Water Quality Analysis of Eutrophication for the Potomac River Washington County Watershed, Washington County, Maryland

FINAL

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Table of Contents

List of Figures

List of Tables

List of Abbreviations

BSID	Biological Stressor Identification
COMAR	Code of Maryland Regulations
CWA	Clean Water Act
Chla	Chlorophyll *a*
DNR	Department of Natural Resources
DO	Dissolved Oxygen
EPA	United States Environmental Protection Agency
EPT	Ephemeroptera, Plecoptera, and Trichoptera
MBSS	Maryland Biological Stream Survey
MDE	Maryland Department of the Environment
MDP	Maryland Department of Planning
MGP	Million Gallons Per Day
MGS	Maryland Geological Survey
mg/l	Milligrams Per Liter
NPDES	National Pollution Discharge Elimination System
NRCS	National Resources Conservation Service
PCB	Polychlorinated biphenyls
SSURGO	Soil Survey Geography
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TSI	Trophic State Index
USGS	United States Geological Survey
WTP	Water Treatment Plant
WQA	Water Quality Analysis
WQLS	Water Quality Limited Segment
µg/l	Micrograms Per Liter

EXECUTIVE SUMMARY

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (EPA) implementing regulations direct each state to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. This list of impaired waters is commonly referred to as the 303(d) List. 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 (CFR 2010). 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 Potomac River Washington County watershed (basin code 02140501) was identified on the Integrated Report under Category 5 as impaired by nutrients and suspended sediments (1996), methylmercury (2002), evidence of biological impacts (2002), and polychlorinated biphenyls (PCBs) in fish tissue (2008) (MDE 2008a). All impairments are listed for non-tidal streams with the exception of the 2002 listing for methylmercury in the Potomac River Dam 4 impoundment. The 2008 Integrated Report specified that the designated use impaired by nutrients and sediment is Aquatic Life and Wildlife. The 1996 suspended sediment listing was refined in the 2008 Integrated Report to a listing for total suspended solids. Similarly, the 1996 nutrients listing was refined in the 2008 Integrated Report, and phosphorus was identified as the specific impairing substance. Consequently, for the purpose of this report the terms "nutrients" and "phosphorus" will be used interchangeably. The 2008 Integrated Report also restricted the impairment for biological impacts to 1st through 4th order streams in the watershed. The listings for sediments, impacts to biological communities, methylmercury, and PCBs in fish tissue will be addressed separately at a future date.

A data solicitation for information pertaining to pollutants, including nutrients, in the Potomac River Washington County watershed was conducted by MDE in November 2009, and all readily available data from the period of 1998 through 2008 have been considered. Currently, there are no specific numeric criteria for nutrients in Maryland's water quality standards for the Aquatic Life Designated Use. Nutrients typically do not have a direct impact on aquatic life; rather, they have indirect impacts through excessive algal growth leading to low dissolved oxygen. Therefore, the evaluation of potentially eutrophic conditions due to nutrient over-enrichment will be based on whether nutrient-related parameters (i.e., dissolved oxygen levels and chlorophyll *a* concentrations) are found to impair the Aquatic Life Use in the Potomac River Washington County watershed.

An analysis of the Department of Natural Resources (DNR) CORE/TREND biological monitoring data confirms that the Potomac River mainstem in Washington County is supporting its aquatic life use. Analyses of observed dissolved oxygen (DO) and chlorophyll *a* (Chla) concentrations in the Potomac River mainstem show no substantial violation of either the DO criterion or Maryland's narrative criterion with respect to Chla. Therefore, it is concluded that

nutrients in general and phosphorus in particular are not impairing the Aquatic Life Use in the Potomac River mainstem in Washington County.

The 1st to 4th order streams in the Potomac River Washington County watershed are listed for biological impacts. Recently, MDE developed a biological stressor identification (BSID) methodology to identify the most probable cause(s) of the existing biological impairments in 1st through 4th order streams in Maryland 8-digit watersheds based on the suite of available physical, chemical, and land use data (MDE 2009a). The BSID analysis for the Potomac River Washington County watershed identifies sediment, instream habitat, and water chemistry as possible biological stressors. The BSID did not identify either total phosphorus or ortho-phosphate as possible biological stressors. The BSID analysis did show one nutrient stressor – total nitrogen (TN) – having a possible association (19% of stream miles) with degraded biological conditions in the Potomac River Washington County watershed. However this is not taken as sufficient evidence of an eutrophication problem unless there is positive evidence the 1st through 4th order streams in the watershed are nitrogen limited. An analysis of the TN:TP ratio of BSID samples clearly confirms the presumption, expressed in the identification of phosphorus as the specific impairing substance, that streams in the watershed are phosphorus limited. Therefore, since the BSID determined that biological impairments in 1st through 4th order streams in the Potomac River Washington County watershed are not associated with phosphorus, it is concluded that excess eutrophication is not a cause of the biological impairments in the watershed.

The results of the BSID study, combined with the analysis of recent water quality data (i.e., dissolved oxygen, chlorophyll *a,* and nutrients) presented in this report, indicate that the Potomac River Washington County watershed is not being impaired by nutrients. This WQA supports the conclusion that a TMDL for nutrients is not necessary to achieve water quality standards for aquatic life in the Potomac River Washington County. Although the waters of the Potomac River Washington County do not display signs of eutrophication, the State reserves the right to require future controls if evidence suggests that nutrients from the watershed are contributing to downstream water quality problems. For instance, reductions may be required by the forthcoming Chesapeake Bay TMDL, currently under development and due to be established by EPA by the end of 2010.

Barring the receipt of contradictory data, this report will be used to support a revision of the phosphorus listing for the Potomac River Washington County watershed, from Category 5 ("waterbody is impaired, does not attain the water quality standard, and a TMDL is required") to Category 2 ("waterbodies meeting some [in this case nutrients-related] water quality standards, but with insufficient data to assess all impairments") when MDE proposes the revision of the Integrated Report. The listings for sediments, impacts to biological communities, methylmercury, and PCBs in fish tissue will be addressed separately at a future date.

1.0 INTRODUCTION

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (EPA) implementing regulations direct each state to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. This list of impaired waters is commonly referred to as the 303(d) List. For each WQLS, the State is required 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 (CFR 2010).

A segment identified as a WQLS may not require the development and implementation of a TMDL if more recent information invalidates previous findings. The most common scenarios that would eliminate the need for a TMDL are: 1) analysis of more recent data indicating that the impairment no longer exists (i.e., water quality standards are being met); 2) results of a more recent and updated water quality modeling which demonstrates that the segment is attaining standards; 3) refinements to water quality standards or to the interpretation of those standards accompanied by analysis demonstrating that the standards are being met; or 4) identification and correction of errors made in the initial listing.

The Potomac River Washington County (basin code 02140501) was identified on the Integrated Report under Category 5 as impaired by nutrients and suspended sediments (1996), methylmercury and evidence of biological impacts (2002), and polychlorinated biphenyls (PCBs) in fish tissue (2008) (MDE 2008a). The 2008 Integrated Report specified that the designated use impaired by nutrients and sediment is Aquatic Life and Wildlife ("Aquatic Life Use"). The 1996 suspended sediment listing was refined in the 2008 Integrated Report to a listing for total suspended solids. Similarly, the 1996 nutrients listing was refined in the 2008 Integrated Report, and phosphorus was identified as the specific impairing substance. Consequently, for the purpose of this report the terms "nutrients" and "phosphorus" will be used interchangeably. The 2008 Integrated Report also restricted the impairment for biological impacts to 1st through 4th order streams in the watershed. The listings for sediments, impacts to biological communities, methylmercury, and PCBs in fish tissue will be addressed separately at a future date.

This report provides an analysis of recent data that supports the removal of the nutrients (phosphorus) listing for the Potomac River Washington County watershed when MDE proposes the revision of the State's Integrated Report. The remainder of this report lays out the general setting of the Potomac River Washington County watershed area, presents a discussion of the water quality characteristics in the basin in terms of the existing water quality standards for aquatic life relating to nutrients, and presents an analysis of the available nutrient data. This analysis supports the conclusion that the waters of the Potomac River Washington County watershed do not display signs of eutrophication or nutrient over-enrichment.

2.0 GENERAL SETTING

Location

The Potomac River Washington County watershed is located in the Upper Potomac River sub-basin (021405) and covers approximately 85 square miles. The mainstem flows 68 miles from Hancock, MD southeastward to the Shenandoah River, creating the border between Maryland and West Virginia. The watershed consists of streams that drain directly to the mainstem of the Potomac River, including Camp Spring Run, Ditch Run, Downey Branch, and Greenspring Run (Figure 1).

Geology/Soils

The Potomac River Washington County watershed lies within the Eastern Valley and Ridge Physiographic Province and is characterized by numerous ridges and valleys that run generally northeast to southwest (Schmidt 1993). The Ridge and Valley Province, which extends from South Mountain in eastern Washington County to Dans Mountain in western Allegany County, contains strongly folded and faulted sedimentary rocks. In the eastern part of the Ridge and Valley Province in Washington County, a wide, open valley called the Great Valley, or the Hagerstown Valley, is formed on Cambrian and Ordovician age carbonate rocks. In Washington County west of Powell Mountain, a more rugged terrain has developed on shale and sandstone bedrock which ranges in age from Silurian to Mississippian. Some of the valleys in this region are underlain by Silurian and Devonian age limestones. (MGS 1981). Limestones and shales, are susceptible to erosion and dissolution from ground water, creating surface sinkholes and underground caverns and streams (NRCS 1996).

The soil makeup of the watershed is very complex and includes the Hagerstown-Duffield-Clarksburg series (35% of total) and the Berks-Weikert-Bedington series (17%). These series tend to form deep and very deep, well drained soils with moderate to moderately rapid permeability (NRCS 1996, 2009).

Land Use

The Potomac River Washington County watershed contains primarily forest land use (46%). Agricultural land use (34%) is secondary and supports livestock/feeding, cropland, and pasture/hay operations. Urban land use contributes 13% and water 7% to the land use distribution (Figure 2) (MDP 2002).

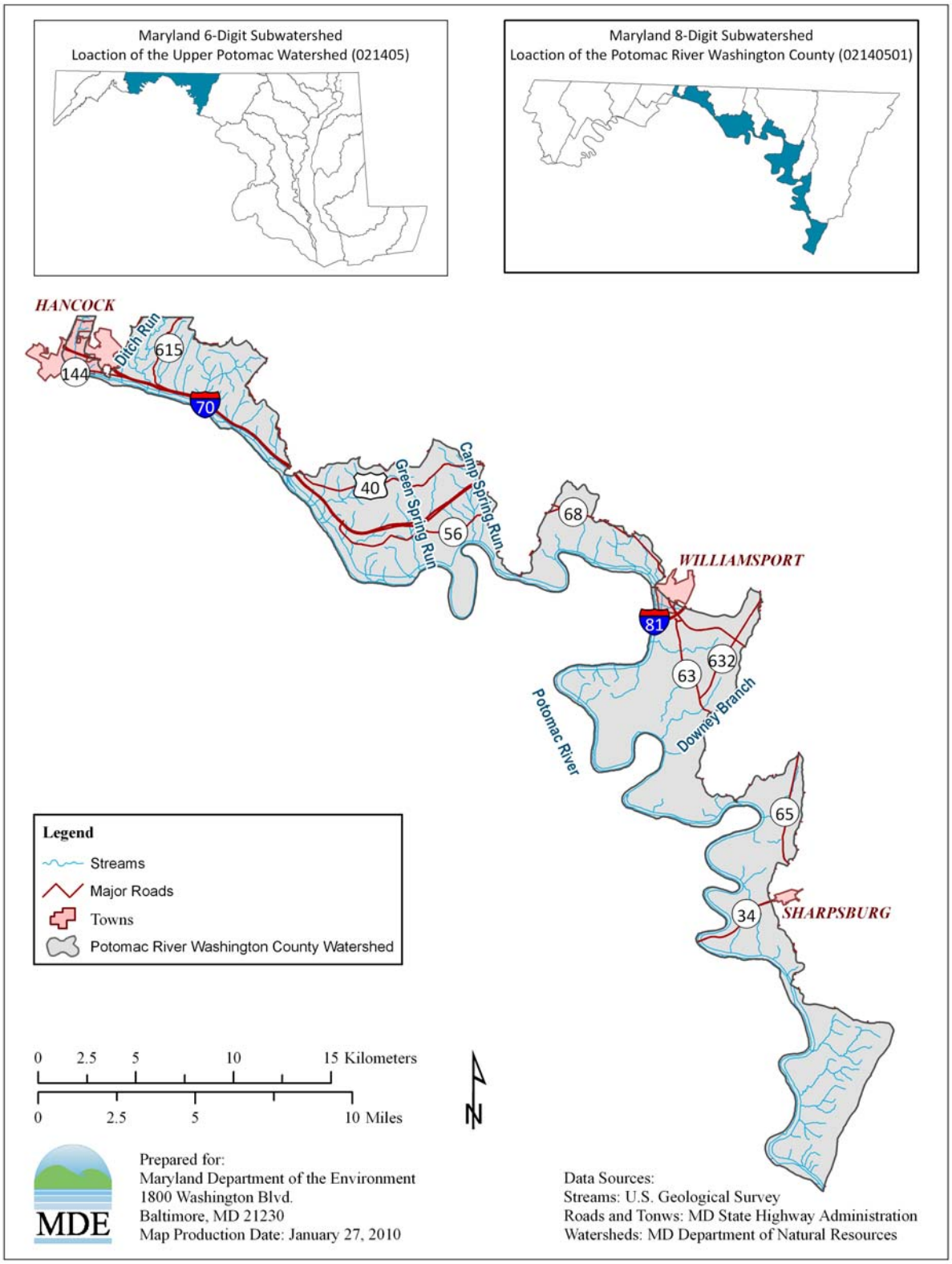

Figure 1. Location Map of the Potomac River Washington County Watershed

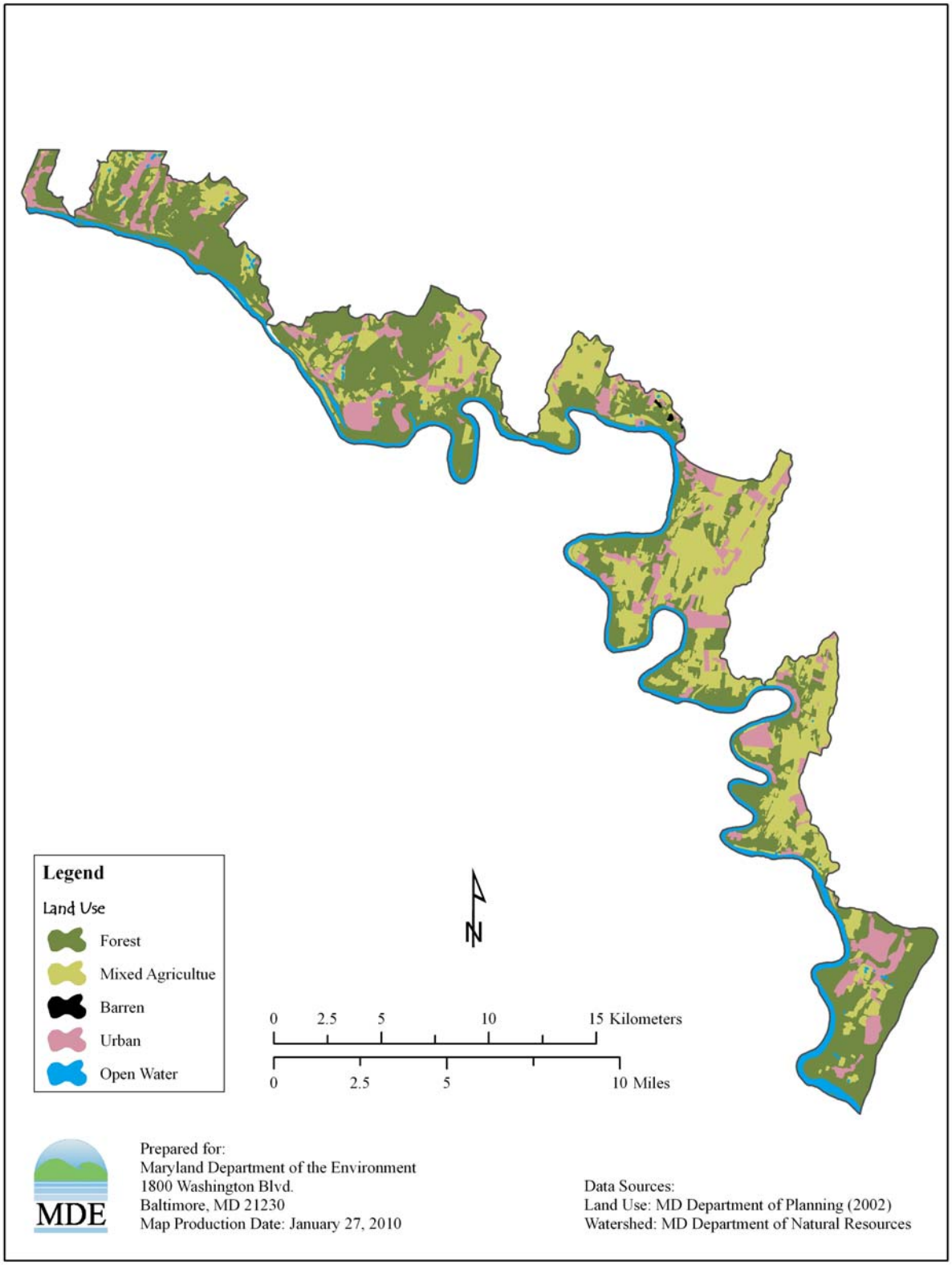

Figure 2. Land Use Map of the Potomac River Washington County Watershed

Point Sources

There are 6 industrial point source facilities with permits regulating their discharges in the Potomac River Washington County. None of these facilities have National Pollution Discharge Elimination Systems (NPDES) permits regulating the discharge of nutrients.

3.0 WATER QUALITY CHARACTERIZATION

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for the Potomac River in Washington County and all tributaries including the Chesapeake and Ohio Canal, Ditch Run, Greenspring Run and Downey Branch have been designated as Use I-P – *water contact recreation, protection of aquatic life, and public water supply*. Camp Spring Run has been designated as Use III-P – *nontidal cold water and public water supply* (COMAR 2008a,b,c).

A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. Designated uses include support of aquatic life, primary or secondary contact recreation, drinking water supply, and shellfish propagation and harvest. Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. The criteria developed to protect the designated use may differ and are dependent on the specific designated use(s) of a waterbody.

Currently, there are no specific numeric criteria for nutrients to protect the Aquatic Life Use in Maryland's water quality standards. Therefore, the evaluation of potentially eutrophic conditions due to nutrient over-enrichment will be based on whether nutrient-related parameters (i.e., dissolved oxygen levels and chlorophyll *a* concentrations) are found to impair designated uses in the Potomac River Washington County. The dissolved oxygen (DO) concentration to protect Use I-P waters "may not be less than 5 milligrams per liter (mg/l) at any time" and to protect Use III-P waters "may not be less than 5 mg/l at any time, with a minimum daily average of not less than 6 mg/l" (COMAR 2008d). Elevated chlorophyll *a* concentrations, a measure of algal growth, may indicate poor water quality that cannot support a waterbody's designated uses and may constitute a nuisance condition. Maryland's general narrative criterion prohibits pollution of waters of the State by any material in amounts sufficient to create a nuisance or interfere with designated uses (COMAR 26.08.02.03B(2)). The water quality data presented in this section will show that DO concentrations in the mainstem Potomac River Washington County meet these criteria, and that Maryland's narrative criteria for chlorophyll *a* are also met.

In addition to the DO and chlorophyll *a* data analysis, the results of a new biological stressor identification (BSID) analysis demonstrate that any biological impairment in the 1st through 4th order streams in the watershed is not likely caused by nutrient enrichment. Instead, the analysis suggests that the degradation to biological communities in the Potomac River Washington County watershed is associated with urban and agricultural sources causing alterations to the flow regime and increased sediment deposition. Elevated levels of sulfate, chlorides, and conductivity were also linked with degraded biological conditions (MDE 2009b).

A data solicitation was conducted by MDE in 2009, and all readily available water quality data from the time period of 1998 through 2008 were considered for this analysis. Water quality data were collected by the DNR CORE/TREND network between January 1998 and June 2007 and by the DNR MBSS program in 2000, 2002, 2003, and 2004. MDE also sampled at one CORE/TREND station (POT1830) between October 2000 and September 2002, and at three other stations between January 2008 and December 2008. The United States Geological Survey (USGS) collected data at one station between October 2000 and August 2002.

3.1 Potomac River Washington County Watershed Monitoring Stations

A total of 33 water quality monitoring stations were used to characterize the Potomac River Washington County watershed. The locations of the water quality monitoring stations are shown in Figure 3, and their geographical coordinates are listed in Table 1. Figures 4 through 7 provide graphical representation of the collected data for the parameters discussed below.

Thirty-one biological/physical habitat monitoring stations from the MBSS program round one and two data collection were used to characterize the Potomac River Washington County watershed in Maryland's 2008 Integrated Report. The BSID analysis used the 26 biological/physical habitat monitoring stations from the MBSS program round two data collection (see Figure 3 and Table 1).

Biological data was also collected at two CORE/TREND stations on the mainstem Potomac River.

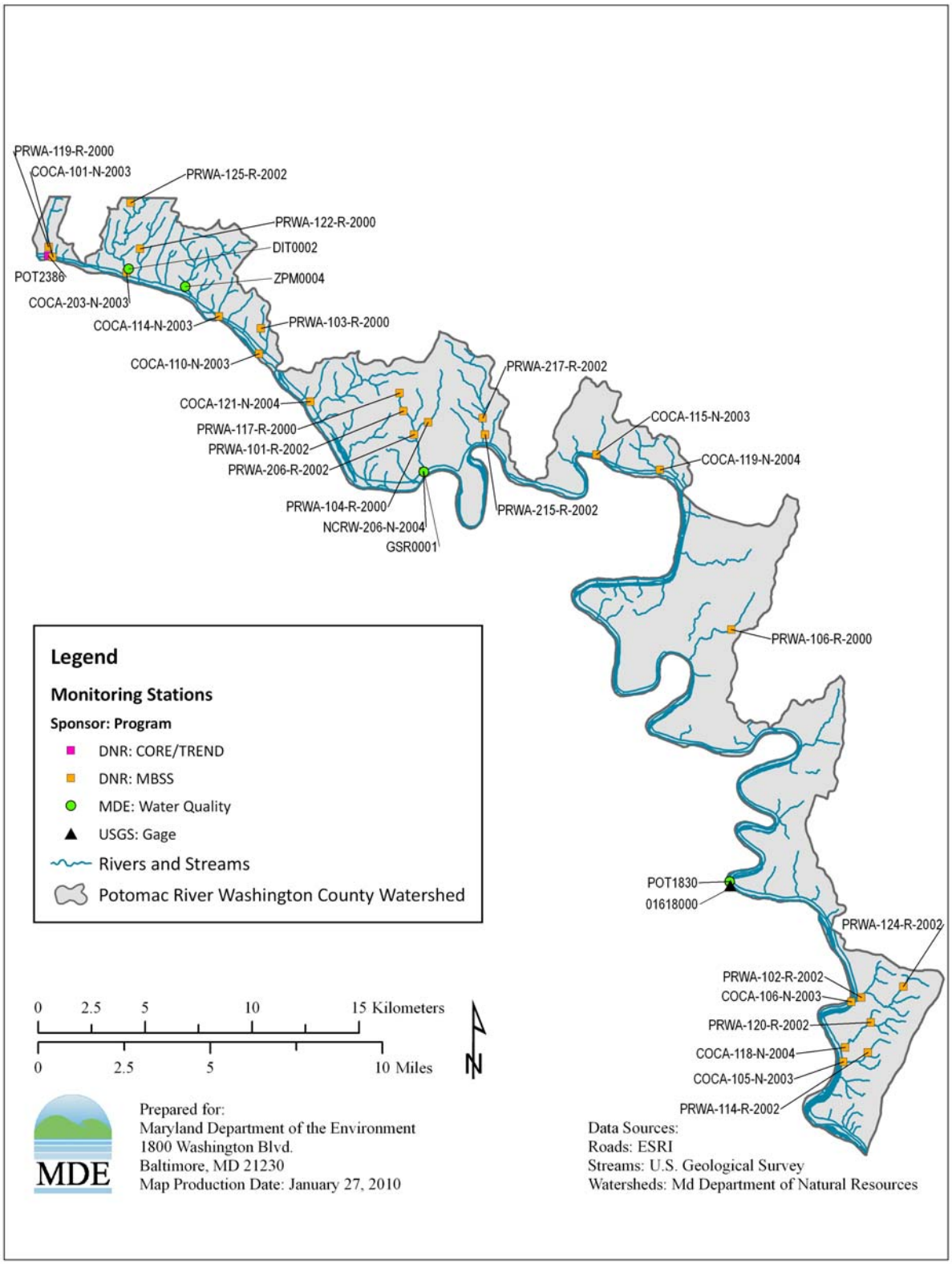

Figure 3. Water Quality Stations in Potomac River Washington County Watershed

Table 1: Water Quality Stations in Potomac River Washington County Watershed Monitored During 1998-2008

Station Number	Sponsor	Site Type	Location	Latitude (Decimal Degree)	Longitude (Decimal Degree)
POT1830	DNR	CORE/TREND	Potomac River	39.4365	-77.8018
POT2386	DNR	CORE/TREND	Potomac River	39.6974	-78.1763
COCA-101-N-2003	DNR	MBSS R2	Potomac River UT9	39.6969	-78.1738
COCA-105-N-2003	DNR	MBSS R2	Potomac River UT15	39.3608	-77.7392
COCA-106-N-2003	DNR	MBSS R2	Potomac River UT17	39.3862	-77.7352
COCA-110-N-2003	DNR	MBSS R2	Potomac River UT8	39.6572	-78.0607
COCA-114-N-2003	DNR	MBSS R2	Potomac River UT24	39.6727	-78.0827
COCA-115-N-2003	DNR	MBSS R2	Potomac River UT23	39.6161	-77.8764
COCA-118-N-2004	DNR	MBSS R2	Potomac River UT16	39.3670	-77.7383
COCA-119-N-2004	DNR	MBSS R2	Potomac River UT31	39.6100	-77.8417
COCA-121-N-2004	DNR	MBSS R2	Potomac River UT30	39.6372	-78.0325
COCA-203-N-2003	DNR	MBSS R2	Ditch Run	39.6906	-78.1335
NCRW-206-N-2004	DNR	MBSS R2	Green Spring Run	39.6083	-77.9706
PRWA-101-R-2002	DNR	MBSS R2	Green Spring Run	39.6337	-77.9817
PRWA-102-R-2002	DNR	MBSS R2	Potomac River UT17	39.3881	-77.7298
PRWA-103-R-2000	DNR	MBSS R2	Potomac River UT8	39.6679	-78.0598
PRWA-104-R-2000	DNR	MBSS R2	Green Spring Run UT1	39.6290	-77.9682
PRWA-106-R-2000	DNR	MBSS R2	Downey Branch	39.5429	-77.8021
PRWA-114-R-2002	DNR	MBSS R2	Potomac River UT15	39.3649	-77.7260
PRWA-117-R-2000	DNR	MBSS R2	Green Spring Run	39.6413	-77.9838
PRWA-119-R-2000	DNR	MBSS R2	Potomac River UT9	39.7011	-78.1761
PRWA-120-R-2002	DNR	MBSS R2	Potomac River UT16	39.3776	-77.7245
PRWA-122-R-2000	DNR	MBSS R2	Potomac River UT10	39.7009	-78.1262
PRWA-124-R-2002	DNR	MBSS R2	Potomac River UT17	39.3928	-77.7070
PRWA-125-R-2002	DNR	MBSS R2	Ditch Run UT2	39.7202	-78.1317
PRWA-206-R-2002	DNR	MBSS R2	Green Spring Run	39.6238	-77.9757
PRWA-215-R-2002	DNR	MBSS R2	Camp Spring Run	39.6241	-77.9371
PRWA-217-R-2002	DNR	MBSS R2	Camp Spring Run	39.6311	-77.9384
DIT0002	MDE	Water Quality	Ditch Run	39.6922	-78.1324
GSR0001	MDE	Water Quality	Green Spring Run	39.6081	-77.9703
POT1830	MDE	Water Quality	Potomac River	39.4365	-77.8018
ZPM0004	MDE	Water Quality	Unnamed Tributary	39.6851	-78.1014
01618000	USGS	Gage	Potomac River	39.4347	-77.8014

The potential impact of eutrophication on water quality is best measured during the growing season, May through October. Water quality data for the mainstem of Potomac River and smaller-order streams will be analyzed separately. The impact of eutrophication on smaller-order streams in the watershed will be evaluated on the basis of the BSID analysis, which

provides necessary and sufficient conditions for determining whether phosphorus is a potential stressor of the biological community in smaller-order streams.

3.2 Dissolved Oxygen

DNR collected samples for its CORE/TREND program in the mainstem Potomac River Washington County from January 1998 through June 2007 and for its MBSS program in tributaries during the summers of 2000 and 2002 - 2004. MDE collected samples in the mainstem from October 2000 through September 2002 and in several tributaries in 2008. USGS mainstem samples are available for October 2000 through August 2002. Samples taken from the mainstem during the growing season (May through October) show DO concentrations ranging from 6.4 to 12.1 mg/l. Given that all samples have DO concentrations above the Use I criterion of 5 mg/l, MDE considers that the water quality standard for DO is being met in the mainstem Potomac River in Washington County.

MDE collected 14 samples during the growing season at three stations on smaller-order tributaries to the Potomac River. Only one of the samples had a DO concentration below 5 mg/l. The median concentration was 9.0 mg/l and the average concentration was 8.5 mg/l. Twenty field measurements of DO were made as part of the MBSS program. Three of these had DO concentrations below 5 mg/l. The field notes for these three samples report that the DO measurements were made in a dry stream or in stagnant pools of a dry or intermittent stream. These low DO concentrations are therefore not representative of permanent flowing streams in the watershed. Excluding these unrepresentative samples, only one out of 31 samples from the 1st through 4th order streams in the Potomac River Washington County watershed had DO concentrations less than 5 mg/l. Given the low frequency of the occurrence of DO concentrations below 5 mg/l, MDE considers that the water quality standard for DO is being met in the 1st through 4th order streams in the Potomac River in Washington County watershed.

The DO data are presented graphically in Figure 4 and in tabular form in Appendix A.

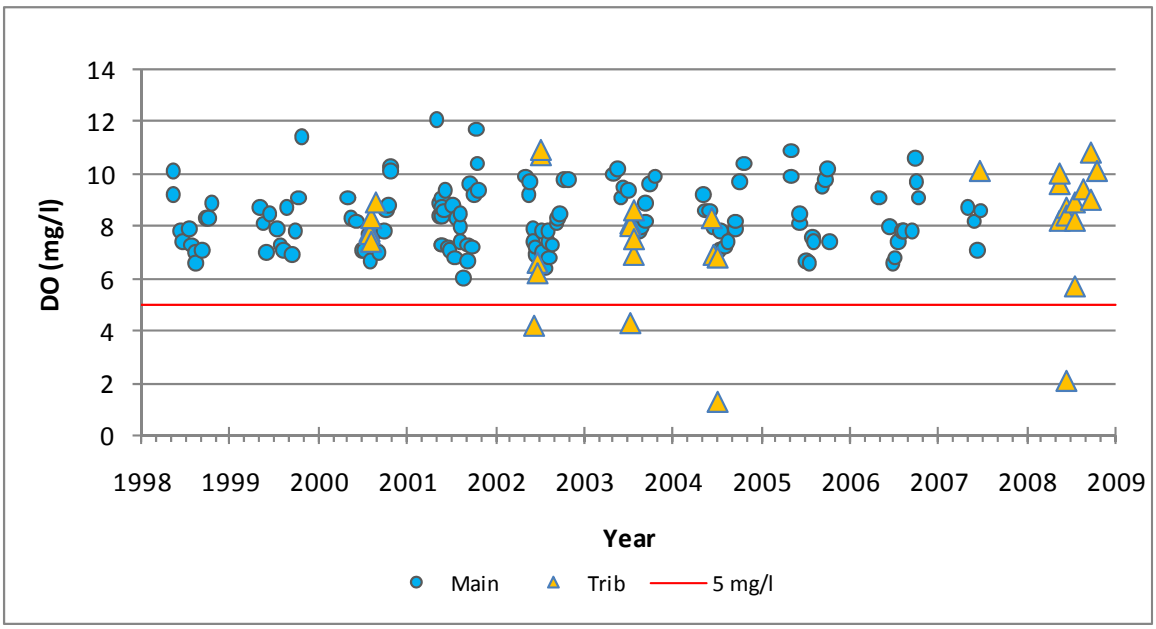

Figure 4: Potomac River Washington County Dissolved Oxygen Data for Growing Season Periods May 1998 through October 2008

3.3 Chlorophyll *a*

Currently, Maryland water quality standards do not specify numeric criteria for chlorophyll *a*. However, pollution of waters of the State by any material in amounts sufficient to create a nuisance or interfere with designated uses is prohibited (COMAR 26.08.02.03B(2)). Elevated chlorophyll *a* concentrations, a measure of algal growth, may indicate poor water quality that cannot support a waterbody's designated uses and may constitute a nuisance condition. Nuisance levels of algae can interfere with uses related to recreational activities such as fishing, boating, and aesthetic appreciation. High chlorophyll *a* levels can also present taste, odor, and treatment problems in water supply systems.

Narrative water quality criteria are an important component of the State's water quality standards, but are difficult to incorporate into quantitative water quality or TMDL analyses. In the case of free-flowing non-tidal waters, there is an insufficient understanding of the relationship between chlorophyll *a* concentrations and the waterbody's support of the Aquatic Life Use. However, the Code of Maryland Regulations (COMAR) includes narrative criteria for acceptable chlorophyll *a* levels in tidal waters. Maryland's numeric interpretation of these criteria for application in estuarine waters, as described in previously approved nutrient TMDLs, is as follows:

> The chlorophyll *a* concentration goal used by the State in estuarine TMDL analyses is based on guidelines set forth by Thomann and Mueller (1987) and by the EPA Technical Guidance Manual for Developing Total Maximum Daily Loads, Book 2, Part 1 (1997). The chlorophyll *a* narrative criterion (COMAR 26.08.02.03-3C(10)) states: "Chlorophyll *a* - Concentrations of chlorophyll *a* in free-floating microscopic aquatic plants (algae) shall not exceed levels that result in ecologically undesirable consequences that would

> render tidal waters unsuitable for designated uses." The Thomann and Mueller guidelines acknowledge that "'Undesirable levels of phytoplankton [chlorophyll *a*] vary considerably depending on water body." MDE has determined, per Thomann and Mueller, that it is acceptable to maintain chlorophyll *a* concentrations below a maximum of 100 µg/L, and to target, with some flexibility depending on waterbody characteristics, a 30-day rolling average of approximately 50 µg/L (with some flexibility depending on waterbody characteristics). (MDE 2006)

Maryland has also developed guidelines for application of the narrative criteria in drinking water reservoirs. The guidelines, as described in previously approved TMDLs, are as follows:

> The chlorophyll *a* endpoints selected for public water supply reservoirs are (a) a ninetieth-percentile instantaneous concentration not to exceed 30 µg/l in the surface layers, and (b) a 30-day moving average concentration not to exceed 10 µg/l in the surface layers. The concentration of 10 µg/l corresponds to a score of approximately 53 on the Carlson's Trophic State Index (TSI). This is at the boundary of mesotrophic and eutrophic conditions, which is an appropriate trophic state at which to manage these reservoirs. Mean chlorophyll *a* concentrations exceeding 10 µg/l are associated with peaks exceeding 30 µg/l, which in turn are associated with a shift to blue-green assemblages, which present taste, odor and treatment problems (Walker 1984). Achieving these chlorophyll *a* endpoints should thus safeguard such reservoirs from nuisance algal blooms. (MDE 2008b)

Using the chlorophyll *a* targets for tidal waters and public water supply reservoirs described above as screening values for non-tidal waters, the following data analysis reflects an absence of excessive algal growth in the Potomac River Washington County , as indicated by low chlorophyll *a* concentrations in comparison with those values.

Samples taken from the mainstem by DNR and MDE during growing season (May through October) show an average chlorophyll *a* concentration of 4 µg/l. Observed concentrations range from 0.1 to 49.3 µg/l, with only 4 out of 120 samples greater than 30 µg/l. The 90^{th} percentile concentration is 9.4 µg/l, well below the 30 µg/l threshold that indicates in reservoirs nuisance levels of Chla. Because high concentrations are less likely to persist in free-flowing rivers where hydrological conditions change frequently, the reservoir thresholds are likely to be more conservative when applied to free-flowing streams.

Only five chlorophyll *a* samples are available for smaller-order tributaries in the Potomac River Washington County watershed during growing season, with observed values ranging from 0.6 to1.5 µg/l. These samples were taken in 2008 by MDE. Overall, the monitoring data values suggest that chlorophyll *a* concentrations are not causing any nuisance in the Potomac River Washington County watershed or interfering with the designated uses of its waters. The chlorophyll *a* data are presented graphically in Figure 5 and in tabular form in Appendix A.

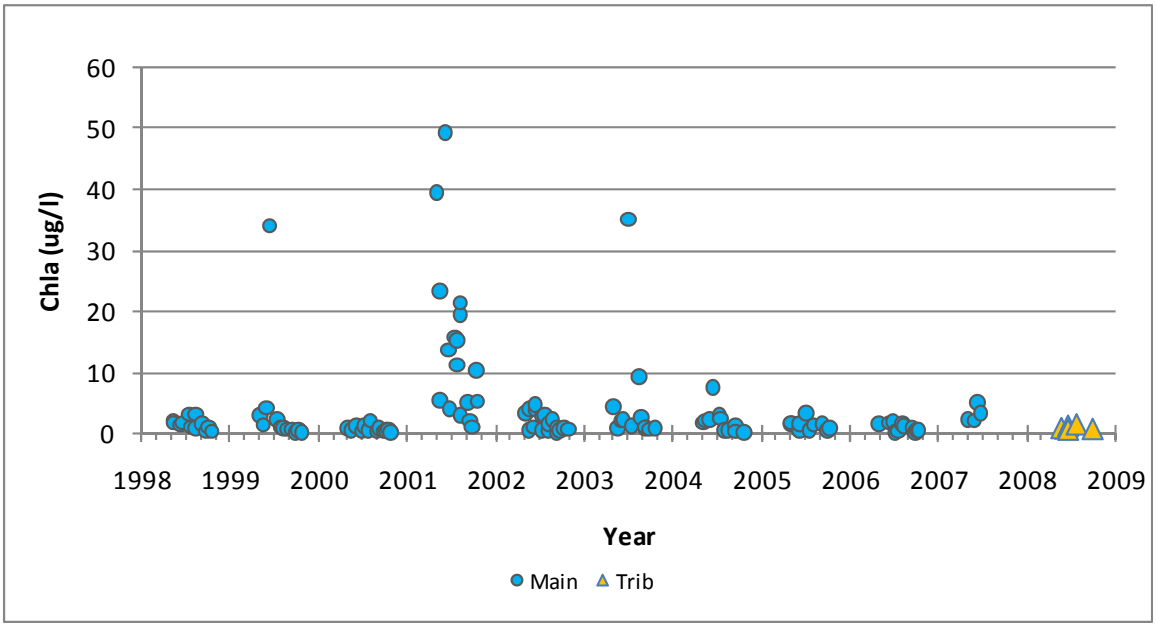

Figure 5: Potomac River Washington County Chlorophyll *a* Data for Growing Season Periods May 1998 through October 2008

3.4 Nutrients

In the absence of State water quality standards with specific numeric limits for nutrients to support aquatic life, evaluation of potentially eutrophic conditions is based on whether nutrient-related parameters (i.e., dissolved oxygen levels and chlorophyll *a* concentrations) are found to impair the designated uses in the Potomac River Washington County watershed. Consequently, the nutrients data presented in this section are for informational purposes only.

Total nitrogen (TN) and total phosphorus (TP) data for the Potomac River Washington County watershed have been analyzed as part of this study. The results are presented here for informational purposes, graphically in Figures 6 and 7, and in tabular form in Appendix A. In the mainstem, DNR, MDE, and USGS data show TN concentrations during the growing season (May through October) ranging from 0.40 to 2.71 mg/l and TP concentrations ranging from 0.01 to 0.12 mg/l.

MDE also sampled several tributaries during the 2008 growing season. These data show TN concentrations ranging from 0.17 mg/l to 2.79 mg/l and TP concentrations ranging from 0.01 to 0.04 mg/l.

Nitrogen and phosphorus are essential nutrients for algae growth. If one nutrient is available in great abundance relative to the other, then the nutrient that is less available limits the amount of plant matter that can be produced; this is known as the "limiting nutrient." The amount of the abundant nutrient does not matter because both nutrients are needed for algae growth. In general, a Nitrogen:Phosphorus (TN:TP) ratio in the range of 5:1 to 10:1 by mass is associated with plant growth being limited by neither phosphorus nor nitrogen. If the TN:TP ratio is greater

than 10:1, phosphorus tends to be limiting; if the TN:TP ratio is less than 5:1, nitrogen tends to be limiting (Chiandani et al., 1974).

In the mainstem Potomac River, the average TN:TP ratio across all three surveys is 29.2, and the median ratio is 26.5, with no samples below 10. None of the 25 samples taken from the tributaries had TN:TP ratios of less than 10. In the tributaries, the average ratio is 61.3 and the median is 59.8. The observed data strongly imply that the streams in Potomac River Washington County watershed are phosphorus limited.

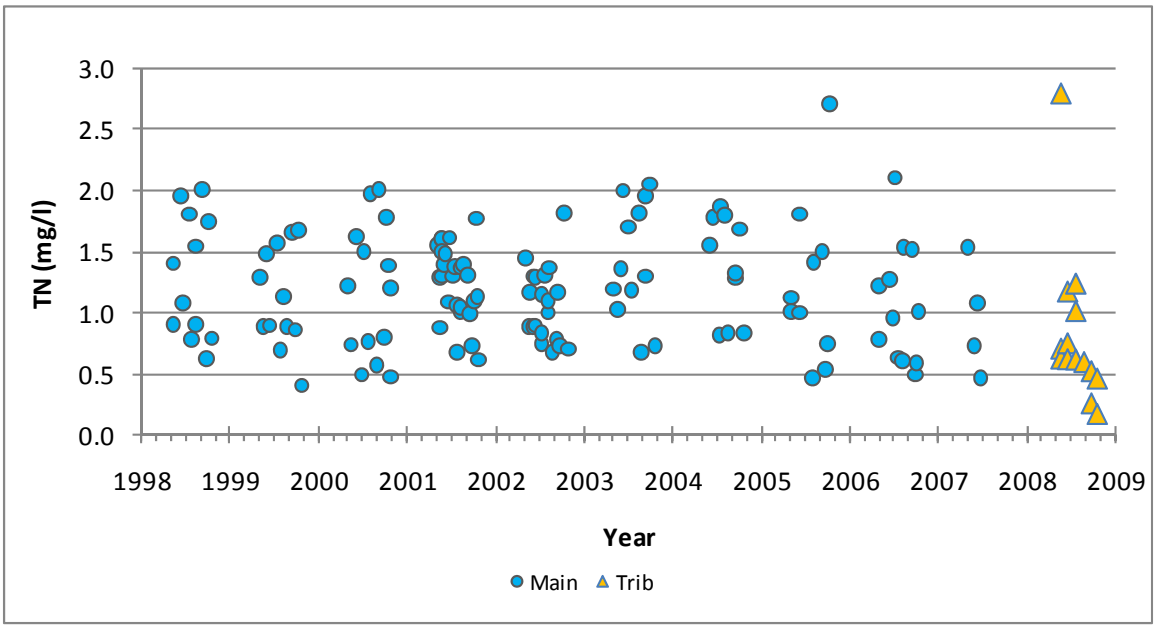

Figure 6: Potomac River Washington County Total Nitrogen for Growing Season Periods May 1998 through October 2008

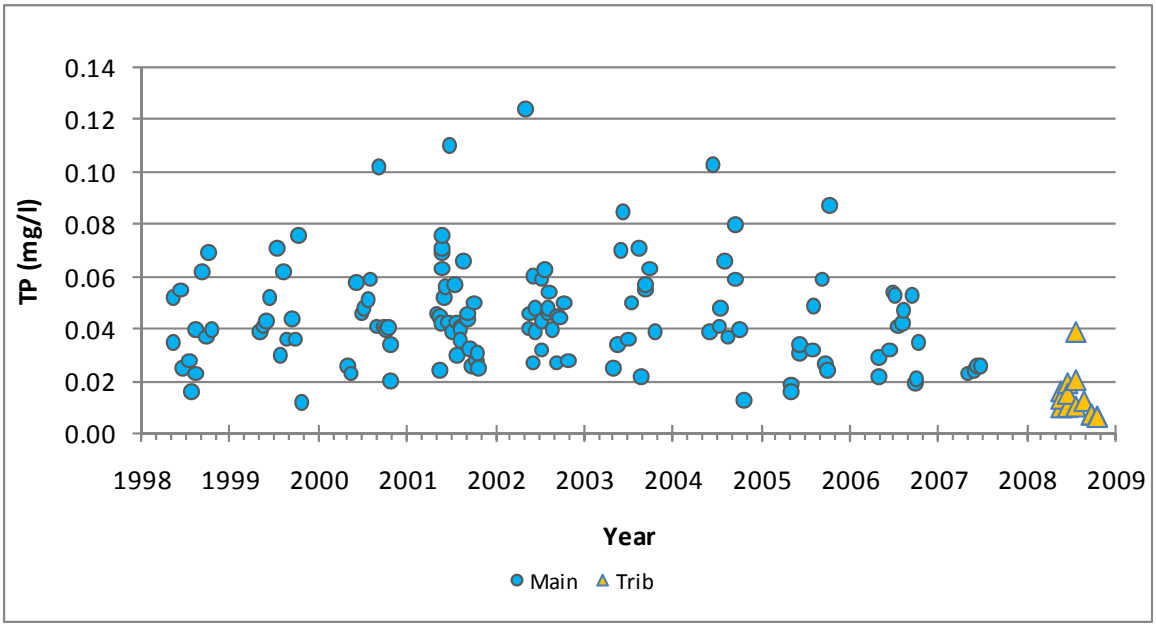

Figure 7: Potomac River Washington County Total Phosphorus Data for Growing Season Periods May 1998 through October 2008

3.5 Biological Stressor Identification Analysis

In the process of evaluating the existing biological impairments in 1st through 4th order streams, MDE developed a biological stressor identification (BSID) methodology (MDE 2009a). The BSID methodology uses data available from the statewide DNR MBSS. Data used in the development of the BSID report for the Potomac River Washington County are presented in Appendix A.

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 presents the results of this assignment in terms of currently used Integrated Report listing categories.

In the 2008 Integrated Report phosphorus was identified as the impairing substance for the nutrient impairment for Potomac River Washington County, based on the presumption that the streams in the watershed are phosphorus limited (MDE 2008a). BSID analysis did not identify either total phosphorus or orthophosphate as potential stressors (MDE, 2009b). BSID analysis did show a possible association (19% of stream miles) between degraded biological conditions in the Potomac River Washington County watershed and total nitrogen. This association by itself is not sufficient to identify nitrogen as a potential stressor. The analysis of observed data in Section 3.4 corroborates the assumption that the small order streams in Potomac River Washington County watershed are phosphorus limited. The level of primary production is therefore controlled by the concentration of phosphorus and in the absence of high phosphorus concentrations, high nitrogen concentrations cannot be the cause of excessive eutrophication. It is likely that high nitrogen concentrations are correlated with the other stressors from agriculture and urban sources discussed below.

The BSID analysis did not identify low DO concentrations (either below 5 mg/l or 6 mg/l) as potential stressors. Low DO concentrations are therefore not associated with biological impairments in the smaller order streams in the Potomac River Washington County watershed.

The BSID does identify numerous potential stressors in the Potomac River Washington County watershed. Potential sediment stressors and habitat stressors predominate. These include high embeddedness, associated with 27% of impaired stream miles; poor epifaunal substrate (15%); moderate to severe erosion (38%); poor bank stability (15%); channelization (22%); marginal to poor habitat structure (25%); poor velocity/depth diversity (15%), and the presence of concrete or gabions (13%). High chlorides (19%), conductivity (17%), and sulfides (12%) are also associated with biological impairments in the watershed.

The BSID analysis results also suggest that biological degradation in the Potomac River Washington County is strongly associated with agricultural and urban sources. As explained in the BSID report, streams in highly agricultural landscapes tend to have poor habitat quality reflected in bank instability, greater deposition of sediments on and within streambeds, and degraded habitats (Roth et al. 1996; Wang et al. 1997). Furthermore, urbanization generates broad and inter-related forms of degradation to the hydrology, morphology, and chemistry of streams that can adversely impact stream ecology and biological communities (MDE 2009b).

Sediment, poor habitat, and other potential stressors to the biological community in the Potomac River Washington County watershed will be addressed at a future date.

3.6 Potomac River Core/Trend Monitoring Stations

Additional biological data for the Potomac River Washington County were obtained from the DNR CORE/TREND program. The program collected benthic macroinvertebrate data between 1976 and 2006. This data was used to calculate four benthic community measures: total number of taxa, Shannon-Weiner diversity index, modified Hilsenhoff biotic index, and percent Ephemeroptera, Plecoptera, and Trichoptera (EPT). DNR has extensive monitoring data for two stations on the mainstem of the Potomac River Washington County through the CORE/TREND program. These stations have between 19 and 26 years of benthic macroinvertebrate data (DNR 2009). A summary of the results for each of the stations is presented in Table 2.

Table 2: Potomac River Washington County CORE/TREND Data

Site Number	Current Water Quality Status	Trend Since 1970's
POT1830	Good	Slight degradation
POT2386	Good/Very good	Moderate improvement

The water quality status of the CORE/TREND stations in the Potomac River Washington County is good or good/very good. This indicates the mainstem Potomac River in Washington County is supporting its Aquatic Life Use and therefore is not impaired by nutrients.

4.0 CONCLUSION

An analysis of available DO and Chla data from the mainstem Potomac River in Washington County shows that both the DO criterion is being met and that Chla concentrations are not at nuisance levels. Based on available biological evidence from the DNR CORE/TREND program, the mainstem Potomac River in Washington County is currently supporting its aquatic life use. Nutrients therefore are not interfering with Aquatic Life Use in the mainstem Potomac River in Washington County.

An analysis of available Chla data from the 1sth through 4th order streams in Potomac River in Washington County watershed shows that Chla concentrations are not at nuisance levels. Only one of 31 DO samples from perennial smaller-order streams in the watershed have concentrations below 5 mg/l, and the BSID analysis concludes that low DO is not associated with biological impairments in the watershed; therefore, DO criteria are also being met in the 1st through 4th order streams draining to the mainstem Potomac River. Analyses of TN:TP ratios in 1st through 4th order streams in the watershed has confirmed that smaller-order streams in the watershed are phosphorus limited. The BSID analysis did not identify phosphorus as a potential stressor of aquatic life in the watershed. Because eutrophication is limited by phosphorus, excess eutrophication is not a cause of the biological impairments in the 1st through 4th order streams in the watershed.

MDE therefore concludes that currently the Aquatic Life Use in the Potomac River Washington County is not being impaired by nutrients. Barring the receipt of contradictory data, this report will be used to support a revision of the phosphorus listing for the Potomac River Washington County watershed, from Category 5 ("waterbody is impaired, does not attain the water quality standard, and a TMDL is required") to Category 2 ("waterbodies meeting some [in this case nutrients-related] water quality standards, but with insufficient data to assess all impairments"), when MDE proposes the revision of Maryland's Integrated Report.

Although the waters of the Potomac River Washington County do not display signs of eutrophication, the State reserves the right to require future controls if evidence suggests that nutrients from the basin are contributing to downstream water quality problems. Nutrient reductions may be required by the forthcoming Chesapeake Bay TMDL, currently under development and due to be established by EPA by the end of 2010.

REFERENCES

CFR (Code of Federal Regulations). 2010. *40 CFR 130.7*. http://frwebgate.access.gpo.gov/cgi-bin/get-cfr.cgi (Accessed January, 2010).

Chiandani, G. and M. Vighi. 1974. The N:P Ratio and Tests with *Selanastrum* to Predict Eutrophication in Lakes. *Water Research*, Vol. 8, pp. 1063-1069.

COMAR (Code of Maryland Regulations). 2008a. *26.08.02.07F(5).* http://www.dsd.state.md.us/comar/26/26.08.02.07.htm (Accessed January, 2010).

————. 2008b. 26.08.02.03-3. http://www.dsd.state.md.us/comar/26/26.08.02.03%2D3.htm (Accessed January, 2010).

————. 2008c. *26.08.02.08Q(4)(e)*. http://www.dsd.state.md.us/comar/26/26.08.02.08.htm (Accessed January, 2010).

————. 2008d. *26.08.02.03-3A(2)* and *26.08.02.03-3D(2)* http://www.dsd.state.md.us/comar/26/26.08.02.03%2D3.htm (Accessed January, 2010).

MGS (Maryland Geological Survey). 1981. *A Brief Description of the Geology of Maryland*, http://www.mgs.md.gov/esic/brochures/mdgeology.html (Accessed January, 2010).

MDE (Maryland Department of the Environment). 2006. *Total Maximum Daily Loads of Nitrogen and Phosphorus for the Upper and Middle Chester Rivers in Kent and Quenn Anne's Counties, Maryland*. Baltimore, MD: Maryland Department of the Environment.

————. 2008a. The *2008 Integrated Report of Surface Water Quality in Maryland*. Baltimore, MD: Maryland Department of the Environment. http://www.mde.state.md.us/Programs/WaterPrograms/TMDL/Maryland%20303%20dlist/2008_Final_303d_list.asp (Accessed January 2010).

————. 2008b. *Total Maximum Daily Loads of Phosphorus and Sediments for Triadelphia Reservoir and Total Maximum Daily Loads of Phosphorus for Rocky Gorge Reservoir, Howard, Montgomery and Prince George's Counties, Maryland*. Baltimore, MD: Maryland Department of the Environment.

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

————. 2009b. *Watershed Report for Biological Impairment of the Potomac River Watershed in Washington County, Maryland - Biological Stressor Identification Analysis Results and Interpretation*. Baltimore, MD: Maryland Department of the Environment.

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

NRCS (Natural Resources Conservation Service). 1996. *Soil Survey of Washington County, Maryland*. Natural Resources Conservation Service United States Department of Agriculture, Natural Resources Conservation Service, in cooperation with the Board of County Commissioners of Washington County, Maryland; Washington County Soil Conservation District; and Maryland Agricultural Experiment Station (University of Maryland). http://soildatamart.nrcs.usda.gov/Manuscripts/MD043/0/MD_Washington.pdf (Accessed January 2010).

————. 2009. Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Soil Survey Geographic (SSURGO) Database for Washington County, Maryland. http://soildatamart.nrcs.usda.gov (Accessed January 2010).

Roth N. E., J.D. Allan, and D. L. Erickson. 1996. *Landscape Influences on Stream Biotic Integrity Assessed at Multiple Spatial Scales*. Landscape Ecology 11: 141–56.

Schmidt, M. F. 1993. *Maryland's Geology.* Centreville, MD: Tidewater Publishers.

Thomann, Robert V., John A. Mueller. 1987. *Principles of Surface Water Quality Modeling and Control*. HarperCollins Publisher Inc., New York.

U.S. EPA. 1997. *Technical Guidance Manual for Developing Total Maximum Daily Loads, Book2: Streams and Rivers, Part 1: Biochemical Oxygen Demand/ Dissolved Oxygen and Nutrients/Eutrophication*, Office of Water, Washington D.C., March 1997.

Walker, W.W., Jr. 1984. *Statistical Bases for Mean Chlorophyll a Criteria*. Lake and Reservoir Management: Proceedings of Fourth Annual Conference. North American Lake Management Society, pp. 57 – 62.

Wang, L., J. Lyons, P. Kanehl, and R. Gatti. 1997. *Influences of Watershed Land Use on Habitat Quality and Biotic Integrity in Wisconsin Streams*. Fisheries 22(6): 6-12.

Appendix A – Tabular Water Quality Data

Table A-1: DNR CORE/TREND Water Quality Data

Station	Sampling Date	Chlorophyll *a* (µg/l)	DO (mg/l)	TN (mg/l)	TP (mg/l)
POT1830	01/21/1998	0.90	12.4	1.73	0.030
POT1830	02/04/1998	0.82	12.3	1.65	0.033
POT1830	03/04/1998	1.25	11.8	1.37	0.035
POT1830	04/01/1998		9.2	1.53	0.018
POT1830	05/13/1998	1.79	10.1	1.41	0.052
POT1830	06/11/1998	1.42	7.8	1.95	0.055
POT1830	07/15/1998	3.18	7.9	1.81	0.028
POT1830	08/12/1998	3.24	6.6	1.55	0.040
POT1830	09/09/1998	1.50	7.1	2.01	0.062
POT1830	10/07/1998	1.05	8.3	1.75	0.069
POT1830	11/12/1998	0.37	11.3	1.59	0.035
POT1830	12/09/1998	2.97	9.6	1.72	0.046
POT1830	01/06/1999	0.80	15.3	2.05	0.038
POT1830	02/03/1999	0.67	12.6	2.50	0.046
POT1830	03/11/1999	1.20	13.5	1.55	0.022
POT1830	04/07/1999	2.09	9.3	1.72	0.039
POT1830	05/05/1999	3.05	8.7	1.29	0.039
POT1830	06/02/1999	4.19	7.0	1.49	0.043
POT1830	07/14/1999	2.24	7.9	1.58	0.071
POT1830	08/11/1999	1.00	7.1	1.13	0.062
POT1830	09/15/1999	0.75	6.9	1.66	0.044
POT1830	10/13/1999	0.56	9.1	1.68	0.076
POT1830	11/09/1999	0.75	10.1	1.09	0.034
POT1830	12/01/1999	0.80	11.1	1.13	0.035
POT1830	01/12/2000	0.75	11.6	1.95	0.042
POT1830	02/09/2000	0.70	13.1	1.92	0.042
POT1830	03/08/2000	1.60	11.0	1.91	0.058
POT1830	04/05/2000	1.35	9.9	1.44	0.016
POT1830	05/03/2000	0.90	9.1	1.22	0.026
POT1830	06/07/2000	1.35	8.2	1.63	0.058
POT1830	07/06/2000	1.35	7.1	1.50	0.048
POT1830	08/02/2000	2.16	6.7	1.98	0.059
POT1830	09/06/2000	0.80	7.0	2.01	0.102
POT1830	10/04/2000	0.60	8.6	1.78	0.040

Station	Sampling Date	Chlorophyll *a* (µg/l)	DO (mg/l)	TN (mg/l)	TP (mg/l)
POT1830	11/01/2000	0.30	9.5	1.72	0.038
POT1830	12/06/2000	2.69	12.3	1.16	0.023
POT1830	01/03/2001	0.50	12.5	1.91	0.027
POT1830	02/07/2001	1.35	13.1	1.95	0.033
POT1830	03/14/2001	7.33	12.1	1.21	0.024
POT1830	04/11/2001	5.55	9.6	1.80	0.056
POT1830	05/02/2001	39.47	12.1	1.55	0.046
POT1830	06/06/2001	49.34	9.4	1.49	0.056
POT1830	07/18/2001	15.85	6.8	1.38	0.057
POT1830	08/08/2001	19.44	8.0	1.37	0.040
POT1830	09/05/2001	5.15	7.3	1.31	0.044
POT1830	10/10/2001	10.47	11.7	1.77	0.028
POT1830	11/07/2001	1.59	11.2	1.17	0.028
POT1830	12/05/2001	1.10	10.4	1.22	0.036
POT1830	01/02/2002	0.90	13.9	1.59	0.029
POT1830	02/06/2002	1.35	12.5	1.32	0.038
POT1830	03/06/2002	2.69	11.9	1.42	0.044
POT1830	04/03/2002	1.94	9.9	1.40	0.034
POT1830	05/01/2002	3.29	9.9	1.45	0.124
POT1830	06/12/2002	3.89	6.9	1.29	0.048
POT1830	07/10/2002	2.80	6.4	1.15	0.059
POT1830	08/07/2002	1.50	6.8	1.37	0.054
POT1830	09/11/2002	1.10	8.3	1.17	0.045
POT1830	10/09/2002	0.80	9.8	1.82	0.050
POT1830	11/06/2002	0.50	10.7	2.37	0.035
POT1830	12/04/2002	0.00	12.3	2.07	0.028
POT1830	01/08/2003	1.50	12.9	2.18	0.031
POT1830	02/05/2003	0.60	13.5	1.88	0.029
POT1830	03/05/2003	1.94	13.4	1.62	0.032
POT1830	04/02/2003	1.50	11.5	2.38	0.022
POT1830	05/01/2003	4.38	10.0	1.20	0.025
POT1830	06/11/2003	2.39	9.5	2.00	0.085
POT1830	07/02/2003	35.14	9.4	1.70	0.036
POT1830	08/13/2003	9.27	7.8	1.82	0.071
POT1830	09/10/2003	1.05	8.9	1.96	0.057
POT1830	10/01/2003	0.75	9.6	2.05	0.063
POT1830	11/12/2003	0.96	10.9	1.51	0.020
POT1830	12/10/2003	0.31	13.5	1.68	0.036

Station	Sampling Date	Chlorophyll *a* (µg/l)	DO (mg/l)	TN (mg/l)	TP (mg/l)
POT1830	01/07/2004	1.20	12.7	1.63	0.037
POT1830	02/11/2004		13.4	1.95	0.069
POT1830	03/10/2004	2.69	12.6		
POT1830	04/07/2004	2.09	11.8		
POT1830	05/05/2004	1.79	9.2		
POT1830	06/02/2004	2.24	8.6	1.55	0.039
POT1830	07/14/2004	2.54	7.8	1.87	0.048
POT1830	08/04/2004	0.54	7.2	1.80	0.066
POT1830	09/15/2004	0.37	8.2	1.32	0.080
POT1830	10/06/2004		9.7	1.69	0.040
POT1830	11/03/2004	0.90	9.7	1.32	0.026
POT1830	12/01/2004	1.79	11.2	1.63	0.040
POT1830	01/05/2005	0.60	11.9	1.54	0.031
POT1830	02/09/2005	0.93	13.5	2.18	0.033
POT1830	03/09/2005	9.27	12.7	1.11	0.023
POT1830	04/13/2005	1.50	10.4	1.89	0.025
POT1830	05/04/2005	1.74	10.9	1.12	0.016
POT1830	06/08/2005	1.58	8.5	1.81	0.034
POT1830	07/06/2005	3.29	6.7		
POT1830	08/03/2005	1.40	7.4	1.41	0.049
POT1830	09/07/2005	1.60	9.5	1.50	0.059
POT1830	10/12/2005	0.82	7.4	2.71	0.087
POT1830	11/09/2005	0.75	9.8	1.86	0.039
POT1830	12/07/2005		12.5	2.29	0.043
POT1830	01/04/2006	5.98	12.8	1.95	0.102
POT1830	02/01/2006	0.75	12.9	1.72	0.032
POT1830	03/01/2006	2.69	13.5	1.67	0.020
POT1830	04/12/2006	3.42	9.5	1.08	0.026
POT1830	05/03/2006	1.50	9.1	1.22	0.029
POT1830	06/14/2006	1.79	8.0	1.28	0.032
POT1830	07/05/2006	0.30	6.8	2.11	0.053
POT1830	08/09/2006	1.16	7.8	1.54	0.047
POT1830	09/13/2006	0.90	7.8	1.52	0.053
POT1830	10/11/2006	0.60	9.1	1.01	0.035
POT1830	11/08/2006	1.20	10.3	1.54	0.038
POT1830	12/06/2006		11.5	1.86	0.026
POT1830	01/03/2007	1.07	12.7	1.80	0.029
POT1830	02/07/2007	0.60	13.9	1.98	0.020

Station	Sampling Date	Chlorophyll *a* (µg/l)	DO (mg/l)	TN (mg/l)	TP (mg/l)
POT1830	03/07/2007		13.0	1.88	0.040
POT1830	04/04/2007	1.28	9.9	1.33	0.024
POT1830	05/02/2007	2.24	8.7	1.54	0.023
POT1830	06/13/2007	5.08	7.1	1.09	0.026
POT2386	01/12/1998	2.80	11.5	1.23	0.042
POT2386	02/02/1998	0.45	12.1	0.97	0.025
POT2386	03/16/1998	0.40	11.8	0.99	0.026
POT2386	04/27/1998	1.12	9.6	0.86	0.020
POT2386	05/11/1998	2.09	9.2	0.90	0.035
POT2386	06/22/1998	1.82	7.4	1.08	0.025
POT2386	07/27/1998	1.05	7.3	0.78	0.016
POT2386	08/10/1998	0.82	7.0	0.90	0.023
POT2386	09/28/1998	0.40	8.3	0.62	0.037
POT2386	10/19/1998	0.37	8.9	0.79	0.040
POT2386	11/04/1998	0.25	10.6	0.63	0.021
POT2386	12/07/1998	1.00	9.9	0.41	0.010
POT2386	01/25/1999	16.95	11.2	2.20	0.098
POT2386	02/22/1999	0.80	13.4	0.87	0.018
POT2386	03/22/1999	3.44	11.4	1.17	0.020
POT2386	04/19/1999	1.35	9.9	0.95	0.012
POT2386	05/17/1999	1.40	8.1	0.89	0.041
POT2386	06/14/1999	34.09	8.5	0.90	0.052
POT2386	07/26/1999	1.08	7.3	0.69	0.030
POT2386	08/23/1999	0.75	8.7	0.89	0.036
POT2386	09/28/1999	0.31	7.8	0.86	0.036
POT2386	10/25/1999	0.10	11.4	0.40	0.012
POT2386	11/15/1999	0.80	10.5	0.40	0.013
POT2386	12/13/1999	0.90	12.7	0.60	0.013
POT2386	01/24/2000	0.42	12.9	1.02	0.017
POT2386	02/22/2000	3.59	11.9	1.27	0.060
POT2386	03/20/2000	0.87	11.2	0.83	0.023
POT2386	04/17/2000	1.42	8.8	0.70	0.032
POT2386	05/15/2000	0.47	8.3	0.74	0.023
POT2386	06/26/2000	0.43	7.1	0.49	0.046
POT2386	07/25/2000	0.47	7.7	0.76	0.051
POT2386	08/28/2000	0.40	7.8	0.57	0.041
POT2386	09/25/2000	0.33	7.8	0.80	0.041
POT2386	10/23/2000	0.30	10.3	0.48	0.020

Station	Sampling Date	Chlorophyll *a* (µg/l)	DO (mg/l)	TN (mg/l)	TP (mg/l)
POT2386	11/27/2000	0.00	13.1	0.89	0.014
POT2386	12/18/2000	17.19	12.5	1.52	0.083
POT2386	01/22/2001	4.78	12.1	1.22	0.046
POT2386	02/05/2001	2.54	12.8	1.39	0.036
POT2386	03/26/2001	5.23	11.1	1.32	0.032
POT2386	04/09/2001	3.99	9.4	1.13	0.038
POT2386	05/14/2001	5.38	8.9	0.88	0.024
POT2386	06/25/2001	4.11	7.1	1.61	0.110
POT2386	07/24/2001	11.21	8.3	0.67	0.030
POT2386	08/06/2001	3.10	7.4	1.01	0.041
POT2386	09/24/2001	1.12	7.2	0.73	0.026
POT2386	10/22/2001		9.4	0.62	0.025
POT2386	11/05/2001	8.82	10.1	0.55	0.031
POT2386	12/03/2001	2.12	11.0	0.64	0.028
POT2386	01/14/2002	0.80	13.3	1.34	0.049
POT2386	02/04/2002	1.89	12.0	0.97	0.026
POT2386	03/04/2002	2.09	11.9	0.83	0.036
POT2386	04/15/2002	2.24	9.8	1.32	0.066
POT2386	05/20/2002	4.06	9.7	1.17	0.046
POT2386	06/03/2002	1.05	7.9	0.89	0.027
POT2386	07/08/2002	0.47	7.0	0.74	0.032
POT2386	08/05/2002	0.52	7.4	1.00	0.046
POT2386	09/09/2002	0.30	8.1	0.78	0.027
POT2386	10/28/2002	0.75	9.8	0.70	0.028
POT2386	11/18/2002	1.50	10.3	1.31	0.049
POT2386	12/02/2002	0.42	12.5	0.95	0.010
POT2386	01/06/2003	1.31	12.3	1.47	0.013
POT2386	02/03/2003	0.30	13.3	1.52	0.042
POT2386	03/03/2003	1.50	12.5	1.38	0.024
POT2386	04/14/2003	1.87	10.4	1.28	0.036
POT2386	05/19/2003	0.90	10.2	1.03	0.034
POT2386	06/02/2003	2.09	9.1	1.36	0.070
POT2386	07/14/2003	1.20	7.9	1.18	0.050
POT2386	08/25/2003	2.63	8.0	0.68	0.022
POT2386	09/08/2003	0.90	8.2	1.30	0.055
POT2386	10/20/2003	1.02	9.9	0.73	0.039
POT2386	11/03/2003	1.40	10.2	0.57	0.037
POT2386	12/08/2003	0.20	13.2	1.15	0.036

Station	Sampling Date	Chlorophyll *a* (µg/l)	DO (mg/l)	TN (mg/l)	TP (mg/l)
POT2386	01/06/2004	1.42	11.9	1.06	0.024
POT2386	02/09/2004		13.5	1.28	0.030
POT2386	03/08/2004	3.74	11.2		
POT2386	04/19/2004	1.20	9.5		
POT2386	05/17/2004	2.09	8.6		
POT2386	06/14/2004	7.48	8.0	1.78	0.103
POT2386	07/12/2004	2.94	7.1	0.82	0.041
POT2386	08/16/2004	0.50	7.4	0.84	0.037
POT2386	09/13/2004	1.20	7.9	1.28	0.059
POT2386	10/18/2004	0.30	10.4	0.83	0.013
POT2386	11/15/2004	1.64	12.4	0.75	0.019
POT2386	12/13/2004	1.50	11.0	1.30	0.029
POT2386	01/05/2005	1.05	11.3	1.11	0.033
POT2386	02/07/2005	0.30	12.9	1.08	0.020
POT2386	03/07/2005	3.29	13.1	0.89	0.021
POT2386	04/04/2005	2.09	11.1	1.13	0.170
POT2386	05/02/2005	1.64	9.9	1.01	0.019
POT2386	06/06/2005	0.45	8.1	1.00	0.031
POT2386	07/18/2005	0.60	6.6		
POT2386	08/01/2005		7.6	0.46	0.032
POT2386	09/19/2005		9.8	0.54	0.027
POT2386	10/03/2005	0.45	10.2	0.75	0.024
POT2386	11/01/2005	0.21	11.7	1.05	0.031
POT2386	12/05/2005	0.75	12.4	1.55	0.038
POT2386	01/17/2006	1.50	12.3	1.09	0.026
POT2386	02/13/2006	1.20	13.0	1.16	0.023
POT2386	03/13/2006	2.09	10.0	0.80	0.019
POT2386	04/10/2006	2.80	9.9	0.57	0.021
POT2386	05/02/2006	1.71	9.1	0.78	0.022
POT2386	06/27/2006	1.87	6.6	0.96	0.054
POT2386	07/18/2006	0.43	7.4	0.63	0.041
POT2386	08/07/2006	1.50	7.8	0.61	0.042
POT2386	09/25/2006	0.30	10.6	0.49	0.019
POT2386	10/02/2006	0.53	9.7	0.59	0.021
POT2386	11/01/2006	1.05	10.0	0.00	0.032
POT2386	12/04/2006	0.80	11.2	0.92	0.029
POT2386	01/16/2007	1.79	10.8	0.92	0.025
POT2386	02/05/2007	0.75	13.4	1.07	0.027

Station	Sampling Date	Chlorophyll *a* (µg/l)	DO (mg/l)	TN (mg/l)	TP (mg/l)
POT2386	03/05/2007	3.29	11.2	1.49	0.057
POT2386	04/03/2007	0.90	9.9	0.85	0.018
POT2386	05/29/2007	2.09	8.2	0.73	0.024
POT2386	06/25/2007	3.39	8.6	0.47	0.026

Table A-2: MBSS Water Quality Data

Station	Sampling Date	DO (mg/l)	TN (mg/l)	TP (mg/l)
COCA-101-N-2003	04/17/2003		0.80	0.019
COCA-101-N-2003	07/14/2003	8.1		
COCA-105-N-2003	04/16/2003		0.49	0.025
COCA-105-N-2003	07/28/2003	8.0		
COCA-106-N-2003	04/16/2003		0.53	0.011
COCA-110-N-2003	04/16/2003		0.23	0.023
COCA-110-N-2003	07/29/2003	6.9		
COCA-114-N-2003	04/17/2003		0.14	0.008
COCA-114-N-2003	07/14/2003	4.3		
COCA-115-N-2003	04/16/2003		8.56	0.057
COCA-115-N-2003	07/29/2003	8.6		
COCA-118-N-2004	04/22/2004		0.78	0.016
COCA-118-N-2004	06/21/2004	8.3		
COCA-119-N-2004	04/22/2004		1.05	0.065
COCA-119-N-2004	07/08/2004	6.9		
COCA-121-N-2004	04/22/2004		8.87	0.558
COCA-121-N-2004	07/08/2004	1.3		
COCA-203-N-2003	04/16/2003		2.63	0.028
COCA-203-N-2003	07/29/2003	7.5		
NCRW-206-N-2004	04/22/2004		0.54	0.010
NCRW-206-N-2004	07/08/2004	6.8		
PRWA-101-R-2002	03/25/2002		0.67	0.013
PRWA-102-R-2002	03/06/2002		0.41	0.006
PRWA-102-R-2002	06/26/2002	4.2		
PRWA-103-R-2000	03/30/2000		0.23	0.007
PRWA-103-R-2000	08/09/2000	7.7		
PRWA-104-R-2000	03/30/2000		0.32	0.005
PRWA-104-R-2000	08/09/2000	7.4		
PRWA-106-R-2000	03/29/2000		7.13	0.040
PRWA-106-R-2000	08/29/2000	8.9		
PRWA-114-R-2002	03/06/2002		0.27	0.010
PRWA-117-R-2000	03/30/2000		0.69	0.007
PRWA-119-R-2000	03/30/2000		0.70	0.004
PRWA-119-R-2000	08/03/2000	7.8		
PRWA-120-R-2002	03/06/2002		0.74	0.011
PRWA-120-R-2002	06/26/2002	6.6		

Station	Sampling Date	DO (mg/l)	TN (mg/l)	TP (mg/l)
PRWA-122-R-2000	03/30/2000		0.67	0.006
PRWA-122-R-2000	08/09/2000	8.3		
PRWA-124-R-2002	03/06/2002		0.61	0.004
PRWA-124-R-2002	06/26/2002	6.2		
PRWA-125-R-2002	03/25/2002		1.95	0.010
PRWA-206-R-2002	03/25/2002		0.64	0.019
PRWA-206-R-2002	07/10/2002	10.7		
PRWA-215-R-2002	03/07/2002		5.48	0.027
PRWA-215-R-2002	07/10/2002	10.9		
PRWA-217-R-2002	03/07/2002		2.52	0.032

Table A-3: MDE Water Quality Data

Station	Sampling Date	Chlorophyll *a* (µg/l)	DO (mg/l)	TN (mg/l)	TP (mg/l)
POT1830	10/18/2000	0.75	8.8	1.39	0.040
POT1830	11/16/2000	0.43	11.3	0.97	0.037
POT1830	12/06/2000	2.69	12.8	1.03	0.021
POT1830	01/10/2001	0.60	12.5	1.63	0.019
POT1830	02/07/2001	1.35	11.7	2.00	0.028
POT1830	03/21/2001	8.22	11.3	1.18	0.024
POT1830	04/18/2001	2.99	10.7	1.53	0.066
POT1830	05/16/2001	23.33	8.4	1.29	0.044
POT1830	06/20/2001	13.76	7.2	1.09	0.043
POT1830	07/25/2001	15.25	8.3	1.07	0.043
POT1830	08/08/2001	21.38	8.5	1.05	0.035
POT1830	09/19/2001	2.09	9.6	0.99	0.032
POT1830	10/18/2001	5.23	10.4	1.13	0.031
POT1830	11/07/2001	1.64	11.1	0.92	0.025
POT1830	12/19/2001	2.69	10.7	1.35	0.047
POT1830	01/24/2002	2.09	11.3	1.22	0.040
POT1830	02/21/2002	2.84	9.9	0.96	0.032
POT1830	03/21/2002	8.97	10.2	1.00	0.097
POT1830	04/18/2002	1.79	8.3	0.98	0.054
POT1830	05/16/2002	0.60	9.2	0.89	0.040
POT1830	06/12/2002	4.78	7.2	0.90	0.039
POT1830	07/25/2002	2.99	6.4	1.31	0.063
POT1830	08/21/2002	2.39	7.3	0.67	0.039
POT1830	09/25/2002	0.60	8.5	0.73	0.044
DIT0002	01/28/2008	0.75	13.6	2.95	0.008
DIT0002	02/19/2008	0.75	13.0	3.45	0.012
DIT0002	03/17/2008	0.30	12.5	3.18	0.014
DIT0002	04/21/2008	2.49	10.1	2.81	0.100
DIT0002	05/19/2008	0.90	10.1	2.79	0.016
DIT0002	06/16/2008	1.28	8.2	1.17	0.019
DIT0002	07/21/2008		2.1	1.23	0.021
DIT0002	11/24/2008		11.7	0.20	0.006
DIT0002	12/15/2008		11.9	4.64	0.017
GSR0001	01/28/2008	0.84	12.4	0.60	0.007
GSR0001	02/19/2008	0.60	12.5	0.83	0.008
GSR0001	03/17/2008	0.30	12.3	0.76	0.008
GSR0001	04/21/2008	1.00	9.9	1.38	0.033

Station	Sampling Date	Chlorophyll *a* (µg/l)	DO (mg/l)	TN (mg/l)	TP (mg/l)
GSR0001	05/19/2008		9.6	0.70	0.010
GSR0001	06/16/2008		8.7	0.74	0.010
GSR0001	07/21/2008		8.2	0.61	0.010
GSR0001	08/25/2008		8.9	0.59	0.012
GSR0001	09/25/2008		9.4	0.52	0.007
GSR0001	10/20/2008		10.8	0.46	0.007
GSR0001	11/24/2008		12.8	0.50	0.003
GSR0001	12/15/2008		11.5	0.99	0.009
ZPM0004	01/28/2008	0.37	13.6	0.62	0.007
ZPM0004	02/19/2008	0.45	13.1	0.73	0.007
ZPM0004	03/17/2008	0.20	12.7	0.57	0.008
ZPM0004	04/21/2008	1.00	10.3	0.94	0.043
ZPM0004	05/19/2008		10.0	0.62	0.013
ZPM0004	06/16/2008	0.64	8.4	0.61	0.015
ZPM0004	07/21/2008	1.50	5.7	1.01	0.039
ZPM0004	09/25/2008	0.75	9.0	0.25	0.007
ZPM0004	10/20/2008		10.1	0.17	0.006
ZPM0004	11/24/2008		12.4	0.19	0.004
ZPM0004	12/15/2008		11.9	1.06	0.015

Table A-4: USGS Water Quality Data at Gageing Station 0161800

Station	Sampling Date	DO (mg/l)	TN (mg/l)	TP (mg/l)
01618000	10/23/2000	10.1	1.20	0.034
01618000	11/20/2000	11.4	1.20	0.025
01618000	12/18/2000	12.6	1.40	0.067
01618000	01/22/2001	13.2	1.80	0.064
01618000	01/31/2001	11.7	1.70	0.070
01618000	02/01/2001	13.5	2.00	0.250
01618000	02/20/2001	12.6	1.30	0.032
01618000	03/06/2001	12.2	1.00	0.028
01618000	03/12/2001	12.7	1.10	0.024
01618000	03/21/2001	7.1	1.20	0.025
01618000	03/22/2001	10.2	1.90	0.280
01618000	03/23/2001	12.2	2.10	0.240
01618000	03/26/2001	13.0		0.040
01618000	04/02/2001	11.9	1.50	0.064
01618000	04/18/2001	11.9	1.60	0.070
01618000	04/30/2001	9.5	1.50	0.035
01618000	05/21/2001	7.3	1.60	0.042
01618000	05/22/2001	7.3	1.60	0.069
01618000	05/23/2001	8.4	1.30	0.063
01618000	05/24/2001	9.1	1.50	0.071
01618000	05/25/2001	8.7	1.50	0.076
01618000	06/05/2001	8.6	1.40	0.052
01618000	07/09/2001	8.8	1.30	0.039
01618000	08/20/2001	6.0	1.40	0.066
01618000	09/05/2001	6.7		0.046
01618000	10/01/2001	9.2	1.10	0.050
01618000	11/19/2001	11.1	0.84	0.036
01618000	12/03/2001	10.1	1.10	0.044
01618000	01/07/2002	13.9	1.10	0.032
01618000	02/04/2002	10.5	1.10	0.058
01618000	03/04/2002	11.6	0.93	0.048
01618000	03/20/2002	9.2	0.95	0.075
01618000	03/21/2002	11.0	1.40	0.172
01618000	03/22/2002	11.6	2.30	0.230
01618000	03/25/2002	11.5	2.10	0.054
01618000	04/01/2002	10.6	1.40	0.042
01618000	04/16/2002	9.0	0.92	0.054

Station	Sampling Date	DO (mg/l)	TN (mg/l)	TP (mg/l)
01618000	04/22/2002	8.0	1.10	0.061
01618000	04/23/2002	9.7	1.70	0.260
01618000	04/26/2002		1.40	0.065
01618000	04/29/2002	10.0	1.40	0.064
01618000	06/03/2002	7.4	1.30	0.060
01618000	07/08/2002	7.8	0.83	0.043
01618000	08/05/2002	7.8	1.10	0.048