Spring 5-8-2017

Coal-Based Power Plants and the Health of the Ohio River

Shelby L. Hesler
Eastern Kentucky University, shelby_hesler1@mymail.eku.edu

Coal-Based Power Plants and the Health of the Ohio River

Shelby Hesler
Eastern Kentucky University
HON 420
Dr. Sherry Harrel
5/8/2017

Abstract

This study was conducted to determine if there is a relationship between the health of the Ohio River and coal based power plants. This was determined using several probes to test for conductivity (µs/cm), pH, salinity (ppt), water temperature (°C), and dissolved oxygen (mg/l and percentage). Testing took place along a 30.4 mile stretch of the Ohio River. The four testing locations included Manchester, OH; Dayton Power and Light Stuart generating station; Maysville, KY; and Augusta, KY.

The Ohio River was chosen as the focus of this study due to the high pollution rate of the river. An article from USA Today which covered the Environmental Protection Agency's Toxic Release Inventory listed the Ohio River as the most polluted river in the United States with more than twice the amount of pollution of the second most polluted river, the Mississippi River (usatoday.com, 2015). The coal-power plants were chosen specifically to test for the possible correlation due to the colloquial association with coal-based power plants and high areas of pollution.

1. Introduction

In the continental United States, there are estimated to be over 250,000 rivers stretching a combined 3,500,000 miles across the landscape (enchantedlearning.com, 2002). The largest of these is the Missouri River with a length of 2,540 miles (water.usgs.gov, 2016) Coming in a lowly 9th place is the Ohio River at 1,310 miles (pubs.usgs.gov, 2005). The Ohio River is neither the largest river nor the river with the highest amount of water discharge, but this ever-important body of water borders six states and stretches straight through the heart of American industry while simultaneously providing the water supply for an estimated five million people (orsanco.org, 2017).

USA Today declared the Ohio River to be the most polluted river in the United States in 2015 based on the data provided by the Environmental Protection Agency's Toxic Release Inventory (usatoday.com, 2015). The Environmental Protection Agency's Toxic Release Inventory is an inventory that tracks the amount of discharge facilities release into the nation's waterways (epa.gov, 2017). These facilities include operations such as factories, mining, power plants, etc.

At the time of the article's release the Toxic Release Inventory was based on the most recent year's compiled data, 2013. At that time, the Ohio River topped the nation's waterway for polluted discharge with 24,180,820 pounds. The river to rank second in polluted discharge was the 2,340-mile-long Mississippi River (water.usgs.gov, 2016) which had roughly half the amount of discharge into the river compared to that of the Ohio River. Of course, both of these rivers are vast bodies of water, leading the Environmental Protection Agency and the Ohio River Valley Water Sanitation Commission to claim dilution of these discharges prevents them from making large environmental impacts. The Ohio River and its health could always improve but for now the Ohio River is within the Environmental Protection Agency's and other environmental and water health guidelines.

The disparity in the effects of what is released is another issue many bring forward when discussing the health of the Ohio River. In 2013, the most common chemical compound to be discharged into the Ohio River was nitrates (usatoday.com, 2015). The Environmental Protection Agency regulates 10 mg/L as the standard for maximum contamination level when dealing with nitrate-nitrogen (water-resesarch.net, 2014). If nitrogen begins to exceed this level the excess amounts of nitrogen can lead to the overstimulation of aquatic plants and algae. High levels of these plants and algae in or on the water can result in the clogging of water intakes, reduction or depletion of available dissolved oxygen, and the blocking of light from reaching deeper sections of the water (water.usgs.gov, 2017).

Often in moving waterways such as the Ohio River nitrogen does not build up along the entirety of the river but rather begins to pool in pockets or short sections of the river (water.usgs.gov, 2017), In 2015 the Kentucky Division of Water released a statement warning of an overstimulated growth of harmful algal blooms most likely caused by either phosphorus or nitrogen in the water of the Ohio River. The blue-green algae at that time was not found in the water being used by residents of the area, but rather the warning was put into place for recreational uses of the Ohio River from Ashland, KY to Maysville, KY such as boating, swimming, fishing, etc. (kydep.wordpress.com, 2015).

The chemical causing the most concern for the Ohio River and its users is not the common nitrate compounds in the water, but rather the release of mercury. Mercury is long lasting in the environment and will continue to build up along the food web from the water itself to fish, to birds, and even to humans. Mercury release was ranked 48th in 2013 but at that time its discharge had increased five hundred percent from 2007 to 2013 (reported 61 pounds to 380 pounds) (usatoday.com, 2015).

According to the Environmental Protection Agency the largest emissions of mercury into the atmosphere itself, not simply waterways, are coal fired power plants. The main source of mercury accumulation in waterways is through atmospheric deposition such as rain, snow, etc. (water.usgs.gov, 2014). This buildup of mercury in the atmospheric deposition is due to the molecules of mercury present in the atmosphere which are brought down to the surface with the individual drops or flakes. Aerial pollutants are also an important part of this study as the core city in the testing zones, Maysville, Kentucky, is listed as the number eight city in the country for the most polluted air by year-round particle pollution by a study completed by the American Lung Association (stateoftheair.org, 2015)

This deposit of aerial pollutants onto the surface by rain occurs due to the nature from which raindrops, or other forms of precipitation, are formed. The atmosphere at any given moment is made up of anywhere from zero to four percent water vapor depending upon location and when testing occurs (climate.ncsu.edu, 2013). Some of this water vapor in the atmosphere will eventually find other particles in the air to cling onto as water vapor alone is too small for them to combine on their own (srh.noaa.gov, 2016). These particles in the air that allow for water vapor to cling to something are called condensation nuclei. Condensation nuclei can be anything from soil particles to manmade silver iodide, theoretically condensation nuclei can be made up of virtually anything as long as it has enough surface area to allow for water vapor to cling. As water vapor begins clinging to these condensation nuclei the vapor slowly becomes larger and larger until different condensation nuclei begin bouncing together to form even larger. After thousands upon thousands of these condensation nuclei and the water vapor they carry have bounced together enough they will eventually form a raindrop which will be dragged down to the surface through gravity. While these condensation nuclei and water vapor molecules are bouncing together they are also picking up traces of other compounds such as the aerated mercury which it will bring with it as these newly formed drops fall to Earth (Yow, 2017). Essentially this process is like rolling a snowball down a hill. As the snowball rolls it will grow larger with more snow being added but it will also pick up other things along the way. The snow ball may start as only snow but by the base of the hill it may be snow, leaves, rocks, and any other substance in its path light enough for the snowball to pick up.

Whether it be nitrogen compounds, mercury, or some other source there is no denying the Ohio River is far from the healthiest body of water due to these discharges. One of the most common sources blamed for the state of the health of the Ohio River is the fifty-eight power plants dotted along the length of the Ohio River. Of these fifty-eight power plants the majority, twenty-nine total, are coal-based (eia.gov, 2016). The Environmental Protection Agency's Toxic Release Inventory lists electric utilities as responsible for thirteen percent of the total disposals in the country, putting this industry in third behind metal mining at thirty-seven percent and chemicals at fifteen percent of the total disposals (epa.gov, 2017). For the Ohio River, specifically, as mentioned before, the most common and potentially influential of these electric utilities are the coal-based power plants which is the focus of this study.

This study was conducted based at two specific coal- based power plants that lie along the shores of the Ohio River. These power plants include Eastern Kentucky Power and Dayton Power and Light. In 2010, Eastern Kentucky Power at its Spurlock generating station in Maysville, Kentucky produced a reported 9,071,650 megawatts of electricity (sourcewatch.com, 2016). In the same year, 2010, Dayton Power and Light at its Stuart generating station in

Aberdeen, Ohio produced a reported 13,460,500 megawatts of electricity. To put this into perspective a survey done by the United States Energy Information Administration found that the average home in the United States used 901 kilowatts of electricity (eia.gov, 2016). A survey conducted by the United States Census Bureau determined there were 1,957,037 housing units in the state of Kentucky (census.gov, 2015). Theoretically, Eastern Kentucky Power would be a capable of powering all of the homes in the state of Kentucky for roughly nine months. Dayton Power and Light could theoretically power all of the homes in the state of Kentucky for over a year.

The specific variables measured in this study included pH, water temperature (°C), conductivity (µs/cm), dissolved oxygen (mg/l and percent saturation), and salinity (ppt). The first of my six testing variables was pH. pH is a measure of how acidic or basic something is. The ideal pH for distilled water is 7.0, but for a "live" water source such as a river the ideal pH is 7.4 (nasa.gov, 2007). The Environmental Protection Agency allows for surface water to be recorded between 6.0 and 9.0 (EPA, 2014). An important thing to remember when testing something like pH are those natural buffers in the environment. Natural buffers are things such as rocks that innately slow large fluctuations of pH due to their own chemical composition. One such example of this is limestone (butane.chem.uiuc.edu, 2011). The floor of the Ohio River is made up of limestone (Feldmann & Hackathorn, 1996). This means it is possible any large fluctuations in pH of the Ohio River by either the power plants or another source could be abated by the natural buffering capabilities of the limestone that line the Ohio River.

For water temperature, the maximum instantaneous water temperature allowed by the Environmental Protection Agency varies from month to month to accommodate for natural changes in temperature due to seasonality temperature changes (EPA, 2014).

Percent Dissolved oxygen, however, is a measure of how much oxygen is available in the water for use by the various organisms that may live in the water. Essentially this is a measure of the free oxygen available in the water. Free oxygen is the oxygen molecules dissolved in the water that are not bonded to another element. These molecules dissolve in much the same way salt does and can be considered one of the most essential factors about water. Without enough free oxygen or with too much free oxygen life in the water will begin to suffer and potentially die off (fondriest.com, 2016).

Percent dissolved oxygen specifically is not measured in simply the amount available but rather it is a proportional measure. Percent dissolved oxygen is calculated by taking the amount of dissolved oxygen available relative to what could be available in that given temperature of water (waterontheweb.org, 2017). As water temperature decreases, the amount of free oxygen it can hold increases (Maine Volunteer Lake Monitoring Program, 2017). Thus, temperature and free oxygen have an inverse relationship with one another and is one limitation of comparing oxygen over several months with changing seasons and subsequent air and water temperatures.

Dissolved oxygen in mg/l is very similar to that of percent dissolved oxygen in that it measures the amount of available oxygen in the water. The Environmental Protection Agency ensures that a concentration of 5.0 mg/l must be maintained in the water at a minimum to ensure the continuation of life in the water source (EPA, 2014).

Conductivity is a measure of the ability for water to conduct electricity. While all water is a conductor, some water is able to conduct more electricity more efficiently. This is essentially a measure of the available ions in the water. These ions come from dissolved salts and other inorganic marital such as chlorides and sulfides. At its base this is a measure of the ability for water to conduct electricity based on how salty the water is (fondriest.com, 2016). While most streams range between 50 µs/cm and 1500 µS/cm, but ideally freshwater would rest between 150 µs/cm and 500 µs/cm to best support a diverse ecosystem (Behar, 1997).

Salinity is a direct measure of the salts dissolved in water. Freshwater should be at 5.0 ppt or less (omp.gso.uri.edu, 2001). Many things can affect the salinity of water including things such as the environment or rock type, the weathering of rocks (Australian Government, 2012), as well as pollutants (sceience.nasa.gov, 2017).

2. Methods

The data for this study was collected using three probes capable of measuring water temperature, dissolved oxygen (YSI Instruments, Yellow Springs, OH), pH, salinity, and conductivity (Pulse Instruments, Camarilla, CA). Each probe was immersed into the water at each of the four testing sites to collect data three times in order to achieve an average reading. Testing commenced on a four-week interval beginning from August 2016 until January 2017.

Each probe was left in the water until the readings settled out on one number. There was no set time for this as different locations and different days took varied amounts of time to settle. Once the readings were settled out the number was recorded and the probe was pulled from the water. Between each of the three tests the probes were rinsed off with clean, filtered water to remove any leftover Ohio River water before the water was tested once again.

Testing was along a 30.4 mile stretch of the Ohio River between Manchester, OH and Augusta, KY which encompasses two coal-based power plants, Dayton Power and Light and Eastern Kentucky Power. The four sites were chosen to test the water upstream of the first power plant (Manchester, OH), the water discharge at Dayton Power and Light itself, between the two power plants (Maysville, KY), and downstream of both of the power plants (Augusta, KY) to discern if there was a noticeable difference in any readings from one site to another.

The specific testing locations were based on the location of the public docks in each city (figure 1). Dayton Power and Light had a section at the discharge open to the public as free public fishing location so testing at this location commenced as close to the actual discharge as was capable. Testing was not available at Eastern Kentucky Power due to a lack of a location to reach this facility’s water discharge without trespassing on private property.

Testing at each of the locations followed one of two alternating patterns in an attempt to negate any effects time of day may have on collection. Testing began as close to 8 AM on the Friday of the testing week as was possible. The patterns were either Augusta, KY; Maysville, KY; Dayton Power and Light; and finally, Manchester, OH or testing began in Manchester, and continued to Dayton Power and Light, Maysville, and finished in Augusta.

3.Results

I. pH

The lowest individual pH recorded during the study was 8.03 in Augusta in November (table 4) while the highest was also in Augusta at 8.80 in August (table 1). The range of pH is 0.77.

Each individual month other than August and October has a general downward trend. The two outlier months continue with the monthly trend until the Maysville testing sight when the pH increases my many points and for August continues to increase and October sees a slight decrease (figure 2).

For the six month average the general trend becomes more apparent with a sharp decrease between Manchester and the Dayton Power and Light discharge (figure 3). A slight increase between Dayton Power and Light followed by a minute decrease into Augusta. The other power plant is between Maysville and Augusta but with no testing available at the site there is no way to directly correlate data between the two power plants. Without the shown Dayton Power and Light data pH would almost be at a constant downward trend.

II. Water Temperature

All testing locations fall under the Environmental Protection Agency's prescribed monthly maximum except for Dayton Power and Light. Each month Dayton Power and Light was a minimum of 3.37°C above the allowed maximum (figure 4). The largest overture was in August at 15.17°C over (table 1) (32°C allowed by the Environmental Protection Agency and the 47.17°C recorded). In each recorded month, the temperature of the water decreased by a minimum of 7.3°C, recorded in December (table 5 and figure 5), between the discharge and the next testing location in Maysville.

The entirety of the testing locations saw an overall stable temperature other than the hot water at the Dayton Power and Light discharge (figure 6). There was very little variation between Manchester, Maysville, and Augusta. The largest change in a single month between these three locations was 2.8°C in August (table 1).

III. Percent Dissolved Oxygen

My data followed a general downward trend (figure 8) except for an increase at Dayton Power and Light as well as two outlier months, December and January (tables 5 and 6 and figure

7). The readings between the Ohio River water at Manchester and the discharge at Dayton Power and Light remained consistently at an increase between the two test zones with an average increase of 14.73%. The biggest change across the river (excluding Dayton Power and Light data) was simply from Manchester to the final testing site of Augusta (figure 8). Except for the outlier months of December and January, the readings straight from the Ohio River, remained a downward trend. The average decrease from Manchester to Augusta was 56.71% even while calculating in the outlier months.

IV. Dissolved Oxygen (mg/l)

The overall average recorded dissolved oxygen for all locations across the six-month time period was a 5.89 mg/l (figure 10). The single largest recorded air saturation was in Maysville and was recorded at 17.99 mg/l in January (table 6). The single smallest air saturation recorded was in Augusta at 0.48 in August (table 1).

The overall six-month average shows a general downward trend of available oxygen (figure 10). Each location decreases slightly from that of the location before it. However, Augusta saw an average decrease by 2.51 mg/l while other locations only saw a change of roughly 1.0 mg/l (figure 9). The recordings in Augusta also dropped below the Environmental Protection Agency required minimum of 5.0 mg/l in three of the six testing months (figure 11). In Augusta in August the dissolved oxygen was recorded at 0.48 mg/l (table 1), in September 4.31 mg/l (table 2), and in November 1.48 mg/l (table 4). This equates to an average deficit of the approved Environmental Protection Agency minimum by 2.51 mg/l.

V. Conductivity

During my study the conductivity was fairly consistent each month except for the outlier of August (table 1 and figure 12). Other than the sharp decline in August the general trend was a sharp increase from Manchester to Dayton Power and Light followed by a sharp decrease to Maysville and then another slight decrease in Augusta (figure 13). The sharp increase between Manchester and Dayton Power and Light was an average increase of only 13.56 µs/cm.

All testing sites remained within the stream range of 50 µs/cm to1500 µs/cm. However, a few were recorded above the ideal freshwater conductivity range of 150 µs/cm to 500 µs/cm. The six-month average for my testing data reads that all locations were within range however during October and November Augusta read slightly above the ideal conductivity level and Dayton Power and light also read above level in October. Neither breach of the ideal level was very large. In October Dayton Power and Light overpassed 500 µs/cm by 5.33µs/cm and Augusta exceeded by 31µs/cm (table 3). In November Augusta exceeded the upper limit by six µs/cm (table 4).

VI. Salinity

My data shows the salinity of my testing zones as low but well within accepted measures. Most months remained at a consistent 0.2 ppt except for October, November, and January (figure 14). In October, the readings in Augusta went up 0.1 ppt to a reading of 0.3 ppt (table 3). In November, Maysville dropped to a reading of 0.17 ppt (table 4). And finally, in January, the readings in Maysville fluctuated again and dropped to 0.1 ppt (table 6). The general trend for the six testing months remains steady at 0.2 ppt through Manchester and Dayton Power and Light but does show those shifts in Maysville, a small drop in average salinity, and again in Augusta, with a slight increase (figure 15). In general, there was very little variation in the salinity of all four locations and all remained below that maximum of 5.0 ppt.

4. Discussion

The goal of this study was not to find a causation relationship between the health of the Ohio River and the coal based power plants that dot its shoreline. Rather the goal was to look into a possible correlation between locations of the power plants and shifts in the testing data of the subsequent testing locations. From this premise, it is important to look at testing locations and their data not only as one general trend but also to break the locations into their correlation with the power plants. Manchester almost acts as the control, this is what the river is at before any water has come into direct contact with anything coming directly from the power plants. Maysville works as the half way point and a way to look at possible changes resulting from only one power plant rather than both. And finally, Augusta is the cumulation of any and all possible effects the power plants could have on the Ohio River.

The testing variables were chosen, much like the locations, to test effects of any changes in the health of the river rather than testing for any one specific pollutant. For example, by testing for temperature I was able to see that the water coming directly from Dayton Power and Light is at an average of roughly 12°C warmer than that of the Ohio River. While it is important to note that the discharge of Dayton Power and Light is not deposited directly into the Ohio River but rather into a short creek that merges with the Ohio River, this kind of temperature difference is something still important to note.

Water at this temperature is going to have an effect on the fish population and in particular their movements. In the summer the water is too hot for fish to bread in but in the winter this bubble of warm water could potentially draw fish in (Agersborg, 1930) where they could potentially be trapped. These temperature readings are only one of the many factors I tested for yet still they are something of importance to note and a prime example of possible evidence for that correlation.

Another factor that potentially shows evidence for correlation is dissolved oxygen. The average general trend of available dissolved oxygen is decidedly at a decline as you move down the Ohio River from Manchester toward Augusta. However, it is not just the downward trend that speaks to possible evidence of correlation it is also those specific readings.

From Manchester to Augusta the readings fall from an Environmental Protection Agency accepted dissolved oxygen minimum to instead fall far below dissolved oxygen readings to support life. At 0.48 mg/l in August, Augusta is below even those life forms that need very minimal free oxygen such as the bottom feeders, crabs, oysters, and worms (fondriest.com, 2016). Fish typically need dissolved oxygen readings to be at that Environmental Protection Agency instantaneous minimum of five mg/l to really support life (fws.gov, 2015). This means that in August, September, and November my data shows that the Augusta area of the Ohio River could lose its ability to support life. Any readings below two mg/l have the potential to be absolutely too low to support fish and possibly even aquatic plants causing any populations in that area to essentially begin to suffocate (fws.gov, 2015).

Augusta is only one of many locations downstream from not only the power plants but also many other power locations, factories, mining, farming, and many other untold operations. The fact of the matter still remains that the difference in readings between Manchester and Augusta a mere 30.4 miles downriver suggest the source of these fluctuations can be found within that 30.4-mile range.

I. Limitations

Most of the limitations for this study steam from either financial limitations or weather effects. For example, weather can affect my readings from a multitude of sources including general solar heating, storms/rain, and even wind.

Solar heating can affect readings due to the heating effect it would have on the water. The probes I was working with did not have cords long enough to go deep enough into the water to negate any chance of solar heating having a noticeable effect. Solar heating can affect the temperature of the water at my testing locations (in the sun compared to in the shade) and also the readings of some of my variables which are affected by temperature such as dissolved oxygen.

Storms/rain can affect readings due to the innate power of rain to wash different pollutants into the river. For example, if one reading was taken during a drought and another taken directly after a storm it is always possible that the second reading is more varied due to those newly introduced pollutants. While this kind of introduction system is standard with a live water source such as the Ohio River, this is still something that can skew results when you are comparing one testing time to another rather than only comparing testing to the regulations set forth by government agencies or the needs of life in the water.

Wind is one of the most unpredictable of weather factors to affect my testing. Wind can not only lower the surface temperatures of the water by increasing the amount of mixing between the river and the colder atmosphere but it can also increase dissolved oxygen readings when the water itself may not actually be at that level. In my testing, I had unprecedented dissolved oxygen readings in December and January. The wind causes that increased mixing of the Ohio

River water and the atmosphere around it. This increased mixing can cause more oxygen to be dissolved into the water and increase the dissolved oxygen readings for the short amount of time the wind is blowing only to have readings drop once the wind settles back out once again. There is no way to prevent these spikes in dissolved oxygen due to the wind. Even if the specific area I am testing I am able to block from the wind, the water flowing into that “protected zone” will still have encountered that mixing upstream.

Weather is undoubtedly a limitation of my study because it is one such force I have zero control over. In the interest of keeping my testing times consistent I must test no matter the weather conditions. Which essentially means if it is sunny or the wind is blowing at record speeds I still had to test and there is no way to negate the possible effects from these conditions.

The other main limitation during my study was funding. All of my testing was conducted for those specific variables that can be affected by different pollutants that are mixed into the water of the Ohio River. In a perfect world, I would have been able to test not only those variables but also tested for specific pollutants in the river. By testing for specific pollutants, I would have been able to further narrow down possibly pollutant source from the non-point source I am currently working with to possibly only a few factors. For example, if there were one chemical introduced into environment for both Dayton Power and Light and Eastern Kentucky Power in the highest amounts and that specific chemical was prevalent in the two testing locations after the plants it is possible it could further point to these variations being formed due to the power plants rather than any other operation.

5. Conclusion

As stated previously, the purpose of this study was not to find causation between the power plants and the health of the Ohio River, but rather to discern if there is a possible correlation. While none of the data is one hundred percent conclusive to there being a strong correlation there is enough data to suggest the potential for correlation.

Finding causation would be ideal to pinpoint not only the power plants but also whether Eastern Kentucky Power or Dayton Power and Light were unequally affecting the Ohio River. The potentially for correlation found in this study is not enough to bring any one group up on pollution charges or to be of concern to the general public but rather it raises more questions and spurs the need for further testing. No water source in today's times is untouched my human impact and perfectly balanced to where it would be in an ideal situation. But no water source should also be churning out dissolved oxygen levels as low as 0.48 mg/l. With further testing by trained professionals with better equipment it is possible they could uncover even more problems than what I came across, or it is entirely possible they find very little to be wrong with Ohio River at all.

No testing is perfect, but the data presented here is still enough for me to comfortably suggest the possibility for correlation but also to urge for further water examinations. The Ohio River after all is the water source for five million people, and a source of recreation for potentially millions as well. This is not just any water source, this is one of the largest and most influential rivers in the country. Not everyone is going to be touched by the Ohio River directly, but everyone in the country will feel the effects of coal-based power plants on waterways like the Ohio River.

Literature Cited

Agersborg, H.P.K. (1930). The influence of temperature on fish. *Ecological Society of America*. Retrieved from https://www.jstor.org/stable/1930786?seq=1#page_scan_tab_contents.

American Lung Association. (2015). Most polluted cities. Retrieved from http://www.stateoftheair.org/2015/city-rankings/most-polluted-cities.html?referrer=http://www.biologicaldiversity.org/news/press_releases/2016/alon-refinery-04-13-2016.html?referrer=http://www.stateoftheair.org/2015/city-rankings/most-polluted-cities.html.

Australian Government. (2012). Salinity and water quality. Retrieved from https://www.environment.gov.au/system/files/resources/a3d7a0ec-249a-498b-a46c-0a24663a957d/files/salinity-and-water-quality-fs.pdf.

Behar, S. (1997). Testing the waters: chemical and physical vital signs of a river. Retrieved from http://fosc.org/WQData/WQParameters.htm.

Bruggers, J. (2015). Ohio river again tops list for industrial pollution. *USA Today*. Retrieved form https://www.usatoday.com/story/news/nation/2015/03/14/ohio-river-tops-list-industrial-pollution/24784863/.

Enchantedlearnering.com. (2016). US rivers. Retrieved from http://www.enchantedlearning.com/usa/rivers/.

Feldmann, R. M. and Hackathorn, M. (1996). Ohio division of geological survey bulletin 70. Retrieved from http://geosurvey.ohiodnr.gov/portals/geosurvey/PDFs/Misc_State_Maps&Pubs/OH_SurfaceRocks_Sediments.pdf.

Fundamentals of Environmental Measurements. (2016). Conductivity, salinity & total dissolved solids. Retrieved from http://www.fondriest.com/environmental-measurements/parameters/water-quality/conductivity-salinity-tds/#cond22.

Fundamentals of Environmental Measurements. (2016). Dissolved Oxygen. Retrieved from http://www.fondriest.com/environmental-measurements/parameters/water-quality/dissolved-oxygen/#11.

Google. (2017). Google maps. Retrieved from https://www.google.com/maps/place/Ohio/@38.7141516,-83.804048,21965m/data=!3m1!1e3!4m5!3m4!1s0x8836e97ab54d8ec1:0xe5cd64399c9fd916!8m2!3d40.4172871!4d-82.907123?hl=en.

Kentucky Department of Environmental Protection. (2015). Harmful algal bloom recreation advisory issued for Ohio river, tributaries. Retrieved from https://kydep.wordpress.com/2015/09/04/harmful-algal-bloom-recreation-advisory-issued-for-ohio-river-tributaries/.

Maine Volunteer Lake Monitoring Program. (2017). Maximum dissolved oxygen concentration saturation table. Retrieved from http://www.mainevlmp.org/wp-content/uploads/2014/01/Maximum-Dissolved-Oxygen-Concentration-Saturation-Table.pdf.

National Aeronautics and Space Administration. (2017). Salinity. Retrieved from https://science.nasa.gov/earth-science/oceanography/physical-ocean/salinity.

National Aeronautics and Space Administration. (2007). Water Quality. Retrieved from https://www.grc.nasa.gov/WWW/k-12/fenlewis/Waterquality.html.

National Weather Service. 2016. All about the clouds. Retrieved from http://www.srh.noaa.gov/jetstream/clouds/cloudwise/learn.html.

North Carolina State University. (2013). Composition of the atmosphere. Retrieved from http://climate.ncsu.edu/edu/k12/.AtmComposition.

Ohio River Valley Water Sanitation Commission. (2017). River facts- river at a glance. Retrieved from http://www.orsanco.org/river-facts/.

Shapley, P. (2011). Limestone and acid rain. University of Illinois. Retrieved from http://butane.chem.uiuc.edu/pshapley/GenChem1/L26/3.html.

Source Watch. (2016). Spurlock power station. Retrieved from http://www.sourcewatch.org/index.php/Spurlock_Power_Station#Table_1:_Death_and_disease_attributable_to_fine_particle_pollution_from_the_Spurlock_Power_Station.

United States Census Bureau. (2015). Quick facts- kentucky. Retrieved from https://www.gov/quickfacts/table/HSG010215/21.

U.S. Department of the Interior. (2005). Largest rivers in the united states. Retrieved from https://pubs.usgs.gov/of/1987/ofr87-242/.

U.S. Department of the Interior. (2016). Lengths of the major rivers. Retrieved from https://water.usgs.gov/edu/riversofworld.html.

U.S. Department of the Interior. (2014). Mercury in aquatic ecosystems. Retrieved from https://water.usgs.gov/nawqa/mercury/MercuryFAQ.html.

U.S. Department of the Interior. (2017). Nitrogen and water. Retrieved form https://water.usgs.gov/edu/nitrogen.html.

U.S Energy Information Administration. (2016). How much electricity does an american home use? Retrieved from https://www.eia.gov/tools/faqs/faq.php?id=97&t=3.

U.S. Energy Information Administration. (2017). U.S. energy mapping system. Retrieved from https://www.eia.gov/state/maps.php.

United States Environmental Protection Agency. (2014). 401 KAR 10.031 surface water standards.

United States Environmental Protection Agency. (2017). Release of chemicals in the 2015 TRI national analysis. Retrieved from https://www.epa.gov/trinationalanalysis/releases-chemicals-2015-tri-national-analysis.

United States Environmental Protection Agency. (2001). Salinity. Retrieved from http://omp.gso.uri.edu/ompweb/doee/science/physical/chsal1.htm.

United States Environmental Protection Agency. (2017). Toxic release inventory (TRI) program. Retrieved from https://www.epa.gov/toxics-release-inventory-tri-program/learn-about-toxics-release-inventory.

U.S. Fish & Wildlife Service. (2015). Fit for a fish: dissolved oxygen. Retrieved from https://www.fws.gov/nc-es/edout/albefitfish2.html.

Water on the Web. (2017). Dissolved oxygen. Retrieved from http://www.waterontheweb.org/under/waterquality/oxygen.html.

Water Research Watershed Center. (2014). Nitrates and nitrites in drinking water and surface waters. Retrieved from http://www.water-research.net/index.php/nitrate.

Yow, D. (2017). Thunderstorms. [Class lecture]. Eastern Kentucky University: GEO 315.

Appendix A

Tables

Table 1

This is the collection data for August 2016. The locations follow the natural path of the water as it moves down the Ohio River. All data was collected using probes three times before it was averaged.

Testing Locations	Testing Variables	Test 1	Test 2	Test 3	Average
Manchester	pH	8.40	8.50	8.50	8.47
	Temp (°C)	29.40	29.30	29.60	29.43
	Dissolved Oxygen (Percent Saturation)	115.10	115.20	113.40	114.57
	Salinity (ppt)	0.20	0.20	0.20	0.20
	Dissolved Oxygen (mg/l)	8.88	8.89	8.70	8.82
	Conductivity (µs/cm)	449.10	448.70	449.40	449.07
DP&L	pH	8.20	8.20	8.20	8.20
	Temp (°C)	47.10	47.20	47.20	47.17
	Dissolved Oxygen (Percent Saturation)	132.60	127.30	128.00	129.30
	Salinity (ppt)	0.20	0.20	0.20	0.20
	Dissolved Oxygen (mg/l)	7.57	7.20	7.30	7.36
	Conductivity (µs/cm)	468.00	468.00	468.00	468.00
Maysville	pH	8.90	8.60	8.50	8.67
	Temp (°C)	30.00	30.10	30.20	30.10
	Dissolved Oxygen (Percent Saturation)	93.50	92.60	92.80	92.97
	Salinity (ppt)	0.20	0.20	0.20	0.20
	Dissolved Oxygen (mg/l)	7.08	7.07	7.09	7.08
	Conductivity (µs/cm)	458.00	456.00	452.30	455.43
Augusta	pH	9.00	8.80	8.80	8.87
	Temp (°C)	27.50	27.60	27.40	27.50
	Dissolved Oxygen (Percent Saturation)	10.40	6.20	43.40/49.90	27.48
	Salinity (ppt)	0.20	0.20	0.20	0.20
	Dissolved Oxygen (mg/l)	0.79	0.38	0.48	0.55
	Conductivity (µs/cm)	348.10	356.90	353.20	352.70

Table 2
This data was collected in September 2016. The locations follow the natural path of the water as it moves down the Ohio River. All data was collected using probes three times before it was averaged. The difference column is comparing table 2 average results to the previous month's results in table 1 to show an increase or decrease in readings.

Testing Locations	Testing Variables	Test 1	Test 2	Test 3	Average	Difference
Manchester	pH	8.80	8.70	8.60	8.70	+0.23
	Temp (°C)	27.60	27.60	27.60	27.60	-1.83
	Dissolved Oxygen (Percent Saturation)	121.40	121.50	120.50	121.13	+6.56
	Salinity (ppt)	0.20	0.20	0.20	0.20	±0.00
	Dissolved Oxygen (mg/l)	9.59	9.60	9.66	9.62	+0.80
	Conductivity (µs)	469.00	469.20	469.00	469.07	+20.00
DP&L	pH	8.50	8.40	8.30	8.40	+0.20
	Temp (°C)	38.20	38.10	38.20	38.17	-9.00
	Dissolved Oxygen (Percent Saturation)	137.20	132.10	130.60	133.30	+4.00
	Salinity (ppt)	0.20	0.20	0.20	0.20	±0.00
	Dissolved Oxygen (mg/l)	8.92	8.84	8.41	8.72	+1.36
	Conductivity (µs)	460.00	460.00	465.00	461.70	-6.30
Maysville	pH	8.30	8.30	8.20	8.27	-0.40
	Temp (°C)	28.40	28.60	28.50	28.50	-1.60
	Dissolved Oxygen (Percent Saturation)	86.80	86.30	86.30	86.47	-6.50
	Salinity (ppt)	0.20	0.20	0.20	0.20	±0.00
	Dissolved Oxygen (mg/l)	6.81	6.70	6.64	6.72	-0.36
	Conductivity (µs)	44.20	442.80	441.00	442.30	-13.13
Augusta	pH	8.20	8.20	8.20	8.20	-0.67
	Temp (°C)	28.60	27.90	28.60	28.37	+0.87
	Dissolved Oxygen (Percent Saturation)	54.80	52.30	58.80	55.30	+27.82
	Salinity (ppt)	0.20	0.20	0.20	0.20	±0.00
	Dissolved Oxygen (mg/l)	4.20	4.24	4.48	4.31	+3.76
	Conductivity (µs)	453.40	452.70	482.10	462.73	+110.03

Table 3
This data was collected in October 2016. The locations follow the natural path of the water as it moves down the Ohio River. All data was collected using probes three times before it was averaged. The difference column is comparing table 3 average results to the previous month's results in table 2 to show an increase or decrease in readings.

Testing Locations	Testing Variables	Test 1	Test 2	Test 3	Average	Difference
Manchester	pH	8.70	8.50	8.30	8.50	-0.20
	Temp (°C)	21.30	21.30	21.30	21.30	-6.30
	Dissolved Oxygen (Percent Saturation)	120.40	117.40	115.10	117.63	-3.50
	Salinity (ppt)	0.20	0.20	0.20	0.20	±0.00
	Dissolved Oxygen (mg/l)	10.83	10.37	10.26	10.49	+0.87
	Conductivity (µs/cm)	479.10	480.00	480.20	479.77	+10.70
DP&L	pH	8.20	8.10	8.10	8.13	-0.27
	Temp (°C)	38.90	38.60	39.00	38.83	+0.66
	Dissolved Oxygen (Percent Saturation)	135.90	133.70	132.20	133.93	+0.63
	Salinity (ppt)	0.20	0.20	0.20	0.20	±0.00
	Dissolved Oxygen (mg/l)	8.76	8.81	8.60	8.72	±0.00
	Conductivity (µs/cm)	505.00	505.00	506.00	505.33	43.63
Maysville	pH	9.20	8.60	8.50	8.77	+0.50
	Temp (°C)	22.30	22.40	22.60	22.43	-6.07
	Dissolved Oxygen (Percent Saturation)	105.40	98.80	99.10	101.10	+14.63
	Salinity (ppt)	0.20	0.20	0.20	0.20	±0.00
	Dissolved Oxygen (mg/l)	9.06	8.70	8.76	8.84	-2.12
	Conductivity (µs/cm)	502.00	479.00	506.00	495.67	+53.37
Augusta	pH	8.70	8.70	8.70	8.70	+0.50
	Temp (°C)	22.00	21.90	22.00	21.97	-6.40
	Dissolved Oxygen (Percent Saturation)	146.20	134.20	134.20	138.20	+82.90
	Salinity (ppt)	0.30	0.30	0.30	0.30	+0.10
	Dissolved Oxygen (mg/l)	12.56	12.03	11.80	12.13	+7.82
	Conductivity (µs/cm)	531.00	531.00	531.00	531.00	+68.27

Table 4
This data was collected in November 2016. The locations follow the natural path of the water as it moves down the Ohio River. All data was collected using probes three times before it was averaged. The difference column is comparing table 4 average results to the previous month's results in table 3 to show an increase or decrease in readings.

Testing Locations	Testing Variables	Test 1	Test 2	Test 3	Average	Difference
Manchester	pH	8.40	8.40	8.40	8.40	-0.10
	Temp (°C)	17.10	17.20	17.20	17.17	-4.13
	Dissolved Oxygen (Percent Saturation)	107.30	103.50	101.60	104.13	-13.50
	Salinity (ppt)	0.10	0.20	0.20	0.17	-0.03
	Dissolved Oxygen (mg/l)	10.31	10.35	10.04	10.23	-0.26
	Conductivity (µs/cm)	439.33	454.40	475.80	456.51	-23.26
DP&L	pH	8.10	8.10	8.10	8.10	-0.03
	Temp (°C)	25.70	25.70	25.70	25.70	-13.13
	Dissolved Oxygen (Percent Saturation)	137.20	134.80	137.40	136.47	+2.54
	Salinity (ppt)	0.20	0.20	0.20	0.20	±0.00
	Dissolved Oxygen (mg/l)	11.23	10.94	11.23	11.13	2.41
	Conductivity (µs/cm)	492.00	492.00	492.00	492.00	-13.33
Maysville	pH	8.30	8.20	8.10	8.20	-0.57
	Temp (°C)	17.60	17.60	17.60	17.60	-4.83
	Dissolved Oxygen (Percent Saturation)	102.60	93.30	104.20	100.03	-1.07
	Salinity (ppt)	0.20	0.20	0.20	0.20	±0.00
	Dissolved Oxygen (mg/l)	9.70	9.63	9.87	9.73	+0.89
	Conductivity (µs/cm)	491.40	491.30	490.80	491.17	-4.50
Augusta	pH	8.00	8.00	8.10	8.03	-0.67
	Temp (°C)	17.40	17.50	17.50	17.47	-4.50
	Dissolved Oxygen (Percent Saturation)	2.30	1.90	65.60	23.27	-114.93
	Salinity (ppt)	0.20	0.20	0.20	0.20	-0.10
	Dissolved Oxygen (mg/l)	0.24	0.17	4.03	1.48	-10.65
	Conductivity (µs/cm)	505.00	507.00	506.00	506.00	-25.00

Table 5
This data was collected in December 2016. The locations follow the natural path of the water as it moves down the Ohio River. All data was collected using probes three times before it was averaged. The difference column is comparing table 5 average results to the previous month's results in table 4 to show an increase or decrease in readings.

Testing Locations	Testing Variables	Test 1	Test 2	Test 3	Average	Difference
Manchester	pH	8.50	8.30	8.30	8.37	-0.03
	Temp (°C)	9.70	9.70	9.70	9.70	-7.47
	Dissolved Oxygen (Percent Saturation)	118.70	116.10	115.30	116.70	+12.57
	Salinity (ppt)	0.20	0.20	0.20	0.20	+0.03
	Dissolved Oxygen (mg/l)	13.45	13.10	13.26	13.27	+3.04
	Conductivity (µs/cm)	380.00	380.70	377.20	379.30	-77.21
DP&L	pH	8.80	8.30	8.40	8.50	+0.40
	Temp (°C)	17.30	17.40	17.40	17.37	-8.33
	Dissolved Oxygen (Percent Saturation)	146.10	147.40	145.00	146.17	+9.70
	Salinity (ppt)	0.20	0.20	0.20	0.20	±0.00
	Dissolved Oxygen (mg/l)	14.14	14.08	14.48	14.23	+3.10
	Conductivity (µs/cm)	382.80	383.40	382.80	383.00	-109.00
Maysville	pH	8.60	8.40	8.20	8.40	+0.20
	Temp (°C)	10.00	10.10	10.10	10.07	-7.53
	Dissolved Oxygen (Percent Saturation)	13.40	110.50	71.50	65.13	-34.90
	Salinity (ppt)	0.20	0.20	0.20	0.20	±0.00
	Dissolved Oxygen (mg/l)	1.80	12.36	5.64	6.60	-3.13
	Conductivity (µs/cm)	368.40	369.80	362.30	366.83	-124.34
Augusta	pH	8.30	8.40	8.30	8.33	+0.30
	Temp (°C)	10.20	10.30	10.20	10.23	-7.24
	Dissolved Oxygen (Percent Saturation)	119.20	118.50	117.90	118.53	+95.26
	Salinity (ppt)	0.20	0.20	0.20	0.20	±0.00
	Dissolved Oxygen (mg/l)	13.39	13.38	13.21	13.33	+11.85
	Conductivity (µs/cm)	373.60	377.20	377.00	375.93	-130.07

Table 6
This data was collected in January 2017. The locations follow the natural path of the water as it moves down the Ohio River. All data was collected using probes three times before it was averaged. The difference column is comparing table 6 average results to the previous month's results in table 5 to show an increase or decrease in readings.

Testing Locations	Testing Variables	Test 1	Test 2	Test 3	Average	Difference
Manchester	pH	8.70	8.50	8.40	8.53	+0.16
	Temp (°C)	4.70	4.90	4.80	4.80	-4.90
	Dissolved Oxygen (Percent Saturation)	114.80	138.10	139.50	130.8	+14.10
	Salinity (ppt)	0.20	0.20	0.20	0.20	±0.00
	Dissolved Oxygen (mg/l)	18.27	17.77	13.30	14.45	+1.18
	Conductivity (µs/cm)	353.30	346.20	311.70	337.07	-42.23
DP&L	pH	8.30	8.20	8.10	8.20	-0.30
	Temp (°C)	15.80	15.90	16.00	15.90	-1.47
	Dissolved Oxygen (Percent Saturation)	148.50	144.40	139.50	144.13	-2.04
	Salinity (ppt)	0.20	0.20	0.20	0.20	±0.00
	Dissolved Oxygen (mg/l)	14.88	14.09	13.91	14.29	+0.06
	Conductivity (µs/cm)	342.00	343.30	342.10	342.47	-40.53
Maysville	pH	8.60	8.30	8.30	8.40	±0.00
	Temp (°C)	4.60	4.70	4.60	4.63	-5.44
	Dissolved Oxygen (Percent Saturation)	144.30	137.70	135.30	139.10	+73.97
	Salinity (ppt)	0.10	0.10	0.10	0.10	-0.10
	Dissolved Oxygen (mg/l)	18.82	17.70	17.45	17.99	+11.39
	Conductivity (µs/cm)	319.10	313.40	313.80	315.43	-51.40
Augusta	pH	8.20	8.30	8.30	8.27	-0.06
	Temp (°C)	4.70	6.30	4.10	5.03	-5.20
	Dissolved Oxygen (Percent Saturation)	135.20	135.70	134.40	135.10	16.57
	Salinity (ppt)	0.20	0.20	0.20	0.20	±0.00
	Dissolved Oxygen (mg/l)	17.36	17.34	17.25	17.32	3.99
	Conductivity (µs/cm)	318.00	318.50	318.50	318.33	-57.60

Appendix B

Figures

Figure 1

This figure shows the location of each of the four testing locations of this study as well as the locations of the two coal-based power plants (google.com, 2017).

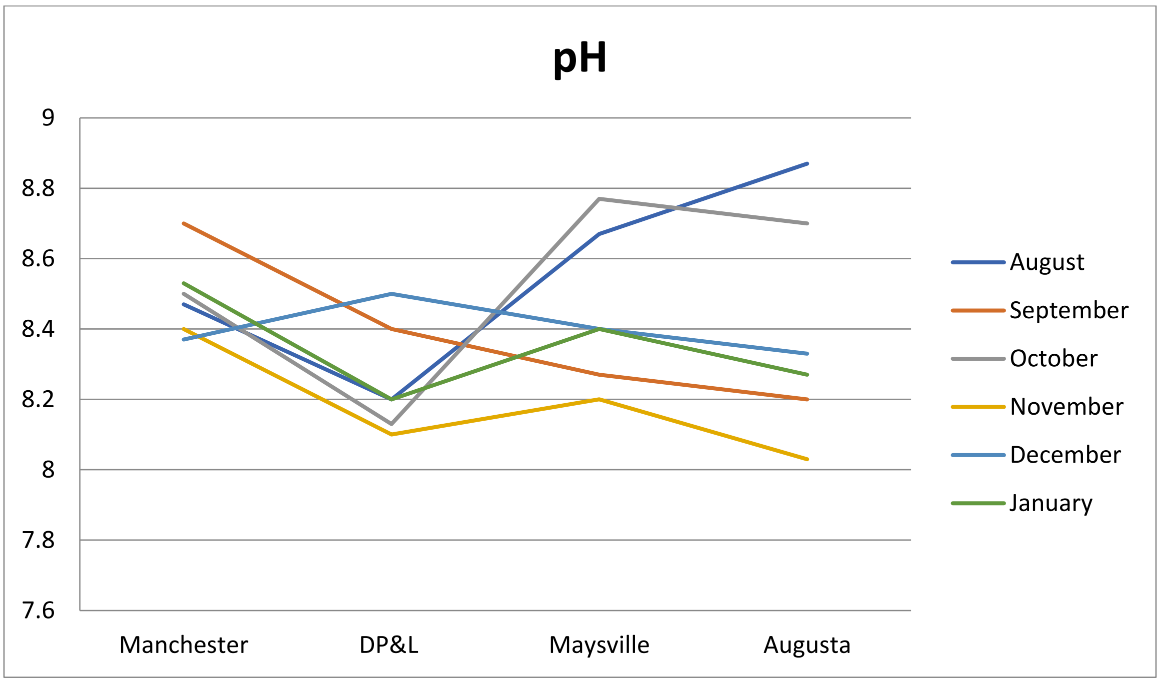

Figure 2
The data shown, average pH each month of the testing window, was collected using a water probe. Each data point is the average of three consecutive tests. The Y axis is the pH while the X axis is the four different testing locations (locations follow the natural downstream flow of the water in the Ohio River). Each line represents a different testing month (August 2016-January 2017).

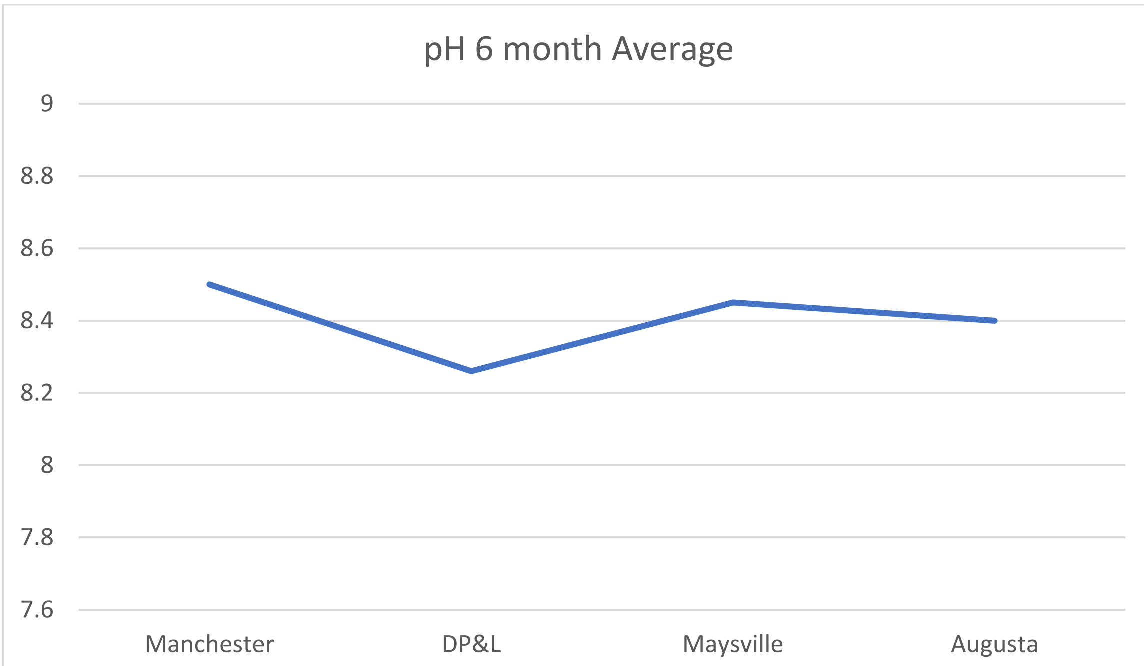

Figure 3
The data shown is the average of six months (August 2016- January 2017) of testing using a water probe. Each data point is the average of the six testing months per each location. The Y axis is the pH while the X axis is the four testing locations (locations follow the natural downstream movement of the water in the Ohio River).

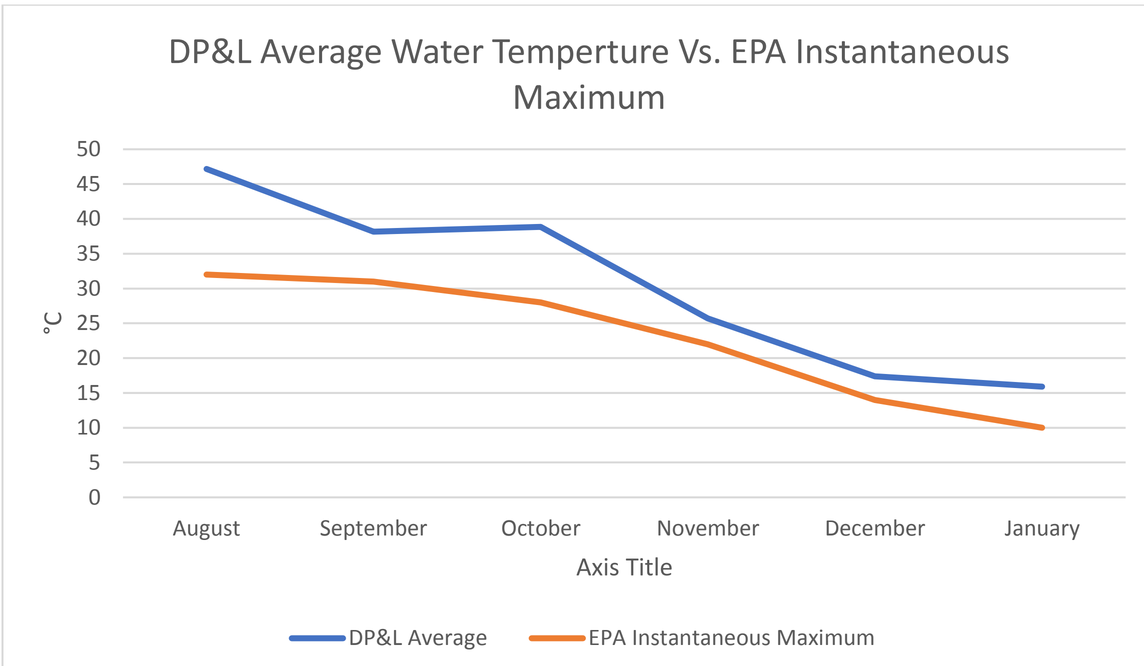

Figure 4

This data is the average water temperature of DP&L compared to approved EPA instantaneous maximum water temperature. The blue line shows the collected and averaged out data for DP&L over the six-month testing window. The orange line is the approved EPA instantaneous maximum for water temperature. The Y axis is the temperatures in Celsius while the X axis is the six testing months (August 2016-January 2017)

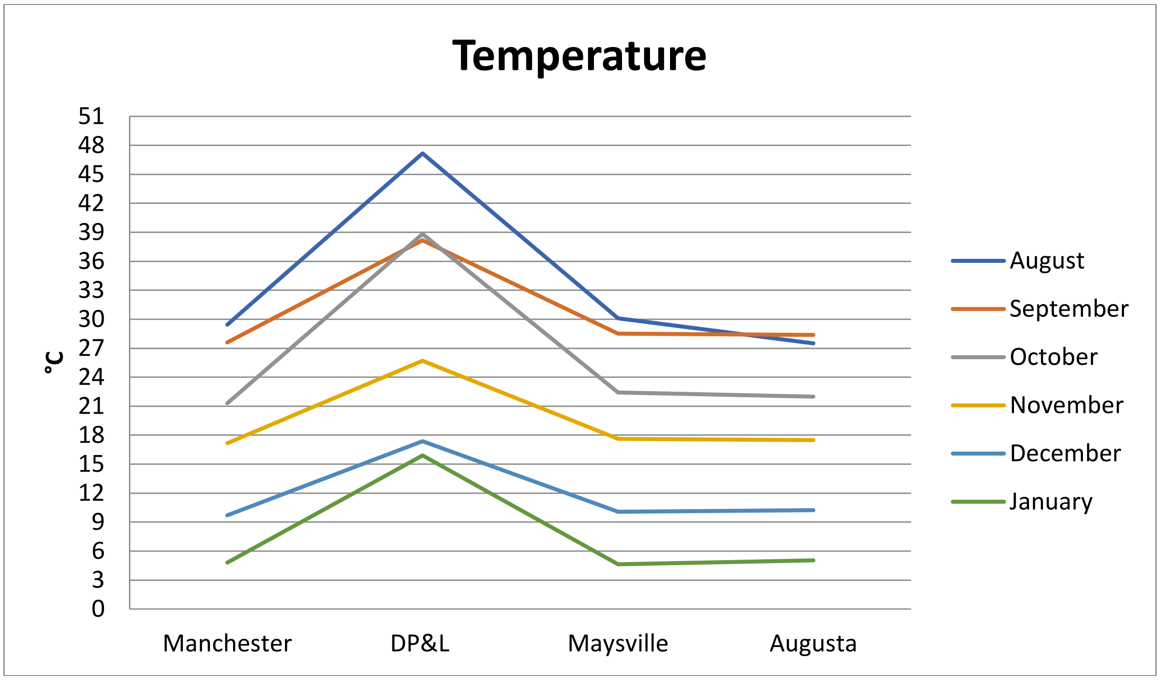

Figure 5
The data shown, average water temperature, was collected using a water probe. Each data point is the average of three consecutive tests. The Y axis is the water temperature in Celsius while the X axis is the four different testing locations (locations follow the natural downstream flow of the water in the Ohio River). Each line represents a different testing month (August 2016-January 2017).

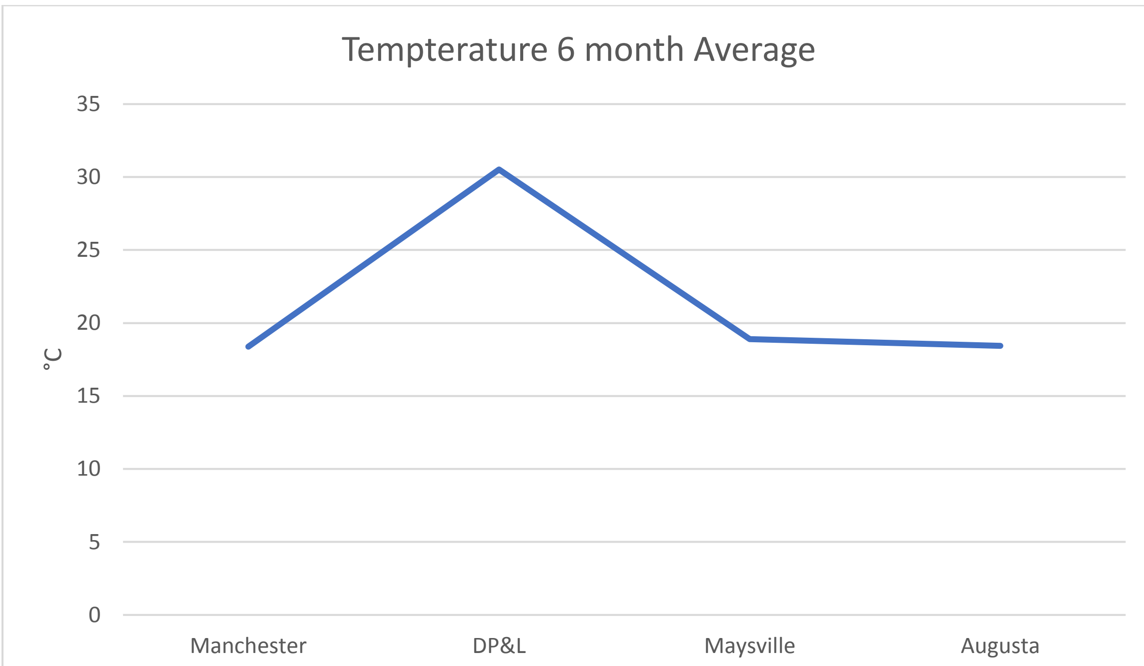

Figure 6
The data shown is the average of six months (August 2016- January 2017) of testing using a water probe. Each data point is the average of the six testing months per each location. The Y axis is the water temperature in Celsius while the X axis is the four testing locations (locations follow the natural downstream movement of the water in the Ohio River).

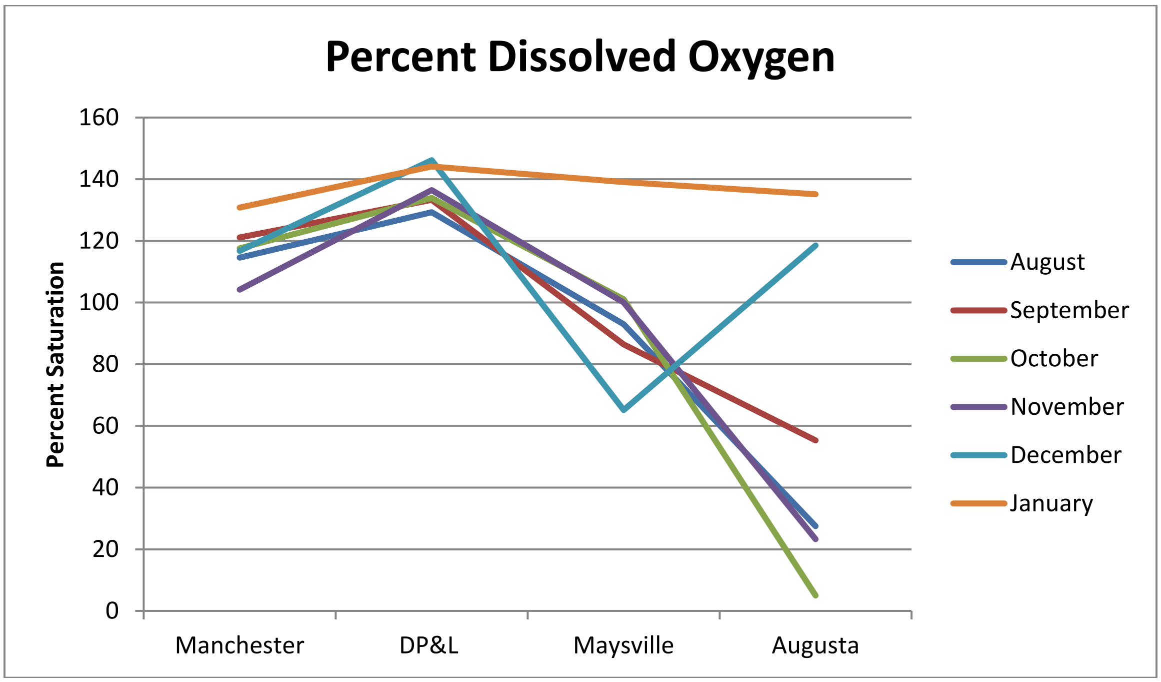

Figure 7
The data shown, average percent dissolved oxygen, was collected using a water probe. Each data point is the average of three consecutive tests. The Y axis is the percent saturation of the dissolved oxygen while the X axis is the four different testing locations (locations follow the natural downstream flow of the water in the Ohio River). Each line represents a different testing month (August 2016-January 2017).

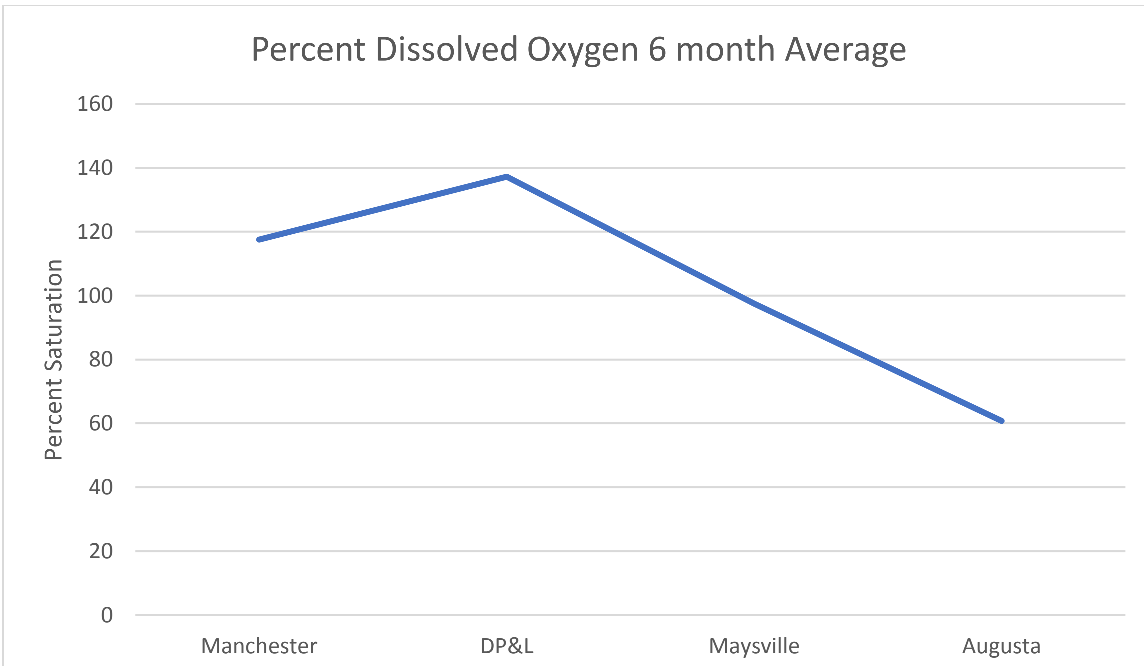

Figure 8
The data shown is the average of six months (August 2016- January 2017) of testing using a water probe. Each data point is the average of the six testing months per each location. The Y axis is the percent saturation of dissolved oxygen in the water while the X axis is the four testing locations (locations follow the natural downstream movement of the water in the Ohio River).

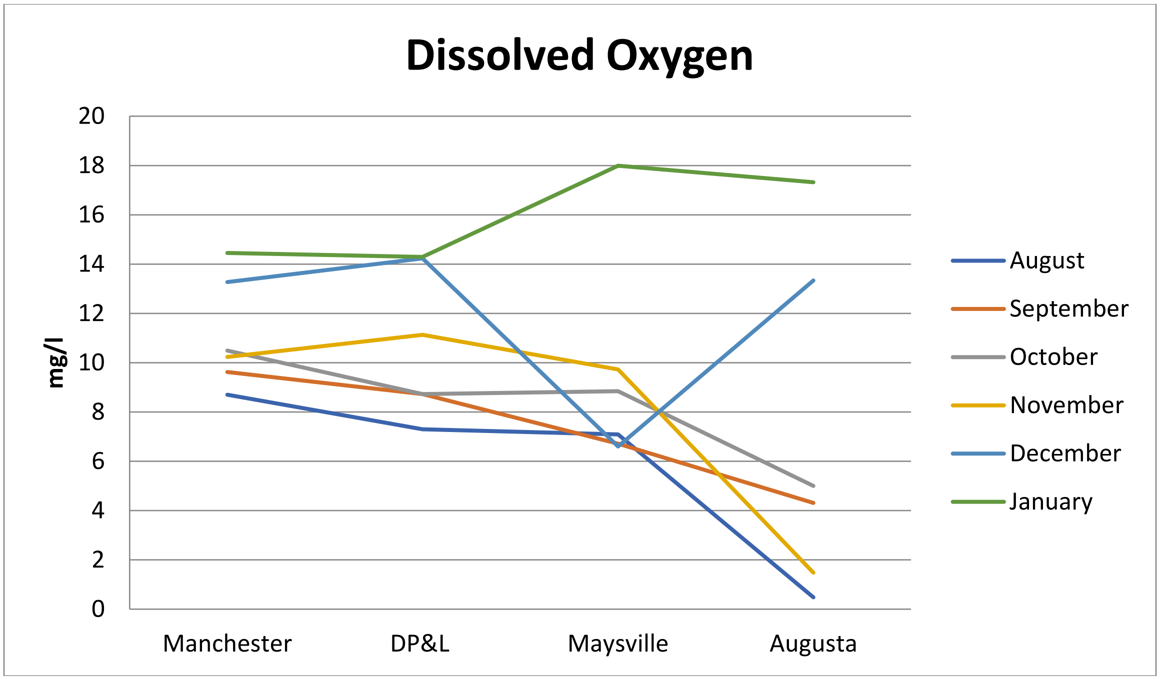

Figure 9
The data shown, average dissolved oxygen in mg/l, was collected using a water probe. Each data point is the average of three consecutive tests. The Y axis is the amount of dissolved oxygen in mg/l while the X axis is the four different testing locations (locations follow the natural downstream flow of the water in the Ohio River). Each line represents a different testing month (August 2016-January 2017).

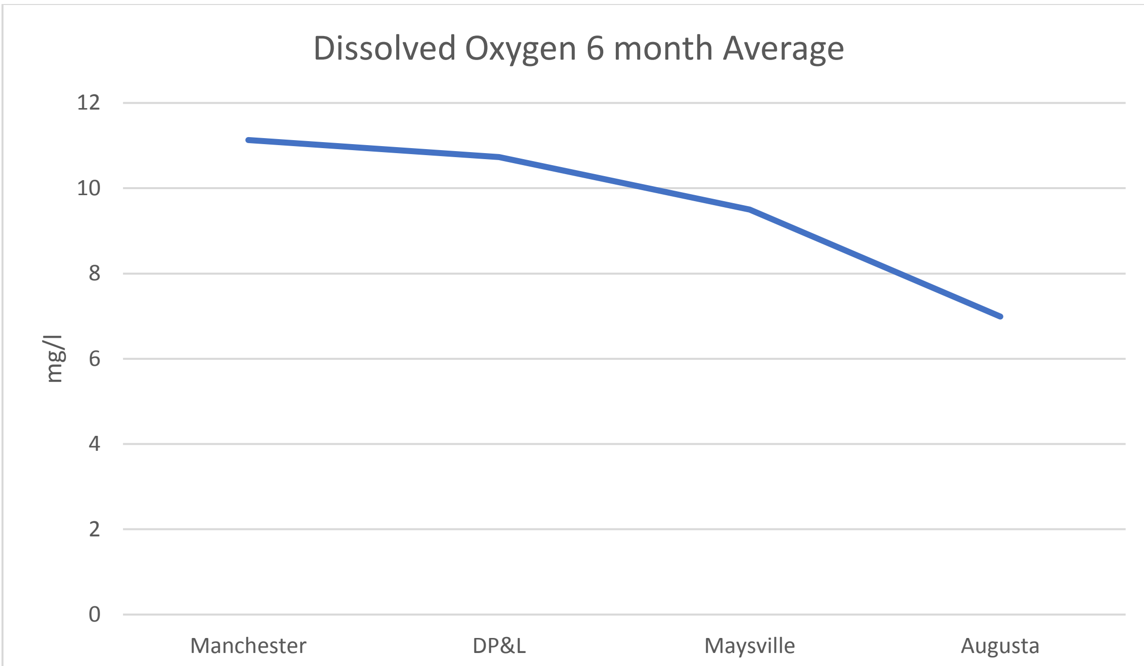

Figure 10
The data shown is the average of six months (August 2016- January 2017) of testing using a water probe. Each data point is the average of the six testing months per each location. The Y axis is the salinity in ppt while the X axis is the four testing locations (locations follow the natural downstream movement of the water in the Ohio River).

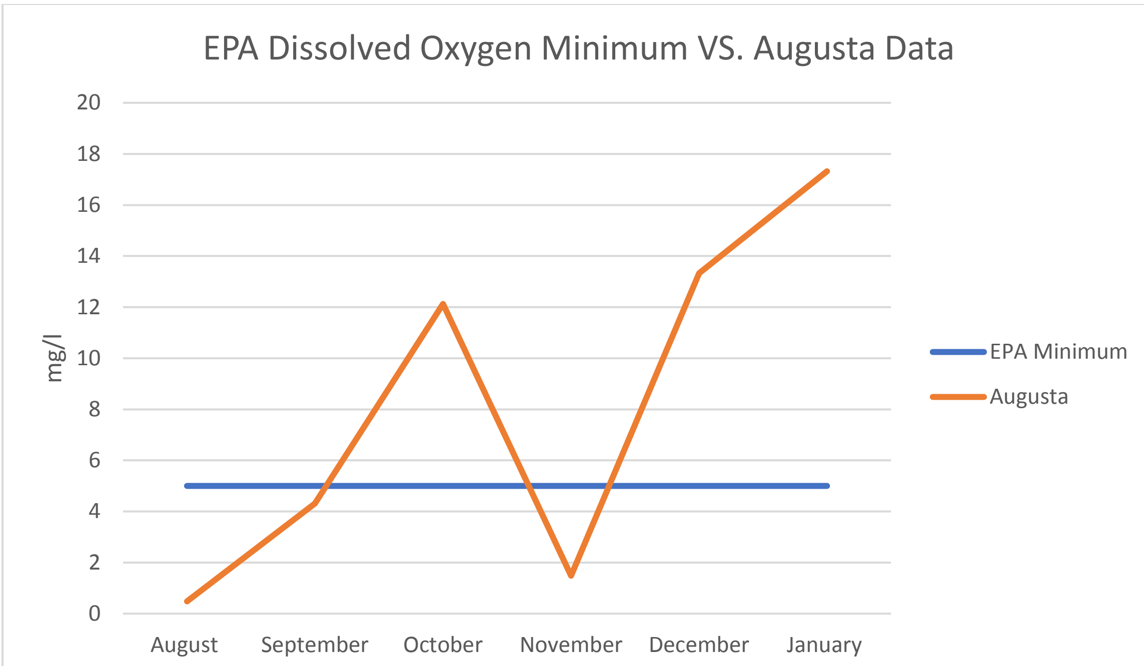

Figure 11
The data shown on this chart is a combination of data collected using a probe and released EPA standards. The figure compares the approved EPA minimum of measured dissolved oxygen to the data physically collected in Augusta, KY. The orange line is the average data collected in Augusta for each of the six testing months (August 2016- January 2017). Each data point is the average of three consecutive tests. The blue line is the released EPA minimum requirement for dissolved oxygen in a freshwater source. The Y axis is mg/l of dissolved oxygen while the X is each testing month.

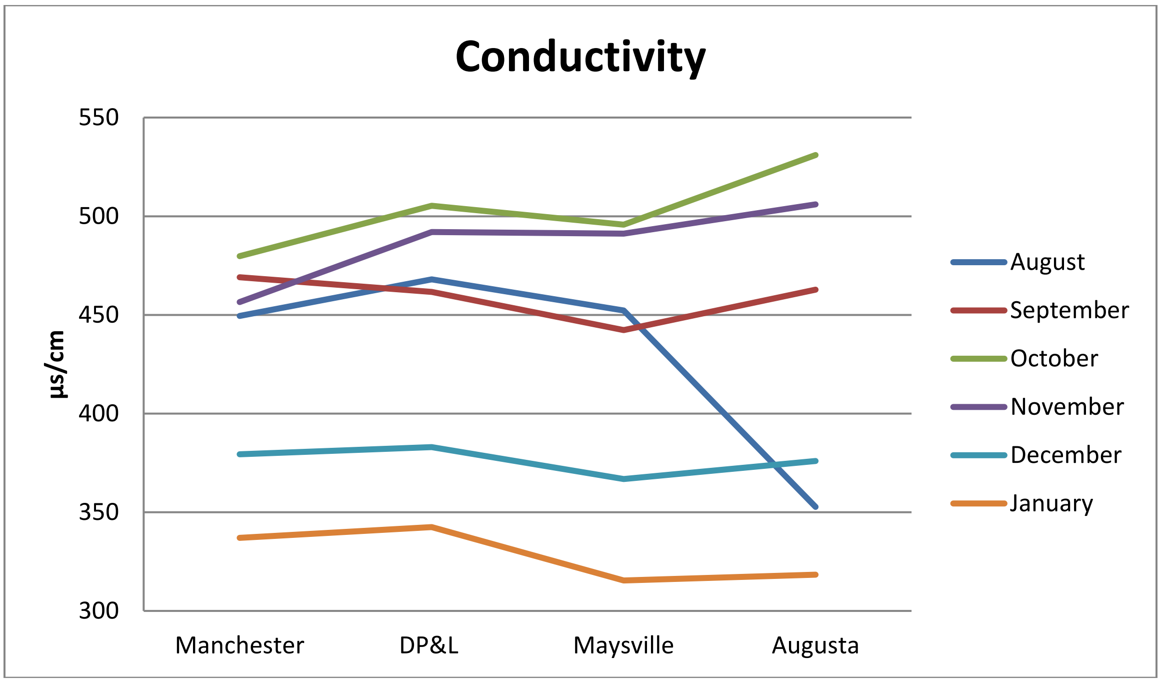

Figure 12
The data shown, average conductivity in µs/cm, was collected using a water probe. Each data point is the average of three consecutive tests. The Y axis is the amount of conductivity in µs/cm while the X axis is the four different testing locations (locations follow the natural downstream flow of the water in the Ohio River). Each line represents a different testing month (August 2016-January 2017).

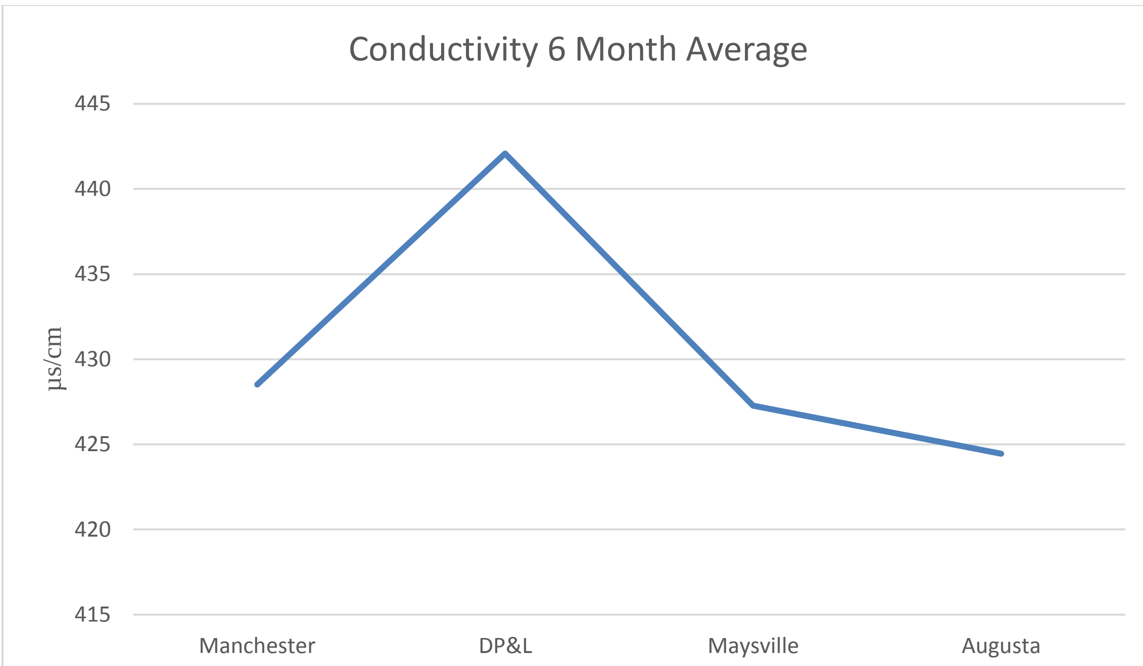

Figure 13
The data shown is the average of six months (August 2016- January 2017) of testing using a water probe. Each data point is the average of the six testing months per each location. The Y axis is the conductivity in µs/cm while the X axis is the four testing locations (locations follow the natural downstream movement of the water in the Ohio River).

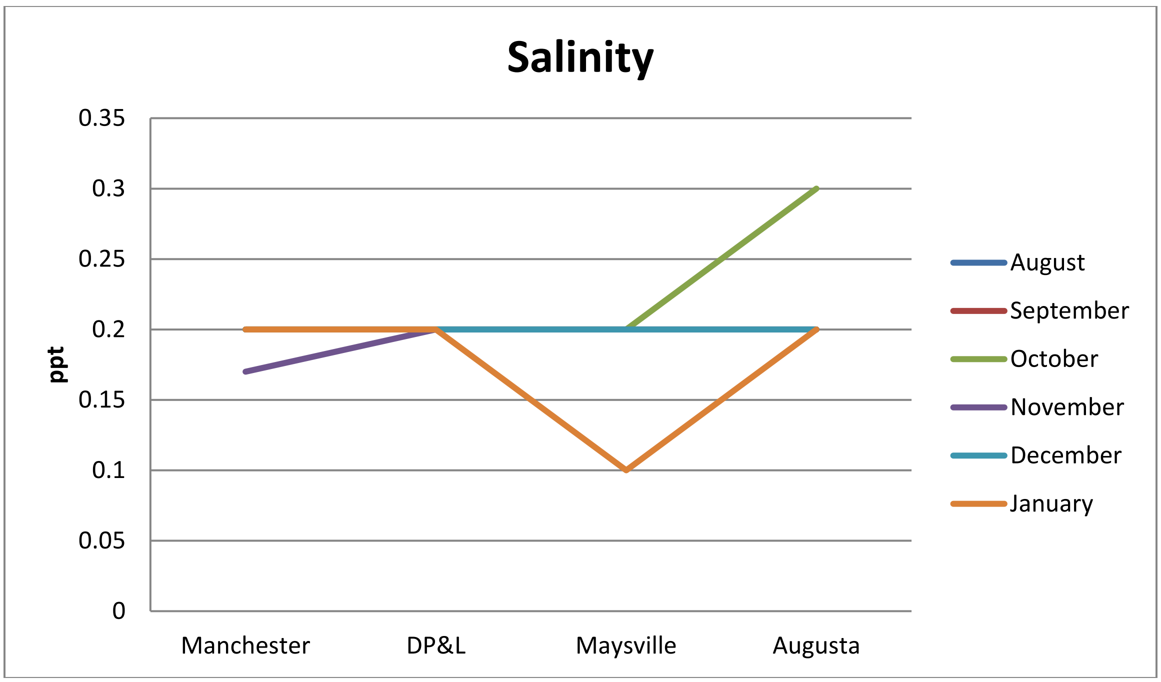

Figure 14
The data shown, average salinity in ppt, was collected using a water probe. Each data point is the average of three consecutive tests. The Y axis is the amount of salinity in ppt while the X axis is the four different testing locations (locations follow the natural downstream flow of the water in the Ohio River). Each line represents a different testing month (August 2016-January 2017).

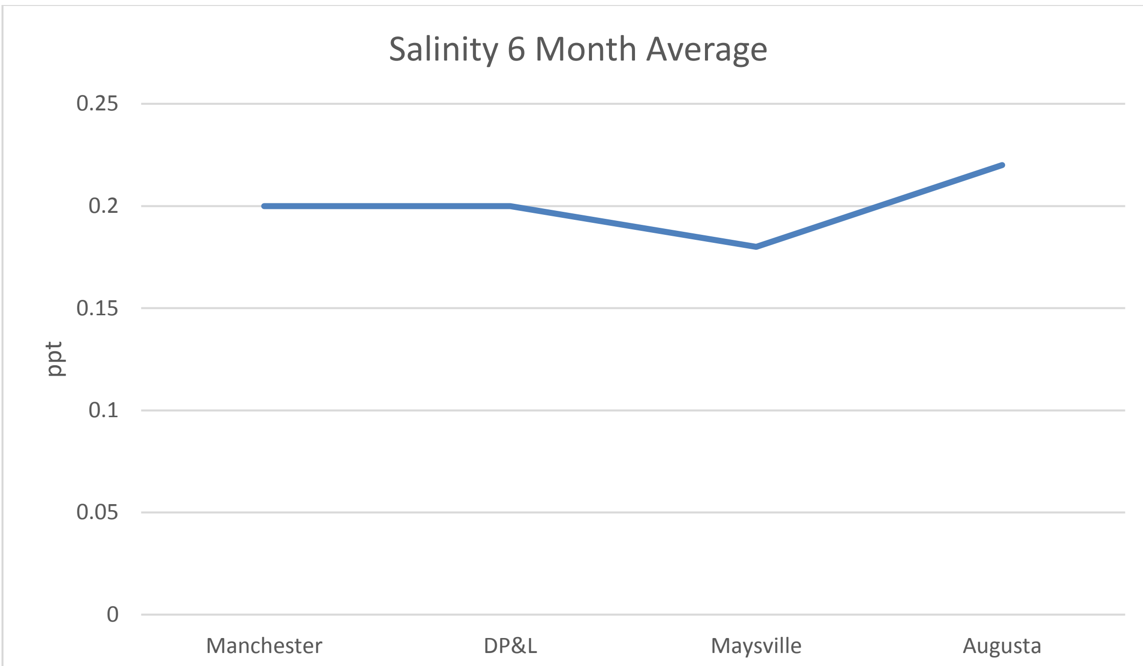

Figure 15
The data shown is the average of six months (August 2016- January 2017) of testing using a water probe. Each data point is the average of the six testing months per each location. The Y axis is the salinity in ppt while the X axis is the four testing locations (locations follow the natural downstream movement of the water in the Ohio River).