Watershed Report for Biological Impairment of the Upper Choptank River Watershed in Caroline, Talbot, and Queen Anne's Counties, Maryland Biological Stressor Identification Analysis Results and Interpretation

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MARYLAND

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

Submitted to:

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

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List of Abbreviations

AR	Attributable Risk
BIBI	Benthic Index of Biotic Integrity
BMPs	Best Management Practices
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
PCBs	Polychlorinated Biphenyls
P/G/E	Pool/Glide/Eddy
PDA	Public Drainage Association
SSA	Science Services Administration
TMDL	Total Maximum Daily Load
USEPA	United States Environmental Protection Agency
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
WQA	Water Quality Analysis
WQLS	Water Quality Limited Segment
WRAS	Watershed Restoration Action Strategy

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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 Upper Choptank River watershed (basin code 02130404), located in Caroline, Talbot, and Queen Anne's Counties, is included in a number of Chesapeake Bay listing segments in the Integrated Report (IR); Choptank River Oligohaline and Choptank River Tidal Fresh. Below is a table identifying the listings associated with this watershed.

Table E1. 2010 Integrated Report Listings for the Upper Choptank River Watershed

Watershed	Basin Code	Non-tidal/Tidal	Designated Use	Year listed	Identified Pollutant	Listing Category
Upper Choptank River	02130404	Non-tidal	Aquatic Life and Wildlife	2002	Impacts to Biological Communities	5
Choptank River Tidal Fresh	CHOTF	Tidal	Seasonal Migratory fish spawning and nursery Subcategory		TN	3
					TP	3
			Aquatic Life and Wildlife	2008	Impacts to Estuarine Biological Communities	3
			Open Water Fish and Shellfish	1996	TN	5
				1996	TP	5
			Seasonal Shallow Water Submerged Aquatic Vegetation	2008	TSS	5

Table E1. 2010 Integrated Report Listings for the Upper Choptank River Watershed (cont)

Watershed	Basin Code	Non-tidal/Tidal	Designated Use	Year listed	Identified Pollutant	Listing Category
Choptank River Oligohaline	CHOOH	Tidal	Seasonal Migratory fish spawning and nursery Subcategory		TN	3
					TP	3
			Aquatic Life and Wildlife	2008	Impacts to Estuarine Biological Communities	3
			Open Water Fish and Shellfish	1996	TN	5
				1996	TP	5
			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 Designation in the Code of Maryland Regulations (COMAR) for Upper Choptank River and all tributaries is Use I designation - *water contact recreation, and protection of nontidal warmwater aquatic life.* In addition most of the mainstem of the Upper Choptank River and some tributaries are Use II designation - s*upport of estuarine and marine aquatic life and shellfish harvesting* (COMAR 2010 a, b, c). The Upper Choptank River watershed is not attaining its *protection of nontidal warmwater aquatic life* 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

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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 Upper 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 Upper 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 Upper Choptank River watershed can be summarized as follows:

- The BSID process has determined that biological communities in the Upper 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 2008 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 Upper 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 Upper Choptank River.

- The BSID process indentified low dissolved oxygen below <6.0 mg/l and low dissolved oxygen saturation as significantly associated with degraded biological conditions; however, elevated phosphorus and/or nitrogen concentrations were not identified. Low dissolved oxygen levels in the watershed are probably due to a combination of low topographic relief of the watershed and seasonal low flow/no flow conditions.

- The BSID process has also determined that biological communities in the Upper Choptank River watershed are likely degraded due to anthropogenic channelization of stream segments. MDE considers channelization as pollution not a pollutant; therefore, a Category 5 listing for this stressor is inappropriate. However, Category 4c is for waterbody segments where the State can demonstrate that the failure to meet applicable water quality standards is a result of pollution. Category 4c listings include segments impaired due to stream channelization or the lack of adequate flow. MDE recommends a Category 4c listing for the Upper Choptank River watershed based on channelization being present in approximately 67% of degraded stream miles.

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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 2008). 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.,

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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 Upper Choptank River watershed, and presents the results and conclusions of a BSID analysis of the watershed.

2.0   Upper Choptank River Watershed Characterization

2.1   Location

The Upper Choptank watershed is approximately 256 square miles and is part of the 6-digit Choptank River basin as shown in (Figure 1). The Upper Choptank extends through three Maryland counties and also into Delaware. The majority of the Maryland 8-digit watershed is located in Talbot and Caroline Counties, with only 3 square miles within Queen Anne's County. The headwaters originate in Delaware and flow in a southwesterly direction into Maryland east of the town of Goldsboro. Once in Maryland it flows predominately in a southerly direction through the towns of Greensboro and Denton. The Upper Choptank River is tidal throughout its navigable reach, which extends from its boundary with the Lower Choptank River watershed for approximately 35 miles upstream to an area north of the Town of Greensboro.

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).
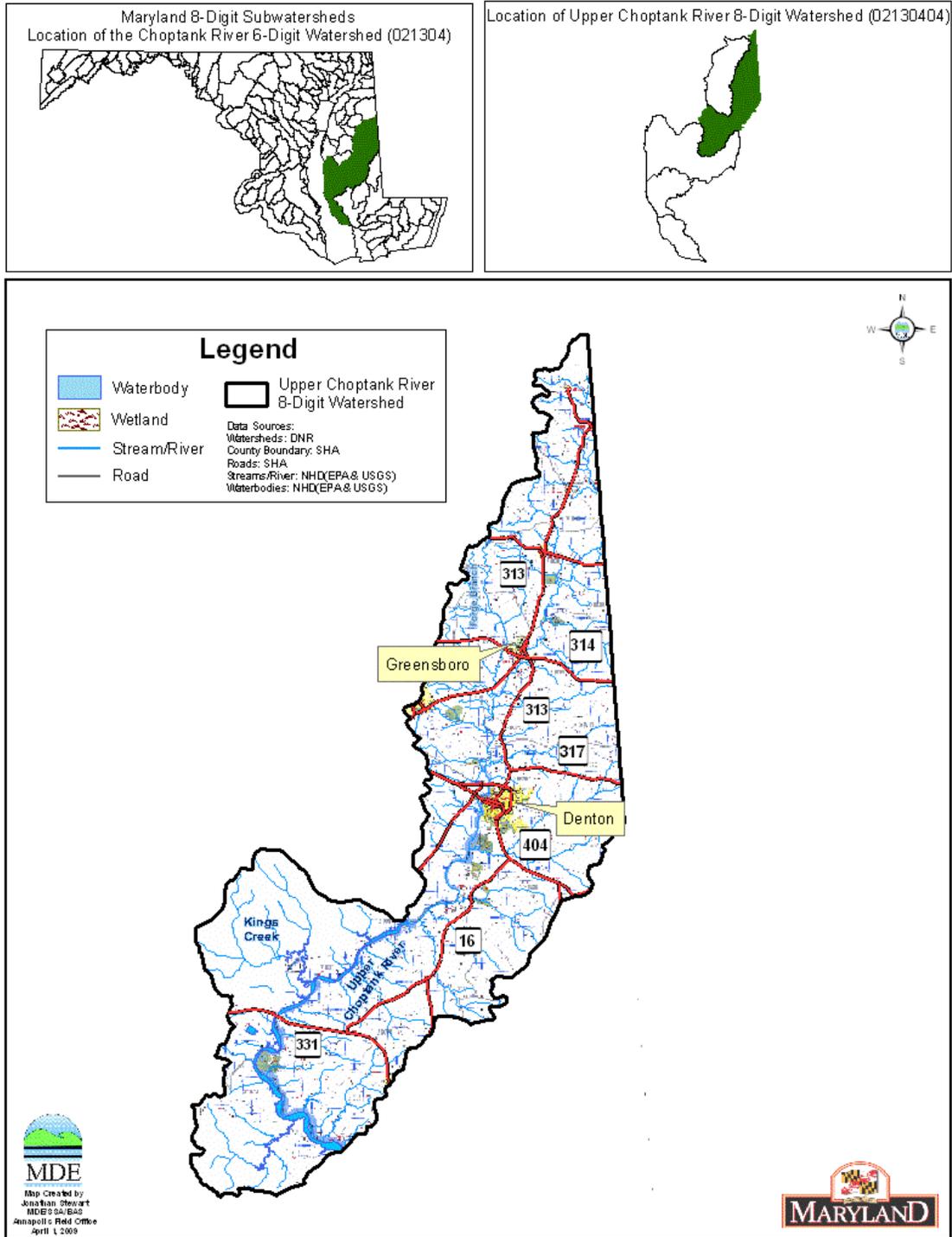
Figure 1. Location Map of the Upper Choptank River Watershed
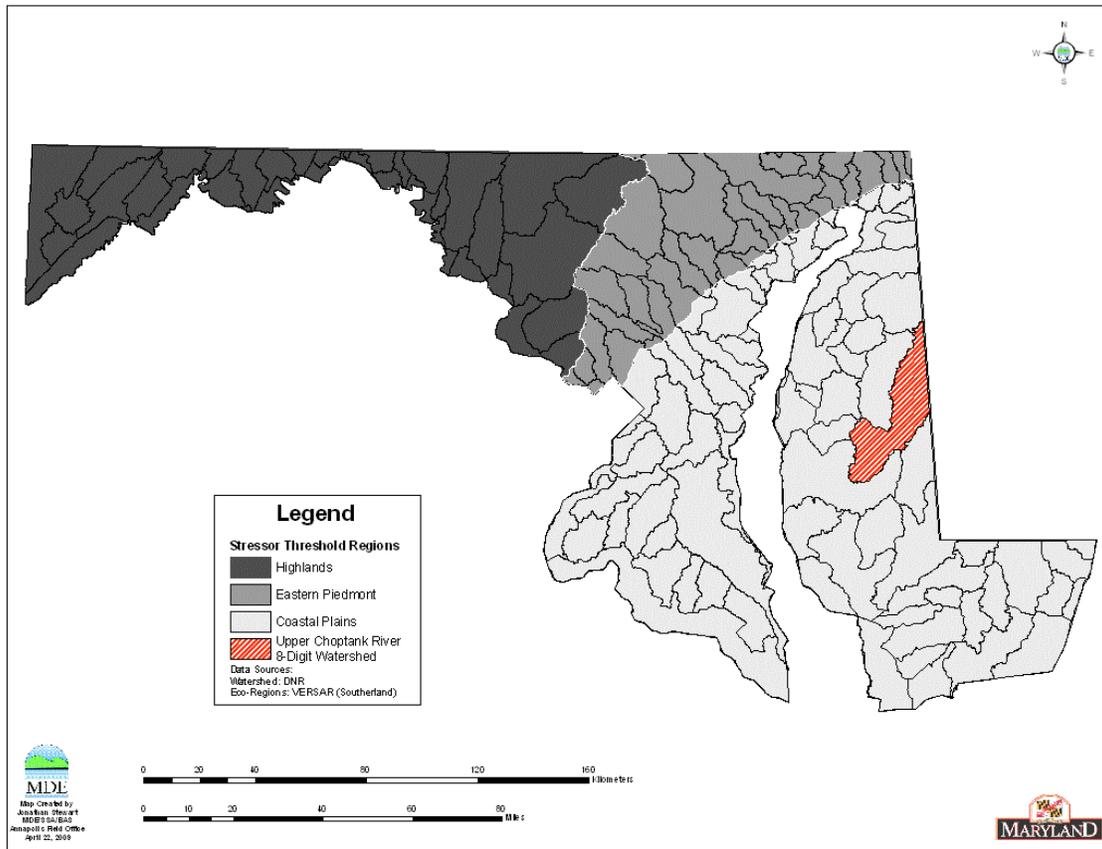
Figure 2. Eco-Region Location Map of the Upper Choptank River Watershed

2.2   Land Use

The Upper Choptank River watershed is predominantly rural with significant agricultural areas, as well as forest, small towns and pockets of suburban development. Large areas of land, which had poorly drained soils, were able to be developed because lands were drained by Public Drainage Association ditches. Maintenance of these ditches is central to continuation of much of the current economic activity in the watershed (MDDNR 2002). About 56% of the Upper Choptank Watershed in Maryland is prime farmland (MDDNR 2002). According to the Chesapeake Bay Program's Phase 5.2 Model, the land use distribution in the watershed is approximately 53% agricultural, 35% forest/herbaceous, and 12% urban (USEPA 2008) (see Figure 3 and Figure 4).
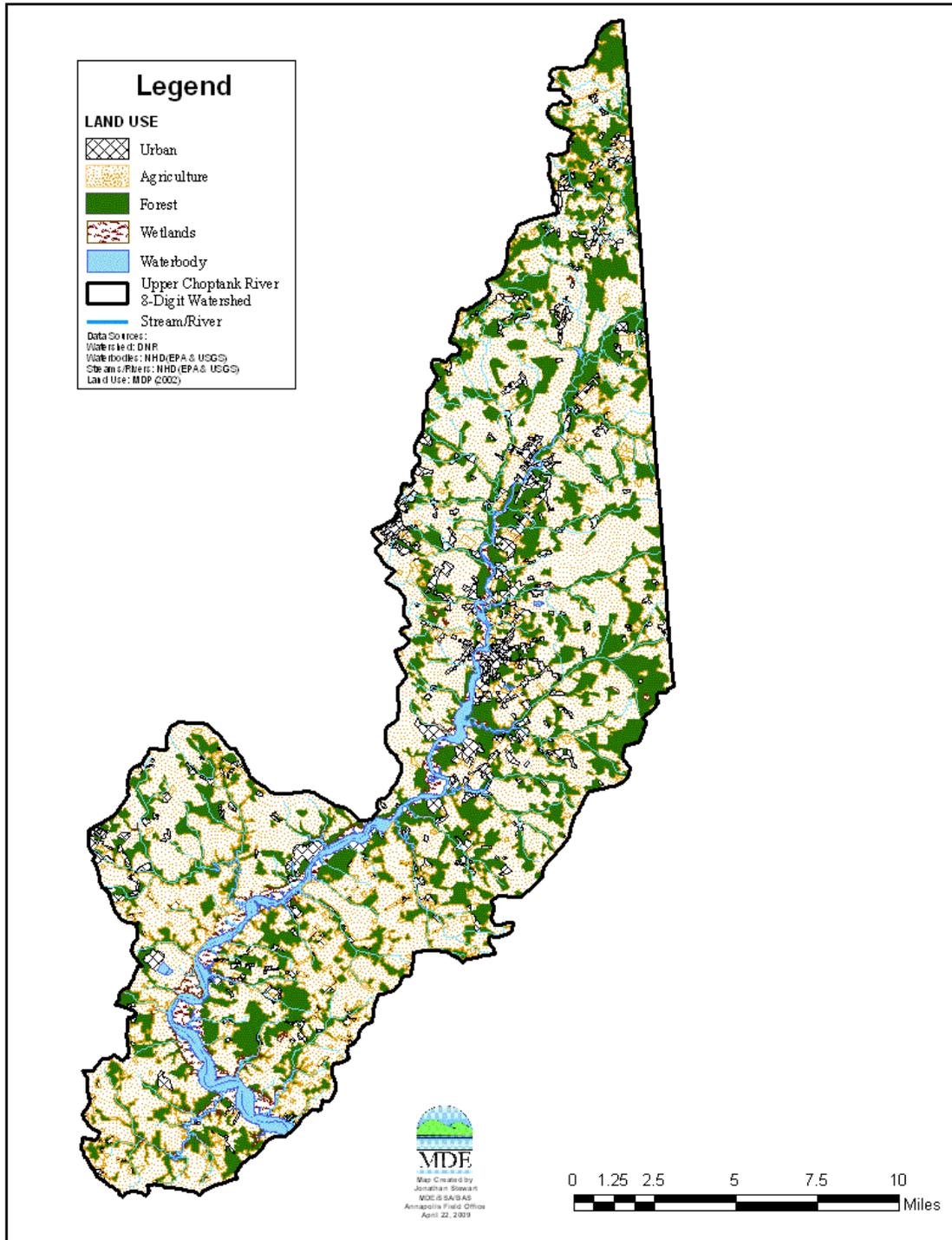
Figure 3. Land Use Map of the Upper Choptank River Watershed

Forest, 35%

Urban, 12%

Agriculture, 53%

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

2.3   Soils/hydrology

The Upper 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).

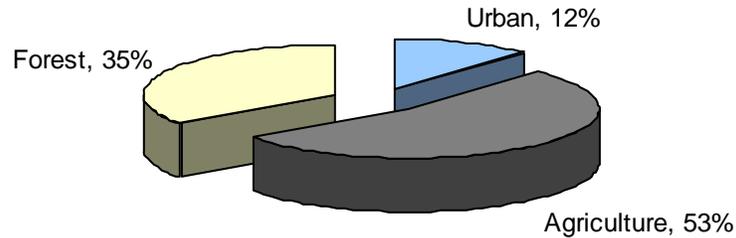Soils typically found in the Upper Choptank River watershed are the Sassafras, Fallsington, Galestown, Matapeake, Westbrook, and Othello series. The Sassafras series consist of very deep, well drained soils on sandy marine and old alluvial sediments. The Fallsington series consist of very deep poorly drained on coastal plain flatlands. Saturated hydraulic conductivity is high in the subsoil and high to very high in the substratum. The Galestown series consist of very deep, somewhat excessively drained soils formed in sandy marine sediments and glacial outwash on glacial terminal moraine. The Matapeake series consist of very deep, well drained soils in silty eolian sediments underlain by coarser fluvial or marine sediments. The Westbrook series consist of very deep, very poorly drained soils formed in organic deposits over loamy mineral material. They are in tidal marshes subject to inundation by salt water twice daily. Saturated hydraulic conductivity is moderately high to very high in the organic layers and low to high in the underlying mineral sediments. The Othello series consist of very deep, poorly drained soils, with saturated hydraulic conductivity being moderately high (USDA 1977).

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3.0 Upper Choptank River Watershed Water Quality Characterization

3.1 Integrated Report Impairment Listings

The Upper Choptank River watershed (basin code 02130404), located in Caroline, Talbot, and Queen Anne's Counties, is included in a number of Chesapeake Bay listing segments in the Integrated Report (IR); Choptank River Oligohaline and Choptank River Tidal Fresh. Below is a table identifying the listings associated with this watershed.

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			Seasonal Shallow Water Submerged Aquatic Vegetation	2008	TSS	5

3.2 Impacts to Biological Communities

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for Upper Choptank River and all tributaries is Use I designation - *water contact recreation, and protection of nontidal warmwater aquatic life.* In addition most of the mainstem of the Upper Choptank River and some tributaries are Use II designation - s*upport of estuarine and marine aquatic life and shellfish harvesting* (COMAR 2010a, 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 Upper Choptank River watershed is listed under Category 5 of the 2008 Integrated Report for impacts to biological communities. Approximately 38% of stream miles in the Upper 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 thirty-two stations. Twelve of the thirty-two 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 thirteen MBSS sites; with five having BIBI and/or FIBI scores lower than 3.0. Figure 5 illustrates principal dataset site locations for the Upper Choptank River watershed.

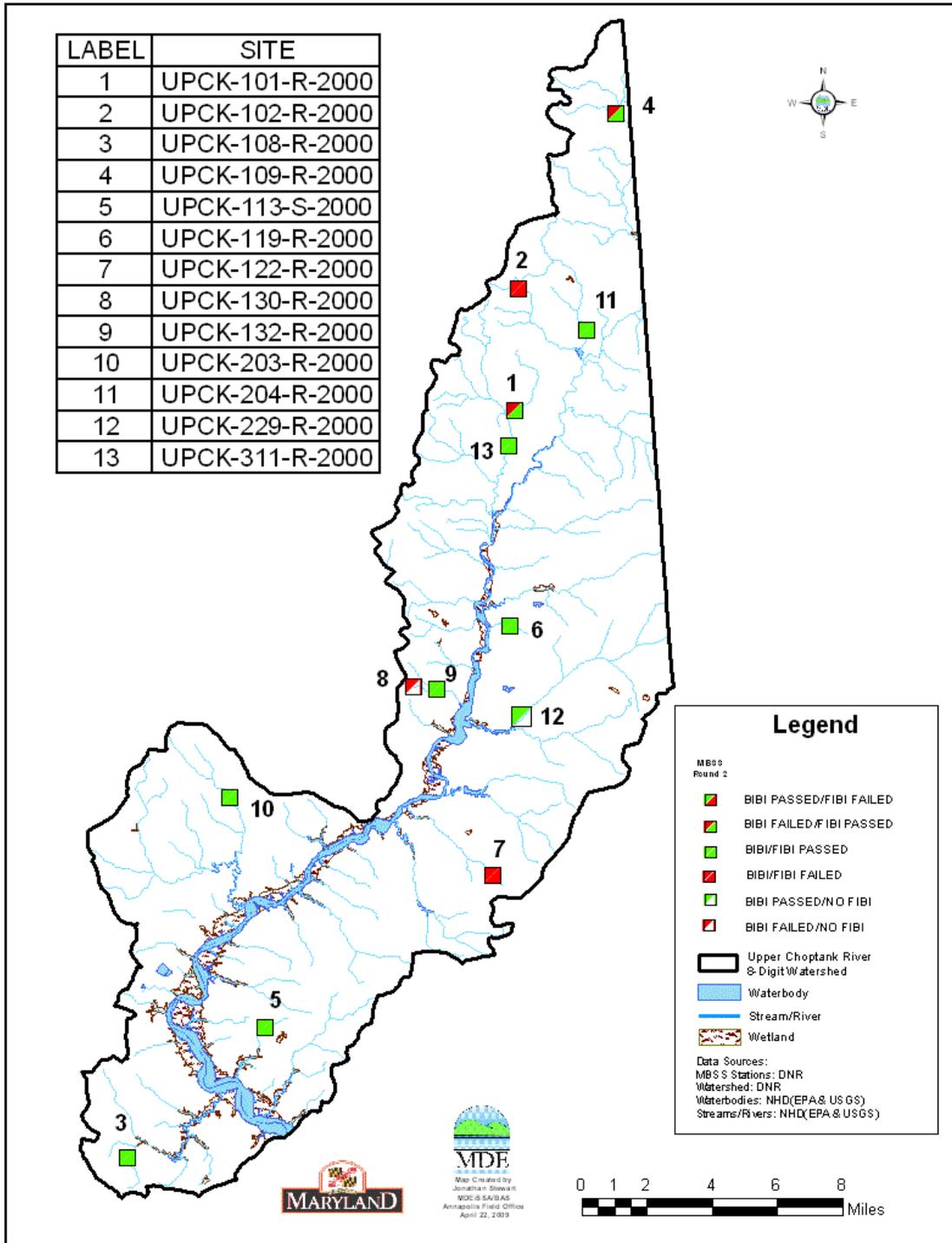| LABEL	SITE
1	UPCK-101-R-2000
2	UPCK-102-R-2000
3	UPCK-108-R-2000
4	UPCK-109-R-2000
5	UPCK-113-S-2000
6	UPCK-119-R-2000
7	UPCK-122-R-2000
8	UPCK-130-R-2000
9	UPCK-132-R-2000
10	UPCK-203-R-2000
11	UPCK-204-R-2000
12	UPCK-229-R-2000
13	UPCK-311-R-2000

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

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

The common odds ratio confidence interval was calculated to determine if the odds ratio was significantly greater than one. The confidence interval was estimated using the Mantel-Haenzel (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 a 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

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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 Upper 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 include cropland in sixty meter riparian buffer and low percentage of forested land use in watershed. Table 3 shows the summary of combined AR values for the source groups in the Upper 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 Upper Choptank River watershed.

Table 2. Stressor Source Identification Analysis Results for the Upper 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	13	5	214	0%	5%	No	----
	high % of high intensity urban in watershed	13	5	214	0%	9%	No	----
	high % of low intensity urban in watershed	13	5	214	0%	4%	No	----
	high % of transportation in watershed	13	5	214	0%	7%	No	----
	high % of high intensity urban in 60m buffer	13	5	212	0%	7%	No	----
	high % of low intensity urban in 60m buffer	13	5	212	0%	5%	No	----
	high % of transportation in 60m buffer	13	5	212	0%	9%	No	----

Table 2. Stressor Source Identification Analysis Results for the Upper 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	13	5	214	40%	18%	No	----
	high % of cropland in watershed	13	5	214	60%	27%	No	----
	high % of pasture/hay in watershed	13	5	214	20%	6%	No	----
	high % of agriculture in 60m buffer	13	5	212	0%	8%	No	----
	high % of cropland in 60m buffer	13	5	212	60%	18%	Yes	42%
	high % of pasture/hay in 60m buffer	13	5	212	20%	8%	No	----
Sources Barren	high % of barren land in watershed	13	5	214	0%	23%	No	----
	high % of barren land in 60m buffer	13	5	212	0%	6%	No	----
Sources Anthropogenic	low % forest in watershed	13	5	214	40%	5%	Yes	35%
	low % of forest in 60m buffer	13	5	212	0%	5%	No	----

Table 2. Stressor Source Identification Analysis Results for the Upper 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	13	5	208	20%	40%	No	----
	AMD acid source present	13	5	208	0%	0%	No	----
	organic acid source present	13	5	208	0%	6%	No	----
	agricultural acid source present	13	5	208	20%	7%	No	----

Table 3. Summary of Combined Attributable Risk Values of the Source Group in the Upper 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	----	
Agriculture	42%	
Barren Land	----	87%
Anthropogenic	35%	
Acidity	----	

Sources Identified by BSID Analysis

The two land use sources identified by the BSID analysis (Table 2), are the result of agricultural development within the Upper Choptank River watershed. According to the Chesapeake Bay Program's Phase 5.2 Model, a significant amount of the watershed is comprised of agricultural land uses (53%) (USEPA 2008). BSID results identified cropland land use within the sixty meter riparian buffer zone as having significant association with degraded biological conditions. The high percentage of cropland within the riparian buffer zone is indicative of the agricultural crops that are cultivated all the way to the stream banks. Although nutrient and best management practices (NMPs and BMPs) are in place to control sediment and nutrient runoff in the watershed, the BSID analyses revealed that agricultural practices especially in the riparian buffer zone continue to create conditions in the watershed that are impacting biological resources. Sediments in runoff from cultivated land are considered to be particularly influential in stream impairment (Waters 1995).

Typical anthropogenic alterations to a stream caused by agricultural development include channelization, 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 source analysis (Table 2) identifies cropland within sixty meter buffer and low percentage of forest in watershed as potential sources of stressors that may cause negative biological impacts. The combined AR for the source group is approximately 87% suggesting these sources potentially impacts a substantial portion of the degraded stream miles in the Upper Choptank River watershed (Table 3).

All the stressors identified in the BSID analysis for the Upper Choptank River watershed can be linked to the typical consequences of agricultural 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 Upper 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	12	5	132	0%	23%	No	----
	moderate bar formation present	12	5	132	0%	55%	No	----
	bar formation present	12	5	132	40%	82%	No	----
	channel alteration marginal to poor	12	5	128	80%	62%	No	----
	channel alteration poor	12	5	128	60%	27%	No	----
	high embeddedness	12	5	132	0%	0%	No	----
	epifaunal substrate marginal to poor	12	5	132	80%	45%	No	----
	epifaunal substrate poor	12	5	132	80%	10%	Yes	70%
	moderate to severe erosion present	12	5	132	0%	45%	No	----
	severe erosion present	12	5	132	0%	14%	No	----
	poor bank stability index	12	5	132	0%	23%	No	----
	silt clay present	12	5	132	100%	99%	No	----

Table 5. Habitat Biological Stressor Identification Analysis Results for the Upper 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	13	5	134	80%	13%	Yes	67%
	in-stream habitat structure marginal to poor	12	5	132	80%	40%	No	----
	in-stream habitat structure poor	12	5	132	40%	5%	Yes	35%
	pool/glide/eddy quality marginal to poor	12	5	132	100%	45%	Yes	55%
	pool/glide/eddy quality poor	12	5	132	40%	3%	Yes	37%
	riffle/run quality marginal to poor	12	5	132	60%	45%	No	----
	riffle/run quality poor	12	5	132	40%	18%	No	----
	velocity/depth diversity marginal to poor	12	5	132	80%	58%	No	----
	velocity/depth diversity poor	12	5	132	40%	14%	No	----
	concrete/gabion present	13	5	138	0%	1%	No	----
	beaver pond present	12	5	131	0%	6%	No	----
Riparian Habitat	no riparian buffer	13	5	134	20%	13%	No	----
	low shading	12	5	132	0%	9%	No	----

Table 6. Water Chemistry Biological Stressor Identification Analysis Results for the Upper 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	13	5	208	40%	25%	No	----
	high total dissolved nitrogen	13	5	44	40%	25%	No	----
	ammonia acute with salmonid present	13	5	208	40%	39%	No	----
	ammonia acute with salmonid absent	13	5	208	40%	26%	No	----
	ammonia chronic with salmonid present	13	5	208	60%	67%	No	----
	ammonia chronic with salmonid absent	13	5	208	40%	57%	No	----
	low lab pH	13	5	208	60%	38%	No	----
	high lab pH	13	5	208	0%	0%	No	----
	low field pH	13	5	207	80%	39%	No	----
	high field pH	13	5	207	0%	0%	No	----
	high total phosphorus	13	5	208	0%	3%	No	----
	high orthophosphate	13	5	208	20%	13%	No	----
	dissolved oxygen < 5mg/l	13	5	206	40%	14%	No	----
	dissolved oxygen < 6mg/l	13	5	206	60%	22%	Yes	38%
	low dissolved oxygen saturation	13	5	184	60%	18%	Yes	42%
	high dissolved oxygen saturation	13	5	184	0%	0%	No	----
	acid neutralizing capacity below chronic level	13	5	208	0%	9%	No	----
	acid neutralizing capacity below episodic level	13	5	208	40%	48%	No	----
	high chlorides	13	5	208	0%	6%	No	----
	high conductivity µS/cm	13	5	208	0%	5%	No	----
	high sulfates	13	5	208	0%	4%	No	----

Table 7. Summary of Combined Attributable Risk Values of the Stressor Group in the Upper 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	70%	
In-Stream Habitat	93%	
Riparian Habitat	----	94%
Water Chemistry	42%	

Stressors Identified by BSID Analysis

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

Sediment Conditions

BSID analysis results for Upper Choptank River watershed identified one 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 (poor)* (Table 4).

Epifaunal substrate (poor) was identified as significantly associated with degraded biological conditions in the Upper Choptank River, and found to impact approximately 70% 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, high sediment loads reduce the amount of available habitat and reduce benthic macroinvertebrate diversity and abundance.

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 70% suggesting these stressors impact a considerable proportion of the degraded stream miles in Upper Choptank River watershed (See Table 7).

In-stream Habitat Conditions

BSID analysis results for the Upper Choptank River watershed identified four habitat parameters that have a statistically significant association with poor to very poor stream biological condition*: channel alteration present, in-stream habitat structure (poor)*, and *pool/glide/eddy quality (marginal to poor & poor)*(Table 5)*.

Channelization present was identified as significantly associated with degraded biological conditions in the Upper Choptank River watershed, and found to impact approximately 67% of the stream miles with poor to very poor biological conditions. This stressor measures the presence/absence of channelization in stream banks. It describes both the straightening of channels and their fortification with concrete or other hard materials. Natural channels have diverse habitats with varying water velocities as the morphology changes between riffles and pools. The diverse nature of natural channels provides slow water refugia during high flow and many resting areas. With less structural diversity, channelized systems have minimal resting areas and organisms are easily swept away during high flows. In low flow periods, natural channels have sufficient water depth to support fish and aquatic species during the dry season, whereas channelized streams often have insufficient depth to sustain diverse aquatic life (Bolton and Shellberg 2001).

In-stream habitat structure (poor) was identified as significantly associated with degraded biological conditions in the Upper Choptank River watershed, and found to impact approximately 35% 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 Upper Choptank River watershed, and found to impact approximately 55% (*marginal to poor* rating) and 37% (*poor* rating) 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.

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 Yonemitsu 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 et al. 1993). The geomorphological characteristics described above are often strongly influenced by land use characteristics,

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e.g., agricultural development within the riparian buffer zone allowing for increased sedimentation and flow to alter natural in-stream habitat.

Sixty-seven percent of degraded stream miles in the watershed are artificially straightened or channelized in some way. During channelization, trees in the riparian buffer zone are often cut and woody debris is removed from the stream channel to allow for efficient movement of water away from agricultural fields. As a result heavily channelized streams are often shallow and offer little habitat diversity. The Delmarva Peninsula contains over 808 miles of Public Drainage Association (PDA) or tax ditches that drain over 143,311 acres of land (Bell and Favero 2000). Caroline County, which is part of the Choptank River watershed, holds the greatest number of tax ditches in the Maryland Eastern Shore, draining over 69,190 acres of cropland. The oldest PDA in the United States is located within the watershed, which was chartered by the State of Maryland in 1789 to drain the Long Marsh area, in order to convert marshland for agricultural development. The historical loss of wetlands in the Upper Choptank River watershed is estimated to be 48,169 acres which is a relatively large loss of wetlands compared with other similar Maryland watersheds (MDDNR 2002).

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 93 % suggesting this stressor impacts almost all of the degraded stream miles in the Upper Choptank River (Table 7).

Riparian Habitat Conditions

BSID analysis results for Upper 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).

Water Chemistry Conditions

BSID analysis results for Upper Choptank River identified only 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). These parameters are *low dissolved oxygen < 6mg/l* and *low dissolved oxygen saturation* (Table 6).

Low dissolved oxygen < 6mg/l was identified as significantly associated with degraded biological conditions and found in 38% of the stream miles with poor to very poor biological conditions in the Upper Choptank River watershed. Low dissolved oxygen (DO) concentrations may indicate organic pollution due to excessive oxygen demand and

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may stress aquatic organisms. The DO threshold value, at which concentrations below 5.0 mg/L may indicate biological degradation, is established by (COMAR 2010d).

Low (< 60%) DO saturation was identified as significantly associated with degraded biological conditions and found in 42% of the stream miles with poor to very poor biological conditions in the Upper Choptank River watershed. Natural diurnal fluctuations can become exaggerated in streams with excessive primary production. High and low DO saturation accounts for physical solubility limitations of oxygen in water and provides a more targeted assessment of oxygen dynamics than concentration alone. High DO saturation is considered to demonstrate oxygen production associated with high levels of photosynthesis. Low DO saturation is considered to demonstrate high respiration associated with excessive decomposition of organic material.

Although low DO concentrations are usually associated with surface waters experiencing eutrophication as the result of excessive nutrient loading, this might not be the case in the Upper Choptank River watershed. A 2002 MDNR Watershed Restoration Action Strategy Report (WRAS) stated that in comparison to the other watersheds that drain to the Chesapeake Bay in Maryland, the Upper Choptank River watershed was among those with lower total phosphorus (TP) and total nitrogen (TN) concentrations based on data from "core" nontidal stream monitoring stations in the watershed.

The 2002 MDDNR Upper Choptank River WRAS also reports that nearly all nontidal monitoring stations had DO concentrations above the 5.0 mg/l standard. However, in Talbot County there was one sample with very low DO concentration below 2.0 mg/l in the unnamed tributary at North Dover Road, which is located near the Easton Wastewater Treatment facility outfall. In Caroline County, the station at Old Town Branch reported one sample with a concentration approaching 3 mg/l (MDDNR 2002). There are three MBSS round two stations that have DO concentrations below the COMAR standard of 5.0 mg/l and four stations with low DO saturation.

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.

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 42 % suggesting this stressor impacts a moderate proportion of the degraded stream miles in the Upper Choptank River watershed (Table 7).

Discussion

The BSID analysis results suggest that degraded biological communities in the Upper Choptank River watershed are a result of increased agricultural development. During the past century, many streams in the coastal plain were channelized to improve drainage of croplands. Channelized streams lead to increased erosion of cropland and increased sedimentation of the receiving streams (Etnier and Starnes 1993). The result of channelization changed many streams into straight shallow ditches with severely depress biodiversity.

Natural channels have diverse habitats with varying water velocities as the morphology changes between riffles and pools. The sediment on the channel bottom is sorted and provides many microhabitats for organisms. In contrast, streams with straightened channels tend to have homogenous flow velocities and substrates that limit the types of habitat available. The diverse nature of natural channels provides slow water refugia during high flow and many resting areas. With less structural diversity, channelized systems have minimal resting areas and organisms are easily swept away during high flows. In low flow periods, natural channels have sufficient water depth to support fish and aquatic species during the dry season; where as, channelized systems often have insufficient depth to sustain required temperatures and dissolved oxygen necessary for healthy biological communities (Brookes 1988).

The ecological effects of channelization consist of both physical and biological effects to the aquatic system. A typical sequence of events is that channelization leads to immediate changes in physical aspects of the channel. These physical changes lead to longer-term biotic responses that extend over space and time (Simpson et al. 1982).

The combined AR for all the stressors is approximately 94%, suggesting that sediment, in-stream habitat, and water chemistry stressors identified in the BSID analysis would account for almost all of the degraded stream miles the Upper 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 Upper Choptank River 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 2010). 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 Upper Choptank River watershed, with pathways to show the watershed's probable stressors as indicated by the BSID analysis.
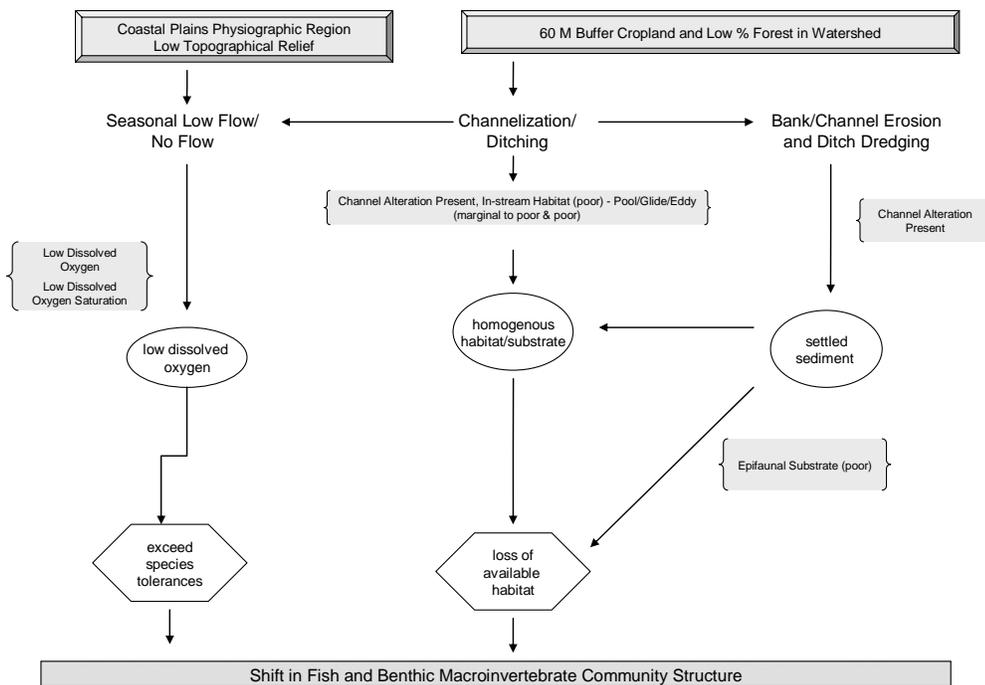
Figure 6. Final Causal Model for the Upper Choptank River Watershed

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5.0 Conclusions

Data suggest that the Upper 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 Upper Choptank River watershed are summarized as follows:

- The BSID process has determined that biological communities in the Upper 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 2008 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 Upper 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 Upper Choptank River.

- The BSID process indentified low dissolved oxygen below <6.0 mg/l and low dissolved oxygen saturation as significantly associated with degraded biological conditions; however, elevated phosphorus and/or nitrogen concentrations were not identified. Low dissolved oxygen levels in the watershed are probably due to a combination of low topographic relief of the watershed and seasonal low flow/no flow conditions.

- The BSID process has also determined that biological communities in the Upper Choptank River watershed are likely degraded due to anthropogenic channelization of stream segments. MDE considers channelization as pollution not a pollutant; therefore, a Category 5 listing for this stressor is inappropriate. However, Category 4c is for waterbody segments where the State can demonstrate that the failure to meet applicable water quality standards is a result of pollution.

Category 4c listings include segments impaired due to stream channelization or the lack of adequate flow. MDE recommends a Category 4c listing for the Upper Choptank River watershed based on channelization being present in approximately 67% of degraded stream miles.

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