# Water Quality Analysis of Eutrophication of the St. Mary's Lake, St. Mary's County, Maryland

**FINAL**

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## List of Abbreviations

| | |
|---|---|
| BOD | Biochemical Oxygen Demand |
| CBL | Chesapeake Biological Laboratory |
| Chl_*a* | Active Chlorophyll |
| 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 (CWA) and the Environmental Protection Agency (EPA)'s implementing regulations direct 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.

St. Mary's Lake in the St. Mary's River watershed (02-14-01-03) was identified on Maryland's 1998 list of WQLSs as being impaired by nutrients, with an additional impairment of mercury appearing on its 2002 list. This report provides an analysis of recent monitoring data, which shows that the dissolved oxygen criterion and designated uses associated with nutrients are being met in St. Mary's Lake. This analysis supports the conclusion that a TMDL for nutrients is not necessary to achieve water quality standards in this case. Barring any the receipt of contradictory data, this report will be used to support the removal of St. Mary's Lake from Maryland's list of WQLSs when MDE proposes the revision of Maryland's 303(d) list for public review in the future. Although the waters of St. Mary's Lake do not display signs of eutrophication, the State reserves the right to require additional pollution controls in the St. Mary's watershed if evidence suggests that nutrients from the basin are contributing to downstream water quality problems. The mercury impairment is being addressed in a document entitled "Total Maximum Daily Load of Mercury for St. Mary's Lake, St. Mary's County, Maryland".

## 1.0 INTRODUCTION

Section 303(d) of the federal Clean Water Act (CWA) and 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 an impairment. Based on EPA's 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 demonstrating that the segment is now attaining standards; 3) refinements to water quality standards, or the interpretation of those standards, resulting in standards being met; or 4) correction to errors made in the initial listing. Scenarios (1) and (3) apply to the present case, with the qualification that the initial listing for nutrients was suspect due to the lack of data.

St. Mary's Lake in the St. Mary's River watershed (02-14-01-03) was identified on Maryland's 1998 list of WQLSs as being impaired by nutrients, with an additional impairment of mercury appearing on its 2002 list. The 1998 listing was prompted by an assessment of data associated with St. Mary's Lake (Maryland Department of Natural Resources [DNR], 1998). This report provides more recent information that supports the removal of the nutrient impairment listing for St. Mary's Lake when the 303(d) list is revised. The mercury impairment is being addressed in a document entitled "Total Maximum Daily Load of Mercury for St. Mary's Lake, St. Mary's County, Maryland".

The remainder of this report describes the general setting of the waterbody within the St. Mary's Lake watershed, presents a discussion of the water quality characterization process, and provides conclusions with regard to the characterization. The data establish that St. Mary's Lake is achieving water quality standards for nutrients.

## 2.0 GENERAL SETTING

St. Mary's Lake is an impoundment located near Leonardtown in St. Mary's County, Maryland (Figure 1). The impoundment, which is owned by the Maryland Department of Natural Resources (DNR), lies on Western Branch, a tributary of the St. Mary's River. An earthen dam was installed in 1975 for the purposes of flood control, recreation, and fish and wildlife.

St. Mary's Lake lies in the Coastal Plain physiographic province. The soils immediately surrounding the lake are the Beltsville-Croom-Sassafras association (Soil Conservation Service,

1978). These soils are typically level to strongly sloping, moderately well drained to well drained silty and loamy upland soils that may have a fragipan or compact gravelly subsoil.

St. Mary's Lake lies in the Mid-Atlantic Coastal Plain ecoregion, which extends from central New Jersey to northern Georgia. Topography is low and flat, soils are sandy, the dominant land use is agricultural, and there are few natural lakes (none in Maryland).

Inflow to the lake is primarily via Western Branch. Discharge from the lake is also to Western Branch, which discharges to the St. Mary's River. The watershed map (Figure 2) shows that land use in the watershed draining to St. Mary's Lake is predominantly forested/herbaceous. Land use distribution in the watershed is approximately 80% forested/herbaceous, 8% developed, 8% agricultural, and 4% open water (Figure 3) (Maryland Department of Planning, 1997).

One permitted point source discharger is located in the watershed. Winters Apartments is permitted to discharge 1,300 gallons per day (gpd) of treated domestic wastewater to a lagoon located on an unnamed tributary of Western Branch. The permit requires this facility to try to avoid discharge from May through September. Additionally, the receiving stream disappears into the groundwater approximately 500 feet from the discharge point, and therefore the wastewater probably never reaches St. Mary's Lake (Luckman, 2002).

Several relevant statistics for St. Mary's Lake are provided below in Table 1.

**Table 1 - Current Physical Characteristics of St. Mary's Lake**

| | |
|---|---|
| Location: | St. Mary's County, MD<br>lat. 38$^{o}$ 15' 07" long. 76$^{o}$ 32' 06" |
| Surface Area: | 250 acres = (10,890,000 ft$^{2}$) = (1,011,681 m$^{2}$) |
| Average Lake Depth: | 12.8 feet |
| Maximum Depth: | 18.0 feet |
| Purpose | Recreation, Flood Control, Fish and Wildlife |
| Basin Code | 02-14-01-03 |
| Volume of Lake: | 3,200 acre-feet (3,947,200 m$^{3}$) |
| Drainage Area to Lake: | 8.80 mi$^{2}$ |

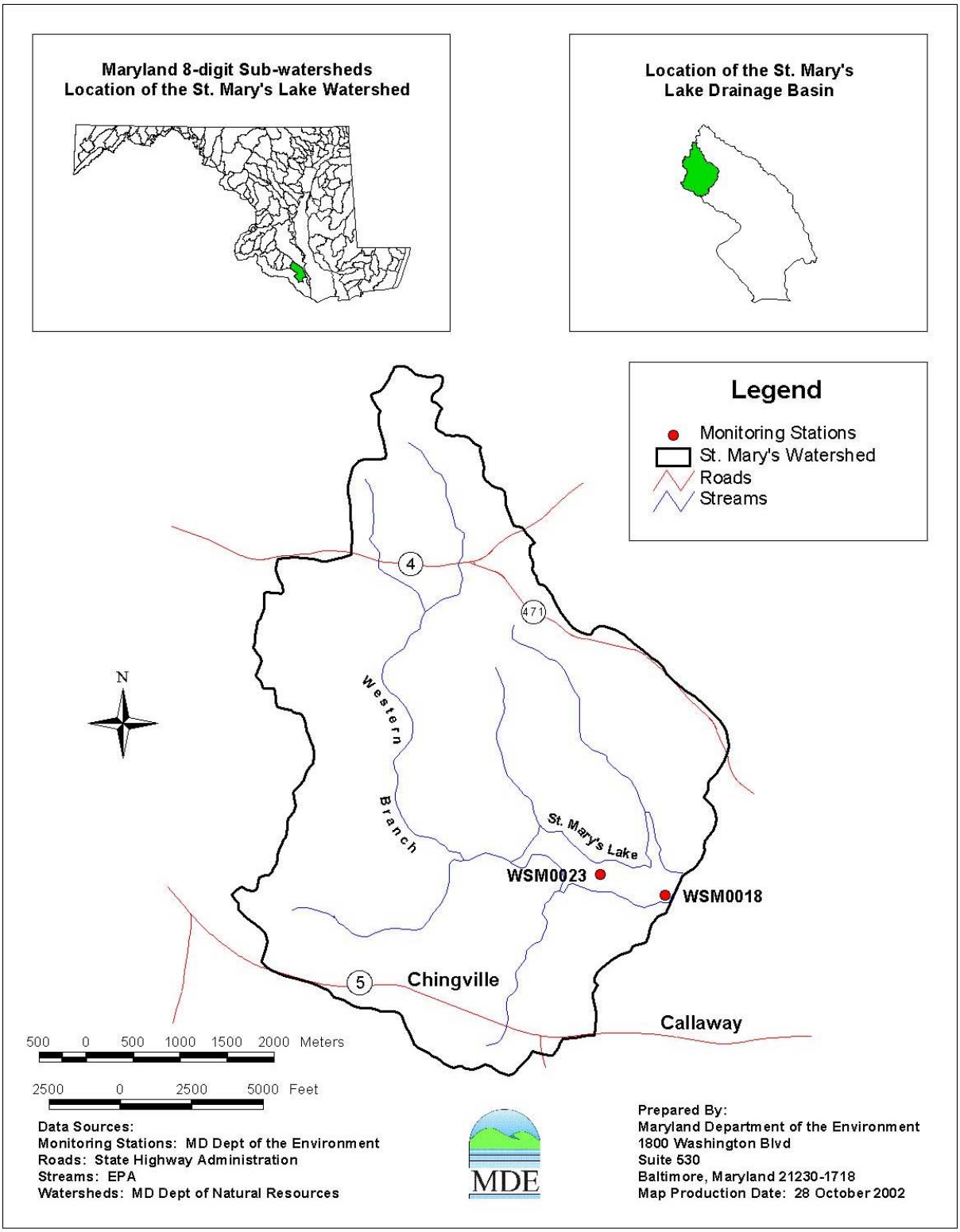


**Figure 1 - Location Map of St. Mary's Lake in St. Mary's County, MD**

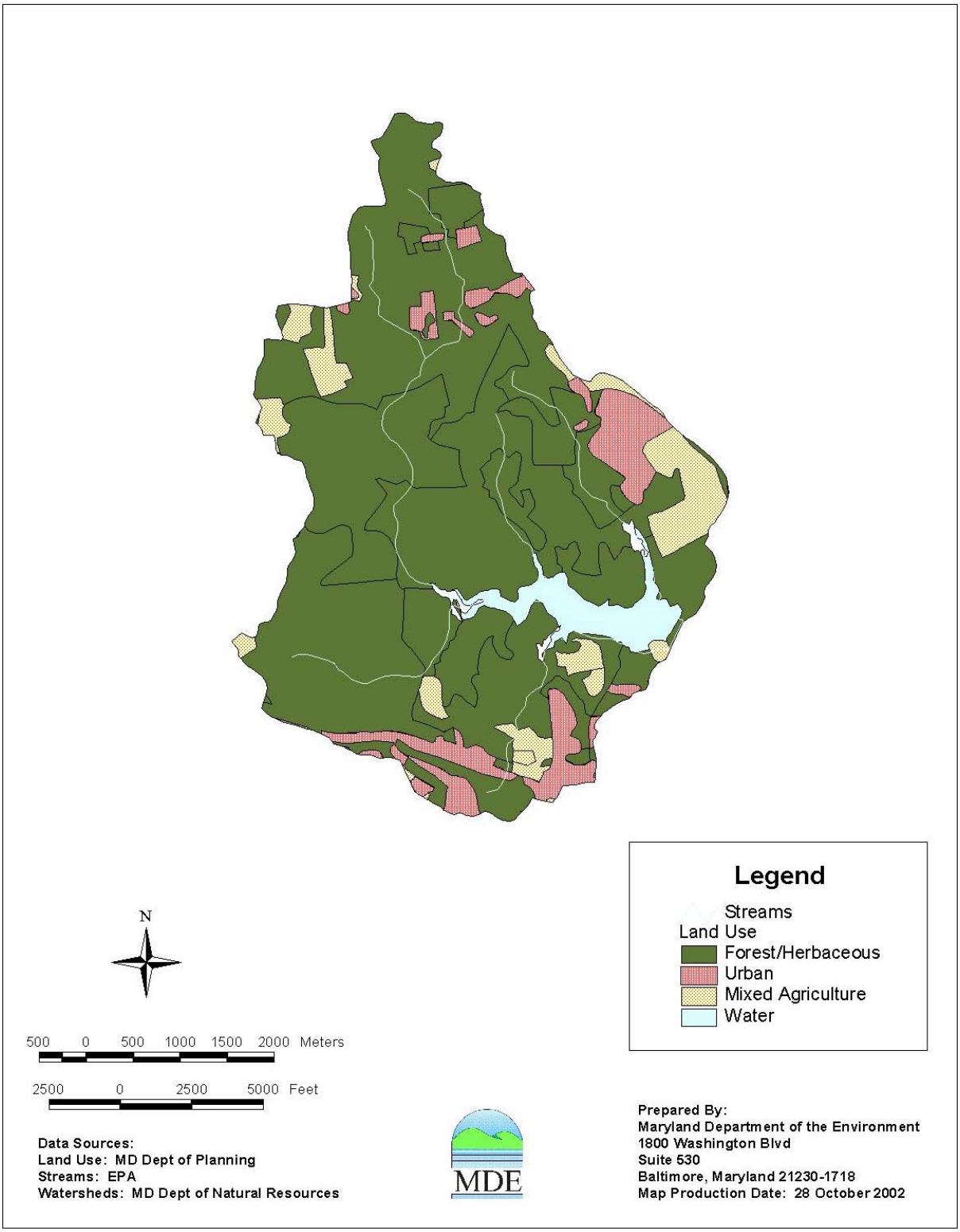


**Figure 2 - Land Use in the St. Mary's Watershed**

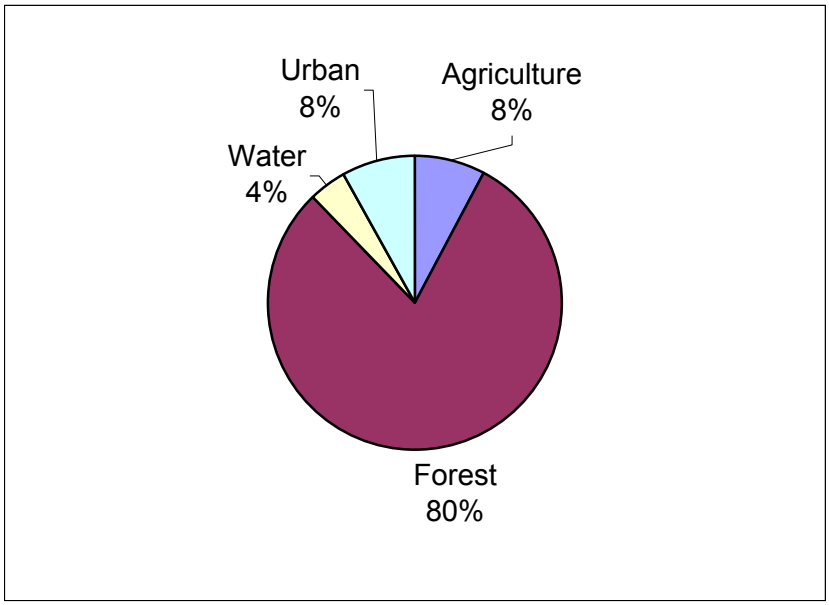


**Figure 3 - Land Use in the St. Mary's Lake Watershed**

## 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 natural trout propagation. 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 resultant low dissolved oxygen (DO). St. Mary's Lake was identified as having low DO levels in the *Maryland Lake Water Assessment Report* (March 1998). As a result of this evaluation, St. Mary's Lake was added to Maryland's 1998 303(d) list as impaired for nutrients.

The Maryland Surface Water Use Designation (COMAR 26.08.02.07) for St. Mary's Lake is Use I – *water contact recreation, and protection of aquatic life*. According to the numeric criteria for DO for Use I waters, concentrations may not be less than 5.0 mg/l at any time (COMAR 26.08.02.03-3A(2)) unless resulting from naturally occurring conditions (COMAR 26.08.02.03.A(2)). In lake environments, low levels of DO are expected in bottom waters even under optimal natural conditions. However, achievement of 5.0 mg/l is expected in the well-

1 Maryland limits the ammonia form of nitrogen from wastewater treatment plants (WWTPs), due its toxic effects on some aquatic organisms.

mixed surface waters. The water quality data presented in this section will show the designated use of this water body is being met.

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.

Because St. Mary's Lake is not used as a drinking water source, the appropriate management goal is to protect the aquatic life and support 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.

Other states have established differing trophic-state endpoints 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).

St. Mary's Lake was monitored in July and August of 1991 (MDE, 1993). This monitoring included two in-lake stations. Physical measurements, including water temperature, pH, conductivity, and DO 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, and chlorophyll *a*.

MDE conducted additional monitoring November and December of 2001 and in January through July of 2002. MDE monitoring included three in-lake stations. 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. Secchi depth was recorded and water samples were collected 0.5 m from water surface. The University of Maryland Chesapeake Biological Laboratory (CBL) conducted analyses on water samples for dissolved and particulate species of nitrogen, phosphorus, and carbon. The DHMH laboratory analyzed water samples for biological oxygen demand (BOD) and chlorophyll *a*. Detailed water quality data are presented in Appendix A (Tables A-1 through A-5).

### 3.1 Nutrients

Total phosphorus (TP) concentrations range from 0.004 – 0.061 mg/l. Total nitrogen (TN) was not reported for the 1991 sampling events; TN concentrations measured in 2001 and 2002 range from 0.4 – 0.8 mg/l. Total Kjeldahl nitrogen (TKN) concentrations measured in 1991 ranged from 0.30 to 0.55 mg/l; TKN was not reported for the 2001 and 2002 sampling events. Tabular data are presented in Appendix A.

### 3.2 Dissolved Oxygen

Water temperatures taken during the 1991 and 2002 sampling periods ranged from 29.9°C to 2.5°C in the 0.3 to 2.0 meter column and 27.2°C to 2.5°C in the 2-5 meter water column. Water temperatures taken during the spring and summer sampling months (April, May, June, July and August) ranged from 29.9°C to 15.9°C in the 0.3 to 2.0 meter column, and 27.2°C to 13.8°C in the 2-5 meter water column. This wide range of water temperatures, with an abrupt discontinuity at about 3 m during the months of April, May, June, July and August, indicates that St. Mary's Lake is thermally stratified and not well mixed.

DO concentrations ranged from 0.1 to over 12.3 mg/l along the vertical profile. Oxygen concentrations along the vertical profile decrease discontinuously, coincident with the depth at which thermal stratification was observed (*i.e*. about 3 m) during the spring and summer sampling events. During the 1991 sampling period (July and August), DO concentrations as high as 7.2 mg/l were observed at the surface (1 m depth) of St. Mary's Lake, with DO values as low as 0.1 mg/l at a depth of 3 meters. The July 2002 samples showed similar stratification. Average DO at the surface was 7.1 mg/l, and less than 1.0 mg/l at a depth below 3 m. All DO concentrations in the surface layer (above a depth of about 3 m) were above the state criterion of 5.0 mg/l. The hypolimnetic DO concentrations observed during periods of stratification are within the range expected for eutrophic lakes (0 – 10% saturation). Please refer to data tables provided in Appendix A.

### 3.3 Chlorophyll *a*

Instantaneous chlorophyll *a* concentrations in St. Mary's Lake ranged from 2.1 to 12.3 µg/l in 1991, and from 1.7 to 7.5 µg/l in 2001 – 2002. While not extreme when compared to peak concentrations (10 to 275 µg/l) in eutrophic lakes (Olem and Flock, 1990), chlorophyll *a* levels above 10 µg/l are associated with eutrophic conditions in lakes (Chapra, 1997). Observed concentrations in St. Mary's Lake were all under 10 µg/l, with the exception one value of 12.3 µg/l occurring in 1991. All values are below the threshold of 20 µg/l consistent with the management goal of this lake.

### 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. However, BOD values in the water are low, and dissolved oxygen values are in acceptable ranges. Thus, BOD does not enter into this analysis.

### 3.5 Note on pH Values

The data presented in Table A-2, "2001-2002 MDE Physical Data" shows values of pH that are slightly below the pH criterion of 6.5. The watershed draining to St. Mary's Lake has significant acres of forested wetlands, causing elevated tannins. This is apparent upon observation of 'black water,' which is the color of dark tea. These marsh settings commonly lead to naturally low values of pH.

## 4.0 CONCLUSION

The data presented in this report suggest that there is no excessive algal growth in St. Mary's Lake, as indicated by chlorophyll *a* concentrations below 20 ug/l. Similarly, DO concentrations meet criterion of 5.0 mg/l for the surface of the lake. The hypolimnetic DO concentrations observed during periods of stratification are within the range expected for eutrophic lakes (0% – 10% saturation).

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 St. Mary's Lake.

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# Appendix A: Tabular Water Quality Data

## Table A-1. Table of 1991 DNR Data

| Station | Date | Time | Depth | Secchi | W Temp | pH | DO | TKN | TP | CHLA |
|---|---|---|---|---|---|---|---|---|---|---|
| WSM0018 | 07/15/1991 | 1118 | 0.3 | | 29.50 | 6.4 | 7.2 | 0.30 | 0.013 | |
| WSM0018 | 07/15/1991 | 1118 | 0.3 | | | | | | | 3.6 |
| WSM0018 | 07/15/1991 | 1118 | 1.0 | | 29.30 | 6.4 | 7.1 | | | |
| WSM0018 | 07/15/1991 | 1118 | 2.0 | | 29.10 | 6.4 | 7.0 | | | |
| WSM0018 | 07/15/1991 | 1118 | 3.0 | | 25.10 | 6.3 | 0.1 | | | |
| WSM0018 | 07/15/1991 | 1118 | 4.0 | | 19.60 | 6.3 | 0.1 | | | |
| WSM0018 | 07/15/1991 | 1118 | 4.8 | | 16.40 | 6.3 | 0.1 | | | |
| WSM0018 | 07/15/1991 | 1118 | | 1.0 | | | | | | |
| WSM0023 | 07/15/1991 | 1145 | 0.3 | | 29.90 | 6.3 | 7.2 | 0.45 | 0.004 | |
| WSM0023 | 07/15/1991 | 1145 | 0.3 | | | | | | | 3.6 |
| WSM0023 | 07/15/1991 | 1145 | 0.3 | | | | | | | 2.1 |
| WSM0023 | 07/15/1991 | 1145 | 0.3 | | 29.30 | 6.3 | 7.0 | 0.40 | 0.013 | |
| WSM0023 | 07/15/1991 | 1145 | 0.3 | | | | | | | 3.3 |
| WSM0023 | 07/15/1991 | 1145 | 0.3 | | | | | | | 3.6 |
| WSM0023 | 07/15/1991 | 1145 | 2.0 | | 28.80 | 6.2 | 6.6 | | | |
| WSM0023 | 07/15/1991 | 1145 | 3.0 | | 25.20 | 6.3 | 0.1 | | | |
| WSM0023 | 07/15/1991 | 1145 | 4.0 | | 19.50 | 6.2 | 0.1 | | | |
| WSM0023 | 07/15/1991 | 1145 | 4.3 | | 18.10 | 6.3 | 0.1 | | | |
| WSM0023 | 07/15/1991 | 1145 | | 1.0 | | | | | | |
| WSM0018 | 08/15/1991 | 1030 | 0.3 | | 27.50 | 6.4 | 7.0 | 0.40 | 0.061 | |
| WSM0018 | 08/15/1991 | 1030 | 0.3 | | | | | | | 9.0 |
| WSM0018 | 08/15/1991 | 1030 | 0.3 | | | | | | | 12.3 |
| WSM0018 | 08/15/1991 | 1030 | 1.0 | | 27.40 | 6.5 | 7.0 | | | |
| WSM0018 | 08/15/1991 | 1030 | 2.0 | | 27.30 | 6.5 | 6.9 | | | |
| WSM0018 | 08/15/1991 | 1030 | 3.0 | | 27.20 | 6.4 | 6.8 | | | |
| WSM0018 | 08/15/1991 | 1030 | 4.0 | | 21.70 | 6.2 | 0.1 | | | |
| WSM0018 | 08/15/1991 | 1030 | 5.0 | | 17.10 | 6.3 | 0.1 | | | |
| WSM0018 | 08/15/1991 | 1030 | 5.7 | | 14.70 | 6.4 | 0.1 | | | |
| WSM0018 | 08/15/1991 | 1030 | | 1.2 | | | | | | |
| WSM0023 | 08/15/1991 | 1054 | 0.3 | | 27.70 | 6.3 | 6.4 | 0.55 | 0.010 | |
| WSM0023 | 08/15/1991 | 1054 | 0.3 | | | | | | | 9.0 |
| WSM0023 | 08/15/1991 | 1054 | 0.3 | | | | | | | 7.1 |
| WSM0023 | 08/15/1991 | 1054 | 1.0 | | 27.60 | 6.2 | 6.4 | | | |
| WSM0023 | 08/15/1991 | 1054 | 2.0 | | 27.40 | 6.3 | 6.1 | | | |
| WSM0023 | 08/15/1991 | 1054 | 3.0 | | 27.20 | 6.3 | 5.6 | | | |
| WSM0023 | 08/15/1991 | 1054 | 4.0 | | 20.20 | 6.1 | 0.1 | | | |
| WSM0023 | 08/15/1991 | 1054 | | 1.1 | | | | | | |

**Water Quality Analysis Stations for St. Mary's Lake, Maryland**

| # | Station I.D. | GPS coordinates | Station Description |
|---|---|---|---|
| 1 | WSM0018 | 38°15.177'<br>76°32.093' | Mid-lake, 100 feet of dam breast |
| 2 | WSM0023 | 38°15.233'<br>76°32.446' | Mid-lake, between boat ramp and small cove on opposite shore |
| 3 | WSM0028 | 38°15.385'<br>76°33.072' | Mid-lake, upstream of cove on north shore |

**Table A-2.Table of 2001/2002 MDE physical data**

| SAMPLING STATION | DATE START SAMPLING | SAMPLE DEPTH (m) | SECCHI DEPTH (m) | WATER TEMPERATURE °C | pH | D.O |
|---|---|---|---|---|---|---|
| WSM0018 | 11/15/2001 | 0.5 | 0.9 | 11.9 | 6.4 | 9.2 |
| | 11/15/2001 | 1.0 | | 11.8 | 6.4 | 9.2 |
| | 11/15/2001 | 2.0 | | 11.7 | 6.3 | 8.7 |
| | 11/15/2001 | 3.0 | | 11.7 | 6.3 | 8.6 |
| | 11/15/2001 | 4.1 | | 11.6 | 6.3 | 8.6 |
| WSM0023 | 11/15/2001 | 0.5 | 0.9 | 11.8 | 6.4 | 9.1 |
| | 11/15/2001 | 1.0 | | 11.7 | 6.4 | 9.0 |
| | 11/15/2001 | 2.0 | | 11.7 | 6.3 | 8.9 |
| | 11/15/2001 | 3.0 | | 11.6 | 6.3 | 8.7 |
| | 11/15/2001 | 3.7 | | 11.6 | 6.2 | 8.7 |
| WSM0028 | 11/15/2001 | 0.5 | 1.1 | 11.3 | 6.4 | 9.3 |
| | 11/15/2001 | 1.2 | | 11.2 | 6.4 | 9.2 |
| WSM0018 | 11/28/2001 | 0.5 | 1.0 | 12.9 | 6.6 | 9.5 |
| | 11/28/2001 | 1.0 | | 12.8 | 6.5 | 9.4 |
| | 11/28/2001 | 2.0 | | 12.5 | 6.5 | 9.3 |
| | 11/28/2001 | 3.0 | | 12.2 | 6.4 | 8.8 |
| | 11/28/2001 | 3.6 | | 11.8 | 6.4 | 8.8 |
| WSM0023 | 11/28/2001 | 0.5 | | 13.1 | 6.5 | 9.4 |
| | 11/28/2001 | 1.0 | | 12.8 | 6.5 | 9.2 |
| | 11/28/2001 | 2.0 | | 12.5 | 6.5 | 8.9 |
| | 11/28/2001 | 3.3 | | 11.7 | 6.4 | 8.4 |
| WSM0028 | 11/28/2001 | 0.5 | 1.0 | 13.1 | 6.5 | 9.1 |
| | 11/28/2001 | 1.5 | | 12.5 | 6.3 | 7.9 |
| WSM0018 | 12/12/2001 | 0.5 | 0.7 | 11.3 | 6.1 | 8.6 |
| | 12/12/2001 | 1.0 | | 11.3 | 6.1 | 8.6 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 12/12/2001 | 1.5 | | 11.3 | 6.1 | 8.6 |
| | 12/12/2001 | 2.0 | | 11.3 | 6.1 | 8.6 |
| | 12/12/2001 | 2.5 | | 11.3 | 6.1 | 8.6 |
| | 12/12/2001 | 3.0 | | 11.2 | 6.1 | 8.6 |
| WSM0023 | 12/12/2001 | 0.5 | 0.6 | 11.2 | 6.1 | 8.6 |
| | 12/12/2001 | 1.0 | | 11.2 | 6.1 | 8.6 |
| | 12/12/2001 | 1.5 | | 11.2 | 6.1 | 8.6 |
| | 12/12/2001 | 2.0 | | 11.3 | 6.1 | 8.6 |
| | 12/12/2001 | 2.5 | | 11.3 | 6.1 | 8.6 |
| | 12/12/2001 | 3.0 | | 11.3 | 6.1 | 8.6 |
| | 12/12/2001 | 3.5 | | 11.2 | 6.1 | 8.7 |
| WSM0028 | 12/12/2001 | 0.5 | 0.8 | 10.8 | 6.2 | 9.1 |
| | 12/12/2001 | 1.0 | | 10.8 | 6.2 | 9.0 |
| | 12/12/2001 | 1.5 | | 10.8 | 6.3 | 9.1 |
| WSM0018 | 01/09/2002 | 0.5 | | 2.5 | 6.3 | 12.1 |
| | 01/09/2002 | 1.0 | | 2.5 | 6.3 | 12.1 |
| | 01/09/2002 | 2.0 | | 2.5 | 6.3 | 12.1 |
| | 01/09/2002 | 3.0 | | 2.5 | 6.3 | 12.1 |
| | 01/09/2002 | 4.0 | | 2.5 | 6.3 | 12.1 |
| | 01/09/2002 | 4.5 | | 2.5 | 6.3 | 12.0 |
| WSM0023 | 01/09/2002 | 0.5 | | 2.8 | 6.3 | 12.1 |
| | 01/09/2002 | 1.0 | | 2.8 | 6.3 | 12.1 |
| | 01/09/2002 | 2.0 | | 2.8 | 6.3 | 12.1 |
| | 01/09/2002 | 3.0 | | 2.8 | 6.3 | 12.2 |
| | 01/09/2002 | 3.5 | | 2.8 | 6.3 | 12.3 |
| WSM0028 | 01/09/2002 | 0.5 | | 2.8 | 6.2 | 12.0 |
| | 01/09/2002 | 1.0 | | 2.8 | 6.2 | 12.0 |
| | 01/09/2002 | 2.0 | | 3.1 | 6.2 | 12.0 |
| WSM0018 | 02/13/2002 | 1.0 | 0.7 | 6.8 | 6.1 | 11.6 |
| | 02/13/2002 | 2.0 | | 6.8 | 6.1 | 11.6 |
| | 02/13/2002 | 3.0 | | 6.8 | 6.1 | 11.6 |
| | 02/13/2002 | 4.0 | | 6.8 | 6.1 | 11.5 |
| WSM0023 | 02/13/2002 | 0.5 | 0.8 | 6.7 | 6.1 | 11.5 |
| | 02/13/2002 | 1.0 | | 6.7 | 6.1 | 11.5 |
| | 02/13/2002 | 2.0 | | 6.7 | 6.1 | 11.6 |
| | 02/13/2002 | 3.0 | | 6.7 | 6.1 | 11.6 |
| | 02/13/2002 | 4.0 | | 6.7 | 6.1 | 11.5 |
| WSM0028 | 02/13/2002 | 0.5 | 0.8 | 6.8 | 6.1 | 11.9 |
| | 02/13/2002 | 1.0 | | 6.7 | 6.1 | 11.9 |
| WSM0018 | 03/27/2002 | 0.5 | 0.6 | 10.9 | 6.1 | 10.6 |
| | 03/27/2002 | 1.0 | | 10.9 | 6.1 | 10.6 |
| | 03/27/2002 | 2.0 | | 10.9 | 6.1 | 10.8 |
| | 03/27/2002 | 3.0 | | 10.9 | 6.1 | 10.8 |
| | 03/27/2002 | 4.1 | | 10.9 | 6.0 | 10.8 |
| WSM0023 | 03/27/2002 | 0.5 | 0.8 | 11.0 | 6.1 | 10.8 |
| | 03/27/2002 | 1.0 | | 10.9 | 6.1 | 10.8 |
| | 03/27/2002 | 2.0 | | 10.9 | 6.1 | 10.8 |

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|---|---|---|---|---|---|---|
| | 03/27/2002 | 3.2 | | 10.9 | 6.1 | 10.9 |
| WSM0028 | 03/27/2002 | 0.5 | 0.7 | 11.8 | 6.0 | 10.9 |
| | 03/27/2002 | 1.2 | | 11.7 | 6.0 | 11.0 |
| WSM0018 | 04/24/2002 | 0.5 | 0.7 | 17.3 | 6.1 | 8.8 |
| | 04/24/2002 | 1.0 | | 17.2 | 6.0 | 8.7 |
| | 04/24/2002 | 2.0 | | 17.1 | 5.9 | 8.6 |
| | 04/24/2002 | 3.0 | | 15.9 | 5.6 | 6.7 |
| | 04/24/2002 | 4.2 | | 13.8 | 5.4 | 5.4 |
| WSM0023 | 04/24/2002 | 0.5 | 0.7 | 17.1 | 6.0 | 8.8 |
| | 04/24/2002 | 1.0 | | 17.1 | 6.0 | 8.8 |
| | 04/24/2002 | 2.0 | | 17.0 | 5.9 | 8.7 |
| | 04/24/2002 | 3.3 | | 16.3 | 5.8 | 8.2 |
| WSM0028 | 04/24/2002 | 0.5 | 0.7 | 15.9 | 5.8 | 8.5 |
| | 04/24/2002 | 1.2 | | 15.9 | 5.7 | 8.6 |
| WSM0018 | 05/22/2002 | 0.5 | 0.9 | 19.2 | 6.0 | 8.7 |
| WSM0018 | 05/22/2002 | 1.0 | | 19.1 | 5.9 | 8.7 |
| WSM0018 | 05/22/2002 | 2.0 | | 19.0 | 5.9 | 8.6 |
| WSM0018 | 05/22/2002 | 3.0 | | 19.0 | 5.9 | 8.6 |
| WSM0018 | 05/22/2002 | 3.8 | | 18.0 | 5.8 | 8.4 |
| WSM0023 | 05/22/2002 | 0.5 | 1.2 | 19.1 | 6.0 | 8.7 |
| WSM0023 | 05/22/2002 | 1.0 | | 19.0 | 6.0 | 8.7 |
| WSM0023 | 05/22/2002 | 2.0 | | 18.8 | 5.9 | 8.4 |
| WSM0023 | 05/22/2002 | 3.0 | | 18.7 | 5.9 | 8.4 |
| WSM0023 | 05/22/2002 | 3.8 | | 18.5 | 5.8 | 8.4 |
| WSM0028 | 05/22/2002 | 0.5 | 1.2 | 18.3 | 5.9 | 8.5 |
| WSM0028 | 05/22/2002 | 1.5 | | 17.8 | 5.8 | 8.5 |
| WSM0018 | 06/05/2002 | 0.5 | 1.6 | 26.0 | 6.4 | 7.9 |
| WSM0018 | 06/05/2002 | 1.0 | | 25.9 | 6.4 | 7.9 |
| WSM0018 | 06/05/2002 | 2.0 | | 25.8 | 6.3 | 7.8 |
| WSM0018 | 06/05/2002 | 3.0 | | 20.7 | 5.8 | 6.5 |
| WSM0018 | 06/05/2002 | 3.7 | | 18.4 | 5.6 | 4.0 |
| WSM0023 | 06/05/2002 | 0.5 | 1.4 | 26.3 | 6.4 | 7.7 |
| WSM0023 | 06/05/2002 | 1.0 | | 26.2 | 6.4 | 7.7 |
| WSM0023 | 06/05/2002 | 2.0 | | 24.6 | 6.0 | 7.5 |
| WSM0023 | 06/05/2002 | 3.0 | | 19.7 | 5.7 | 5.7 |
| WSM0023 | 06/05/2002 | 4.0 | | 18.0 | 5.6 | 2.4 |
| WSM0023 | 06/05/2002 | 4.6 | | 17.3 | 5.7 | 1.4 |
| WSM0028 | 06/05/2002 | 0.5 | 1.6 | 26.7 | 6.4 | 7.7 |
| WSM0028 | 06/05/2002 | 1.0 | | 26.5 | 6.4 | 7.5 |
| WSM0018 | 06/19/2002 | 0.5 | 1.5 | 25.8 | 6.5 | 7.8 |
| WSM0018 | 06/19/2002 | 1.0 | | 25.7 | 6.4 | 7.8 |
| WSM0018 | 06/19/2002 | 2.0 | | 25.6 | 6.2 | 7.5 |
| WSM0018 | 06/19/2002 | 3.0 | | 22.9 | 5.7 | 1.8 |
| WSM0018 | 06/19/2002 | 4.2 | | 18.5 | 5.8 | 0.2 |
| WSM0023 | 06/19/2002 | 0.5 | 2.0 | 26.0 | 6.5 | 7.9 |
| WSM0023 | 06/19/2002 | 1.0 | | 26.0 | 6.4 | 7.8 |
| WSM0023 | 06/19/2002 | 2.0 | | 25.8 | 6.2 | 7.4 |

| | | | | | | |
|---|---|---|---|---|---|---|
| WSM0023 | 06/19/2002 | 3.0 | | 23.3 | 5.7 | 2.8 |
| WSM0023 | 06/19/2002 | 3.8 | | 19.4 | 5.8 | 0.2 |
| WSM0028 | 06/19/2002 | 0.5 | 2.1 | 26.0 | 6.4 | 7.6 |
| WSM0028 | 06/19/2002 | 1.3 | | 26.0 | 6.3 | 7.5 |
| WSM0018 | 07/10/2002 | 0.5 | 2.1 | 28.8 | 6.5 | 7.0 |
| WSM0018 | 07/10/2002 | 1.0 | | 28.8 | 6.5 | 6.9 |
| WSM0018 | 07/10/2002 | 2.0 | | 28.7 | 6.3 | 6.7 |
| WSM0018 | 07/10/2002 | 3.0 | | 25.0 | 5.7 | 0.6 |
| WSM0018 | 07/10/2002 | 4.0 | | 19.0 | 6.4 | 0.4 |
| WSM0018 | 07/10/2002 | 5.0 | | 16.9 | 6.6 | 0.4 |
| WSM0023 | 07/10/2002 | 0.5 | 2.1 | 28.8 | 6.5 | 6.7 |
| WSM0023 | 07/10/2002 | 1.0 | | 28.8 | 6.4 | 6.6 |
| WSM0023 | 07/10/2002 | 2.0 | | 28.2 | 6.2 | 5.9 |
| WSM0023 | 07/10/2002 | 3.0 | | 25.2 | 5.7 | 0.4 |
| WSM0023 | 07/10/2002 | 3.6 | | 21.4 | 6.3 | 0.4 |
| WSM0028 | 07/10/2002 | 0.5 | 2.0 | 28.4 | 6.5 | 6.6 |
| WSM0028 | 07/10/2002 | 1.0 | | 28.2 | 6.5 | 6.4 |
| WSM0018 | 07/31/2002 | 0.5 | 1.4 | 29.6 | 6.7 | 7.5 |
| WSM0018 | 07/31/2002 | 1.0 | | 29.4 | 6.6 | 7.2 |
| WSM0018 | 07/31/2002 | 2.0 | | 28.8 | 6.4 | 6.3 |
| WSM0018 | 07/31/2002 | 3.0 | | 25.8 | 6.0 | 1.9 |
| WSM0018 | 07/31/2002 | 4.5 | | 19.0 | 6.5 | 0.3 |
| WSM0023 | 07/31/2002 | 0.5 | 1.4 | 29.6 | 6.7 | 7.5 |
| WSM0023 | 07/31/2002 | 1.0 | | 29.3 | 6.6 | 7.3 |
| WSM0023 | 07/31/2002 | 2.0 | | 28.8 | 6.4 | 6.8 |
| WSM0023 | 07/31/2002 | 3.0 | | 26.3 | 6.0 | 2.9 |
| WSM0028 | 07/31/2002 | 0.5 | 1.4 | 28.9 | 6.6 | 7.5 |
| WSM0028 | 07/31/2002 | 1.0 | | 28.6 | 6.5 | 7.4 |

**Table A-3.Table of 2001/2002 MDE Chlorophyll *a* data**

| SAMPLING STATION IDENTIFIER | DATE START SAMPLING | SAMPLE DEPTH FROM SURFACE METERS | SECCHI DEPTH METERS | WATER TEMPERATURE °C | ACTIVE CHLOROPHYLL A µG/L | PHEOPHYTIN A µG/L |
|---|---|---|---|---|---|---|
| WSM0018 | 11/15/2001 | 0.5 | 0.9 | 11.9 | 5.98 | 0.00 |
| WSM0023 | 11/15/2001 | 0.5 | 0.9 | 11.8 | 6.73 | 0.60 |
| WSM0028 | 11/15/2001 | 0.5 | 1.1 | 11.3 | 5.98 | 0.30 |
| WSM0018 | 11/28/2001 | 0.5 | 1 | 12.9 | 6.48 | 0.15 |
| WSM0023 | 11/28/2001 | 0.5 | 1 | 13.1 | 6.48 | 1.55 |
| WSM0028 | 11/28/2001 | 0.5 | 1 | 13.1 | 5.98 | 0.30 |
| WSM0018 | 12/12/2001 | 0.5 | 0.7 | 11.3 | 2.39 | 1.17 |
| WSM0023 | 12/12/2001 | 0.5 | 0.6 | 11.2 | 2.09 | 1.88 |
| WSM0028 | 12/12/2001 | 0.5 | 0.8 | 10.8 | 2.69 | 1.08 |
| WSM0018 | 01/09/2002 | 0.5 | | 2.5 | 1.99 | 0.45 |
| WSM0023 | 01/09/2002 | 0.5 | | 2.8 | 2.24 | 0.72 |
| WSM0028 | 01/09/2002 | 0.5 | | 2.8 | 1.74 | 0.70 |
| WSM0018 | 02/13/2002 | 0.5 | 0.7 | 6.8 | 2.70 | 1.10 |
| WSM0023 | 02/13/2002 | 0.5 | 0.8 | 6.7 | 3.00 | 0.50 |
| WSM0028 | 02/13/2002 | 0.5 | 0.8 | 6.8 | 1.90 | 1.50 |
| WSM0018 | 03/27/2002 | 0.5 | 0.6 | 10.9 | 4.50 | 1.40 |
| WSM0023 | 03/27/2002 | 0.5 | 0.8 | 11 | 4.50 | 1.60 |
| WSM0028 | 03/27/2002 | 0.5 | 0.7 | 11.8 | 4.20 | 1.30 |
| WSM0018 | 04/24/2002 | 0.5 | 0.7 | 17.3 | 4.50 | 1.40 |
| WSM0023 | 04/24/2002 | 0.5 | 0.7 | 17.1 | 4.90 | 1.70 |
| WSM0028 | 04/24/2002 | 0.5 | 0.7 | 15.9 | 3.50 | 1.00 |
| WSM0018 | 05/22/2002 | 0.5 | 0.9 | 19.2 | 7.50 | 1.90 |
| WSM0023 | 05/22/2002 | 0.5 | 1.2 | 19.1 | 6.00 | 0.30 |
| WSM0028 | 05/22/2002 | 0.5 | 1.2 | 18.3 | 3.70 | 1.00 |
| WSM0018 | 06/05/2002 | 0.5 | 1.6 | 26 | 5.50 | -0.20 |
| WSM0023 | 06/05/2002 | 0.5 | 1.4 | 26.3 | 3.50 | 0.30 |
| WSM0028 | 06/05/2002 | 0.5 | 1.6 | 26.7 | 3.50 | 1.00 |
| WSM0018 | 06/19/2002 | 0.5 | 1.5 | 25.8 | 5.60 | 1.50 |
| WSM0023 | 06/19/2002 | 0.5 | 2 | 26 | 2.70 | 0.90 |
| WSM0028 | 06/19/2002 | 0.5 | 2.1 | 26 | 2.20 | 0.20 |
| WSM0018 | 07/10/2002 | 0.5 | 2.05 | 28.8 | 1.70 | 0.20 |
| WSM0023 | 07/10/2002 | 0.5 | 2.06 | 28.8 | 2.20 | -0.10 |
| WSM0028 | 07/10/2002 | 0.5 | 1.95 | 28.4 | 2.00 | 0.40 |
| WSM0018 | 07/31/2002 | 0.5 | 1.4 | 29.6 | 4.50 | 0.40 |
| WSM0023 | 07/31/2002 | 0.5 | 1.4 | 29.6 | 3.50 | 1.00 |
| WSM0028 | 07/31/2002 | 0.5 | 1.4 | 28.9 | 3.20 | 0.40 |

**Table A-4. Table of 2001/2002 MDE Nutrient Data**

| STATION | DATE | TIME | BOD | NH4 MG/L | NO2 + NO3 MG/L | PN MG/L | TN MG/L | PO4 MG/L | TP MG/L | TSS MG/L |
|---|---|---|---|---|---|---|---|---|---|---|
| WSM0018 | 11/15/2001 | 10:40 | 0.9 | 0.0820 | 0.0178 | 0.1230 | 0.7130 | 0.0013 | 0.0154 | 2.4 |
| WSM0023 | 11/15/2001 | 10:50 | | 0.0880 | 0.0190 | 0.1020 | 0.6020 | 0.0011 | 0.0172 | 2.4 |
| WSM0028 | 11/15/2001 | 11:00 | 0.9 | 0.0660 | 0.0177 | 0.1230 | 0.6230 | 0.0015 | 0.0156 | 2.7 |
| WSM0018 | 11/28/2001 | 10:00 | 1.4 | 0.0890 | 0.0268 | 0.0992 | 0.6392 | 0.0016 | 0.0147 | 2.4 |
| WSM0023 | 11/28/2001 | 10:10 | | 0.0880 | 0.0244 | 0.1030 | 0.6330 | 0.0020 | 0.0184 | 4.0 |
| WSM0028 | 11/28/2001 | 10:20 | 1.4 | 0.0760 | 0.0218 | 0.0843 | 0.6043 | 0.0019 | 0.0156 | 3.0 |
| WSM0018 | 12/12/2001 | 9:45 | 1.3 | 0.1490 | 0.0370 | 0.0743 | 0.6843 | 0.0016 | 0.0176 | 3.5 |
| WSM0023 | 12/12/2001 | 9:35 | | 0.1720 | 0.0353 | 0.0830 | 0.7030 | 0.0019 | 0.0165 | 2.4 |
| WSM0028 | 12/12/2001 | 9:25 | 1.3 | 0.1580 | 0.0362 | 0.0761 | | 0.0014 | | 3.5 |
| WSM0018 | 01/09/2002 | 10:47 | 1.5 | 0.1920 | 0.0660 | 0.1170 | 0.7970 | 0.0018 | 0.0216 | 5.2 |
| WSM0023 | 01/09/2002 | 10:40 | | 0.1990 | 0.0654 | 0.0922 | 0.8022 | 0.0023 | 0.0195 | 4.0 |
| WSM0028 | 01/09/2002 | 10:30 | 1.4 | 0.1910 | 0.0682 | 0.0698 | 0.7598 | 0.0018 | 0.0179 | 2.4 |
| WSM0023 | 02/13/2002 | 10:50 | | 0.1300 | 0.1280 | 0.0898 | 0.4498 | 0.0051 | 0.0173 | 4.0 |
| WSM0028 | 02/13/2002 | 10:35 | 1.0 | 0.1140 | 0.1240 | 0.0925 | 0.4425 | 0.0052 | 0.0173 | 4.0 |
| WSM0018 | 03/27/2002 | 10:10 | 1.0 | 0.0420 | 0.1630 | 0.1390 | 0.6990 | 0.0011 | 0.0220 | 4.4 |
| WSM0023 | 03/27/2002 | 10:00 | | 0.0440 | 0.1680 | 0.1380 | 0.6980 | 0.0019 | 0.0204 | 5.6 |
| WSM0028 | 03/27/2002 | 9:50 | 1.0 | 0.0350 | 0.1630 | 0.1360 | 0.6860 | 0.0017 | 0.0241 | 6.0 |
| WSM0018 | 04/24/2002 | 9:55 | 3.3 | 0.0220 | 0.0953 | 0.1730 | 0.6730 | 0.0013 | 0.0220 | 5.3 |
| WSM0023 | 04/24/2002 | 9:45 | | 0.0230 | 0.0960 | 0.1440 | 0.6840 | 0.0009 | 0.0218 | 5.3 |
| WSM0028 | 04/24/2002 | 9:30 | 1.8 | 0.0440 | 0.1040 | 0.1200 | 0.6500 | 0.0017 | 0.0224 | 5.0 |
| WSM0018 | 05/22/2002 | 925 | | 0.0070 | 0.0551 | 0.1260 | 0.5460 | 0.0019 | 0.0247 | 8.0 |
| WSM0023 | 05/22/2002 | 935 | | 0.0070 | 0.0588 | 0.1020 | 0.5820 | 0.0010 | 0.0206 | 4.0 |
| WSM0028 | 05/22/2002 | 945 | | 0.0100 | 0.0595 | 0.0851 | | 0.0011 | | 4.4 |
| WSM0018 | 06/05/2002 | 1015 | | 0.0100 | 0.0092 | 0.1240 | 0.5040 | 0.0019 | 0.0196 | 4.0 |
| WSM0023 | 06/05/2002 | 1030 | | 0.0120 | 0.0022 | 0.1360 | 0.5360 | 0.0015 | 0.0178 | 4.0 |
| WSM0028 | 06/05/2002 | 1040 | | 0.0120 | 0.0023 | 0.1150 | 0.4950 | 0.0011 | 0.0169 | 3.6 |
| WSM0018 | 06/19/2002 | 940 | | 0.0030 | 0.0021 | 0.1200 | 0.5000 | 0.0016 | 0.0189 | 4.4 |
| WSM0023 | 06/19/2002 | 930 | | 0.0090 | 0.0026 | 0.0784 | 0.4584 | 0.0015 | 0.0151 | 2.4 |
| WSM0028 | 06/19/2002 | 920 | | 0.0090 | 0.0023 | 0.0764 | 0.4564 | 0.0018 | 0.0135 | 2.4 |
| WSM0018 | 07/10/2002 | 1030 | | 0.0050 | 0.0018 | 0.0663 | 0.4563 | 0.0010 | 0.0148 | 2.4 |
| WSM0023 | 07/10/2002 | 1041 | | 0.0030 | 0.0028 | 0.0790 | 0.4590 | 0.0009 | 0.0130 | 2.4 |
| WSM0028 | 07/10/2002 | 1050 | | 0.0030 | 0.0010 | 0.0676 | 0.4576 | 0.0007 | 0.0142 | 2.4 |

**Table A-5. Table of 2001/2002 MDE DOC data**

| SAMPLING STATION IDENTIFIER | DATE START SAMPLING | SAMPLE DEPTH FROM SURFACE METERS | DISSOLVED ORGANIC CARBON, MG/L | PARTICULATE CARBON, MG/L | TOTAL ORGANIC CARBON, MG/L |
|---|---|---|---|---|---|
| WSM0018 | 11/15/2001 | 0.5 | 9.27 | 0.953 | 10.223 |
| WSM0018 | 11/15/2001 | 1 | | | |
| WSM0018 | 11/15/2001 | 2 | | | |
| WSM0018 | 11/15/2001 | 3 | | | |
| WSM0018 | 11/15/2001 | 4.1 | | | |
| WSM0018 | 11/28/2001 | 0.5 | 8.55 | 0.773 | 9.323 |
| WSM0018 | 11/28/2001 | 1 | | | |
| WSM0018 | 11/28/2001 | 2 | | | |
| WSM0018 | 11/28/2001 | 3 | | | |
| WSM0018 | 11/28/2001 | 3.6 | | | |
| WSM0018 | 12/12/2001 | 0.5 | 8.16 | 0.994 | 9.154 |
| WSM0018 | 12/12/2001 | 1 | | | |
| WSM0018 | 12/12/2001 | 1.5 | | | |
| WSM0018 | 12/12/2001 | 2 | | | |
| WSM0018 | 12/12/2001 | 2.5 | | | |
| WSM0018 | 12/12/2001 | 3 | | | |
| WSM0018 | 01/09/2002 | 0.5 | 7.44 | 1.21 | 8.65 |
| WSM0018 | 01/09/2002 | 1 | | | |
| WSM0018 | 01/09/2002 | 2 | | | |
| WSM0018 | 01/09/2002 | 3 | | | |
| WSM0018 | 01/09/2002 | 4 | | | |
| WSM0018 | 01/09/2002 | 4.5 | | | |
| WSM0018 | 02/13/2002 | 0.5 | 6.7 | 0.985 | 7.685 |
| WSM0018 | 02/13/2002 | 1 | | | |
| WSM0018 | 02/13/2002 | 2 | | | |
| WSM0018 | 02/13/2002 | 3 | | | |
| WSM0018 | 02/13/2002 | 4 | | | |
| WSM0018 | 03/27/2002 | 0.5 | 6.62 | 1.26 | 7.88 |
| WSM0018 | 03/27/2002 | 1 | | | |
| WSM0018 | 03/27/2002 | 2 | | | |
| WSM0018 | 03/27/2002 | 3 | | | |
| WSM0018 | 03/27/2002 | 4.1 | | | |
| WSM0018 | 04/24/2002 | 0.5 | 7.05 | 1.39 | 8.44 |
| WSM0018 | 04/24/2002 | 1 | | | |
| WSM0018 | 04/24/2002 | 2 | | | |
| WSM0018 | 04/24/2002 | 3 | | | |
| WSM0018 | 04/24/2002 | 4.2 | | | |
| WSM0018 | 05/22/2002 | 0.5 | 6.96 | 1.15 | 8.11 |
| WSM0018 | 05/22/2002 | 1 | | | |
| WSM0018 | 05/22/2002 | 2 | | | |
| WSM0018 | 05/22/2002 | 3 | | | |

| | | | | | |
|---|---|---|---|---|---|
| WSM0018 | 05/22/2002 | 3.8 | | | |
| WSM0018 | 06/05/2002 | 0.5 | 7.21 | 1.06 | 8.27 |
| WSM0018 | 06/05/2002 | 1 | | | |
| WSM0018 | 06/05/2002 | 2 | | | |
| WSM0018 | 06/05/2002 | 3 | | | |
| WSM0018 | 06/05/2002 | 3.7 | | | |
| WSM0018 | 06/19/2002 | 0.5 | 6.96 | 1.06 | 8.02 |
| WSM0018 | 06/19/2002 | 1 | | | |
| WSM0018 | 06/19/2002 | 2 | | | |
| WSM0018 | 06/19/2002 | 3 | | | |
| WSM0018 | 06/19/2002 | 4.2 | | | |
| WSM0023 | 11/15/2001 | 0.5 | 8.94 | 0.942 | 9.882 |
| WSM0023 | 11/15/2001 | 1 | | | |
| WSM0023 | 11/15/2001 | 2 | | | |
| WSM0023 | 11/15/2001 | 3 | | | |
| WSM0023 | 11/15/2001 | 3.7 | | | |
| WSM0023 | 11/28/2001 | 0.5 | 8.43 | 0.923 | 9.353 |
| WSM0023 | 11/28/2001 | 1 | | | |
| WSM0023 | 11/28/2001 | 2 | | | |
| WSM0023 | 11/28/2001 | 3.3 | | | |
| WSM0023 | 12/12/2001 | 0.5 | 7.99 | 1.07 | 9.06 |
| WSM0023 | 12/12/2001 | 1 | | | |
| WSM0023 | 12/12/2001 | 1.5 | | | |
| WSM0023 | 12/12/2001 | 2 | | | |
| WSM0023 | 12/12/2001 | 2.5 | | | |
| WSM0023 | 12/12/2001 | 3 | | | |
| WSM0023 | 12/12/2001 | 3.5 | | | |
| WSM0023 | 01/09/2002 | 0.5 | 7.53 | 0.822 | 8.352 |
| WSM0023 | 01/09/2002 | 1 | | | |
| WSM0023 | 01/09/2002 | 2 | | | |
| WSM0023 | 01/09/2002 | 3 | | | |
| WSM0023 | 01/09/2002 | 3.5 | | | |
| WSM0023 | 02/13/2002 | 0.5 | 6.43 | 0.686 | 7.116 |
| WSM0023 | 02/13/2002 | 1 | | | |
| WSM0023 | 02/13/2002 | 2 | | | |
| WSM0023 | 02/13/2002 | 3 | | | |
| WSM0023 | 02/13/2002 | 4 | | | |
| WSM0023 | 03/27/2002 | 0.5 | 6.48 | 1.25 | 7.73 |
| WSM0023 | 03/27/2002 | 1 | | | |
| WSM0023 | 03/27/2002 | 2 | | | |
| WSM0023 | 03/27/2002 | 3.2 | | | |
| WSM0023 | 04/24/2002 | 0.5 | 7.19 | 1.28 | 8.47 |
| WSM0023 | 04/24/2002 | 1 | | | |
| WSM0023 | 04/24/2002 | 2 | | | |
| WSM0023 | 04/24/2002 | 3.3 | | | |
| WSM0023 | 05/22/2002 | 0.5 | 7.1 | 0.776 | 7.876 |

| | | | | | |
|---|---|---|---|---|---|
| WSM0023 | 05/22/2002 | 1 | | | |
| WSM0023 | 05/22/2002 | 2 | | | |
| WSM0023 | 05/22/2002 | 3 | | | |
| WSM0023 | 05/22/2002 | 3.8 | | | |
| WSM0023 | 06/05/2002 | 0.5 | 6.93 | 1.13 | 8.06 |
| WSM0023 | 06/05/2002 | 1 | | | |
| WSM0023 | 06/05/2002 | 2 | | | |
| WSM0023 | 06/05/2002 | 3 | | | |
| WSM0023 | 06/05/2002 | 4 | | | |
| WSM0023 | 06/05/2002 | 4.6 | | | |
| WSM0023 | 06/19/2002 | 0.5 | 6.97 | 0.607 | 7.577 |
| WSM0023 | 06/19/2002 | 1 | | | |
| WSM0023 | 06/19/2002 | 2 | | | |
| WSM0023 | 06/19/2002 | 3 | | | |
| WSM0023 | 06/19/2002 | 3.8 | | | |
| WSM0028 | 11/15/2001 | 0.5 | 8.74 | 0.978 | 9.718 |
| WSM0028 | 11/15/2001 | 1.2 | | | |
| WSM0028 | 11/28/2001 | 0.5 | 8.43 | 0.727 | 9.157 |
| WSM0028 | 11/28/2001 | 1.5 | | | |
| WSM0028 | 12/12/2001 | 0.5 | 8.05 | 0.944 | 8.994 |
| WSM0028 | 12/12/2001 | 1 | | | |
| WSM0028 | 12/12/2001 | 1.5 | | | |
| WSM0028 | 01/09/2002 | 0.5 | 7.37 | 0.661 | 8.031 |
| WSM0028 | 01/09/2002 | 1 | | | |
| WSM0028 | 01/09/2002 | 2 | | | |
| WSM0028 | 02/13/2002 | 0.5 | | 0.727 | |
| WSM0028 | 02/13/2002 | 1 | | | |
| WSM0028 | 03/27/2002 | 0.5 | 6.69 | 1.36 | 8.05 |
| WSM0028 | 03/27/2002 | 1.2 | | | |
| WSM0028 | 04/24/2002 | 0.5 | 6.85 | 1.06 | 7.91 |
| WSM0028 | 04/24/2002 | 1.2 | | | |
| WSM0028 | 05/22/2002 | 0.5 | 6.93 | 0.833 | 7.763 |
| WSM0028 | 05/22/2002 | 1.5 | | | |
| WSM0028 | 06/05/2002 | 0.5 | 7.05 | 0.916 | 7.966 |
| WSM0028 | 06/05/2002 | 1 | | | |
| WSM0028 | 06/19/2002 | 0.5 | 6.84 | 0.5 | 7.34 |
| WSM0028 | 06/19/2002 | 1.3 | | | |

**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-6).

**Table A-6**

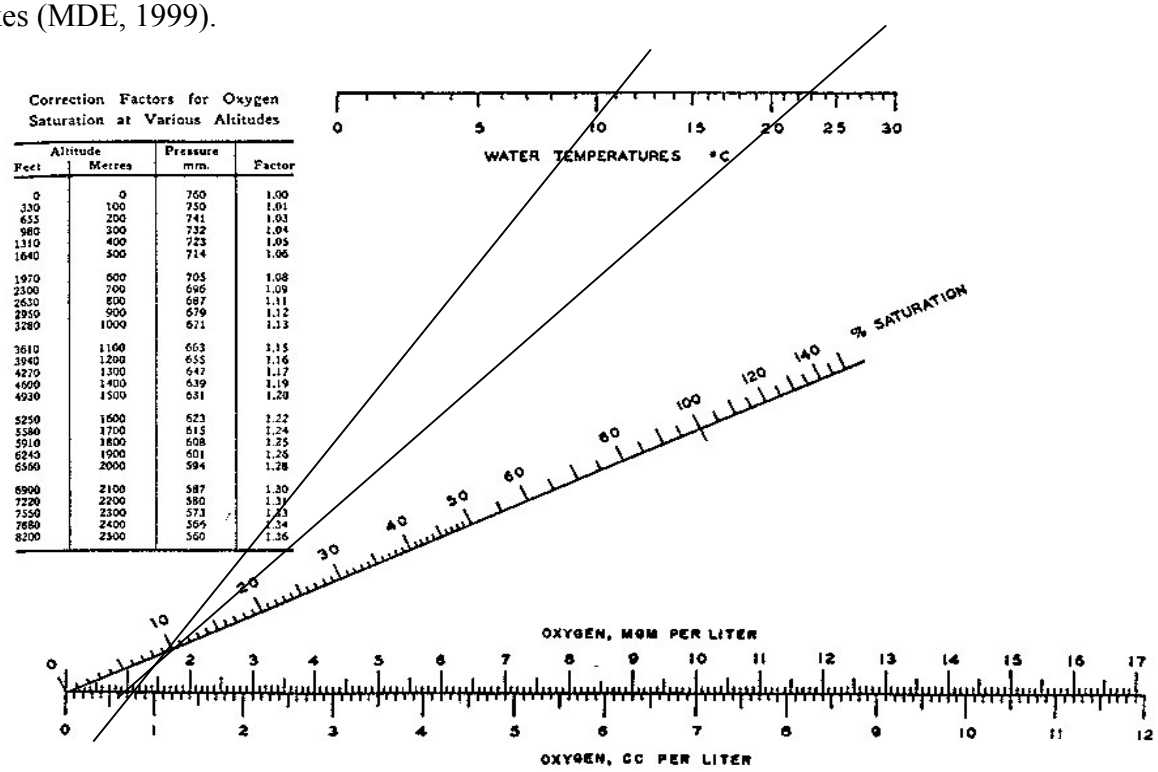
**Relationship between Lake Trophic Status and Dissolved Oxygen Saturation in the Hypolimnion of a Thermally Stratified Lake**

| 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 St. Mary's Lake are consistent with the interim interpretation of Maryland's water quality criterion for dissolved oxygen in thermally stratified lakes (MDE, 1999).



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 | 566 | 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).