Watershed Report for Biological Impairment of the Lower Choptank River Watershed in Caroline, Talbot, and Dorchester Counties, Maryland
Biological Stressor Identification Analysis Results and Interpretation

FINAL

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List of Abbreviations

AR	Attributable Risk
BIBI	Benthic Index of Biotic Integrity
BMPs	Best Management Practices
BOD	Biological Oxygen Demand
BSID	Biological Stressor Identification
COMAR	Code of Maryland Regulations
CWA	Clean Water Act
DO	Dissolved Oxygen
FIBI	Fish Index of Biologic Integrity
IBI	Index of Biotic Integrity
IR	Integrated Report
MBSS	Maryland Biological Stream Survey
MDDNR	Maryland Department of Natural Resources
MDE	Maryland Department of the Environment
MH	Mantel-Haenzel
mg/L	Milligrams per liter
µS/cm	Micro Siemens per centimeter
NMPs	Nutrient Management Practices
OP	Orthophosphate
P/G/E	Pool/Glide/Eddy
PCBs	Polychlorinated Biphenyls
PDA	Public Drainage Association
SSA	Science Services Administration
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
USEPA	United States Environmental Protection Agency
WQA	Water Quality Analysis
WQLS	Water Quality Limited Segment
WRAS	Watershed Restoration Action Strategy

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 Lower Choptank River watershed (basin code 02130403), located in Caroline, Talbot, and Dorchester Counties, is associated with four assessment units in the Integrated Report (IR): non-tidal (8-digit basin) and multiple estuary portions (Chesapeake Bay segments). The Chesapeake Bay segments related to the Lower Choptank River are: Choptank River Mesohaline Mouth 1, Choptank River Mesohaline Mouth 2, Choptank River Oligohaline. Below is a table identifying the listings associated with this watershed.

Table E1. 2010 Integrated Report Listings for Lower Choptank River Watershed

Watershed	Basin Code	Non-tidal/Tidal	Subwatershed	Designated Use	Year listed	Identified Pollutant	Listing Category
Lower Choptank River	02130403	Non-tidal		Aquatic Life and Wildlife	2002	Impacts to Biological Communities	5
			Unnamed Tributary to La Trappe Creek		2002	BOD (carbonaceous)	4a
					2002	BOD (nitrogenous)	4a
		Impoundment	La Trappe Creek Pond		2002	TP	4a
Choptank River Mesohaline Mouth 1	CHOMH1	Tidal		Seasonal Migratory fish spawning and nursery Subcategory		TP	3
						TN	3
				Aquatic Life and Wildlife	2010	Impacts to Estuarine Biological Communities	5
			Town Creek		2002	BOD	4a
				Open Water Fish and Shellfish	1996	TP	5
					1996	TN	5
				Seasonal Shallow Water Submerged Aquatic Vegetation	1996	TSS	5
			Tred Avon River	Shellfishing	1996	Fecal Coliform	4a
			Tar Creek		1996	Fecal Coliform	2
			San Domingo Creek NE Branch		1996	Fecal Coliform	4a
			San Domingo Creek NW Branch		1996	Fecal Coliform	4a
			Cummings Creek			Fecal Coliform	2
			Northeast Branch			Fecal Coliform	4a

Table E1. 2010 Integrated Report Listings for Lower Choptank River Watershed

Watershed	Basin Code	Non-tidal/Tidal	Subwatershed	Designated Use	Year listed	Identified Pollutant	Listing Category
Choptank Mesohaline Mouth 2	CHOMH2	Tidal		Seasonal Migratory fish spawning and nursery Subcategory		TP	3
						TN	3
				Aquatic Life and Wildlife	2010	Impacts to Estuarine Biological Communities	5
				Open Water Fish and Shellfish	1996	TP	5
					1996	TN	5
				Seasonal Shallow Water Submerged Aquatic Vegetation	1996	TSS	5
				Fishing	2008	PCBs	5
						Mercury	2
			Jenkins Creek	Shellfishing		Fecal Coliform	2
			Indian Creek		1996	Fecal Coliform	4a
			Warwick River		1996	Fecal Coliform	4a
			Whitehall Creek			Fecal Coliform	2
			Goose Creek	Shellfishing	1996	Fecal Coliform	4a
			Mainstem	Shellfishing	1996	Fecal Coliform	4a
			Mainstem 2 (extended area)	Shellfishing	2010	Fecal Coliform	5
Choptank Oligohaline	CHOOH	Tidal		Aquatic Life and Wildlife		Impacts to Estuarine Biological Communities	3
				Open Water Fish and Shellfish	1996	TN	5
					1996	TP	5
				Seasonal Migratory fish spawning and nursery		TN	3
						TP	3
				Seasonal Shallow Water Submerged Aquatic Vegetation	2008	TSS	5

In 2002, the State began listing biological impairments on the Integrated Report. The current Maryland Department of the Environment (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, TMDLs are developed, and implementation is targeted. The listing methodology assesses the condition of Maryland 8-digit watersheds by measuring the percentage of stream miles that have poor to very poor biological conditions, and calculating whether this is significantly different from a reference condition watershed (i.e., healthy stream, <10% stream miles with poor to very poor biological condition).

The Maryland Surface Water Use Designations in the Code of Maryland Regulations (COMAR) for Lower Choptank River and all tributaries are Use I designation - w*ater contact recreation, and protection of nontidal warmwater aquatic life and* Use II designation - s*upport of estuarine and marine aquatic life and shellfish harvesting* (COMAR 2011 a, b). The Lower Choptank River watershed is not attaining its *nontidal warmwater aquatic life* use designation because of impacts 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 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 Lower Choptank River watershed report presents a brief discussion of the BSID process on which the watershed analysis is based, and which may be reviewed in more detail in the report entitled *Maryland Biological Stressor Identification Process* (MDE 2009). Data suggest that the biological communities of the Lower Choptank River watershed are strongly influenced by agricultural land use and its concomitant effects: altered stream morphology (channelization) and elevated levels of sediments. The development of landscapes creates broad and interrelated forms of degradation that can affect stream ecology and biological composition. Peer-reviewed scientific literature establishes a link between agricultural landscapes and degradation in the aquatic health of non-tidal stream ecosystems.

The results of the BSID analysis, and the probable causes and sources of the biological impairments in the Lower Choptank River watershed can be summarized as follows:

- The BSID process has determined that the biological communities in the Lower Choptank River watershed are likely degraded due to water chemistry related stressors. Specifically, agricultural land use practices have resulted in the potential elevation of orthophosphate inputs throughout the watershed, which are in turn the probable causes of impacts to biological communities. In addition, the BSID process identified low dissolved oxygen below <6.0 mg/l as significantly associated with degraded biological conditions. Low dissolved oxygen levels in the watershed are probably due to a combination of low topographic relief of the watershed, seasonal low flow/no flow conditions, and elevated orthophosphate concentrations. The BSID results confirm the tidal 1996 Category 5 listing for nitrogen and phosphorus as an appropriate management action in the watershed, and links these pollutants to biological conditions in these waters and extend the impairment to the watershed's non-tidal waters. Therefore, the establishment of nitrogen and phosphorus TMDL in 2010 through the Chesapeake Bay TMDL was an appropriate management action to begin addressing these stressors to the biological communities in the Lower Choptank River watershed. In addition, the BSID results support the identification of the non-tidal portion of this watershed in Category 5 of the Integrated Report as impaired by nitrogen and phosphorus to begin addressing the impacts of these stressors on the biological communities in the Lower Choptank River.

- The BSID process has determined that biological communities in the Lower Choptank River watershed are likely degraded due to sediment and in-stream habitat related stressors. Anthropogenic changes to the natural channel structure of streams in the watershed have resulted in degraded in-stream habitat conditions. Loss of optimal habitat results in lower diversity of a stream's microhabitats and substrates, subsequently causing a reduction in the diversity of biological communities. Also, agricultural runoff has led to increased settling of sediment in the stream substrate throughout the watershed. The BSID results confirm the tidal 1996 Category 5 listing for total suspended solids (TSS) as an appropriate management action in the watershed, and links this pollutant to biological conditions in these waters and extend the impairment to the watershed's non-tidal waters. Therefore, the establishment of total suspended solids TMDL in 2010 through the Chesapeake Bay TMDL was an appropriate management action to begin addressing this stressor to the biological communities in the Lower Choptank River watershed. In addition, the BSID results support the identification of the non-tidal portion of this watershed in Category 5 of the

Integrated Report as impaired by TSS to begin addressing the impacts of this stressor on the biological communities in the Lower Choptank River.

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 2010). 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 Maryland Department of Natural Resources Maryland Biological Stream Survey (MDDNR MBSS) dataset (2000–2004) 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 Lower Choptank River watershed, and presents the results and conclusions of a BSID analysis of the watershed.

2.0 Lower Choptank River Watershed Characterization

2.1 Location

The Lower Choptank watershed is approximately 306 square miles and is part of the 6-digit Choptank River basin as shown in (Figure 1). The Lower Choptank extends through three Maryland counties including Dorchester, Talbot, and Caroline, with the majority of the Maryland 8-digit watershed being located in Talbot and Dorchester Counties. The Lower Choptank River is tidal throughout its reach, which extends from its confluence with the Chesapeake Bay for approximately 39 miles upstream to the start of the Upper Choptank watershed. The watershed contains the urban centers of Easton, Cambridge, Oxford, and portions Trappe and Preston.

The watershed is entirely located within the Coastal Plains physiographic region. There are three distinct eco-regions identified in the MDDNR MBSS Index of Biological Integrity (IBI) metrics (Southerland et al. 2005) (see Figure 2).

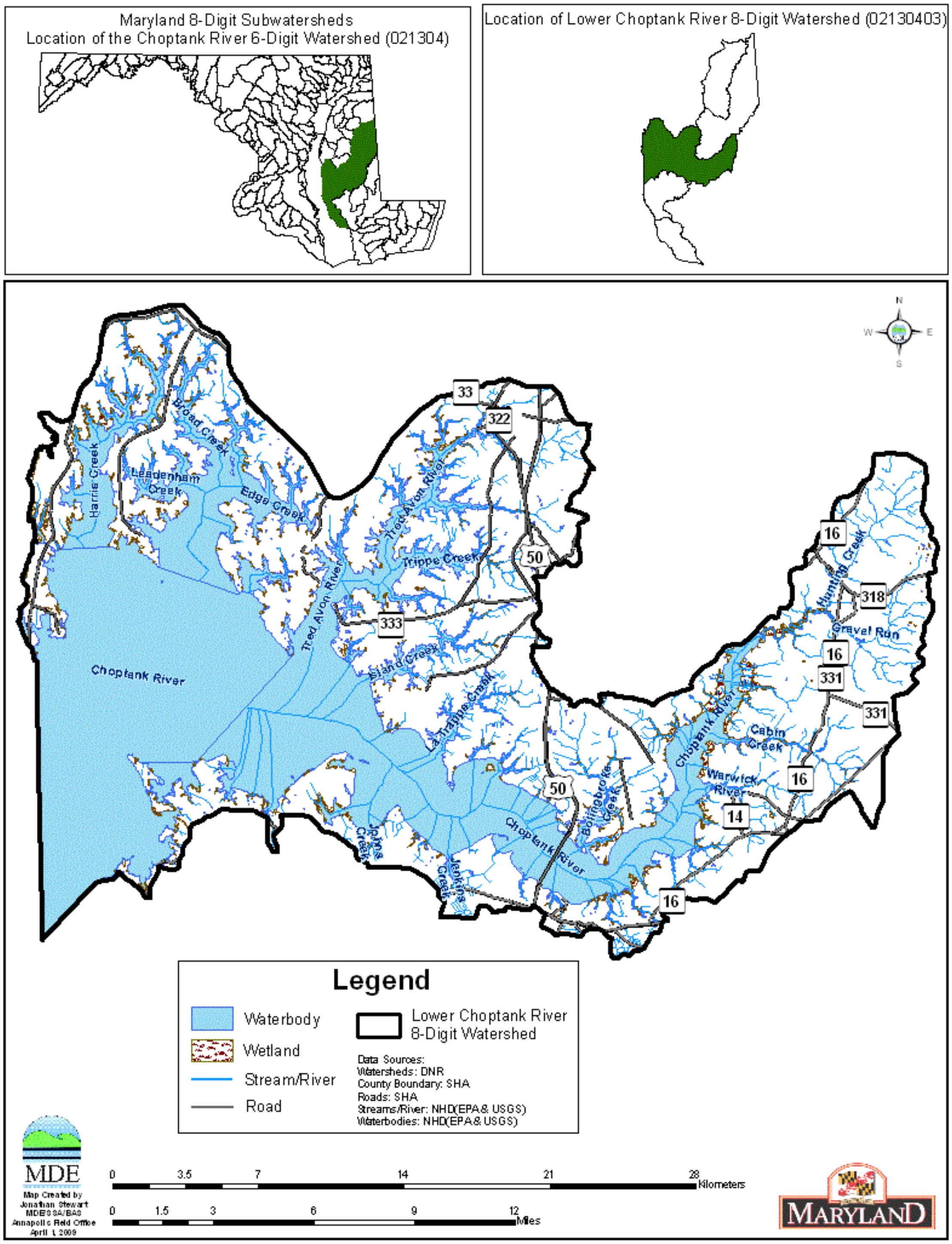

Figure 1. Location Map of the Lower Choptank River Watershed

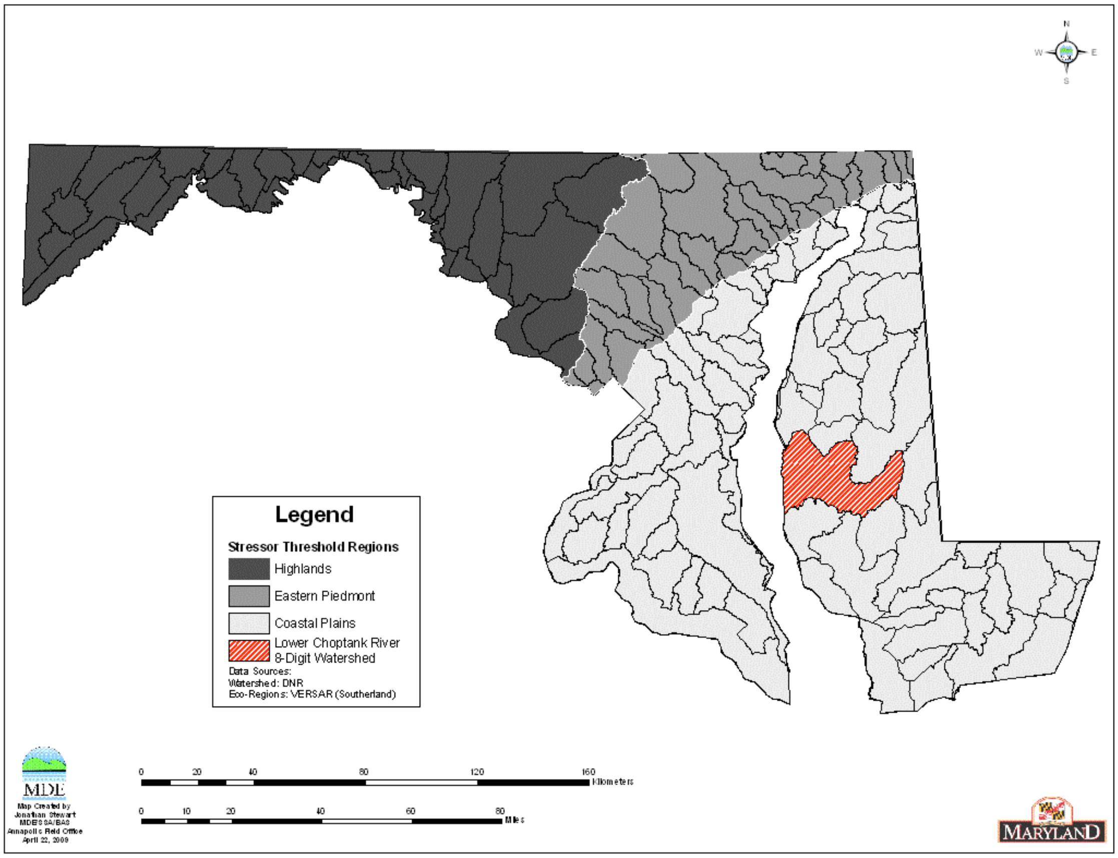

Figure 2. Eco-Region Location Map of the Lower Choptank River Watershed

2.2 Land Use

The Lower Choptank River watershed is predominantly rural with significant agricultural areas, as well as forest, small towns and pockets of urban development. The Choptank River Basin, like all of the Eastern Shore, is largely agricultural, at present, agricultural land use is most often dedicated to crop production of corn, soybean, wheat, and barley. There are also small to medium animal feeding operations located within the watershed. Poultry production is the most prevalent animal production industry. Chicken litter from poultry houses is routinely recycled as a fertilizer on the corn and soybean production fields (McCarty et al. 2007). According to the Chesapeake Bay Program's Phase 5.2 Model the land use distribution in the watershed is approximately 49% agricultural, 32% forest/herbaceous, and 19% urban (USEPA 2010b) (see Figure 3 and Figure 4).

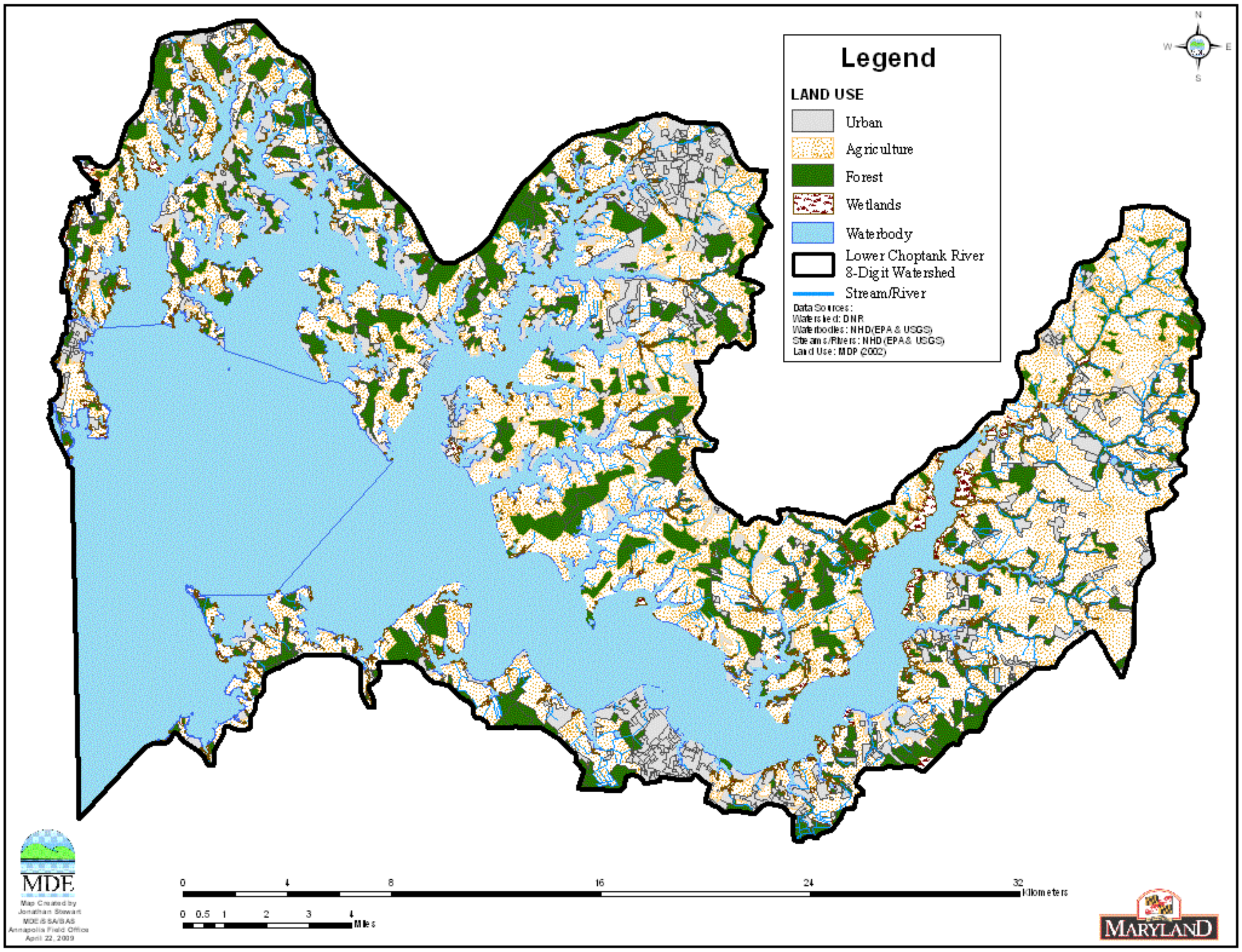

Figure 3. Land Use Map of the Lower Choptank River Watershed

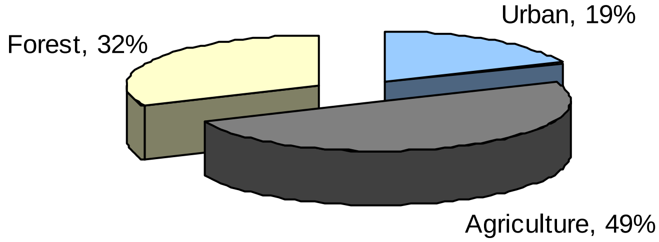

Figure 4. Proportions of Land Use in the Lower Choptank River Watershed

2.3 Soils/hydrology

The Lower Choptank watershed lies within the Coastal Plain physiographic region, which is a wedge-shaped mass of primarily unconsolidated sediments of the Lower Cretaceous, Upper Cretaceous and Pleistocene Ages covered by sandy soils. The Coastal Plain region is characterized by lower relief, and is drained by slowly meandering streams with shallow channels and gentle slopes (MGS 2007).

Soils typically found in the Lower Choptank River watershed are the Sassafras, Fallsington, and Othello series. The Sassafras series consist of very deep, well drained soils on sandy marine and old alluvial sediments. The Fallsington series consist of very deep poorly drained soils on coastal plain flatlands. Saturated hydraulic conductivity is high in the subsoil and high to very high in the substratum. The Othello series consist of very deep, poorly drained soils, with saturated hydraulic conductivity being moderately high (USDA 1977).

3.0 Lower Choptank River Watershed Water Quality Characterization

3.1 Integrated Report Impairment Listings

The Lower Choptank River watershed (basin code 02130403), located in Caroline, Talbot, and Dorchester Counties, is associated with four assessment units in the Integrated Report (IR): non-tidal (8-digit basin) and multiple estuary portions

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						TN	3
				Aquatic Life and Wildlife	2010	Impacts to Estuarine Biological Communities	5
			Town Creek		2002	BOD	4a
				Open Water Fish and Shellfish	1996	TP	5
					1996	TN	5
				Seasonal Shallow Water Submerged Aquatic Vegetation	1996	TSS	5
			Tred Avon River	Shellfishing	1996	Fecal Coliform	4a
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			San Domingo Creek NE Branch		1996	Fecal Coliform	4a
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			Cummings Creek			Fecal Coliform	2
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						TN	3
				Aquatic Life and Wildlife	2010	Impacts to Estuarine Biological Communities	5
				Open Water Fish and Shellfish	1996	TP	5
					1996	TN	5
				Seasonal Shallow Water Submerged Aquatic Vegetation	1996	TSS	5
				Fishing	2008	PCBs	5
						Mercury	2
			Jenkins Creek	Shellfishing		Fecal Coliform	2
			Indian Creek		1996	Fecal Coliform	4a
			Warwick River		1996	Fecal Coliform	4a
			Whitehall Creek			Fecal Coliform	2
			Goose Creek	Shellfishing	1996	Fecal Coliform	4a
			Mainstem	Shellfishing	1996	Fecal Coliform	4a
			Mainstem 2 (extended area)	Shellfishing	2010	Fecal Coliform	5
Choptank Oligohaline	CHOOH	Tidal		Aquatic Life and Wildlife		Impacts to Estuarine Biological Communities	3
				Open Water Fish and Shellfish	1996	TN	5
					1996	TP	5
				Seasonal Migratory fish spawning and nursery		TN	3
						TP	3
				Seasonal Shallow Water Submerged Aquatic Vegetation	2008	TSS	5

3.2 Impacts to Biological Communities

The Maryland Surface Water Use Designations in the Code of Maryland Regulations (COMAR) for Lower Choptank River and all tributaries are Use I designation - w*ater contact recreation, and protection of nontidal warmwater aquatic life and* Use II designation - s*upport of estuarine and marine aquatic life and shellfish harvesting* (COMAR 2011 a, 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 trout waters. 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 Lower Choptank River watershed is listed under Category 5 of the 2008 Integrated Report for impacts to biological communities. Approximately 45% of stream miles in the Lower Choptank River watershed are estimated as having benthic and/or fish indices of biological integrity 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 eleven stations. Five of the eleven stations have benthic and/or fish index of biotic integrity (BIBI, FIBI) scores significantly lower than 3.0 (i.e., poor to very poor). The principal dataset, MBSS round two, contains six MBSS sites; with three having BIBI and/or FIBI scores lower than 3.0. Figure 5 illustrates principal dataset site locations for the Lower Choptank River watershed.

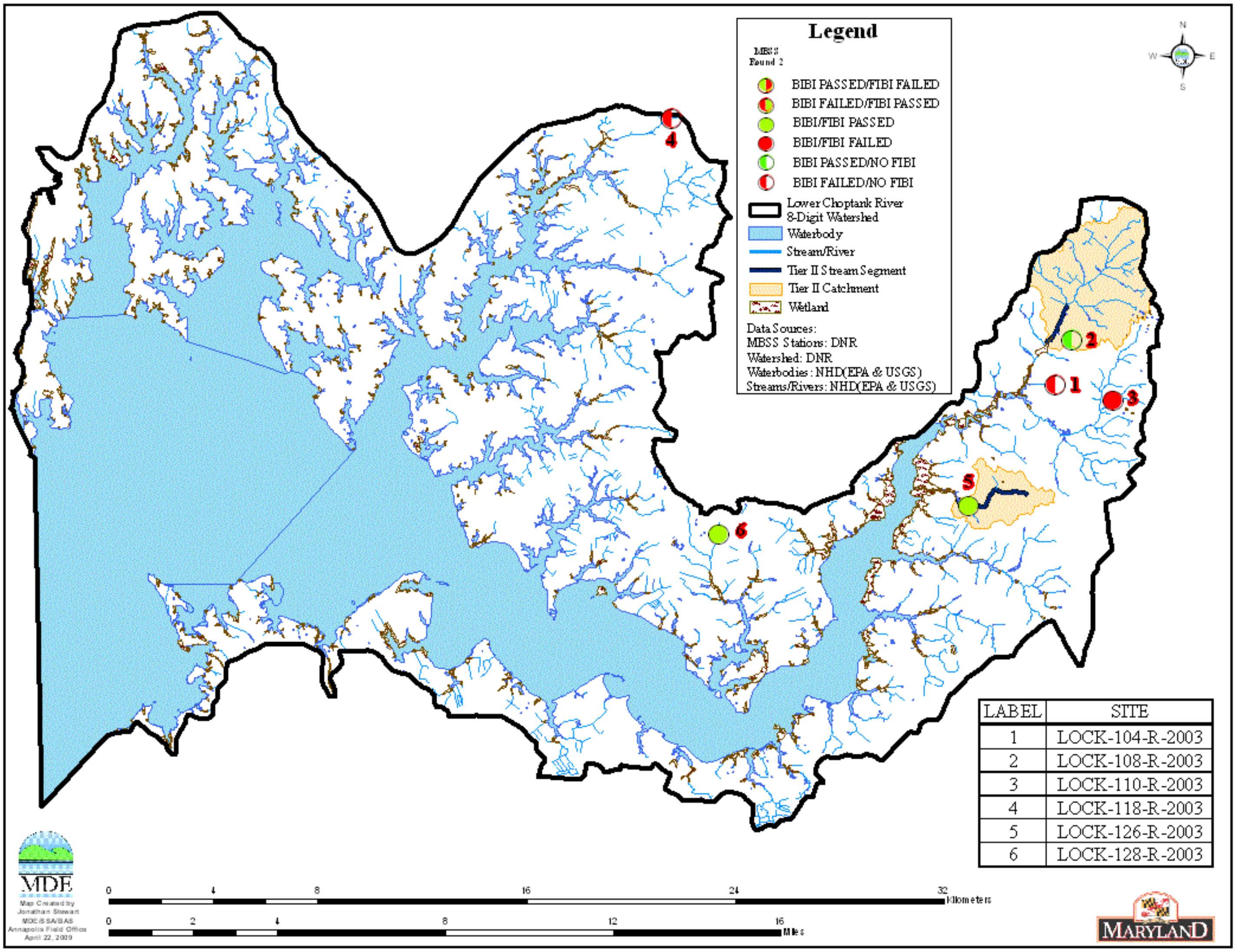

Figure 5. Principal Dataset Sites for the Lower Choptank River Watershed

4.0 Stressor Identification Results

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

The BSID data analysis tests for the strength of association between stressors and degraded biological conditions by determining if there is an increased risk associated with the stressor being present. More specifically, the assessment compares the likelihood that a stressor is present, given that there is a degraded biological condition, by using the ratio of the incidence within the case group as compared to the incidence in the control group (odds ratio). The case group is defined as the sites within the assessment unit with BIBI/FIBI scores lower than 3.0 (i.e., poor to very poor). The controls are sites with similar physiographic characteristics (Highland, Eastern Piedmont, and Coastal region), and stream order for habitat parameters (two groups – 1^{st} and 2^{nd}-4^{th} order), that have 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 (MH) (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 data analysis of the Lower Choptank River watershed, MDE identified sources, sediment, in-stream habitat, and water chemistry stressors as having significant association with poor to very poor fish and/or benthic biological conditions. Parameters identified as representing possible sources are listed in Table 2 and are high percentage of transportation land use in watershed and agricultural acid source present. Table 3 shows the summary of combined AR values for the source groups in the Lower Choptank River watershed. As shown in Table 4 through Table 6, numerous parameters from the sediment, in-stream habitat, and water chemistry groups were identified as possible biological stressors. Table 7 shows the summary of combined AR values for the stressor groups in the Lower Choptank River watershed.

Table 2. Stressor Source Identification Analysis Results for the Lower Choptank River Watershed

Parameter Group	Source	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites with fair to good Fish and Benthic IBI)	% of case sites with source present	% of control sites with source present	Possible stressor (Odds of stressor in cases significantly higher than odds of sources in controls using p<0.1)	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Source
Sources Urban	high impervious surface in watershed	6	3	214	0%	5%	No	----
	high % of high intensity urban in watershed	6	3	214	33%	9%	No	----
	high % of low intensity urban in watershed	6	3	214	33%	4%	No	----
	high % of transportation in watershed	6	3	214	67%	7%	Yes	59%
	high % of high intensity urban in 60m buffer	4	2	212	0%	7%	No	----
	high % of low intensity urban in 60m buffer	4	2	212	50%	5%	No	----
	high % of transportation in 60m buffer	4	2	212	0%	9%	No	----

Table 2. Stressor Source Identification Analysis Results for the Lower Choptank River Watershed (Cont.)

Parameter Group	Source	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites with fair to good Fish and Benthic IBI)	% of case sites with source present	% of control sites with source present	Possible stressor (Odds of stressor in cases significantly higher than odds of sources in controls using p<0.1)	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Source
Sources Agriculture	high % of agriculture in watershed	6	3	214	33%	18%	No	----
	high % of cropland in watershed	6	3	214	33%	27%	No	----
	high % of pasture/hay in watershed	6	3	214	0%	6%	No	----
	high % of agriculture in 60m buffer	4	2	212	50%	8%	No	----
	high % of cropland in 60m buffer	4	2	212	0%	18%	No	----
	high % of pasture/hay in 60m buffer	4	2	212	50%	8%	No	----
Sources Barren	high % of barren land in watershed	6	3	214	0%	23%	No	----
	high % of barren land in 60m buffer	4	2	212	0%	6%	No	----
Sources Anthropogenic	low % forest in watershed	6	3	214	33%	5%	No	----
	low % of forest in 60m buffer	4	2	212	50%	5%	No	----

Table 2. Stressor Source Identification Analysis Results for the Lower Choptank River (Cont.)

Parameter Group	Source	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites with fair to good Fish and Benthic IBI)	% of case sites with source present	% of control sites with source present	Possible stressor (Odds of stressor in cases significantly higher than odds of sources in controls using p<0.1)	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Source
Sources Acidity	atmospheric deposition present	6	3	208	0%	40%	No	----
	AMD acid source present	6	3	208	0%	0%	No	----
	organic acid source present	6	3	208	0%	6%	No	----
	agricultural acid source present	6	3	208	67%	7%	Yes	60%

Table 3. Summary of Combined Attributable Risk Values of the Source Group in the Lower Choptank River Watershed

Source Group	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Parameter Group(s) (Attributable Risk)	
Urban	59%	93%
Agriculture	----	
Barren Land	----	
Anthropogenic	----	
Acidity	60%	

Sources Identified by BSID Analysis

The transportation land use and agricultural acid source identified by the BSID analysis (Table 2), are the result of urban and agricultural development within the Lower Choptank River watershed. A significant amount of the watershed is comprised of agricultural land uses (49%) and urban development (19%).

The Choptank River Basin, like all of the Eastern Shore, is largely agricultural, but also has a sizeable amount of forested areas. Its preponderance of poorly draining soils and forest makes this basin atypical compared to much of the Eastern Shore. Most of the Choptank River Basin is drained through ditches that have been installed over many decades to drain the flatlands for agriculture use. The drains are typically kept clear of vegetation, expediting flow; consequently there is less opportunity for nutrient uptake and denitrification (USGS 2000).

Typical anthropogenic alterations to a stream caused by agricultural development include ditching, substrate disturbance or dredging, nutrient eutrophication, hydrological changes, and riparian removal (Hynes 1970; Allan 1995). Some of the alterations have direct in-stream effects on structure or water chemistry (e.g., dredging, nutrient additions due to lack of riparian buffer), some have geomorphological repercussions (e.g., channelization), and some have indirect effects on these two areas through changes in landscape (e.g., deforestation, groundwater withdrawal for irrigation).

The BSID analysis identified agricultural sources of acidity as having significant association with degraded biological conditions. Fertilizers used in agricultural practices often contain high levels of nitrogen, or other acidifying compounds, which are sources of acidification in surface waters. Agricultural activities in watersheds affect stream chemistry by lowering the acid neutralizing capacity (ANC), from soil liming practices, and strong acid anions from nitrogen fertilizers.

Transportation land use in the watershed was significantly associated with degraded biological conditions and found in 59% of the stream miles with poor to very poor biological conditions. There are four main transportation corridors in the watershed: Maryland-Route 50, which runs through the middle of the watershed; Routes 16 and 331 border the eastern edge and run the length of the watershed, and Route 322 in the northern portion. 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.

The BSID source analysis (Table 2) identifies high percentage of transportation in watershed and agricultural acid sources as potential sources of stressors that may cause negative biological impacts. The combined AR for the source group is approximately 93% suggesting these sources potentially impacts a substantial portion of the degraded stream miles in the Lower Choptank River watershed (Table 3).

All the stressors identified in the BSID analysis for the Lower Choptank River watershed can be linked to the typical consequences of anthropogenic development. The remainder of this section will discuss identified stressors and their link to degraded biological conditions in the watershed.

Table 4. Sediment Biological Stressor Identification Analysis Results for the Lower Choptank River Watershed

Parameter Group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites with fair to good Fish and Benthic IBI)	% of case sites with stressor present	% of control sites with stressor present	Possible stressor (Odds of stressor in cases significantly higher than odds of stressor in controls using p<0.1)	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Stressor
Sediment	extensive bar formation present	6	3	132	0%	23%	No	----
	moderate bar formation present	6	3	132	67%	55%	No	----
	bar formation present	6	3	132	67%	82%	No	----
	channel alteration marginal to poor	6	3	128	100%	62%	No	----
	channel alteration poor	6	3	128	0%	27%	No	----
	high embeddedness	6	3	132	0%	0%	No	----
	epifaunal substrate marginal to poor	6	3	132	100%	45%	Yes	55%
	epifaunal substrate poor	6	3	132	67%	10%	Yes	57%
	moderate to severe erosion present	6	3	132	0%	45%	No	----
	severe erosion present	6	3	132	0%	14%	No	----
	poor bank stability index	6	3	132	0%	23%	No	----
	silt clay present	6	3	132	100%	99%	No	----

Table 5. Habitat Biological Stressor Identification Analysis Results for the Lower Choptank River Watershed

Parameter Group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites with fair to good Fish and Benthic IBI)	% of case sites with stressor present	% of control sites with stressor present	Possible stressor (Odds of stressor in cases significantly higher than odds of stressor in controls using p<0.1)	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Stressor
In-Stream Habitat	channelization present	6	3	134	33%	13%	No	----
	in-stream habitat structure marginal to poor	6	3	132	100%	40%	Yes	60%
	in-stream habitat structure poor	6	3	132	33%	5%	No	----
	pool/glide/eddy quality marginal to poor	6	3	132	100%	45%	Yes	55%
	pool/glide/eddy quality poor	6	3	132	33%	3%	No	----
	riffle/run quality marginal to poor	6	3	132	67%	45%	No	----
	riffle/run quality poor	6	3	132	67%	18%	Yes	48%
	velocity/depth diversity marginal to poor	6	3	132	100%	58%	No	----
	velocity/depth diversity poor	6	3	132	67%	14%	Yes	53%
	concrete/gabion present	6	3	138	0%	1%	No	----
	beaver pond present	6	3	131	0%	6%	No	----
Riparian Habitat	no riparian buffer	6	3	134	0%	13%	No	----
	low shading	6	3	132	0%	9%	No	----

Table 6. Water Chemistry Biological Stressor Identification Analysis Results for the Lower Choptank River Watershed

Parameter Group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites with fair to good Fish and Benthic IBI)	% of case sites with stressor present	% of control sites with stressor present	Possible stressor (Odds of stressor in cases significantly higher than odds of stressor in controls using p<0.1)	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Stressor
Water Chemistry	high total nitrogen	6	3	208	67%	25%	No	----
	high total dissolved nitrogen	0	0	0	0%	0%	No	----
	ammonia acute with salmonid present	6	3	208	33%	39%	No	----
	ammonia acute with salmonid absent	6	3	208	33%	26%	No	----
	ammonia chronic with salmonid present	6	3	208	100%	67%	No	----
	ammonia chronic with salmonid absent	6	3	208	67%	57%	No	----
	low lab pH	6	3	208	100%	38%	Yes	62%
	high lab pH	6	3	208	0%	0%	No	----
	low field pH	6	3	207	100%	39%	Yes	61%
	high field pH	6	3	207	0%	0%	No	----
	high total phosphorus	6	3	208	0%	3%	No	----
	high orthophosphate	6	3	208	67%	13%	Yes	54%
	dissolved oxygen < 5mg/l	6	3	206	33%	14%	No	----
	dissolved oxygen < 6mg/l	6	3	206	100%	22%	Yes	78%
	low dissolved oxygen saturation	5	2	184	50%	18%	No	----
	high dissolved oxygen saturation	5	2	184	0%	0%	No	----
	acid neutralizing capacity below chronic level	6	3	208	0%	9%	No	----
	acid neutralizing capacity below episodic level	6	3	208	67%	48%	No	----
	high chlorides	6	3	208	0%	6%	No	----
	high conductivity µS/cm	6	3	208	0%	5%	No	----
	high sulfates	6	3	208	0%	4%	No	----

Table 7. Summary of Combined Attributable Risk Values of the Stressor Group in the Lower Choptank River Watershed

Stressor Group	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Parameter Group(s) (Attributable Risk)	
Sediment	79%	86%
In-Stream Habitat	78%	
Riparian Habitat	----	
Water Chemistry	84%	

Stressors Identified by BSID Analysis

All ten stressor parameters identified by the BSID analysis (Table 2, 3, and 4), as being significantly associated with biological degradation in the Lower Choptank River watershed are emblematic of urban and agriculturally developed landscapes.

Sediment Conditions

BSID analysis results for Lower Choptank River watershed identified two sediment parameter that had statistically significant association with a poor to very poor stream biological condition (i.e., removal of stressors would result in improved biological community). The parameter is *epifaunal substrate (marginal to poor & poor)* (Table 4).

Epifaunal substrate (marginal to poor & poor) was identified as significantly associated with degraded biological conditions in the Lower Choptank River watershed, and found to impact approximately 55% (*marginal to poor* rating) and 57% (*poor* rating) of the stream miles with poor to very poor biological conditions. Epifaunal substrate is a visual observation of the abundance, variety, and stability of substrates that offer the potential for full colonization by benthic macroinvertebrates. The varied habitat types such as cobble, woody debris, aquatic vegetation, undercut banks, and other commonly productive surfaces provide valuable habitat for benthic macroinvertebrates. Epifaunal substrate is confounded by natural variability (i.e., streams will naturally have more or less available productive substrate). Greater availability of productive substrate increases the potential for full colonization; conversely, less availability of productive substrate decreases or inhibits colonization by benthic macroinvertebrates. Epifaunal substrate conditions are described categorically as optimal, sub-optimal, marginal, or poor. Conditions indicating biological degradation are set at two levels: 1) poor, where stable substrate is lacking, or particles are over 75% surrounded by fine sediment and/or flocculent material; and 2) marginal to poor, where large boulders and/or bedrock are prevalent and cobble, woody debris, or other preferred surfaces are uncommon.

Elevated sediment loads tend to reduce the stability and complexity of stream bottoms, which results in the loss of habitat for aquatic organisms. Since many benthic organisms such as mayflies and stoneflies use the spaces between stones and sand as living quarters, therefore; high sediment loads reduce the amount of available habitat and reduce benthic macroinvertebrate diversity and abundance.

Agricultural development typically results in increased sediment deposition throughout the streambed primarily through settling of sediment in the stream substrate, as demonstrated by the lack of adequate epifaunal substrate. This effect is compounded by the low topographic relief throughout the watershed that does not allow for sediment transport to downstream reaches. Sediment deposited on the streambed can suffocate benthic organisms, especially in the embryonic and larval stages (NRCS 1997). The sediment deposition in the watershed has led to a loss of suitable habitat to support the full colonization of a healthy fish and benthic macroinvertebrate 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 the sediment stressor group is approximately 79% suggesting these stressors impact a substanial proportion of the degraded stream miles in Lower Choptank River watershed (See Table 7).

In-stream Habitat Conditions

BSID analysis results for the Lower Choptank River watershed identified four habitat parameters that have a statistically significant association with poor to very poor stream biological condition*: in-stream habitat structure (marginal to poor), pool/glide/eddy quality (marginal to poor), riffle/run quality (poor), and velocity/depth/diversity (poor) (*Table 5).

In-stream habitat structure (marginal to poor) was identified as significantly associated with degraded biological conditions in the Lower Choptank River watershed, and found to impact approximately 60% of the stream miles with poor to very poor biological conditions. In-stream habitat is a visual rating based on the perceived value of habitat within the stream channel to the fish community. Multiple habitat types, varied particle sizes, and uneven stream bottoms provide valuable habitat for fish. In-stream habitat is confounded by natural variability (i.e., some streams will naturally have more or less in-stream habitat). High in-stream habitat scores are evidence of the lack of sediment deposition. Low in-stream habitat values can be caused by high flows that collapse undercut banks and by sediment inputs that fill pools and other fish habitats. In-stream habitat conditions are described categorically as optimal, sub-optimal, marginal, or poor. Conditions indicating biological degradation are set at two levels: 1) poor, which is defined as less than 10% stable habitat where lack of habitat is obvious; and 2) marginal to poor, where there is a 10-30% mix of stable habitat but habitat availability is less than desirable.

Pool/glide/eddy quality was identified as significantly associated with degraded biological conditions in the Lower Choptank River watershed, and found to impact approximately 55% of the stream miles with poor to very poor biological conditions. Pool/glide/eddy (P/G/E) quality is a visual observation and quantitative measurement of the variety and spatial complexity of slow or still water habitat and cover within a stream segment referred to as P/G/E. Stream morphology complexity directly increases the diversity and abundance of fish species found within the stream segment. The increase in heterogeneous habitat such as a variety in depths of pools, slow moving water, and complex covers likely provide valuable habitat for fish species; conversely, a lack of heterogeneity within the pool/glide/eddy habitat decreases valuable habitat for fish species. P/G/E quality conditions are described categorically as optimal, sub-optimal, marginal, or poor. Conditions indicating biological degradation are set at two levels 1) poor, defined as minimal heterogeneous habitat with a max depth of <0.2 meters or being absent completely; and 2) marginal, defined as <10% heterogeneous habitat with shallow areas (<0.2 meters) prevalent and slow moving water areas with little cover.

Riffle/run quality (poor) was identified as significantly associated with degraded biological conditions in the Lower Choptank River watershed and found to impact approximately 48% of the stream miles with poor to very poor biological conditions. Riffle/run quality is a visual observation and quantitative measurement based on the depth, complexity, and functional importance of riffle/run habitat within the stream segment. An increase in the heterogeneity of riffle/run habitat within the stream segment likely increases the abundance and diversity of fish species, while a decrease in heterogeneity likely decreases abundance and diversity. Riffle/run quality conditions indicating biological degradation are set at two levels: 1) poor, defined as riffle/run depths < 1 cm or riffle/run substrates concreted; and 2) marginal to poor, defined as riffle/run depths generally 1 – 5 cm with a primarily single current velocity.
The presence of a well-developed riffle/run system is indicative of different types of habitat within a stream reach, and thereby an assumed higher biodiversity of organisms (Richards, Host, and Arthur 1993). Because stream organisms are highly specialized in many cases, a diverse array of habitat typically leads to a diverse array of macroinvertebrates (Karr 1997).

Velocity/depth diversity (poor) was identified as significantly associated with degraded biological conditions in the Lower Choptank River watershed, and found to impact approximately 53% of the stream miles with poor to very poor biological conditions. Velocity/depth diversity is a visual observation and quantitative measurement based on the variety of velocity/depth regimes present at a site (i.e., slow-shallow, slow-deep, fast-shallow, and fast-deep). Like riffle/run quality, the increase in the number of different velocity/depth regimes likely increases the abundance and diversity of fish species within the stream segment. The decrease in the number of different velocity/depth regimes likely decreases the abundance and diversity of fish species within the stream segment. The poor velocity/depth/diversity category could identify the absence of available habitat to sustain a diverse aquatic community. This measure may reflect natural conditions (e.g., bedrock), anthropogenic conditions (e.g., widened channels, dams, channel dredging, etc.), or excessive erosional conditions (e.g., bar formation, entrenchment, etc.). Poor velocity/depth diversity conditions are defined as the stream segment being dominated by one velocity/depth regime. Velocity is one of the critical variables that controls the presence and number of species (Gore 1978). Many invertebrates depend on certain velocity ranges for either feeding or breathing (Brookes 1988).

All the in-stream habitat parameters identified by the BSID analysis are intricately linked with habitat heterogeneity, the presence of these stressors indicates a lower diversity of a stream's microhabitats and substrates, subsequently causing a reduction in the diversity of biological communities. Substrate is an essential component of in-stream habitat to macroinvertebrates for several reasons. First, many organisms are adapted to living on or obtaining food from specific types of substrate, such as cobble or sand. The group of organisms known as scrapers, for instance, cannot easily live in a stream with no large substrate because there is nothing from which to scrape algae and biofilm. Hence substrate diversity is strongly correlated with macroinvertebrate assemblage composition (Cole, Russel, and Mabee 2003). Second, obstructions in the stream such as cobble or boulders slow the movement of coarse particulate organic matter, allowing it to break down and feed numerous insects in its vicinity (Hoover, Richardson, and Yonesmitsu 2006).

The presence of a well-developed pool/glide/eddy system is indicative of different types of habitat, and is typically assumed to have a higher biodiversity of organisms (Richards, Host, and Arthur 1993). Often sedimentation and increased flooding can disrupt pool/glide/eddy sequences (Richards, Host, and Arthur 1993). The geomorphological characteristics described above are often strongly influenced by land use characteristics, e.g., urban and agricultural development allowing for increased sedimentation and flow to alter natural in-stream habitat.

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 in-stream habitat stressor group is approximately 78% suggesting this stressor impacts a substantial portion of the degraded stream miles in the Lower Choptank River (Table 7).

Riparian Habitat Conditions

BSID analysis results for Lower Choptank River 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) (Table 5).

<u>Water Chemistry Conditions</u>

BSID analysis results for Lower Choptank River 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 improved biological community) (Table 6). These parameters are *low lab pH, low field pH, high orthophosphate,* and *low dissolved oxygen < 6mg/l.*

Low lab pH & low field pH were identified as significantly associated with degraded biological conditions and found in 62% and 61%, respectively, of the stream miles with poor to very poor biological conditions in the Lower Choptank River watershed. pH is a measure of acidity that uses a logarithmic scale ranging 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* values (less than 6.5) can be damaging to aquatic life. The pH threshold values, at which levels below 6.5 and above 8.5 may indicate biological degradation, are established from state regulations (COMAR 2011c). Many biological processes, such as reproduction, cannot function in acidic waters. Common sources of acidity include mine drainage, atmospheric deposition, runoff from mine tailings, agricultural fertilizers, and natural organic sources. The BSID analysis identified agricultural sources of acidity as having significant association with degraded biological conditions. Fertilizers used in agricultural practices often contain high levels of nitrogen, and other acidifying compounds, which are sources of acidification in surface waters. Agricultural activities in watersheds (49%) affect stream chemistry by lowering the acid neutralizing capacity (ANC), from soil liming practices, and strong acid anions from nitrogen fertilizers.

In 1998, MDDNR published an environmental assessment of stream conditions for the Choptank River Basin stating that less than 2% of the stream miles in the Choptank River (6-digit) watershed had pH values less than 6, indicating that stream water acidity is not a widespread problem (MDNR 1998). Additional state water quality data was analyzed to determine if water acidity was prevalent in the Lower Choptank watershed. During the years of 1998, 2003, 2005, and 2010, MDE collect five hundred fifty-five water quality samples. Only three samples had pH values below the water quality standard of 6.5, with a value of 6.3 as the lowest. All three samples were collect in 2003 at station UHN0001, which is located five hundred feet below the Preston Wastewater Treatment Facility outfall on an unnamed tributary of Hunting Creek. MDE water quality data indicates that stream water acidity is not a widespread problem in the watershed.

High orthophosphate concentrations were identified as significantly associated with degraded biological conditions in the Lower Choptank River watershed, and found to impact approximately 54% of the stream miles with poor to very poor biological conditions. The orthophosphate (OP) parameter is the measure of the amount of OP in the water column. OP is the most readily available form of phosphorus for uptake by aquatic organisms. Phosphorus forms the basis of a very large number of compounds, the most important class of which is the phosphates. For every form of life, phosphates play an essential role in all energy-transfer processes such as metabolism and photosynthesis. Excessive phosphorus concentrations in surface water can accelerate eutrophication, resulting in increased growth of undesirable algae and aquatic weeds. Eutrophication can potentially results in low dissolved oxygen and high pH levels, which can exceed tolerance levels of many biological organisms. OP loads to surface waters typically increases in watersheds where urban and agricultural developments are predominant.

Low dissolved oxygen < 6mg/l was identified as significantly associated with degraded biological conditions and found in 78% of the stream miles with poor to very poor biological conditions in the Lower Choptank River watershed. Low dissolved oxygen (DO) concentrations may indicate organic pollution due to excessive oxygen demand and may stress aquatic organisms. The DO threshold value, at which concentrations below 5.0 mg/L may indicate biological degradation, is established by (COMAR 2011c).

One major difference between the Coastal Plain and the other Physiographic Provinces in Maryland is the response of streams to organic enrichment. Because of the lower gradient and naturally limited capacity to mechanically aerate the water and replace oxygen lost via biochemical oxygen demand (BOD), streams in the Coastal Plain more often tend to become more over enriched than elsewhere in the State. However, according to the Chesapeake Bay River Input Monitoring Program, of the nine major rivers monitored the Choptank River (6-digit watershed) contributes less than 1 % of the stream flow, total nitrogen load, and total phosphorus load to Chesapeake Bay (Belval and Sprague 1999). Results of Chesapeake Bay Watershed Model simulations indicate that in 1998, agriculture was the largest contributor to the total phosphorus budget, at 80%. Urban and forested areas contributed 14% and 2%, respectively (USGS 2000).

Although low DO concentrations are usually associated with surface waters experiencing eutrophication as the result of excessive nutrient loading, this might not be the only cause in the Lower Choptank River watershed. Of the three MDDNR MBSS monitoring stations with BIBI and /or FIBI below 3.0 only one had DO concentrations below the 5.0 mg/l COMAR standard. MBSS site LOCK-118 R-2003 located in an unnamed tributary just east of Route 50, which is located in the Town of Easton had a DO concentration of 1.5 mg/l.

Within Maryland, the Choptank River basin is among the lowest in elevation, ranging from twenty to sixty feet above sea level. Because of the low topographic relief of the watershed and the Coastal Plains physiographic ecoregion in general, streams tend to have very gentle slopes with few riffles to aerate the water. Many first order streams on the Maryland eastern shore tend to have very little or no flow during long stretches of the year. Low DO values are not uncommon in small low gradient streams with low or stagnant flows. MBSS field crew comments for site LOCK-118 R-2003 were as follows: spring comment "heavy vegetation, site may be dry during summer, very little flow" and summer comments "no fish, no measurable flow, low DO".

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 84% suggesting this stressor impacts a substantial proportion of the degraded stream miles in the Lower Choptank River watershed (Table 7).

Discussion

The BSID analysis results suggest that degraded biological communities in the Lower Choptank River watershed are a result of stressors associated with poor stream habitat quality, sedimentation, low DO, and elevated OP concentrations. Even though agricultural land use was not identified in the BSID analysis, approximately 49% of the Lower Choptank River watershed contains various types of this land use. The historical legacy impacts to water quality and stream habitat from agricultural land use is prevalent in the Delmarva Peninsula.

Based on literature review, Allan (1995) reported declines in water quality, habitat, and biological assemblages as the extent of agricultural land increases within catchments; also streams draining agricultural lands support fewer species of sensitive benthic and fish taxa than streams draining forested catchments. Agricultural land use degrades streams by increasing nonpoint source loads of pollutants, zones, stream habitats, and impacting riparian buffer.

Agricultural land use in watersheds often results in alterations of stream geomorphic structure. Such disturbances lead to increased fine sediment input to the stream along with direct changes in channel structure. Embeddedness and siltation often eliminate natural riffle-pool complexes and loss of stable diverse substrates. Loss of quality in-stream habitats, riffle/pool/glides, and velocity/depth diversities are serious habitat related problems in the Lower Choptank River. As the variety and abundance of substrates decreases, habitat structure becomes monotonous, diversity decreases, and potential for recovery following disturbances decreases. As the physical habitat changes, increased stress is placed on aquatic organisms. These stresses, depending on the tolerance of the species and individuals, may limit growth, abundance, reproduction and survival (Lynch, Corbett, and Hoopes 1977).

The combined AR for all the stressors is approximately 86%, suggesting that sediment, in-stream habitat, and water chemistry stressors identified in the BSID analysis impact a substantial portion of the degraded stream miles the Lower Choptank River watershed (Table 7).

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

Final Causal Model for the Lower Choptank River Run 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 2010a). 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 causal model for the Lower Choptank River watershed, with pathways to show the watershed's probable stressors as indicated by the BSID analysis.

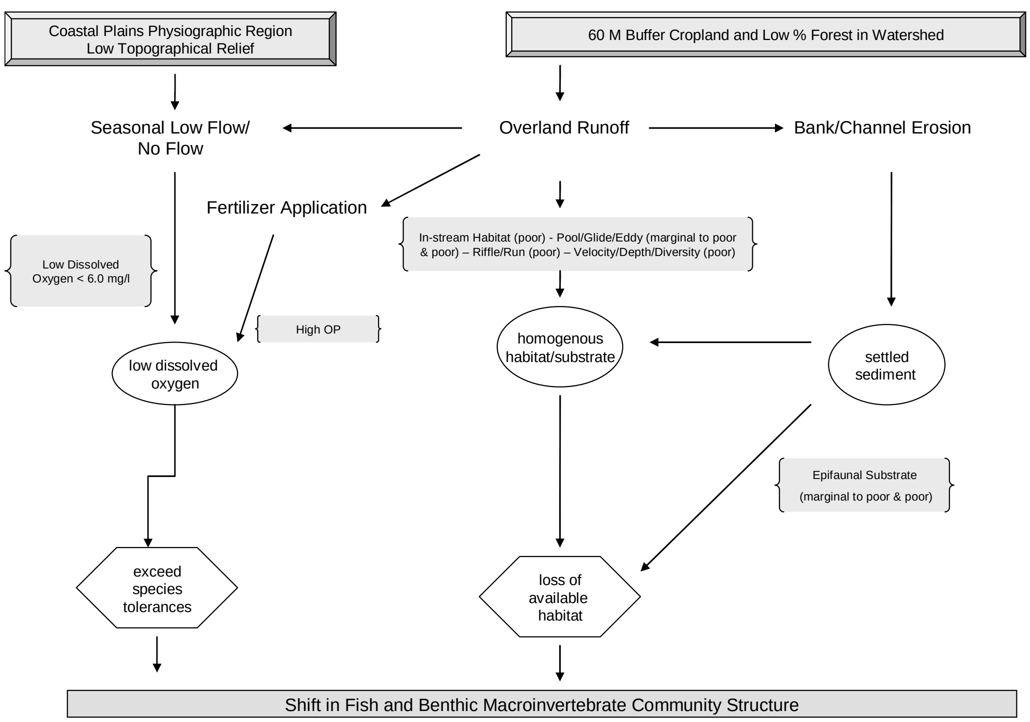

Figure 6. Final Causal Model for the Lower Choptank River Watershed

5.0 Conclusions

Data suggest that the Lower Choptank River watershed's biological communities are strongly influenced by agricultural land use, which has altered the stream geomorphology, resulting in loss of diverse and stable habitat. There is an abundance of scientific research that documents the declines in water quality, habitat, and biological assemblages as the extent of agricultural land increases within catchments (Roth, Allan, and Erickson 1996 & Wang et al. 1997). Based upon the results of the BSID analysis, the probable causes and sources of the impacts to biological communities in the Lower Choptank River watershed are summarized as follows:

- The BSID process has determined that the biological communities in the Lower Choptank River watershed are likely degraded due to water chemistry related stressors. Specifically, agricultural land use practices have resulted in the potential elevation of orthophosphate inputs throughout the watershed, which are in turn the probable causes of impacts to biological communities. In addition, the BSID process identified low dissolved oxygen below <6.0 mg/l as significantly associated with degraded biological conditions. Low dissolved oxygen levels in the watershed are probably due to a combination of low topographic relief of the watershed, seasonal low flow/no flow conditions, and elevated orthophosphate concentrations. The BSID results confirm the tidal 1996 Category 5 listing for nitrogen and phosphorus as an appropriate management action in the watershed, and links these pollutants to biological conditions in these waters and extend the impairment to the watershed's non-tidal waters. Therefore, the establishment of nitrogen and phosphorus TMDL in 2010 through the Chesapeake Bay TMDL was an appropriate management action to begin addressing these stressors to the biological communities in the Lower Choptank River watershed. In addition, the BSID results support the identification of the non-tidal portion of this watershed in Category 5 of the Integrated Report as impaired by nitrogen and phosphorus to begin addressing the impacts of these stressors on the biological communities in the Lower Choptank River.

- The BSID process has determined that biological communities in the Lower Choptank River watershed are likely degraded due to sediment and in-stream habitat related stressors. Anthropogenic changes to the natural channel structure of streams in the watershed have resulted in degraded in-stream habitat conditions. Loss of optimal habitat results in lower diversity of a stream's microhabitats and substrates, subsequently causing a reduction in the diversity of biological communities. Also, agricultural runoff has led to increased settling of sediment in the stream substrate throughout the watershed. The BSID results confirm the tidal 1996 Category 5 listing for total suspended solids (TSS) as an appropriate management action in the watershed, and links this pollutant to biological conditions in these waters and extend the impairment to the watershed's non-tidal waters. Therefore, the establishment of total suspended solids TMDL in 2010 through the Chesapeake Bay TMDL was an appropriate management action to begin addressing this stressor to the biological communities in the Lower Choptank River watershed. In addition, the BSID results support the identification of the non-tidal portion of this watershed in Category 5 of the Integrated Report as impaired by TSS to begin addressing the impacts of this stressor on the biological communities in the Lower Choptank River.

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