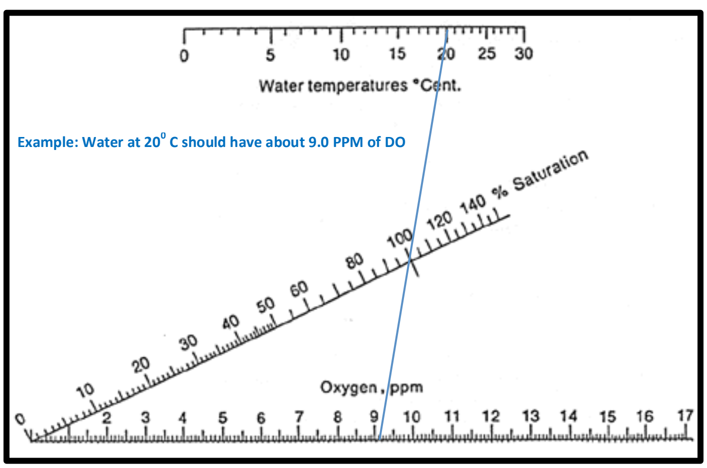
2015 Water Quality Summary Series – Dissolved Oxygen

Twenty times a year since 2003, **Barr Lake** and **Milton Reservoir** have been observed and sampled for many water quality parameters. These 240 trips to both reservoirs have produced an abundance of data and information. This is Part 3 of a continuing series summarizing the 2015 water quality data. The first two summaries focused on pH and chlorophyll-a; this one discusses dissolved oxygen (DO).

The Big Picture – Many lakes, reservoirs, and even estuaries and bays throughout the world experience "*cultural eutrophication*". This term means that water bodies tend to become more productive and shallower over relatively short periods of time due to increased inputs of nutrients and sediments from human impacts in the watershed. Eutrophication is a natural process, but it generally occurs over a much longer geological period. This accelerated aging of lakes causes a quick biological response – severe algae growth. This response then leads to other chemical and physical changes within the water column – pH, oxygen, water clarity, water color, and aesthetics.

DO – Oxygen is the most fundamental parameter of lakes aside from water itself. All aquatic organisms, from fish to microscopic bacteria, need oxygen to live. DO is the measurement of how much oxygen gas is dissolved in the water. The two mechanisms that control oxygen dissolution are photosynthesis and diffusion from the atmosphere. DO concentrations are typically expressed in units of milligrams per liter (mg/L) or parts per million (ppm). Concentrations below 1 mg/L are considered anoxic – void of oxygen.

Water temperature, pressure (atmospheric and hydrostatic), and the amount of dissolved salts determines the solubility of oxygen. The colder the water the more oxygen it can hold. At 32^{o} F, one liter of water can hold about 14 mg of oxygen. The same liter of water at 80^{o} F can hold about 8 mg – *lakes during the summer have less DO*. The higher the pressure, the less likely bubbles will form so it holds the oxygen in solution better – *lakes at higher elevation have less DO*. Water with more dissolved salts has less room for oxygen molecules – *lakes in agricultural areas have less DO*. At a given temperature, pressure, and salt content, there is a limited amount of DO that the water can keep soluble. This is the 100% DO level. Percent DO (%DO) is another way of looking at oxygen.



Quick Saturation Chart – draw a straight line from a water temperature to a DO concentration. The %DO is where the line crosses the % saturation line (note: this nonogram is for sea level).

DO or %DO can change quickly and exhibit large differences between the top, middle, and bottom water in productive lakes. Algae and wave action occurs at the top of a lake so when in equilibrium the DO should be 100%. If it is >100%, it is because of additional oxygen from photosynthesis. At the bottom of a lake there is no photosynthesis and the water is not in contact with the atmosphere, but at the same time it is colder and there is more hydrostatic pressure. Bottom water DO can be less than 100% due to decomposition and chemical reactions. Fish are able to avoid low DO areas and swim where there is acceptable amount of DO. This is why the DO water quality standard for Colorado lakes (deeper than 5 meters) only applies to the top water (0.5 – 2.0 meters). The DO standard for **Barr Lake** and **Milton Reservoir** is 5.0 mg/L or higher.

2015 DO Data – DO profile data are collected throughout the entire water column in half meter increments during each visit. DO data from 0.5 to 2.0 meters are then averaged for each visit for the top water. For 2015, there were 20 DO averages recorded for each reservoir (Table 1). For **Barr Lake**, concentrations remained above the standard all year long. **Milton Reservoir** had DO above 5.0 mg/L the entire year as well. Both reservoirs saw a decrease in DO in April and September.

Table 1. Barr Lake and Milton Reservoir DO data for 2015 (mg/L and %). Bold values exceed water quality target.

Month	DO (Barr)	DO (Milton)
Jan	13.1(113%)	11.4(96%)
Feb	16.9(159%)	16.0(155%)
Mar	16.4(154%)	23.3(222%)
Mar	12.6(139%)	13.1(146%)
Apr	9.9(110%)	5.2(58%)
Apr	5.3(60%)	7.4(84%)
May	7.4(86%)	7.6(87%)
May	8.8(102%)	8.9(102%)
Jun	10.0(135%)	10.3(138%)
Jun	10.8(151%)	11.2(151%)
Jul	13.2(185%)	8.0(112%)
Jul	8.5(118%)	9.9(140%)
Aug	6.9(96%)	7.0(98%)
Aug	7.9(106%)	10.0(134%)
Sep	5.0(68%)	6.1(80%)
Sep	7.8(104%)	8.84(109%)
Oct	7.8(93%)	9.5(124%)
Oct	5.7(65%)	12.8(138%)
Nov	9.1(97%)	21.3(220%)
Dec	17.7(158%)	15.9(150%)

Because of the growth of algae year round, both reservoirs tend to have sufficient DO – 13 of the 20 averages in 2015 were over 100% DO for **Barr Lake** and 14 out of 20 for **Milton Reservoir**. Only during the late summer when the reservoirs are shallow, very warm, and the July/August algae blooms starts to decay, do you see a drop in DO concentrations. Occasionally, DO will also drop during the winter when the reservoirs have a thick ice cover, but both reservoirs had a strong diatom bloom in the fall/winter of 2015.

For **Barr Lake**, Chl-a in March and early April was over 25 µg/L. During this period, %DO was well over 100%. This typical diatom bloom caused an increase in pH, DO, and Chl-a, and it later caused a decrease in DO due to decomposition.

The growing season (July – September) average for **Barr Lake** was 8.24 mg/L (113%) and 8.31 mg/L (112%) for **Milton Reservoir**. In general, there is plenty of oxygen except for isolated situations when consumption is faster than the supply.

Figure 1

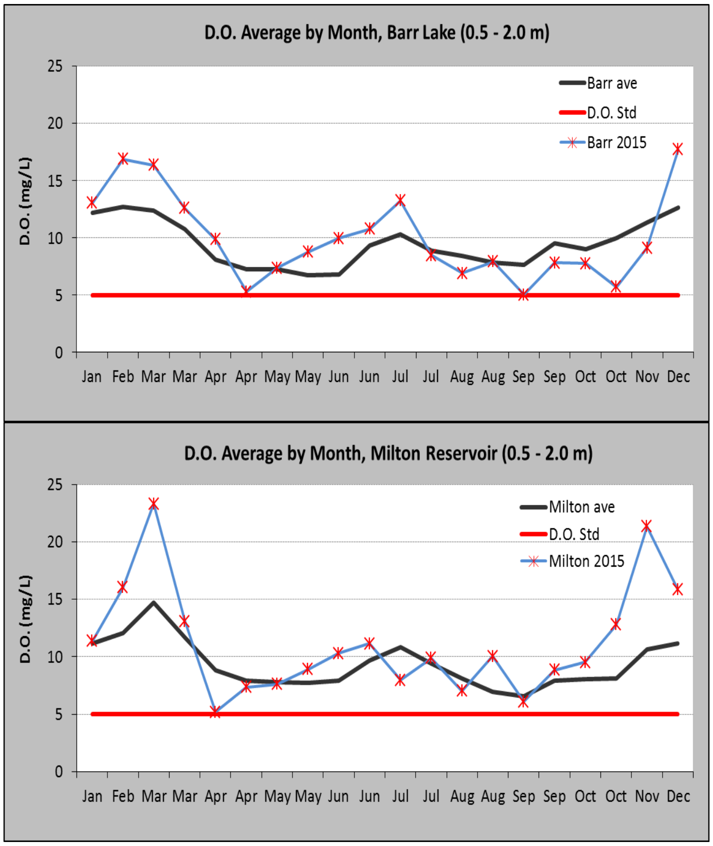


Figure 1 shows the average annual cycle of DO along with 2015 data for both reservoirs. **Barr Lake** followed the annual pattern except for a dip in DO in September and October. **Milton Reservoir** had a pretty typical DO year except for October and November during the drawdown.

Oxygen Deficit Rate – Figure 2 shows the average DO for each level in Barr Lake (top, middle, and bottom). The oxygen Deficit Rate (ODR) is the slope of the line when DO declines. It tells you how many milligrams of oxygen are being consumed over a given period of time per unit area. The ODR for **Barr Lake** in April/May 2015 was about 1,700 mg of DO/m^2-Day. The oxygen consumption rate is the ODR applied to the sediment area of the bottom water (the bottom 2 meters). The consumption rate was just over 10,000 Kg of oxygen per day. This information is useful when considering in-lake aeration systems.

The reservoir is fully mixing top to bottom when all three DO lines are the same. As soon as the bottom water is not mixing, respiration starts to consume the DO. When there is an increase in top water DO, this is caused either by photosynthesis or wave action. When middle and bottom water DO increases, this is usually caused by wind mixing or algal growth in shallow conditions.

Figure 2