The Effects of Tributary Health on Lake Heritage

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Abstract

This experiment focused on the question, “How is Lake Heritage affected by the water quality in its tributaries?” The hypothesis states that the Plum Run tributary will contribute more nutrient pollution and sediment load to Lake Heritage than the unnamed tributary because Plum Run is surrounded by farmland and housing developments, both of which will contribute nutrients and sediment to the lake through runoff due to fertilizer use and erosion by pastureland. The independent variable is location. The dependent variables are nitrates in parts per million, pH in logarithmic units, water temperature in Celsius, dissolved oxygen in parts per million, phosphates in ppm, and water transparency in centimeters. The controls for this experiment are the times of observation, the study sites, the testing equipment, and the GLOBE protocols. The experiment was conducted using CHEMets dissolved oxygen, phosphates, and nitrates kits, a Hanna Instruments pH meter, an alcohol filled thermometer, and a transparency tube according to GLOBE protocols. Water was collected at each site and the water quality tests were completed according to the instructions and protocols. The data partially supported the hypothesis. Plum Run did display higher nitrates levels, lower transparency, and high phosphate levels throughout the eight weeks of data collection. However, the contribution of the tributary to Lake Heritage was not entirely consistent. On most occasions, the data did seem to be more influenced by Plum Run or equally influenced by both tributaries. All of the parameters followed two trends: the lake data was closer to one tributary or the other or the lake data was in between the levels of the tributaries. On some occasions, neither of these trends applied, which could be due to precipitation events. If this experiment were to be continued, more data would be collected to create a more detailed picture of the trends in the data. This project is important to the real world

because a comprehensive plan for the remediation of Lake Heritage can be composed using the findings of this project. This plan could also be used as a model for larger watersheds, such as the Chesapeake Bay, which has a similar problem.

Keywords: nitrates, dissolved oxygen, pH, water temperature, phosphates, water transparency, sediment load, nutrients, and tributary

The Effects of Tributary Health on Lake Heritage

Research Question

This experiment is designed to find which tributary of Lake Heritage contributes the most nutrient pollution and sediment load to the lake. The independent variable is location. The dependent variables are nitrates in parts per million, pH in logarithmic units, water temperature in Celsius, dissolved oxygen in parts per million, phosphates in ppm, and water transparency in centimeters. The controls for this experiment are the times of observation, the study sites, the testing equipment, and the GLOBE protocols. The hypothesis states that the Plum Run tributary will contribute more nutrient pollution and sediment load to Lake Heritage than the unnamed tributary because Plum Run is surrounded by farmland and housing developments, both of which will contribute nutrients and sediment to the lake through runoff due to fertilizer use and erosion by pastureland.

Introduction and Background Research

Freshwater ecosystems, including lakes, rivers, and streams, are low in salt and can be seasonal or permanent bodies of water. The mineral composition and water chemistry can depend on the surrounding environment and soils the water has passed through. The upper parts of a stream are usually fast-flowing and narrow. This is also where riffles and runs are common. Riffles are fast-flowing, shallow areas with tumultuous waters running over rocks. Runs are similar, but are deeper. A glide is similar to a run, but has no surface turbulence. The middle is wide and slower. The lower end is the slowest flowing part of the river. The cloudiness, the strength of the current, oxygen levels, nutrient content, and temperature depend on the volume of water and the land cover the stream runs through (Morgan, 1995). Water chemistry can change

quickly, and reflect a spill or weather event, but unless the measurements are taken right after the occurrence, it may be difficult to detect the change.

Water temperature is vital to the health of streams and the aquatic life that lives in these bodies of water. Most vegetation and aquatic organisms thrive in a specific range of temperature. Temperature affects other aspects of water chemistry, which is why it is referred to as the "master variable." Higher temperatures can reduce the dissolved oxygen in water, which can damage biodiversity in aquatic species. pH is also inversely affected by water temperature. Temperatures naturally change at different points in the length of a stream depending on the source of water, geographical location, and other factors. Some specific factors include melted snow, precipitation, groundwater, the amount of water in the stream, air temperature, and vegetation (EPA, 2019).

pH is the measure of acidity or alkalinity of water. pH has a range of 0-14 with 7 indicating a neutral pH. A pH lower than 7 is acidic and above 7 is alkaline. pH measures the amount of hydrogen and hydroxyl ions present. Water containing more hydrogen ions is considered acidic. Water containing more hydroxyl ions present is considered alkaline. pH is measured in logarithmic units. Every number denotes a 10 fold change in acidity or alkalinity of the water. The pH of water dictates the solubility and biological availability of chemical components such as heavy metals. Normal rainfall has a pH of about 5.6, which is moderately acidic in part to carbon dioxide gas from the atmosphere. Pollution can change the pH of water, which in turn can harm animals and vegetation existing in the water (USGS, 2019).

Nitrates (NO_3) are an essential source of nitrogen (N) for plants. Nitrogen is a vital nutrient for the growth of organisms. Although, excess nitrates can cause negative effects on the

aquatic ecosystem. When nitrogen fertilizers are used to enrich soils, nitrates may be carried by rain, irrigation and other surface waters through the soil into groundwater. When it flows into the nearest body of water or groundwater is discharged, it can decrease the amount of dissolved oxygen in the water due to eventual eutrophication. Eutrophication is the process in which excessive nutrients cause the overwhelming growth of algae on the surface of the water. This does not allow for sunlight to penetrate to the depths of the body of water. Without sunlight to photosynthesize, plants die, resulting in the build up of organic material. Aquatic animals suffer in eutrophic conditions because each species has a range of water quality to which they can survive in. Most organisms cannot survive in severe conditions, killing marine populations and decreasing the biodiversity of the ecosystem (USGS, 2019).

Dissolved oxygen (DO) in a body of water may vary from 0 ppm to 18 ppm. Readings above 18 ppm are physically impossible. If the weather becomes cloudy for many days, the plants will consume much of the DO. When the increased numbers of aquatic plants eventually die, they support tremendous amounts of bacteria which also consume large amounts of DO as the bacteria decompose the dead plants (EPA, 2019). Temperature has an inverse effect on dissolved oxygen. Warmer temperatures cause lower dissolved oxygen levels which could be harmful to aquatic life. Cold water can sustain more dissolved oxygen. Oxygen can enter water through groundwater discharge and the atmosphere. Gases in the atmosphere amalgamate with water in riffles in streams, causing higher dissolved oxygen in these areas (USGS, 2019).

Water transparency is the measure of clarity in a body of water. Suspended particles in water decrease the depth that light can pass through, reducing the spaces that plants can thrive. Transparency is crucial to the ability of aquatic plants to photosynthesize using the sunlight that

reaches past the surface of the water. One of the most common particles that decreases transparency is sediment. Land with little or scattered vegetation releases more sediment, which can wash away during precipitation events (GLOBE, 2019).

Phosphorus is present on earth in many compound forms, such as phosphate. Phosphorus, similar to nitrogen, is a nutrient that is crucial to the growth of organisms. Phosphorus is ordinarily found in small quantities, limiting growth of organisms to a normal pace. An excess of phosphorus causes abnormally quick growth, which can result in eutrophic bodies of water (EPA, 2019).

The water quality of a stream is greatly impacted by the land use around the site. The agricultural industry, which covers a substantial amount of land in Pennsylvania, contributes to much of the nutrient pollution throughout the Chesapeake Bay watershed. Fertilizers and manure are saturated with nitrogen and phosphorus. These elements enter water in different forms. Nitrogen has to undergo the nitrogen fixation cycle to be in a form that can be used by most living organisms. Nitrogen can be fixed through bacteria in soil, which only produces ammonia. Nitrates are produced when atmospheric nitrogen comes into contact with lightning and falls with precipitation to the earth's surface. Although, scientists have found ways to convert nitrogen in a controlled setting for industrial purposes. Organisms consume the nitrates and other nutrients, ultimately decompose, and this produces ammonia. Ammonia can then proceed to the cycle of nitrification, in which bacteria converts ammonia into nitrates and nitrites. The fertilizers used for agricultural purposes are also used in domestic yards, creating similar conditions with runoff and nutrient pollution (Science Learning Hub, 2018).

Problematic water quality has plagued Lake Heritage since its creation. Lake Heritage is a man-made lake that was previously active farmland. In October 1965, dam construction was completed and the lake began to fill. The lake was not considered finished until almost 2 years later in March 1967. The lake was stocked with fish in 1968. The first evidence of water quality concerns was noted in 1969 when septic systems were not functioning properly and sewage was noted in the lake water (Lake Heritage 50th Anniversary Committee, 2015).

In 1971, the fish population declined because of an increased amount of bacteria in the northern end of the lake. The lake was also experiencing an issue with erosion and sediment. The goal was to dredge the bottom of the lake to clear extra sediment, remove decaying vegetation, and thus improve the water clarity. The lake was dredged in 1973, 1976, 1979, 1985 and 2013. The year after the lake was first dredged, chemical imbalances further developed, an increase in invasive algae occurred, and a significant decrease in the fish population as reported by fishing members of the community. The first dredging removed and interrupted the soil and plant life on the bottom of the lake and the vegetation did not re-establish. The decrease in noninvasive plants to soak up the extra nutrients changed the chemical composition of the water and allowed algae to flourish. Lake Heritage was first treated for algae in the 1970s. Algae was treated in the lake through the 1990s and still was a persistent problem. Members of the Lake Heritage Board have made attempts to improve the water quality of the lake since then by treating it with several chemicals that were supposed to improve all aspects of water quality, but all attempts have not proven to be consistent solutions. Thus far, the water quality of the lake was first monitored by the Fishing Club. Official equipment was purchased in 1976 to monitor the oxidation, food chain

stability, and lake pollution. After this, the responsibility was handed over to Northeastern Aquatic Services of Scranton (Lake Heritage 50th Anniversary Committee, 2015).

According to *Our Lake, Our Heritage, Our History,* in 1990, a drive to save the water quality was set into action with three goals:

1. To reduce nutrients reaching the lake by curbing fertilization, asking farmers to reduce manure within the watershed, and by discouraging the duck population. A typical duck was estimated to dump 80 pounds of dung a year into the lake.
2. To reduce silt by seawall construction.
3. To reduce bacteria through treatment.

When the water quality had not improved despite restoration efforts, three solutions were considered:

1. Runoff control ponds.
2. Gabion cages to trap sediment.
3. An alum blanket to trap phosphorus on the bottom.

On September 10, 2012, volunteers cleaned several pounds of dead fish from the lake. Observations concluded that these fish were killed by the lowered levels of dissolved oxygen. This not only signaled the water quality issues, but also a significant decrease in predatory fish in the lake which were keeping the White Perch population in check. In 2013, the lake was dredged again and a system of channel deflectors, stream gabion check dams, and stream-side retention areas were installed in Lake Heritage and the streams that flow into Lake Heritage from bordering farm land, including Plum Run and the unnamed tributary (Lake Heritage 50th

Anniversary Committee, 2015). In 2016, aerators, which mix a substance with oxygen, in this case water, were added to the lake to increase water circulation and dissolved oxygen levels. Small plant islands have also been added to the lake. These continually decrease phosphorus and nitrate levels by soaking up the extra nutrients that are no longer being consumed by natural plants. Unfortunately, these plant islands have since degraded and become trash and debris (Verdirame & Tucci, 2017).

Water quality is a complex system of interconnected parameters that contribute to the overall health of an ecosystem. Upstream water quality has been directly linked to the health of the Chesapeake Bay. Therefore, the question is, how does the health of tributaries affect the water quality of Lake Heritage? Dissolved oxygen, nitrates, pH, water temperature, phosphate, and transparency play crucial roles in improving the water quality of Lake Heritage and the health of the aquatic organisms that inhabit the body of water, which will be impacted by the quality of tributaries.

Materials

- CHEMets Dissolved Oxygen Kit
    - 1 comparator
    - 1 25 mL sample cup
    - CHEMets self filling ampoules
- CHEMets Nitrates Kit
    - CHEMets ampoules
    - Cadmium foil packs
    - 1 25 mL sample cup

    - 1 low range comparator
    - 1 high range comparator.
- CHEMets Phosphate Kit
    - CHEMets ampoules
    - 1 container of activator solution
    - 1 25 mL sample cup
    - 1 sample cup cap
    - 1 low range comparator
    - 1 high range comparator.
- Hanna Instruments pH Meter
- Alcohol filled thermometer
- 1 transparency tube
    - 1 measuring tape
    - 1 pipe cap
    - 1 tube
    - glue
- 1 cup
- 1 pair of goggles
- 1 box of gloves
- GLOBE Hydrosphere Investigation Data Sheet
- Distilled water

Methods

Collect water quality data every Wednesday. Collect samples 25 meters away from the mouth of each tributary. Collect lake data at the midpoint between the tributaries in Lake Heritage. Perform three trials per water quality parameter. Record weather for the 24 hours before data collection.

Dissolved Oxygen

As stated from GLOBE Protocols:

1. Fill in the top of the Hydrosphere Investigation Data Sheet.
2. Put on the gloves and goggles.
3. Rinse the sample bottle and hands with sample water three times.
4. Place the cap on the empty sample bottle.
5. Submerge the sample bottle in the sample water.
6. Remove the cap and let the bottle fill with water. Move the bottle gently or tap it to get rid of air bubbles.
7. Put the cap on the bottle while it is still under the water.
8. Remove the sample bottle from the water. Turn the bottle upside down to check for air bubbles. If there are air bubbles, discard this sample. Collect another sample.
9. Follow the directions in the dissolved oxygen kit to test the water sample.

    Instructions for CheMets Dissolved Oxygen Test Kit

    a. Fill the sample cup to the 25 mL mark with your sample.

b. Place the CHEMets ampoule in the sample cup. Snap the tip by pressing the ampoule against the side of the cup. The ampoule will fill, leaving a small bubble to facilitate mixing.

c. Mix the contents of the ampoule by inverting it several times, allowing the bubble to travel from end to end each time. Wipe all liquid from the exterior of the ampoule. Wait 2 minutes for color development.

d. Hold the comparator in a nearly horizontal position while standing directly beneath a bright source of light. Place the CHEMet ampoule between the color standards moving from left to right along the comparator until the best color match is found. If the color of the CHEMet ampoule is between two color standards, a concentration estimate can be made.

10. Record the dissolved oxygen in water sample on the data sheet.
11. Calculate the average of the three measurements.
12. Each of the three measurements should be within 1 ppm of the average. If one of the measurements is not within 1 ppm of the average, find the average of the other two measurements. If both of these measurements are within 1 ppm of the new average, record this average.
13. Discard all used chemicals. Clean dissolved oxygen kit with distilled water.

Nitrates

As stated from GLOBE Protocols:

1. Fill out the top portion of the Hydrosphere Investigation Data Sheet. In the nitrates section, fill in the kit manufacturer and model.

2. Put on gloves and goggles.
3. Follow the instructions in the kit to measure the nitrate-nitrogen. Use the Low Range Test (0 – 1 ppm) unless previous results indicate that the site typically has greater than 1 ppm nitrate-nitrogen. If using powdered reagents, use the surgical mask when opening these products. Use clock or watch to measure the time if the kit requires shaking the sample.

    Instructions for CHEMets Nitrates Test Kit

    a. Fill the sample cup to the 15 mL mark with the sample.
    b. Empty the contents of one A-900 Cadmium Foil Pack into the sample cup. Cap the sample cup and shake it vigorously for exactly 3 minutes. Allow the sample to sit undisturbed for 30 seconds.
    c. Place the CHEMets ampoule in the sample cup. Snap the tip by pressing the ampoule against the side of the cup. The ampoule will fill leaving a small bubble to facilitate mixing.
    d. Mix the contents of the ampoule by inverting it several times, allowing the bubble to travel from end to end each time. Wipe all liquid from the exterior of the ampoule. Wait 10 minutes for color development.
    e. Use the appropriate comparator to determine the level of nitrate-nitrogen in the sample. If the color of the CHEMets ampoule is between two color standards, a concentration estimate can be made.

        1. Low range comparison: Place the CHEMets ampoule, flat end downward into the center tube of the low range comparator. Direct the top of the comparator up toward a source of bright light while

viewing from the bottom. Rotate the comparator until the color standard below the CHEMets ampoule shows the closest match.

2. High range comparison: Hold the high range comparator in a nearly horizontal position while standing directly beneath a bright source of light. Place the CHEMets ampoule between the color standards moving it from left to right along the comparator until the best color match is found.

4. Match the color of the treated sample water with a color in the test kit. Record the value as ppm nitrate-nitrogen for the matching color. Record all three nitrate-nitrogen values on the data sheet.
5. Calculate the average of the three measurements.
6. Check to see if each of the three measurements are within 0.1 ppm of the average (or within 1.0 ppm of the average if using the high range test). If they are, record the average on the data sheet. If they are not, read the color measurements again. Calculate a new average. If the measurements are still not within range discuss possible problems with the teacher.

Water Temperature

As stated from GLOBE Protocols:

1. Fill out the top portion of the Hydrosphere Investigation Data Sheet.
2. Put on the gloves.
3. Slip the rubber band around the wrist so that the thermometer is not accidentally lost or dropped into the water.

4. Check the alcohol column on the thermometer to make sure there are no air bubbles trapped in the liquid. If the liquid line is separated, notify the teacher.
5. Put the bulb end of the thermometer into the sample water to a depth of 10 cm.
6. Leave the thermometer in the water for three minutes.
7. Read the temperature without removing the bulb of the thermometer from the water.
8. Let the thermometer stay in the water sample for one more minute.
9. Read the temperature again. If the temperature has not changed, go to Step 10. If the temperature has changed since the last reading, repeat Step 8 until the temperature stays the same.
10. Record the temperature on the Hydrosphere Investigation Data Sheet.
11. Calculate the average of the three measurements.
12. All temperatures should be within 1.0˚ C of the average. If they are not, repeat the measurement.

pH

As stated from GLOBE Protocols:

1. Fill in the top portion of the Hydrosphere Investigation Data Sheet. Check pH meter as the instrument.
2. Put on the gloves.
3. Remove the cap from the meter that covers the electrode.
4. Rinse the electrode on the meter and the area around it with distilled water in the wash bottle. Blot the meter dry with a clean paper towel. Do not rub the electrode or touch it with the fingers.

5. Rinse the electrode with distilled water and blot dry again.
6. Calibrate the pH meter according to the manufacturer's directions.
7. Rinse a 100-mL beaker three times with sample water.
8. Pour 50 mL of sample water into the 100-mL beaker.
9. Put the electrode part of the meter into the water.
10. Stir once with meter. Do not let the meter touch the bottom or sides of the beaker. Wait for one minute. If the pH meter is still changing numbers, wait another minute.

Water Transparency

As stated from GLOBE Protocols:

1. Fill in the top portion of the Hydrosphere Investigation Data Sheet.
2. Record the cloud and contrail types and cover (see the Cloud Protocols in the Atmosphere Investigation).
3. Put on gloves.
4. Collect a surface water sample.
5. Stand against the sun so that the transparency tube is shaded.
6. Pour sample water slowly into the tube using the cup. Look straight down into the tube with the eye close to the tube opening. Stop adding water when the pattern at the bottom of the tube is not visible.
7. Rotate the tube slowly to make sure none of the pattern at the bottom of the tube is visible.

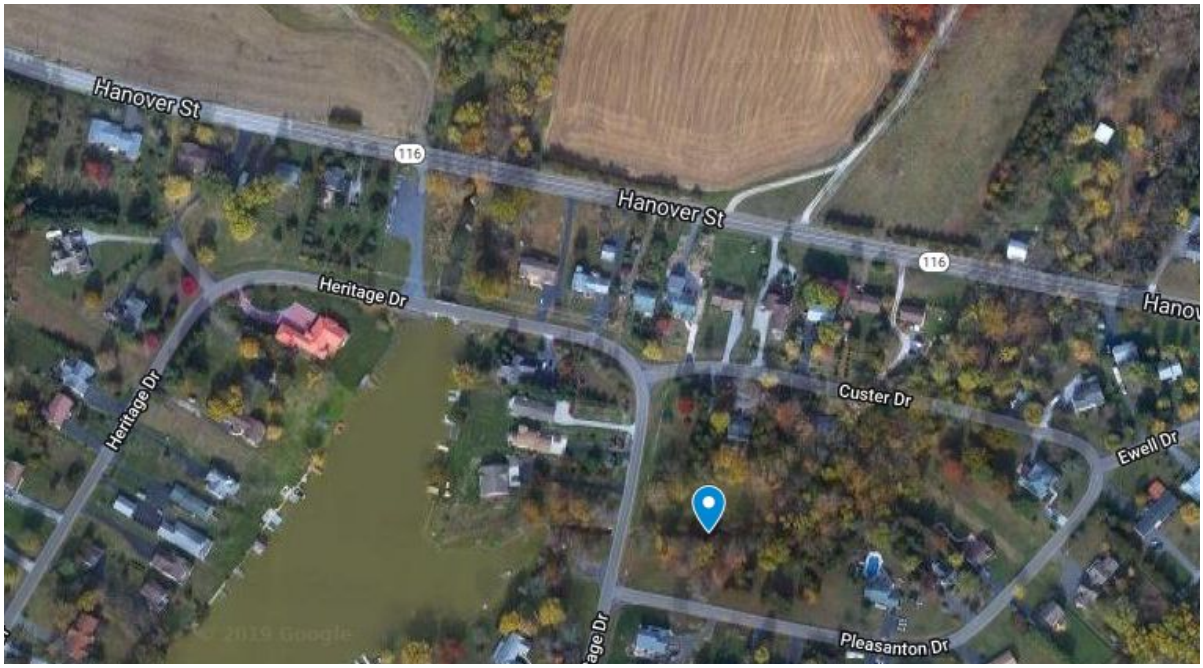
8. Record the depth of water in the tube on the Hydrosphere Investigation Data Sheet to the nearest cm. If the disk on the bottom of the tube is still visible after the tube is filled, record the depth as >120 cm.
9. Pour the water from the tube back into the sample bucket or mix up the remaining sample.
10. Repeat the measurement two more times using the same sample water.

Phosphate

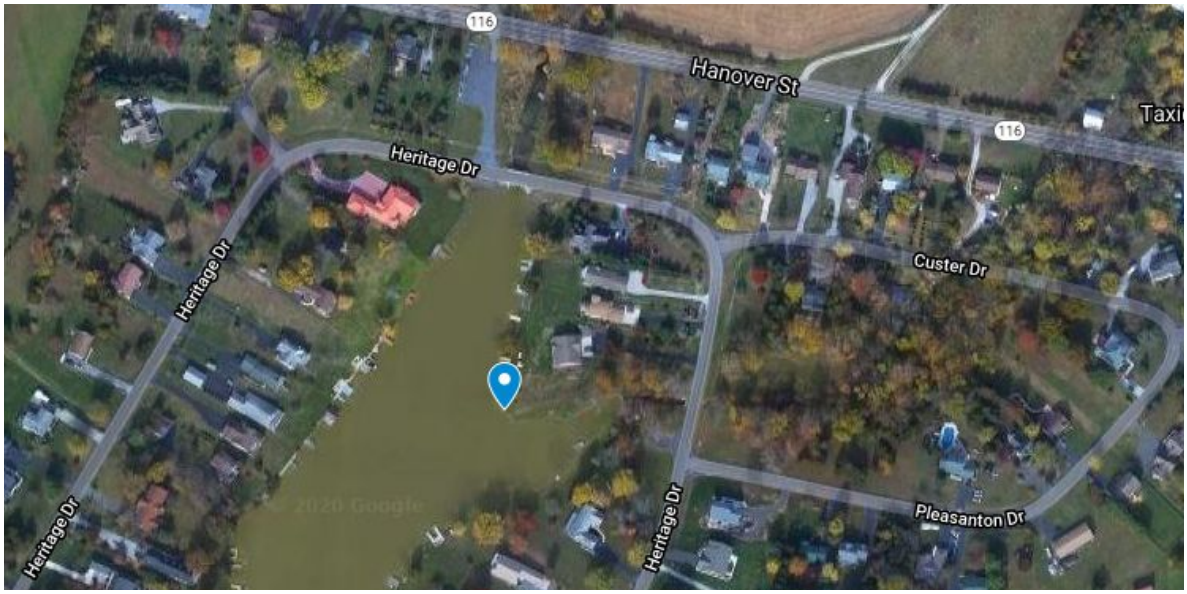
1. Put on gloves.
2. Follow instructions as follows:
    a. Fill the sample cup to the 25 mL mark with the sample to be tested.
    b. Add 2 drops of A-8500 Activator Solution.
    c. Cap the sample cup and shake it to mix the contents well.
    d. Place the CHEMet ampoule, tip first, into the sample cup. Snap the tip. The ampoule will fill leaving a bubble for mixing.
    e. To mix the ampoule, invert it several times, allowing the bubble to travel from end to end.
    f. Dry the ampoule. Obtain a test result 2 minutes after snapping the tip. Obtain a test result using the appropriate comparator.
    g. Low Range Comparator:
        i. Place the ampoule, flat end first, into the comparator. Hold the comparator up toward a source of light and view from the bottom. Rotate the comparator until the best color match is found.

h. High Range Comparator:

    i. Place the ampoule between the color standards until the best color match is found.

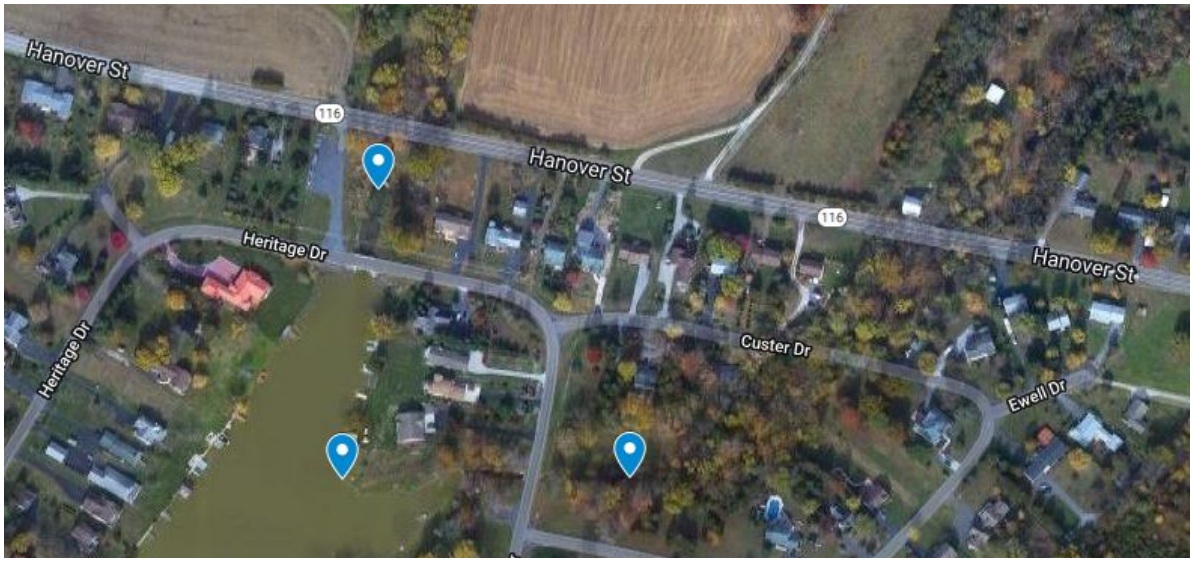


Map 1: This depicts a satellite image of Study Site 1, the unnamed stream using Google Maps. This stream is surrounded by trees and houses.



Map 2: This depicts a satellite image of Study Site 2, Lake Heritage. This site is the estimated midpoint on public property between the mouths of the two tributaries.

Map 3: This depicts a satellite image of Study Site 3, Plum Run, which is surrounded by farmland.



Map 4: This depicts a satellite image of each of the study sites in relation to one another.

Results

Date	DO (ppm)	Nitrates (ppm)	pH (logarithmic units)	Temperature (Celsius)	Transparency (cm)	Phosphates (ppm)
11/13/19	12	2	9	5	120	1
11/20/19	12	2	8.2	8	95	1
11/27/19	6	2.5	8.1	8	120	1
12/4/19	10	2	8.2	8	66	1
12/11/19	10	1	8	7	120	1
12/18/19	10	1.5	8.6	8	120	1
12/25/19	8	1	8	8	120	1
1/1/20	12	3	8.5	7	120	1

Figure 1: This table shows the averages for test site one, the unnamed stream, from November 13, 2019 to January 1, 2020.

Date	DO (ppm)	Nitrates (ppm)	pH (logarithmic units)	Temperature (Celsius)	Transparency (cm)	Phosphates (ppm)
11/13/19	12	2	9.1	8	85	1
11/20/19	6	1	8.4	8	42	1
11/27/19	12	1	8.6	8	26	1
12/4/19	12	2	8	6	28	1
12/11/19	9	2	8.5	6	85	1
12/18/19	10	2	9	8	63	1
12/25/19	10	2	8.6	8	50	1
1/1/20	10	1.5	8.6	5	65	1

Figure 2: This table displays the averages for test site two, Lake Heritage, from November 13, 2019 to January 1, 2020.

Date	DO (ppm)	Nitrates (ppm)	pH (logarithmic units)	Temperature (Celsius)	Transparency (cm)	Phosphates (ppm)
11/13/19	6	1.5	8.5	4	120	1
11/20/19	8	1.5	8.7	8	65	1
11/27/19	12	2.5	8	9	65	1
12/4/19	10	2.5	8.6	9	68	1
12/11/19	10	1	8.3	6	96	1
12/18/19	10	1.5	8.7	8	75	1
12/25/19	10	3.5	8.3	7	76	1
1/1/20	12	3.5	9	6	120	1

Figure 3: This table shows the averages for test site three, Plum Run, from November 13, 2019 to January 1, 2020.

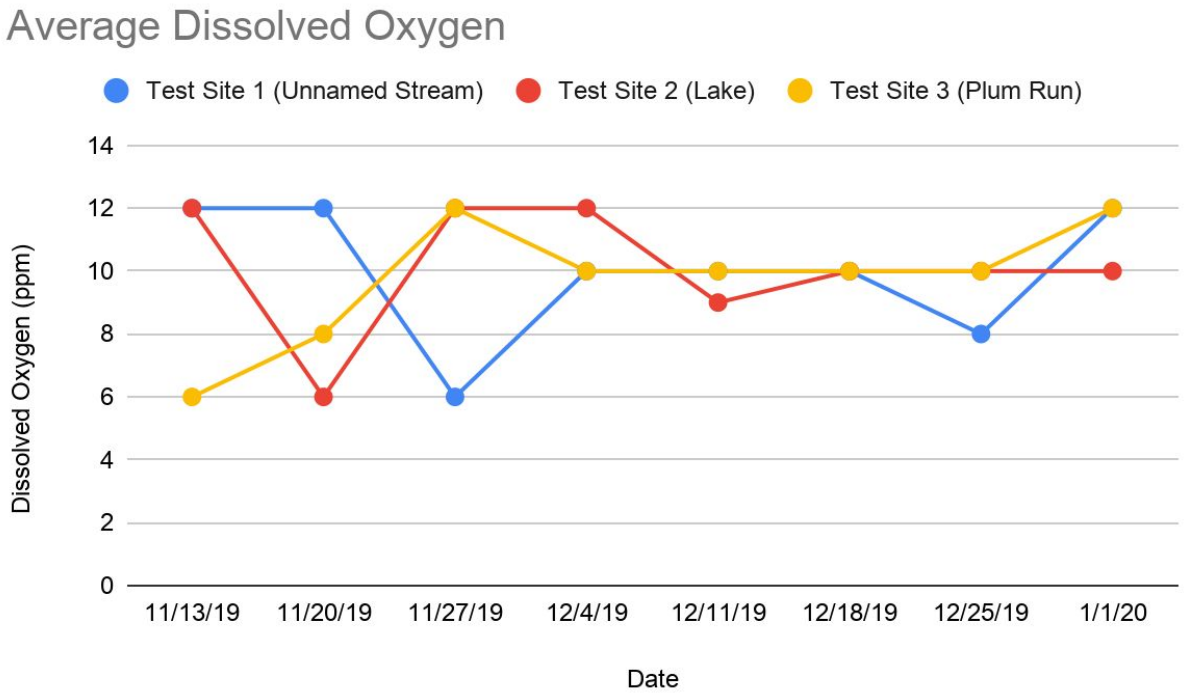


Figure 4: This graph displays the average dissolved oxygen levels for the eight weeks of testing. Two trends can be observed in the data. The levels of test site two, the lake, appear to fall in between the levels of test sites one and three. When this does not apply, the dissolved oxygen seems to fall closer to one test site or the other.

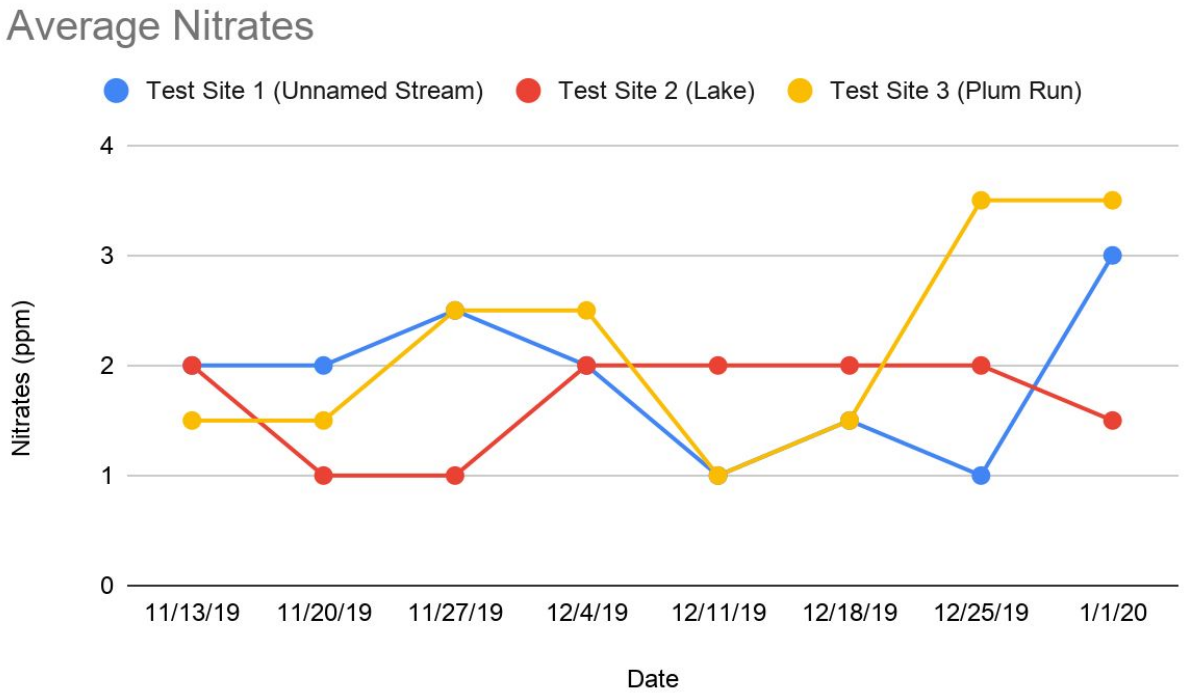


Figure 5: The nitrates data displayed similar trends to the dissolved oxygen. The prevalent trends appear to include the nitrates level of the lake falling in between the levels of the two tributaries or being closer to one tributary or the other.

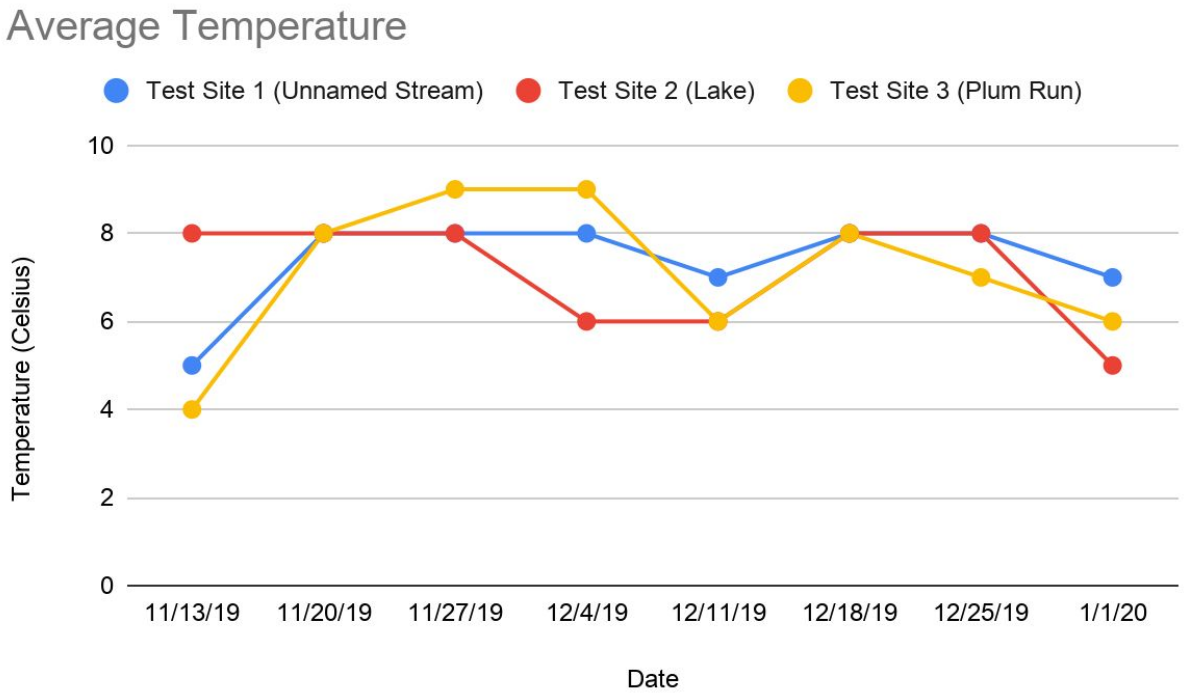


Figure 6: This graph shows the average temperature in Celsius of the three test sites.

Temperature is a vital variable that affects pH and dissolved oxygen inversely.

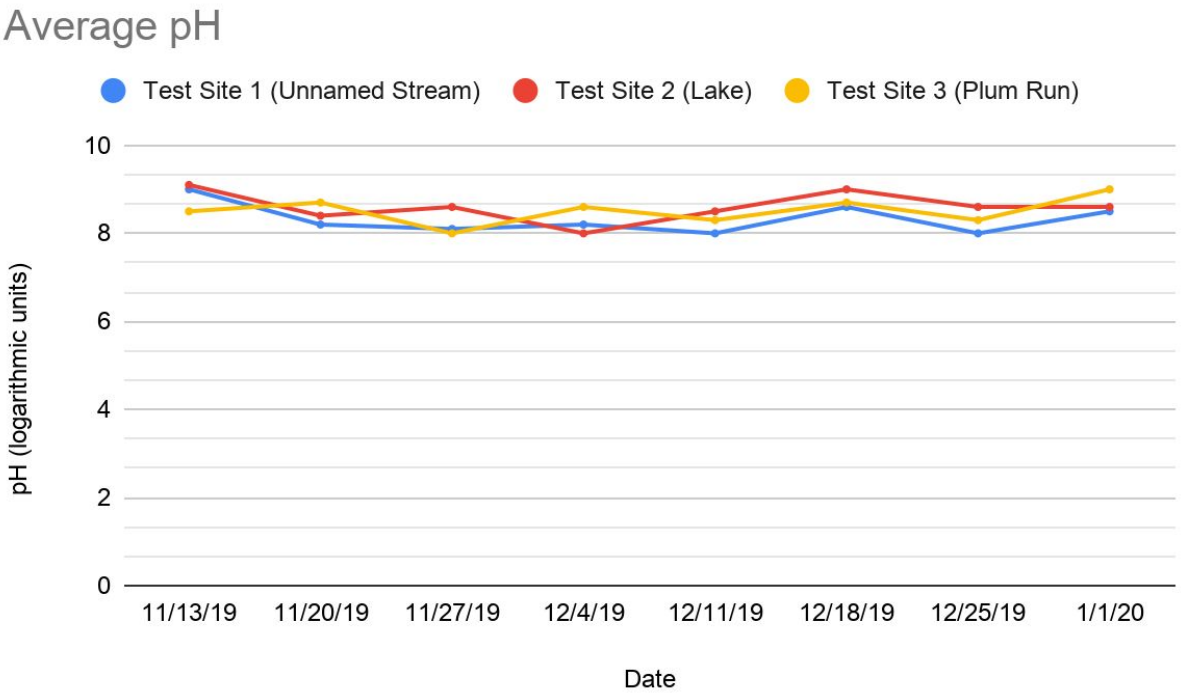


Figure 7: The pH of the three sites appears to follow the same trends as the nitrates and dissolved oxygen. The pH, however, seems to follow the patterns more consistently, with exception of November 27, 2019, when the lake pH was higher than both of the tributaries.

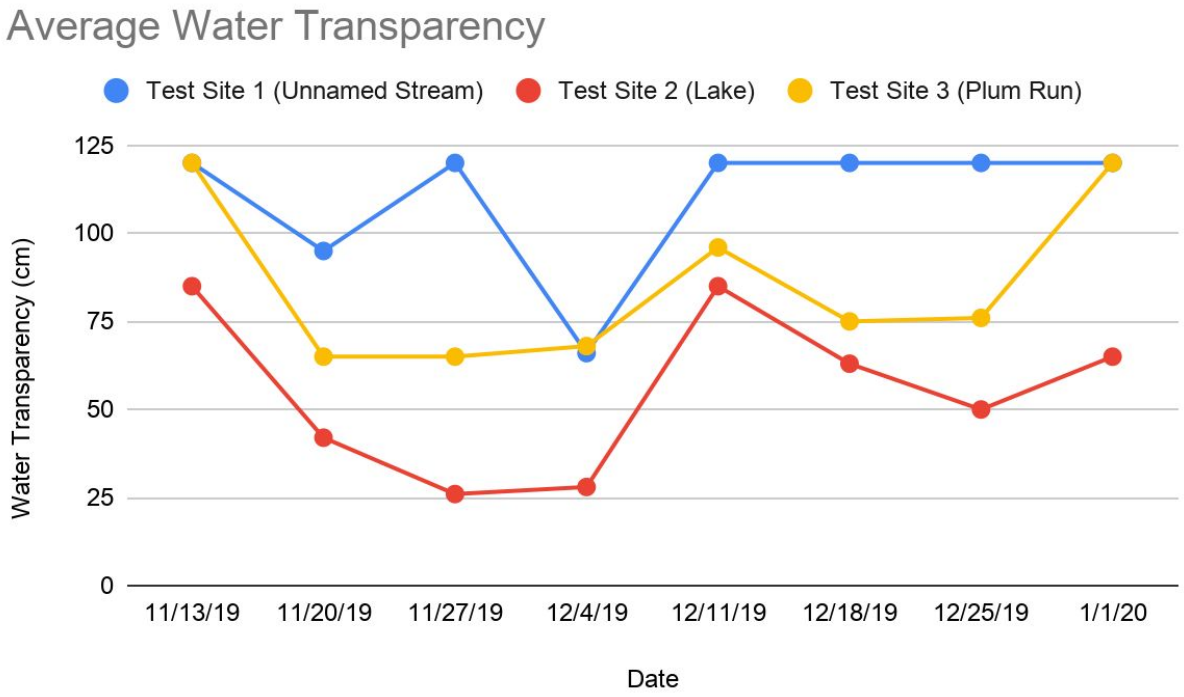


Figure 8: The transparency of test site two was consistently, drastically lower than both of the tributaries, but the levels were closer to test site three. This suggests that other water sources, such as direct runoff from the yards that surround the lake, have a large impact on the transparency of Lake Heritage. The higher the transparency, the better aquatic organisms can maneuver through the water. However, some suspended solids can provide organisms with better protection from predators. Levels closer to 120 cm are more optimal and the test site one was the clearest water most weeks, except weeks one and four, when test site three was close or the same as test site one.

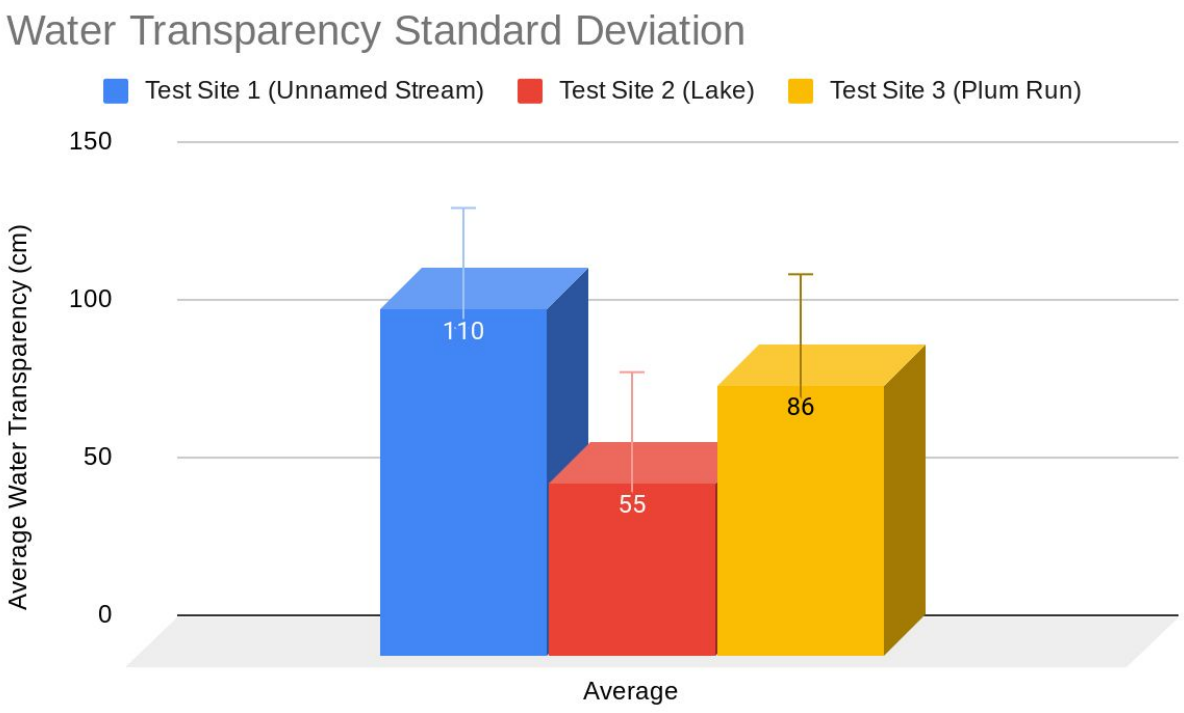


Figure 9: This graph displays the standard deviation for the water transparency data. The trials deviated 19 cm from the total average for test site one. Test site two and test site three deviated 22 cm. This means that the data over the eight weeks of testing varied greatly. This could be due to weather or other sources of sediment load.

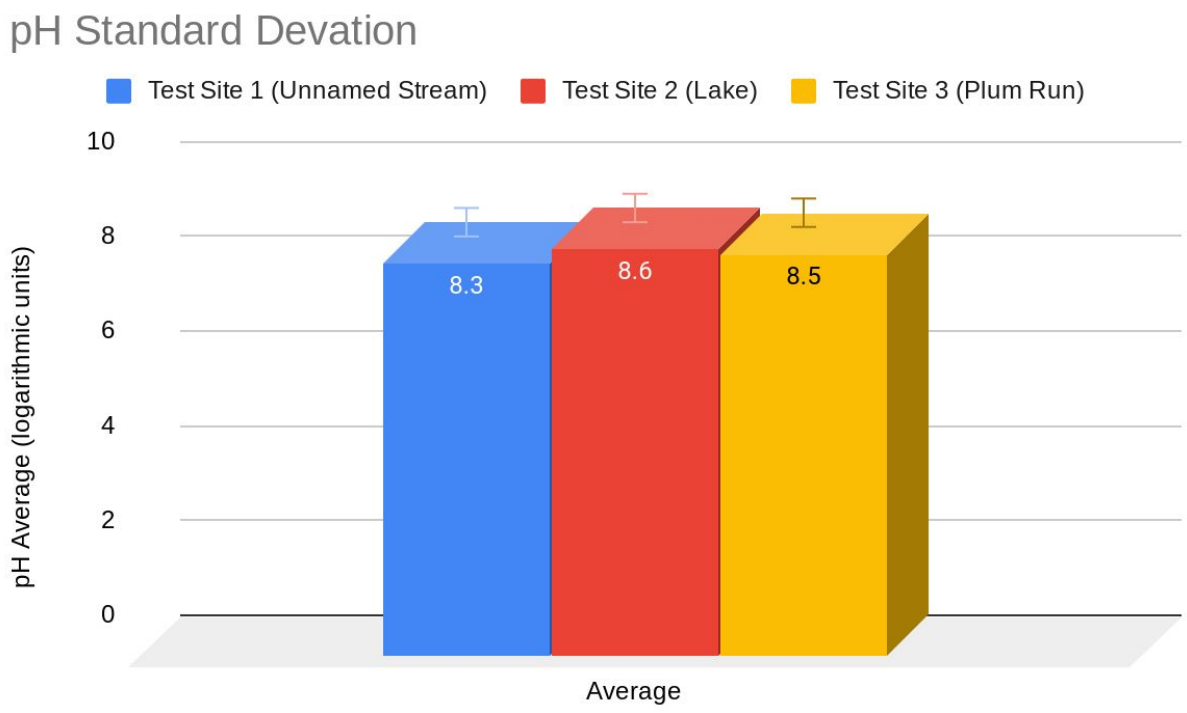


Figure 10: The standard deviation of the pH for all of the test sites is 0.3 units. The data did not deviate from the total average more than expected. It is normal for a standard deviation of this number because of the numerous factors that affect water quality, including season and weather.

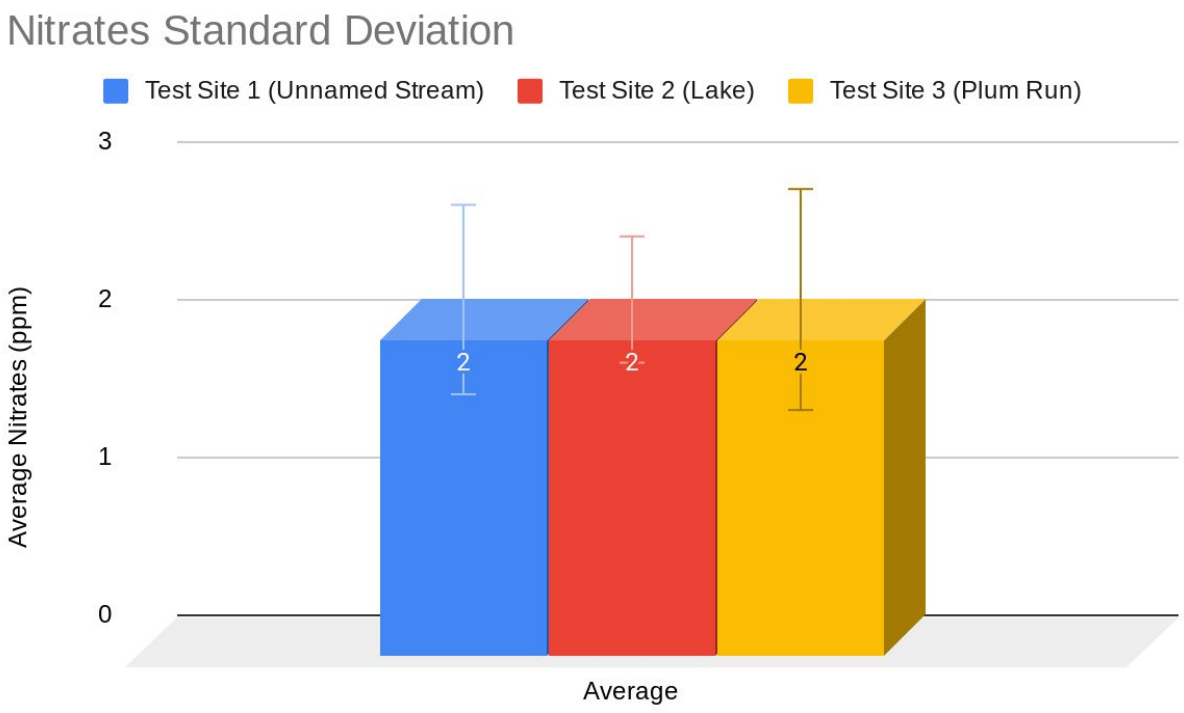


Figure 11: The nitrates data deviated 0.6 ppm for test site one, 0.4 ppm for test site two, and 0.7 ppm for test site three. This standard deviation slightly higher than expected. The sources of nitrates in a body of water come from fertilizer use, bacteria, and a variety of other sources. It is expected for deviation from the total average to occur because of the inconsistent contribution of nitrates from various sources.

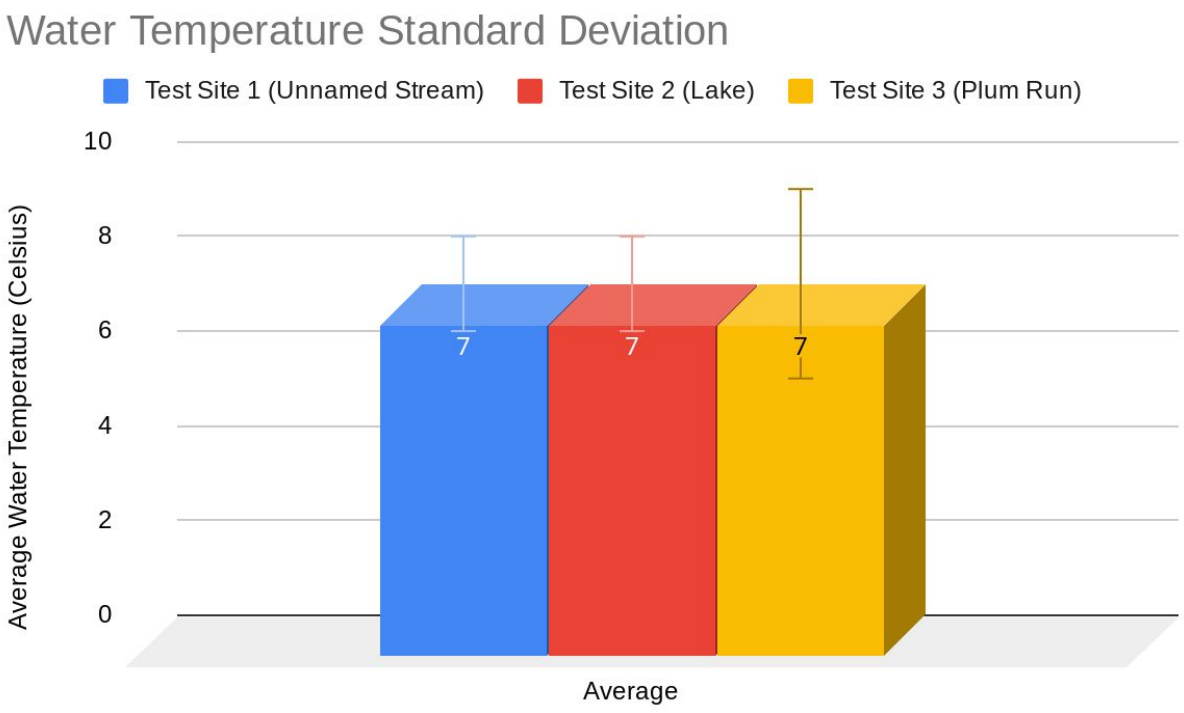


Figure 12: The standard deviation for the water temperature is as follows: test site one deviated one degree, test site two deviated one degree, and test site three deviated two degrees. This was anticipated because of the normal change in weather patterns.

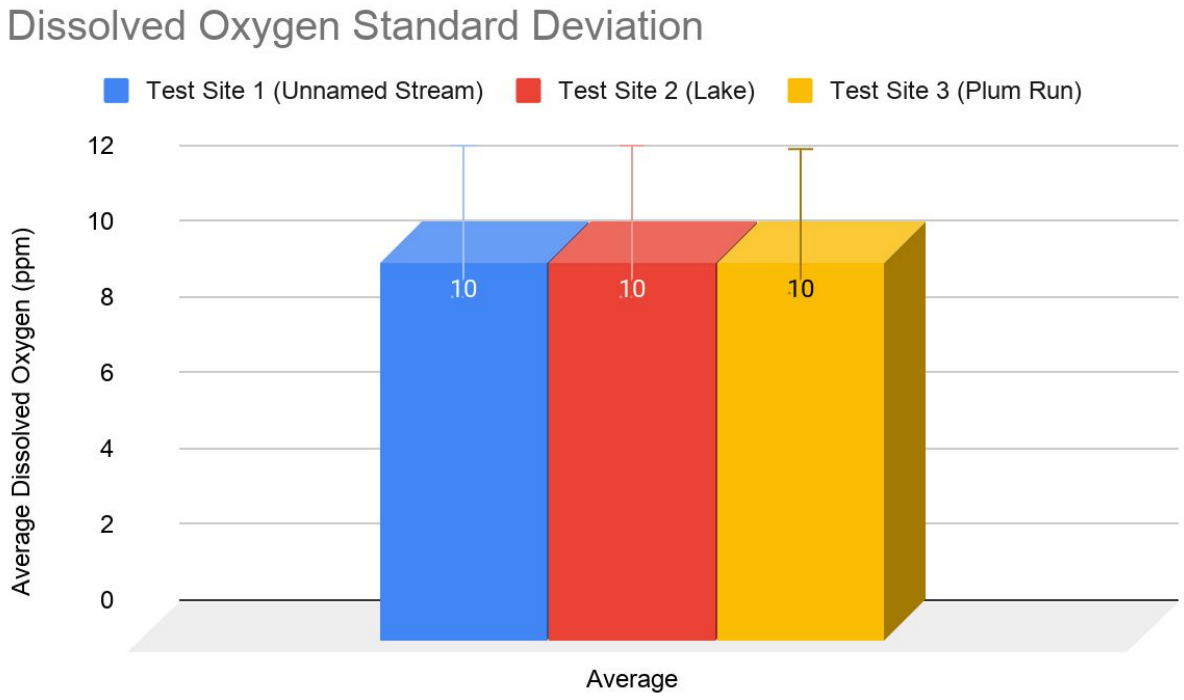


Figure 13: Dissolved oxygen deviated two ppm for all test sites. Overall, this is not a large standard deviation considering that dissolved oxygen fluctuates inversely with the water temperature.

Discussion

Two patterns were observed in the data: Lake Heritage data was in between the two tributaries or the lake data was closer to the levels of one tributaries. However, on some weeks, the Lake Heritage data was not near the levels of either tributary. On November 20, 2019, the dissolved oxygen of the lake was slightly lower than test site three, but drastically lower than test site one, illustrating the second pattern. Dissolved oxygen levels higher than six are the most optimal for higher biodiversity of aquatic life. The data does reflect this range. This is

unexpected because of the little amounts of life present in the lake and its tributaries. Neither pattern was exhibited in the nitrates on November 27 and December 11, 2019, when the data was not close to the tributaries. The nitrates of test site three, Plum Run, were typically higher or the same as test site one. The best range of nitrates in this type of ecosystem is less than 1 ppm. However, most organisms survive in higher concentrations, others thrive in it, such as algae. All of the data points are above this range, possibly due to the runoff from the farms and housing that surround the tributary streams and Lake Heritage. The water transparency of the lake was consistently the lowest and was closer to Plum Run than the unnamed tributary. The water temperature data for Lake Heritage typically was closer to one tributary, which changed each week. However, the temperature of the other tributary was still close to the lake and the tributary it followed. All three patterns were found in the pH data, on alternating weeks. The optimal range of pH in a freshwater environment is between six and eight units. The levels just barely touch the higher end of the spectrum on some dates, however, the data points are not much higher than the optimal range and would still support most aquatic forms of life. The phosphate data was consistently one ppm across all tributaries, much higher than the 0.1 ppm recommended level.

Data collected from November to January communicated that the data from Lake Heritage was in between the levels of the two tributaries or closer to the levels of one tributary. However, on some occasions, the lake data did not follow either tributary. The dissolved oxygen data, as shown in figure four, followed both trends. The lake data most commonly followed the trend of being closer to the levels of Plum Run. The data for all three locations was optimal for aquatic life, a surprising result considering the lack of organisms that live in the lake and its

tributaries. The nitrates data also followed both patterns, but did not follow either pattern on more than one occasion. However, on 11/13/19 and 12/4/19, the data was closer to the levels of test site one. On 12/25/19, the lake nitrates fell in between the two tributaries. Another important feature of the data was that the nitrates of Plum Run were significantly higher than the unnamed tributary. Although, the contribution of nitrates to the lake were not consistent. The temperature data displayed the typical fluctuations to be expected in a body of water, but the data also followed the two trends seen in other water quality parameters. The pH of the lake seemed to follow closely to both tributaries, except on few occasions when it fell in between or away from both tributaries. The water transparency data of the lake was the lowest every week. The transparency of Plum Run, test site three, was slightly above test site two. This suggests that Plum Run does contribute a significant amount of sediment to Lake Heritage, but other factors, including runoff and current, also greatly impacts the transparency. The unnamed stream was very clear, with the exception of 12/4/19, when the transparency dropped to 66 cm. This could be explained by the precipitation events that occured in the 24 hours before testing. The phosphates remained one ppm for each test site each week. The recommended level of phosphates is 0.1 ppm. A result of this nature could explain the expansive algae blooms in the summer months in Lake Heritage. The standard deviation for the water transparency deviated 19 cm, 22 cm, and 22 cm in test site order. This indicates that the individual trials deviated about 19 cm or 22 cm lower or higher than the average. A standard deviation of this number is not unexpected because of the various sources of sediment and conditions that impact sediment contribution. The pH deviated 0.3 units, which can be expected considering pH is inversely influenced by temperature. The nitrates data deviated 0.6 ppm for test site one, 0.4 ppm for test site two, and 0.7 ppm for test site

three. The variety of sources of nitrates and the inconsistent contributions of nutrients these sources provide could explain the standard deviation. The standard deviation for the water temperature is as follows: test site one deviated one degree, test site two deviated one degree, and test site three deviated two degrees. This was anticipated because of the normal change in weather patterns. The dissolved oxygen deviated two ppm for all test sites. Similar to the pH, dissolved oxygen is inversely affected by temperature, which accounts for the fluctuations in levels throughout the eight weeks of testing. The phosphates were consistently one ppm each week for all test sites. Therefore, the standard deviation was zero.

Conclusion

The experiment focused on determining which tributary contributed the most nutrient pollution and sediment load to Lake Heritage. The hypothesis states that the Plum Run tributary will contribute more nutrient pollution and sediment load to Lake Heritage than the unnamed tributary because Plum Run is surrounded by farmland and housing developments, both of which will contribute nutrients and sediment to the lake through runoff due to fertilizer use and erosion by pastureland. The data partially supported the hypothesis. Plum Run did display high nitrates levels, low transparency, and high phosphate levels throughout the eight weeks of data collection. However, the contribution of the tributary to Lake Heritage was not entirely consistent. On most occasions, the data did seem to be more influenced by Plum Run or equally influenced by both tributaries. The data followed both of the previously mentioned trends or was not close to either tributary, possibly due to precipitation events. The dissolved oxygen was within the optimal range for most aquatic organisms for all study sites, which decreases the possibility of it being the limiting factor for aquatic life. The pH was far above the high end of

the range optimal for most aquatic animals. However, it still would support many organisms. The temperature displayed the expected fluctuations dependent on the weather. The nitrates were high for each study site, but particularly site three, Plum Run. The phosphates were consistent at one ppm each week, 0.9 ppm higher than the recommended level. The combination of high nitrates and phosphates would fuel the large algae blooms that occur in the summer. The transparency was very low in the lake, slightly higher in Plum Run, and very clear in the unnamed stream. This falls in line with the pattern expected in the hypothesis. More data could provide more consistent and distinct trends in the water quality data. The standard deviation showed that the data deviated somewhat from the average, but not drastically more than expected.

During testing, possible areas of error in measuring the data include error in reading the data and malfunction of the equipment. Problems encountered in this experiment include flooding of the study site, learning how to use new materials, and data being unavailable because of the weather. This has been addressed by testing the equipment before logging down data and planning ahead of testing. If this experiment was repeated, data would be collected more often and longer to create a more detailed picture of the trends in the data.

This experiment is important to the community because it lets people know what is really going on in the local bodies of water. The quality of the lake impacts the community because if conditions worsen, it could make the lake completely unsuitable for life in the next few years. The few species that call Lake Heritage home could no longer be able to survive off of the limited resources the lake provides. To help improve the conditions of the lake, a

recommendation would be to add vegetated buffers along the perimeter of the public lake property and tributaries to soak up extra nutrients that would come into the lake through runoff.

The data from this experiment can be used to create a comprehensive plan to take action against nutrient pollution and sediment load. This could not only be used for Lake Heritage, but similar plans could be used for the Chesapeake Bay, which has a similar problem. Data needs to be collected throughout the watershed to try to see firsthand how the quality of upstream waters affect the entire watershed. With the Chesapeake Bay being such a "National Treasure," and laws being passed in New York and Pennsylvania, it is important for people not in direct contact with the bay to understand how individual actions influence the bay. It is certainly not, "Out of sight, out of mind," but that is what seems to have been happening these past decades. This idea also readily applies to the much smaller, but still important, habitat and watershed of Lake Heritage. The more studies there are on individual ecosystems, the better scientists can understand hydrology and other sciences as a whole.

Data will still continue to be sought out to further support the findings presented in this experiment. Data will be taken over the course of the school year to see how the trends change over the different seasons. Talking with experts like Emily Thorpe and other staff from the Chesapeake Bay Foundation, Mr. Joe Hallinan from our Adams County Watershed and those on the Lake Heritage board have helped tremendously with insight into the water quality issue.

Data Scientist

This experiment deeply analyzed the data collected, including comparison of the pH, DO, and water temperature, calculating the standard deviation, and many other techniques. All of the patterns evident in the data were pointed out, including the two aforementioned patterns and the

occasions when the Lake Heritage Data was collected. In the future, data could be collected from the Chesapeake Bay watershed to compare the effects of tributary health on the bodies of water. The limitations of the data were clearly identified, including the impact of precipitation events and malfunction of equipment.

Make an Impact

This experiment is a vital source for targeting the source of nutrient and sediment pollution in Lake Heritage, a local treasure. A comprehensive plan to remediate Lake Heritage can be made using the data from this project. This plan could also be a model for larger watersheds with the same problem, such as the Chesapeake Bay. This national treasure has been struggling with poor water quality for many years. The conclusions of this experiment can be presented to the board of Lake Heritage, who oversee the quality management of the lake.

STEM Professional

Several STEM professionals were consulted during the course of this experiment. Mr. Hallinan, an expert on Adams county water bodies, Mrs. Bird of Gettysburg College, Emily Thorpe and Cassie Fenn of the Chesapeake Bay Foundation, and Mrs. Gadow and Mrs. Woods, current and former science teachers were instrumental in the data collection, data analysis, and background research aspects of my project. Each of these STEM professionals were enlightening on new ways to take action on water quality, see beyond the obvious patterns in data, and inspirational role models in the environmental science field.

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I would like to thank my former and current science teachers, Mrs. Woods and Mrs. Gadow, for supporting me throughout the entire process and lending materials, my grandparents

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