Watershed Report for Biological Impairment of the Upper North Branch Potomac River Watershed, Garrett County, Maryland Biological Stressor Identification Analysis Results and Interpretation

FINAL

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List of Abbreviations

Al	Aluminum
AMD	Acid Mine Drainage
ANC	Acid Neutralizing Capacity
AR	Attributable Risk
BIBI	Benthic Index of Biotic Integrity
BSID	Biological Stressor Identification
COMAR	Code of Maryland Regulations
CWA	Clean Water Act
DO	Dissolved Oxygen
Fe	Iron
$FeSo_2$	Mineral Pyrite
FIBI	Fish Index of Biologic Integrity
IBI	Index of Biotic Integrity
MDDNR	Maryland Department of Natural Resources
MDE	Maryland Department of the Environment
MBSS	Maryland Biological Stream Survey
MH	Mantel-Haenszel
mg/L	Milligrams per liter
Mn	Manganese
NH_3	Ammonia
NH_4	Ammonium
NPDES	National Pollution Discharge Elimination System
PCBs	Polychlorinated Biphenyls
SSA	Science Services Administration
TMDL	Total Maximum Daily Load
UNB	Upper North Branch
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 Upper North Branch (UNB) of the Potomac River watershed (basin 02141005), located in Garrett County, was identified on the States list of WQLSs and listed in the Integrated Report under Category 5 as impaired by metals, sediments, nutrients, low pH (1996 listings) and evidence of biological impacts (2004 listing). All impairments are listed for non-tidal streams. The Jennings Randolph Reservoir has a Category 5 listing for polychlorinated biphenyls (PCBs). A WQA for eutrophication to address the 1996 listing for nutrients was approved by the United States Environmental Protection Agency (USEPA) in 2006. A TMDL for sediments to address the 1996 listing was approved by the USEPA in 2007. The 1996 Category 5 listing for low pH to was amended to Category 4a based on approval of a pH TMDL by the USEPA in 2008; however, a number of subwatersheds were listed for various metals. Based on impairment listing methodologies applied by MDE, the tributaries in the Upper North Branch Potomac River with two exceedances (Laurel Run (Mn and Fe), Elk Lick Run (Mn) and Three Forks Run (Mn, Al, and Fe)) are impaired and were placed in Category 5 of the Integrated Report. The tributaries in the UNB Potomac River with only one exceedance (Sand Run (Fe) and Laurel Run (Al)) contain insufficient data to determine if an impairment exists. Additional monitoring is necessary to establish whether the exceedance was the result of a single anomalous event or further exceedances will occur resulting in an impairment. These tributaries will be placed in Category 3 ("waterbodies having insufficient data or information to determine impairment status") of the Integrated Report. The North Branch Potomac River mainstem above Jennings Randolph Lake will be placed in Category 3 of the Integrated Report.

In 2002, the State began listing impacts to biological communities 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 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 conditions).

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for the UNB Potomac River are designated as a Use I-P - *water contact recreation, protection of aquatic life, and public water supply*. All other tributaries of the Upper North Branch Potomac River are designated Use III-P, *nontidal cold water and public water supply (COMAR 2010a,b,c).* The UNB Potomac River watershed is not attaining its designated use of protection of aquatic life because of biological impairments. As an indicator of designated use attainment, MDE uses Benthic and Fish Indices of Biotic Integrity (BIBI/FIBI) developed by the Maryland Department of Natural Resources Maryland Biological Stream Survey (MDDNR MBSS).

The current listings for biological impairments represent degraded biological conditions for which the stressors, or causes, are unknown. The MDE Science Services Administration (SSA) has developed a biological stressor identification (BSID) analysis that uses a case-control, risk-based approach to systematically and objectively determine the predominant cause of reduced biological conditions, thus enabling the Department to most effectively direct corrective management action(s). The risk-based approach, adapted from the field of epidemiology, estimates the strength of association between various stressors, sources of stressors and the biological community, and the likely impact 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 UNB Potomac River 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 2009). Data suggest that acidity is the probable cause of biological community degradation in the UNB Potomac River watershed. Low pH results from low acid neutralizing capacity of streams in the watershed and anthropogenic sources (acid mine drainage (AMD), and increased exposure of sulfur bearing geology to groundwater).

The results of the BSID process, and the probable causes and sources of the biological impairments of the UNB Potomac River can be summarized as follows:

- The BSID analysis has determined that the biological communities in the UNB Potomac River Watershed are likely degraded due to acidity related stressors. Acidity is indicated directly by the strong association of low pH and low Acid Neutralizing Capacity (ANC) with biological impairments. The BSID results confirm the 2008 Category 4a listing for pH as an impairing substance.

- The BSID process has determined that the biological communities in the UNB Potomac River Watershed are likely degraded due to inorganic pollutants (i.e., sulfates). Sulfates levels are significantly associated with degraded biological conditions and found in approximately 71% of the stream miles with poor to very poor biological conditions in the watershed. AMD has caused an increase in sulfate loads to surface waters in the watershed. Discharges of any 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 sulfates as an appropriate management action to begin addressing the impacts of these stressors on the biological communities in the UNB Potomac River watershed.

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

- The BSID analysis did not identify any nutrient stressors present and/or nutrient stressors showing a significant association with degraded biological conditions; therefore, the 2006 WQA for nitrogen and phosphorus was an appropriate management action.

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 classified as impaired (Category 5), then a stressor identification analysis is completed to determine if a TMDL is necessary.

The MDE biological stressor identification (BSID) analysis applies a case-control, risk-based approach that uses the principal dataset, with considerations for ancillary data, to identify potential causes of the biological impairment. Identification of stressors responsible for biological impairments was limited to the round two Maryland Department of Natural Resources Maryland Biological Stream Survey (MDDNR MBSS) dataset (2000–2004) because it provides a broad spectrum of paired data variables (i.e., biological monitoring and stressor information) to best enable a complete stressor analysis. The BSID analysis then links potential causes/stressors with general causal scenarios and concludes with a review for ecological plausibility by State scientists.

Once the BSID analysis is completed, one or several stressors (pollutants) may be identified as probable or unlikely causes of the poor biological conditions within the Maryland 8-digit watershed. BSID analysis results can be used together with a variety of water quality analyses to update and/or support the probable causes and sources of biological impairment in the Integrated Report.

The remainder of this report provides a characterization of the UNB Potomac River watershed, and presents the results and conclusions of a BSID analysis of the watershed.

2.0 Upper North Branch Potomac River Watershed Characterization

2.1 Location

The North Branch of the Potomac River forms the border between Maryland and West Virginia from its origin at the Fairfax Stone downstream to its confluence with the South Branch of the Potomac River. The Upper North Branch (UNB) of the Potomac River is defined as the reach between its headwaters in West Virginia and its confluence with the Savage River (see Figure 1). The drainage area of the Upper North Branch Potomac River Watershed is 182,200 acres. This consists of approximately 67,700 acres in Maryland and 119,500 acres in West Virginia. The Maryland portion of the watershed is located entirely in Garrett County. There are no significant high-density urban areas in the watershed. The watershed is located in the Highland region of three distinct eco-regions identified in the MBSS indices of biological integrity (IBI) metrics (Southerland et al. 2005) (see Figure 2).

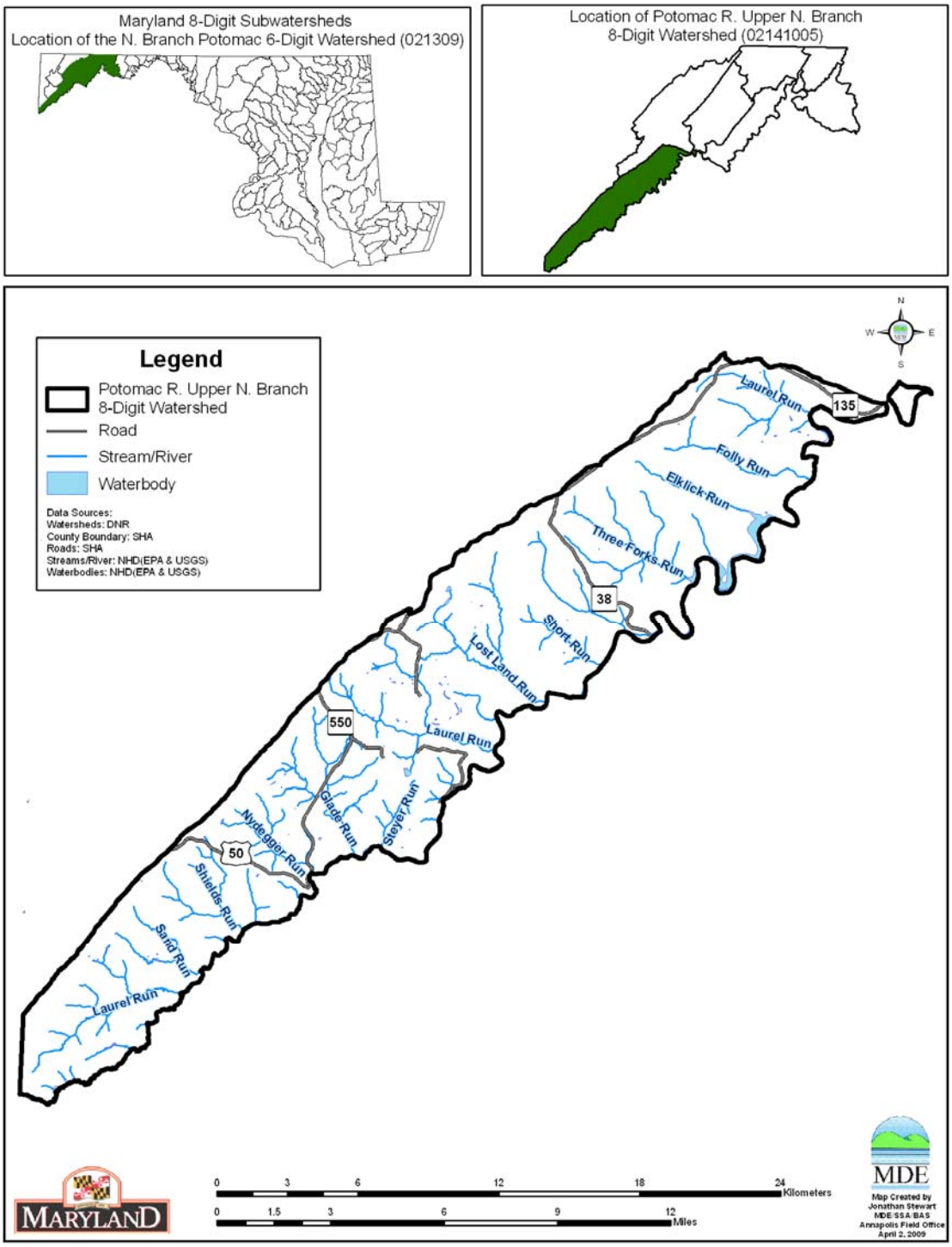

Figure 1. Location Map of the Upper North Branch Potomac River Watershed

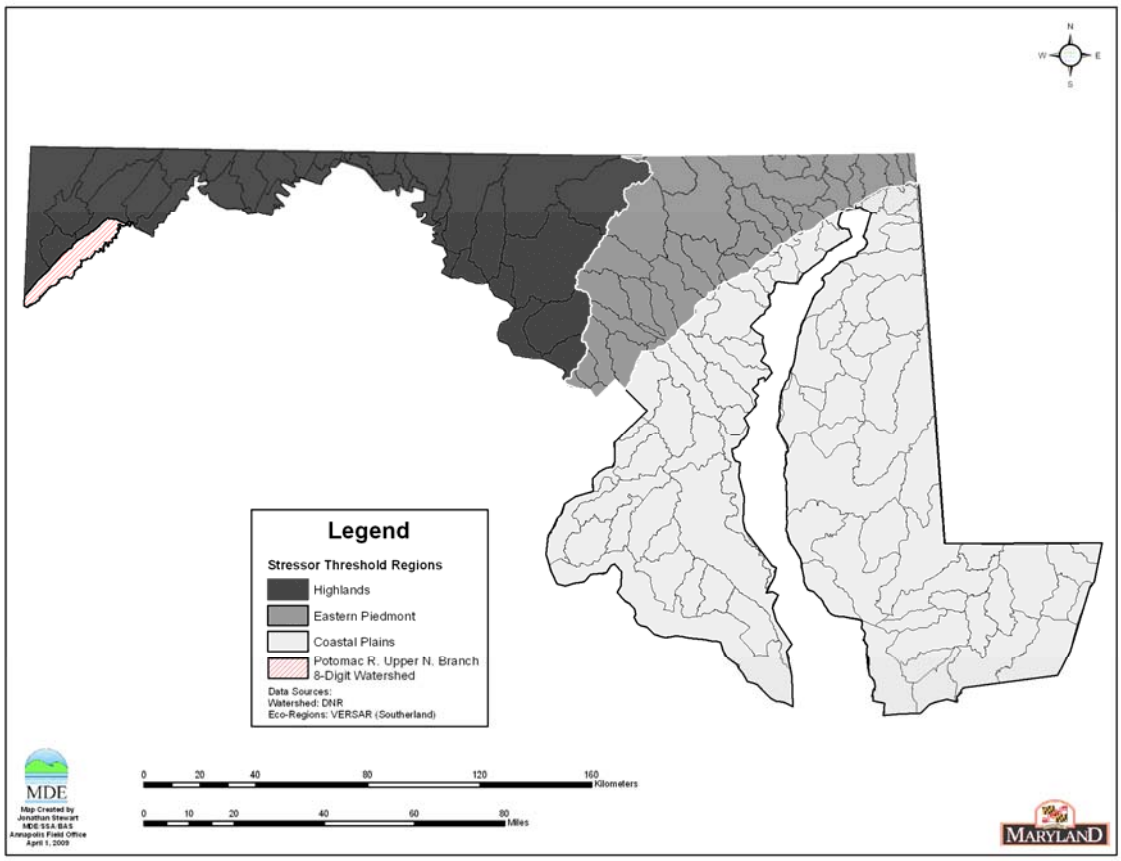

Figure 2. Eco-Region Map of the Upper North Branch Potomac River

2.2 Land Use

The drainage area of the UNB Potomac River Watershed is 182,200 acres. This consists of approximately 67,500 acres in Maryland and 119,500 acres in West Virginia. For this report the land use was evaluated for the Maryland 8-digit watershed UNB Potomac River. The predominant land use in the Maryland 8-digit watershed is forest with 82%. The UNB Potomac River watershed contains extractive, urban, agricultural, and forested land use (see Figure 3). According to the Chesapeake Bay Program's Phase 5.2 Model the land use distribution in the watershed is approximately 1% extractive, 5% urban, 12% agricultural, and 82% forest (see Figure 4) (USEPA 2010).

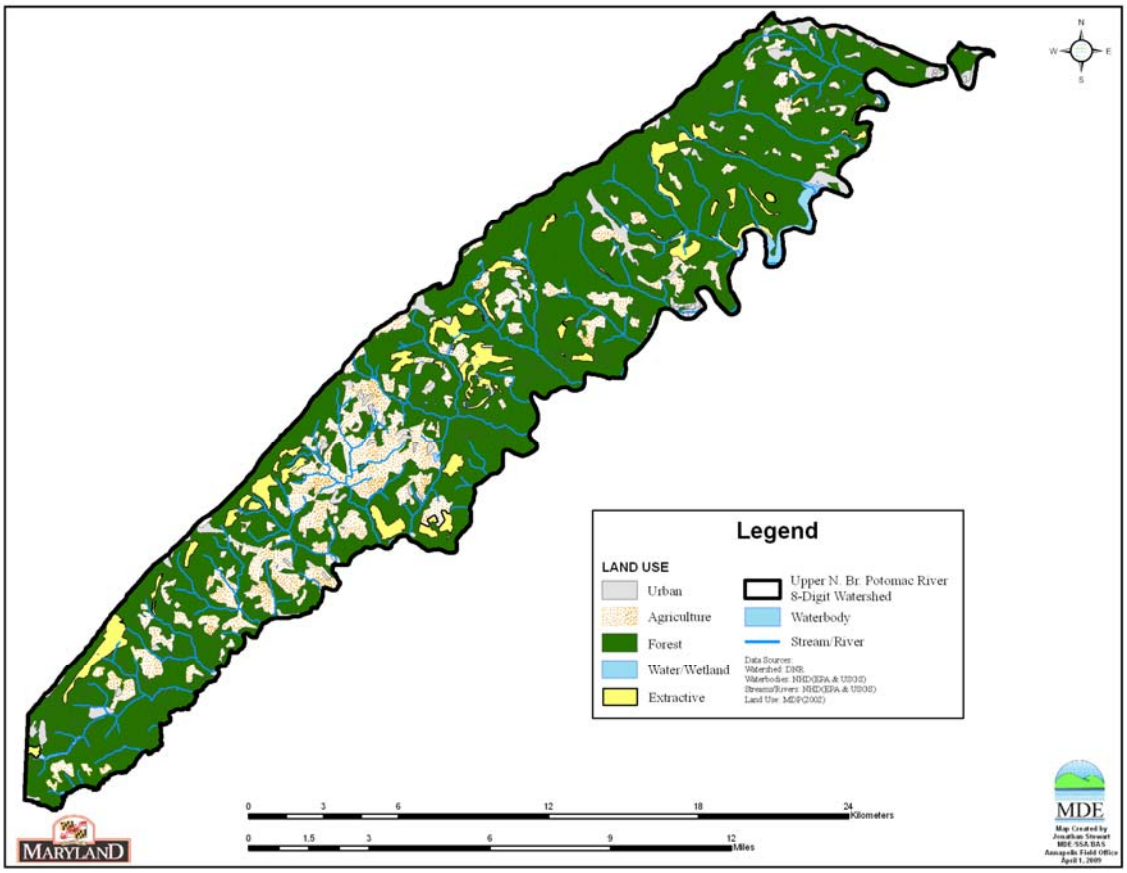

Figure 3. Land Use Map of the Upper North Branch Potomac River Watershed

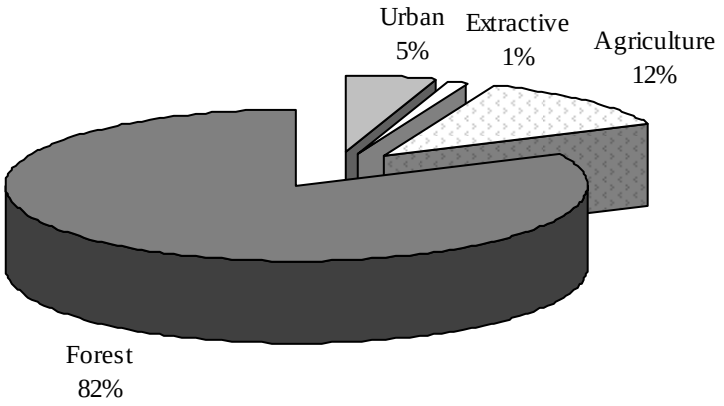

Figure 4. Proportions of Land Use in the Upper North Branch Potomac River Watershed

2.3 Soils/hydrology

The UNB Potomac River watershed is situated within the Appalachian Plateau Province region of western Maryland. The surficial geology of the Appalachian Plateau Province is characterized by gently folded shale, siltstone, and sandstone. Folding has produced elongated arches across the region, which exposes Devonian rocks at the surface, and coal bearing strata are preserved in the intervening synclinal basins of these folds. Consequently, this region has been a productive source for coal mining. The topography in the watershed is often steep and deeply carved by winding streams, with elevations ranging up to 3,200 feet (DNR, 2007a; MGS, 2007; and MDE, 2000).

The Maryland portion of the UNB Potomac River Watershed lies primarily in the Dekalb soil series. The Dekalb soil series consists of moderately deep, well drained, loamy soils that developed in material weathered in place from sandstone and some conglomerate and shale bedrock. These nearly level to very steep soils are normally found in stony, mountainous regions. Dekalb soils have rapid permeability and internal drainage (USDA – SCS, 1974).

3.0 Upper North Branch Potomac River Water Quality Characterization

3.1 Integrated Report Impairment Listings

The UNB of the Potomac River watershed (basin 02141005), located in Garrett County, was identified on the States list of WQLSs and listed in the Integrated Report under Category 5 as impaired by metals, sediments, nutrients, low pH (1996 listings) and impacts to biological communities (2004 listing). All impairments are listed for non-tidal streams. The Jennings Randolph Reservoir has a Category 5 listing for polychlorinated biphenyls (PCBs). A WQA for eutrophication to address the 1996 listing for nutrients was approved by the United States Environmental Protection Agency (USEPA) in 2006. A TMDL for sediments to address the 1996 listing was approved by the USEPA in 2007. The 1996 Category 5 listing for low pH to was amended to Category 4a based on approval of a pH TMDL by the USEPA in 2008; however, a number of subwatersheds were listed for various metals. Based on impairment listing methodologies applied by MDE, the tributaries in the UNB Potomac River with two exceedances (Laurel Run (Mn and Fe), Elk Lick Run (Mn) and Three Forks Run (Mn, Al, and Fe)) are impaired and will be placed in Category 5 of the Integrated Report. The tributaries in the UNB Potomac River with only one exceedance (Sand Run (Fe) and Laurel Run (Al)) contain insufficient data to determine if an impairment exists. Additional monitoring is necessary to establish whether the exceedance was the result of a single anomalous event or further exceedances will occur resulting in an impairment. These tributaries will be placed in Category 3 ("waterbodies having insufficient data or information to determine impairment status") of the Integrated Report. The North Branch Potomac River mainstem above Jennings Randolph Lake will be placed in Category 3 of the Integrated Report.

3.2 Impacts to Biological Communities

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for the UNB Potomac River are designated as a Use I-P - *water contact recreation, protection of aquatic life, and public water supply*. All other tributaries of the UNB Potomac River are designated Use III-P, *nontidal cold water and public water supply (COMAR 2010 a,b,c).* 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 UNB Potomac River watershed is listed under Category 5 of the 2008 Integrated Report as impaired for impacts to biological communities. Approximately 62% of stream miles in the UNB Potomac River basin are estimated as having fish and and/or benthic indices of biological impairment in the poor to very poor category. The biological impairment listing is based on the combined results of MDDNR MBSS round one (1995-

1997) and round two (2000-2004) data, which include twenty-one sites. Thirteen of the twenty-one have benthic and/or fish indices of biotic integrity (BIBI, FIBI) scores significantly lower than 3.0 (i.e., poor to very poor). The principal dataset, i.e. MBSS Round 2, contains twelve MBSS sites, with eight having BIBI and/or FIBI scores lower than 3.0. Figure 5 illustrates principal dataset site locations for the UNB Potomac River watershed.

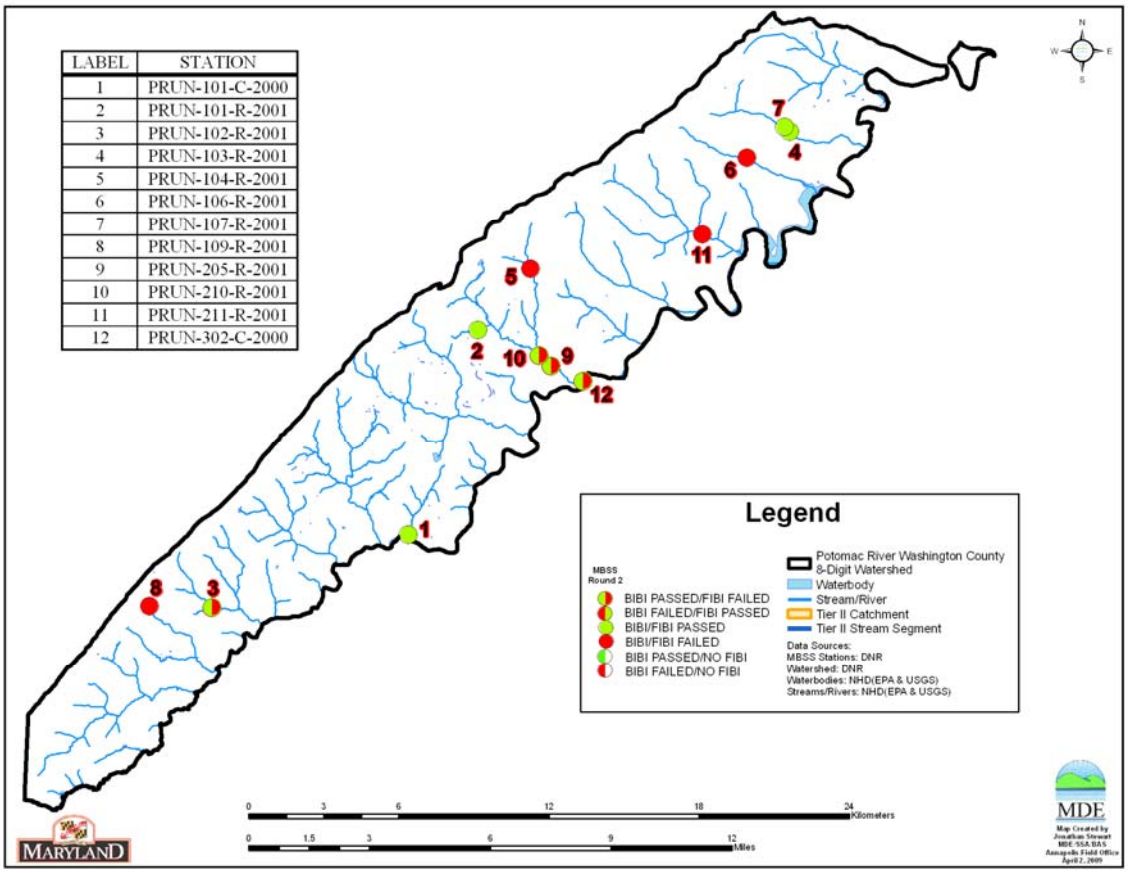

Figure 5. Principal Dataset Sites for the UNB Potomac River Watershed

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-Haenszel (MH) (1959) approach and is based on the exact method due to the small sample size for cases. A common odds ratio significantly greater than one indicates that there is a statistically significant higher likelihood that the stressor is present when there are poor to very poor biological conditions (cases) than when there are fair to good biological conditions (controls). This result suggests a statistically significant positive association between the stressor and poor to very poor biological conditions and is used to identify potential stressors.

Once potential stressors are identified (i.e., odds ratio significantly greater than one), the risk attributable to each stressor is quantified for all sites with poor to very poor biological conditions within the watershed (i.e., cases). The attributable risk (AR) defined herein is the portion of the cases with poor to very poor biological conditions that are associated with the stressor. The AR is calculated as the difference between the proportion of case sites with the stressor present and the proportion of control sites with the stressor present.

Once the AR is calculated for each possible stressor, the AR for groups of stressors is calculated. Similar to the AR calculation for each stressor, the AR calculation for a

group of stressors is also summed over the case sites using the individual site characteristics (i.e., stressors present at that site). The only difference is that the absolute risk for the controls at each site is estimated based on the stressor present at the site that has the lowest absolute risk among the controls.

After determining the AR for each stressor and the AR for groups of stressors, the AR for all potential stressors is calculated. This value represents the proportion of cases, sites in the watershed with poor to very poor biological conditions, which would be improved if the potential stressors were eliminated (Van Sickle and Paulsen 2008). The purpose of this metric is to determine if stressors have been identified for an acceptable proportion of cases (MDE 2009).

The parameters used in the BSID analysis are segregated into five groups: land use sources, and stressors representing sediment, in-stream habitat, riparian habitat, and water chemistry conditions. Through the BSID analysis of the UNB Potomac River watershed, MDE identified water chemistry parameters and a source of acid mine drainage (AMD) as having significant association with poor to very poor benthic and/or fish biological conditions. As shown in Table 1 through Table 3, parameters from the water chemistry group are identified as possible biological stressors in the UNB Potomac River. The parameter acid source - AMD is identified as a possible source is listed in Table 4. A summary of combines AR values for each stressor group is shown in Table 5. A summary of combines AR values for each source group is shown in Table 6.

Table 1. Sediment Biological Stressor Identification Analysis Results for Upper North Branch Potomac River

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 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	12	8	77	0%	10%	No	----
	moderate bar formation present	12	8	77	25%	46%	No	----
	bar formation present	12	8	77	100%	89%	No	----
	channel alteration marginal to poor	12	8	77	25%	44%	No	----
	channel alteration poor	12	8	77	0%	10%	No	----
	high embeddedness	12	8	76	0%	3%	No	----
	epifaunal substrate marginal to poor	12	8	77	0%	19%	No	----
	epifaunal substrate poor	12	8	77	0%	3%	No	----
	moderate to severe erosion present	12	8	77	13%	25%	No	----
	severe erosion present	12	8	77	0%	3%	No	----
	poor bank stability index	12	8	77	0%	5%	No	----
	silt clay present	12	8	77	63%	99%	No	----

Table 2. Habitat Biological Stressor Identification Analysis Results for the Upper North Branch Potomac River

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 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	12	8	80	13%	11%	No	----
	instream habitat structure marginal to poor	12	8	77	0%	21%	No	----
	instream habitat structure poor	12	8	77	0%	2%	No	----
	pool/glide/eddy quality marginal to poor	12	8	77	13%	44%	No	----
	pool/glide/eddy quality poor	12	8	77	0%	6%	No	----
	riffle/run quality marginal to poor	12	8	77	0%	31%	No	----
	riffle/run quality poor	12	8	77	0%	7%	No	----
	velocity/depth diversity marginal to poor	12	8	77	13%	48%	No	----
	velocity/depth diversity poor	12	8	77	0%	7%	No	----
	concrete/gabion present	12	8	80	0%	4%	No	----
	beaver pond present	12	8	77	0%	2%	No	----
Riparian Habitat	no riparian buffer	12	8	80	25%	23%	No	----
	low shading	12	8	77	25%	12%	No	----

Table 3. Water Chemistry Biological Stressor Identification Analysis Results for the Upper North Branch Potomac River

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 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 TN	12	8	159	0%	8%	No	----
	high TDN	2	1	50	0%	6%	No	----
	ammonia acute with salmonid present	12	8	159	0%	2%	No	----
	ammonia acute with salmonid absent	12	8	159	0%	1%	No	----
	ammonia chronic with salmonid present	12	8	159	38%	4%	Yes	34%
	ammonia chronic with salmonid absent	12	8	159	25%	2%	Yes	23%
	low lab pH	12	8	159	38%	5%	Yes	32%
	high lab pH	12	8	159	0%	1%	No	----
	low field pH	12	8	154	25%	14%	No	----
	high field pH	12	8	154	0%	0%	No	----
	high TP	12	8	159	0%	3%	No	----
	high OP	12	8	159	0%	4%	No	----
	DO < 5mg/l	12	8	154	0%	3%	No	----
	DO < 6mg/l	12	8	154	0%	7%	No	----
	low DO saturation	12	8	138	0%	4%	No	----
	high DO saturation	12	8	138	25%	1%	Yes	24%
	acid neutralizing capacity below chronic level	12	8	159	38%	6%	Yes	31%
	acid neutralizing capacity below episodic level	12	8	159	63%	43%	No	----
	high chlorides	12	8	159	0%	7%	No	----
	high conductivity	12	8	159	0%	4%	No	----
	high sulfates	12	8	159	75%	4%	Yes	71%

Table 4. Stressor Source Identification Analysis Results for the Upper North Branch Potomac River

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 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	12	8	156	0%	1%	No	----
	high % of high intensity urban in watershed	12	8	159	0%	4%	No	----
	high % of low intensity urban in watershed	12	8	159	0%	8%	No	----
	high % of transportation in watershed	12	8	159	0%	9%	No	----
	high % of high intensity urban in 60m buffer	12	8	159	0%	6%	No	----
	high % of low intensity urban in 60m buffer	12	8	159	0%	7%	No	----
	high % of transportation in 60m buffer	12	8	159	0%	9%	No	----
Sources Agriculture	high % of agriculture in watershed	12	8	159	0%	6%	No	----
	high % of cropland in watershed	12	8	159	0%	6%	No	----
	high % of pasture/hay in watershed	12	8	159	0%	8%	No	----
	high % of agriculture in 60m buffer	12	8	159	0%	6%	No	----
	high % of cropland in 60m buffer	12	8	159	0%	4%	No	----
	high % of pasture/hay in 60m buffer	12	8	159	0%	8%	No	----
Sources Barren	high % of barren land in watershed	12	8	159	0%	7%	No	----
	high % of barren land in 60m buffer	12	8	159	0%	6%	No	----

Table 4. Stressor Source Identification Analysis Results for the Upper North Branch Potomac 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 per strata with source present	Possible stressor2 (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	12	8	159	0%	5%	No	----
	low % of forest in 60m buffer	12	8	159	0%	6%	No	----
Sources Acidity	atmospheric deposition present	12	8	159	13%	39%	No	----
	AMD acid source present	12	8	159	50%	4%	Yes	46%
	organic acid source present	12	8	159	0%	3%	No	----
	agricultural acid source present	12	8	159	0%	1%	No	----

Table 5. Summary AR Values for Stressor Groups for Upper North Branch Potomac River

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	----	97%
In-Stream Habitat	----	
Riparian Habitat	----	
Water Chemistry	97%	

Table 6. Summary AR Values for Source Groups for Upper North Branch Potomac River

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	----	46%
Agriculture	----	
Barren Land	----	
Anthropogenic	----	
Acidity	46%	

Sediment Conditions

BSID analysis results for the UNB Potomac River did not identify any sediment parameters that have statistically significant association with a poor to very poor stream biological condition (i.e., removal of stressors would result in improved biological community) (Table 1).

In-stream Habitat Conditions

BSID analysis results for the UNB Potomac River did not identify any in-stream habitat parameters that have statistically significant association with a poor to very poor stream biological condition (i.e., removal of stressors would result in improved biological community) (Table 2).

Riparian Habitat Conditions

BSID analysis results for the UNB Potomac 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 2).

Water Chemistry

BSID analysis results for the Lower Monocacy River identified six 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 lab pH, acid neutralizing capacity (ANC) below chronic level, ammonia chronic with salmonid present & absent, high dissolved oxygen saturation,* and *high sulfates.*

Low lab pH levels below 6.5 was identified as significantly associated with degraded biological conditions in the UNB Potomac River, and found to impact approximately 32% of the stream miles with poor to very poor biological conditions. pH is a measure of the acid balance of a stream and uses a logarithmic scale range from 0 to 14, with 7 being neutral. MDDNR MBSS collects pH samples once during the spring, which are analyzed in the laboratory (*pH lab*), and measured once in situ during the summer (*pH field*). Most stream organisms prefer a pH range of 6.5 to 8.5. The pH threshold values, at which levels below 6.5 and above 8.5 may indicate biological degradation, are established from state regulations in COMAR. Many biological processes, such as reproduction, cannot function in acidic waters. Acidic conditions also aggravate toxic contamination problems because sediments release toxicants (such as copper, zinc, nitrite and aluminum) in acidic waters. Some types of plants and animals are able to tolerate acidic waters. Others, however, are acid-sensitive and will be lost as the pH declines. Generally, the young of most species are more sensitive to environmental conditions than adults. At pH 5, most fish eggs cannot hatch. At lower pH levels, some adult fish die (USEPA 2008). Common sources of acidity include mine drainage, atmospheric deposition, runoff from mine tailings, agricultural fertilizers, and natural organic sources.

Low ANC below chronic level was identified as significantly associated with degraded biological conditions in the UNB Potomac River and found in approximately 31% of the stream miles with poor to very poor biological conditions. Acid neutralizing capacity (ANC) is a measure of the capacity of dissolved constituents in the water to react with and neutralize acids. ANC can be used as an index of the sensitivity of surface waters to acidification. The higher the ANC, the more acid a system can assimilate before experiencing a decrease in pH. Repeated additions of acidic materials, like those found in AMD, generally cause a decrease in ANC. ANC values less than 50µeq/l are considered to demonstrate chronic (highly sensitive to acidification) exposures for aquatic organisms, and values less than 200 are considered to demonstrate episodic (sensitive to acidification) exposures (Kazyak et al 2005, Southerland et al 2007).

Ammonia chronic concentrations were identified as significantly associated with degraded biological conditions in the UNB Potomac River, and found to impact approximately 34% (*with salmonid present*) and 23% (*with salmonid absent*) of the stream miles with poor to very poor biological conditions. In surface water ammonia can be found in two forms ionized ammonia or ammonium (NH_4) and unionized ammonia (NH_3). Ammonium is a nitrogen nutrient species and is not considered toxic to aquatic organisms; however, ammonia in excessive amounts has potential toxic effects. The

degree to which form of ammonia is present depends on the pH of the surface waters. If the pH is low and ammonia is present, a significant amount of it reacts with the hydronium ions in water to form ammonium. If the pH is high (the concentration of hydronium ions is low), the equillibrium shifts and the hydroxide ion abstracts a proton from the ammonium ion, generating ammonia. Chronic ammonia toxicity refers to potential exceedences of species tolerance caused by repeated exposure over a long period of time. Ammonia chronic with salmonid present/absent is a USEPA water quality criteria for NH_3 concentrations causing chronic toxicity in surface waters where salmonid species of fish are present/absent (USEPA 2006). There are three sites in the UNB Potomac River watershed with chronic ammonia toxicity. One site is located on a 1st order stream affected by AMD, comments by field crews report "mine drainage impact, substrates are concreted w/ Al and Fe precipitates". The second site is located in the extreme headwaters of a stream in close proximity to a minor municipal wastewater discharge and affected by AMD. The third site is also located on a stream affected by AMD; a lime doser was placed on this stream to remediate low pH. Water chemistry samples collect in 2005 by MDE scientist from this stream indicates pH levels fluctuate widely with samples ranging from 4.8 to 11.8. During times where pH values are elevated above 8.5, the ammonia dissolved in surface waters become more toxic. Most streams affected by AMD typically have pH levels that fluctuate widely. Wastewater can also be a typical source of ammonia.

There are twelve MBSS stations in the UNB Potomac River watershed and minimal sampling for ammonia was conducted (onetime sample) at each station. Acute ammonia toxicity refers to potential exceedences of species tolerance caused by a one-time, sudden, high exposure of ammonia. However, chronic ammonia toxicity refers to potential exceedences of species tolerance caused by repeated exposure over a long period of time. To make an accurate determination of acute and chronic ammonia toxicity, MDE reviewed additional data to determine if there is ammonia toxicity impairment in these waters. During the years of 1999through 2005, and 20097, MDE collected three hundred and eighty water quality samples from the UNB Potomac River watershed. Samples were collect at twenty-eight stations through out the watershed, with most stations being sampled monthly for approximately a year. Of these samples, only six sample (<1.6%) had ammonia values above the USEPA water quality criteria for chronic toxicity, and there was only one sample (<0.26%) with ammonia values above the ammonia acute toxicity criteria (USEPA 2006). Due to these results from the MDE water quality data analysis, it was determined that ammonia toxicity is not a significant stressor in the UNB Potomac River watershed.

High dissolved oxygen saturation was identified as significantly associated with degraded biological conditions in the UNB Potomac River and found in approximately 24% of the stream miles with poor to very poor biological conditions. DO saturation accounts for physical solubility limitations of oxygen in water and provides a more targeted assessment of oxygen dynamics than concentration alone. Percent saturation is relative to the amount of oxygen that water can hold, as determined by temperature and atmospheric pressure. The DO saturation threshold values, at which concentrations

above 125% may indicate biological degradation, are established from peer-reviewed literature (CIESE 2008). DO saturation greater than 125% is considered to demonstrate oxygen production associated with high levels of photosynthesis. Natural diurnal fluctuations in DO saturation can become exaggerated in streams with excessive primary production. The BSID analysis did not identify high DO, low DO, low DO saturation, nitrogen or phosphorus concentrations as being significantly associated with poor biological conditions in the watershed. If excessive primary production was occurring in the watershed, typically these stressors would be present.

High sulfates were identified as significantly associated with degraded biological conditions in the UNB Potomac River and found in approximately 71% of the stream miles with poor to very poor biological conditions. Sulfate loads to surface waters can be naturally occurring or originate from urban runoff, agricultural runoff, acid mine drainage, atmospheric deposition, and wastewater dischargers. There are six National Permitted Discharge Elimination System (NPDES) municipal and industrial discharges in the UNB Potomac River that are regulated for various parameters including metals, temperature, and pH. Since NPDES permitting enforcement does not require sulfate testing at any of these facilities, data was not available to verify/identify sulfate as a specific pollutant in this watershed. AMD waters can contain significant concentrations of sulfate. Coal mining is very prevalent in the Appalachian Plateau region. The UNB Potomac watershed contains five operational coal mines, many with multiple outfalls, as well as a number of abandoned mines. AMD is a probable source of sulfate loads to the UNB Potomac River.

Water chemistry is another major determinant of the integrity of surface waters that is strongly influenced by land-use. Land development especially extractive land uses can cause increases in contaminant loads from point and nonpoint sources by adding sediments, AMD, toxics, and inorganic pollutants to surface waters. Currently in Maryland there are no specific numeric criteria that quantify the impact of sulfates on the aquatic health of non-tidal stream systems.

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 UNB Potomac River (Table 3).

Sources

All six stressor parameters, identified in Tables 1-3, that are significantly associated with biological degradation in the UNB Potomac River watershed are representative of impacts from extractive landscapes. The watershed contains numerous active and abandoned mining operations.

AMD acid source present was identified as significantly associated with degraded biological conditions in the UNB Potomac River and found to impact approximately 46% of the stream miles with poor to very poor biological conditions (Table 4). AMD results from mineral pyrite oxidation (from mine spoils and abandoned mine shafts) and is known to cause extreme acidification of surface waters as well as affect stream physical substrate. Streams strongly affected by AMD often exhibit high levels of sulfate, manganese, iron, aluminum, and conductivity. Highly acidic waters (pH < 3) can solubilise heavy metals and other toxic elements from soil and cause them to be transported into nearby surface waters. The high acidity of acid mine drainage and the high amounts of dissolved heavy metals generally make acid mine drainage extremely toxic to most organisms (Penreath, 1994).

The BSID source analysis (Table 4) identifies AMD as a potential source of stressors that may cause negative biological impacts. The combined AR for this source group is approximately 46% suggesting that the presence of AMD potentially impacts a moderate proportion of the degraded stream miles in the UNB Potomac River (Table 6).

Discussion

Acidity and elevated sulfate concentrations are the most probable causes associated with biological impairment in the UNB Potomac River watershed. The presence of AMD in the UNB Potomac River is an obvious source of acidity and sulfates. Mining activities in the watershed increase exposure of the mineral pyrite (FeS_2) to water and air to accelerate production of sulfuric acid in mining and groundwater discharges. Natural levels of acidic groundwater discharges associated with sulfur-laden rock commonly found in coal mining areas could also be contributing to acidity and sulfate levels.

Chronic ammonia and high DO saturation stressors were also identified in BSID analyses, which do not align with acidity related impairment. These findings demonstrate the complex nature of stressor identification and the often occurrence of numerous stressors contributing to the degradation of aquatic biological communities. However, these stressors are either insignificant or a secondary cause of degradation to acidity in the UNB Potomac River.

In summary, acidity is the most probable cause associated with biological impairment in the UNB Potomac River watershed. Due to the increased proportions of extractive land use and AMD in the UNB Potomac River, the watershed has experienced an increase in contaminant loads from point and nonpoint sources, resulting in levels of inorganic pollutants and acidity that can potentially be extremely toxic to aquatic organisms. The

combined AR for all the stressors is approximately 97%, suggesting that the water chemistry stressors identified in the BSID analysis would adequately account for the biological impairment in the UNB Potomac River watershed (Table 5).

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 North Branch Potomac River

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, 1991and 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 UNB Potomac River, with pathways to show the watershed's probable stressors as indicated by the BSID analysis.

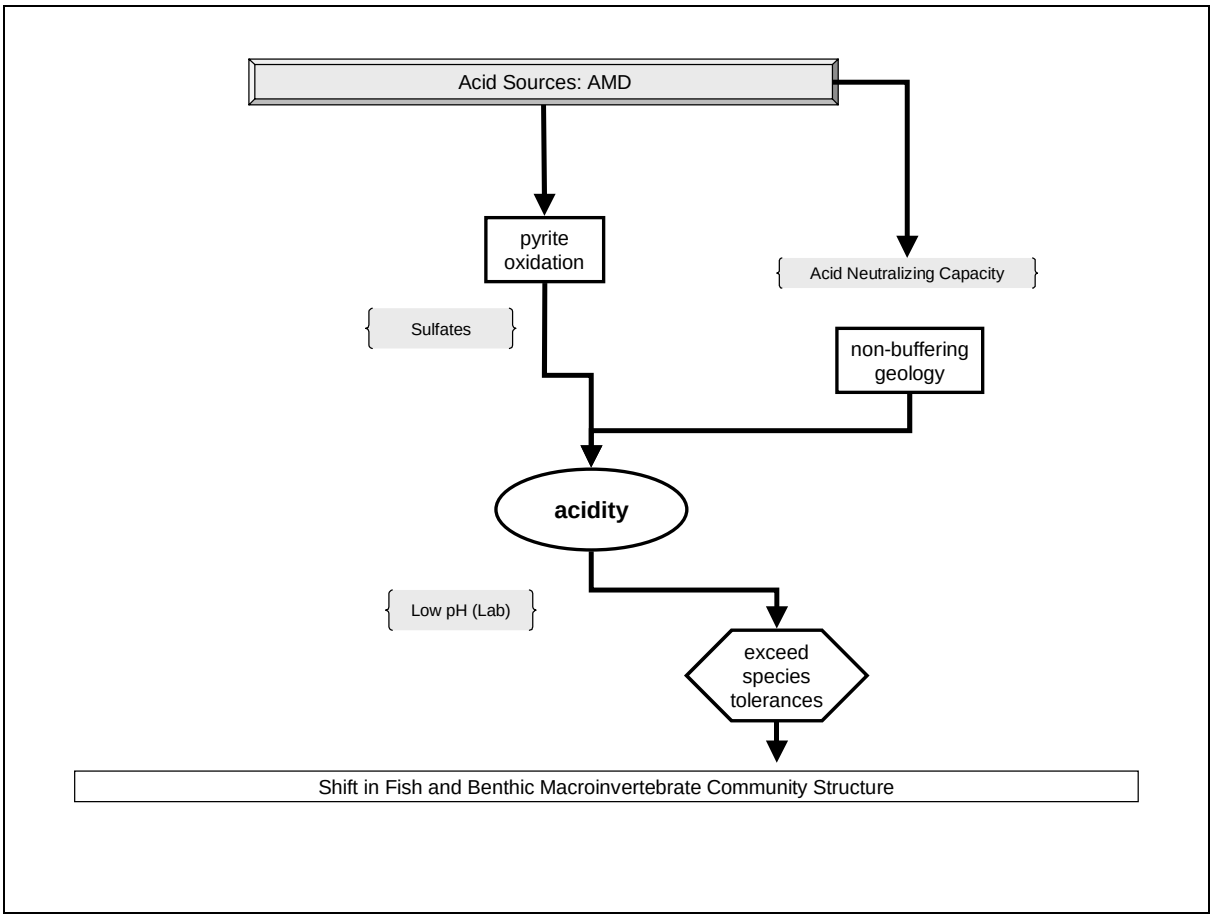

Figure 6. Final Causal Model for the Upper North Branch Potomac River Watershed

5.0 Conclusion

Data suggest that the UNB Potomac River watershed's biological communities are strongly influenced by acidity and elevated sulfate concentrations. This conclusion supports the Category 4a listing for pH impairment, since the TMDL was approved by USEPA in 2008. Based upon the results of the BSID process, the probable causes and sources of the biological impairments of the UNB Potomac River are summarized as follows:

- The BSID process has determined that the biological communities in the UNB Potomac River Watershed are likely degraded due to acidity related stressors. Acidity is indicated directly by the strong association of low pH and low Acid Neutralizing Capacity (ANC) with biological impairments. The BSID results confirm the 2008 Category 4a listing for pH as an impairing substance.

- The BSID process has determined that the biological communities in the UNB Potomac River Watershed are likely degraded due to inorganic pollutants (i.e., sulfates). Sulfates levels are significantly associated with degraded biological conditions and found in approximately 71% of the stream miles with poor to very poor biological conditions in the watershed. AMD has caused an increase in sulfate loads to surface waters in the watershed. Discharges of any 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 sulfates as an appropriate management action to begin addressing the impacts of these stressors on the biological communities in the UNB Potomac River watershed.

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

- The BSID analysis did not identify any nutrient stressors present and/or nutrient stressors showing a significant association with degraded biological conditions; therefore, the 2006 WQA for nitrogen and phosphorus was an appropriate management action.

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