Water Quality Analysis of Eutrophication for the Tidal Lower Susquehanna River, Harford and Cecil Counties, Maryland

FINAL

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List of Abbreviations

BOD	Biochemical Oxygen Demand
CBP	Chesapeake Bay Program
Cd	Cadmium
COMAR	Code of Maryland Regulation
CWA	Clean Water Act
DNR	Department of Natural Resources
DO	Dissolved Oxygen
EPA	Environmental Protection Agency
MD-DNR	Maryland Department of Natural Resources
MDE	Maryland Department of the Environment
MDP	Maryland Department of Planning
mg/l	Milligrams Per Liter
PCB	Polychlorinated Biphenyl
SRBC	Susquehanna River Basin Commission
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
USGS	United States Geological Survery
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 (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.

Lower Susquehanna River (basin code 02-12-02-01) was identified on the State's list of WQLSs as impaired by nutrients (1996 listing), sediments (1996 listing), cadmium (Cd) (1996 listing), polychlorinated biphenyls (PCBs) in fish tissue (2002 listing) and evidence of biological impacts (2002 listing). The biological impairment listing is designated for two non-tidal streams, Herring Run and an unnamed tributary of the Lower Susquehanna River, while the remaining listings apply to the tidal portion. This document addresses the nutrient impairment in the tidal portion of the Lower Susquehanna River; the sediment, Cd, PCB, and biological impairments will be addressed at a future date.

An analysis of recent monitoring data shows that the dissolved oxygen criterion and designated uses that could be impacted by excess nutrients are being met in Lower Susquehanna River. This analysis supports the conclusion that a TMDL for nutrients is not necessary to achieve water quality in this case. Barring any contradictory future data, this report will be used as supporting material when Maryland Department of the Environment (MDE) proposes the revision of Maryland's 303(d) list for public review. Although the waters of Lower Susquehanna River do not display signs of eutrophication, the State reserves the right to require future controls in the Lower Susquehanna River watershed if evidence suggests nutrients from the basin are contributing to downstream water quality problems.

1.0 INTRODUCTION

Section 303(d) of the federal Clean Water Act (CWA) and 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.

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

Lower Susquehanna River (basin code 02-12-02-01) 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, sediments, and cadmium (Cd) with polychlorinated biphenyls (PCBs) in fish tissue and biological impairment added to the list in 2002. The biological impairment listing is designated for two non-tidal streams, Herring Run and an unnamed tributary of the Lower Susquehanna River, while the remaining listings apply to the tidal portion. This report provides more recent information that supports the removal of the nutrients listing for the tidal portion of the Lower Susquehanna River when the 303(d) list is revised; therefore, the aforementioned first scenario most closely applies, with the qualification that initial listing for nutrients was suspect due to the lack of data. The sediment, Cd, PCB and biological impairments will be addressed at a future date.

The remainder of this report lays out the general setting of the waterbody within the Lower Susquehanna River 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 data will establish that the Lower Susquehanna River is achieving water quality standards.

2.0 GENERAL SETTING

Lower Susquehanna River is located in Cecil and Harford County, Maryland and flows from the outlet of the Conowingo Dam south into the headwaters of the Chesapeake Bay. The Lower Susquehanna River, Deer Creek, Octoraro Creek, and Broad Creek are all part of the network of streams that make up the basin. Lower Susquehanna River is approximately 10 miles in length, with a watershed area of approximately 19,885 acres (Figure 1). The land uses in the watershed are mixed agricultural (5,719 or 28.8% of the area), forest (8,589 mi^2 or 43.2% of the area) and urban (5,577 mi^2 or 28% of the area). Please refer to Figure 2 for a map of these land uses (MDP, 2000).

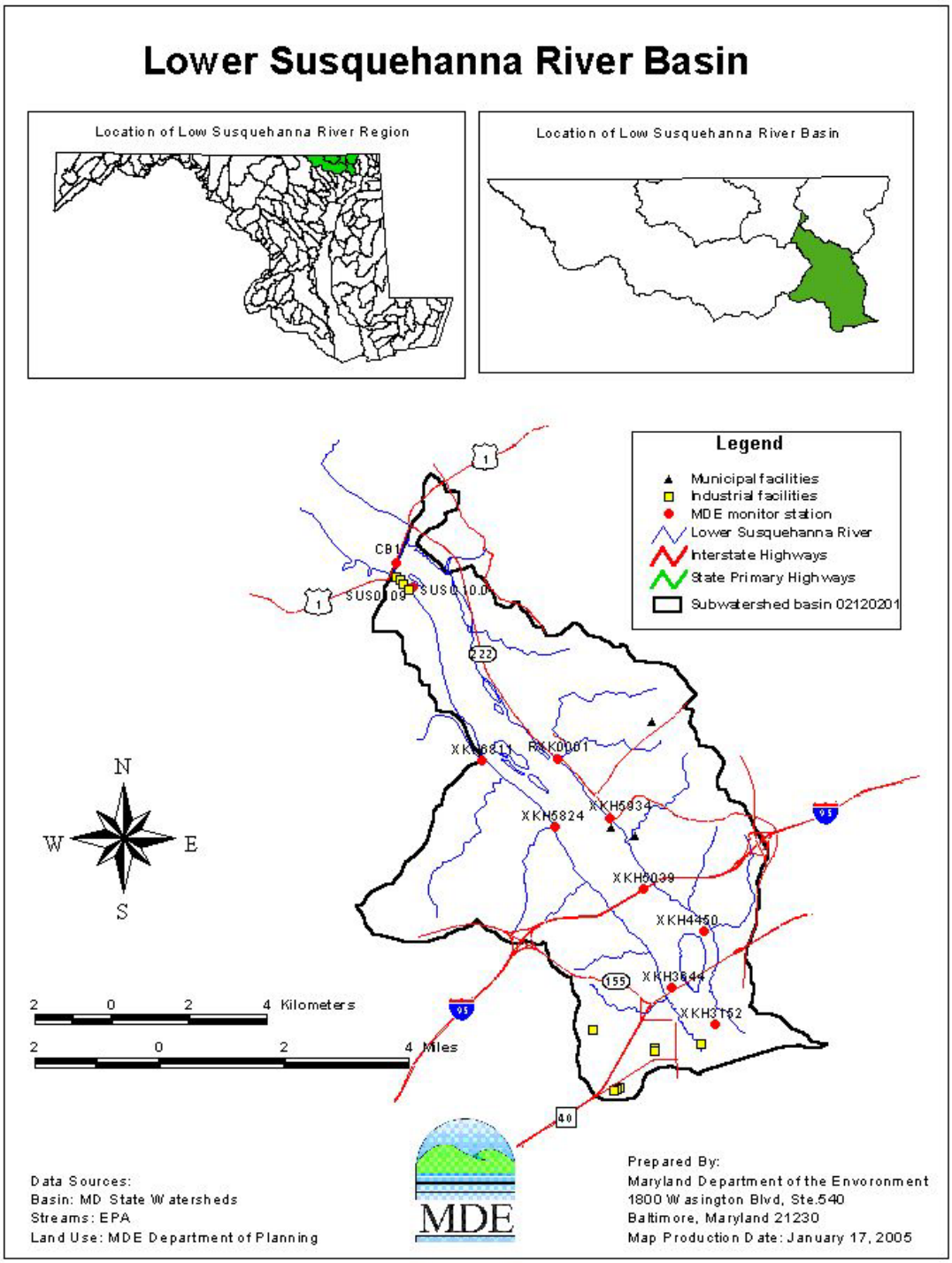

Figure 1: Lower Susquehanna River Location Map and Monitoring Stations

The Lower Susquehanna River watershed lies within the Piedmont province in Central Maryland. The Piedmont province is characterized by gentle to steep rolling topography, low hills and ridges. The surficial geology is characterized by crystalline rocks of volcanic origin consisting primarily of schist and gneiss. These formations are resistant to short-term erosion and often determine the limits of stream bank and stream bed. (Coastal Environmental Services, 1995).

The Lower Susquehanna River basin has a temperate climate. The average annual temperature for the area is about 50 degrees Fahrenheit. Long periods of extreme cold or heat are infrequent. Mean annual precipitation ranges from 38 to 44 inches. Mean annual runoff ranges from about 15 inches in the southern part of the basin to 25 inches in the higher elevations. Most of the runoff results from snowmelt and rainfall in spring and early summer (United States Geological Survey, 1991).

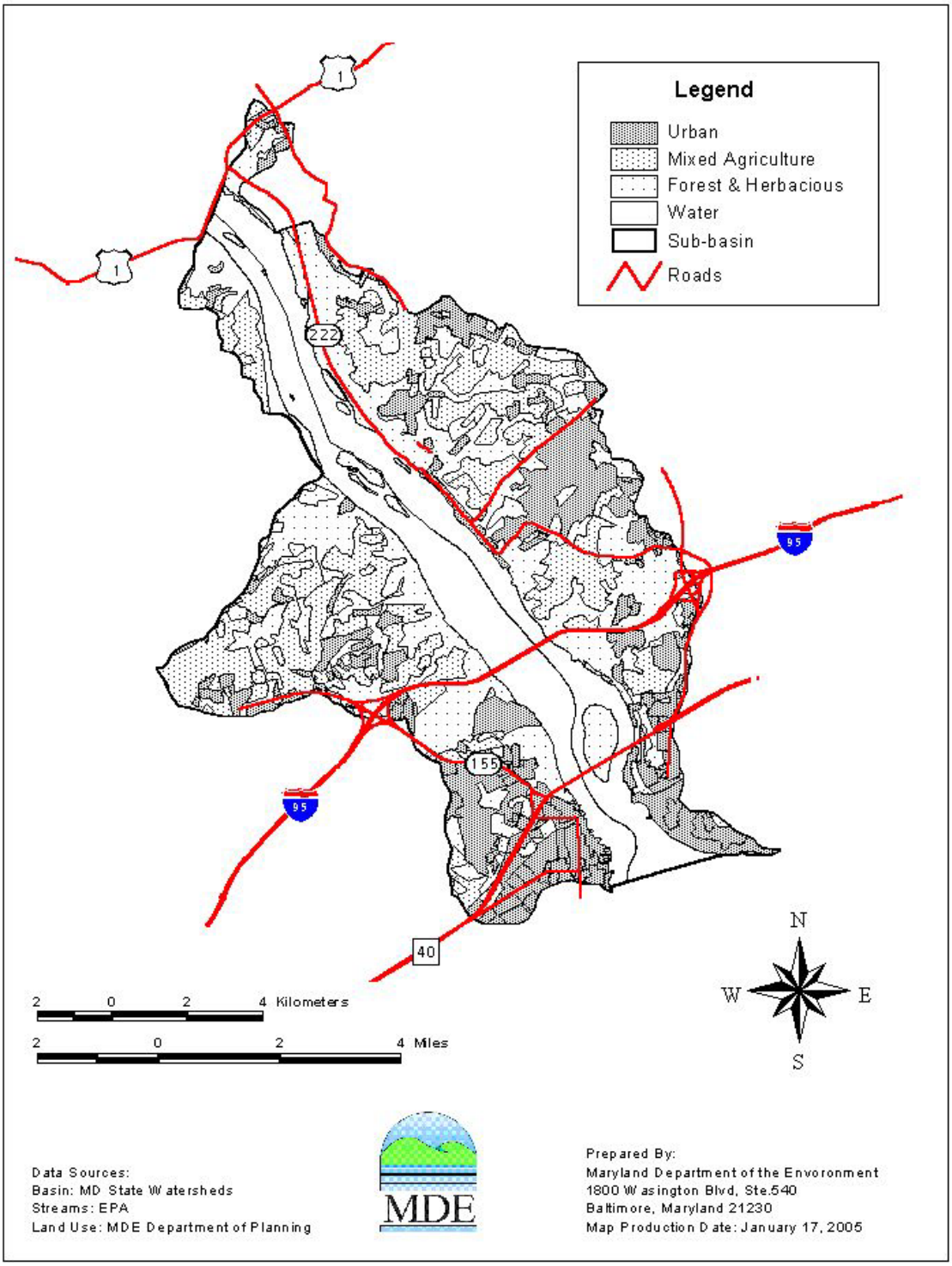

Figure 2: Land Use Map of the Lower Susquehanna River Watershed

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 swimming, drinking water supply, 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.

Maryland's water quality standards presently do not impose a limit on the concentration of nutrients in the water column[1]. Rather, Maryland manages nutrients indirectly by limiting their effects expressed in terms of excess algal growth and low dissolved oxygen (DO). Because biochemical oxygen demand (BOD) also consumes DO, this potentially confounding factor must be considered in the analysis if low DO is observed.

The Maryland Surface Water Use Designation (Code of Maryland Regulations (COMAR) 26.08.02.07) for the tidal portion of Lower Susquehanna River is Use I-P – *water contact recreation, protection of aquatic life, and public water supply*. According to Maryland's numeric criterion for DO, concentrations may not be less than 5.0 mg/l at any time (COMAR 26.08.02.03-3C(2)), unless resulting from natural conditions (COMAR 26.08.02.03.A(2)). The water quality data presented in this section will show the designated use of this water body is being met as it relates to nutrients.

Maryland's general water quality criteria prohibit pollution of waters of the State by any material in amounts sufficient to create nuisance or interfere with designated uses (COMAR 26.08.02.03B(2)). Excessive eutrophication, indicated by elevated levels of chlorophyll *a*, can produce nuisance levels of algae and interfere with designated uses such as fishing and swimming; therefore, a desired peak chlorophyll a level of 50 µg/l has been established for tidal waters. The chlorophyll *a* level is based on the designated use, 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).

All readily available water quality data for the last five years pertaining to the tidal portion of Lower Susquehanna River was considered for this analysis. Water quality data from MDE surveys conducted at eight stations along the Lower Susquehanna River during November 1998 through September 1999 (which covers both the high-flow and the low-flow conditions) was used to perform this analysis. The analysis was aided by data from Susquehanna River Basin Commission (SRBC) for 1998-2003 and the Chesapeake Bay Program (CBP) for 1998-2002. Table 1 shows the list of stations with their geographical coordinates and descriptive location in the Lower Susquehanna River watershed. Figure 3 provides graphical representation of the collected data for the parameters discussed below.

1 Maryland does limit the ammonia form of nitrogen from the Waste Water Treatment Plants due to its toxic effects on some aquatic organisms.

Table 1: Locations of Water Quality Stations Monitored in Lower Susquehanna River.

Water Quality Station	Latitude Degrees	Longitude Degrees	Sources
RXK0001 *	39 36.786	76 07.575	MDE
CB1.0 **	39 39.523	76 10.447	CBP, 2004
SUS10.0 **	39 39.180	76 10.164	SRBC, 2004
SUS0109 **	39 39.160	76 10.243	MDE
XKH3152	39 33.074	76 04.784	MDE
XKH3644	39 33.598	76 05.560	MDE
XKH4450	39 34.360	76 04.984	MDE
XKH5039	39 34.959	76 06.067	MDE
XKH5824	39 35.845	76 07.644	MDE
XKH5934	39 35.945	76 06.652	MDE
XKH6811	39 36.767	76 08.945	MDE

* This is a non-tidal station presented here for informational purposes, but not within the subject segment.
** These are tidal-fresh stations

3.1 Nutrients

During the data analysis period from 1998-2003, total phosphorus (TP) concentrations in the tidal waters ranged from 0.012 mg/l to 0.17 mg/l and total nitrogen (TN) concentrations ranged from 0.75 mg/l to 2.7 mg/l. Please refer to Figure 3 for graphical representations of this data; data tables are presented in Appendix A.

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3.2 Dissolved Oxygen

During the data analysis period from 1998-2003 sampling period, DO concentrations ranged from 3.5 mg/l to 13.7 mg/l. The data shows that DO values between 3.5 mg/l to 5.0 mg/l represented approximately 3% of the observations in the waterbody segment, and 3 of 5 observations less than 5.0 mg/l were in between 4.5 and 5.0 mg/l. This data is summarized in Figure 3. Tabular data is presented in Appendix A.

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3.3 Chlorophyll *a*

Chlorophyll *a* data was observed during the entire period from 1998 to 2003 covering algal growing season, when concentrations are at their peak. Observed chlorophyll *a* concentrations are low (< 23 µg/l) and do not reach levels higher than the water quality threshold of 50 µg/l in the tidal portion of Lower Susquehanna River.

The low chlorophyll *a* concentrations found in Lower Susquehanna River suggests that chlorophyll *a* photosynthesis and respiration will have no significant effect on observed DO values. This data is summarized in Figure 3. Tabular data is presented in Appendix A.

3.4 Biochemical Oxygen Demand (BOD)

Because BOD also consumes DO, this potentially confounding factor must be considered in the analysis if low DO is observed. During the data analysis period from 1998-2003, BOD concentrations ranged from 0.4 mg/l to 6.7 mg/l. Again, please refer Figure 3 for graphical representations of this data; data tables are presented in Appendix A.

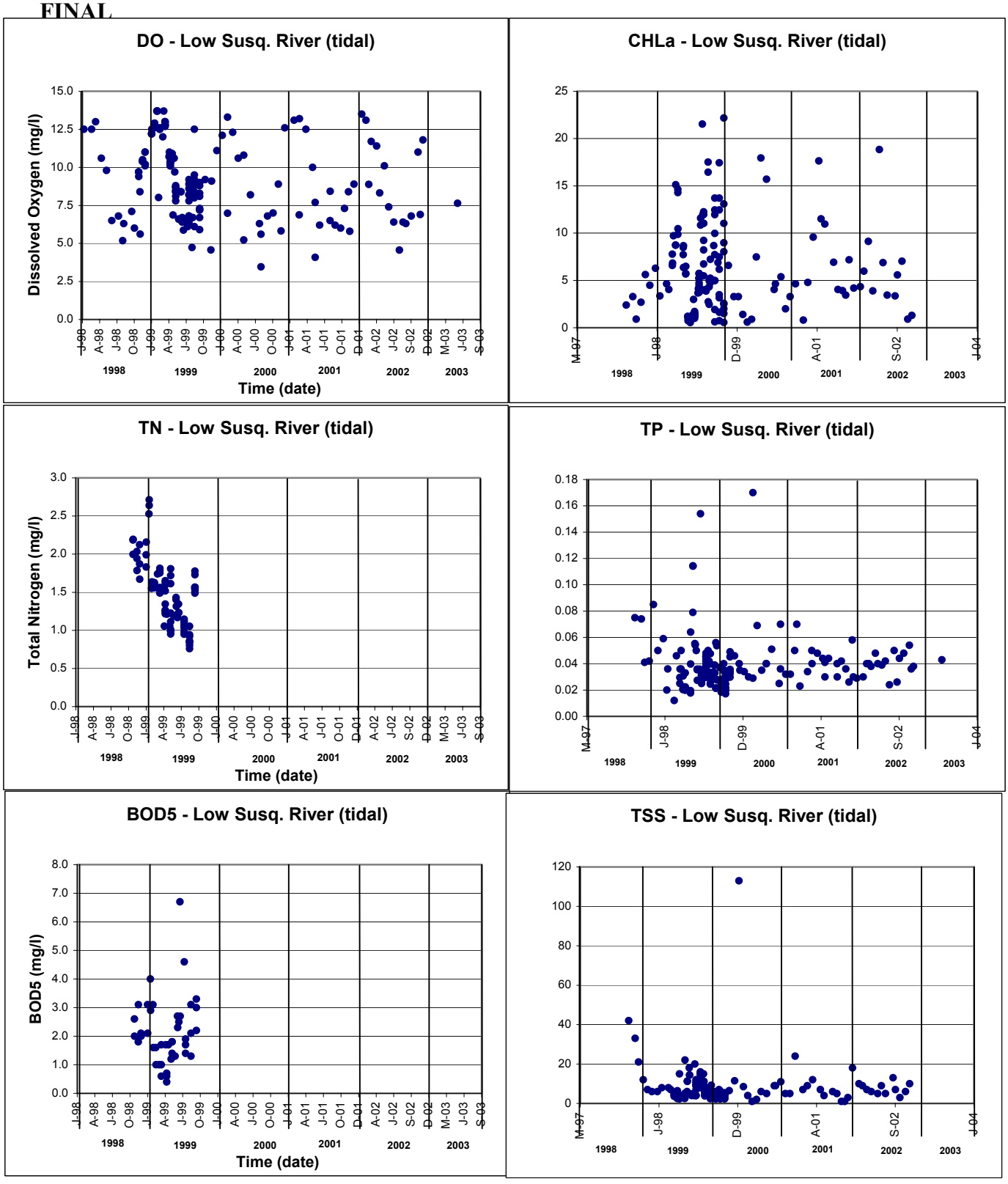

Figure 3: Lower Susquehanna Water Quality Data from 1998 through 2003 (Tidal & Tidal-fresh Stations)

4.0 CONCLUSION

The data presented above clearly demonstrate that excessive algal growth does not exist in the tidal portion of Lower Susquehanna River, as indicated by low chlorophyll *a*. Similarly, 97% of the DO observations are above the criterion of 5.0 mg/l. Based on the MDE synoptic surveys conducted during 1998-1999, no values below 5.0 mg/l were observed; data from SRBC (1998-2003) and CBP (1998-2002) indicates that Lower Susquehanna River has no eutrophication-related water quality impairments, except some occasional occurrences of low DO (<3%). Based on 305(b) guidance, MDE applies a "rule-of-thumb" that a waterbody is impaired by a chemical contaminant in the water column when greater than 10% of the samples, with a minimum of ten samples collected over a three-year period, exceed the applicable criteria (EPA, 1997). This water quality analysis shows only 3% exceedance of criteria within the watershed at Station susq10.0, which does not exceed the 10% rule MDE has defined as a standard for impairment. Based on this evidence, the water quality for this basin is adequate to support the aquatic life use because the exceendances of the criterion are infrequent (<3% of the time) and are localized. Barring any contradictory future data, this information provides sufficient justification to revise Maryland's 303(d) list to remove nutrients as an impairing substance in relation to the tidal Lower Susquehanna River.

REFERENCES

Chesapeake Bay Program. Data Hub 2004

Coastal Environmental Service, Inc. "Patapsco/Back River Watershed Study," prepared for the MDE and TARSA, September 30, 1995.

Code of Maryland Regulations, 26.08.02.07, 26.08.02.03-3C(2), 26.08.02.03A(2), 26.08.02.03B(2)

Maryland Department of Planning. Digital Land Use/Land Cover Data for Maryland. 2000.

Susquehanna River Basin Commission. Lower Susquehanna Basin Data 2004

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

U.S. Environmental Protection Agency, "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.

USGS, K.J. Breen, R.A. Hainly, and S.A. Hoffman, National Water Quality Assessment Program. The Fact Sheet, Lower Susquehanna River Basin," 1991

Appendix A: Tabular Water Quality Data

STATION	DATE	TOTAL DEPTH METERS	SAMPLE DEPTH METERS	BOD5, MG/L	DO_FLD MG/L	TN, MG/L	TP, MG/L	TSS, MG/L	CHL A, µG/L	Tidal / Nontidal
XKH3152	10/28/98	19.5	0.5	2.6	9.7	2.185	0.0295	4.6	7.775	Tidal
XKH3152	10/28/98	19.5	0.5		9.7	1.9969	0.025	3.6	6.579	Tidal
XKH3152	11/17/98	18.2	0.5	1.8	10.4	1.944	0.0208	2.5	8.722	Tidal
XKH3152	11/17/98	18.2	0.5		10.4	2.034	0.0203	3.2	8.722	Tidal
XKH3152	12/1/98	17.4	0.5	2.1	11	1.871	0.0224	3	14.288	Tidal
XKH3152	12/1/98	17.4	0.5		11	2.124	0.0198	2.3	14.620	Tidal
XKH3152	1/4/99	18.5	0.5	3.1	12.2	1.992	0.0195	2.7	8.473	Tidal
XKH3152	1/4/99	18.5	0.5		12.2	1.831	0.0177	2.5	7.725	Tidal
XKH3152	1/20/99	19	0.5	2.9	12.9	2.713	0.1144	11.3	6.479	Tidal
XKH3152	1/20/99	19	0.5		12.9	2.639	0.1141	11.2	5.732	Tidal
XKH3152	2/3/99	17.5	0.5	1.6	13.7	1.636	0.0542	14.4	0.748	Tidal
XKH3152	2/3/99	17.5	0.5		13.7	1.63	0.0548	14.4	0.997	Tidal
XKH3152	2/16/99	18	0.5	1.6	12.5	1.6276	0.0354	4.8	0.748	Tidal
XKH3152	2/16/99	18	0.5		12.5	1.615	0.0358	4.4	0.748	Tidal
XKH3152	3/16/99	18.7	0.5	1	12.8	1.5618	0.025	4	1.495	Tidal
XKH3152	4/13/99	18.2	0.5	0.7	10.3	1.251	0.0436	14.8	5.233	Tidal
XKH3152	4/22/99	19	0.5	1.7	10.9	1.212	0.0337	12	11.588	Tidal
XKH3152	4/22/99	19	0.5		10.9	1.227	0.0319	11.5	10.840	Tidal
XKH3152	5/11/99	13.2	0.5	1.4	8.7	0.988	0.0285	5.6	11.027	Tidal
XKH3152	5/27/99	16.8	0.5	1.3	6.6	1.189	0.0332	7.2	3.863	Tidal
XKH3152	5/27/99	16.8	0.5		6.6	1.197	0.0333	6.4	4.037	Tidal
XKH3152	6/8/99	20.8	0.5	2.7	8.4	1.404	0.039	6	16.447	Tidal
XKH3152	6/8/99	20.8	0.5		8.4	1.432	0.0387	4	17.515	Tidal
XKH3152	6/15/99	20.6	0.5	2.5	6.4	1.175	0.0216	3	4.984	Tidal
XKH3152	6/15/99	20.6	0.5		6.4	1.167	0.0213	2.4	4.320	Tidal
XKH3152	6/22/99	15.8	0.5	2.7	6.5	1.23	0.0278	5	5.233	Tidal
XKH3152	6/22/99	15.8	0.5		6.5	1.233	0.0277	4.5	7.227	Tidal
XKH3152	7/20/99	20	0.5	1.7	8.9	0.948	0.0261	3.2	11.962	Tidal
XKH3152	8/17/99	20.6	0.5	2.1	8	0.919	0.0296	5.2	12.460	Tidal
XKH3152	9/14/99	20.3	0.5	3.3	7.2	1.536	0.0348	4.4	8.037	Tidal
XKH3644	3/16/99	8.5	0.5		12.8	1.5559	0.0283	9	1.196	Tidal
XKH3644	4/13/99	9.7	0.5		10.3	1.217	0.0386	13.2	4.486	Tidal
XKH3644	5/11/99	13	0.5		8.7	0.992	0.0317	8.5	11.962	Tidal
XKH3644	7/20/99	8.8	0.5		8.6	1.034	0.0238	3.8	13.706	Tidal
XKH3644	8/17/99	8.7	0.5		8.8	0.943	0.031	5.6	17.444	Tidal
XKH3644	9/14/99	8	0.5		7.3	1.503	0.035	4.2	8.971	Tidal
XKH4450	3/16/99	18.7	0.5		12.7	1.5424	0.0312	7	0.997	Tidal
XKH4450	4/13/99	18.3	0.5		10.4	1.265	0.0457	14.8	5.233	Tidal
XKH4450	5/11/99	17	0.5		8.8	0.952	0.0244	3.8	12.261	Tidal
XKH4450	7/20/99	18	0.5		8.2	1.091	0.0271	4	12.460	Tidal
XKH4450	8/17/99	18.6	0.5		9.2	0.86	0.0279	4.4	13.706	Tidal
XKH4450	9/14/99	18	0.5		7.2	1.565	0.0351	4	11.027	Tidal
XKH5039	3/16/99	13	0.5	0.6	12.7	1.4898	0.0271	4	1.196	Tidal

STATION	DATE	TOTAL DEPTH METERS	SAMPLE DEPTH METERS	BOD5, MG/L	DO_FLD MG/L	TN, MG/L	TP, MG/L	TSS, MG/L	CHL A, µG/L	Tidal / Nontidal
XKH5039	4/13/99	12.5	0.5	0.6	10.3	1.246	0.0449	15.6	5.233	Tidal
XKH5039	5/11/99	10.4	0.5	1.8	8.1	1.008	0.0253	4	11.027	Tidal
XKH5039	7/20/99	11.4	0.5	1.4	8.2	1.12	0.0236	2.4	9.968	Tidal
XKH5039	8/17/99	9.8	0.5	1.3	8.4	0.843	0.0218	2.6	7.476	Tidal
XKH5039	9/14/99	11.9	0.5	2.2	8.1	1.567	0.0357	3.2	13.083	Tidal
XKH5824	3/16/99		0	1.7	13	1.7853	0.0312	9.6	1.282	Tidal
XKH5824	4/13/99		0	0.4	10.3	1.595	0.048	16	3.738	Tidal
XKH5824	5/11/99		0	1.8	7.8	1.809	0.0476	6	3.987	Tidal
XKH5824	7/20/99		0	1.9	9.2	1.041	0.0257	2.6	1.922	Tidal
XKH5824	8/17/99		0	3.1	12.5	0.8022	0.0245	4.6	1.631	Tidal
XKH5824	9/14/99		0	3	8.3	1.5469	0.0298	2.4	1.994	Tidal
XKH5934	3/16/99		0		13	1.814	0.0341	9	1.495	Tidal
XKH5934	3/16/99		0		13	1.7537	0.0344	11	1.709	Tidal
XKH5934	4/13/99		0		10.1	1.625	0.0455	11.2	5.732	Tidal
XKH5934	4/13/99		0		10.1	1.652	0.0417	9.2	5.732	Tidal
XKH5934	5/11/99		0		8.4	1.613	0.0304	4.5	6.728	Tidal
XKH5934	5/11/99		0		8.4	1.719	0.0326	6	5.482	Tidal
XKH5934	7/20/99		0		6.8	1.067	0.0272	2.4	7.725	Tidal
XKH5934	7/20/99		0		6.8	1.077	0.0281	3.2	4.984	Tidal
XKH5934	8/17/99		0		8.8	0.8453	0.0203	2.4	3.157	Tidal
XKH5934	8/17/99		0		8.8	0.8544	0.0198	2.4	3.489	Tidal
XKH5934	9/14/99		0		9	1.73	0.0452	4.4	22.179	Tidal
XKH5934	9/14/99		0		9	1.778	0.049	5.4	1.495	Tidal
XKH6811	3/16/99		0		12.9	1.4966	0.0314	10.4	1.282	Tidal
XKH6811	4/13/99		0		10.3	1.518	0.0415	12	3.738	Tidal
XKH6811	5/11/99		0		8.7	1.226	0.0398	7.5	8.224	Tidal
XKH6811	7/20/99		0		7.8	0.981	0.0184	2.4	0.623	Tidal
XKH6811	8/17/99		0		9.5	0.7595	0.0171	2.4	0.748	Tidal
XKH6811	9/14/99		0		8.8	1.4881	0.0327	2.4	0.561	Tidal
SUS0109	10/29/98		0	2	9.4	2.194	0.0359	4.5	6.835	Tidal-fresh
SUS0109	11/18/98		0	3.1	10.5	1.785	0.0307	6.4	15.118	Tidal-fresh
SUS0109	12/2/98		0	2	10.2	1.671	0.022	4.1	10.466	Tidal-fresh
SUS0109	1/5/99		0	2.1	12.2	2.158	0.0398	5.2	6.355	Tidal-fresh
SUS0109	1/19/99		0	4	12.6	2.528	0.079	6	5.682	Tidal-fresh
SUS0109	2/1/99		0	3.1	13.7	1.551	0.0553	18	1.196	Tidal-fresh
SUS0109	2/17/99		0	1	12.6	1.5593	0.0274	4	0.544	Tidal-fresh
SUS0109	3/4/99		0	1	12	1.7404	0.0358	4	1.359	Tidal-fresh
SUS0109	3/16/99		0		12.8	1.544	0.0351	12	1.495	Tidal-fresh
SUS0109	4/8/99		0	1.7	11	1.0547	0.0295	9.4	4.112	Tidal-fresh
SUS0109	4/13/99		0		10.3	1.346	0.036	8	4.735	Tidal-fresh
SUS0109	5/6/99		0	1.2	9.7	1.053	0.0333	11.2	11.962	Tidal-fresh
SUS0109	5/11/99		0		8.5	1.111	0.0296	6.4	9.220	Tidal-fresh
SUS0109	6/9/99		0	2.3	6.5	1.316	0.033	5.7	2.741	Tidal-fresh
SUS0109	6/21/99		0	6.7	5.87	1.346	0.0537	9.2	4.735	Tidal-fresh
SUS0109	7/20/99		0		6.4	1.145	0.0256	5.2	4.984	Tidal-fresh

STATION	DATE	TOTAL DEPTH METERS	SAMPLE DEPTH METERS	BOD5, MG/L	DO_FLD MG/L	TN, MG/L	TP, MG/L	TSS, MG/L	CHL A, µG/L	Tidal / Nontidal
SUS0109	8/17/99		0		6.1	1.054	0.0346	6.3	6.168	Tidal-fresh
SUS0109	9/14/99		0		6.7	1.564	0.0353	4.8	2.492	Tidal-fresh
CB1.0	1/13/98		0		12.5		0.075	42	2.39	Tidal-fresh
CB1.0	2/23/98		0		12.5		0.074	33	3.29	Tidal-fresh
CB1.0	3/16/98		0		13		0.041	21	0.9	Tidal-fresh
CB1.0	4/15/98		0		10.6		0.042	12	2.69	Tidal-fresh
CB1.0	5/12/98		0		9.8		0.085	7	5.61	Tidal-fresh
CB1.0	6/9/98		0		6.5		0.05	6	4.49	Tidal-fresh
CB1.0	7/14/98		0		6.8		0.059	6	6.28	Tidal-fresh
CB1.0	8/11/98		0		6.3		0.036	8	3.36	Tidal-fresh
CB1.0	9/22/98		0		7.1		0.012	8	4.64	Tidal-fresh
CB1.0	10/6/98		0		6		0.046	7	4.04	Tidal-fresh
CB1.0	11/4/98		0		8.4		0.036	5	9.72	Tidal-fresh
CB1.0	12/1/98		0		10.1		0.033	15	9.87	Tidal-fresh
CB1.0	1/5/99		0		12.5		0.064	22	8.67	Tidal-fresh
CB1.0	3/9/99		0		13.7		0.154	20	2.99	Tidal-fresh
CB1.0	4/6/99		0		10.7		0.031	9	3.663	Tidal-fresh
CB1.0	5/3/99		0		10.6		0.042	15	21.531	Tidal-fresh
CB1.0	6/15/99		0		6.7		0.056	5	2.467	Tidal-fresh
CB1.0	7/13/99		0	4.6	6.1		0.037	6	8.672	Tidal-fresh
CB1.0	8/9/99		0		6.7		0.034	7	6.878	Tidal-fresh
CB1.0	9/14/99		0		5.9		0.033	5	2.572	Tidal-fresh
CB1.0	10/13/99		0		9.2		0.046	6.5	6.579	Tidal-fresh
CB1.0	11/16/99		0		9.1		0.035	11.5	3.289	Tidal-fresh
CB1.0	12/14/99		0		11.1		0.034	113	3.289	Tidal-fresh
CB1.0	1/11/00		0		12.1		0.03	8.5	1.396	Tidal-fresh
CB1.0	2/8/00		0		13.3		0.029	4	0.598	Tidal-fresh
CB1.0	3/6/00		0		12.3		0.069	1	0.897	Tidal-fresh
CB1.0	4/4/00		0		10.6		0.035	2	7.476	Tidal-fresh
CB1.0	5/3/00		0		10.8		0.04	6	17.942	Tidal-fresh
CB1.0	6/7/00		0		8.2		0.051	5	15.7	Tidal-fresh
CB1.0	7/25/00		0		6.3		0.025	9	4.04	Tidal-fresh
CB1.0	8/2/00		0		5.6		0.036	9	4.64	Tidal-fresh
CB1.0	9/5/00		0		6.8		0.032	11	5.38	Tidal-fresh
CB1.0	10/4/00		0		7		0.032	5	1.99	Tidal-fresh
CB1.0	11/1/00		0		8.9		0.05	5	3.29	Tidal-fresh
CB1.0	12/5/00		0		12.6		0.023	24	4.64	Tidal-fresh
CB1.0	1/23/01		0		13.1		0.034	7	0.8	Tidal-fresh
CB1.0	2/20/01		0		13.2		0.04	9	4.78	Tidal-fresh
CB1.0	3/26/01		0		12.5		0.048	12	9.57	Tidal-fresh
CB1.0	4/30/01		0		10		0.044		17.64	Tidal-fresh
CB1.0	5/14/01		0		7.7		0.041	7	11.51	Tidal-fresh
CB1.0	6/6/01		0		6.2		0.044	4	10.96	Tidal-fresh
CB1.0	7/31/01		0		6.5		0.04	6	6.92	Tidal-fresh
CB1.0	8/27/01		0		6.2		0.042	5	4.04	Tidal-fresh

STATION	DATE	TOTAL DEPTH METERS	SAMPLE DEPTH METERS	BOD5, MG/L	DO_FLD MG/L	TN, MG/L	TP, MG/L	TSS, MG/L	CHL A, µG/L	Tidal / Nontidal
CB1.0	9/25/01		0		6		0.036	1	3.92	Tidal-fresh
CB1.0	10/15/01		0		7.3		0.026	1	3.44	Tidal-fresh
CB1.0	11/5/01		0		8.4		0.058	3	7.18	Tidal-fresh
CB1.0	12/4/01		0		8.9		0.029	18	4.19	Tidal-fresh
CB1.0	1/14/02		0		13.5		0.03	10	4.34	Tidal-fresh
CB1.0	2/5/02		0		13.1		0.04	9	5.98	Tidal-fresh
CB1.0	3/5/02		0		11.7		0.038	7	9.12	Tidal-fresh
CB1.0	4/2/02		0		11.4		0.048	6	3.89	Tidal-fresh
CB1.0	5/13/02		0		10.1		0.039	5	18.84	Tidal-fresh
CB1.0	6/5/02		0		7.4		0.042	9	6.88	Tidal-fresh
CB1.0	7/1/02		0		6.4		0.024	5	3.44	Tidal-fresh
CB1.0	8/19/02		0		6.4		0.026	13	3.36	Tidal-fresh
CB1.0	9/3/02		0		6.3		0.044	7	5.58	Tidal-fresh
CB1.0	10/1/02		0		6.8		0.048	3	7.03	Tidal-fresh
CB1.0	11/6/02		0		11		0.054	6	0.9	Tidal-fresh
CB1.0	12/2/02		0		11.8		0.038	10	1.3	Tidal-fresh
susq10.0	8/5/98		0		5.2		0.020	No data	No data	Tidal-fresh
susq10.0	11/5/98		0		5.6		0.050	No data	No data	Tidal-fresh
susq10.0	2/10/99		0		8.0		0.050	No data	No data	Tidal-fresh
susq10.0	4/27/99		0		6.9		0.050	No data	No data	Tidal-fresh
susq10.0	8/5/99		0		4.7		0.040	No data	No data	Tidal-fresh
susq10.0	11/12/99		0		4.6		0.040	No data	No data	Tidal-fresh
susq10.0	2/8/00		0		7.0		0.170	No data	No data	Tidal-fresh
susq10.0	5/3/00		0		5.2		0.040	No data	No data	Tidal-fresh
susq10.0	8/2/00		0		3.5		0.070	No data	No data	Tidal-fresh
susq10.0	11/15/00		0		5.8		0.070	No data	No data	Tidal-fresh
susq10.0	2/19/01		0		6.9		0.050	No data	No data	Tidal-fresh
susq10.0	5/14/01		0		4.1		0.030	No data	No data	Tidal-fresh
susq10.0	8/1/01		0		8.4		0.030	No data	No data	Tidal-fresh
susq10.0	11/12/01		0		5.8		0.030	No data	No data	Tidal-fresh
susq10.0	2/20/02		0		8.9		0.040	No data	No data	Tidal-fresh
susq10.0	4/18/02		0		8.3		0.040	No data	No data	Tidal-fresh
susq10.0	7/31/02		0		4.6		0.050	No data	No data	Tidal-fresh
susq10.0	11/18/02		0		6.9		0.036	No data	No data	Tidal-fresh
susq10.0	6/2/03		0		7.6		0.043	No data	No data	Tidal-fresh
RXK0001	3/16/99		0	2.4	13.3	2.3488	0.0263	2.4	1.296	Tidal-fresh
RXK0001	4/13/99		0	0.5	11.6	2.5185	0.0333	2.4	2.617	Tidal-fresh
RXK0001	5/11/99		0	1.2	10.3	4.0040	0.0631	4.9	1.246	Tidal-fresh
RXK0001	7/20/99		0	1.1	8.6	2.7592	0.1072	4.4	1.282	Tidal-fresh
RXK0001	8/17/99		0	0.6	8.3	2.1301	0.105	2.6	0.816	Tidal-fresh
RXK0001	9/14/99		0	3.4	8.6	2.304	0.0941	2.4		Tidal-fresh

Table A1: Field and Laboratory Protocols

Parameter	Units	Detection Limits	Method Reference
IN SITU:			
Flow	cfs	0.01 cfs	Meter (Marsh-McBirney Model 2000 Flo-Mate)
Temperature	degrees Celsius	-5 deg. C to 50 deg. C	Linear thermistor network; Hydrolab Multiparameter Water Quality Monitoring Instruments Operating Manual (1995) Surveyor 3 or 4 (HMWQMIOM)
Dissolved Oxygen	mg/L	0 to 20 mg/l	Au/Ag polargraphic cell (Clark); HMWQMIOM
Conductivity	micro Siemens/cm (μS/cm)	0 to 100,000 μS/cm	Temperature-compensated, five electrode cell Surveyor 4; or six electrode Surveyor 3 (HMWQMIOM)
pH	pH units	0 to 14 units	Glass electrode and Ag/AgCl reference electrode pair; HMWQMIOM
Secchi Depth	meters	0.1 m	20.3 cm disk
GRAB SAMPLES:			
Ammonium	mg N / L	0.003	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Nitrate + Nitrite	mg N / L	0.0007	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Nitrite	mg N / L	0.0003	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Total Dissolved Nitrogen	mg N / L	0.03	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Particulate Nitrogen	mg N / L	0.0123	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Ortho-phosphate	mg P / L	0.0007	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Total Dissolved Phosphorus	mg P / L	0.0015	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Total Phosphorus	mg P / L		Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Particulate Phosphorus	mg P / L	0.0024	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Dissolved Organic Carbon	mg C / L	0.15	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Particulate Carbon	mg C / L	0.0759	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Silicate	mg Si / L	0.01	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Total Suspended Solids	mg / L	2.4	Chesapeake Biological Laboratory. Standard Operating Procedures. TR No. 158-97
Chlorophyll *a*	μg/L	1 mg/cu.M	Standard methods for the Examination of Water and Wastewater (15th ed.) #1002G. Chlorophyll. Pp 950-954
BOD_5	mg/l	0.01 mg/l	Oxidation ** EPA No. 405