Watershed Report for Biological Impairment of the Piscataway Creek in Prince George County, Maryland Biological Stressor Identification Analysis Results and Interpretation

FINAL

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List of Abbreviations

AFB	Air Force Base
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
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
PISTF	Piscataway Tidal Fresh
PSU	Primary Sampling Unit
SSA	Science Services Administration
SSO	Sanitary Sewage Overflow
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 Piscataway Creek watershed (basin code 02140203) is located in Prince George's County, MD. It is associated with two assessment units in the Integrated Report (IR): an 8-digit non-tidal basin and a Chesapeake Bay Segment Piscataway Creek Tidal Fresh (PISTF) basin. Below is a table identifying the listings associated with this watershed (MDE 2012).

Table E1. 2012 Integrated Report Listings for the Piscataway Creek Watershed

Watershed	Basin Code	Non-tidal/ Tidal	Designated Use	Year listed	Identified Pollutant	Listing Category
Piscataway Creek	02140203	Non-tidal	Aquatic Life and Wildlife	2004	Impacts to Biological Communities	5
			Water Contact Sports	2002	Escherichia coli	4a
		Piscataway Creek Tidal Fresh (PISTF)	Seasonal Migratory Fish Spawning and Nursery Subcategory	2012	TN	4a
					TP	
			Open-Water Fish and Shellfish Subcategory	1996	TN	4a
					TP	
			Seasonal Shallow-Water Submerged 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 Piscataway Creek watershed's tributary Saint James Run is designated as Use Class I – *Water Contact Recreation, and Protection of Aquatic Life and Public Water Supply* and Use Class II - *Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting* (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 Piscataway Creek 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 Piscataway 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 2014). Data suggest that the degradation of biological communities in the Piscataway Creek 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 (inorganics) 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 Piscataway Creek watershed can be summarized as follows:

- The BSID process has determined that biological communities in the Piscataway Creek watershed are likely degraded due to sediment related stressors. Specifically, altered hydrology and increased runoff from urban landscapes have resulted in increased habitat homogeneity and subsequent elevated suspended sediment in the watershed, which are in turn the probable causes of impacts to biological communities. The BSID results thus support a Category 5 listing of the Piscataway Creek watershed for the non-tidal portion of the 8-digit watershed as an appropriate management action to begin addressing the impacts of these streams on the biological communities in the Piscataway Creek watershed.

- The BSID process has determined that the biological communities in the Piscataway Creek watershed are likely degraded due to inorganics (i.e., chlorides and conductivity). Chlorides and conductivity levels are significantly associated with degraded biological conditions and found, respectively, in approximately 55% and 48% of the stream miles with poor to very poor biological conditions in the Piscataway Creek watershed. The BSID results thus support a Category 5 listing of Piscataway Creek for the non-tidal portion of the 8-digit watershed as an appropriate management action to begin addressing the impact of these stressors on the biological communities in the Piscataway Creek 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.

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 a watershed is classified as impaired (Category 5), then a stressor identification analysis is completed to determine if a TMDL is necessary. A Category 5 listing can be amended to a Category 4a if a TMDL is established and approved by the USEPA.

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 Piscataway Creek watershed, and presents the results and conclusions of a BSID analysis of the watershed.

2.0 Piscataway Creek Watershed Characterization

2.1 Location

The Piscataway Creek watershed is located entirely within Prince George's County, Maryland (see Figure 1). The Piscataway Creek watershed encompasses approximately 43,500 acres (USEPA 2010). Headwaters originate to the west and east of Andrews Air Force Base (AFB) in the vicinity of Camp Springs, Clinton and Woodyard. The base sits atop a north-south drainage divide, in the vicinity of the runways, that separates the Potomac River Basin to the west and the Patuxent River Basin to the east. The area surrounding Andrews AFB to the east is residential, commercial, light and heavy industrial, agricultural and some open land.

On the southwest side of Andrews AFB two branches join to form Tinkers Creek, the major tributary to Piscataway Creek. Surface water runoff flows into Tinkers Creek, to Piscataway Creek, and eventually into the Potomac River. From the southeast of Andrews AFB, the mainstem receives drainage from nearly 1,500 acres of the base and is partially redirected to a man- made lake (Base Lake) on base. The Piscataway Creek mainstem has two named tributaries: Dower House Branch to the northeast and Butler Branch to the southwest. There are several small unnamed tributaries supplying input to Piscataway Creek. The northern region of the Piscataway Creek watershed is the most developed; it is between Andrews AFB and Louise F. Cosca Regional Park.

The southern region comprises the area between Louise F. Cosca Regional Park and Piscataway Creek drainage. The land use to the south is mostly forested, some open and row-crop agricultural land, residential, commercial, and light industrial. Butler Branch (tributary to Piscataway Creek) flows through Louise F. Cosca Regional Park and it forms a lake within the park. To the south the land is more forested and agricultural with the encroachment of rural development. Along Accokeek Road (Route 373) between Dyson Road and Bealle Road there are older homes with septic systems. To the south along Indian Head Highway (Route 210) there is extensive urban development and homes with septic systems (MDE 2006).

The watershed is located in the Coastal Plain region, one of three distinct eco-regions identified in the Maryland Department of Natural Resources Maryland Biological Stream Survey (MDDNR MBSS) Index of Biological Integrity (IBI) metrics (Southerland et al. 2005a) (see Figure 2).

Figure 1. Location Map of the Piscataway Creek Watershed

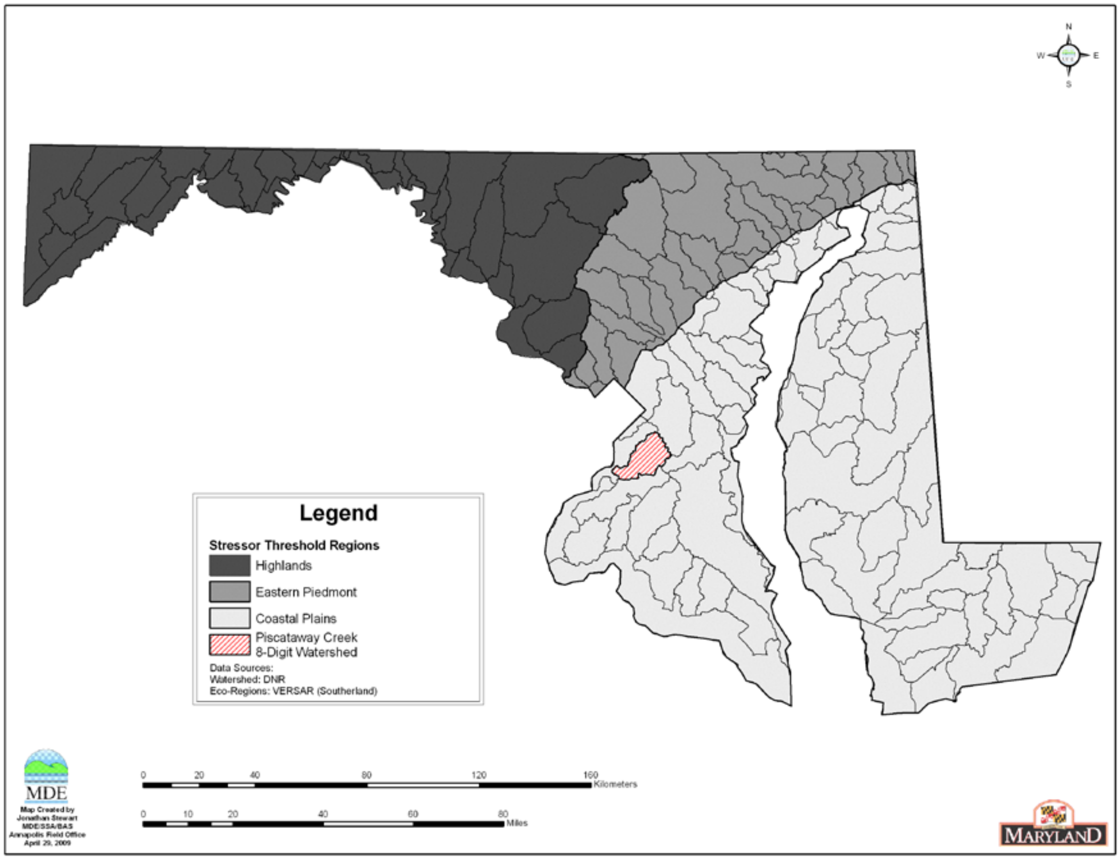

Figure 2. Eco-Region Location Map of the Piscataway Creek Watershed

2.2 Land Use

The non-tidal Piscataway Creek basin has an area of approximately 43,500 acres. There is urban/residential, forest and agricultural land use in the watershed. Park and forest lands include the Fort Washington Forest, Piscataway Creek Park, Tinkers Creek Park and L. F. Cosca Regional Park. Crops and pasture lands are dispersed through the watershed with higher concentration of croplands towards the southwest region of the watershed. The commercial land use is largely confined to the northeast region of the basin south of Andrews AFB (MDE 2006).

The Piscataway Creek watershed has primarily urban land use; forest land use is secondary (see Figure 3). The Phase 5.2 Chesapeake Bay Watershed Model reports the land use distribution in the watershed as approximately 50% urban, 42% forest/herbaceous, and 8% agriculture, (see Figure 4). Urban impervious surface is 9% of the total land use in the watershed (USEPA 2010).

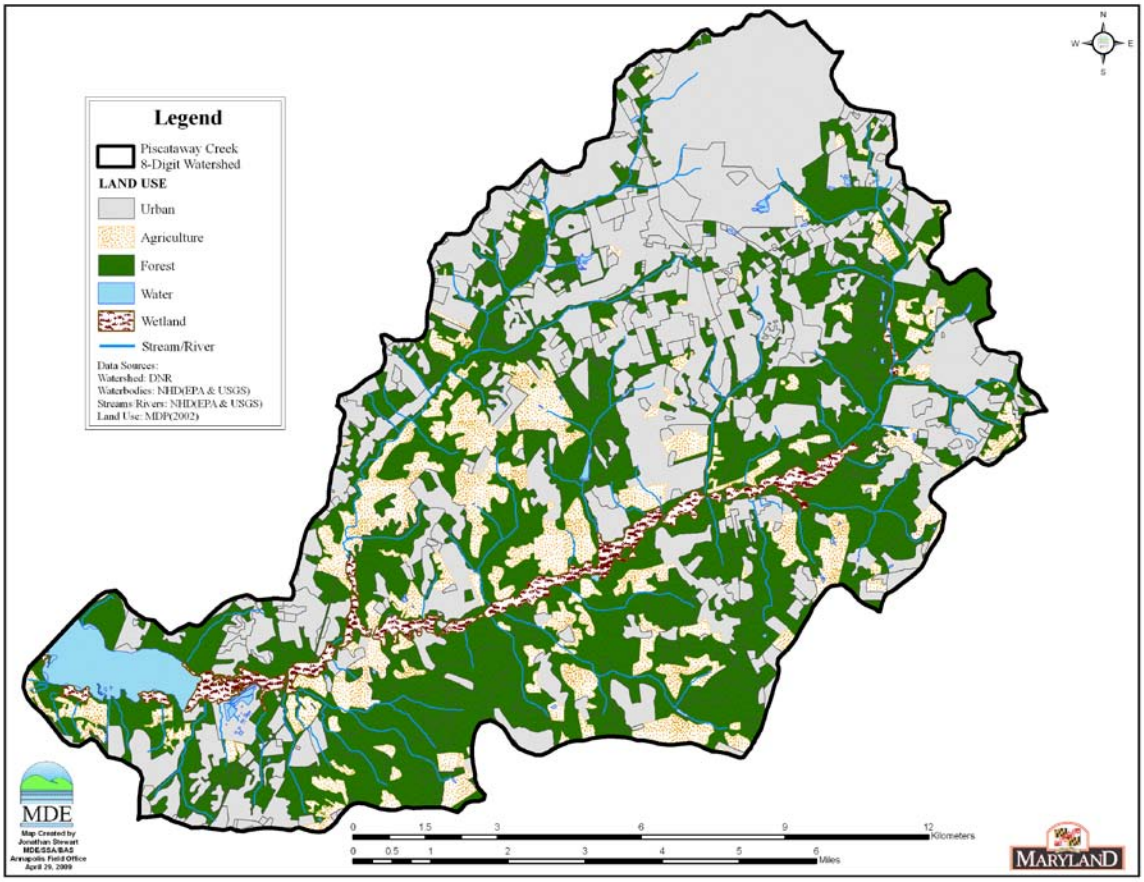

Figure 3. Land Use Map of the Piscataway Creek Watershed

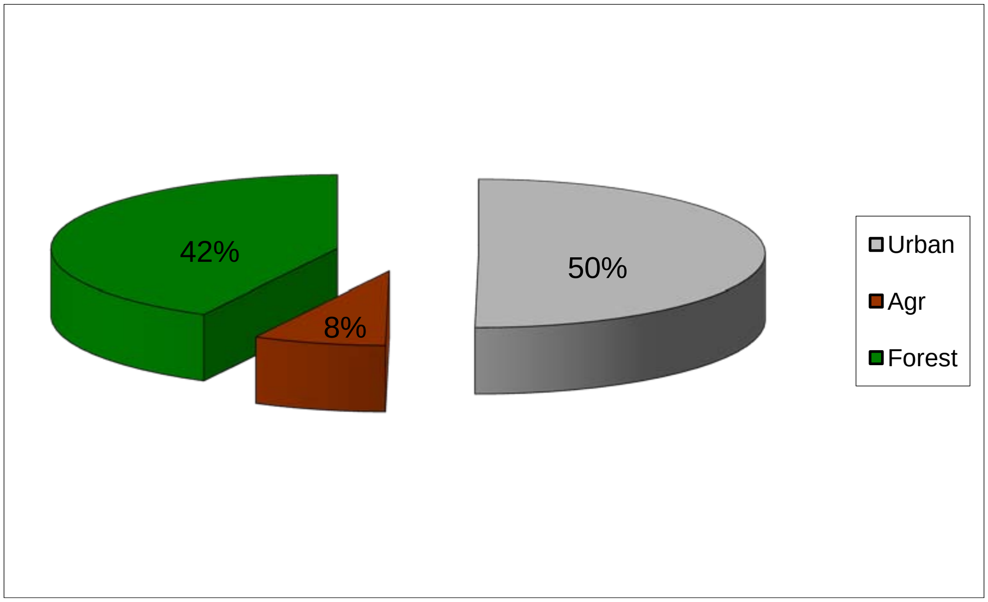

Figure 4. Proportions of Land Use in the Piscataway Creek Watershed

2.3 Soils/hydrology

The Piscataway Creek watershed is in the Coastal Plain Province, draining to the Potomac River. A wedge of unconsolidated sediments including gravel, sand, silt and clay underlies this physiographic province. The topography varies from level to hilly in the watershed, with slopes ranging from sea level to 200 feet. The creek and its tributaries follow a dendritic pattern (a branching tree-like effect). The main source of water in the Coastal Plain is groundwater. Because unconsolidated sediments underlie the region, precipitation usually sinks in easily. The mainstem of the non-tidal Piscataway Creek and its tributaries lie predominantly in the Beltsville series. Beltsville soils are moderately deep, well drained to poorly drained, dominantly gently sloping soils that have a compact subsoil or substratum. A small portion of the watershed at the headwaters of the Creek lies in the Westphalia soil series. The Westphalia soil series are deep, well drained to excessively drained soils of uplands that are mostly moderately sloping to steep (Soil Conservation Service, 1967;MDE 2006).

3.0 Piscataway Creek Watershed Water Quality Characterization

3.1 Integrated Report Impairment Listings

The Maryland Department of the Environment has identified the non-tidal areas of the Piscataway Creek watershed under Category 5 of the State's Integrated Report as impaired for impacts to biological communities (2004 listings). The Piscataway Creek watershed (basin code 021401203) is located in Prince George's County, MD. It is associated with two assessment units in the Integrated Report (IR), an 8-digit non-tidal basin and a Chesapeake Bay Segment Piscataway Creek Tidal Fresh (PISTF) basin. Below is a table identifying the listings associated with this watershed (MDE 2012).

Table 1. 2012 Integrated Report Listings for the Piscataway Creek Watershed

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					TP	
			Seasonal Shallow-Water Submerged Aquatic Vegetation Subcategory		TSS	

3.2 Biological Impairment

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for the Piscataway Creek watershed's tributary Saint James Run is designated as Use Class I – *Water Contact Recreation, and Protection of Aquatic Life and Public Water Supply* and Use Class II - *Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting* (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 Piscataway Creek watershed is listed under Category 5 of the 2012 IR as impaired for impacts to biological communities. Approximately 36% of the Piscataway Creek watershed is estimated as having fish and/or benthic 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), round two (2000-2004), and round 3 (2007-2009) data, which include 22 stations. Eight of the twenty-two 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, i.e. MBSS rounds two and three (2000-2009) contains seventeen sites, of which eleven sites have BIBI and/or FIBI scores lower than 3.0. Figure 5 illustrates principal dataset site locations for the Piscataway Creek watershed.

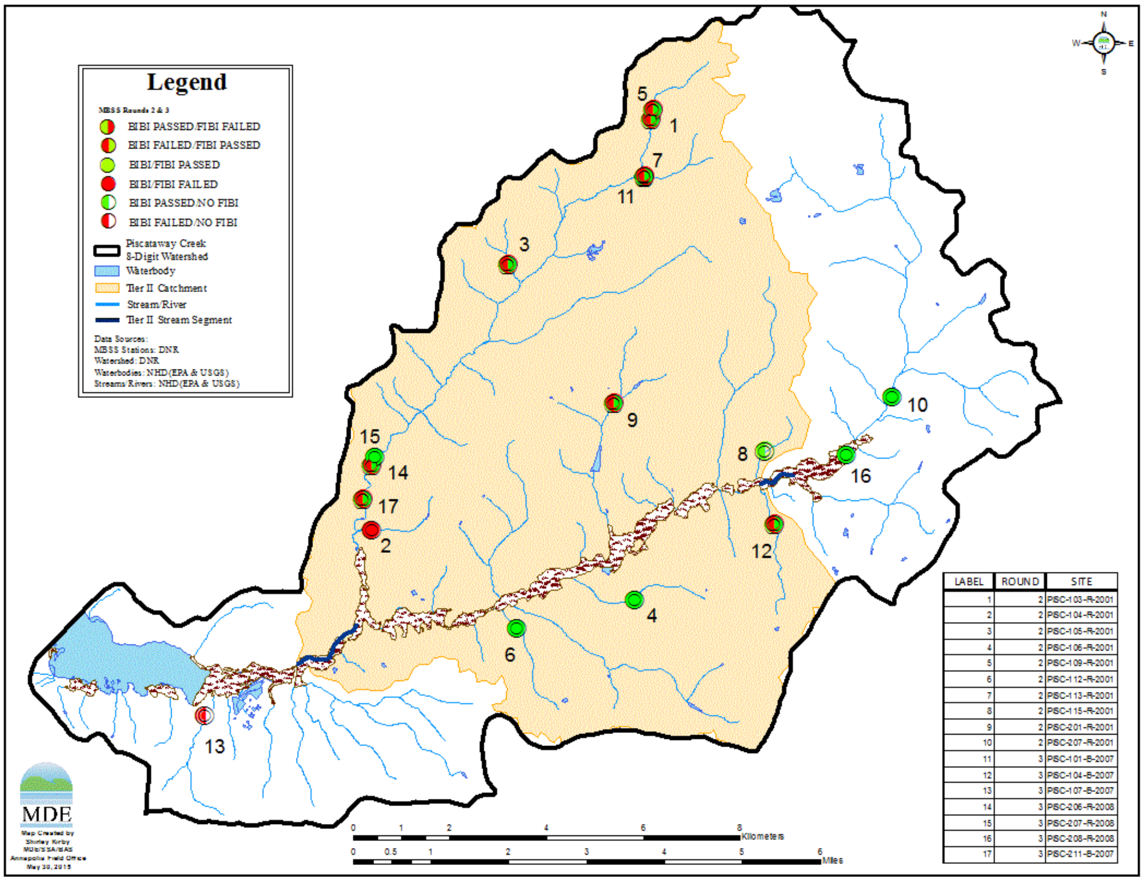

Figure 5. Principal Dataset Sites for the Piscataway Creek Watershed

4.0 Stressor Identification Results for the Piscataway Creek Watershed

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 – 1st and 2nd-4th 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 2014).

Through the BSID data analysis, MDE identified sediment, water chemistry (inorganics), and 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 Piscataway 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 Piscataway 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	17	11	274	0%	7%	1	No	_
	AMD acid source present	17	11	274	0%	0%	1	No	_
	Organic acid source present	17	11	275	0%	7%	1	No	_
Sources - Agricultural	High % of agriculture in watershed	17	11	279	0%	3%	1	No	_
	High % of agriculture in 60m buffer	17	11	279	0%	4%	1	No	_
Sources - Anthropogenic	Low % of forest in watershed	17	11	279	9%	6%	0.532	No	_
	Low % of wetland in watershed	17	11	279	55%	11%	0.001	Yes	44%
	Low % of forest in 60m buffer	17	11	279	0%	8%	1	No	_
	Low % of wetland in 60m buffer	17	11	279	45%	10%	0.005	Yes	35%
Sources - Impervious	High % of impervious surface in watershed	17	11	279	55%	4%	0	Yes	50%
	High % of impervious surface in 60m buffer	17	11	279	27%	5%	0.024	Yes	22%
	High % of roads in watershed	17	11	279	0%	0%	1	No	_
	High % of roads in 60m buffer	17	11	279	0%	5%	1	No	_
Sources - Urban	High % of high-intensity developed in watershed	17	11	279	55%	8%	0	Yes	47%
	High % of low-intensity developed in watershed	17	11	279	73%	6%	0	Yes	66%
	High % of medium-intensity developed in watershed	17	11	279	18%	2%	0.032	Yes	16%
	High % of residential developed in watershed	17	11	279	9%	8%	0.62	No	_
	High % of rural developed in watershed	17	11	279	0%	5%	1	No	_
	High % of high-intensity developed in 60m buffer	17	11	279	18%	6%	0.171	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	17	11	279	55%	5%	0	Yes	50%
	High % of medium-intensity developed in 60m buffer	17	11	279	18%	3%	0.06	Yes	15%
	High % of residential developed in 60m buffer	17	11	279	0%	8%	1	No	_
	High % of rural developed in 60m buffer	17	11	279	0%	5%	1	No	_

Table 3. Summary of Combined Attributable Risk Values for Source Groups in the Piscataway Creek Watershed

Source Group	% of degraded sites associated with specific source group (attributable risk)
Sources - Anthropogenic	53%
Sources - Impervious	59%
Sources - Urban	69%
All Sources	***78%***

4.1 Sources Identified by BSID Analysis

The sources identified by the BSID analysis (Table 2) are the result of anthropogenic impacts and urban development in the watershed, which has significant association with degraded biological conditions in the Piscataway Creek watershed. The watershed is comprised of 50% urban and 42% forest land uses; 9% of the total watershed is impervious surface. The BSID analysis identified several stressor sources including low-, medium-, and high-intensity urban development in the watershed and 60m buffer zone, and impervious surface 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 78%, suggesting that these stressors are a probable cause of the biological impairments in the Piscataway Creek watershed (Table 3).

Table 4. Sediment Biological Stressor Identification Analysis Results for the Piscataway 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	16	10	143	90%	20%	0	Yes	71%
	Moderate bar formation present	16	10	142	90%	49%	0.01	Yes	42%
	Channel alteration moderate to poor	10	6	121	100%	59%	0.045	Yes	41%
	Channel alteration poor	10	6	121	100%	25%	0	Yes	76%
	High embeddedness	16	10	142	0%	0%	1	No	_
	Epifaunal substrate marginal to poor	16	10	142	40%	42%	0.624	No	_
	Epifaunal substrate poor	16	10	142	10%	10%	0.65	No	_
	Moderate to severe erosion present	16	10	142	80%	42%	0.02	Yes	39%
	Severe erosion present	16	10	142	10%	11%	0.67	No	_

Table 5. Habitat Biological Stressor Identification Analysis Results for the Piscataway 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	17	11	154	9%	13%	0.801	No	_
	Concrete/gabion present	13	7	131	0%	2%	1	No	_
	Beaver pond present	16	10	140	0%	7%	1	No	_
	Instream habitat structure marginal to poor	16	10	142	30%	35%	0.708	No	_
	Instream habitat structure poor	16	10	142	0%	5%	1	No	_
	Pool/glide/eddy quality marginal to poor	16	10	142	30%	39%	0.771	No	_
	Pool/glide/eddy quality poor	16	10	142	0%	3%	1	No	_
	Riffle/run quality marginal to poor	16	10	142	40%	49%	0.792	No	_
	Riffle/run quality poor	16	10	142	0%	21%	1	No	_
	Velocity/depth diversity marginal to poor	16	10	142	30%	56%	0.967	No	_
	Velocity/depth diversity poor	16	10	142	0%	13%	1	No	_
Riparian Habitat	No riparian buffer	17	11	154	0%	5%	1	No	_
	Low shading	16	10	142	0%	3%	1	No	_

Table 6. Water Chemistry Biological Stressor Identification Analysis Results for the Piscataway 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	17	11	279	64%	8%	0	Yes	55%
	High conductivity	17	11	279	55%	6%	0	Yes	48%
	High sulfates	17	11	279	18%	8%	0.243	No	_
Chemistry - Nutrients	Dissolved oxygen < 5mg/l	16	10	261	20%	17%	0.542	No	_
	Dissolved oxygen < 6mg/l	16	10	261	20%	25%	0.763	No	_
	Low dissolved oxygen saturation	16	10	261	10%	6%	0.483	No	_
	High dissolved oxygen saturation	16	10	261	10%	3%	0.263	No	_
	Ammonia acute with salmonid present	17	11	279	0%	0%	1	No	_
	Ammonia acute with salmonid absent	17	11	279	0%	0%	1	No	_
	Ammonia chronic with early life stages present	17	11	279	0%	0%	1	No	_
	Ammonia chronic with early life stages absent	17	11	279	0%	0%	1	No	_
	High nitrites	17	11	279	0%	3%	1	No	_
	High nitrates	17	11	279	0%	7%	1	No	_
	High total nitrogen	17	11	279	0%	6%	1	No	_
	High total phosphorus	17	11	279	9%	9%	0.665	No	_
	High orthophosphate	17	11	279	0%	5%	1	No	_
Chemistry - pH	Acid neutralizing capacity below chronic level	17	11	279	0%	9%	1	No	_
	Low field pH	16	10	262	20%	40%	0.955	No	_
	High field pH	16	10	262	0%	1%	1	No	_
	Low lab pH	17	11	279	9%	38%	0.994	No	_
	High lab pH	17	11	279	0%	0%	1	No	_

Table 7. Summary of Combined Attributable Risk Values for Stressor Groups in the Piscataway Creek Watershed

Stressor Group	% of degraded sites associated with specific stressor group (attributable risk)
Sediment	79%
Chemistry - Inorganic	57%
All Chemistry	57%
All Stressors	***87%***

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 Piscataway Creek watershed and are representative of impacts from urban developed landscapes.

Sediment Conditions

BSID analysis results for the Piscataway Creek watershed identified five 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): *extensive bar formation present, moderate bar formation present, channel alteration moderate to poor, channel alteration poor, and moderate to severe erosion present.* (Table 4).

Extensive bar formation present and *moderate bar formation present* were identified as significantly associated with degraded biological conditions and found respectively in 71% and 42% of the stream miles with very poor to poor biological conditions in the Piscataway Creek 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 moderate to poor and *channel alteration poor* were identified as significantly associated with degraded biological conditions and found respectively in 41% and 76% of the stream miles with poor to very poor biological conditions in the

Piscataway Creek watershed. 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. Poor ratings are expected in unstable stream channels that experience frequent high flows.

Moderate to severe erosion present was identified as significantly associated with degraded biological conditions in the Piscataway Creek watershed, and found to impact approximately 39% of the stream miles with poor to very poor biological conditions. Erosion severity represents a visual observation that the stream discharge is frequently exceeding the ability of the channel and/or floodplain to attenuate flow energy, resulting in channel instability, which in turn affects bank stability. Where such conditions are observed, flow energy is considered to have increased in frequency or intensity, accelerating channel and bank erosion. Increased flow energy suggested by this measure is also expected to negatively influence stream biology. Erosion severity is described categorically as minimal, moderate, or severe. Conditions indicating biological degradation are set at two levels, moderate and severe. A level of *severe* indicates that a substantial amount of stream banks show severe erosion and the stream segment exhibits high levels of instability due to erosion.

Coastal Plain regions do not have the required characteristics to exhibit optimal erosion or sediment scores, because they naturally have a higher percentage of sediment loading than other physiographic regions. The Piscataway Creek watershed is located in the mid-Atlantic Coastal Plain; the soils (i.e., Beltsville and Westphalia) have a silt loam and sand consistency, and are highly erodible. Since this watershed contains highly erodible soils it is naturally more susceptible to surface erosion, sedimentation, streambank erosion, stream channel modification, and other problems related to soil movement. All of the major streams in this region are normally sluggish, and many have large accumulations of silt (Soil Conservation Service 1967). After the decline of agriculture in the watershed much of the land was converted back to forest; however, many areas have become developed for residential uses. As the land in these small areas was developed, many miles of stream channels were altered and destabilized, as evidenced by poor to moderate channel alteration results. Sediment pollution in the Piscataway watershed has resulted in the exceedance of species tolerances and subsequent trophic alteration (e.g., shift to more silt-tolerant species). Consequently, an impaired biological community with poor IBI scores is observed.

The combined AR is used to measure the extent of stressor impact of degraded stream miles, poor to very poor biological conditions. The combined AR for the sediment stressor group is approximately 79%, suggesting that this stressor is a probable cause of the biological impairments in the Piscataway Creek watershed (Table 7).

Instream Habitat Conditions

BSID analysis results for the Piscataway Creek watershed did not identify instream habitat parameters that have statistically significant associations with poor to very poor stream biological condition, i.e., removal of stressors would result in improved biological community (Table 5).

Riparian Habitat Conditions

BSID analysis results for the Piscataway Creek watershed did not identify riparian habitat parameters that have statistically significant associations with poor to very poor stream biological condition (Table 5).

Water Chemistry

BSID analysis results for the Piscataway Creek watershed identified two 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 improved biological community): *high chlorides and high conductivity.* (Table 6).

High chlorides were identified as significantly associated with degraded biological conditions and found in 50% of the stream miles with very poor to poor biological conditions in the Piscataway Creek 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 conductivity levels were identified as significantly associated with degraded biological conditions and found to impact approximately 48% of the stream miles with poor to very poor biological conditions in the Piscataway 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.

Application of road salts in the watershed is a likely source of the high chlorides and conductivity levels. 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 m (average of 300 m) on each side of four-lane roads. Roads tend to capture and export more stormwater pollutants than other land covers. Sanitary sewage overflows are also likely a source of elevated concentrations of chloride and conductivity. Surface flows due to the impervious surface (9%) of the watershed are also a factor.

Wastewater treatment plant (WWTP) discharges, and sanitary sewer overflows are also a likely source of high chlorides and conductivity levels. There are two municipal treatment plants in the Piscataway Creek watershed, the Piscataway Creek WWTP and the Cheltenham Boys Facility’s WWTP. The Piscataway Creek WWTP receives wastewater from the entire sewer collection system within Piscataway Creek, but the Piscataway Creek WWTP has not discharged into Piscataway Creek for over 20 years. There is a pipeline that transports its effluent to the middle of the Potomac River (basin number 02140201). The Cheltenham Boys Facility’s WWTP, located in the northeastern part of the Piscataway Creek near the town of Cheltenham, currently discharges into one of the tributaries of the Piscataway Creek. There are also septic systems found in the east and in the southern half of the Piscataway Creek watershed. Andrews AFB and the region near the base are mostly residential and serviced by sewer systems. Sanitary Sewer Overflows (SSO) occur when the capacity of a separate sanitary sewer is exceeded. There were total of 25 sanitary sewer overflows reported between July 27, 2001 and September 14, 2004, in the Prince George’s County portion of Piscataway Creek watershed. Approximately 3,196,000 gallons of SSO discharge was released through various waterways (surface water, groundwater, sanitary sewers, etc.) in the Piscataway Creek watershed (MDE 2006).

Currently in Maryland there are no specific numeric criteria that quantify the impact of conductivity and chlorides 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 of degraded stream miles with poor to very poor biological conditions. The combined AR for the water chemistry stressor group is approximately 57%, suggesting that these stressors are a probable cause of the biological impairments in the Piscataway Creek watershed (Table 7).

4.3 Discussion of BSID Results

The BSID analysis results suggest that degraded biological communities in the Piscataway Creek watershed are a result of stressors associated with sedimentation and inorganic pollutants (i.e., chlorides). Conductivity was also identified but it serves as an indicator of an inorganic contaminant. Schlesinger (2004) estimated that more than 140 trillion kilograms of chloride are annually cycled through various reservoirs on Earth, almost all of it due to human activities. Anthropogenic and urban land use sources are identified as significantly associated with degraded biological conditions in the Piscataway Creek watershed. Possible land use sources of chloride include human sewage, synthetic fertilizer, and road salt runoff.

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. 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. Hopefully with continued efforts in implementing and enforcing the 2010 Chesapeake Bay TMDL by State and local agencies, sediment loads in the Piscataway Creek watershed will decrease and stream habitat will improve.

According 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. The MDDNR MBSS noted evidence of sediment deposition and erosion, but also sewage line access adjacent to a site, the smell of raw sewage, and a sewage manhole next to a stream within Piscataway Creek watershed sampling sites. The effects of increasing transportation 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., road salts) 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). In watersheds already experiencing anthropogenic stress, hydrologic variability is exacerbated by urbanization, which increases the amount of impervious surface in a basin and causes higher overland flows to streams, especially during storm events (Southerland et al. 2005b).

The BSID analysis results suggest that degraded biological communities in the Piscataway Creek 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 Piscataway Creek 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 87%, suggesting that these stressors are a probable cause of the biological impairments in the Piscataway 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

Causal model development provides a visual linkage among 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 2014). 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 Piscataway Creek watershed, with pathways bolded or highlighted to show the watershed's probable stressors as indicated by the BSID analysis.

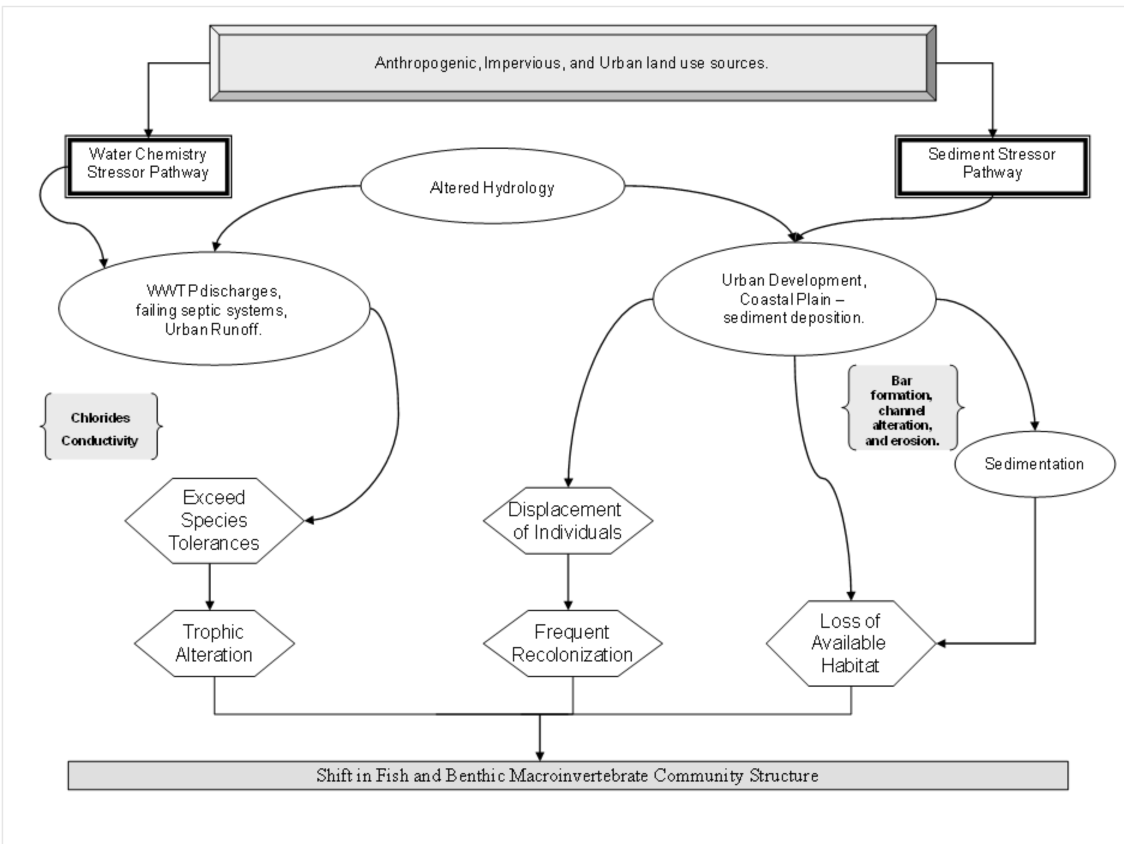

Figure 6. Final Causal Model for the Piscataway Creek Watershed

5.0 Conclusions

Data suggest that the Piscataway Creek watershed's biological communities are strongly influenced by urban land use, which alters the hydrologic regime resulting in increased sediment and inorganic 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 Piscataway Creek watershed are summarized as follows:

- The BSID process has determined that biological communities in the Piscataway Creek watershed are likely degraded due to sediment related stressors. Specifically, altered hydrology and increased runoff from urban landscapes have resulted in increased habitat homogeneity and subsequent elevated suspended sediment in the watershed, which are in turn probable causes of impacts to biological communities. The BSID results thus support a Category 5 listing of the Piscataway Creek watershed for the non-tidal portion of the 8-digit watershed as an appropriate management action to begin addressing the impacts of these streams on the biological communities in the Piscataway Creek watershed.

- The BSID process has determined that the biological communities in the Piscataway Creek watershed are likely degraded due to inorganics (i.e., chlorides and conductivity). Chlorides and conductivity levels are significantly associated with degraded biological conditions and found, respectively, in approximately 55% and 48% of the stream miles with poor to very poor biological conditions in the Piscataway Creek watershed. The BSID results thus support a Category 5 listing of Piscataway Creek for the non-tidal portion of the 8-digit watershed as an appropriate management action to begin addressing the impact of these stressors on the biological communities in the Piscataway Creek 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.

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