Watershed Report for Biological Impairment of the Conococheague Creek Watershed, Washington County, Maryland Biological Stressor Identification Analysis Results and Interpretation

FINAL

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Table of Contents

List of Figures

List of Tables

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
MD	Maryland
MDDNR	Maryland Department of Natural Resources
MDE	Maryland Department of the Environment
MBSS	Maryland Biological Stream Survey
mg/L	Milligrams per liter
MS4	Municipal Separate Stormwater Systems
NMPs	Nutrient Management Practices
NPDES	National Pollution Discharge Elimination System
OP	Orthophosphate
SSA	Science Services Administration
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TN:TP	Total Nitrogen:Total Phosphorus
TP	Total Phosphorus
µS/cm	Micro Siemens per Centimeter
USEPA	United States Environmental Protection Agency
WQA	Water Quality Analysis
WQLS	Water Quality Limited Segment

Executive Summary

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

The Maryland Department of the Environment (MDE) has identified the waters of the Conococheague Creek watershed (basin number 02140504) has having multiple listings on the State's Integrated Report (Table E1).

Table E1. 2010 Integrated Report Listings for Conococheague Creek Watershed

Watershed	Basin Code	Non-tidal/Tidal	Designated Use	Year listed	Identified Pollutant	Listing Category
Conococheague Creek	02140504	Non-Tidal	Aquatic Life and Wildlife	-	BOD	2
				1996	TSS	4a
				2002	pH, High	5
				2004	Impacts to Biological Communities	5
			Fishing	2008	PCBs (Fish Tissue)	5
				-	Mercury (Fish Tissue)	2
			Water Contact Sports	2002	Fecal Coliform	4a

In 2002, the State began listing biological impairments on the Integrated Report. The current MDE biological assessment methodology assesses and lists only at the Maryland 8-digit watershed scale, which maintains consistency with how other listings on the Integrated Report are made, how TMDLs are developed, and how implementation is targeted. The listing methodology assesses the condition of Maryland 8-digit watersheds with multiple impacted sites by measuring the percentage of stream miles that have an Index of Biotic Integrity (IBI) score less than 3, and calculating whether this is significant from a reference condition watershed (i.e., healthy stream, <10% stream miles degraded).

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for Conococheague Creek and its tributaries are designated as Use IV-P - *recreational trout waters and public water supply*. In addition, COMAR requires all waterbodies to support at a minimum the Use I-P designation - *water contact recreation, protection of nontidal warmwater aquatic life, public water supply* (COMAR 2012 a, b). The Conococheague Creek watershed is not attaining its Use I-P designation because of biological impairments. As an indicator of designated use attainment, MDE uses Benthic and Fish Indices of Biotic Integrity (BIBI/FIBI) developed by the Maryland Department of Natural Resources Maryland Biological Stream Survey (MDDNR MBSS).

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

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

This Conococheague Creek watershed report presents a brief discussion of the BSID process on which the watershed analysis is based, and may be reviewed in more detail in the report entitled “Maryland Biological Stressor Identification Process” (MDE 2009a). Data suggest that the degradation of biological communities in Conococheague Creek is strongly influenced by urban and agricultural land use and its concomitant effects: altered hydrology and elevated levels of sediments, nutrients, and inorganic pollutants. The development of landscapes creates broad and interrelated forms of degradation (i.e., hydrological, morphological, and water chemistry) that can affect stream ecology and biological composition. Peer-reviewed scientific literature establishes a link between highly urbanized and agricultural landscapes and degradation in the aquatic health of non-tidal stream ecosystems.

The results of the BSID process, and the probable causes and sources of the biological impairments of the Conococheague Creek watershed can be summarized as follows:

- The BSID process has determined that the biological communities in Conococheague Creek are likely degraded due to sediment and habitat related stressors. Specifically, altered hydrology and runoff from urban and agriculturally developed landscapes have resulted in erosion and subsequent elevated suspended sediment that are, in turn, the probable causes of impacts to biological communities in the watershed. The BSID results confirm the establishment of a USEPA approved sediment TMDL for the Conococheague Creek watershed was an appropriate management action to begin addressing the impacts of sediment stressors on the biological communities in the watershed.

- The BSID analysis has determined that both phosphorus and nitrogen are probable causes of impacts to biological communities in the Conococheague Creek watershed. Total phosphorus, orthophosphate, and total nitrogen were all identified as having significant association with degraded biological conditions. An analysis of observed TN:TP ratios, however, indicate that phosphorus is the limiting nutrient in the Conococheague Creek watershed. Therefore, excess nitrogen per se is not the cause of the biological impairment in watershed, and the reduction of nitrogen loads would not be an effective means of ensuring that the Conococheague Creek watershed is free from impacts on aquatic life from eutrophication. Therefore, load allocations for the Conococheague Creek Nutrient TMDL will apply only to total phosphorus. The BSID results thus support a Category 5 listing of Total Phosphorus for the non-tidal portion of the 8-digit watershed as an appropriate management action to begin addressing the impacts of nutrient stressors on the biological communities in the Conococheague Creek watershed.

- The BSID process has also determined that the biological communities in the Conococheague Creek watershed are likely degraded due to inorganic pollutants (i.e., chlorides and sulfates). Chloride and sulfate levels are significantly associated with degraded biological conditions and found in 93% and 85% of the stream miles with poor to very poor biological conditions in the Conococheague Creek watershed. Runoff from roads, urban, and agricultural land uses cause an increase in contaminant loads from nonpoint sources by delivering an array of inorganic pollutants to surface waters. Discharges of inorganic compounds are very intermittent; concentrations vary widely depending on the time of year as well as a variety of other factors may influence their impact on aquatic life. Future monitoring of these parameters will help in determining the spatial and temporal extent of these impairments in the watershed. The BSID results thus support a Category 5 listing of chloride and sulfates for the 8-digit watershed as an appropriate management action to begin addressing the impacts of these stressors on the biological communities in the Conococheague Creek watershed.

1.0 Introduction

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

The current MDE biological assessment methodology is a three-step process: (1) a data quality review, (2) a systematic vetting of the dataset, and (3) a watershed assessment that guides the assignment of biological condition to Integrated Report categories. In the data quality review step, available relevant data are reviewed to ensure they meet the biological listing methodology criteria of the Integrated Report (MDE 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 classified as impaired (Category 5), then a stressor identification analysis is completed to determine if a TMDL is necessary. A Category 5 listing can be amended to a Category 4a if a TMDL was established and approved by USEPA or Category 4b if other pollution control requirements (*i.e.*, permits, consent decrees, etc.) are expected to attain water quality standards. If the State can demonstrate that watershed impairment is a result of pollution, not a specific pollutant, the watershed is listed under Category 4c.

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 Biological Stream Survey (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 Conococheague Creek watershed, and presents the results and conclusions of a BSID analysis of the watershed.

2.0 Conococheague Creek Watershed Characterization

2.1 Location

The MD 8-digit Conococheague Creek watershed is located in the Potomac River basin within Washington County, Maryland (see Figure 1). Conococheague Creek is a free-flowing stream that originates in Pennsylvania and travels southward for 80 miles to end its journey at the Potomac River near Williamsport, Maryland. The Conococheague Creek watershed is located in both Maryland (MD) and Pennsylvania, with a drainage area of 568 square miles. The majority (88.4%) of the watershed is in Pennsylvania (in Franklin, Adams, Cumberland and Perry Counties) with a portion in Washington County, MD. The tributaries of Conococheague Creek in MD include Semple Run, Meadow Brook, Rush Run, Toms Run, and Rockdale Run. The watershed is located in Highland region of three distinct eco-regions identified in the MBSS indices of biological integrity (IBI) metrics (Southerland et al. 2005) (see Figure 2).

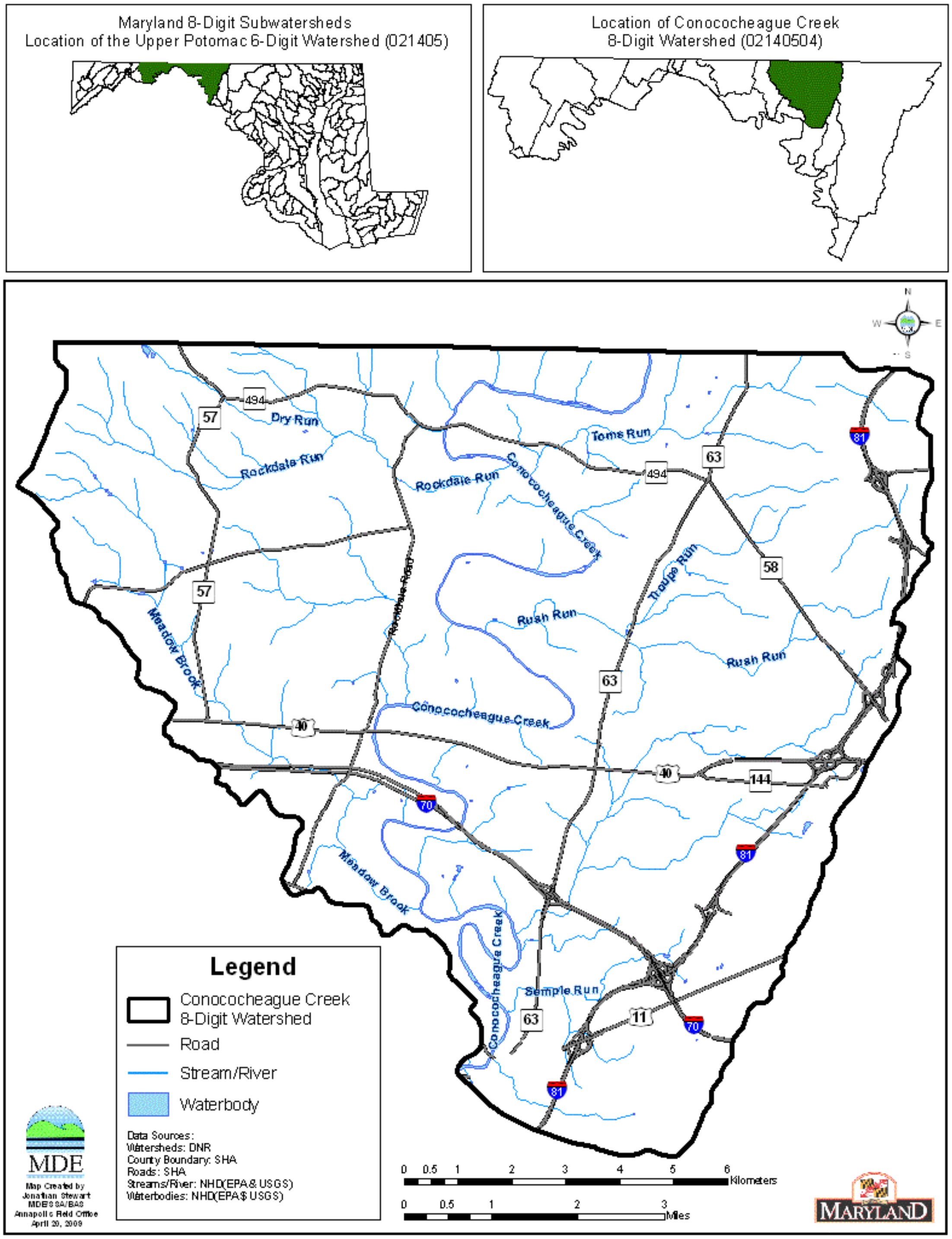

Figure 1. Location Map of the Conococheague Creek Watershed

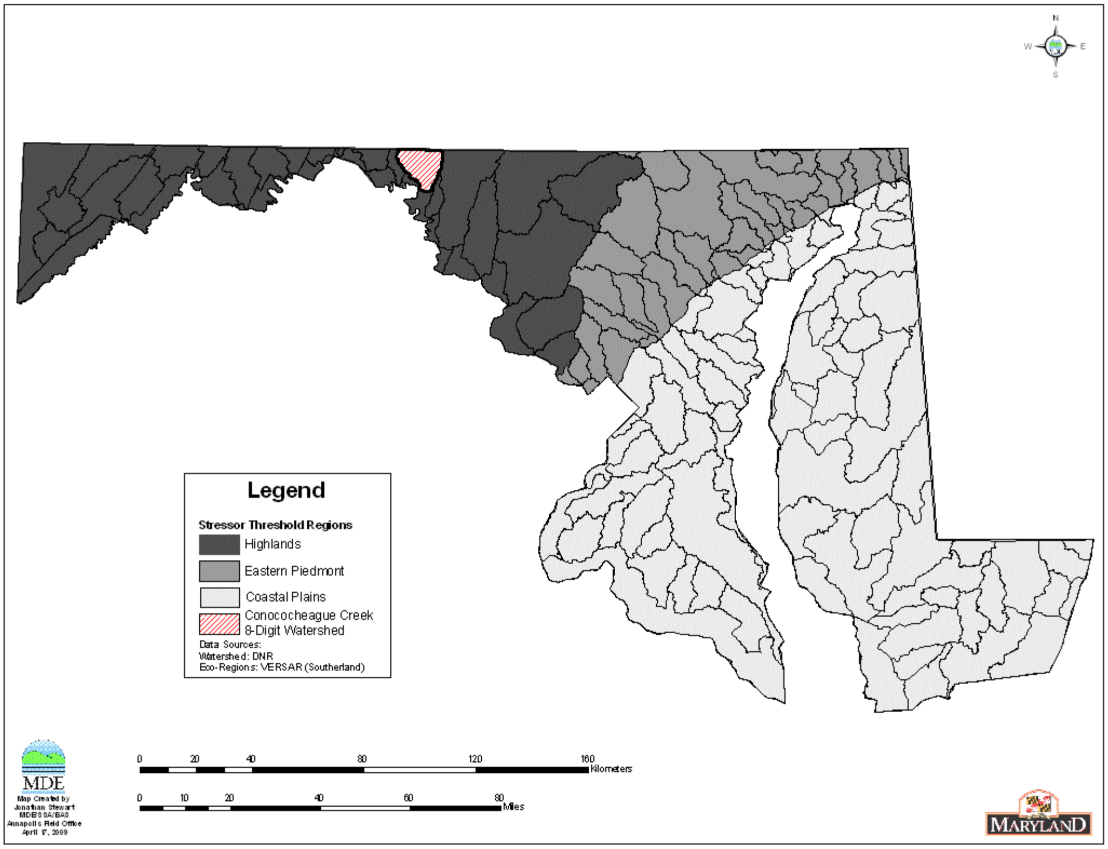

Figure 2. Eco-Region Location Map of the Conococheague Creek Watershed

2.2 Land Use

Conococheague Creek and its tributaries flow through several towns including Chambersburg, Greencastle and Mercersburg in PA and Williamsport in MD. Many of these areas were built before modern stormwater runoff controls were required by the State. There is also a significant amount of agriculture within the watershed, which consists mostly of cropland with lesser amounts of pasture. Conococheague Creek watershed contains urban, agricultural, and forested land use (see Figure 3). The land use distribution in the watershed is approximately 53.5% agricultural, 30% urban, and 16.5% forest/herbaceous (see Figure 4). Impervious surfaces encompass 6% of the total land use in the watershed (USEPA 2010).

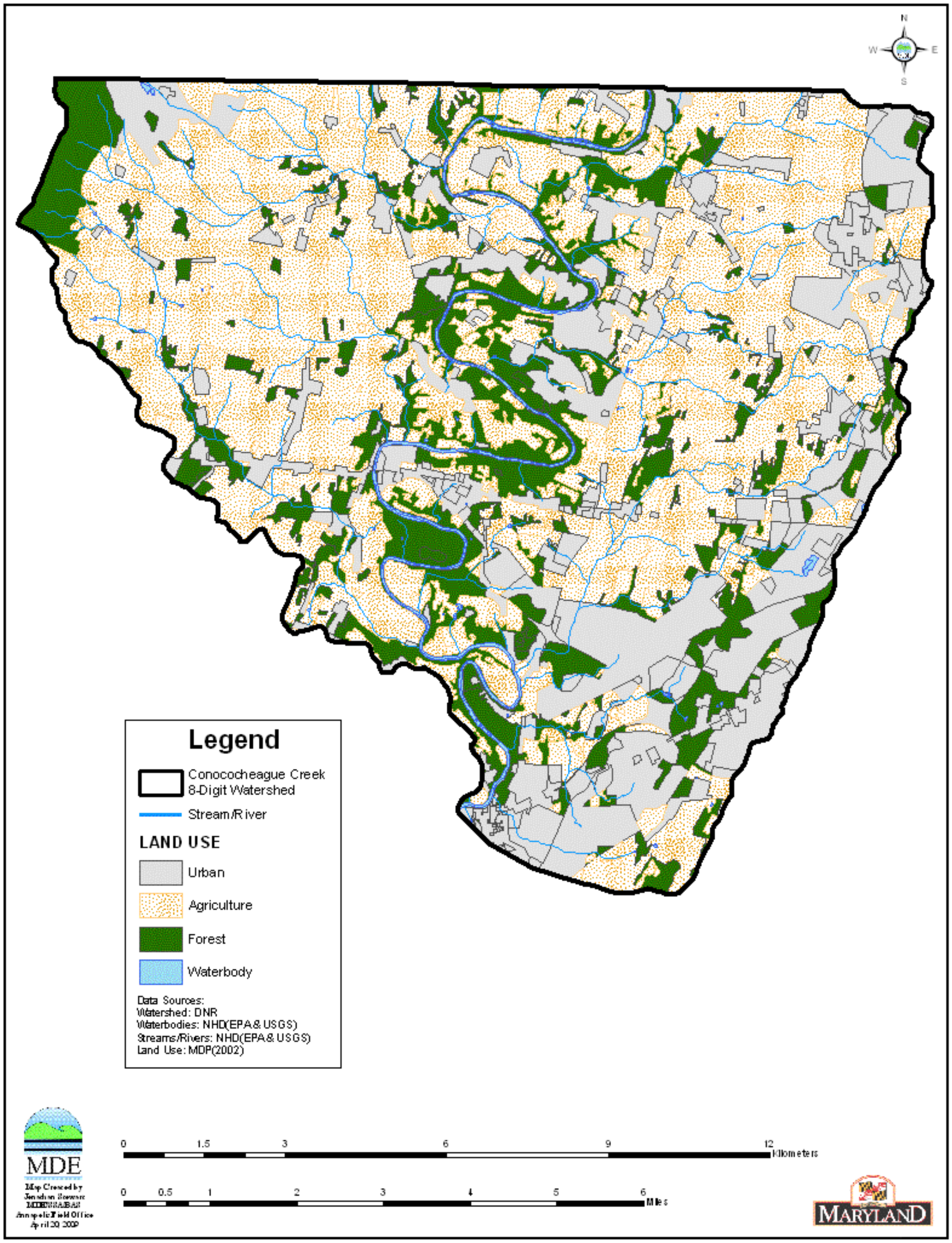

Figure 3. Land Use Map of the Conococheague Creek Watershed

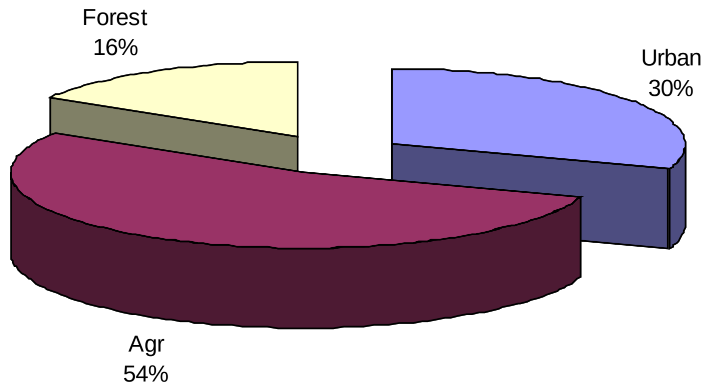

Figure 4. Proportions of Land Use in the Conococheague Creek Watershed

2.3 Soils/hydrology

The Conococheague Creek watershed lies within the Highland eco-region in an area known as the Ridge and Valley Province of Western Maryland, between South Mountain and Dans Mountain. Two distinct topographic and geologic zones separate the Province: the Great Valley (Hagerstown Valley) and the Allegheny Ridge. The Great Valley is a wide, flat, and open valley formed on Cambrian and Ordovician limestone, dolomite, and alluvial fan deposits alongside the bordering mountains. The Allegheny Ridge is characterized by erosion-resistant sandstone aligned in the northeast-southwest direction. The surface geology is characterized by folded and faulted sedimentary rocks, layered limestone and shale, and mountainous soils composed of clay, clay loams, and sandy and stony loams (MDDNR 2007; MGS 2007; MDE 2000).

The soils in the watershed are in the Elliber-Dekalb-Opequon Association. The Elliber soils are very deep on both the tops and sides of the ridges where they cover a cherty limestone. They also contain large quantities of chert fragments. The Dekalb soils are moderately deep, very stony, and cover a sandstone, and the Opequon soils are generally found on the sides of the limestone ridges (USDA 1962).

3.0 Conococheague Creek Water Quality Characterization

3.1 Integrated Report Impairment Listings

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The Maryland Department of the Environment (MDE) has identified the waters of the Conococheague Creek watershed (basin number 02140504) has having multiple listings on the State's Integrated Report (Table 1).

Table 1. 2010 Integrated Report Listings for Conococheague Creek Watershed

Watershed	Basin Code	Non-tidal/Tidal	Designated Use	Year listed	Identified Pollutant	Listing Category
Conococheague Creek	02140504	Non-Tidal	Aquatic Life and Wildlife		BOD	2
				1996	TSS	4a
				2002	pH, High	5
				2004	Impacts to Biological Communities	5
			Fishing	2008	PCBs (Fish Tissue)	5
					Mercury (Fish Tissue)	2
			Water Contact Sports	2002	Fecal Coliform	4a

3.2 Biological Impairment

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for Conococheague Creek and its tributaries are designated as Use IV-P - *recreational trout waters and public water supply*. In addition, COMAR requires these waterbodies to support at a minimum the Use I-P designation - *water contact recreation, protection of nontidal warmwater aquatic life, public water supply* (COMAR 2012 a, b). The Conococheague Creek watershed is not attaining its Use I-P designation because of biological impairments. 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 Conococheague Creek watershed is listed under Category 5 of the 2010 Integrated Report as impaired for impacts to biological communities. Approximately 85% of stream miles in the Conococheague Creek basin are estimated as having fish and and/or benthic indices of biological impairment in the very poor to 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 thirteen sites. Eleven of the thirteen 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, i.e. MBSS Round 2 contains ten MBSS sites with nine having BIBI and/or FIBI scores lower than 3.0. Figure 5 illustrates principal dataset site locations for the Conococheague Creek watershed.

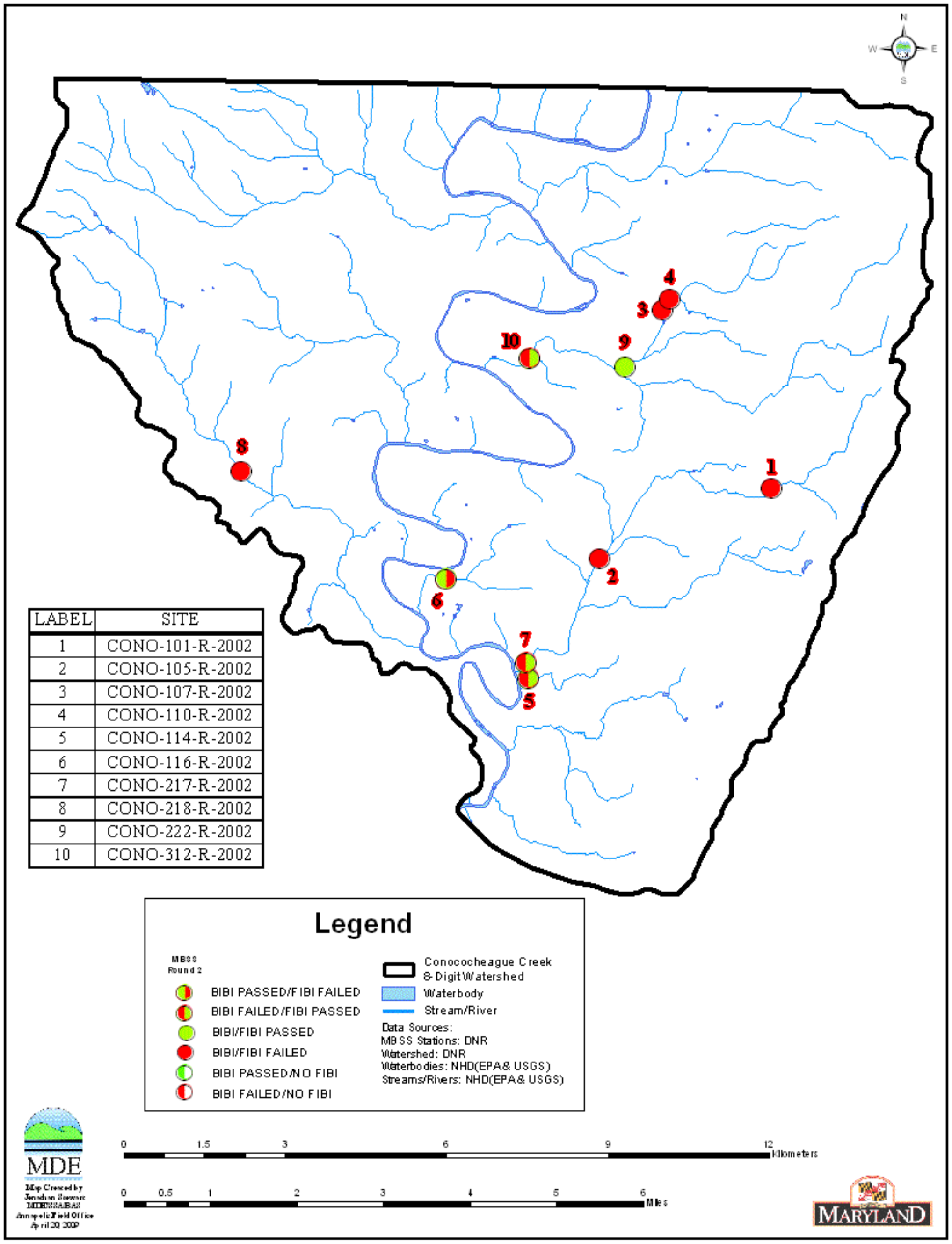

Figure 5. Principle Dataset Sites for the Conococheague Creek Watershed

4.0 Conococheague Creek Watershed Stressor Identification Results

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

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

The common odds ratio confidence interval was calculated to determine if the odds ratio was significantly greater than one. The confidence interval was estimated using the Mantel-Haenzel (1959) approach and is based on the exact method due to the small sample size for cases. A common odds ratio significantly greater than one indicates that there is a statistically significant higher likelihood that the stressor is present when there are very poor to 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 very poor to 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 very poor to poor biological conditions within the watershed (i.e., cases). The attributable risk (AR) defined herein is the portion of the cases with very poor to 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 2009a).

The parameters used in the BSID analysis are segregated into five groups: land use sources, and stressors representing sediment, in-stream habitat, riparian habitat, and water chemistry conditions. Through the BSID analysis, MDE identified parameters from all five groups has having significant association with degraded fish and/or benthic biological conditions. Parameters identified as representing sources are listed in Table 2. A summary of combined AR values for each source group is shown in Table 3. As shown in Table 4 through Table 6, parameters from all stressor groups were identified as possible biological stressors in the Conococheague Creek watershed. A summary of combined AR values for each stressor group is shown in Table 7.

Table 2. Stressor Source Identification Analysis Results for the Conococheague Creek 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 per strata with fair to good Fish and Benthic IBI)	% of case sites with source present	% of control sites per strata 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	10	9	156	33%	1%	Yes	33%
	high % of high intensity urban in watershed	10	9	159	89%	4%	Yes	85%
	high % of low intensity urban in watershed	10	9	159	56%	8%	Yes	48%
	high % of transportation in watershed	10	9	159	89%	9%	Yes	80%
	high % of high intensity urban in 60m buffer	10	9	159	56%	6%	Yes	50%
	high % of low intensity urban in 60m buffer	10	9	159	44%	7%	Yes	38%
	high % of transportation in 60m buffer	10	9	159	56%	9%	Yes	47%
Sources Agriculture	high % of agriculture in watershed	10	9	159	44%	6%	Yes	39%
	high % of cropland in watershed	10	9	159	56%	6%	Yes	50%
	high % of pasture/hay in watershed	10	9	159	0%	8%	No	----
	high % of agriculture in 60m buffer	10	9	159	56%	6%	Yes	50%
	high % of cropland in 60m buffer	10	9	159	78%	4%	Yes	73%
	high % of pasture/hay in 60m buffer	10	9	159	0%	8%	No	----
Sources Barren	high % of barren land in watershed	10	9	159	22%	7%	No	----
	high % of barren land in 60m buffer	10	9	159	11%	6%	No	----

Table 2. Stressor Source Identification Analysis Results for the Conococheague Creek (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 per strata with fair to good Fish and Benthic IBI)	% of case sites with source present	% of control sites per strata with source present	Possible stressor (Odds of stressor in cases significantly higher that odds or 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 Anthropogenic	low % of forest in watershed	10	9	159	89%	5%	Yes	84%
	low % of forest in 60m buffer	10	9	159	78%	6%	Yes	72%
Sources Acidity	atmospheric deposition present	10	9	159	0%	39%	No	----
	AMD acid source present	10	9	159	0%	4%	No	----
	organic acid source present	10	9	159	0%	3%	No	----
	agricultural acid source present	10	9	159	0%	1%	No	----

Table 3. Summary of Combined AR Values for Source Groups for the Conococheague Creek 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	87%	97%
Agriculture	73%	
Barren Land	----	
Anthropogenic	84%	
Acidity	----	

4.1 Sources Identified by BSID Analysis

All thirteen source parameters, identified in the BSID analysis for the Conococheague Creek watershed are representative of impacts from urban and agricultural landscapes. The watershed contains portions of two major urban centers Williamsport and Hagerstown. Many of these areas were built before modern stormwater runoff controls were required by the State. There is also a significant amount of agriculture within the watershed, which consists mostly of row crop.

Urban land uses comprise thirty percent of the Conococheague Creek watershed. The scientific community (Booth 1991, Konrad and Booth 2002, and Meyer, Paul, and Taulbee 2005) has consistently identified negative impacts to biological conditions as a result of increased urbanization. A number of systematic and predictable environmental responses have been noted in streams affected by urbanization, and this consistent sequence of effects has been termed “urban stream syndrome” (Meyer, Paul, and Taulbee 2005). Symptoms of urban stream syndrome include flashier hydrographs, altered habitat conditions, degradation of water quality, and reduced biotic richness, with increased dominance of species tolerant to anthropogenic (and natural) stressors. Impervious cover reduces base flow by limiting the amount of ground water recharge in the watershed. Flow volumes and velocities in streams generally increase during storm events due to the higher quantity of water that runs off impervious surfaces and into the stream channels. This creates a very unstable system that goes from destructive floods to total de-watering in very short time intervals resulting in biological communities under constant stress and adjustment (CAWPD 2000).

Increases in impervious surface cover that accompany urbanization alters stream hydrology, forcing runoff to occur more readily and quickly during rainfall events, decreasing the time it takes water to reach streams and causing them to be more “flashy” (Walsh et al. 2005). Land development can also cause an increase in contaminant loads from point and nonpoint sources by adding sediments, nutrients, road salts, toxics, and inorganic pollutants to surface waters. In virtually all studies, as the amount of impervious area in a watershed increases, fish and benthic communities exhibit a shift away from sensitive species to assemblages consisting of mostly disturbance-tolerant taxa (Walsh et al. 2005).

Numerous studies have also documented 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, and Bis, Zdanowicz, and Zalewski 2000). Researchers commonly report that streams draining agricultural lands support fewer species of sensitive benthic and fish taxa than streams draining forested catchments (Wang et al. 1997). Agricultural land use degrades streams by increasing nonpoint inputs of pollutants, impacting riparian and stream channel habitat, and altering flows.

Agricultural land uses comprise 54% of the Conococheague Creek watershed. Agricultural land use within the watershed, as well as within the sixty meter riparian zone, were found to be significantly associated with poor to very poor biological conditions in the watershed. The high percentage of agricultural land use within the 60 meter (M) buffer zone is indicative of the agricultural crops that are cultivated to the stream banks. Although nutrient management practices (NMPs) and best management practices (BMPs) are in place to control nutrient runoff in the watershed, the BSID analyses revealed that agricultural practices continue to create conditions in the watershed that are impacting biological resources. The excess nitrogen and phosphorus from fertilizer applications is leading to eutrophication in the watershed, as evidenced by the low dissolved oxygen stressors identified as significantly associated with degraded biological conditions in the watershed.

Streams in highly agricultural landscapes tend to have poor habitat quality, reflected in declines in habitat indices and bank stability, as well as greater deposition of sediments on and within the streambed (Roth, Allan, and Erickson 1996 & Wang et al. 1997). Sediments in runoff from cultivated land and livestock trampling are considered to be particularly influential in stream impairment (Waters 1995). The BSID analysis identified row crop land use as significant not only in the watershed but also in the riparian buffer zone. Agricultural land use is an important source of pollution when rainfall carries sediment, fertilizers, manure, and pesticides into streams. The three major nutrients in fertilizers and manure are nitrogen, phosphorus, and potassium. The agricultural land uses in the Conococheague Creek watershed are potential sources for the elevated levels of nutrients, inorganic pollutants, and conductivity identified in the BSID analysis.

The BSID source analysis (Table 2) identifies various types of urban and agricultural land uses as potential sources of stressors that may cause negative biological impacts. The combined AR for this source group is approximately 97% suggesting that urban and agricultural development impacts a substantial proportion of the degraded stream miles in Conococheague Creek (Table 3).

Table 4. Sediment Biological Stressor Identification Analysis Results for Conococheague Creek Watershed

Parameter Group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites per strata with fair to good Fish and Benthic IBI)	% of case sites with stressor present	% of control sites per strata with stressor present	Possible stressor (Odds of stressor in cases significantly higher than odds of stressors 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	10	9	78	11%	9%	No	----
	moderate bar formation present	10	9	78	22%	44%	No	----
	bar formation present	10	9	78	44%	88%	No	----
	channel alteration marginal to poor	10	9	78	22%	42%	No	----
	channel alteration poor	10	9	78	11%	9%	No	----
	high embeddedness	10	9	77	78%	4%	Yes	74%
	epifaunal substrate marginal to poor	10	9	78	89%	20%	Yes	69%
	epifaunal substrate poor	10	9	78	56%	4%	Yes	52%
	moderate to severe erosion present	10	9	78	22%	25%	No	----
	severe erosion present	10	9	78	11%	2%	No	----
	poor bank stability index	10	9	78	0%	4%	No	----
	silt clay present	10	9	78	100%	99%	No	----

Table 5. Habitat Biological Stressor Identification Analysis Results for the Conococheague Creek Watershed

Parameter Group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites per strata with fair to good Fish and Benthic IBI)	% of case sites with stressor present	% of control sites per strata with stressor present	Possible stressor (Odds of stressor in cases significantly higher than odds of stressors 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	10	9	81	11%	10%	No	----
	in-stream habitat structure marginal to poor	10	9	78	44%	24%	No	----
	in-stream habitat structure poor	10	9	78	22%	3%	Yes	20%
	pool/glide/eddy quality marginal to poor	10	9	78	78%	51%	No	----
	pool/glide/eddy quality poor	10	9	78	33%	7%	Yes	26%
	riffle/run quality marginal to poor	10	9	78	22%	36%	No	----
	riffle/run quality poor	10	9	78	11%	7%	No	----
	velocity/depth diversity marginal to poor	10	9	78	78%	56%	No	----
	velocity/depth diversity poor	10	9	78	22%	9%	No	----
	concrete/gabion present	10	9	81	0%	3%	No	----
	beaver pond present	10	9	78	0%	2%	No	----
Riparian Habitat	no riparian buffer	10	9	81	33%	24%	No	----
	low shading	10	9	78	44%	9%	Yes	35%

Table 6. Water Chemistry Biological Stressor Identification Analysis Results for the Conococheague Creek Watershed

Parameter Group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites per strata with fair to good Fish and Benthic IBI)	% of case sites with stressor present	% of control sites per strata with stressor present	Possible stressor (Odds of stressor in cases significantly higher than odds of stressors 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	10	9	159	89%	8%	Yes	81%
	high total dissolved nitrogen	0	0	0	0%	0%	No	----
	ammonia acute with salmonid present	10	9	159	11%	2%	No	----
	ammonia acute with salmonid absent	10	9	159	11%	1%	No	----
	ammonia chronic with salmonid present	10	9	159	11%	4%	No	----
	ammonia chronic with salmonid absent	10	9	159	11%	2%	No	----
	low lab pH	10	9	159	0%	5%	No	----
	high lab pH	10	9	159	0%	1%	No	----
	low field pH	10	9	154	0%	14%	No	----
	high field pH	10	9	154	0%	0%	No	----
	high total phosphorus	10	9	159	44%	3%	Yes	41%
	high orthophosphate	10	9	159	22%	4%	Yes	18%
	dissolved oxygen < 5mg/l	10	9	154	22%	3%	Yes	20%
	dissolved oxygen < 6mg/l	10	9	154	33%	7%	Yes	26%
	low dissolved oxygen saturation	10	9	138	11%	4%	No	----
	high dissolved oxygen saturation	10	9	138	0%	1%	No	----
	acid neutralizing capacity below chronic level	10	9	159	0%	6%	No	----
	acid neutralizing capacity below episodic level	10	9	159	0%	43%	No	----
	high chlorides	10	9	159	100%	7%	Yes	93%
	high conductivity	10	9	159	100%	4%	Yes	96%
	high sulfates	10	9	159	89%	4%	Yes	85%

Table 7. Summary of Combined AR Values for Stressor Groups for the Conococheague Creek 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	84%	97%
In-Stream Habitat	30%	
Riparian Habitat	35%	
Water Chemistry	97%	

4.2 Stressors Identified by BSID Analysis

<u>Sediment Conditions</u>

BSID analysis results for the Conococheague Creek identified three sediment parameters that have a statistically significant association with poor to very poor stream biological condition: *high embeddedness, epifaunal substrate (marginal to poor* & *poor).*

High embeddedness was identified as significantly associated with degraded biological conditions in the Conococheague Creek, and found to impact approximately 74% of the stream miles with poor to very poor biological conditions. Embeddedness is determined by the percentage of fine sediment surrounding gravel, cobble, and boulder particles in the streambed. Embeddedness is categorized as a percentage from 0% to 100% with low values as optimal and high values as poor. High embeddedness is a result of excessive sediment deposition. High embeddedness suggests that sediment may interfere with feeding or reproductive processes and result in biological impairment. Although embeddedness is confounded by natural variability (e.g., Coastal Plain streams will naturally have more embeddedness than Highlands streams), embeddedness values higher than reference streams are indicative of anthropogenic sediment inputs from overland flow or stream channel erosion.

Epifaunal Substrate was identified as significantly associated with degraded biological conditions in the Conococheague Creek, and found to impact approximately 69% (*marginal to poor* rating) and 52% (*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. Like embeddedness and in-stream habitat, 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.

The Conococheague Creek and its tributaries pass through low to high-density urban areas including portions of Williamsport and Hagerstown. Many portions of these areas were built before modern stormwater runoff controls were required by the State. The realization that human activities can seriously harm and degrade waterways led to the authorization of sediment control regulations in the early 1960s but a statewide sediment and erosion control program did not exist until 1970. About ten years later, in 1982, the Maryland General Assembly passed the State Stormwater Management Act, designed to address stormwater runoff generated during the land development process. Stormwater management helps to settle and filter many pollutants before runoff is discharged into a receiving body of water. But research indicates that most conventional stormwater management controls can still harm streams and rivers. Accelerated flow from stormwater management discharges can scour streams banks, deposit sediments, and decrease overall stream health, stability, and habitat diversity (FCG 2009).

As development and urbanization increased in the Conococheague Creek watershed so did the morphological changes that affect a stream's habitat. The most critical of these environmental changes are those that alter the watershed's hydrologic regime causing streams to be more "flashy" (Walsh et al. 2005). When stormwater flows through stream channels faster, more often, and with more force, the results are highly unstable stream channels with widening, downcutting, and streambed scouring. The scouring associated with these increased flows leads to accelerated channel and bank erosion, thereby increasing sediment deposition throughout the streambed either through the formation of bars or settling of sediment in the stream substrate. Some of the impacts associated with sedimentation are smothering of benthic communities, reduced survival rate of fish eggs, and reduced habitat quality from embedding of the stream bottom (Hoffman, Rattner, and Burton 2003). All of the stressors identified for the sediment group (e.g., high embeddedness and poor epifauanal substrate), indicate channel instability related to frequent and intense high flows that scour streambeds then quickly dissipate and rapidly lose the capacity to transport the sediment loads downstream.

In addition to the impact of flow extremes on erosion and habitat, high flows can also eliminate taxa if such events occur during sensitive life stages. Macroinvertebrates that are able to withstand dislodgement, have short and fast life cycles, and good colonizing ability tend to be the dominant species in highly urbanized streams (Richards et al. 1997). Rivers and streams with frequent high flows or no-flow periods have relatively simple trophic structure, low taxonomic diversity, and high dominance by a few taxa (Powers and Stewart 1987, Death and Winterbourn 1995).

The Conococheague Creek watershed also contains a significant amount of agriculture within the watershed, which consists mostly of row crop. An average of seven tons/acre/year of soil erodes from agricultural fields in the United States, whereas erosion rates of 4-5 tons/acre/year are considered acceptable (such losses can be replaced by natural processes) (OSU 2011). Eroded soil clogs streams and rivers, resulting in increased flooding, and destruction of habitats for many species of fish and other aquatic life. The eroded soils contain nutrients and other pollutants that are beneficial on agricultural fields, but can impair water quality when carried away by erosion. Agricultural land use degrades streams by increasing inputs of sediments, impacting riparian and stream channel habitat, and altering flows (Cooper 1993). All of these processes result in an unstable stream ecosystem that impacts habitat and the dynamics (structure and abundance) of stream benthic organisms (Allan 2004). An unstable stream ecosystem often results in loss of habitat heterogeneity, a continuous displacement of biological communities that require frequent re-colonization, and the loss of sensitive taxa, with a shift in biological communities to more tolerant species.

The combined AR is used to measure the extent of stressor impact of degraded stream miles with very poor to poor biological conditions. The combined AR for the sediment stressor group is approximately 84% suggesting these stressors impact a substantial proportion of the degraded stream miles in the Conococheague Creek (See Table 7).

In-stream Habitat Conditions

BSID analysis results for the Conococheague Creek identified two in-stream habitat parameters that have a statistically significant association with poor to very poor stream biological condition: *in-stream habitat structure (poor),* and *pool/glide/eddy quality (poor).*

Instream habitat structure (poor) was identified as significantly associated with degraded biological conditions in the Conococheague Creek and found to impact approximately 20% 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. High in-stream habitat scores are evidence of the lack of sediment deposition. Like embeddedness, in-stream habitat is confounded by natural variability (i.e., some streams will naturally have more or less in-stream habitat). 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 habit 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 (marginal to poor) was identified as significantly associated with degraded biological conditions in the Conococheague Creek watershed, and found to impact approximately 26% of the stream miles with poor to very poor biological conditions.

Pool/glide/eddy 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 pool/glide/eddy. 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. Poor pool/glide/eddy quality conditions are defined as minimal heterogeneous habitat with a max depth of <0.2 meters or being absent completely.

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).

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. 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., agricultural and urban development within the riparian buffer zone 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 very poor to poor biological conditions. The combined AR for the in-stream habitat stressor group is approximately 30% suggesting this stressor impacts a moderate proportion of the degraded stream miles in the Conococheague Creek (See Table 7).

Riparian Habitat Conditions

BSID analysis results for the Conococheague Creek identified one riparian habitat parameter that has a statistically significant association with poor to very poor stream biological condition: *low shading.*

Low shading was identified as significantly associated with degraded biological conditions and found to impact approximately 35% of the stream miles with poor to very poor biological conditions in the Conococheague Creek watershed. This stressor indicates the percentage of the stream segment that is shaded, taking duration into account. Solar radiation can increase the temperature of stream segments causing thermal stress on fish and invertebrates. Detrimental impacts include increased temperature of stream segments resulting in thermal stress on fish and invertebrates, and decreased dissolved oxygen due to high instream temperatures and increased bacterial and algal growth.

The Conococheague Creek watershed contains a considerable proportion of agricultural and row crop land use; to a lesser extent the watershed also includes urban development. Stream channel shading is reduced or eliminated as forests and other riparian vegetation are replaced with agricultural, livestock industries and urban development (Allan 2004; Kline, Hilderbrand, and Hairston-Strang 2005; Southerland et al. 2005). Local riparian vegetation is a secondary predictor of stream integrity; the extent of riparian vegetation may affect the volume of pollutants in runoff (Kline, Hilderbrand, and Hairstan-Strang 2005; Roth, Allan, and Erickson 1996). Anthropogenic replacement of mature riparian vegetation by successional species or crops decreases shading and eliminates the buffer between terrestrial and aquatic components of a drainage basin, resulting in increased inputs of sediments and nutrients (Delong and Brusven 1994). The elimination of riparian vegetation can be a result of extreme overuse by livestock; riparian-aquatic zones are more heavily grazed upon than upland-terrestrial zones (Armour, Duff, and Elmore 1991). Due to low shading, stream segments are also exposed to increased thermal energy, this factor plus increased nutrient input usually results in increased primary productivity (i.e., eutrophication, algal growth), which leads to a decrease in dissolved oxygen, ultimately resulting in the tolerance exceedence of biological communities and a shift in community structure.

The combined AR is used to measure the extent of stressor impact of degraded stream miles with very poor to poor biological conditions. The combined AR for the riparian habitat stressor group is approximately 35%, suggesting this stressor impacts a moderate proportion of the degraded stream miles in the Conococheague Creek (See Table 7).

Water Chemistry

BSID analysis results for the Conococheague Creek identified eight water chemistry parameters that have statistically significant association with a very poor to poor stream biological condition (i.e., removal of stressors would result in improved biological community). These parameters are *high total nitrogen, high total phosphorus, high orthophosphate, low dissolved oxygen < 5.0 mg/L & <6.0 mg/L, high chlorides, high conductivity,* and *high sulfates.*

High total nitrogen concentrations were identified as significantly associated with degraded biological conditions and found to impact approximately 81% of the stream miles with poor to very poor biological conditions in the Conococheague Creek watershed. The total nitrogen (TN) parameter is the measure of the amount of TN in the water column. TN is comprised of organic nitrogen, ammonia nitrogen, nitrite and nitrate. Nitrogen plays a crucial role in primary production. Elevated levels of nitrogen can lead to excessive growth of filamentous algae and aquatic plants. Excessive nitrogen input also can lead to increased primary production, which potentially results in species tolerance exceedances of dissolved oxygen and pH levels. Runoff and leaching from agricultural and urban land uses can generate high in-stream levels of nitrogen.

High total phosphorus (TP) concentrations were identified as significantly associated with degraded biological conditions and found to impact approximately 41% of the stream miles with poor to very poor biological conditions in the Conococheague Creek watershed. This stressor is a measure of the amount of TP in the water column. 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 result in low dissolved oxygen and high pH levels, which can exceed tolerance levels of many biological organisms. TP input to surface waters typically increases in watersheds where agricultural and urban developments are predominant.

High orthophosphate concentrations were identified as significantly associated with degraded biological conditions and found to impact approximately 18% of the stream miles with poor to very poor biological conditions in the Conococheague Creek watershed. 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. Excessive OP input can also lead to increased primary production (accelerating eutrophication), which potentially results in species tolerance exceedences of dissolved oxygen and pH levels. OP loads to surface waters typically increases in watersheds where urban and agricultural developments are predominant.

Low (< 5mg/L) & (< 6mg/L) dissolved oxygen (DO) concentrations were identified as significantly associated with degraded biological conditions and found in 20% *(< 5mg/L),* and 26% *(< 6mg/L)* of the stream miles with poor to very poor biological conditions in the Conococheague Creek watershed. Low 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 2012c.

High chlorides concentration was identified as significantly associated with degraded biological conditions and found in approximately 93% (*high* rating) of the stream miles with poor to very poor biological conditions in the Conococheague Creek watershed. Chloride can play a critical role in the elevation of conductivity. Chloride in surface waters can result from both natural and anthropogenic sources, such as run-off containing road de-icing salts, the use of inorganic fertilizers, landfill leachates, septic tank effluents, animal feeds, industrial effluents, irrigation drainage, and seawater intrusion in coastal areas. Smith, Alexander, and Wolman 1987, have identified that, although chloride can originate from natural sources, in urban watersheds road salts (i.e., sodium chloride) can be a likely source of high chloride and conductivity levels.

High sulfates concentration was identified as significantly associated with degraded biological conditions and found in 85% of the stream miles with poor to very poor biological conditions in the Conococheague Creek watershed. Sulfates can play a critical role in the elevation of conductivity. Other detrimental impacts of elevated sulfates are their ability to form strong acids, which can lead to changes of pH levels in surface waters. Sulfate loads to surface waters can be naturally occurring or originate from urban runoff, agricultural runoff, acid mine drainage, atmospheric deposition, and wastewater dischargers. When naturally occurring, they are often the result of the breakdown of leaves that fall into a stream, of water passing through rock or soil containing gypsum and other common minerals. Sulfate in urban areas can be derived from natural and anthropogenic sources, including combustion of fossil fuels such as coal, oil, diesel, discharge from industrial sources, and discharge from municipal wastewater treatment facilities. Typically sulfates derived from agricultural landscapes are associated with fertilizers which often contain various types and concentrations of sulfate anions.

High conductivity levels were identified as significantly associated with degraded biological conditions and found to impact approximately 96% of the stream miles with poor to very poor biological conditions in the Conococheague Creek watershed. Conductivity is a measure of water's ability to conduct electrical current and is directly related to the total dissolved salt content of the water. Conductivity can serve as an indicator that a pollution discharge or some other source of inorganic contaminant has entered a stream. Increased levels of inorganic pollutants can be toxic to aquatic organisms and lead to exceedences in species tolerances. Most of the total dissolved salts of surface waters are comprised of inorganic compounds or ions, such as chloride, sulfate, carbonate, sodium, and phosphate (IDNR 2008). Urban and agricultural runoffs (i.e., fertilizers), septic drainage, as well as leaking wastewater infrastructure are typical sources of inorganic compounds. Conococheague Creek, falling in the Highland region, is a limestone influenced stream in which higher conductivity levels above 300 µS/cm are not uncommon. In the Highland region, where limestone influenced streams are prevalent, the conductivity threshold has been set at 500 µS/cm.

Water chemistry is a major determinant of the integrity of surface waters that is strongly influenced by land-use. Agricultural land uses comprise 54% of the Conococheague Creek watershed. Agricultural land uses within the watershed as well as within the sixty meter riparian zone were found to be significantly associated with poor to very poor biological conditions in the watershed. Developed landscapes, particularly the proportion of agriculture in the catchments and the riparian zone, often results in increased inputs of nitrogen, phosphorus, and suspended sediments to surface waters. Although NMPs and BMPs are in place to control nutrient runoff in the watershed, the BSID analysis revealed that agricultural practices continue to create conditions that are negatively impacting biological resources. The excess phosphorus and nitrogen from fertilizer applications is leading to eutrophication in the watershed, as evidenced by the *high total nitrogen*, *high total phosphorus* and *orthophosphate*, and the *low dissolved oxygen* stressors identified as significantly associated with degraded biological conditions in the watershed.

Nitrogen and phosphorus are essential nutrients for algae growth. If one nutrient is available in great abundance relative to the other, then the nutrient that is less available limits the amount of plant matter that can be produced; this is known as the “limiting nutrient.” The amount of the abundant nutrient does not matter because both nutrients are needed for algae growth. In general, a Nitrogen: Phosphorus (TN:TP) ratio in the range of 5:1 to 10:1 by mass is associated with plant growth being limited by neither phosphorus nor nitrogen. If the TN:TP ratio is greater than 10:1, phosphorus tends to be limiting; if the TN:TP ratio is less than 5:1, nitrogen tends to be limiting (Chiandani and Vighi 1974).

The BSID results demonstrate that total phosphorus (41%) and orthophosphate (18%) concentrations are less of an impact on stream miles with poor to very poor biological conditions in the watershed, as compared to nitrogen concentrations (81%); therefore, phosphorus may be a limiting nutrient in the watershed (Allan 1996). Due to anthropogenic sources, the watershed is vulnerable to nutrient fluxes (e.g., rain events and stormwater) that could be detrimental to the biological community, additional analysis of available data (i.e., TN:TP ratio) is necessary to confirm if phosphorus concentrations are limiting in the watershed.

To make an accurate determination of whether phosphorus or nitrogen concentrations are limiting in the watershed, MDE reviewed additional data. During the years of 1999, 2000, 2001, 2002, 2003, 2004, and 2009, MDE collected five hundred and sixty-six water quality samples from the Conococheague Creek watershed. Samples were collected at twenty-one stations throughout the watershed, with most stations being sampled monthly for multiple years. According to samples collected by MDE in the Conococheague Creek watershed, 99% of the samples have TN:TP ratios above 10 and less than 1% had TN:TP ratios below 5. The observed data strongly implies that the streams in the Conococheague Creek watershed are phosphorus limited.

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

In the Conococheague Creek watershed there are several heavily traveled road routes, such as Interstates 70, 40 and 81, connecting the urban areas of the watershed. Application of road salts in the watershed is a likely source of the chlorides and high conductivity levels. Although chlorides can originate from natural sources, most of the chlorides that enter the environment are associated with the storage and application of road salt (Smith, Alexander, and Wolman 1987). For surface waters associated with roadways or storage facilities, episodes of salinity have been reported during the winter and spring in some urban watercourses in the range associated with acute toxicity in laboratory experiments (EC 2001). These salts remain in solution and are not subject to any significant natural removal mechanisms; road salt accumulation and persistence in watersheds poses risks to aquatic ecosystems and to water quality (Wegner and Yaggi 2001). According to Forman and Deblinger (2000), there is a “road-effect zone” over which significant ecological effects extend outward from a road; these effects extend 100 to 1,000 meters on each side of four-lane roads. Roads tend to capture and export more stormwater pollutants than other land covers. On-site septic systems, sanitary sewage overflows, and stormwater discharges are quite frequent in the watershed and are also likely sources of elevated concentrations of chloride, sulfates, and conductivity. Surface flows due to the high imperviousness of the watershed are also a factor.

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

Point source discharges are a potential source of nutrient, inorganics, and suspended solids to surface waters. Based on MDE’s point source permitting information, there are twenty-six active municipal National Pollutant Discharge Elimination System (NPDES) permitted point source facilities in the Conococheague Creek Watershed. The types of permits identified include individual municipal, general mineral mining, general industrial stormwater, and general municipal separate storm sewer systems (MS4s). The permits can be grouped into two categories, process water and stormwater. Maryland’s portion of the Conococheague Creek watershed is located entirely in Washington County. Washington County, along with Hagerstown, is covered by a general Phase II NPDES MS4 permit (MDE 2009b).

Another potential nonpoint source of nutrients and inorganic compounds into a watershed is on-site disposal (septic) systems. In 2009, approximately 2,826 septic systems were located throughout the Conococheague Creek watershed (MDE 2009b). Nutrient and suspended solid loads from any wastewater treatment facility, MS4 discharge, or septic system is dependent on discharge volume, level of treatment process, and sophistication of the processes and equipment.

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 97% suggesting that these stressors impact a substantial proportion of degraded stream miles in the Conococheague Creek (Table 7).

4.3 Discussion of Stressors Identified by BSID Analysis

The BSID analysis results suggest that degraded biological communities in the Conococheague Creek watershed are a result of increased urban and agricultural land uses causing alteration to hydrology and increased sedimentation, resulting in an unstable stream ecosystem that eliminates habitat heterogeneity. High proportions of these types of land uses also typically results in increased contaminant loads from point and nonpoint sources by adding sediments, nutrients, and inorganics to surface waters, resulting in concentrations that can potentially be toxic to aquatic organisms. Alterations to the hydrologic regime, physical habitat, and water chemistry have all combined to degrade the Conococheague Creek, leading to a loss of diversity in the biological community. The combined AR for all the stressors is approximately 97%, suggesting that altered hydrology/sediment, habitat, and water chemistry stressors adequately account for the biological impairment in the Conococheague Creek.

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

4.4 Final Causal Model for the Conococheague Creek Watershed

Causal model development provides a visual linkage between biological condition, habitat, chemical, and source parameters available for stressor analysis. Models were developed to represent 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, and USEPA-CADDIS 2012). 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 Conococheague Creek, with pathways bolded or highlighted to show the watershed's probable stressors as indicated by the BSID analysis.

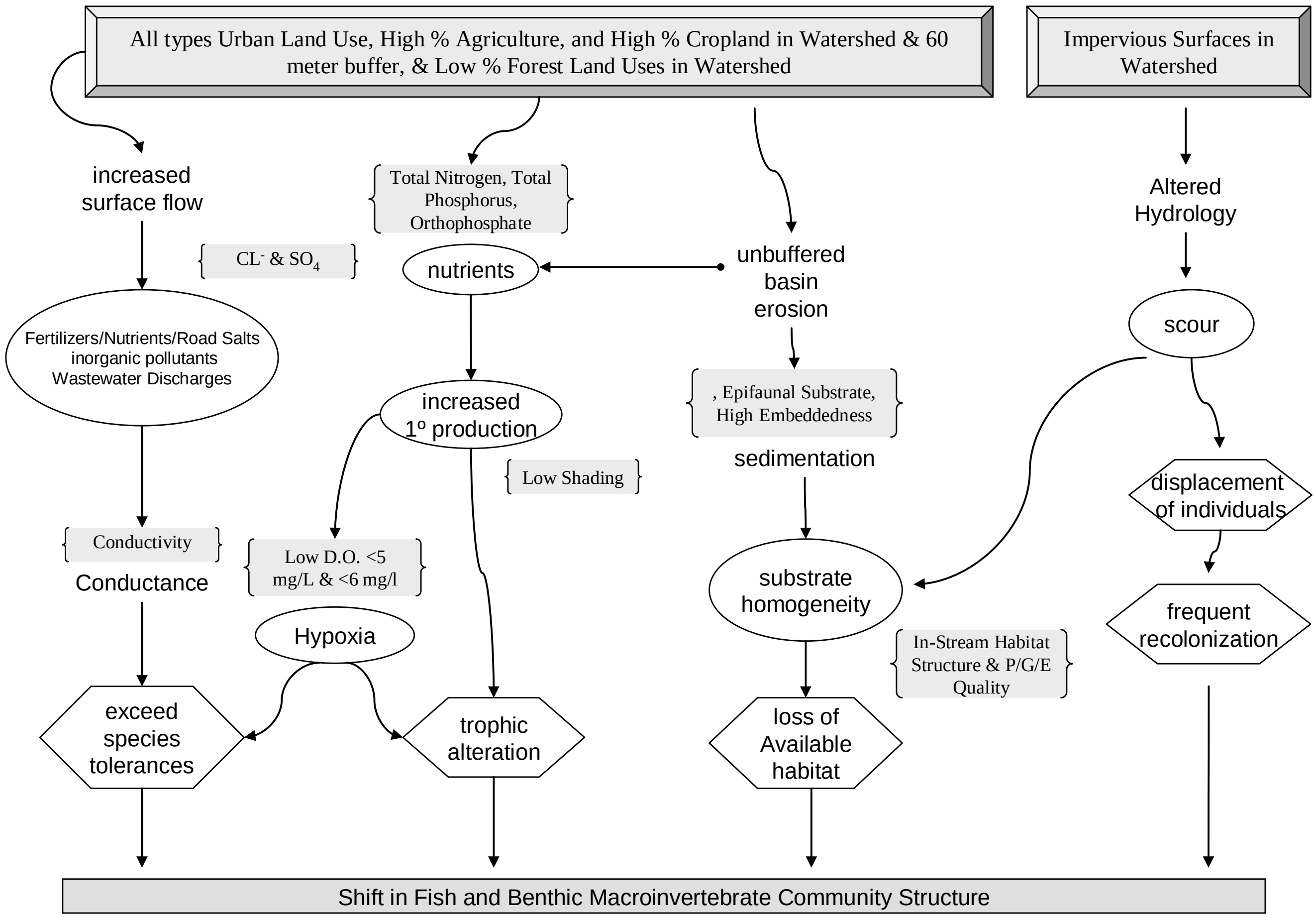

Figure 6. Final Causal Model for the Conococheague Creek Watershed

5.0 Conclusion

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

- The BSID process has determined that the biological communities in Conococheague Creek are likely degraded due to sediment and habitat related stressors. Specifically, altered hydrology and runoff from urban and agriculturally developed landscapes have resulted in erosion and subsequent elevated suspended sediment that are, in turn, the probable causes of impacts to biological communities in the watershed. The BSID results confirm the establishment of a USEPA approved sediment TMDL for the Conococheague Creek watershed was an appropriate management action to begin addressing the impacts of sediment stressors on the biological communities in the watershed.

- The BSID analysis has determined that both phosphorus and nitrogen are probable causes of impacts to biological communities in the Conococheague Creek watershed. Total phosphorus, orthophosphate, and total nitrogen were all identified as having significant association with degraded biological conditions. An analysis of observed TN:TP ratios, however, indicate that phosphorus is the limiting nutrient in the Conococheague Creek watershed. Therefore, excess nitrogen per se is not the cause of the biological impairment in watershed, and the reduction of nitrogen loads would not be an effective means of ensuring that the Conococheague Creek watershed is free from impacts on aquatic life from eutrophication. Therefore, load allocations for the Conococheague Creek Nutrient TMDL will apply only to total phosphorus. The BSID results thus support a Category 5 listing of Total Phosphorus for the non-tidal portion of the 8-digit watershed as an appropriate management action to begin addressing the impacts of nutrient stressors on the biological communities in the Conococheague Creek watershed.

- The BSID process has also determined that the biological communities in the Conococheague Creek watershed are likely degraded due to inorganic pollutants (i.e., chlorides and sulfates). Chloride and sulfate levels are significantly associated with degraded biological conditions and found in 93% and 85% of the stream miles with poor to very poor biological conditions in the Conococheague Creek watershed. Runoff from roads, urban, and agricultural land uses cause an increase in contaminant loads from nonpoint sources by delivering an array of inorganic pollutants to surface waters. Discharges of inorganic compounds are very intermittent; concentrations vary widely depending on the time of year as well as a variety of other factors may influence their impact on aquatic life. Future monitoring of these parameters will help in determining the spatial and temporal extent of these impairments in the watershed. The BSID results thus support a Category 5 listing of chloride and sulfates for the the 8-digit watershed as an appropriate management action to begin addressing the impacts of these stressors on the biological communities in the Conococheague Creek watershed.

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