

## 2016 Water Quality Summary Series – Water Temperature

Twenty times a year since 2003, **Barr Lake** and **Milton Reservoir** have been observed and sampled for many water quality parameters. These 260 trips to both reservoirs have produced an abundance of data and information. This is Part 4 of a continuing series summarizing the 2016 water quality data. The first three summaries focused on pH, chlorophyll-a, and dissolved oxygen; this one discusses water temperature.

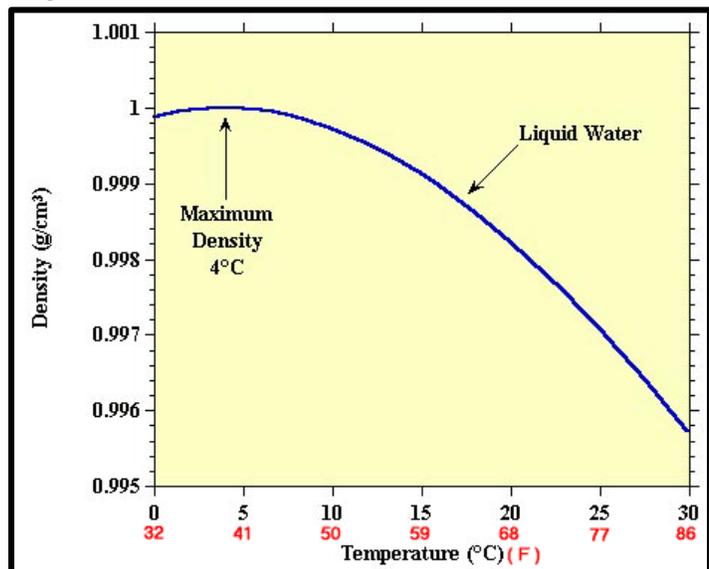
**The Big Picture** – Many lakes, reservoirs, and even estuaries and bays throughout the world experience “*cultural eutrophication*”. This term means that water bodies tend to become more productive and shallower over relatively short periods of time due to increased inputs of nutrients and sediments 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.

**Temperature** – A unique property of water is the temperature/density relationship (Figure 1). Water changes density as it changes temperature. Water is heaviest at 4 °C. Any warmer or colder and the water will float. This is why ice (0 °C) floats during the winter and warm water (25 °C) floats during the summer. The bottom water temperature in most deep lakes is between 4 °C and 10 °C. This density gradient associated with temperature defines a lake’s ecology and annual cycles.

A lake’s annual temperature cycle is determined by its local climate and angle to the sun (latitude). **Barr Lake** and **Milton Reservoir** are considered *dimictic* when deeper than about 7.0 meters – mixing twice a year, once in the spring and again in the fall with thermal stratification occurring during the winter and summer months. If the reservoirs are less than 7.0 meters, they become *polymictic* – they mix multiple times when wind and wave action is strong enough to mix the entire water column.

Thermal stratification is important to understand. It is the layering of water caused by temperature differences. During the summer, the uppermost warmest layer (epilimnion) is the lightest and well mixed. The middle water is where the temperature transitions to the bottom cooler water. Each change in temperature forms a layer of non-mixing water (metalimnion). It only takes a half of a Celsius degree to form stratification. The bottom layer (hypolimnion) is the coldest and is isolated from any other water.

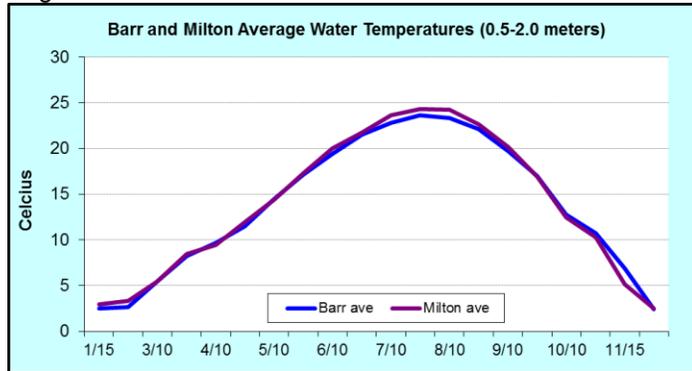
Figure 1.



It takes a large amount of energy to change the temperature of water. This is why the unit of energy (Calorie) uses water in its definition. A dietary Calorie is the amount of energy it takes to heat up 1 kilogram of water by 1 °C.

Because of this thermal resistance, lakes tend to have very predictable and gradual temperature cycles. This is good for aquatic organisms and explains why they have evolved to have specific temperature ranges for various life stages (e.g. spawning). The annual temperature cycle for both **Barr Lake** and **Milton Reservoir** changes little from year to year (Figure 2). The warmest water occurs during the last week of July and the coldest in December.

Figure 2.



The temperature standard for warm-water, Colorado lakes (deeper than 5 meters) only applies to the top water (0.5 – 2.0 meters). The temperature standard for **Barr Lake** and **Milton Reservoir** is 26.2 °C (chronic) and 29.3 °C (acute) between April and December and 13.1 °C (chronic) and 24.1 °C (acute) between January and March.

Table 1. Barr and Milton Temperature Data for 2016 (degrees Celsius).

Month	Temperature (Barr)	Temperature (Milton)
Jan	2.11	1.84
Feb	2.81	2.70
Mar	6.12	6.65
Mar	6.98	7.00
Apr	14.01	13.18
Apr	11.70	11.73
May	13.04	13.80
May	15.92	17.89
Jun	21.14	20.33
Jun	23.30	23.89
<b>Jul</b>	<b>23.57</b>	<b>24.14</b>
<b>Jul</b>	<b>23.88</b>	<b>24.60</b>
<b>Aug</b>	<b>24.04</b>	<b>24.93</b>
<b>Aug</b>	<b>21.84</b>	<b>21.66</b>
<b>Sep</b>	<b>19.66</b>	<b>17.97</b>
<b>Sep</b>	<b>17.73</b>	<b>16.88</b>
Oct	14.21	14.77
Oct	12.00	10.43
Nov	11.22	9.79
Dec	1.82	4.08

Acute is a daily maximum average, and chronic is the maximum average during the growing season (July – September). A lake can exceed these temperatures as long as there is deeper water that meets both the temperature and dissolved oxygen standards.

**2016 Temperature Data –** Temperature data are collected throughout the entire water column in half meter increments during each visit. Temperature data from 0.5 meter to 2.0 meters are averaged for each visit. For 2016, there were 20 temperature averages recorded for each reservoir (Table 1). For **Barr Lake** and **Milton Reservoir**, the temperature standard was achieved.

The growing season average (Jul – Sep) for **Barr Lake** was 21.79 °C and 21.70 °C for **Milton Reservoir**.

*Celsius to Fahrenheit = double it and add 32*

$$F = (1.8 \times C) + 32$$

Figure 3 shows the long term temperature averages for the top water in both reservoirs. Both reservoirs are below the chronic and acute standards for both seasons (dashed lines).

**Relative Thermal Resistance to Mixing (RTRM)** – It takes a small change in temperature to keep water from mixing due to density differences. RTRM is a way to measure this resistance throughout the water column. The greater the temperature difference, the greater the density difference; therefore, the more energy it takes to mix.

RTRM is a ratio that looks at each half meter layer and compares the density changes to the density difference between water at 5 °C and 4 °C. Barr Lake’s temperature profile from 06/06/16 is a good example (Figure 4). The top water (surface to 3.0 meters) was the warmest while the bottom water quickly changed to 16.0 °C. For every half meter depth change, the RTRM was calculated. When full in early summer, the top water was warm and capable of mixing down to 3 meters. The top meter can warm up during the day but then mix at night with the epilimnion. The metalimnion was gradually cooling from 3 to 5 meter depths. Each half meter had resistance to mixing so the metalimnion was stratified. The bottom meter was fully mixing and provided a large hypolimnion.

Figure 3.

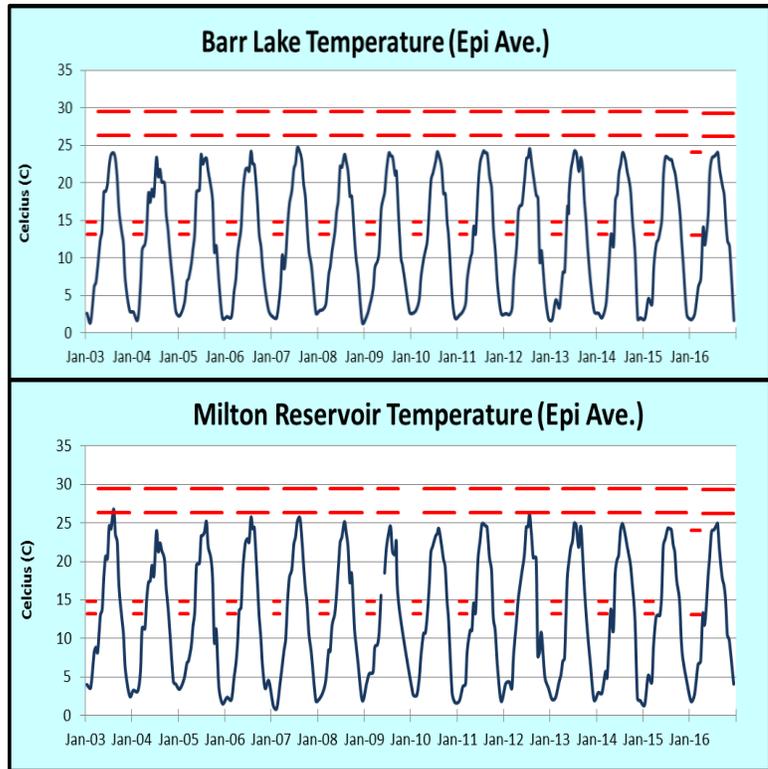
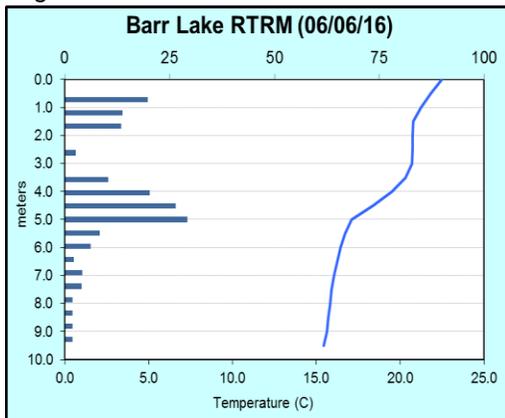


Figure 4.



values) in lakes can bring up bottom water that includes nutrients from the sediments, but at the same time it can also push algae into the darker water to control their growth.

This is a common profile for Barr because the reservoir is not that deep compared to natural lakes. Adding up the RTRM values yields a value of 169. This accumulative RTRM can be used to compare to other lakes, to help size aeration systems to avoid destratification, and to determine when a lake is about to mix. The higher the number, the more energy it takes to mix. Periodic mixing events (i.e., low RTRM