

**TOTAL MAXIMUM DAILY LOAD ASSESSMENT (Addendum)
BARR LAKE AND MILTON RESERVOIR**

COSPMS04

Dissolved Oxygen

ADAMS COUNTY AND WELD COUNTY, COLORADO

May 2013

TMDL Summary					
Waterbody Description / WBID/HUC	Barr Lake and Milton Reservoir, COSPMS04, 10190003				
Pollutants Addressed	Dissolved oxygen				
Relevant Portion of Segment (as applicable)	All				
Use Classifications / Designation	Aquatic Life Warm 2, Recreation E, Water Supply, Agriculture				
Water Quality Target	<table border="1"> <tbody> <tr> <td>Dissolved Oxygen</td> <td>5.0 mg/L (minimum)</td> </tr> <tr> <td>Total Phosphorus</td> <td>0.100 mg/L (maximum) 0.040-0.060 mg/L (average)</td> </tr> </tbody> </table>	Dissolved Oxygen	5.0 mg/L (minimum)	Total Phosphorus	0.100 mg/L (maximum) 0.040-0.060 mg/L (average)
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TMDL Goal	Attainment of assigned use classification standards for DO.				

Dissolved Oxygen TMDL Addendum to Barr Lake and Milton Reservoir pH TMDL

Phased TMDLs were developed for Barr Lake (Barr) and Milton Reservoir (Milton) to address aquatic life impairments due to exceedances of the pH standard. Subsequent to completion of the Barr and Milton pH TMDLs (BMW pH TMDLs), but prior to submittal of the TMDLs to the U.S. Environmental Protection Agency, Region 8 (EPA), Milton was identified on the 2010 303(d) list of impaired waters for exceedance of the dissolved oxygen (DO) standard. Barr also shows symptoms of dissolved oxygen impairment, but was added to the 2010 Monitoring and Evaluation List, rather than the 303(d) list. In 2012, Barr Lake was added to the 303(d) list (WQCC 2012a).

The BMW pH TMDLs developed for Barr and Milton address the pH impairment through reductions of total phosphorus (TP). Because both pH and DO exceedances are related to excess nutrients (eutrophication), Colorado's approach to addressing these impairments is through reductions of TP. This addendum is written to include DO TMDLs with the BMW pH TMDLs for Barr and Milton.

Several lines of evidence supporting TP reductions are presented in the BMW pH TMDLs. One of the approaches selects chlorophyll a (Chl) targets that would result in attainment of the pH standard. Several models were used to estimate TP concentrations that would attain the Chl targets. The maximum Chl target is set at 25 ug/L for Barr and Milton. Because the water from Barr conditions the water in Milton, it is expected that reductions in TP that attain pH and DO standards in Barr will contribute to attainment of pH and DO standards in Milton.

TP of 100 ug/L is identified as the maximum concentration that would achieve the Chl target and thus the pH standard. This maximum TP concentration is expected to produce an average of 40-60 ug/L TP. Through evaluation of other lakes in Colorado, it was determined that the Chl and TP targets and related TP reductions set to attain the pH standards in both lakes also will result in attainment of the DO standards in both lakes. As with the BMW pH TMDLs, there is a great deal of uncertainty in these targets, and therefore, the DO TMDLs for Barr and Milton are proposed as phased TMDLs.

The State of Colorado currently does not have statewide nutrient criteria or standards, which makes setting Chl and TP targets for TMDLs somewhat challenging. Ideally, attainment of DO standards is linked to a Chl target which is linked to a TP target. Several lines of evidence are used to determine the Chl and TP TMDL targets and the required TP reductions. Approaches used for identifying a Chl target and related TP target to attain DO standards are discussed below.

1. Utilize Water Quality Control Division (Division) draft proposed interim nutrient values for TP and Chl; and
2. Examine data from other Colorado lakes.

One approach is to use the Division's draft proposed interim nutrient values for the TMDL targets. Although these values are not yet adopted by the Water Quality Control Commission (WQCC), they are set to protect aquatic life uses which we assume dovetails with other Aquatic Life Use-based standards related to eutrophication (DO and pH standards) and thus represent reasonable targets for Barr and Milton. Colorado's draft proposed interim nutrient values for lakes, as of October 2010 are shown in Table 1. Note that the aquatic life numbers are for the 80th percentile of summer averages.

Classification	Recreation ¹	Aquatic Life ²		
	Chlorophyll (ug/L)	Chlorophyll (ug/L)	Total P (mg/L)	Total N (mg/L)
Cold	20	8	0.024	0.412
Warm	30	20	0.081	0.851
1 – 85 th percentile of summer measurements				
2 – 80 th percentile of summer average				

Table 1. Colorado draft proposed criteria for lakes.

Another approach to setting TMDL targets is to examine data pooled from other Colorado lakes with similar characteristics. An assessment conducted for another Colorado warm-water reservoir impaired for DO is applied to Barr and Milton. Barr and Milton are warm lakes that stratify intermittently. Colorado warm water lakes were grouped as those that stratify persistently, stratify intermittently, or do not stratify. Of the group that stratifies intermittently, the comparison was narrowed to those that were in the range of 7-9 meters median depth. Data from these Colorado lakes show attainment of the DO standard, and the associated Chl and TP data are generally in a lower range than those observed in Barr Lake and Milton Reservoir. The lakes used were: Boulder Reservoir, Cherry Creek Reservoir, Fruitgrowers Reservoir, Lonetree Reservoir, Loveland Reservoir, Totten Reservoir, Puett Reservoir, Quincy Reservoir, Sweitzer Reservoir and Union Reservoir. These 10 lakes yielded 365 growing season sampling events. Although Barr and Milton are somewhat shallower than these lakes, the assessment should be applicable to Barr and Milton.

Scatter plots of DO vs. Chl, and Chl vs. TP were examined for relationships between the variables. Regressions were not strong; however thresholds were observed that represent potential targets for TMDLs for DO impairments.

In determining thresholds for attaining the DO standards, data for individual sampling events for all of the selected lakes are used because DO attainment is assessed based on individual profiles. The analysis is limited to sampling events during the growing season of July through September, as this typically is the critical period for Colorado lakes. The Division’s assessment approach for DO in lakes is to evaluate the upper layer defined as the average of profile measurements from 0.5 meters to 2.0 meters for lakes 5 meters or greater in depth. Using this assessment methodology, upper layer profile averages for DO are plotted against Chl in order to identify a maximum Chl concentration for which the DO standard of 5.0 mg/L is attained. The regression is not strong. However by close examination of the lower left side of the plot (by fixing the maximum values for the X and Y axes), it is observed that below 25 ug/L Chl, DO rarely falls below the standard of 5.0. (Figure 1)

A scatter plot of DO vs. Chl, where DO is calculated for a deeper profile interval based on measurements from 0.5 meters to 3.0 meters, shows DO is not exceeded when Chl is below 25 ug/L (Figure 2).

Figure 1. Dissolved oxygen (0.5- 2.0 m interval) vs. chlorophyll.

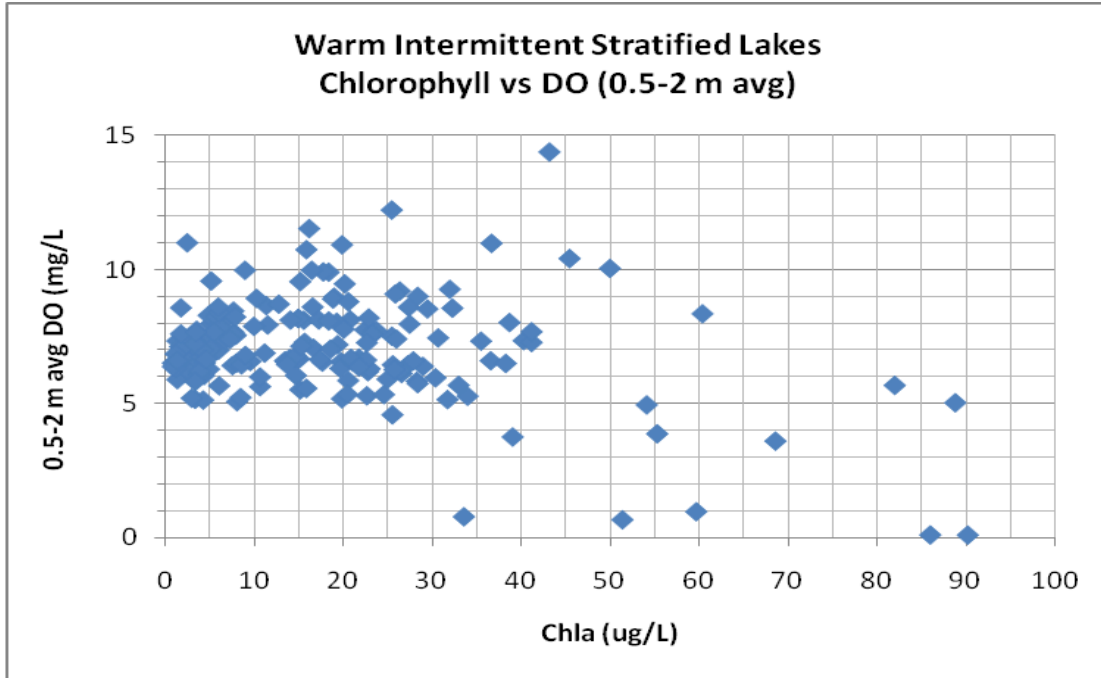
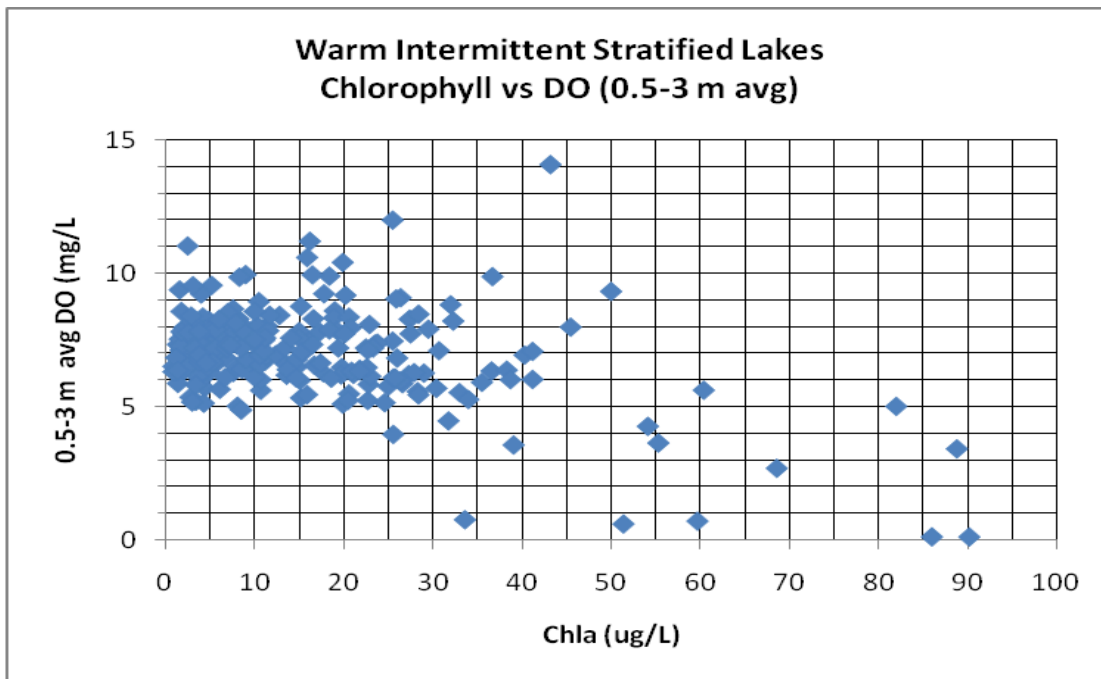


Figure 2. Dissolved oxygen (0.5- 3.0 m interval) vs. chlorophyll.



Although this Chl threshold (25 ug/L) is somewhat higher than the WQCD's draft proposed interim Chl value (20 ug/L for warm lakes), the WQCD proposed Chl value is the 80th percentile of summer

averages, while the 25 ug/L identified above represents an instantaneous maximum threshold. The proposed Chl value is based on summer averages rather than individual samples within one season. These two Chl levels are similar to the Chl targets described in the BMW pH TMDL.

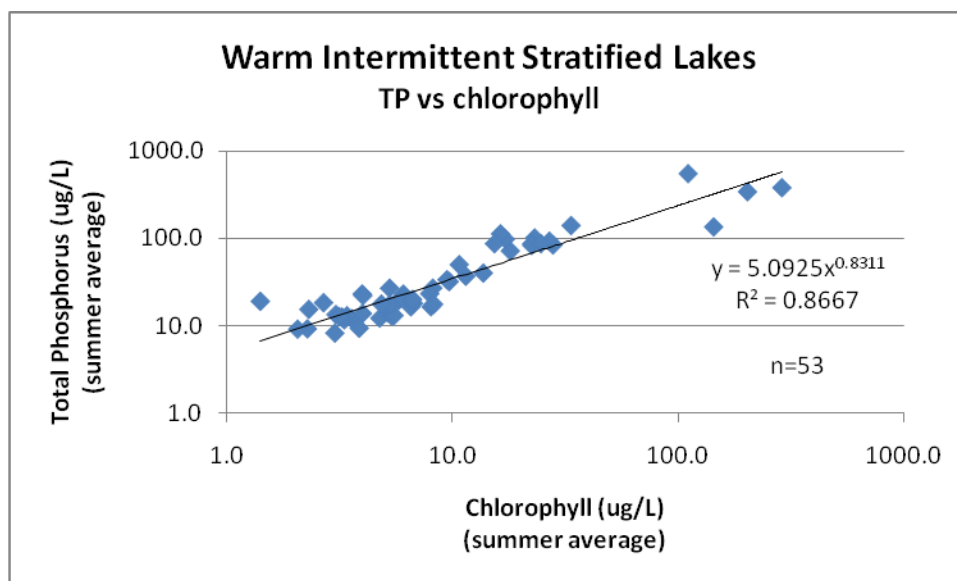
The BMW pH TMDL identifies two Chl targets. Based on observations of Barr data, a 21 ug/L Chl target would attain the pH standard for Barr Lake, and the same target is recommended for Milton Reservoir. Based on data from other Denver area lakes, a Chl target of 25 ug/L is also recommended.

For this DO TMDL, appropriate Chl targets to attain the DO standard are 20 ug/L as 80th percentile of summer averages and as a maximum of 25 ug/L.

Using the 80th percentile assumes a Chl exceedance frequency of 1 in 5 years. Note, however, that these targets are set to attain the DO standard. There is no exceedance frequency for the DO standard. To be consistent with the Division's proposed approach, the Division's proposed value of 20 ug/L Chl as 80th percentile of summer average could be used for this TMDL's Chl target. The median seasonal average Chl associated with the 80th percentile for the seasonal Chl averages in the data set used for this TMDL is approximately 15 ug/L. The median represents what the typical summer average would be.

Several approaches were used to relate a TP concentration to the 20 ug/L Chl target. One approach used an inverse regression in which summer average total phosphorus was regressed on summer average Chl. The power equation for the regression predicted 61 ug/L total phosphorus for the target 20 ug/L Chl. The regression was relatively strong with an $r^2=0.8667$ (Fig 3).

Figure 3. Inverse regression of Total Phosphorus vs Chlorophyll



Another approach to setting the TP target, the Dillon-Rigler model (1974), was also considered.

$$\text{Chlorophyll } a = 0.0731 * \text{TP}^{1.449} \text{ (ug/L)}$$

This model is widely used and was developed by correlating summer Chl with spring total phosphorus from many North American lakes. Although data from individual samples from an individual lake would not be expected to fit the model line exactly, it is useful for supporting the development of a TP target. In this case, summer TP values were used, rather than spring values.

The Dillon-Rigler model was used to back-calculate a TP value for 20 ug/L Chl. The model result for 20 ug/L Chl was 48 ug/L TP.

Finally, the data set for intermittently stratified lakes was used to determine the median (typical) and 80th percentile for summer averages for each lake for Chl and TP. These values related TP to Chl in order to calculate TP concentrations related to the Chl targets (15 and 20 ug/L). The data set was made up of 53 lake summer averages for 10 lakes. Using this approach, the median (or typical) summer average total phosphorus related to the 80th percentile Chl of 20 ug/L was approximately 43 ug/L. The results from the approaches described above are reasonable given the limited data and the uncertainty inherent in these approaches.

The TP estimates from the various approaches described above range from 43 ug/L to 61 ug/L as summer averages and medians, to 82 ug/L as an 80th percentile. These values are in the ranges of those described for the BMW pH TMDLs which are 100 ug/L TP as a maximum and 40-60 ug/L as the range for average conditions. It is expected that the Chl and TP targets, as well as the loading analysis and resulting Load Allocations and Wasteload Allocations for the pH TMDL, will also result in attainment of the DO standards.

As stated above, these DO TMDLs will be phased with the phased pH TMDLs. The Implementation Plan developed for the pH TMDLs includes ongoing monitoring, as well as other special studies that will address data uncertainty and the linkages of pH with Chl and of Chl with TP. These studies should also provide relevant information for the DO TMDLs. Attainment of the TMDLs is determined by attainment of the DO standards. If, after implementation of the TMDLs, the DO standards are not attained, the targets may be revised as necessary.

Public Participation:

The DO TMDL is the subject of an independent public process. This DO TMDL report was made available for public review and comment concurrently with the Barr and Milton pH TMDL report during a 30 day public notice period in May 2011 which was extended through August 15, 2011. A summary of the comments received during the public notice period and the responses to those comments is included as an appendix to the BMW pH TMDL.

Post Public Notice

Subsequent to the public notice of this DO TMDL report but prior to the finalization and submittal to EPA, the WQCC held a rule-making hearing (RMH) for nutrient criteria. The proposed interim numeric values for nutrients discussed in this report were modified before the RMH. The final

values adopted by the WQCC into Regulation 31 (effective date September 20, 2012) are presented in Table 2 below (WQCC 2012c).

Classification	Aquatic Life ²		
	Chlorophyll (ug/L)	Total P (ug/L)	Total N (mg/L)
Cold	8 ²	25 ¹	0.426
Warm	20 ²	83 ¹	0.910
1 – summer (July 1-September 30) average Total Phosphorus (ug/L) in the mixed layer of lakes (median of multiple depths), allowable exceedance frequency 1-in-5 years.			
2 – summer (July 1-September 30) average chlorophyll a (ug/L) in the mixed layer of lakes (median of multiple depths), allowable exceedance frequency 1-in-5 years.			

Table 2. Colorado final interim numeric values for lakes.

Final draft pH TMDL and DO TMDL reports and the Implementation Plan were provided to the Barr Milton Watershed Association (BMWA) in August 2012. At the request of BMWA, additional meetings were held throughout the remainder of 2012 to discuss revisions to the TMDL documents and Implementation Plan. The Division agreed with BMWA’s revisions to the pH TMDL report and Implementation Plan documents. These revisions were completed by BMWA and submitted to the Division in March 2013.

The Division prepared additional responses to comments and finalized the documents. The TMDL reports and Implementation Plan were submitted to EPA in May 2013.

Literature Citation

Dillon, P. J., and F. H. Rigler. 1974. The phosphorus-chlorophyll relationship in lakes. *Limnol. Oceanogr.* 19:767-773.

WQCC 2012a. Colorado Department of Public Health and Environment, Water Quality Control Commission, *Colorado's Section 303(d) List of Impaired Waters and Monitoring and Evaluation List*, Regulation 93, Effective March 30, 2012.

WQCC 2010b. Colorado Department of Public Health and Environment, Water Quality Control Commission, *Classification and Numeric Standards for Gunnison and Lower Dolores River Basins, Regulation 38, amended effective March 1, 2013.*

WQCC 2012c. Colorado Department of Public Health and Environment, Water Quality Control Commission, *The Basic Standards and Methodologies for Surface Water, Regulation No. 31.* Effective 9/30/12.