The Upstream Effect

Keefer Stiles

GLOBE International Virtual Science Symposium

March 10, 2020

Table of Contents

Abstract 3

Research Question and Hypothesis 4

Introduction 5

Materials and Methods 13

Data 27

Results 41

Conclusion 43

Acknowledgements 46

Badges 47

References 49

Abstract

This experiment is designed to see if the water from Marsh Creek and Rock Creek (by testing at an unnamed tributary), is somehow polluting the Monocacy River. Marsh Creek and Rock Creek are the main contributors to the Monocacy River. The question, “How does the DO, temperature, transparency, pH, salt, and nitrates levels upstream affect the levels downstream?”, was asked, with The hypothesis stating that if the levels of dissolved oxygen, temperature, transparency, pH, salt, and nitrates at the upstream creeks are different levels than that of the downstream levels, then it will show that the two creeks contribute negatively to the southern river. This is because the creeks and streams are heavily shade, buffered by forests, roads and agricultural sources. The roads cross over or beside the creeks and rivers cause salt and pollution on the roads to flow into the rivers. The agricultural sources cause nutrient enrichment, like nitrates and phosphates, to flow into the rivers. There would be an indication of a source of pollution/sediment, flowing into the Monocacy River from Marsh Creek or Rock Creek (through unnamed tributary), by having similar results at the locations. CHEMets® Kits, Water Quality meters, a transparency tube, and other safety equipment were used during the experiments. The procedures were created by following GLOBE and the kits/instrument instructions. The data seemed to support the hypothesis, on a broader scale. The conclusion stated that Marsh Creek and Rock Creek do have an impact on the Monocacy River, but both a positive (ex. Dissolved Oxygen, Salt) and negative (Nitrates, Salt) impact. Since the Monocacy River is a contributor to the Chesapeake Bay and the Bay is struggling to become more healthy, restoration efforts are being implemented to improve the quality of the Chesapeake Bay and everywhere.

Keywords: Water Quality, Monocacy River, Marsh Creek, Rock Creek, Chesapeake Bay, Upstream-Downstream Effect.

The Upstream Effect

Research Question and Hypothesis

This experiment is designed to see if the water from Marsh Creek and Rock Creek (through unnamed tributary), is somehow polluting the Monocacy River, with sediment, or other pollutants. Marsh Creek and Rock Creek are the main contributors to the Monocacy River, and make up the majority of it. This experiment asks the question, “How does the DO, temperature, transparency, pH, salt, and nitrates levels upstream affect the levels downstream?” The independent variable for the experiment is the location of the testing sites (Unnamed Rock Creek Tributary, Marsh Creek, and the Monocacy River). The dependent variables are levels of dissolved oxygen (mg/L), temperature (C), transparency(cm), pH, salt (ppt), and nitrates (ppm). The controlled variables are the amount of time, the amount of testing water, amount of trials (3), the same spot of collection, the protocols followed, and the materials used. The hypothesis states that if the levels of dissolved oxygen, temperature, transparency, pH, salt, and nitrates at the upstream creeks are different levels than that of the downstream levels, then it will show that the two creeks contribute negatively to the southern river. This is because the creeks and streams are heavily shade, buffered by forests, roads and agricultural sources. The roads cross over or beside the creeks and rivers cause salt and pollution active on the roads to flow into the rivers. The agricultural sources cause nutrient enrichment, like nitrates and phosphates, to flow into the rivers. There would be an indication of a source of pollution/sediment, flowing into the

Monocacy River from Marsh Creek or Rock Creek (through unnamed tributary), by having similar results at the locations.

Introduction

Water is a molecule called H_2O that contains two atoms of hydrogen and 1 atom of oxygen. Water is generally a liquid that takes the form of the shape of a container. It can be a solid or a gas as well. When water is in liquid form, it is possible to mix substances, in which some substances dissolve. Water is a transparent, odorless liquid that can be found in lakes, rivers, and oceans. It falls from the sky as rain, snow, or ice. Fresh water is the result of the earth's water in the hydrologic cycle.

Water is important to human life and other organisms. The quality of water can have an effect on those humans and organisms (Lawrence, 2013). Water quality is a measure of the physical, chemical, biological, and microbiological characteristics of water. Why monitor water quality? Monitoring provides objective evidence necessary to make sound decisions on managing water quality. Results from a 27,000 groundwater investigation stated that more than half of the groundwater sites could contain corrosive water, as may occur in homes dependent on untreated water from private wells, because of low pH. Monitoring water quality in the 21st century is a growing challenge because of the large number of chemicals in everyday lives and that they can make it into the water (Meyer, 2018).

Natural water quality varies from place to place. Seasons, climate, and different types of soils and rocks through which the water moves, are all factors into why it varies. When water from rain or snow moves over the land, and goes into the ground, the water dissolves minerals in rocks and soils, filters through organic material such as roots and leaves, and reacts with algae, bacteria, and other microscopic organisms. Water carries debris, sand, silt, and clay to rivers and streams, making the water look muddy and adding sediment to the water body. Each of these natural processes change the water quality and potentially the water use. To determine water quality, scientists first measure and analyze the characteristics of the water such as temperature, dissolved mineral content, and the number of bacteria. All characteristics are tested by state guidelines to determine the use (Cordy, 2014).

Most common substances in water are common constituents, plant nutrients, and trace elements. Common constituents are not considered harmful to human health, but they can affect the taste, smell, or clarity of the water. Common constituents include calcium, sodium, bicarbonate, and chloride. Plant nutrients and trace elements in water are harmful to human health and aquatic life if they exceed standards or guidelines. Trace elements include selenium, chromium, and arsenic. Plant nutrients include nitrates and phosphorus. Nitrogen and phosphorus fertilizers that are applied to crops and lawns, can be easily dissolved in rainwater, but excess nutrients can be carried in streams and lakes causing an abundant growth of algae, which leads to less oxygen and dead organisms after the algae uses up all the excess nutrients. Adequate oxygen levels in water are a necessity for fish and other aquatic life. Urban and industrial development, farming, mining, combustion of fossil fuels, stream channeled alterations, animal feeding operations, and other human activities can change the quality of natural waters. There are so many chemicals used today that determining the risk to human health and aquatic life is a very complex task (Cordy, 2014).

The quality of water cannot be assured by chemical analysis alone. Disease-causing pathogens can enter the water from leaking septic tanks or out-of-date city-wide sewer systems

(Cordy, 2014). Efforts to improve water quality focus largely or reducing the amount of nutrients, sediments, and chemicals (CBF, 2019).

Chemical analysis, such as dissolved oxygen, salinity, pH, nitrates, and physical analysis, such as temperature and transparency are good ways to see the quality of testing sites. These are some of the most common tests for water quality. Dissolved oxygen is the amount of oxygen in the water. Salinity and pH affect the bio-community. Certain animals can not live in water that is too salty, or not enough, or water that is too acidic or alkaline. Nitrates can affect the health of a stream, causing algae blooms, but also provide a food source for animals. The temperature also affects the amount of biodiversity present in a stream or creek. The transparency helps to test how much sediment and other visible pollutants are present in the water.

Dissolved oxygen (DO) is the test of the amount of molecular oxygen (O_2) dissolved in water. It does not measure the amount of oxygen in the water molecule (H_2O). There is much more oxygen available in the atmosphere for animal respiration than in water. Cold water can dissolve more oxygen than warm water. For example, at 25°C, dissolved oxygen solubility is 8.3 mg/L, whereas at 4°C the solubility is 13.1 mg/L. Dissolved oxygen can be added to water by plants, during photosynthesis, through diffusion from the atmosphere, or by aeration. Aeration occurs when water is mixed with air, such as in waves, riffles, and waterfalls. Extra dissolved oxygen would then eventually be released back into the air or be removed through respiration of aquatic animals. DO changes due to seasonal differences in temperature, seasonal changes in the flow of the stream, changes in transparency, or changes in productivity (amount of growth of plants and animals in the water) will cause changes in dissolved oxygen levels. Saturated DO refers to the maximum oxygen that water can hold at a particular temperature, pressure and salinity. Oxygen solubility is dependent on temperature. It is therefore important to collect water temperature data along with dissolved oxygen data. ("Dissolved Oxygen Protocol," 2019). The amount of oxygen water can hold depends upon temperature (more oxygen can be dissolved in colder water), pressure (more oxygen can be dissolved in water at greater pressure), and salinity (more oxygen can be dissolved in water of lower salinity) (Blanchfield, 2011).

Salt comes from eroded rocks and has a big impact on the water quality and biodiversity, just like dissolved oxygen. Rainwater carries salt and minerals to the rivers and streams which carry them to the ocean (Leslie, 2015). When water warms up, it holds less oxygen. The sun's heat evaporates the water but not the salt. When it is cool, there is plenty of oxygen and a low amount of salt. When it is warm, there is less oxygen and more salt (Bredeson, 1999). This is due to the fact that when the sun warms the water, the oxygen molecules go up with the evaporated water but the salt does not. In water, salt grains fall apart until they are so small that they are unseen among the water molecules (Richards, 2008). This is important to the research because if the temp is high, the observer can inference what the result of the DO and salt are. Following the record-breaking snowfall in 2014, many states remedied icy road conditions with greater amounts of road salt. According to a report, done by the USGS National Water Quality Assessment Program, since salt was introduced as a deicing agent, the application of salt has increased dramatically. While sodium chloride improves roads and road conditions by effectively melting ice, these salts are also ending up in streams and rivers. Studies have shown the increasing saltiness of freshwater sources, also known as salinization. Water dissolves lots of sediment and it also breaks salt rocks. If salt levels rise above their recommended level, the DO will drop, causing more algae and less fish (Stroud Center, 2014). Road salt does not just disappear when the snow and ice melts. Researchers in Minnesota found that 70% of the road salt stays within the region's watershed. Road salt washes into the creek, rivers, streams, and lakes, and seeps into the groundwater supply (Rastogi, 2010).

Temperature influences the amount and diversity of aquatic life. Lakes that are cold and have little plant life in winter, bloom in spring and summer when water temperatures rise and the nutrient-rich bottom waters mix with the upper waters. Because of this mixing and the warmer water temperatures, the spring overturn is followed by a period of rapid growth of microscopic aquatic plants and animals. Many fish and other aquatic animals also spawn at this time of year when the temperatures rise and food is abundant. Shallow lakes are an exception to this cycle, as they mix throughout the year. Temperature is an easy measurement to make. It is, however, very important because it allows scientists to better understand other measurements in the hydrosphere investigation such as dissolved oxygen, pH and conductivity. Water temperature is important for understanding local and global weather patterns as well (Water Temperature Protocol, 2019)

How clear is the water? This is an important question for everyone who drinks water. It is an even more important question for the plants and animals that live in the water. Suspended particles in water behave similarly to dust in the atmosphere. They reduce the depth to which light can penetrate. Sunlight provides the energy for photosynthesis (the process by which plants grow by taking up carbon, nitrogen, phosphorus and other nutrients, and releasing oxygen). How deeply light penetrates into a water body determines the depth to which aquatic plants can grow. Sediments can come from natural and human sources. Land with little vegetative cover (such as agricultural land and deforested land) can be major sources of sediments. Water transparency depends on how many particles are in the water. The more sediment and particles in the water, it lessens the ability to see how clear the water is. If water is filled with particles and sediment, and the body of water is a source for drinking water, more particles could pass through, hurting humans, but also potentially blocking animals abilities to see and find food (Transparency Protocol, 2020).

pH is a measure of how acidic or basic something is. pH is really a measure of the relative amount of free hydrogen and hydroxide ions in the water. The pH determines the solubility (amount that can be dissolved in the water), and biological availability (amount that can be used by aquatic life) of chemical constituents such as nutrients (phosphorus, nitrogen, and carbon). pH is a number used to determine the amount of hydrogen ions in a solution (Perlman, 2018). pH stands for "potential hydrogen." A pH below 7 is acidic and above 7 is basic. The scale is 0 to 14. Pure water is neither so it has a pH of 7. pH is either measured with an electric pH meter or special dyes known as acidic-base indicators (World Book INC (P), 353). It is important to test the water for pH to make sure that the water is not too acidic or too basic for humans and organisms that use it. This is because if humans and organisms drink water that is too acidic, that would be like drinking battery acid (which could be fatal). If someone drinks water that is too alkaline, that would be like drinking bleach (which could also be fatal). Drinking water should be around the pH level of 7-8. Excessively high and low pHs can be detrimental to whatever is using that water. High pH can cause a bitter taste, water pipes, and water-using appliances become encrusted with deposits and depresses the effectiveness of the chlorine, thereby causing the use of more chlorine when pH is higher. Low pH water will corrode or dissolve metals and other substances (Perlman, 2018).

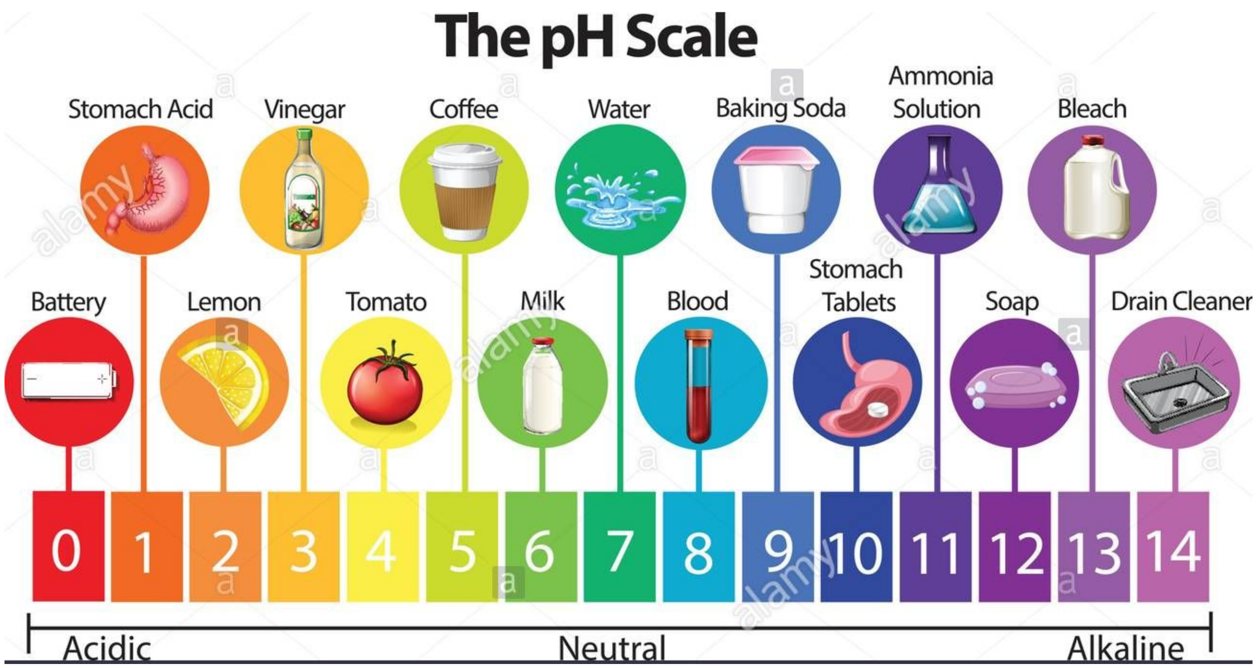


Image 1: This shows pH scale of 0-14. It gives examples of each number in physical examples. (Cole).

Nitrate is a compound that contains the inorganic nitrate ion. Nitrates naturally exist within the environment at relatively low levels (TestAssured, 2016). There are two important kinds of nitrates, potassium and ammonium nitrates. Most people get nitrates from vegetables (World Book INC (N), 125). This is important because the amount of nitrates in the water increases the amount of sediment and vegetation getting into drinking water sources. Increased levels of nitrates can cause serious health issues, especially for pregnant women and children. The level of recommended nitrate is 10 ppm. High levels of nitrates can impact hemoglobin levels in blood. Hemoglobin transports oxygen from one cell to another cell. Excessive levels change Hemoglobin into methemoglobin, which reduces the blood's ability to transfer oxygen throughout the body. The human body normally contains 2.5% of methemoglobin, but that rate is increased when nitrates are present. Nitrate water contamination is particularly dangerous for pregnant women because pregnancy increases levels of methemoglobin. Babies are also highly vulnerable to this type of water contamination because they have exceptionally high pH levels in their stomachs. Infants under six months old who drink contaminated water can become dangerously ill and, if untreated, may die (TestAssured, 2016). Although nitrates do impose threats to humans and to animals, nitrates can also produce a food source for animals. Nitrates can produce algae blooms, destroying dissolved oxygen, but also providing a food source for many animals. It can also help to block the sun and keep the temperature of bodies of water cooler.

Marsh Creek is a 77 square-mile watershed. It is used for fishing and is a water source for drinking water, for the Gettysburg Municipal Authority. It starts near South Mountain and Michaux State Forest. Marsh Creek is rated a CWF - Cold Water Fishes (fish maintenance and propagation, or both, of fish species including the family Salmonide and additional flora and fauna which are indigenous to a cold water habitat) and a MF - Migratory Fish (Passage, maintenance and propagation of anadromous and catadromous fish and other fish which moves to or from flowing waters to complete their cycle in other waters)(Hallinan, 2018).

With Marsh Creek, Rock Creek becomes the Monocacy River, which then drains to the Potomac River and finally to the Chesapeake Bay. Rock Creek has issues consisting of improper herbicide application, old farm and household dump, non-migratory geese population, groundwater pumping by Valley Quarry, and more (WAAC, 2019). Rock Creek can be used for fishing, but is not used for many other recreational purposes.

The Monocacy River begins near the Pennsylvania border and flows through Maryland into the Potomac River, and eventually into the Chesapeake Bay. The Monocacy is a recreational river, where people can fish, canoe, swim, and a water source, in certain parts of the river. It provides a drinking source for many of the Maryland counties. Sycamores, maples, and oaks, line the water, shading the waterway seasonally. More than 970 square miles, of agricultural and developed lands, also border the river. These land practices have been negatively affecting the quality and quantity of the water flowing downstream. In 1974, Maryland designated the Monocacy River a state scenic river. By doing this, a management plan was developed to guide future restoration and protection efforts. As a result of the highetend awareness, the initiation of conservation projects was founded (Chesapeake Bay Gateway Networks, 2019). One reason the Monocacy River was designated to be a Maryland scenic river, was to improve its water quality (Gilford, 1990).

Within the Chesapeake Bay itself, blooms of algae have been devastating portions of the bay's ecosystem. However, through years of expensive rehabilitation and conservation, it has begun to show improvements, by implementing jurisdiction on the Total Maximum Daily Load of sediments and nutrients entering the water (Hogan, 2018). The Chesapeake Bay provides a huge economic profit to those who seek it. Destruction of oyster beds, algae blooms, and other devastating negative effects on the economic value of the bay. These negative effects also destroy the cleanliness of the water, which is a vital source of food and of drinking water for many. The water quality of the Chesapeake Bay is deteriorating, mostly due to pollution being brought down from Pennsylvania. The Chesapeake is valuable and needs to be saved. (Moran, 2020). The community all wants clean water, it is imperative that the primary cause of the problem be identified in order for the problem to be solved. It is acknowledged that expanding forest buffers along a waterway has been documented to mitigate runoff. (Kaplan, 2018).

Materials and Methods

- Dissolved Oxygen Kit - CHEMets® Kits (K-7512)
    - 1 25mL Sample Cup
    - 30 CHEMet Self-Filling Ampoules (R-7512)
    - 1 Comparator of DO levels from 1-12ppm
- Nitrate Kit - CHEMets® Kits (K-6902)
    - 1 25mL Sample Cup
    - 1 Sample Cup Top
    - 30 CHEMets Self-Filling Ampoules (R-6902)
    - 30 Cadmium Foil Packets (A-6900, R-6902)
    - 1 Comparator of Nitrate levels from 0-1ppm
    - 1 Comparator of Nitrate levels from 1-5ppm
- Salt/Temperature Meter - AZ Water Quality Meter
    - Conductivity/TDS/Salinity/Temperature Pen Type
        - Salinity Pen (8372)
- pH Meter - HANNA Instruments
    - pH/EC/TDS Waterproof Meter
        - Combo pH & EC
- Transparency Tube - GLOBE Instrument Construction Transparency Tube
    - Transparency Tube
        - 1 Clear tube (approximately 4.5cm x 120cm)
        - 1 PVC Cap (to fit snugly over one end of the tube)

        - 1 Meter Tape (that measures to about 125cm)
        - Packing Tape
        - 1 Permanent, waterproof black marker
    - 1 7L Pitcher
- Hydrospheric Investigation Data Sheets
- Logbook
- 1 Pair of Safety Glasses
- 1 Box of Gloves
- Distilled Water and Dispenser
- Means of Transportation
- Pen
- iPhone and iPad

Dissolved Oxygen - Procedures (as per GLOBE protocols)

1. Fill in the top of the Hydrosphere Investigation Data Sheet.
2. Rinse the sample bottle and the observer's hands with sample water three times.
3. Fill the sample cup to the 25mL mark with your sample.
4. Place the CHEMet ampoule in the sample cup.
5. Snap the tip by pressing the ampoule against the side of the cup. (The ampoule will fill, leaving a small bubble to facilitate mixing).
6. Remove the ampoule from the sample cup.
7. Mix the contents of the ampoule by inverting it several times, allowing the bubble to travel from end to end each time.

8. Wipe all liquid from the exterior of the ampoule.
9. Wait 2-minutes for color development.
10. Hold the comparator in a nearly horizontal position while standing directly beneath a bright source of light.
11. Place the CHEMets ampoule between the color standards, moving it left to right, along the comparator until the best color match is found.
12. If the color of the CHEMets ampoule is between two color standards, a concentration estimate can be made.
13. Record the dissolved oxygen in the observer's water sample on the Data Sheet as Test 1.
14. Repeat step 3-13, 2 more times and mark as test 2 and 3. Repeat the measurement using a new water sample each time.
15. Calculate the average of the three measurements.
16. Each of the five measurements should be within 1 mg/L of the average. If one of the measurements is not within 1 mg/L of the average, find the average of the other two measurements. If both of these measurements are within 1 mg/L of the new average, record this average

Nitrates - Procedures (as per GLOBE protocols)

1. Fill out the top portion of the Hydrosphere Investigation Data Sheet. In the Nitrate 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 mg/L) unless previous results indicate that the site typically has greater than 1

mg/L nitrate nitrogen. If using powdered reagents, use the surgical mask when opening these products. Use a clock or watch to measure the time if the kit requires to shake sample.

4. Fill the sample cup to the 15mL mark with the sample.
5. Empty the contents of one A-6900 (R-6902) Cadmium Foil Packet into the sample cup.
6. Cap the sample cup.
7. Shake vigorously for exactly 3-minutes.
8. Allow the sample to sit undisturbed for 30 seconds.
9. Take off the cap of the sample cup.
10. Place the CHEMets ampoule in the sample cup.
11. Snap the tip by pressing the ampoule against the side of the cup.
12. The ampoule will fill, leaving a small bubble to facilitate mixing.
13. Mix the contents of the ampoule by inverting it several times, allowing the bubble to travel from end to end each time.
14. Wipe all liquid from the exterior of the ampoule.
15. Wait 10 minutes for the color development.
16. Use the appropriate comparator to determine the level of nitrate-nitrogen (NO_3-N) in the sample.
17. If the color of the CHEMet ampoule is between two color standards, a concentration estimate can be made.
18. Hold the high range comparator in a nearly horizontal position while standing directly beneath a bright source of light.

19. Place the CHEMet ampoule between the color standards, moving it left and right, along the comparator until the best color match is found.
20. Repeat steps 4-19, two more times.
21. Record all three nitrate-nitrogen values on the Data Sheet.
22. Calculate the average of the three measurements.
23. Check to see if each of the three measurements is 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 (Note: do not read again if it has been more than 5 minutes).
24. Calculate a new average. If the measurements are still not within range, discuss possible problems with the teacher.

Water Temperature - Procedures (as per GLOBE protocols)

1. Make sure that the temperature probe and meter have been calibrated within the last 24 hours.
2. Fill out the top portion of the Hydrosphere Investigation Data Sheet.
3. Put the probe into the sample water to a depth of 10 cm.
4. Leave the probe in the water for three minutes.
5. Read the temperature on the meter without removing the probe from the water.
6. Let the thermometer probe stay in the water sample for one more minute.
7. Read the temperature again. If the temperature has not changed, go to Step 8. If the temperature has changed since the last reading, repeat Step 6 until the temperature stays the same.

8. Record the temperature on the Hydrosphere Investigation Data Sheet.
9. Repeat the measurement with new water samples.
10. Calculate the average of the three measurements.
11. All temperatures should be within 1.0˚ C of the average. If they are not, repeat the measurement.

Water Transparency - Procedures (as per GLOBE protocols)

1. Fill in the top portion of the Hydrosphere Investigation Data Sheet.
2. Record the cloud and contrail types and cover.
3. Put on gloves.
4. Collect a surface water sample.
5. Stand with your back to 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 your eye close to the tube opening. Stop adding water when the pattern at the bottom of the tube is no longer visible.
7. Rotate the tube slowly as the observer looks to make sure the pattern cannot be seen.
8. Record the depth of water in the tube on the Hydrosphere Investigation Data Sheet to the nearest cm. Note: If can still see the disk on the bottom of the tube 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 with different observers using the same sample water.

pH - Procedures (as per GLOBE protocols)

1. Fill in the top portion of the Hydrosphere Investigation Data Sheet. Check the pH meter as the instrument.
2. Put on the latex gloves.
3. Remove the cap from the meter that covers the electrode (the glass bulb on the pH meter).
4. Calibrate the pH meter according to the manufacturer's directions.
5. Press the power button on the pH meter.
6. Place the meter in the water.
7. Read the pH level off the meter.
8. Record the pH value on the Data Sheet under Observer 1.
9. Repeat steps 4-6 twice using new water samples. The observer does NOT need to calibrate the pH meter again. Record conductivity and pH values on Data Sheet as trial 2 and 3.
10. Check to see if each of the three observations are within 0.2 of the average. If all three are within 0.2, record the average on the Data Sheet. If all three observations are not within 0.2, repeat the measurements.
11. Calculate the average of the three observations and record on the Data Sheet.
12. Turn off the meter. Put on the cap.
13. If the observer cannot get all three measurements within 0.2 of one another, talk to the teacher about possible problems.

Salt - Procedures (as per GLOBE protocols)

1. Fill out the top portion of the Hydrosphere Investigation Data Sheet.
2. Press the “Set” button to turn on the meter.
3. Dip the meter into the water.
4. Wait 1-minute for the meter to finish calibrating.
5. Record the results down on the Hydrosphere Investigation Data Sheets.
6. Calculate the average of the three measurements
7. Each of the three measurements should be within 2 ppt of the average. If one or more of the observations is not within 2.0 ppt, do the measurement again and calculate a new average. If the measurements are still not within 2.0 ppt of the new average, talk to the observer’s teacher about possible problems.

Directions to Unnamed Rock Creek Tributary

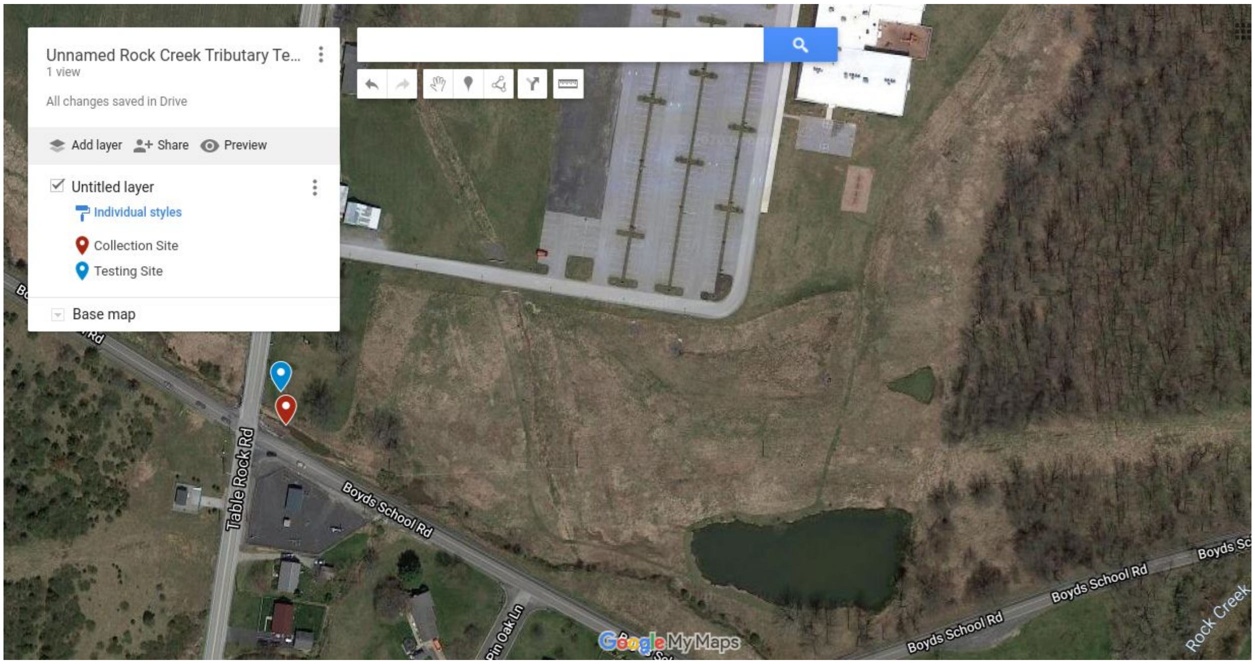
1. Head northeast on Highland Ave toward King St - (0.64km)
2. Turn left onto Johns Ave - (75m)
3. Turn left onto S Washington St - (0.32km)
4. Turn right onto South St - (0.16km)
5. Turn left onto Baltimore St - (0.48km)
6. At the traffic circle, continue straight onto PA-34 N/Carlisle St/Lincoln Square
7. Continue to follow PA-34 N - (1.77km)
8. Slight right onto Table Rock Rd - (1.44km)
9. Destination will be on the right

Directions to Marsh Creek (@Sachs Covered Bridge) (from Unnamed Rock Creek Tributary Site)

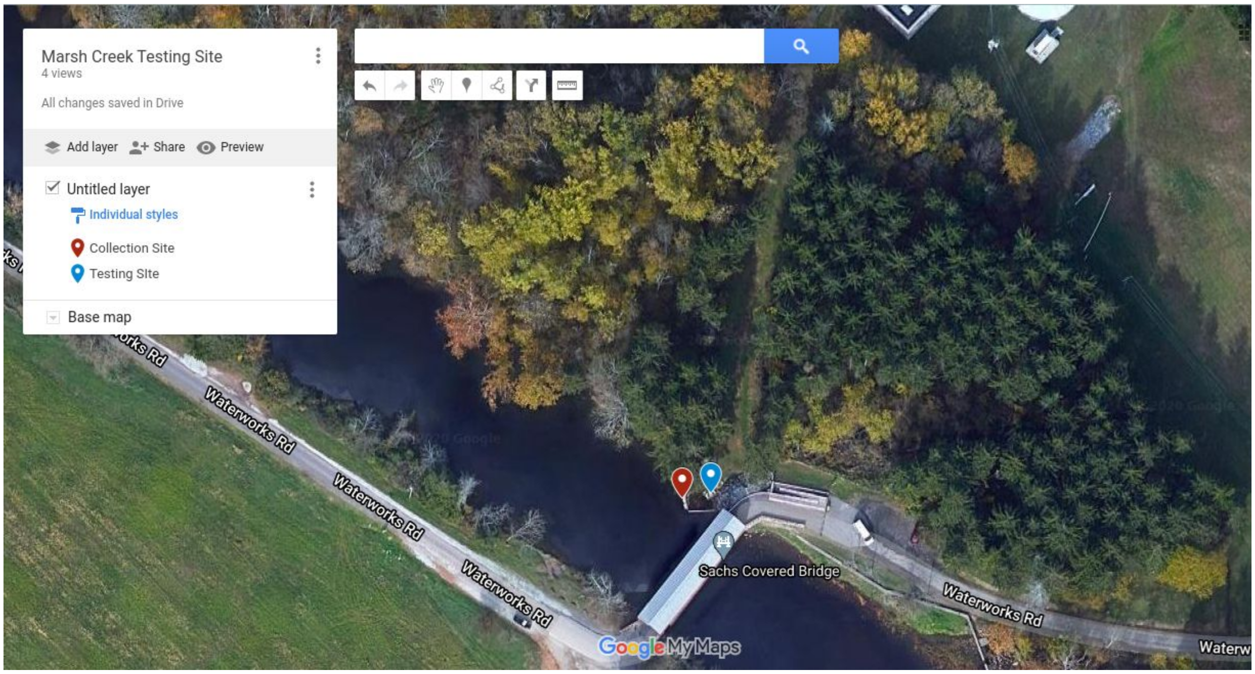
1. Head south on Table Rock Rd toward Boyds School Rd - (1.44km)
2. Slight left onto PA-34 S - (1.77km)
3. Pass by Subway - (1.6km)
4. At the traffic circle, continue straight onto Baltimore St/Lincoln Square
5. Continue to follow Baltimore St. - (0.8km)
6. Slight right onto US-15 BUS S/Steinwehr Ave - (3.05km)
7. Continue to follow US-15 BUS S
8. Pass by Friendly's - (0.8km)
9. Turn right onto Millerstown Rd - (1.44km)
10. Continue onto Pumping Station Rd - (0.32km)
11. Turn left onto Roberta Way - (0.32km)
12. Turn right onto Waterworks Rd - (0.48km)

Directions to Monocacy River (from Marsh Creek Site)

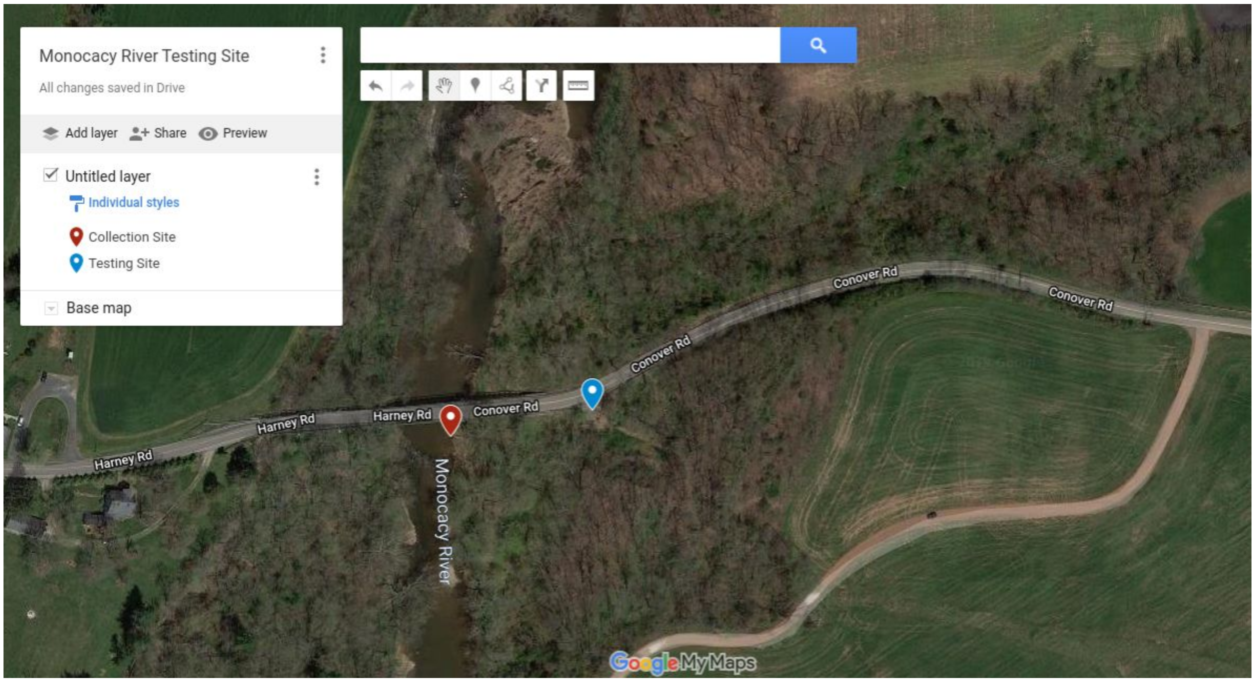
1. Head east on Waterworks Rd toward Roberta Way - (0.48km)
2. Turn left onto Roberta Way - (0.32km)
3. Turn right onto Pumping Station Rd - (0.32km)
4. Continue onto Millerstown Rd - (1.44km)
5. Continue onto Wheatfield Rd - (1.93km)
6. Turn right onto PA-134 S - (9.65km)
7. Entering Maryland
8. Turn right onto Conover Rd - (0.8km)



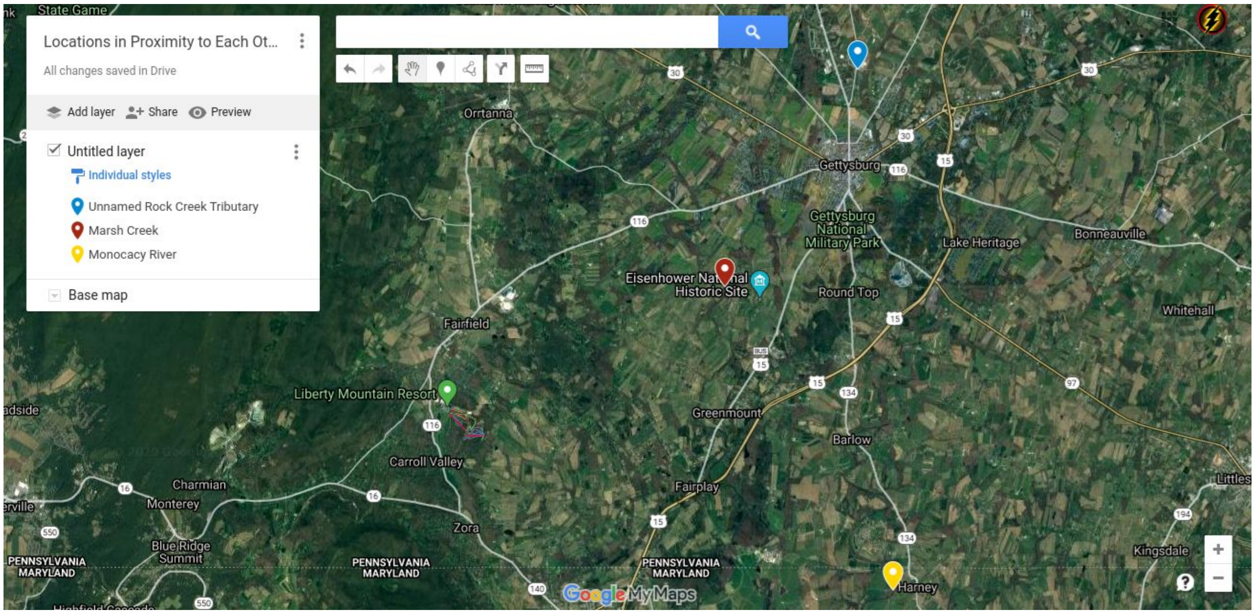
Map 1: This Google Map shows the collection and testing sites at the Unnamed Rock Creek Tributary Testing Site, which is near the St. Francis Xavier Catholic School. This is not Rock Creek, however it is an accessible site for collection that is close to Rock Creek. Rock Creek can be found southeast of the testing site (about 25m). There are some remnants of the styrofoam board that was used to form and expand the bridge near the testing site.



Map 2: This Google Map shows the collection and testing sites at the Marsh Creek Testing Site, which is near Sachs Covered Bridge, the Gettysburg Municipal Authority's water treatment facility, and the new Gettysburg Nature Alliance Environmental Education barn. This area is clean and blooming with wildlife and agriculture.



Map 3: This Google Map shows the collection and testing sites at the Monocacy River Testing Site, which is near the town of Harney. There is a little inlet for a parking spot to hike downhill to the shore of the river. This area is heavily polluted and littered with trash.



Map 4: This Google Map shows the locations of each of the testing sites in proximity to each other.

<u>Unnamed Rock Creek Tributary:</u> There are some remnants of the styrofoam board that was used to form and expand the bridge near the testing site.

<u>Marsh Creek:</u> This area is clean and blooming with wildlife and agriculture.

<u>Monocacy River:</u> This area is heavily polluted and littered with trash.

Data

Unnamed Rock Creek Tributary	Dissolve Oxygen (mg/L)	Salt (ppt)	pH	Nitrate (ppm)	Temperature (C)	Transparency (cm)
Week 1 (12/8/19)	7	0.1	7.8	0.3	5.5	96
Week 2 (12/22/19)	7	0.1	8.3	0.7	2.3	89
Week 3 (12/28/19)	8	0.1	8.3	0.5	4.1	118
Week 4 (1/12/20)	10	0.1	8.1	0.2	11.5	63
Week 5 (1/19/20)	6	0.2	8.7	0.5	4.2	75
Week 6 (1/26/20)	6	0.1	8.1	0.5	7.3	95
Week 7 (2/2/20)	8	0.1	8.1	0.3	7.9	120
Week 8 (2/9/20)	8	0.1	8.8	0.2	6.6	120

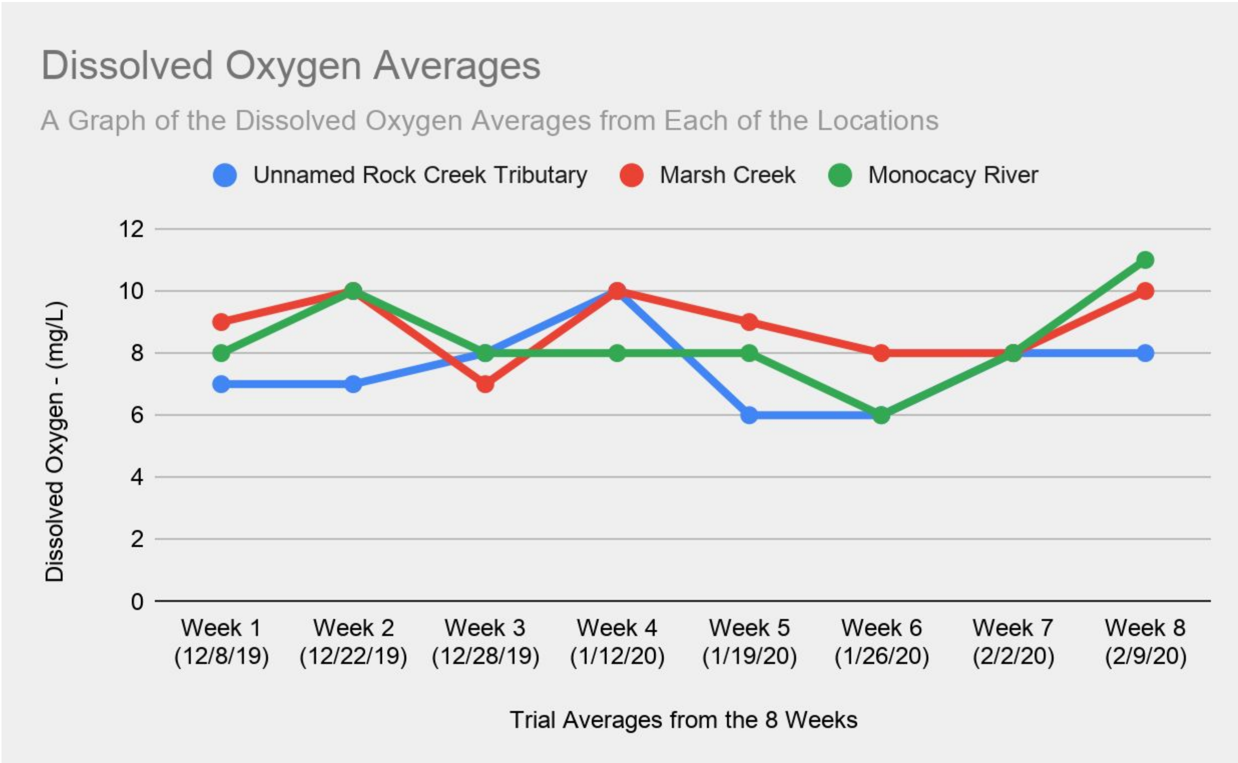
Table 1: This table shows the averages of each of the water quality tests at the Rock Creek testing site, from the eight weeks. The majority of the averages do not fall into the recommended levels, as per GLOBE. Most of the averages changed from week to week.

Marsh Creek	Dissolve Oxygen (mg/L)	Salt (ppt)	pH	Nitrate (ppm)	Temperature (C)	Transparency (cm)
Week 1 (12/8/19)	9	0	7.5	0	5.4	120
Week 2 (12/22/19)	10	0	7.7	0.3	2.2	115
Week 3 (12/28/19)	7	0	8.2	0	3.9	120
Week 4 (1/12/20)	10	0	7.8	0	11.6	19
Week 5 (1/19/20)	9	0	7.7	0.2	1	120
Week 6 (1/26/20)	8	0	8.1	0.2	5.3	120
Week 7 (2/2/20)	8	0	8.1	0	5.2	120
Week 8 (2/9/20)	10	0	7.8	0	5.4	120

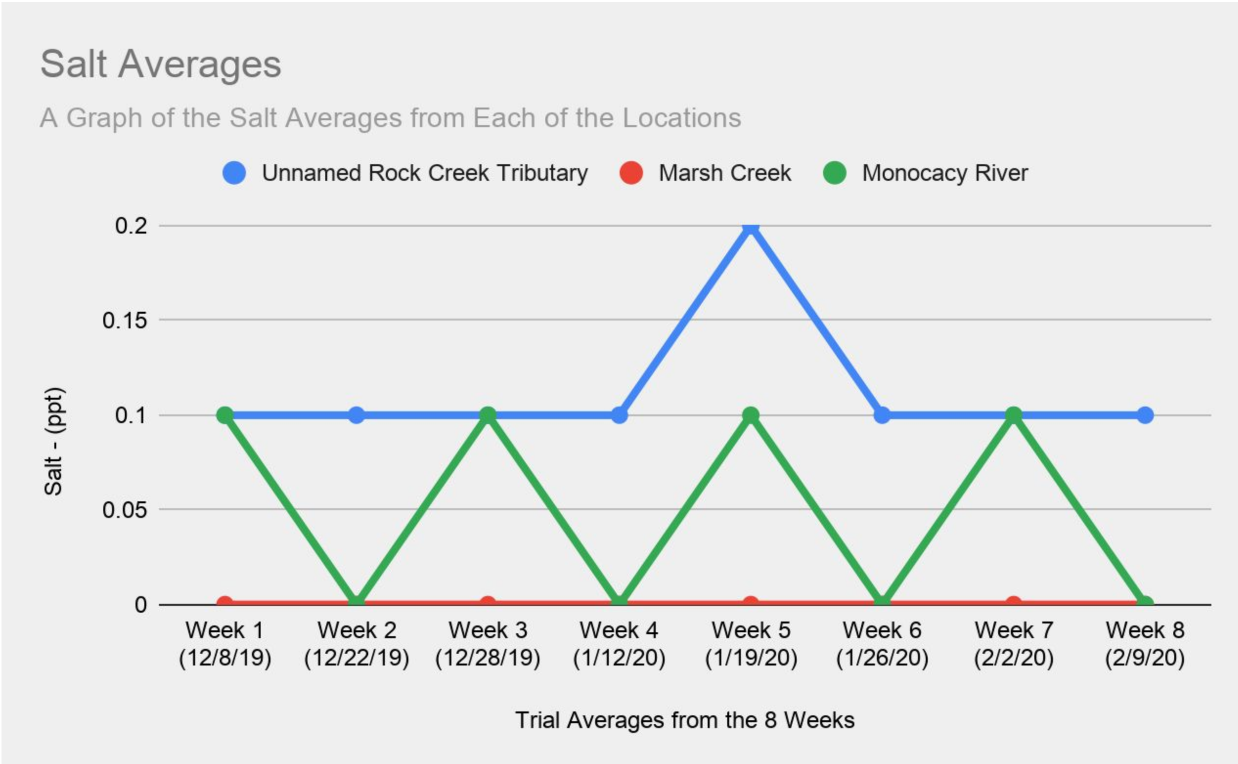
Table 2: This table shows the averages of each of the water quality tests at the Marsh Creek testing site, from the eight weeks. The averages mostly fell within the standards, as posted by GLOBE. There was a more consistent average between the 8bweeks, from week to week.

Monocacy River	Dissolve Oxygen (mg/L)	Salt (ppt)	pH	Nitrate (ppm)	Temperature (ºC)	Transparency (cm)
Week 1 (12/8/19)	8	0.1	7.8	0.5	5.4	120
Week 2 (12/22/19)	10	0	8.1	0.2	2.2	87
Week 3 (12/28/19)	8	0.1	7.9	0.5	3.7	118
Week 4 (1/12/20)	8	0	7.4	1	11.7	12
Week 5 (1/19/20)	8	0.1	7.4	0.3	2.5	120
Week 6 (1/26/20)	6	0	7.9	0.3	5	57
Week 7 (2/2/20)	8	0.1	8	0.2	5.2	120
Week 8 (2/9/20)	11	0	7.7	0.5	5.2	89

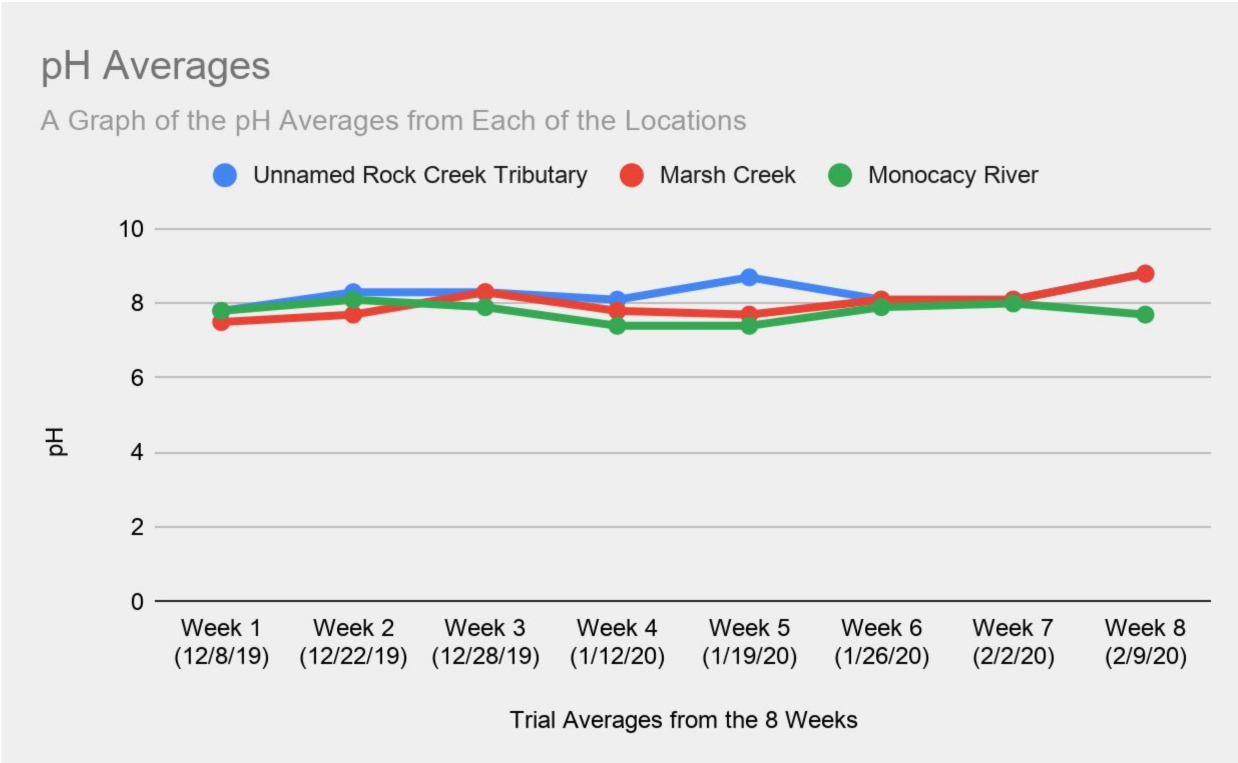
Table 3: This table shows the averages of each of the water quality tests at the Monocacy River testing site, from the eight weeks. The averages mostly fluctuated between the recommended levels, as posted by GLOBE. There was no consistent average from week to week.



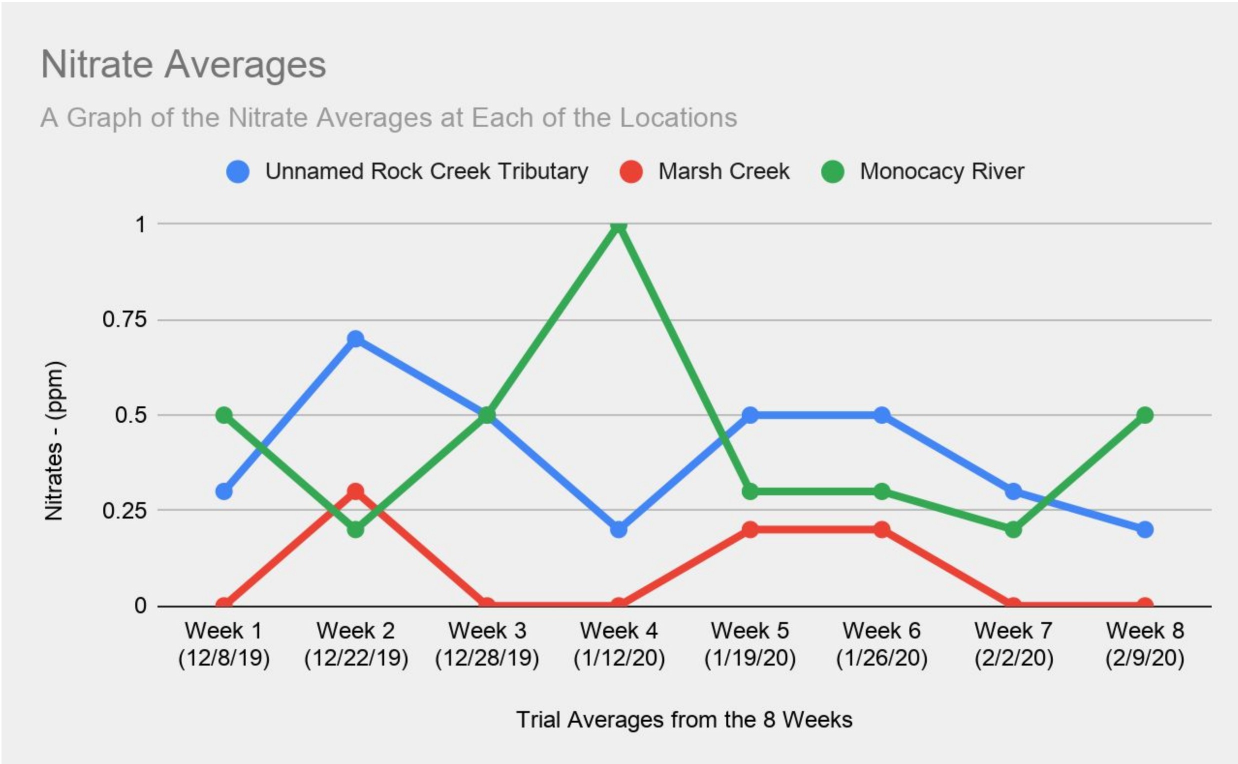
Graph 1: This graph shows the comparison of dissolved oxygen (mg/L) at the 3 testing sites. It is shown that the DO levels fluctuated from week to week. The most consistent average was from the three week testing (four week span), in the Monocacy River. Marsh Creek seemed to have stayed in the high road except for “Week 3.” The DO stayed high, which is what is expected to see.



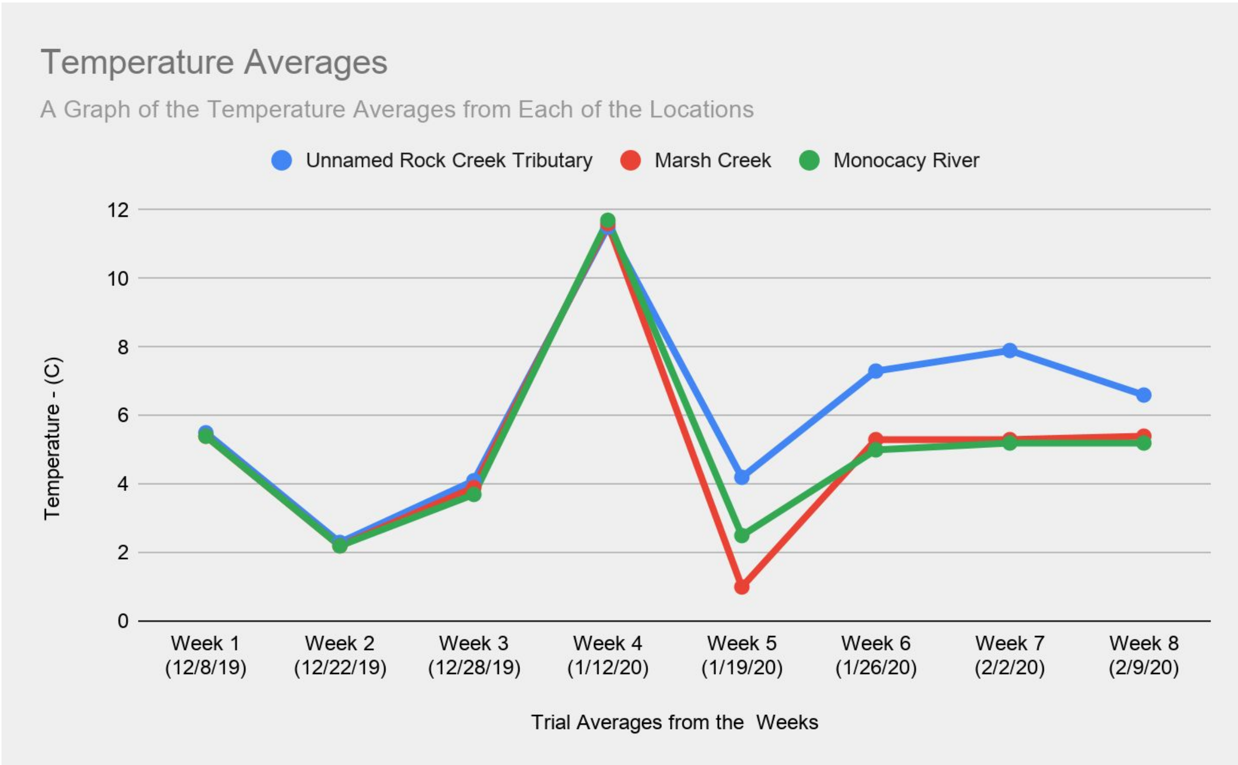
Graph 2: This graph shows the comparison of salt (ppt) at the 3 testing sites. The Salt stayed consistent and generally did not go above the 0.1 ppt line (except for the one week in the Unnamed Rock Creek Tributary), which is good.



Graph 3: This graph shows the comparison of pH at the 3 testing sites. The pH was very close in level proximity between each location, making the graph look like a DNA double-helix, but showing the similar levels and how the Unnamed Rock Creek Tributary and Marsh are able to show the impact on the Monocacy River.

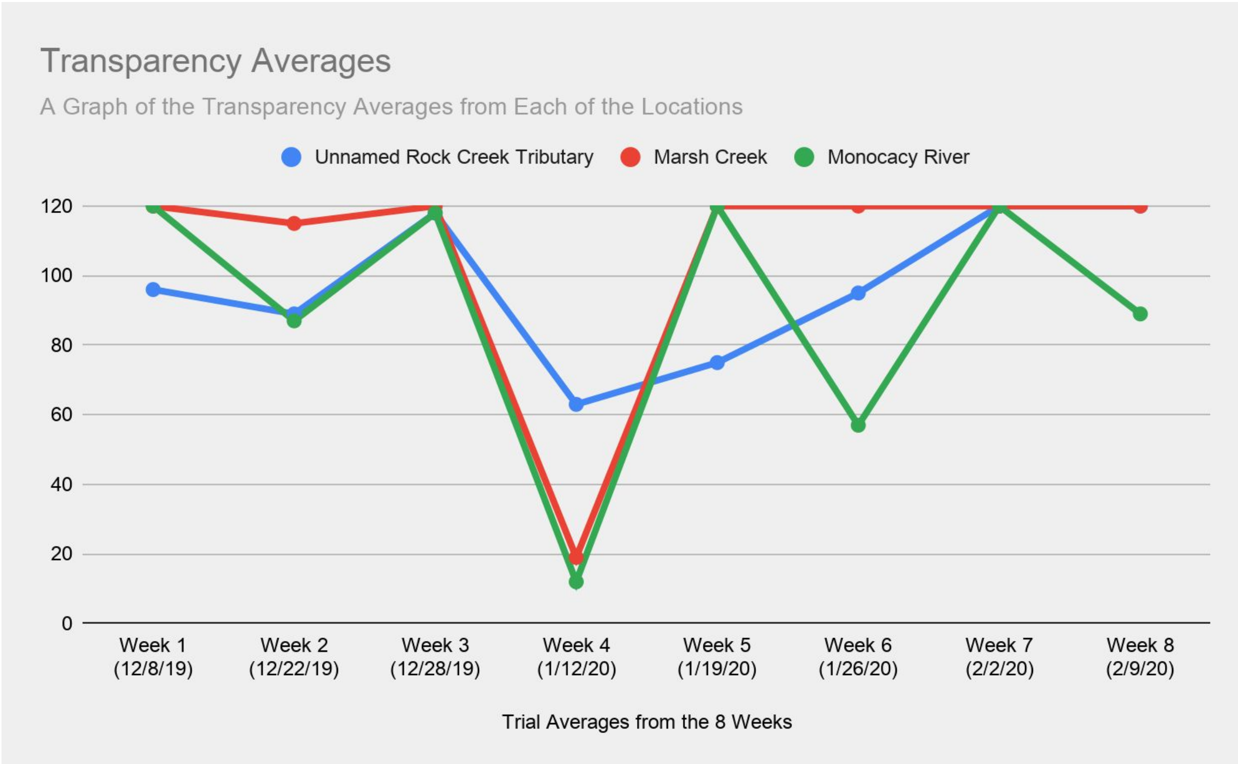


Graph 4: This graph shows the comparison of nitrates (ppm) at the 3 testing sites. The nitrates negatively and positively affect the water quality and the biodiversity. It is good that the nitrates do not exceed 1 ppm of the nitrates, showing that the streams are not picking up too many sediment pollutants.

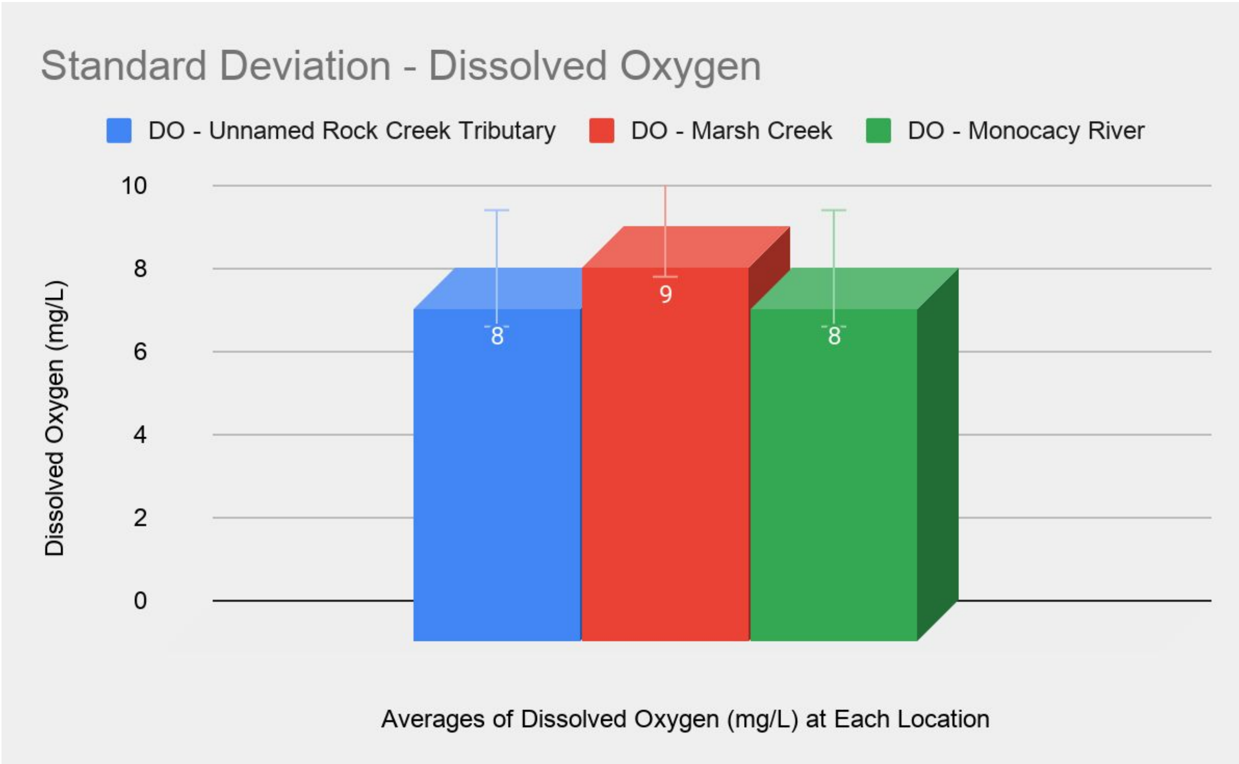


Graph 5: This graph shows the comparison of Temperature (ºC) at the 3 testing sites.

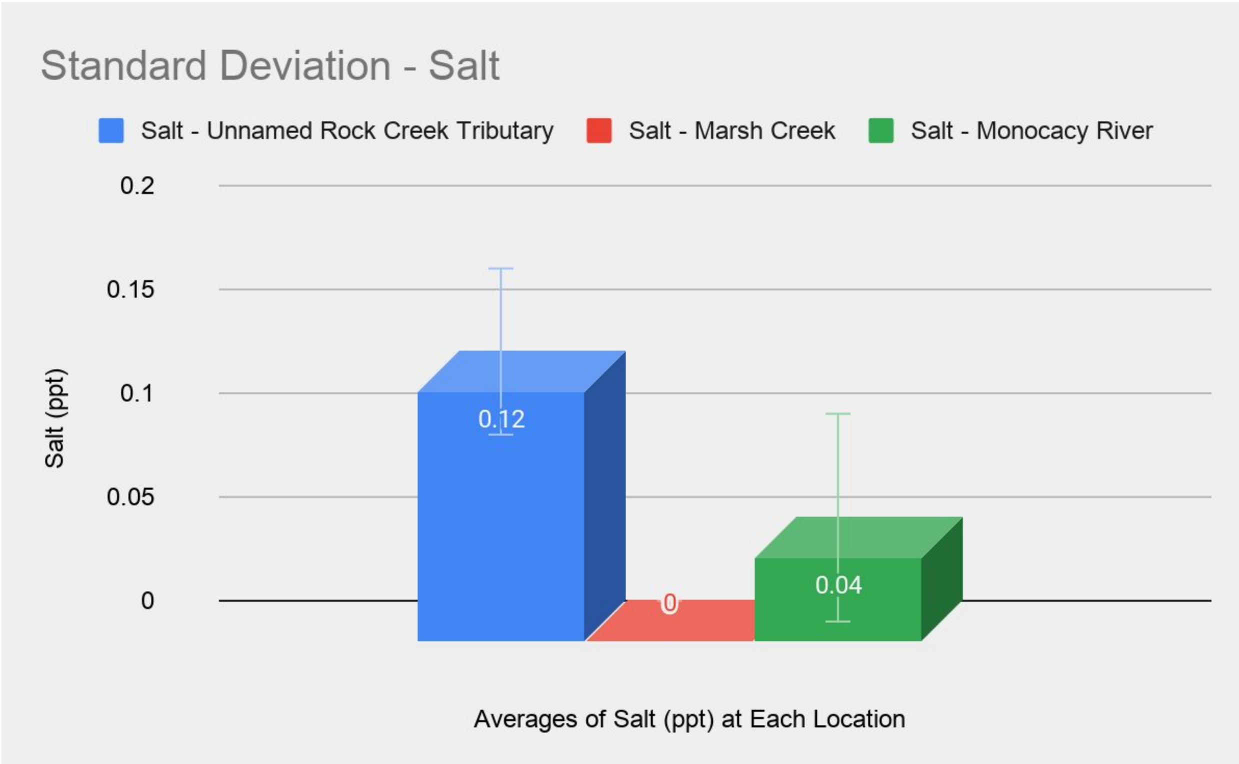
Temperature often impacts DO and the salinity of water.



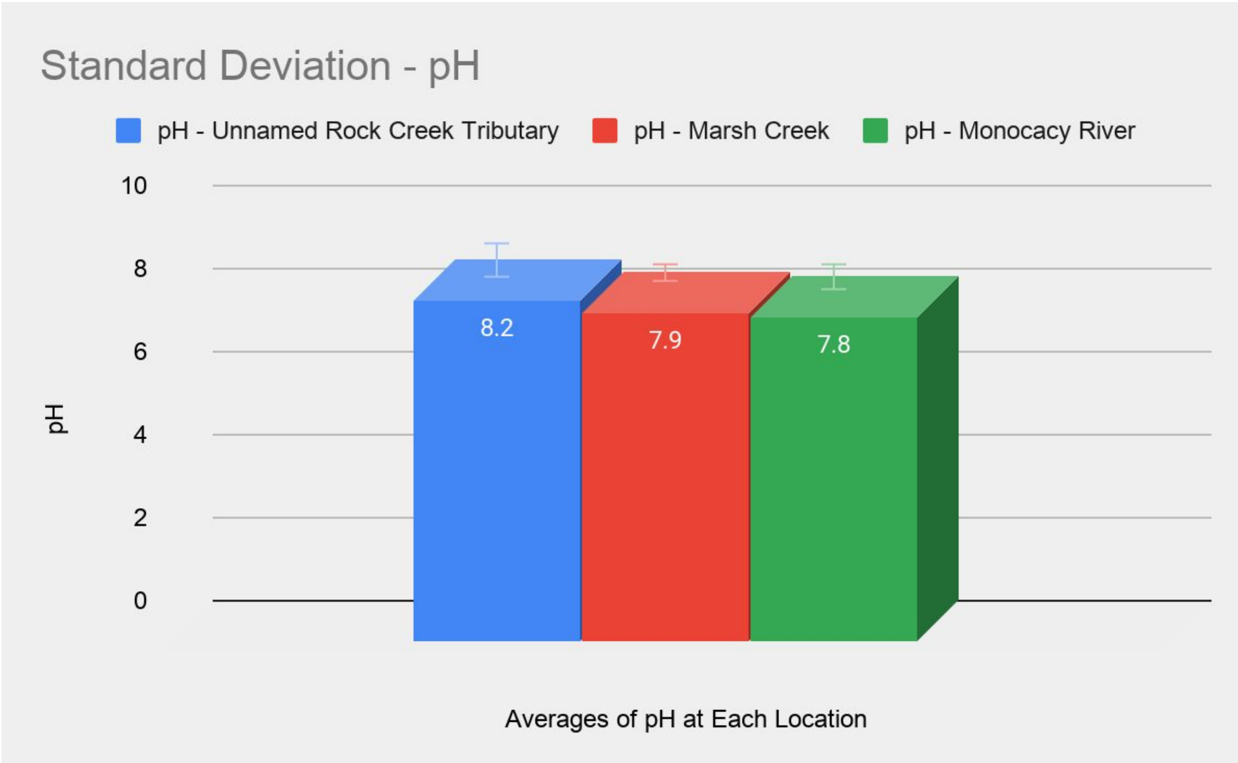
Graph 6: This graph shows the comparison of transparency (cm) at the 3 testing sites. The transparency shows that there is not a lot of sediment runoff going downstream (except for Week 4, which had a massive storm go through the area).



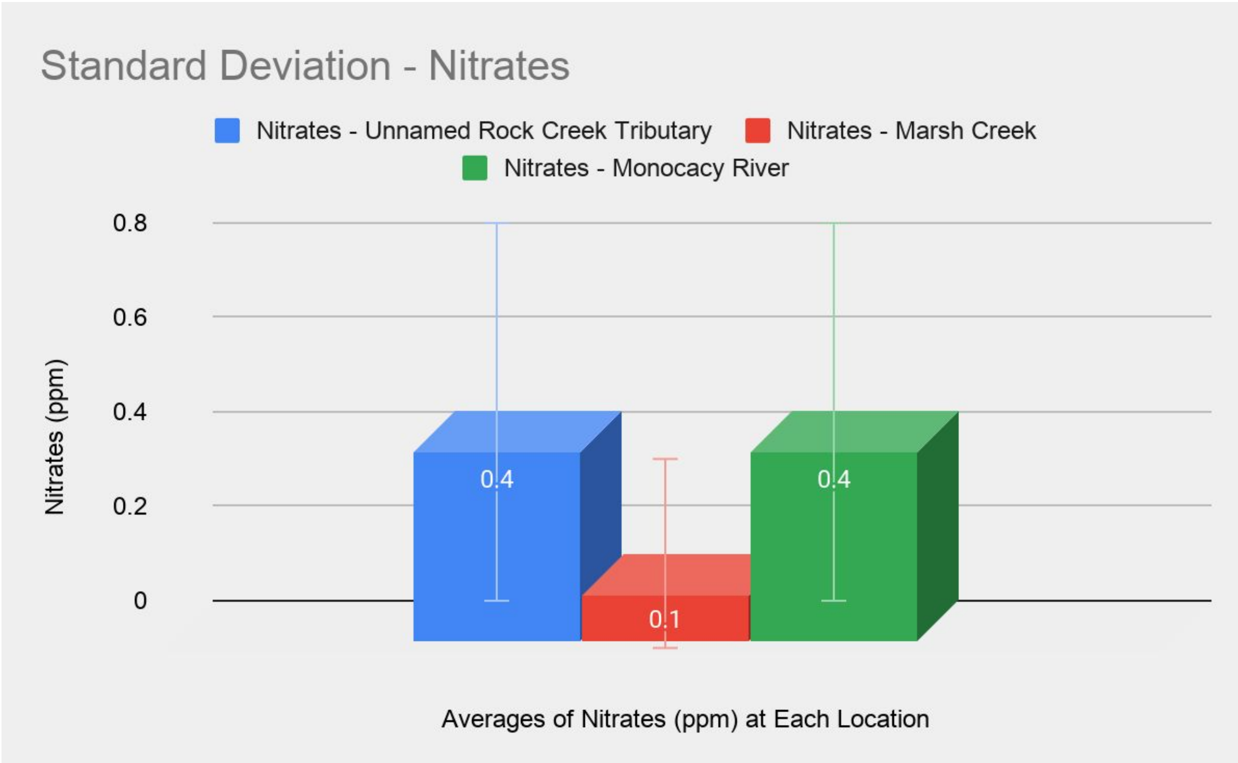
Graph 7: This shows the overall averages, from the raw data, of dissolved oxygen (mg/L) at each location. Standard deviation is a quantity calculated to indicate the extent of deviation for a group as a whole. The error bars show the variance of the row. The error bars show a medium amount of variance. This does fall within the accepted values, because it falls within the accepted values of 7mg/L and 10mg/L, which were the values of the raw data.



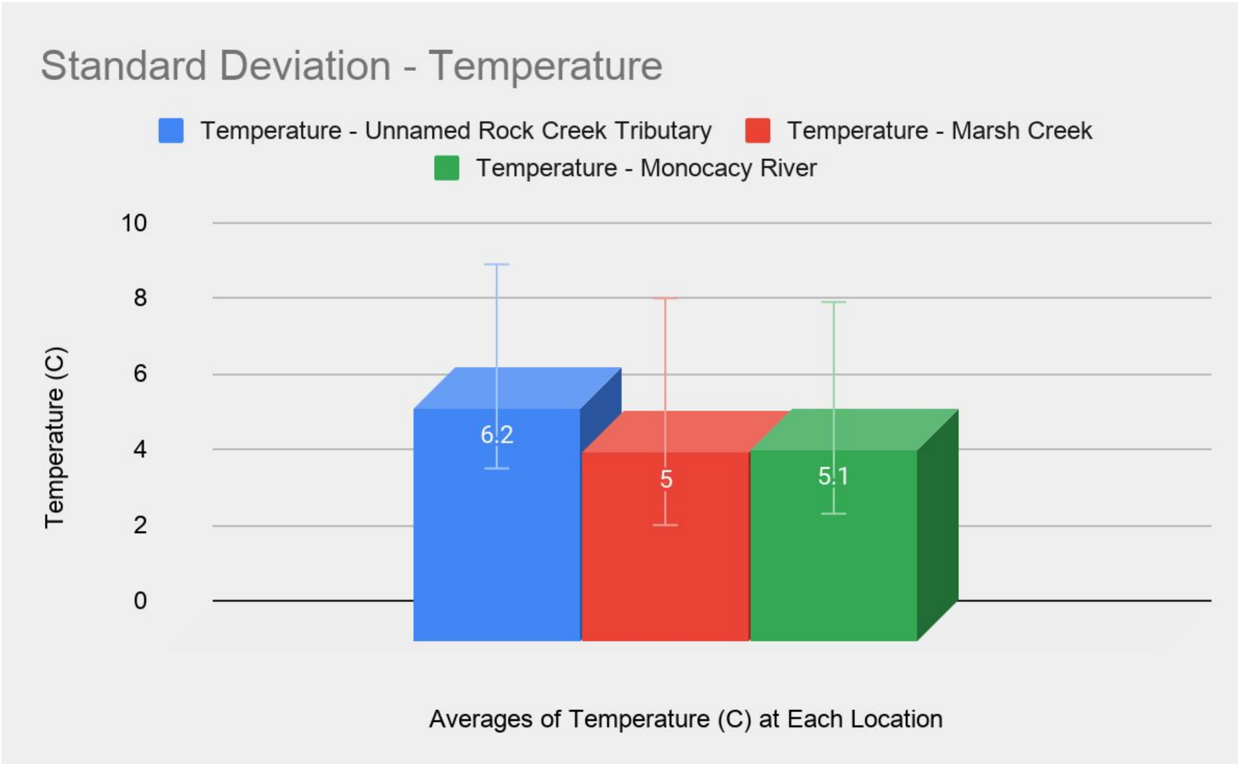
Graph 8: This shows the overall averages, from the raw data, of salt (ppt) at each location. Standard deviation is a quantity calculated to indicate the extent of deviation for a group as a whole. The error bars show the variance of the row. The error bars show a lot of variance in the data. The Rock Creek average is a little above the recommended levels. The error bar on the Monocacy River passes the 0 line, because it uses the zeroes from the raw data.



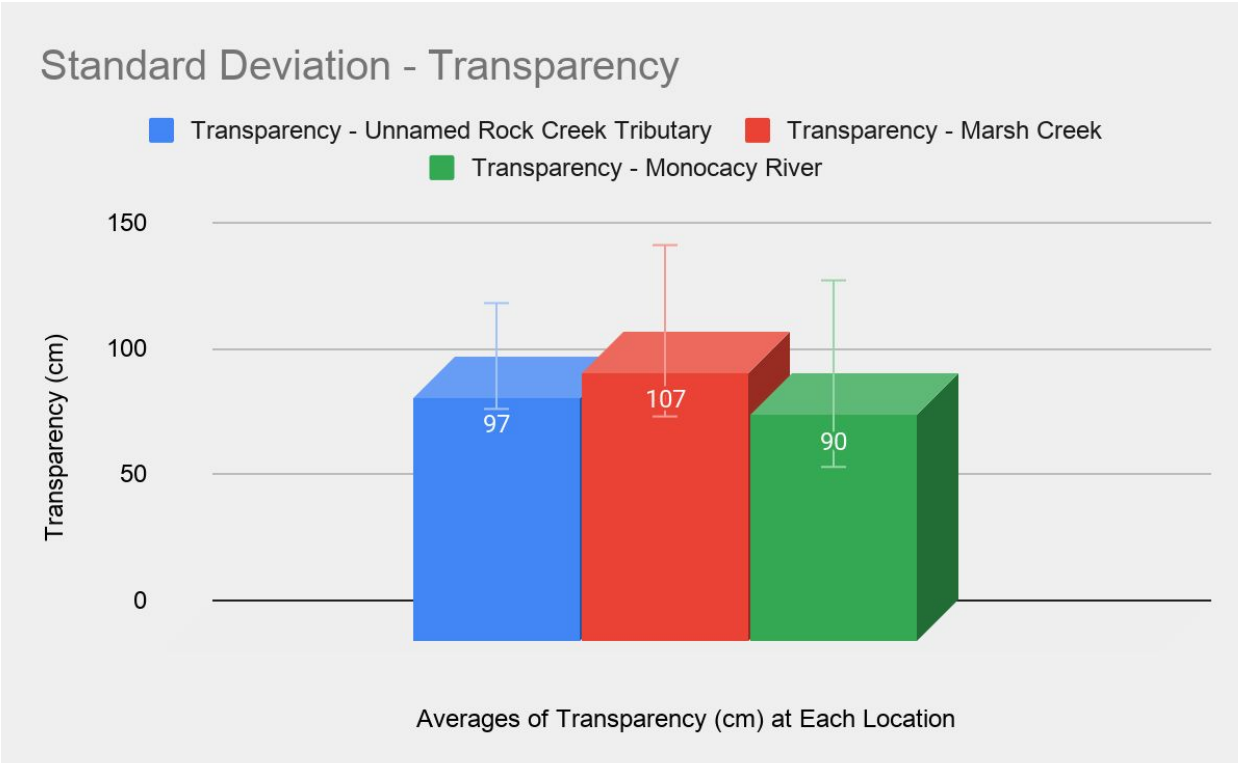
Graph 9: This shows the overall averages, from the raw data, of pH at each location. Standard deviation is a quantity calculated to indicate the extent of deviation for a group as a whole. The error bars show the variance of the row. The error bars show very little variance of the data. The levels of pH were a little higher than that which would have been thought. The recommended levels for pH were 6.5 to 8.



Graph 10: This shows the overall averages, from the raw data, of nitrates (ppm) at each location. Standard deviation is a quantity calculated to indicate the extent of deviation for a group as a whole. The error bars show the variance of the row. The error bars show a large variance in the data. The nitrates are a little higher than that of what was thought to be shown. The error bars do show error bars that go below, and into the negatives, because it uses the raw data, which consisted of zeroes.



Graph 11: This shows the overall averages, from the raw data, of temperature (ºC) at each location. Standard deviation is a quantity calculated to indicate the extent of deviation for a group as a whole. The error bars show the variance of the row. The error bars show a large variance in the data. The error bars do not show the entire range of the data.



Graph 12: This shows the overall averages, from the raw data, of transparency at each location. Standard deviation is a quantity calculated to indicate the extent of deviation for a group as a whole. The error bars show the variance of the row. The error bars show a larger variance in the data.

Results

Rock Creek

There was a very consistent average in the salt testing between the eight weeks, except for "Week 5," which could be an outlier. Although "Week 4" has an exceptional average of 10 mg/L for Dissolved Oxygen, when these tests had been conducted, a very heavy storm had just passed, so "Week 4" could be lower or higher, due to the fact that the storm system had just gone through the area. Since not all the averages are within the prefered levels, this could show that

Rock Creek contributes a lot to the Monocacy River, explaining if PA, more specifically Gettysburg, is contributing to the Monocacy River, which is a main contributor to the Potomac River.

Marsh Creek

There was a very consistent average in the salt testing between the eight weeks, showing that there was no salinity pollution from the very dry winter we had. The transparency stayed almost constant except for the "Week 4," which, when these tests had been conducted, a very heavy storm had just passed, so "Week 4" is lower, due to the fact that the storm system that went through the area, kicking up sediment and other visible pollutants. Since the majority of the averages are within the prefered levels, this shows that Marsh Creek does not contribute a lot of the negative effects to the Monocacy River, because Marsh Creek has been conducted as a healthy creek.

Monocacy River

The averages changed mostly every week. The transparency had an exceptionally low level on "Week 4," which, when these tests had been conducted, a very heavy storm had just passed, so "Week 4" is lower, due to the fact that the storm system that went through the area, kicking up sediment and other visible pollutants. Since the majority of the averages are changed and fluctuated between the prefered levels, this shows that Monocacy River is affected by both Marsh Creek and by Rock Creek. The Monocacy River shows characteristics of both Rock Creek and Marsh Creek.

Originally testing was supposed to occur every Saturday and Monday until YCSEF, with back up dates of Sundays and Tuesdays. As the process went on, the weekdays became too hectic to keep up with, so it was changed to Sundays with backup days of Saturday, since it seemed to work out better that way. There were two weekends (12/14/19) and (1/4/20), where no testing was able to occur, due to how busy it was for the observer and for the observer's family. The results were taken from the beginning of December up until February to encompass the winter months, and continue on during the spring months as well. The results had shown that the Unnamed Rock Creek Tributary and Marsh Creek both affect the Monocacy River. The Monocacy River levels had been a mix of the two creeks. The pH levels of the testing sites had been very similar in the results, while the salt had been mostly complete opposites between the sites. The salt graph is where it is really evident that both the Unnamed Rock Creek Tributary and Marsh Creek have an impact on the Monocacy, by having the Monocacy River in between the levels of the Unnamed Rock Creek Tributary and Marsh Creek. The DO results had come out lower than what was expected. The expected results had been higher, due to previous research on the creeks, and their backgrounds of flowing downstream. The nitrates had been fairly low, which is a good sign, showing that there is not a lot of nutrient rich pollutants flowing down through the Monocacy, and eventually ending up it the Chesapeake Bay. The one week of rain (Week 4), had severely damaged the transparency levels, with levels as low as 12cm. Some of the nitrates were at their highest that week, although the others were not. The amount of nutrient pollutant versus the amount of sediment and visible pollutant made the difference when testing downstream. The dependent variables had stayed mostly within their recommended levels, as per GLOBE. Since Marsh Creek and the Monocacy River are both used as drinking sources, it is reassuring that they are very healthy.

Conclusion

The project had asked the question, “How does the DO, temperature, transparency, pH, salt, and nitrates levels upstream affect the levels downstream?” with the hypothesis stating that if the levels of dissolved oxygen, temperature, transparency, pH, salt, and nitrates at the upstream creeks are different levels than that of the downstream levels, then it will show that the two creeks contribute negatively to the southern river. This is because the creeks and streams are heavily shade, buffered by forests, roads and agricultural sources. The roads cross over or beside the creeks and rivers cause salt and pollution active on the roads to flow into the rivers. The agricultural sources cause nutrient enrichment, like nitrates and phosphates, to flow into the rivers. There would be an indication of a source of pollution/sediment, flowing into the Monocacy River from Marsh Creek or Rock Creek (through unnamed tributary), by having similar results at the locations.

The results showed fluctuated results between similar results and different results. Each location had shown different levels and different environments, but they also showed similar levels, mostly in the pH. The data had partially supported the hypothesis. It might not look like the hypothesis was supported, since the levels were so close in proximity, but it was supported on a broader level. The fact that it had shown that the levels of the Unnamed Rock Creek Tributary and Marsh Creek had been similar or that the Unnamed Rock Creek Tributary and Marsh Creek levels, combined would equal the Monocacy River levels, had really showed that the hypothesis was sort of supported. The Monocacy River is impacted by the two upstream creeks. The two creeks both impact the Monocacy positively and negatively, which when the hypothesis was being formed, it was more looking at the negative side of possible results, instead of both the positive and negative results. Therefore the hypothesis will be revised as, if the levels of dissolved oxygen, temperature, transparency, pH, salt, and nitrates at the upstream creeks are different levels than that of the downstream levels, then it will show that the two creeks contribute negatively to the southern river. But if the upstream creeks have similar levels of that of the downstream levels, then it will show that the upstream creeks are producing positive results for the downstream river. This is because the creeks and streams are heavily shade, buffered by forests, roads and agricultural sources. The roads cross over or beside the creeks and rivers cause salt and pollution active on the roads to flow into the rivers. The agricultural sources cause nutrient enrichment, like nitrates and phosphates, to flow into the rivers. There would be an indication of a source of pollution/sediment, flowing into the Monocacy River from Marsh Creek or Rock Creek (through unnamed tributary), by having similar results at the locations. If the levels of the three testing sites match similarly, then it can be inferenced that the Monocacy River and the two upstream creeks, are not negatively influencing that of the Chesapeake Bay.

Problems, such as, broken ampoules, incorrect observations, and weather had all impacted the project in ways that made it more challenging. Getting new equipment was also a challenge and the analysis of the ampoules was tricky, as for in the light, they look very similar. If this project was going to change, there would be new testing of phosphate and lead, since they are also two other water quality tests that impact water greatly. The phosphates would be because of the amount of farmland and other nutrient pollution that can come from the land surrounding it through erosion and weathering. Testing for lead would also be beneficial especially after the Flint, Michigan incident, where new lead pipes caused a disinfection in their drinking water and drinking source. So, these are two important things to test for as well. Another addition would be that of testing sites. Adding a Potomac River testing site and Chesapeake Bay testing site (near the mouth of the Potomac River), using buoys by NOAA, would help to see if the upstream creeks are directly affecting the Chesapeake Bay, by using all of the collected results to put together an experiment that combines it all, to finally see what the impact of the upstream creeks on the downstream rivers and eventually the Chesapeake Bay. Further research would also prove to be beneficial on how these upstream bodies of water affects downstream bodies of water.

This is important to the community because it provides information about how they are contributing to their streams and creeks and how they are eventually contributing to the Chesapeake Bay. Since PA has been shown as one of the biggest negative contributors to the Chesapeake Bay, it shows if these are part of the negative contributions. By first seeing hard evidence that their local creeks and streams are negatively impacting the Chesapeake Bay, it can help to implement regulations and restorations for these helping to "Save a National Treasure," and by doing good for the community, the country, and the world.

Acknowledgements

I would like to acknowledge the many people who have taken their time to help me with my project. First I would like to thank my father, Jonathan Stiles, my mother, Carol Stiles, and my grandfather, George Turek. They have been of many help to my project in assisting me to the Unnamed Rock Creek Tributary, Marsh Creek and Monocacy River. I would also like to thank my fellow classmates Arielle Snyder and Lily Shriner. They have also been of many help when I was figuring out my variables, proofreading, and setting me on a path to GLOBE. Thank you to Ms. Nancy Duffy, Ms. Ruthann Pinkos, Mr. William Smith, and Ms. Beth Sneeringer. They are english, chemistry, physics, and algebra teachers at my school. They helped with interviews, looking over my paper and board, and checking my graphs to make sure they are correct. Thank you to Ms. Emily Thorpe, Mrs. Kassie Fenn, Mr. Joe Hallinan, and Mrs. Bird. These adults are STEM professionals, who helped to consult my project, provide research, and much more. They also serve as wonderful role models for my future careers. And Finally a HUGE THANK YOU to Mrs. Amy Woods and Mrs. Janice Gadow, who has been the constant support and supplier to my project. They have been breathing down my back to help me do well, and I feel that it has paid off. She has been constantly helping and helping and it has been helpful. Thank you very much.

Badges

Be A Data Scientist - The analysis and observations were recorded every week, and were taken over three months, with resuming collection for the SRS. Using Google Sheets to analyze data, calculate the average and standard deviation, and to generate the graphs, helped to give more precise analysis readings. Consultation with the teachers gave more insightful views as to the impact each test has and to the impact of water quality on the environment and the world, through one small project.

Make and Impact Badge - This is important to the community because it provides information about how they are contributing to their streams and creeks and how they are eventually contributing to the Chesapeake Bay. Since PA has been shown as one of the biggest negative contributors to the Chesapeake Bay, it shows if these are part of the negative contributions. By first seeing hard evidence that their local creeks and streams are negatively impacting the Chesapeake Bay, it can help to implement regulations and restorations for these help save our world.

Be A STEM Professional - I had discussions and worked with, Emily Thorpe, Kassie Fenn and the Chesapeake Bay Foundation Staff, Joe Hallinan and the Watershed Alliance of Adams County, Mrs. Bird and Gettysburg College, Nancy Duffy, Ruthann Pinkos, William Smith, and Beth Sneeringer, Janis Gadow, and Amy Woods who all helped too enhanced the research methods, contributed to improved precision, and supported more sophisticated analyses and interpretations of results.

References

Bredeson, C. (1999). Tide pools. New York: F. Watts. page 16

CBGN. (2019). Monocacy Scenic River: Water Trail Map and Guide. Retrieved February 15, 2020, from "Monocacy Scenic River: Water Trail Map and Guide website: https://frederickcountymd.gov/DocumentCenter/View/1275/Monocacy-River-Water-Trail-Map--Guide?bidId=

CNN Editorial Research. (2019, December 13). Flint Water Crisis Fast Facts. Retrieved February 15, 2020, from CNN website: https://www.cnn.com/2016/03/04/us/flint-water-crisis-fast-facts/index.html

Cole, D. (2018, June 8). Stock Vector - The Science PH Scale Illustration. Retrieved February 15, 2020, from Alamy Stock Vector website: http://www.alamy.com/the-science-ph-scale-illustration-image211289543.htm

Cordy, G. E. (2014, February 18). A Primer On Water Quality. Retrieved March 1, 2019, from https://pubs.usgs.gov/fs/fs-027-01/

CWF. (2019). 6 Things You Should Know about Your Water. Retrieved February 15, 2020, from

Clean Water Fredrick website: http://www.cleanwaterfrederick.org/water-facts

Ditchfield, C. (2002). Water. New York: Childrens Press.

Gilford, D. J. H. (1990). Maryland Scenic Rivers: The Monocacy. Retrieved from https://frederickcountymd.gov/DocumentCenter/View/3894/Cover-Table-of-Contents--Intro

GLOBE. (2014). Dissolved Oxygen Protocol. Retrieved February 15, 2020, from The GLOBE Program website: http://www.globe.gov/documents/11865/f9946a8c-7aa9-4634-a39d-d0f876b00c35.

GLOBE. (2014). Nitrate Protocol. Retrieved March 1, 2019, from The GLOBE Program website https://www.globe.gov/documents/11865/cb21cfd4-6eb6-4479-af0d-d7a5a0b7468d

GLOBE. (2014). pH Protocol. Retrieved March 1, 2019, from The GLOBE Program website https://www.globe.gov/documents/11865/42e3b8fe-847c-429a-a105-d18691d99e32

GLOBE. (2014). Salinity Protocol. Retrieved March 1, 2019, from The GLOBE Program website https://www.globe.gov/documents/11865/212b555a-247c-4ccb-8357-b61b33d999f5

GLOBE. (2014). Water Temperature Protocol. Retrieved February 15, 2020, from The GLOBE Program website: http://www.globe.gov/documents/11865/0fd40183-f2ea-480f-82b6-8d62180d9291.

GLOBE. (2014). Water Transparency Protocol. Retrieved February 15, 2020, from The GLOBE Program website:

http://www.globe.gov/documents/11865/6384d688-d6bc-4d35-bf5d-cf3b1292a9b3.

Hallinan, J. (2018). Marsh Creek and Rock Creek Information. Retrieved October, 2018

Hogan, S. (2018, April 22). The River's Toll: How the Monocacy Feeds into the Chesapeake Bay's Problems. Retrieved February 15, 2020, from Frederick News-Post website: http://www.fredericknewspost.com/news/environment/pollution/the-river-s-toll-how-the-monocacy-feeds-into-the/article_f21a7dde-7eb7-56c8-9170-1954f856392a.html.

How to Test Nitrates in Water - Nitrates in Water. (2016). Retrieved March 1, 2019, from https://watertestingkits.com/nitrates-and-nitrites/

Kaplan, D. (2018, May 1). Monocacy River: Identifying the Problem. Retrieved February 15, 2020, from Frederick News-Post website: http://www.fredericknewspost.com/opinion/letter_to_editor/monocacy-river-identifying-the-problem/article_233c0301-c7e3-5847-a73d-0720cfa2571a.html.

Kurlansky, M., & Schindler, S. D. (2014). The story of salt. New York: Puffin Books. pages: 6,7,15,16,17

Lawrence, E. (2013). Water. New York. New York: Bearport Pub. pages: 6,8,12

Leslie, C. W. (2015). Curious nature guide. Storey Publishing Llc. page: 104

Lin, Y. S. (2012). Fahrenheit, Celsius, and their temperature scales. New York: PowerKids Press.

Lubner, D. T. (2019). Water Basics. Retrieved February 15, 2020, from Water Quality Association website: http://www.wqa.org/learn-about-water/water-basics.

Moran, A. (2020). Restoring the Bay Is Imperative to Human Health. Retrieved February 14, 2020, from Chesapeake Bay Foundation website:

https://www.cbf.org/issues/what-we-have-to-lose/cost-to-human-health.html

Mulder, M. (2014). Every last drop: Bringing clean water home. Victoria: Orca.

Myers, D. N. (2018). Retrieved March 1, 2019, from https://water.usgs.gov/owq/WhyMonitorWaterQuality.pdf

Naugle, P. (2019). Rock Creek Watershed. Retrieved February 15, 2020, from Watershed Alliance of Adams County website: http://adamswatersheds.org/images/rockcreekwatershed.pdf

Naugle, S. (2019). Gettysburg Fall/Winter Newsletter. Retrieved February 15, 2020, from Gettysburg Borough website: http://www.gettysburgpa.gov/sites/gettysburgpa/files/pages/newsletter_fall_winter_2019_v5.pdf

Newton, D. E. (2016). Background and History. In Contemporary World Issues: The Global Water Crisis: A Reference Handbook (pp. 14-28). ABC-CLIO, LLC.

Perlman, H. (2018, August 8). PH -- Water properties. Retrieved March 1, 2019, from https://water.usgs.gov/edu/ph.html

Rastogi, N. S. (2010, February 16). Does road salt harm the environment? Retrieved March 1, 2019, from https://slate.com/technology/2010/02/does-road-salt-harm-the-environment.html

Richards, J. (2008). Chemicals & reactions. New York: PowerKids Press. page 8

Robson, P. (2001). Geography for Fun Ecosystem. Brookfield, CT: Copper Beech Books. Page 24&25

Stroud Water Research Center. (2018, November 29). Freshwater Sources Less "Fresh" from

Greater Salt Use, Scientists Say. Retrieved March 1, 2019, from https://stroudcenter.org/news/road-salt-in-streams/

The Elements book. (2017). Place of publication not identified: Dk Publishing. pages:26,27,180,181

The World Book encyclopedia 2010. (2009). World Book, Inc.: Chicago, IL. Books: C-Ch (pg;517), N-O (pg;125), P (pg;353), S-Sn (pg;72)

VelocityEHS (Ed.). (2015, May 14). Calcium Chloride Safety Tips. Retrieved February 15, 2020,

from MSDSOnline website: http://www.msdsonline.com/2015/05/14/calcium-chloride-safety-tips/.

Water Quality. (2019). Retrieved March 1, 2019, from http://baybackpack.com/collections/water_quality

Water Quality Association. (2019). Water Basics. Retrieved March 1, 2019, from https://www.wqa.org/learn-about-water/water-basics

Water Research on Phosphates. (2017). Retrieved March 1, 2019, from https://www.water-research.net/index.php/phosphates

Water Treatment Solutions. (2019). Retrieved March 1, 2019, from https://www.lenntech.com/periodic/elements/cl.htm

Wisner, O. (2019). Water Quality. Retrieved February 15, 2020, from ay Backpack THE Source f

for Chesapeake Bay Education Resources for Teachers and Watershed Educators website:

http://baybackpack.com/collections/water_quality.

"Why Salt is Bad. (2008). Retrieved March 1, 2019, from http://www.bloodpressureuk.org/microsites/salt/Home/Whysaltisbad