Watershed Report for Biological Impairment of the Casselman River in Garrett County, Maryland Biological Stressor Identification Analysis Results and Interpretation

FINAL

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Table of Contents

List of Figures

List of Tables

List of Abbreviations

AMD	Acid Mine Drainage
ANC	Acid Neutralizing Capacity
AR	Attributable Risk
BIBI	Benthic Index of Biotic Integrity
BSID	Biological Stressor Identification
COMAR	Code of Maryland Regulations
CWA	Clean Water Act
DO	Dissolved Oxygen
FIBI	Fish Index of Biologic Integrity
IBI	Index of Biotic Integrity
MD	Maryland
MDDNR	Maryland Department of Natural Resources
MDE	Maryland Department of the Environment
MBSS	Maryland Biological Stream Survey
mg/L	Milligrams per liter
NADP	National Atmospheric Deposition Program
NPDES	National Pollution Discharge Elimination System
NRCS	Natural Resources Conservation Service
PA	Pennsylvania
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.

The Casselman River (watershed code 05020204), located in Garrett County, was identified on the 2008 Integrated Report under Category 5 as impaired by pH, nutrients (1996 listings), and impacts to biological communities (2002 listing). Big Piney Reservoir (watershed code 050202040038) was identified as impaired by methylmercury in fish tissue (2002). All impairments are listed for non-tidal streams. A TMDL to address the pH listings was approved by the USEPA in 2008. A WQA of eutrophication was completed in 2000. A TMDL to address the methylmercury listing for Big Piney Reservoir was approved by the USEPA in 2004.

In 2002, the State began listing biological impairments on the *Integrated Report*. The current MDE biological assessment methodology assesses and lists only at the Maryland 8-digit watershed scale, which maintains consistency with how other listings on the Integrated Report are made, how TMDLs are developed, and how implementation is targeted. The listing methodology assesses the condition of Maryland 8-digit watersheds with multiple impacted sites by measuring the percentage of stream miles that have poor to very poor biological conditions, and calculating whether this is significantly different from a reference condition watershed (i.e., healthy stream, <10% stream miles with poor to very poor biological condition).

The Maryland Surface Water Use Designations in the Code of Maryland Regulations (COMAR) for the Casselman River and its tributaries are Use I (Water Contact Recreation, and Protection of Nontidal Warmwater Aquatic Life), Use I-P (Water Contact Recreation, Protection of Aquatic Life, and Public Water Supply), Use III (Nontidal Cold Water) and Use IV (Recreational Trout Waters). The South Branch Casselman above the confluence with the North Branch and Piney Creek and all its tributaries in Maryland (MD) including Church Creek from the MD/Pennsylvania (PA) State line to the confluence of Church Creek are designated as Use III. Piney Creek and all its tributaries above the confluence with Church Creek are designated as Use I-P. The remaining streams and tributaries are designated as Use I (COMAR 2010a,b,c,d,e). The Casselman River watershed is not attaining its designated use of protection of aquatic life because of biological impairments. As an indicator of designated use attainment, MDE

uses Benthic and Fish Indices of Biotic Integrity (BIBI/FIBI) developed by the Maryland Department of Natural Resources Maryland Biological Stream Survey (MDDNR MBSS).

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

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

This Casselman River watershed report presents a brief discussion of the BSID process on which the watershed analysis is based, and which may be reviewed in more detail in the report entitled "Maryland Biological Stressor Identification Process" (MDE 2009). Data suggest that acidity is the predominate cause of biological community degradation in the Casselman River. Low pH results from both natural (e.g., organic acidity from wetlands, low neutralizing capacity of geology, and groundwater associated with sulfur bearing geology) and anthropogenic sources (atmospheric deposition and acid mine drainage (AMD). A secondary cause of biological community degradation is increased chloride concentrations resulting from non-point source run off of transportation corridors.

The results of the BSID process, and the probable causes and sources of the biological impairments in the Casselman River, can be summarized as follows

- The BSID process has determined that the biological communities in the Casselman River Watershed are likely degraded due to acidity related stressors. Acidity is indicated directly by the strong association of low pH and low Acid Neutralizing Capacity (ANC) with biological impairments. The BSID results confirm that the establishment of a pH TMDL was an appropriate management action to begin addressing the biological impairment in the Casselman River watershed.

- The BSID process has also determined that the biological communities in the Casselman River Watershed are likely degraded due to inorganic pollutants (i.e., chlorides and conductivity). Impacts on water quality due to 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 and transportation land uses cause an increase in contaminant loads 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 analysis did not identify any nutrient stressors present and/or nutrient stressors showing a significant association with degraded biological conditions; therefore, the 2000 WQA for nitrogen and phosphorus was an appropriate management action.

1.0 Introduction

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

The current MDE biological assessment methodology is a three-step process: (1) a data quality review, (2) a systematic vetting of the dataset, and (3) a watershed assessment that guides the assignment of biological condition to Integrated Report categories. In the data quality review step, available relevant data are reviewed to ensure they meet the biological listing methodology criteria of the Integrated Report (MDE 2008). In the vetting process, an established set of rules is used to guide the removal of sites that are not applicable for listing decisions (e.g., tidal or black water streams). The final principal database contains all biological sites considered valid for use in the listing process. In the watershed assessment step, a watershed is evaluated based on a comparison to a reference condition (i.e., healthy stream, <10% degraded) that accounts for spatial and temporal variability, and establishes a target value for "aquatic life support." During this step of the assessment, a watershed that differs significantly from the reference condition is listed as impaired (Category 5) on the Integrated Report. If a watershed is not determined to differ significantly from the reference condition, the assessment must have an acceptable precision (i.e., margin of error) before the watershed is listed as meeting water quality standards (Category 1 or 2). If the level of precision is not acceptable, the status of the watershed is listed as inconclusive and subsequent monitoring options are considered (Category 3). If a watershed is classified as impaired (Category 5), then a stressor identification analysis is completed to determine if a TMDL is necessary.

The MDE biological stressor identification (BSID) analysis applies a case-control, risk-based approach that uses the principal dataset, with considerations for ancillary data, to identify potential causes of the biological impairment. Identification of stressors responsible for biological impairments was limited to the round two of the Maryland Department of Natural Resources Maryland Biological Stream Survey (MDDNR MBSS) dataset (2000 – 2004) because it provides a broad spectrum of paired data variables (i.e., biological monitoring and stressor information) to best enable a complete stressor analysis. The BSID analysis then links potential causes/stressors with general causal scenarios and concludes with a review for ecological plausibility by State scientists. Once the BSID analysis is completed, one or several stressors (pollutants) may be identified as probable or unlikely causes of the poor biological conditions within the Maryland 8-digit watershed. BSID analysis results can be used together with a variety of water quality analyses to update and/or support the probable causes and sources of biological impairment in the Integrated Report.

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

2.0 Casselman River Watershed Characterization

2.1 Location

The Casselman River is located in Garrett County, Maryland just west of the Eastern Continental Divide (see Figure 1). Maryland possesses the headwaters of the Casselman, which occurs within the Monongahela River Watershed, a part of the Ohio River drainage. The Casselman Valley occupies the Berlin Syncline and owes its east and west boundaries to the erosion resistant sandstone outcrops of the Allegheny/Pottsville Formation that now form the peaks of Meadow Mountain (eastern boundary) and Negro Mountain (western boundary). In Maryland, the Casselman drains approximately 70 square miles beginning just south of the Deep Creek Lake Watershed, and extends north to Pennsylvania. The basin widens to the north, extending east to the Allegany Front. The watershed area is located in the Highlands eco-region identified in the MBSS Index of Biotic Integrity (IBI) metrics (Southerland et al. 2005) (Figure 2).

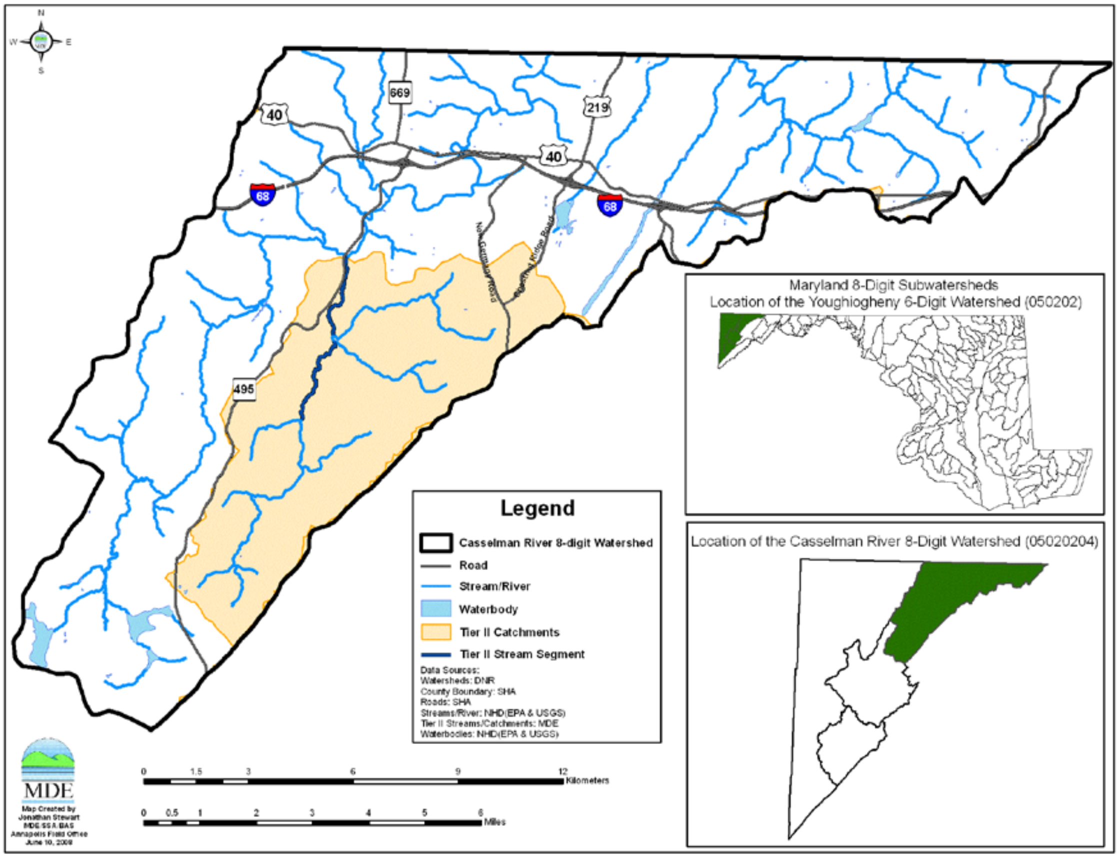

Figure 1. Location Map of the Casselman River Watershed

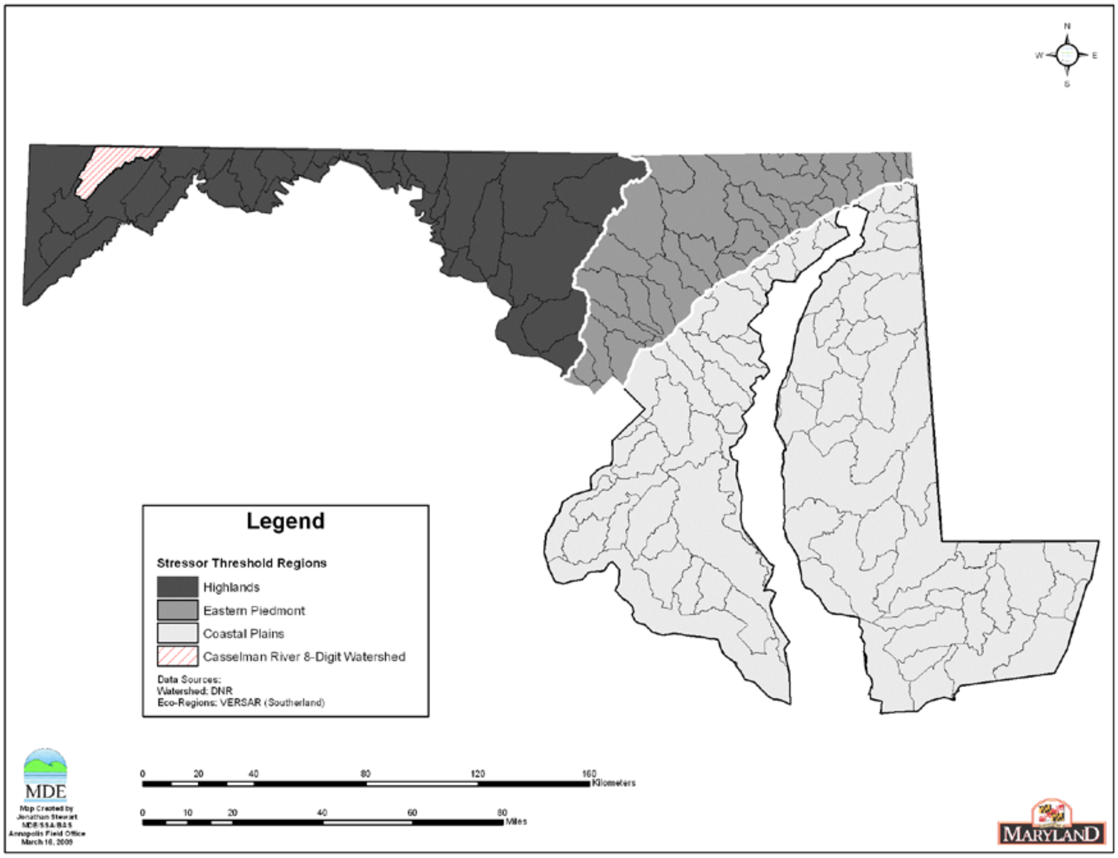

Figure 2. The Eco-Region Location Map for the Casselman River Watershed

2.2 Land Use

Low, rolling hills and wetlands best describe the terrain of most of the Casselman River Basin in Maryland, particularly throughout the southern and eastern extents. A high plateau in the northwest portion of the basin supports the largest development, which includes low density residential, industrial, and high intensity agriculture. Development in the northwest ends abruptly as a high plateau descends to the wide valley of the Casselman River. The remainder of the basin contains sparse roadside residences and large low intensity agriculture (Figure 3). Steep terrain along the slopes of Meadow Mountain and Negro Mountain contain limited development and are largely forested, containing portions of the Savage River State Forest. Underlying the basin, the coal bearing rocks of the Pennsylvanian age (including the Conemaugh, Allegheny, and Pottsville Formations) have supported mining that began in the middle 1800's and peaked around 1945. Currently, there are no active mines in the basin, and many inactive mines have been reclaimed. The coal mining history of the Casselman continues to influence water quality through various legacy pathways including acid mine drainage (AMD) and subsidence (Skelly and Loy 1976). The basin contains 71% forest, 19% agriculture, and 9% urban land use (Figure 4) (MDP 2002).

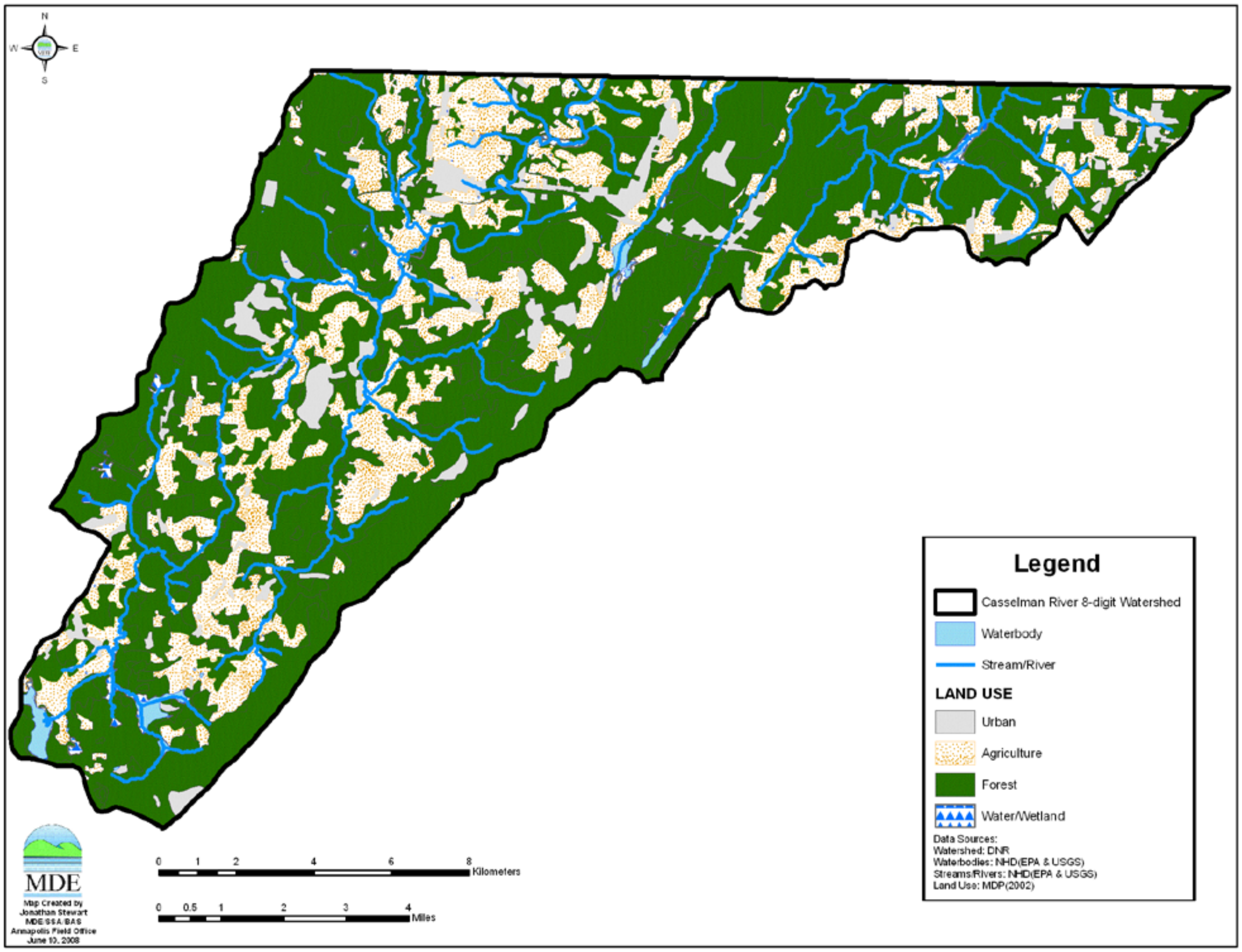

Figure 3. Land Use Map of the Casselman River Watershed

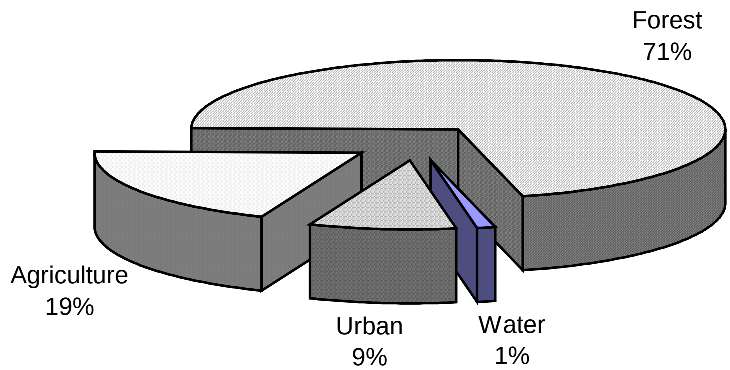

Figure 4. Proportions of Land Use in the Casselman River Watershed

2.3 Soils/hydrology

The Natural Resources Conservation Service (NRCS) has defined four hydrologic soil groups providing a means for grouping soils by similar infiltration and runoff characteristics during periods of prolonged wetting. Typically, clay soils (Group D) that are poorly drained have the lowest infiltration rates with the highest amount of runoff, while sandy soils (Group A) that are well drained have high infiltration rates, with little runoff. The Casselman River watershed mostly consists of C soils. Group C soils typically have slow infiltration rates. Most soils in this classification include a layer that impedes downward water movement and/or have a moderately fine-to-fine texture (NRCS 1976).

The Casselman River originates from wetlands along the high plateau of its southern watershed boundary. The North Branch (to the west) and the South Branch (to the east) flow northward nearly parallel to each other and join approximately mid-basin to form the Casselman proper. The South Branch Casselman is a small stream with few significant tributaries south of Jennings. The South Branch has a pool-run hydrology and flows relatively fast through a steep valley. Little Laurel Run and Big Laurel Run confluence with the South Branch near Jennings and approximately double the South Branch flow. The South Branch assumes a meandering hydrology from Jennings to the confluence with the North Branch. The North Branch is more sluggish than its sister branch, as it flows through a wider, less steep valley. Also in contrast to the South Branch, the North Branch receives tributaries evenly along its length, so that flow gradually increases downstream. A pool-riffle hydrology is maintained along the North Branch with fewer riffle sections downstream. The North and South Branches contribute nearly equal flows to the Casselman River proper. The Casselman River is a slow moving, meandering river with areas of wide shallow riffles.

3.0 Casselman River Water Quality Characterization

3.1 Integrated Report Impairment Listings

The Casselman River (watershed code 05020204), located in Garrett County, was identified on the 2008 Integrated Report under Category 5 as impaired by pH, nutrients (1996 listings), and impacts to biological communities (2002 listing). Big Piney Reservoir (watershed code 050202040038) was identified as impaired by methylmercury in fish tissue (2002). All impairments are listed for non-tidal streams. A TMDL to address the pH listings was approved by the USEPA in 2008. A WQA of eutrophication was completed in 2000. A TMDL to address the methylmercury listing for Big Piney Reservoir was approved by the USEPA in 2004.

3.2 Biological impairment

The Maryland Surface Water Use Designations in the Code of Maryland Regulations (COMAR) for the Casselman River and its tributaries are Use I (Water Contact Recreation, and Protection of Nontidal Warmwater Aquatic Life), Use I-P (Water Contact Recreation, Protection of Aquatic Life, and Public Water Supply), Use III (Nontidal Cold Water) and Use IV (Recreational Trout Waters). The South Branch Casselman above the confluence with the North Branch and Piney Creek and all its tributaries in Maryland (MD) including Church Creek from the MD/Pennsylvania (PA) State line to the confluence of Church Creek are designated as Use III. Piney Creek and all its tributaries above the confluence with Church Creek are designated as Use I-P. The remaining streams and tributaries are designated as Use I (COMAR 2010a,b,c,d,e). 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. 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 Casselman River watershed is listed under Category 5 of the 2008 Integrated Report as impaired for evidence of biological impacts. Approximately 29% of stream miles in the Casselman River basin are estimated as having fish and and/or benthic indices of biological impairment in the poor to very poor category. The biological impairment listing is based on the combined results of MDDNR MBSS round one (1995-1997) and round two (2000-2004) data, which include thirty-four stations. Ten of the thirty-four 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, ie MBSS round two contains ten MBSS sites; with six having BIBI and/or FIBI scores lower than 3.0. (Figure 5) illustrates principal dataset site locations for the Casselman River watershed.

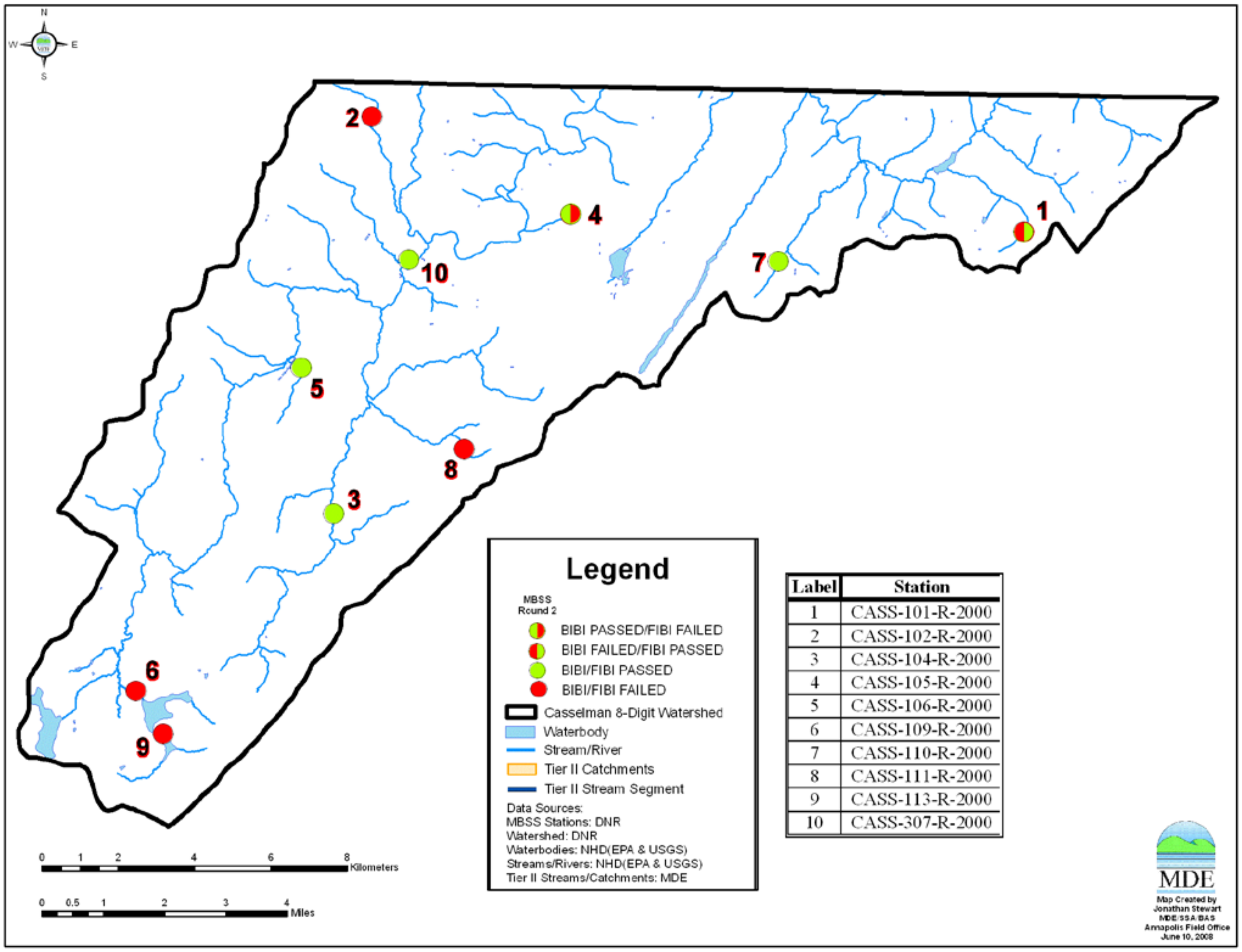

Figure 5. Principal Dataset Sites for the Casselman River Watershed

4.0 Stressor Identification Results

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

The BSID data analysis tests for the strength of association between stressors and degraded biological conditions by determining if there is an increased risk associated with the stressor being present. More specifically, the assessment compares the likelihood that a stressor is present, given that there is a degraded biological condition, by using the ratio of the incidence within the case group as compared to the incidence in the control group (odds ratio). The case group is defined as the sites within the assessment unit with BIBI/FIBI scores 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 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 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 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, and water chemistry groups are identified as possible biological stressors in the Casselman River. Parameters identified as representing possible sources are listed in Table 4. Table 5 summarizes the combined AR for each stressor group in the Casselman River. A summary of combined AR values for each source group is shown in Table 6.

Table 1. Sediment Biological Stressor Identification Analysis Results for the Casselman River Watershed

Parameter Group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites 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	10	6	80	0%	8%	No	----
	moderate bar formation present	10	6	80	50%	40%	No	----
	bar formation present	10	6	80	50%	88%	No	----
	channel alteration marginal to poor	10	6	80	50%	38%	No	----
	channel alteration poor	10	6	80	0%	8%	No	----
	high embeddedness	10	6	80	17%	5%	No	----
	epifaunal substrate marginal to poor	10	6	80	33%	23%	No	----
	epifaunal substrate poor	10	6	80	17%	5%	No	----
	moderate to severe erosion present	10	6	80	33%	24%	No	----
	severe erosion present	10	6	80	17%	0%	Yes	17%
	poor bank stability index	10	6	80	0%	3%	No	----
	silt clay present	10	6	80	100%	99%	No	----

Table 2. Habitat Biological Stressor Identification Analysis Results for the Casselman River Watershed

Parameter Group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites 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	10	6	85	17%	8%	No	----
	instream habitat structure marginal to poor	10	6	80	0%	30%	No	----
	instream habitat structure poor	10	6	80	0%	4%	No	----
	pool/glide/eddy quality marginal to poor	10	6	80	67%	65%	No	----
	pool/glide/eddy quality poor	10	6	80	17%	10%	No	----
	riffle/run quality marginal to poor	10	6	80	67%	48%	No	----
	riffle/run quality poor	10	6	80	17%	9%	No	----
	velocity/depth diversity marginal to poor	10	6	80	83%	70%	No	----
	velocity/depth diversity poor	10	6	80	0%	13%	No	----
	concrete/gabion present	10	6	85	0%	1%	No	----
	beaver pond present	9	5	80	20%	3%	No	----
Riparian Habitat	no riparian buffer	10	6	85	33%	25%	No	----
	low shading	10	6	80	33%	3%	Yes	31%

Table 3. Water Chemistry Biological Stressor Identification Analysis Results for the Casselman River Watershed

Parameter Group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites 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	10	6	159	0%	8%	No	----
	high total disolved nitrogen	10	6	50	0%	6%	No	----
	ammonia acute with salmonid present	10	6	159	17%	2%	No	----
	ammonia acute with salmonid absent	10	6	159	17%	1%	No	----
	ammonia chronic with salmonid present	10	6	159	17%	4%	No	----
	ammonia chronic with salmonid absent	10	6	159	17%	2%	No	----
	low lab pH	10	6	159	67%	5%	Yes	62%
	high lab pH	10	6	159	0%	1%	No	----
	low field pH	10	6	154	33%	14%	No	----
	high field pH	10	6	154	0%	0%	No	----
	high total phosphorus	10	6	159	0%	3%	No	----
	high orthophosphate	10	6	159	0%	4%	No	----
	dissolved oxygen < 5mg/l	10	6	154	0%	3%	No	----
	dissolved oxygen < 6mg/l	10	6	154	0%	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	10	6	159	67%	6%	Yes	60%
	acid neutralizing capacity below episodic level	10	6	159	67%	43%	No	----
	high chlorides	10	6	159	33%	7%	Yes	26%
	high conductivity	10	6	159	33%	4%	Yes	30%

	high sulfates	10	6	159	0%	4%	No	----

Table 4. Stressor Source Identification Analysis Results for the Casselman River Watershed

Parameter Group	Source	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites with fair to good Fish and Benthic IBI)	% of case sites with source present	% of control sites per strata with source present	Possible stressor (Odds of stressor in cases significantly higher than odds of sources in controls using p<0.1)	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Source
Sources Urban	high impervious surface in watershed	10	6	156	0%	1%	No	----
	high % of high intensity urban in watershed	10	6	159	33%	4%	Yes	31%
	high % of low intensity urban in watershed	10	6	159	0%	8%	No	----
	high % of transportation in watershed	10	6	159	33%	9%	No	----
	high % of high intensity urban in 60m buffer	10	6	159	33%	6%	Yes	28%
	high % of low intensity urban in 60m buffer	10	6	159	17%	7%	No	----
	high % of transportation in 60m buffer	10	6	159	33%	9%	No	----
Sources Agriculture	high % of agriculture in watershed	10	6	159	0%	6%	No	----
	high % of cropland in watershed	10	6	159	0%	6%	No	----
	high % of pasture/hay in watershed	10	6	159	0%	8%	No	----
	high % of agriculture in 60m buffer	10	6	159	0%	6%	No	----
	high % of cropland in 60m buffer	10	6	159	17%	4%	No	----
	high % of pasture/hay in 60m buffer	10	6	159	0%	8%	No	----
Sources Barren	high % of barren land in watershed	10	6	159	0%	7%	No	----
	high % of barren land in 60m buffer	10	6	159	0%	6%	No	----

Table 4. Stressor Source Identification Analysis Results for the Casselman River 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 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	10	6	159	0%	5%	No	----
	low % of forest in 60m buffer	10	6	159	33%	6%	Yes	28%
Sources Acidity	atmospheric deposition present	10	6	159	50%	39%	No	----
	AMD acid source present	10	6	159	33%	4%	Yes	30%
	organic acid source present	10	6	159	0%	3%	No	----
	agricultural acid source present	10	6	159	0%	1%	No	----

Table 5. Summary AR Values for Stressor Groups for Casselman River Watershed

Stressor Group	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Parameter Group(s) (Attributable Risk)	
Sediment	17%	96%
In-Stream Habitat	----	
Riparian Habitat	31%	
Water Chemistry	95%	

Table 6. Summary AR Values for Source Groups for Casselman River Watershed

Source Group	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Parameter Group(s) (Attributable Risk)	
Urban	30%	63%
Agriculture	----	
Barren Land	----	
Anthropogenic	28%	
Acidity	30%	

Sediment Conditions

BSID analysis results for the Casselman River identified one sediment parameter that has a statistically significant association with poor to very poor stream biological condition *severe erosion.*

Severe erosion present was also identified as significantly associated with degraded biological conditions in the Casselman River, and found in 17% of the stream miles with poor to very poor biological conditions. Erosion severity represents a visual observation that the stream discharge is frequently exceeding the ability of the channel and/or floodplain to attenuate flow energy, resulting in channel instability, which in turn affects bank stability. Erosion severity is described categorically as minimal, moderate, or severe.

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 17% suggesting that this stressor affects a minimal proportion of the degraded stream miles in the Casselman River watershed (Table 5).

In-stream Habitat

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

Riparian Habitat

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

Low shading was identified as significantly associated with degraded biological conditions and found in 31% of the stream miles with poor to very poor biological conditions in the Casselman River. This stressor value represents the percentage of the stream segments that are shaded, taking duration into account. Solar radiation can increase the temperature of stream segments causing thermal stress on fish and invertebrates. Other potential impacts from increased water temperature are decreased dissolved oxygen (DO), and increased bacterial and algal growth.

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 riparian habitat stressor group is approximately 31% suggesting that this stressor impacts a moderate proportion of the degraded stream miles in the Casselman River watershed (Table 5).

Water Chemistry

BSID analysis results for the Casselman River identified four water chemistry parameters that have statistically significant association with a poor to very poor stream biological condition (i.e., removal of stressors would result in improved biological community). These parameters include *low lab pH, low acid neutralizing capacity (ANC), high conductivity, and high chlorides.*

Low lab pH was identified as significantly associated with degraded biological conditions in the Casselman River and found in approximately 62% of the stream miles with poor to very poor biological conditions. pH is a measure of acidity that uses a logarithmic scale ranging from 0 to 14, with 7 being neutral. MDDNR MBSS collects pH samples once during the spring, which are analyzed in the laboratory (*pH lab*), and measured once in situ during the summer (*pH field*). Most stream organisms prefer a pH range of 6.5 to 8.5. 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. The pH threshold values, at which levels below 6.5 and above 8.5 may indicate biological degradation, are established from state regulations (COMAR 2010). Many biological processes, such as reproduction, cannot function in acidic waters. Acidic conditions also aggravate toxic contamination problems because sediments release toxicants (such as copper, zinc, nitrite and aluminum) in acidic waters. Common sources of acidity include mine drainage, atmospheric deposition, runoff from mine tailings, agricultural fertilizers, and natural organic sources.

Low ANC was identified as significantly associated with degraded biological conditions in the Casselman River and found in approximately 60% of the stream miles with poor to very poor biological conditions. Acid neutralizing capacity (ANC) is a measure of the capacity of dissolved constituents in the water to react with and neutralize acids. ANC can be used as an index of the sensitivity of surface waters to acidification. The higher the ANC, the more acid a system can assimilate before experiencing a decrease in pH. Repeated additions of acidic materials 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).

High conductivity levels were identified as significantly associated with degraded biological conditions in the Casselman River and found in approximately 30% of the stream miles with poor to very poor biological conditions. Conductivity is a measure of water's ability to conduct electrical current and is directly related to the total dissolved salt (i.e., ionic) content of the water. Most of the total dissolved salts of surface waters result from the dissolution of inorganic compounds such as halides, sulfates, chlorides, carbonates, sodium, and phosphates. Conductivity is also related to acidity because low pH could increase the dissolution of inorganic compounds.

High chloride levels were identified as significantly associated with degraded biological conditions in the Casselman River and found to impact approximately 26% of the stream miles with poor to very poor biological conditions. Chloride in surface waters can result from both natural and anthropogenic sources, such as run-off containing road de-icing salts, the use of inorganic fertilizers, landfill leachates, septic tank effluents, animal feeds, industrial effluents, irrigation drainage, and seawater intrusion in coastal areas. Smith et al. (1987) have identified that, although chloride can originate from natural sources, in urban watersheds road salts (NaCl) can be a likely source of high chloride and conductivity levels. There are no major National Pollutant Discharge Elimination System (NPDES) permitted municipal or industrial discharges in the watershed; however, there are two minor municipal facilities that are regulated for various parameters. Because NPDES permitting enforcement does not require chloride testing at any of these facilities, data was not available to verify/identify chlorides as a specific pollutant in this watershed. There are no MBSS sites downstream from either municipal facility. The two MBSS sites that have degraded biological conditions and exceed the target value for chlorides and conductivity are located in close proximity to Interstate 68, which is a major transportation route through western Maryland; therefore, application of road salts is a likely source of the chlorides and high conductivity levels.

Water chemistry is another major determinant of the integrity of surface waters that is strongly influenced by land-use. Land development causes an increase in contaminant loads from point and nonpoint sources by adding sediments, nutrients, road salts, AMD, toxics, petroleum products, and inorganic pollutants to surface waters. Increased levels of many pollutants like chlorides and AMD 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 and chlorides 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.

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 95% suggesting these stressors impact a substantial proportion of the degraded stream miles in the Casselman River watershed (Table 5).

Sources

The BSID source analysis (Table 4) identifies two types of urban land uses as potential sources of stressors that may be significantly associated with degraded biological conditions in the Casselman River and found to impact approximately 30% of the stream miles with poor to very poor biological conditions. The *low % of forest in 60m buffer* (AR 28%) is likely a result of the increased urbanization in the sixty meter riparian buffer zone, which would account for the stressor low shading in the riparian habitat parameters.

The scientific community (Booth 1991, Konrad and Booth 2002, and Meyer, Paul, and Taulbee 2005) has consistently identified negative impacts to biological conditions as a result of increased urbanization. A number of systematic and predictable environmental responses have been noted in streams affected by urbanization, and this consistent sequence of effects has been termed “urban stream syndrome” (Meyer, Paul, and Taulbee 2005). Symptoms of urban stream syndrome include flashier hydrographs, altered habitat conditions, degradation of water quality, and reduced biotic richness, with increased dominance of species tolerant to anthropogenic (and natural) stressors.

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

Even though the BSID source analysis identified urban land uses as significantly associated with degraded stream miles in the watershed, stressors typically linked to symptoms of "urban stream syndrome" were not identified. Severe erosion present was the only stressor identified. The combined AR for this stressor is 17%, suggesting that addressing severe erosion would only account for a marginal proportion of the degraded stream miles the Casselman River watershed. Urban land uses comprises nine percent of the Casselman River watershed, and only two of the six MBSS stations with BIBI/FIBI scores lower than 3.0 had these land use categories in their catchment basin.

AMD acid source present was identified as significantly associated with degraded biological conditions in the Casselman River and found to impact approximately 30% of the stream miles with poor to very poor biological conditions (Table 4). Acid mine drainage (AMD) results when mineral pyrite oxidation (from mine spoils and abandoned mine shafts) and is known to cause extreme acidification of surface waters as well as affect stream physical substrate. Streams strongly affected by AMD exhibit high levels of sulfate, manganese, iron, aluminum, and conductivity. Highly acidic waters ($pH < 3$) can solubilise heavy metals and other toxic elements from soil and cause them to be transported into nearby surface waters. The high acidity of acid mine drainage and the high amounts of dissolved heavy metals (such as copper and zinc) generally make acid mine drainage extremely toxic to most organisms (Penreath, 1994).

The BSID source analysis (Table 4) identifies urban land uses and presence of AMD as potential sources of stressors that may cause negative biological impacts. The combined AR for the source group is approximately 63% suggesting that these sources potentially impact a considerable proportion of the degraded stream miles in the Casselman River (Table 6).

Discussion

Acidity is the most probable cause associated with biological impairment in the Casselman River watershed. The presence of AMD in the Casselman is an obvious source of acidity due to the coal reserves in the watershed. This source should have a broader scope to recognize possible natural levels of acidity in groundwater discharges of sulfur-laden rock which is prevalent in coal mining areas.

The Casselman naturally experiences low ANC primarily due to the nature of exposed sandstone on the ridges outlining the basin. Siliciclastic bedrock types (such as sandstone) have very low buffering capacity (Bulger, A., J. Cosby, and R. Webb. 1998) partly because it weathers very slowly. Slow weathering is also the reason that sandstone outcrops exist along the Casselman's watershed boundaries. The geology and soils of the Casselman River Valley provide more neutralizing capacity; however, the valley contains more impervious surfaces, which could essentially function to duplicate the qualities of sandstone and expand the influence of acidity throughout the watershed by disconnecting precipitation from materials with buffering capacity.

Atmospheric deposition could also be a possible source of acidity in the watershed. Acid rain is produced when atmospheric moisture reacts with gases to form sulfuric acid and nitric acids. These gases are primarily formed from nitrogen dioxides and sulfur dioxide, which enter the atmosphere through exhaust and smoke from burning fossil fuels such as gas, oil, and coal.

While atmospheric deposition concentrations are not recorded in the principal dataset, it is widely recognized as an issue in the Eastern United States and is supported by a National Atmospheric Deposition Program (NADP) monitoring station located in the Casselman River watershed near Piney Reservoir. Atmospheric deposition in the Casselman watershed is more than ten times the mean concentrations from another NADP station in western Tennessee, which is outside of the Ohio River air-shed (NADP 2009). Atmospheric deposition could be a possible source of acidity in the Casselman not recognized in BSID analyses.

Impacts from elevated chlorides and conductivity concentrations only impacts 26% - 30% of the degraded stream miles in the watershed. The two MBSS sites that have exceedences for chlorides and conductivity are located in close proximity to Interstate 68, which is a major transportation route through western Maryland. The application of road salts is a likely source of these stressors.

In summary, acidity is the most probable cause associated with biological impairment in the Casselman River watershed. Due to the presence AMD and atmospheric deposition the watershed has experienced an increase in contaminant loads from point and nonpoint sources, resulting in levels of acidity that can potentially be extremely toxic to aquatic organisms.

Sediment and riparian habitat stressors identified in BSID analyses, severe erosion and low shading, do not align with acidity related impairment. These findings demonstrate the complex nature of stressor identification and the often occurrence of numerous stressors contributing to the degradation of aquatic biological communities. However, these stressors are secondary to acidity in the Casselman River. The combined AR for all the stressors is approximately 96%, suggesting that sediment, riparian habitat and water chemistry stressors identified in the BSID analysis would adequately account for the biological impairment in the Casselman River watershed (Table 5).

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

Final Causal Model for the Casselman River

Causal model development provides a visual linkage between biological condition, habitat, chemical, and source parameters available for stressor analysis. Models were developed to represent the ecologically plausible processes when considering the following five factors affecting biological integrity: biological interaction, flow regime, energy source, water chemistry, and physical habitat (Karr, 1991and USEPA 2007). The five factors guide the selections of available parameters applied in the BSID analyses and are used to reveal patterns of complex causal scenarios. Figure 6 illustrates the final causal model for the Casselman River, with pathways to show the watershed's probable stressors as indicated by the BSID analysis.

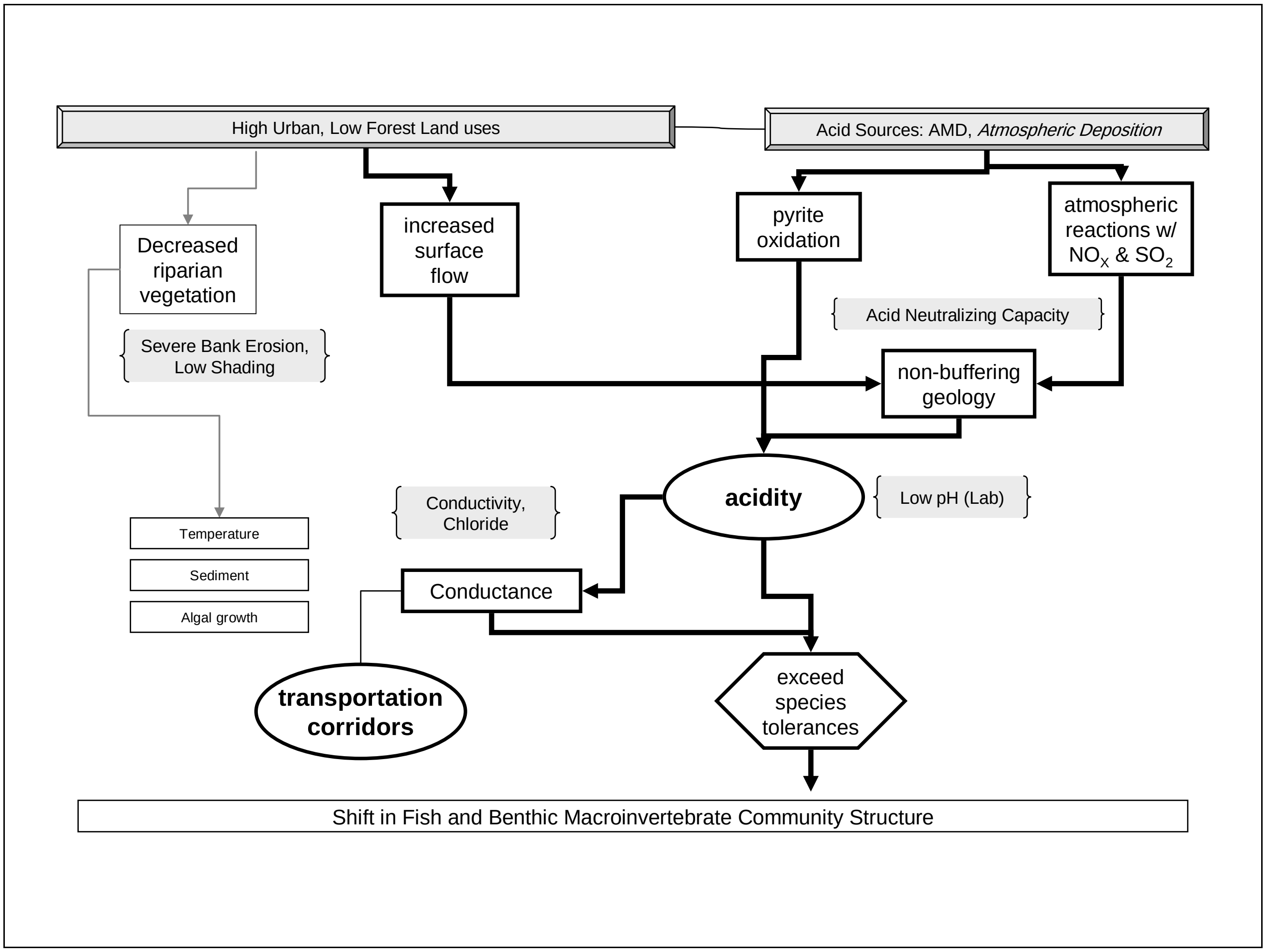

Figure 6. Final Causal Model for the Casselman River Watershed

5.0 Conclusions

Data suggest that acidity is the predominate cause of biological community degradation in the Casselman River watershed. Low pH results from both natural (e.g., low neutralizing capacity of geology and groundwater associated with sulfur bearing geology) and anthropogenic sources (atmospheric deposition and AMD). A secondary cause of biological degradation is the increased chloride concentrations resulting from non-point source run off of transportation corridors.

Based upon the results of the BSID process, the probable causes and sources of the biological impairments of the Casselman River are summarized as follows:

- The BSID process has determined that the biological communities in the Casselman River Watershed are likely degraded due to acidity related stressors. Acidity is indicated directly by the strong association of low pH and low Acid Neutralizing Capacity (ANC) with biological impairments. The BSID results confirm that the establishment of a pH TMDL was an appropriate management action to begin addressing the biological impairment in the Casselman River watershed.

- The BSID process has determined that the biological communities in the Casselman River Watershed are likely degraded due to inorganic pollutants (i.e., chlorides and conductivity). Impacts on water quality due to 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. Impervious surfaces and transportation land uses cause an increase in contaminant loads 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 analysis did not identify any nutrient stressors present and/or nutrient stressors showing a significant association with degraded biological conditions; therefore, the 2000 WQA for nitrogen and phosphorus was an appropriate management action.

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