Water Quality Analysis of Sediment for Town Creek, Allegany County, Maryland

FINAL

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

Submitted to:

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

September 2006

EPA Submittal Date: Sept. 29, 2006
EPA Approval Date: Dec. 27, 2006

Table of Contents

List of Figures

List of Tables

List of Abbreviations

BIBI	Benthic Index of Biotic Integrity
CBP P5	Chesapeake Bay Program Phase V
CWA	Clean Water Act
EOF	Edge-of-Field
EOS	Edge-of-Stream
EPA	Environmental Protection Agency
ETM	Enhanced Thematic Mapper
FIBI	Fish Index of Biologic Integrity
GIS	Geographic Information System
MDE	Maryland Department of the Environment
MBSS	Maryland Biological Stream Survey
NPS	Non-Point Source
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resource Conservation Service
NRI	Natural Resources Inventory
RESAC	Regional Earth Science Applications Center
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids
TM	Thematic Mapper
USGS	United Stated Geological Survey
WQA	Water Quality Analysis
WQIA	Water Quality Improvement Act
WQLS	Water Quality Limited Segment

EXECUTIVE SUMMARY

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency (EPA)'s 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. This list of impaired waters is commonly referred to as the "303(d) List". For each WQLS, 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 that water quality standards are being met (CWA, 2006).

Town Creek (basin code 02140512) was identified on the State's 1996 list of WQLSs as impaired by nutrients and sediments. In 2002 and 2004, Town Creek was also listed for impacts to biological communities (MDE, 2006a). A data solicitation for sediments was conducted by MDE, and all readily available data from the past five years have been considered. This document addresses the sediment impairment in Town Creek; the nutrient impairment is currently being addressed via a separate report and biological impairments will be addressed at a future date.

This water quality analysis (WQA) of the Town Creek watershed evaluates whether the watershed's forest normalized sediment load is above a level to support aquatic life. The watershed's forest normalized sediment load represents how many times greater the current watershed sediment load is than the all forested sediment load. Currently in Maryland, there are no specific numeric criteria that quantify the impact of sediment on the aquatic health of non-tidal stream systems. Therefore, to determine the assimilative capacity of the watershed stream system, a reference watershed approach was used and resulted in the establishment of a *sediment loading threshold* (Currey *et al.*, 2006). This threshold is based on a detailed analysis of sediment loads from watersheds that are identified as supporting aquatic life (i.e., reference watersheds) based on Maryland's biocriteria (Roth *et al*., 2000, Roth *et al.*, 1998 and Stribling *et al.*, 1998). The sediment loading threshold was determined to be approximately 3.3 times the sediment load of an all forested watershed.

The Town Creek Maryland 8-digit watershed was evaluated using two TMDL analysis segments, which include loads from both Maryland and Pennsylvania. The current watershed sediment load for TMDL Segment 1 is approximately 2.0 times the all forested condition, and TMDL Segment 2 is approximately 2.1 times the all forested condition. The forest normalized sediment loads for TMDL Segments 1 and 2 are well below the threshold of 3.3. This analysis indicates that in both segments sediment loads do not exceed levels that support aquatic health, and confirms that the Town Creek watershed is not impaired by elevated sediment loads to the stream system. Further analysis of watershed embeddedness and epifaunal substrate samples demonstrates that the distributions of observed values are not significantly different than embeddedness and epifaunal substrate values at sites supporting aquatic health (i.e., BIBI/FIBI $\geq$ 3.0). Embeddedness is the fraction of surface area of larger particles surrounded by finer sediments, and epifaunal substrate is the amount and variety of hard, stable substrates used by benthic macroinvertebrates. Therefore, there is no sediment impact to the Town Creek Watershed based on the water quality criteria established for aquatic health; thus, the current sediment loads support the designated uses of the Town Creek watershed (basin code 02140512).

Barring the receipt of contradictory data, this report will be used to support the sediment listing change for the Town Creek watershed from Category 5 ("waterbodies impaired by one or more pollutants requiring a TMDL") to Category 2 ("surface watersheds that are meeting some standards and have insufficient information to determine attainment of other standards") when MDE proposes the revision of Maryland's 303(d) List for public review in the future. Although the waters of Town Creek do not display signs of a sediment impairment, the State reserves the right to require future controls in the Town Creek watershed if evidence suggests sediments from the basin are contributing to downstream water quality problems.

1.0 INTRODUCTION

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency (EPA)'s 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. This list of impaired waters is commonly referred to as the "303(d) List". For each WQLS, 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 that water quality standards are being met (CWA, 2006).

In addition to the development of a TMDL, there are four other scenarios that may be used to address an impaired waterbody: 1) more recent data indicate that the impairment no longer exists (*i.e.*, water quality standards are being met); 2) more recent and updated water quality modeling demonstrates that the segment is now attaining standards; 3) refinements are made to water quality standards, or the interpretation of those standards, which result in standards being met; or 4) corrections are made to errors in the initial listing.

Town Creek (basin code 02140512) was first identified on the 1996 303(d) List, submitted to EPA by the Maryland Department of the Environment (MDE), as being impaired by nutrients and sediments. Biological impairment was identified on the 2002 and 2004 303(d) Lists (MDE, 2006a). This report provides a revised analysis that supports the removal of the sediments listing for Town Creek when the 303(d) List is revised; therefore, the aforementioned scenarios two and three most closely apply, with the qualification that the initial listing for sediment was suspect due to the lack of data and that the listing was based solely on best professional judgment. The biological impairments will be addressed at a future date and a water quality analysis (WQA) for nutrients is currently in development.

The remainder of this report lays out the general setting of the waterbody within the Town Creek watershed, presents a discussion of the water quality characteristics in the basin, and provides conclusions with regard to the current water quality characteristics and the current standards. The analysis will demonstrate that there is no sediment impact to the Town Creek Watershed based on the current water quality criteria indicative of aquatic health (i.e. BIBI/FIBI $\geq$ 3.0).

Currently in Maryland, there are no specific numeric criteria that quantify the impact of sediment on the aquatic health of non-tidal stream systems. Therefore, to determine the assimilative capacity of the watershed stream system, a reference watershed approach was used and resulted in the establishment of a *sediment loading threshold* (Currey *et al.*, 2006). This threshold is based on a detailed analysis of sediment loads from watersheds that are identified as supporting aquatic life (i.e., reference watersheds) based on Maryland's biocriteria (Roth *et al.*, 2000, Roth *et al.*, 1998 and Stribling *et al.*, 1998). The sediment loading threshold was determined to be approximately 3.3 times the sediment load of an all forested watershed.

2.0 GENERAL SETTING

2.1 Location and Description

The Town Creek watershed is located in the Upper Potomac Basin in Allegany County, Maryland (see Figure 1). The watershed covers 157 square miles of Bedford County, Pennsylvania and Allegany County, Maryland. In Maryland, the watershed covers approximately 43,409 acres in the Ridge and Valley Province, one fourth of which are preserved as state forests and game lands. Eighty percent of the watershed is forested. The rugged terrain, narrow farmable valley and lack of commercially available minerals have kept the watershed relatively undeveloped.

Town Creek begins in the Pennsylvania highlands and flows south, winding 52 miles through a narrow valley of mostly small farms before it joins the Potomac River near Old Town, Maryland. It enters Maryland at an elevation of 900 feet and drops 360 feet during its 30-mile journey to the Potomac. Stream gradient is rather low, averaging about 12 feet per mile. Town Creek consists of relatively large pool areas connected by productive riffle areas. The average width of the stream is about 50 feet. The stream bottom consists primarily of cobble and scoured bedrock.

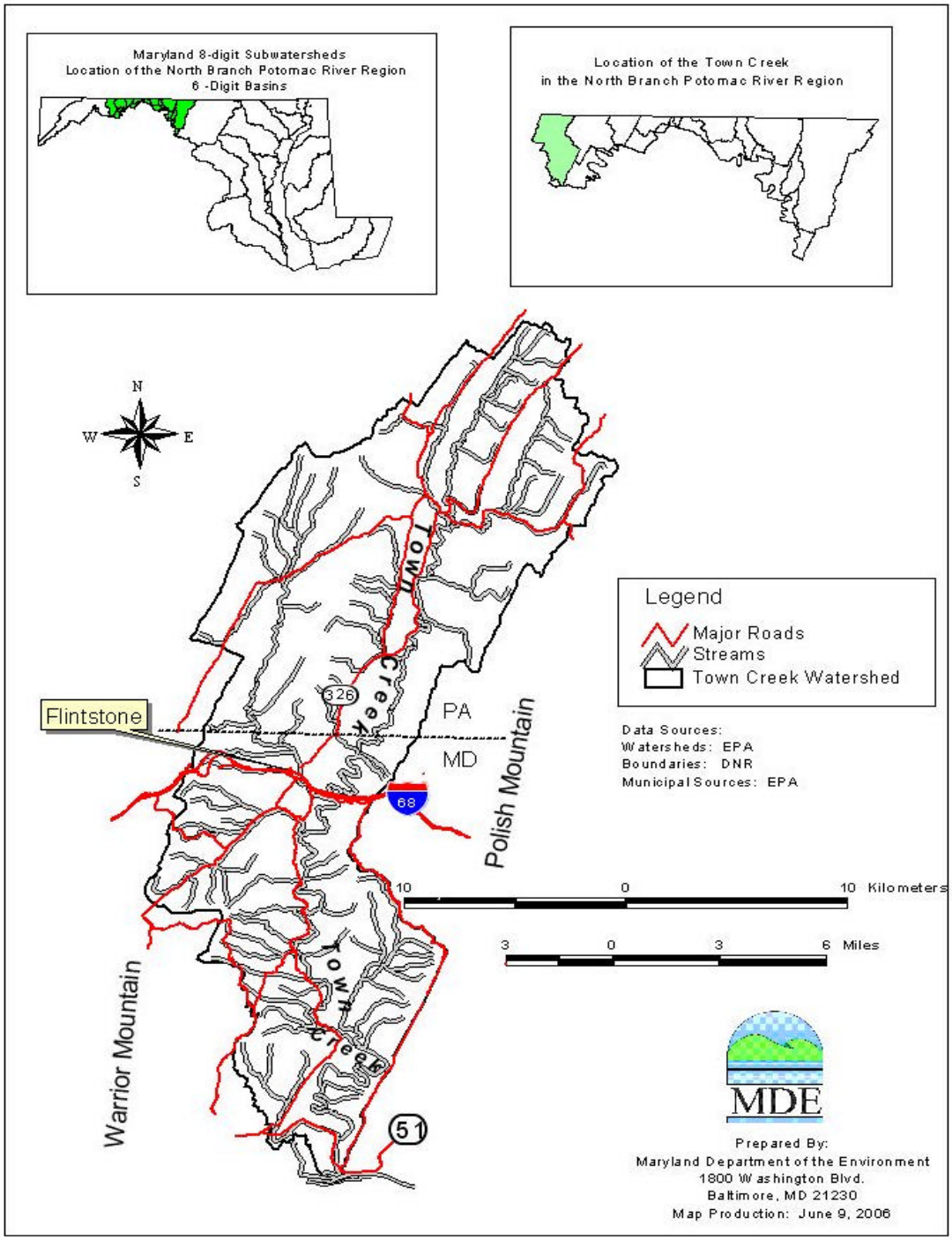

Figure 1: Town Creek Location Map and Monitoring Stations

2.2 Land Use

Land Use Methodology

The land use framework used to develop this WQA was originally developed for the Chesapeake Bay Program Phase V (CBP P5) watershed model.[1] This land use dataset is used because it is consistent with the methodology used to identify whether or not there is a sediment impact to a stream's aquatic health (fish and benthic community). The CBP P5 land use Geographic Information System (GIS) framework was based on two distinct layers of development. The first GIS layer was developed by the Regional Earth Science Applications Center (RESAC) at the University of Maryland and was based on satellite imagery (Landsat 7-Enhanced Thematic Mapper (ETM) and 5-Thematic Mapper (TM)) (Goetz et al., 2004). This layer did not provide the required level of accuracy that is especially important when developing agricultural land uses. In order to develop accurate agricultural land use calculations, the CBP P5 used county level U.S. Agricultural Census data as a second layer (USDA, 1982, 1987, 1992, 1997 and 2002).

Given that land cover classifications based on satellite imagery are likely to be least accurate at edges (*i.e.* boundaries between covers), the RESAC land uses bordering agricultural areas were analyzed separately. If the agricultural census data accounted for more agricultural use than the RESAC's data, appropriate acres were added to agricultural land uses from non-agricultural land uses. Similarly, if census agricultural land estimates were smaller than RESAC's, appropriate acres were added to non-agricultural land uses.

Adjustments were also made to the RESAC land cover to determine developed land uses. RESAC land cover was originally based on the United States Geological Survey (USGS) protocols used to develop the 2000 National Land Cover Database. The only difference between the RESAC and USGS approaches was RESAC's use of town boundaries and road densities to determine urban land covered by trees or grasses. This approach greatly improved the accuracy of the identified urban land uses, but led to the misclassification of some land adjacent to roads and highways as developed land. This was corrected by subsequent analysis. To ensure that the model accurately represented development over the simulation period, post-processing techniques that reflected changes in urban land use have been applied.

The result of this approach is that CBP P5 land use does not exist in a single GIS coverage; instead it is only available in a tabular format. The CBP P5 watershed model is comprised of 25 land uses. Most of these land uses are differentiated only by their nitrogen and phosphorus loading rates. The land uses are divided into 14 classes with distinct sediment erosion rates. Table 1 lists the CBP P5 generalized land uses and detailed land uses, which are classified by their erosion rates, and the acres of each land use in the Town Creek watershed. Details of the land use development methodology will be included in the report entitled "Chesapeake Bay Phase V Community Watershed Model: Tracking Nutrient and Sediment Loads on a Regional and Local Scale" (USEPA - CBP, 2006).

1 The EPA Chesapeake Bay Program developed the first watershed model in 1982. There have been many upgrades since the first phase of this model. The CBP P5 was developed to estimate flow, nutrient, and sediment loads to the Bay. The CBP P5 model is currently in the final stages of development.

Town Creek Watershed Land Use Distribution

Town Creek land use was evaluated separately for both Maryland and Pennsylvania. The predominant land use in both regions is forest (84% for Maryland and 90% for Pennsylvania). In Maryland the remaining land use is approximately 7% pasture, 5% crop, and 4% urban. In Pennsylvania, the remaining land use distribution is 6% crop, 3% pasture, and 2% urban.

A land cover use is provided in Figure 2 and a summary of the watershed land use areas is presented in Table 1.

Table 1: Land Use Percentage Distribution for Town Creek Watershed

		Maryland			Pennsylvania		
General Land Use	**Detailed Land Use**	**Area (Acres)**	**Percent**	**Grouped Percent of Total**	**Area (Acres)**	**Percent**	**Grouped Percent of Total**
Crop	Animal Feeding Operations	0.5	0.0		5.9	0.0	
	Hay	2,150.5	5.0		2,001.9	3.5	
	High Till	48.0	0.1		1,190.8	2.1	
	Low Till	50.1	0.1		30.2	0.1	
	Nursery	72.2	0.2	5.4	65.4	0.1	5.8
Extractive	Extractive	13.0	0.0	0.0	1.0	0.0	0.0
Forest	Forest	35,634.2	82.7		50,282.7	88.8	
	Harvested Forest	359.9	0.8	83.5	507.9	0.9	89.7
Pasture	Natural Grass	200.9	0.5		82.9	0.1	
	Pasture	2,778.3	6.4		1,396.7	2.5	
	Trampled Pasture	14.5	0.0	6.9	7.3	0.0	2.6
Urban	Urban: Barren	55.0	0.1		8.2	0.0	
	Urban: Imp	119.0	0.3		18.4	0.0	
	Urban: perv	1,585.8	3.7	4.1	1,022.7	1.8	1.9
	Total	43,082.0	100.0	100.0	56,622.1	100.0	100.0

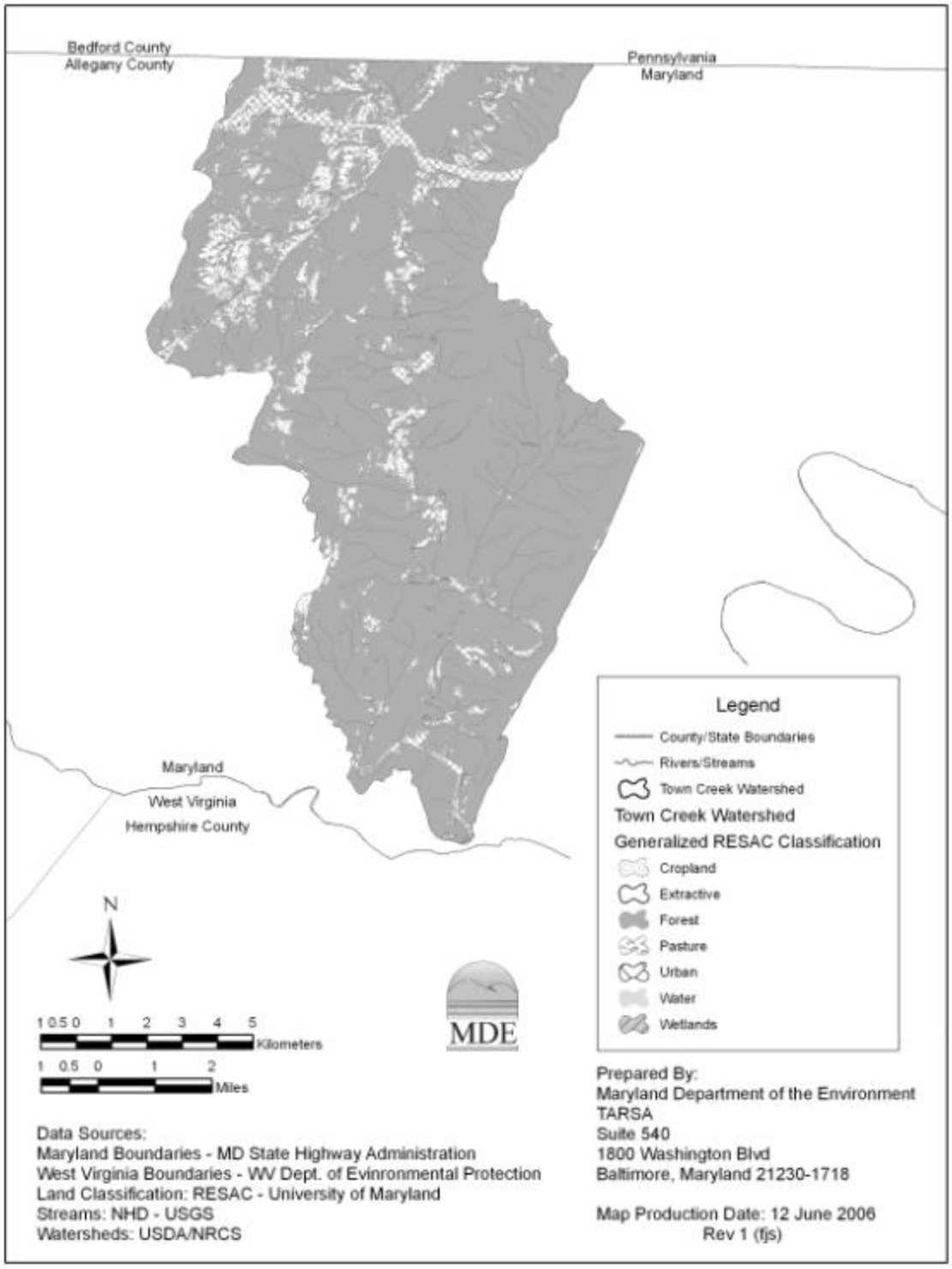

Figure 2: Land Use Map of the Town Creek Watershed

3.0 Water Quality Characterization

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 activities such as fishing, swimming, drinking water supply, protection of aquatic life, and shellfish propagation and harvest. Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. Criteria may differ among waters with different designated uses.

The Maryland Surface Water Use Designation for Town Creek is Use IV-P (Recreational Trout waters and public water supply) (COMAR, 2006a). The tributaries to Town Creek are designated as Use III-P (nontidal cold waters and public water supply) (COMAR, 2006b). The Town Creek watershed was originally listed on Maryland's 1996 303(d) List as impaired by elevated sediments from nonpoint sources, with supporting evidence cited in Maryland's 1996 305(b) report. The 1996 305(b) report did not directly state that elevated sediments were a concern, but the watershed was listed using best professional judgment (MDE, 2006a and DNR, 1996).

To provide a water quality characterization of the Town Creek watershed, it must first be determined how elevated sediment loads are linked to degraded stream water quality. While currently in Maryland there are no specific numeric criteria that quantify the impact of sediment on the aquatic health of non-tidal stream systems, it was outlined in the Maryland 2004 303(d) listing methodology that degraded stream water quality resulting in a sediment impairment is characterized by erosional impacts, depositional impacts, and decreased water clarity (MDE, 2006b). For this report, cumulative erosional and depositional impacts were evaluated based on two site-specific water quality parameters – embeddedness and epifaunal substrate condition. Embeddedness is the fraction of surface area of larger particles surrounded by finer sediments, and epifaunal substrate is the amount and variety of hard, stable substrates used by benthic macroinvertebrates. In general, low embeddedness and high epifaunal substrate are beneficial to the aquatic life of a stream system. The analysis was based on the data collected by the Maryland Biological Stream Survey (MBSS) program (see Table 2, Figure 3, and Appendix A). In addition to the characterizations outlined in the Maryland 2004 303(d) report, sediment load was also used to characterize the watershed. Sediment load is a quantitative measure of the total sediment transported to the highest order stream draining the watershed. A data solicitation for sediments was conducted by MDE, and all readily available data from the past five years have been considered.

Table 2: MBSS Round Two Data Stations in the Town Creek Watershed

Site	Date Sampled	Latitude (dec degrees)	Longitude (dec degrees)
TOWN-101-R-2000	10AUG2000	39.56792	78.5629
TOWN-102-R-2000	31JUL2000	39.61274	78.56364
TOWN-104-R-2000	15AUG2000	39.57412	78.56019
TOWN-104-R-2002	01JUL2002	39.60241	78.5651
TOWN-105-R-2000	10APR2000	39.66162	78.60308
TOWN-106-R-2000	31JUL2000	39.56027	78.53346
TOWN-108-R-2002	10JUL2002	39.62917	78.58569
TOWN-110-R-2000	15AUG2000	39.64441	78.55346
TOWN-110-R-2002	10JUL2002	39.63743	78.58308
TOWN-111-R-2002	13JUN2002	39.66348	78.54126
TOWN-113-R-2000	02AUG2000	39.61562	78.51271
TOWN-116-R-2002	10JUL2002	39.62233	78.5863
TOWN-201-R-2002	13AUG2002	39.54276	78.56956
TOWN-205-R-2002	16JUL2002	39.66325	78.61572
TOWN-408-R-2000	31AUG2000	39.70614	78.54473
TOWN-409-R-2000	05SEP2000	39.64447	78.55536
TOWN-412-R-2000	06SEP2000	39.6329	78.55664
TOWN-417-R-2002	16JUL2002	39.52652	78.54197
TOWN-419-R-2002	15JUL2002	39.69612	78.54888
TOWN-420-R-2002	15JUL2002	39.70044	78.53949

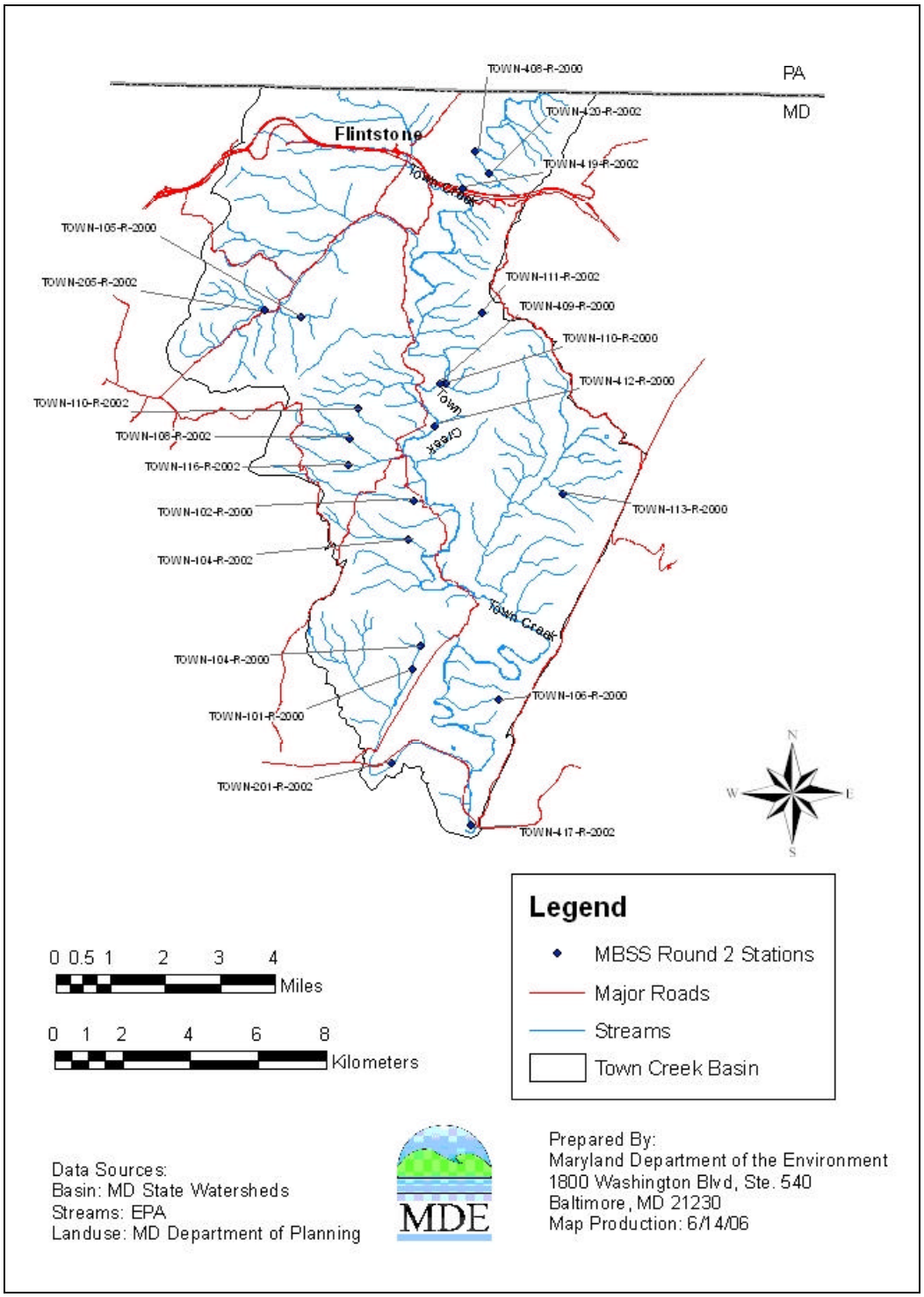

Figure 3: MBSS Stations in the Town Creek Watershed

Increasing embeddedness and decreasing epifaunal substrate condition scores indicate possible erosional or depositional impacts from elevated sediment loads. There are no numeric criteria for embeddedness and epifaunal substrate condition. Instead, monitoring results were compared to values observed in streams identified as having a healthy benthic community (*i.e.*, reference

sites). The benthic community was chosen for comparison because it is more directly impacted than are fish by the physical conditions of the streambed. Impacts or changes to the streambed could affect the benthic community by altering food quality, covering habitat, filling interstitial space, and altering water movement (Minshall, 1984).

Reference sites used for comparison were selected from the non-coastal physiographic region (Highland and Piedmont) and were required to have Benthic Index of Biotic Integrity (BIBI) scores significantly greater than 3.0 (based on a scale of 1 to 5). A threshold of 3.0 was selected because this is the level indicative of satisfactory water quality in Maryland's biocriteria (Roth *et al*., 2000, Roth *et al.*, 1998 and Stribling *et al.*, 1998). In determining if the site score is significantly greater than 3.0, a default confidence interval was applied that is based on the coefficient of variation from replicate samples. A comparison of MBSS sampling results to reference sites is presented in Figure 4 below.

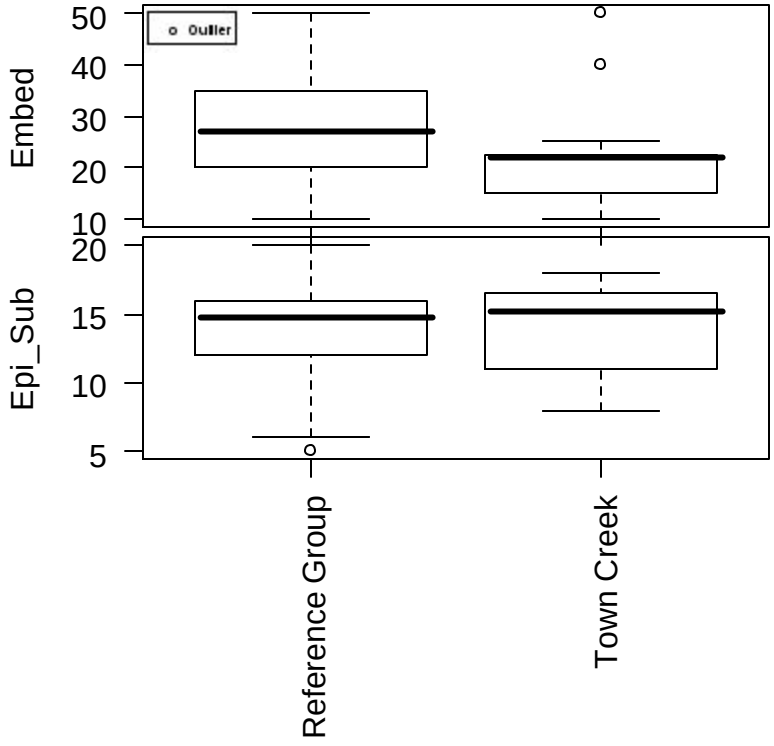

Figure 4: Town Creek Embeddedness and Epifaunal Substrate Compared to Reference Sites

MBSS sampling also includes turbidity samples, which provide an instantaneous measure for evaluating water clarity. These samples were collected during the summer low flow period and are only collected one time per site. Since the representativeness of these samples to the overall stream water quality is limited, they were not used in this analysis.

In the absence of specific numeric criteria that quantify the impact of a sediment on the aquatic health of non-tidal stream systems, the average annual sediment load is the only currently

available target that accounts for the potential effect of both water clarity and erosional/ depositional impacts to the aquatic community. Thus, it is used in this analysis as the final determining factor for assessing if there is a sediment impact to aquatic health. In general, an elevated sediment load results from increased Total Suspended Solids (TSS) concentrations with an effect of reduced water clarity in the water column. Sources of the increased sediment load (and TSS concentrations) are typically terrestrial and channel erosion. Increases in both sources potentially decrease water clarity and, based on stream transport capacity, increase the likelihood of depositional impacts, where an increase in the channel erosion load will result in physical alterations to the stream system. The combined effects of increased terrestrial and channel erosion are captured within the current watershed sediment load, which can be linked to the long term effects on aquatic health (i.e. water clarity, altered habitat through erosion and deposition).

The average annual watershed sediment load used in this analysis is an estimate from the CBP P5 model and provides a quantitative estimate of the sediment load to the highest order (largest) stream in the watershed. This sediment load is estimated for the rainfall driven sediment, which is the most significant sediment source in a non-tidal watershed. The watershed segmentation applied in the analysis is based on the CBP P5 model and results in two TMDL analysis segments for the Town Creek watershed (see Figure 5). TMDL Segment 1 represents the sediment loads transported from Pennsylvania to the Maryland state line via the Town Creek mainstem, and includes a small section of Maryland in the southeast corner of the watershed. TMDL Segment 2 represents the majority of the sediment loads generated in Maryland and includes the sediment loads from Pennsylvania that flow into Maryland in the northwest portion of the watershed.

Since there are no established numeric criteria for watershed sediment loads, the watershed sediment load in the Town Creek watershed was compared to loads estimated for reference watersheds. Reference watersheds were determined based on having Benthic and/or Fish Index of Biotic Integrity (BIBI/FIBI) average watershed scores significantly greater than 3.0 (based on a scale of 1 to 5). A threshold of 3.0 was selected because this is the level indicative of satisfactory water quality per Maryland's biocriteria (Roth *et al*., 2000; Roth *et al.*, 1998 and Stribling *et al.*, 1998). In determining if the average watershed score is significantly greater than 3.0, a 90% confidence interval was calculated for each watershed based on the individual MBSS sampling results.

Comparison of watershed sediment loads to loads from reference watersheds requires that the watersheds be similar in physical and hydrological characteristics. To satisfy this requirement, reference watersheds were selected only from the Highland and Piedmont physiographic regions. This region is consistent with the non-coastal region that was identified in the 1998 development of FIBI and subsequently used in the development of the BIBI (Roth *et al.*, 1998 and Stribling *et al.*, 1998). To control for the variability in soil type, rainfall, and topography, individual watershed sediment loads were normalized by their all forested condition sediment load. The normalization calculation divides the current watershed sediment load by the sediment load assuming an all forested condition. This resulting factor, the forest normalized sediment load, represents how many times greater the current watershed sediment load is than the all forested sediment load. A comparison of the Town Creek watershed forest normalized sediment load

(estimated as 2.0 and 2.1 for TMDL Segments 1 and 2 respectively) to the forest normalized reference sediment load (also referred to as the sediment loading threshold) is shown in Figure 6.

Finally, the distribution of land use for the Town Creek watershed was compared to the reference watersheds and determined to be within the ranges found in the reference watersheds. Comparison of the Town Creek land use to the range of land uses in the reference watersheds is illustrated in Figure 7.

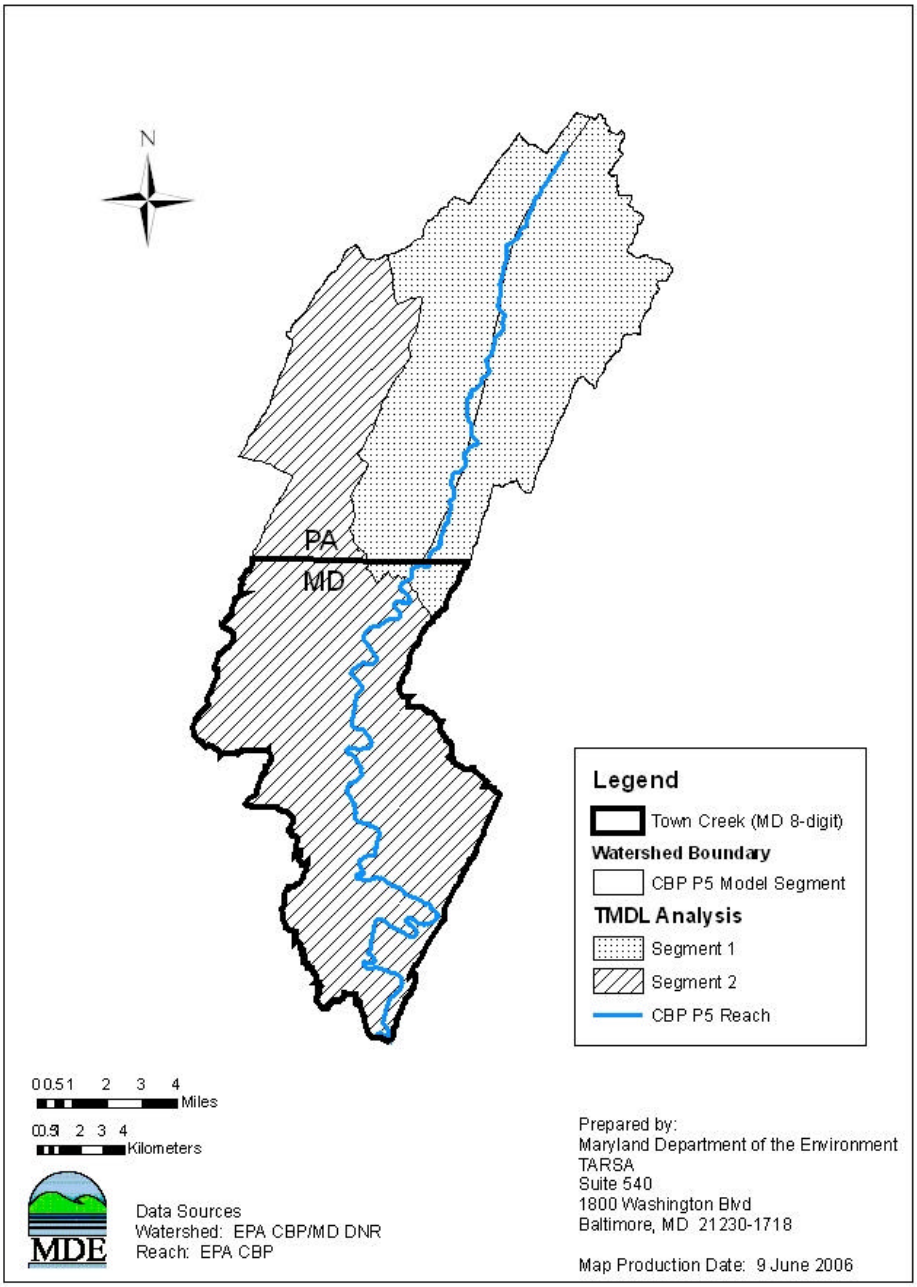

Figure 5: Town Creek Watershed Characterization Segmentation

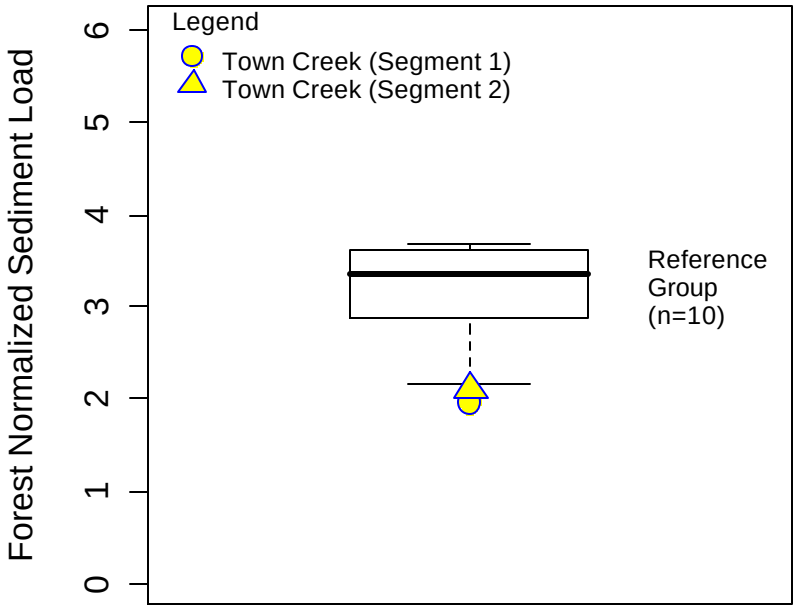

Figure 6: Town Creek Forest Normalized Sediment Load Compared to Reference Watershed Group

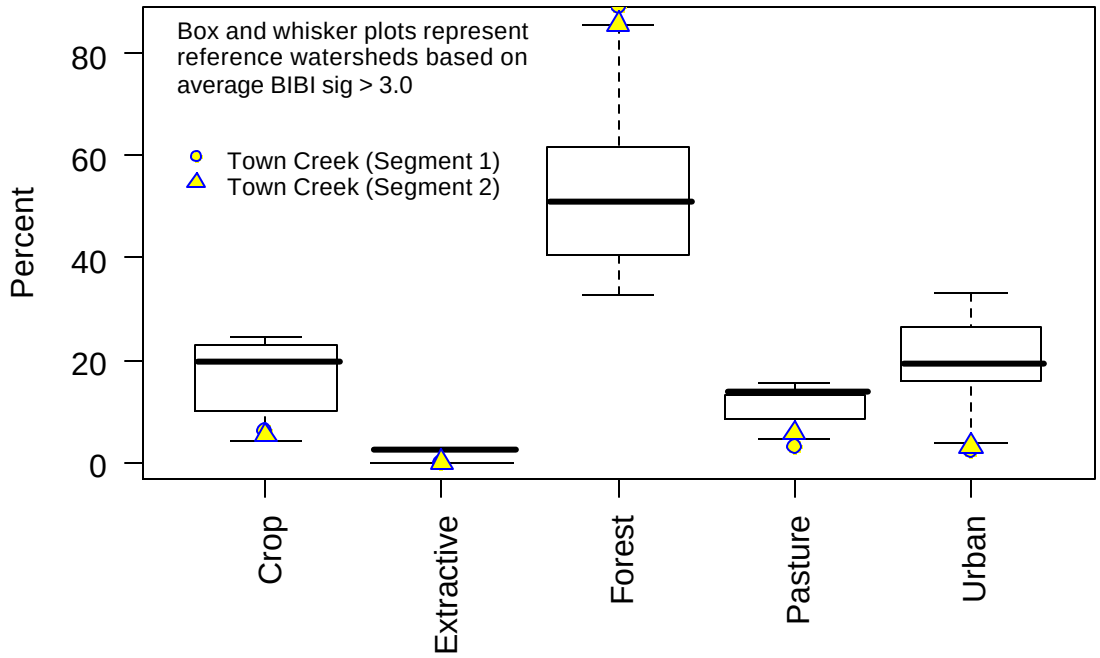

Figure 7: Town Creek Land Use Compared to Reference Watershed Group

4.0 Assessment of a Sediment Impact to Aquatic Health

This water quality analysis of the Town Creek watershed determines whether the watershed sediment load is above a level compatible with the support of aquatic life. Currently in Maryland there are no specific numeric criteria that quantify the impact of sediment on the aquatic health of non-tidal stream systems. Therefore, to determine the assimilative capacity of the watershed stream system, a reference watershed approach was used and resulted in the establishment of a sediment loading threshold (Currey *et al.*, 2006). This threshold is based on a detailed analysis of sediment loads from watersheds that are identified as supporting aquatic life (i.e., reference watersheds) based on Maryland's biocriteria (Roth *et al*., 2000, Roth *et al.*, 1998 and Stribling *et al.*, 1998). The sediment loading threshold was determined to be approximately 3.3 times the sediment load of an all forested watershed. This value is representative of watersheds in the Highland and Piedmont physiographic regions with land use distributions within the range of the reference watersheds.

The Town Creek watershed was evaluated using two watershed TMDL segments (see Figure 5). The forest normalized sediment load for TMDL Segment 1 is approximately 2.0, and TMDL Segment 2 is approximately 2.1 (See Appendices B and C for methodology and data respectively). Both are well below the sediment loading threshold of 3.3 as estimated from reference watersheds. This analysis indicates that in both TMDL segments, sediment loads are at levels that support aquatic health, and it confirms that the Town Creek watershed is not impaired by elevated sediment loads to the stream system. Further details can be found in Tables A-1 for reference watersheds and A-4 for Town Creek.

MBSS embeddedness and epifuanal substrate scores provide additional supporting evidence. A nonparametric statistical test comparing the Town Creek sites to the reference sites showed that the distributions were not significantly different ($p<0.1$) for either embeddedness or epifaunal substrate.

5.0 Conclusion

The WQA establishes that there is no adverse sediment impact to the stream aquatic community (fish and benthic). The watershed load does not exceed a level compatible with the support of aquatic health, and the watershed embeddedness and epifuanal substrate scores are not significantly different than values at sites supporting aquatic health. Therefore, there is no sediment impact to the Town Creek Watershed based on the established water quality criteria for aquatic health. The current sediment loads support the previously mentioned designated uses of the Town Creek watershed (basin code 02140512).

Barring the receipt of contradictory data, this report will be used to support the sediment listing change for the Town Creek watershed from Category 5 ("waterbodies impaired by one or more pollutants requiring a TMDL") to Category 2 ("surface watersheds that are meeting some standards and have insufficient information to determine attainment of other standards") when MDE proposes the revision of Maryland's 303(d) List for public review in the future. Although the waters of Town Creek do not display signs of sediment impacts, the State reserves the right to require future controls in the Town Creek watershed if evidence suggests sediments from the basin are contributing to downstream water quality problems.

REFERENCES

COMAR (Code of Maryland Regulations). 2006a. "26.08.02.08Q(6)(a)". http://www.dsd.state.md.us/comar/26/26.08.02.08.htm (accessed May, 2006).

_____. 2006b. "26.08.02.08(4)(a)". http://www.dsd.state.md.us/comar/26/26.08.02.07.htm (accessed May, 2006).

Currey, D. L, Kasko, A.A, Mandel, R., and M.J. Brush. 2006. "A Methodology for Addressing Sediment Impairments in Maryland's Non-tidal Rural Watersheds". *Maryland Department of the Environment Technical and Regulatory Service Administration*. http://www.mde.state.md.us/Programs/WaterPrograms/TMDL/Pub_Notice/index.asp (accessed in May, 2006).

CWA (Clean Water Act). 2006. "Federal Water Pollution Control Act. U.S. Code. 33 U.S.C. §§ 1251 et seq". §303(d)(1)(C). Amended: 2002. http://www.epa.gov/r5water/cwa.htm (accessed May, 2006).

DNR (Department of Natural Resources). 1996. "Maryland Water Quality Inventory, 1993-1995: A report on The Status of Natural Waters in Maryland Required by Section 305(b) of the Federal Water Pollution Control Act and Reported to the US Environmental Protection Agency and Citizens of the State of Maryland".

Goetz, S. J., Jantz, C. A., Prince, S. D., Smith, A. J., Wright, R., and D. Varlyguin. 2004. "Integrated Analysis of Ecosystem Interactions with Land Use Change: the Chesapeake Bay Watershed", in *Ecosystems and Land Use Change*, edited by R. S. DeFries, G. P. Asner and R. A. Houghton, 263-275. Washington, DC: American Geophysical Union.

MDE (Maryland Department of the Environment). 2006a. "2004 303(d) List Searchable Database". http://www.mde.state.md.us/Programs/WaterPrograms/TMDL/Maryland 303 dlist/303d_search/ (accessed May, 2006).

_____. 2006b. "Appendix C Listing Methodologies", in *2004 List of Impaired Surface Waters [303(d) List] and Integrated Assessment of Water Quality in Maryland Submitted in Accordance with Sections 303(d) and 305(b) of the Clean Water Act*. Original Publication Date: 2002. http://www.mde.state.md.us/Programs/WaterPrograms/TMDL/Maryland%20303%20dlist/final_2004_303dlist.asp (accessed May, 2006).

Minshall, G.W. 1984. "Aquatic Insect-substratum Relationships", in *The Ecology of Aquatic Insects*, edited by V.H. Resh and D.M. Rosenberg, 358-400. New York: Praeger.

Nusser, S. M., and J. J. Goebel. 1997. "The National Resources Inventory: A Long-Term Multi-Resource Monitoring Program". *Environmental and Ecological Statistics* 4: 181-204.

Roth, N., Southerland, M.T, Chaillou, J.C., Klauda, R., Kazyak, P.F., Stranko, S.A., Weisberg, S., Hall Jr., L., and R. Morgan II. 1998. "Maryland Biological Stream Survey: Development of a Fish Index of Biotic Integrity". *Environmental Management and Assessment* 51: 89-106.

Roth, N.E., Southerland, M.T., Chaillou, J.C., Kazyak, P.F., and S.A. Stranko. 2000. "Refinement and validation of a fish Index of Biotic Integrity for Maryland streams". *Versar, Inc*., Columbia, MD, with *Maryland Department of Natural Resources, Monitoring and Non-Tidal Assessment Division*. CBWP-MANTA-EA-00-2.

Stribling, J.B., Jessup, B.K., White, J.S., Boward, D., and M. Hurd. 1998. "Development of a Benthic Index of Biotic Integrity for Maryland Streams". *Tetra Tech, Inc*., Owings Mills, MD and *Maryland Department of Natural Resources, Monitoring and Non-Tidal Assessment Program*. CBWP-MANTA-EA-98-3.

USDA (U.S. Department of Agriculture). 1982. "1982 Census of Agriculture".

_____. 1987. "1987 Census of Agriculture".

_____. 1992. "1992 Census of Agriculture".

_____. 1997. "1997 Census of Agriculture".

_____. 2002. "2002 Census of Agriculture".

USDA – NRCS (U.S. Department of Agriculture – National Resources Conservation Service. 1983. "Sediment sources, yields, and delivery ratios". *National Engineering Handbook, Section 3, Sedimentation*. Washington, D.C: Government Printing Office.

_____. 2006. "State Soil Geographic (STATSGO) Database for Maryland". http://www.ncgc.nrcs.usda.gov/products/datasets/statsgo/index.html (accessed May, 2006).

USEPA – CBP (U.S. Environmental Protection Agency – Chesapeake Bay Program). 2006. *In Preparation*. "Chesapeake Bay Phase V Community Watershed Model: Tracking Nutrient and Sediment Loads on a Regional and Local Scale". *Summary document from Nutrient Subcommittee Workgroup*.

USEPA – OST (U.S. Environmental Protection Agency – Office of Science and Technology). 2000. "Nutrient Criteria Technical Guidance Manual: Rivers and Streams".

APPENDIX A – Watershed Characterization Data

Table A-1: Reference Watersheds

MD 8-digit Name[1]	MD 8-digit	FIBI n	BIBI n	FIBI	BIBI	Forest Normalized Sediment Load[2]
Deer Creek	2120202	28	28	Ind.	Pass	3.63
Broad Creek	2120205	10	10	Ind.	Pass	3.67
Little Gunpowder Falls	2130804	19	20	Ind.	Pass	3.26
Prettyboy Reservoir	2130806	11	11	Pass	Pass	2.87
Liberty Reservoir	2130907	31	31	Pass	Pass	3.28
S Branch Patapsco	2130908	10	10	Pass	Pass	3.57
Rocky Gorge Dam	2131107	10	10	Pass	Pass	3.43
Brighton Dam	2131108	11	11	Ind.	Pass	3.61
Town Creek	2140512	16	20	Ind.	Pass	2.17
Savage River	2141006	13	14	Pass	Pass	2.48
Median[3]						3.3
5th Percentile						3.6

Notes: 1. Potomac River Lower North Branch determined to be an outlier through statistical analysis and best professional judgment; Fifteen Mile Creek watershed removed because the majority of watershed is in Pennsylvania.

2. Forest Normalized Sediment Load based on Maryland watershed area only (Consistent with MBSS random monitoring data).
3. Median rounded down (3.36 to 3.3) as conservative estimate.
4. Ind.= Indeterminate.

Table A-2: Reference Watersheds Land Use

MD 8-digit Name	MD 8-digit	Crop	Extractive	Forest	Pasture	Urban
Deer Creek	2120202	23	0	50	11	16
Broad Creek	2120205	24	0	48	10	17
Little Gunpowder Falls	2130804	15	0	45	16	23
Prettyboy Reservoir	2130806	20	0	50	14	16
Liberty Reservoir	2130907	22	0	38	10	30
S Branch Patapsco	2130908	23	0	33	11	33
Rocky Gorge Dam	2131107	15	0	40	12	33
Brighton Dam	2131108	17	0	41	25	17
Town Creek	2140512	5	0	84	7	4
Savage River	2141006	5	0	86	4	5

Note: 1. All values have been rounded to nearest whole number percentage.

Table A-3: MBSS Data for Sites with BIBI sig > 3

MBSS Site	Epifaunal Substrate	Embeddedness
PRMO-110-R-2002	14	30
PRMO-115-R-2002	16	25
PRMO-202-R-2002	13	35
PRMO-304-R-2002	13	25
SENE-104-R-2001	10	25
UMON-119-R-2000	18	25
UMON-221-R-2000	16	30
UMON-230-R-2000	20	20
UMON-304-R-2000	16	30
DOUB-116-R-2002	16	20
DOUB-119-R-2002	12	35
DOUB-221-R-2002	14	35
DOUB-407-R-2002	8	45
CATO-104-R-2003	14	15
CATO-106-R-2003	14	30
CATO-214-R-2003	12	40
PRWA-103-R-2000	10	30
PRWA-122-R-2000	12	20
PRWA-124-R-2002	11	35
ANTI-113-R-2003	14	35
ANTI-208-R-2003	9	30
LCON-119-R-2004	15	25
LIKG-103-R-2004	18	20
LIKG-113-R-2004	16	25
LIKG-115-R-2004	8	42
LIKG-211-R-2004	16	30
PRAL-107-R-2001	14	15
PRAL-208-R-2001	16	10
SIDE-402-R-2001	16	15
SIDE-410-R-2001	16	20
FIMI-106-R-2000	12	10
FIMI-109-R-2000	17	10
FIMI-110-R-2000	14	10
FIMI-202-R-2000	14	10
FIMI-401-R-2000	17	10
FIMI-407-R-2000	18	10
TOWN-101-R-2000	11	25
TOWN-102-R-2000	10	10
TOWN-108-R-2002	15	20
TOWN-110-R-2000	15	10
TOWN-113-R-2000	11	15

MBSS Site	Epifaunal Substrate	Embeddedness
TOWN-116-R-2002	12	40
TOWN-205-R-2002	14	20
TOWN-408-R-2000	17	15
TOWN-409-R-2000	16	15
TOWN-412-R-2000	18	10
TOWN-417-R-2002	18	20
TOWN-419-R-2002	17	20
TOWN-420-R-2002	16	20
PRLN-104-R-2003	11	35
PRLN-107-R-2003	8	35
PRLN-108-R-2003	11	35
PRLN-109-R-2003	19	15
PRLN-113-R-2003	19	15
PRLN-115-R-2003	16	20
PRLN-119-R-2003	13	25
PRLN-122-R-2003	17	30
PRLN-201-R-2003	11	35
PRLN-306-R-2003	13	25
PRLN-316-R-2003	12	35
PRLN-318-R-2003	17	20
PRLN-321-R-2003	13	40
EVIT-102-R-2004	6	30
EVIT-110-R-2004	9	35
WILL-105-R-2004	10	35
WILL-109-R-2004	10	35
WILL-115-R-2004	15	30
WILL-120-R-2004	14	30
WILL-404-R-2004	10	25
GEOR-103-R-2003	16	45
GEOR-106-R-2003	13	35
GEOR-107-R-2003	12	35
GEOR-114-R-2003	12	35
GEOR-211-R-2003	12	30
PRUN-102-R-2001	14	45
PRUN-107-R-2001	17	15
PRUN-205-R-2001	18	15
SAVA-103-R-2002	12	30
SAVA-104-R-2002	19	15
SAVA-105-R-2002	13	35
SAVA-116-R-2002	15	25
SAVA-117-R-2002	12	20
SAVA-119-R-2002	18	15
SAVA-120-R-2002	17	15

MBSS Site	Epifaunal Substrate	Embeddedness
SAVA-206-R-2002	12	20
SAVA-308-R-2002	18	20
SAVA-312-R-2002	18	15
SAVA-401-R-2002	18	20
SAVA-410-R-2002	17	25
SAVA-414-R-2002	18	20
YOUG-101-R-2001	13	20
YOUG-106-R-2001	16	15
YOUG-107-R-2001	15	38
YOUG-117-R-2001	11	35
YOUG-123-R-2001	14	20
YOUG-208-R-2001	16	25
YOUG-221-R-2001	18	35
YOUG-320-R-2001	13	25
LYOU-110-R-2004	5	50
LYOU-118-R-2004	9	50
LYOU-219-R-2004	8	50
DCRL-109-R-2004	6	40
CASS-104-R-2000	17	15
CASS-106-R-2000	12	35
CASS-307-R-2000	14	25

Table A-4: Town Creek MBSS data

Site	Date Sampled Summer	Date Sampled Spring	FIBI	BIBI	Epifaunal Substrate	Percent Embeddedness
TOWN-101-R-2000	10AUG2000	23MAR2000	2.00	3.75	11	25
TOWN-102-R-2000	31JUL2000	23MAR2000	1.67	4.00	10	10
TOWN-104-R-2000	15AUG2000	23MAR2000	1.00	3.25	8	15
TOWN-104-R-2002	01JUL2002	26MAR2002	1.00	3.25	12	25
TOWN-105-R-2000	NS	10APR2000	NS	2.75	NS	NS
TOWN-106-R-2000	31JUL2000	23MAR2000	NS	2.50	NS	NS
TOWN-108-R-2002	10JUL2002	26MAR2002	1.33	4.00	15	20
TOWN-110-R-2000	15AUG2000	10APR2000	2.33	3.75	15	10
TOWN-110-R-2002	10JUL2002	26MAR2002	NS	1.75	NS	NS
TOWN-111-R-2002	13JUN2002	26MAR2002	NS	1.50	NS	NS
TOWN-113-R-2000	02AUG2000	23MAR2000	1.00	3.50	11	15
TOWN-116-R-2002	10JUL2002	26MAR2002	1.67	4.00	12	40
TOWN-201-R-2002	13AUG2002	26MAR2002	2.67	2.50	11	50
TOWN-205-R-2002	16JUL2002	27MAR2002	4.33	4.00	14	20
TOWN-408-R-2000	31AUG2000	03APR2000	4.33	3.75	17	15
TOWN-409-R-2000	05SEP2000	10APR2000	5.00	3.75	16	15
TOWN-412-R-2000	06SEP2000	10APR2000	4.33	3.75	18	10
TOWN-417-R-2002	16JUL2002	27MAR2002	4.67	4.25	18	20
TOWN-419-R-2002	15JUL2002	10APR2002	4.33	4.00	17	20
TOWN-420-R-2002	15JUL2002	10APR2002	4.33	4.25	16	20
Average			2.87 ± 0.49	3.41 ± 0.23		

Notes: 1. Summer sampling includes FIBI, epifaunal substrate, and embeddedness.
2. Spring sampling includes BIBI.
3. NS = No sample collected.

APPENDIX B – Watershed Sediment Loads Calculation Methodology

General Load Estimation Methodology

Nonpoint source sediment loads in the Town Creek watershed are estimated based on the *edge-of-stream (EOS) calibration target loading rates* from the CBP P5 model. This approach is based on the fact that not all of the *edge-of-field* (EOF) sediment load is delivered to the stream or river (some of it is stored on fields down slope, at the foot of hillsides, or in smaller rivers or streams that are not represented in the model). To calculate the actual EOS loads, a *sediment delivery ratio* (the ratio of sediment reaching a basin outlet compared to the total erosion within the basin) is used. Details of the methods used to calculate sediment load have been summarized in the report entitled "Chesapeake Bay Phase V Community Watershed Model: Tracking Nutrient and Sediment Loads on a Regional and Local Scale" (USEPA - CBP, 2006).

Edge-of-Field Target Erosion Rate Methodology

EOF target erosion rates for agricultural land uses and forested land use were based on erosion rates determined by the National Resource Inventory (NRI). NRI is a statistical survey of land use and natural resource conditions conducted by the Natural Resources Conservation Service (NRCS) (USDA – NRCS, 2006). Sampling methodology is explained by Nusser and Goebel (1997).

Estimates of average annual erosion rates for pasture and cropland are available on a county basis at five year intervals, starting in 1982. Erosion rates for forested land uses are not available on a county basis from NRI, however for the purpose of the CBP Phase 2 watershed model, NRI calculated average annual erosion rates for forested land uses on a watershed basis. These rates are still being used as targets in the CBP P5 model.

The average value of the 1982 and 1987 surveys was used as the basis for EOF target loads. The erosion rates from this period do not reflect best management practices (BMPs) or other soil conservation policies introduced in the wake of the effort to restore the Chesapeake Bay.

Sediment Delivery Ratio: The base formula for calculating sediment delivery ratios in the CBP P5 model is the same as the formula used by the NRCS (USDA-NRCS, 1983).

$$DF = 0.417762 * A^{-0.134958} - 0.127097 \qquad \text{(Equation B-1)}$$

where
DF (delivery factor) = the sediment delivery ratio
A = drainage area in square miles

In order to account for the differences in sediment loads due to distance traveled to the stream, the CBP P5 model uses the sediment delivery ratio. Land use specific sediment delivery ratios were calculated for each river segment using the following procedure:

(1) Mean distance of each land use from the river reach was calculated;

(2) Sediment delivery ratios for each land use were calculated (drainage area in Equation B-1 was assumed to be equal to the area of a circle with radius equal to the mean distance between the land use and the river reach).

Edge-of-Stream Loads

Edge-of-Stream loads are the loads that actually enter the river reaches (*i.e.* the mainstem of a watershed). Such loads represent not only the erosion from the land but all of the intervening processes of deposition on hillsides and sediment transport through smaller rivers and streams. Table C-1 lists the nonpoint source sediment budget for Town Creek in Maryland and Pennsylvania, respectively.

APPENDIX C – Town Creek Watershed Sediment Loads

Sediment loads were estimated for the current condition and the all forested watershed condition. The forest normalized sediment load (representing how many times greater the current watershed sediment load is than the all forested sediment load) is calculated as the current watershed sediment load divided by the all forested sediment load. A summary of the current sediment budget and the forest normalized sediment loads for Town Creek are presented in table C-1 and C-2.

Table C-1: Sediment Budget for the Town Creek Watershed

		Segment 1			Segment 2		
General Land Use	**Description**	**Load (Ton/Yr)**	**Percent**	**Grouped Percent of Total**	**Load (Ton/Yr)**	**Percent**	**Grouped Percent of Total**
Crop	Animal Feeding Operations	11.4	0.3	40.3	1.0	0.0	23.2
	Hay	505.4	11.5		462.6	14.7	
	High Till	1,118.60	25.5		199.9	6.3	
	Low Till	18.3	0.4		24	0.8	
	Nursery	111.5	2.5		43.9	1.4	
Extractive	Extractive	0	0.0	0	17.3	0.5	0.5
Forest	Forest	1,975.90	45.1	50.4	1,272.00	40.4	48.5
	Harvested Forest	231	5.3		255.3	8.1	
Pasture	Natural Grass	21.8	0.5	5.6	136.6	4.3	14.7
	Pasture	211.3	4.8		311.3	9.9	
	Trampled Pasture	10.5	0.2		15.5	0.5	
Urban	Urban: Barren	2.6	0.1	3.7	54.7	1.7	13.1
	Urban: Imp	10	0.2		124.8	4.0	
	Urban: perv	149.9	3.4		232.3	7.4	
	Total	4378.2	100.0	100.0	3151.2	100.0	100.0

Table C-2: Sediment Loads for the Town Creek Watershed

Watershed	Segment	Area (Acres)	Current Watershed Sediment Load (Ton/Yr)	All Forested Load (Ton/Yr)	Forest Normalized Sediment Load
Town Creek	1	42,215.0	4,378.1	2,243.5	2.0
Town Creek	2	57,489.2	3,151.2	1,502.6	2.1