Watershed Report for Biological Impairment of the Mattawoman Watershed in Charles and Prince George's Counties, Maryland Biological Stressor Identification Analysis Results and Interpretation

FINAL

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List of Abbreviations

ANC	Acid Neutralizing Capacity
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
MATTF	Mattawoman Tidal Fresh
MBSS	Maryland Biological Stream Survey
MDDNR	Maryland Department of Natural Resources
MDE	Maryland Department of the Environment
mg/L	Milligrams per liter
MSSCS	Maryland's Synoptic Stream Chemistry Survey
NADP	National Atmospheric Deposition Program
NOx	Nitrous Oxides
SO_2	Sulfur Dioxide
SSA	Science Services Administration
TMDL	Total Maximum Daily Load
µeg/L	Micro-equivalents per liter
µS/cm	Micro Siemens per centimeter
USEPA	United States Environmental Protection Agency
WQA	Water Quality Analysis
WQLS	Water Quality Limited Segment

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 Mattawoman Creek watershed (basin code 02140111), located in Charles and Prince George's Counties, is associated with two assessment units in the Integrated Report: non-tidal (8-digit basin) and an estuarine portion, which is part of the Mattawoman Creek Tidal Fresh Chesapeake Bay segment (MATTF). Below is a table identifying the listings associated with this watershed.

Table E1. 2012 Integrated Report Listings for Mattawoman Creek Watershed

Watershed	Basin Code	Non-tidal/Tidal	Designated Use	Year listed	Identified Pollutant	Listing Category
Mattawoman Creek	02140111	Non-tidal	Aquatic Life and Wildlife	2002	Impacts to Biological Communities	5
Mattawoman Creek Tidal Fresh	MATTF	Tidal	Fishing	-	PCBs in Fish Tissue	2
					Mercury in Fish Tissue	2
			Aquatic Life and Wildlife	-	Estuarine Bioassessments	3
			Seasonal Migratory Fish spawning and nursery Subcategory	1996	TN	4a
				1996	TP	4a
			Open-Water Fish and Shellfish	1996	TP	4a
				1996	TN	4a
			Seasonal Shallow-Water Submerged Aquatic Vegetation	-	TSS	2
Myrtle Grove Lake	021401110 782	Impoundment	Aquatic Life and Wildlife	-	TP	3
			Fishing	-	Mercury in Fish Tissue	2

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 on 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 Mattawoman Creek watershed is Use I – *water contact recreation, and protection of nontidal warmwater aquatic life.* The Mattawoman Tidal Fresh (MATTF) portion of the watershed, which includes up to: Cornwallis Neck, 0.25 miles NW of Deep Pt., Stump Neck, E of radio towers and W of Roach Rd., and 2,300 feet downstream of Routes 224/225 are designated as Use II - *support of estuarine and marine aquatic life and shellfish harvesting (*COMAR 2012a,b*).* The Mattawoman Creek watershed is not attaining its Use I designation because of biological impairments. 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 this stressor has 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 Mattawoman Creek 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 2009). Data suggest that acidity is the probable cause of biological community degradation in the Mattawoman Creek watershed. Low pH and low acid neutralizing capacity of streams in the watershed result from anthropogenic sources (atmospheric deposition) and natural conditions (geology and soils). Peer-reviewed scientific literature establishes a link between acidity and degradation 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 Mattawoman Creek watershed can be summarized as follows:

- The BSID process has determined that the biological communities in the Mattawoman Creek watershed are likely degraded due to acidity related stressors. Acidity is indicated directly by the strong association between low pH and low Acid Neutralizing Capacity (ANC) and biologically impaired sites in this watershed. Mattawoman Creek watershed experiences localized acidity caused by atmospheric deposition and natural conditions in areas where the geology has little buffering capacity. The BSID results thus support a Category 5 listing of low pH for the 8-digit watershed as an appropriate management action to begin addressing the impacts of these stressors on the biological communities in the Mattawoman Creek watershed.

- The BSID process has also determined that the biological communities in the Mattawoman Creek watershed are likely degraded due to inorganic pollutants (i.e., chlorides). Chloride levels are significantly associated with degraded biological conditions and found in 32% of the stream miles with poor to very poor biological conditions in watershed. Runoff from roads, urban, and agricultural land uses cause an increase in contaminant loads from 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 results thus support a Category 5 listing of chloride for the 8-digit watershed as an appropriate management action to begin addressing the impacts of these stressors on the biological communities in the Mattawoman Creek watershed.

- The BSID analysis did not identify any sediment, in-stream habitat, or riparian habitat stressors present and/or showing a significant association with degraded biological conditions.

- The BSID analysis did not identify any nutrient stressors present and/or nutrient stressors showing a significant association with degraded biological conditions.

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 black water 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, <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 a watershed is not determined to differ significantly from the reference condition, the assessment must have an acceptable precision (i.e., margin of error) before the watershed is listed as meeting water quality standards (Category 1 or 2). If the level of precision is not acceptable, the status of the watershed is listed as inconclusive and subsequent monitoring options are considered (Category 3). If a watershed is still considered impaired but has a TMDL that has been completed or submitted to EPA it will be 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 the round two and three Maryland Department of Natural Resources Maryland Biological Stream Survey (MDDNR MBSS) dataset (2000–2009) 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 Mattawoman Creek watershed, and presents the results and conclusions of a BSID analysis of the watershed.

2.0 Mattawoman Creek Watershed Characterization

2.1 Location

Mattawoman Creek is approximately a thirty mile long coastal-plain tributary to the tidal Potomac River with the confluence at Indian Head, Maryland (see Figure 1). The creek consists of a twenty-three mile non-tidal river flowing through Prince George's and Charles Counties, and a seven mile tidal-freshwater estuary in Charles County. About three-fourths of the 60,300 acre watershed lies in Charles County, with the remainder in Prince George's County immediately to the north. The watershed area is located in the Coastal Plains region of three distinct eco-regions identified in the MDDNR MBSS Index of Biological Integrity (IBI) metrics (Southerland et al. 2005) (see Figure 2).

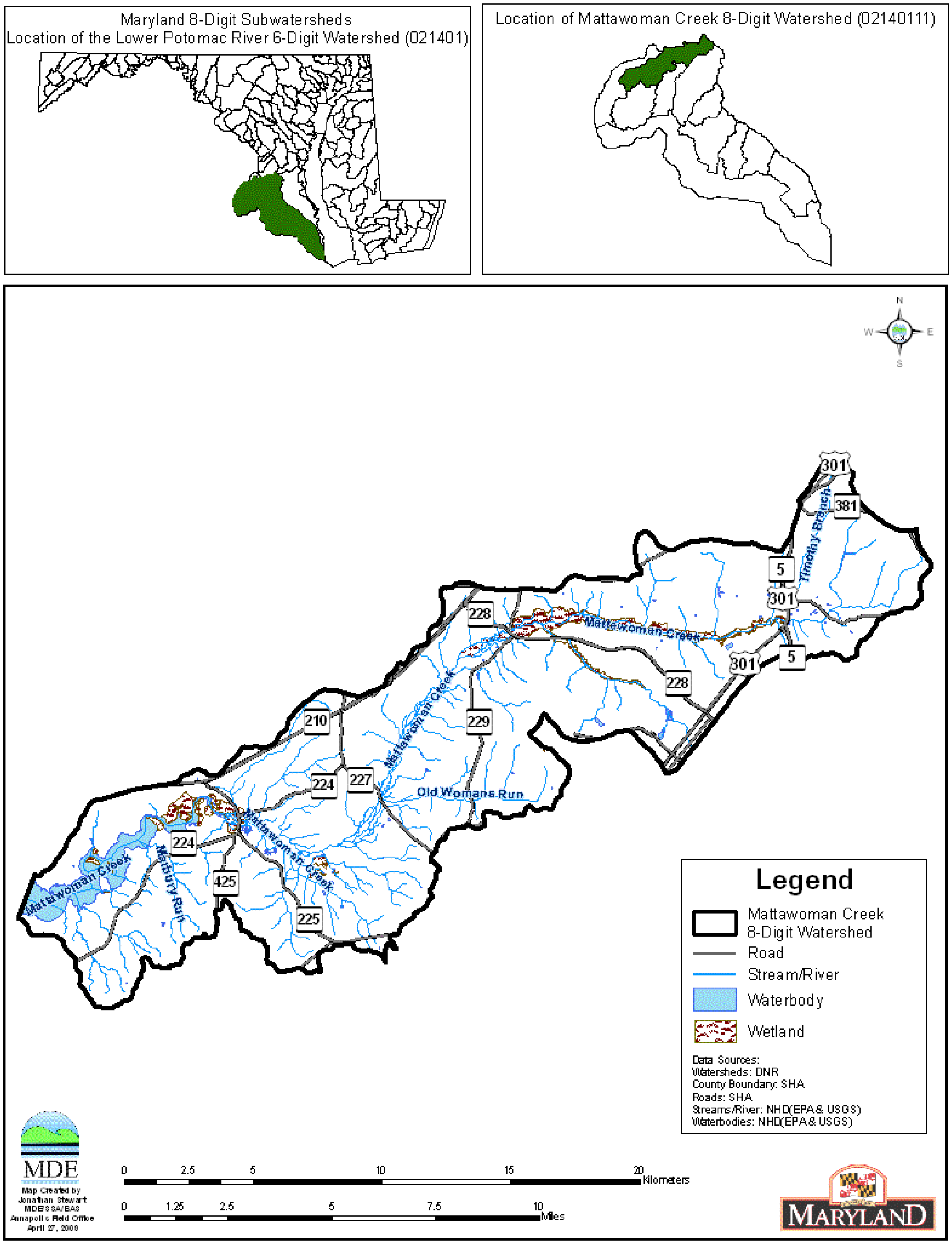

Figure 1. Location Map of the Mattawoman Creek Watershed

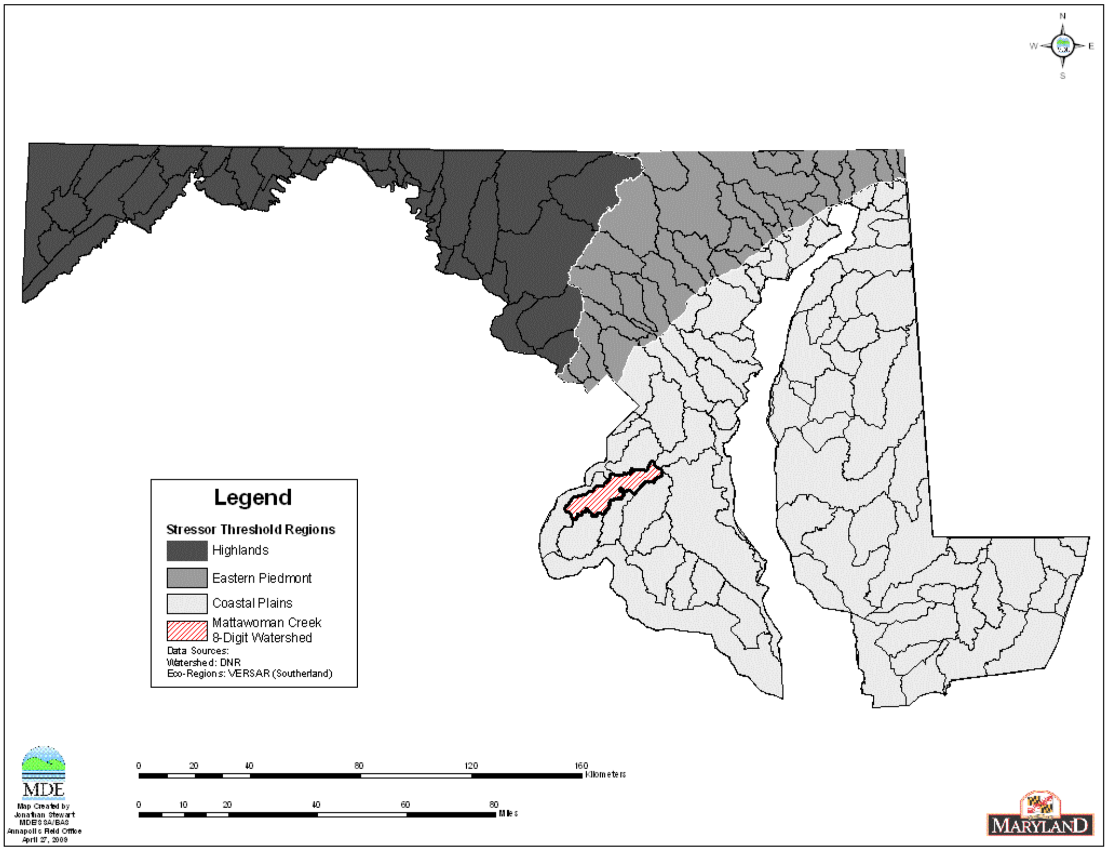

Figure 2. Eco-Region Location Map of the Mattawoman Creek Watershed

2.2 Land Use

The Mattawoman Creek watershed comprises 60,300 acres of drainage area in Charles and Prince George's Counties. Most of the Mattawoman Creek watershed is forested; however the watershed has undergone significant urbanization in recent years (see Figure 3). A vast majority of the watershed is within the Charles County's Development District, and has experienced tremendous growth in terms of population and development over the past 20 years (MDDNR 2012a). The main transportation corridor in the watershed is Maryland-Route 301, which runs the length of the watershed. According to the Chesapeake Bay Program's Phase 5.2 watershed model land use, the land use distribution in the watershed is approximately 31% urban (5% impervious), 63% forested/wetland, and 6% agricultural (USEPA 2010) (see Figure 4).

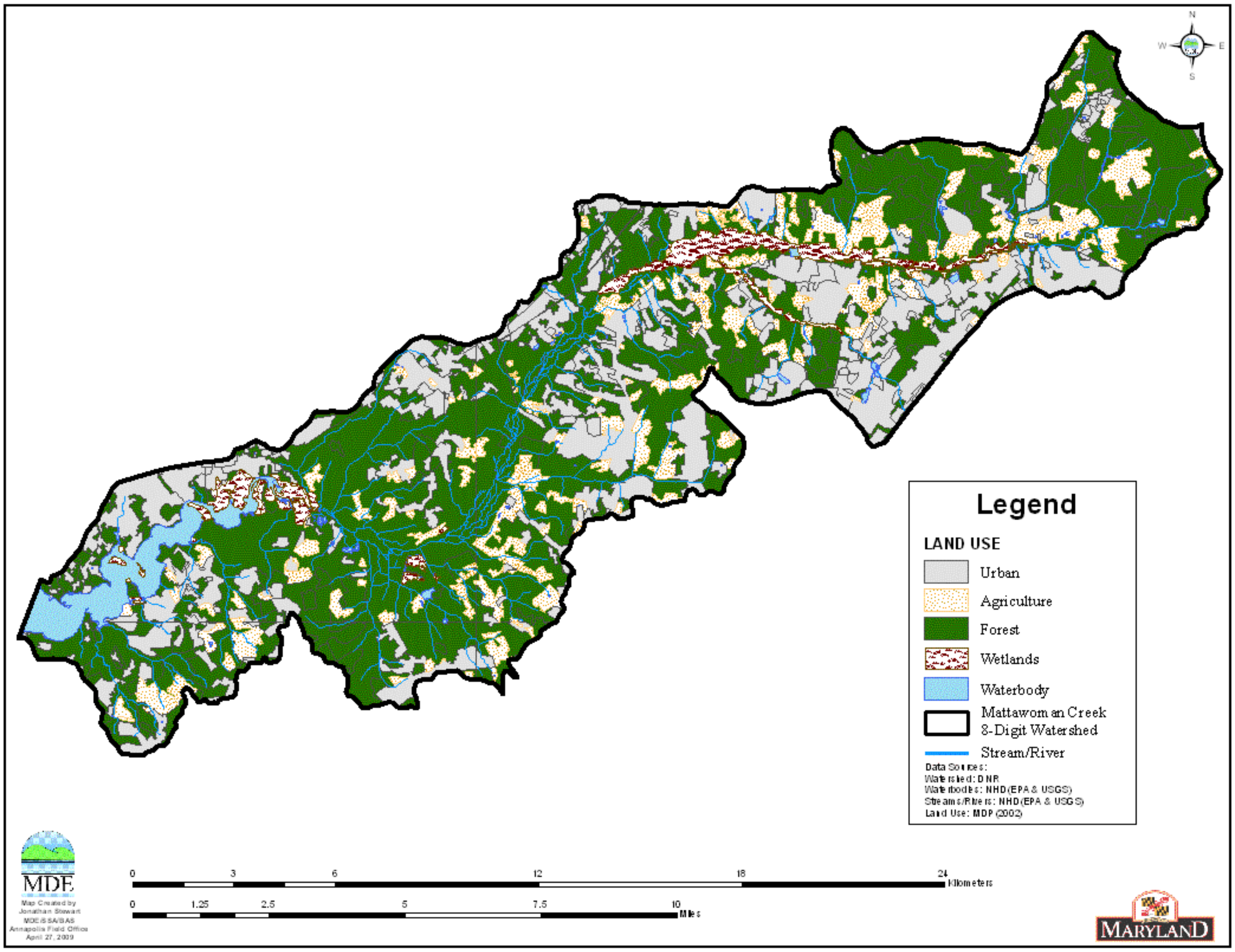

Figure 3. Land Use Map of the Mattawoman Creek Watershed

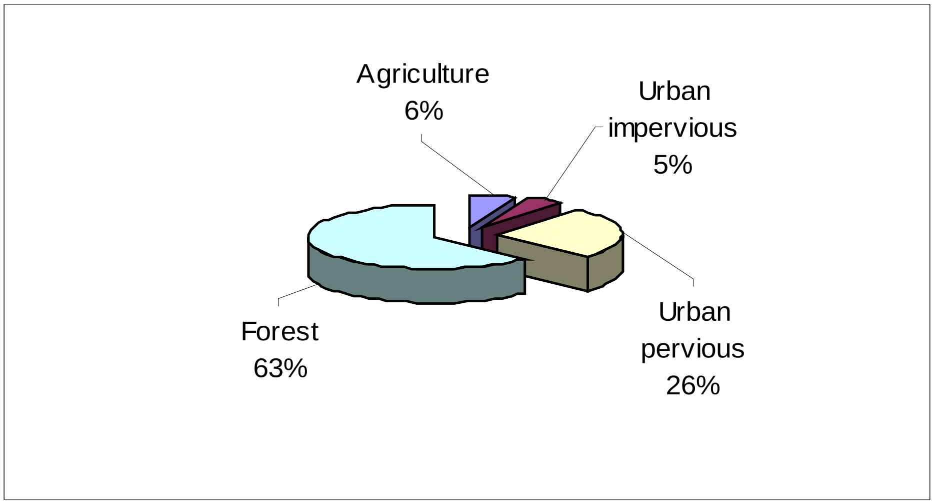

Figure 4. Proportions of Land Use in the Mattawoman Creek Watershed

2.3 Soils/hydrology

The Mattawoman Creek watershed lies in the Coastal Plains physiographic province. The Coastal Plain region is characterized by flat or gently rolling topography and elevations rising from sea level to about 100 feet (MDDNR 2012b). The Coastal Plain Province is underlain by a wedge of unconsolidated sediments including gravel, sand, silt, and clay (MGS 2012).

The soils underlying the watershed are predominantly in the Beltsville series which consists of nearly level to moderately sloping, moderately deep, moderately well drained soils. Soils are strongly acidic and slowly permeable. Beltsville soils are formed in silty and moderately sandy material containing moderate amounts of clay (SCS 1974).

3.0 Mattawoman Creek Watershed Water Quality Characterization

3.1 Integrated Report Impairment Listings

The Mattawoman Creek watershed (basin code 02140111), located in Charles and Prince George's Counties, is associated with two assessment units in the Integrated Report: non-tidal (8-digit basin) and an estuarine portion, which is part of the Mattawoman Creek Tidal Fresh Chesapeake Bay segment (MATTF). Below is a table identifying the listings associated with this watershed.

Table 1. 2012 Integrated Report Listings for Mattawoman Creek Watershed

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<tr><td>Mattawoman Creek</td><td>02140111</td><td>Non-tidal</td><td>Aquatic Life and Wildlife</td><td>2002</td><td>Impacts to Biological Communities</td><td>5</td></tr>
<tr><td rowspan="9">Mattawoman Creek Tidal Fresh</td><td rowspan="9">MATTF</td><td rowspan="9">Tidal</td><td rowspan="2">Fishing</td><td rowspan="2">-</td><td>PCBs in Fish Tissue</td><td>2</td></tr>
<tr><td>Mercury in Fish Tissue</td><td>2</td></tr>
<tr><td>Aquatic Life and Wildlife</td><td>-</td><td>Estuarine Bioassessments</td><td>3</td></tr>
<tr><td rowspan="2">Seasonal Migratory Fish spawning and nursery Subcategory</td><td>1996</td><td>TN</td><td>4a</td></tr>
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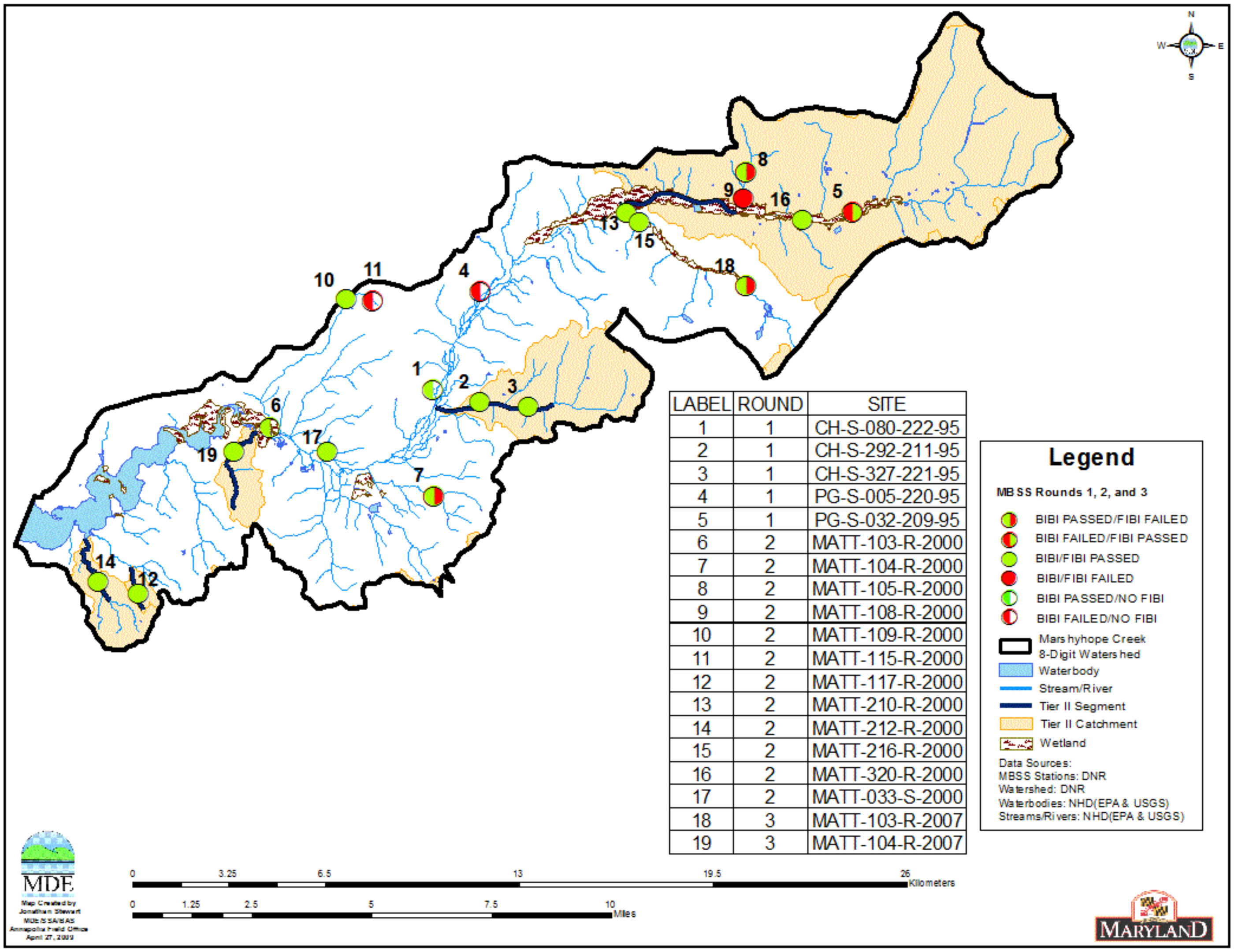
<tr><td>Seasonal Shallow-Water Submerged Aquatic Vegetation</td><td>-</td><td>TSS</td><td>2</td></tr>
<tr><td rowspan="2">Myrtle Grove Lake</td><td rowspan="2">021401110782</td><td rowspan="2">Impoundment</td><td>Aquatic Life and Wildlife</td><td>-</td><td>TP</td><td>3</td></tr>
<tr><td>Fishing</td><td>-</td><td>Mercury in Fish Tissue</td><td>2</td></tr>
</table>

3.2 Biological Impairment

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for the Mattawoman Creek watershed is Use I – *water contact recreation, and protection of nontidal warmwater aquatic life.* The Mattawoman Tidal Fresh portion of the watershed, which includes up to: Cornwallis Neck, 0.25 miles NW of Deep Pt., Stump Neck, E of radio towers and W of Roach Rd., and 2,300 downstream of Rts. 224/225 are designated as Use II - *support of estuarine and marine aquatic life and shellfish harvesting (COMAR 2012a,b).* 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. Designated uses include support of aquatic life; primary or secondary contact recreation, drinking water supply, and shellfish propagation and harvest. 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 Mattawoman Creek watershed is listed under Category 5 of the 2012 Integrated Report as impaired for evidence of biological impacts (MDE 2012). Approximately 36% of stream miles in the Mattawoman Creek watershed are estimated as having benthic and/or fish indices of biological impairment in the poor to very poor category. The biological impairment listing is based on the combined results of MDDNR MBSS round one (1995-1997) and round two (2000-2004) data, which include nineteen stations. Five of the nineteen have benthic and/or fish index of biotic integrity (BIBI, FIBI) scores significantly lower than 3.0 (i.e., poor to very poor).

For the Mattawoman Creek watershed, MDE chose to include all the MBSS data rounds (1995-2009) in the BSID analysis, which contains nineteen MBSS sites with seven having BIBI and/or FIBI scores lower than 3.0. This management decision was made due to the results of the BSID analysis of MBSS round two and three data did not yield an acceptable attributable risk (AR) value for all identified stressors (73% AR). By including the five MBSS round one sites to the BSID analysis, the AR value for all stressors identified was increased to a more acceptable value, which MDE considers would sufficiently account for the biological degradation in the watershed. The BSID analysis and AR calculations will be explained in the next section. Figure 5 illustrates principal dataset (round one, two, and three) site locations for the Mattawoman Creek watershed, and Tier II catchments.



LABEL	ROUND	SITE
1	1	CH-S-080-222-95
2	1	CH-S-292-211-95
3	1	CH-S-327-221-95
4	1	PG-S-005-220-95
5	1	PG-S-032-209-95
6	2	MATT-103-R-2000
7	2	MATT-104-R-2000
8	2	MATT-105-R-2000
9	2	MATT-108-R-2000
10	2	MATT-109-R-2000
11	2	MATT-115-R-2000
12	2	MATT-117-R-2000
13	2	MATT-210-R-2000
14	2	MATT-212-R-2000
15	2	MATT-216-R-2000
16	2	MATT-320-R-2000
17	2	MATT-033-S-2000
18	3	MATT-103-R-2007
19	3	MATT-104-R-2007

Figure 5. Principal Dataset Sites for the Mattawoman Creek Watershed

4.0 Mattawoman Creek Watershed Stressor Identification Results

The BSID process uses results from the BSID data analysis to evaluate each biologically impaired watershed and determine 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 – 1st and 2nd-4th order), that have fair to 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-Haenzel (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).

The parameters used in the BSID analysis are segregated into five groups: land use sources, and stressors representing sediment, in-stream habitat, riparian habitat, and water chemistry conditions. Through the BSID analysis, MDE identified land use sources and water chemistry parameters significantly associated with degraded fish and/or benthic biological conditions. Parameters identified as representing sources are listed in Table 2. A summary of combined AR values for each source group is shown in Table 3. As shown in Table 4 through Table 6, only parameters from the water chemistry group were identified as possible biological stressors in the Mattawoman Creek 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 Mattawoman Creek 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	19	7	426	0%	6%	1	No	_
	AMD acid source present	19	7	426	0%	0%	1	No	_
	Organic acid source present	19	7	427	0%	5%	1	No	_
Sources - Agricultural	High % of agriculture in watershed	19	7	430	0%	3%	1	No	_
	High % of agriculture in 60m buffer	19	7	430	0%	4%	1	No	_
Sources - Anthropogenic	Low % of forest in watershed	19	7	430	0%	5%	1	No	_
	Low % of wetland in watershed	19	7	430	0%	8%	1	No	_
	Low % of forest in 60m buffer	19	7	430	14%	7%	0.425	No	_
	Low % of wetland in 60m buffer	19	7	430	14%	8%	0.445	No	_
Sources - Impervious	High % of impervious surface in watershed	19	7	430	29%	7%	0.077	Yes	22%
	High % of impervious surface in 60m buffer	19	7	430	43%	10%	0.03	Yes	33%
	High % of roads in watershed	19	7	430	14%	0%	0.016	Yes	14%
	High % of roads in 60m buffer	19	7	430	0%	6%	1	No	_
Sources - Urban	High % of high-intensity developed in watershed	19	7	430	29%	8%	0.117	No	_
	High % of low-intensity developed in watershed	19	7	430	14%	6%	0.351	No	_
	High % of medium-intensity developed in watershed	19	7	430	14%	3%	0.205	No	_
	High % of residential developed in watershed	19	7	430	14%	7%	0.405	No	_
	High % of rural developed in watershed	19	7	430	0%	5%	1	No	_
	High % of high-intensity developed in 60m buffer	19	7	430	14%	7%	0.384	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	19	7	430	29%	6%	0.059	Yes	23%
	High % of medium-intensity developed in 60m buffer	19	7	430	14%	6%	0.34	No	_
	High % of residential developed in 60m buffer	19	7	430	0%	6%	1	No	_
	High % of rural developed in 60m buffer	19	7	430	0%	4%	1	No	_

Table 3. Summary of Combined Attributable Risk Values of the Source Group in the Mattawoman Creek Watershed

Source Group	% of degraded sites associated with specific source group (attributable risk)
Sources - Impervious	53%
Sources - Urban	23%
All Sources	***53%***

4.1 Sources Identified by BSID Analysis

BSID analysis results for the Mattawoman Creek watershed identified various urban land use source parameters that have statistically significant association with a poor to very poor stream biological condition (i.e., removal of stressors would result in improved biological community).

Mattawoman Creek drains the town of Indian Head, Bryans Road, and most of Waldorf, the largest community in Charles County. The watershed remains over 60% forested but impervious surface cover is 5% and increasing annually. Impervious surface cover of

10% is often cited as the threshold for significant degradation of water quality and species diversity in surface waters. Continued loss of forest and increases in impervious cover are anticipated, as most of the watershed in Charles County falls within a designated development district. In regards to the projected growth in the watershed, the Mattawoman Creek Watershed Management Plan authored by the U.S. Army Corps of Engineers notes that “these intense development practices would have severe repercussions on the biological community and would decrease the habitat quality within the estuary” (USACE 2003).

The BSID source analysis (Table 2) identified various urban land uses in the watershed and in the riparian buffer zone as potential sources of the stressors that may be causing negative biological impacts. The combined AR for the source group is approximately 53% (Table 3).

The remainder of this section will discuss the four stressors identified by the BSID analysis (Table 4, 5, and 6) and their link to degraded biological conditions in the watershed.

Table 4. Sediment Biological Stressor Identification Analysis Results for the Mattawoman Creek 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	5	161	20%	21%	1	No	_
	Moderate bar formation present	13	5	160	60%	49%	0.682	No	_
	Channel alteration moderate to poor	15	5	167	40%	62%	0.371	No	_
	Channel alteration poor	15	5	167	20%	26%	1	No	_
	High embeddedness	17	6	195	0%	0%	1	No	_
	Epifaunal substrate marginal to poor	17	6	195	50%	46%	1	No	_
	Epifaunal substrate poor	17	6	195	17%	16%	1	No	_
	Moderate to severe erosion present	13	5	160	0%	43%	0.078	No	_
	Severe erosion present	13	5	160	0%	13%	1	No	_

Table 5. Habitat Biological Stressor Identification Analysis Results for the Mattawoman Creek 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	19	7	212	0%	15%	0.598	No	_
	Concrete/gabion present	17	6	190	0%	2%	1	No	_
	Beaver pond present	17	7	197	14%	5%	0.319	No	_
	Instream habitat structure marginal to poor	17	6	195	17%	40%	0.402	No	_
	Instream habitat structure poor	17	6	195	0%	6%	1	No	_
	Pool/glide/eddy quality marginal to poor	17	6	195	17%	42%	0.39	No	_
	Pool/glide/eddy quality poor	17	6	195	0%	4%	1	No	_
	Riffle/run quality marginal to poor	17	6	195	67%	50%	0.682	No	_
	Riffle/run quality poor	17	6	195	17%	19%	1	No	_
	Velocity/depth diversity marginal to poor	17	6	195	33%	58%	0.238	No	_
	Velocity/depth diversity poor	17	6	195	0%	14%	1	No	_
Riparian Habitat	No riparian buffer	16	5	175	0%	12%	1	No	_
	Low shading	17	6	195	0%	3%	1	No	_

Table 6. Water Chemistry Biological Stressor Identification Analysis Results for the Mattawoman Creek 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	14	5	279	40%	8%	0.063	Yes	32%
	High conductivity	19	7	431	29%	5%	0.051	Yes	23%
	High sulfates	19	7	431	0%	8%	1	No	_
Chemistry - Nutrients	Dissolved oxygen < 5mg/l	17	6	405	17%	14%	1	No	_
	Dissolved oxygen < 6mg/l	17	6	405	50%	22%	0.129	No	_
	Low dissolved oxygen saturation	17	6	405	17%	5%	0.294	No	_
	High dissolved oxygen saturation	17	6	405	0%	6%	1	No	_
	Ammonia acute with salmonid present	14	5	279	0%	0%	1	No	_
	Ammonia acute with salmonid absent	14	5	279	0%	0%	1	No	_
	Ammonia chronic with early life stages present	14	5	279	0%	0%	1	No	_
	Ammonia chronic with early life stages absent	14	5	279	0%	0%	1	No	_
	High nitrites	14	5	279	0%	3%	1	No	_
	High nitrates	19	7	431	0%	6%	1	No	_
	High total nitrogen	14	5	279	0%	6%	1	No	_
	High total phosphorus	14	5	279	0%	9%	1	No	_
	High orthophosphate	14	5	279	0%	5%	1	No	_
Chemistry - pH	Acid neutralizing capacity below chronic level	19	7	431	43%	8%	0.017	Yes	35%
	Low field pH	17	6	406	83%	33%	0.018	Yes	50%
	High field pH	17	6	406	0%	0%	1	No	_
	Low lab pH	19	7	431	71%	35%	0.104	No	_
	High lab pH	19	7	431	0%	0%	1	No	_

Table 7. Summary of Combined Attributable Risk Values of the Stressor Group in the Mattawoman Creek Watershed

Stressor Group	% of degraded sites associated with specific stressor group (attributable risk)
Chemistry - Inorganic	23%
Chemistry - pH	67%
All Chemistry	86%
All Stressors	***86%***

4.2 Stressors Identified by BSID Analysis

<u>Sediment Conditions</u>

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

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

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

<u>Water Chemistry Conditions</u>

BSID analysis results for the Mattawoman Creek watershed identified four water chemistry parameters that have statistically significant association with a poor to very poor stream biological condition (i.e., removal of stressors would result in an improved biological community). These parameters are *high chlorides, high conductivity, low field pH and acid neutralizing capacity (ANC) below chronic level.*

High chlorides concentration was identified as significantly associated with degraded biological conditions and found in approximately 32% of the stream miles with poor to very poor biological conditions in the Mattawoman Creek watershed. Chloride can play a critical role in the elevation of conductivity. Chloride in surface waters can result from both natural and anthropogenic sources, such as run-off containing road de-icing salts, the use of inorganic fertilizers, landfill leachates, septic tank effluents, animal feeds, industrial effluents, irrigation drainage, and seawater intrusion in coastal areas. Smith, Alexander, and Wolman (1987), have identified that, although chloride can originate from natural sources, in urban watersheds road salts (i.e., sodium chloride) can be a likely source of high chloride and conductivity levels.

High conductivity levels were identified as significantly associated with degraded biological conditions and found to impact approximately 23% of the stream miles with poor to very poor biological conditions in the Mattawoman Creek 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. Conductivity can serve as an indicator that a pollution discharge or some other source of inorganic contaminant has entered a stream. Increased levels of inorganic pollutants can be toxic to aquatic organisms and lead to exceedences in species tolerances. 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 and agricultural runoffs (i.e., fertilizers), septic drainage, as well as leaking wastewater infrastructure are typical sources of inorganic compounds.

Elevated concentrations of chloride and conductivity identified by the BSID analysis can also be indicative of urban developed landscapes. Anthropogenic activities associated with urban land uses degrade water quality by causing an increase in contaminant loads from various point and nonpoint sources especially during storm events. These sources can add inorganic pollutants to surface waters at levels potentially toxic to aquatic organisms.

In the Mattawoman Creek watershed, there are several heavily traveled road routes, such as Routes 301, 5, 210 among others, connecting the urban areas of the watershed. Application of road salts in the watershed is a likely source of the chlorides and high conductivity levels. Although chlorides can originate from natural sources, most of the chlorides that enter the environment are associated with the storage and application of road salt (Smith, Alexander, and Wolman 1987). For surface waters associated with roadways or storage facilities, episodes of salinity have been reported during the winter and spring in some urban watercourses in the range associated with acute toxicity in laboratory experiments (EC 2001). 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 meters on each side of four-lane roads. Roads tend to capture and export more stormwater pollutants than other land covers. On-site septic systems and stormwater discharges are quite frequent in the watershed and are also likely sources of elevated concentrations of chloride, sulfates, and conductivity.

Currently in Maryland there are no specific numeric criteria that quantify the impact of chlorides, sulfates, or conductivity 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.

Low field pH levels below 6.5 were identified as significantly associated with degraded biological conditions in Mattawoman Creek watershed, and found to impact approximately 50% of the stream miles with poor to very poor biological conditions. pH is a measure of the acid balance of a stream and uses a logarithmic scale range from 0 to 14, with 7 being neutral. MDDNR MBSS collects pH samples once during the spring, which are analyzed in the laboratory (*pH lab*), and measured once in situ during the summer (*pH field*). Most stream organisms prefer a pH range of 6.5 to 8.5. Low pH may allow concentrations of toxic substances (such as ammonia, nitrite, and aluminum) and dissolved heavy metals (such as copper and zinc) to be mobilized for uptake by aquatic plants and animals. The pH threshold values, at which levels below 6.5 and above 8.5 may indicate biological degradation, are established from state regulations (COMAR 2012c). Some types of plants and animals are able to tolerate acidic waters. Others, however, are acid-sensitive and will be eliminated as the pH declines. Generally, the young of most species are more sensitive to environmental conditions than adults. At pH 5, most fish eggs cannot hatch. At lower pH levels, some adult fish die (USEPA 2013a). Common sources of acidity include mine drainage, atmospheric deposition, runoff from mine tailings, agricultural fertilizers, and natural organic sources.

Low ANC below chronic level was identified as significantly associated with degraded biological conditions in the Mattawoman Creek watershed and found in approximately 35% of the stream miles with poor to very poor biological conditions. ANC is a measure of the capacity of dissolved constituents in the water to react with and neutralize acids. ANC can be used as an index of the sensitivity of surface waters to acidification. The higher the ANC, the more acid a system can assimilate before experiencing a decrease in pH. Repeated additions of acidic materials, like those found in atmospheric deposition, generally cause a decrease in ANC. ANC values less than 50µeq/l are considered to demonstrate chronic (highly sensitive to acidification) exposures for aquatic organisms, and values less than 200 are considered to demonstrate episodic (sensitive to acidification) exposures (Kazyak et al. 2005; Southerland et al. 2007).

The acidity related water chemistry parameters identified by the BSID are indicative of soils and geology with a limited buffering capacity to neutralize acidic compounds entering the stream. Acid from coal mine drainage, atmospheric deposition, and agricultural runoff is deleterious for freshwater streams, rivers, and lakes. Non-tidal streams in the Mattawoman Creek watershed, a region in the Coastal Plains of Maryland with inherently poor buffering capacity in the rocks and soils, are more susceptible to acidification from these and other acid sources than streams in the Piedmont region. The primarily sandy soils in the Mattawoman Creek watershed provide little buffering ability.

The results of the National Atmospheric Deposition Program/National Trends Network indicate that Maryland is in or near the region of most acidic precipitation and receives some of the highest concentrations of sulfate and nitrate deposition in the United States (MDDNR 2010). In 1987, Maryland's Synoptic Stream Chemistry Survey (MSSCS) concluded that approximately one-third of all headwater streams in Maryland are sensitive to acidification or already acidic as a result of atmospheric deposition. The MSSCS estimated that most of the acidic or acid-sensitive streams are located in the Southern Coastal Plains and the Appalachian Plateau (MDDNR 2010). This finding is consistent with the results of several studies conducted during the 1980s in Maryland (Janicki and Greening 1987; Janicki and Cummins 1983; Janicki et al. 1990; MDDNR 2012a). In response to the concern of acidic conditions in the region, a multi-year project was launched in 1987 to test the ability of an automated limestone-slurry doser to neutralize acidic pulses in Mattawoman Creek (Hall et al. 1994; MDDNR 2012a). Since the soils and geology of the Mattawoman Creek watershed has limited buffering capacity, wet and dry acid deposition falling on the landscape will experience minimal neutralization before it runs off into streams resulting in acidic waters.

MDDNR repeated portions of the 1987 MSSCS in 2012, to see if streams in the region are recovering from the detrimental effects of atmospheric deposition. Seven stream sites in the Mattawoman Creek watershed were sampled as part of the 2012 MSSCS. Currently, results of the survey have not been made public.

In 1990 the United States Congress enacted Title IV, part of the Clean Air Act Amendments, which required significant decreases in sulfur dioxide (SO_2) and nitrous oxides (NOx) emissions, major contributors of acid deposition, from fossil fuel-burning power plants. Implementation of Title IV has substantially reduced emissions of SO_2 and NOx, and has also decreased sulfate and inorganic nitrogen deposition in the eastern U.S. Acidity from atmospheric deposition in the eastern United States is demonstrated by National Atmospheric Deposition Program (NADP) monitoring data (NADP 2012). Figure 6 illustrates sulfate deposition over the continental United States over the time period stream data was collected in Maryland to assess biological integrity and diagnose biological impairments (1996-2004). An additional 2008 image is included to illustrate the trend of decreasing atmospheric deposition, presumably caused by implementation of Title IV.

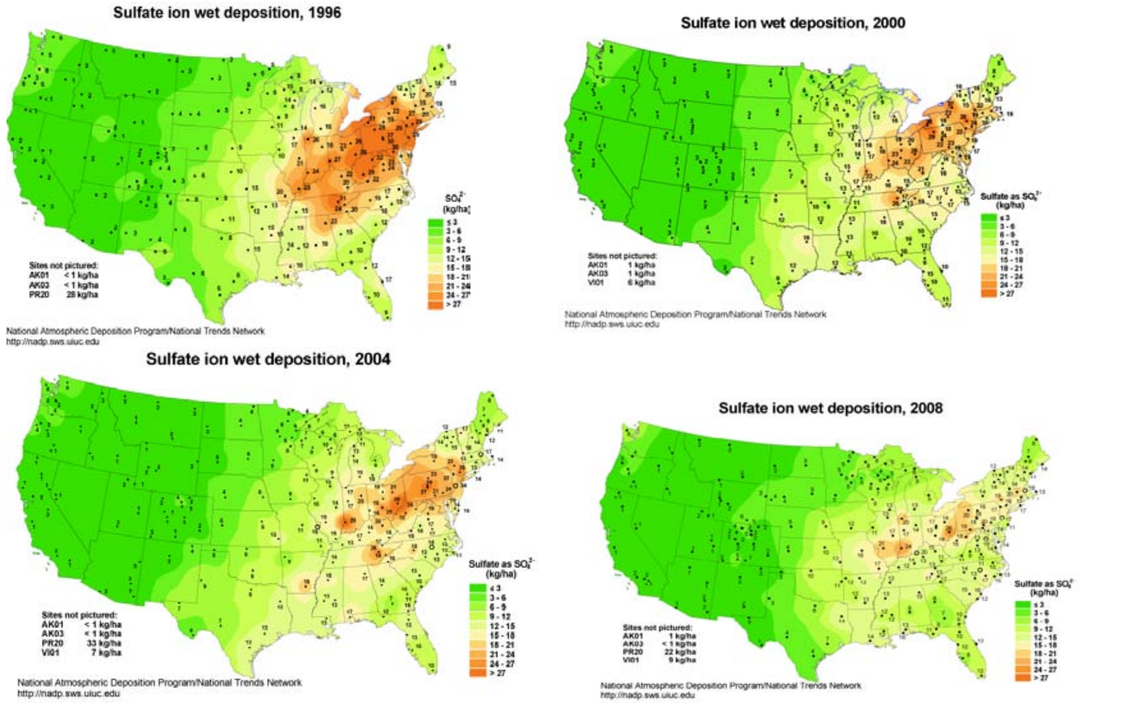


Figure 6. Sulfate Deposition in the Continental United States 1996-2008.

In 2007, the State of Maryland passed the Maryland Healthy Air Act. The first phase requires reductions of NOx emissions by almost 70%, and SO_2 emissions by 80%. In 2012/ 2013 the second phase of emission controls will reduce NOx and SO_2 by another 5%. In 2011, NOx emissions were at approximately 13,000 tons statewide, which represents a decrease of about 60,000 tons (82%) from 2002, prior to the implementation of Maryland's HAA, which were at about 73,000 tons. Maryland's HAA, which imposed stricter emissions standards for electric generating units (EGUs) in Maryland, was supposed to be at full implementation by 2013.

The Mattawoman Creek watershed also has organic inputs causing acidity from natural sources. These acids are derived from the leaching of leaves and wood that fall into streams. Slow moving and poorly-buffered streams, like those in the Mattawoman Creek watershed, are often naturally acidic. Their pH values can fall far below neutral (7.0), but the organic chemicals associated with natural acidity usually prevent the formation of toxic aluminum forms (MDDNR 2012a). In streams where naturally acidic conditions have existed over evolutionary time aquatic communities consist of adaptive and specialized species that can tolerate mildly acidic conditions. However, when natural organic acidity is amplified by atmospheric sources of acidity, even these specialized aquatic communities can be detrimentally affected.

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 the water chemistry stressor group is approximately 86% suggesting these stressors are associated with biological impairments in the Mattawoman Creek (Table 5).

4.3 Discussion of Stressors Identified by BSID Analysis

Assessments made by MDDNR have found "Mattawoman represents as near to ideal conditions as can be found in the northern Chesapeake Bay" and "Mattawoman is the best, most productive tributary in the Bay". The watershed is considered to be a high quality aquatic ecosystem, and supports rare and diverse animal assemblages. Portions of the non-tidal stream system have excellent water quality and biodiversity, including one MDDNR MBSS Sentinel Site, Tier II waters, and stronghold watersheds. The Mattawoman Creek watershed contains stronghold watersheds because there are the stream segments with rare, threatened, or endangered freshwater fish, amphibians, reptiles, or mussel species. Mattawoman Creek is the eighth ranked watershed for freshwater stream biodiversity (of 137 watersheds in Maryland) and is home to six stream species that are referenced within the Rare, Threatened, and Endangered animals of Maryland (MDDNR 2012a).

Mattawoman Creek is considered to be one of the highest quality streams in Maryland: however, the watershed is not without anthropogenic alterations. There is a presence of chemical, physical, and biological stress from increased urbanization within the watershed and region. The presence of major transportation corridors in the watershed have lead to increased loading of inorganic pollutants like chlorides, which can reach potentially toxic levels for aquatic organisms. The BSID analysis also indicates biological communities appear to be affected by acidic deposition and acidic waters (pH less than 6.0). With the inherently poor buffering capacity of the geology as well as natural sources of organic acidity, the non-tidal streams in the watershed are extremely susceptible to acidification from atmospheric deposition. The atmospheric induced acidic conditions of streams in the watershed should continue to improve due to clean air regulations and more stringent emission reduction standards.

The combined AR for all the stressors is approximately 86%, suggesting that water chemistry stressors identified in the BSID analysis would adequately account for the biological impairment in the Mattawoman Creek 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.

4.4 Final Causal Model for the Antietam Creek Watershed

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 2013b). 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 7 illustrates the final causal model for the Mattawoman Creek watershed, with pathways to show the watershed's probable stressors as indicated by the BSID analysis.

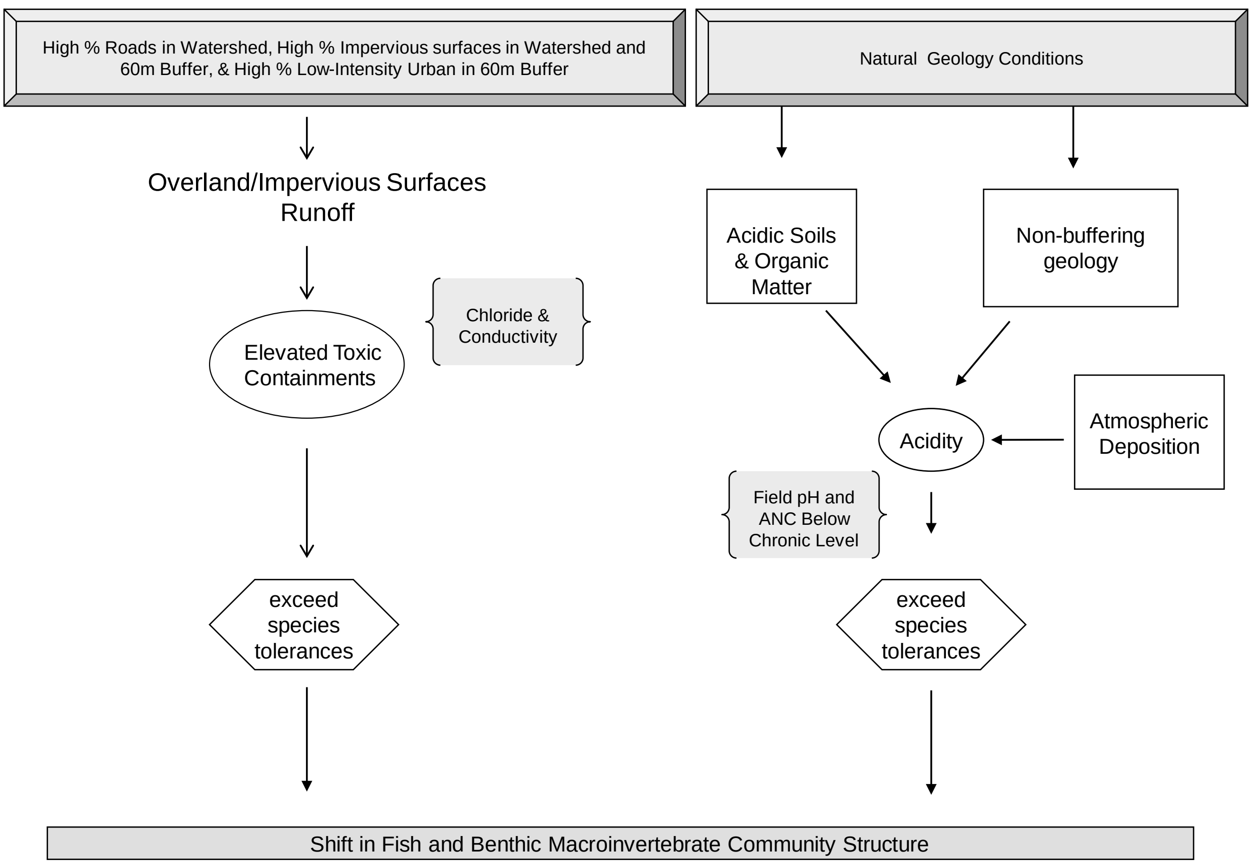


Figure 7. Final Causal Model for the Mattawoman Creek Watershed

5.0 Conclusions

Data suggest that the Mattawoman Creek watershed's biological communities are strongly influenced by the underlying geology and soils, which results in low ANC and increased acidity of surface water. Based upon the results of the BSID analysis, the probable causes of the biological impairments in the Mattawoman Creek watershed are summarized as follows:

- The BSID process has determined that the biological communities in the Mattawoman Creek watershed are likely degraded due to acidity related stressors. Acidity is indicated directly by the strong association between low pH and low Acid Neutralizing Capacity (ANC) and biologically impaired sites in this watershed. Mattawoman Creek watershed experiences localized acidity caused by atmospheric deposition and natural conditions in areas where the geology has little buffering capacity. The BSID results thus support a Category 5 listing of low pH for the 8-digit watershed as an appropriate management action to begin addressing the impacts of these stressors on the biological communities in the Mattawoman Creek watershed.

- The BSID process has also determined that the biological communities in the Mattawoman Creek watershed are likely degraded due to inorganic pollutants (i.e., chlorides). Chloride levels are significantly associated with degraded biological conditions and found in 32% of the stream miles with poor to very poor biological conditions in watershed. Runoff from roads, urban, and agricultural land uses cause an increase in contaminant loads from 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 results thus support a Category 5 listing of chloride for the 8-digit watershed as an appropriate management action to begin addressing the impacts of these stressors on the biological communities in the Mattawoman Creek watershed.

- The BSID analysis did not identify any sediment, in-stream habitat, or riparian habitat stressors present and/or showing a significant association with degraded biological conditions.

- The BSID analysis did not identify any nutrient stressors present and/or nutrient stressors showing a significant association with degraded biological conditions.

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