Watershed Report for Biological Impairment of the Non-Tidal Port Tobacco River Watershed, Charles County, Maryland Biological Stressor Identification Analysis Results and Interpretation

FINAL

DEPARTMENT OF THE ENVIRONMENT
1800 Washington Boulevard, Suite 540
Baltimore, Maryland 21230-1718

Submitted to:

Water Protection Division
U.S. Environmental Protection Agency, Region III
1650 Arch Street
Philadelphia, PA 19103-2029

September 2015

Table of Contents

List of Figures

List of Tables

List of Abbreviations

AR	Attributable Risk
BIBI	Benthic Index of Biotic Integrity
BSID	Biological Stressor Identification
COMAR	Code of Maryland Regulations
CWA	Clean Water Act
FIBI	Fish Index of Biologic Integrity
IBI	Index of Biotic Integrity
INDR	Iowa Department of Natural Resources
MBSS	Maryland Biological Stream Survey
MDDNR	Maryland Department of Natural Resources
MDE	Maryland Department of the Environment
mg/L	Milligrams per liter
n	Number
NH_4^+	Ammonia
NO_3^-	Nitrate
NO_2^-	Nitrite
NPDES	National Pollution Discharge Elimination System
POTOH	Lower Potomac River Oligohaline
POTOH2	Port Tobacco River Oligohaline
PSU	Primary Sampling Unit
SSA	Science Services Administration
TN	Total Nitrogen
TP	Total Phosphorous
TSS	Total Suspended Solids
TMDL	Total Maximum Daily Load
µeq/L	Micro equivalent per liter
µS/cm	Micro Siemens per centimeter
USEPA	United States Environmental Protection Agency
WQA	Water Quality Analysis
WQLS	Water Quality Limited Segment
WWTP	Waste Water Treatment Plant

Executive Summary

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (USEPA) implementing regulations direct each state to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. For each WQLS listed on the *Integrated Report of Surface Water Quality in Maryland* (Integrated Report)**,** the State is to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate via a Water Quality Analysis (WQA) that water quality standards are being met.

The Port Tobacco watershed is located in Charles County, MD. It is associated with three assessment units, the non-tidal 8-digit basin (basin code 02140109), and the Lower Potomac River Oligohaline (POTOH) and Port Tobacco River Oligohaline (POTOH2), in the Integrated Report. Below is a table identifying the listings associated with this watershed (MDE 2014).

Table E1. 2012 Integrated Report Listings for the Port Tobacco Watershed

<table>
<tr><th colspan="2">Watershed</th><th>Basin Code</th><th>Non-tidal/ Tidal</th><th>Designated Use</th><th>Year listed</th><th>Identified Pollutant</th><th>Listing Category</th></tr>
<tr><td rowspan="6">Port Tobacco</td><td></td><td rowspan="6">02140109</td><td rowspan="6">Non-tidal</td><td>Aquatic Life and Wildlife</td><td>2008</td><td>Impacts to Biological Communities</td><td>5</td></tr>
<tr><td>Wills Branch</td><td rowspan="5">Water Contact Sports</td><td rowspan="5">2006</td><td rowspan="5">Enterococcus</td><td rowspan="4">5</td></tr>
<tr><td>Hoghole Run</td></tr>
<tr><td>Jenny Run</td></tr>
<tr><td>Port Tobacco Creek</td></tr>
<tr><td>Multiple subsegments</td><td>2</td></tr>
<tr><td>Lower Potomac River Oligohaline (POTOH)</td><td></td><td></td><td>Tidal</td><td>Aquatic Life and Wildlife</td><td>2010</td><td>Benthic IBI</td><td>5</td></tr>
<tr><td rowspan="4">Port Tobacco River Oligohaline (POTOH2)</td><td rowspan="4"></td><td rowspan="4"></td><td rowspan="4"></td><td>Open-Water Fish and Shellfish Subcategory</td><td rowspan="4">1996</td><td>TN</td><td>4a</td></tr>
<tr><td rowspan="2">Seasonal Migratory Fish Spawning and Nursery Subcategory</td><td>TP</td><td rowspan="2">4a</td></tr>
<tr><td>TN</td></tr>
<tr><td>Seasonal Shallow-Water Submerged</td><td>TP</td><td>4a</td></tr>
</table>

				Aquatic Vegetation Subcategory		TSS	

In 2002, the State began listing biological impairments on the Integrated Report. The current MDE biological assessment methodology assesses and lists only at the Maryland 8-digit watershed scale, which maintains consistency with how other listings in the Integrated Report are made, how TMDLs are developed, and how implementation is targeted. The listing methodology assesses the condition of Maryland 8-digit watersheds with multiple impacted sites by measuring the percentage of stream miles that have an Index of Biotic Integrity (IBI) score of less than three, and calculating whether this is a significant deviation from reference condition watersheds (i.e., healthy stream, less than 10% stream miles degraded).

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for the non-tidal Port Tobacco River are designated as a Use class I - *water contact recreation, and protection of nontidal warmwater aquatic life* and Use class II - *Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting* for the tidal portion (COMAR 2015a, b). Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. The criteria developed to protect the designated use may differ and are dependent on the specific designated use(s) of a waterbody. The Port Tobacco River watershed is not attaining its designated use of protection of aquatic life because of impairments to biological communities. As an indicator of designated use attainment, MDE uses Benthic and Fish Indices of Biotic Integrity (BIBI/FIBI) developed by the Maryland Department of Natural Resources Maryland Biological Stream Survey (MDDNR MBSS).

The current listings for biological impairments represent degraded biological conditions for which the stressors, or causes, are unknown. The MDE Science Services Administration (SSA) has developed a biological stressor identification (BSID) analysis that uses a case-control, risk-based approach to systematically and objectively determine the predominant cause of reduced biological conditions, thus enabling the Department to most effectively direct corrective management action(s). The risk-based approach, adapted from the field of epidemiology, estimates the strength of association between various stressors, sources of stressors and the biological community, and the likely impact these stressors would have on the degraded sites in the watershed.

The BSID analysis uses data available from the statewide MDDNR MBSS. Once the BSID analysis is completed, a number of stressors (pollutants) may be identified as probable or unlikely causes of poor biological conditions within the Maryland 8-digit watershed study. BSID analysis results can be used as guidance to refine biological impairment listings in the Integrated Report by specifying the probable stressors and sources linked to biological degradation.

This Port Tobacco River watershed report presents a brief discussion of the BSID process on which the watershed analysis is based, and which may be reviewed in more detail in the report entitled “Maryland Biological Stressor Identification Process” (MDE 2014). Data suggest that the degradation of biological communities in the Port Tobacco River watershed is due to urban land use and its altered hydrology concomitant effects: altered hydrology and elevated levels of sediments and inorganics. The development of landscapes creates broad and interrelated forms of degradation (i.e., hydrological, morphological, and water chemistry) that can affect stream ecology and biological composition. Peer-reviewed scientific literature establishes a link between highly urbanized landscapes and degradation, e.g., urban runoff contamination of surface waters, in the aquatic health of non-tidal stream ecosystems.

The results of the BSID process, and the probable causes and sources of the biological impairments in the Port Tobacco River watershed can be summarized as follows:

- The BSID process has determined that biological communities in the Port Tobacco River watershed are likely degraded due to sediment related stressors. Specifically, natural sediment conditions exacerbated by anthropogenic sources in the Coastal Plain physiographic region have resulted in altered habitat heterogeneity and subsequent elevated suspended sediment in the watershed, which are in turn the probable causes of impacts to biological communities. The BSID results thus confirm the establishment of sediment TMDL in 2010 through the Chesapeake Bay TMDL was an appropriate management action to begin mitigating the impacts of sediment to the biological communities in the Port Tobacco River watershed. The BSID results also confirm the 1996 (tidal) Category 5 listing for sediment as an impairing substance in the Port Tobacco River watershed, and links this pollutant to biological conditions in these waters, and extend the impairment to the watershed’s non-tidal waters. The BSID results thus support a Category 5 listing of sediment for the non-tidal portion of the 8-digit watershed as an appropriate management action to begin addressing these stressor’s impacts on the biological communities in the Port Tobacco River watershed.

- The BSID process has determined that the biological communities in the Port Tobacco River watershed are likely degraded due to inorganics (i.e., chlorides, sulfates, and conductivity). Chlorides, sulfates, and conductivity levels are significantly associated with degraded biological conditions and found, respectively, in approximately 42%, 42%, and 61% of the stream miles with poor to very poor biological conditions in the Port Tobacco River watershed. The BSID results thus support a Category 5 listing of chlorides and sulfates as impairing substances of the non-tidal portion of the 8-digit watershed Port Tobacco River as an appropriate management action to begin addressing the impact of these stressors on the biological communities in the Port Tobacco River watershed. Impervious surfaces and urban runoff cause an increase in contaminant loads from point and nonpoint sources by delivering an array of inorganic pollutants to surface waters. Discharges of inorganic compounds are very intermittent; concentrations vary widely depending on the time of year as well as a variety of other factors may influence their impact on aquatic life. Future monitoring of these parameters will help in determining the spatial and temporal extent of these impairments in the watershed.

- The BSID process has determined that nutrients, specifically nitrite and total phosphorus, are associated with degradation of biological communities in the Port Tobacco River. The BSID analysis uses a case-control, risk-based approach to systematically and objectively determine the predominant cause(s) and source of degraded biological conditions. Currently, there is no scientific consensus on numeric nutrient criteria for non-tidal streams (ICPRB 2011). Nutrients in excess do not act directly as pollutants in aquatic systems but, rather, manifest their negative effects via changes in chemical and biological metrics. For this reason, numeric thresholds or ranges of nutrient concentrations should not, by themselves, be used to list non-tidal stream segments as impaired by nutrients (Category 5). Maryland has thus taken an alternative, multi-faceted 'causal pathway' approach. Under this approach, a stream segment may be listed as impaired by nutrients only when poor biological conditions are demonstrated (via low Indices of Biotic Integrity or IBIs) in conjunction with (1) high nutrient concentrations, and (2) one or more of the following stressors known to be associated with nutrient over-enrichment and having scientifically defensible regulatory limits: (a) Low dissolved oxygen (DO) concentrations; (b) low or high DO saturation; (c) high pH. Since none of the stressors known to be associated with nutrient over enrichment were identified in the BSID analysis, a Category 5 listing for nutrients is not recommended for Port Tobacco River. In the absence of a firm causal pathway as described above, concluding that Port Tobacco River is impaired by nutrients could result in unnecessary planning and pollution control implementation costs.

1.0 Introduction

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (USEPA) implementing regulations direct each state to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS listed on the *Integrated Report of Surface Water Quality in Maryland* (Integrated Report), the State is to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate via a Water Quality Analysis (WQA) that water quality standards are being met. In 2002, the State began listing biological impairments on the Integrated Report. Maryland Department of the Environment (MDE) has developed a biological assessment methodology to support the determination of proper category placement for 8-digit watershed listings.

The current MDE biological assessment methodology is a three-step process: (1) a data quality review, (2) a systematic vetting of the dataset, and (3) a watershed assessment that guides the assignment of biological condition to Integrated Report categories. In the data quality review step, available relevant data are reviewed to ensure they meet the biological listing methodology criteria of the Integrated Report (MDE 2012). In the vetting process, an established set of rules is used to guide the removal of sites that are not applicable for listing decisions (e.g., tidal or blackwater streams). The final principal database contains all biological sites considered valid for use in the listing process. In the watershed assessment step, a watershed is evaluated based on a comparison to a reference condition (i.e., healthy stream, less than 10% degraded) that accounts for spatial and temporal variability, and establishes a target value for "aquatic life support." During this step of the assessment, a watershed that differs significantly from the reference condition is listed as impaired (Category 5) on the Integrated Report. If the watershed is meeting water quality standards for some substances but not for others, the status of the watershed for those substances meeting water quality standards is listed as Category 2. Watersheds that are impaired but have a TMDL that has been completed or submitted to EPA are listed as Category 4a. If a watershed is classified as impaired (Category 5), then a stressor identification analysis is completed to determine if a TMDL is necessary.

The MDE biological stressor identification (BSID) analysis applies a case-control, risk-based approach that uses the principal dataset, with considerations for ancillary data, to identify potential causes of the biological impairment. Identification of stressors responsible for biological impairments was limited to rounds two and three of the Maryland Biological Stream Survey (MBSS) dataset (2000–2004; 2007-2009) because it provides a broad spectrum of paired data variables (i.e., biological monitoring and stressor information) to best enable a complete stressor analysis. The BSID analysis then links potential causes/stressors with general causal scenarios and concludes with a review for ecological plausibility by State scientists. Once the BSID analysis is completed, one or several stressors (pollutants) may be identified as probable or unlikely causes of the poor biological conditions within the Maryland 8-digit watershed. BSID analysis results can be used together with a variety of water quality analyses to update and/or support the probable causes and sources of biological impairment in the Integrated Report.

The remainder of this report provides a characterization of the Port Tobacco River watershed, and presents the results and conclusions of a BSID analysis of the watershed.

2.0 Port Tobacco River Watershed Characterization

2.1 Location

The Port Tobacco River watershed is located entirely in Charles County, MD, and drains to the Lower Potomac River (see Figure 1). The Port Tobacco River watershed encompasses approximately 28,000 acres, and is southwest of La Plata, MD. At the northwest region of the watershed the Thomas Stone National Historical Site is located along the Hoghole Run tributary. The park has several trails and old trace roads for walking and hiking, on its 322 acres. The Port Tobacco Courthouse Historic Site and Charles County Museum are located in the northeast region of the watershed along Tobacco Creek. Chapel Point State Park is located on the mainstem of Port Tobacco River; it is an undeveloped 600 acre multi-use park that provides fishing, hiking, hunting, and camping. The watershed is located in the Coastal Plain region of three distinct eco-regions identified in the MBSS indices of biological integrity (IBI) metrics (Southerland et al. 2005a) (see Figure 2).

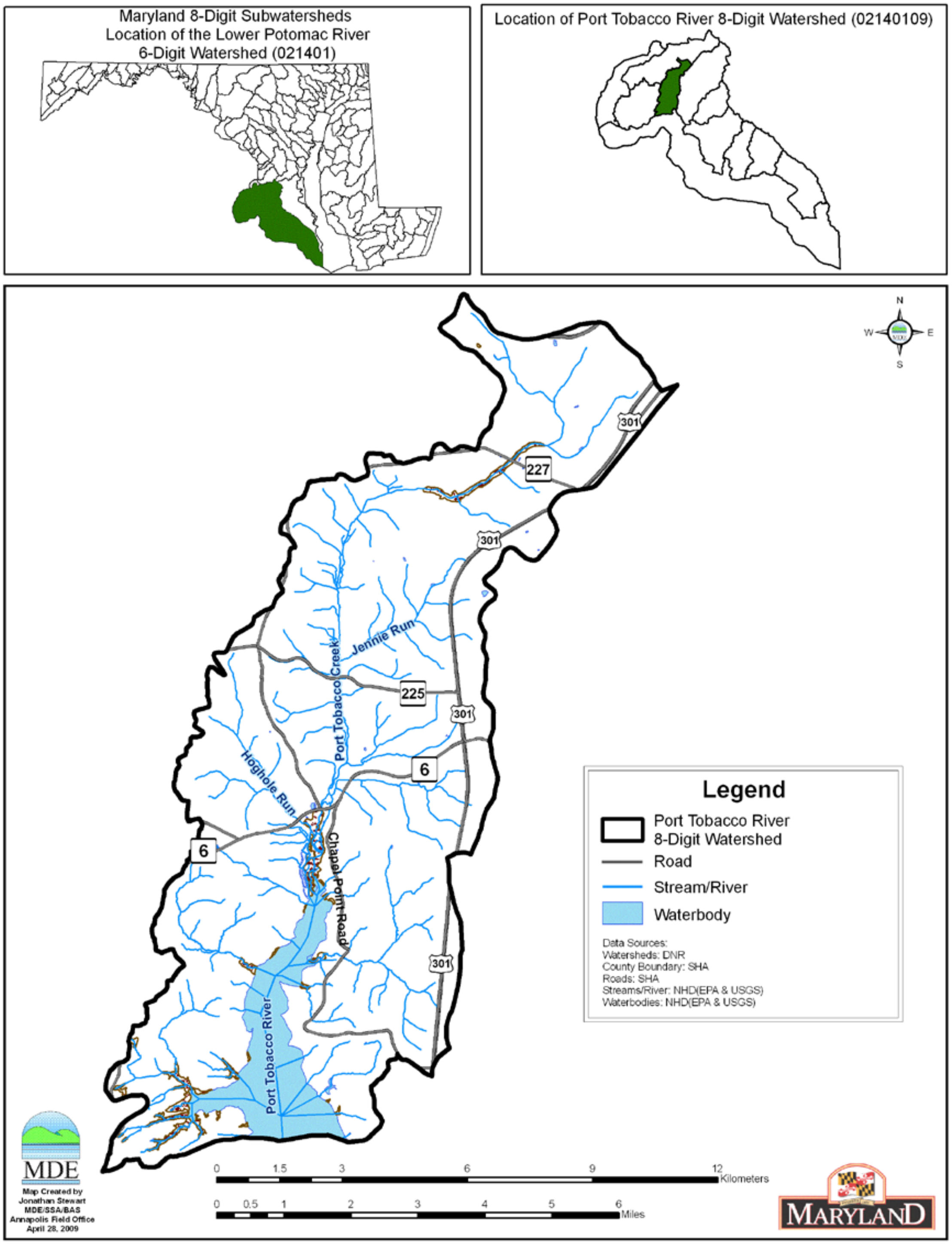

Figure 1. Location Map of the Port Tobacco River Watershed

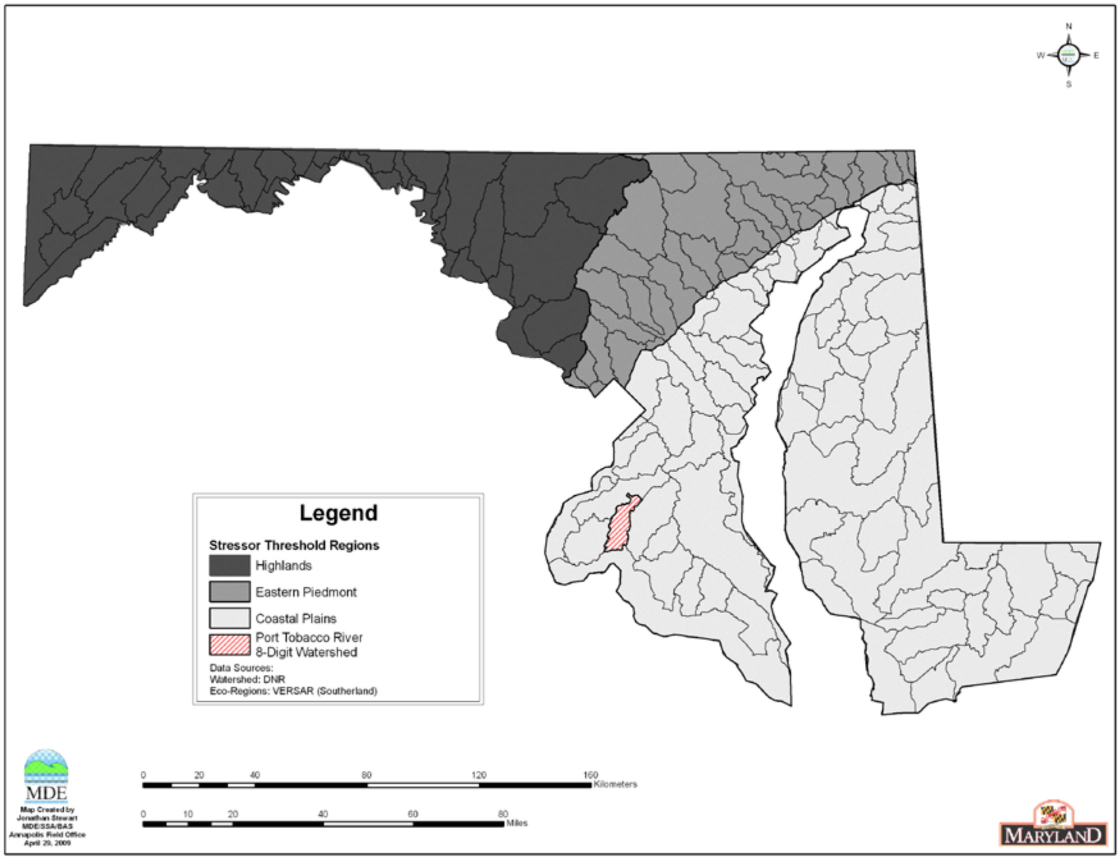

Figure 2. Eco-Region Map of the Port Tobacco River Watershed

2.2 Land Use

The drainage area of the Port Tobacco River watershed is approximately 28,000 acres. The Port Tobacco River watershed contains urban, agricultural, and forested land uses (see Figure 3). The predominant land use in the Maryland 8-digit watershed is forest; however, some of the watershed is urbanized, particularly in the area of La Plata and the town of Waldorf. According to the 2006 Charles County Comprehensive Plan, the population of La Plata has nearly doubled in the past 25 years, and will increase an additional 64% in the next twenty years (MDE 2006). The Phase 5.2 Chesapeake Bay Watershed Model reports the land use distribution in the Port Tobacco watershed as forest (68%), urban pervious (20%), agricultural (9%) and urban impervious (2%) (see Figure 4) (USEPA 2010).

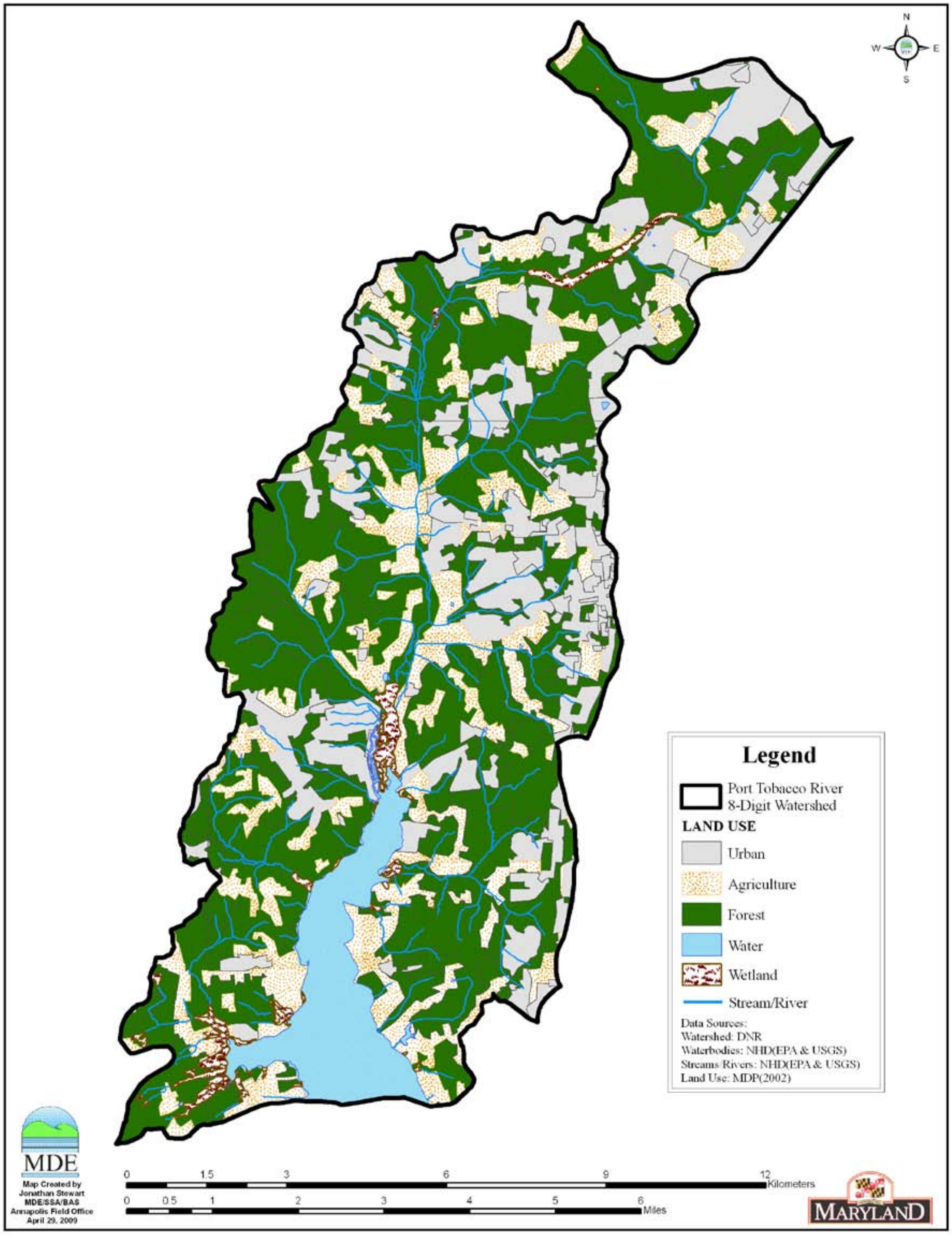

Figure 3. Land Use Map of the Port Tobacco River Watershed

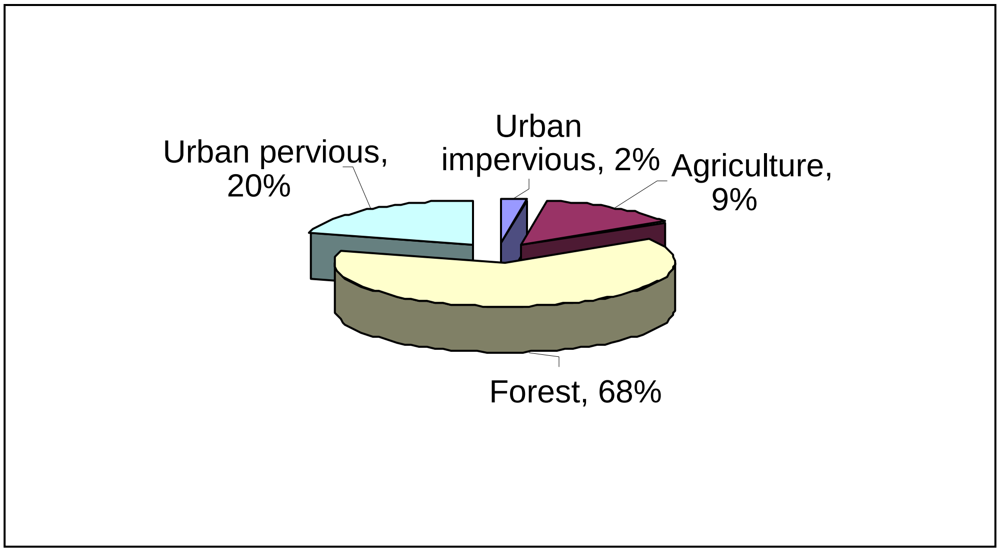

Figure 4. Proportions of Land Use in the Port Tobacco River Watershed

2.3 Soils/hydrology

The Port Tobacco River lies in the Coastal Plain physiographic province. The Coastal Plain region is characterized by flat or gently rolling topography and elevations rising from sea level to about 100 feet. The Coastal Plain Province is underlain by a wedge of unconsolidated sediments including gravel, sand, silt, and clay (MGS 2007). Overall, about 3,036 acres of the watershed is prime agricultural soil that does not require drainage or irrigation.

3.0 Port Tobacco River Water Quality Characterization

3.1 Integrated Report Impairment Listings

The Maryland Department of the Environment has identified the non-tidal areas of the Port Tobacco watershed under Category 5 of the State's Integrated Report as impaired for impacts to biological communities (2008 listings). The watershed is associated with three assessment units: the non-tidal 8-digit basin (basin code 02140109), the Lower Potomac River Oligohaline (POTOH) and Port Tobacco River Oligohaline (POTOH2), in the Integrated Report. Below is a table identifying the listings associated with this watershed (MDE 2012).

Table 1. 2012 Integrated Report Listings for the Port Tobacco Watershed

<table>
<tr><th colspan="2">Watershed</th><th>Basin Code</th><th>Non-tidal/ Tidal</th><th>Designated Use</th><th>Year listed</th><th>Identified Pollutant</th><th>Listing Category</th></tr>
<tr><td rowspan="6">Port Tobacco</td><td></td><td rowspan="6">02140109</td><td rowspan="6">Non-tidal</td><td>Aquatic Life and Wildlife</td><td>2008</td><td>Impacts to Biological Communities</td><td>5</td></tr>
<tr><td>Wills Branch</td><td rowspan="5">Water Contact Sports</td><td rowspan="5">2006</td><td rowspan="5">Enterococcus</td><td rowspan="4">5</td></tr>
<tr><td>Hoghole Run</td></tr>
<tr><td>Jenny Run</td></tr>
<tr><td>Port Tobacco Creek</td></tr>
<tr><td>Multiple subsegments</td><td>2</td></tr>
<tr><td>Lower Potomac River Oligohaline (POTOH)</td><td></td><td></td><td>Tidal</td><td>Aquatic Life and Wildlife</td><td>2010</td><td>Benthic IBI</td><td>5</td></tr>
<tr><td rowspan="5">Port Tobacco River Oligohaline (POTOH2)</td><td rowspan="5"></td><td rowspan="5"></td><td rowspan="5"></td><td>Open-Water Fish and Shellfish Subcategory</td><td rowspan="5">1996</td><td>TN</td><td>4a</td></tr>
<tr><td rowspan="2">Seasonal Migratory Fish Spawning and Nursery Subcategory</td><td>TP</td><td rowspan="2">4a</td></tr>
<tr><td>TN</td></tr>
<tr><td rowspan="2">Seasonal Shallow-Water Submerged Aquatic Vegetation Subcategory</td><td>TP</td><td rowspan="2">4a</td></tr>
<tr><td>TSS</td></tr>
</table>

3.2 Biological Impairment

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for the non-tidal Port Tobacco River are designated as a Use class I - *water contact recreation, and protection of nontidal warmwater aquatic life* and Use class II - *Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting* for the tidal portion (COMAR 2015a, b). The watershed includes two Tier II stream segments, Hoghole Run and Jennie Run. Hoghole Run is associated with a Tier II catchment designation. Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. The criteria developed to protect the designated use may differ and are dependent on the specific designated use(s) of a waterbody.

The Port Tobacco River watershed is listed under Category 5 of the 2012 Integrated Report as impaired for impacts to biological communities. Approximately 46% of the Port Tobacco River watershed is estimated as having fish and/or benthic indices of biological impairment in the poor to very poor category. The Port Tobacco River watershed dataset does not include round one (1995-1997) data; therefore, the biological impairment listing is based on the results of MDDNR MBSS round two (2000-2004) and round three (2004-2007) data, which include thirteen sites. Six of the thirteen stations have degraded benthic and/or fish indices of biotic integrity (BIBI, FIBI) scores significantly lower than 3.0 (i.e., poor to very poor). The principal dataset reflects the same scenario, i.e. MBSS round two and round three contains thirteen MBSS sites with six having BIBI and/or FIBI scores lower than 3.0. Figure 5 illustrates principal dataset site locations for the Port Tobacco River watershed.

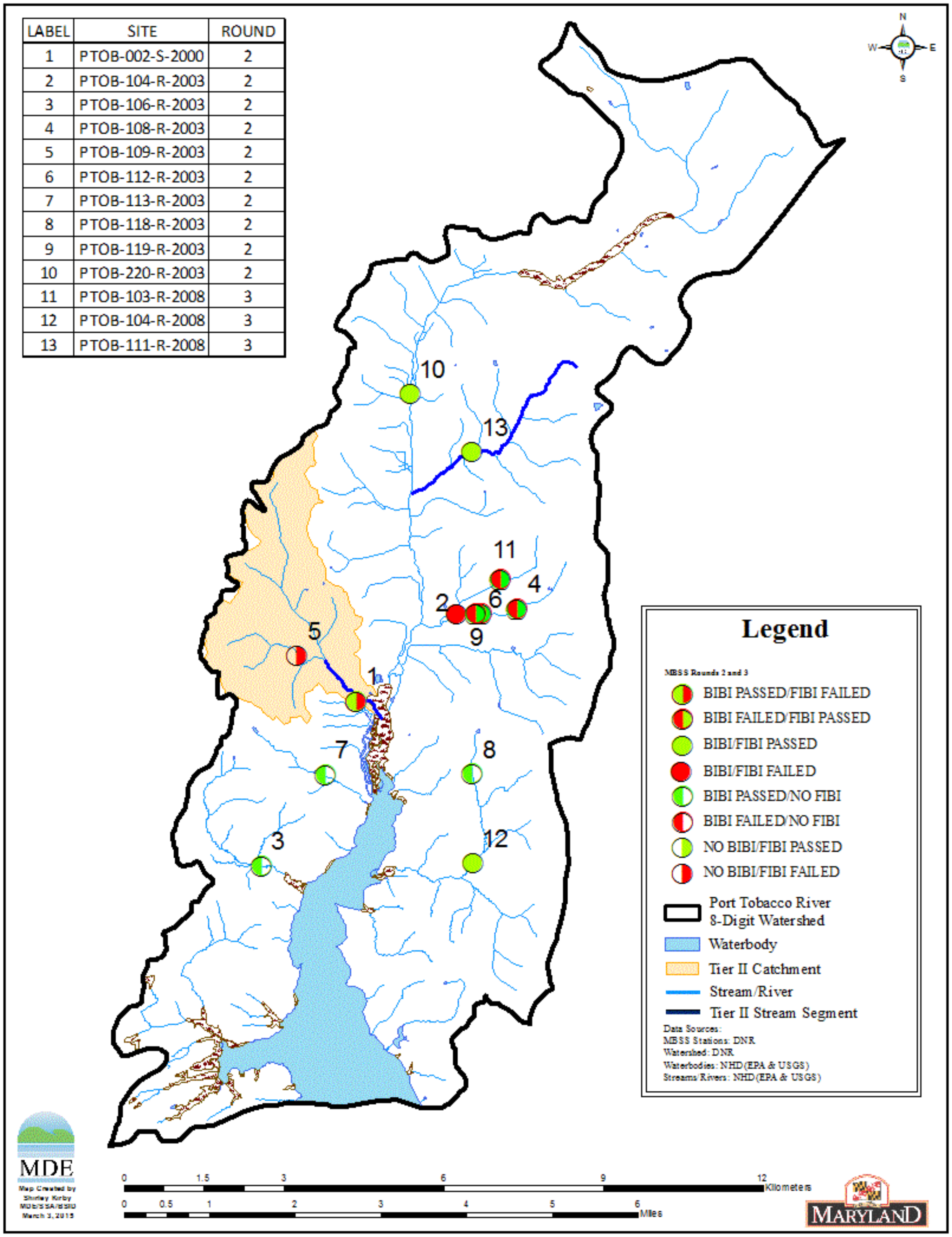

Figure 5. Principal Dataset Sites for the Port Tobacco River Watershed

4.0 Stressor Identification Results

The BSID process uses results from the BSID data analysis to evaluate each biologically impaired watershed and determines potential stressors and sources. Interpretation of the BSID data analysis results is based upon components of Hill's Postulates (Hill 1965), which propose a set of standards that could be used to judge when an association might be causal. The components applied are: 1) the strength of association, which is assessed using the odds ratio; 2) the specificity of the association for a specific stressor (risk among controls); 3) the presence of a biological gradient; 4) ecological plausibility, which is illustrated through final causal models; and 5) experimental evidence gathered through literature reviews to help support the causal linkage.

The BSID data analysis tests for the strength of association between stressors and degraded biological conditions by determining if there is an increased risk associated with the stressor being present. More specifically, the assessment compares the likelihood that a stressor is present, given that there is a degraded biological condition, by using the ratio of the incidence within the case group as compared to the incidence in the control group (odds ratio). The case group is defined as the sites within the assessment unit with BIBI/FIBI scores lower than 3.0 (i.e., poor to very poor). The controls are sites with similar physiographic characteristics (Highland, Eastern Piedmont, and Coastal region), and stream order for habitat parameters (two groups – 1^{st} and 2^{nd}-4^{th} order), that have good biological conditions.

The common odds ratio confidence interval was calculated to determine if the odds ratio was significantly greater than one. The confidence interval was estimated using the Mantel-Haenszel (1959) approach and is based on the exact method due to the small sample size for cases. A common odds ratio significantly greater than one indicates that there is a statistically significant higher likelihood that the stressor is present when there are poor to very poor biological conditions (cases) than when there are fair to good biological conditions (controls). This result suggests a statistically significant positive association between the stressor and poor to very poor biological conditions and is used to identify potential stressors.

Once potential stressors are identified (i.e., odds ratio significantly greater than one), the risk attributable to each stressor is quantified for all sites with poor to very poor biological conditions within the watershed (i.e., cases). The attributable risk (AR) defined herein is the portion of the cases with poor to very poor biological conditions that are associated with the stressor. The AR is calculated as the difference between the proportion of case sites with the stressor present and the proportion of control sites with the stressor present.

Once the AR is calculated for each possible stressor, the AR for groups of stressors is calculated. Similar to the AR calculation for each stressor, the AR calculation for a group of stressors is also summed over the case sites using the individual site characteristics (i.e., stressors present at that site). The only difference is that the absolute risk for the controls at each site is estimated based on the stressor present at the site that has the lowest absolute risk among the controls.

After determining the AR for each stressor and the AR for groups of stressors, the AR for all potential stressors is calculated. This value represents the proportion of cases, sites in the watershed with poor to very poor biological conditions, which would be improved if the potential stressors were eliminated (Van Sickle and Paulsen 2008). The purpose of this metric is to determine if stressors have been identified for an acceptable proportion of cases (MDE 2009).

Through the BSID data analysis, MDE identified sediment and water chemistry as potential sources significantly associated with degraded fish and/or benthic macroinvertebrate biological conditions. Parameters identified as representing possible sources are listed in Table 2 and include various urban land use types. A summary of combined AR values for each source group is shown in Table 3. As shown in Table 4 and Table 6, parameters from the sediment and water chemistry groups are identified as possible biological stressors in the Port Tobacco River watershed. A summary of combined AR values for each stressor group is shown in Table 7.

Table 2. Stressor Source Identification Analysis Results for the Port Tobacco River Watershed

Parameter group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Benthic or Fish IBI)	Controls (average number of reference sites with fair to good Benthic or Fish IBI)	% of case sites with stressor present	% of control sites per stratum with stressor present	Statistical probability that the stressor is not impacting biology (p value)	Possible stressor (odds of stressor in cases significantly higher than odds of stressor in controls using p<0.1)	% of case sites associated with the stressor (attributable risk)
Sources - Acidity	Agricultural acid source present	13	6	274	0%	7%	1	No	_
	AMD acid source present	13	6	274	0%	0%	1	No	_
	Organic acid source present	13	6	275	0%	7%	1	No	_
Sources - Agricultural	High % of agriculture in watershed	13	6	279	0%	3%	1	No	_
	High % of agriculture in 60m buffer	13	6	279	0%	4%	1	No	_
Sources - Anthropogenic	Low % of forest in watershed	13	6	279	0%	6%	1	No	_
	Low % of wetland in watershed	13	6	279	50%	11%	0.022	Yes	39%
	Low % of forest in 60m buffer	13	6	279	0%	8%	1	No	_
	Low % of wetland in 60m buffer	13	6	279	33%	10%	0.13	No	_
Sources - Impervious	High % of impervious surface in watershed	13	6	279	50%	4%	0.002	Yes	46%
	High % of impervious surface in 60m buffer	13	6	279	0%	5%	1	No	_
	High % of roads in watershed	13	6	279	0%	0%	1	No	_
	High % of roads in 60m buffer	13	6	279	33%	5%	0.034	Yes	29%
Sources - Urban	High % of high-intensity developed in watershed	13	6	279	67%	8%	0.001	Yes	59%
	High % of low-intensity developed in watershed	13	6	279	83%	6%	0	Yes	77%
	High % of medium-intensity developed in watershed	13	6	279	17%	2%	0.14	No	_
	High % of residential developed in watershed	13	6	279	83%	8%	0	Yes	75%
	High % of rural developed in watershed	13	6	279	0%	5%	1	No	_
	High % of high-intensity developed in 60m buffer	13	6	279	0%	6%	1	No	_

Parameter group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Benthic or Fish IBI)	Controls (average number of reference sites with fair to good Benthic or Fish IBI)	% of case sites with stressor present	% of control sites per stratum with stressor present	Statistical probability that the stressor is not impacting biology (p value)	Possible stressor (odds of stressor in cases significantly higher than odds of stressor in controls using p<0.1)	% of case sites associated with the stressor (attributable risk)
	High % of low-intensity developed in 60m buffer	13	6	279	17%	5%	0.263	No	_
	High % of medium-intensity developed in 60m buffer	13	6	279	17%	3%	0.194	No	_
	High % of residential developed in 60m buffer	13	6	279	83%	8%	0	Yes	76%
	High % of rural developed in 60m buffer	13	6	279	17%	5%	0.263	No	_

Table 3. Summary of Combined Attributable Risk Values for Source Groups in the Port Tobacco River Watershed

Source Group	% of degraded sites associated with specific source group (attributable risk)
Sources - Anthropogenic	39%
Sources - Impervious	62%
Sources - Urban	77%
All Sources	***94%***

4.1 Sources Identified by BSID Analysis

The sources identified by the BSID analysis (Table 2) are the result of urban development in the watershed, which has significant association with degraded biological conditions in the Port Tobacco River watershed. The watershed is comprised of 20% urban and 2% impervious surface land uses. The BSID analysis identified several stressor sources including impervious surface in the watershed and 60-meter buffer zone, and urban development (low to high intensity, residential and rural) in the watershed and 60-meter buffer zone.

The BSID source analysis (Table 2) identifies various types of urban land uses as potential sources of stressors that may cause negative biological impacts. The combined AR for the source group is approximately 94%, suggesting that these stressors are a probable cause of the biological impairments in the Port Tobacco River watershed (Table 3).

Table 4. Sediment Biological Stressor Identification Analysis Results for the Port Tobacco River Watershed

Parameter group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Benthic or Fish IBI)	Controls (average number of reference sites with fair to good Benthic or Fish IBI)	% of case sites with stressor present	% of control sites per stratum with stressor present	Statistical probability that the stressor is not impacting biology (p value)	Possible stressor (odds of stressor in cases significantly higher than odds of stressor in controls using p<0.1)	% of case sites associated with the stressor (attributable risk)
Sediment	Extensive bar formation present	13	6	161	33%	21%	0.383	No	_
	Moderate bar formation present	13	6	160	100%	49%	0.016	Yes	51%
	Channel alteration moderate to poor	10	5	131	100%	60%	0.081	Yes	40%
	Channel alteration poor	10	5	131	40%	26%	0.399	No	_
	High embeddedness	13	6	160	0%	0%	1	No	_
	Epifaunal substrate marginal to poor	13	6	160	67%	46%	0.286	No	_
	Epifaunal substrate poor	13	6	160	0%	13%	1	No	_
	Moderate to severe erosion present	13	6	160	67%	43%	0.225	No	_
	Severe erosion present	13	6	160	17%	13%	0.562	No	_

Table 5. Habitat Biological Stressor Identification Analysis Results for the Port Tobacco River Watershed

Parameter group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Benthic or Fish IBI)	Controls (average number of reference sites with fair to good Benthic or Fish IBI)	% of case sites with stressor present	% of control sites per stratum with stressor present	Statistical probability that the stressor is not impacting biology (p value)	Possible stressor (odds of stressor in cases significantly higher than odds of stressor in controls using p<0.1)	% of case sites associated with the stressor (attributable risk)
Instream Habitat	Channelization present	13	6	172	0%	13%	1	No	_
	Concrete/gabion present	13	6	148	0%	1%	1	No	_
	Beaver pond present	13	6	159	0%	7%	1	No	_
	Instream habitat structure marginal to poor	13	6	160	17%	40%	0.952	No	_
	Instream habitat structure poor	13	6	160	0%	6%	1	No	_
	Pool/glide/eddy quality marginal to poor	13	6	160	33%	46%	0.851	No	_
	Pool/glide/eddy quality poor	13	6	160	0%	3%	1	No	_
	Riffle/run quality marginal to poor	13	6	160	33%	53%	0.911	No	_
	Riffle/run quality poor	13	6	160	0%	21%	1	No	_
	Velocity/depth diversity marginal to poor	13	6	160	50%	61%	0.828	No	_
	Velocity/depth diversity poor	13	6	160	0%	16%	1	No	_
Riparian Habitat	No riparian buffer	13	6	172	0%	5%	1	No	_
	Low shading	13	6	160	0%	3%	1	No	_

Table 6. Water Chemistry Biological Stressor Identification Analysis Results for the Port Tobacco River Watershed

Parameter group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Benthic or Fish IBI)	Controls (average number of reference sites with fair to good Benthic or Fish IBI)	% of case sites with stressor present	% of control sites per stratum with stressor present	Statistical probability that the stressor is not impacting biology (p value)	Possible stressor (odds of stressor in cases significantly higher than odds of stressor in controls using p<0.1)	% of case sites associated with the stressor (attributable risk)
Chemistry - Inorganic	High chlorides	13	6	279	50%	8%	0.011	Yes	42%
	High conductivity	13	6	279	67%	6%	0	Yes	61%
	High sulfates	13	6	279	50%	8%	0.011	Yes	42%
Chemistry - Nutrients	Dissolved oxygen < 5mg/l	13	6	261	0%	17%	1	No	_
	Dissolved oxygen < 6mg/l	13	6	261	0%	25%	1	No	_
	Low dissolved oxygen saturation	13	6	261	0%	6%	1	No	_
	High dissolved oxygen saturation	13	6	261	0%	3%	1	No	_
	Ammonia acute with salmonid present	13	6	279	0%	0%	1	No	_
	Ammonia acute with salmonid absent	13	6	279	0%	0%	1	No	_
	Ammonia chronic with early life stages present	13	6	279	0%	0%	1	No	_
	Ammonia chronic with early life stages absent	13	6	279	0%	0%	1	No	_
	High nitrites	13	6	279	50%	3%	0.001	Yes	47%
	High nitrates	13	6	279	0%	7%	1	No	_
	High total nitrogen	13	6	279	0%	6%	1	No	_
	High total phosphorus	13	6	279	67%	9%	0.001	Yes	57%
	High orthophosphate	13	6	279	0%	5%	1	No	_
Chemistry - pH	Acid neutralizing capacity below chronic level	13	6	279	17%	9%	0.453	No	_
	Low field pH	13	6	262	33%	40%	0.774	No	_
	High field pH	13	6	262	0%	1%	1	No	_
	Low lab pH	13	6	279	17%	38%	0.941	No	_
	High lab pH	13	6	279	0%	0%	1	No	_

Table 7. Summary AR Values for Stressor Groups for the Port Tobacco River Watershed

Stressor Group	% of degraded sites associated with specific stressor group (attributable risk)
Sediment	51%
Chemistry - Inorganic	61%
Chemistry - Nutrients	78%
All Chemistry	79%
All Stressors	***88%***

4.2 Stressors Identified by BSID Analysis

All seven stressor parameters identified by the BSID analysis (Tables 4 and 6) are significantly associated with biological degradation in the Port Tobacco River watershed and are representative of impacts from urban developed landscapes.

Sediment Conditions

BSID analysis results for the Port Tobacco River watershed identified two sediment parameters that have a statistically significant association with a very poor to poor stream biological condition (i.e., removal of stressors would result in improved biological community). These parameters are *moderate bar formation present* and *channel alteration moderate to poor*.

Moderate bar formation present was identified as significantly associated with degraded biological conditions and found in 51% (*moderate* rating) of the stream miles with very poor to poor biological conditions in the Port Tobacco River watershed. This stressor measures the movement of sediment in a stream system, and typically results from significant deposition of gravel and fine sediments. Although some bar formation is natural, extensive bar formation indicates channel instability related to frequent and intense high flows that quickly dissipate and rapidly lose the capacity to transport the sediment loads downstream. Excessive sediment loading is expected to reduce and homogenize available feeding and reproductive habitat, degrading biological conditions.

Channel alteration was identified as significantly associated with degraded biological conditions in the Port Tobacco River watershed, and found to impact approximately 40% (*moderate to poor* rating) of the stream miles with poor to very poor biological conditions. *Channel alteration* measures large-scale modifications in the shape of the stream channel due to the presence of artificial structures (channelization) and/or bar formations. Moderate to poor and poor ratings are expected in unstable stream channels that experience frequent high flows.

The BSID analysis results include stressors (*bar formation and channel alteration*), which are often typically associated with the effects of urban and agricultural land use. The primary land use in the Port Tobacco River watershed is forest, but the watershed also includes urban (22%) and agricultural (9%) land uses. According to Wang et al. (2001), even under the best-case urban development scenarios, stream fish communities will decline substantially in quality even while a watershed remains largely rural in character. There is a minimal concentration of agricultural land use in the watershed, but it can contribute sources to sediment stressors. Agricultural land use results in increased sediment deposition within a watershed; sediment "pollution" is the number one impairment of streams nationwide (Southerland et al. 2005b).

The combined AR is used to measure the extent of stressor impact to stream miles with very poor to poor biological conditions. The combined AR for the sediment stressor group is approximately 51%, suggesting that these stressors are a probable cause of the biological impairments in the Port Tobacco River watershed (Table 7).

<u>In-stream Habitat Conditions</u>

BSID analysis results for the Port Tobacco River watershed did not identify any in-stream habitat parameters that have statistically significant association with a very poor to poor stream biological condition (i.e., removal of stressors would result in improved biological community).

<u>Riparian Habitat Conditions</u>

BSID analysis results for the Port Tobacco River watershed did not identify any riparian habitat parameters that have statistically significant association with a very poor to poor stream biological condition (i.e., removal of stressors would result in improved biological community).

<u>Water Chemistry</u>

BSID analysis results for the Port Tobacco River watershed identified five water chemistry parameters that have a statistically significant association with a very poor to poor stream biological condition (i.e., removal of stressors would result in improved biological community). These parameters are *high nitrites, high total phosphorus, high conductivity, high chlorides* and *high sulfates*.

High nitrites levels are significantly associated with degraded biological conditions and found in approximately 47% of the stream miles with poor to very poor biological conditions in the Port Tobacco River watershed. Nitrite (NO_2^-) is a measure of the amount of NO_2^- in the water column. NO_2^- is an inorganic ion formed as an intermediate from ammonium (NH_4^+) to nitrate (NO_3^-) by bacteria in soil, sewage, and water. It can lead to eutrophication, can bioaccumulate in organisms, and causes biological harm to benthics and fish mainly through anoxia. Human sources that increase NO_2^- concentrations include agriculture, sewage, and some industrial processes (Lewis and Morris 1986, Doull et al. 1980).

High total phosphorus levels are significantly associated with degraded biological conditions and found in approximately 57% of the stream miles with poor to very poor biological conditions in the Port Tobacco River watershed. Total Phosphorus (TP) is a measure of the amount of TP in the water column. Phosphorus occurs naturally in rocks and other mineral deposits, and is usually found in the form of phosphates in natural waters. Anthropogenic sources of phosphorus are fertilizers, chemicals, animal wastes and municipal sewage. TP input to surface waters typically increases in watersheds where urban or agricultural land uses are predominant.

High conductivity was identified as significantly associated with degraded biological conditions and found in 61% of the stream miles with very poor to poor biological conditions in the Port Tobacco River watershed. Conductivity is a measure of water's ability to conduct electrical current and is directly related to the total dissolved salt content of the water. Most of the total dissolved salts of surface waters are comprised of inorganic compounds or ions such as chloride, sulfate, carbonate, sodium, and phosphate (IDNR 2008). Urban runoff, road salts, fertilizers, and leaking wastewater infrastructure are typical sources of inorganic compounds. Conductivity levels typically increase in watersheds where urban land uses are predominant. Conductivity, chlorides and sulfates are closely related. Streams with elevated levels of chlorides and sulfates typically display high conductivity.

High chlorides were identified as significantly associated with degraded biological conditions and found in 42% of the stream miles with very poor to poor biological conditions in the Port Tobacco River watershed. High concentrations of chlorides can result from industrial discharges, metals contamination, and application of road salts in urban landscapes. Although chloride can originate from natural sources and point source discharges, usually most of the chloride that enters the environment is associated with the storage and application of road salt (Smith, Alexander, and Wolman 1987). According to Church and Friesz (1993), road salt accumulation and persistence in watersheds poses risks to aquatic ecosystems and to water quality. Approximately 55% of road-salt chlorides are transported in surface runoff, with the remaining 45% infiltrating through soils and into groundwater aquifers.

High sulfates was identified as significantly associated with degraded biological conditions and found in 42% of the stream miles with very poor to poor biological conditions in the Port Tobacco River watershed. Sulfate in urban areas can be derived from natural and anthropogenic sources, including combustion of fossil fuels such as coal, oil, diesel, discharge from industrial sources, and discharge from municipal wastewater treatment facilities.

The BSID analysis results identify several parameters of water chemistry as significant stressors in the Port Tobacco River watershed. In urban areas, excessive fertilization of lawns can be significant contributors of nutrients (Weibel 1969). In Wisconsin streams, Wang, Robertson and Garrison (2006) found that many macroinvertebrate and fish measures were significantly correlated with phosphorus and nitrogen concentrations, implying that nutrients have direct and/or indirect links with those biological assemblages. There are several National Pollutant Discharge Elimination System (NPDES) permits for surface water discharges in the Port Tobacco River watershed that include municipal and industrial discharges (MDE 2006). Both sewer and septic systems service the Port Tobacco River; wastewater collected is treated at the La Plata Treatment Plant (WWTP). Nutrient and suspended solid loads from any wastewater treatment facility is dependent on discharge volume, level of treatment process, and sophistication of the processes and equipment. Due to land use, the watershed is vulnerable to nutrient fluxes (e.g., stormwater) that are detrimental to the biological community, additional analysis of available data (i.e., TN:TP ratio) is necessary to confirm if phosphorus concentrations are limiting in the watershed (Allan and Castillo 1995).

Nitrite concentrations can be toxic to humans and animals, and nitrogen and phosphorus are essential nutrients for algae growth. If one nutrient is available in great abundance relative to the other, then the nutrient that is less available limits the amount of plant matter that can be produced; this is known as the “limiting nutrient.” The amount of the abundant nutrient does not matter because both nutrients are needed for algae growth. In general, a Nitrogen:Phosphorus (TN:TP) ratio in the range of 5:1 to 10:1 by mass is associated with plant growth being limited by neither phosphorus nor nitrogen. If the TN:TP ratio is greater than 10:1, phosphorus tends to be limiting; if the TN:TP ratio is less than 5:1, nitrogen tends to be limiting (Chiandani and Vighi 1974). A TN:TP analysis of MDE data was completed; the results show that 24% of the samples collected by MDE in the Port Tobacco River watershed during 2002 and 2008 have TN:TP ratios above 10.

The Coastal Plain region has a legacy of high sulfate concentrations due to natural conditions (e.g., wetlands), atmospheric deposition, and agricultural practices (MAPSS 2006). When these local soils are excavated too deeply, they can give rise to severe active acid sulfate soil problems if the underlying un-oxidized zone of the soil-geologic column that still contains sulfide minerals is exposed (MAPSS 2006). As stated, there are NPDES permitted discharge facilities including the La Plata WWTP in the Port Tobacco River watershed. NPDES permitting enforcement does not require sulfate testing; therefore data was not available to verify/identify sulfate as a specific pollutant in this watershed.

Application of road salts in the Port Tobacco River watershed is a likely source of the high chlorides and conductivity levels. Surface flows due to the imperviousness of the watershed (2%) exacerbate the issue. These salts remain in solution and are not subject to any significant natural removal mechanisms; road salt accumulation and persistence in watersheds poses risks to aquatic ecosystems and to water quality (Wegner and Yaggi

2001). According to Forman and Deblinger (2000), there is a "road-effect zone" over which significant ecological effects extend outward from a road; these effects extend 100 to 1,000 m (average of 300 m) on each side of four-lane roads. Sanitary sewage overflows are also likely a source of elevated concentrations of chloride and conductivity.

Currently in Maryland there are no specific numeric criteria that quantify the impact of conductivity, chlorides, and sulfates on the aquatic health of non-tidal stream systems. Since the exact sources and extent of inorganic pollutant loadings are not known, MDE determined that current data are not sufficient to enable identification of the specific pollutant(s) causing degraded biological communities from the array of potential inorganic pollutants loading from urban development.

The combined AR is used to measure the extent of stressor impact to stream miles with very poor to poor biological conditions. The combined AR for the water chemistry stressor group is approximately 79% suggesting that these stressors are probable cause of the biological impairments in the Port Tobacco River watershed (Table 7).

4.1 Discussion of BSID Results

The BSID analysis results suggest that degraded biological communities in the Port Tobacco River watershed are a result of stressors associated with sedimentation. Watersheds in the Coastal Plain physiographic region are naturally impacted by sediment deposition due to the region's soil types and hydrology. Streams with a lack of diverse substrates, typically the case with streams in this region, have little habitat heterogeneity because of channel alterations and erosion. Altered flow regimes create a less stable stream channel, leading to excessive bank erosion, loss of pool habitat and instream cover, and excessive streambed scour and sediment deposition (Wang et al. 2001). Historical loss of forest cover in the watershed and its replacement with urban development have exacerbated loss of habitat heterogeneity and lowered aquatic species diversity. In urbanized areas, lawns are frequently and severely mowed; as a result, soils can be more easily eroded and transported to streams.

The MDDNR MBSS noted evidence of sediment deposition and erosion, recent logging near stream banks, and the smell of sewage at several of the Port Tobacco River sampling sites. Increased inputs of sediments impact riparian and stream channel habitat, and alter flows (Cooper 1993). The MDDNR MBSS also noted tornado damage (e.g., large debris, mud), which, based on the poor BIBI results, may have impacted the benthic macroinvertebrate more than the fish community. There is a 1996 Integrated Report sediment listing for the Port Tobacco River Oligohaline (POTOH2), which was addressed by the 2010 Chesapeake Bay TMDL. Hopefully with continued efforts in implementing and enforcing the 2010 Chesapeake Bay TMDL by State and local agencies, sediment loads in the Port Tobacco River watershed will decrease and stream habitat will improve.

The effects of increasing transportation due to urbanization in the watershed may also be related to degraded stream miles, and altered stream hydrology, in the watershed. Roads tend to capture and export more stormwater pollutants (e.g., sulfates) than other land covers; as rainfall amounts become larger, previously pervious areas in most residential landscapes become more significant sources of runoff, including sediment (NRC 2008). For surface waters associated with roadways or storage facilities, episodes of salinity (e.g., chlorides, conductivity) have been reported during the winter and spring in some urban watercourses in the range associated with acute toxicity in laboratory experiments (EC 2001).

The BSID results demonstrate that nitrites (47%) and phosphorus concentrations (57%) are an impact on stream miles with very poor to poor biological conditions in the Port Tobacco River watershed. But none of the stressors (dissolved oxygen, pH) known to be associated with nutrient over-enrichment were identified in the BSID analysis; nutrients in excess are not a direct causal pathway of biological impairment. Due to anthropogenic sources, the watershed is vulnerable to nutrient fluxes (e.g., stormwater) that could be detrimental to the biological community; therefore additional analysis of available data may be necessary.

The BSID analysis results suggest that degraded biological communities in the Port Tobacco River watershed are a result of increased urban land uses causing alteration to hydrology, increased sedimentation, loss of available habitat, and increased inorganic pollutants resulting in an unstable stream ecosystem with degraded biological communities. Alterations to the hydrologic regime, physical habitat, and water chemistry have all combined to degrade the Port Tobacco River watershed, leading to a loss of diversity in the biological community.

The combined AR is used to measure the extent of stressor impact of degraded stream miles with poor to very poor biological conditions. The combined AR for all the stressors is approximately 88%, suggesting that the stressors identified in the BSID analysis would account for a substantial portion of the degraded stream miles within the Port Tobacco River watershed (Table 7).

The BSID analysis evaluates numerous key stressors using the most comprehensive data sets available that meet the requirements outlined in the methodology report. It is important to recognize that stressors could act independently or act as part of a complex causal scenario (e.g., eutrophication, urbanization, habitat modification). Also, uncertainties in the analysis could arise from the absence of unknown key stressors and other limitations of the principal data set. The results are based on the best available data at the time of evaluation.

4.2 Final Causal Model

Causal model development provides a visual linkage between biological condition, habitat, chemical, and source parameters available for stressor analysis. Models were developed to represent the ecologically plausible processes when considering the following five factors affecting biological integrity: biological interaction, flow regime, energy source, water chemistry, and physical habitat (Karr 1991; USEPA 2015). The five factors guide the selections of available parameters applied in the BSID analyses and are used to reveal patterns of complex causal scenarios. Figure 6 illustrates the final casual model for the Port Tobacco River watershed, with pathways bolded or highlighted to show the watershed's probable stressors as indicated by the BSID analysis.

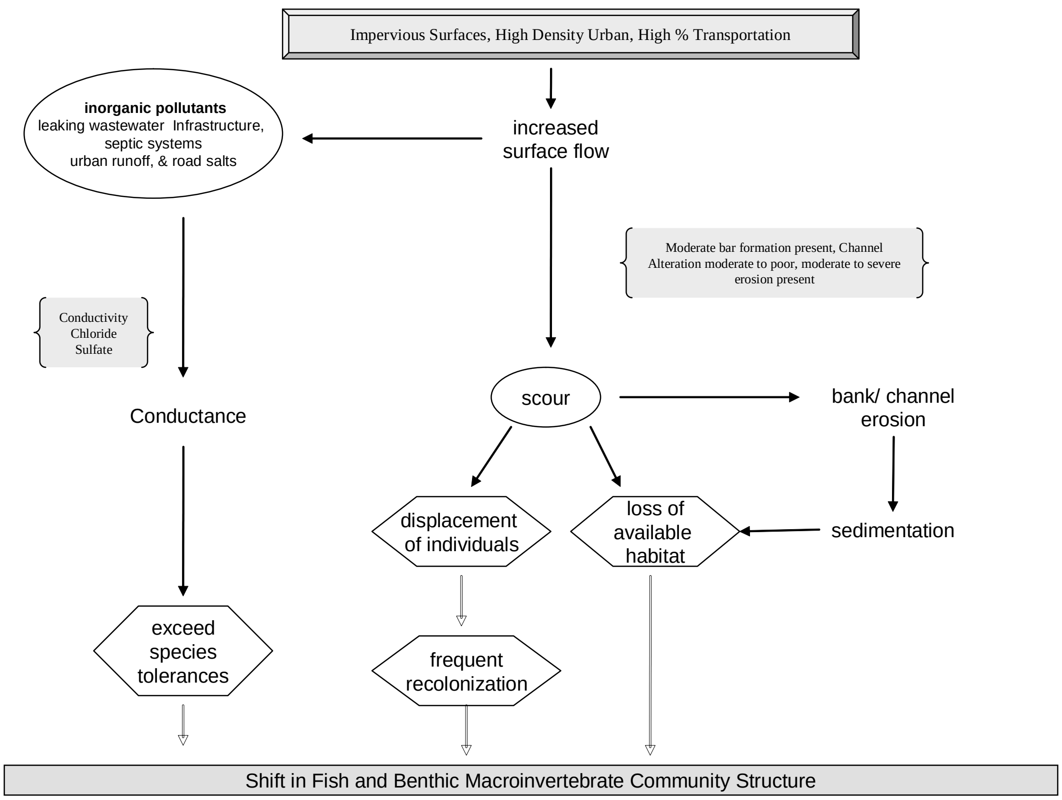

Figure 6. Final Causal Model for the Port Tobacco River Watershed

5.0 Conclusion

Data suggest that the Port Tobacco River watershed's biological communities are strongly influenced by urban land use, which alters the hydrologic regime resulting in increased sediment, inorganics, and nutrient pollutant loading. There is an abundance of scientific research that directly and indirectly links degradation of the aquatic health of streams to urban landscapes, which often cause flashy hydrology in streams and increased contaminant loads from runoff. Based upon the results of the BSID process, the probable causes and sources of the biological impairments of the Port Tobacco River watershed are summarized as follows:

- The BSID process has determined that biological communities in the Port Tobacco River watershed are likely degraded due to sediment related stressors. Specifically, natural sediment conditions exacerbated by anthropogenic sources in the Coastal Plain physiographic region have resulted in altered habitat heterogeneity and subsequent elevated suspended sediment in the watershed, which are in turn the probable causes of impacts to biological communities. The BSID results thus confirm the establishment of sediment TMDL in 2010 through the Chesapeake Bay TMDL was an appropriate management action to begin mitigating the impacts of sediment to the biological communities in the Port Tobacco River watershed. The BSID results also confirms the 1996 (tidal) Category 5 listing for sediment as an impairing substance in the Port Tobacco River watershed, and links this pollutant to biological conditions in these waters, and extend the impairment to the watershed's non-tidal waters. The BSID results thus support a Category 5 listing of sediment for the non-tidal portion of the 8-digit watershed as an appropriate management action to begin addressing these stressor's impacts on the biological communities in the Port Tobacco River watershed.

- The BSID process has determined that the biological communities in the Port Tobacco River watershed are likely degraded due to inorganics (i.e., chlorides, sulfates, and conductivity). Chlorides, sulfates, and conductivity levels are significantly associated with degraded biological conditions and found, respectively, in approximately 42%, 42%, and 61% of the stream miles with poor to very poor biological conditions in the Port Tobacco River watershed. The BSID results thus support a Category 5 listing of chlorides and sulfates as impairing substances of the non-tidal portion of the 8-digit watershed Port Tobacco River as an appropriate management action to begin addressing the impact of these stressors on the biological communities in the Port Tobacco River watershed. Impervious surfaces and urban runoff cause an increase in contaminant loads from point and nonpoint sources by delivering an array of inorganic pollutants to surface waters. Discharges of inorganic compounds are very intermittent; concentrations vary widely depending on the time of year as well as a variety of other factors may influence their impact on aquatic life. Future monitoring of these parameters will help in determining the spatial and temporal extent of these impairments in the watershed.

- The BSID process has determined that nutrients, specifically nitrites and total phosphorus, are associated with degradation of biological communities in the Port Tobacco River. The BSID analysis uses a case-control, risk-based approach to systematically and objectively determine the predominant cause(s) and source of degraded biological conditions. Currently, there is no scientific consensus on numeric nutrient criteria for non-tidal streams (ICPRB 2011). Nutrients in excess do not act directly as pollutants in aquatic systems but, rather, manifest their negative effects via changes in chemical and biological metrics. For this reason, numeric thresholds or ranges of nutrient concentrations should not, by themselves, be used to list non-tidal stream segments as impaired by nutrients (Category 5). Maryland has thus taken an alternative, multi-faceted 'causal pathway' approach. Under this approach, a stream segment may be listed as impaired by nutrients only when poor biological conditions are demonstrated (via low Indices of Biotic Integrity or IBIs) in conjunction with (1) high nutrient concentrations, and (2) one or more of the following stressors known to be associated with nutrient over-enrichment and having scientifically defensible regulatory limits: (a) Low dissolved oxygen (DO) concentrations; (b) low or high DO saturation; (c) high pH. Since none of the stressors known to be associated with nutrient over enrichment were identified in the BSID analysis, a Category 5 listing for nutrients is not recommended for Port Tobacco River. In the absence of a firm causal pathway as described above, concluding that Port Tobacco River is impaired by nutrients could result in unnecessary planning and pollution control implementation costs.

References

Allan, J. D., and M. M. Castillo. 1995. *Stream Ecology: Structure and Function of Running Waters*. Norwell, MA: Kluwer Academic Publishers.

Chiandani, G. and M. Vighi. 1974. The N:P Ratio and Tests with *Selanastrum* to Predict Eutrophication in Lakes. *Water Research*, Vol. 8, pp. 1063-1069.

Church, P., and P. Friesz. 1993. *Effectiveness of Highway Drainage Systems in preventing Road-Salt Contamination of Groundwater: Preliminary Findings*. Transportation Research Board. Transportation Research Record 1420.

COMAR (Code of Maryland Regulations). 2015a. 26.08.02.02. http://www.dsd.state.md.us/comar/26/26.08.02.02.htm (Accessed May, 2015).

______________. 2015b. *26.08.02.08 (N), (2), (a), (c).* http://www.dsd.state.md.us/comar/26/26.08.02.08.htm (Accessed May, 2015).

Cooper, C. M. 1993. Biological effects of agriculturally derived surface water pollutants on aquatic systems—a review. *Journal on Environmental Quality* 22: 402–8.

Delong, M. D., and M. A. Brusven. 1994. Allochthonous Input of Organic Matter from Different Riparian Habitats of an Agriculturally Impacted Stream. *Environmental Management* 18 (1): 59-71.

Doull, John, Curtis D. Klaassen, and Mary O. Amdur, eds. *Casarett and Doull's Toxicology*. New York: Macmillan Publishing Co., Inc., 1980.

EC (Environmental Canada). 2001. 1999 Canadian Environmental Protection Act: Priority Substances List Assessment Report, Road Salts. Available at http://www.hc-sc.gc.ca/ewh-semt/alt_formats/hecs-sesc/pdf/pubs/contaminants/psl2-lsp2/road_salt_sels_voirie/road_salt_sels_voirie-eng.pdf (Accessed May, 2015).

Forman, R. T. T., and R. D. Deblinger. 2000. The Ecological Road-Effect Zone of a Massachusetts (U.S.A) Suburban Highway. *Conservation Biology* 14(1): 36-46

Hill, A. B. 1965. *The Environment and Disease: Association or Causation?* Proceedings of the Royal Society of Medicine, 58: 295-300.

IDNR (Iowa Department of Natural Resources). 2009. *Iowa's Water Quality Standard Review –Total Dissolved Solids (TDS).* http://www.iowadnr.gov/portals/idnr/uploads/water/standards/ws_review.pdf

(Accessed May, 2015).

ICPRB (Interstate Commission on the Potomac River Basin). 2011. *Data Analysis to Support Development of Nutrient Crtiteris for Maryland Free-Flowing Waters*. http://www.potomacriver.org/cms/publicationspdf/ICPRB11-02.pdf (Accessed May 2015).

Karr, J. R. 1991. *Biological integrity - A long-neglected aspect of water resource management*. Ecological Applications. 1: 66-84.

Lewis, W. M. Jr. and D. P. Morris. 1986. Toxicity of Nitrate to Fish: A Review. *Transactions of the American Fisheries Society* 115: 183-195.

Mantel, N., and W. Haenszel. 1959. Statistical aspects of the analysis of data from retrospective studies of disease. *Journal of the National Cancer Institute* 22: 719-748.

MAPSS (Mid-Atlantic Association of Professional Soil Scientists. 2006. Pedologue Newsletter Spring 2006. Available at http://sawgal.umd.edu/mapss/ (Accessed May, 2015).

MDE **(**Maryland Department of the Environment). 2012. *Final Integrated Report of Surface Water Quality in Maryland*. Baltimore, MD: Maryland Department of the Environment. Also Available at http://www.mde.maryland.gov/programs/Water/TMDL/Integrated303dReports/Documents/Integrated_Report_Section_PDFs/IR_2012/MD_Final_2012_IR_Parts_A-E.pdf (Accessed May, 2015).

_________. 2014. *2009 Maryland Biological Stressor Identification Process.* Baltimore, MD: Maryland Department of the Environment. Available at http://www.mde.state.md.us/programs/Water/TMDL/Documents/www.mde.state.md.us/assets/document/BSID_Methodology_Final.pdf (Accessed May, 2015).

_________. 2006. *Port Tobacco River Watershed Characterization*. Baltimore, MD: Maryland Department of the Environment. Available at http://www.dnr.state.md.us/irc/docs/00012411.pdf (Accessed May, 2015).

_________. 1999. *Total Maximum Daily Loads of Nitrogen and Phosphorous for the Port Tobacco River Watershed.* Baltimore, MD: Maryland Department of the Environment. Available at http://www.mde.maryland.gov/assets/document/tmdl/porttobacco/pt_tmdl_fin.PDF (Accessed May, 2015).

MGS (Maryland Geological Survey). 2007. *A Brief Description of the Geology of*

Maryland. http://www.mgs.md.gov/esic/brochures/mdgeology.html (Accessed May, 2015).

NRC (National Research Council). 2008. *Urban Stormwater Management in the United States*. Committee on Reducing Stormwater Discharge Contributions to Water Pollution. Water Science and Technology Board. Division on Earth and Life Studies. National Research Council of the National Academies. Washington, D.C. Available at http://www.epa.gov/npdes/pubs/nrc_stormwaterreport.pdf (Accessed May, 2015).

Quinn J.M. 2000. *Effects of pastoral development*. In New Zealand Stream Invertebrates:Ecology and Implications for Management, ed. KJ Collier,MJWinterbourn, pp. 208–29. Christchurch, NZ: Caxton

Smith, R. A., R. B. Alexander, and M. G. Wolman. 1987. *Water Quality Trends in the Nation's Rivers*. Science. 235:1607-1615.

Southerland, M. T., G. M. Rogers, R. J. Kline, R. P. Morgan, D. M. Boward, P. F. Kazyak, R. J. Klauda and S. A. Stranko. 2005a. *New biological indicators to better assess the condition of Maryland Streams.* Columbia, MD: Versar, Inc. with Maryland Department of Natural Resources, Monitoring and Non-Tidal Assessment Division. CBWP-MANTA-EA-05-13. http://www.dnr.state.md.us/streams/pubs/ea-05-13_new_ibi.pdf (Accessed May, 2015).

Southerland, M. T., L. Erb, G. M. Rogers, R. P. Morgan, K. Eshleman, M. Kline, K. Kline, S. A. Stranko, P. F. Kazyak, J. Kilian, J. Ladell, and J. Thompson. 2005b. *Maryland Biological Stream Survey 2000 – 2004 Volume XIV: Stressors Affecting Maryland Streams.* Columbia, MD: Versar, Inc. with Maryland Department of Natural Resources, Monitoring and Non-Tidal Assessment Division. CBWP-MANTA-EA-05-11. http://www.dnr.state.md.us/streams/pubs/ea05-11_stressors.pdf (Accessed Accessed May, 2015).

USEPA (United States Environmental Protection Agency). 2015. *The Causal Analysis/Diagnosis Decision Information System.* http://www.epa.gov/caddis (Accessed May, 2015).

__________. 2010. Chesapeake Bay Phase 5 Community Watershed Model. Annapolis MD:Chesapeake Bay Program Office. In Preparation EPA XXX-X-XX-008 February 2010. http://www.chesapeakebay.net/model_phase5.aspx?menuitem=26169 (Accessed May, 2015).

Van Sickle, J., and Paulson, S.G. 2008. *Assessing the attributable risks, relative risks, and regional extents of aqautic stressors*. Journal of the North American Benthological Society 27: 920-931.

Wang, L., D. M. Robertson, and P. J. Garrison. 2006. Linkages Between Nutrients and Assemblages of Macroinvertebrates and Fish in Wadeable Streams: Implication to Nutrient Criteria Development. *Environmental Management* 39: 194-212.

Wang, L., J. Lyons, P. Kanehl, and R. Bannerman. 2001. Impacts of Urbanization on Stream Habitat and Across Multiple Spatial Scales. *Environmental Management* 28(2): 255-266.

Weibel, S. R. 1969. Urban drainage as a factor in eutrophication. In *Eutrophication: causes, consequences, corrections.* Washington, DC: National Academy of Sciences.

Wegner, W., and M. Yaggi. 2001. *Environmental Impacts of Road Salt and Alternatives in the New York City Watershed.* Stormwater: The Journal for Surface Water Quality Professionals. Available at http://www.newyorkwater.org/downloadedArticles/ENVIRONMENTANIMPACT.cfm (Accessed May, 2015).