MARYLAND
DEPARTMENT OF
NATURAL RESOURCES

Martin O'Malley, Governor
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Upper Western Shore Basin
Water Quality and Habitat Assessment

Maryland Department of Natural Resources
Tidewater Ecosystem Assessment

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Information on the water and habitat quality of Maryland's rivers and bays is available due to the hard work of many dedicated staff including:

- staff who are in the field collecting the samples year-round, sometimes under less than desirable weather conditions
- laboratory staff who perform the chemical tests to determine what exactly is in those water samples
- data management staff who collect the resulting information, confirm the accuracy and quality of the data, and organize and maintain the databases and
- analytical staff who interpret the data to answer the question 'how is the river/Bay doing?'

There are too many individuals to directly name from more than 25 years of monitoring, so we simply wish to commend all of them for their commitment to collecting high quality information and making it available and useful to the citizens of Maryland.

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Overall Condition

Healthy rivers and bays support a diverse population of aquatic life as well as recreational uses, such as swimming and fishing. To be healthy, rivers and bays need to have good water and habitat quality. High levels of nutrients and sediments lead to poor water quality. Poor water quality reduces habitat quality, including water clarity (how much light can get to the bottom) and the amount of dissolved oxygen in the water. In turn, habitat quality affects where plants and animals can live. The Maryland Department of Natural Resources (DNR) is responsible for monitoring water and habitat quality in the Chesapeake Bay and rivers, as well as the health of aquatic plants and animals. DNR staff use this information to answer common questions like "How healthy is my river?", "How does my river compare to other rivers?", "What needs to be done to make my river healthy?" and "What has already been done to improve water and habitat quality in my river?"

The Upper Western Shore includes the Bush, Gunpowder and Middle rivers. The upper region of the basin drains to the Susquehanna River, but this river is not included in the Upper Western Shore basin Water Quality and Habitat Assessment due to the overwhelming influence of the portions of the river's watershed that are in Pennsylvania and New York.

How healthy are the Upper Western Shore Rivers?

Bush River Water quality in the tidal river is fair to good, but is worsening due to increasing phosphorus levels. Water clarity is poor and reduces the habitat quality for underwater grasses. Underwater grasses cover more area than in the 1980s, but as of 2010 grasses cover only 67% of the area designated as the restoration goal. Underwater grass coverage has steadily declined since a high of 1,024 acres in 2005. Summer bottom dissolved oxygen levels are good, and bottom dwelling animals are healthy in the middle and lower river, but unhealthy in the upper river.

Gunpowder River Water quality in non-tidal streams is impaired by nitrogen concentrations that are too high, but has improved due to reductions in phosphorus and sediment levels. Water quality in the tidal river is fair to good, but is worsening due to increasing phosphorus levels. This disconnect in phosphorus levels is likely due to urban areas being lower in the watershed than where non-tidal streams are monitored and the impact of waste-water treatment plants that discharge directly to the tidal river. Habitat quality for underwater grasses is impaired due to high sediments, high algal density and poor water clarity. Underwater grasses cover more area than in the 1980s, but as of 2010 grasses cover only 71% of the area designated as the restoration goal. Habitat quality is good and bottom dwelling animals are healthy.

Middle River Water quality is improving due to reductions in nitrogen levels, but is also degrading due to increasing phosphorus levels. Sediment levels are good. Habitat quality for underwater grasses has improved due to lower algal densities and improved water clarity in the early period (1985-1997), but habitat quality is worsening in the recent period due to decreasing water clarity. Underwater grasses covered the largest area in 2008 when 94% of the restoration goal was reached, but only 75% of the goal was reached in 2010. Good summer bottom dissolved oxygen levels create good habitat quality for bottom dwelling animals.

Table 1. Summary of trends for non-tidal loadings (1985-2010) and non-tidal water quality parameters trends (1999-2010).
Loadings trends are only available for one station.

	Loadings			Water Quality		
	Nitrogen	Phosphorus	Sediments	Nitrogen	Phosphorus	Sediments
Non-tidal Gunpowder River				INCREASE	DECREASE	
		DECREASE	INCREASE	INCREASE	Maybe Decrease	
					DECREASE	DECREASE

Table 2. Summary of tidal habitat quality and water quality indicators.
Algal densities, water clarity, inorganic phosphorus and sediments either 'Meet' or 'Fail' SAV habitat requirements (Appendix 5). Dissolved nitrogen levels below the level for nitrogen limitation 'Meet' criteria, otherwise 'Fail' criteria. Summer bottom dissolved oxygen levels above 3 mg/l 'Meet' criteria, otherwise 'Fail' criteria. Annual trends for 1999-2010 either 'Increase' or 'Decrease' if significant at $p \leq 0.01$ or 'Maybe Increase' or 'Maybe Decrease' at $0.01 < p < 0.05$; blanks indicate no significant trend. Improving trends are in green, degrading trends are in red. Nitrogen trends are for total nitrogen, phosphorus trends are for total phosphorus, water clarity trends are for Secchi depth. Depth 'Shallow' is from the shallow water monitoring program, 'Open' is from the long-term monitoring program.

River	Water Depths	Habitat Quality			Water Quality		
		Algal Densities	Water Clarity	Dissolved Oxygen	Nitrogen	Phosphorus	Sediments
Bush River	Shallow	FAIL	FAIL	MEET	FAIL	MEET	FAIL
	Open	FAIL	FAIL	MEET Maybe Decrease	MEET	MEET Maybe Increase	FAIL
Gunpowder River	Shallow	MEET	FAIL	MEET	FAIL	MEET	MEET
	Open	FAIL	FAIL Maybe Decrease	MEET	MEET	MEET	FAIL
Middle River	Shallow*	MEET	FAIL	MEET	FAIL	MEET	MEET
	Open	MEET	FAIL DECREASE	MEET	MEET	MEET	MEET

How do the Upper Western Shore basin Rivers compare to other Maryland rivers?

The Bush River is in the 'High Urban, Low Agriculture' land use category (Figure 1). Nitrogen and sediment levels are moderate and phosphorus levels are high compared with other high urban systems, but algal densities are among the highest of all Maryland rivers and bays (Figure 2). Summer bottom dissolved oxygen levels are higher than similar systems, but water clarity is among the worst of the high urban land use systems.

The Gunpowder River is in the 'High Urban, High Agriculture' land use category. Middle River is included as part of the Gunpowder River watershed for land use assessments, so it is not separately comparable to the other Maryland rivers and bays. Total nitrogen load per acre is the lowest in the Gunpowder and total phosphorus loads are lower than in most of the other tributaries. Compared to other similar systems, the Gunpowder has moderate nitrogen, phosphorus and sediment levels. Algal densities are slightly higher than the reference level of 15µg/l. Summer bottom dissolved oxygen levels are similar to other systems with good dissolved oxygen levels, but water clarity is among the worst of the high urban systems.

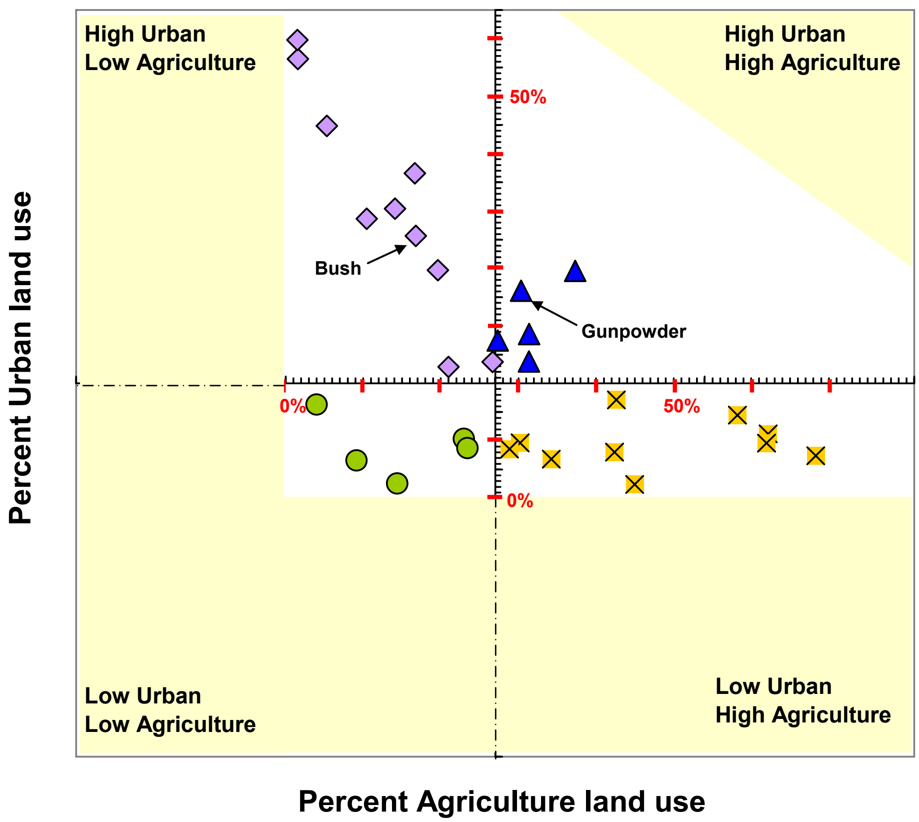

Figure 1. Classification of Maryland rivers and bays by land use.
The medians of all systems percent agriculture and percent urban land use are used to create a grid with four categories. Systems with percent urban less than the median are considered low urban. Systems with percent agriculture less than the median are considered low agriculture. Each system was categorized based on placement on the grid. Note that yellow areas are not mathematically possible (i.e. there is not a negative percent agriculture land use, and it is not possible for percent agriculture + percent urban to be greater than 100%). These groupings were used to evaluate each system relative to other rivers with similar land use characteristics. Middle River is included as part of the Gunpowder River watershed for land use assessments, so it is not separately comparable to the other Maryland rivers and bays.

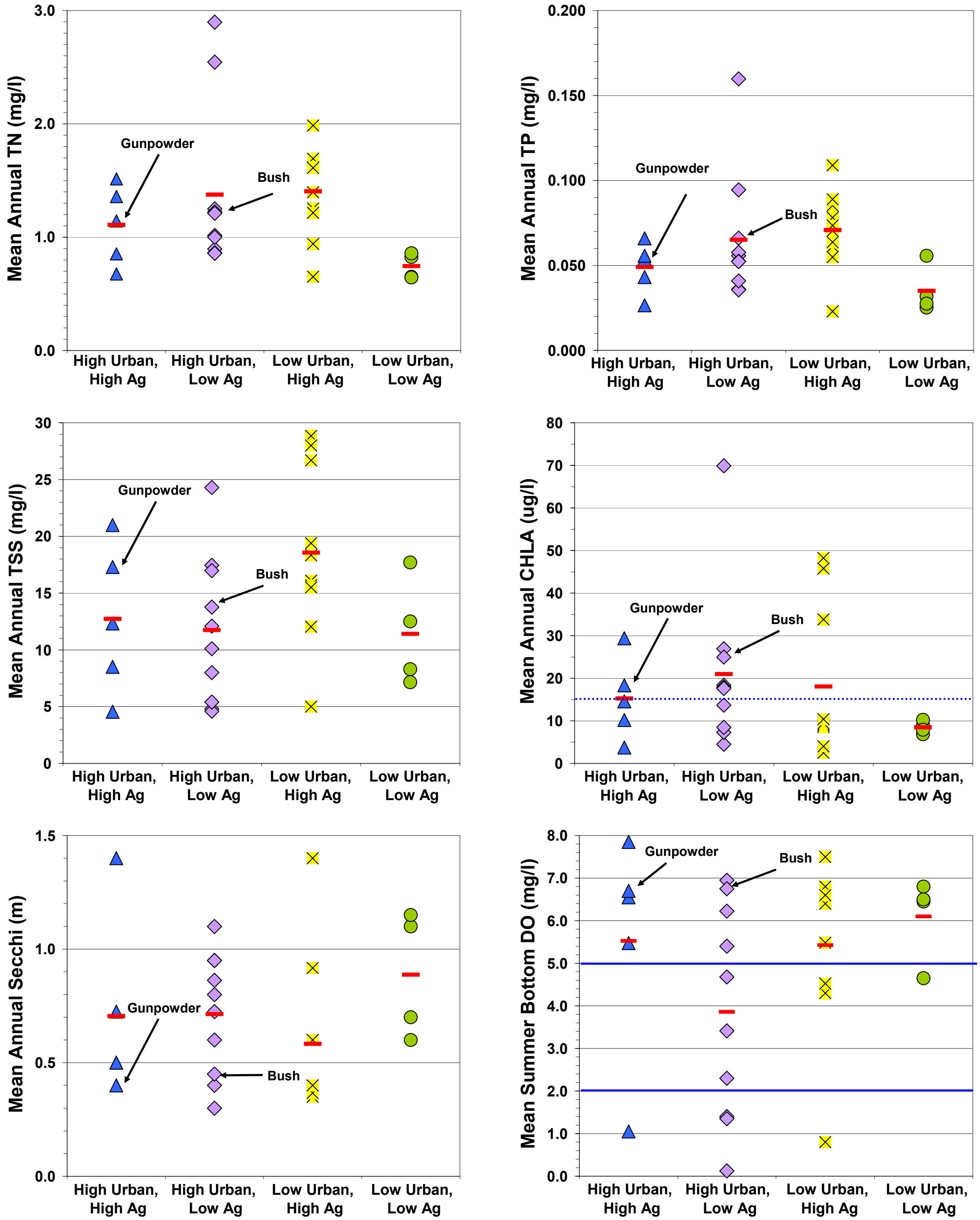

Figure 2. Comparison of the Bush and Gunpowder Rivers to similar systems.
The mean annual concentration or depth (bottom dissolved oxygen is only summer) for 2008-2010 data. Red bars indicate the mean of all systems within a category. Reference lines are included on the CHLA and BDO graphs. Middle River is included as part of the Gunpowder River watershed for land use assessments, so it is not separately comparable to the other Maryland rivers and bays.

What needs to be done to make the Upper Western Shore Rivers healthy?

The most important problems that should be addressed are phosphorus and sediment loadings, excessive nitrogen levels in the tidal waters, and the large amounts of impervious surfaces in the watershed. Efforts to lower nitrogen and sediment loadings from urban and agricultural areas are needed, especially to reduce turbidity in the shallow water areas. Reducing nitrogen loadings from septic systems should also be a priority. With lower nutrients and sediments, water clarity should improve which will improve habitat quality for underwater grasses. Reductions in nutrients will also lead to lower algal densities and reduce the frequency and duration of harmful algal blooms. While habitat quality is already good for bottom dwelling animals, reductions in nutrients are expected to lead to more diverse and stable populations.

What has already been done to improve water and habitat quality in the Upper Western Shore Rivers?

A variety of actions have already been taken to lower phosphorus and sediment loadings, and the excessive nitrogen levels in the tidal waters. To reduce nutrient inputs from urban lands, these actions include upgrades to wastewater treatment plants, managing stormwater runoff and retrofitting septic systems. While specific goals have not been set for this basin, improvements are being made. Upgrades to the largest wastewater treatment plant that discharges to the Bush River are under construction and will be completed by 2014. Previous upgrades to the facility have already reduced the nitrogen loadings by half. Upgrades at the largest treatment plant that discharges to the Gunpowder River will be complete in 2013. Previous upgrades drastically reduced both nitrogen and phosphorus loads. No major wastewater treatment plants discharge to the Middle River. Stormwater retrofits have reduced nitrogen loadings and prevented nearly 50,000 pounds of nitrogen from entering the rivers since 2003, and 191 septic system retrofits were completed between 2008-2010.

To address nutrient inputs from agricultural lands, additional management actions have been taken. In 2010 there were 9,500 acres of cover crops planted in between growing seasons to absorb excess nutrients and prevent sediment erosion. Fencing on over 14,600 acres of farmland was used to keep livestock out of streams and prevent streambank erosion. More than 450 containment structures had been built to store animal wastes to allow these nutrients to be applied to the land in the most effective manner at the appropriate time. A total of 3,080 acres of stream buffers were also in place, allowing areas next to streams to remain in a natural state with grasses, trees and wetlands.

Maryland also has a number of programs in place to reduce the impacts of continued development and increasing amounts of impervious surfaces in the Upper Western Shore basin. Program Open Space projects have conserved nearly 800 acres of land for outdoor recreation opportunities. Rural Legacy Program projects have protected more than 8,800 acres, with special focus on areas with important cultural sites and natural resources and to ensure large areas of habitat. Maryland Environmental Trust projects have helped individual land owners protect more than 5,300 acres. Maryland Agricultural Land Preservation Program projects have preserved almost 3,400 acres of agricultural land from development.

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Introduction

Water quality is measured as the level of nutrients and sediments in the water. Habitat quality is determined by how nutrients and sediments impact water clarity, algal populations and bottom dissolved oxygen levels. Habitat quality is also determined by salinity and water temperatures, but these measures are not changed by nutrients and sediments. Habitat quality determines if and where underwater grasses, fish and bottom dwelling animals can live. Reducing the levels of nutrients and sediments is a major focus of restoration efforts. The goal is to reduce nutrient and sediment levels so that habitat quality is improved and high quality habitat is expanded. Assessing water and habitat quality is an important first step in making decisions on what needs to be done to improve water and habitat quality.

Habitat quality can be assessed by looking at the health of the aquatic plants and animals that remain in the same location, such as underwater grasses and bottom dwelling animals. The health of these organisms depends on habitat that is suitable for growth and survival, so healthy organisms indicate healthy habitats. Changes in the populations of these plants and animals can often be linked to specific parts of habitat quality that are poor, such as water clarity or bottom dissolved oxygen. This additional information helps managers better pinpoint what needs to be changed to improve water and habitat quality.

Land use in a watershed is linked to the human population density. Rivers with high urban land uses have higher population densities and more impervious surfaces. Rivers with high agricultural land uses in rural areas have lower population densities and less impervious surfaces. Higher population densities are often linked to management of human wastes through wastewater treatment plants, while septic systems are more prevalent in areas with lower population density. Pollutant loadings from undeveloped lands such as forests are different from loadings from more developed areas. Information on human population and land use help managers decide the best methods for reducing nutrients and sediments going from the land into the water.

The Upper Western Shore Basin Water Quality and Habitat Assessment includes a variety of information. Land use data and census data are examined to understand how the watersheds are impacted by human uses. Loadings data is examined to identify how much nutrient and sediment is entering the non-tidal streams from the watershed. Data from long-term non-tidal and tidal water quality monitoring programs are examined for current water and habitat quality and changes over time. Data from monitoring in shallow water habitats are examined to determine water and habitat quality in the areas most important for underwater grasses and the organisms that live there. Data from monitoring of algal populations, underwater grasses and bottom dwelling organisms are examined to determine how well the resulting habitat quality supports healthy plant and animal populations.

Land use and Human population

Maryland's Upper Western Shore basin includes all of Harford County and portions of Carroll, Baltimore, and Cecil Counties (Figure 3). The basin drains approximately 900 square miles in 18 sub-watersheds (Figure 4). Larger water bodies include the Susquehanna River, Bush River, Gunpowder River and Middle River. Most of this basin lies in the Piedmont physiographic province, but some of it lies in the Coastal Plain province. Major towns include Aberdeen, Bel Air, Havre de Grace and Port Deposit.

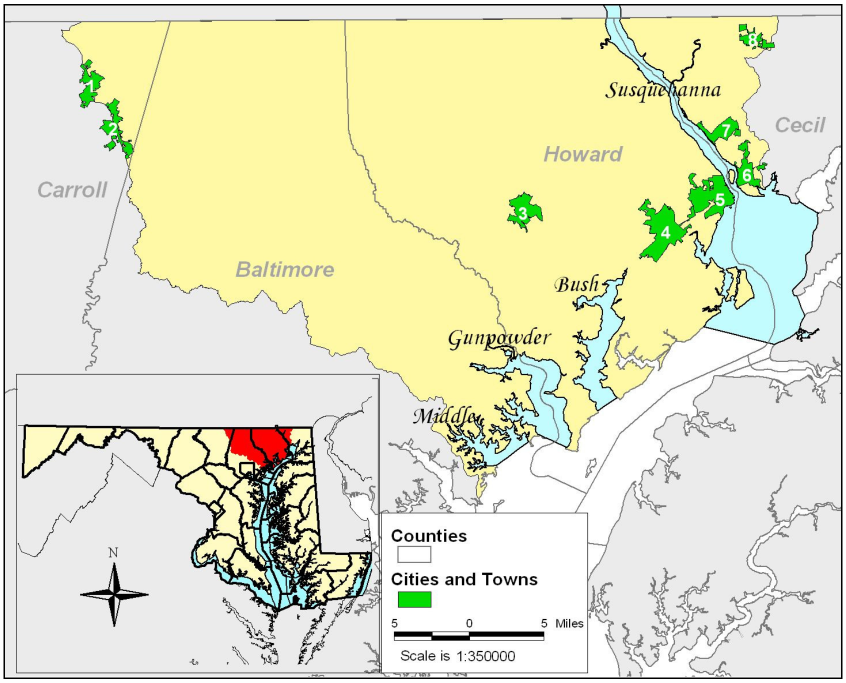

Figure 3. Upper Western Shore basin
Rivers, counties, cities and towns and major watersheds. Cities and towns, numbered left to right, are 1-Manchester, 2- Hampstead, 3- Bel Air, 4-Aberdeen, 5- Havre de Grace, 6- Perryville, 7- Port Deposit, 8-Rising Sun.

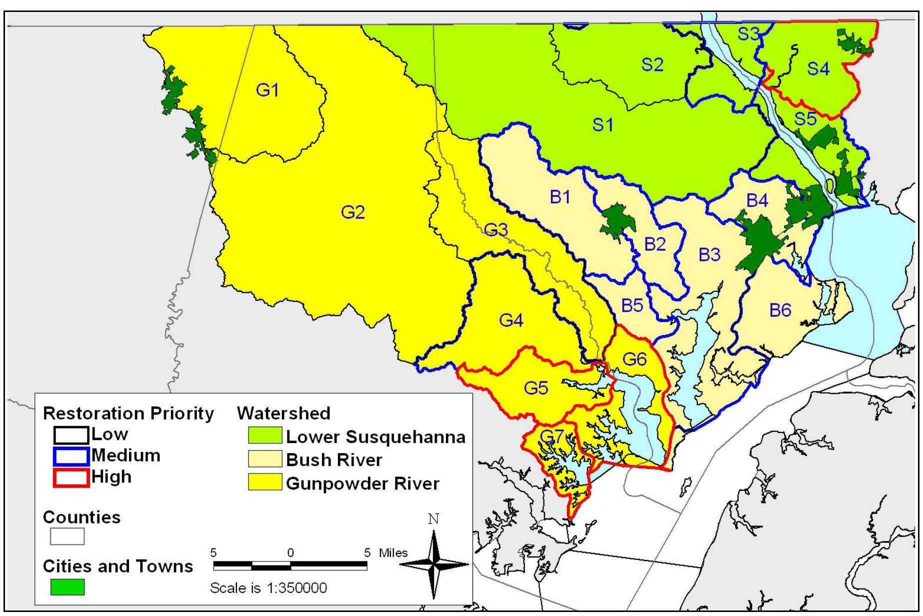

Figure 4. Upper Western Shore basin watersheds and sub-watersheds.
Trust Fund Restoration Priority designation (high, medium, low) is shown. Sub-watersheds (8-digit) are: G1- Prettyboy Reservoir, G2-Loch Raven Reservoir, G3- Little Gunpowder Falls, G4- Lower Gunpowder Falls, G5- Bird River, G6- Gunpowder River, G7- Middle River, B1-Atkisson Reservoir, B2-Byrum Run, B3-Bush River, B4- Swan Creek, B5-Lower Winters Run, B6- Aberdeen Proving Ground, S1-Deer Creek, S2- Broad Creek, S3-Conwingo Dam Susquehanna River, S4-Octoraro Creek, S5-Lower Susquehanna River.

In 2010 there were approximately 540,000 people living in the basin in Maryland and an additional 8,000 in Pennsylvania (Figure 5).[1] Population density was mostly between 100-1,000 people mi^2, though densities of 1,000-10,000 people mi^2 were common in the areas surrounding cities and towns. There were also a few pockets of both lower (10-100 people mi^2) and very high density (10,000-100,000 people mi^2).

In 2010 land use in the Upper Western Shore basin as a whole was roughly one-third urban, one-third forest and one-third agriculture (Figure 6, Appendix 1).[2] Between 2000 and 2010, urban land use increased by 11% (Figure 7). Impervious surfaces cover 7% of the basin overall.

The Octoraro Creek sub-watershed is a high priority Trust Fund Restoration watershed. Conowingo Dam, Deer Creek and Lower Susquehanna River sub-watersheds are medium priority restoration watersheds.[3] Stream health in all of the sub-watersheds is categorized as fair.[4] A Watershed Restoration Action Strategy (WRAS) was developed for the Deer Creek watershed in 2005.[5]

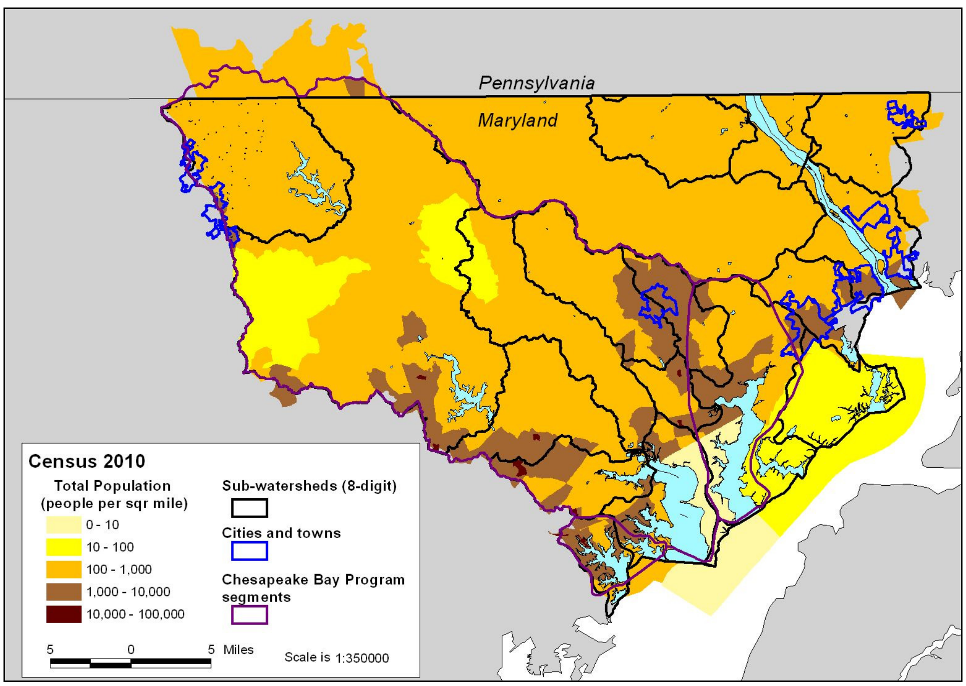

Figure 5. Upper Western Shore basin 2010 Census data for total population by block group. Total population per square mile is shown using a log scale. Pennsylvania data is included for the corresponding watersheds that also drain to the Upper Western Shore basin (based on the Chesapeake Bay Program segment watersheds). Differences between the watershed boundaries and the Census bureau block group boundaries result in non-exact matching of the population data to the given watershed.

[1] 2010 data from the U.S. Census Bureau available online at http://www2.census.gov/census_2010/04-Summary_File_1/

[2] Maryland Department of Planning data for 2010 available at http://www.planning.maryland.gov/OurWork/landUse.shtml

[3] Information on Maryland's Trust Fund is available at http://www.dnr.maryland.gov/ccp/funding/pdfs/TrustFundPriorities.pdf

[4] Maryland Department of Natural Resources data available at www.streamhealth.maryland.gov/stream_health.asp

[5] Detailed reports are available at http://dnr.maryland.gov/watersheds/surf/proj/wras.html.

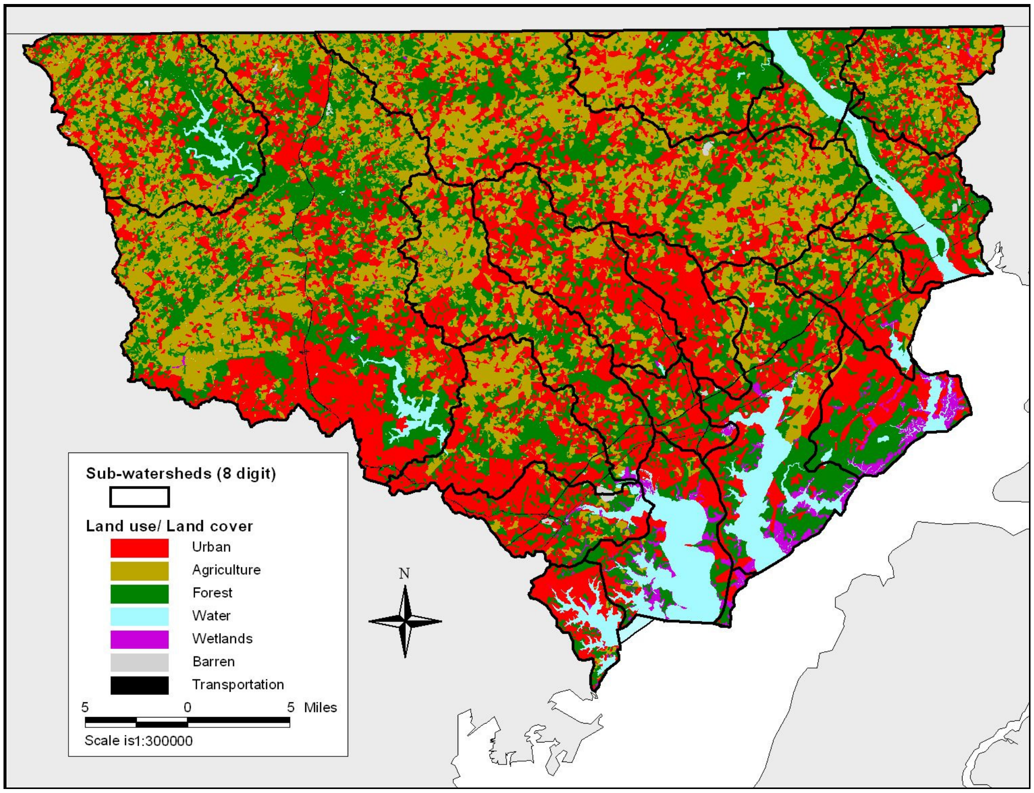

Figure 6. Upper Western Shore basin land use/land cover data for 2010.
See Appendix 1 for detailed land use/land cover information.

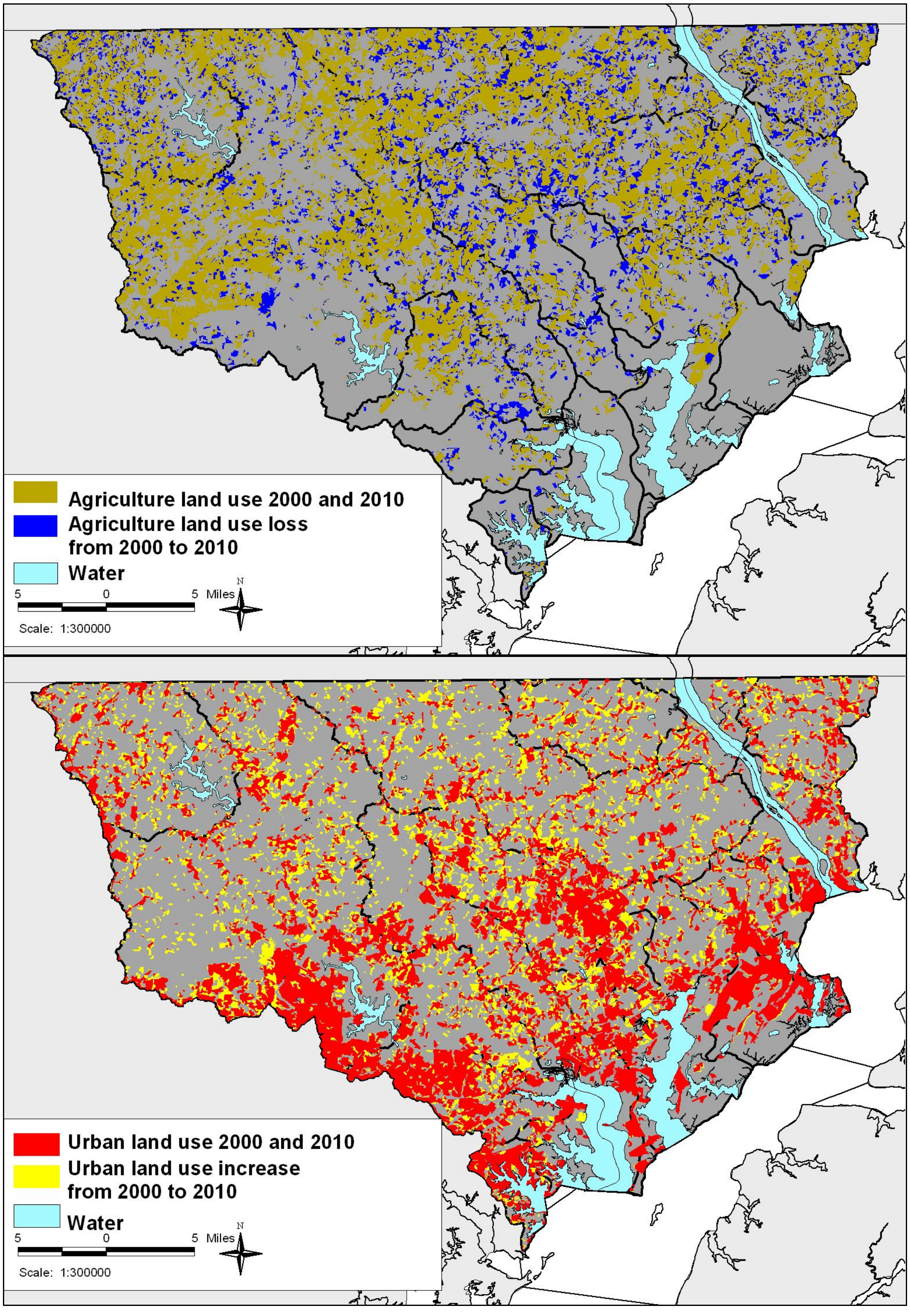

Figure 7. Land use change from 2000 to 2010.
Left panel shows change in agricultural land use in blue. Right panel shows change in urban land use in yellow.

Watersheds in the upper part of the basin drain to the Lower Susquehanna River. In this region agriculture is the dominant land use. Since 2000, agriculture has decreased by 10% and urban has increased by 13% of the total area.

Watersheds in the central basin drain to the Bush River. Urban use is the dominant land use in this region, covering almost half of the land area, while forest land use covers about one-third. Urban land use has increased by 11% since 2000, and impervious surfaces cover 12% of the total area. Stream health in Adkisson Reservoir and Lower Winters Run sub-watersheds is 'Fair'. Stream health in all other sub-watersheds is poor. All of the sub-watersheds except Aberdeen Proving Ground are medium priority for Trust Fund Restoration efforts. A Watershed Restoration Action Strategy (WRAS) was developed for the Bush River watershed in 2002.

The lower part of the basin drains to the Gunpowder River (Middle River is included in this drainage basin). Land use in the lower region is approximately one-third each agriculture, forest and urban land use. Urban land use in the lower region has increased by 11% since 2000. Impervious surfaces cover 7% of the total area. Stream health in the Lower Gunpowder Falls, Bird River and Gunpowder sub-watersheds is poor, and stream health is fair in the remaining sub-watersheds. Bird River, Middle River and Gunpowder River sub-watersheds are Maryland Trust Fund high priority watersheds. A Watershed Restoration Action Strategy (WRAS) is in development for Prettyboy Reservoir[6].

Maryland has a number of programs in place to reduce the impacts of continued development and increasing amounts of impervious surfaces in the Upper Western Shore basin. Program Open Space projects have conserved nearly 800 acres of land for outdoor recreation opportunities.[7] Rural Legacy Program projects have protected more than 8,800 acres, with special focus on areas with important cultural sites and natural resources and to ensure large areas of habitat. Maryland Environmental Trust projects have helped individual land owners protect more than 5,300 acres. Maryland Agricultural Land Preservation Program projects have preserved almost 3,400 acres of agricultural land from development.

Nutrient and Sediment Loadings

In accordance with the Chesapeake Bay Total Maximum Daily Load (TMDL), Maryland has developed a Watershed Implementation Plan (WIP) for making reductions in nitrogen, phosphorus and sediment loads to the Chesapeake Bay.[8] Maryland is required to reduce loads to Final Target loads by 2025. Maryland's Interim Target loads are set at 60% of the Final Target loads by 2017. Progress toward these Interim and Final Target loads is further broken into 2-year milestone loads. The first of these 2-year milestones is set for July 1, 2011- June 30, 2013.[9]

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[6] Detailed reports are available at http://dnr.maryland.gov/watersheds/surf/proj/wras.html.

[7] Information on land conservation programs in Maryland is available at http://www.dnr.state.md.us/land/landconservation.asp

[8] Maryland's Phase II Watershed Implementation Plan is online at www.mde.state.md.us/programs/Water/TMDL/TMDLImplementation/Pages/FINAL_PhaseII_WIPDocument_Main.aspx

[9] Progress toward meeting the 2011-2013 milestones is available on BayStat at www.baystat.maryland.gov/milestone_information.html

The rivers in the Upper Western Shore basin are combined with the Patapsco, Back and Lower Western Shore basin rivers into a single category- the Western Shore Basin. Final Target Loads for the Western Basin are 9.77 million pounds per year of nitrogen, 0.55 million pounds per year of phosphorus and 243 million pounds per year of sediments. The information below is loadings in 2009.

Bush River

The Bush River receives 0.9 million lbs/yr of nitrogen, 0.06 million lbs/yr of phosphorus, and 35 million lbs/yr of sediment from the surrounding watershed (Appendix 2). Point sources were the largest contributor of nitrogen (38%) and phosphorus (55%) to the Bush River (Figure 8). Urban runoff was the largest contributor of sediments (55%) to the river, and an important source of nitrogen (23%) and phosphorus (29%). Agriculture sources were also important to sediment loadings (32%).

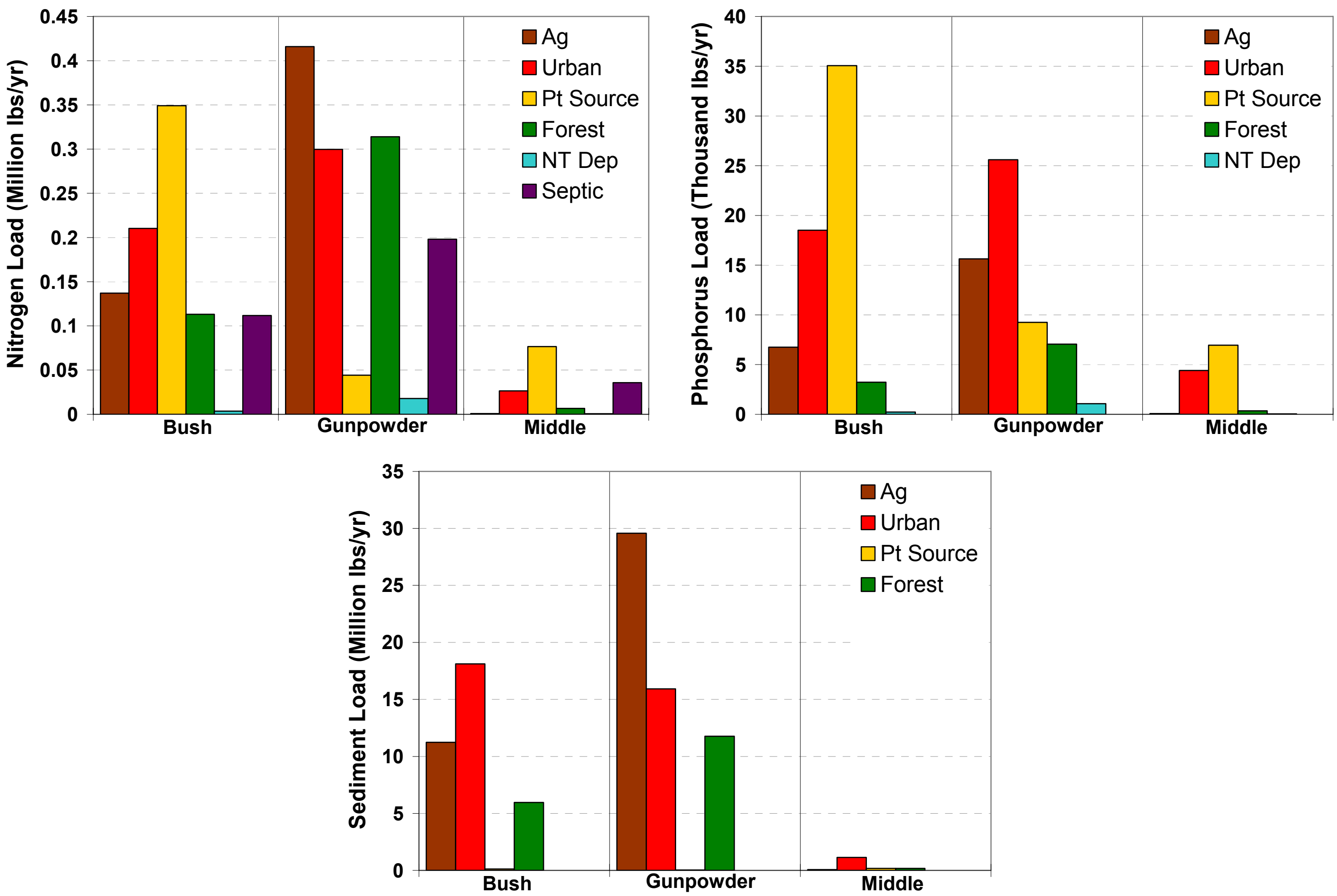

Figure 8. Nitrogen, phosphorus and sediment loadings per year.
Delivered loadings by category in million lbs/yr. Septic is not a source of phosphorus or sediment loadings and water deposition (NT Deposition) is not a source of sediment loadings. See Appendix 2 for additional detail.

Gunpowder River
The Gunpowder River receives 1.3 million lbs/yr of nitrogen, 0.06 million lbs/yr of phosphorus and 57 million lbs/yr of sediment from the surrounding watershed. Agriculture sources were the largest contributor of nitrogen (32%) and sediments (52%), and an important source of phosphorus (27%). Urban runoff was the largest contributor of phosphorus (44%) to the river, and an important source of nitrogen (23%) and sediments (28%). Forest sources were also important to nitrogen (24%) and sediment loadings (21%).

Middle River
The Middle River receives 0.15 million lbs/yr of nitrogen, 0.1 million lbs/yr of phosphorus, and 1.4 million lbs/yr of sediment from the surrounding watershed. Point sources were the largest contributor of nitrogen (52%) and phosphorus (59%). However, no major WWTP discharge to the Middle River. Urban runoff was the largest contributor of sediments (73%) to the basin, and an important source of phosphorus (37%). Septic sources were also important to nitrogen loadings (24%).

Point Source Loads

Nutrient loadings from point sources (including wastewater treatment plants, WWTPs) are the easiest to measure. Point source loads are often the most cost-effective to manage. A major focus of management actions to reduce nutrient loads has been upgrades to WWTPs. In 2004 Maryland passed legislation creating the Chesapeake Bay Restoration Fund specifically to fund WWTP upgrades to enhanced nutrient removal (ENR).[10] The program is working to complete ENR upgrades to 67 major WWTPs, including 5 facilities in the Upper Western Shore basin.[11] Upgrades to two Upper Western Shore basin facilities were complete by the end of 2010: APG-Aberdeen WWTP which discharges to the Bush River and Havre de Grace WWTP which discharges directly to the main Bay.

Point sources were the largest contributor of nitrogen and phosphorus to the Bush River. Three major WWTPs discharge into the Bush River Watershed. Sod Run WWTP is the largest, with a 20 million gallons per day (MGD) capacity, and contributes more than 90% of the nitrogen and phosphorus loads from WWTPs. BNR was implemented at Sod Run in 2000, and ENR construction has started and is expected to be complete by mid 2014.[12] Nitrogen loadings from Sod Run WWTP were cut in half by the implementation of BNR but still are above the loading caps (Figure 9). Phosphorus loads have been variable but have not continued to increase with increased flows. Phosphorus loads are also above loading caps.

The other major WWTPs that discharge to the Bush are Aberdeen WWTP (4 MGD) and Aberdeen Proving Grounds-Edgewood (3 MGD). Aberdeen WWTP discharges to Swan Creek,

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[10] The Chesapeake Bay Restoration Fund collects fees from wastewater treatment plant users to pay for the upgrades. A similar fee is paid by septic system users to upgrade onsite systems and implement cover crops to reduce nitrogen loading to the Bay. For more information on the Chesapeake Bay Restoration Fund see http://www.mde.state.md.us/programs/Water/BayRestorationFund/Pages/index.aspx.
[11] Major wastewater treatment plants (WWTP) are those with greater than 0.5 million gallons per day (MGD) design flow.
[12] Biological nutrient removal (BNR) technology removes additional nitrogen than traditional methods, bringing nitrogen levels in effluent to below 8 mg/l. Enhanced nutrient removal (ENR) reduces nitrogen levels to below 3 mg/l and phosphorus levels to below 0.3 mg/l in effluent.

a tributary of the Bush. BNR was implemented at Aberdeen WWTP in late 1998 and upgrades to ENR are expected to be complete by the end of 2012. Aberdeen Proving Ground- Edgewood WWTP discharges to the Bush River. Aberdeen Proving Grounds-Edgewood WWTP implemented BNR in 2006.[13]

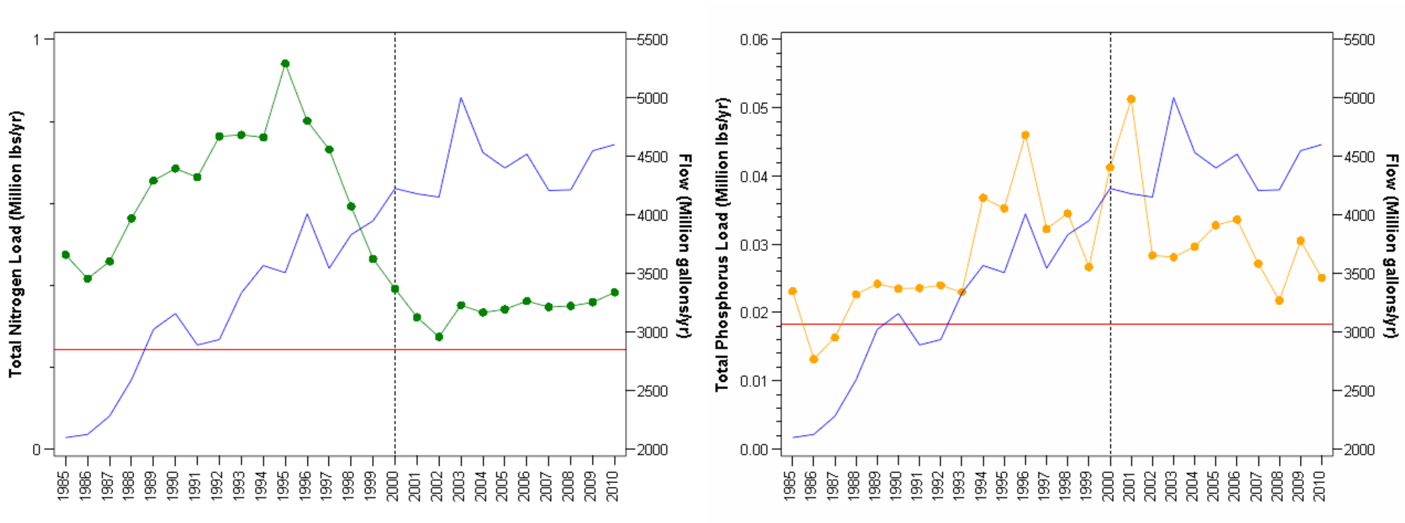

Figure 9. Annual total nitrogen and total phosphorus loadings and effluent flow from Sod Run WWTP to the Bush River.
Red horizontal line indicates the loading cap for the facility following implementation of ENR. The dotted vertical line indicates when BNR was implemented.

Point sources were not a large contributor of nitrogen (3%) but were a contributor of phosphorus (16%) to the Gunpowder River. The Gunpowder River receives effluent discharge from the Joppatowne WWTP (0.95 MGD) and the Hampstead WWTP (0.9 MGD). Nitrogen loadings from Hampstead are twice those from Joppatowne while phosphorus loadings from Hampstead were one-fifth those from Joppatowne (Figure 10).

BNR was implemented in mid 1996 at the Joppatowne facility, and ENR construction is expected to be complete by the end of 2013. Nitrogen loadings from Joppatowne WWTP were drastically reduced by the implementation of BNR. Nitrogen loadings from Joppatowne WWTP have met loading caps in some post-BNR years, and now fluctuate with the total flow. Phosphorus loads have also been drastically reduced and are approaching loading caps.

The Hampstead WWTP discharges to Piney Run, which flows through Western Run to Loch Raven Reservoir to the Gunpowder. Construction of ENR upgrades is scheduled to begin in late 2013 and be complete by the end of 2015. Nitrogen loadings have continued to increase with increasing flow through the facility, while phosphorus loads are very low and have decreased.

[13] Aberdeen Proving Grounds-Edgewood WWTP is a Federal facility, ENR upgrade information was not available.

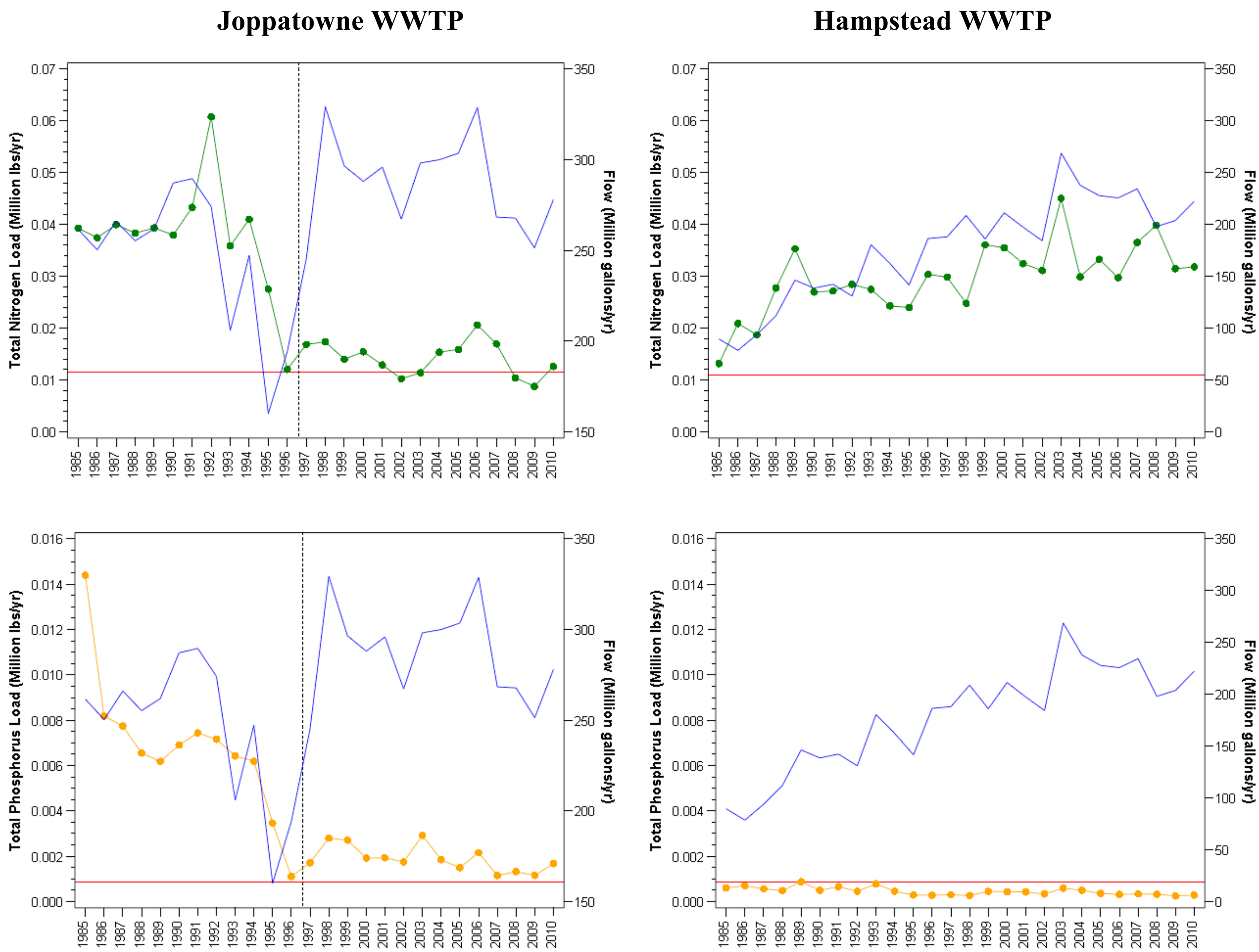

Figure 10. Annual total nitrogen and total phosphorus loadings and effluent flow from Joppatown WWTP and Hampstead WWTP to the Gunpowder River.
Top graphs are total nitrogen load (green) and bottom graphs are total phosphorus load (orange) plotted on the left axis.. Blue line on each graph shows total annual effluent flow (right axis). Red horizontal line indicates the loading cap for the facility following implementation of ENR. The dotted vertical line indicates when BNR or ENR was implemented.

Non Point Source Loads

In 1998, Maryland passed the Water Quality Improvement Act, which requires farmers to reduce nitrogen and phosphorus loadings from agricultural lands.[14] Soil Conservation and Water Quality Plans (SCWQPs) are developed to determine what the appropriate actions, or best management plans (BMPs), are for a given area.[15] Each of Maryland's counties has a Soil Conservation District Office with staff to help farmers develop and implement SCWQPs. The total number of BMPs in place in the basin as a whole (not by individual farm) is used to measure progress.[16] In 2010 there were 9,500 acres of cover crops planted in between growing seasons to absorb excess nutrients and prevent sediment erosion. Fencing on over 14,600 acres of farmland was used to keep livestock out of streams and prevent streambank erosion. More than 450 containment structures had been built to store animal wastes to allow these nutrients to be applied to the land in the most effective manner at the appropriate time. A total of 3,080 acres of stream buffers were also in place, allowing areas next to streams to remain in a natural state with grasses, trees and wetlands.

Water and Habitat Quality

Non-tidal water quality monitoring is done year-round at five stations to characterize conditions in free-flowing freshwater (Figure 11, Appendix 3). Two of these stations are within the lower Susquehanna watershed, and the other three stations are in the Gunpowder watershed. For these sites, only surface measurements are collected.

At two of the long-term non-tidal stations (DER0015 and GUN0258) stream gauges are installed which provide flow data. The USGS uses the flow data and the nutrient data to calculate nitrogen, phosphorus and sediment loadings to the streams.[17] Flow data has been collected at the Gunpowder Falls station since 1985 and at the Deer Creek station since 2006. Trends are calculated for the Gunpowder Falls station but not the Deer Creek station.

Tidal water quality monitoring is done year-round at three stations that have been monitored since 1985 (Figure 11, Appendix 3).

For non-tidal and tidal stations, the following parameters were evaluated: total nitrogen (TN), total phosphorus (TP) and total suspended solids (TSS). For tidal stations, additional parameters were evaluated: dissolved inorganic nitrogen (DIN), dissolved inorganic phosphorus (PO_4), algal abundance (as measured by chlorophyll *a*, CHLA), water clarity (as measured with a Secchi disc and by calculating the percent light through water, PLW), summer bottom dissolved oxygen (BDO), salinity and water temperature.

Assessment methods are described in Appendix 4. Selected graphical results are included with the text. Non-tidal and tidal water quality trends results discussed in the text refer to the 1999-2010 trends. Significant trends for 1985-2010 (tidal) or 1986-2010 (non-tidal) are noted in the footnotes. Seasons for 1999-2010 tidal trends are: spring (March-May), summer (July-

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[14] For more information, please see the Maryland Department of Agriculture website http://mda2.maryland.gov/resource_conservation/Pages/nutrient_management.aspx

[15] For more information see http://mda.maryland.gov/pdf/scwqplan.pdf

[16] Progress on different BMPs is available at http://www.baystat.maryland.gov/milestone_information.html

[17] For USGS methods see http://md.water.usgs.gov/publications/sir-2006-5178/index.html

September)[18] and SAV growing season (Apr-October). Significant trends for 1985-2010 (tidal) or 1986-2010 (non-tidal) are noted in the footnotes. Figure and Appendix references apply to all rivers and are given only the first time referenced. Summary results are presented in Table 1 and Table 2 in the 'Overall Assessment' section. Detailed tabular results tabular results are included in the Appendices 6, 7 and 8.

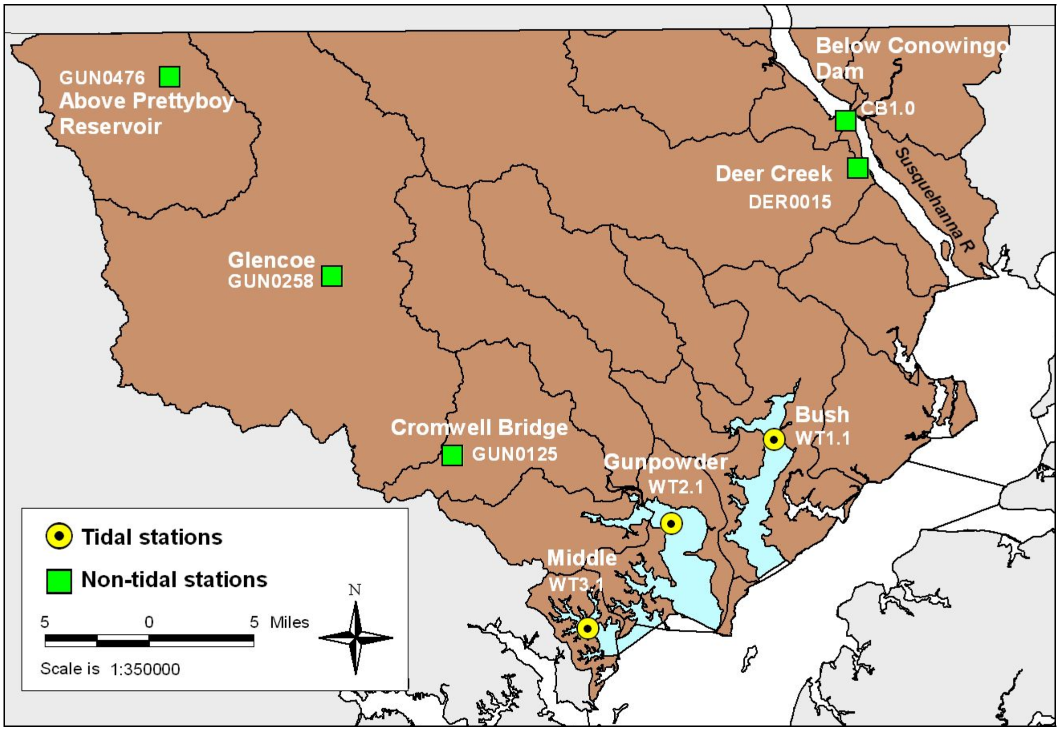

Figure 11. Long-term non-tidal and tidal water quality monitoring stations. Sub-watersheds (8-digit) also shown.

Non-tidal streams

Lower Susquehanna watershed

There are two non-tidal stations in the Lower Susquehanna watershed. TN increased at the station on Deer Creek, but TP may have decreased (Figure 12).[19] Total nitrogen and sediment loadings at the Conowingo Dam decreased from 1985-2010, but sediments also increased from 2001-2010 (Figure 13).[20]

TN levels are much higher at the Deer Creek station than at the Conowingo Dam station, but TP and sediment levels are similar at both. Higher flow in some years (1996) led to higher TP and TSS levels at the Deer Creek station, but TP and TSS loads in more recent higher flow years (2003) have been less elevated.

[18] For summer bottom dissolved oxygen analysis, the months used are June-September.
[19] TN levels decreased and TSS levels may have increased at the station below Conowingo Dam from 1986-2010. TP levels may have decreased at the Deer Creek station from 1986-2010.
[20] Non-tidal loadings trends are from USGS (Langland, pers. communication).

Gunpowder watershed

There are three non-tidal stations in the Gunpowder watershed. Loadings information is collected at the middle station. At the upper station (GUN0476), TN levels increased but TP levels decreased (Figure 14).[21] At the middle station (GUN0258), TN levels increased and TP levels may have decreased. TP and TSS decreased at the lower station (GUN0125, Figure 15).

TN loadings at the middle station significantly increased from 2001-2010. TP loadings decreased from 1985-2010. Sediment loadings increased for recent (2001-2010) and long-term (1985-2010) time periods.

TN levels decrease from upper to lower stations, but TP and TSS levels are similar throughout the watershed.

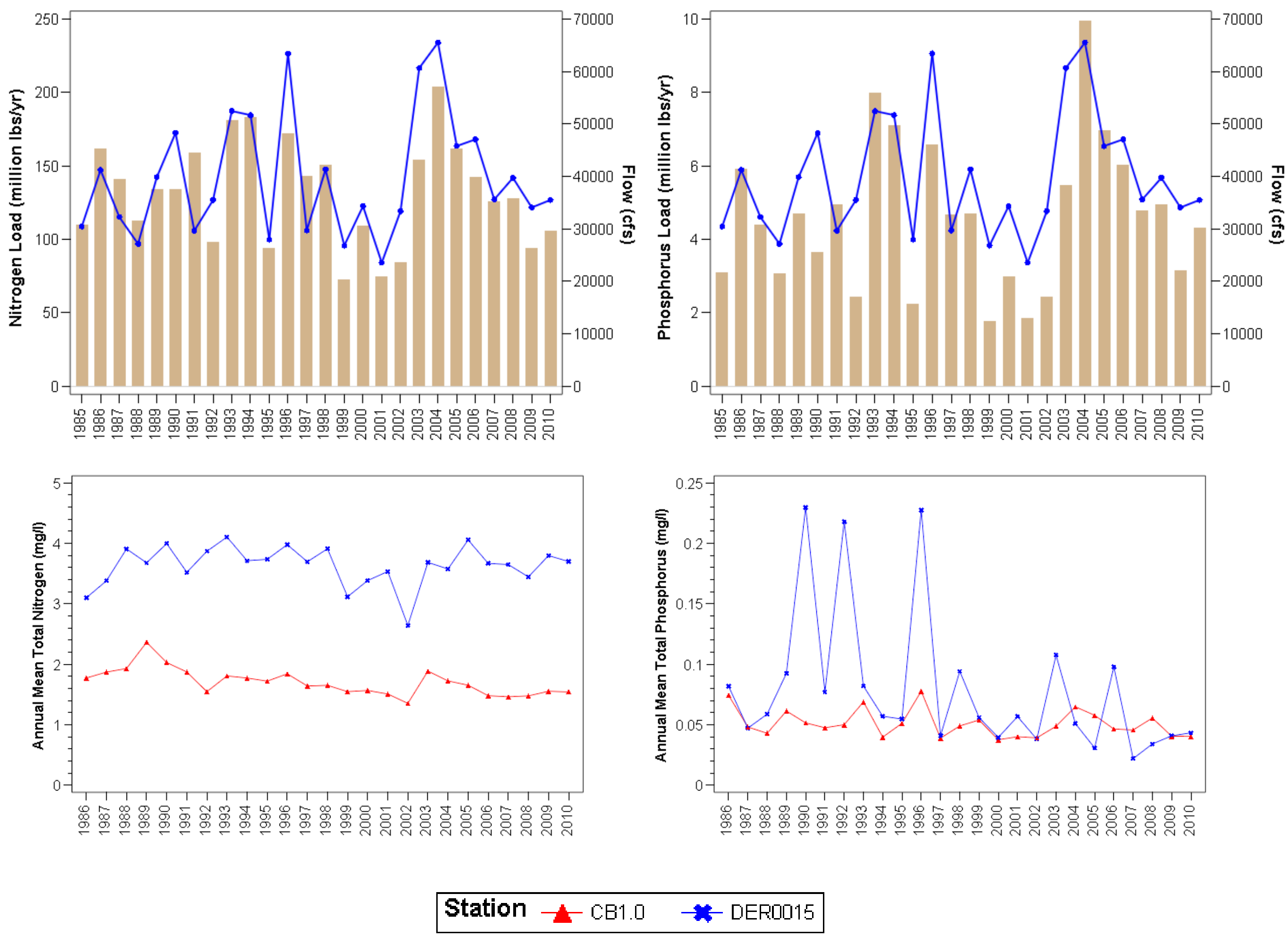

Figure 12. Annual nitrogen and phosphorus load and concentration for non-tidal stations in the Lower Susquehanna watershed

Top graphs show annual nitrogen and phosphorus (tan bars, left axis) and flow (blue line, right axis) for Susquehanna River. Bottom graphs show annual mean concentrations for total nitrogen and total phosphorus in the Susquehanna River and Deer Creek.

[21] TP and TSS decreased at the upper station in the Gunpowder watershed from 1985-2010 but TN may have increased. TP decreased at the middle station and TN, TP and TSS decreased at the lower station from 1985-2010.

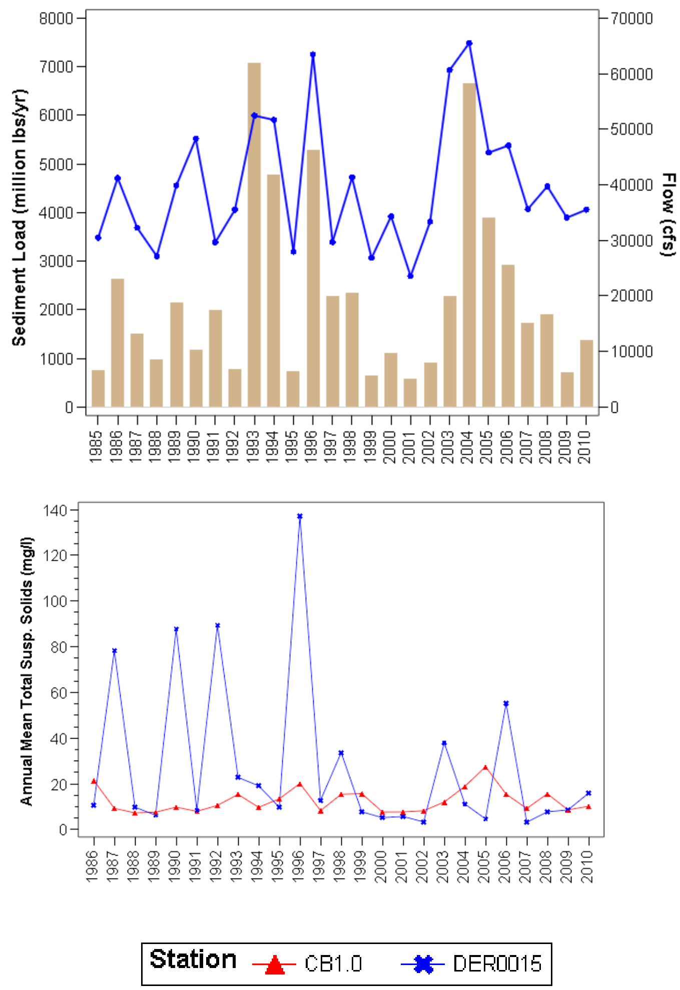

Figure 13. Annual sediment load and total suspended solids concentration for non-tidal stations in the Lower Susquehanna watershed
Top graph shows annual sediment load (tan bars, left axis) and flow (blue line, right axis) for Susquehanna River. Bottom graph shows annual mean concentrations for total suspended solids at the Susquehanna River and Deer Creek.

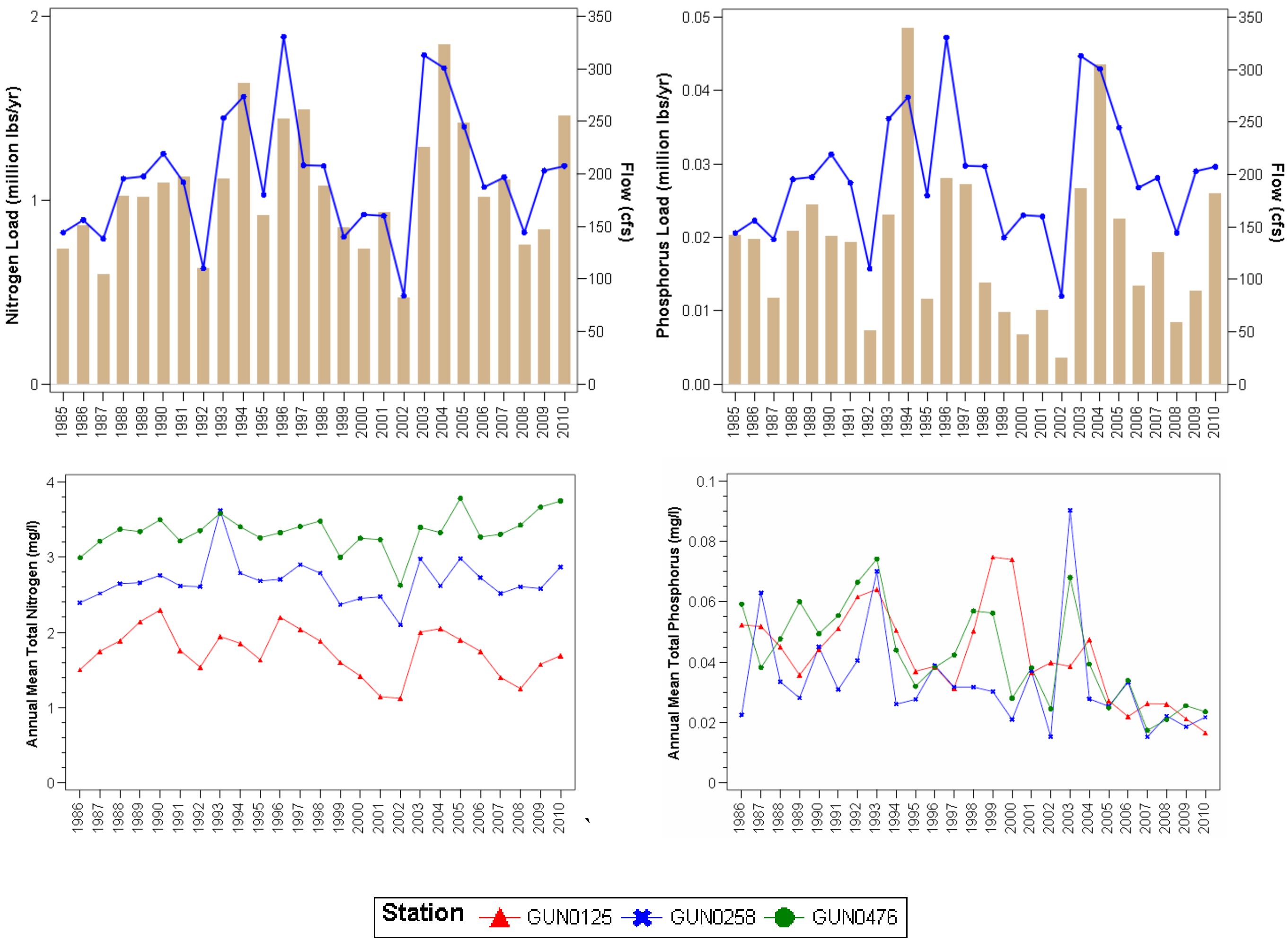

Figure 14. Annual nitrogen and phosphorus load and concentration for non-tidal stations in the Gunpowder River watershed

Top graphs show annual nitrogen and phosphorus (tan bars, left axis) and flow (blue line, right axis) for Gunpowder River. Bottom graphs show annual mean concentrations for total nitrogen and total phosphorus at the long-term non-tidal stations.

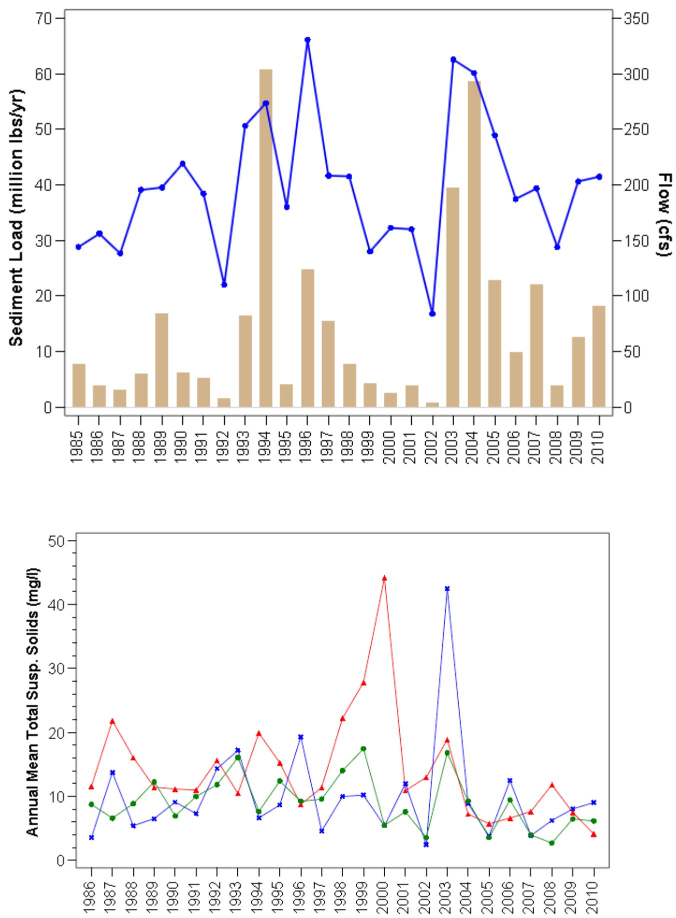

Figure 15. Annual sediment load and total suspended solids concentration for non-tidal stations in the Gunpowder River watershed.
Top graph shows annual sediment load (tan bars, left axis) and flow (blue line, right axis) for Gunpowder River. Bottom graph shows annual mean concentrations for total suspended solids at the long-term non-tidal stations.

Tidal rivers

Bush River

TN levels in the Bush River were relatively fair and DIN levels were relatively good, but there were no annual or seasonal trends (Figure 16).[22] Summer DIN levels were low enough that nitrogen limitation of algal growth occurred in most years and in the fall in some years, but not in the other seasons (Figure 17).

TP and PO_4 levels in the Bush River were relatively good. PO_4 degraded in the summer and both may have degraded annually. PO_4 levels for the SAV growing season were low enough for

[22] TN in the Bush River may have improved from 1985-2010. The DIN:PO_4 ratio decreased from 1985-1997 but is still over 120. TP degraded from 1985-1997. CHLA may have degraded from 1985-2010; summer bottom DO may have degraded from 1985-2010.

the Bush River to meet the SAV habitat requirement (Figure 18). TSS levels were good but TSS levels were too high and failed the meet the SAV habitat requirement.

Algal abundance was relatively poor and CHLA levels for the SAV growing season were too high to meet the habitat requirement. Water clarity was relatively poor and failed to meet the SAV habitat requirement. Summer BDO levels were always above 5 mg/l but may have degraded (Figure 19).

Gunpowder River

TN and DIN levels in the Gunpowder River were relatively good. DIN levels were below the threshold for nitrogen limitation of algal growth in the summer in most years and in the fall in some years, but not in the other seasons.

TP, PO_4 and TSS levels in the Gunpowder River were relatively good. PO_4 degraded in the summer and SAV growing season and may have degraded annually. PO_4 levels for the SAV growing season met the habitat requirement. TSS levels met the SAV habitat requirement in the some years but not in 2008 or 2010.

Algal abundance was relatively poor.[23] CHLA levels for the SAV growing season were borderline and failed to meet the habitat requirement in 2008 and 2010. Water clarity was relatively poor and degraded in the SAV growing season and may have degraded in the summer and annually as well. Water clarity failed to meet the SAV habitat requirement. Summer BDO levels were good and were always above 5 mg/l. Salinity may have declined annually.

Middle River

TN and DIN levels were relatively good in Middle River, and DIN levels may have improved in the summer.[24] Summer DIN levels were low enough for nitrogen limitation of algal growth to occur, and in fall in some years, but not in the other seasons. The DIN:PO_4 ratio may have decreased, but annual means ranged from 130-170 from 2008-2010, indicating that nitrogen levels are greatly in excess relative to phosphorus levels.

TP, PO_4 and TSS levels were all relatively good in Middle River. PO_4 degraded in the summer, and summer TP levels may have degraded. PO_4 levels in the SAV growing season met habitat requirements and TSS levels met the requirements in all years except 2009.

Algal abundance was relatively poor but median CHLA levels for the SAV growing season were met the habitat requirement in most years but not in 2008.[25] Water clarity was good but failed to meet the SAV habitat requirements. Secchi depth degraded annually, in summer and in the SAV growing season. Summer BDO levels were good and monthly average BDO was above 5 mg/l. Salinity declined in the summer and may have declined annually as well.

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[23] CHLA improved in the Gunpowder River from 1985-2010. Summer bottom DO degraded from 1985-2010. Salinity may have declined from 1985-1997 but the overall 1985-2010 trend was not significant.

[24] TN in Middle River may have improved from 1985-2010. The DIN:PO_4 ratio decreased from 1985-1997 but is still greater than 100.

[25] Middle River CHLA and Secchi depth improved from 1985-1997 but have been degrading since the late 1990s. Salinity may have declined from 1985-2010.

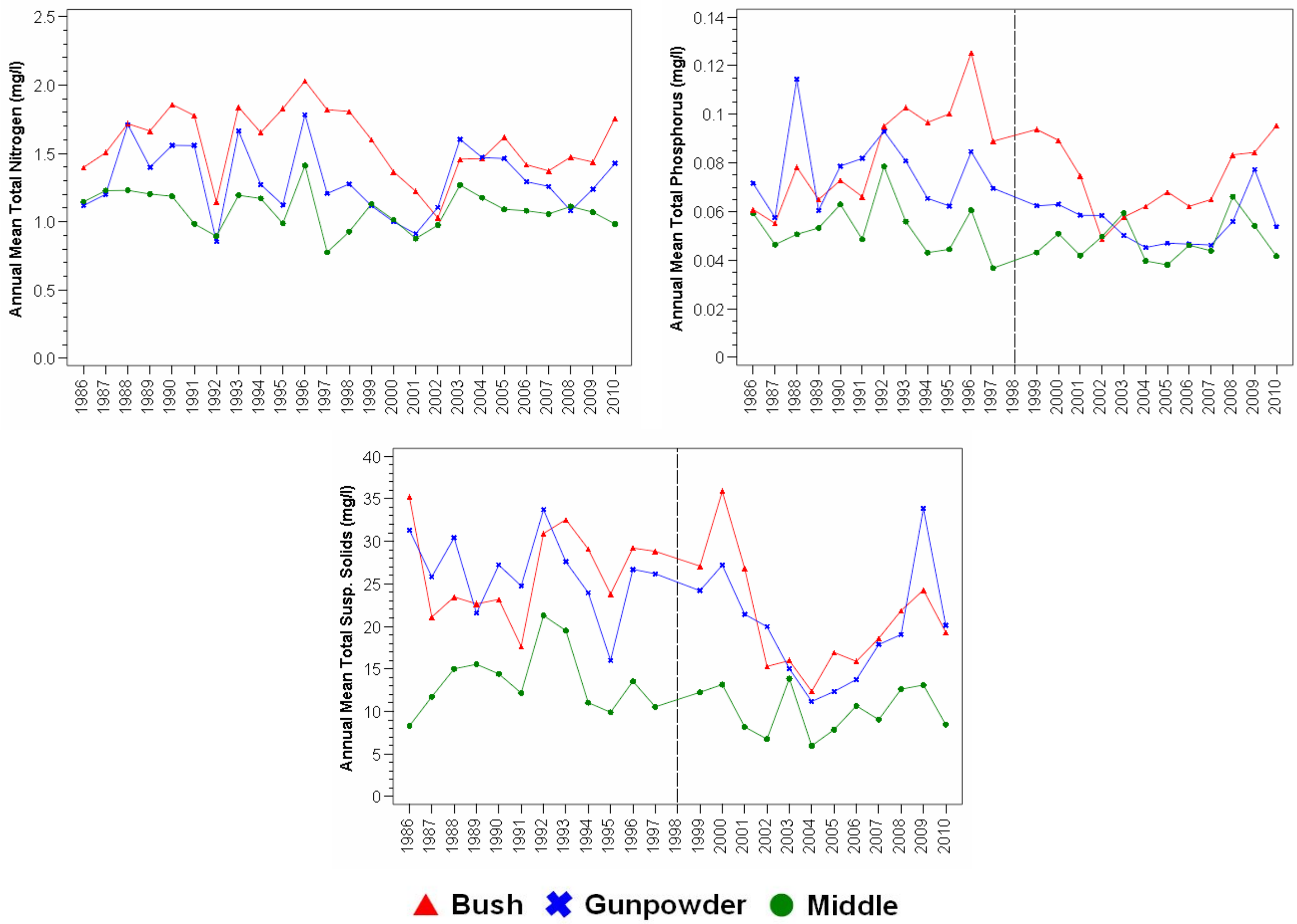

Figure 16. Annual means for total nitrogen, total phosphorus and total suspended solids in the tidal portions of Bush, Gunpowder and Middle rivers.
Dotted line (1998) indicates when the lab change occurred that may have impacted TP and TSS. Caution should be used in making comparisons for TP and TSS from before to after the lab change.

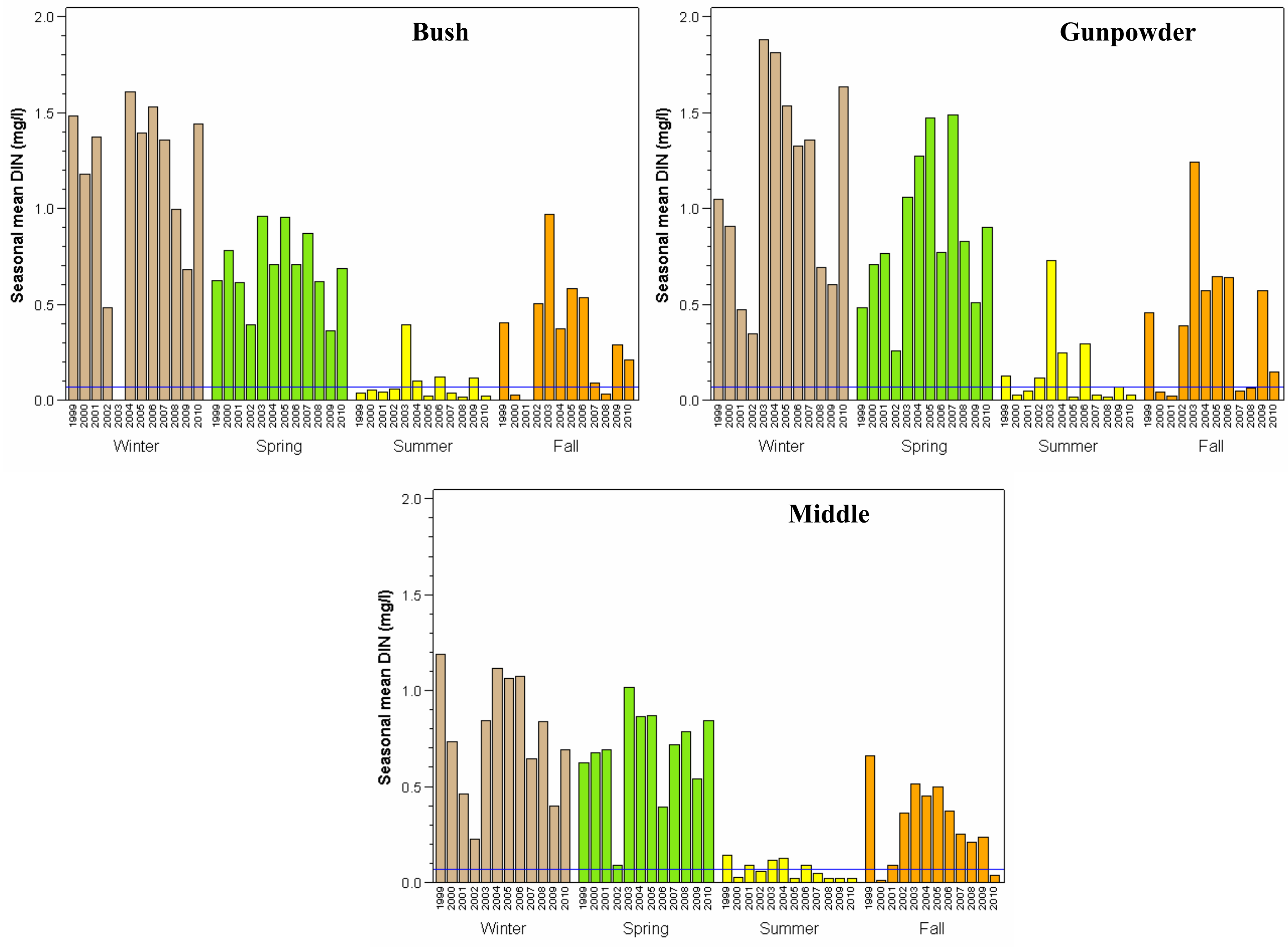

Figure 17. Mean dissolved inorganic nitrogen by season.
The blue line at 0.07 mg/l indicates the DIN level below which nitrogen limitation likely occurs. Winter season includes December (of the previous year), January and February. Spring season includes March-May. Summer season includes July-August (June is a transition month and not included). Fall season includes October and November. Biological nutrient removal of nitrogen at WWTPs is most effective in warmer months, and seasonal changes in phytoplankton populations (blooms in spring and fall) reduce DIN.

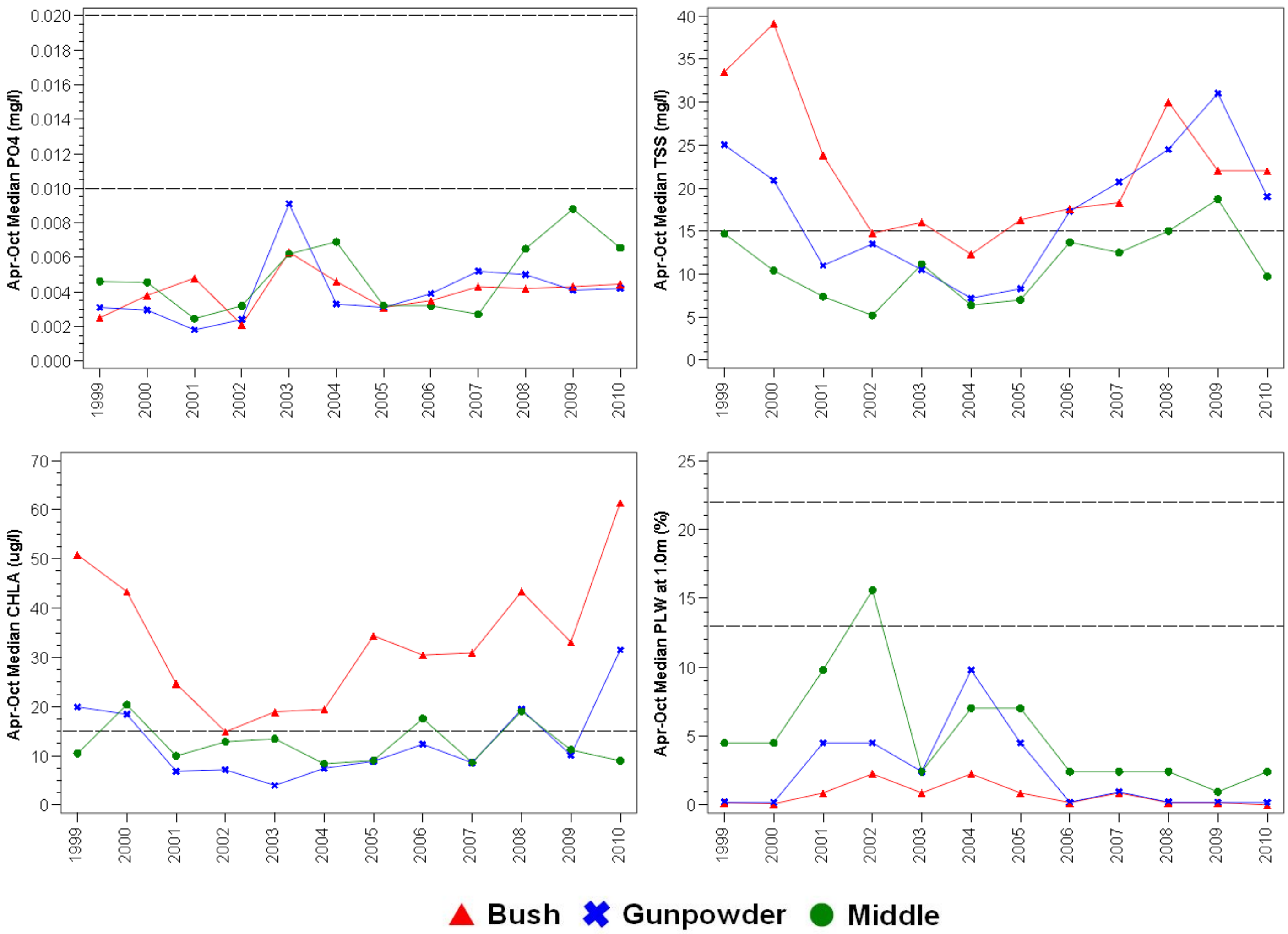

Figure 18. SAV habitat requirement parameters.
SAV growing season (April-October) median values for PO_4, TSS, PLW and CHLA. Threshold values are shown with dashed lines (Appendix 5). To meet or pass the habitat requirements, levels of PO_4, TSS and CHLA need to be lower than the threshold and PLW needs to be above the threshold. All three rivers need to meet the tidal fresh/oligohaline thresholds.

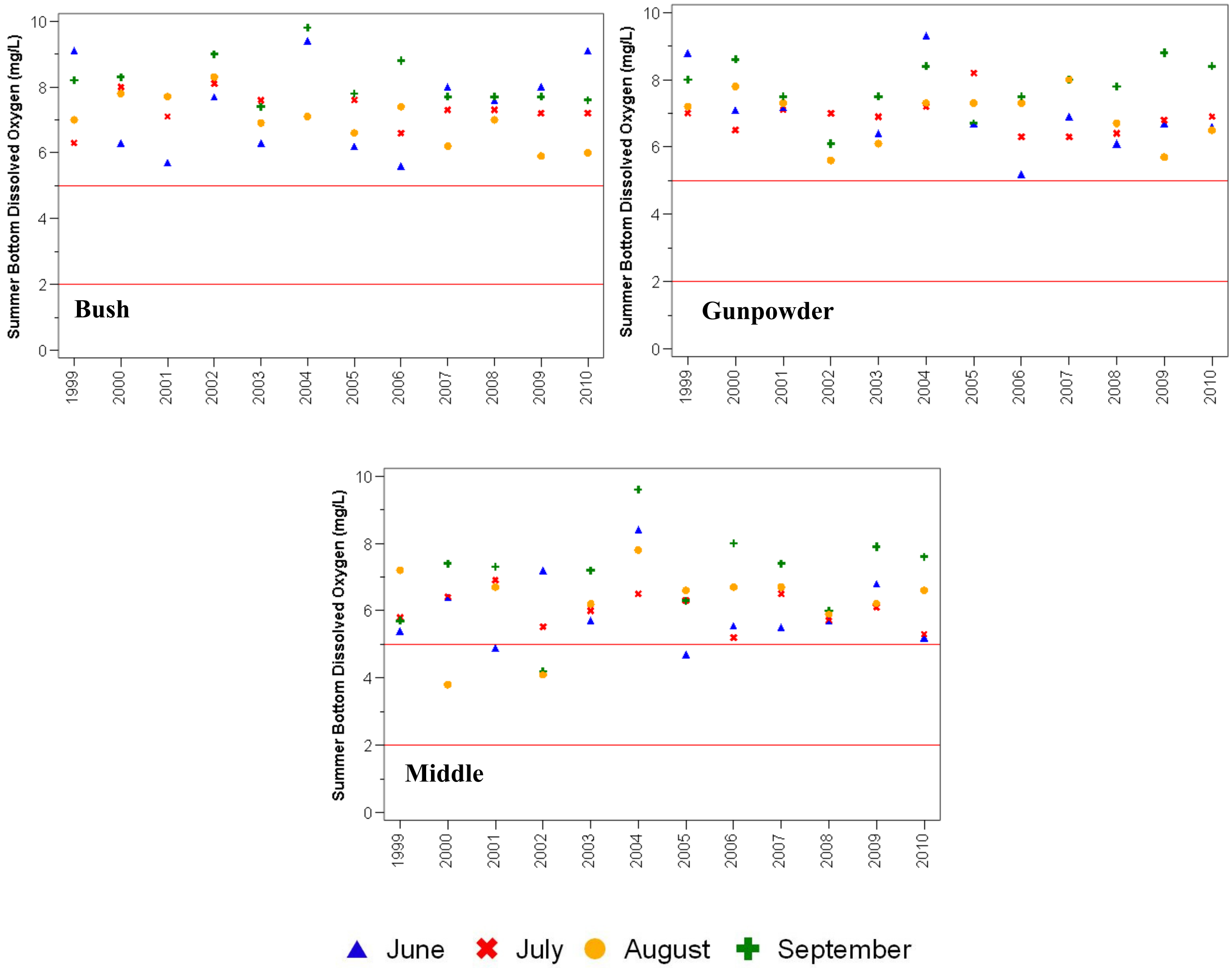

Figure 19. Summer bottom dissolved oxygen levels
Monthly bottom dissolved oxygen levels with threshold values of 5 mg/l and 3 mg/l shown with red reference lines.

Shallow water

The tidal long-term monitoring program samples at a fixed point that is generally in the center channel and deeper waters of a river. Sampling is usually done once or twice a month. The strength of this type of monitoring is that the repetition of sampling over many years (more than two decades) measures how water quality has changed over time and in response to management actions, land use changes, etc. However, conditions at the long-term monitoring station may not adequately capture water quality conditions in shallow waters, the river as a whole or on short time scales. The shallow water monitoring program is designed to measure conditions in the areas closest to land that are critical habitat areas, especially in the areas with underwater grass beds. Sampling in a river is done for a 3-year period to determine short-term changes in water quality that occur due to weather, such as between a year with very high rainfall and a year with low rainfall. Some shallow water stations have been monitored for longer periods.

The first part of the shallow water monitoring program uses instruments that stay in the water for extended periods (usually April-October) and collect information every 15 minutes; this is called the continuous monitoring program. Instead of the one or two samples a month typical of the long-term monitoring program, the continuous monitoring program can collect more than 2,800 samples a month.[26] This type of monitoring 1) measures water quality changes that occur between night and day, between days and at longer times spans; 2) determines how long water quality problems persist, such as algal blooms or low oxygen water; and 3) measures water quality changes that occur related to weather events such as storms.

The second part of the monitoring program samples all of the shallow waters of a river (or river segment in larger rivers) once a month from April-October; this is the water quality mapping program. Data is collected nearly constantly as a boat moves along the entire shoreline, so changes in water quality can be measured from one part of the river to another. This data captures water quality in very localized areas and can identify places with better or worse water quality than the river overall. This monitoring is also able to capture changes in water quality related to events that occur in only part of the river such as algal blooms or in response to localized nutrient sources.

The Shallow Water Monitoring Program conducted an intensive monitoring and assessment study of the major tributaries of the Upper Western Shore during the years 2003-2005. Two continuous monitors were placed in each of the rivers (Figure 20, Appendix 3).[27] Water quality mapping was also conducted in the Bush, Gunpowder and Middle rivers during 2003-2005.[28]

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[26] Nutrient samples are collected twice a month instead of continuously.
[27] An interactive map of all continuous monitoring stations and complete archived data are available at http://mddnr.chesapeakebay.net/newmontech/contmon/archived_results.cfm.
[28] Interpolated maps for all cruises are available on the Maryland Department of Natural Resources "Eyes on the Bay" website http://mddnr.chesapeakebay.net/sim/dataflow_data.cfm

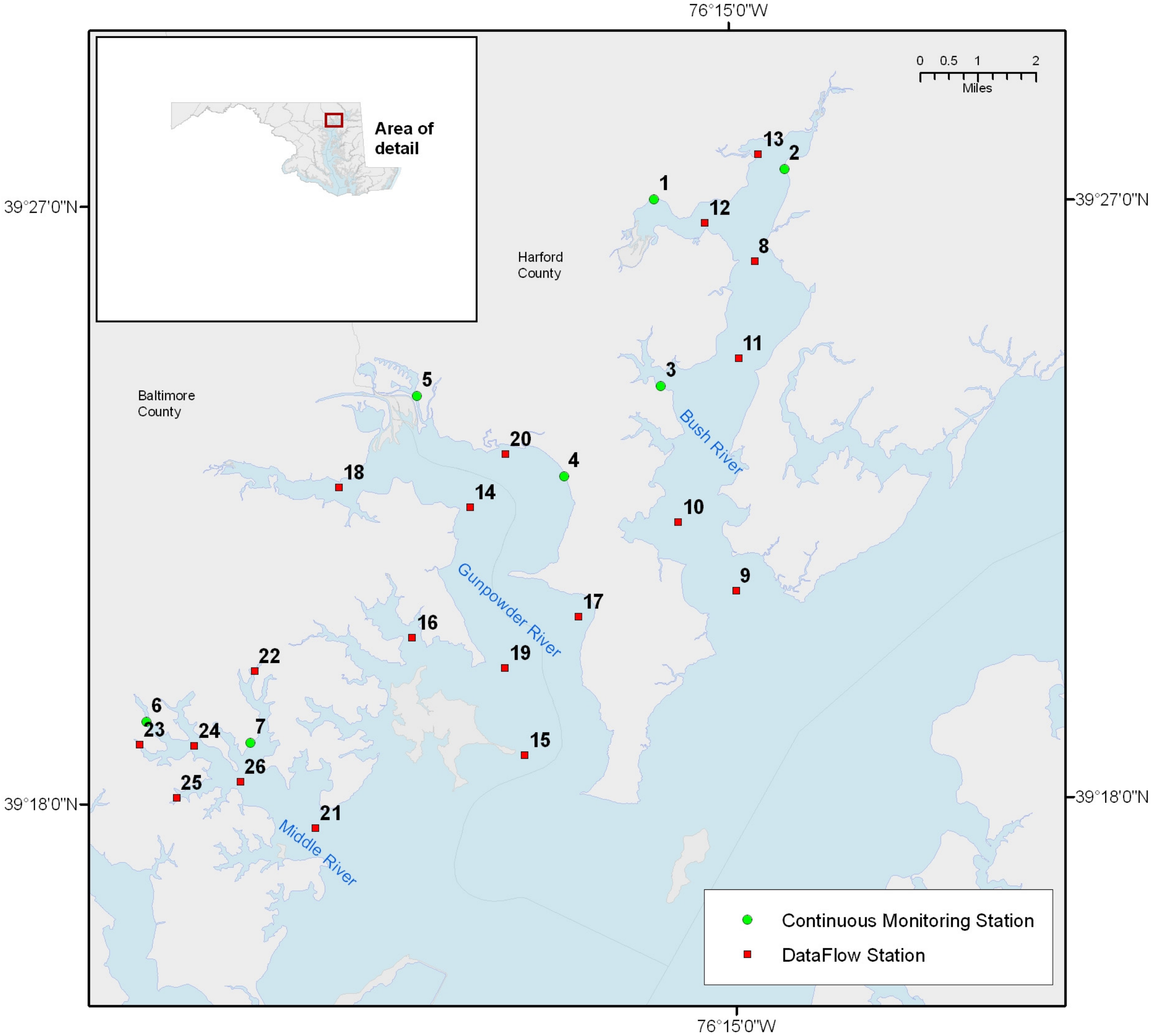

Figure 20. Shallow water calibration stations in the Upper Western Shore basin. Green circles show the continuous monitoring locations. Bush River: 1. XJG7035 Otter Point Creek, 2. XJG7461 Church Point, 3. XJG4337 Lauderick Creek; Gunpowder River: 4. XJG2718 APG @ Edgewood, 5. XJF4289 Mariners Point Park; Middle River: 6. MDR0038 Cutter Marina, 7. FRG0002 Strawberry Point. Red squares show water quality mapping calibration stations. Bush River: **8. WT1.1**., 9. XJG1149,10. XJG2340, 11. XJG4451, 12. XJG6745, 13. XJG7856; Gunpowder River: **14. WT2.1**, 15. XIG8710, 16. XJF0588, 17. XJF0821, 18. XJF2675, 19. XJG0006, 20. XJG3207; Middle River: 21. MDR0002, 22. FRG0018, 23. HOK0005, 24. MDR0028, 25. NOM0007, **26. WT3.1**. Stations listed in **bold** are also long-term monitoring program stations. Only two sites on the Bush River (Church Point and Otter Point Creek) were operating during 2010.

With cooperative funding from Harford County and NOAA's National Estuarine Research Reserve System (NERRS) Program, the Church Point and Otter Point Creek continuous monitoring stations in the Bush River remained deployed beyond the conclusion of the three-year assessment. Also, the monitor at Lauderick Creek was moved to Church Point in 2008 in order to expand continuous monitoring coverage of the Bush River watershed. Only two sites on the Bush River (Church Point and Otter Point Creek) were operating during 2010.

Current Conditions

Bush River

In 2010, the Bush River continuous monitoring sites were located at similar distances from the mouth of the river and exhibited similar variability in water quality (Figures 21-22). Water temperature at both Church Point and Otter Point Creek rose predictably as air temperatures increased during the summer months and peaked in August. Salinity levels for both sites increased during the late summer and early fall, before dropping off in late September following the influx of fresh water from the remnants of Tropical Storm Nicole. Church Point salinity levels peaked at 3.4 ppt and Otter Point Creek levels peaked at 2.6 ppt.

Church Point and Otter Point Creek displayed similar variability in pH levels. Both sites displayed a dip in pH in early April 2010, following the second wettest March on record at BWI Marshall Airport. Another dip in mid-July coincided with a heavy rain event across Maryland. Of note, pH at both sites dropped dramatically in late September following an influx of fresh water into the system from heavy rain and a discharge event associated with the remnants of Tropical Storm Nicole.

In general, dissolved oxygen levels at both stations were concentrated around 6-13 mg/l during the summer months. The highest dissolved oxygen concentration measured at Church Point was 19.27 mg/l on July 6th, and the lowest was 1.84 mg/l on August 12th. At Otter Point Creek, dissolved oxygen concentrations reached a high of 18.27 mg/l on August 28th and a low of 1.60 mg/l on July 11th. Both sites experienced relatively few days of dissolved oxygen concentrations below 5 mg/l, a threshold below which detrimental effects on living resources may occur.

Algal blooms in waterways are identified by measuring chlorophyll concentrations. A drop in chlorophyll levels may indicate the die-off of an algal bloom and the onset of decomposition of algal biomass. The decomposition process can consume significant amounts of dissolved oxygen in the water and can lead to conditions harmful to aquatic organisms. For example, decreases in dissolved oxygen levels at Church Point to 4.76 mg/l on June 30th, 3.95 mg/l on July 11th, 4.36 mg/l on September 3rd, and 3.31mg/l on September 13th coincided with drops in chlorophyll levels. Decreases in dissolved oxygen levels at Otter Point Creek to 1.60 mg/l on July 11th and 5.50 mg/l on October 3rd also coincided with drops in chlorophyll levels.

Very few chlorophyll readings were greater than 50 µg/l (levels that are indicative of significant algal blooms) or 100µg/l (levels indicative of severe blooms). At Church Point, chlorophyll levels briefly spiked above 100 µg/l in mid-May and again in early November. During the remainder of the year, chlorophyll readings were greater than 50 µg/l in mid- to late April, mid-August, late September, and mid-October. At Otter Point Creek, chlorophyll levels briefly spiked above 50 µg/l several times throughout the year, but never went above 65 µg/l.

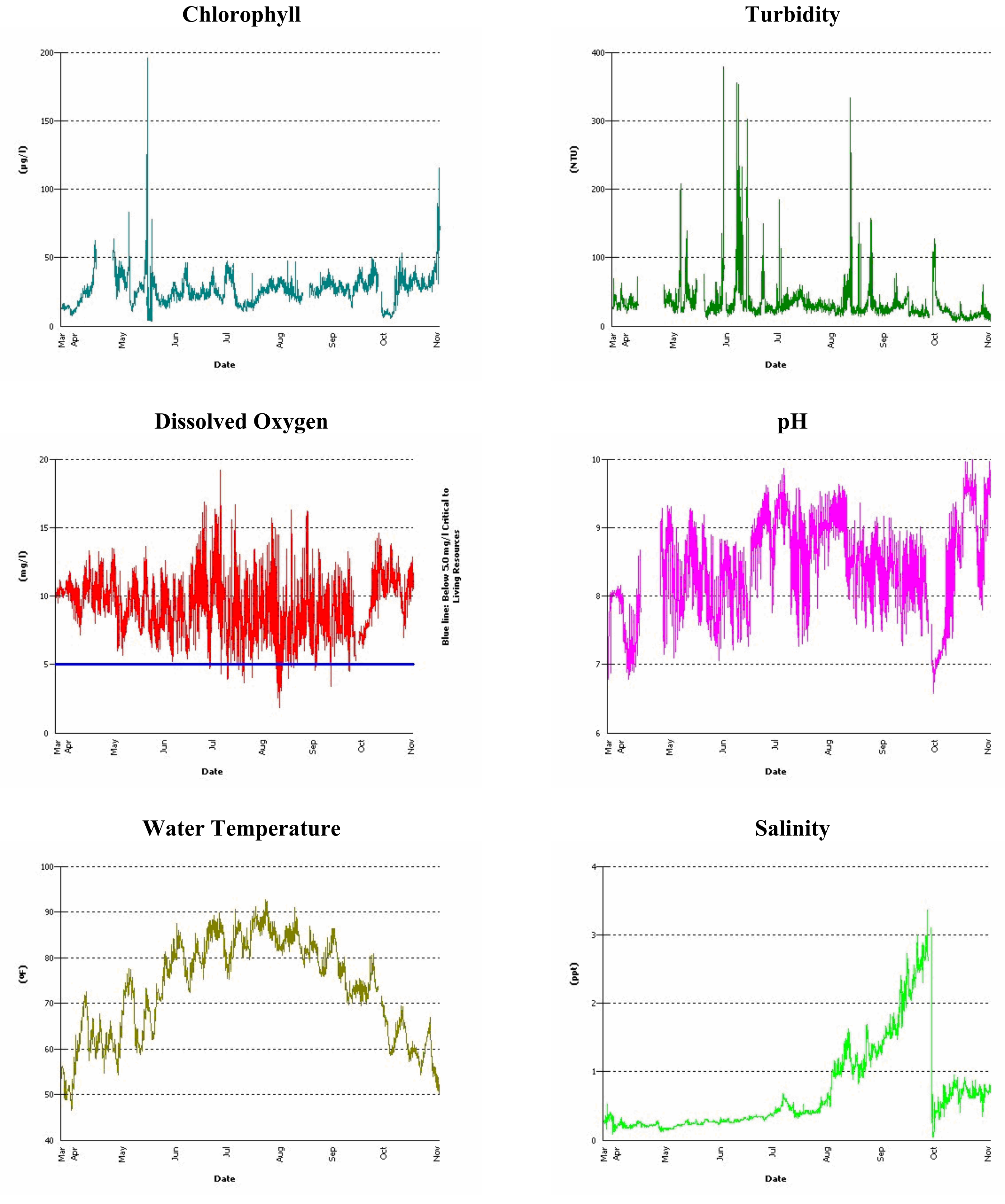

Figure 21. Continuous monitoring results at Church Point, Bush River in 2010.

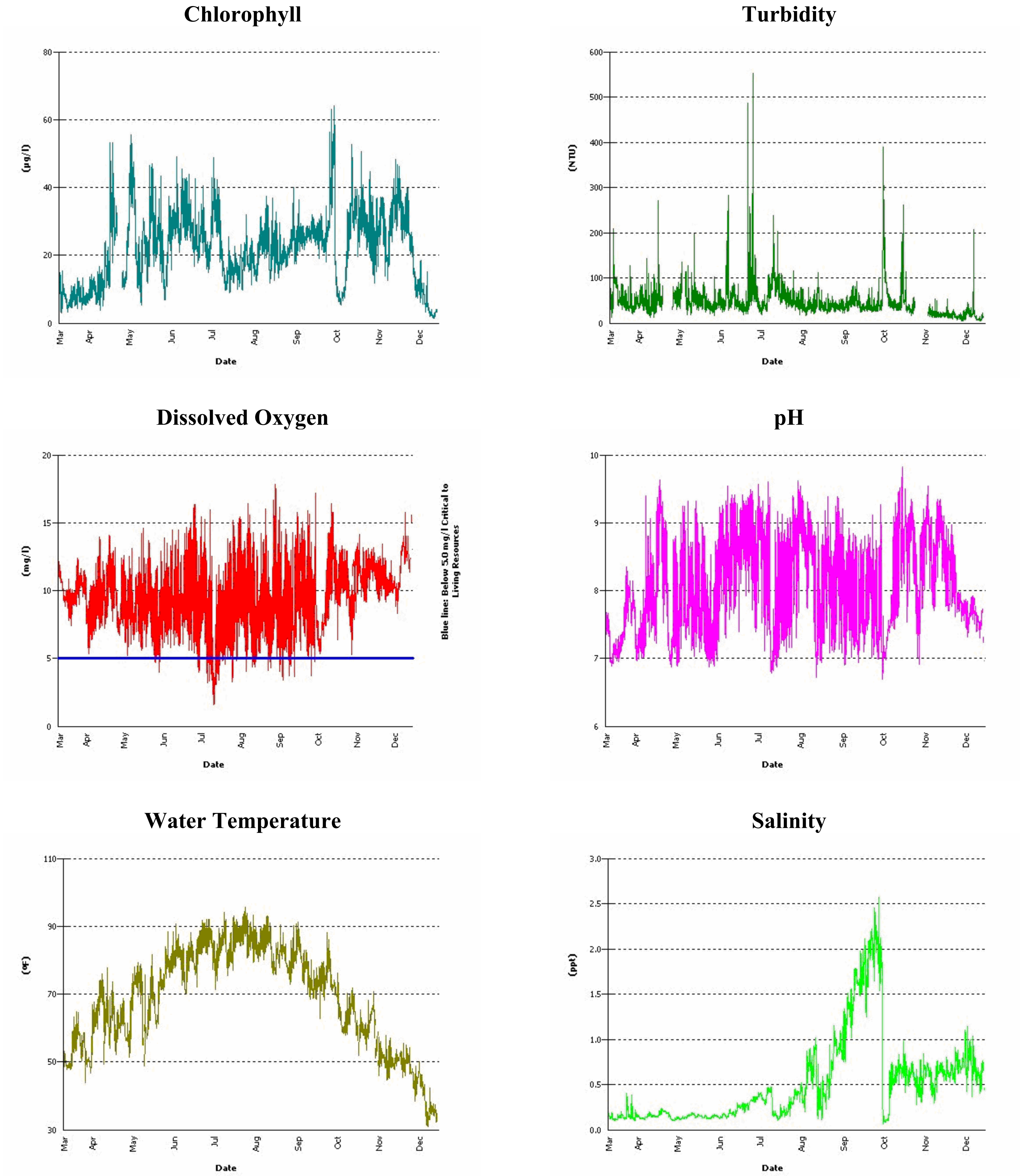

Figure 22. Continuous monitoring results at Otter Point Creek, Bush River in 2010.

Both continuous monitoring sites on the Bush River experienced spikes and declines in turbidity levels that followed weather patterns and chlorophyll levels. Also, some heavy rain events caused sanitary sewer overflows in the watershed that contributed to high turbidity readings. Turbidity levels at Church Point spiked above 200 NTU in early May and to almost 400 NTU in early June, which coincided with chlorophyll levels greater than 80µg/l and 40µg/l, respectively. A spike above 300 NTU occurred in mid-August during a storm event that impacted northeast Maryland, and another above 100 NTU occurred in early October following Tropical Storm Nicole and the associated sanitary sewer overflows in the watershed. At Otter Point Creek, elevated chlorophyll levels above 50 µg/l also coincided with turbidity levels above 150 NTU in early May. Turbidity levels also spiked to 254 NTU in mid-July following a sanitary sewer overflow and heavy rain in the watershed, and above 380 NTU on September 30th during the heavy rain event associated with Tropical Storm Nicole.

Continuous monitoring chlorophyll data are calculated from measured fluorescence values. Blue-green algal species fluoresce outside of the range of the standard chlorophyll probe deployed with the monitoring instrument. As the result, this method does not adequately describe the abundance of blue-green algae in the water column. Blue-green algae are of interest because of their potential toxicity and potential association with other toxic phytoplankton. As a calibration exercise, chlorophyll concentrations measured in the laboratory were compared to the *in situ* data collected by the monitoring sondes at all continuous monitoring stations in 2010.

Almost all stations had a good match between laboratory and sonde chlorophyll values. Church Point and Otter Point Creek on the Bush River were exceptions (Figure 23). At these stations the chlorophyll laboratory values are noticeably greater than the sonde measurements for chlorophyll, with the difference possibly due to the presence of blue-green algae.

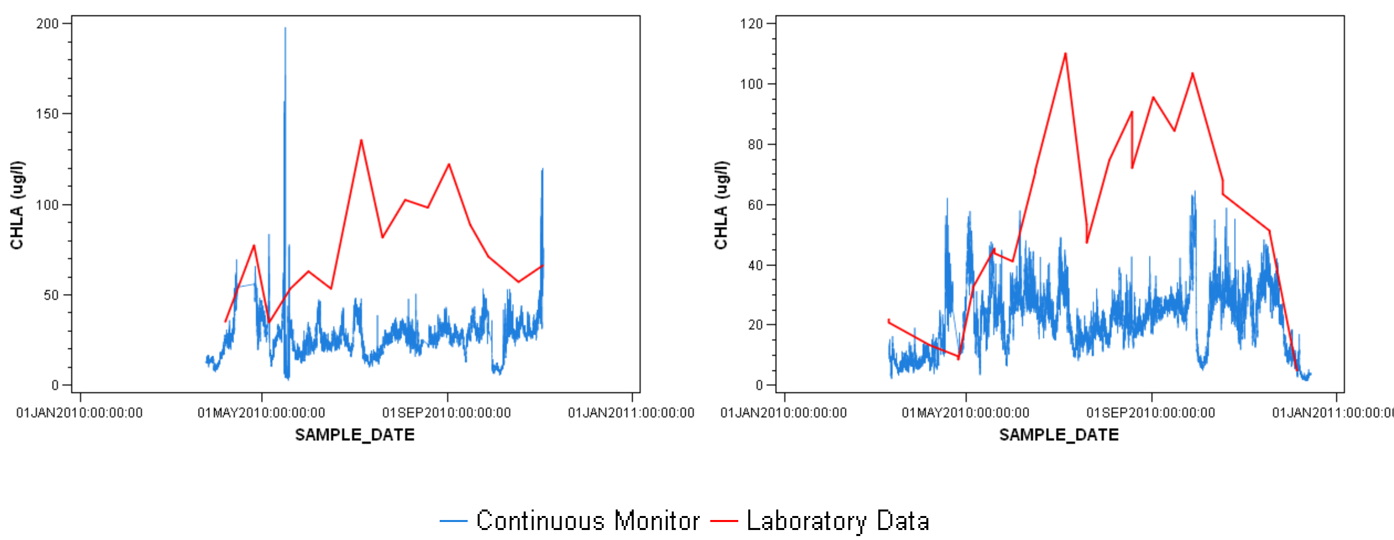

Figure 23. Comparison of *in situ* continuous monitoring data and laboratory data for chlorophyll in the Bush River during 2010.
Data for Church Point (left panel) compared to data from Otter Point Creek (right panel). Note that the scale of the y-axes differ.

Temporal and Spatial conditions

Water and habitat quality in the shallow water was evaluated in two ways. The first was a temporal assessment. High temporal frequency data from the continuous monitoring program were used to determine how often water quality met conditions needed for healthy habitats. Percent failures are defined as the percent of values in each year that did not meet the water quality thresholds (see Appendix 4 for methods). Data for the years 2003-2010 were used. Chlorophyll and turbidity measurements collected during the SAV growing season (April through October) and summer dissolved oxygen values (June through September) were included in the analysis. The percent failures for all stations are shown in Appendix 9.

The second method was a spatial assessment. The nutrient data collected at continuous monitoring and water quality mapping calibration stations for April-October were compared to the SAV habitat requirements (Appendix 9). Water quality and habitat conditions were also compared between the shallow water stations and the long-term station.

Bush River

In general, less than 1% of dissolved oxygen readings in the Bush River dropped below 3.2 mg/l (Appendix 9). At Otter Point Creek, however, 7% and 5% of measurements failed the 3.2 mg/l threshold in 2004 and 2005, respectively. For chlorophyll, Otter Point Creek had approximately half of the monitoring years yield percent failures of less than 40% for the 15 µg/l threshold. By comparison, Lauderick Creek had a chlorophyll failure rate of less than 40% for nearly all years, while Church point consistently had failure rates well above 40%. Turbidity exceedences in the Bush River were very common, with all stations recording over 95% of measurements above the 7 NTU turbidity threshold during most years.

Continuous monitoring and water quality mapping calibration data were collected at three locations in 2008-2010. At Otter Point Creek, only PO_4 levels met the SAV habitat requirements (Table 3). At Church Point and the long-term station, PO_4 levels in all three years and DIN levels in 2008 and 2010 met the requirement. TSS levels were significantly higher in the shallow water but PO_4 levels were significantly higher at the long-term station.[29] In the shallow water, DIN levels were higher at Otter Point Creek.[30]

Water quality mapping calibration data was collected at six locations (including the two continuous monitoring stations) in the Bush River in 2003-2005.[31] All locations met the SAV habitat requirement for PO_4 and all but Lauderick Creek failed to meet the DIN threshold (Appendix 9). Only one station (XJG2340) met the TSS habitat requirement in two of the three years. CHLA levels at the long-term station (WT1.1) and one other station (XJG4451) failed to meet the SAV habitat goal in two of the three years.

CHLA and PO_4 levels at the long-term station were significantly lower than at Lauderick Creek and XJG2340 while Secchi depth was significantly higher at XJG2340 than the other stations.[32]

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[29] Bush River TP levels were significantly higher at Church Point.
[30] Bush River TN levels were significantly higher in the shallow water.
[31] Only the Otter Point Creek station was monitored in both 2003-2005 and 2008-2010.
[32] TN at the long-term station was higher than at Lauderick Creek, XJG4451 and XJ2340. TP was significantly higher at XJG7856 than the long-term station and XJG2340.

DIN levels were significantly higher at XJG7856 than at Lauderick Creek. TSS levels were similar throughout the shallow waters.

Table 3. Shallow water monitoring data compared to SAV habitat requirements in the Bush River for 2008-2010.
All calibration data for a station (water quality mapping and continuous monitoring) were used to calculate a monthly median. Monthly medians for April-October were used to calculate the SAV growing season median, which was compared to habitat requirements (Appendix 5). Note that the long-term stations include data from long-term and water quality mapping calibration sampling.

Station		year	Chla mg/l		TSS mg/l		DIN mg/l		PO4 mg/l		DO mg/l	
XJG7461	Church Point	2008	45.9	FAIL	34.0	FAIL	0.035	MEET	0.0037	MEET	8.5	MEET
		2009	28.3	FAIL	37.0	FAIL	0.095	FAIL	0.0032	MEET	7.5	MEET
		2010	74.3	FAIL	36.0	FAIL	0.045	MEET	0.0033	MEET	7.7	MEET
XJG7035	Otter Point Creek	2008	27.7	FAIL	28.6	FAIL	0.317	FAIL	0.0038	MEET	8.1	MEET
		2009	32.8	FAIL	39.0	FAIL	0.492	FAIL	0.0036	MEET	8.0	MEET
		2010	68.1	FAIL	48.4	FAIL	0.304	FAIL	0.0038	MEET	8.2	MEET
WT1.1	Long-term	2008	36.9	FAIL	31.0	FAIL	0.029	MEET	0.0042	MEET	9.6	MEET
		2009	33.1	FAIL	27.0	FAIL	0.086	FAIL	0.0041	MEET	8.1	MEET
		2010	61.4	FAIL	22.0	FAIL	0.027	MEET	0.0046	MEET	9.4	MEET

Gunpowder River

Continuous monitoring data was collected at two locations in the Gunpowder River in 2003-2005. Among the three river systems in the Upper Western Shore basin, the Gunpowder River showed the least percent failures of the water quality thresholds (Table 3). In the Gunpowder River, dissolved oxygen almost never dropped below 3.2 mg/l throughout all three years. Furthermore, less than 20% of the chlorophyll measurements were above 15 µg/l in the Gunpowder River. However, turbidity values above the 7 NTU threshold were more common, with over 40% of readings in the Gunpowder failing the turbidity threshold in all three years.

Water quality mapping calibration data was collected at six locations (including the two continuous monitoring stations) in 2003-2005. All locations met the SAV habitat requirement for PO_4 and failed to meet the DIN threshold. All but one station (XJF2675) met the CHLA and TSS habitat requirements at least two of the three years. There were no differences in TSS or PO_4 levels between the stations, but one station (XJF0588) had significantly higher CHLA levels than the long-term station (ET2.1). DIN levels at this station were significantly lower than the two stations (XJF4289 and ET2.1). The other stations were not different from the long-term station or each other for CHLA or DIN.[33] For 2008-2010, the long-term station met all of the habitat requirements except DIN.

[33] TN and TP levels in the Gunpowder River were also not different.

Middle River
Continuous monitoring data was collected at two locations in the Middle River in 2003-2005. Middle River had only slightly more measurements fail the water quality thresholds than the Gunpowder River (Table 3). Percent failures for dissolved oxygen less than 3.2 mg/l ranged from 0% to less than 1%. In the Middle River during all three years, 15%-54% of chlorophyll values exceeded the 15 µg/l chlorophyll threshold, and more than 40% of turbidity values exceeded the 7 NTU turbidity threshold.

Water quality mapping calibration data was collected at six locations (including the two continuous monitoring stations) in 2003-2005. All locations met the SAV habitat requirement for PO_4 and all stations met the TSS habitat requirement at least two of the three years. Only Strawberry Point met the habitat requirement for DIN in all three years. The long-term station and Cutter Marine station met the habitat requirement for CHLA. There was no difference in CHLA, TSS or DIN levels between the stations.[34] PO_4 levels at Cutter Marine were significantly higher than at Strawberry Point, and Secchi depth was significantly higher at Cutter Marine and the long-term station than at the other stations. In 2010, the long-term station met all of the habitat requirements.

Health of Key Plants and Animals

Phytoplankton

Phytoplankton (generally algae) are the primary producers in the Chesapeake Bay and rivers and the base of the food chain. High algal density (algal blooms) can degrade habitat quality. Blooms of certain species of phytoplankton (harmful algae) can also degrade habitat quality. . Routine samples collected in the long-term tidal and shallow water monitoring programs estimate the abundance of algae but can not determine the health of the population overall or distinguish between good and harmful algae. Additional samples are taken at some locations to determine what algal species are present and in what densities. When a bloom occurs, samples are taken to test for the presence and levels of toxins, which can be released by some types of harmful algae. Fortunately, of the more than 700 species of algae in Chesapeake Bay, less than 2% of them are believed to have the ability to produce toxic substances.[35]

Blue-green algae are generally smaller cells and not as nutritious and edible to small animals (zooplankton). Blooms of blue-green algae look like blue-green paint floating at or near the water surface (Figure 24). Blue-green algae can only live in low salinity waters. Some species of blue-green algae (*Microcystis* and *Anabaena*) can produce a toxin that is released into the water. Contact with or ingestion of water containing high toxin levels can cause human health impacts (skin irritation, gastrointestinal discomfort), and can be harmful or even fatal to livestock and pets.

Blooms of some species of dinoflagellates are known as ‘mahogany tides’ because the color of the algae and the density of algae in the bloom make the water appear brown or reddish-brown (Figure 22). These conditions are most often caused by blooms of *Prorocentrum minimum*. While *Prorocentrum* frequently blooms in the spring, blooms have been observed in Maryland

[34] TN and TP levels in the Gunpowder River were also not different
[35] Information on Harmful Algal Blooms is available at http://mddnr.chesapeakebay.net/eyesonthebay/habs.cfm

waters in all seasons. These algae do not produce a toxin, but the magnitude of the bloom can harm fish and shellfish by replacing more nutritious algae, depleting oxygen in the water column or clogging gills. The darkened waters can also reduce the light reaching underwater grasses.

Other harmful algal species can lead to fish kills. *Karlodinium venificum* can release a toxin that harms fish, and densities above 20,000 cells/milliliter can be acutely toxic to fish. Extremely low dissolved oxygen is often the result of the abrupt die off of a bloom, when the process of decomposing the large amount of plant material uses up the oxygen in the water. The combination of the toxin and low dissolved oxygen can lead to fish kills.

Figure 24. Harmful algal blooms.
Left panel: Blue-green algae bloom. Right panel: 'Mahogany tide' bloom.

Blooms of blue-green algae are a recurring issue in the Upper Western Shore rivers. These rivers usually have low salinities, which are suitable habitat for blue-green algae. Toxin levels associated with blooms in the Bush River have exceeded the World Health Organization drinking water quality guidelines (1 µg/l) for human health safety from long term, chronic toxin exposure.

Other harmful algal species, including *Pfiesteria piscicida*, have occurred in Middle and Gunpowder rivers. The toxin produced by *Pfiesteria piscicida* can have human health impacts, and is known to be harmful to fish. *Heterosigma akashiwo* also produces a toxin that can be harmful to fish. This species was first identified in the Chesapeake Bay system in Middle River in 2002, but this species has not caused any known fish or human health impacts in Maryland waters.

Underwater grasses

Water quality determines the distribution and abundance of underwater grasses (submerged aquatic vegetation, SAV). For this reason, SAV communities are good barometers of the health of the tidal rivers and bays. SAV is also a critical nursery habitat for many bay animals. Similarly, several species of waterfowl are dependant on SAV as food when they over-winter in the Chesapeake region. SAV distribution is determined through the compilation of aerial photography directed by the Virginia Institute of Marine Science (VIMS).[36]

Bush River

The Bush River has only supported SAV periodically, though there was a phenomenal expansion of SAV in 2000 (Figure 25). Acreage expanded again in 2004 to 1,024 acres, or 293% of its 350 acre SAV restoration goal. SAV declined to 725 acres in 2005, and in 2006, declined again to 321 acres, or 92% of the restoration goal. The goal was exceeded again in 2008 and 2009, with 519.13 and 381.29 acres of SAV, respectively. In 2010, SAV acreage fell to 236.11 acres, only 67% of the restoration goal (Figure 26).

Gunpowder River

The Gunpowder River had generally low abundance of SAV until 1996. In 2000, the SAV coverage reached 2,424 acres, or 99% of the 2,432 acre SAV restoration goal. Although acreage fluctuated between 2000 and 2005, SAV coverage was down to 35% of its goal at 839 acres in 2006. The past three years failed to meet the restoration goal at any time, but SAV coverage increased substantially since 2006. In 2008, 1,719.30 acres of SAV were identified. That total increased to 1,887.67 acres in 2009, but in 2010, SAV coverage fell to 1,730 acres, which only represents 71% of the restoration goal.

Middle River

The Middle River has a restoration goal of 879 acres, but has had variable SAV coverage over the years. In 2000, 740 acres were mapped by the VIMS aerial surveys, or 84% of the SAV restoration goal. 2002 and 2003 showed declines in coverage (629 and 391 acres, respectively), but SAV acreage rebounded in 2004 to 670 acres. SAV declined again to 454 acres in 2005, and continued to fall to 229 acres in 2006. Phenomenally, in 2008, 94% of the restoration goal was met with an SAV expansion of 826.68 identified. That SAV coverage fell to 780.35 acres in 2009, and again to 658.28 acres in 2010. 2010 SAV acreage represents only 75% of the restoration goal.

[36] Reports detailing methodology and annual SAV coverage are available at www.vims.edu/bio/sav . Details on species of SAV discussed in this report can be found at www.dnr.maryland.gov/bay/sav/key

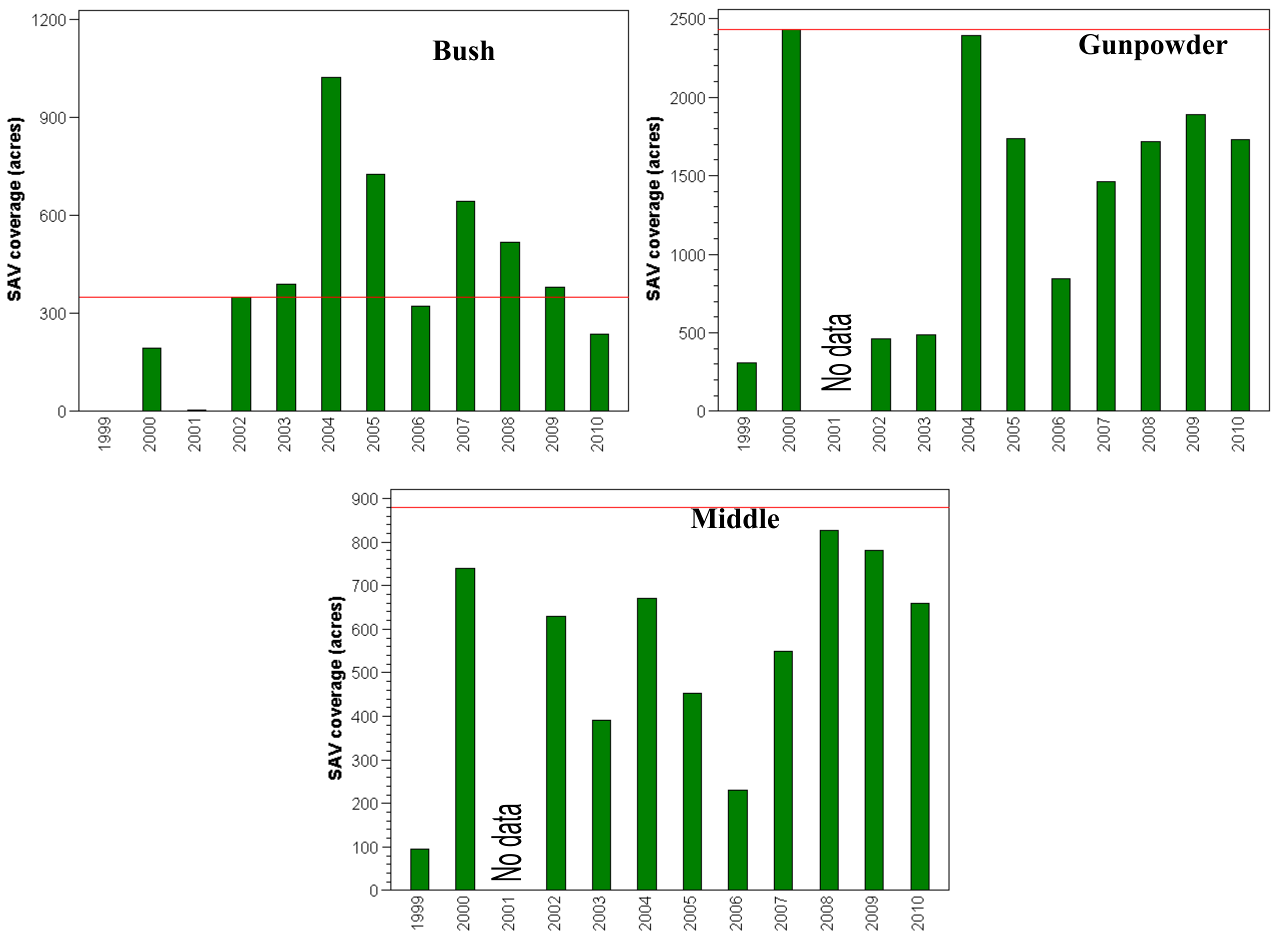

Figure 25. SAV coverages in the Middle, Gunpowder and Bush Rivers 1999-2010.
SAV data provided by the Virginia Institute of Marine Science. Red line shows the restoration goal for each river.

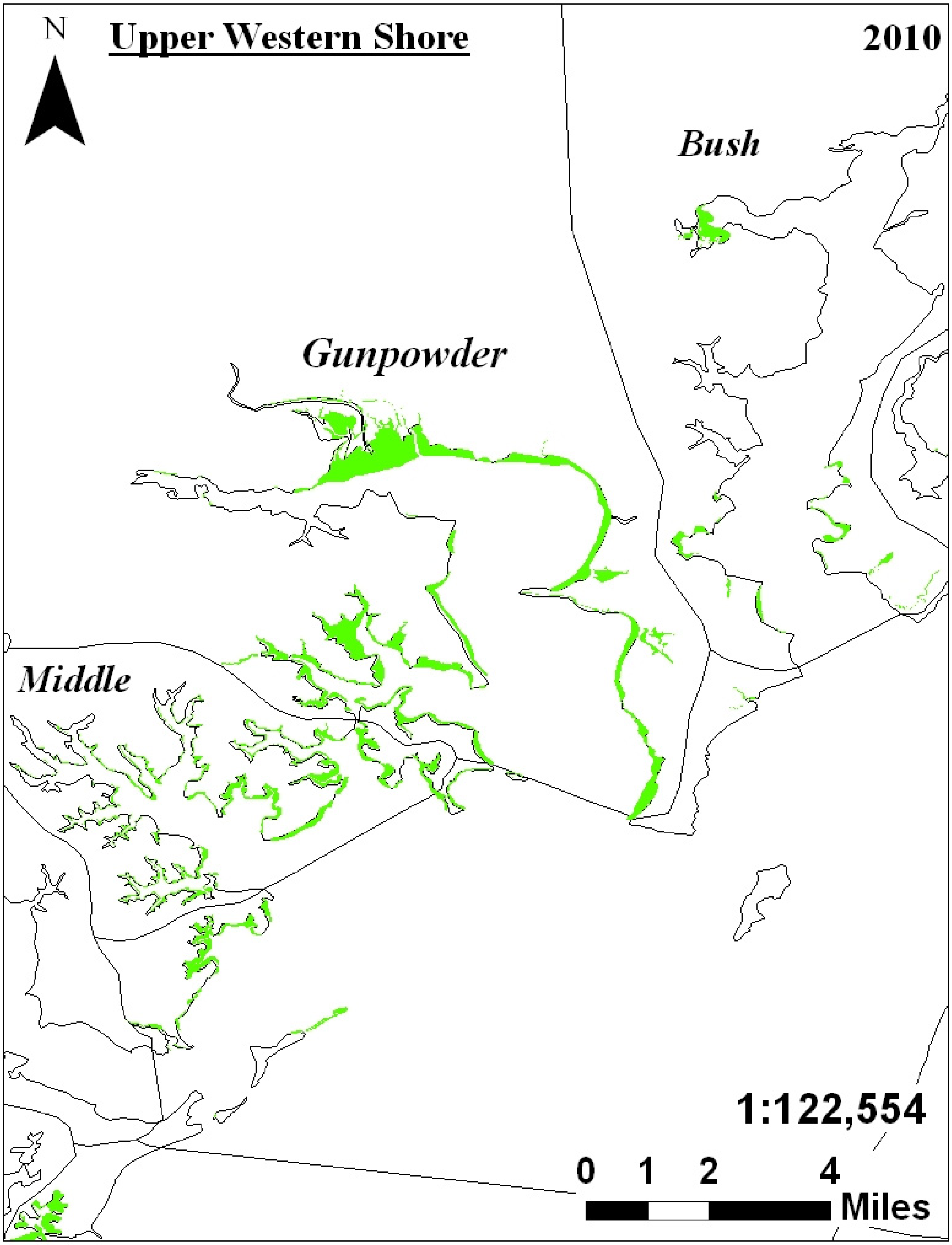

Figure 26. SAV beds (in green) in the Middle, Gunpowder and Bush Rivers in 2010. SAV data provided by the Virginia Institute of Marine Science.

Benthic animals

Benthic animals are the animals that live in or on the bottom of the bay. To determine the health of benthic animal communities, starting in 1994 samples were collected from all of the rivers and mainstem Bay each year from randomly selected locations. Within the smaller western shore rivers (excludes the Patuxent and Potomac), there are not a fixed number of samples each year in any particular river and each river is not sampled in every year. Larger rivers end up with more samples collected over time. The benthic index of biotic integrity (BIBI) assesses the health of the benthic community.[37] A BIBI score of greater than 3 is considered meeting the goal for benthic community health.

In 2008-2010, 22 samples were randomly collected in the Upper Western Shore basin (Figure 27). Degraded conditions were found at 36% of sites in the Bush River (4 of 11 sampled) and 20% in the Gunpowder River (2 of 10 sampled). Middle River was only sampled once during this period, in 2009, and met goals. The results indicated that 10% of the total benthic habitat was degraded in 2008 and 25% was degraded in 2009.[38] Benthic community health in the rivers results from the combined effects of low dissolved oxygen, high nutrient loadings and sediment contamination with toxic chemicals (in some locations). The Upper Western Shore rivers are less impacted by low dissolved oxygen levels than the rest of the western shore rivers, and benthic community health is much better as the result.

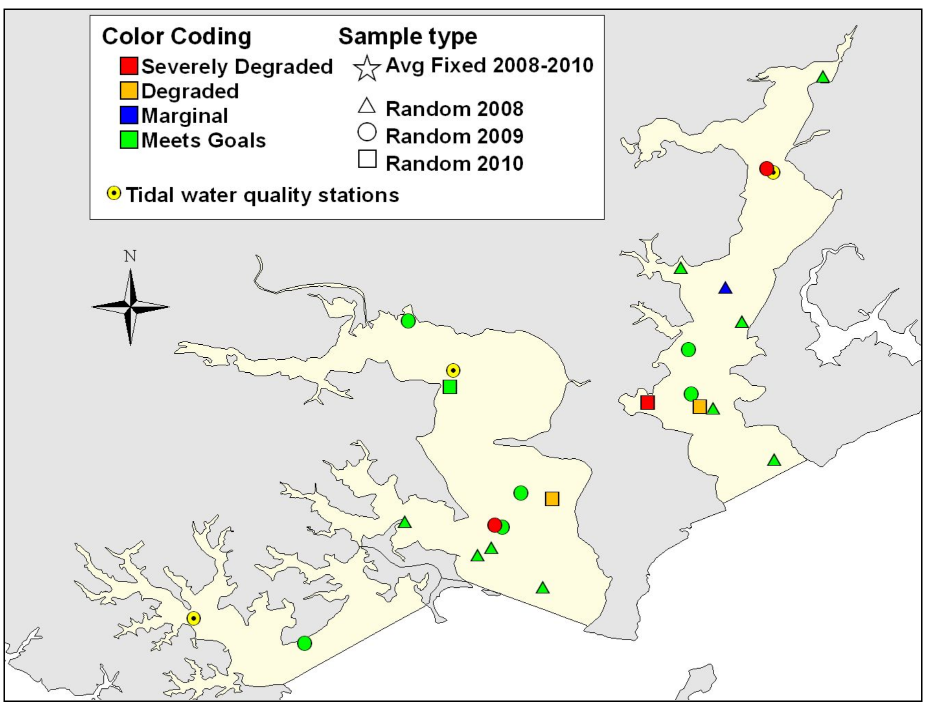

Figure 27. Benthic Index of Biotic Integrity results.
Random samples were collected in 22 locations in 2008-2010. Yellow circles show locations of long-term tidal water quality monitoring stations. A BIBI score of 3 or greater Meets Goals. BIBI scores of 2.7-2.9 are Marginal, 2.1-2.6 are Degraded and less than 2.1 are Severely Degraded.

[37] Methods for calculation of the BIBI are available at http://www.baybenthos.versar.com/DsgnMeth/Analysis.htm#BIBI.
[38] Percent degraded habitat for 2010 was estimated to be 75%, but only 4 samples were collected. Annual reports for 2008, 2009 and 2010 are available online at http://www.baybenthos.versar.com/referenc.htm.

Summary of Water Quality and Habitat Conditions

Information on current water and habitat quality and the changes through time is needed to assess the health of a river. Many types of information are needed to most completely understand the current conditions. In some instances the assessment is straight forward and all of the information indicates both good water quality and healthy habitats. Most often, some aspects of the overall picture indicate good conditions and other aspects indicate poor conditions. The summary presented here is intended to best represent an overall condition. This is a simplified version and can not capture all the detail presented in the previous sections of this report. Informing the public about the overall health of a river is often best done with a summary of all of the data. Management decisions can benefit from both the summarized and the detailed information.

The Upper Western Shore basin can be divided into three regions. The upper region drains to the Susquehanna. The central region drains to the Bush River. The lower region drains to the Gunpowder and Middle Rivers. Differences in land use, percent impervious surfaces and human population density contribute to variable water and habitat quality conditions in the three major rivers (the Susquehanna is not included in the assessments due to the overwhelming influence of the portions of the watershed that are in Pennsylvania and New York). These differences also lead to different management needs and strategies for each region.

Upper Region

Of the five sub-watersheds in the Upper region, one is high priority and two are moderate priority for restoration efforts through Maryland's Trust Fund Program. Stream health in this region is good, and human population density is moderate. Land use is roughly equally divided amounts urban, forest and agricultural uses. Urban land use increased by 7% from 2000 to 2010, and 7% of the area was covered with impervious surfaces. A WRAS project is underway for the Deer Creek sub-watershed. Non-tidal water quality has improved with decreases in phosphorus (P), but also worsened with increased nitrogen (N) and sediments (S).

Central Region

Five of the six sub-watersheds in the central region are moderate priority for restoration efforts through Maryland's Trust Fund Program. Stream health is poor and human population density is moderate to high. Urban land uses comprise approximately half of the basin, and urban land use has increased by 11% since 2000. Impervious surfaces cover 12% of this region. A WRAS project is underway for the Bush River.

In the central region, point sources are the most important contributor of nitrogen and phosphorus. Biological nitrogen removal (BNR) was implemented at the largest wastewater treatment plant (WWTP) but enhanced nutrient removal (ENR) will not be in place until 2014. BNR improvements reduced N loads by half, but N loads have been slowly increasing since 2002 and are still above the loadings cap. Phosphorus loads are variable and above the cap. The largest sources of sediments to the region are urban runoff and agricultural land uses.

There is no water quality monitoring in non-tidal streams of the central region. Tidal water monitoring in the Bush River found improvements in water quality due to reductions in N in the early period (prior to 1997) but not in later years. N levels are low enough for nitrogen limitation of algal growth in the summer. Monitoring data also show worsening water quality due to increases in P, but habitat requirements for submerged aquatic vegetation (SAV) are met for P though not for S. Habitat quality for SAV is also impaired due to worsening algal densities and poor water clarity. In addition, harmful algal blooms occur in most years. Bottom dissolved oxygen levels are good and habitat quality for benthos is good.

Shallow water monitoring in Church Point Creek and Otter Point Creek indicates turbidity failed to meet good habitat quality requirements more than 60% of the time and failed more than 95% of the time in most years. Chlorophyll levels at Otter Point Creek failed to meet criteria 80% of the time in 2010, and more than 50% of the time in 2008 and 2009. Blue-green algae, an important component of the algal population, are not measured with the instrument methods and laboratory samples indicate this could be a substantial portion on the algal population. Summer dissolved oxygen levels in the shallow waters were above 3.2 mg/l criteria 99% of the time. TSS levels were significantly higher in the shallow water but PO_4 levels were significantly higher at the long-term station. DIN levels were higher at Otter Point Creek and only PO_4 levels met the SAV habitat requirements. At Church Point and the long-term station, PO_4 levels in all three years and DIN levels in 2008 and 2010 met the requirements.

SAV populations fluctuated over the years, with grass beds covering as much as 92% of restoration goals in 2006, but only 67% in 2010. Monitoring of benthic populations, though limited in the Bush, has found impaired populations in the upper river (near the long-term tidal water quality station) but healthy populations from mid-river to the mouth.

Lower Region

Three of the six sub-watersheds in the lower region are high priority Trust Fund Restoration watersheds. Stream health in this region is fair to poor. Human population density is moderate to high with some very high density areas on the outskirts of Baltimore City. Land use is roughly one-third agriculture, forest and urban. Urban land uses have increased 11% since 2000 and 7% of the region is covered with impervious surfaces. A WRAS project is underway for the Prettyboy Reservoir sub-watershed.

Gunpowder River

Agriculture is the largest source of N and S loads to the Gunpowder River. Urban runoff is the largest source of P loads; point sources are also a source for P but not N. P loads decreased after BNR was implemented at the largest WWTP in 1997, and ENR is expected to be operational by 2012.

Monitoring of non-tidal streams in the Lower region indicates worsening water quality due to increasing N levels in the upper and middle watershed streams, but improving water quality and decreasing N levels in the lowest stream site. Water quality has also improved with decreased P levels. Sediment levels in the water have improved, but sediment loadings are increasing.

Tidal water quality monitoring in the Gunpowder indicates good N levels and nitrogen limitation of algal growth is possible in the summer. Water quality is degrading due to worsening P levels. Habitat quality for SAV is impaired due to high sediment and algal population levels and poor water clarity. In addition, harmful algal blooms occur in some years. Summer bottom dissolved oxygen levels are good and habitat quality is good for benthic populations. Shallow water monitoring in 2003-2005 also found that turbidity failed to meet good water quality criteria, while algal densities and dissolved oxygen levels were good. SAV population coverages in 2000 were 99% of the restoration goal but were only 71% of the goal in 2010. Benthic populations are healthy throughout the Gunpowder River.

Middle River
Point sources are the largest source of N and P loads to Middle River, though there are no major WWTP that discharge to the river. Septic sources of N are also important. Urban runoff is the largest source of S loads.

Monitoring of the tidal waters indicates improving water quality due to reductions in N levels, and N levels are low enough to limit algal growth in the summer. Water quality is degrading due to increasing P levels, but P levels still meet SAV habitat requirements. S levels are good.

Habitat quality for SAV has improved due to lower algal populations and improved water clarity in the early period (1985-1997), but habitat quality is worsening in the recent period due to decreasing water clarity. In addition, harmful algal blooms occur in some years. Good summer bottom dissolved oxygen levels create good habitat quality for benthic populations. Shallow water monitoring in 2003-2005 found that turbidity failed to meet good water quality criteria, while dissolved oxygen levels were good.

SAV populations were largest in 2008 when 94% of the restoration goal was reached, but only 75% of the goal was reached in 2010. There is not enough information to evaluate benthic population health, but with good bottom dissolved oxygen levels benthic populations are expected to be healthy.

Appendix 1

Land use/Land cover for 2000 and 2010 and Amount of Impervious Surface

Land-use/Land-cover 2000 and 2010 from the Maryland Department of Planning. 2010 data is available at www.planning.maryland.gov/OurWork/landUse.shtml. 2000 data is available from Maryland Department of Planning, Planning Data Services, (410) 767-4450. Use codes are from the Maryland Department of Planning Land Use/ Land Cover Classification Definitions (http://www.planning.maryland.gov/PDF/OurWork/LandUse/AppendixA_LandUseCategories.pdf). Impervious surface calculated from definitions in Cappiella and Brown, Urban Cover and Land Use in the Chesapeake Bay watershed, Center for Watershed Protection, 2001, as referenced in Table 4.1 of a User's Guide to Watershed Planning in Maryland http://dnr.maryland.gov/watersheds/pubs/userguide.html

Sub-watershed	Land use/ Land cover	Area in 2000 (sqr miles)	%Total in 2000	Area in 2010 (sqr miles)	%Total in 2010	Area Change (sqr miles)	%Total Area change
L Susquehanna River	AGRICULTURE	8.69	**28%**	6.66	**21%**	2.03	7%
	BARREN LAND	0.03	0%	0.13	0%	-0.10	0%
	FOREST	13.32	**43%**	12.35	**40%**	0.97	3%
	TRANSPORTATION	0.00	0%	0.37	1%	-0.37	-1%
	URBAN	9.08	**29%**	11.64	**37%**	-2.56	-8%
	WETLANDS	0.05	0%	0.05	0%	0.00	0%
	IMPERVIOUS SURFA(	2.40	8%	2.98	10%	-0.58	-2%
Deer Creek	AGRICULTURE	81.05	**56%**	65.24	**45%**	15.81	**11%**
	BARREN LAND	0.17	0%	0.22	0%	-0.05	0%
	FOREST	46.46	**32%**	41.51	**28%**	4.96	3%
	TRANSPORTATION	0.02	0%	0.04	0%	-0.03	0%
	URBAN	18.30	13%	39.01	**27%**	-20.71	**-14%**
	WETLANDS	0.02	0%	0.02	0%	0.00	0%
	IMPERVIOUS SURFA(	3.24	2%	4.67	3%	-1.43	-1%
Octoraro Creek	AGRICULTURE	17.63	**51%**	13.35	**38%**	4.28	**12%**
	BARREN LAND	0.01	0%	0.01	0%	0.00	0%
	FOREST	10.73	**31%**	11.12	**32%**	-0.38	-1%
	TRANSPORTATION	0.00	0%	0.00	0%	0.00	0%
	URBAN	6.46	19%	10.31	**30%**	-3.85	**-11%**
	WETLANDS	0.01	0%	0.04	0%	-0.03	0%
	IMPERVIOUS SURFA(	1.30	4%	1.56	4%	-0.26	-1%
Conowingo Dam Susq R	AGRICULTURE	6.44	**35%**	5.04	**27%**	1.40	8%
	BARREN LAND	0.00	0%	0.06	0%	-0.06	0%
	FOREST	9.43	**51%**	8.97	**49%**	0.46	2%
	TRANSPORTATION	0.00	0%	0.00	0%	0.00	0%
	URBAN	2.52	14%	4.31	**23%**	-1.79	**-10%**
	WETLANDS	0.00	0%	0.00	0%	0.00	0%
	IMPERVIOUS SURFA(	0.48	3%	0.62	3%	-0.14	-1%
Broad Creek	AGRICULTURE	22.40	**55%**	17.99	**44%**	4.42	**11%**
	BARREN LAND	0.00	0%	0.04	0%	-0.04	0%
	TRANSPORTATION	0.00	0%	0.00	0%	0.00	0%
	FOREST	13.80	**34%**	11.72	**29%**	2.08	5%
	URBAN	4.60	11%	11.04	**27%**	-6.45	**-16%**
	WETLANDS	0.00	0%	0.00	0%	0.00	0%
	IMPERVIOUS SURFA(	0.82	2%	1.26	3%	-0.44	-1%
Lower Susquenahanna Total	AGRICULTURE	136.22	**50%**	108.29	**40%**	27.93	**10%**
	BARREN LAND	0.21	0%	0.46	0%	-0.25	0%
	FOREST	93.75	**35%**	85.67	**32%**	8.08	3%
	TRANSPORTATION	0.02	0%	0.42	0%	-0.40	0%
	URBAN	40.96	15%	76.31	**28%**	-35.35	**-13%**
	WETLANDS	0.08	0%	0.11	0%	-0.03	0%
	IMPERVIOUS SURFA(	8.25	3%	11.09	4%	-2.85	-1%

Sub-watershed	Land use/ Land cover	Area in 2000 (sqr miles)	%Total in 2000	Area in 2010 (sqr miles)	%Total in 2010	Area Change (sqr miles)	%Total Area change
Bush River	AGRICULTURE	11.50	20%	9.22	16%	2.28	4%
	BARREN LAND	0.18	0%	0.23	0%	-0.04	0%
	FOREST	27.26	**47%**	24.62	**42%**	2.64	5%
	TRANSPORTATION	0.00	0%	0.63	1%	-0.63	-1%
	URBAN	14.83	**26%**	19.08	**33%**	-4.24	-7%
	WETLANDS	4.21	7%	4.21	7%	0.01	0%
	IMPERVIOUS SURFA(	4.48	8%	5.73	10%	-1.25	-2%
Lower Winters Run	AGRICULTURE	2.14	16%	1.17	9%	0.98	7%
	BARREN LAND	0.00	0%	0.02	0%	-0.02	0%
	FOREST	5.34	**41%**	3.72	**28%**	1.62	**12%**
	TRANSPORTATION	0.00	0%	0.40	3%	-0.40	-3%
	URBAN	5.44	**41%**	7.63	**58%**	-2.19	**-17%**
	WETLANDS	0.26	2%	0.25	2%	0.01	0%
	IMPERVIOUS SURFA(	1.50	11%	2.18	17%	-0.68	-5%
Atkisson Reservoir	AGRICULTURE	18.01	**40%**	11.44	**25%**	6.58	**14%**
	BARREN LAND	0.04	0%	0.01	0%	0.03	0%
	FOREST	11.88	**26%**	9.61	**21%**	2.28	5%
	TRANSPORTATION	0.00	0%	0.16	0%	-0.16	0%
	URBAN	15.54	**34%**	24.26	**53%**	-8.72	**-19%**
	WETLANDS	0.04	0%	0.04	0%	0.00	0%
	IMPERVIOUS SURFA(	3.28	7%	4.37	10%	-1.09	-2%
Bynum Run	AGRICULTURE	5.19	**23%**	3.30	14%	1.89	8%
	BARREN LAND	0.06	0%	0.05	0%	0.01	0%
	FOREST	5.35	**23%**	3.81	17%	1.54	7%
	TRANSPORTATION	0.00	0%	0.08	0%	-0.08	0%
	URBAN	12.27	**54%**	15.62	**68%**	-3.35	**-15%**
	WETLANDS	0.00	0%	0.00	0%	0.00	0%
	IMPERVIOUS SURFA(	3.11	14%	3.80	17%	-0.69	-3%
Aberdeen Proving Ground	AGRICULTURE	0.36	1%	0.39	1%	-0.03	0%
	BARREN LAND	0.00	0%	0.00	0%	0.00	0%
	FOREST	13.28	**43%**	13.08	**42%**	0.20	1%
	TRANSPORTATION	0.00	0%	0.03	0%	-0.03	0%
	URBAN	12.50	**40%**	12.63	**41%**	-0.14	0%
	WETLANDS	4.98	16%	4.98	16%	0.01	0%
	IMPERVIOUS SURFA(	4.18	13%	4.25	14%	-0.08	0%
Swan Creek	AGRICULTURE	8.38	**33%**	6.68	**26%**	1.69	7%
	BARREN LAND	0.04	0%	0.00	0%	0.04	0%
	FOREST	8.60	**34%**	7.38	**29%**	1.22	5%
	TRANSPORTATION	0.00	0%	0.37	1%	-0.37	-1%
	URBAN	8.17	**32%**	10.75	**42%**	-2.58	**-10%**
	WETLANDS	0.16	1%	0.16	1%	0.00	0%
	IMPERVIOUS SURFA(	2.03	8%	2.97	12%	-0.93	-4%
Bush River Total	AGRICULTURE	45.59	**23%**	32.20	16%	13.39	7%
	BARREN LAND	0.32	0%	0.31	0%	0.01	0%
	FOREST	71.72	**37%**	62.22	**32%**	9.50	5%
	TRANSPORTATION	0.00	0%	1.67	1%	-1.67	-1%
	URBAN	68.76	**35%**	89.98	**46%**	-21.22	**-11%**
	WETLANDS	9.65	5%	9.63	5%	0.02	0%
	IMPERVIOUS SURFA(	18.58	9%	23.30	12%	-4.72	-2%

Sub-watershed	Land use/ Land cover	Area in 2000 (sqr miles)	%Total in 2000	Area in 2010 (sqr miles)	%Total in 2010	Area Change (sqr miles)	%Total Area change
Gunpowder River	AGRICULTURE	1.02	5%	0.74	3%	0.28	1%
	BARREN LAND	0.03	0%	0.03	0%	0.00	0%
	FOREST	9.32	**42%**	8.50	**38%**	0.82	4%
	TRANSPORTATION	0.00	0%	0.05	0%	-0.05	0%
	URBAN	8.77	**39%**	9.83	**44%**	-1.07	-5%
	WETLANDS	3.16	14%	3.16	14%	0.00	0%
	IMPERVIOUS SURFAC	2.51	11%	2.67	12%	-0.16	-1%
Lower Gunpowder Falls	AGRICULTURE	14.99	**33%**	11.77	**26%**	3.22	7%
	BARREN LAND	0.05	0%	0.25	1%	-0.20	0%
	FOREST	15.45	**34%**	12.76	**28%**	2.69	6%
	TRANSPORTATION	0.00	0%	0.23	0%	-0.23	0%
	URBAN	15.06	**33%**	20.59	**45%**	-5.53	**-12%**
	WETLANDS	0.14	0%	0.12	0%	0.02	0%
	IMPERVIOUS SURFAC	3.37	7%	4.10	9%	-0.74	-2%
Bird River	AGRICULTURE	3.52	13%	2.40	9%	1.12	4%
	BARREN LAND	0.08	0%	0.41	2%	-0.33	-1%
	FOREST	8.89	**34%**	7.52	**29%**	1.37	5%
	TRANSPORTATION	0.00	0%	0.52	2%	-0.52	-2%
	URBAN	12.85	**49%**	14.46	**56%**	-1.61	-6%
	WETLANDS	0.73	3%	0.69	3%	0.03	0%
	IMPERVIOUS SURFAC	3.81	15%	4.57	18%	-0.77	-3%
Little Gunpowder Falls	AGRICULTURE	24.97	**43%**	20.90	**36%**	4.07	7%
	BARREN LAND	0.02	0%	0.02	0%	0.00	0%
	FOREST	19.16	**33%**	16.11	**28%**	3.05	5%
	TRANSPORTATION	0.00	0%	0.18	0%	-0.18	0%
	URBAN	13.98	**24%**	20.92	**36%**	-6.94	**-12%**
	WETLANDS	0.31	1%	0.31	1%	0.00	0%
	IMPERVIOUS SURFAC	2.51	4%	3.21	5%	-0.70	-1%
Loch Raven Reservoir	AGRICULTURE	85.35	**39%**	71.83	**33%**	13.52	6%
	BARREN LAND	0.51	0%	0.29	0%	0.22	0%
	FOREST	83.74	**38%**	71.69	**33%**	12.05	5%
	TRANSPORTATION	0.06	0%	0.91	0%	-0.85	0%
	URBAN	48.12	**22%**	72.82	**33%**	-24.71	**-11%**
	WETLANDS	0.18	0%	0.16	0%	0.02	0%
	IMPERVIOUS SURFAC	9.51	4%	11.62	5%	-2.10	-1%
Prettyboy Reservoir	AGRICULTURE	33.32	**47%**	27.32	**39%**	6.00	8%
	BARREN LAND	0.01	0%	0.10	0%	-0.09	0%
	FOREST	26.77	**38%**	24.85	**35%**	1.92	3%
	TRANSPORTATION	0.00	0%	0.00	0%	0.00	0%
	URBAN	10.32	15%	18.06	**26%**	-7.74	**-11%**
	WETLANDS	0.07	0%	0.07	0%	0.00	0%
	IMPERVIOUS SURFAC	1.68	2%	2.03	3%	-0.35	0%
Middle River - Browns	AGRICULTURE	0.69	6%	0.36	3%	0.33	3%
	BARREN LAND	0.00	0%	0.00	0%	0.00	0%
	FOREST	3.09	**29%**	2.49	**23%**	0.60	6%
	TRANSPORTATION	0.00	0%	0.01	0%	-0.01	0%
	URBAN	6.70	**63%**	7.55	**71%**	-0.86	-8%
	WETLANDS	0.16	1%	0.23	2%	-0.07	-1%
	IMPERVIOUS SURFAC	2.31	22%	2.46	23%	-0.15	-1%
Gunpowder River Total	AGRICULTURE	163.85	**36%**	135.32	**30%**	28.53	6%
	BARREN LAND	0.71	0%	1.10	0%	-0.39	0%
	FOREST	166.42	**37%**	143.92	**32%**	22.51	5%
	TRANSPORTATION	0.06	0%	1.90	0%	-1.83	0%
	URBAN	115.79	**26%**	164.24	**36%**	-48.45	**-11%**
	WETLANDS	4.74	1%	4.75	1%	0.00	0%
	IMPERVIOUS SURFAC	25.70	6%	30.66	7%	-4.96	-1%

Sub-watershed	Land use/ Land cover	Area in 2000 (sqr miles)	%Total in 2000	Area in 2010 (sqr miles)	%Total in 2010	Area Change (sqr miles)	%Total Area change
Entire UWS basin	AGRICULTURE	345.66	**38%**	275.81	**30%**	69.85	8%
	BARREN LAND	1.24	0%	1.87	0%	-0.62	0%
	FOREST	331.88	**36%**	291.80	**32%**	40.08	4%
	TRANSPORTATION	0.08	0%	3.98	0%	-3.90	0%
	URBAN	225.50	**25%**	330.53	**36%**	-105.02	**-11%**
	WETLANDS	14.47	2%	14.49	2%	-0.01	0%
	IMPERVIOUS SURFAC	52.53	6%	65.05	7%	-12.52	-1%

Appendix 2

Delivered Loads to the Upper Western Shore

Phase 5.3 2009 Progress Run 8/25/2010

Chesapeake Bay Program. Accessed January 10, 2012 from
http://www.chesapeakebay.net/watershedimplementationplantools.aspx?menuitem=52044
File
(ftp://ftp.chesapeakebay.net/Modeling/phase5/Phase53_Loads-Acres-BMPs/MD/
Load_Acres_MDWIP_08252010.xls)

Loadings by source

Loadings > 20% are in **BOLD**

River	CBP segment	Category	N load (Million lbs per yr)	% Total N Load	P load (Million lbs per yr)	% Total P Load	Sed load (Million lbs per yr)	% Total Sed Load
Bush	BSHOH	Agriculture	0.137	15%	0.0068	11%	11.22	**32%**
		Forest	0.113	12%	0.0032	5%	5.96	17%
		Non-tidal Water Depo:	0.004	0%	0.0002	0%		
		Septic	0.112	12%				
		Urban Runoff	0.210	**23%**	0.0185	**29%**	18.11	**51%**
		Point Source	0.349	**38%**	0.0351	**55%**	0.12	0%
		TOTAL	**0.925**		**0.0638**		**35.41**	
Gunpowder	GUNOH	Agriculture	0.416	**32%**	0.0156	**27%**	29.57	**52%**
		Forest	0.314	**24%**	0.0071	12%	11.76	**21%**
		Non-tidal Water Depo:	0.018	1%	0.0011	2%		
		Septic	0.198	15%				
		Urban Runoff	0.300	**23%**	0.0256	**44%**	15.93	**28%**
		Point Source	0.044	3%	0.0092	16%	0.02	0%
		TOTAL	**1.290**		**0.0586**		**57.28**	
Middle	MIDOH	Agriculture	0.001	1%	0.0001	1%	0.06	4%
		Forest	0.007	5%	0.0003	3%	0.19	12%
		Non-tidal Water Depo:	0.001	0%	0.0000	0%		
		Septic	0.036	**24%**				
		Urban Runoff	0.027	18%	0.0044	**37%**	1.15	**73%**
		Point Source	0.077	**52%**	0.0070	**59%**	0.18	11%
		TOTAL	**0.147**		**0.0118**		**1.57**	

Appendix 3

Station names, locations and descriptions

Long-term non-tidal and tidal water quality stations

Station Name	Location/Depth	Latitude/ Longitude (NAD83 DMS)	Characterizes
CB1.0	Susquehanna River at Conowingo Dam Gage Station	39° 39.373'N 76° 10.502'W	Free-flowing freshwater
DER0015	Deer Creek Bridge on Stafford Bridge Road	39° 37.409'N 76° 09.886'W	Free-flowing freshwater; flow gauge
GUN0125	Gunpowder Falls Bridge on Cromwell Bridge Road	39° 25.538'N 76° 31.734'W	Free-flowing freshwater
GUN0258	Gunpowder Falls 4 End Glenco Road above old bridge crossing	39° 33.039'N 76° 38.152'W	Free-flowing freshwater; flow gauge
GUN0476	Gunpowder Falls Bridge at Gunpowder Road	39° 41.362'N 76° 46.829'W	Free-flowing freshwater
WT1.1	Bush River E of Gum Point, E of Fl G9 on power line support; 2.0 m.	39° 26.107'N 76° 14.523'W	Salinity transition zone
WT2.1	Gunpowder River, 200 yds E of Oliver Point at buoy G15; 2.5 m.	39° 22.648'N 76° 20.079'W	Salinity transition zone
WT3.1	Middle River East of Wilson Point at channel junction daymarker WP; 3.0 m.	39° 18.323'N 76° 24.572'W	Salinity transition zone

Shallow water monitoring locations and dates

Waterbody	Segment	Station Name	Station	Years deployed	LAT (NAD83)	LONG (NAD83)
Bush River	BSHOH	Church Point	XJG7461	2008 – 2010	39° 27.492' N	76° 13.936' W
		Otter Point Creek	XJG7035	2003 – present	39° 27.047' N	76° 16.474' W
		Lauderick Creek	XJG4337	2003 – 2007	39° 24.233' N	76° 16.365' W
		Additional water quality mapping calibration stations	WT1.1	2003 – 2005	39° 26.106' N	76° 14.526' W
			XJG1149	2003	39° 21.150' N	76° 14.940' W
			XJG2340	2003 – 2005	39° 22.182' N	76° 16.050' W
			XJG4451	2003 – 2005	39° 24.642' N	76° 14.856' W
			XJG6745	2003	39° 26.688' N	76° 15.492' W
			XJG7856	2003 – 2005	39° 27.720' N	76° 14.442' W
Gunpowder River	GUNOH	Mariners Point Park	XJF4289	2003 – 2005	39° 24.114' N	76° 21.098' W
		APG at Edgewood	XJG2718	2003 – 2005	39° 22.892' N	76° 18.258' W
		Additional water quality mapping calibration stations	WT2.1	2003 – 2005	39° 22.434' N	76° 20.082' W
			XJF0588	2003 – 2005	39° 20.478' N	76° 21.222' W
			XJF0821	2003 – 2005	39° 20.772' N	76° 18.000' W
			XJF2675	2003 – 2005	39° 22.746' N	76° 22.626' W
			XJG0006	2003	39° 20.010' N	76° 19.428' W
			XJG3207	2003	39° 23.232' N	76° 19.386' W
	CB2OH		XIG8710	2003	39° 18.690' N	76° 19.056' W
Middle River	MIDOH	Cutter Marina	FRG0002	2003 – 2005	39° 18.912' N	76° 24.366' W
		Strawberry Point	MDR0038	2003 – 2005	39° 19.235' N	76° 26.380' W
		Additional water quality mapping calibration stations	MDR0002	2003	39° 17.622' N	76° 23.118' W
			FRG0018	2003 – 2005	39° 19.986' N	76° 24.282' W
			HOK0005	2003 – 2005	39° 18.894' N	76° 26.520' W
			MDR0028	2003	39° 18.870' N	76° 25.458' W
			NOM0007	2003 – 2005	39° 18.084' N	76° 25.806' W
			WT3.1	2003 – 2005	39° 18.324' N	76° 24.570' W

Appendix 4

Water and Habitat Quality Data Assessment Methods

Loadings
For USGS methods see http://md.water.usgs.gov/publications/sir-2006-5178/index.html

Current condition- Status
Tidal station nutrient concentrations and physical properties were evaluated to determine the current health of the rivers (status). Relative status was determined for total nitrogen (TN), dissolved inorganic nitrogen (DIN), total phosphorus (TP), dissolved inorganic phosphorus (PO_4), total suspended solids (TSS), algal abundance (as measured by chlorophyll *a*, CHLA) and water clarity (as measured with a Secchi disc) for the 2008-2010 period. For status calculation methods see
http://mddnr.chesapeakebay.net/eyesonthebay/documents/ICPRB09-4_StatusMethodPaperMolson2009.pdf.

Results for some parameters are compared with established threshold values to evaluate habitat quality. Summer bottom dissolved oxygen (BDO) is compared to US EPA Chesapeake Bay dissolved oxygen criteria for deep-water seasonal designated use (June- September). Summer dissolved oxygen is considered healthy if levels are 5 mg/l or greater and impaired if levels are less than 3 mg/l. For more details see
www.chesapeakebay.net/content/publications/cbp_13142.pdf. DIN is compared to a nitrogen limitation threshold value of less than 0.07 mg/l (Fisher and Gustafson 2002, available online at http://www.hpl.umces.edu/gis_group/Resource%20Limitation/2002_report_27Oct03.htm#es). Submerged aquatic vegetation (SAV) growing season median concentrations for 2008-2010 for PO_4, TSS, CHLA and percent-light through water (PLW) are compared to SAV habitat requirements (Appendix 5) using the methods of Kemp et al. (2004) available online at http://archive.chesapeakebay.net/pubs/sav/savreport.pdf

Change over time- Trends
Nutrient levels and physical properties were evaluated to determine progress toward improved water quality (trends). For trends calculation methods see
http://mddnr.chesapeakebay.net/eyesonthebay/documents/stat_trend_hist.pdf. For non-tidal water quality stations, concentrations of TN, TP and TSS were evaluated. For tidal water quality stations, the following parameters were evaluated: TN, DIN, TP, PO_4, TSS, algal abundance (as measured by chlorophyll *a*, CHLA), water clarity (as measured with a Secchi disc), summer BDO, salinity and water temperature. In order to understand results in the primary parameters, additional parameters were examined including nitrate-nitrite (NO_{23}), ammonium (NH_4) and ratios of nutrient concentrations (TN:TP, DIN:PO_4) that may explain more about nutrient use by aquatic plants and limitations of available nutrients.

Non-tidal water quality data was tested for linear trends for 1999-2010 and 1986-2010. Tidal water quality data were tested for linear trends for 1985-1997, 1999-2010 and 1985-2010. Tests for non-linear trends were also done for 1985-2010 with the tidal water quality data. Trends are significant if $p \leq 0.01$; also included in the discussion are trends that 'may be' significant when $0.01 < p < 0.05$. Due to a laboratory change in 1998 that affects the tidal water quality data, a step trend may occur for TP, PO_4 and TSS. For these parameters, trends are determined for 1985-1997 and 1999-2010 only.

In addition to annual trends for the various time ranges above, tidal water quality data was tested for seasonal trends for 1999-2010. Seasons tested were spring (March-May), summer (July-September) and SAV growing season (April-October).

Shallow water Temporal Assessment (Percent failure analysis)

Continuous monitoring data were compared to water quality thresholds. Measurements of dissolved oxygen taken during the months of June through September were compared to the US EPA threshold value of 3.2 mg/l for shallow water bay grass use (instantaneous minimum). This time period was used because the summer months typically experience the lowest dissolved oxygen levels and are the most critical for living resources. Chlorophyll and turbidity measurements collected during the SAV growing season of April through October were compared to threshold levels of 15 µg/l and 7 NTU, respectively. Values above these levels can inhibit light penetration through the water column and impact growth of underwater grasses. Percent failures are defined as the percent of values in each year that did not meet the water quality thresholds.

Shallow water Spatial Assessment

Algal density, sediment and nutrient samples were collected from calibration sites on water quality mapping cruises, some of which were also at continuous monitoring sites. In addition, samples were collected at the continuous monitoring sites when the equipment was serviced (approximately every two weeks). All data for a station (water quality mapping calibration and continuous monitoring calibration) were used to calculate a monthly median. Monthly medians for April-October were used to calculate the SAV growing season median. Note that the long-term stations include data from long-term and water quality mapping sampling. The median CHLA, TSS, PO_4 and DIN levels and Secchi depths for the April-October SAV growing season were compared to the habitat requirements in the same manner as the long-term tidal data (Appendix 5).

Non-parametric one-way ANOVAs were used to determine if there were differences between stations (SAS Institute software). Where a significant difference was present, a Tukey's Studentized Range (HSD) test was performed to determine which stations were different from each other. Tests were considered significant at $p < 0.05$.

Appendix 5

Submerged Aquatic Vegetation Habitat Requirements

Submerged Aquatic Vegetation (SAV) habitat requirements by salinity regime (from Habitat Requirements for Submerged Aquatic Vegetation in Chesapeake Bay: Water Quality, Light Regime, and Physical-Chemical Factors. W. M. Kemp, R. Batiuk, R. Bartleson, P. Bergstrom, V. Carter, C. L. Gallegos, W. Hunley, L. Karrh, E. W. Koch, J. M. Landwehr, K. A. Moore, L. Murray, M. Naylor, N. B. Rybicki, J. C. Stevenson and D. J. Wilcox. Estuaries. 2004. 27:363–377 available online at http://archive.chesapeakebay.net/pubs/sav/savreport.pdf.).

SAV growing season for all three regimes in Maryland is from April-October. Median seasonal values are compared to the listed habitat requirement to determine if water quality is suitable for SAV growth and survival. Note that the dissolved inorganic nitrogen (DIN) requirement for mesohaline waters exceeds the 0.07 mg/l level where nitrogen limitation of algal growth likely occurs. The more stringent nitrogen limitation DIN level is used for interpretation of habitat quality instead. Due to issues with the model calibration, instead of Percent light at leaf (PLL) water clarity is assessed with percent light through water (PLW) at 1.0 meter depth (L. Karrh, personal communication). PLW can be calculated for the long-term stations that were sampled from 1985-2010. For all stations, Secchi depth can also be used to estimate PLW (L. Karrh, personal communication).

Salinity Regime (ppt)	Water Column Light Requirement (PLW) (%) or Secchi Depth (m)	Total Suspended Solids (mg/l)	Plankton Chlorophyll-*a* (µg/l)	Dissolved Inorganic Nitrogen (mg/l)	Dissolved Inorganic Phosphorus (mg/l)
Tidal Fresh <0.5 ppt	>13% or 0.725 m	< 15	< 15	Not applicable	< 0.02
Oligohaline 0.5-5 ppt	>13% or 0.725 m	< 15	< 15	Not applicable	< 0.02
Mesohaline 5-18 ppt	>22% or 0.97 m	< 15	< 15	< 0.15 (Nitrogen Limitation < 0.07)	< 0.01

Appendix 6

Annual trends results from non-tidal water quality stations
Trend results from 1999-2010 and 1986-2010

Data is from the surface layer. Red colored results indicate degrading conditions. Green colored results indicate improving conditions. Grey shading of the 1985-2010 Linear Trend results indicates the non-linear trend is significant and the linear trend results should not be reported. For trends significant at $p \leq 0.01$, results are abbreviated as IMP (improving), DEG (degrading), INC (increasing), DEC (decreasing), U (u-shaped non-linear trend) and INV-U (inverse u-shaped non-linear trend). For trends significant at $0.01 < p < 0.05$, NT (no trend) precedes the abbreviation. NT alone indicates trend is not significant at $p < 0.05$.

PARAM	STATION	1999-2010 Linear	1986-2010 Linear	1986-2010 non-linear	Non-linear date
TN	CB1.0	NT	DEC		
	DER0015	INC	NT		
	GUN0125	NT	DEC		
	GUN0258	INC	NT		
	GUN0476	INC	NTINC	U	Jul-94
TP	CB1.0	NT	NT		
	DER0015	NTDEC	NTDEC		
	GUN0125	DEC	DEC	INV-U	Jun-93
	GUN0258	NTDEC	DEC		
	GUN0476	DEC	DEC		
TSS	CB1.0	NT	NTINC		
	DER0015	NT	NT		
	GUN0125	DEC	DEC	INV-U	Apr-96
	GUN0258	NT	NT		
	GUN0476	NT	DEC	INV-U	Nov-95

Appendix 7

Current status and annual trends results from the tidal water quality stations.
Trend results from 1985-1997, 1999-2010 and 1985-2010

Data is from the surface layer with the exception of dissolved oxygen, which is from the bottom and the dissolved oxygen trends are for summer only (June-September). Red colored status and trends results indicate poor or degrading conditions. Green colored status and trends results indicate good or improving conditions. Blue colored status indicates fair status. Blue colored trends indicate decreasing trends where a qualitative assessment (improving or degrading) is not applicable; purple colored trends indicate increasing trends in the same parameters. Grey shading of the 1985-2010 Linear Trend results indicates the non-linear trend is significant and the linear trend results should not be reported. For trends significant at $p \leq 0.01$, results are abbreviated as IMP (improving), DEG (degrading), INC (increasing), DEC (decreasing), U (u-shaped non-linear trend) and INV-U (inverse u-shaped non-linear trend). For trends significant at $0.01 < p < 0.05$, NT (no trend) precedes the abbreviation. NT alone indicates trend is not significant at $p < 0.05$.

Param	Station	Initial 2-yr Median	2008-2010 Median	2008-2010 Status	1985-1997 Linear Trend	1999-2010 Linear Trend	1985-2010 Linear Trend	1985-2010 Non-Lin Trend	Non-linear inflection
TN	WT1.1	1.370	1.465	FAIR	NT DEG	NT	NTIMP		
	WT2.1	0.940	1.144	GOOD	NT	NT	NT		
	WT3.1	1.160	0.958	GOOD	NT	NT	NTIMP		
DIN	WT1.1	0.459	0.185	GOOD	NT	NT	Not evaluated due to lab change		
	WT2.1	0.450	0.423	GOOD	NT	NT			
	WT3.1	0.184	0.208	GOOD	NT	NT			
TP	WT1.1	0.078	0.087	GOOD	DEG	NTDEG	Not evaluated due to lab change		
	WT2.1	0.056	0.056	GOOD	NT	NT			
	WT3.1	0.054	0.045	GOOD	NT	NT			
PO4	WT1.1	0.005	0.004	GOOD	UNKNOWN	NTDEG	Not evaluated due to lab change		
	WT2.1	0.005	0.004	GOOD	UNKNOWN	NTDEG			
	WT3.1	0.005	0.004	GOOD	UNKNOWN	NT			
TSS	WT1.1	29.5	18.2	GOOD	NT	NT	Not evaluated due to lab change		
	WT2.1	15.0	17.3	GOOD	NT	NT			
	WT3.1	10.0	9.3	GOOD	NT	NT			
CHLA	WT1.1	15.3	36.3	POOR	NT DEG	NT	NTDEG		
	WT2.1	11.7	18.3	POOR	NT	NT	IMP		
	WT3.1	19.7	13.7	POOR	IMP	NT	IMP	U	Aug-00
SECCHI	WT1.1	0.4	0.3	POOR	NT	SLOPE=0	SLOPE=0		
	WT2.1	0.5	0.4	POOR	NT	NTDEG	NT		
	WT3.1	0.7	0.6	GOOD	IMP	DEG	NT	INV-U	May-97
DO	WT1.1	7.1	7.5	GOOD	NT	NTDEG	NTDEG		
	WT2.1	6.9	6.7	GOOD	NT	NT	DEG		
	WT3.1	7.2	6.1	GOOD	NT	NT	NTDEG		

Param.	Station	Initial 2-yr Median	2008-2010 Median	2008-2010 Status	1985-1997 Linear Trend	1999-2010 Linear Trend	1985-2010 Linear Trend	1985-2010 Non-Lin Trend	Non-linear inflection
WTEMP	**WT1.1**	19.1	14.6	**INC**	NT	NT	NT		
	WT2.1	17.4	14.4	**INC**	NT	NT	NT		
	WT3.1	17.0	15.2	**INC**	NT	NT	NT		
SALINITY	**WT1.1**	0.7	0.4	**DEC**	NT DEC	NT	NT		
	WT2.1	2.6	1.4	**DEC**	NT DEC	NTDEC	NT		
	WT3.1	3.4	3.1	**INC**	NT DEC	NTDEC	NT		
NH4	**WT1.1**	0.035	0.014	**GOOD**	NT	NT	Not evaluated due to lab change		
	WT2.1	0.036	0.010	**GOOD**	SLOPE = 0	**IMP**			
	WT3.1	0.010	0.009	**GOOD**	NT	**IMP**			
NO23	**WT1.1**	0.420	0.183	**GOOD**	NT	NT	Not evaluated due to lab change		
	WT2.1	0.280	0.407	**GOOD**	NT	NT			
	WT3.1	0.160	0.186	**GOOD**	NT	NT			
TN:TP	**WT1.1**	43	38	NOD	NT	NT	Not evaluated due to lab change		
	WT2.1	41	38	NOD	NT	NT			
	WT3.1	42	41	NOD	NT	NT			
DIN:PO4	**WT1.1**	172	123	**DEC**	**DEC**	NT	Not evaluated due to lab change		
	WT2.1	199	175	**DEC**	**DEC**	NT			
	WT3.1	81	101	**DEC**	**DEC**	NTDEC			

Appendix 8

Seasonal trends results for long-term tidal water quality data

Seasonal trends results for surface data from 1999-2010. Color codes and abbreviations are the same as used in Appendix 7.

param	station	ANNUAL Jan-Dec	SPRING Mar-May	SUMMER Jun-Sep	SAV Apr-Oct
TN	WT1.1	NT	NT	NT	NT
	WT2.1	NT	NT	NT	NT
	WT3.1	NT	NT	NT	NT
DIN	WT1.1	NT	NT	NT	NT
	WT2.1	NT	NT	NT	NT
	WT3.1	NT	NT	NTIMP	NT
TP	WT1.1	NTDEG	NT	NT	NT
	WT2.1	NT	NT	NT	NT
	WT3.1	NT	NT	NTDEG	NT
PO4	WT1.1	NTDEG	NT	NT	**DEG**
	WT2.1	NTDEG	NT	**DEG**	**DEG**
	WT3.1	NT	NT	**DEG**	NT
TSS	WT1.1	NT	NT	NT	NT
	WT2.1	NT	NT	NT	NT
	WT3.1	NT	NT	NT	NT
CHLA	WT1.1	NT	NT	NT	NT
	WT2.1	NT	NT	NT	NT
	WT3.1	NT	NT	NT	NT
SECCHI	WT1.1	SLOPE=0	NT	SLOPE=0	SLOPE=0
	WT2.1	NTDEG	NT	NTDEG	**DEG**
	WT3.1	**DEG**	NT	**DEG**	**DEG**
WTEMP	WT1.1	NT	NT	NT	NT
	WT2.1	NT	NT	NT	NT
	WT3.1	NT	NT	NT	NT
SALINITY	WT1.1	NT	NT	NT	NT
	WT2.1	NTDEC	NT	NT	NT
	WT3.1	NTDEC	**DEC**	NT	NT
NH4	WT1.1	NT	NT	NT	NT
	WT2.1	**IMP**	NT	NT	NTIMP
	WT3.1	**IMP**	NT	NT	**IMP**
NO23	WT1.1	NT	NT	NT	NT
	WT2.1	NT	NT	NT	NT
	WT3.1	NT	NT	NT	NT

Appendix 9

Shallow water monitoring water and habitat quality

Temporal Assessment- Percent failures

Continuous monitoring data for the years 2003-2010. Instantaneous measurements of dissolved oxygen taken during June through September were compared to threshold value 3.2 mg/l. Chlorophyll and turbidity measurements collected during the SAV growing were compared to threshold levels of 15 µg/l and 7 NTU, respectively. The percent of values in each year that did not meet the water quality thresholds are presented as "percent failures".

Station	Location	Year	Dissolved Oxygen Threshold % < 3.2 mg/l	Chlorophyll Threshold % > 15 ug/l	Turbidity Threshold % > 7 NTU
XJG7461	*Bush River* Church Point	2008	0.23	85.77	99.94
		2009	0.74	69.45	100.00
		2010	0.23	89.55	99.87
XJG7035	*Bush River* Otter Point Creek	2003	0.29	2.97	80.96
		2004	7.31	8.06	57.39
		2005	5.00	26.41	95.11
		2006	0.28	53.24	99.91
		2007	1.20	24.93	84.02
		2008	0.88	53.95	97.30
		2009	0.11	53.19	98.35
		2010	1.09	81.31	100.00
XJG4337	*Bush River* Lauderick Creek	2003	0.22	3.34	80.87
		2004	0.00	18.77	96.86
		2005	0.03	39.24	99.18
		2006	0.09	27.52	99.83
		2007	0.00	43.65	99.98
XJF4289	*Gunpowder River* Mariners Point Park	2003	0.00	1.80	95.73
		2004	0.00	14.49	67.72
		2005	0.00	17.47	74.24
XJG2718	*Gunpowder River* APG at Edgewood	2003	0.02	6.17	86.69
		2004	0.00	11.93	54.87
		2005	0.00	15.62	41.78
FRG0002	*Middle River* Cutter Marina	2003	0.00	29.08	74.29
		2004	0.58	14.87	57.55
		2005	0.08	27.11	44.53
MDR0038	*Middle River* Strawberry Point	2003	0.00	53.80	95.88
		2004	0.00	40.87	68.33
		2005	0.41	52.79	73.65

< 10 % failure

40 - 70 % failure

10 - 40 % failure

> 70 % failure

Spatial Assessment

Shallow water monitoring data for 2003-2005 compared to SAV habitat requirements in the Upper Western Shore basin.
All data for a station (water quality mapping and continuous monitoring) were used to calculate a monthly median. Monthly medians for April-October were used to calculate the SAV growing season median, which was compared to habitat requirements (Appendix 5). Note that the long-term stations include data from long-term and water quality mapping sampling. In 2010, DIN and PO_4 was not measured at some stations.

Water body	Station		year	Chla mg/l		TSS mg/l		DIN mg/l		PO4 mg/l		DO mg/l		Secchi Depth	Salinity	Salinity Zone	TN mg/l	TP mg/l
BUSH RIVER 2003-2005	XJG2340		2003	11.2	MEET	16.0	FAIL	0.606	FAIL	0.0063	MEET	7.5	MEET	0.40	0.3	OH	1.170	0.0527
			2004	9.3	MEET	10.8	MEET	0.476	FAIL	0.0114	MEET	7.9	MEET	0.65	0.0	TF	1.033	0.0530
			2005	11.7	MEET	9.4	MEET	0.363	FAIL	0.0030	MEET	8.7	MEET	0.50	2.2	OH	0.973	0.0368
	XJG4337	Lauderick Creek	2003	6.5	MEET	8.5	MEET	0.374	FAIL	0.0115	MEET	7.2	MEET	0.65	0.0	TF	0.909	0.0566
			2004	14.2	MEET	15.5	FAIL	0.056	MEET	0.0054	MEET	7.8	MEET	0.50	0.0	TF	1.060	0.0654
			2005	34.8	FAIL	21.3	FAIL	0.059	MEET	0.0035	MEET	9.1	MEET	0.30	1.3	OH	1.190	0.0800
	XJG4451		2003	14.8	MEET	12.0	MEET	0.525	FAIL	0.0097	MEET	7.4	MEET	0.40	0.0	TF	1.230	0.0468
			2004	26.9	FAIL	16.0	FAIL	0.268	FAIL	0.0059	MEET	8.2	MEET	0.50	0.0	TF	1.019	0.0677
			2005	32.9	FAIL	18.7	FAIL	0.172	FAIL	0.0030	MEET	10.1	MEET	0.30	1.0	OH	1.113	0.0637
	XJG7035	Otter Point Creek	2003	6.6	MEET	21.5	FAIL	0.914	FAIL	0.0051	MEET	8.4	MEET	0.30	0.0	TF	1.660	0.0645
			2004	7.5	MEET	15.5	FAIL	0.685	FAIL	0.0063	MEET	7.3	MEET	0.55	0.0	TF	1.382	0.0584
			2005	30.3	FAIL	29.3	FAIL	0.548	FAIL	0.0040	MEET	8.8	MEET	0.30	0.0	TF	1.785	0.0842
	XJG7856		2003	10.1	MEET	13.0	MEET	1.149	FAIL	0.0063	MEET	7.6	MEET	0.40	0.0	TF	1.462	0.0547
			2004	19.7	FAIL	15.4	FAIL	0.356	FAIL	0.0037	MEET	8.7	MEET	0.45	0.0	TF	1.514	0.0773
			2005	41.9	FAIL	21.0	FAIL	0.289	FAIL	0.0030	MEET	8.9	MEET	0.20	0.0	TF	1.750	0.0715
	WT1.1	Long-term	2003	13.2	MEET	17.0	FAIL	0.678	FAIL	0.0056	MEET	7.7	MEET	0.40	0.0	TF	1.241	0.0588
			2004	25.0	FAIL	14.5	MEET	0.273	FAIL	0.0040	MEET	8.1	MEET	0.50	0.0	TF	1.103	0.0549
			2005	41.4	FAIL	16.3	FAIL	0.113	FAIL	0.0029	MEET	9.5	MEET	0.40	0.6	OH	1.530	0.0723
BUSH RIVER 2008-2010	XJG7461	Church Point	2008	45.9	FAIL	34.0	FAIL	0.035	MEET	0.0037	MEET	8.5	MEET	0.30	0.0	TF	1.351	0.1147
			2009	28.3	FAIL	37.0	FAIL	0.095	FAIL	0.0032	MEET	7.5	MEET	0.30	0.1	OH	1.318	0.0971
			2010	74.3	FAIL	36.0	FAIL	0.045	MEET	0.0033	MEET	7.7	MEET	0.30	0.1	OH	1.750	0.1320
	XJG7035	Otter Point Creek	2008	27.7	FAIL	28.6	FAIL	0.317	FAIL	0.0038	MEET	8.1	MEET	0.30	0.0	TF	1.415	0.0783
			2009	32.8	FAIL	39.0	FAIL	0.492	FAIL	0.0036	MEET	8.0	MEET	0.30	0.0	TF	1.502	0.0896
			2010	68.1	FAIL	48.4	FAIL	0.304	FAIL	0.0038	MEET	8.2	MEET	0.30	0.0	TF		
	WT1.1	Long-term	2008	36.9	FAIL	31.0	FAIL	0.029	MEET	0.0042	MEET	9.6	MEET	0.25	0.0	TF	1.091	0.0958
			2009	33.1	FAIL	27.0	FAIL	0.086	FAIL	0.0041	MEET	8.1	MEET	0.30	0.4	OH	1.255	0.0964
			2010	61.4	FAIL	22.0	FAIL	0.027	MEET	0.0046	MEET	9.4	MEET	0.20	0.4	OH	1.601	0.1149

Water body	Station		year	Chla mg/l		TSS mg/l		DIN mg/l		PO4 mg/l		DO mg/l		Secchi Depth	Salinity	Salinity Zone	TN mg/l	TP mg/l	Wtemp °C
GUNPOWDER RIVER 2003-2005	XJF0588		2003	16.3	FAIL	22.3	FAIL	0.139	FAIL	0.0040	MEET	7.4	MEET	0.35	1.2	OH	0.931	0.0606	23.4
			2004	11.1	MEET	14.8	MEET	0.282	FAIL	0.0017	MEET	7.6	MEET	0.70	0.5	OH	0.776	0.0419	24.4
			2005	13.8	MEET	8.4	MEET	0.175	FAIL	0.0035	MEET	7.1	MEET	0.80	3.6	OH	1.096	0.0392	26.4
	XJF0821		2003	18.3	FAIL	20.5	FAIL	0.440	FAIL	0.0023	MEET	8.1	MEET	0.40	0.5	OH	0.980	0.0547	18.8
			2004	6.5	MEET	11.0	MEET	0.588	FAIL	0.0016	MEET	7.9	MEET	0.70	0.2	OH	1.105	0.0421	23.2
			2005	8.7	MEET	6.8	MEET	0.121	FAIL	0.0028	MEET	8.5	MEET	0.60	2.8	OH	1.146	0.0328	24.9
	XJF2675		2003	25.6	FAIL	27.8	FAIL	0.784	FAIL	0.0041	MEET	8.4	MEET	0.30	0.0	TF	1.434	0.0715	21.3
			2004	24.9	FAIL	28.5	FAIL	0.674	FAIL	0.0022	MEET	8.4	MEET	0.20	0.0	TF	1.345	0.0622	24.1
			2005	19.1	FAIL	19.0	FAIL	0.123	FAIL	0.0030	MEET	9.2	MEET	0.30	0.1	OH	1.143	0.0807	25.5
	XJF4289	Mariner's Point Park	2003	7.9	MEET	14.0	MEET	0.345	FAIL	0.0039	MEET	8.0	MEET	0.60	0.0	TF	1.003	0.0502	19.2
			2004	9.1	MEET	13.7	MEET	0.716	FAIL	0.0048	MEET	8.2	MEET	0.60	0.0	TF	1.304	0.0443	23.6
			2005	10.7	MEET	16.5	FAIL	0.351	FAIL	0.0035	MEET	7.7	MEET	0.50	0.2	OH	1.192	0.0469	24.2
	XJG2718	APG at Edgewood	2003	9.3	MEET	8.7	MEET	0.450	FAIL	0.0039	MEET	8.8	MEET	0.60	0.0	TF	1.194	0.0492	24.2
			2004	8.6	MEET	7.3	MEET	0.377	FAIL	0.0037	MEET	8.9	MEET	0.80	0.0	TF	0.890	0.0372	24.0
			2005	8.1	MEET	6.0	MEET	0.160	FAIL	0.0037	MEET	8.2	MEET	0.85	1.0	OH	1.066	0.0408	24.4
	WT2.1	Long-term	2003	5.0	MEET	10.5	MEET	0.828	FAIL	0.0092	MEET	7.3	MEET	0.60	0.0	TF	1.396	0.0509	19.9
			2004	7.3	MEET	11.9	MEET	0.669	FAIL	0.0044	MEET	7.9	MEET	0.60	0.0	TF	1.189	0.0407	23.5
			2005	8.4	MEET	8.8	MEET	0.096	FAIL	0.0027	MEET	8.1	MEET	0.60	0.8	OH	0.768	0.0326	25.9
GUNPOWDER RIVER 2008-2010	WT2.1	Long-term	2008	19.4	FAIL	24.5	FAIL	0.042	MEET	0.0050	MEET	8.0	MEET	0.30	0.5	OH	0.786	0.0571	22.6
			2009	10.2	MEET	31.0	FAIL	0.292	FAIL	0.0041	MEET	8.1	MEET	0.30	1.3	OH	1.098	0.0689	21.3
			2010	31.5	FAIL	19.0	FAIL	0.017	MEET	0.0042	MEET	8.6	MEET	0.30	1.0	OH	0.847	0.0677	21.7
MIDDLE RIVER 2003-2005	FRG0002	Cutter Marine	2003	12.0	MEET	12.0	MEET	0.196	FAIL	0.0044	MEET	7.8	MEET	0.50	1.1	OH	0.898	0.0581	22.8
			2004	10.5	MEET	8.3	MEET	0.235	FAIL	0.0057	MEET	8.7	MEET	0.70	0.9	OH	0.826	0.0478	24.9
			2005	13.5	MEET	10.0	MEET	0.108	FAIL	0.0029	MEET	8.4	MEET	0.80	3.3	OH	0.973	0.0426	24.6
	FRG0018		2003	20.9	FAIL	16.0	FAIL	0.101	FAIL	0.0027	MEET	7.3	MEET	0.40	0.8	OH	1.088	0.0514	24.1
			2004	17.2	FAIL	11.5	MEET	0.076	FAIL	0.0023	MEET	7.4	MEET	0.60	0.8	OH	1.057	0.0414	23.7
			2005	21.5	FAIL	11.6	MEET	0.033	MEET	0.0027	MEET	7.5	MEET	0.50	2.8	OH	0.925	0.0357	25.4
	HOK0005		2003	19.4	FAIL	12.0	MEET	0.253	FAIL	0.0031	MEET	7.9	MEET	0.40	0.8	OH	1.013	0.0631	25.8
			2004	22.2	FAIL	13.6	MEET	0.034	MEET	0.0028	MEET	6.9	MEET	0.40	0.9	OH	0.796	0.0476	23.4
			2005	19.1	FAIL	18.3	FAIL	0.181	FAIL	0.0029	MEET	7.7	MEET	0.30	2.2	OH	0.999	0.0531	23.6
	MDR0038	Strawberry Point	2003	21.4	FAIL	12.0	MEET	0.025	MEET	0.0028	MEET	8.1	MEET	0.55	1.2	OH	0.775	0.0550	23.2
			2004	15.0	MEET	10.0	MEET	0.037	MEET	0.0035	MEET	8.0	MEET	0.60	0.8	OH	0.806	0.0457	25.1
			2005	17.9	FAIL	13.3	MEET	0.041	MEET	0.0030	MEET	7.7	MEET	0.50	2.9	OH	1.012	0.0589	25.1
	NOM0007		2003	21.7	FAIL	13.0	MEET	0.069	MEET	0.0025	MEET	8.3	MEET	0.40	1.0	OH	1.092	0.0617	23.7
			2004	19.1	FAIL	13.5	MEET	0.127	FAIL	0.0021	MEET	8.1	MEET	0.40	1.0	OH	0.737	0.0466	23.6
			2005	19.8	FAIL	17.5	FAIL	0.048	MEET	0.0028	MEET	7.6	MEET	0.40	3.2	OH	0.882	0.0487	24.5
	WT3.1	Long-term	2003	14.6	MEET	8.7	MEET	0.216	FAIL	0.0037	MEET	8.4	MEET	0.50	1.2	OH	0.883	0.0492	21.7
			2004	9.0	MEET	7.0	MEET	0.254	FAIL	0.0052	MEET	8.2	MEET	0.70	1.0	OH	0.854	0.0367	23.2
			2005	11.7	MEET	7.0	MEET	0.085	FAIL	0.0028	MEET	8.1	MEET	0.70	3.4	OH	0.845	0.0342	23.9
MIDDLE RIVER 2008-2010	WT3.1	Long-term	2008	16.4	FAIL	9.7	MEET	0.041	MEET	0.0066	MEET	7.5	MEET	0.50	2.3	OH	0.942	0.0483	23.3
			2009	11.2	MEET	18.7	FAIL	0.149	FAIL	0.0088	MEET	8.2	MEET	0.40	3.2	OH	0.863	0.0573	18.6
			2010	9.0	MEET	8.5	MEET	0.022	MEET	0.0061	MEET	8.2	MEET	0.50	3.0	OH	0.772	0.0451	22.0