Watershed Report for Biological Impairment of the Little Tonoloway Creek Watershed in Washington County, MD Biological Stressor Identification Analysis Results and Interpretation

FINAL

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

Submitted to:

Water Protection Division
U.S. Environmental Protection Agency, Region III
1650 Arch Street
Philadelphia, PA 19103-2029

January 2014

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List of Abbreviations

ANC	Acid neutralizing capacity
AR	Attributable Risk
BIBI	Benthic Index of Biotic Integrity
BSID	Biological Stressor Identification
COMAR	Code of Maryland Regulations
CWA	Clean Water Act
DO	Dissolved Oxygen
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
MH	Mantel-Haenzel
mg/L	Milligrams per liter
NOx	Nitrous Oxides
SO_2	Sulfur Dioxide
SSA	Science Services Administration
TMDL	Total Maximum Daily Load
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.

Little Tonoloway Creek Watershed (watershed code 02140509), located along the western margin of Washington County, was identified on the 2002 Integrated Report under Category 5 as impaired for impacts to biological communities. There are no additional impairments listed in the 8-digit watershed.

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, TMDLs are developed, and implementation is targeted. The listing methodology assesses the condition of Maryland 8-digit watersheds by measuring the percentage of stream miles that have poor to very poor biological conditions, and calculating whether this is significant from a reference condition watershed (i.e., healthy stream, <10% stream miles with poor to very poor biological condition).

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for Little Tonoloway Creek and its tributaries are designated as Use I-P - *water contact recreation, and protection of nontidal warmwater aquatic life/ public water supply.* In addition, COMAR requires all waterbodies to support at a minimum the Use I designation - *water contact recreation, protection of nontidal warmwater aquatic life* (COMAR 2010 a, b). Little Tonoloway Creek watershed is not attaining its Use I and I-P designation because of biological impairments. As an indicator of designated use attainment, MDE uses Benthic and Fish Indices of Biotic Integrity (BIBI/FIBI) developed by the Maryland Department of Natural Resources Maryland Biological Stream Survey (MDDNR MBSS).

The current listing for biological impairments represents 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 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 Little Tonoloway Creek 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 Little Tonoloway Creek watershed is associated with urban land use, impervious surface and their concomitant effects including elevated levels of chlorides, accelerated erosion, and minimal buffering capacity. The development of landscapes creates broad and interrelated forms of degradation that can affect stream ecology and biological composition. Peer-reviewed scientific literature establishes a link between urban landscapes and degradation in the aquatic health of non-tidal stream ecosystems.

The results of the BSID analysis, and the probable causes and sources of the biological community impairment in the Little Tonoloway Creek watershed can be summarized as follows:

- The BSID process has determined that numerous sediment and instream habitat stressors affect biological communities in the Little Tonoloway Creek watershed. Although these stressors are divided into two groups in this analysis, they demonstrate the common effects of accelerated surface water delivery to receiving streams. Impervious surfaces associated with roads and residential development increase the volume, velocity, and power of surface water flow, thus accelerating the erosion of soils from land surfaces, and the erosion of soils from stream banks (i.e., along stream channels), as well as the continued erosion/deposition of sediments within stream channels. The BSID results thus support a Category 5 listing of total suspended solids on the Integrated Report as an appropriate management action to begin addressing the impact of these stressors on the biological communities in the Little Tonoloway Creek watershed.

- The BSID process has also determined that the biological communities in the Little Tonoloway Creek watershed are likely degraded due to inorganic water chemical pollutants, including chloride and conductivity. Conductivity is a general stressor variable that includes chloride in addition to a plethora of other chemicals. The BSID results thus support a Category 5 listing of chloride on the Integrated Report as an appropriate management action to begin addressing the impacts of this stressor on the biological communities. Discharges of inorganic compounds like chloride are 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 this parameter will help in determining the spatial and temporal extent of these impairments in the watershed.

- The BSID process has also determined that the biological communities in the Little Tonoloway Creek watershed are likely degraded due to acidity related stressors. There are likely two sources causing acidity impairments in the watershed, increased urban development and atmospheric deposition. Acidity related stressors are associated with increased "direct connect" of runoff from impervious surfaces to surface waters. Infiltration of surface runoff into underlying soils and geology can provide the neutralizing capacity need to reduce the acidity impacts of regional atmospheric deposition. Possible habitat and stormwater restoration in the urban areas of the watershed could increase infiltration of surface runoff. Little Tonoloway Creek watershed also experiences localized acidity caused by atmospheric deposition in areas where the geology has little buffering capacity. Therefore, the biological impairment listing should be amended to a Category 4b of the Integrated Report since the Clean Air Act Amendments of 1990 should be sufficient to meet the reductions. The 1990 changes to the Clean Air Act introduced a nationwide approach to reducing acid pollution. The law is designed to reduce acid rain and improve public health by dramatically reducing emissions of sulfur dioxide (SO_2) and oxides of nitrogen (NOx) by the year 2010. In 2007, the State of Maryland passed the Maryland Healthy Air Act. The first phase requires reductions of NOx emissions by almost 70%, and SO_2 emissions by 80%. In 2012/ 2013 the second phase of emission controls will reduce NOx and SO_2 by another 5%.

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 2012). In the vetting process, an established set of rules is used to guide the removal of sites that are not applicable for listing decisions (e.g., tidal or black water streams). The final principal database contains all biological sites considered valid for use in the listing process. In the watershed assessment step, a watershed is evaluated based on a comparison to a reference condition (i.e., healthy stream, <10% degraded) that accounts for spatial and temporal variability, and establishes a target value for "aquatic life support." During this step of the assessment, a watershed that differs significantly from the reference condition is listed as impaired (Category 5) on the Integrated Report. If a watershed is not determined to differ significantly from the reference condition, the assessment must have an acceptable precision (i.e., margin of error) before the watershed is listed as meeting water quality standards (Category 1 or 2). If the level of precision is not acceptable, the status of the watershed is listed as inconclusive and subsequent monitoring options are considered (Category 3). If a watershed is still considered impaired but has a TMDL that has been completed or submitted to EPA it will be listed as Category 4a. If a watershed is classified as impaired (Category 5), then a stressor identification analysis is completed to determine if a TMDL is necessary.

The MDE biological stressor identification (BSID) analysis applies a case-control, risk-based approach that uses the principal dataset, with considerations for ancillary data, to identify potential causes of the biological impairment. Identification of stressors responsible for biological impairments was limited to the round two and three Maryland Department of Natural Resources Maryland Biological Stream Survey (MDDNR MBSS) dataset (2000–2009) 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 Little Tonoloway Creek watershed, and presents the results and conclusions of a BSID analysis of the watershed.

2.0 Little Tonoloway Creek Watershed Characterization

2.1 Location

The Little Tonoloway Creek watershed is is located in the Potomac River basin within Washington County, Maryland (see Figure 1). Little Tonoloway Creek is a free-flowing stream that originates in Maryland and travels in a northeasterly direction for approximately 8 miles to end its journey at the Potomac River in Hancock, Maryland. The watershed is located in both Maryland (MD) and Pennsylvania, with a drainage area of 9,850 acres. Less than half of the total acres of the watershed are in Fulton County, Pennsylvania, which consist of Minnow Run and other small tributaries crossing the Maryland boundary and flowing into Little Tonoloway Creek. The tributaries of Little Tonoloway Creek in MD include Semple Run, Meadow Brook, Rush Run, Toms Run, and Rockdale Run. The watershed occurs in the Valley and Ridge physiographic province, which is part of the Highlands Eco-region. There are three distinct eco-regions identified in the MDDNR MBSS Index of Biological Integrity (IBI) metrics (Southerland et al. 2005) (see Figure 2).

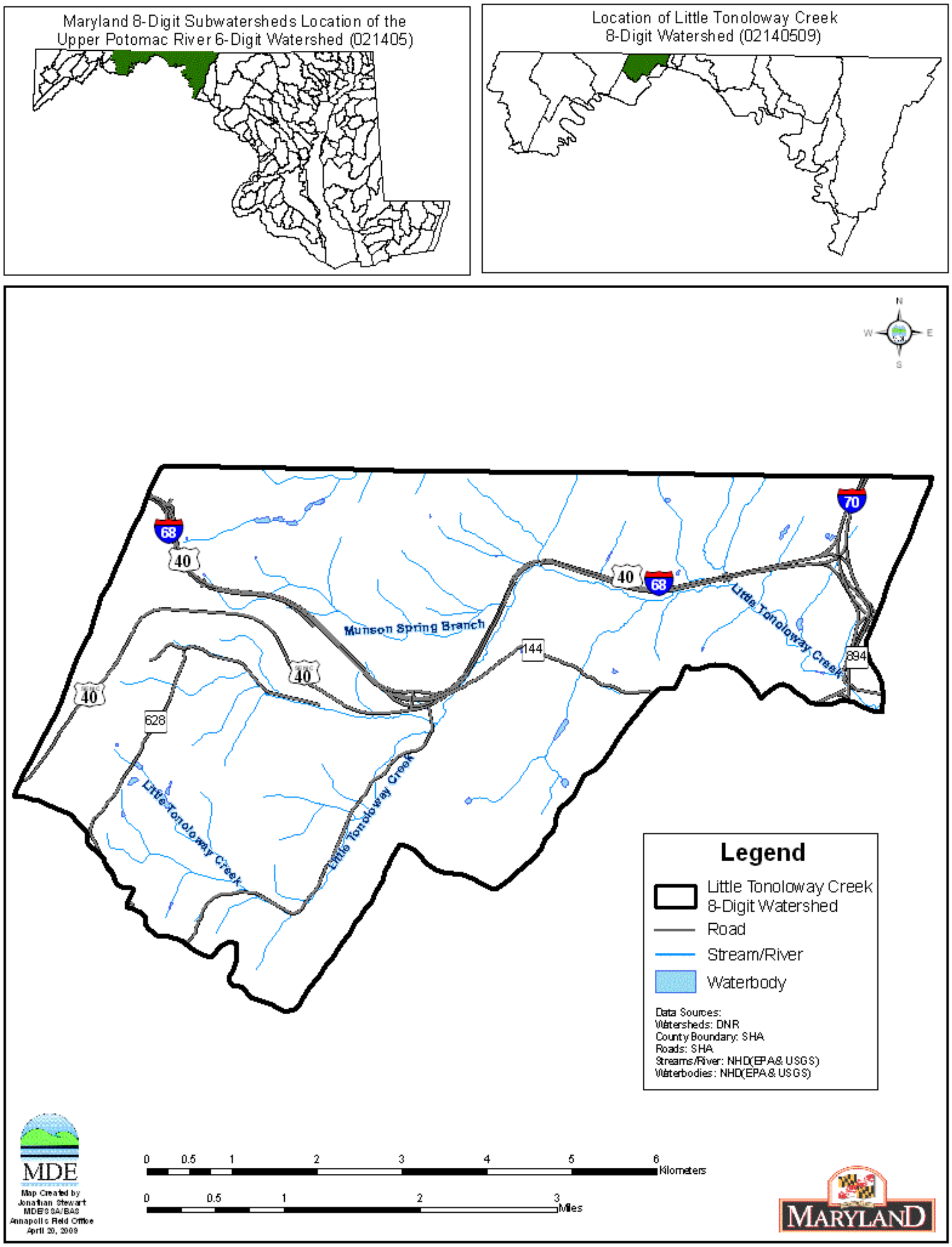


Figure 1. Location Map of the Little Tonoloway Creek Watershed

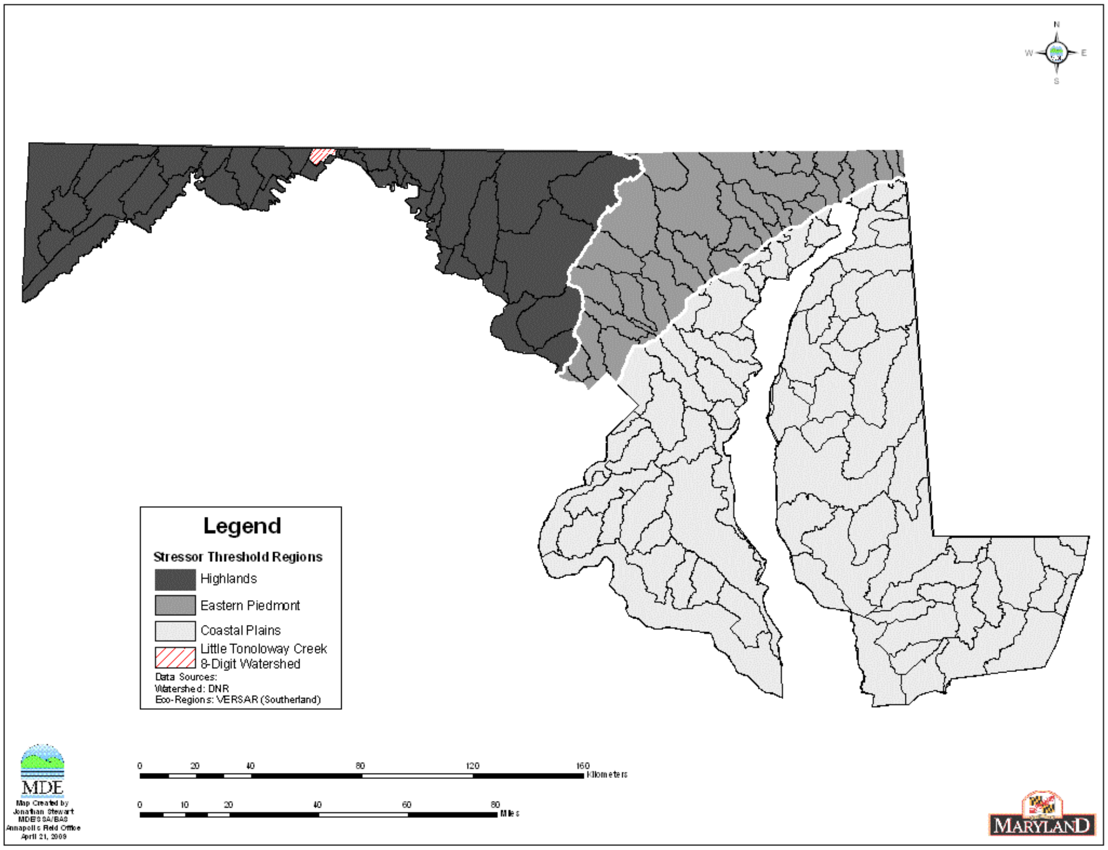


Figure 2. Eco-Region Location Map of the Little Tonoloway Creek Watershed

2.2 Land Use

The land use in the Little Tonoloway Creek watershed is predominately forest (see Figure 3). Forests in this watershed are oak dominated (formerly American Chestnut dominated). Forest types include Appalachian oak forest, oak-hickory-pine forest, and northern hardwood forest. On drier sites, oaks are mixed with pitch and Virginia pine (McNab and Avers 1994).

There are some areas of localized agriculture in the watershed, which increases slightly in the eastern portion of the watershed. Except for the town of Hancock, scattered residences represent the only urban centers in the watershed. According to the Chesapeake Bay Program's Phase 5.2 watershed model land use, Little Tonoloway Creek watershed consists of approximately 71% forested, 18% agricultural, and 11% urban land uses (USEPA 2010) (see Figure 4).

Land use proportions alone do not adequately represent the landscape in the Little Tonoloway Creek watershed. The extent and proximity of roadways to streams is a critically important element of this landscape. The watershed is transected by a number of major transportation corridors including Interstates 68 and 70, as well as State Routes

40, 40 alt., and 144. Many of these roads parallel and/or cross streams for large portions of their total length in the basin (see Figure 3 and Figure 1).

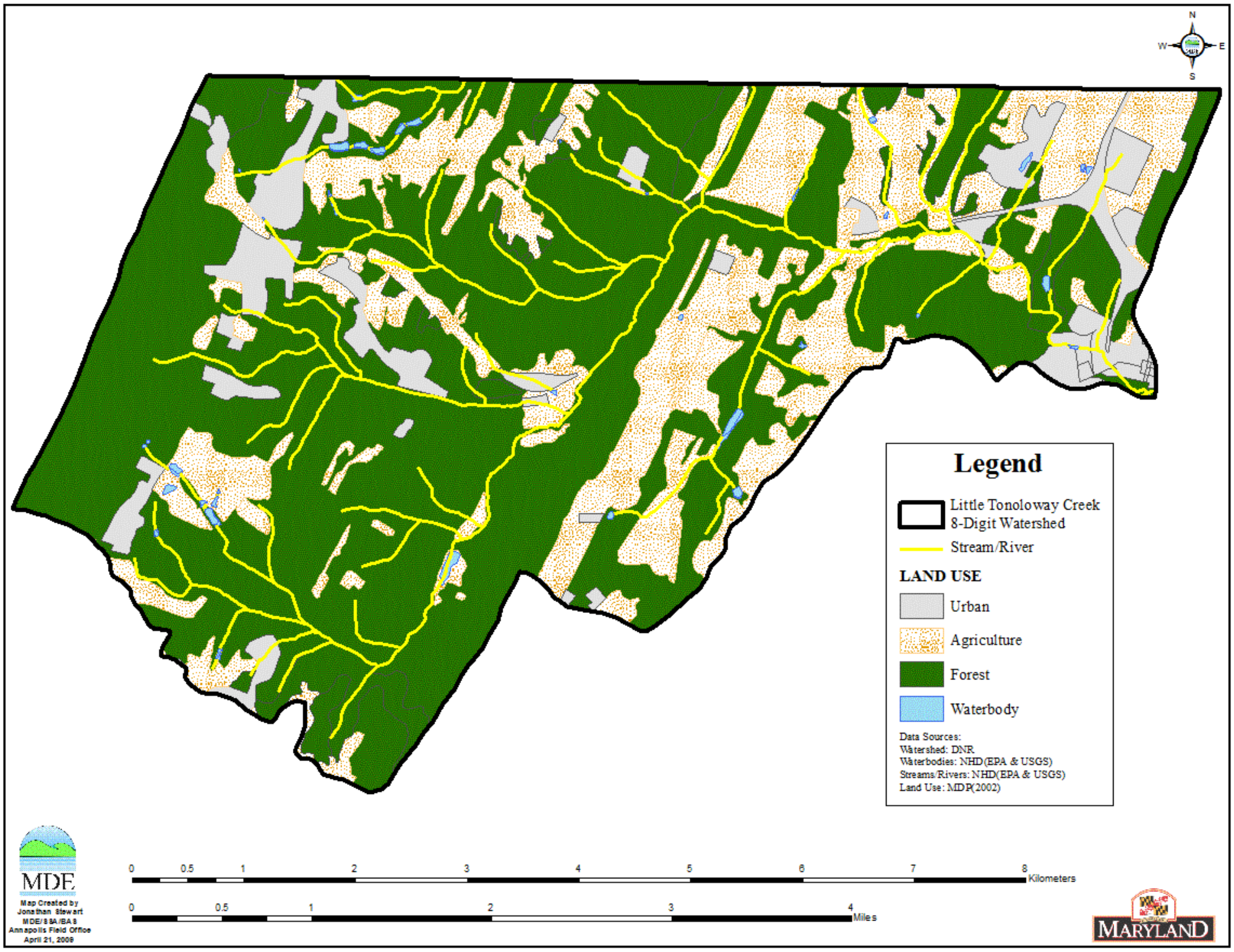


Figure 3. Land Use Map of the Little Tonoloway Creek Watershed

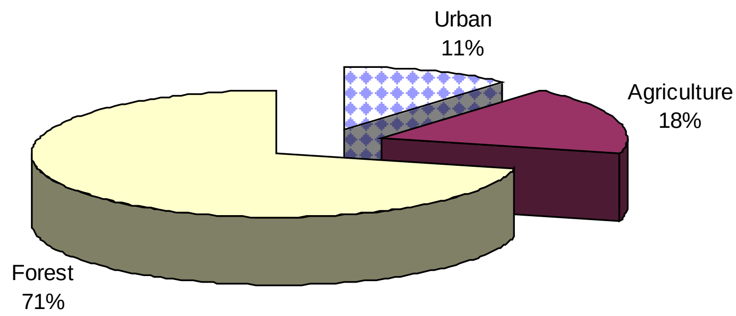


Figure 4. Proportions of Land Use in the Little Tonoloway Creek Watershed

2.3 Soils/hydrology

Little Tonoloway Creek watershed occurs in the Valley and Ridge Physiographic Province. The Valley and Ridge is characterized by numerous long and narrow ridges separated by valleys that extend from southwest to northeast. Sandstone, chert, and some of the tougher carbonates occur in most of the upland areas of this Province, while weaker carbonates and shale underlie most valleys.

Groundwater availability is typically low in the region because shale rock layers can rapidly transmit groundwater through fractures or breaks where storage can also be limited. The watershed's presence in the rain shadow from the Appalachian Plateau also diminishes water available for groundwater recharge. Negligible groundwater amounts reduce the capacity to sustain stream base flows. Many streams in the watershed have little or no flow during summer months and high flooding events in the spring due to the nature of the geology and precipitation patterns experienced by the region (McNab and Avers 1994).

Soils typically found in Little Tonoloway Creek watershed are the Ernest, Westmoreland, Ellibar, Hazelton, and Dekalb series. The Ernest and Westmoreland series are the most extensive soils in the watershed, and both consists of deep, well drained soils that are formed from shale, siltstone, sandstone, and limestone. These soils are either cultivated for crops and pasture or remain forested. The remainder soil types Elliber, Dekalb, and

Hazelton are deep, well drained soils from various types of shale, siltstone, sandstone, and limestone. Most of these soil types are associated with forested lands (NRCS 1977).

3.0 Little Tonoloway Creek Watershed Water Quality Characterization

3.1 Integrated Report Impairment Listings

Little Tonoloway Creek Watershed (watershed code 02140509), located along the western margin of Washington County, was identified on the 2002 Integrated Report under Category 5 as impaired for impacts to biological communities. There are no additional impairments listed in the 8-digit watershed.

3.2 Biological Impairment

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for Little Tonoloway Creek and its tributaries are designated as Use I-P - *water contact recreation, and protection of nontidal warmwater aquatic life/ public water supply*. In addition, COMAR requires all waterbodies to support at a minimum the Use I designation - *water contact recreation, protection of nontidal warmwater aquatic life* (COMAR 2010 a, b). A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. Designated uses include support of aquatic life; primary or secondary contact recreation, agricultural/industrial water supply, and public drinking water supply. 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.

Little Tonoloway Creek watershed is listed under Category 5 of the 2012 Integrated Report for impacts to biological communities. Approximately 58% of stream miles in Little Tonoloway Creek watershed are estimated as having benthic and/or fish 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 nine stations. Seven of the nine stations have benthic and/or fish index of biotic integrity (BIBI, FIBI) scores significantly lower than 3.0 (i.e., poor to very poor). The principal dataset, MBSS round two and round three (2000-2009) contains nine MBSS sites; with eight having BIBI and/or FIBI scores lower than 3.0. Figure 5 illustrates principal dataset site locations for Little Tonoloway Creek watershed.

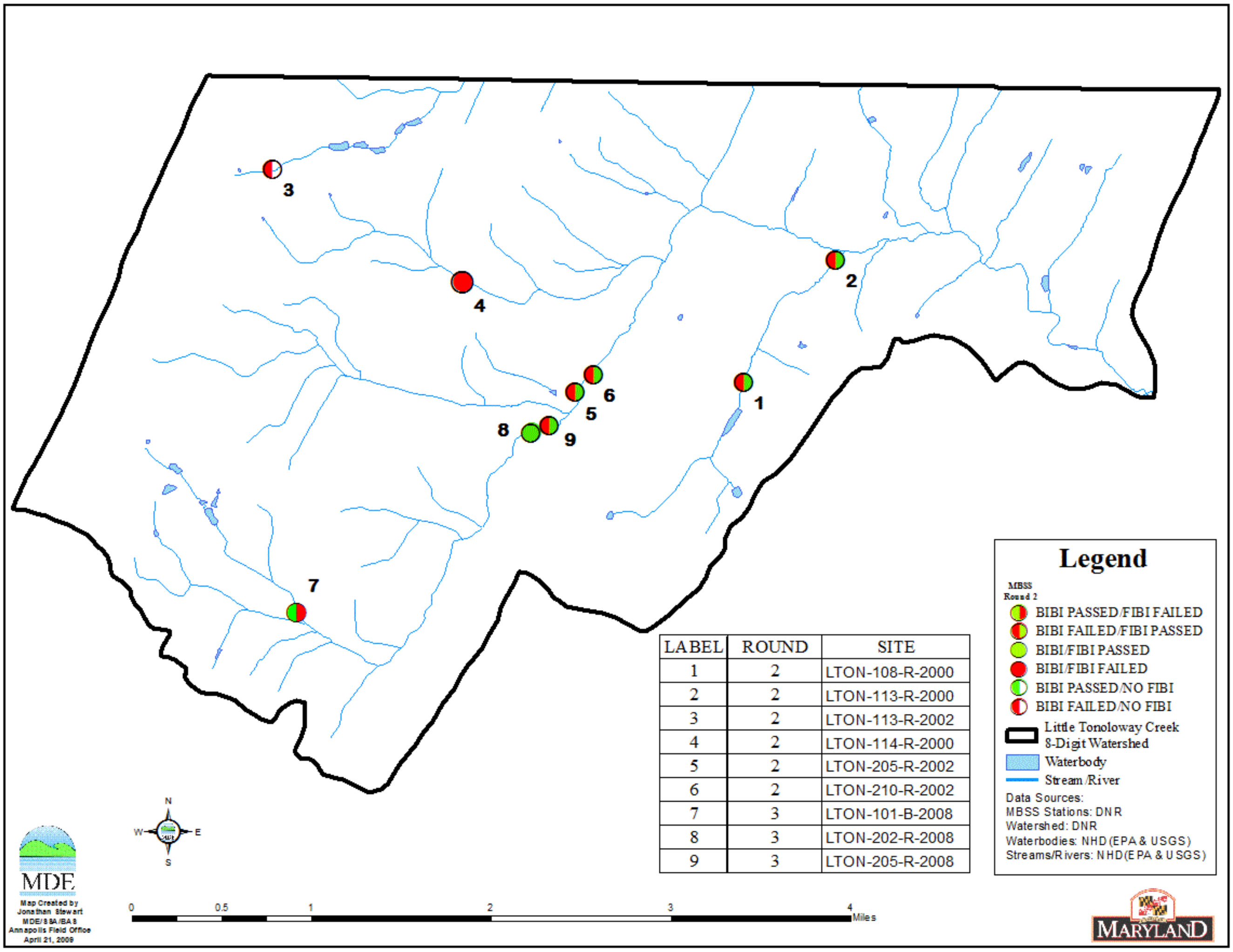


Figure 5. Principal Dataset Sites for the Little Tonoloway Creek Watershed

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 lower than 3.0 (i.e., poor to very poor). The controls are sites with similar physiographic characteristics (Highland, Eastern Piedmont, and Coastal region), and stream order for habitat parameters (two groups – 1^{st} and 2^{nd}-4^{th} order), that have fair to good biological conditions.

The common odds ratio confidence interval was calculated to determine if the odds ratio was significantly greater than one. The confidence interval was estimated using the Mantel-Haenzel (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 for each stressor, the AR for a group of stressors is also calculated from individual sites' characteristics (stressors present at that site). The only difference is that the group AR calculations combine each site's lowest relative stressor risk among the controls. The same process is run for all land use sources.

After determining the AR for each stressor/sources and the AR for groups of stressors/sources, the AR for all potential stressors/sources 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/sources were eliminated (Van Sickle and Paulsen 2008). The purpose of this metric is to determine if stressors/sources have been identified for an acceptable proportion of cases (MDE 2009).

The parameters used in the BSID analysis are segregated into five groups: land use sources, and stressors representing sediment, in-stream habitat, riparian habitat, and water chemistry conditions. Through the BSID data analysis of Little Tonoloway Creek watershed, MDE identified sources and numerous stressors as having significant association with poor to very poor fish and/or benthic biological conditions. Parameters identified as representing possible sources are listed in Table 1 and include various urban land uses. Table 2 shows the summary of combined AR values for the source groups in Little Tonoloway Creek watershed. As shown in Table 3 through Table 5, parameters from three of the four stressor groups were identified as possible biological stressors. Table 6 shows the summary of combined AR values for the stressor groups in Little Tonoloway Creek watershed.

Table 1. Stressor Source Identification Analysis Results for the Little Tonoloway 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 Benthic or Fish IBI)	Controls (average number of reference sites with fair to good Benthic or Fish IBI)	% of case sites with stressor present	% of control sites per stratum with stressor present	Statistical probability that the stressor is not impacting biology (p value)	Possible stressor (odds of stressor in cases significantly higher than odds of stressor in controls using p<0.1)	% of case sites associated with the stressor (attributable risk)
Sources - Acidity	Agricultural acid source present	9	8	168	0%	1%	1	No	_
	AMD acid source present	9	8	168	0%	5%	1	No	_
	Organic acid source present	9	8	168	0%	0%	1	No	_
Sources - Agricultural	High % of agriculture in watershed	9	8	171	0%	11%	1	No	_
	High % of agriculture in 60m buffer	9	8	171	0%	6%	1	No	_
Sources - Anthropogenic	Low % of forest in watershed	9	8	171	0%	5%	1	No	_
	Low % of wetland in watershed	9	8	171	0%	0%	1	No	_
	Low % of forest in 60m buffer	9	8	171	0%	2%	1	No	_
	Low % of wetland in 60m buffer	9	8	171	0%	0%	1	No	_
Sources - Impervious	High % of impervious surface in watershed	9	8	171	13%	5%	0.344	No	_
	High % of impervious surface in 60m buffer	9	8	171	13%	12%	1	No	_
	High % of roads in watershed	9	8	171	25%	8%	0.153	No	_
	High % of roads in 60m buffer	9	8	171	38%	8%	0.03	Yes	29%
Sources - Urban	High % of high-intensity developed in watershed	9	8	171	0%	2%	1	No	_
	High % of low-intensity developed in watershed	9	8	171	0%	3%	1	No	_
	High % of medium-intensity developed in watershed	9	8	171	0%	4%	1	No	_
	High % of residential developed in watershed	9	8	171	25%	2%	0.024	Yes	23%
	High % of rural developed in watershed	9	8	171	25%	3%	0.033	Yes	22%
	High % of high-intensity developed in 60m buffer	9	8	171	0%	1%	1	No	_

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 Benthic or Fish IBI)	Controls (average number of reference sites with fair to good Benthic or Fish IBI)	% of case sites with stressor present	% of control sites per stratum with stressor present	Statistical probability that the stressor is not impacting biology (p value)	Possible stressor (odds of stressor in cases significantly higher than odds of stressor in controls using p<0.1)	% of case sites associated with the stressor (attributable risk)
	High % of low-intensity developed in 60m buffer	9	8	171	0%	5%	1	No	_
	High % of medium-intensity developed in 60m buffer	9	8	171	0%	1%	1	No	_
	High % of residential developed in 60m buffer	9	8	171	25%	5%	0.079	Yes	20%
	High % of rural developed in 60m buffer	9	8	171	25%	7%	0.121	No	_

Table 2. Summary of Combined Attributable Risk Values of the Source Group in the Little Tonoloway Creek Watershed

Source Group	% of degraded sites associated with specific source group (attributable risk)
Sources - Impervious	29%
Sources - Urban	48%
All Sources	***71%***

4.1 Sources Identified by BSID Analysis

There were four sources identified by the BSID analysis (Table 1) including residential and rural development in the watershed and in the sixty meter riparian buffer zone. A high percentage of transportation land use was also identified in the sixty meter riparian buffer zone.

Even though the majority of the Little Tonoloway Creek watershed contains forested land use (71%), the BSID analysis indicates that the localized areas of urban development and transportation corridors are sources of biological degradation. The watershed contains localized areas of urban and impervious surfaces (transportation corridors), which alter the hydrologic cycle, leading to increased runoff and decreased infiltration. Many areas within the Little Tonoloway Creek watershed were developed before regulatory requirements were in place to treat the runoff to remove some of the pollutants or to reduce the flows and volumes running off the hard surfaces into nearby streams. The combined AR for this source group is approximately 71% suggesting these sources are probable causes of biological impairments in the Little Tonoloway Creek watershed (Table 2).

The remainder of this section will discuss stressors identified by the BSID analysis (Table 3, 4, and 5) and their link to degraded biological conditions in the watershed.

4.2 Stressors Identified by BSID Analysis

Table 3. Sediment Biological Stressor Identification Analysis Results for the Little Tonoloway 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 Benthic or Fish IBI)	Controls (average number of reference sites with fair to good Benthic or Fish IBI)	% of case sites with stressor present	% of control sites per stratum with stressor present	Statistical probability that the stressor is not impacting biology (p value)	Possible stressor (odds of stressor in cases significantly higher than odds of stressor in controls using p<0.1)	% of case sites associated with the stressor (attributable risk)
Sediment	Extensive bar formation present	9	8	82	0%	7%	1	No	_
	Moderate bar formation present	9	8	84	50%	38%	0.711	No	_
	Channel alteration moderate to poor	6	6	69	83%	38%	0.04	Yes	44%
	Channel alteration poor	6	6	69	0%	6%	1	No	_
	High embeddedness	9	8	82	25%	3%	0.033	Yes	22%
	Epifaunal substrate marginal to poor	9	8	82	38%	17%	0.156	No	_
	Epifaunal substrate poor	9	8	82	25%	2%	0.015	Yes	23%
	Moderate to severe erosion present	9	8	82	25%	26%	1	No	_
	Severe erosion present	9	8	82	13%	2%	0.203	No	_

Table 4. Habitat Biological Stressor Identification Analysis Results for the Little Tonoloway 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 Benthic or Fish IBI)	Controls (average number of reference sites with fair to good Benthic or Fish IBI)	% of case sites with stressor present	% of control sites per stratum with stressor present	Statistical probability that the stressor is not impacting biology (p value)	Possible stressor (odds of stressor in cases significantly higher than odds of stressor in controls using p<0.1)	% of case sites associated with the stressor (attributable risk)
Instream Habitat	Channelization present	9	8	86	13%	10%	0.566	No	_
	Concrete/gabion present	9	8	75	13%	2%	0.206	No	_
	Beaver pond present	9	8	82	13%	1%	0.123	No	_
	Instream habitat structure marginal to poor	9	8	82	25%	20%	0.655	No	_
	Instream habitat structure poor	9	8	82	0%	0%	1	No	_
	Pool/glide/eddy quality marginal to poor	9	8	82	63%	47%	0.445	No	_
	Pool/glide/eddy quality poor	9	8	82	25%	5%	0.076	Yes	20%
	Riffle/run quality marginal to poor	9	8	82	88%	30%	0.001	Yes	57%
	Riffle/run quality poor	9	8	82	0%	5%	1	No	_
	Velocity/depth diversity marginal to poor	9	8	82	63%	54%	0.701	No	_
	Velocity/depth diversity poor	9	8	82	13%	6%	0.395	No	_
Riparian Habitat	No riparian buffer	6	6	71	33%	21%	0.601	No	_
	Low shading	9	8	82	0%	4%	1	No	_

Table 5. Water Chemistry Biological Stressor Identification Analysis Results for the Little Tonoloway 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 Benthic or Fish IBI)	Controls (average number of reference sites with fair to good Benthic or Fish IBI)	% of case sites with stressor present	% of control sites per stratum with stressor present	Statistical probability that the stressor is not impacting biology (p value)	Possible stressor (odds of stressor in cases significantly higher than odds of stressor in controls using p<0.1)	% of case sites associated with the stressor (attributable risk)
Chemistry - Inorganic	High chlorides	9	8	171	50%	6%	0.002	Yes	44%
	High conductivity	9	8	171	75%	8%	0	Yes	67%
	High sulfates	9	8	171	25%	8%	0.137	No	_
Chemistry - Nutrients	Dissolved oxygen < 5mg/l	9	8	165	0%	2%	1	No	_
	Dissolved oxygen < 6mg/l	9	8	165	0%	5%	1	No	_
	Low dissolved oxygen saturation	9	8	165	0%	7%	1	No	_
	High dissolved oxygen saturation	9	8	165	0%	4%	1	No	_
	Ammonia acute with salmonid present	9	8	171	0%	0%	1	No	_
	Ammonia acute with salmonid absent	9	8	171	0%	0%	1	No	_
	Ammonia chronic with early life stages present	9	8	171	0%	0%	1	No	_
	Ammonia chronic with early life stages absent	9	8	171	0%	0%	1	No	_
	High nitrites	9	8	171	0%	6%	1	No	_
	High nitrates	9	8	171	0%	6%	1	No	_
	High total nitrogen	9	8	171	0%	6%	1	No	_
	High total phosphorus	9	8	171	0%	8%	1	No	_
	High orthophosphate	9	8	171	0%	8%	1	No	_
Chemistry - pH	Acid neutralizing capacity below chronic level	9	8	171	25%	5%	0.079	Yes	20%
	Low field pH	9	8	165	13%	11%	1	No	_
	High field pH	9	8	165	0%	1%	1	No	_
	Low lab pH	9	8	171	25%	5%	0.079	Yes	20%
	High lab pH	9	8	171	0%	2%	1	No	_

Table 6. Summary of Combined Attributable Risk Values of the Stressor Group in the Little Tonoloway Creek Watershed

Stressor Group	% of degraded sites associated with specific stressor group (attributable risk)
Sediment	57%
Instream Habitat	70%
Chemistry - Inorganic	68%
Chemistry - pH	20%
All Chemistry	69%
All Stressors	***94%***

<u>Sediment and Habitat Conditions</u>

BSID analysis results for the Little Tonoloway Creek identified three sediment parameters that have statistically significant association with poor to very poor stream biological condition: *channel alteration (moderate to poor)*, *high embeddedness,* and *epifaunal substrate (poor)* (Table 3).

Channel alteration (*moderate to poor* rating) was identified as significantly associated with degraded biological conditions in the Little Tonoloway Creek watershed, and found to impact approximately 44% of the stream miles with poor to very poor biological conditions. *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 from excess sediment loads. Marginal to poor and poor ratings are expected in unstable stream channels that experience frequent high flows.

High embeddedness was identified as significantly associated with degraded biological conditions in the Little Tonoloway Creek watershed, and found to impact approximately 22% of the stream miles with poor to very poor biological conditions. Embeddedness is determined by the percentage of fine sediment surrounding gravel, cobble, and boulder particles in the streambed. Embeddedness is categorized as a percentage from 0% to 100% with low values as optimal and high values as poor. High embeddedness is a result of excessive sediment deposition. High embeddedness suggests that sediment may interfere with feeding or reproductive processes and result in biological impairment. Although embeddedness is confounded by natural variability (e.g., Coastal Plain streams will naturally have more embeddedness than Highlands streams), embeddedness values higher than reference streams are indicative of anthropogenic sediment inputs from overland flow or stream channel erosion.

Epifaunal Substrate (poor) was identified as significantly associated with degraded biological conditions in the Little Tonoloway Creek watershed, and found to impact approximately 23% of the stream miles with poor to very poor biological conditions. Epifaunal substrate is a visual observation of the abundance, variety, and stability of substrates that offer the potential for full colonization by benthic macroinvertebrates. The varied habitat types such as cobble, woody debris, aquatic vegetation, undercut banks, and other commonly productive surfaces provide valuable habitat for benthic macroinvertebrates. Like embeddedness and in-stream habitat, epifaunal substrate is confounded by natural variability (i.e., streams will naturally have more or less available productive substrate). Greater availability of productive substrate increases the potential for full colonization; conversely, less availability of productive substrate decreases or inhibits colonization by benthic macroinvertebrates. Epifaunal substrate conditions are described categorically as optimal, sub-optimal, marginal, or poor. Conditions indicating biological degradation are set at two levels: 1) poor, where stable substrate is lacking, or particles are over 75% surrounded by fine sediment and/or flocculent material; and 2) marginal to poor, where large boulders and/or bedrock are prevalent and cobble, woody debris, or other preferred surfaces are uncommon.

The Little Tonoloway Creek watershed has a low proportion of urban land use (11%); however, most of the development is concentrated around the town of Hancock. As development and urbanization increased in Hancock, so did the morphological changes that affect a stream's habitat. The most critical of these environmental changes are those that alter the watershed's hydrologic regime. Increases in impervious surface cover that accompany urbanization alter stream hydrology, forcing runoff to occur more readily and quickly during rainfall events, thus decreasing the amount of time it takes water to reach streams, causing urban streams to be more "flashy" (Walsh et al. 2005). When stormwater flows through stream channels faster, more often, and with more force, the results are stream channel alteration and streambed scouring. The scouring associated with these increased flows leads to accelerated channel erosion, thereby increasing sediment deposition throughout the streambed either through the formation of bars or settling of sediment in the stream substrate. Some of the impacts associated with sedimentation are smoothing of benthic communities, reduced survival rate of fish eggs, and reduced habitat quality from embedding of the stream bottom (Hoffman, Rattner, and Burton 2003). All of these processes result in an unstable stream ecosystem that impacts habitat and the dynamics (structure and abundance) of stream benthic organisms (Allan 2004). An unstable stream ecosystem often results in a loss of available habitat and continuous displacement of biological communities from scouring that requires frequent re-colonization and the loss of sensitive taxa, with a shift in biological communities to more tolerant species. All of the stressors identified for the sedimentation parameter groups (e.g., channel alteration, high embeddedness, and poor epifauanal substrate) are the typical effects of the scouring associated with a "flashy" hydrological regime.

The combined AR is used to measure the extent of stressor impact of degraded stream miles with poor to very poor biological conditions. The combined AR for the sediment stressor group is approximately 57% suggesting these stressors are probable causes of biological impairments in Little Tonoloway Creek watershed (Table 6).

In-stream Habitat Conditions

BSID analysis results for Little Tonoloway Creek watershed identified two habitat parameters that have a statistically significant association with poor to very poor stream biological condition: *pool/glide/eddy quality (poor),* and *riffle/run quality (marginal to poor)* (Table 4).

Pool/glide/eddy quality (poor) was identified as significantly associated with degraded biological conditions in the Little Tonoloway Creek watershed, and found to impact approximately 20% of the stream miles with poor to very poor biological conditions. Pool/glide/eddy quality is a visual observation and quantitative measurement of the variety and spatial complexity of slow or still water habitat and cover within a stream segment referred to as pool/glide/eddy. Stream morphology complexity directly increases the diversity and abundance of fish species found within the stream segment. The increase in heterogeneous habitat such as a variety in depths of pools, slow moving water, and complex covers likely provide valuable habitat for fish species; conversely, a lack of heterogeneity within the pool/glide/eddy habitat decreases valuable habitat for fish species. Poor pool/glide/eddy quality conditions are defined as minimal heterogeneous habitat with a max depth of <0.2 meters or being absent completely.

Riffle/run quality (marginal to poor) was identified as significantly associated with degraded biological conditions in the Little Tonoloway Creek watershed, and found to impact approximately 57% of the stream miles with poor to very poor biological conditions. Riffle/run quality is a visual observation and quantitative measurement based on the depth, complexity, and functional importance of riffle/run habitat within the stream segment. An increase in the 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. Riffle/run quality conditions indicating biological degradation are set at two levels: 1) poor, defined as riffle/run depths < 1 cm or riffle/run substrates concreted; and 2) marginal to poor, defined as riffle/run depths generally 1 – 5 cm with a primarily single current velocity.

The stressors identified for the in-stream habitat parameter group are intricately linked with habitat heterogeneity. The presence of these in-stream habitat stressors lowers the diversity of a stream’s microhabitats and substrates, subsequently causing a reduction in the diversity of biological communities. The scouring of streambeds, which often occurs in streams with “flashy” hydrologic regimes, results in a more homogeneous in-stream habitat.

The combined AR is used to measure the extent of stressor impact of degraded stream miles with poor to very poor biological conditions. The combined AR for the in-stream habitat stressor group is approximately 70% suggesting these stressors are probable causes of biological impairments in Little Tonoloway Creek watershed (Table 6).

Riparian Habitat Conditions

BSID analysis results for the Little Tonoloway Creek watershed did not identify any riparian habitat parameters that have statistically significant association with a poor to very poor stream biological condition (Table 4).

Water Chemistry Conditions

BSID analysis results for the Little Tonoloway Creek watershed identified four water chemistry parameters that have statistically significant association with a poor to very poor stream biological condition: *high chlorides, high conductivity, acid neutralizing capacity below chronic level (ANC), and low lab pH* (Table 5).

High chlorides concentration was identified as significantly associated with degraded biological conditions and found in approximately 44% of the stream miles with poor to very poor biological conditions in the Little Tonoloway Creek watershed. Chloride can play a critical role in the elevation of conductivity. Chloride in surface waters can result from both natural and anthropogenic sources, such as run-off from impervious surfaces containing road de-icing salts, the use of inorganic fertilizers, landfill leachates, septic tank effluents, animal feeds, and industrial effluents. Smith, Alexander, and Wolman (1987), have identified that, although chloride can originate from natural sources, in urban watersheds, road salts (i.e., sodium chloride) are the most likely source of high chloride and conductivity levels.

High conductivity levels were identified as significantly associated with degraded biological conditions and found to impact approximately 67% of the stream miles with poor to very poor biological conditions in the Little Tonoloway Creek watershed. Conductivity is a measure of water's ability to conduct electrical current and is directly related to the total dissolved salt content of the water. Conductivity can serve as an indicator that a pollution discharge or some other source of inorganic contaminant has entered a stream. Increased levels of inorganic pollutants can be toxic to aquatic organisms and lead to exceedences in species tolerances. Most of the total dissolved salts of surface waters are comprised of inorganic compounds or ions, such as chloride, sulfate, carbonate, sodium, and phosphate (IDNR 2008). Urban and agricultural runoffs (i.e., fertilizers), septic drainage, as well as leaking wastewater infrastructure are typical sources of inorganic compounds. Little Tonoloway Creek, falling in the Highland region, is a limestone influenced stream in which higher conductivity levels above 300 µS/cm are not uncommon. In the Highland region, where limestone influenced streams are prevalent, the conductivity threshold has been set at 500 µS/cm.

Low ANC below chronic level was identified as significantly associated with degraded biological conditions in the Little Tonoloway Creek watershed and found to impact approximately 20% of the stream miles with poor to very poor biological conditions. ANC is a measure of the capacity of dissolved constituents in the water to react with and neutralize acids. ANC can be used as an index of the sensitivity of surface waters to acidification. The higher the ANC, the more acid a system can assimilate before experiencing a decrease in pH. Frequent inputs of acidic materials into a system may cause a decrease in ANC. ANC values less than 50µeq/l are considered to demonstrate chronic (highly sensitive to acidification) exposures for aquatic organisms, and values less than 200 are considered to demonstrate episodic (sensitive to acidification) exposures (Kazyak et al. 2005; Southerland et al. 2007).

Low lab pH was identified as significantly associated with degraded biological conditions in the Little Tonoloway Creek watershed and found to impact approximately 20% of the stream miles with poor to very poor biological conditions. MDDNR MBSS collects pH samples once during the spring, which are analyzed in the laboratory (*pH lab*), and measured once in situ during the summer (*pH field*). pH is a measure of acidity that uses a logarithmic scale ranging from 0 to 14, with 7 being neutral. Most stream organisms prefer a pH range of 6.5 to 8.5. Low pH values (less than 6.5) can be damaging to aquatic life. Low pH may allow concentrations of toxic elements (such as ammonia, nitrite, and aluminum) and high amounts of dissolved heavy metals (such as copper and zinc) to be mobilized for uptake by aquatic plants and animals.

Water chemistry is another major determinant of the integrity of surface waters that is strongly influenced by land use. Impervious surfaces, especially transportation corridors, allow many types of pollutants, derived from a variety of sources, to accumulate upon them. Many of these pollutants are subsequently washed into water bodies by storm water runoff, severely degrading water quality. Land development and increased impervious surfaces within the Little Tonoloway Creek watershed has lead to increases in contaminant loads from nonpoint sources by inorganic pollutants to surface waters.

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 69%, suggesting these stressors are probable causes of biological impairments in Little Tonoloway Creek watershed (Table 6).

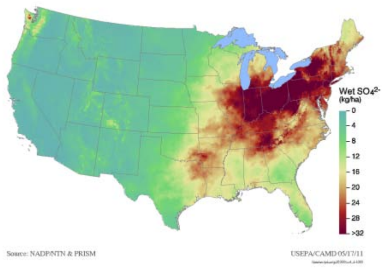
4.3 Discussion

The combined AR for all stressors identified in the BSID analysis is approximately 94%, suggesting that removal of these stressors would address the majority of biological impairment in Little Tonoloway Creek watershed (Table 6).

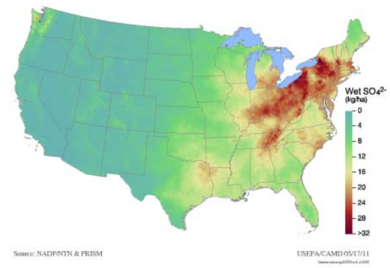
Data suggest that the degradation of biological communities in the Little Tonoloway Creek watershed is associated with urban land use, impervious surface and their concomitant effects including elevated levels of chlorides, accelerated erosion, and minimal buffering. Although the affects of urbanization and imperviousness are complex and diverse, increased surface flow represents a common thread to a scenario that encapsulates all of the physical stressors and some of the chemical stressors revealed in this BSID. Increased overland flow erodes and transports more soils to waterways. Likewise, increased surface flow volume and delivery rate increases the lateral and vertical erosion within stream channels. Sediments resulting from deposition of newly eroded soils join the existing stream sediments as they are repeatedly transported and deposited during storm events. Channel alteration, high embeddedness, epifaunal substrate, pool/glide/eddy quality, and riffle/run quality are all results of channel erosion or deposition associated with increase surface flow. Acidity related stressors identified in this BSID (low pH, low ANC) are also associated with this surface flow scenario because increased surface flow inhibits infiltration of surface flow into the underlying soils where acid neutralizing capacity of the geology could reduce the acidity impacts of regional atmospheric deposition.

The Little Tonoloway Creek watershed also experiences localized acidity in areas where the geology has little buffering capacity. Regional atmospheric deposition is the probable source of acidity, which exceeds the natural acid neutralizing capacity of local geology. Siliciclastic bedrock types (such as sandstone), which are found in the watershed have very low buffering capacity (Bulger, Cosby, andWebb 1998) partly because it weathers very slowly.

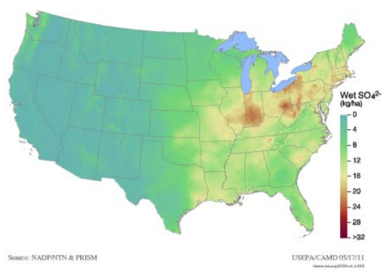
In 1990, the United States Congress enacted Title IV, part of the Clean Air Act Amendments, which required significant decreases in sulfur dioxide (SO_2) and nitrous oxides (NOx) emissions, major contributors of acid deposition, from fossil fuel-burning power plants. Implementation of Title IV has substantially reduced emissions of SO_2 and NOx, and has also decreased sulfate and inorganic nitrogen deposition in the eastern U.S. Acidity from atmospheric deposition in the eastern United States is demonstrated by National Atmospheric Deposition Program (NADP) monitoring data (NADP 2012). Figure 6 illustrates sulfate deposition over the continental United States during the time period stream data was collected in Maryland to assess biological integrity and diagnose biological impairments (2000-2008). Additional 1990 and 2011 images are included to illustrate the trend of decreasing atmospheric deposition, presumably caused by implementation of Title IV. None of the MBSS round three sites (2008) were associated with acidity related stressors, suggesting reductions of SO_2 and NOx emissions required by the Clean Air Amendment may be reducing detrimental effects of atmospheric deposition in the Little Tonoloway Creek watershed.



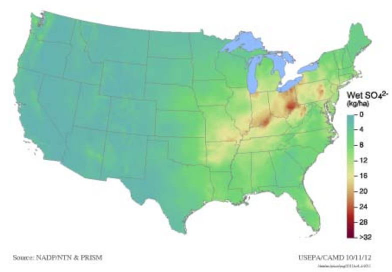
1990 SO_4^{-2} Emissions



2000 SO_4^{-2} Emissions



2008 SO_4^{-2} Emissions



2011 SO_4^{-2} Emissions

Figure 6. Sulfate Deposition Over the Continental United States (1990-2011)

Land use proportions in the Little Tonoloway Creek watershed do not adequately represent the significance of landscape impacts in the watershed. The extent and proximity of roadways to streams is a critically important element of this landscape. The watershed is transected by a number of major transportation corridors including Interstate 68 and 70 as well as Routes 40, 40 alt., and 144. Many of these roads parallel and/or cross streams for large portions of their total length in the basin. 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). The BSID analysis identified transportation corridors as a significant land use within the riparian buffer zones. 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 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., urbanization, habitat modification). Also, uncertainties in the analysis could arise from the absence of unknown key stressors and other limitations of the principal data set. The results are based on the best available data at the time of evaluation.

4.4 Final Causal Model for the Little Tonoloway Creek Watershed

Causal model development provides a visual linkage between biological condition, habitat, chemical, and source parameters available for stressor analysis. Models were developed to represent 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 2013). 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 Little Tonoloway Creek watershed, with pathways to show the watershed's probable stressors as indicated by the BSID analysis.

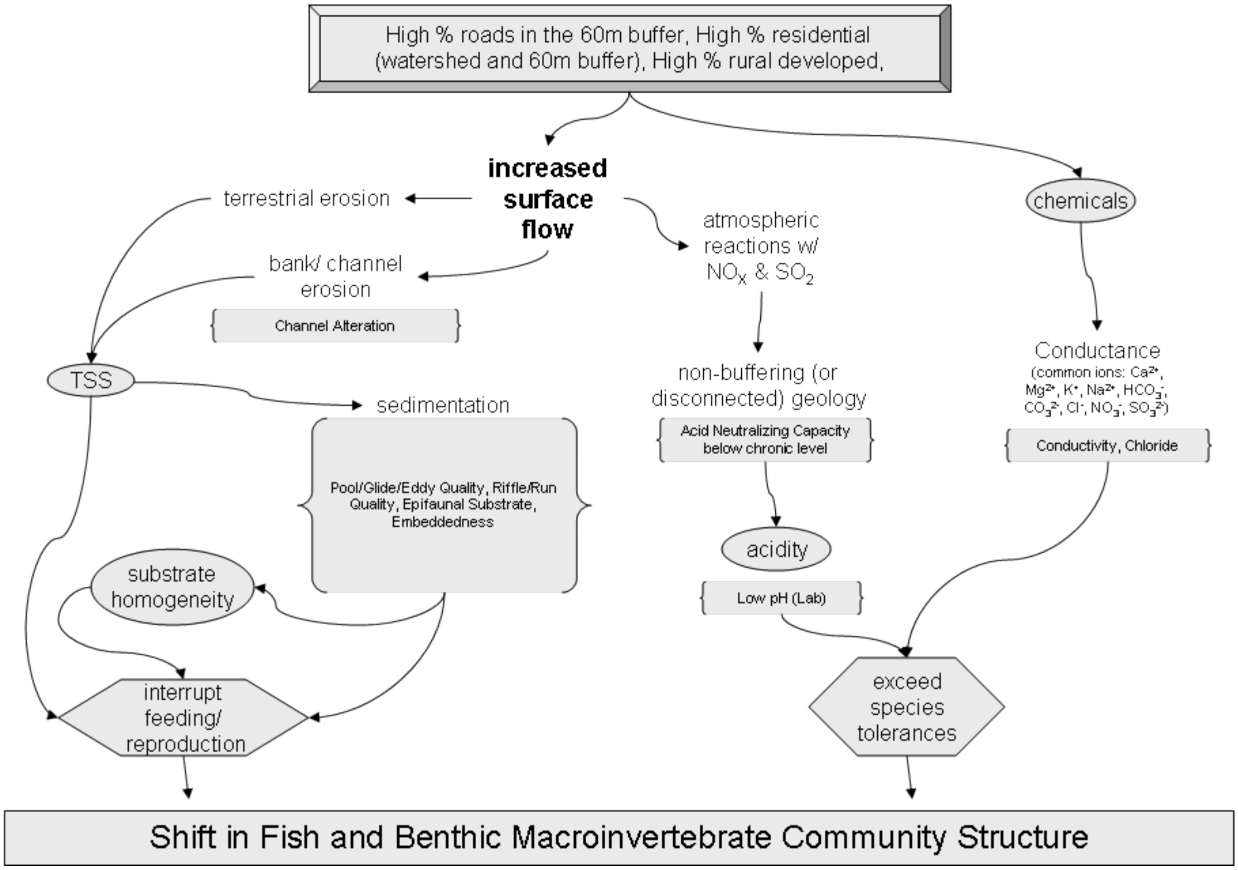


Figure 7. Final Causal Model for the Little Tonoloway Creek Watershed

5.0 Conclusions

Data suggest that the degradation of biological communities in the Little Tonoloway Creek watershed is associated with urban land use, impervious surface and their concomitant effects including elevated levels of chlorides, accelerated erosion, and minimal buffering capacity. The development of landscapes creates broad and interrelated forms of degradation that can affect stream ecology and biological composition. Peer-reviewed scientific literature establishes a link between urban landscapes and degradation in the aquatic health of non-tidal stream ecosystems.

The results of the BSID analysis, and the probable causes and sources of the biological impairments in the Little Tonoloway Creek watershed can be summarized as follows:

- The BSID process has determined that numerous sediment and instream habitat stressors affect biological communities in the Little Tonoloway Creek watershed. Although these stressors are divided into two groups in this analysis, they demonstrate the common effects of accelerated surface water delivery to receiving streams. Impervious surfaces associated with roads and residential development increase the volume, velocity, and power of surface water flow, thus accelerating the erosion of soils from land surfaces, and the erosion of soils from stream banks (i.e., along stream channels), as well as the continued erosion/deposition of sediments within stream channels. The BSID results thus support a Category 5 listing of total suspended solids on the Integrated Report as an appropriate management action to begin addressing the impact of these stressors on the biological communities in the Little Tonoloway Creek watershed.

- The BSID process has also determined that the biological communities in the Little Tonoloway Creek watershed are likely degraded due to inorganic water chemical pollutants, including chloride and conductivity. Conductivity is a general stressor variable that includes chloride in addition to a plethora of other chemicals. The BSID results thus support a Category 5 listing of chloride on the Integrated Report as an appropriate management action to begin addressing the impacts of this stressor on the biological communities. Discharges of inorganic compounds like chloride are 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 this parameter will help in determining the spatial and temporal extent of these impairments in the watershed.

- The BSID process has also determined that the biological communities in the Little Tonoloway Creek watershed are likely degraded due to acidity related stressors. There are likely two sources causing acidity impairments in the watershed, increased urban development and atmospheric deposition. Acidity related stressors are associated with increased “direct connect” of runoff from impervious surfaces to surface waters. Infiltration of surface runoff into underlying soils and geology can provide the neutralizing capacity need to reduce the acidity impacts of regional atmospheric deposition. Possible habitat and stormwater restoration in the urban areas of the watershed could increase infiltration of surface runoff. Little Tonoloway Creek watershed also experiences localized acidity caused by atmospheric deposition in areas where the geology has little buffering capacity. Therefore, the biological impairment listing should be amended to a Category 4b of the Integrated Report since the Clean Air Act Amendments of 1990 should be sufficient to meet the reductions. The 1990 changes to the Clean Air Act introduced a nationwide approach to reducing acid pollution. The law is designed to reduce acid rain and improve public health by dramatically reducing emissions of sulfur dioxide (SO_2) and oxides of nitrogen (NOx) by the year 2010. In 2007, the State of Maryland passed the Maryland Healthy Air Act. The first phase requires reductions of NOx emissions by almost 70%, and SO_2 emissions by 80%. In 2012/ 2013 the second phase of emission controls will reduce NOx and SO_2 by another 5%.

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