Watershed Report for Biological Impairment of the Back River in Baltimore City and Baltimore County, Maryland Biological Stressor Identification Analysis Results and Interpretation

FINAL

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

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Water Protection Division
U.S. Environmental Protection Agency, Region III
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List of Abbreviations

AR	Attributable Risk
BACOH	Back River Oligohaline
BIBI	Benthic Index of Biotic Integrity
BSID	Biological Stressor Identification
COMAR	Code of Maryland Regulations
CSO	Combined Sewage Overflow
CSS	Combined Sewer Systems
CWA	Clean Water Act
FIBI	Fish Index of Biologic Integrity
IBI	Index of Biotic Integrity
MBSS	Maryland Biological Stream Survey
MDDNR	Maryland Department of Natural Resources
MDE	Maryland Department of the Environment
mg/L	Milligrams per liter
MH	Mantel-Haenszel
MS4	Municipal Separate Storm Sewer System
n	Number
NPDES	National Pollution Discharge Elimination System
PSU	Primary Sampling Unit
SCS	Soil Conservation Service
SSA	Science Services Administration
SSO	Sanitary Sewer Overflow
SSURGO	Soil Survey Geographic
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids
µeq/L	Micro equivalent per liter
µS/cm	Micro Siemens per centimeter
USEPA	United States Environmental Protection Agency
WQA	Water Quality Analysis
WQLS	Water Quality Limited Segment

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 Back River watershed (basin code 02130901), located in Baltimore County and Baltimore City, MD, is associated with two assessment units in the Integrated Report (IR): non-tidal (8-digit basin) and an estuary portion (Chesapeake Bay segment). The Chesapeake Bay segment related to the Back River is the Back River Oligohaline. Below is a table identifying the listings associated with this watershed.

Table E1. 2010 Integrated Report Listings for the Back River Watershed

Watershed	Basin Code	Non-tidal/Tidal	Subwatershed	Designated Use	Year listed	Identified Pollutant	Listing Category
Back River	02130901	Non-tidal		Aquatic Life and Wildlife	2002	Impacts to Biological Communities	5
			Back River 0213090140	Water Contact Sports	2002	Fecal Bacteria	4a
			Herring Run 021390141				
			Herring Run 0213090142				
Back River Oligohaline	BACOH	Tidal		Seasonal Migratory Fish spawning and nursery Subcategory	1996	TP	4a
						TN	
				Aquatic Life and Wildlife	1998	PCB	5
						TSS	
					1996	Zinc	2
						Estuarine Bioassessments	3
				Open-Water Fish and Shellfish	1996	TN	4a
						TP	
				Fishing	2008	PCB in Fish Tissue	5
					1996	Chlordane	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 of less than three, and calculating whether this is a significant deviation from reference condition watersheds (i.e., healthy stream, less than 10% stream miles degraded).

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for the Back River watershed's tributaries including Brien Run, Duck Creek (confluent to Creek), Herring Run, Redhouse Creek and Stemmer's Run are designated as Use I - *water contact recreation, and protection of nontidal warmwater aquatic life.* The Back River, Bread and Cheese Creek, Deep Creek, Duck Creek (confluent to Deep Creek), Muddy Gut, and Northeast Creek designated as Use II - *support of estuarine and marine aquatic life and shellfish harvesting*. Chinquapin Run, Moores Run and Herring Run are designated as Use IV – recreational trout waters (COMAR 2011 a, b). The Back 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 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 Back River watershed report presents a brief discussion of the BSID process on which the watershed analysis is based, and which may be reviewed in more detail in the report entitled "Maryland Biological Stressor Identification Process" (MDE 2009). Data suggest that the degradation of biological communities in the Back River watershed is due to urban land use and its concomitant effects: altered hydrology and elevated levels of sediments, and inorganic pollutants. Peer-reviewed scientific literature establishes a link between highly urbanized 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 in the Back River watershed can be summarized as follows:

- The BSID process has determined that biological communities in Back River watershed are likely degraded due to flow/sediment and in-stream habitat related stressors. Specifically, anthropogenic and urban sources have resulted in altered habitat heterogeneity and subsequent elevated suspended sediment in the watershed, which are in turn the probable causes of impacts to biological communities. The BSID results confirm the tidal 1998 Category 5 listing for total suspended solids (TSS) as an appropriate management action in the watershed, and links this pollutant to biological conditions in these waters and extend the impairment to the watershed's non-tidal waters. Therefore, the establishment of total suspended solids TMDL in 2010 through the Chesapeake Bay TMDL was an appropriate management action to begin addressing this stressor to the biological communities in the Back River watershed. In addition, the BSID results support the identification of the non-tidal portion of this watershed in Category 5 of the Integrated Report as impaired by TSS to begin addressing the impacts of this stressor on the biological communities in the Back River.

- The BSID process has also determined that the biological communities in the Back River watershed are likely degraded due to inorganic pollutants (i.e., chloride and sulfates). Sulfate and chloride levels are significantly associated with degraded biological conditions and found in 96% and 83%, respectively of the stream miles with poor to very poor biological conditions in the Back River watershed. Impervious surfaces and urban runoff cause an increase in contaminant loads from point and nonpoint sources by delivering an array of inorganic pollutants to surface waters. Discharges of inorganic compounds are very intermittent; concentrations vary widely depending on the time of year as well as a variety of other factors may influence their impact on aquatic life. Future monitoring of these parameters will help in determining the spatial and temporal extent of these impairments in the watershed. The BSID results thus support a Category 5 listing of chloride and sulfates for the non-tidal portion of the 8-digit watershed as an appropriate management action to begin addressing the impacts of these stressors on the biological communities in the Back River watershed.

- The BSID process has also determined that biological communities in the Back River watershed are likely degraded due to anthropogenic channelization of stream segments. MDE considers channelization as pollution not a pollutant; therefore, a Category 5 listing for this stressor is inappropriate. However, Category 4c is for waterbody segments where the State can demonstrate that the failure to meet applicable water quality standards is a result of pollution. Category 4c listings include segments impaired due to stream channelization or the lack of adequate flow. MDE recommends a Category 4c listing for the Back River watershed based on channelization being present in approximately 45% of degraded stream miles.

- The BSID process has also determined that biological communities in the Back River watershed are likely degraded due to anthropogenic alterations of riparian buffer zones. MDE considers inadequate riparian buffer zones as pollution not a pollutant; therefore, a Category 5 listing for this stressor is inappropriate. However, Category 4c is for waterbody segments where the State can demonstrate that the failure to meet applicable water quality standards as a result of pollution. MDE recommends a Category 4c listing for the Back River watershed based on inadequate riparian buffer zones in approximately 69% of degraded stream miles.

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 2009). In the vetting process, an established set of rules is used to guide the removal of sites that are not applicable for listing decisions (e.g., tidal or blackwater streams). The final principal database contains all biological sites considered valid for use in the listing process. In the watershed assessment step, a watershed is evaluated based on a comparison to a reference condition (i.e., healthy stream, less than 10% degraded) that accounts for spatial and temporal variability, and establishes a target value for "aquatic life support." During this step of the assessment, a watershed that differs significantly from the reference condition is listed as impaired (Category 5) on the Integrated Report. If a watershed is 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 the state can demonstrate that a watershed impairment is a result of pollution, but not a pollutant the watershed is listed under Category 4c. 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 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 Back River watershed, and presents the results and conclusions of a BSID analysis of the watershed.

2.0 Back River Watershed Characterization

2.1 Location

The Back River watershed is located in the western shore region of Maryland in Baltimore City and Baltimore County, northeast of the Baltimore Harbor and drains into the Chesapeake Bay (see Figure 1). The watershed is a relatively small estuary, with average depths of approximately 25 feet (near mouth), nine feet (lower estuary), and five feet (upper estuary). The tidal range in the estuary is approximately 1.2 feet (MES 1974). The basin is part of the Patapsco/Back River Tributary Strategy Basin. The total drainage area of the Maryland 8-digit watershed is approximately 39,075 acres. The watershed is located in the Coastal Plain and Piedmont regions, two of three distinct eco-regions identified in the MDDNR MBSS Index of Biological Integrity (IBI) metrics (Southerland et al. 2005a) (see Figure 2).

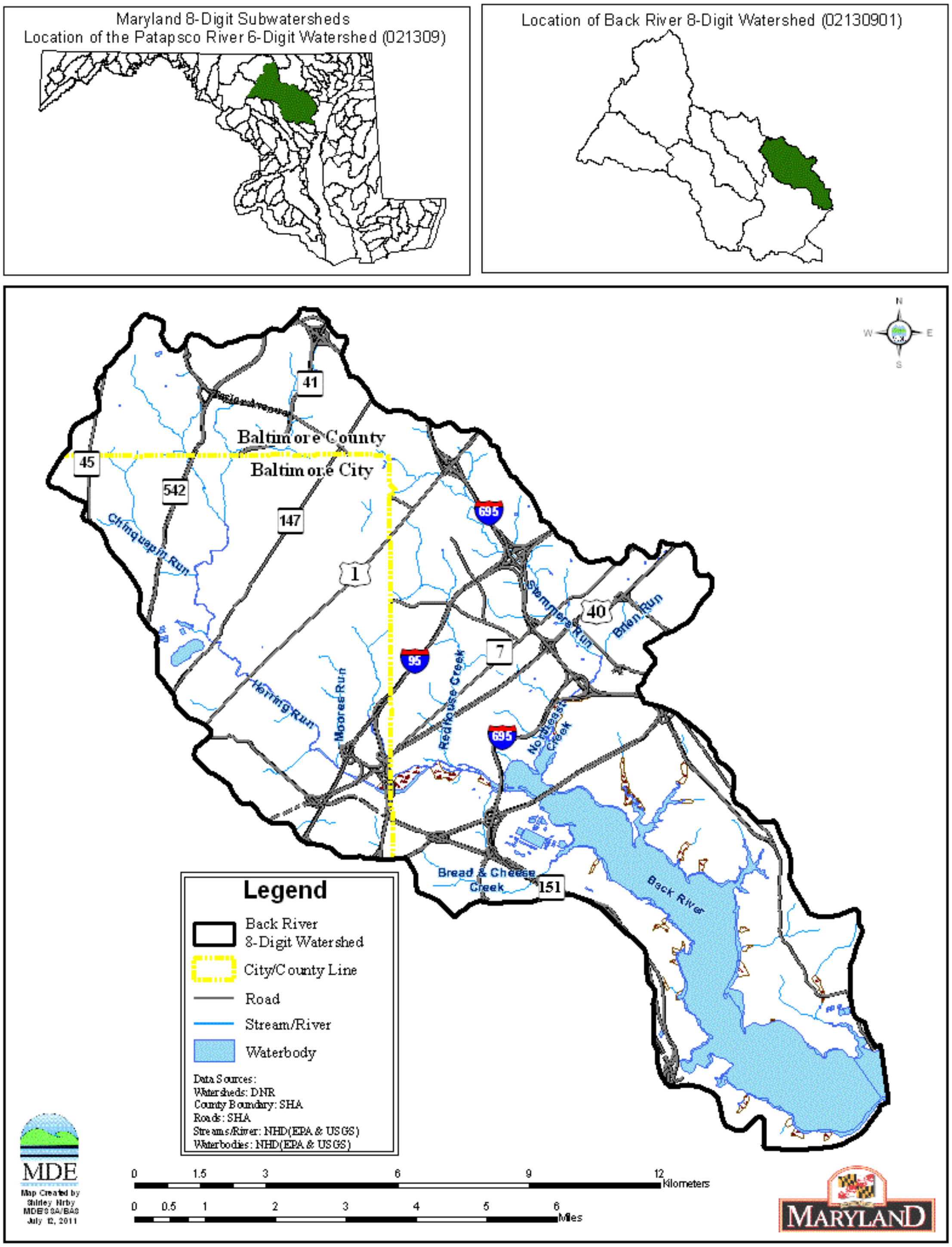

Figure 1. Location Map of the Back River Watershed

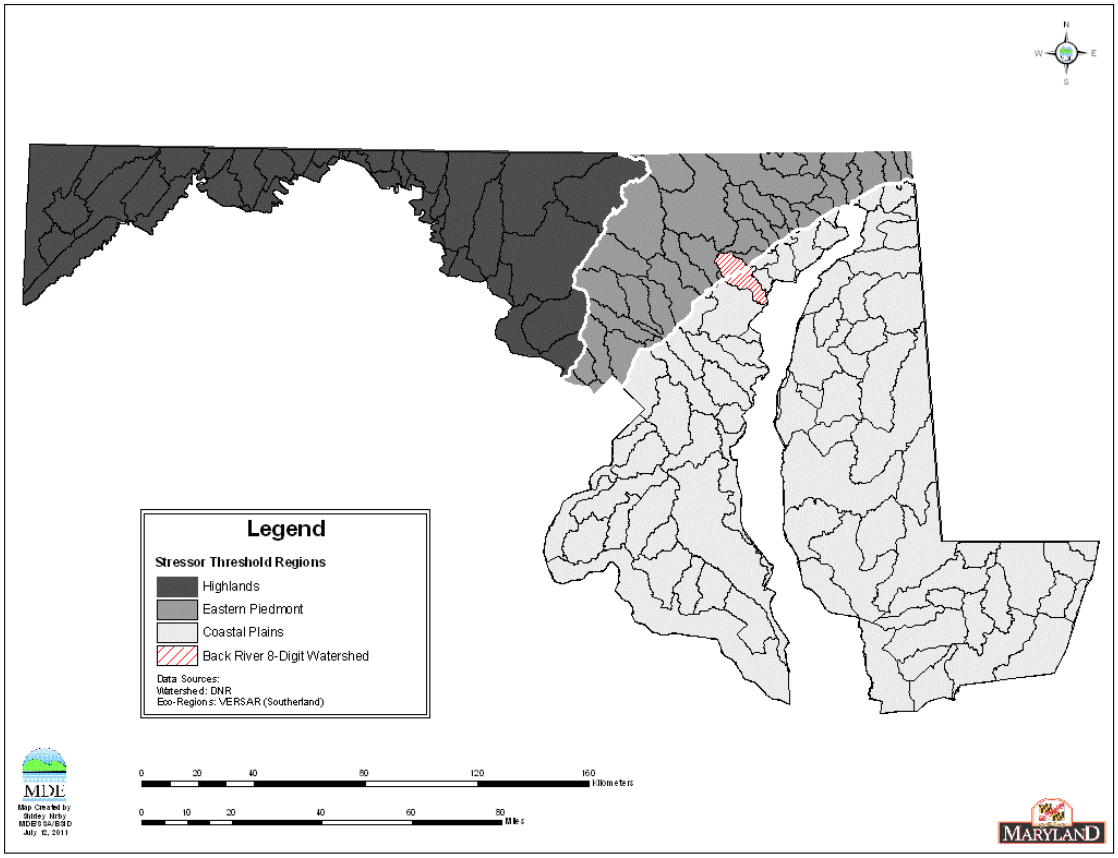

Figure 2. Eco-Region Location Map of the Back River Watershed

2.2 Land Use

The Back River watershed lies within the Coastal Plain and Piedmont Physiographic Provinces. Land use in the Back River watershed is primarily urban but also consists of some forested areas, rural areas and farms, suburban areas, and industrial areas (see Figure 3). State and county paved roads, such as Interstates 95 and 695, US 1 and 40, Route 147 and several minor roads interconnect points within the watershed. The land use distribution in the watershed is approximately 79% urban, 18% forest/herbaceous, and 2% agricultural (see Figure 4) (MDP 2002). Impervious surfaces encompass 35% of the total land use in the watershed (USEPA 2010).

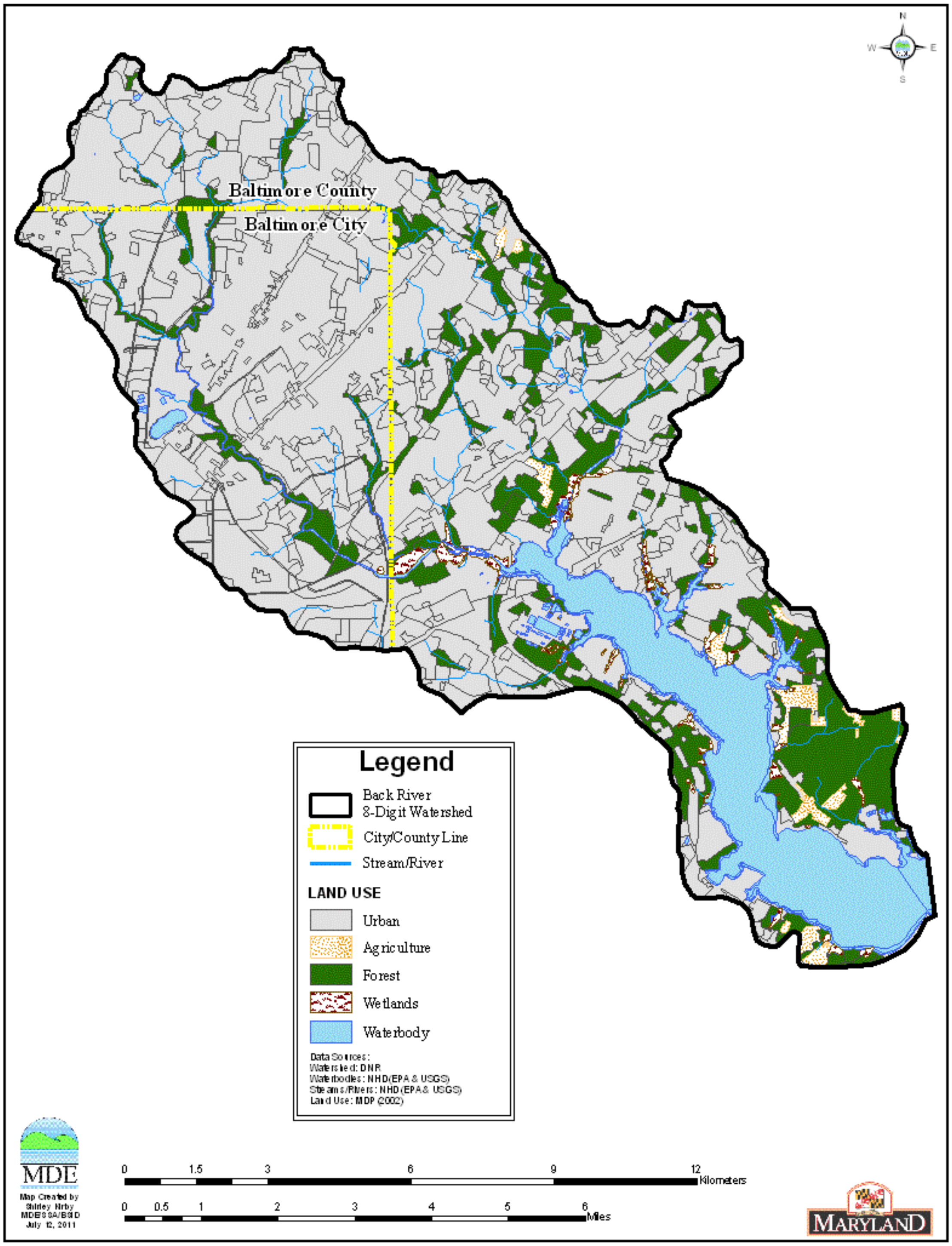

Figure 3. Land Use Map of the Back River Watershed

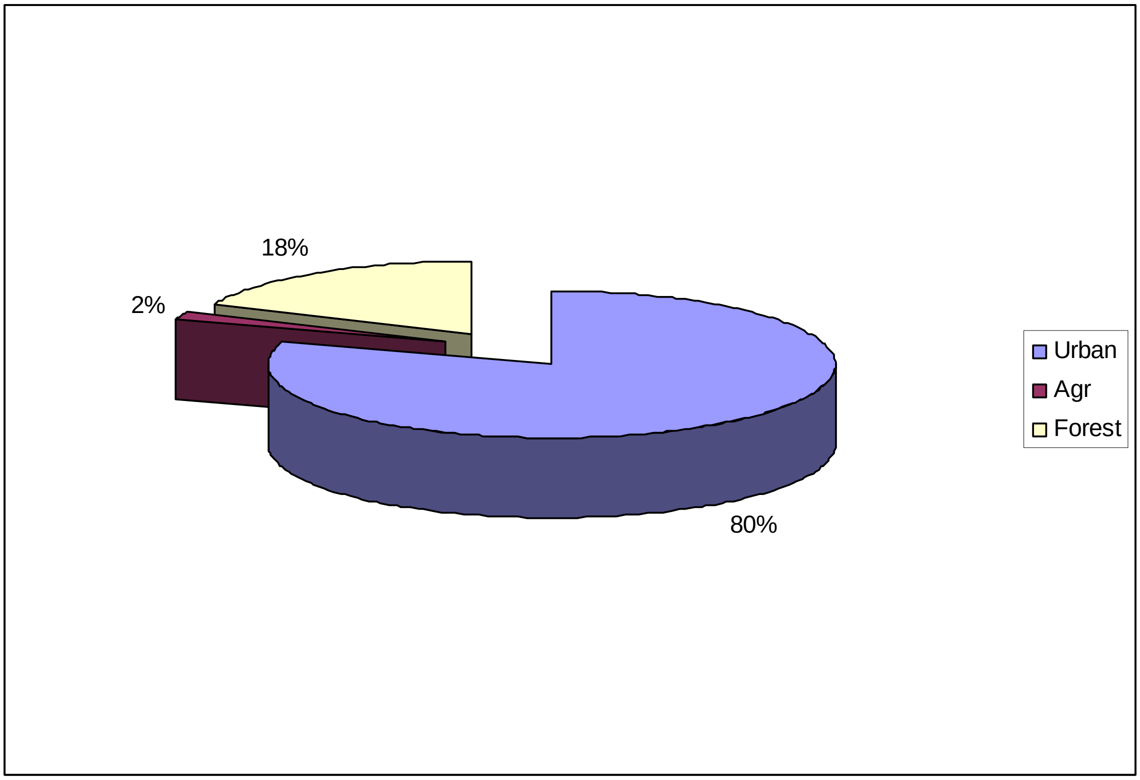

Figure 4. Proportions of Land Use in the Back River Watershed

2.3 Soils/hydrology

The Back River watershed is in the Coastal Plain and Piedmont Physiographic Provinces, in Baltimore City and Baltimore County. The Piedmont Province is characterized by gentle to steep rolling topography, low hills and ridges. The surficial geology is characterized by crystalline rocks of volcanic and sedimentary origin consisting primarily of schist and gneiss. These formations are resistant to short-term erosion, and often determine the limits of stream bank and streambed. These crystalline formations decrease in elevation from northwest to southwest and eventually extend beneath the younger sediments of the Coastal Plain. The fall line represents the transition between the Atlantic Coastal Plain Province and the Piedmont Province. The Atlantic Coastal Plain surficial geology is characterized by thick, unconsolidated marine sediments deposited over the crystalline rock of the piedmont province (CES 1995).

The Back River watershed drains from northwest to southeast, following the dip of the underlying crystalline bedrock in the Piedmont Province. The surface elevations range from approximately 500 feet to sea level at the Chesapeake Bay shorelines. Stream channels of the sub-watersheds are well incised in the Eastern Piedmont, and exhibit relatively straight reaches and sharp bends, reflecting their tendency to following zones of fractured or weathered rock. The stream channels broaden abruptly as they flow down across the fall line and into the soft, flat Coastal Plain sediments (CES 1995).

The watershed is comprised primarily of B and C type soils. Soil type is categorized by four hydrologic soil groups developed by the Soil Conservation Service (SCS). The definitions of the groups are as follows (SCS 1976):

> Group A: Soils with high infiltration rates, typically deep well-drained to excessively drained sands or gravels.
>
> Group B: Soils with moderate infiltration rates, generally moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures.
>
> Group C: Soils with slow infiltration rates, mainly soils with a layer that impedes downward water movement or soils with moderately fine to fine texture.
>
> Group D: Soils with very slow infiltration rates, mainly clay soils, soils with a permanently high water table, and shallow soils over nearly impervious material.

The soil distribution within the watershed is approximately 1.6% soil group A, 38.2% soil group B, 38.7% soil group C and 21.5% soil group D. Soil data was obtained from Soil Survey Geographic (SSURGO) coverages created by the National Resources Conservation Service (SCS 1976).

3.0 Back River Watershed Water Quality Characterization

3.1 Integrated Report Impairment Listings

The Maryland Department of the Environment has identified the non-tidal areas of the Back River watershed on the State's Integrated Report under Category 5 as impaired by evidence of biological impacts (2002 listings). The Back River watershed, located in Baltimore County and Baltimore City, MD, is associated with two assessment units in the Integrated Report (IR): non-tidal (8-digit basin) and an estuary portion (Chesapeake Bay segment). The Chesapeake Bay segment related to the Back River is the Back River Oligohaline. Below is a table identifying the listings associated with this watershed.

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						TN	
				Aquatic Life and Wildlife	1998	PCB	5
						TSS	
					1996	Zinc	2
						Estuarine Bioassessments	3
				Open-Water Fish and Shellfish	1996	TN	4a
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3.2 Biological Impairment

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for the Back River watershed's tributaries including Brien Run, Duck Creek (confluent to Creek), Herring Run, Redhouse Creek and Stemmer's Run are designated as Use I - *water contact recreation, and protection of nontidal warmwater aquatic life.* The Back River, Bread and Cheese Creek, Deep Creek, Duck Creek (confluent to Deep Creek), Muddy Gut, and Northeast Creek designated as Use II - *support of estuarine and marine aquatic life and shellfish harvesting*. Chinquapin Run, Moores Run and Herring Run are designated as Use IV – recreational trout waters (COMAR 2011 a, b). Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. The criteria developed to protect the designated use may differ and are dependent on the specific designated use(s) of a waterbody.

The Back River watershed is listed under Category 5 of the 2008 Integrated Report as impaired for impacts to biological communities. Approximately 100% of stream miles in the Back River watershed are estimated as having fish and/or benthic indices of biological impairment in the poor to very poor category. The biological impairment listing is based on the combined results of MDDNR MBSS round one (1995-1997) and round two (2000-2004) data, which include twenty-one stations. All twenty-one stations have degraded 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 nine sites; all nine having BIBI and/or FIBI scores lower than 3.0. Figure 5 illustrates principal dataset site locations for the Back River watershed.

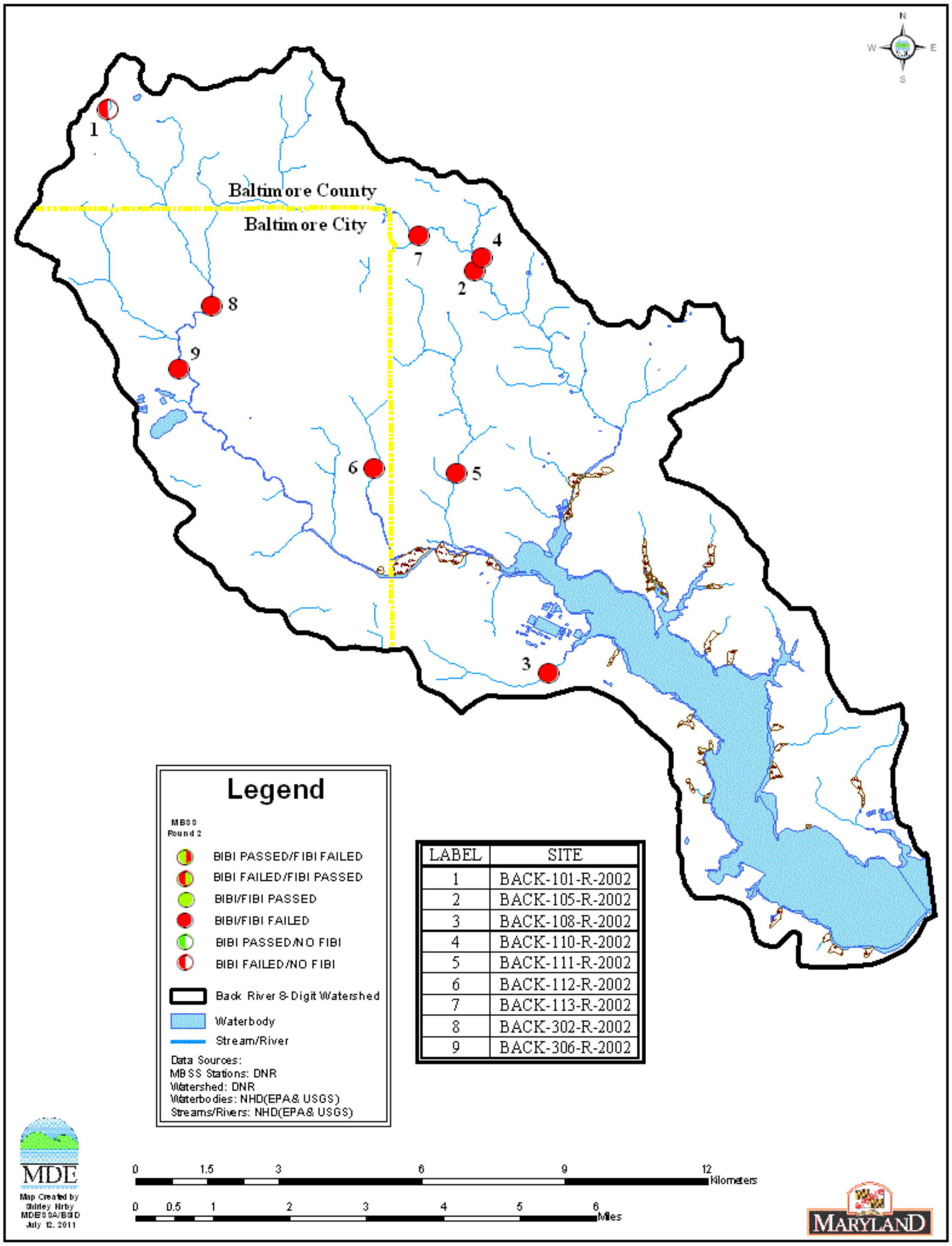

Figure 5. Principal Dataset Sites for the Back River Watershed

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 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).

Through the BSID data analysis, MDE identified sediment, instream and riparian habitat, water chemistry, and potential sources significantly associated with degraded fish and/or benthic macroinvertebrate biological conditions. Parameters identified as representing possible sources are listed in Table 2 and include various urban land use types. A summary of combined AR values for each source group is shown in Table 3. As shown in Table 4, Table 5 and Table 6, parameters from the sediment, instream and riparian, habitat and water chemistry groups are identified as possible biological stressors in the Back River 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 Back River Watershed

Parameter Group	Source	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites per strata1 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 – Urban	high impervious surface in watershed	9	9	181	100%	4%	Yes	96%
	high % of high intensity urban in watershed	9	9	181	100%	16%	Yes	83%
	high % of low intensity urban in watershed	9	9	181	100%	5%	Yes	95%
	high % of transportation in watershed	9	9	181	78%	8%	Yes	69%
	high % of high intensity urban in 60m buffer	9	9	180	89%	5%	Yes	84%
	high % of low intensity urban in 60m buffer	9	9	180	100%	6%	Yes	94%
	high % of transportation in 60m buffer	9	9	180	56%	7%	Yes	48%
Sources – Agr	high % of agriculture in watershed	9	9	181	0%	21%	No	----
	high % of cropland in watershed	9	9	181	0%	13%	No	----
	high % of pasture/hay in watershed	9	9	181	0%	20%	No	----
	high % of agriculture in 60m buffer	9	9	180	0%	11%	No	----
	high % of cropland in 60m buffer	9	9	180	0%	9%	No	----
	high % of pasture/hay in 60m buffer	9	9	180	0%	17%	No	----
Sources – Barren	high % of barren land in watershed	9	9	181	0%	15%	No	----
	high % of barren land in 60m buffer	9	9	180	0%	8%	No	----
Sources - Anthropogenic	low % of forest in watershed	9	9	181	100%	7%	Yes	93%
	low % of forest in 60m buffer	9	9	180	89%	7%	Yes	82%
Sources – Acidity	atmospheric deposition present	9	9	179	0%	18%	No	----
	AMD acid source present	9	9	179	0%	0%	No	----
	organic acid source present	9	9	179	0%	2%	No	----
	agricultural acid source present	9	9	179	0%	4%	No	----

Table 3. Summary of Combined Attributable Risk Values for Source Groups in the Back River Watershed

Source Group	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Parameter Group(s) (Attributable Risk)	
Urban	97%	97%
Agriculture	----	
Barren Land	----	
Anthropogenic	93%	
Acidity	----	

Sources Identified by BSID Analysis

All the sources identified by the BSID analysis (Table 2), are the result of urban development within the Back River watershed. The watershed is comprised of 80% urban land uses, BSID results show that urban and transportation development in the watershed and within the sixty meter riparian buffer zone has significant association with degraded biological conditions. Due to this development there is a resulting low percentage of forest in the watershed and the sixty meter riparian buffer zone. The watershed has 35% impervious surface, BSID results show that impervious surface has a 96% significant association with degraded biological conditions.

High impervious surface in watershed was 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 Back River watershed. Impervious surface is any land area that does not permit precipitation to percolate into the ground, including natural and anthropogenic surfaces. Human development typically increases the amount of impervious surface in a watershed by replacing natural vegetation and soils with buildings and pavement. A high proportion of impervious surface will result in increased surface flow and more rapid transport of precipitation out of a watershed. Increased surface flows to streams can result in more pollutant transport that may exceed species tolerances. The increased speed of runoff also overpowers any natural stream morphology formed to attenuate flow energy, such as meanders and floodplains. As streams adjust to changes in flow energy, they are unstable and are subject to rapid changes in morphology that could episodically displace aquatic organisms as habitats are gained and lost. Aquatic organisms may also be repeatedly scoured from stream channels where high flows are experienced more frequently than in watersheds with low amounts of impervious surface.

High % of high intensity urban in watershed was identified as significantly associated with degraded biological conditions and found to impact approximately 83% of the stream miles with poor to very poor biological conditions in the Back River watershed. Watershed high intensity urban represents the proportion of medium and high intensity developed land as well as transportation area within the entire drainage basin for each stream station. As with measures of impervious surface, high intensity urban increases surface water flow, or otherwise speeds water delivery to stream channels (e.g., storm water pipes), increasing the energy of flowing water and the potential to erode soils (on the terrain and in stream channels), carry pollutants, and displace organisms. Expedited transport of water from a basin decreases groundwater recharge and amplifies both high and low flow extremes. Increased pollutant transport could include nutrients, organics, and/or inorganics from residential, commercial, and/or industrial activities associated with this land usage. Reduction of available heterotrophic material could also shift trophic conditions in aquatic systems to more autotrophic that could also alter biological community structure.

High % of low intensity urban in watershed was identified as significantly associated with degraded biological conditions and found to impact approximately 95% of the stream miles with poor to very poor biological conditions in the Back River watershed. Watershed low intensity urban represents the proportion of low intensity developed land as well as urban/residential land areas dominated by deciduous trees, evergreen trees, mixed trees/forest, or recreational grasses within the entire drainage basin for each stream station. While impervious surface is expected in this land use classification, it is considered to be less extensive than in high intensity urban areas. Pollutant types are expected to be similar to those associated with high intensity urban. Episodic acute loads may equal the magnitude of high intensity area due, for example, to potential seasonal application of lawn fertilizers/pesticides or random illegal dumping of pollutants. However, chronic pollutant loads are expected to be less than those in high intensity settings due to the implied presence of natural vegetation associated with this land use classification.

High % of transportation in watershed was identified as significantly associated with degraded biological conditions and found to impact approximately 69% of the stream miles with poor to very poor biological conditions in the Back River watershed. This land use classification is a subset of high intensity urban because it one of the original Regional Earth Science Applications Center categories that were reclassified to create the high intensity classification. Independently, it generally conveys the potential for increased surface runoff and transport of pollutants due to the largely impervious nature of roadways and railways.

High % of high intensity urban in 60m buffer was identified as significantly associated with degraded biological conditions and found to impact approximately 84% of the stream miles with poor to very poor biological conditions in the Back River watershed. Stream buffer high intensity urban represents the proportion of medium and high intensity developed land and transportation area within 60 meters of the streams upstream from sample stations. This measure does not convey the total system flow energy potential or whole basin high intensity urban proportions. Instead, it demonstrates the increased potential for pollutants to enter streams due to proximity and the corresponding lack of natural buffers to filter pollutants. High proportions also demonstrate the increased potential for encroachment of urban development on floodplains, which could reduce flow attenuation properties thereby increasing storm flow velocity and channel erosion.

High % of low intensity urban in 60m buffer was identified as significantly associated with degraded biological conditions and found to impact approximately 94% of the stream miles with poor to very poor biological conditions in the Back River watershed. Stream buffer low intensity urban represents the proportion of low intensity developed land as well as urban/residential land areas dominated by deciduous trees, evergreen trees, mixed trees/forest, or recreational grasses within 60 meters of streams upstream from sample stations. Episodic pollutant loads from this primarily residential land use have increased potential compared to whole basin classifications due to the proximity to streams.

High % of transportation in 60m buffer was identified as significantly associated with degraded biological conditions and found to impact approximately 48% of the stream miles with poor to very poor biological conditions in the Back River watershed. Roadways and railways within 60 meters of streams upstream from sample stations is a subset of high intensity urban within buffers. Independently, this land use measure demonstrates the exaggerated potential of channel modifying encroachments of paved surfaces, walls, culverts, and bridges into flood plains. Reduced flow attenuation properties of floodplains as well as rapid delivery of surface flow and pollutants are potential effects associated with high proportions of this measure.

Low % of forest in watershed was identified as significantly associated with degraded biological conditions and found to impact approximately 93% of the stream miles with poor to very poor biological conditions in the Back River watershed. The amount of forested land reveals the general extent of urban and agricultural development within a watershed. Forested land use encompasses natural areas dominated by tree cover with an understory of natural plant material or ground cover. Due to processes such as evaporation, water uptake, and transpiration, watersheds with high forest proportions demonstrate natural hydrological regimes. High forest proportions also suggest that erosion will be limited due to canopies that reduce the impact of heavy rain events, along with roots and leaf litter that secure soils from transport in any overland water flow. Due to the retention of precipitation by living vegetation and leaf litter there is less surface water flow; therefore there is less of a chance for the transport of pollutants (e.g., nutrients, organic, and inorganic contaminants). High forest proportion also suggests that heterotrophic material will be in abundance, and that autochthonous production will be minimal due to the presence of canopies over small water bodies. Thus, decreased amounts of forested land use within a watershed will affect hydrological regimes, nutrient loads, trophic conditions, and inorganic pollutant contaminants on surface waters.

Low % of forest in 60m buffer was identified as significantly associated with degraded biological conditions and found to impact approximately 82% of the stream miles with poor to very poor biological conditions in the Back River watershed. This measure represents the proportion forested land use within 60 meters of the streams upstream from sample stations. Low forest riparian proportions should associate with higher anthropogenic disturbances and pollutant loadings to surface waters. Riparian zones serve a number of critical ecological functions. They control erosion and sedimentation, modulate stream temperature, provide organic matter, and maintain benthic macroinvertebrate communities and fish assemblages (Lee, Smyth, and Boutin 2004).

The scientific community (Booth 1991; Meyer, Paul, and Taulbee 2005; Wang et al. 2001; Southerland et al. 2005b) has consistently identified negative impacts to biological conditions as a result of increased urbanization. The consequences of urbanization include loss of large woody debris, increased erosion, and channel destabilization; the most critical of these environmental changes are those that alter the watershed's hydrologic regime. 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. Overall urban development causes an increase in contaminant loads from point and nonpoint sources by adding sediments, nutrients, road salts, toxics, petroleum products, and inorganic pollutants to surface and groundwaters.

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).

In recent years impervious cover has emerged as a key indicator to explain and sometimes predict how severely streams change in response to different levels of watershed development (CWP 2003). The Center for Watershed Protection has integrated these research findings into a general watershed planning model, known as the impervious cover model (ICM). The ICM predicts that most stream quality indicators decline when watershed impervious cover exceeds 10%, with severe degradation expected beyond 25% impervious cover. The model classifies subwatersheds into one of three categories: sensitive (0-10%), impacted (11-25%), and non-supporting (over 25%).

The Back River watershed has approximately 35% impervious cover which would place the watershed in the non-supporting category. Once watershed impervious cover exceeds 25%, stream quality crosses a second threshold. Streams in this category essentially become conduits for conveying stormwater flows, and can no longer support a diverse stream community. The stream channel becomes highly unstable, and many stream reaches experience severe widening, downcutting, and streambank erosion. Pool and riffle structure needed to sustain fish is diminished or eliminated and the substrate can no longer provide habitat for aquatic insects, or spawning areas for fish. Water quality is consistently rated as fair to poor, and water recreation often is no longer possible due to the presence of high bacterial levels. The biological quality of non-supporting streams is generally considered poor, and is dominated by pollution tolerant insects and fish. Most researchers acknowledge that streams with more than 25% impervious cover in their watersheds cannot support their designated uses or attain water quality standards and are severely degraded from a physical and biological standpoint. As a consequence, many of these streams are listed for non-attainment under the Clean Water Act and are subject to TMDL regulations (CWP 1998).

The BSID results indicate that various urban land uses in the riparian buffer zones has significant association with degraded biological conditions. Rich vegetation growing along the edges of a stream is commonly referred to as a riparian zone. These areas are called riparian buffers, and they are beneficial because they slow water runoff, trap sediment, and enhance infiltration. Often, the natural transition zone is altered through various land uses, and the protective nature of the riparian zone becomes ineffective or even detrimental to the health of the water body. Some typical quality problems for watersheds with anthropogenic disturbances in riparian buffer zones involve an influx of chemicals and excessive sediment from both agricultural and urban sources.

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

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

Parameter Group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites per strata1 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 that odds or 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	9	9	102	100%	18%	Yes	83%
	moderate bar formation present	9	9	102	100%	48%	Yes	53%
	bar formation present	9	9	102	100%	87%	No	----
	channel alteration moderate to poor	9	9	100	100%	50%	Yes	52%
	channel alteration poor	9	9	100	100%	19%	Yes	83%
	high embeddedness	9	9	102	22%	5%	Yes	17%
	epifaunal substrate marginal to poor	9	9	102	33%	27%	No	----
	epifaunal substrate poor	9	9	102	11%	6%	No	----
	moderate to severe erosion present	9	9	102	56%	55%	No	----
	severe erosion present	9	9	102	11%	13%	No	----
	poor bank stability index	9	9	102	22%	13%	No	----
	silt clay present	9	9	102	100%	100%	No	----

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

Parameter Group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites per strata1 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 that odds or 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	9	9	103	56%	11%	Yes	45%
	instream habitat structure marginal to poor	9	9	102	67%	24%	Yes	46%
	instream habitat structure poor	9	9	102	11%	2%	No	----
	pool/glide/eddy quality marginal to poor	9	9	102	67%	46%	No	----
	pool/glide/eddy quality poor	9	9	102	0%	2%	No	----
	riffle/run quality marginal to poor	9	9	102	78%	29%	Yes	52%
	riffle/run quality poor	9	9	102	22%	9%	No	----
	velocity/depth diversity marginal to poor	9	9	102	78%	52%	Yes	29%
	velocity/depth diversity poor	9	9	102	11%	6%	No	----
	concrete/gabion present	9	9	104	33%	1%	Yes	32%
	beaver pond present	9	9	101	0%	5%	No	----
Riparian Habitat	no riparian buffer	9	9	103	89%	19%	Yes	69%
	low shading	9	9	102	0%	8%	No	----

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

Parameter Group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites per strata1 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 that odds or 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	9	9	179	0%	38%	No	----
	high total dissolved nitrogen	0	0	0	0%	0%	No	----
	ammonia acute with salmonid present	9	9	179	0%	18%	No	----
	ammonia acute with salmonid absent	9	9	179	0%	12%	No	----
	ammonia chronic with salmonid present	9	9	179	11%	35%	No	----
	ammonia chronic with salmonid absent	9	9	179	0%	25%	No	----
	low lab pH	9	9	179	0%	16%	No	----
	high lab pH	9	9	179	11%	1%	No	----
	low field pH	9	9	178	0%	18%	No	----
	high field pH	9	9	178	11%	1%	No	----
	high total phosphorus	9	9	179	11%	5%	No	----
	high orthophosphate	9	9	179	11%	10%	No	----
	dissolved oxygen < 5mg/l	9	9	178	11%	6%	No	----
	dissolved oxygen < 6mg/l	9	9	178	33%	10%	Yes	24%
	low dissolved oxygen saturation	8	8	164	25%	8%	No	----
	high dissolved oxygen saturation	8	8	164	13%	0%	Yes	13%
	acid neutralizing capacity below chronic level	9	9	179	0%	4%	No	----
	acid neutralizing capacity below episodic level	9	9	179	0%	23%	No	----
	high chlorides	9	9	179	89%	6%	Yes	83%
	high conductivity	9	9	179	100%	6%	Yes	94%
	high sulfates	9	9	179	100%	4%	Yes	96%

Table 7. Summary of Combined Attributable Risk Values for Stressor Groups in the Back River Watershed

Stressor Group	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Parameter Group(s) (Attributable Risk)	
Sediment	85%	98%
In-Stream Habitat	87%	
Riparian Habitat	69%	
Water Chemistry	97%	

Stressors Identified by BSID Analysis

All sixteen stressor parameters identified by the BSID analysis (Tables 4, 5 and 6), are significantly associated with biological degradation in the Back River watershed and are representative of impacts from urban developed landscapes.

Sediment Conditions

BSID analysis results for the Back River watershed identified five sediment parameters that have a statistically significant association with poor to very poor stream biological condition, i.e., removal of stressors would result in improved biological community: *extensive bar formation present, moderate bar formation present, channel alteration (moderate to poor), channel alteration (poor)* and *high embeddedness* (Table 4).

Bar formation present was identified as significantly associated with degraded biological conditions and found to impact approximately 83% *(extensive)* and 53% *(moderate)* respectively, of the stream miles with poor to very poor biological conditions in the Back River watershed. Bar formation represents deposition of sand, gravel, and small stones in an area of the stream with a gentle slope and an elevation very close to the stream's water level. Bar formation typically reflects the overall sediment transport capacity of the stream with observed categories of moderate to extensive or extensive bar formation present. Moderate to extensive bar formation indicates channel instability related to frequent and intense high stream velocities that quickly dissipate and rapidly lose the capacity to transport excessive sediment loads downstream.

Sediment loads may originate from terrestrial (surface) erosion or from in-stream channel/bank erosion. Excessive sediment loading is expected to reduce and homogenize available feeding and reproductive habitat, degrading biological conditions. Distinguishing between terrestrial or aquatic sources of sediment is not possible from this measure. Since many pollutants readily attach to sediment particles, it is possible that this parameter may also represent the presence of pollutants other than sediment. For example, sediment loads from terrestrial erosion may also introduce phosphorus into the stream segment.

Channel alteration was identified as significantly associated with degraded biological conditions and found to impact approximately 52% (*moderate to poor*) and 83% *(poor)* respectively, of the stream miles with poor to very poor biological conditions in the Back River watershed. Channel alteration measures large-scale modifications in the shape of the stream channel due to the presence of artificial structures (*channelization*) and/or *bar formations*. A marginal to poor rating is expected in unstable stream channels that experience frequent high flows.

High embeddedness was identified as significantly associated with degraded biological conditions and found to impact approximately 17% of the stream miles with poor to very poor biological conditions in the Back River watershed. This stressor measures the percentage of fine sediment surrounding gravel, cobble, and boulder particles in the streambed. 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 and/or stream channel erosion.

The BSID analysis results include stressors (*bar formation, channel alteration,* and *high embeddedness*) are often typically associated with the effects of urban and agricultural land use. The Back River watershed contains a considerable proportion (80%) urban development. Altered flow regimes create a less stable stream channel, leading to excessive bank erosion, loss of pool habitat and instream cover, and excessive streambed scour and sediment deposition (Wang et al. 2001). In urbanized areas, lawns are frequently and severely mowed; as a result soils can be more easily eroded and transported to streams. There is a minimal concentration of agricultural land use in the watershed (2%), but it can contribute sources to sediment stressors. Agricultural land use results in increased sediment deposition within a watershed, sediment “pollution” is the number one impairment of streams nationwide Southerland et al (2005b). Sediment pollution in the Back River watershed has resulted in the exceedance of species tolerances and subsequent trophic alteration (e.g., shift to more silt-tolerant species). Consequently, an impaired biological community with poor IBI scores is observed.

The combined AR is used to measure the extent of stressor impact of degraded stream miles, poor to very poor biological conditions. The combined AR for the sediment stressor group is approximately 85% suggesting that this stressor group impacts a substantial proportion of the degraded stream miles in the Back River (Table 7).

Instream Habitat Conditions

BSID analysis results for the Back River watershed identified five habitat parameters that have a statistically significant association with poor to very poor stream biological condition, i.e., removal of stressors would result in improved biological community: *channelization present, instream habitat structure (marginal to poor), riffle/run quality (marginal to poor), velocity/depth velocity (poor),* and *concrete/gabion present* (Table 5).

Channelization present was identified as significantly associated with degraded biological conditions and found to impact approximately 45% of the stream miles with poor to very poor biological conditions in the Back River watershed. Channelized describes a condition determined by visual observation of the presence or absence of the channelization of the stream segment and the extent of the channelization. Channelization is the human alteration of the natural stream morphology by altering the stream banks, (i.e., concrete, rip rap, and ditching). Streams are channelized to increase the efficiency of the downstream flow of water. Channelization likely inhibits heterogeneity of stream morphology needed for colonization, abundance, and diversity of fish and benthic communities.

Instream habitat structure (marginal to poor) was identified as significantly associated with degraded biological conditions and found to impact approximately 46% of the stream miles with poor to very poor biological conditions in the Back River watershed. Instream habitat structure 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 instream habitat scores are evidence of the lack of sediment deposition. Low instream habitat values can be caused by high flows that collapse undercut banks and by sediment inputs that fill pools and other fish habitats. A marginal to poor rating of this measure indicates excessive erosion and/or sedimentation.

Riffle/run quality was identified as significantly associated with degraded biological conditions and found to impact approximately 52% *(marginal to poor)* of the stream miles with poor to very poor biological conditions in the Back River watershed. Riffle/run quality is a visual observation including quantitative measurements based on the depth, complexity, and functional importance of riffle/run habitat within the stream segment. An increase of heterogeneity of riffle/run habitat within the stream segment likely increases the abundance and diversity of fish species, while a decrease in heterogeneity likely decreases abundance and diversity. Marginal to poor and poor ratings are expected in unstable stream channels that experience frequent high flows.

Velocity/depth velocity was identified as significantly associated with degraded biological conditions and found to impact approximately 29% *(marginal to poor)* of the stream miles with poor to very poor biological conditions in the Back River watershed. Velocity/depth diversity is a visual observation including quantitative measurements based on the variety of velocity/depth regimes present at a site (i.e., slow-shallow, slow-deep, fast-shallow, and fast-deep). Like riffle/run quality, the increase in the number of different velocity/depth regimes likely increases the abundance and diversity of fish species within the stream segment. The decrease in the number of different velocity/depth regimes likely decreases the abundance and diversity of fish species within the stream segment. The ‘poor’ diversity categories could identify the absence of available habitat to sustain a diverse aquatic community. This measure may reflect natural conditions (e.g., bedrock), anthropogenic conditions (e.g., widened channels, dams, channel dredging, etc.) or excessive erosional conditions (e.g., bar formation, entrenchment, etc.).

Concrete/gabion present was identified as significantly associated with degraded biological conditions and found to impact approximately 32% of the stream miles with poor to very poor biological conditions in the Back River watershed. The presence or absence of concrete is determined by a visual observation within the stream segment, resulting from the field description of the types of channelization. Like ‘channelization present’, concrete inhibits the heterogeneity of stream morphology needed for colonization, abundance, and diversity of fish and benthic communities. Concrete channelization increases flow and provides a homogeneous substrate, conditions which are detrimental to diverse and abundant colonization.

All of the instream habitat parameters identified as significantly associated with degraded conditions in the Back River watershed are primarily linked to the watershed’s high percentage of urban land use development. Channelization has been used extensively in urban landscapes for flood control, and has resulted in significant channel and streambed alteration. These alterations significantly impact the other habitat parameters identified as significantly associated with degraded conditions in the watershed. Channelization is detrimental for the "well being" of streams and rivers through the elimination of suitable habitat and the creation of excessive flows, e.g. flashiness. Stream bottoms are made more uniform. Habitats of natural streams contain numerous bends, riffles, runs, pools and varied flows, and tend to support healthier and more diversified plant and animal communities than those in channelized streams. The overall densities and biomasses of macroinvertebrates in channelized streams are very low by comparison with intact natural streams (Laasonen, Muotka, and Kivikaervi 1998; Haapala and Muotka 1998).

The combination of the altered flow regime and stream morphology in the Back River watershed has resulted in loss of available habitat and an unstable stream ecosystem, characterized by a continuous displacement of biological communities that require frequent re-colonization. Consequently, an impaired biological community with poor IBI scores is observed.

The combined AR is used to measure the extent of stressor impact of degraded stream miles, poor to very poor biological conditions. The combined AR for the instream habitat stressor group is approximately 87% suggesting that this stressor group impacts a substantial proportion of the degraded stream miles in the Back River (Table 7).

Riparian Habitat Conditions

BSID analysis results for the Back River watershed identified one habitat parameter that has a statistically significant association with poor to very poor stream biological condition, i.e., removal of stressors would result in improved biological community: *no riparian buffer* (Table 5).

No riparian buffer was identified as significantly associated with degraded biological conditions and found to impact approximately 69% of the stream miles with poor to very poor biological conditions in the Back River watershed. Riparian buffer width represents the minimum width of vegetated buffer in meters, looking at both sides of the stream. Riparian buffer width is measured from 0 m to 50 m, with 0 m having no buffer and 50 m having a full buffer. Riparian buffers serve a number of critical ecological functions. They control erosion and sedimentation, modulate stream temperature, provide organic matter, and maintain benthic macroinvertebrate communities and fish assemblages (Lee, Smyth, and Boutin 2004).

The Back River watershed contains a considerable proportion (80%) of urban land use, and to a lesser extent (2%) agricultural land use. Stream channel shading is reduced or eliminated as forests and other riparian vegetation are replaced with urban development (Allan 2004; Kline, Hilderbrand, and Hairston-Strang 2005; Southerland et al. 2005b). 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 Hairston-Strang 2005; Roth et al. 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 combined AR is used to measure the extent of stressor impact of degraded stream miles, poor to very poor biological conditions. The combined AR for the riparian habitat stressor group is approximately 69% suggesting that this stressor group impacts a considerable proportion of the degraded stream miles in the Back River (Table 7).

Water Chemistry

BSID analysis results for the Back River watershed identified five 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): *dissolved oxygen <6 mg/L, high dissolved oxygen saturation, high chloride, high conductivity, and high sulfate* (Table 6).

Dissolved oxygen (DO) <6 mg/L concentration was identified as significantly associated with degraded biological conditions and found to impact approximately 24% of the stream miles with poor to very poor biological conditions in the Back River 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 2011c.

High (> 125%) *DO saturation* concentration was identified as significantly associated with degraded biological conditions and found to impact approximately 13% of the stream miles with very poor to poor biological conditions in the Back River watershed. Natural diurnal fluctuations can become exaggerated in streams with excessive primary production. High DO saturation accounts for physical solubility limitations of oxygen in water and provides a more targeted assessment of oxygen dynamics than concentration alone. High DO saturation is considered to demonstrate oxygen production associated with high levels of photosynthesis.

High chloride concentration was identified as significantly associated with degraded biological conditions and found to impact approximately 83% of the stream miles with poor to very poor biological conditions in the Back River watershed. High concentrations of chloride can result from industrial discharges, metals contamination, and application of road salts in urban landscapes.

High conductivity concentration was identified as significantly associated with degraded biological conditions and found to impact approximately 94% of the stream miles with poor to very poor biological conditions in the Back River 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. 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). Conductivity, chloride, and sulfate are closely related. Streams with elevated levels of chlorides and sulfates typically display high conductivity.

High sulfate concentration was 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 Back River watershed. 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.

The BSID analysis results identify several parameters of water chemistry as significant stressors in the Back River watershed; water chemistry is a major determinant of the integrity of surface waters that is strongly influenced by land use. The urban land use in the Back River watershed is a potential source for decreased oxygen concentration (24%), high dissolved oxygen saturation (13%), and elevated levels of chloride (83%), conductivity (94%), and sulfate (96%).

Natural and anthropogenic changes to an aquatic environment can affect the availability of dissolved oxygen (DO). The normal diurnal fluctuations of a system can be altered resulting in large fluctuations in DO levels which can occur throughout the day. The low DO concentration results may be associated with the impacts of sewage, low precipitation, and the decomposition of leaf litter, grass clippings. The Back River watershed was sampled in 2002 by MDDNR MBSS; three of nine sampling sites had DO concentrations less than 6 mg/L. Two of the sites (DO 5.4 and 5.9 mg/L) are in the Herring Run tributary in Baltimore City; approximately 124,198,400 gallons of SSO discharge were released through various waterways (surface water, groundwater, sanitary sewers, etc.) in the Herring Run mainstem and tributaries between January 2002 and December 2004 (MDE 2007). The third and only site with DO values below COMAR water quality standard of 5.0 mg/L(DO 2.2 mg/L), is in the Bread and Cheese tributary upstream from the Back River Wastewater Treatment Plant (WWTP). They were sampled between 9am and 12pm, this may be a contributing factor due to the effects of overnight DO respiration, but also the MDDNR MBSS noted strong sewage smells at this site. There was also a severe drought in 2002, precipitation had a -6.25 inch departure from 30-year average overall for round 2 sampling in the watershed (Kilian and Stranko 2003). During drought conditions there is less freshwater input, therefore less DO in a system. Two stations on Stemmers Run, sampled on the same day between 11am to 2pm with close proximity to one another exhibited high DO saturation results, this could be indicative of excessive primary production due to excess sunlight (i.e., lack of riparian buffer); however, no nutrient stressors were identified as having significant association with degraded biological conditions.

The Back River WWTP discharges approximately 120 million gallons/day of treated waste water to the upper tidal reaches of the estuarine portion of the system (MDE 1999). NPDES permitting enforcement does not require sulfate testing; therefore data was not available to verify/identify sulfate as a specific pollutant in this 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 m (average of 300 m) on each side of four-lane roads. Roads tend to capture and export more stormwater pollutants than other land covers. The presence of salts also limits the DO concentration in water. As noted in the sources analysis, sanitary sewage overflows are quite frequent in the watershed and are also likely a source of elevated concentrations of chloride, conductivity, and sulfate. 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.

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 this stressor impacts a substantial proportion of the degraded stream miles in the Back River watershed (Table 7).

Discussion/Summary

Back River watershed encompasses seventy-three miles of streams located in urban and suburban portions of southeastern Baltimore County and includes the northeastern quadrant of Baltimore City. The watershed is currently 79% urban land uses and much of the existing development occurred in the 1960s and 1970s. Because this development predates current stormwater management regulations the streams within the watershed are subject to extensive stormwater/urban runoff and other forms of water pollution.

Due to significant anthropogenic changes of natural stream channels and riparian buffers zones within the watershed, health and diversity of biological communities are severely impacted. The stressors c*hannelization present* and *no riparian buffer* were identified as significantly associated with degraded biological conditions, and found to impact approximately 45% and 69% of the stream miles with poor to very poor biological conditions in the Back River watershed.

The BSID analysis results suggest that degraded biological communities in the Back River watershed are a result of increased urban land uses causing alteration to hydrology, stream habitat, repeated streambed scouring, and increased sedimentation, resulting in an unstable stream ecosystem that eliminates habitat heterogeneity. High proportions of these land uses also typically results in increased contaminant loads from point and nonpoint sources by adding sediments and inorganic pollutants to surface waters, resulting in levels that can potentially be toxic to aquatic organisms. Alterations to the hydrologic regime, physical habitat, and water chemistry, have all combined to degrade the Back River, leading to a loss of diversity in the biological community. The combined AR for all the stressors is approximately 98%, suggesting that altered ydrology/sediment, habitat, and water chemistry stressors adequately account for the biological impairment in the Back River.

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 Back River Watershed

Causal model development provides a visual linkage between biological condition, habitat, chemical, and source parameters available for stressor analysis. Models were developed to represent the ecologically plausible processes when considering the following five factors affecting biological integrity: biological interaction, flow regime, energy source, water chemistry, and physical habitat (Karr 1991; USEPA 2011). The five factors guide the selections of available parameters applied in the BSID analyses and are used to reveal patterns of complex causal scenarios. Figure 6 illustrates the final casual model for the Back River watershed, with pathways bolded or highlighted to show the watershed's probable stressors as indicated by the BSID analysis.

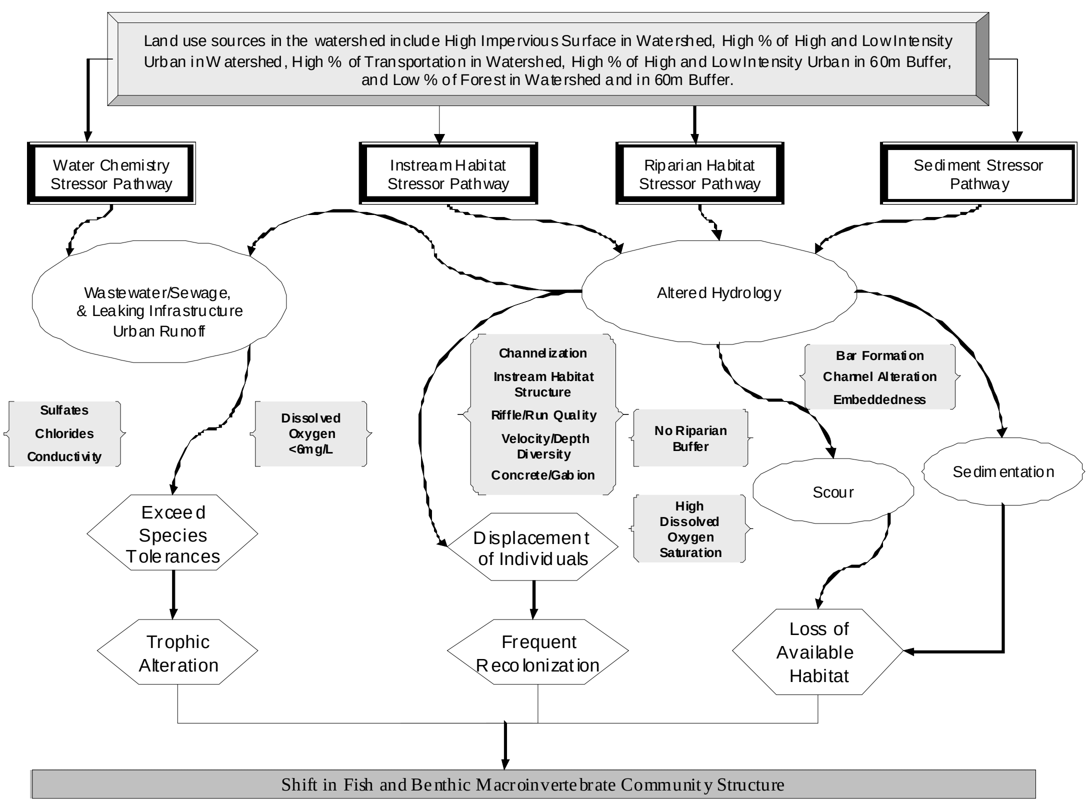

Figure 6. Final Causal Model for the Back River Watershed

5.0 Conclusions

Data suggest that the Back River watershed's biological communities are influenced by urban land use. This land use alters the hydrologic regime of a watershed resulting in increased habitat homogeneity. There is an abundance of scientific research that directly and indirectly links degradation of the aquatic health of streams to urban landscapes, which often cause flashy hydrology in streams and increased contaminant loads from runoff. Based upon the results of the BSID process, the probable causes and sources of the biological impairments of the Back River watershed are summarized as follows:

- The BSID process has determined that biological communities in Back River watershed are likely degraded due to flow/sediment and in-stream habitat related stressors. Specifically, anthropogenic and urban sources have resulted in altered habitat heterogeneity and subsequent elevated suspended sediment in the watershed, which are in turn the probable causes of impacts to biological communities. The BSID results confirm the tidal 1998 Category 5 listing for total suspended solids (TSS) as an appropriate management action in the watershed, and links this pollutant to biological conditions in these waters and extend the impairment to the watershed's non-tidal waters. Therefore, the establishment of total suspended solids TMDL in 2010 through the Chesapeake Bay TMDL was an appropriate management action to begin addressing this stressor to the biological communities in the Back River watershed. In addition, the BSID results support the identification of the non-tidal portion of this watershed in Category 5 of the Integrated Report as impaired by TSS to begin addressing the impacts of this stressor on the biological communities in the Back River.

- The BSID process has also determined that the biological communities in the Back River watershed are likely degraded due to inorganic pollutants (i.e., chloride and sulfates). Sulfate and chloride levels are significantly associated with degraded biological conditions and found in 96% and 83%, respectively of the stream miles with poor to very poor biological conditions in the Back River watershed. Impervious surfaces and urban runoff cause an increase in contaminant loads from point and nonpoint sources by delivering an array of inorganic pollutants to surface waters. Discharges of inorganic compounds are very intermittent; concentrations vary widely depending on the time of year as well as a variety of other factors may influence their impact on aquatic life. Future monitoring of these parameters will help in determining the spatial and temporal extent of these impairments in the watershed. The BSID results thus support a Category 5 listing of chloride and sulfates for the non-tidal portion of the 8-digit watershed as an appropriate management action to begin addressing the impacts of these stressors on the biological communities in the Back River watershed.

- The BSID process has also determined that biological communities in the Back River watershed are likely degraded due to anthropogenic channelization of stream segments. MDE considers channelization as pollution not a pollutant; therefore, a Category 5 listing for this stressor is inappropriate. However, Category 4c is for waterbody segments where the State can demonstrate that the failure to meet applicable water quality standards is a result of pollution. Category 4c listings include segments impaired due to stream channelization or the lack of adequate flow. MDE recommends a Category 4c listing for the Back River watershed based on channelization being present in approximately 45% of degraded stream miles.

- The BSID process has also determined that biological communities in the Back River watershed are likely degraded due to anthropogenic alterations of riparian buffer zones. MDE considers inadequate riparian buffer zones as pollution not a pollutant; therefore, a Category 5 listing for this stressor is inappropriate. However, Category 4c is for waterbody segments where the State can demonstrate that the failure to meet applicable water quality standards as a result of pollution. MDE recommends a Category 4c listing for the Back River watershed based on inadequate riparian buffer zones in approximately 69% of degraded stream miles.

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