Mapping Dissolved Oxygen and Temperature in the Upper Mystic Lake, Arlington/Winchester, MA

Objectives

Our group wishes to see how the dissolved oxygen (DO) content and the temperature change in the Upper Mystic Lake and surrounding area with respect to longitude, latitude, and depth. To do this, we must first gather sufficient data. Second, we import the collected data into the ArcGIS software package to conduct analysis. Analysis will include interpolations of the data (assuming we gathered enough data to make a reasonable interpolation), and observations on how longitude, latitude, and depth affect the DO and temperature (e.g. observing a thermocline).

Logistics

All data gathered was in the Upper Mystic Lake, located in Winchester and Arlington, MA, and in the adjacent lakes above the Upper Mystic Lake. Our group, which included Alexandros Machairas, Samuel Haffey, Matthew Andrews, and Joseph Lin, along with Christiaan Adams, took all samples on November 6, 2003, from 9:30 A.M. to 1:30 P.M. The group used a motor boat to travel around the lake. Future samplers in this lake should be aware that motor boats are not allowed unless appropriate permission is allowed. In addition, the area where the Upper and Lower Mystic Lake meet is quite shallow and has many rocks. Be sure to stay away from that area, as our group unfortunately damaged the propeller on the rocks.

The measuring device used to get DO and temperature was a YSI model 57 DO meter and probe; the DO could be read with ±0.1 mg/L accuracy, and the temperature could be read with ±0.5 degrees Celsius accuracy. Be sure to calibrate the meter before heading out on the lake. For example, the meter we used required a freshwater sample at a known temperature and pressure.

Gathering the Data

The group measured DO and temperature at 34 different spots in the Upper Mystic Lake and adjacent northern lakes. To determine the boat's position a GPS device was used with accuracy of 5 meters. Sampling points were separated by a minimum of 50 meters; therefore overlap was of points due to the GPS inaccuracy was not a concern.

To determine the depth of the probe equidistant marks on the cord connecting the probe to the meter were used. The marks were separated by half meter. Thus, if we let the probe drop to the second mark, the probe would be one meter into the water. In addition, an anchor was added near the probe such that the probe would drop and not float in the water. No matter the location, a measurement was always taken at the second mark. Also, depending on how deep the lake was, measurements were taken at the one-half, fifth, tenth, fifteenth, twentieth, and twenty-fifth mark (Note: divide the mark number by two to get the meters). A Map showing the measurement locations can be viewed below:

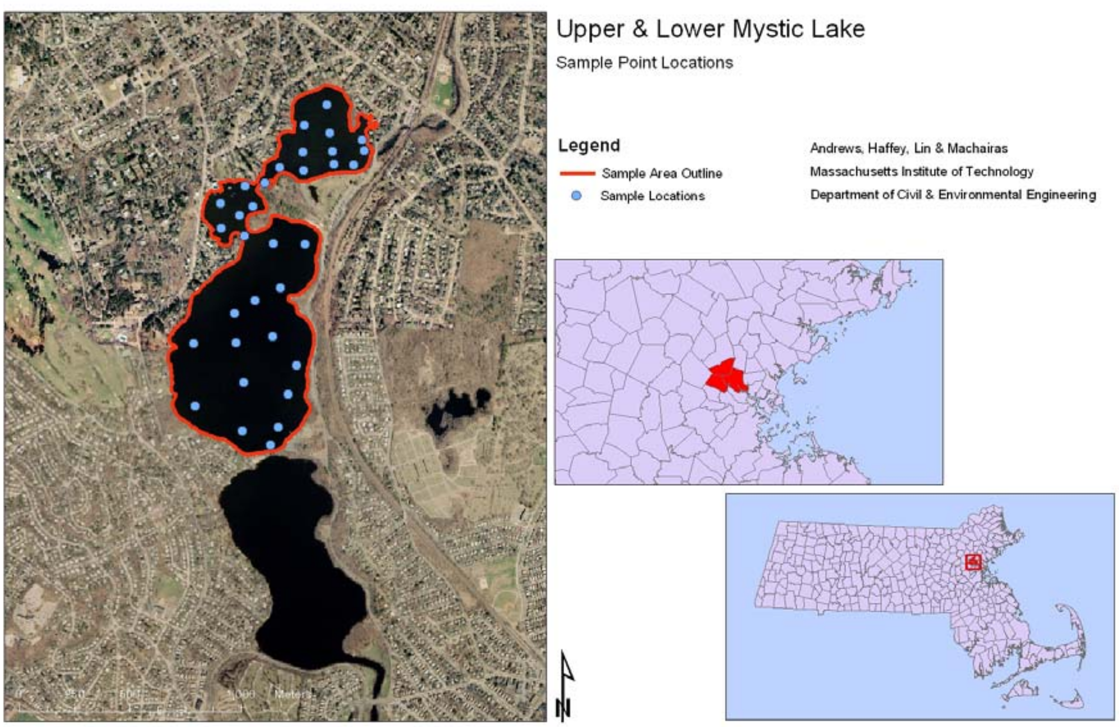

Figure 1: Location of Sample Points

Entering the Data into ArcGIS: Initial Observations

Originally, our group wanted to use a hand-held personal computer to enter the data at the actual lake. This hand-held PC had ArcPad, which could directly input the GPS readings, the depth, the DO, and the temperature into an ArcGIS point shapefile. Unfortunately, the ArcPad software was malfunctioning while we were on the lake. This required us to use a handheld GPS, recording position as Longitude and Latitude in the WGS 1984 coordinate system. The position and measurement data was recorded by hand on a paper pad. Longitude and Latitude was recorded using the hddd^{o}mm’ss.s’’ form.

Upon returning, the data from the paper pad was then transcribed into an Excel spreadsheet with columns for Longitude, Latitude, Depth, DO and Temperature. Longitude and latitude were converted as follows: hddd + (mm/60) + (ss.s/3600). In addition longitudes were multiplied by -1 to indicate western hemisphere. The spreadsheet was further transcribed to a separate spreadsheet that did not include equations, had the area of the sheet containing data defined with the name database and had all the proper formatting on the columns (ie. Numbers with proper decimal places). This spreadsheet was saved as a Dbase IV file and used to create a Point shapefile with ArcCatalog using the Longitude and Latitude as the X and Y coordinates. The data was split into two different shapefiles: one for the Upper Mystic Lake itself, and the other for the adjacent northern areas. This was done because the properties of each of these two areas differed significantly, especially in the depth.

<u>Interpolating the Data Using ArcGIS</u>

Once all the data had been entered, we interpolated the data to estimate the DO and temperature throughout the lake. In order to restrict the interpolation to the body of the lake a ployline shape file was created that outlined the border of the lake. The line was constructed by tracing the outline of the lake as viewed on an orthophoto of the Upper Mystic Lake. The use of the border restricted our choice of interpolation to the Inverse Distance Weighted method. Since ArcView does not offer the use of a border in the other interpolation methods. We then segregated the data by depth and interpolated over the area of the lake for each depth at which we took measurements. Since we only had data for the entire lake at 1 meter, interpolations at other depths were restricted to the lower half of the lake where bathymetry permitted taking deeper measurements. These horizontal interpolations were then laid out to show the progressions of temperature and DO horizontally at each measurement depth. Space restrictions required us to divide the layout into the following two maps:

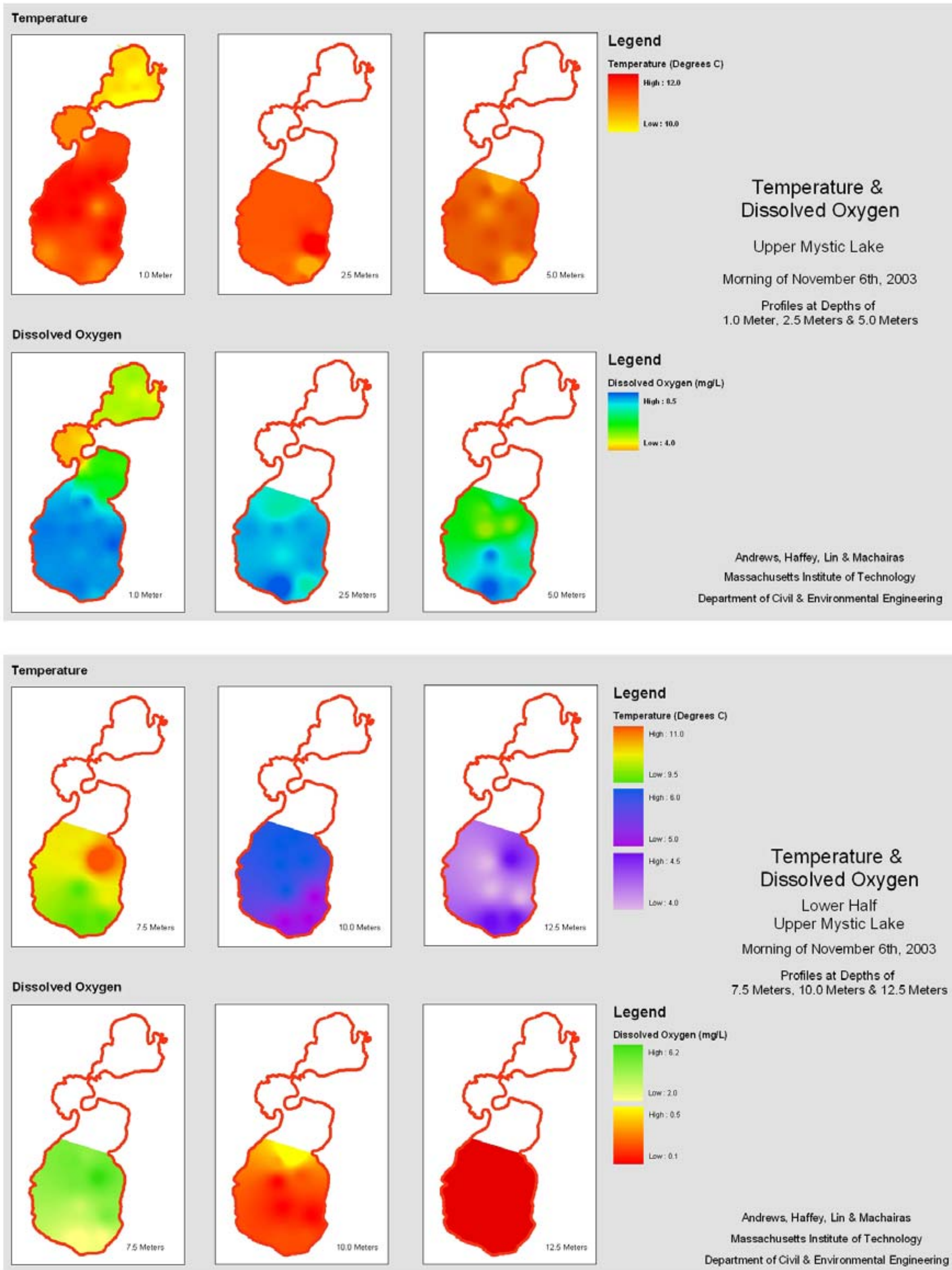

Figure 2: Temperature and DO Variation with Depth

The second form of interpolation used in this project was interpolation over depth in a cross section of the lake. Our motivation for this was the observation of stratification in the main body of Upper Mystic Lake. In order to be able to display this stratification graphically we selected a line of points having roughly the same latitude but differing in longitude. This line was used to obtain a latitude – depth plane over which we could interpolate the DO and temperature values over depth. To achieve this we translated the depth coordinates into WGS 1984 coordinates using a transform function. The transform function was defined by using the measurement tool in ArcGIS to measure the distance in meters between the points along the line of cross section. Using this distance we determined the number of meters in a second of latitude at Upper Mystic Lake. Knowing the depth in meters we were now able to transform the depth coordinate into longitude and apply some exaggeration to obtain a visually satisfying cross section. The Spline method of interpolation was used to interpolate DO and temperature across this cross section the results of which can be viewed below.

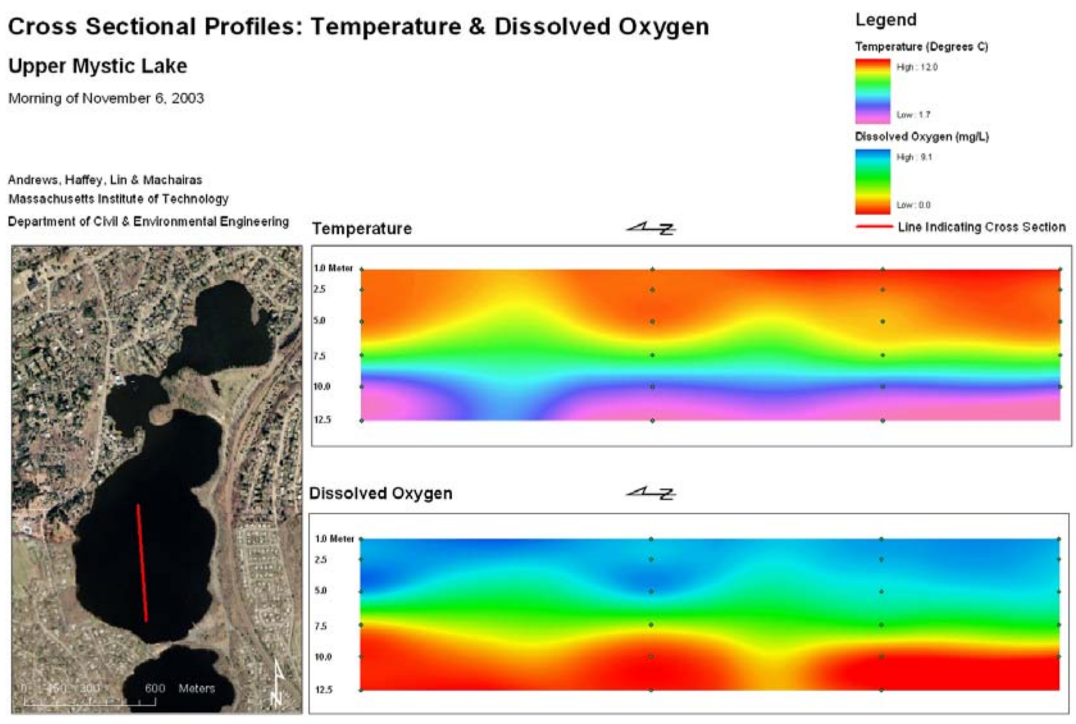

Figure 3: Cross Sectional Interpolation

Viewing the Data in 3D Using ArcGIS

Our original intensions were to create a 3D interpolation of the Temperature and the Dissolved Oxygen field in Upper Mystic Lake. Unfortunately ArcMap does not support this kind of interpolations. Because our data were collected in a 3D spatial grid it is very interesting to produce 3D maps of the sampling points and the relevant values. This was done in ArcScene and the following figures have been produced.

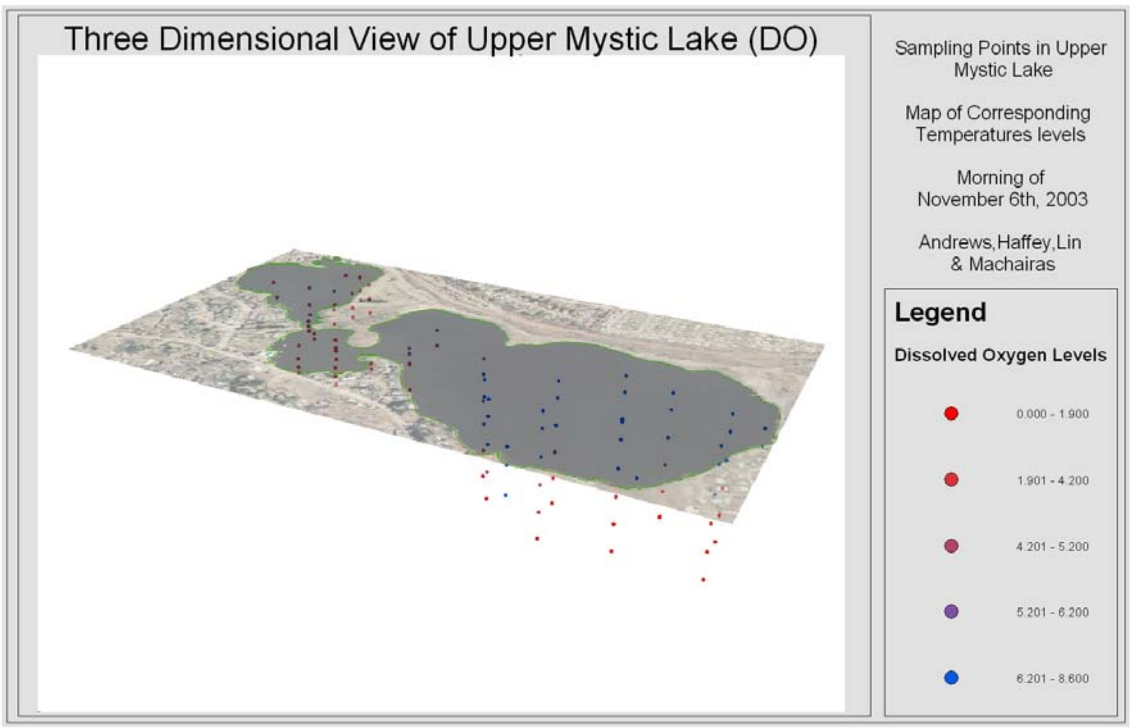

Figure 4: 3D View of Upper Mystic Lake, Sampling Points and DO levels

It has to be mentioned that figures 4,5 are maps containing pictures since that is the only form that ArcScene can export data.

In addition we fully used ArcScene's unique ability of creating 3D animations. We produced several short 3D animations that give a interesting insight in the region of study and show some of the spatial patterns that we identified in Upper Mystic Lake. During the presentation one of the animations, the most interesting we think, will be projected in the classroom. Regrettably, we were not able to export the animation to a video file because there is some problem with the software. Instead we will project the animation through ArcScene.

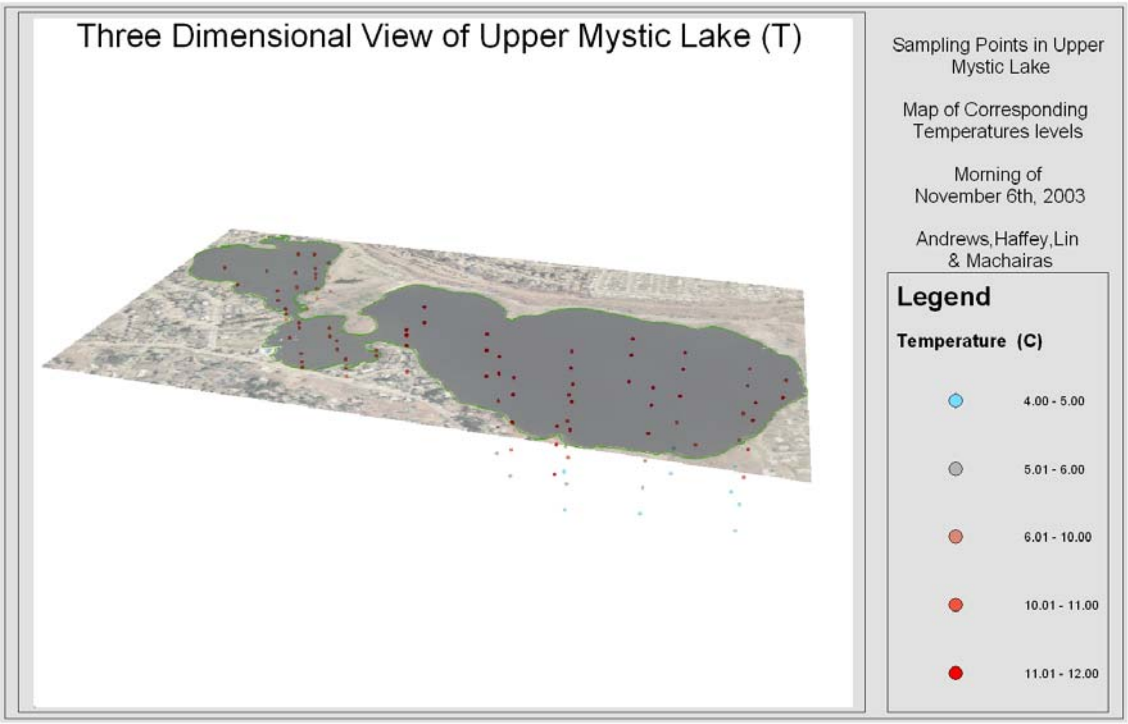

Figure 5: 3D View of Upper Mystic Lake, Sampling Points and Temperature levels

<u>Analysis of the Data</u>

So how do the DO and temperature of the Upper Mystic Lake and adjacent lakes change with latitude, longitude, and depth? First, we examine the differences between the adjacent lakes with the Upper Mystic Lake, using the 1-meter data in figure 2. The temperatures in the adjacent lakes are less than the Upper Mystic Lake. The most likely explanation would be the changes in the weather. In late October 2003, the temperature had increasingly been dropping. In fact, the mean temperature at the Winchester /Arlington, MA area for October 30, 2003 was 11 °C. Thus, the shallower adjacent lakes change more readily to the weather, while the Upper Mystic Lake responds more slowly to the decrease in temperature because of its large volume. Another reason for the temperature difference may be to wind exposure. Although this cannot be confirmed, the average wind speed in the upper adjacent lakes may be higher than the average wind speed in the Upper Mystic Lake.

The dissolved oxygen was also very different for the adjacent lakes compared to the Upper Mystic Lake. The most likely reason for this phenomenon also comes from the shallow depths. The bottom sediment of the lakes is a significant source of biological oxygen demand (BOD). The atmosphere provides the oxygen by reaerating the lakes. In equilibrium, without any BOD, the normal DO concentration in a lake is ~8-9 mg/L. But, for the shallower waters, the consumption of oxygen by the bottom sediment lowers the DO concentration. As the water travels closer to the Upper Mystic Lake, the concentration continues to decrease. This makes sense as long as the consumption rate of oxygen by the bottom sediment was larger the reaeration rate.

For the Upper Mystic Lake, the DO at the 1-m depth seems to be in equilibrium with the atmosphere. This was true because a thermocline seems to exist in the bottom of the lake. By looking at the other depths for DO and temperature, the thermocline was present around 7.5 to 10 meters. This was easily observed due to significant drops in DO (changing from ~4.0 mg/L @ 7.5 meters to ~0.2 mg/L @ 10 meters) and temperature (changing from ~10 °C @ 7.5 meters to ~5.5 °C @ 10 meters). See figure 1 and 2 for more details. If an ideal thermocline existed, the DO @ 7.5 meters would be close to equilibrium. But, since the weather was getting progressively colder, a small amount of mixing may be occurring between the two layers in the lake.

Conclusions

Our group has learned quite a bit of information about the Upper Mystic Lake, the adjacent lakes to the north, and the ArcMap software. Through the maps created, our data definitely indicates that a thermocline exists in the Upper Mystic Lake. Future users of these maps must be aware of how many data points were taken, the uncertainty of the accuracy of the data, and the uncertainty in the interpolation methods.