Water Quality Analysis of Eutrophication for Lake Needwood, Montgomery County, MD

FINAL

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List of Abbreviations

BOD	Biochemical Oxygen Demand
CEES	Center for Estuarine and Environmental Science
COMAR	Code of Maryland Regulation
CWA	Clean Water Act
DHMH	Department of Health and Mental Hygiene
DNR	Department of Natural Resources
DO	Dissolved Oxygen
EPA	Environmental Protection Agency
m	Meters
MDE	Maryland Department of the Environment
mg/l	Milligrams Per Liter
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
USDA	United States Department of Agriculture
WQLS	Water Quality Limited Segment
µg/l	Micrograms Per Liter

EXECUTIVE SUMMARY

Section 303(d) of the federal Clean Water Act (the Act) directs States to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS, 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.

Lake Needwood in the Rock Creek watershed (02-14-02-06) was identified on Maryland's 1998 list of water quality limited segments (WQLSs) as being impaired by nutrients. This report analyzes recent monitoring data, showing that the dissolved oxygen criterion and designated uses associated with nutrients are being met in Lake Needwood. This analysis supports the conclusion that a TMDL for nutrients is not necessary to achieve water quality standards in this case. Barring the receipt of any contradictory data, this report will be used to support the removal of Lake Needwood from Maryland's list of WQLSs for nutrients when the Maryland Department of the Environment (MDE) proposes the revision of Maryland's 303(d) list for public review in the future. Although the waters of Lake Needwood do not display signs of eutrophication, the State reserves the right to require additional pollution controls in the Rock Creek 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.

A segment identified as a WQLS may not require the development and implementation of a TMDL if current information contradicts the previous finding of impairment. As per EPA guidance, reasons obviating the need for a TMDL include the following: 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 that demonstrates that the segment is attaining standards; 3) refinements to water quality standards, or the interpretation of those standards, that result in standards being met; or 4) correction to errors made in the initial listing. Scenarios 1, 2 and 3 all apply to the present case.

Lake Needwood in the Rock Creek watershed (02-14-02-06) was identified in the *Maryland Lake Water Quality Assessment* (DNR, 1995) as having dissolved oxygen (DO) levels in the subsurface waters below the applicable numeric criterion. The low DO levels were attributed to nutrients; therefore, Lake Needwood was added to Maryland's 1998 303(d) list of water quality limited segments as impaired by nutrients. This report provides more recent information that supports the removal of the Lake Needwood listing when the 303(d) list is revised.

The remainder of this report describes the general setting of the Lake Needwood watershed, presents a discussion of the water quality characterization process, and provides conclusions with regard to the characterization. The data establish that Lake Needwood achieves water quality standards.

2.0 GENERAL SETTING

Lake Needwood is an impoundment located near Rockville in Montgomery County, Maryland (Figure 1). The impoundment, which is owned by the Maryland - National Capital Park and Planning Commission, lies on Rock Creek, a tributary of the Potomac River. An earthen dam was installed in 1965 for the purpose of sediment and flood control and creating a lake for recreational uses. The lake was periodically dredged, ending in 1990.

Lake Needwood lies in the Piedmont physiographic province. The soils immediately surrounding the lake are the Glenelg-Gaila-Occoquan association (Soil Conservation Service, 1994). These soils generally range from fine-loamy, mixed, mesic Ochreptic Hapludults to mesic Typic Hapludults. They are very deep and well drained. They form in material weathered from quartz muscovite schist, schist and gneiss. The outer watershed area is comprised of soils of the Urban Land-Wheaton-Glenelg association. These soils are very deep and well drained (USDA, 1994).

Lake Needwood lies in the Piedmont ecoregion, which lies between the Appalachian Mountains and the Atlantic Coastal Plain on the East Coast. The Piedmont has a rolling to moderately hilly topography with variable soils. Common Piedmont land use includes forest, agriculture, and development. There are few natural lakes in this ecoregion (none in Maryland).

Inflow to the lake is primarily via Rock Creek and Mill Creek. Discharge from the lake is to Rock Creek, which discharges to the Potomac River. The watershed map (Figure 2) shows that land use in the watershed draining to Lake Needwood is predominantly developed. Land use distribution in the watershed is 52% developed, 25% forested, less than 1% water, and 22% agricultural (Figure 3) (Maryland Department of Planning, 2000).

Agricultural land use has gradually decreased within the watershed, concurrent with an increase in forested land (MCDEP, 2001). At the same time, the character of agriculture has shifted from dairy farming and intensive row cropping to horse operations (D. Harber, Montgomery County, pers. comm., 2002).

Several relevant statistics for Lake Needwood are provided below in Table 1.

Table 1

Current Physical Characteristics of Lake Needwood

Location:	Montgomery County, MD lat. 39° 06' 30" long. 77° 07' 20"
Surface Area:	74 acres = 3,223,660 ft^2 = 299,478 m^2
Length:	1.1 mi
Maximum Width:	1,125 feet
Average Lake Depth:	8.11 feet
Maximum Depth:	20.5 feet
Purpose:	Recreation and Flood Control
Basin Code	02-14-02-06
Volume of Lake:	600 acre-feet (740,100 m^3)
Drainage Area to Lake:	12.8 mi^2
Average Discharge:	15.8 cfs

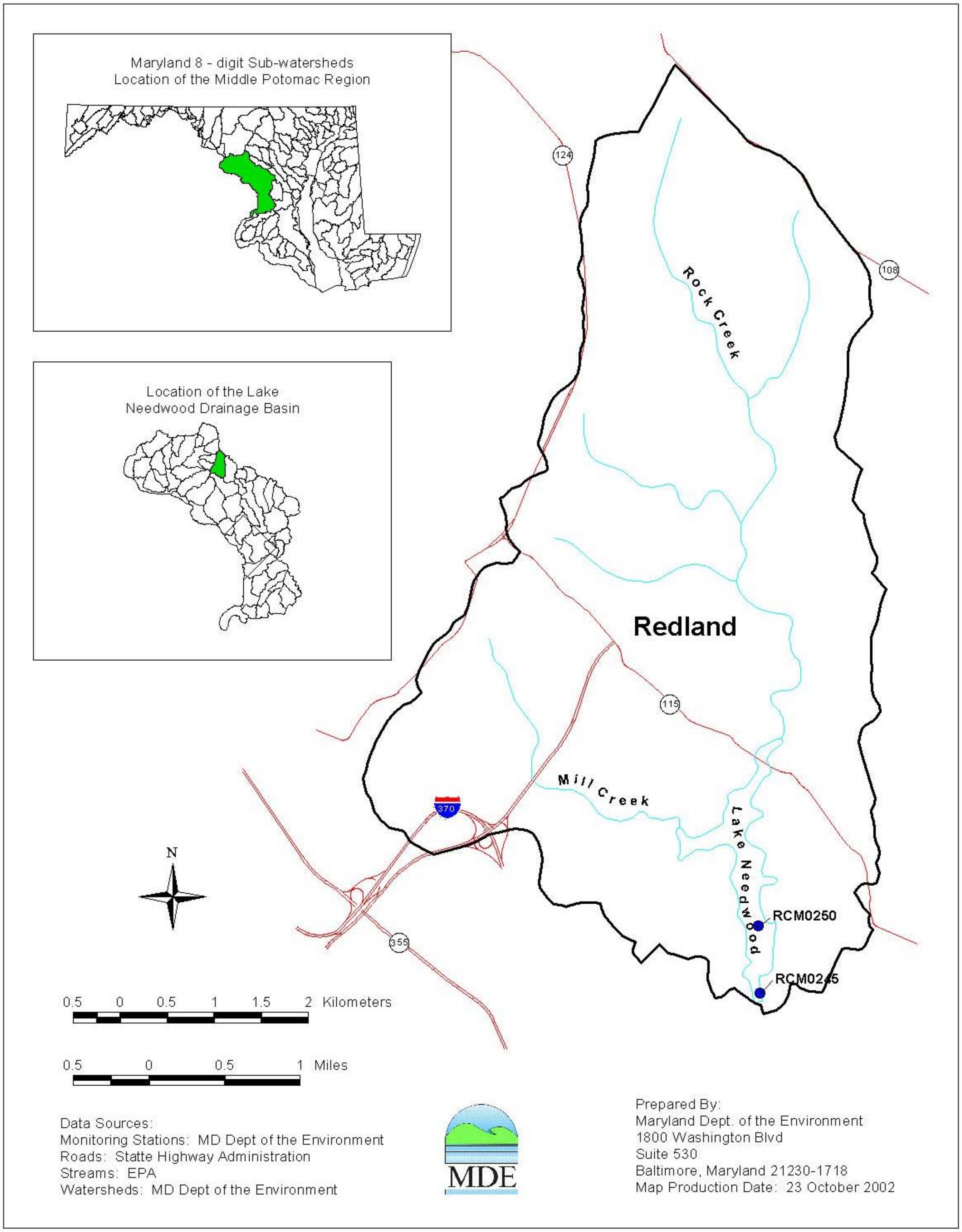

Figure 1 – Location Map of Lake Needwood in Montgomery County, MD

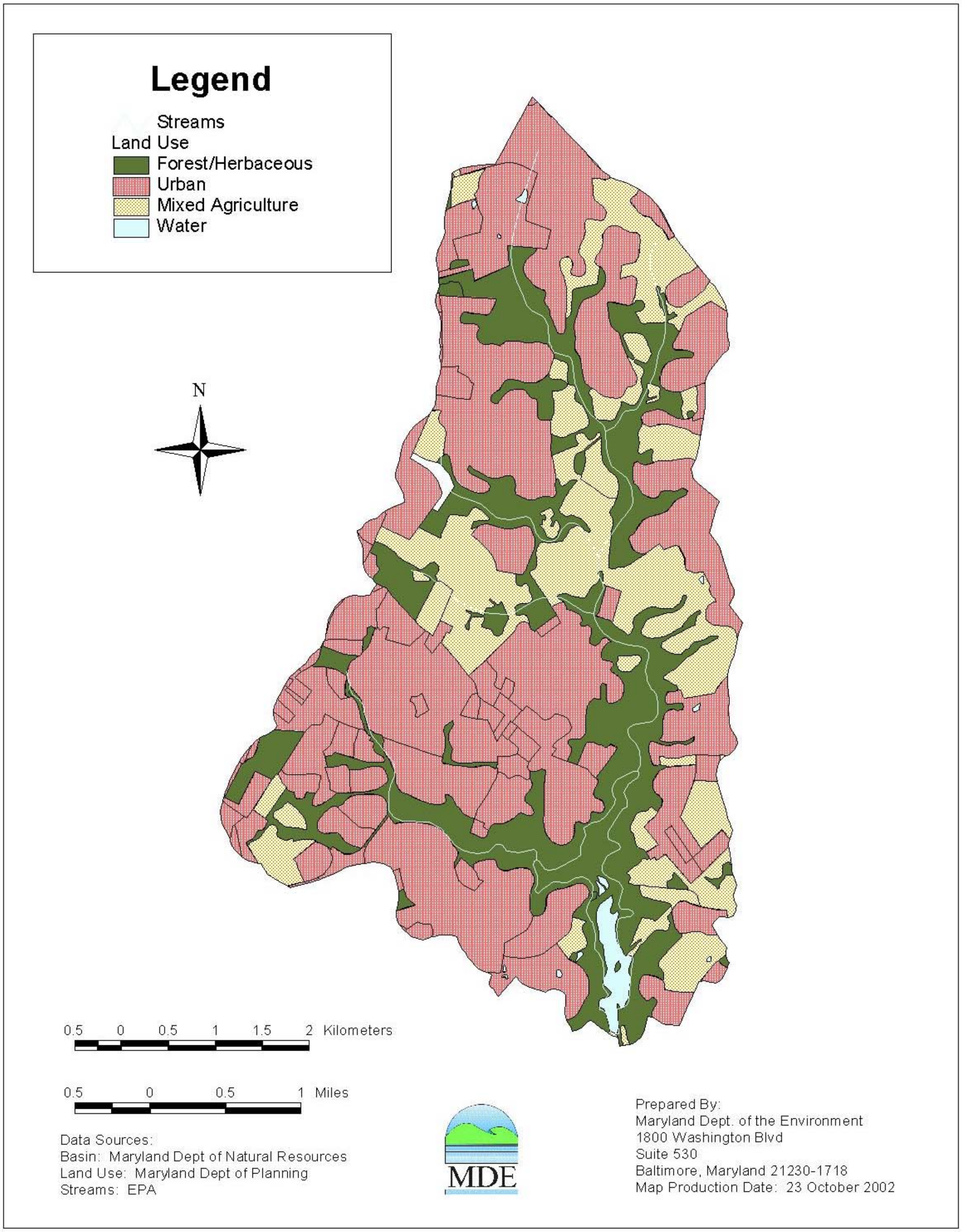

Figure 2 – Predominant Land Use in the Lake Needwood Watershed

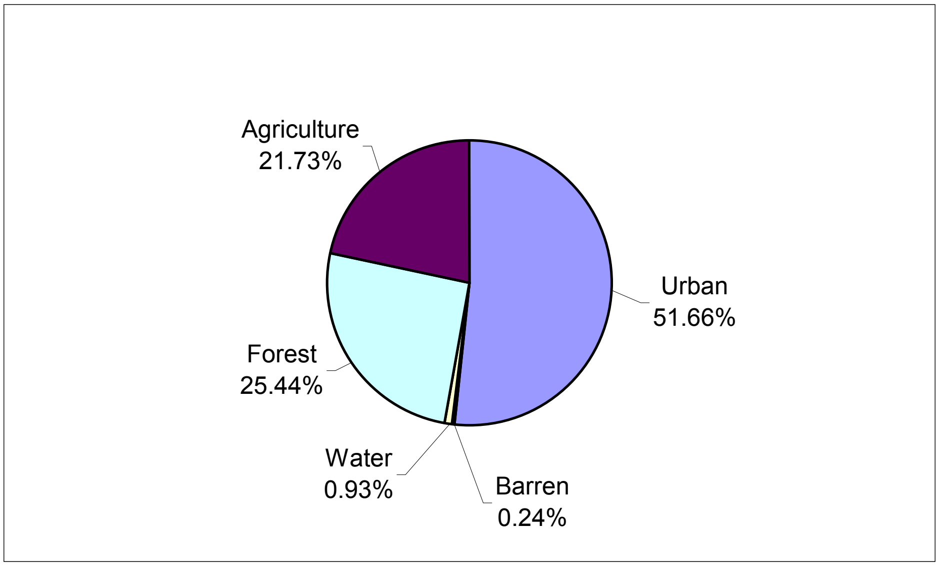

Figure 3. Land Use in Drainage Basin of Lake Needwood

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 designated to protect that use. Designated uses include activities such as swimming, drinking water supply, and trout 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 resulting low DO.

Lake Needwood was identified in the *Maryland Lake Water Quality Assessment* (DNR, 1995) as having DO levels below the applicable numeric criterion. As a result of this evaluation, Lake Needwood was added to Maryland's 1998 303(d) list. Low DO levels occur only in the subsurface waters.

Lake Needwood has been designated a Use IV water body, pursuant to which it is protected for water contact recreation, fishing, aquatic life and wildlife, and holding and supporting adult trout for put-and-take fishing. See Code of Maryland Regulations (COMAR) 26.08.02.07. Use I waters are subject to a DO criterion of not less than 5.0 mg/l at any time unless natural conditions result in lower levels of DO (COMAR 26.08.02.03A(2)). The DO concentration in the bottom waters of Lake Needwood occasionally falls below the criterion of 5.0 mg/l.

[1] Maryland limits the ammonia form of nitrogen from the Waste Water Treatment Plants, due to its toxic effects on some aquatic organisms.

Maryland's General Water Quality Criteria prohibit pollution of waters of the State by any material in amounts sufficient to create a nuisance or interfere directly or indirectly with designated uses. See 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. The chlorophyll *a* endpoint selected for Lake Needwood is a maximum concentration of 20 µg /l, or approximately 60 on the Carlson's Trophic State Index (TSI) (Carlson 1977). This is in the lower range of eutrophy, which is an appropriate trophic state at which to manage this impoundment.

Other states have established their trophic-states for lakes or impoundments with differing uses. Minnesota, for example, uses an ecoregion-based approach. Heiskary (2000) reports that individuals utilizing lakes for recreational purposes (water contact, fishing) demanded relatively clear, less enriched lakes in the Northern Lakes and Forest (NLF) and North Central Hardwood Forest (NCHF) ecoregions. In the Western Corn Belt Plains (WCBP) and Northern Glaciated Plains (NGP) ecoregions; however, users accepted relatively greater enrichment and less clarity. Under Minnesota's classification system, lakes in the NLF and NCHF ecoregions are considered to fully meet use support with TSIs of about 53 and 57, respectively. Lakes in the other two ecoregions, both of which are largely agricultural, are considered to fully support use with TSIs of about 60 (Heiskary, 2000).

Because Lake Needwood is not used as a drinking water source, the appropriate management goal is to protect the aquatic life and support for recreational uses, *e.g.* fishing and boating. Moderate degrees of eutrophication are compatible with these uses. A maximum chlorophyll *a* threshold of 20 µg/l represents an acceptable level at which nuisance algal blooms and excessive aquatic macrophyte growth will be kept in check.

Monitoring for the DNR lake assessment was conducted in August 1993. Physical measurements, including water temperature, pH, conductivity, and dissolved oxygen, were recorded at 0.3 m from the surface, at 0.3 m from the bottom, and at every whole meter in between. Water samples were collected at 0.3 m from the water surface. The Maryland Department of Health and Mental Hygiene (DHMH) laboratory analyzed water samples for total phosphorus, total Kjeldahl nitrogen (TKN), and chlorophyll *a*.

MDE conducted additional monitoring in July and August 2001. MDE monitoring included 3 in-lake stations. In-lake physical measurements, including water temperature, pH, conductivity, and DO, were recorded at 0.5 m from the surface, at 1.0 m from the bottom, and at every whole meter in between. Water samples were collected 0.5 m from water surface. The University of Maryland Center for Estuarine and Environmental Science (CEES) laboratory conducted analyses on water samples for dissolved and particulate species of nitrogen and phosphorus. The DHMH laboratory analyzed the water samples for chlorophyll *a*.

Detailed water quality data from the aforementioned 1993 and 2001 sampling events are presented in the Appendix. Table A1 contains the physical water quality data (i.e., temperature, pH, DO, and conductivity), nutrient data are presented in Table A2, and chlorophyll *a* data are presented in Table A3.

3.1 Nutrients

Total phosphorus (TP) concentration data for 1993 are unavailable; TP measured in 2001 ranged from 0.02 mg/l to 0.03 mg/l. TKN concentrations measured in 1993 ranged from 0.60 mg/l to 0.80 mg/l; TKN data for 2001 are unavailable. Total nitrogen (TN) was not reported for the 1993 sampling event; TN concentrations measured in 2001 ranged from 0.87 mg/l to 1.26 mg/l.

As stated in Section 2.2, the lake was periodically dredged until 1990. The effects of the cessation of this practice on the phosphorus budget of the lake are unknown.

3.2 Dissolved Oxygen

Water temperatures taken during the summer sampling periods of 1993 and 2001 ranged from 29.5°C to 22.6°C in the 0.3 - 2 meter water column, 26.5°C to 13.5°C in the 2 – 4 meter water column, and 20.3°C to 11.9°C in the 5 - 7 meter water column. An abrupt discontinuity in water temperature at about 2 m indicates that Lake Needwood is thermally stratified and not well mixed. DO concentrations ranged from 0.1 to 12.3 mg/l along the vertical profile (Figures A1-A3 in Appendix). Oxygen concentrations along the vertical profile decrease discontinuously, coincident with the depth at which thermal stratification begins (*i.e.* about 2 m). DO concentrations in the surface layer (above a depth of about 2 m) between 7.5 and 12.3 mg/l are contrasted by DO concentrations as low as 0.1 mg/l at and below 3 m. In 1991, two near-surface (2 m) DO samples fell below the State's standard of 5.0 mg/l (3.5 mg/l and 4.7 mg/l, respectively). Observed hypolimnetic DO concentrations fall below 10% saturation. Although this concentration is below 5.0 mg/l of the DO criterion, it is consistent with natural conditions in the hypolimnia of stratified eutrophic lakes, which is documented in MDE's interim interpretation for stratified lakes (see Appendix).

3.3 Chlorophyll *a*

A chlorophyll *a* concentration of 10 µg/l is typically associated with the boundary between eutrophic and mesotrophic states of a lake (Chapra, 1997). Instantaneous chlorophyll *a* concentrations ranging from 8.2 to 38.6 µg/l in 1993, and 7.5 to 15.5 µg/l in 2001, were observed in Lake Needwood. The maximum observed values in Lake Needwood, though associated with eutrophic conditions, are not extreme when compared to peak concentration of 275 µg/l in hyper-eutrophic lakes (Olem and Flock, 1990).

Chlorophyll *a* measured in Lake Needwood indicates an improvement in water quality between 1993 and 2001. Because data were not collected in intervening years, an exact time at which this shift occurred cannot be determined. However, land use changes, the cessation of dredging in the lake, and a gradual phase-in of stormwater and agricultural best management practices within the watershed may account for the change.

4.0 CONCLUSION

An impairment as defined by chlorophyll *a* concentrations in excess of 20 µg/l was apparent during sampling in 1993. Additionally, two near-surface (2 m) DO samples collected during

1993 fell below the standard of 5.0 mg/l. However, the data collected more recently and presented in this report suggest that there is no longer excessive algal growth in Lake Needwood, as indicated by low chlorophyll *a*. Similarly, DO concentrations meet standards. Some of the observed water quality improvement is probably a result of a cumulative reduction in sediment and phosphorus loadings over the years, through the aforementioned land use changes, cessation of dredging, and a gradual phase-in of (mandatory) urban and (voluntary) agricultural best management practices over time (MCDEP, 2001). 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 Lake Needwood.

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APPENDIX A

Table A-1
Physical Water Quality Data—Lake Needwood

SAMPLING STATION IDENTIFIER	DATE START SAMPLING	TIME START SAMPLING	SAMPLE DEPTH (m)	WATER TEMP (°C)	FIELD PH	DO obs. (mg/l)	DO SAT %	COND (µmhos/cm)
RCM0245	08/03/1993	1010	0.3	25.7	9.3	11.6	143.2278	124
RCM0245	08/03/1993	1055	1.0	25.6	9.2	11.7	143.1532	124
RCM0245	08/03/1993	1055	2.0	23.4	7.8	9.1	106.887	123
RCM0245	08/03/1993	1055	3.0	21.4	6.9	3.7	41.82747	123
RCM0245	08/03/1993	1055	4.0	17.5	6.9	1.0	10.45466	118
RCM0245	08/03/1993	1055	5.0	14.5	7.0	0.2	1.961968	125
RCM0245	08/03/1993	1055	5.7	13.2	7.0	0.2	1.906602	156
RCM0250	08/03/1993	1320	0.3	26.1	9.2	11.6	143.2278	123
RCM0250	08/03/1993	1320	1.0	25.8	9.2	11.4	139.9925	122
RCM0250	08/03/1993	1320	1.5	24.0	8.7	9.7	115.225	122
RCM0245	08/03/1993	1055	0.3	27.0	9.4	11.8	148.0819	135
RCM0245	08/03/1993	1055	1.0	26.9	9.4	11.8	147.8165	135
RCM0245	08/03/1993	1055	2.0	26.5	7.3	3.5	43.52929	133
RCM0245	08/03/1993	1055	3.0	25.6	7.0	0.1	1.223531	137
RCM0245	08/03/1993	1055	4.0	22.6	6.8	0.1	1.156895	164
RCM0245	08/03/1993	1320	5.0	20.3	6.8	0.1	1.106363	197
RCM0245	08/03/1993	1320	5.5	18.6	6.8	0.1	1.069309	265
RCM0250	08/03/1993	1320	0.3	27.3	9.4	12.3	155.1875	134
RCM0250	08/03/1993	1320	1.0	27.1	9.4	11.9	149.6047	133
RCM0250	08/03/1993	1320	1.6	26.8	9.1	9.1	113.7894	130
RCM0245	07/18/2001	9:45	0.5	27	9.3	10.8	135.5326	143
RCM0245	07/18/2001	9:45	0.5	27	9.3	10.8	135.5326	143
RCM0245	07/18/2001	9:45	1	27	9.3	10.8	54.58163	142
RCM0245	07/18/2001	9:45	2	22.8	7	4.7	32.14147	137
RCM0245	07/18/2001	9:45	3	17.1	6.9	3.1	4.798374	160
RCM0245	07/18/2001	9:45	4	13.5	6.9	0.5	4.607837	235
RCM0245	07/18/2001	9:45	4.8	11.7	7	0.5	4.607837	323
RCM0250	07/18/2001	10:10	0.5	27	9.2	10.7	134.2777	145
RCM0250	07/18/2001	10:10	0.5	27	9.2	10.7	134.2777	145
RCM0250	07/18/2001	10:10	1	26.5	9	10.2	126.8568	145
RCM0245	07/23/2001	10:30	0.5	26.5	9.2	11.1	138.05	149
RCM0245	07/23/2001	10:30	0.5	26.5	9.2	11.1	138.05	149
RCM0245	07/23/2001	10:30	1	26.3	9.2	11.1	137.5519	148
RCM0245	07/23/2001	10:30	2	25.3	8.8	11.2	136.2848	145
RCM0245	07/23/2001	10:30	3	19.1	7	5.7	61.57031	149
RCM0245	07/23/2001	10:30	4	14.7	7	0.6	5.911543	214
RCM0245	07/23/2001	10:30	5.1	11.9	7	0.9	8.332067	326
RCM0250	07/23/2001	11:50	0.5	27	9.2	11.3	141.8073	150
RCM0250	07/23/2001	11:50	0.5	27	9.2	11.3	141.8073	150

SAMPLING STATION IDENTIFIER	DATE START SAMPLING	TIME START SAMPLING	SAMPLE DEPTH (m)	WATER TEMP (°C)	FIELD PH	DO obs. (mg/l)	DO SAT %	COND (µmhos/cm)
RCM0250	07/23/2001	11:50	1.2	26.5	8.9	10.8	134.3189	151
RCM0245	07/31/2001	8:40	0.5	24.4	8.7	8.5	101.7258	144
RCM0245	07/31/2001	8:40	0.5	24.4	8.7	8.5	101.7258	144
RCM0245	07/31/2001	8:40	1	24.4	8.7	8.4	100.529	143
RCM0245	07/31/2001	8:40	2	24.3	8.6	8.1	96.75861	143
RCM0245	07/31/2001	8:40	2.9	21	6.4	0.6	6.730157	141
RCM0250	07/31/2001	9:00	0.5	24.6	8.7	8.6	103.3053	145
RCM0250	07/31/2001	9:00	0.5	24.6	8.7	8.6	103.3053	145
RCM0250	07/31/2001	9:00	1	24.6	8.7	8.5	102.104	145
RCM0250	07/31/2001	9:00	1.8	24.1	7.5	6.8	80.92726	147
RCM0245	08/08/2001	9:51	0.5	29.2	8.4	10.2	133.0801	150
RCM0245	08/08/2001	9:51	0.5	29.2	8.4	10.2	133.0801	150
RCM0245	08/08/2001	9:51	1	28.9	8.8	10.9	141.4696	150
RCM0245	08/08/2001	9:51	2	26.1	8.5	11.2	138.2889	148
RCM0245	08/08/2001	9:51	3	21.5	5.9	0.5	5.663346	142
RCM0245	08/08/2001	9:51	4	15.7	6.1	0.3	3.020037	226
RCM0245	08/08/2001	9:51	4.7	13.4	6	0.7	6.702844	274
RCM0250	08/08/2001	10:08	0.5	29.5	8.8	11.3	148.2038	150
RCM0250	08/08/2001	10:08	0.5	29.5	8.8	11.3	148.2038	150
RCM0250	08/08/2001	10:08	1	29	8.8	12.2	158.6194	149
RCM0250	08/08/2001	10:08	1.7	27.5	7.6	8.3	105.0953	147

Table A-2
Water Quality (Nutrient) Data Lake Needwood

SAMPLING STATION IDENTIFIER	DATE START SAMPLING	TIME START SAMPLING	SAMPLE DEPTH	TOTAL NITROGEN MG/L	TOTAL KJELDAHL NITROGEN MG/L	TOTAL PHOSPHORUS MG/L
RCM0245	07/07/1993	11:25	0.3		0.75	0.028
RCM0250	07/07/1993	14:05	0.3		0.6	0.052
RCM0250			0.3			
RCM0250			0.3			
RCM0250			0.3			
RCM0250			1.0			
RCM0250			1.5			
RCM0245	07/07/1993	13:35	0.3		0.85	0.037
RMC0250	07/07/1993	14:10	0.3		0.8	0.035
RCM0250			0.3			
RCM0250			0.3			
RCM0250			0.3			
RCM0250			1.0			
RCM0250			1.6			
RCM0245	07/18/2001	9:45	0.5	1.164		0.0207
RCM0245	07/18/2001	9:45	0.5			
RCM0245	07/18/2001	9:45	1			
RCM0245	07/18/2001	9:45	2			
RCM0245	07/18/2001	9:45	3			
RCM0245	07/18/2001	9:45	4			
RCM0245	07/18/2001	9:45	4.8			
RCM0250	07/18/2001	10:10	0.5	1.262		0.0267
RCM0250	07/18/2001	10:10	0.5			
RCM0250	07/18/2001	10:10	1			
RCM0245	07/23/2001	10:30	0.5			
RCM0245	07/23/2001	10:30	0.5			
RCM0245	07/23/2001	10:30	1			
RCM0245	07/23/2001	10:30	2			
RCM0245	07/23/2001	10:30	3			
RCM0245	07/23/2001	10:30	4			
RCM0245	07/23/2001	10:30	5.1			
RCM0250	07/23/2001	11:50	0.5			
RCM0250	07/23/2001	11:50	0.5			
RCM0250	07/23/2001	11:50	1.2			
RCM0245	07/31/2001	8:40	0.5	1.083		0.0327
RCM0245	07/31/2001	8:40	0.5			
RCM0245	07/31/2001	8:40	1			
RCM0245	07/31/2001	8:40	2			
RCM0245	07/31/2001	8:40	2.9			
RCM0250	07/31/2001	9:00	0.5	1.055		0.0289
RCM0250	07/31/2001	9:00	0.5			
RCM0250	07/31/2001	9:00	1			

SAMPLING STATION IDENTIFIER	DATE START SAMPLING	TIME START SAMPLING	SAMPLE DEPTH	TOTAL NITROGEN MG/L	TOTAL KJELDAHL NITROGEN MG/L	TOTAL PHOSPHORUS MG/L
RCM0250	07/31/2001	9:00	1.8			
RCM0245	08/08/2001	9:51	0.5	0.8713		0.017
RCM0245	08/08/2001	9:51	0.5			
RCM0245	08/08/2001	9:51	1			
RCM0245	08/08/2001	9:51	2			
RCM0245	08/08/2001	9:51	3			
RCM0245	08/08/2001	9:51	4			
RCM0245	08/08/2001	9:51	4.7			
RCM0250	08/08/2001	10:08	0.5	0.962		0.0205
RCM0250	08/08/2001	10:08	0.5			
RCM0250	08/08/2001	10:08	1			
RCM0250	08/08/2001	10:08	1.7			

Table A-3
Water Quality (Chlorophyll a) Data Lake Needwood

SAMPLING STATION IDENTIFIER	DATE START SAMPLING	TIME START SAMPLING	SAMPLE DEPTH	CHLOROPHYLL A µG/L	PHEOPHYTIN A µG/L
RCM0245	06/23/1993	1440	0.3	8.2	0.7
RCM0245	07/06/1993	0920	0.3	8.4	-0.7
RCM0245			0.3		
RCM0245			1.0		
RCM0245			2.0		
RCM0245			3.0		
RCM0245			4.0		
RCM0245			5.0		
RCM0245			5.7		
RCM0250	07/06/1993	1150	0.3	11.0	-1.7
RCM0250	07/06/1993	0855	0.3	10.5	-0.8
RCM0250			0.3		
RCM0250			1.0		
RCM0250			1.5		
RCM0245	06/23/1993	1315	0.3	24.5	2.5
RCM0245	06/23/1993	1325	0.3	26.9	0.7
RCM0245			0.3		
RCM0245			1.0		
RCM0245			2.0		
RCM0245			3.0		
RCM0245			4.0		
RCM0245			5.0		
RCM0245			5.5		
RCM0250	07/06/1993	1000	0.3	38.6	-5.5
RCM0250	07/06/1993	1150	0.3	30.2	2.7
RCM0250			0.3		
RCM0250			1.0		
RCM0250			1.6		
RCM0245	07/18/2001	9:45	0.5	8.1	0.9
RCM0245	07/18/2001	9:45	0.5	8.2	2.1
RCM0245	07/18/2001	9:45	1		
RCM0245	07/18/2001	9:45	2		
RCM0245	07/18/2001	9:45	3		
RCM0245	07/18/2001	9:45	4		
RCM0245	07/18/2001	9:45	4.8		
RCM0250	07/18/2001	10:10	0.5	9.7	1.5
RCM0250	07/18/2001	10:10	0.5	9.7	0.9
RCM0250	07/18/2001	10:10	1		
RCM0245	07/23/2001	10:30	0.5	9.3	0.0
RCM0245	07/23/2001	10:30	0.5	8.7	0.3
RCM0245	07/23/2001	10:30	1		
RCM0245	07/23/2001	10:30	2		
RCM0245	07/23/2001	10:30	3		

SAMPLING STATION IDENTIFIER	DATE START SAMPLING	TIME START SAMPLING	SAMPLE DEPTH	CHLOROPHYLL A µG/L	PHEOPHYTIN A µG/L
RCM0245	07/23/2001	10:30	4		
RCM0245	07/23/2001	10:30	5.1		
RCM0250	07/23/2001	11:50	0.5	9.3	0.4
RCM0250	07/23/2001	11:50	0.5	9.3	0.1
RCM0250	07/23/2001	11:50	1.2		
RCM0245	07/31/2001	8:40	0.5	13.9	0.0
RCM0245	07/31/2001	8:40	0.5	15.5	0.95
RCM0245	07/31/2001	8:40	1		
RCM0245	07/31/2001	8:40	2		
RCM0245	07/31/2001	8:40	2.9		
RCM0250	07/31/2001	9:00	0.5	11.9	0.86
RCM0250	07/31/2001	9:00	0.5	15.6	0.3
RCM0250	07/31/2001	9:00	1		
RCM0250	07/31/2001	9:00	1.8		
RCM0245	08/08/2001	9:51	0.5	10.2	0.4
RCM0245	08/08/2001	9:51	0.5	7.5	0.0
RCM0245	08/08/2001	9:51	1		
RCM0245	08/08/2001	9:51	2		
RCM0245	08/08/2001	9:51	3		
RCM0245	08/08/2001	9:51	4		
RCM0245	08/08/2001	9:51	4.7		
RCM0250	08/08/2001	10:08	0.5		
RCM0250	08/08/2001	10:08	0.5		
RCM0250	08/08/2001	10:08	1		
RCM0250	08/08/2001	10:08	1.7		

Supporting Determination of the Expected Minimum DO Below Epilimnion

As noted in the main body of this document, DO concentration in the surface waters currently meets State standards.

During periods of thermal stratification in a lake, DO concentration below the epilimnion is largely determined by the relationship between trophic status and the saturation potential of oxygen. Because DO concentration is a function of temperature, the minimum allowable DO concentration cannot be specified *per se*, but can be determined graphically by reading the expected DO concentration at a specified percent saturation from a published nomogram.

Chapra (1997) presents ranges of hypolimnetic DO saturation as a function of trophic status in eutrophic, mesotrophic and oligotrophic lakes (Table A-4).

Table A-4

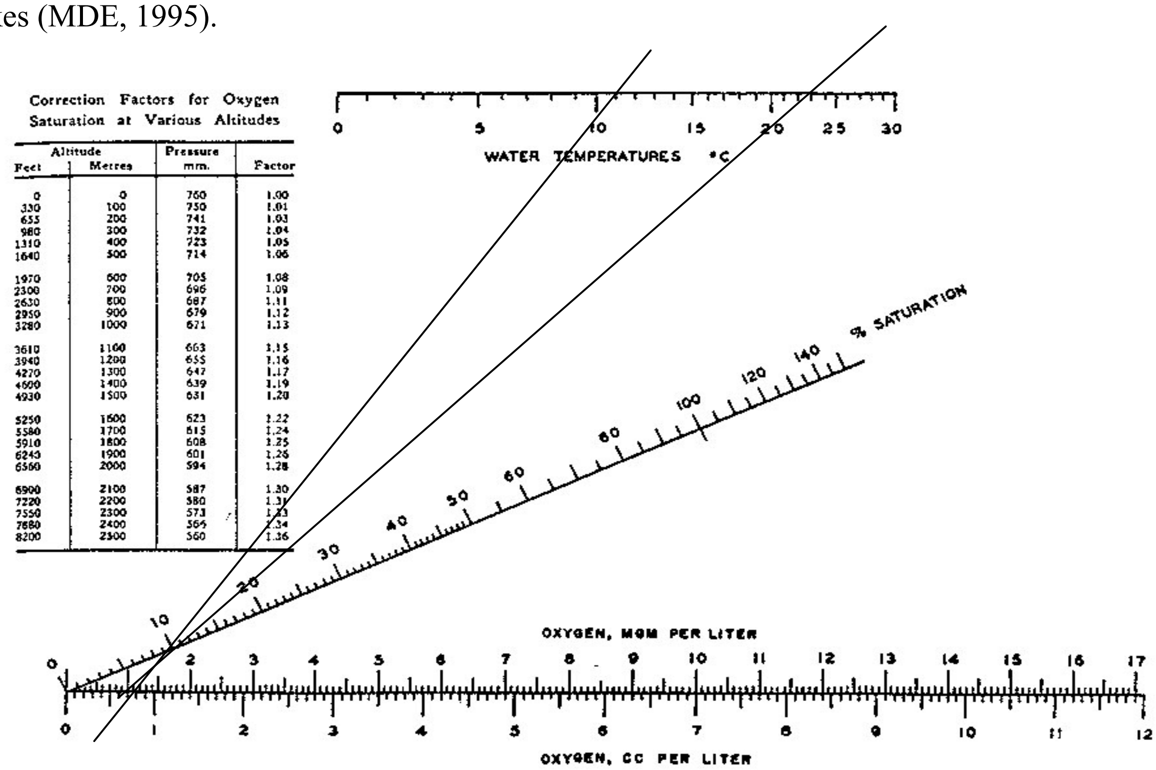
Relationship between Lake Trophic Status and Dissolved Oxygen Saturation in the Hypolimnion of a Thermally Stratified Lake

Trophic Status	Hypolimnetic Dissolved Oxygen Saturation
Eutrophic	0% - 10%
Mesotrophic	10% - 80%
Oligotrophic	80% - 100%

Adapted from Chapra (1997)

Because DO concentration is a function of water temperature, a single expected DO concentration cannot be predicted. However, the nomogram in Figure A-1 may be used to determine a range of dissolved oxygen concentrations expected for a given temperature range. Equation (1) below presents an equivalent, computational method.

The observed hypolimnetic DO concentrations in Lake Needwood are consistent with the interim interpretation of Maryland's water quality criterion for dissolved oxygen in thermally stratified lakes (MDE, 1995).



Correction Factors for Oxygen Saturation at Various Altitudes

Altitude Feet	Altitude Metres	Pressure mm.	Factor
0	0	760	1.00
330	100	750	1.01
655	200	741	1.03
980	300	732	1.04
1310	400	723	1.05
1640	500	714	1.06
1970	600	705	1.08
2300	700	696	1.09
2630	800	687	1.11
2950	900	679	1.12
3280	1000	671	1.13
3610	1100	663	1.15
3940	1200	655	1.16
4270	1300	647	1.17
4600	1400	639	1.19
4930	1500	631	1.20
5250	1600	623	1.22
5580	1700	615	1.24
5910	1800	608	1.25
6240	1900	601	1.26
6560	2000	594	1.28
6900	2100	587	1.30
7220	2200	580	1.31
7550	2300	573	1.33
7880	2400	565	1.34
8200	2500	560	1.36

Figure A-1. Nomogram (adapted from Reid 1961) showing expected sub-epilimnetic DO concentrations at ambient temperatures in Lake Needwood during periods of stratification.

$$\ln C^* = -139.34410 + (1.575701x10^5 / T) -$$
$$(6.642308x10^7 / T^2) + (1.243800x10^{10} / T^3)$$
$$- (8.621949x10^{11} / T^4)$$

Equation (1) (Benson and Krause 1980, *in* Mortimer 1981).