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

REVISED FINAL

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List of Abbreviations

AMD	Acid Mine Drainage
AR	Attributable Risk
BIBI	Benthic Index of Biotic Integrity
BSID	Biological Stressor Identification
COMAR	Code of Maryland Regulations
CWA	Clean Water Act
FIBI	Fish Index of Biologic Integrity
IBI	Index of Biotic Integrity
MD DNR	Maryland Department of Natural Resources
MDE	Maryland Department of the Environment
MBSS	Maryland Biological Stream Survey
MH	Mantel-Haenzel
mg/L	Milligrams per liter
NPDES	National Pollution Discharge Elimination System
SSA	Science Services Administration
TMDL	Total Maximum Daily Load
US EPA	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 (US EPA) 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.

Evitts Creek (basin code 02141002), located in Allegany County, was identified on the State's Integrated Report as impaired by low pH (1996 listing, Rocky Gap Run – 2006 listing), nutrients (1996 listing, Lake Habeeb -1998 listing), sediments (1996 listing), and impacts to biological communities (2006 listing) (MDE 2008). The 1996 nutrients listing was refined in the 2008 Integrated Report and phosphorus was identified as the specific impairing substance. A WQA for low pH was completed in 2005 to address the 1996 listing. A TMDL for nutrients to address the 1998 Lake Habeeb listing was completed in 1999, and the 1996 sediment listing, which was refined in the 2008 Integrated Report to a listing for total suspended solids, was addressed via a TMDL completed in 2006. The remainder of this report will address the biological listing, and the 8-digit watershed listing for nutrients and the 2006 Rocky Gap Run pH listing will be addressed separately at a future date.

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

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for Evitts Creek is Use IV-P - *Recreational Trout Waters and Public Water Supply* for the mainstem only and Use III-P – *Nontidal Coldwater and Public Water Supply* for its tributaries (COMAR 2009a,b,c). The Evitts Creek watershed is not attaining its designated use of supporting aquatic life. 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 (MD DNR) Maryland Biological Stream Survey (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 stressors 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 the 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 Evitts Creek watershed report presents a brief discussion of the BSID process on which the watershed analysis is based, and may be reviewed in more detail in the report entitled *Maryland Biological Stressor Identification Process* (MDE 2009). Data suggest that the degradation of biological communities in Evitts Creek are strongly influenced by urban land use and its concomitant effects: altered hydrology and elevated levels of sulfates, chlorides, and conductivity (a measure of the presence of dissolved substances). The urbanization of landscapes creates broad and interrelated forms of degradation (i.e., hydrological, morphological, and water chemistry) that can affect stream ecology and biological composition. Peer-reviewed scientific literature establishes a link between highly urbanized 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 Evitts Creek can be summarized as follows:

- The BSID process has determined that biological communities in Evitts Creek are likely degraded due to flow/sediment related stressors. Sediment stressors are significantly associated with degraded biological conditions and are found to be impacting approximately 37% of the stream miles with very poor to poor biological conditions in the Evitts Creek watershed. Specifically, altered hydrology and increased runoff from urban impervious surfaces have resulted in marginal to poor substrate condition, likely caused by elevated suspended sediment transport in the watershed, which are in turn the probable causes of impacts to biological communities. The BSID results thus confirm the Integrated Report Category 4a listing for total suspended solids as an impairing substance in Evitts Creek, for which a TMDL has been developed, and links this pollutant to biological conditions in these waters.

- The BSID process has determined that the biological communities in Evitts Creek are also likely degraded due to inorganic pollutants (sulfates, chlorides, and conductivity). Inorganic pollutants levels are significantly associated with degraded biological conditions and are found to be impacting approximately 25% of the stream miles with very poor to poor biological conditions in the Evitts Creek watershed. Impacts on water quality due to sulfates, chlorides, and conductivity are dependent on prolonged exposure; future monitoring of these inorganic pollutants will help in determining the spatial and temporal extent of this impairment in the watershed. Urban runoff causes an increase in contaminant loads from point and nonpoint sources by delivering an array of inorganic pollutants to surface waters. Currently, there is a lack of monitoring data for many of these substances; therefore, additional monitoring of priority inorganic pollutants is needed to more precisely determine the specific cause(s) of impairment.

- The BSID process has also determined that biological communities in the Evitts Creek 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 is a result of pollution. MDE recommends a Category 4c listing for the Evitts Creek watershed based on inadequate riparian buffer zones in approximately 33% of degraded stream miles.

- Although there is presently a Category 5 listing for phosphorus in Maryland's 2008 Integrated Report, the BSID analysis did not identify any nutrient stressors (i.e., total nitrogen, total phosphorus, and dissolved oxygen, etc.) present and/or nutrient stressors showing a significant association with degraded biological conditions.

1.0 Introduction

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (US EPA) 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 Biological Stream Survey Dataset (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 Evitts Creek watershed, and presents the results and conclusions of a BSID analysis of the watershed.

2.0 Evitts Creek Watershed Characterization

2.1 Location

The Evitts Creek watershed is located in the North Branch Potomac River Sub-basin of the Chesapeake Bay watershed. The watershed area covers 19,600 acres in Allegany County, Maryland and 39,800 acres in Bedford County, Pennsylvania. The watershed drains from Bedford County, Pennsylvania in a southwesterly direction into Allegany County, Maryland, and flows into the North Branch Potomac River just southeast of the City of Cumberland (Figure 1). Due to the steep terrain, geologic structure, and rock units, sub-watersheds have headwaters on steep slopes (ACPD 2007). 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) (Figure 2).

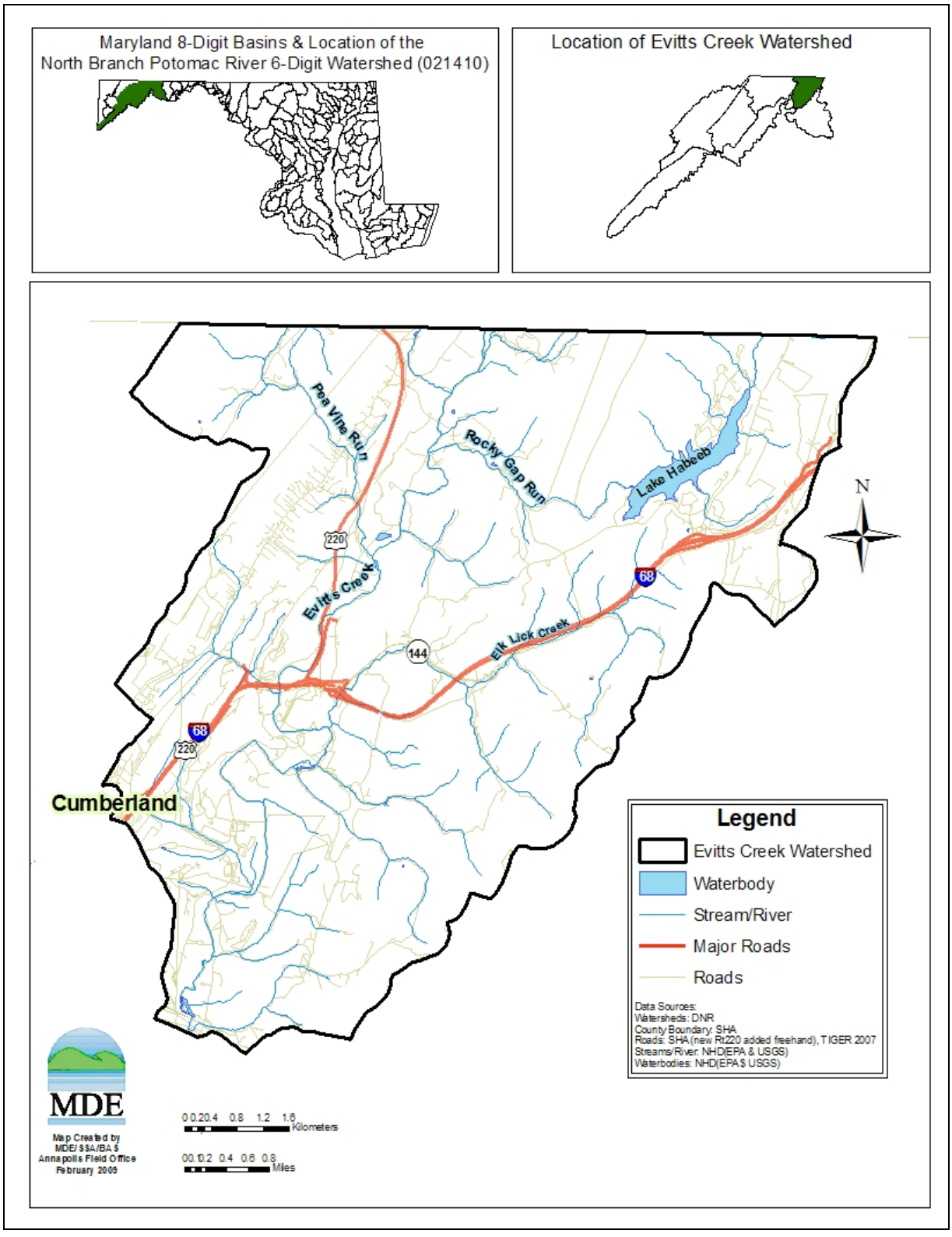

Figure 1. Location Map of the Evitts Creek Watershed

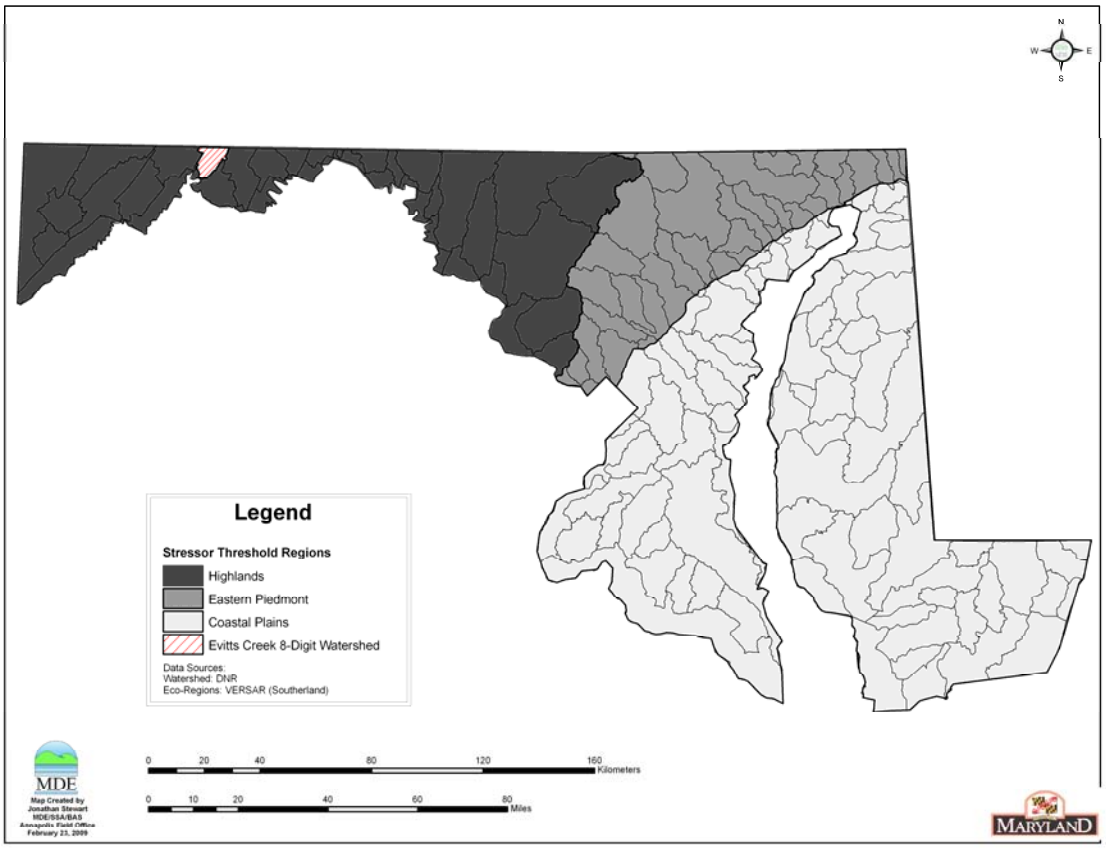

Figure 2. Eco-Region Location Map for the Evitts Creek Watershed

2.2 Land Use

Development in the Evitts Creek watershed is largely concentrated around stream channels due to steep slopes that rise abruptly from the edge of valley bottoms. The valley of the mainstem of Evitts Creek is much wider than the valleys occupied by its tributaries and thus contains the largest amount of development and population. The land use distribution in the Maryland portion of the Evitts Creek watershed is predominantly forested (68%) (13,328 acres) with approximately 18% (3,528 acres) urban and 14% (2,744 acres) agricultural land use/land cover (see Figure 3 and Figure 4) (MDP 2002).

Highland areas of the watershed are relatively pristine as they contain most of the basin's forested land area and are the least populous. Steep slopes of mountains to the north (e.g., Wills Mountain, Shriver Ridge, Evitts Mountain) and east (e.g., Martin Mountain, Irons Mountain) limit the extent of urban development primarily to the southwest quarter of the Evitts Creek watershed. The Evitts Creek watershed is also a major travel corridor because it contains the intersection of Interstate 68 and US Route 220, with the surrounding area containing high proportions of urban land use. The large urban area around Lake Habeeb in the northeast portion of the watershed includes the Rocky Gap State Park/Lodge and its amenities such as a golf course, parking lots, and campground.

Sewer service areas best illustrate areas of high population. A single NPDES wastewater outfall occurs on Rocky Gap Run, just downstream of Lake Habeeb, and there are several combined sewer and sanitary sewer overflows that occur around the periphery of the sewer service area (Figure 5) (MDE 2007).

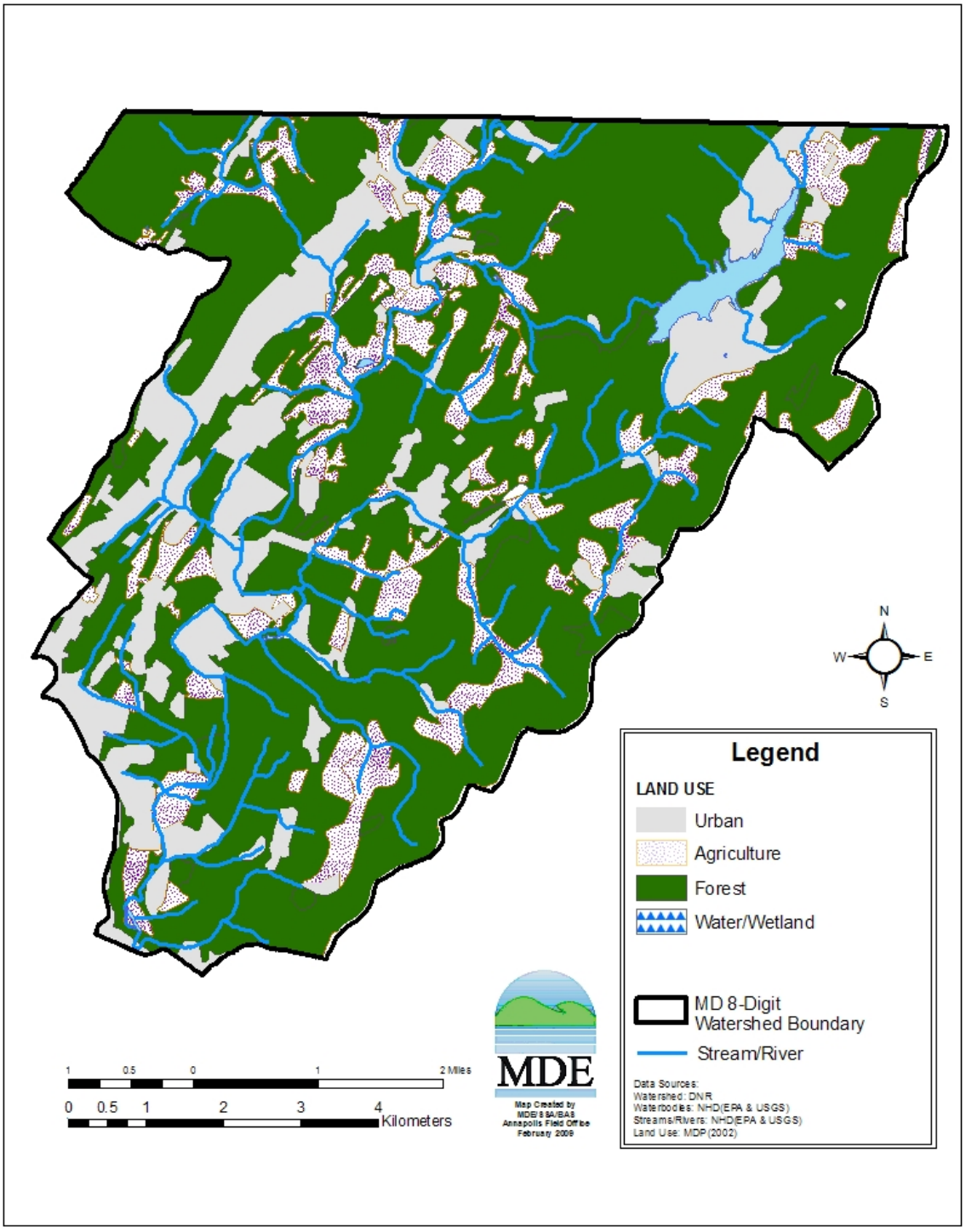

Figure 3. Land Use Map of the Evitts Creek Watershed

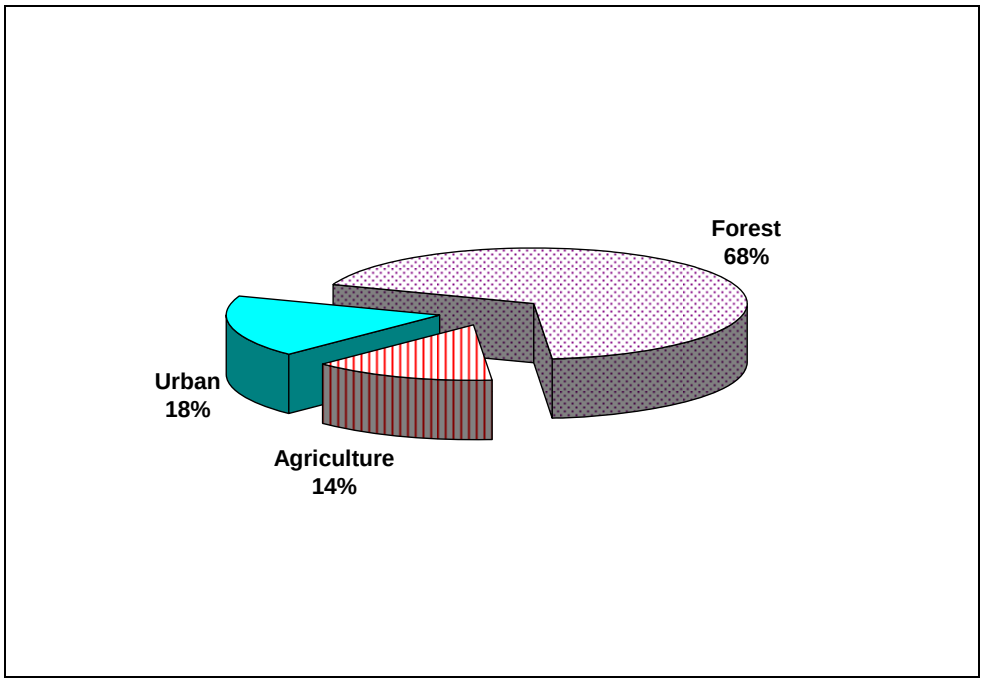

Figure 4. Proportions of Land Use in the Evitts Creek Watershed

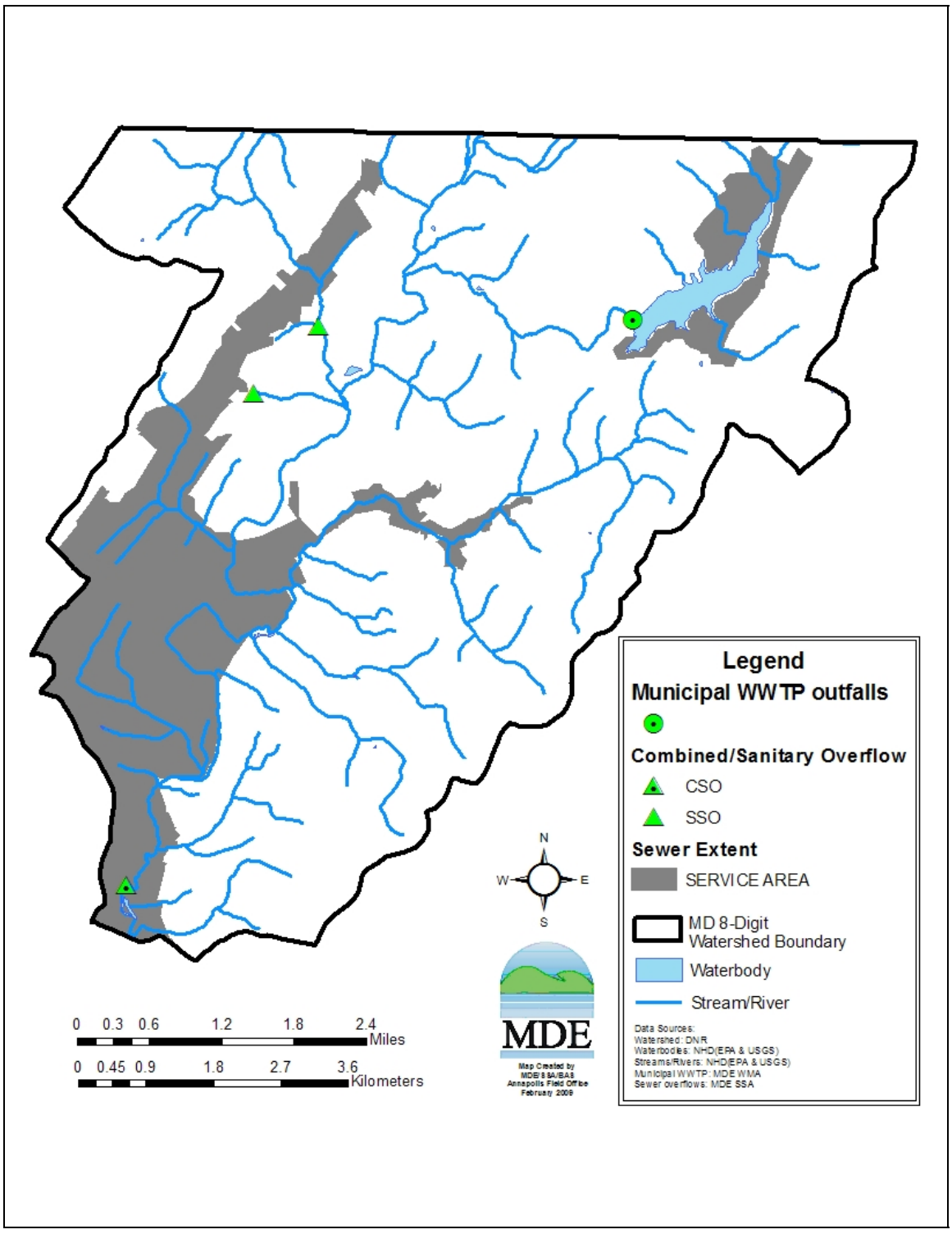
Legend
Municipal WWTP outfalls
Combined/Sanitary Overflow
CSO
SSO
Sewer Extent
SERVICE AREA
MD 8-Digit Watershed Boundary
Waterbody
Stream/River
Data Sources:
Watershed: DNR
Waterbodies: NHD(EPA & USGS)
Streams/Rivers: NHD(EPA & USGS)
Municipal WWTP: MDE WMA
Sewer overflows: MDE SSA
N
W
E
S
MDE
Map Created by MDE/ SA/BAS Annapolis Field Office February 2009
0 0.3 0.6 1.2 1.8 2.4 Miles
0 0.45 0.9 1.8 2.7 3.6 Kilometers

Figure 5. Sewer Service Area and Sewer Overflow Locations for the Evitts Creek Watershed

2.3 Soils/hydrology

The Evitts Creek watershed is situated within the Appalachian Plateau and the Ridge and Valley Provinces in western Maryland. The surficial geology of the western portion of the Ridge and Valley Provinces is characterized by strongly folded and faulted sedimentary rock, producing a rugged surface terrain. 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 rock at the surface (MGS 2009). Coal-bearing strata are preserved in the intervening synclinal basins of these folds. Consequently, this region in western Allegany County has been a productive source for coal mining.

The soils in the watershed are in the Elliber-Dekalb-Opequon Association. The Elliber soils are on both the top and sides of the ridges and are deep over cherty limestone. They also contain large quantities of chert fragments. The Dekalb soils are moderately deep over sandstone and are mostly very stony. The Opequon soils are generally on the sides of the limestone ridges (USDA 1977).

Evitts Creek drains the Cumberland Valley, which ascends slowly as it extends northeast from the Potomac River at an elevation of 600 feet (and the City of Cumberland) through Allegany County, Maryland and into Bedford County, Pennsylvania (~780 feet at state line). The stream network in the Evitts Creek watershed has a trellis pattern. Small tributaries typically cascade nearly strait down the steeply sloped mountains within and surrounding the basin to join larger streams perpendicularly. The trellis pattern is only interrupted by the meandering of Evitts Creek as its valley widens in the southern portion of the watershed, and by a handful of significant tributaries that carve between mountains, including Rocky Gap Run, Pea Vine Run, and Elk Lick Creek.

Evitts Creek has a pool/riffle hydrology structured by cobble bars. The Evitts Creek stream channel meanders increasingly as it flows southward over a substrate of cobble and sand. Cascades and plunge pools where the substrate includes boulders, cobbles, and sand typically dominate tributary hydrology. Several impoundments are located throughout the Evitts Creek watershed. Lake Koon and Lake Gordon result from impoundments three miles upstream of the Pennsylvania boundary. Lake Gordon is a public drinking water source for the City of Cumberland. Lake Habeeb results from an impoundment on Rocky Gap Run. The lake is the recreational centerpiece of Rocky Gap State Park and provides a drinking water source for the park and resort. A three foot impoundment created using boulders and tarpaulins also exists just south of the Maryland/Pennsylvania boundary.

3.0 Evitts Creek Water Quality Characterization

3.1 Integrated Report Impairment Listings

Evitts Creek (basin code 02141002), located in Allegany County, was identified on the State's Integrated Report as impaired by low pH (1996 listing, Rocky Gap Run – 2006 listing), nutrients (1996 listing, Lake Habeeb -1998 listing), sediments (1996 listing), and impacts to biological communities (2006 listing) (MDE 2008). The 1996 nutrients listing was refined in the 2008 Integrated Report and phosphorus was identified as the specific impairing substance. A WQA for low pH was completed in 2005 to address the 1996 listing. A TMDL for nutrients to address the 1998 Lake Habeeb listing was completed in 1999, and the 1996 sediment listing, which was refined in the 2008 Integrated Report to a listing for total suspended solids, was addressed via a TMDL completed in 2006. The remainder of this report will address the biological listing, and the 8-digit watershed listing for nutrients and the 2006 Rocky Gap Run pH listing will be addressed separately at a future date.

3.2 Biological impairment

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for Evitts Creek is Use IV-P - *Recreational Trout Waters and Public Water Supply* for the mainstem only and Use III-P – *Nontidal Coldwater and Public Water Supply* for its tributaries (COMAR 2009a,b,c). A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. Designated uses include support of aquatic life; primary or secondary contact recreation, drinking water supply, and shellfish propagation and harvest. 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 Evitts Creek watershed is listed under Category 5 of the 2008 Integrated Report as impaired for impacts to biological communities. Approximately 50% of stream miles in the Evitts Creek basin are estimated as having fish and and/or benthic indices of biological impairment in the very poor to poor category. The biological impairment listing is based on the combined results of Maryland Department of Natural Resources (MD DNR) MBSS round one (1995-1997) and round two (2000-2004) data, which include fourteen stations. Seven of the fourteen have benthic and/or fish index of biotic integrity (BIBI/FIBI) scores significantly lower than 3.0 (i.e., poor to very poor). The principal dataset (i.e., MBSS Round 2) contains eleven MBSS sites, with seven stations having BIBI and/or FIBI scores lower than 3.0. Figure 6 illustrates principal dataset site locations for the Evitts Creek watershed.

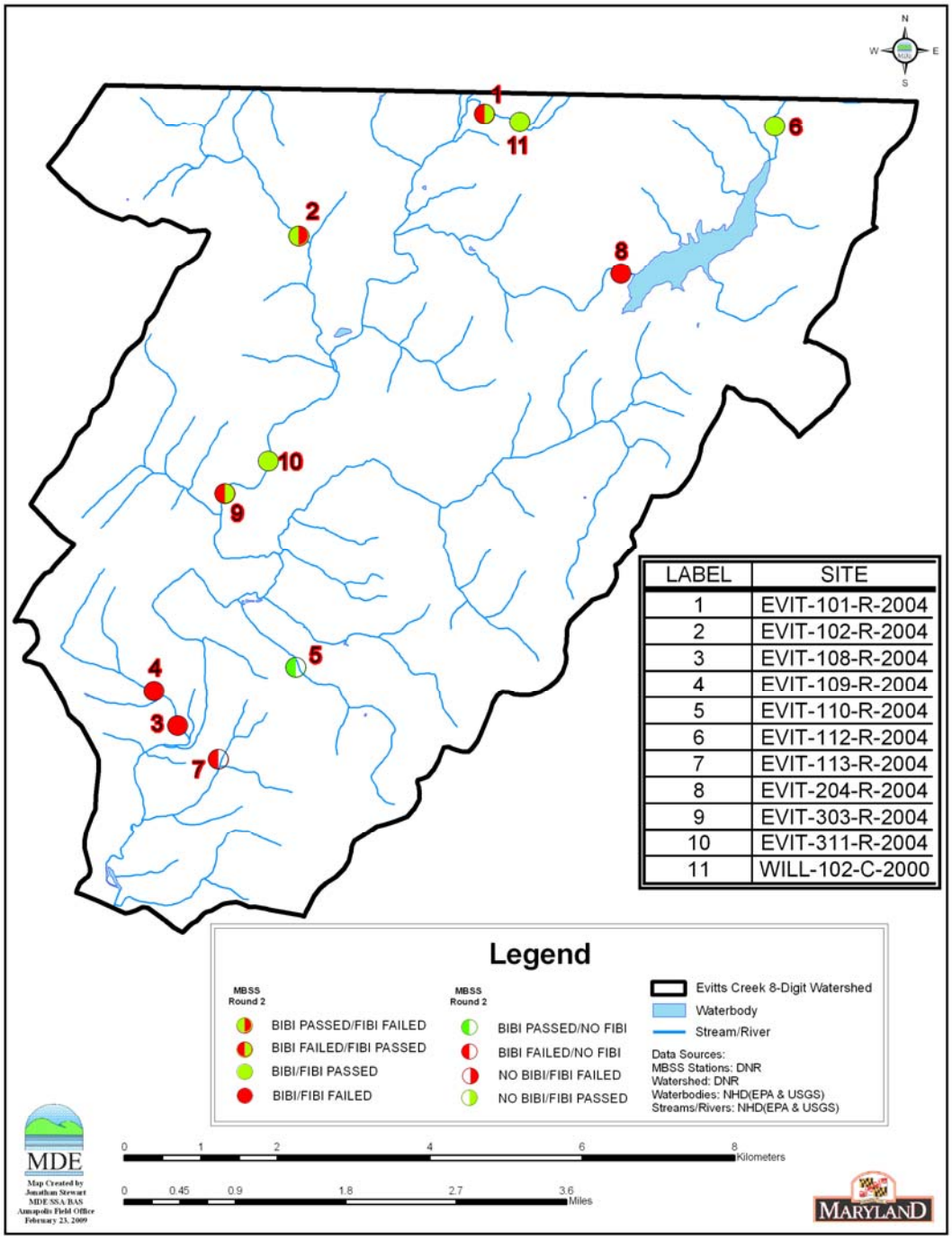

Figure 6. Principal Dataset Sites for the Evitts Creek Watershed

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 significantly lower than 3.0 (i.e., poor to very poor). The controls are sites with similar physiographic characteristics (Highland, Eastern Piedmont, and Coastal region), and stream order for habitat parameters (two groups – 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-Haenzel (MH) (1959) approach and is based on the exact method due to the small sample size for cases. A common odds ratio significantly greater than one indicates that there is a statistically significant higher likelihood that the stressor is present when there are very poor to poor biological conditions (cases) than when there are fair to good biological conditions (controls). This result suggests a statistically significant positive association between the stressor and very poor to poor biological conditions and is used to identify potential stressors.

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

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

After determining the AR for each stressor and the AR for groups of stressors, the AR for all potential stressors is calculated. This value represents the proportion of cases, sites in

the watershed with poor to very poor biological conditions, which would be improved if the potential stressors were eliminated (Van Sickle and Paulsen 2008). The purpose of this metric is to determine if stressors have been identified for an acceptable proportion of cases (MDE 2009).

Through the BSID analysis, MDE identified sediment, riparian habitat, water chemistry parameters, and potential sources significantly associated with poor to very poor fish and/or benthic biological conditions. As shown in Table 1 through Table 3, parameters from the sediment, riparian habitat, and water chemistry groups are identified as possible biological stressors in Evitts Creek. Parameters identified as representing possible sources are listed in Table 4 and include various urban land use types. Table 5 shows the summary of combined AR values for the stressor groups in the Evitts Creek watershed. Table 6 shows the summary of combined AR values for the source groups in the Evitts Creek watershed.

Table 1. Sediment Biological Stressor Identification Analysis Results for the Evitts Creek Watershed

Parameter Group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites per strata with fair to good Fish and Benthic IBI)	% of case sites with stressor present	% of control sites per strata with stressor present	Possible stressor (Odds of stressor in cases significantly higher than odds of stressor in controls using p<0.1)	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Stressor
Sediment	extensive bar formation present	11	7	78	14%	9%	No	----
	moderate bar formation present	11	7	78	29%	43%	No	----
	bar formation present	11	7	78	100%	88%	No	----
	channel alteration marginal to poor	11	7	78	29%	41%	No	----
	channel alteration poor	11	7	78	14%	9%	No	----
	high embeddedness	11	7	78	0%	4%	No	----
	epifaunal substrate marginal to poor	11	7	78	57%	21%	Yes	37%
	epifaunal substrate poor	11	7	78	0%	4%	No	----
	moderate to severe erosion present	11	7	78	29%	25%	No	----
	severe erosion present	11	7	78	0%	1%	No	----
	poor bank stability index	11	7	78	0%	4%	No	----
	silt clay present	11	7	78	100%	99%	No	----

Table 2. Habitat Biological Stressor Identification Analysis Results for the Evitts Creek Watershed

Parameter Group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites per strata with fair to good Fish and Benthic IBI)	% of case sites with stressor present	% of control sites per strata with stressor present	Possible stressor (Odds of stressor in cases significantly higher than odds of stressor in controls using p<0.1)	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Stressor
In-Stream Habitat	channelization present	11	7	82	29%	10%	No	----
	instream habitat structure marginal to poor	11	7	78	43%	25%	No	----
	instream habitat structure poor	11	7	78	0%	3%	No	----
	pool/glide/eddy quality marginal to poor	11	7	78	43%	53%	No	----
	pool/glide/eddy quality poor	11	7	78	14%	8%	No	----
	riffle/run quality marginal to poor	11	7	78	57%	38%	No	----
	riffle/run quality poor	11	7	78	14%	8%	No	----
	velocity/depth diversity marginal to poor	11	7	78	57%	58%	No	----
	velocity/depth diversity poor	11	7	78	0%	10%	No	----
	concrete/gabion present	11	7	82	0%	3%	No	----
	beaver pond present	11	7	78	0%	2%	No	----
Riparian Habitat	no riparian buffer	11	7	82	57%	24%	Yes	33%
	low shading	11	7	78	0%	8%	No	----

Table 3. Water Chemistry Biological Stressor Identification Analysis Results for the Evitts Creek Watershed

Parameter Group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites per strata with fair to good Fish and Benthic IBI)	% of case sites with stressor present	% of control sites per strata with stressor present	Possible stressor (Odds of stressor in cases significantly higher than odds of stressor in controls using p<0.1)	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Stressor
Water Chemistry	high total nitrogen	11	7	146	0%	8%	No	----
	high total dissolved nitrogen	0	0	0	0%	0%	No	----
	ammonia acute with salmonid present	11	7	159	0%	2%	No	----
	ammonia acute with salmonid absent	11	7	159	0%	1%	No	----
	ammonia chronic with salmonid present	11	7	159	0%	4%	No	----
	ammonia chronic with salmonid absent	11	7	159	0%	2%	No	----
	low lab pH	11	7	159	0%	5%	No	----
	high lab pH	11	7	159	0%	1%	No	----
	low field pH	11	7	154	14%	14%	No	----
	high field pH	11	7	154	0%	0%	No	----
	high total phosphorus	11	7	146	0%	3%	No	----
	high orthophosphate	11	7	159	0%	4%	No	----
	dissolved oxygen < 5mg/l	11	7	154	0%	3%	No	----
	dissolved oxygen < 6mg/l	11	7	154	14%	7%	No	----
	low dissolved oxygen saturation	10	6	138	0%	4%	No	----
	high dissolved oxygen saturation	10	6	138	0%	1%	No	----
	acid neutralizing capacity below chronic level	11	7	159	0%	6%	No	----
	acid neutralizing capacity below episodic level	11	7	159	0%	43%	No	----
	high chlorides	11	7	159	29%	7%	Yes	22%
	high conductivity	11	7	159	29%	4%	Yes	25%
	high sulfates	11	7	159	29%	4%	Yes	25%

Table 4. Stressor Source Identification Analysis Results for the Evitts Creek Watershed

Parameter Group	Source	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites per strata with fair to good Fish and Benthic IBI)	% of case sites with source present	% of control sites per strata with source present	Possible stressor (Odds of stressor in cases significantly higher than odds of sources in controls using p<0.1)	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Source
Sources Urban	high impervious surface in watershed	11	7	156	29%	1%	Yes	28%
	high % of high intensity urban in watershed	11	7	159	29%	4%	Yes	25%
	high % of low intensity urban in watershed	11	7	159	29%	8%	No	----
	high % of transportation in watershed	11	7	159	29%	9%	No	----
	high % of high intensity urban in 60m buffer	11	7	159	29%	6%	Yes	23%
	high % of low intensity urban in 60m buffer	11	7	159	29%	7%	Yes	22%
	high % of transportation in 60m buffer	11	7	159	29%	9%	No	----
Sources Agriculture	high % of agriculture in watershed	11	7	159	0%	6%	No	----
	high % of cropland in watershed	11	7	159	0%	6%	No	----
	high % of pasture/hay in watershed	11	7	159	0%	8%	No	----
	high % of agriculture in 60m buffer	11	7	159	0%	6%	No	----
	high % of cropland in 60m buffer	11	7	159	14%	4%	No	----
	high % of pasture/hay in 60m buffer	11	7	159	0%	8%	No	----
Sources Barren	high % of barren land in watershed	11	7	159	0%	7%	No	----
	high % of barren land in 60m buffer	11	7	159	0%	6%	No	----

Table 4. Stressor Source Identification Analysis Results for the Evitts Creek Watershed (Cont.)

Parameter Group	Source	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites per strata with fair to good Fish and Benthic IBI)	% of case sites with source present	% of control sites per strata with source present	Possible stressor (Odds of stressor in cases significantly higher than odds of sources in controls using p<0.1)	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Source
Sources Anthropogenic	low % of forest in watershed	11	7	159	29%	5%	Yes	24%
	low % of forest in 60m buffer	11	7	159	29%	6%	Yes	23%
Sources Acidity	atmospheric deposition present	11	7	159	0%	39%	No	----
	AMD acid source present	11	7	159	0%	4%	No	----
	organic acid source present	11	7	159	0%	3%	No	----
	agricultural acid source present	11	7	159	0%	1%	No	----

Table 5. Summary of Combined Attributable Risk Values for the Stressor Groups in the Evitts Creek Watershed

Stressor Group	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Parameter Group(s) (Attributable Risk)	
Sediment	37%	84%
In-Stream Habitat	----	
Riparian Habitat	33%	
Water Chemistry	25%	

Table 6. Summary of Combined Attributable Risk Values for the Source Groups in the Evitts Creek Watershed

Source Group	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Parameter Group(s) (Attributable Risk)	
Urban	28%	28%
Agriculture	----	
Barren Land	----	
Anthropogenic	24%	
Acidity	----	

Sediment Conditions

BSID analysis results for the Evitts Creek watershed identified one sediment parameter that has a statistically significant association with poor to very poor stream biological condition: *epifaunal substrate* (*marginal to poor*).

Epifaunal substrate (marginal to poor) was identified as significantly associated with degraded biological conditions and found to impact 37% of the stream miles with very poor to poor biological conditions in the Evitts Creek watershed. Epifaunal substrate is a visual observation of the abundance, variety, and stability of substrates that offer the potential for full colonization by benthic macroinvertebrates. The varied habitat types such as cobble, woody debris, aquatic vegetation, undercut banks, and other commonly productive surfaces provide valuable habitat for benthic macroinvertebrates. Conditions indicating biological degradation are indicative of marginal to poor substrate, where stable substrate is lacking, or particles are over 75% surrounded by fine sediment and/or flocculent material, and where large boulders and/or bedrock are prevalent and cobble, woody debris, or other preferred surfaces are uncommon. Epifaunal substrate is confounded by natural variability (i.e., streams will naturally have more or less available productive substrate). Greater availability of productive substrate increases the potential for full colonization; conversely, less availability of productive substrate decreases or inhibits colonization by benthic macroinvertebrates.

Development in the Evitts Creek watershed is concentrated along streams due to the steep nature of the drainage basin. Anthropogenic causal sources (i.e., urbanization of landscapes), as indicated in the BSID results, can alter the hydrologic regime of a stream by increasing surface flow and flashiness. Marginal to poor epifaunal substrate levels

could be the combined result of the broad influence of urbanization along with "localized" flow modification affected by dams (Lake Koon/Gordon and Lake Habeeb) that could decrease stream habitat diversity by attenuating storm flows. An altered flow regime and increased sediment results in an unstable stream ecosystem, characterized by a continuous displacement of biological communities that require frequent re-colonization, particularly in streams with little or no riparian buffers where refuge areas such as organic detritus and large woody debris are lacking (Winterbourne and Townsend 1991). 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 with poor to very poor biological conditions. The combined AR for the stressor group indicates that approximately 37% of the biologically degraded stream miles in the Evitts Creek watershed are impacted by sediment stressors (Table 5).

In-stream Habitat Conditions

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

Riparian Habitat Conditions

BSID analysis results for the Evitts Creek watershed identified one riparian habitat parameter that has a statistically significant association with poor to very poor stream biological condition: *no riparian buffer.*

No riparian buffer was identified as significantly associated with degraded biological conditions and found to impact 33% of the stream miles with poor to very poor biological conditions in the Evitts Creek 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 et al. 2004). Natural forested headwater streams generally rely on allochthonous input of leaf litter as the major energy source, but urban developed landscapes typically reduce the amount of trees in the riparian area that would contribute detritus. Decreased riparian buffer also leads to reduced amounts of large wood in the stream. Stable wood substrate in streams performs multiple functions, influencing channel features, flow, habitat, and providing cover for fish.

Development in the Evitts Creek watershed is concentrated along streams due to the steep nature of the drainage area. Absence of adequate riparian buffer zones reported in 33%

of degraded sites in the Evitts Creek watershed is potentially the result of high and low intensity urban land use in the 60 meter buffer zone.

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 stressor group indicates that approximately 33% of the biologically degraded stream miles in the Evitts Creek watershed are impacted by riparian habitat stressors (Table 5).

Water Chemistry

BSID analysis results for the Evitts Creek watershed identified three water chemistry parameters that have a statistically significant association with a very poor to poor stream biological condition (i.e., removal of stressors would result in improved biological community). These parameters are *high conductivity*, *high chlorides*, and *high sulfates*.

High conductivity levels were identified as significantly associated with degraded biological conditions and found to impact 25% of the stream miles with poor to very poor biological conditions in the Evitts Creek watershed. Conductivity is a measure of water's ability to conduct electrical current and is directly related to the total dissolved salt content of the water. 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 2009). Conductivity, chlorides and sulfates are closely related. Streams with elevated levels of chlorides and sulfates typically display high conductivity.

High chloride levels were identified as significantly associated with degraded biological conditions and found to impact 22% of the stream miles with poor to very poor biological conditions in the Evitts Creek watershed. Chlorides occur naturally in our environment and are important to human health for both metabolic and nervous function. However, high concentrations of chlorides can result from municipal or industrial discharges, metals contamination, and application of road salts in urban landscapes (Kaushal et al. 2005). There are no major National Pollutant Discharge Elimination System (NPDES) permitted municipal or industrial discharges in the watershed; however, there is one minor municipal facility. Because NPDES permitting enforcement does not require chloride testing at any of these facilities, data was not available to verify/identify this point sources as a source of chlorides in this watershed. There was one MBSS site downstream from this municipal wastewater facility, which did not have an elevated chloride level. Since there is no significant metals impairment in the watershed, as determined by the 2005 WQA for low pH, application of road salts in the watershed is a likely source of the chlorides and high conductivity levels. Smith et al. (1997) reported that most of the chloride that enters the environment is associated with the storage and application of road salt. An accumulation of road salt chlorides can prove toxic to certain fish and benthic organisms (Bubeck et al. 1971; Hawkins and Judd 1972). Acidity may increase chloride by accelerating dissolution of halides. Approximately 55% of road-salt chlorides are transported in surface runoff, with the remaining 45% infiltrating through soils and into groundwater aquifers (Church and Friesz 1993).

High sulfate concentrations were identified as significantly associated with degraded biological conditions and found to impact 25% of the stream miles with poor to very poor biological conditions in the Evitts Creek watershed. Sulfate loads to surface waters can be naturally occurring or originate from urban runoff, agricultural runoff, acid mine drainage (AMD), atmospheric deposition, and wastewater dischargers. Sulfate in urban areas can be derived from combustion of fossil fuels such as coal, oil, and diesel. There is only one NPDES permitted municipal discharge in Evitts Creek. Since NPDES permitting enforcement does not require sulfate testing at this facility, data was not available to verify/identify this point source as a source of sulfate in this watershed. There was one MBSS site downstream from the municipal wastewater facility, which has failing BIBI and FIBI scores but did not have an elevated sulfate level.

In summary, water chemistry can be another major determinant of the integrity of surface waters that is strongly influenced by land-use. Land development in the riparian zones of the Evitts Creek watershed has lead to increases in contaminant loads from point and nonpoint sources by adding sediments, nutrients, road salts, toxics, petroleum products, and inorganic pollutants to surface waters. Increased levels of many pollutants like chlorides and sulfates can be toxic to aquatic organisms and lead to exceedences in species tolerances.

Currently in Maryland there are no specific numeric criteria that quantify the impact of conductivity, chlorides, and sulfates 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) from the array of potential inorganic pollutants inferred from the BSID analysis, and further information is required.

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 stressor group indicates that approximately 25% of the biologically degraded stream miles in the Evitts Creek watershed are impacted by water chemistry stressors (Table 5).

Sources

All five stressor parameters, identified in Tables 1-3, that are significantly associated with biological degradation are representative of impacts from urban/developed landscapes. The scientific community (Booth 1991; Konrad and Booth 2002; Meyer et al. 2005) has consistently identified negative impacts to biological conditions as a result of increased urbanization. A number of systematic and predictable environmental responses have been noted in streams affected by urbanization, and this consistent sequence of effects has been termed “urban stream syndrome” (Meyer et al. 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.

Alteration of stream hydrology that often accompanies urbanization forces 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 has also likely caused an increase in contaminant loads from point and nonpoint sources to surface waters. In virtually all studies, as the amount of urbanized landscapes 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).

The BSID source analysis (Table 4) identifies various types of urban land uses and anthropogenic land uses resultant from urban development as potential sources of stressors that may cause negative biological impacts. The combined AR for the source groups indicates that approximately 28% of the biologically degraded stream miles in the Evitts Creek watershed are impacted by the entirety of stressor sources (Table 6).

Summary

The BSID analysis results suggest that degraded biological communities in the Evitts Creek watershed are a result of increased urban land use, especially in the riparian areas, which is causing an alteration to hydrology and leading to loss of optimal habitat. Although large portions of the Evitts Creek watershed are forested and undeveloped, development is concentrated in stream valleys and often extends close to stream margins. Thus, surface runoff is increased, but perhaps without the damaging forces that may accompany larger percentages of urban land use (e.g. bank erosion and bar formation), which were not observed in this dataset. Only epifaunal substrate measurements reveal the potential excessive transport of sediment through the system and associated reduction of available habitat. Decreased groundwater flow associated with development could increase low flow intensity and frequency, particularly in low order streams and possibly result in intermittent stream flows. The absence of riparian buffers may additionally reduce available habitat because woody debris would be less available to diversify flow patterns and provide shelter.

Within a stream ecosystem there are many biological variables, which are not represented in the MBSS dataset. It is possible that trout stocking programs could influence fish and benthic macroinvertebrate communities in Evitts Creek, particularly given the reduced available habitat for organisms to use for shelter. Evitts Creek is scheduled to receive 7,225 Rainbow Trout and Brown Trout in 2009 to support a put and take fishery (MD DNR 2009). Stocked trout diets can include terrestrial organisms as well as stream fishes like Stonerollers (*Campostoma*) and Sculpin (*Cottus*) and invertebrates like Ephemeroptera, Diptera, Tricoptera, Isopoda, Amphipoda, and Plecoptera (Damer and Bettoli 2008). Brown Trout and Rainbow Trout are top predators that could modify community structure by feeding on macroinvertebrates and fishes, particularly where habitat is limited.

In summary, the altered hydrology has caused frequent high flow events and increased sediment loads, resulting in an unstable stream ecosystem that eliminates optimal habitat. Urban development in the riparian buffer zones often results in degradation to stream water quality and habitat. Due to the increased proportion of urban land use, the Evitts Creek watershed has experienced an increase in contaminant loads from point and nonpoint sources, resulting in levels of inorganic pollutants that can potentially be toxic to aquatic organisms. Stressors and sources identified by BSID for degraded biological conditions in Evitts Creek align with the urban stream syndrome scenario. Relatively little improvement in biological condition is expected to be associated with the removal of individual stressors (AR ranging from 22% to 37%) or even groups of stressors (sediment 37%, riparian habitat 33%, and water chemistry 25%). However, the combined AR for all stressors is 84%, suggesting that altered hydrology/sediment, riparian habitat, and water chemistry stressors adequately account for the biological impairment in Evitts Creek (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 complex causal scenarios (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 Evitts Creek

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; US EPA 2009). 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 7 illustrates the final causal model for the Evitts Creek, with pathways bolded or highlighted to show the watershed's probable stressors as indicated by the BSID analysis.

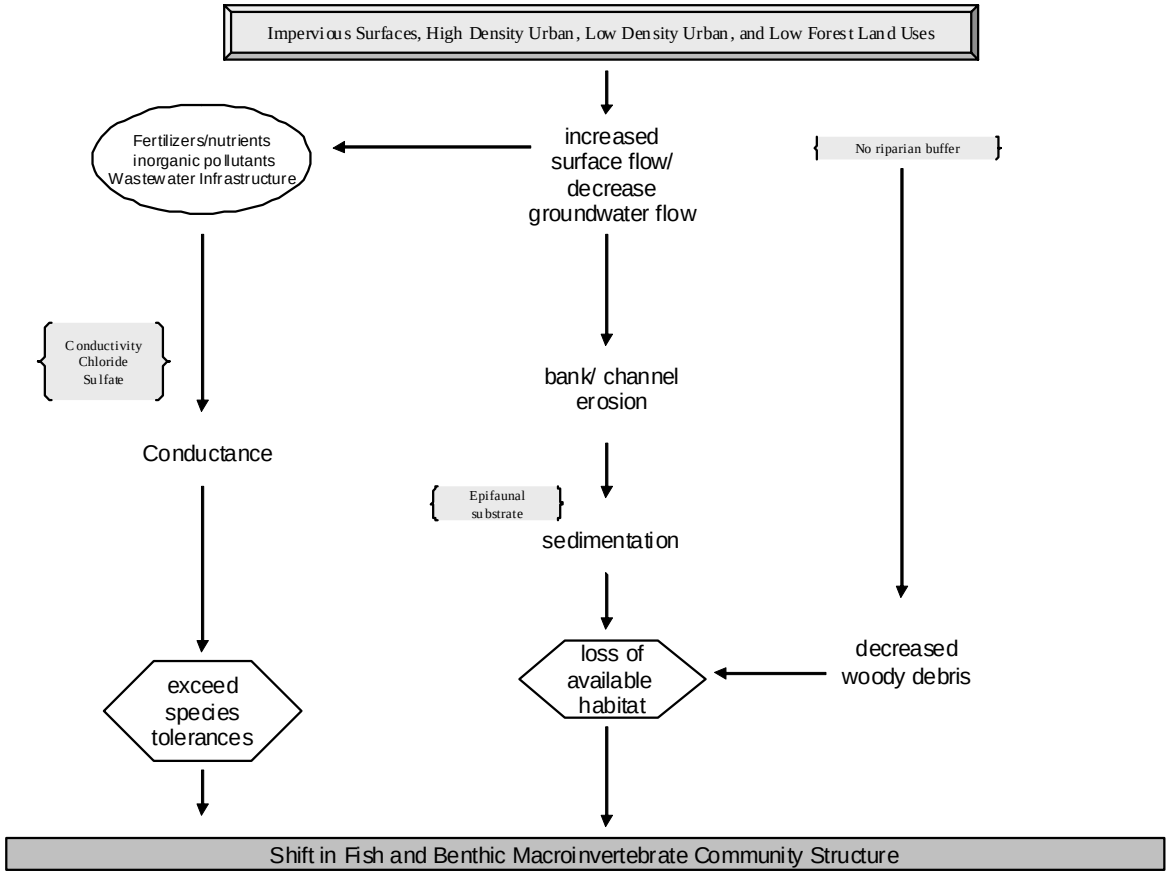

Figure 7. Final Causal Model for the Evitts Creek Watershed

5.0 Conclusions

Data suggest that the most probable cause of biological impairment in the Evitts Creek watershed is the combined effect of urbanization on habitat and water chemistry. 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 Evitts Creek are summarized as follows:

- The BSID process has determined that biological communities in Evitts Creek are likely degraded due to flow/sediment related stressors. Sediment stressors are significantly associated with degraded biological conditions and are found to be impacting approximately 37% of the stream miles with very poor to poor biological conditions in the Evitts Creek watershed. Specifically, altered

hydrology and increased runoff from urban impervious surfaces have resulted in marginal to poor substrate condition, likely caused by elevated suspended sediment transport in the watershed, which are in turn the probable causes of impacts to biological communities. The BSID results thus confirm the Integrated Report Category 4a listing for total suspended solids as an impairing substance in Evitts Creek, for which a TMDL has been developed, and links this pollutant to biological conditions in these waters.

- The BSID process has determined that the biological communities in Evitts Creek are also likely degraded due to inorganic pollutants (sulfates, chlorides, and conductivity). Inorganic pollutants levels are significantly associated with degraded biological conditions and are found to be impacting approximately 25% of the stream miles with very poor to poor biological conditions in the Evitts Creek watershed. Impacts on water quality due to sulfates, chlorides, and conductivity are dependent on prolonged exposure; future monitoring of these inorganic pollutants will help in determining the spatial and temporal extent of this impairment in the watershed. Urban runoff causes an increase in contaminant loads from point and nonpoint sources by delivering an array of inorganic pollutants to surface waters. Currently, there is a lack of monitoring data for many of these substances; therefore, additional monitoring of priority inorganic pollutants is needed to more precisely determine the specific cause(s) of impairment.

- The BSID process has also determined that biological communities in the Evitts Creek 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 is a result of pollution. MDE recommends a Category 4c listing for the Evitts Creek watershed based on inadequate riparian buffer zones in approximately 33% of degraded stream miles.

- Although there is presently a Category 5 listing for phosphorus in Maryland's 2008 Integrated Report, the BSID analysis did not identify any nutrient stressors (i.e., total nitrogen, total phosphorus, and dissolved oxygen, etc.) present and/or nutrient stressors showing a significant association with degraded biological conditions.

References

ACPD (Allegany County Planning Division). 2007. *Allegany County Water and Sewer Plan*. Cumberland, MD: Allegany County Planning Division. Also Available at http://gov.allconet.org/plan/docs/water_sewer/WaterSewer2007_080608.pdf.

Booth, D. 1991. Urbanization and the natural drainage system – impacts, solutions and prognoses. *Northwest Environmental Journal* 7: 93-118.

Bubeck, R. C., W. H. Diment, B. L. Deck, A. L. Baldwin, and S. D. Lipton. 1971. Runoff of deicing salt: Effect on Irondequoit Bay, Rochester, New York. *Science* 172: 1128-1132.

Church, P., and P. Friesz. 1993. *Effectiveness of Highway Drainage Systems in preventing Road-Salt Contamination of Groundwater: Preliminary Findings*. Transportation Research Board. Transportation Research Record 1420.

COMAR (Code of Maryland Regulations). 2009a. *26.08.02.02.* http://www.dsd.state.md.us/comar/26/26.08.02.02.htm (Accessed February, 2009).

_____. 2009b. *26.08.02.08 R(6)(b).* http://www.dsd.state.md.us/comar/26/26.08.02.08.htm (Accessed February, 2009).

_____. 2009c. *26.08.02.08 R(4).* http://www.dsd.state.md.us/comar/26/26.08.02.08.htm (Accessed February, 2009).

Damer, J., and P. W. Bettoli. 2008. *The Fate of Brook Trout Stocked in the Watauga River Below Wilbur Dam*. Nashville, TN: Tennessee Cooperative Fishery Research Unit, Tennessee Wildlife Resources Agency.

MD DNR (Maryland Department of Natural Resources). 2009. *Spring 2009 Trout Stocking Schedule*. http://www.dnr.state.md.us/fisheries/stocking/springstocktable.html#Allegany (Accessed March 2009).

Hawkins, R. H., and J. H. Judd. 1972. Water pollution as affected by street salting. *Water Resource Bulletin* 8: 1246-1252.

Hill, A. B. 1965. The Environment and Disease: Association or Causation?. *Proceedings of the Royal Society of Medicine* 58: 295-300.

IDNR (Iowa Department of Natural Resources). 2009. *Iowa's Water Quality Standard Review –Total Dissolved Solids (TDS).* http://www.iowadnr.gov/water/standards/files/tdsissue.pdf (Accessed March, 2009)

Karr, J. R. 1991. Biological integrity - A long-neglected aspect of water resource management. *Ecological Applications* 1: 66-84.

Kaushal, S. S., P. M. Groffman, G. E. Likens, K. T. Belt, W. P. Stack, V. R. Kelly, L. E. Band, and G. T. Fisher. 2005. Increased Salinization of Fresh Water in the Northeastern United States of America. *Proceedings of the National Academy of Sciences of the United States of America* 102: 13517–13520.

Konrad, C. P., and D. B. Booth. 2002. Hydrologic trends associated with urban development for selected streams in the Puget Sound Basin. *Western Washington. Water-Resources Investigations Report* 02-4040. Denver, CO: US Geological Survey.

Lee, P., C. Smyth, and S. Bout in. 2004. Quantities review of riparian buffer guidelines from Canada and the United States. *Journal of Environmental Management*. 70: 165-180.

Mantel, N., and W. Hansel. 1959. Statistical aspects of the analysis of data from retrospective studies of disease. *Journal of the National Cancer Institute* 22: 719-748.

Meyer, J. L., M. J. Paul, and W. K. Taube. 2005. Stream ecosystem function in urbanizing landscapes. *Journal of the North American Ethological Society* 24: 602–612.

MDE (Maryland Department of the Environment). 2007. Total Maximum Daily Load of Sediment in the Evitts Creek Watershed, Allegany County, Maryland. Baltimore, MD: Maryland Department of the Environment. Also Available at http://www.mde.state.md.us/assets/document/Evitts_Creek_TMDL_20060928_final.pdf.

_____. 2008. *2008 Integrated Report of Surface Water Quality in Maryland*. Baltimore, MD: Maryland Department of the Environment. Also Available at http://www.mde.state.md.us/Programs/WaterPrograms/TMDL/Maryland%20303%20dlist/2008_303d_pubnotice.asp.

_____. 2009. *Maryland Biological Stressor Identification Process*. Baltimore, MD: Maryland Department of the Environment.

MDP (Maryland Department of Planning). 2002. *2002 Land Use/Land Cover*. Baltimore, MD: Maryland Department of Planning.

MGS (Maryland Geological Survey). 2009. *A Brief Description of the Geology of Maryland*. http://www.mgs.md.gov/esic/brochures/mdgeology.html (Accessed March, 2009).

Smith, R. A., R. B. Alexander, and M. G. Wolman. 1987. Water Quality Trends in the Nation's Rivers. *Science* 235: 1607-1615.

Southerland, M. T., G. M. Rogers, R. J. Kline, R. P. Morgan, D. M. Board, P. F. Kayak, R. J. Claude, and S. A. Stank. 2005. *New biological indicators to better assess the condition of Maryland Streams.* Columbia, MD: Versa, Inc. with Maryland Department of Natural Resources, Monitoring and Non-Tidal Assessment Division. Also Available at http://www.dnr.state.md.us/streams/pubs/ea-05-13_new_ibi.pdf.

USDA (United States Department of Agriculture). 1977. *Soil Survey of Allegany County, Maryland*. Washington, D.C: United States Department of Agriculture, Natural Resources Conservation Service.

US EPA (U.S. Environmental Protection Agency). 2009. *The Causal Analysis/Diagnosis Decision Information System*. hhtp://www.epa.gov/caddis (Accessed March 2009).

Van Sickle, J., and S. G. Paulsen. 2008. Assessing the attributable risks, relative risks, and regional extents of aquatic stressors. *Journal of the North American Benthological Society* 27 (4): 920-931.

Walsh, C. J., A. H. Roy, J. W. Feminella, P. D. Cottingham, P. M. Groffman, and R. P. Morgan. 2005. The urban stream syndrome: current knowledge and the search for a cure. *Journal of the North American Benthological Society* 24 (3):706–723.

Winterbourn, M., and C. Townsend C. 1991. Streams and rivers: One- way flow systems. In *Fundamentals of Aquatic Ecology*, edited by R. Barnes and K. Mann. Oxford, United Kingdom: Blackwell Scientific Publications.