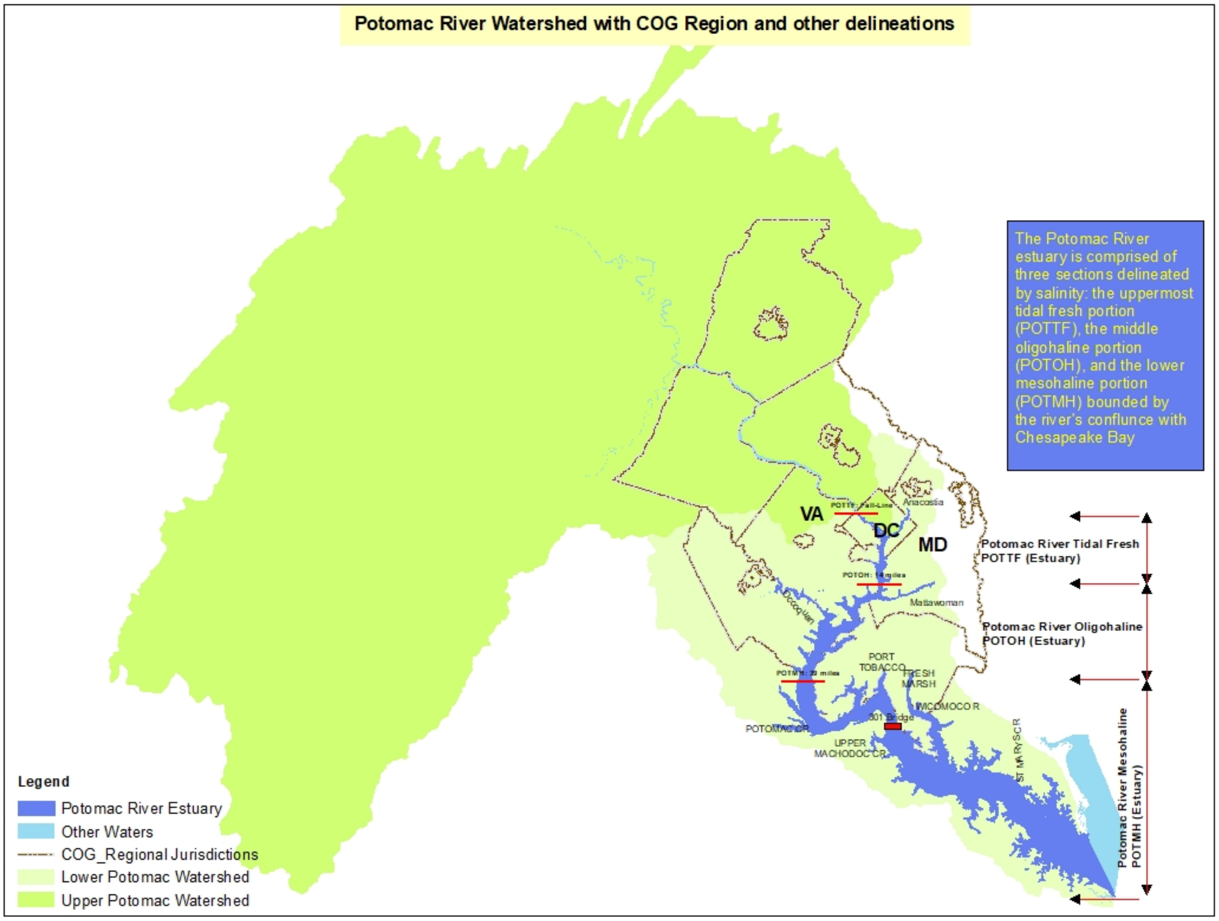
There are a number of other water quality issues in the Potomac caused both by these pollutants and other factors. These include harmful algal blooms above the Chain Bridge fall line that release toxins of concern to drinking water providers and man-made chemicals that may cause intersex fish and other problems. These are noted, but not discussed in detail, in the report.

In broad terms, water quality in the Potomac estuary is determined by three major inputs:

- **Discharge from Wastewater Treatment Plants (WWTPs)** - about 83 percent of total wastewater discharge in the Potomac watershed, including the bulk of the region's wastewater discharge, flows directly into the estuary
- **Across the Fall Line** - The quality of the water flowing across the main Potomac River fall line at Chain Bridge. The watershed upstream of Chain Bridge has a higher percentage of agriculture than elsewhere in the watershed.

- **Below the Fall Line** - The quality of the water that drains to the river below Chain Bridge. A much larger percentage of the land draining to the river below Chain Bridge compared to above Chain Bridge is urbanized; here the quality of stormwater runoff is a critical factor.

MAP OF THE POTOMAC RIVER WATERSHED – ABOVE AND BELOW THE FALL LINE

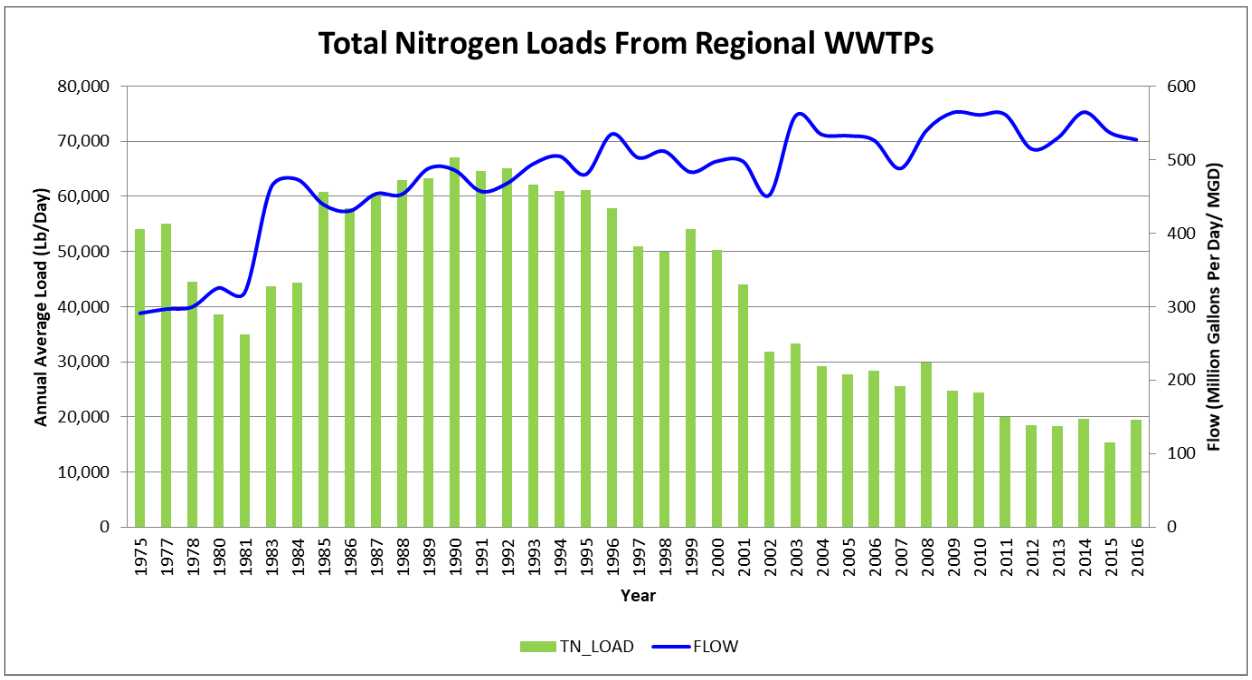


Source: COG

Wastewater

Reductions in the amount of nitrogen and phosphorus in the effluent discharged by wastewater treatment facilities account for the most significant progress, by far, in the 35-year history of the Chesapeake Bay restoration effort. These wastewater reductions account for about 75 percent of total reductions of nitrogen and phosphorus from all sources since 1985, according to the Chesapeake Bay Program. The share is even higher in the Potomac watershed. The success is derived from a funding partnership among all levels of government. Federal grants helped local governments pay for the original round of phosphorus controls; state and federal funds are helping pay now for a further round of nitrogen controls.

Total Nitrogen Loads from Regional WWTPs



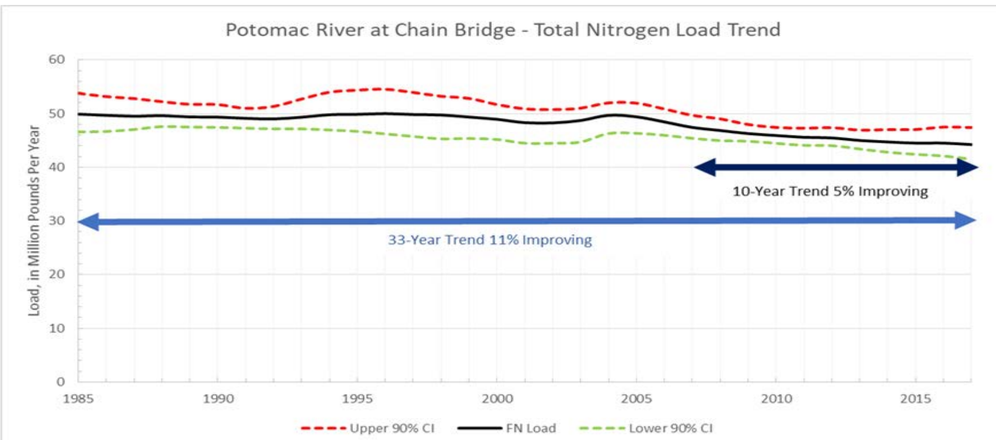
Source: COG

The reduction in nutrient discharges from wastewater treatment plants is all the more impressive because it has been achieved while population and job growth have continued in the region. The nutrient reduction performance gives the region a cushion to accommodate future growth without exceeding the Bay TMDL's nutrient caps.

Monitoring Pollution at Chain Bridge

The U.S. Geological Survey (USGS) maintains a Potomac River fall line monitoring station at Chain Bridge, one of a series of river input monitoring stations that analyze water quality flowing into the Bay from its major tributaries. Data in this section is drawn from the USGS Chain Bridge station, in place since 1985, and addresses the three major pollutants regulated by the Bay TMDL: total nitrogen, total phosphorus and total sediment.

Figure 1: Total Nitrogen Load Trend at Chain Bridge



Source: USGS

The USGS data show nutrient reduction efforts above the Potomac fall line have led to decreasing trends for nitrogen since 1985 (11 percent) and since 2008 (5 percent).

Nonpoint Source Loads below the Fall Line

Efforts to reduce the amount of nutrients and sediment in stormwater runoff are still in their infancy compared to wastewater nutrient reduction efforts. All of COG's members are subject to stormwater permitting requirements, either through Phase I or Phase II Municipal Separate Storm Sewer System (MS4) permits for their stormwater conveyance systems. These permits require the jurisdictions to pursue a variety of actions to minimize the pollution carried by their stormwater systems.

Unlike the concentrated discharge from a wastewater plant, county-wide stormwater systems interact with natural waters at hundreds, even thousands, of stormwater outfalls. Reducing nutrients, sediment or other pollutants from stormwater systems requires the implementation of thousands of small-scale "best management practices" across the urban landscape, which has proven to be both a programmatic and financial challenge for COG's members. Nevertheless, some signs have emerged of progress in reducing nutrient loads from urban stormwater in portions of the metropolitan region.

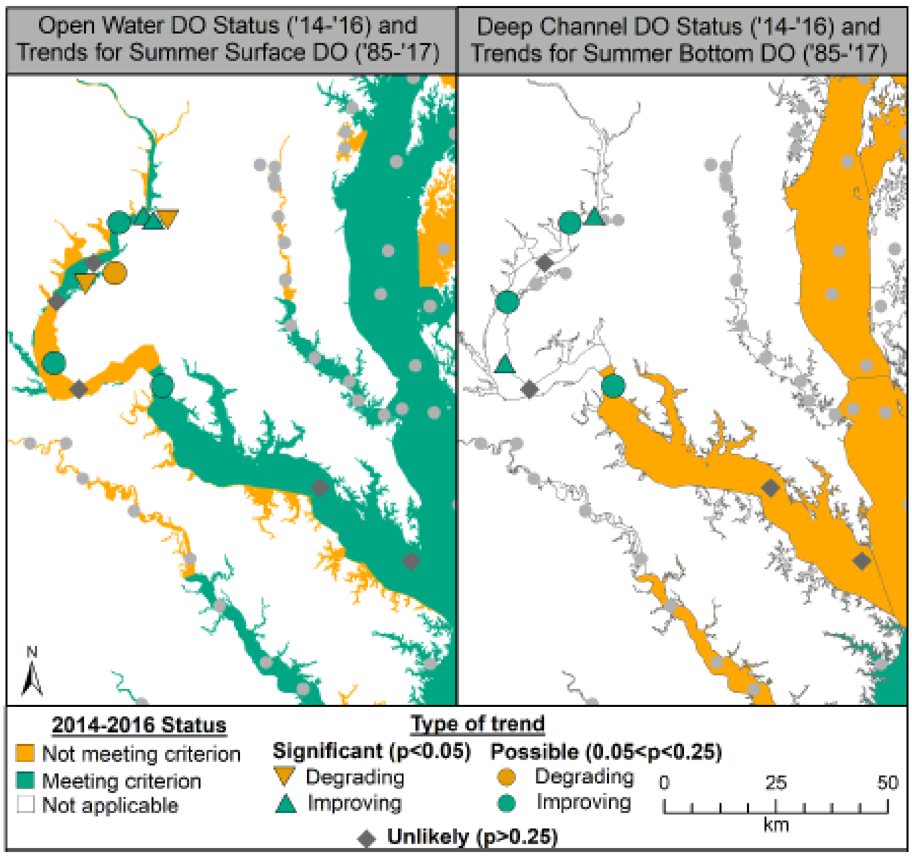
Estuary Water Quality

Water quality data gathered in the Potomac River estuary and the Chesapeake Bay since 1985 provides a mixed picture of progress, with certain parameters showing signs of improvement while others have degraded. The dissolved oxygen (DO) figure illustrates the complex nature of assessing progress. In general, DO attainment is better in the open water habitat in the Potomac estuary (as shown by the predominance of green in the map on the left) than it is in the segments where deep water or deep channel habitat exists (as shown by the predominance of orange in the map on the right). Similarly, the long-term trend indicators on these maps point to both improving and degrading trends.

Water quality standards are regulatory provisions that describe the desired condition of a water body and the means by which that condition will be protected or achieved. Attainment with the standards is measured by criteria based on the levels of dissolved oxygen, chlorophyll-a and water clarity.

The data in this figure comes from the Chesapeake Bay Program's (CBP) tidal monitoring program, which collects water quality samples from the Bay and its tidal tributaries and analyzes them in a uniform fashion. Dissolved oxygen is one of three means of assessing attainment with water quality standards

Figure 3: Oxygen criterion status for Potomac segments along with long-term trends in DO concentrations

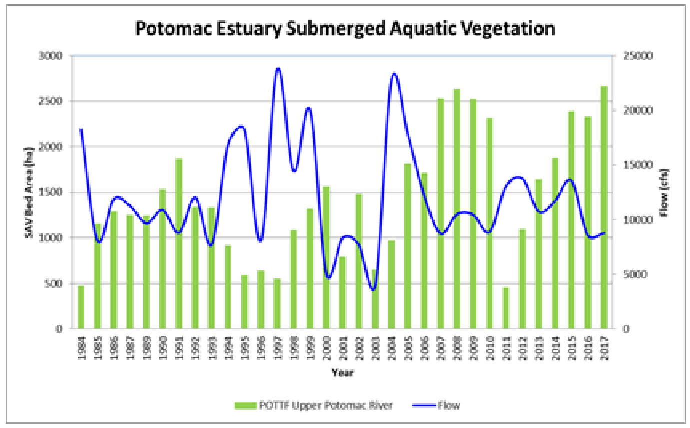


Source: Chesapeake Bay Program

Success Stories – Submerged Aquatic Vegetation (SAV)

Submerged aquatic vegetation (SAV) in the freshwater portion of the Potomac estuary (indicated as POTTF in the adjacent graph, it stretches from the Chain Bridge fall line to the river's confluence with Mattawoman Creek) is one of the success stores of the restoration effort.

Figure 4: Potomac Estuary SAV (Upper Portion) and Flow at Chain Bridge



Source: Virginia Institute of Marine Science

As can be seen in the graph, the amount of SAV growing in the upper estuary fluctuates annually because of changes in weather conditions such as the amount of river flow driven by the pattern of rainfall, and other factors, but overall it has increased significantly in recent years as nutrient levels in the water have decreased. Fewer nutrients leads to less algal growth, which in turn increases the amount of light that reaches underwater grasses. In addition to the greater extent of SAV growth, the upper estuary also has seen the diversity of underwater grasses increase in recent years.

Summary

Local governments and utilities in the COG region are making great progress in reducing the amount of nutrients discharged from wastewater plants in the region. As a result, harmful algal blooms have been reduced, submerged aquatic vegetation has returned, and the populations of several fish and waterfowl species have increased. There also has been some progress, albeit smaller, in achieving reductions from other nutrient sources in the Potomac watershed. But these reductions are not yet enough to completely achieve water quality standards.

Researchers are investigating to what extent nutrient and sediment concentrations must decline further to achieve water quality standards, but the calculation is not a simple linear relationship in which a certain amount of pollution reduction leads to a certain amount of improvement in water quality. The complexity of factors that affect the estuary includes more than simply the levels of nutrients and sediment in the water. Additional issues such as chemical contaminants and climate change also have major impacts on water quality. This complexity explains some of the mixed signals presented by water quality data in the Potomac estuary, with both improving and degrading trends.

Because wastewater has already implemented most of what technology can achieve in the way of nutrient reduction, further progress in improving water quality conditions depends on further efforts to reduce nutrients and sediment from nonpoint sources, such as agriculture and urban runoff. Here, too, there is uncertainty and mixed signals, with many improving trends but some degrading ones as well. Scientists are still interpreting how much time elapses between various nutrient reduction efforts and when their impact shows up in the Bay. What is certain is that additional efforts to reduce nutrients and sediment from nonpoint sources will be needed to achieve the river's long-term water quality goals.

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OVERVIEW

Progress, But More to be Done

The Metropolitan Washington Council of Governments' (COG) assessment of water quality in the Potomac River shows that the billions of dollars invested by the region's local governments and utilities on water quality improvements have reduced pollution significantly. COG's assessment, which covers the period from 1985 to 2016 and which focuses on the Potomac River estuary, finds that there have been substantial improvements in water quality. Among the success stories: the amount of nitrogen and phosphorus discharged by wastewater plants in the metropolitan Washington region has declined dramatically since the 1980s and is on track for further reductions. As a result, the number and extent of harmful algal blooms in the upper Potomac estuary has declined significantly. Populations of some of the plants and animals that live in this portion of the river, such as submerged aquatic vegetation and American shad, have grown closer to their historical abundances.

But these improvements do not mean that either the river itself has fully recovered from the poor conditions of previous decades or that further efforts are unnecessary. In this, the river's situation mirrors that of the larger Chesapeake Bay watershed, of which it is an integral part.

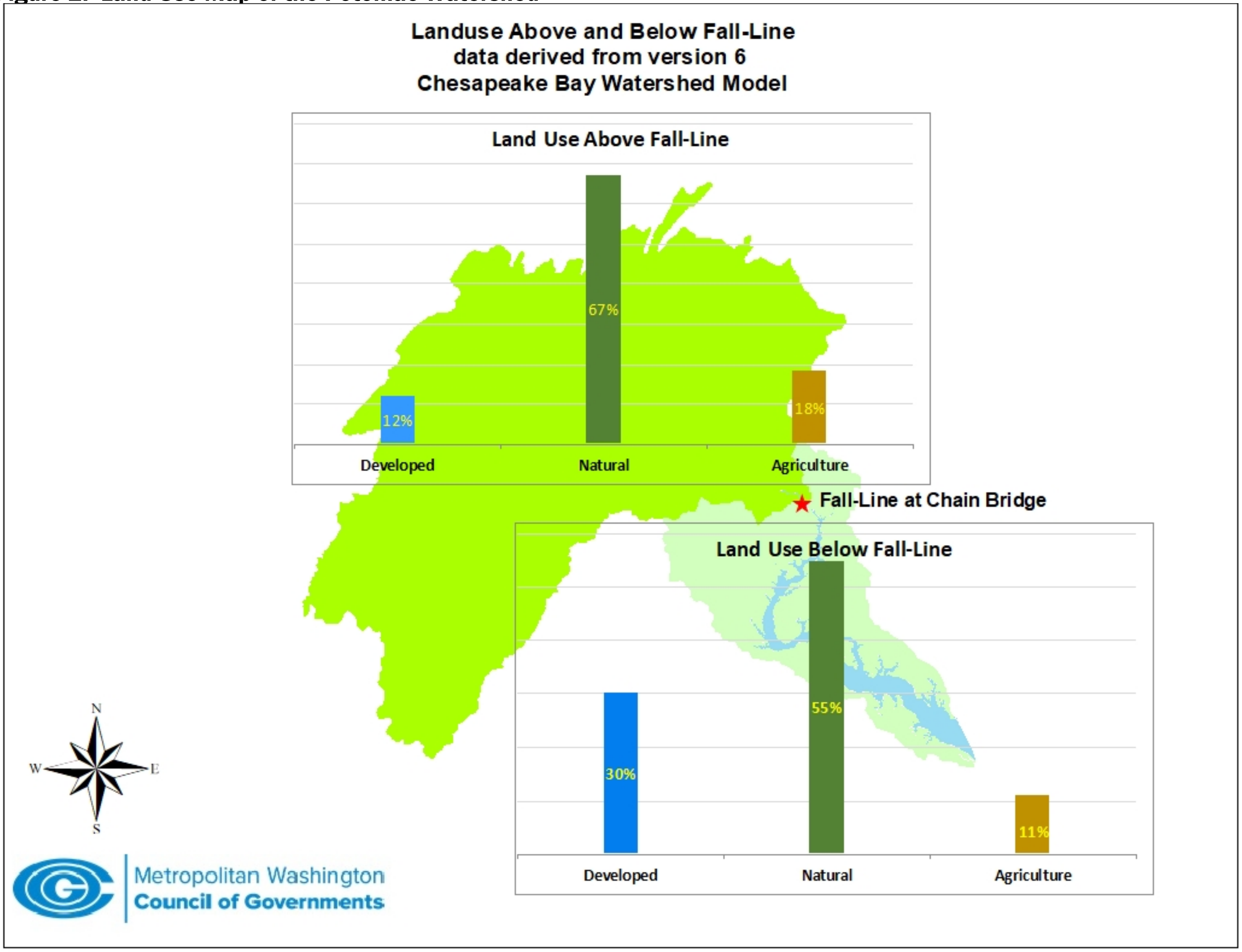
Report Focus

This report presents data collected by various entities and compiled by COG to provide a broad overview of water quality conditions in the Potomac River, particularly the portion that flows through the Washington region. It focuses on both the key water quality parameters – dissolved oxygen, water clarity and chlorophyll-a -- and the major pollutants -- nitrogen, phosphorus and sediment -- that are targeted by the Chesapeake Bay Total Maximum Daily Load (TMDL). Almost all of the data in the report is trend data; that is, it shows the direction of change over time, either positive (improving) or negative (degrading) and it is designed to answer the question: are we making progress in our efforts to improve water quality.

In broad terms, water quality in the Potomac estuary is determined by three major inputs:

- **Discharge from Wastewater Treatment Facilities –** although these plants are located throughout the watershed, about 83 percent of their total discharge, including the bulk of the region's wastewater discharge, flows directly into the estuary.
- **Across the Fall Line** - the quality of the water flowing across the main Potomac River fall line at Chain Bridge. The watershed upstream of Chain Bridge has a higher percentage of agriculture than elsewhere in the watershed.
- **Below the Fall Line** - the quality of the water that drains to the river below Chain Bridge. A much larger percentage of the land draining to the river below Chain Bridge compared to above Chain Bridge is urbanized; here the quality of urban stormwater runoff is a critical factor.

Figure 2: Land Use Map of the Potomac Watershed



Source: Chesapeake Bay Watershed Model Phase 6

Potomac Watershed at a Glace:

Length – 383 miles from orgins in West Virginia to confluence with the Chesapeake Bay Area
Area - At 14,670 square miles, the watershed comprises about 23 percent of the overall Bay watershed
Nature - Free-flowing to the fall line at Chain Bridge, a tidally-influenced estuary for the rest of its length
Population - About 6 million, 80 percent of whom live in the COG region
Land Use - Primarily forested in the portion that drains above Chain Bridge, somewhat urban in the portion that drains below Chain Bridge

Determining how much pollution arises from the watershed’s different land uses is key to understanding what management actions are necessary to further improve water quality.

Section 1. Inputs to the Estuary - Regional Wastewater Treatment

Starting in the early 1960s and continuing through today, the area's wastewater treatment plants have made many upgrades to increase the efficiency at which they capture nutrients and other sources of pollution from their effluent.

Phosphorus was the first major nutrient of concern because it plays an important role in stimulating harmful algal blooms in the freshwater portion of the Potomac estuary. Area treatment plants began implementing phosphorus controls in the 1970s to meet what were then – and remain today – some of the most stringent discharge requirements in the country. These efforts, which pre-dated the first Chesapeake Bay Agreement in 1983, reduced the amount discharged by about 96 percent and remain in place today.

The reduction in nutrient discharges from wastewater treatment plants is all the more impressive because it has been achieved despite increases in wastewater flow (depicted by blue lines in the accompanying charts) to the plants as a result of population and job growth in the region. The improvement in nutrient reduction efforts has given the region a cushion to accommodate future growth without exceeding the Bay TMDL's nutrient caps.

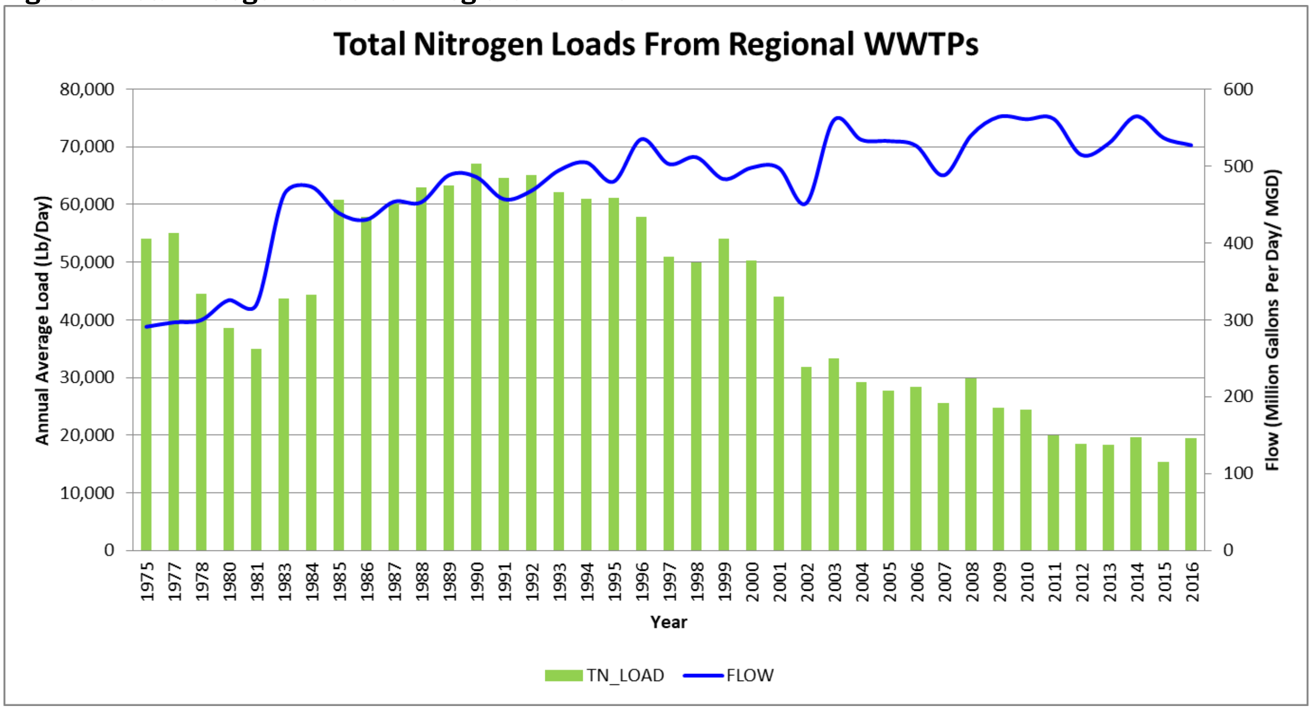
Beginning in the late 1980s, wastewater plants began to focus on reducing discharges of nitrogen. The first round of such reduction efforts, known as biological nutrient removal, reduced wastewater loadings 40 - 50 percent from previous levels. Starting in 2010, the region's wastewater plants began implementing a second round of nitrogen reductions that is now nearly complete and that has yielded significant additional reductions in wastewater pollutant loads.

Reductions in wastewater nutrient loadings account for the most significant progress, by far, in the 35-year history of the Chesapeake Bay restoration effort. According to Chesapeake Bay Program (CBP) calculations, the wastewater sector accounts for about 75 percent of total reductions of nitrogen and phosphorus since 1985.

The success in reducing pollution is derived from a funding partnership among wastewater utilities and all levels of government. Federal grants helped utilities and local governments pay for capital improvements needed in the original round of phosphorus controls; local, state and federal funds are also helping to pay now for capital improvements to achieve further nitrogen controls and ongoing costs to operate and maintain wastewater infrastructure are all paid by utilities and local governments.

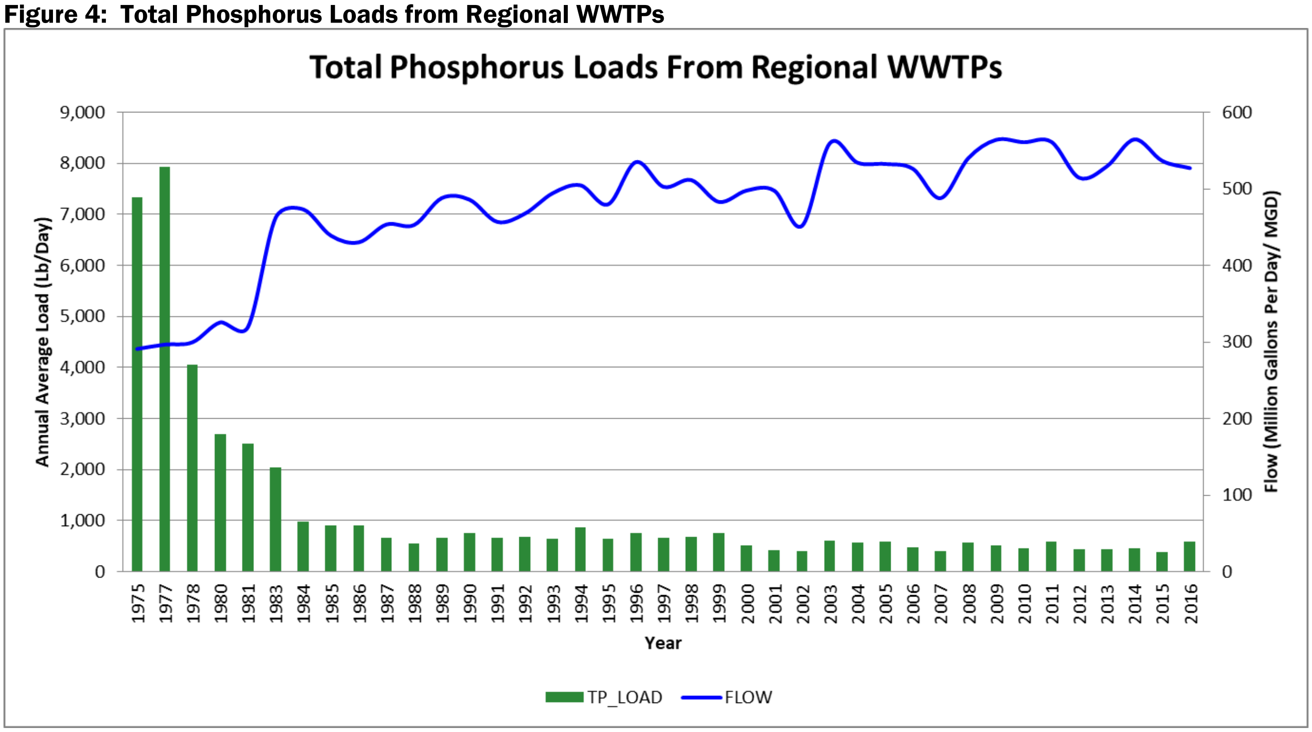
Although indicators of water quality remain mixed, it is possible to document the impact of reductions in wastewater pollutants on improving water quality in the Potomac River, particularly in the upper estuary into which almost all of the metropolitan Washington region's plants discharge their effluent. Water quality monitoring efforts here have shown improvements in dissolved oxygen levels, a reduced incidence and severity of harmful algal blooms, and increasing populations of several critical living resources, including submerged aquatic vegetation.

Figure 3: Total Nitrogen Loads from Regional WWTPs



Source: COG

Figure 4: Total Phosphorus Loads from Regional WWTPs



Source: COG

Section 2. Inputs to the Estuary - Monitoring Pollutant Loads at Chain Bridge

The U.S. Geological Survey has maintained a Potomac River fall line monitoring station at Chain Bridge since 1985, one of a series of river input monitoring stations that analyze water quality flowing into the Bay from its major tributaries. Data in this section is drawn from the USGS Chain Bridge station and addresses the three major pollutants regulated by the Bay TMDL: total nitrogen, total phosphorus and total sediment.

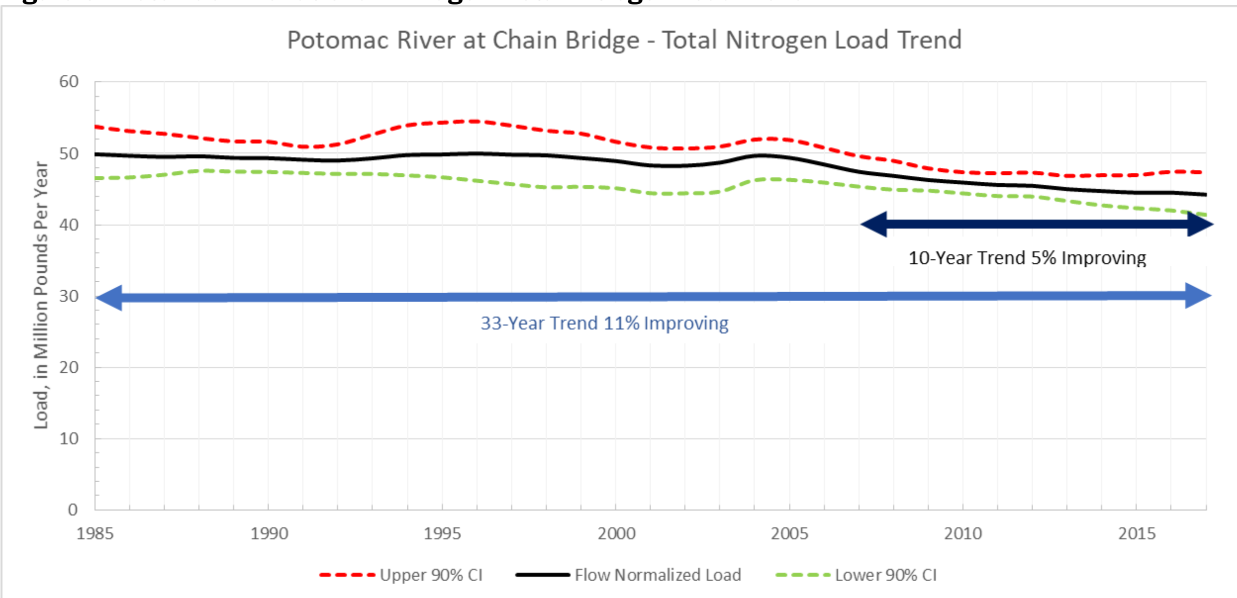
COG would like to know from this data if the Bay Program's pollution reduction efforts are working, that is, whether the trend for these parameters is increasing or decreasing. (It's important to note that almost all of the wastewater effluent from plants in the COG region is discharged into the river below Chain Bridge; water quality at Chain Bridge reflects some impacts from upstream wastewater plants, but it is more affected by nonpoint sources, particularly agriculture.)

However, this task is complicated by several factors. Foremost of these is the variability created by changing weather patterns. On a year-to-year basis, the total amount, or load, of these pollutants will fluctuate with the flows resulting from differing patterns of precipitation. To discern water quality trends impacted only by human activities, the USGS has developed a method for estimating flow-normalized loads and trends in load. This method (known by its acronym, as WRTDS) produced the data shown in this section[i]; it also provides some of the data used to establish loads for the Bay TMDL and to calibrate the CBP watershed model.

USGS uses statistical techniques to remove most of the variability in actual loads introduced by fluctuating hydrology. The resulting flow-normalized loads provide an illustration of how nutrient and sediment loads have altered because of man-made changes.

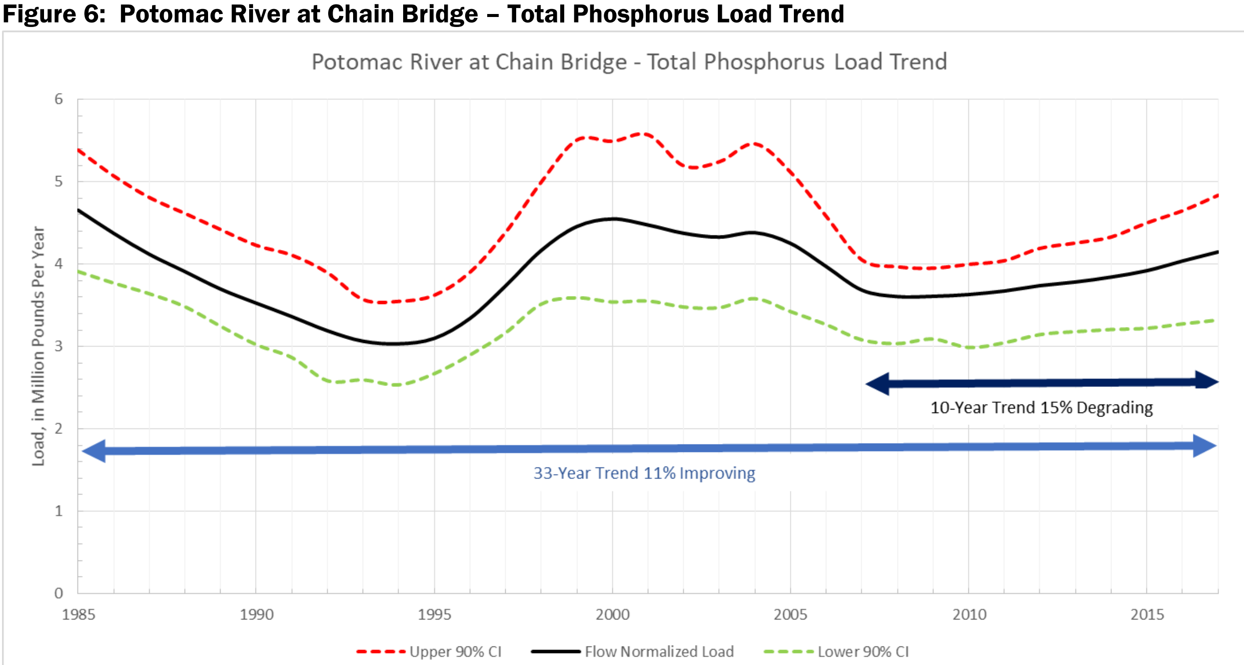
These charts show the trends in flow-normalized loads of the major Bay pollutants measured at the Potomac fall line at Chain Bridge by USGS. Total nitrogen (TN), total phosphorus (TP) and total sediment (TS) loads are shown in millions of pounds/year in Figures 4, 5 and 6, respectively.

Figure 5: Potomac River at Chain Bridge – Total Nitrogen Load Trend



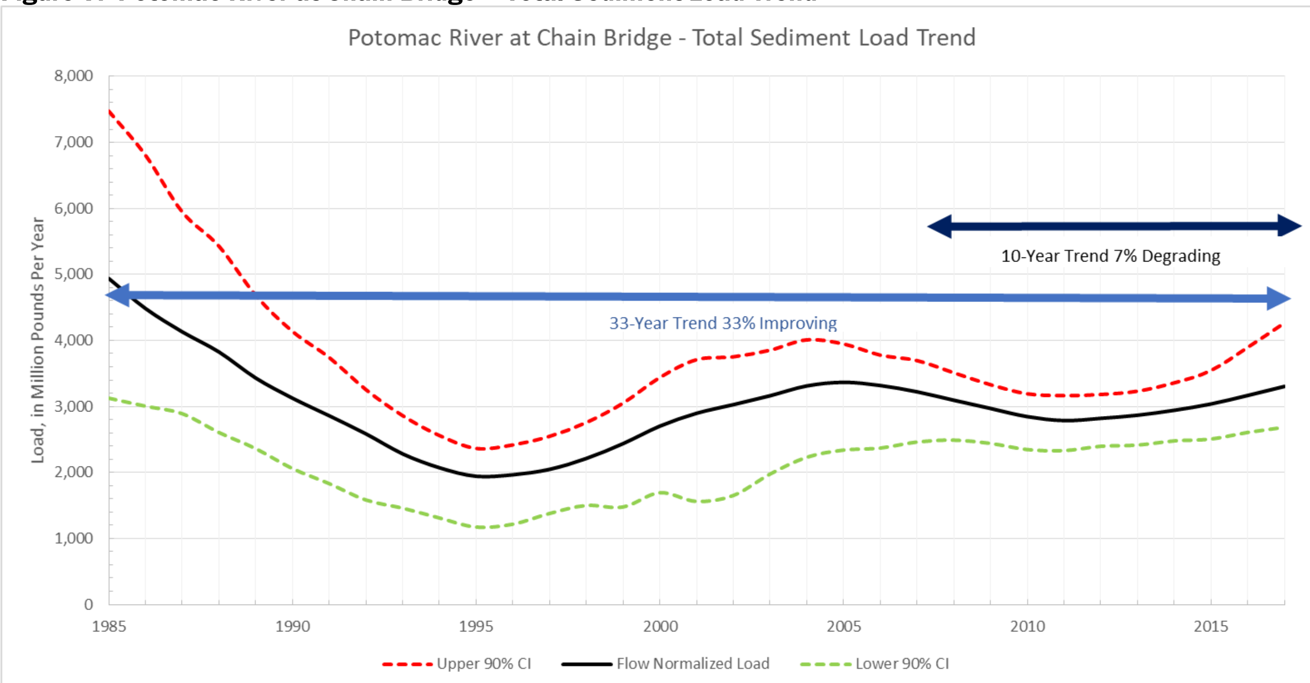
Source: USGS

Figure 6: Potomac River at Chain Bridge – Total Phosphorus Load Trend



Source: USGS

Figure 7: Potomac River at Chain Bridge – Total Sediment Load Trend



Source: USGS

The USGS data shows that loads of the three major pollutants at the Potomac fall line are lower now than in 1985, most likely due to nutrient reduction efforts in this portion of the watershed. However, the patterns differ between nitrogen on the one hand and both phosphorus and sediment on the other. Observed loads of TN have been flat to steadily declining over the 33-year span of the USGS monitoring data. Observed TP and TS loads over the same period have gone up and down and in both cases show increases (i.e. degrading trends) in the most recent 10 years. There is not a definitive explanation for the drivers of these observed changes in loads. Reductions in nutrients from wastewater plants and from the entire agricultural sector probably account for most of the progress. In the case of the recent increases in flow-normalized TP and TS loads, it is thought that increases in animal agriculture and the resulting manure in certain portions of the watershed and increases in the amount of developed land above the Chain Bridge fall line (mostly outside the COG region) have contributed to these degrading trends.

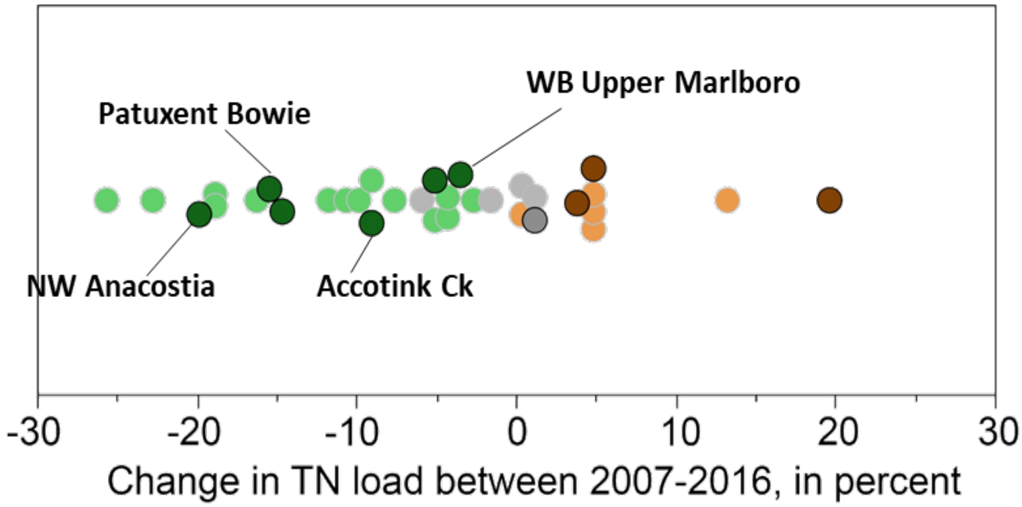
Section 3. Inputs to the Estuary - Nonpoint Source Loads from below the Fall Line

Although urban land in the metropolitan Washington region drains both above and below the Potomac fall line at Chain Bridge, the quality of urban stormwater runoff is most critical to the loads coming into the river from below the fall line. Efforts to reduce nutrient and sediment loads from urban landscapes are still in their infancy compared to wastewater nutrient reduction efforts. All of COG's member jurisdictions are subject to stormwater permitting requirements, either through Phase I or Phase II Municipal Separate Storm Sewer System (MS4) permits for their stormwater conveyance systems. These permits require the jurisdictions to pursue a variety of actions to minimize the pollution carried by their stormwater systems. The most recent MS4 permits focus in particular on reductions of nutrients and sediment to meet Bay TMDL goals, but there also are requirements to address impairments in local streams and lakes.

Unlike the concentrated discharge from a wastewater plant, county-wide stormwater systems interact with natural waters at hundreds, even thousands, of stormwater outfalls. Reducing nutrients, sediment or other pollutants from stormwater systems requires the implementation of thousands of small-scale BMPs across the urban landscape, which has proven to be both a programmatic and financial challenge for COG's members. The challenge is made even greater by the limitations of stormwater permits in addressing stormwater runoff from private property. Nor do the stormwater permits apply to runoff from farms.

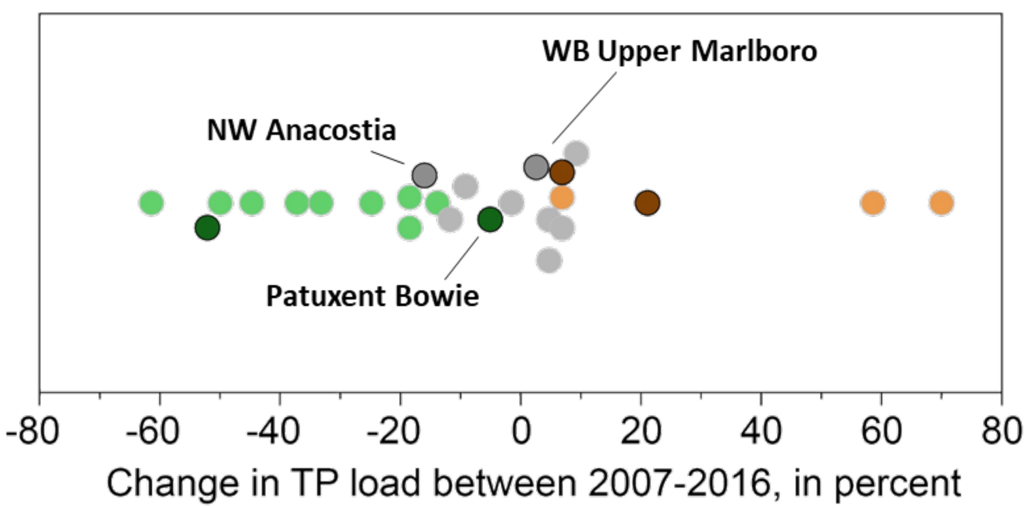
Nevertheless, some signs have emerged of progress in reducing nutrient loads from urban stormwater in portions of the COG region. The following charts show TN and TP load data from all of the USGS nontidal monitoring stations in the Potomac and Patuxent watersheds in the 10 years from 2007 - 2016. Improving load trends (shown as green circles) indicate stations where pollution reduction progress has been measured; brown circles indicate stations with degrading load trends; the grey circles indicate stations where the data shows no particular trend. The stations at Northwest Anacostia (covering the Northwest Branch portion of the river's watershed), Patuxent Bowie (covering the river's watershed upstream of the city), Accotink Creek (covering the creek's watershed upstream of Annandale), and Western Branch Upper Marlboro (covering almost all of this watershed) all drain primarily urban areas. They all show improving trends for TN and Patuxent Bowie and Northwest Anacostia also show improving trends for TP. However, these trends are not definitive and there are other COG stations that drain urban watersheds that still show degrading trends.

Figure 8: USGS Nontidal Monitoring Station – Change in TN Load 2007-2016



Source: USGS

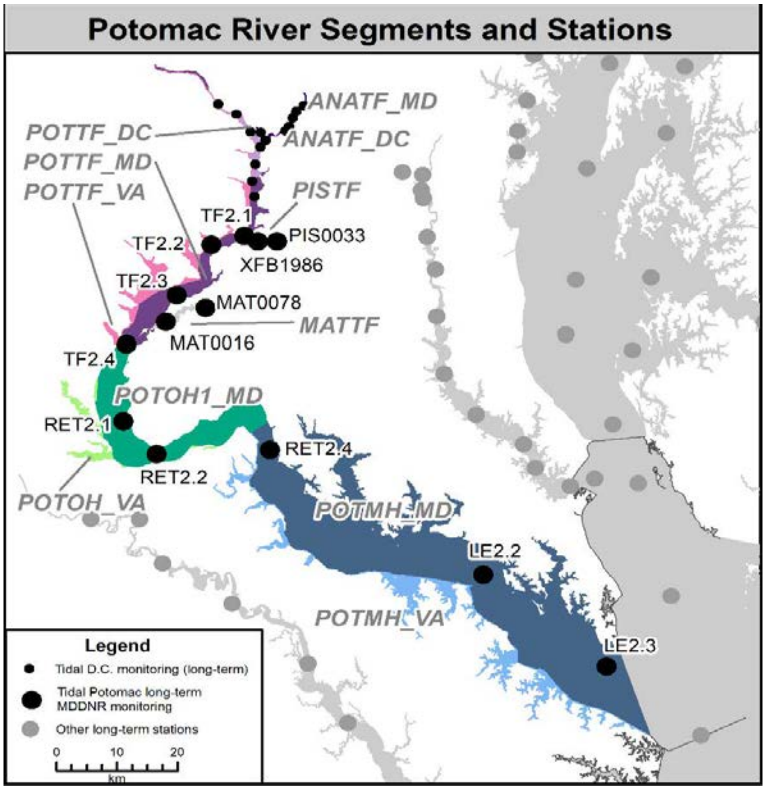
Figure 9: USGS Nontidal Monitoring Station – Change in TP Load 2007-2016



Source: USGS

Section 4. Estuarine Water Quality

Figure 10: Map of Water Quality Monitoring Stations in the Potomac Watershed



Source: Chesapeake Bay Program

Water quality data gathered in the Potomac River estuary and the Chesapeake Bay since 1985 provides a mixed picture of progress, with certain parameters showing signs of improvement while others have degraded. The data in the following charts is derived from the Chesapeake Bay Program's (CBP) tidal monitoring program, under which the Maryland Department of Natural Resources (MDDNR) and Virginia Department of Environmental Quality (VADEQ) in collaboration with the CBP collect water quality samples from the Bay and its tidal tributaries (Most of these charts are a subset of the larger CBP 2016 tidal trends release provided courtesy of R. Murphy, UMCES-CBP {CBP 2017[ii]}.) At most stations, samples are collected twice a month in the warmer months, when living resources are most active and environmental stresses are most acute, and monthly in the winter. The data is analyzed and presented in the same way across all the stations, allowing for uniform assessments of the degree to which the water is meeting water quality standards.

Water quality standards are regulatory provisions that describe the desired condition of a water body and the means by which that condition will be protected or achieved. For example, meeting the desired condition for aquatic resources in the deep channel habitat of the mainstem of the Chesapeake Bay requires dissolved oxygen levels of 1 milligram/liter or higher.

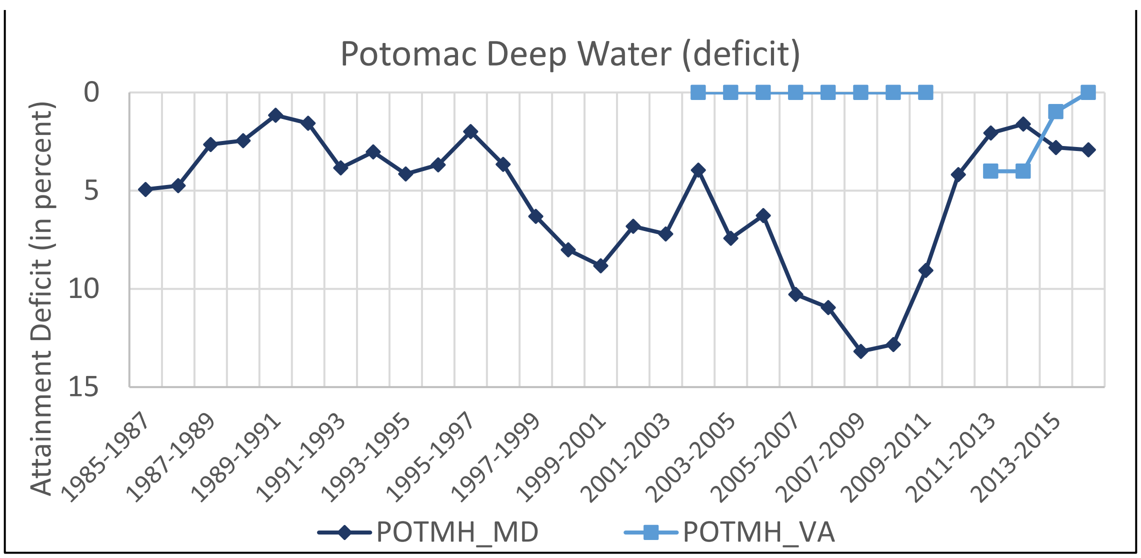
There are three official water quality parameters for assessing attainment of Chesapeake Bay water quality standards: dissolved oxygen, water clarity and chlorophyll-a (a measure of algal abundance). The Bay Program provided guidance to the states in selecting threshold values or criteria for each of these based on different habitat zones within the Bay. The different segments into which the Bay and its tidal tributaries have been divided are designated as in or out of attainment based on a criteria assessment procedure that uses the monitoring data (USEPA 2003[iii]; USEPA 2010[iv]).

Estuarine water quality is a complex phenomenon and the data we use to measure it depicts a mixed picture. For example, there are sections in the river where there is sufficient dissolved oxygen to meet water quality standards, but the trends over time are degrading. In general, dissolved oxygen levels meet their criteria in the upper portion of the estuary, but fail to do so in the deeper waters of the lower estuary, which is a similar pattern to what we see in the Chesapeake Bay as a whole. Thus, improving dissolved oxygen levels in the lower estuary are the main drivers for the level of nutrient reductions necessary to return the river to full health. Even in the upper estuary, further reductions in pollutants are necessary to reverse degrading trends and achieve all the conditions to meet water quality standards.

Because a simple in- or out-of-attainment metric does not convey the extent of non-attainment nor lend itself to an assessment of progress, Bay Program analysts have developed other ways of evaluating the data. One of these is "attainment deficit," which incorporates estimates of the volume of water and the amount of time that a particular tidal water segment is determined to be out of attainment for a particular parameter during the critical summer months when environmental stresses tend to be most severe (Zhang et al. 2018[v]).

The following charts are all based on attainment deficits for summer (i.e. June- September) dissolved oxygen levels, a key water quality endpoint for which the Bay TMDL was designed. They are calculated for rolling three-year periods. Values at "0" in these charts means the segment is in attainment. The degree to which a segment is out of attainment is the distance from the measured values for each three-year period (the dark blue or light blue lines in the charts) to the zero line; the greater the distance, the more the extent of non-attainment.

Figure 11: Attainment Deficit for the Potomac Deep Water Stations in MD and VA

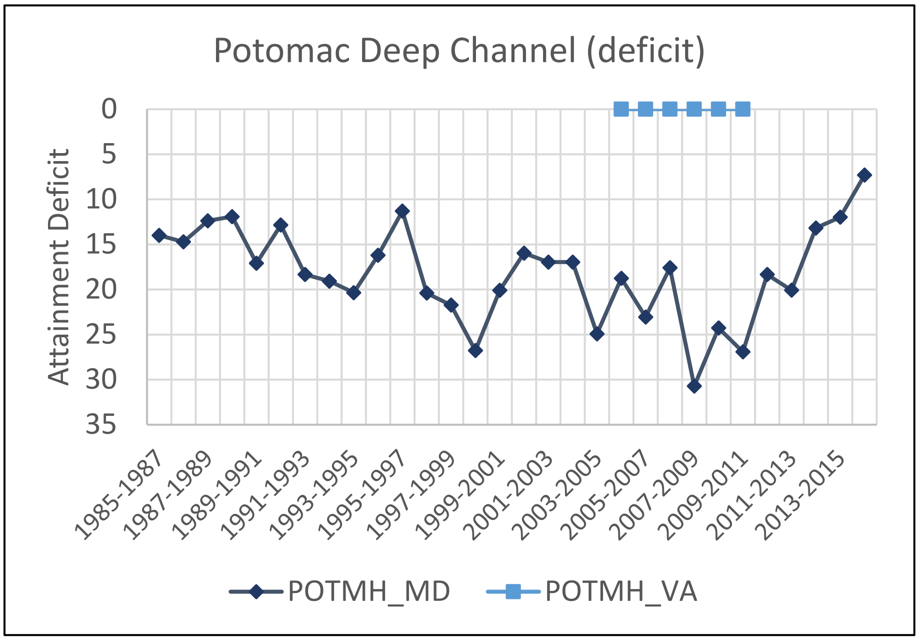


Source: Chesapeake Bay Program

The two charts show attainment deficit for the deep channel and the adjacent deeper waters in the lower portion, or mesohaline section, of the Potomac estuary. POTMH-MD represents the Maryland portion of these waters, which comprise the bulk of the mainstem; POTMH-VA comprises Virginia's portion, which includes a number of embayments on its side of the river. There is much less data for these Virginia waters and its water quality does not necessarily correspond to conditions in the main part of the estuary.

Although the charts show deficits in the range of 5 – 15 percent on a time- and volume-weighted basis for these segments (which means they actually are in attainment most of the time), it does appear that water quality degradation bottomed out in the 2007-2009 period and has been improving since then, which analysts attribute largely to reductions in wastewater nutrients. And there is other data that provides evidence of recent improvement in water quality in the Potomac estuary.

Figure 12: Attainment Deficit for the Potomac Deep Channel Stations in MD and VA

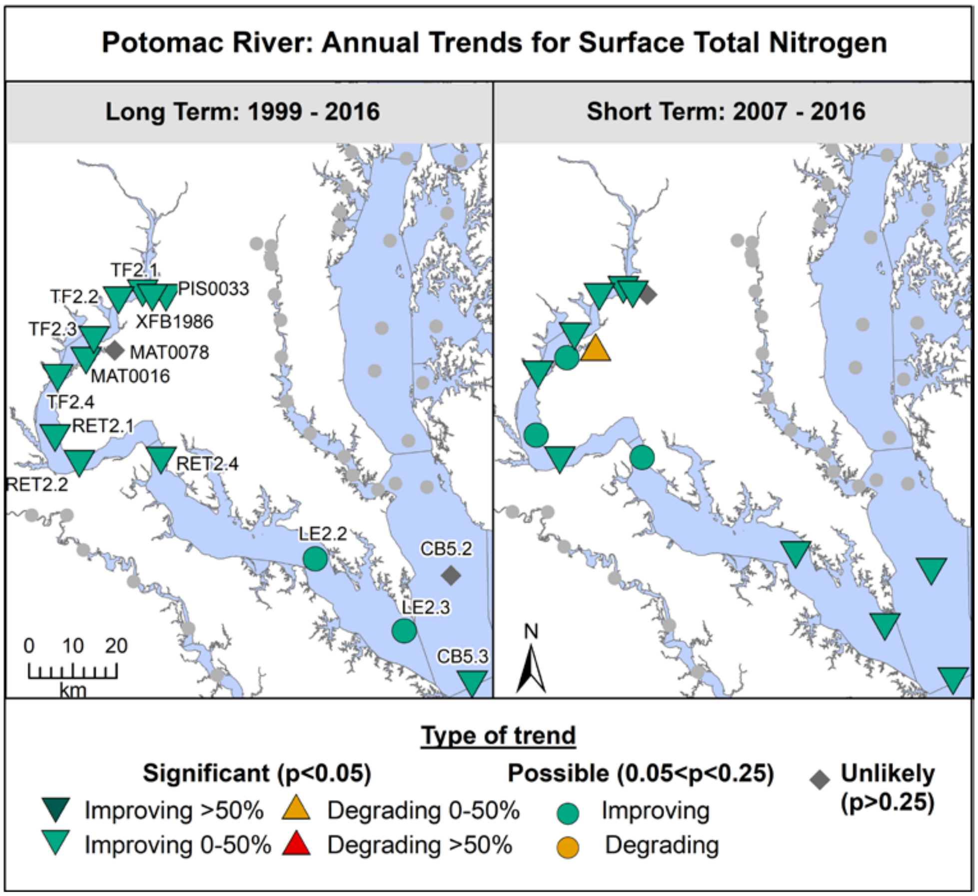


Source: Chesapeake Bay Program

Assessing Trends

Working in concert with analysts for the Maryland Department of Natural Resources, Bay Program staff has begun using a new statistical technique known as Generalized Additive Models (or GAMs) to discern trends and other patterns in the data over time (Murphy et al. in review[vi]). In the following charts, GAM-based trend results are shown for both the long-term and short-term data records for multiple parameters.

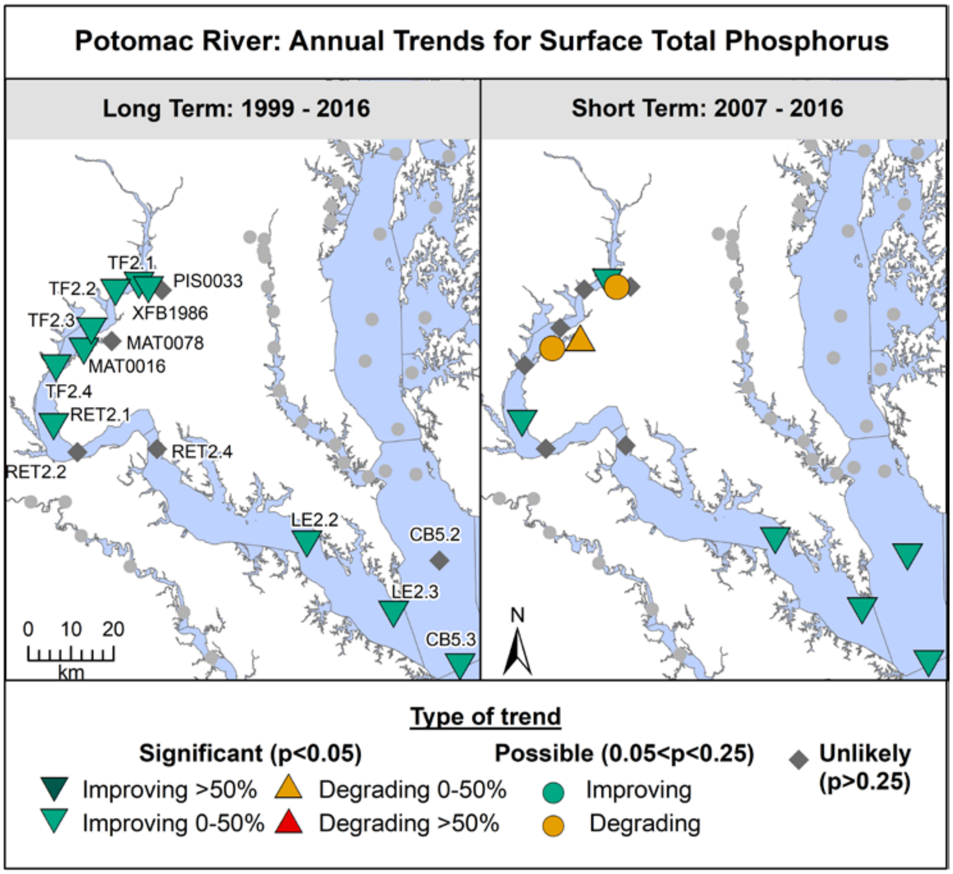
Figure 13: Potomac River Annual Trends for Surface Total Nitrogen



Source: Chesapeke Bay Program "Tidal Trends in Water Quality: Potomac River 2016 Tributary Summary."

The charts show trends for a variety of water quality parameters measured by the tidal water monitoring program. They all employ the same visual symbols, indicating whether the trends are improving (in green arrows or circles), degrading (in either red or yellow arrows or circles) or not significant (grey diamonds). Darker green indicates a more significant improving trend (more than 50 percent), just as red indicates a more significant degrading trend (more than 50 percent).

Figure 14: Potomac River Annual Trends for Surface Total Phosphorus



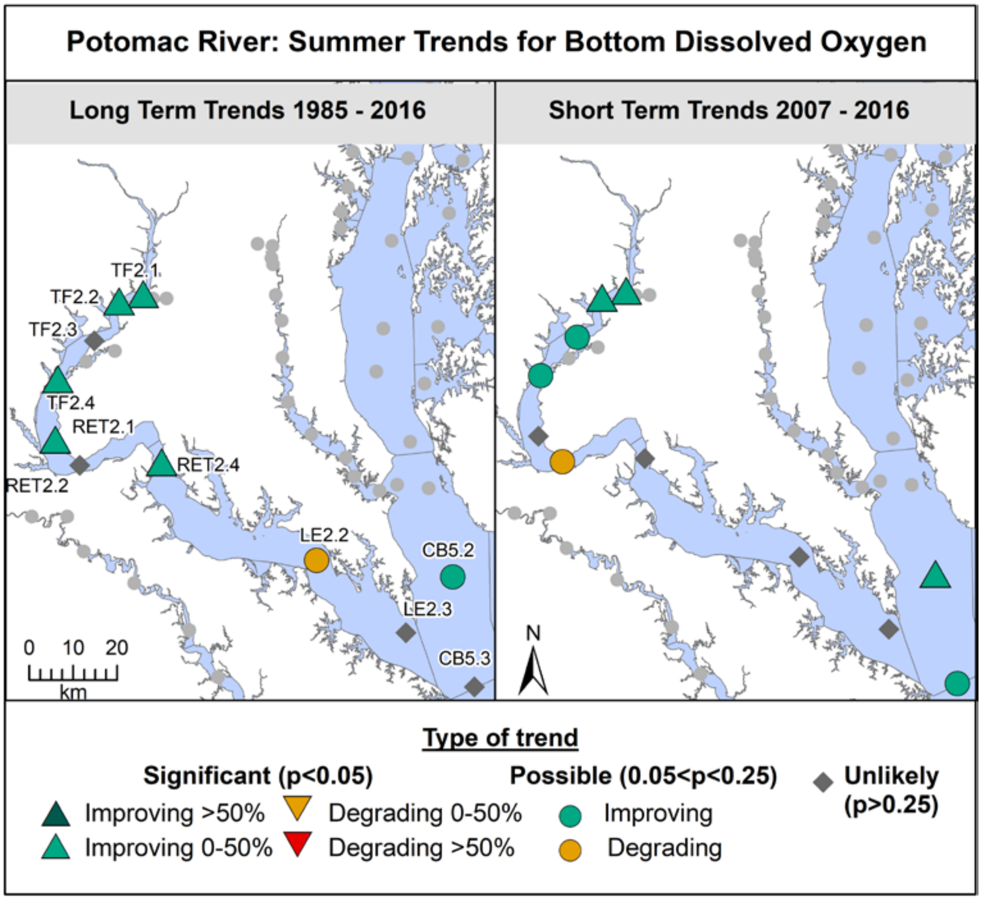
Source: Chesapeake Bay Program "Tidal Trends in Water Quality: Potomac River 2016 Tributary Summary."

Most of the trends in both surface nitrogen and surface phosphorus concentrations in all portions of the estuary show significant improvement (i.e. reductions) in both the short- (10 years) and long-term (20 years). Reductions in the nutrients discharged from wastewater plants are likely the major cause for this improvement, although reductions from other sources also contributed to the trends.

However, improvements in other water quality parameters are harder to discern, both because such improvements tend to lag behind reductions in the pollutants that are the root cause of degradation and because other factors come into play in the complex estuarine environments.

For example, dissolved oxygen has shown a significant long-term improving trend at almost all of the upstream stations since 1985 and at ones in the uppermost tidal fresh portion of the estuary since 2007. However, the lowermost stations – LE2.2 and LE2.3 – have mostly shown no trends or degrading trends during these same periods. However, these stations represent the deepest waters in the Potomac estuary, typically where low oxygen conditions are hardest to overcome, and also are more influenced by water quality in the mainstem of the Bay than the other Potomac stations.

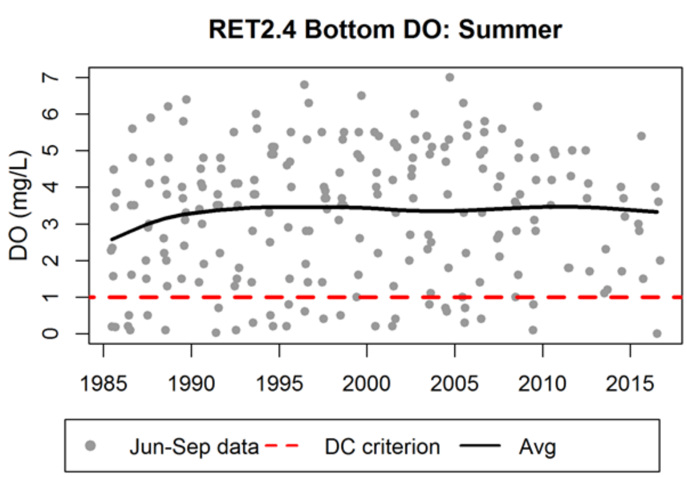
Figure 15: Summer Trends for Bottom Dissolved Oxygen



Source: Chesapeake Bay Program "Tidal Trends in Water Quality: Potomac River 2016 Tributary Summary."

Even where overall statistical analysis shows no signs of improvement, analysts believe they can pick out smaller signs that progress is being made. At the RET 2.4 station near the Route 301 Bridge, for example, the monitoring data from recent years has only 1 value below the deep channel instantaneous criterion of of 1 milligram/liter.

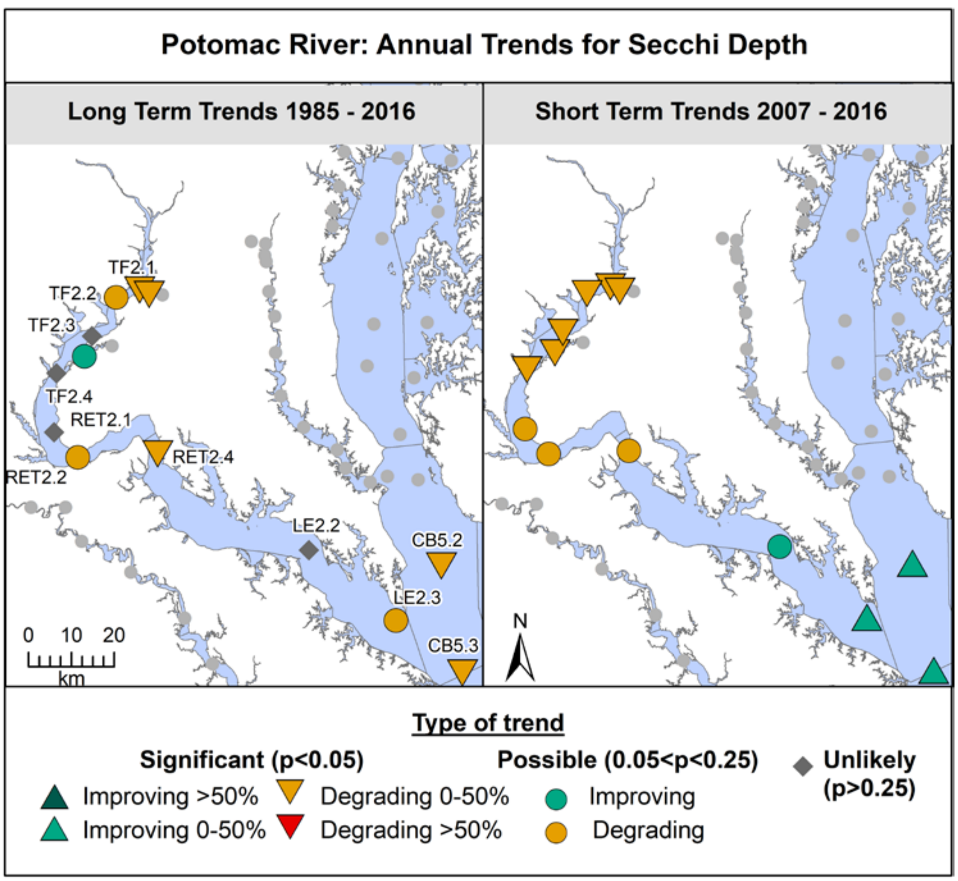
Figure 16: Bottom Dissolved Oxygen: Summer for station RET2.4



Source: Chesapeake Bay Program "Tidal Trends in Water Quality: Potomac River 2016 Tributary Summary."

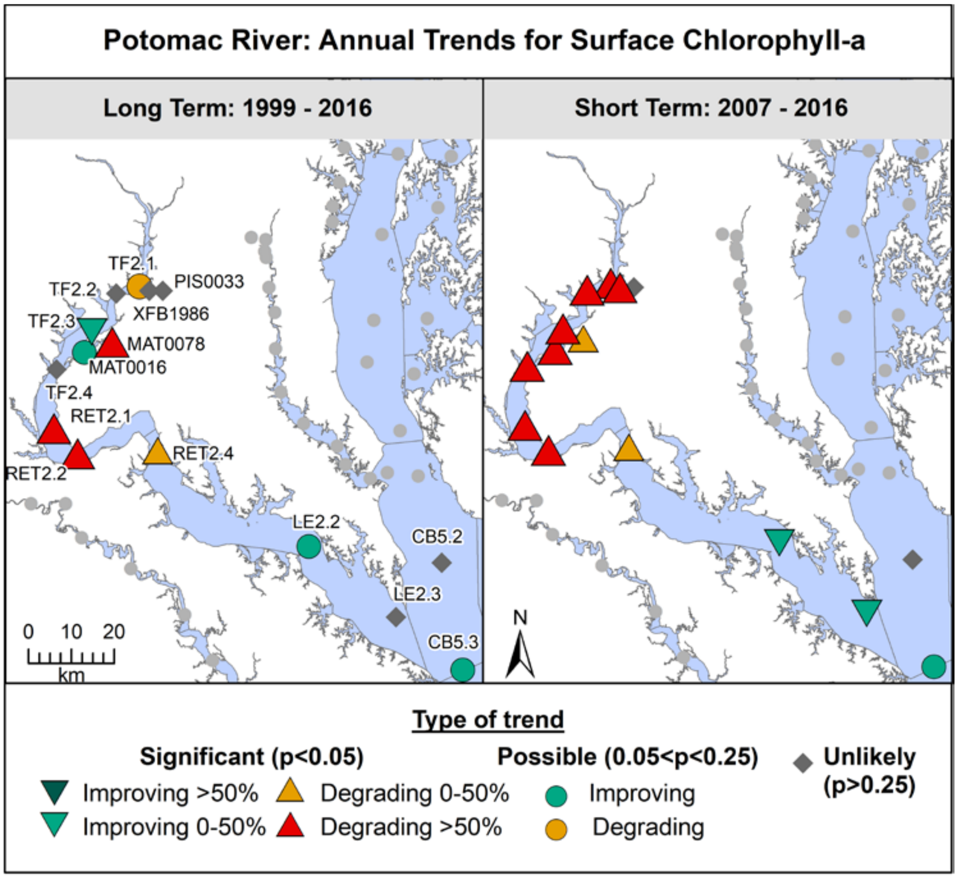
The trends for Secchi disk depth (a measure of water clarity) and chlorophyll-a (a measure of algal amounts) are mostly degrading, especially in the upper portion of the estuary where the impact of wastewater nutrient reduction should be the greatest. For the Secchi measurements, the sensitivities of the various statistical means of analysis may account for some of these mixed signals. The connections linking nutrient and sediment levels in the water column to the levels of these other major water quality parameters are not as well understood as the links between nutrient reduction and increased dissolved oxygen. Scientists are trying to figure out how to weight the various factors and interactions among factors that drive algal population dynamics in the estuary. They are beginning to look at factors that were previously ignored, such as changes in cloud cover and temperature, and fluctuations in the populations of various clam species, to account for why the trends in chlorophyll-a and water clarity do not match the trends in dissolved oxygen. The consensus around the need to further reduce nutrients and sediment to further improve water quality has not weakened, but the mixed nature of this water quality trend data does show that restoration progress does not necessarily proceed in a strictly straightforward way.

Figure 17: Annual Trends for Secchi Disk Depth



Source: Chesapeake Bay Program "Tidal Trends in Water Quality: Potomac River 2016 Tributary Summary."

Figure 18: Long and Short Term Annual Trends for Chlorophyll-a



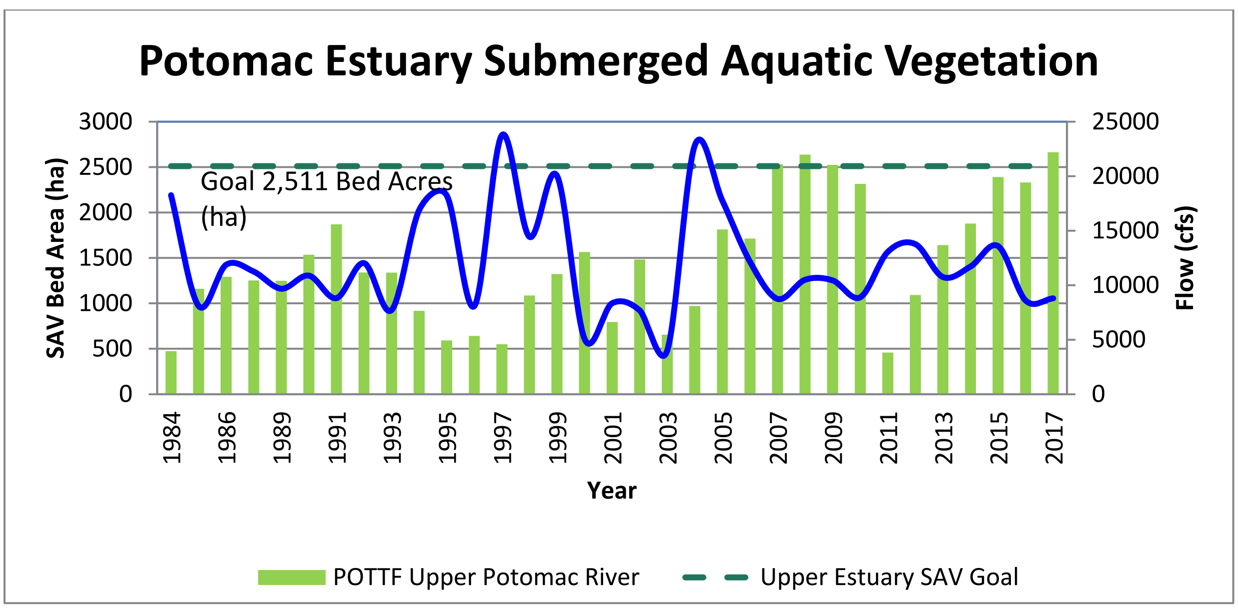
Source: Chesapeke Bay Program "Tidal Trends in Water Quality: Potomac River 2016 Tributary Summary."

Section 5. Success Stories – Submerged Aquatic Vegetation (SAV)

Source: **Brian LeCouteur, COG Staff**

Although water quality in the river does not fully meet the water quality goals established under the Clean Water Act, there are success stories where concerted action has led to significant improvements in some conditions and where in recent years the populations of certain species of plants or animals have rebounded from previously low levels. Most of the Potomac's successes, which include more acres of submerged aquatic vegetation (SAV) and increases in the numbers of certain fish species, derive largely from the reductions of nutrients from wastewater plants in the Washington region. These improvements show up most clearly in the freshwater portion of the Potomac estuary, which stretches from the river's fall line at Chain Bridge in Washington, D.C., downriver to the mouth of Mattawoman Creek. (See Figure 18.)

Figure 19: Potomac Estuary SAV (Upper Portion) and Flow at Chain Bridge



Source: VIMS

The amount of SAV growing in the upper estuary fluctuates annually because of changes in weather conditions and other factors, but overall it has increased significantly in recent years as nutrient levels in the water have decreased. Fewer nutrients tends to lead to less algal growth, which in turn increases the amount of light that reaches underwater grasses. In addition to greater overall SAV growth, the upper estuary also has seen the diversity of underwater grasses increase in recent years. *Hydrilla verticillata*, an invasive exotic species that was the first type of SAV to recolonize shallow water habitat in the estuary, now comprises less than 10 percent of total SAV abundance in most years, compared t0 80 percent in the 1990s. In addition to *Hydrilla*, the estuary now has populations of 12 different species of SAV.

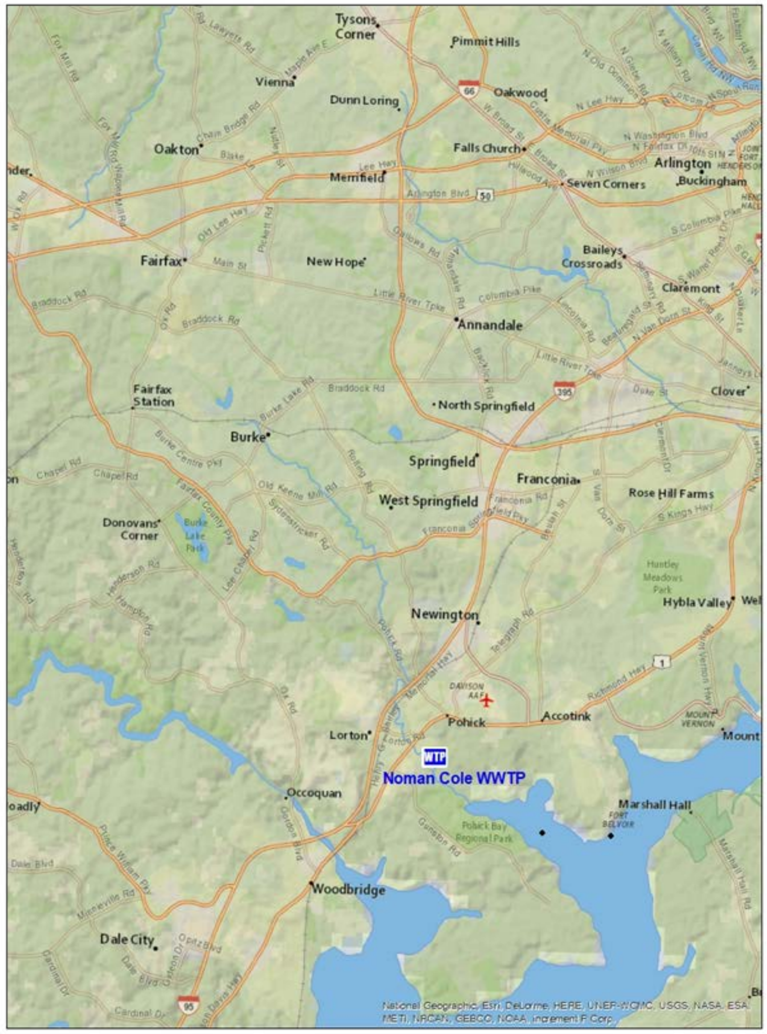
The SAV success story is still somewhat limited, however. The Chesapeake Bay Program has established initial targets for the extent of SAV acreage in different parts of the Bay and the tidal waters of its tributaries, including the Potomac. SAV growth in the tidal freshwater portion of the Potomac estuary consistently met this target in recent years, except for 2011 and 2012. The underwater grass populations in the river remain sensitive to environmental disturbance and in 2011 and 2012, weather conditions that favored greater algal growth resulted in fewer acres of underwater grasses in the upper estuary. Moreover, SAV growth tends to drop off in the lower, saltier portions of the estuary, where the amount of SAV acreage has not yet met any of the initial Bay Program targets. While some areas like the Upper Potomac Estuary have met initial restoration targets, the entire Chesapeake Bay remains far short of the ultimate goal: underwater grasses growing in all of the shallow water habitat of the Bay and the tidal waters of its tributaries.

Local Water Quality in Gunston Cove – A Case Study

Although restoration of the Chesapeake Bay has been the main driver behind many of the water quality improvement efforts undertaken in the region, the improvement of water quality in smaller, localized water bodies is also an important reason for action. Local streams, many of which have been degraded by decades of urbanization, are targeted for a variety of restoration measures by local government stormwater management programs. Where wastewater discharges occur into local rivers or Potomac River embayments, reductions in the discharge of nutrients and other pollutants can have a major impact on improving local water quality conditions.

Information in Section 3,"Nonpoint Source Loads from below the Fall Line," indicated that smaller tributary watersheds in the COG region present a mixed picture of progress; some have improving trends and others have degrading trends for nutrients and sediment. Despite improvements in some local streams, almost all of the smaller watersheds in the region are at most only partly restored and will require decades of further work to return to fully fishable and swimmable conditions.

Figure 19: Map of Gunston Cove

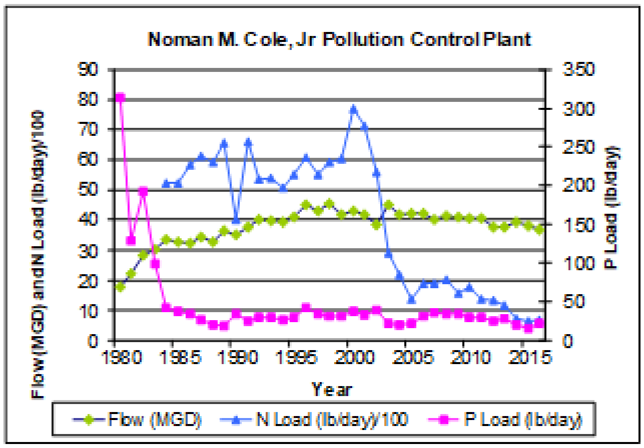


Source: COG

Perhaps the most encouraging case study of how restoration efforts can improve local waters is provided by Gunston Cove, a Potomac River embayment on the edge of Fairfax County, into which the county's Noman M. Cole Jr wastewater plant discharges its effluent. Water quality in the cove has been extensively studied for decades by a research team from George Mason University led by Dr. Chris Jones. Data in this section is derived from this research[vii].

Historically, water quality and living resources in Gunston Cove experienced the same overall response pattern as have tidal waters throughout the Bay. As water quality continued to decline in response to increasing pollution, living resources were increasingly stressed, and in some cases, disappeared. By the mid-20th Century, summer conditions in the embayment came to be dominated by algal blooms, stimulated by an excess of nutrients. The surface-growing algae decreased light to the SAV, which disappeared entirely from Gunston Cove by the 1960s and 1970s.

Figure 20. Flow and Loads at Noman Cole Plant



Source: George Mason University

Gunston Cove's road to recovery began with a ban on phosphates in detergents in the 1980s and the implementation of phosphorus controls at all of the major wastewater plants discharging to the estuary in the late 1970s and early 1980s, including the Noman Cole plant in Fairfax County. These were followed by controls on nitrogen discharges in successive periods from 2000-2005 and again since 2015. (*See Figure 20.*)

Noman Cole WWTP

Between 1980 and 1985, the amount of phosphorus discharged into the lower Pohick Creek by the Noman Cole plant decreased by about 85 percent and the amount of phosphorus leaving the plant has remained at the same low level despite increases in the flow of wastewater to the plant. The discharge of nitrogen continued to increase until 2000-2005, when Noman Cole implemented its first round of biological nitrogen removal, achieving reductions of about 85 percent. Noman Cole implemented its second round of nitrogen reductions in 2013.

The water quality response can be seen in figures 21 and 22 - a small amount of SAV growth was seen in the wake of the initial reductions in wastewater phosphorus. However, summertime levels of chlorophyll-A, a measure of the amount of algal growth, remained elevated and, correspondingly, water clarity, as measured by Secchi disk depth, remained relatively poor through 2000. Then, at various points between 2001 and 2005, chlorophyll-A levels declined dramatically – indicating a major reduction in algal populations – and water clarity improved. These are believed to be major factors in the significant expansion of SAV acreage subsequently seen in Gunston Cove.

Although the general pattern of nutrient reductions leading to water quality improvements seems clear and has been observed in other parts of the Bay, water quality scientists are not certain of all the details and there are individual differences at play as well. Jones believes that the chlorophyll-A, water clarity and SAV acreage changes in Gunston Cove were triggered by the phosphorus reductions at Noman Cole, even though several decades elapsed between these two sets of events. He attributes this response lag to the persistence of phosphorus in bottom sediments in the cove; it is only when this phosphorus reservoir was depleted that the algal populations declined and the SAV rebounded.

Figure 21. SAV Extent in Gunston Cove in 2005

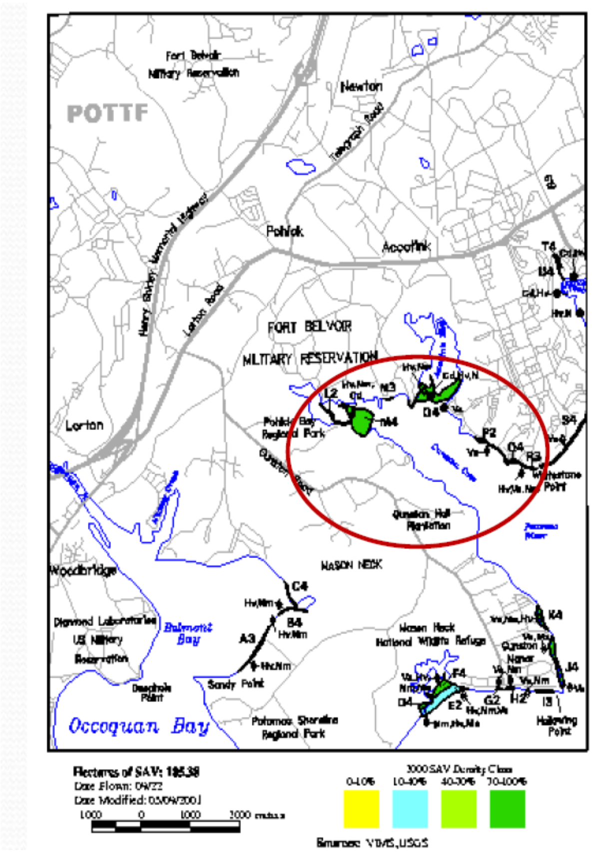
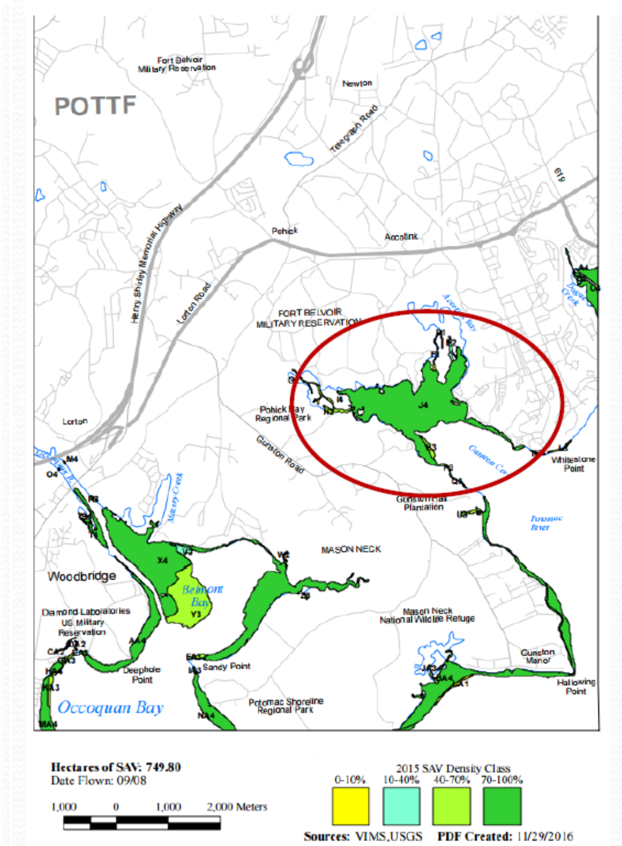
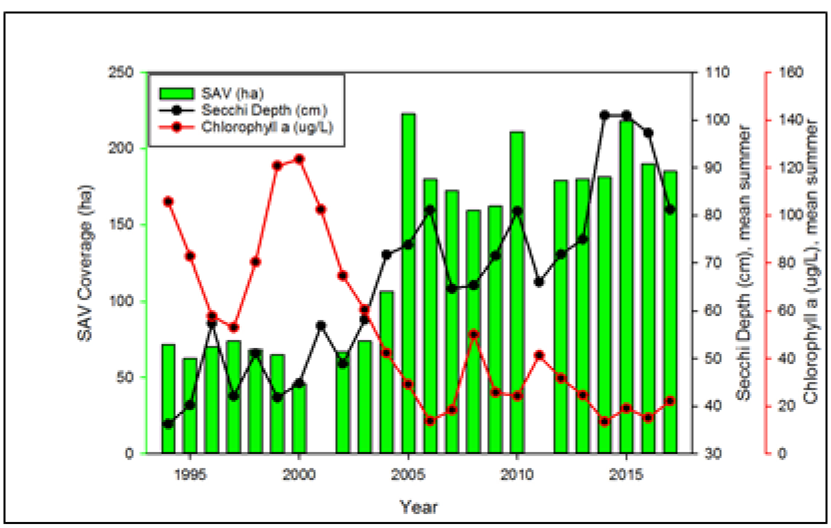


Figure 22. SAV Extent in Gunston Cove in 2015



Source: George Mason University

Figure 23. Various Water Quality Parameters in Gunston Cove



Source: George Mason University

Section 6: Other Issues

This report is focused on the major pollutants that are the focus of the Chesapeake Bay TMDL and also drive much of the water quality dynamics in the Potomac estuary: nitrogen, phosphorus and sediment. However, there are a number of other water quality issues in the Potomac caused both by these pollutants and other factors. These include harmful algal blooms above the Chain Bridge fall line that release toxins of concern to drinking water providers and toxic man-made chemicals that may cause intersex fish and other problems.

The rapid spurts in algal populations known as blooms have been a common occurrence in the Potomac estuary, but they also can occur in upstream portions of the river. The main driver of such harmful algal populations is excessive nutrients, just as it is in tidal waters. Maryland DNR staff is currently gathering data on the production of toxins by cyanobacteria in the free-flowing portion of the river and whether the levels are of concern to the drinking water intakes for the metropolitan Washington region.

Monitoring has detected the presence of a number of toxic chemical contaminants in the Potomac River, ranging from various types of metals to organic compounds. These include mercury, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), pesticides and pharmaceuticals and personal care products that have been linked to reproductive disruptions in fish and other species.

Intersex characteristics in fish, particularly smallmouth bass, were discovered in the South Branch of the Potomac River by USGS scientists more than 10 years ago. The condition is thought to be linked to the presence of endocrine disrupting compounds that originate from a variety of human and animal-waste sources.[viii]

Another water quality issue that has prompted increasing concern in the last few years is the presence of salts, particularly sodium chloride, in the watershed. Although the levels of such salts tend to be highest in smaller streams in the watershed, data from Potomac monitoring[ix] shows increasing concentrations in the free-flowing river, which is a concern for the region's drinking water providers.

Summary

Local governments and utilities in the metropolitan Washington region have made great progress in reducing the amount of nutrients discharged from wastewater plants in the region. As a result, harmful algal blooms have been reduced, submerged aquatic vegetation has returned, and the populations of several fish and waterfowl species have rebounded. There also has been some progress, albeit smaller, in achieving reductions from other nutrient sources in the Potomac watershed.

But these reductions are not yet enough to completely achieve water quality standards. Researchers are investigating to what extent nutrient and sediment concentrations must decline further to achieve the standards, but the calculation is not a simple linear relationship. It is complicated by dynamic processes on the land and in the water that are affected by more than just nutrients and sediment. Additional issues such as toxics and chemical contaminants, intersex fish, and climate change also have major impacts on water quality. This complexity underlies some of the mixed signals presented by water quality data in the Potomac estuary, with both improving and degrading trends.

Because wastewater has already implemented most of what technology can achieve in the way of nutrient reduction, further progress in improving water quality conditions depends on further efforts to reduce nutrients and sediment from nonpoint sources, such as agriculture and urban runoff. Here, too, there is uncertainty and also mixed signals, with many improving trends but some degrading ones as well. Scientists are still interpreting the effects of time lags, for instance, in the flow of nitrate-enhanced groundwater that gradually feeds surface waters and the ability of BMPs to reduce extensive phosphorus reservoirs in certain soils. What is certain is that additional efforts to reduce nutrients and sediment from these nonpoint sources will be needed to achieve the Potomac River's long-term water quality goals.

For More Information

More in-depth information is available from the following sources:
https://www.chesapeakebay.net/who/group/integrated_trends_analysis_team
https://www.chesapeakebay.net/content/publications/cbp_51366.pdf
https://toxics.usgs.gov/highlights/edcs_bass_nests.html
https://www.chesapeakebay.net/content/publications/cbp_13142.pdf
https://cos.gmu.edu/perec/.XlGWSihKhPY

Endnotes

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https://www.chesapeakebay.net/who/group/integrated_trends_analysis_team

[iii] U.S. Environmental Protection Agency (2003a). Ambient water quality criteria for dissolved oxygen, water clarity and chlorophyll-a for the Chesapeake Bay and its tidal tributaries. USEPA Region III Chesapeake Bay Program Office EPA 903-R-03-002. Annapolis, Maryland.
https://www.chesapeakebay.net/content/publications/cbp_13142.pdf

[iv] U.S. Environmental Protection Agency (2010a). Ambient water quality criteria for dissolved oxygen, water clarity and chlorophyll a for the Chesapeake Bay and its tidal tributaries: 2010 technical support for criteria assessment protocols addendum. USEPA Region III Chesapeake Bay Program Office EPA 903-R-10-002. Annapolis, Maryland.
https://www.chesapeakebay.net/content/publications/cbp_51366.pdf.

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[vi] Murphy, R.R., E. Perry, J. Harcum, and J. Keisman. A Generalized Additive Model approach to evaluating water quality in Chesapeake Bay. In Review at Environmental Modelling and Software.

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[viii] https://toxics.usgs.gov/highlights/edcs_bass_nests.html

[ix] Kaushal, Sujay, Gene E. Likens, Ryan M. Utz, Michael L. Pace, Melissa Grese, and Metthea Yepsen, Increased River Alkalinization in the Eastern U.S., Environmental Science & Technology 2013 47 (18), 10302-10311 DOI: 10.1021/es401046s