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# Monitoring Siebert Creek Water Quality and Analysis of JMU Stormwater Restoration Efforts

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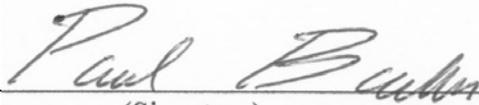
*A final report submitted to the  
Integrated Science and Technology Program  
at James Madison University  
in fulfillment of ISAT 493*

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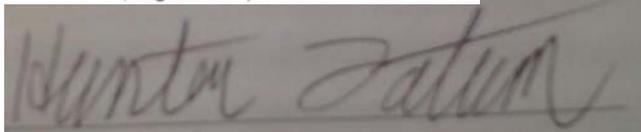
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## Abstract

Urban stormwater is one of the leading causes of water quality degradation in the U.S. This project was designed to monitor the quality of stormwater on James Madison University's campus. Stormwater was sampled within the JMU Arboretum and in Siebert Creek above and below Newman Lake. These locations were equipped with pressure probes that were constantly collecting data which were used to calculate stream flow. In addition to flow, levels of phosphorus, suspended solids, chloride, sulfate, and nitrate were measured at various time intervals throughout storm events. The data shows that storm events adversely affect the water quality in our local streams through a variety of contaminants. During storm events, levels of phosphorus and suspended solids significantly increased. The data collected during this project can be used to help implement and improve stormwater management on the James Madison University campus.

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## Introduction

“The university will be an environmentally literate community whose members think critically and act, individually and collectively, as model stewards of the natural world”  
-James Madison University

Environmental quality is a concern that has taken a forefront in federal, state, and local policies. James Madison University is no exception. As JMU expands, so does its impact on the surrounding environment (**Error! Reference source not found.**). Development can increase runoff by as much as 45 percent. James Madison currently encompasses 686 acres of developed and undeveloped lands along with 20,000 students and 3,000 faculty and staff.

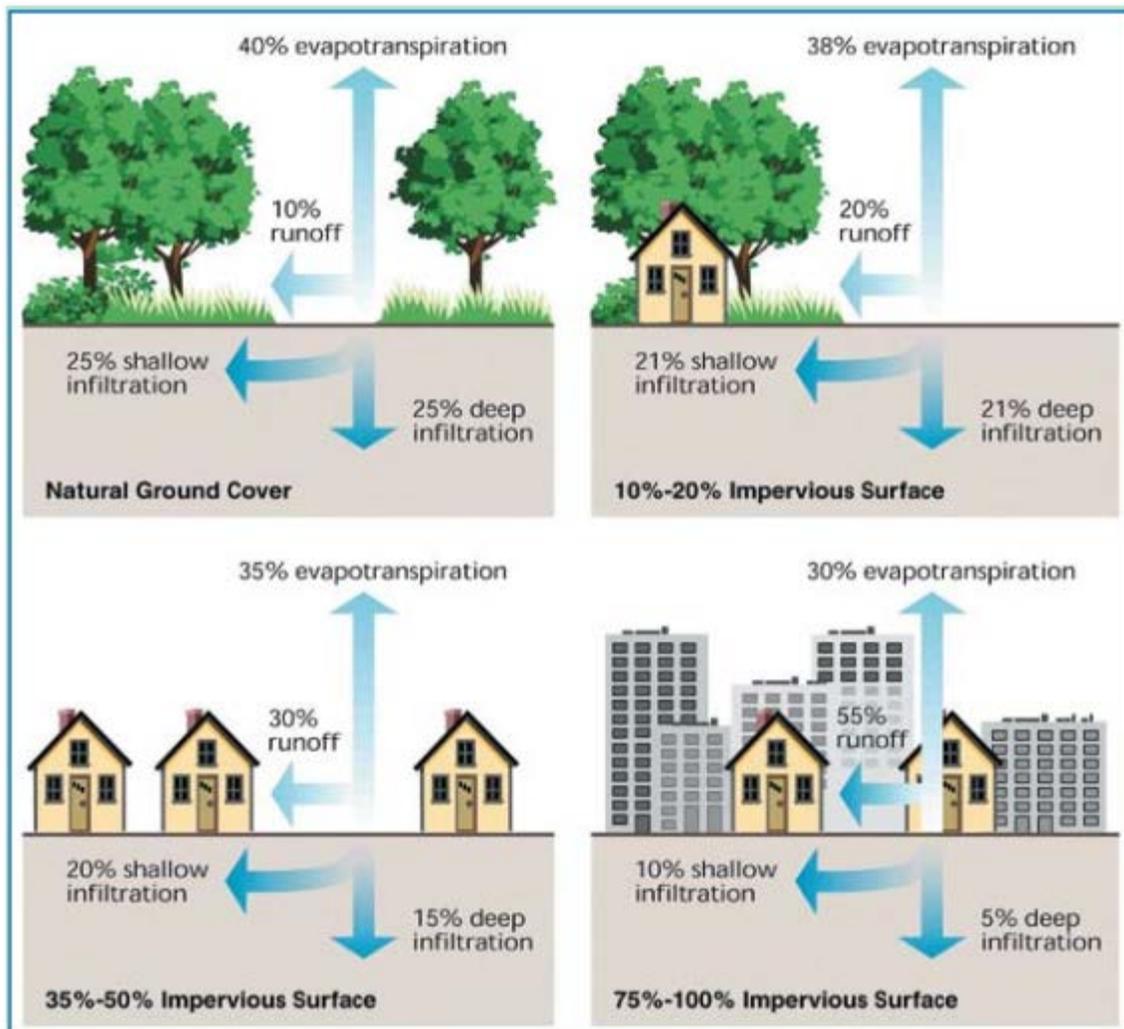


Figure 1. Illustrates the changes in storm water destination as development increases. In a natural state, an environment produces 10 percent runoff. In a developed area such as Harrisonburg, this number can be as high as 55 percent.

117 acres of this watershed drains directly into Blacks Run. Another 539 acres drain into Siebert Creek or Newman Lake. In addition to campus, the Siebert Creek and Newman Lake watershed includes additional Harrisonburg land bringing the watershed to a total of 2400 acres. Siebert Creek then continues after Newman Lake and eventually merges into Blacks Run. These sources flow into the Shenandoah River and ultimately the Chesapeake Bay.

## **Environmental Commitment**

With this large of a campus community, and the additional Harrisonburg community, James Madison University has become a local and regional leader in environmental quality improvement. The beginning of James Madison University's commitment to improving its impact on the environment can be traced back to as early as 1989, when JMU started its recycling plan. From there, JMU signed "The Tolloires Plan" which instituted a ten-point action plan to improve the environment and awareness. In 2009, James Madison University adopted its eighteenth defining characteristic stating that "all divisions of the university are charged with a responsibility for environmental stewardship" (JMU). A campus wide initiative consisting of "over eighty faculty, staff, student, and local government representatives" was implemented in 2008 and called the Office of Environmental Stewardship and Sustainability (JMU).

James Madison University has been diligent in maintaining its environmental commitments. The fall of 2010 brought a dynamic change to the university water infrastructure. Using \$124,000 of grant money assigned to stormwater management, JMU decided to conduct restoration projects on two of the streams that run through campus. The first step of these projects was to construct a bioretention filter along Siebert Creek near the Hillside Dormitories and parking lot. The filter is comprised of native plants that were planted alongside a retention basin and water is filtered by the plants and soil. This filter treats 2.5 acres of runoff before it enters the creek. This runoff is mainly from the Hillside and softball parking lots (Kaufman, 2011). The purpose of this project was to catch the storm water and filter contaminants out before it reaches Siebert Creek.

More improvements to Siebert Creek came in the summer of 2011. It was during this time that "approximately 1900 linear feet of Siebert Creek was restored with oversight from Louise Finger, a stream restoration specialist with the Virginia Department of Game and Inland Fisheries (Kaufman, 2011). This restoration was deemed necessary after the creek was labeled as being a "heavily degraded urban stream channel with severe erosion problems" (Kaufman, 2011). These improvements were made upstream from our Godwin sampling site and are shown in Figure 2 on the next page.



Figure 2. Shows Siebert Creek before and after the restoration. The pictures are beside the C4 lot (top), by the Hillside Bridge (middle), and by the Paul Street Bridge (bottom). These techniques can effectively minimize the effects of storm water on the creek bed and banks. Photo courtesy of HR Horizons.

Another stream that garnered the attention of JMU Facilities Management was East Campus Creek that flows between the ISAT and UREC buildings. This restoration incorporated 1000 feet of stream channel. Included in the restoration was a “10-15 foot riparian buffer on each side with a seed mix of native grasses and flowering plants, 800 plugs of sedges and rushes, 72 large trees, and 91 landscape quality shrubs” (HR Horizons). These upgrades were downstream from our Arboretum sampling site.

## Stormwater Overview

Stormwater runoff is produced when precipitation or water from melting snow is not absorbed into the ground. The water is then left to run over land and impervious surfaces (roads, parking lots, rooftops). Impervious surfaces increase water flow and intensity. This can lead to “scoured streambeds channels, in stream sedimentation and loss of habitat” (Washington Department of Ecology, 2013). Furthermore, the water collects contaminants as it travels over these surfaces. These contaminants include “debris, chemicals, sediment or other pollutants that

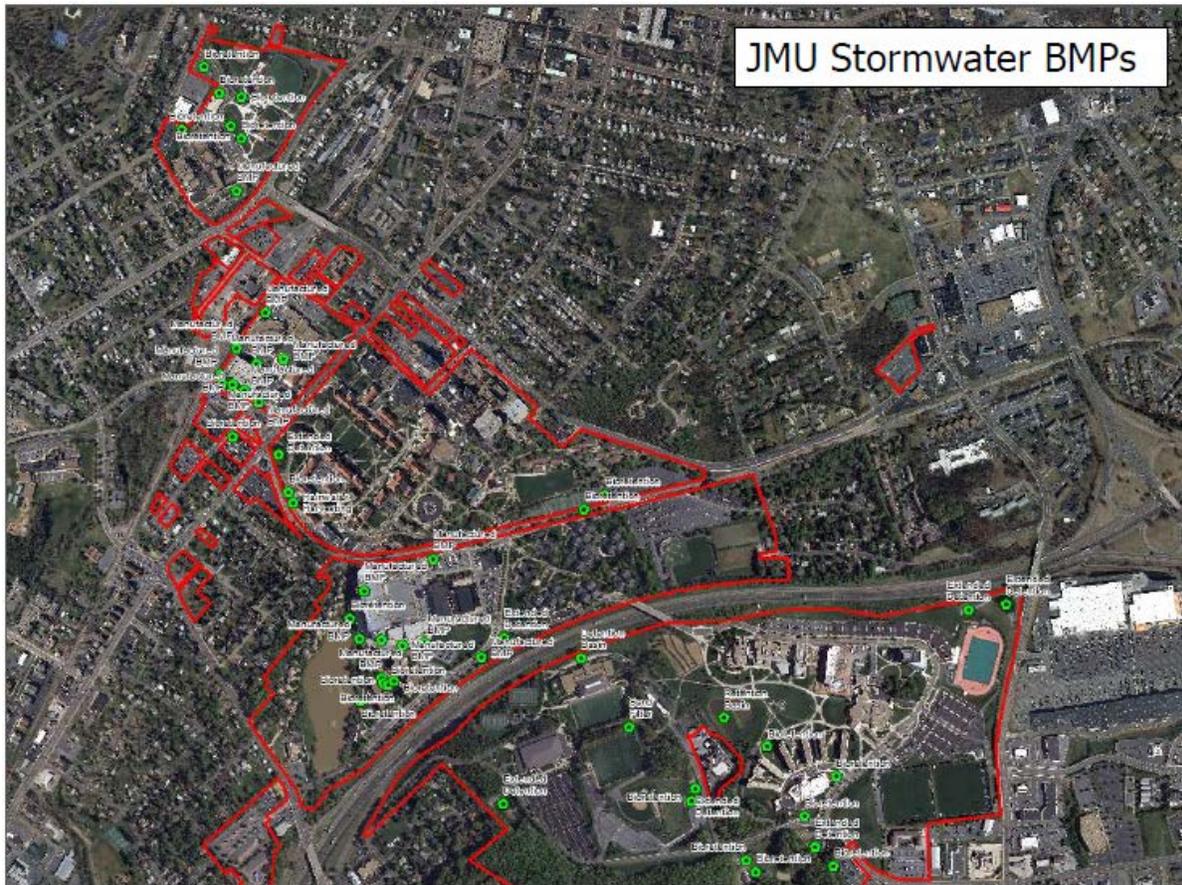


Figure 3. Shows the JMU campus outlined in red. The green dots show where best management practices have been installed. (Abe Kaufman)

could adversely affect water quality if the runoff is discharged untreated” (EPA). The best way to handle this situation is by using Best Management Practices (BMP’s). The James Madison Campus currently has 52 BMP’s employed across campus, shown in Figure 3 (Kaufman).

## Specific Stormwater Management Techniques

“A number of areas on the James Madison University campus are subject to flash floods, typically caused by sudden, excessive rainfall that sends the campus streams rapidly out of their banks. Often this occurs in a short amount of time, over several hours or even less. Campus flood prone areas include but are not limited to the low-lying land around Newman Lake, Blacks Run, Sibert Creek, and the Arboretum basin and its drainage to Newman Lake.”- JMU Flood Emergency Response Plan

James Madison University has invested a sizeable sum of money and man power to the restoration of these streams. These streams funnel a large amount of water through campus. When this system is disrupted or overhauled, flash flooding—a sudden local flood of great volume and short duration—can occur. With flash flooding, more erosion occurs to the stream bed and bank. In addition, more pollutants are carried into the waterway. Storm water management techniques are implemented to help correct these issues.

## Riparian Buffers

Riparian buffers were instrumental to the restoration of Siebert Creek and East Campus Creek. A riparian buffer is an area adjacent to a waterway that has vegetation to protect the water system from pollution sources. The buffer can also help stabilize banks as well as aquatic and land based habitats (NCSU, 1997). The pollution deterred by riparian buffers comes in many forms; it can be soil erosion, pesticides, herbicides, or other chemicals found in runoff water. In addition, nitrates, which flow through the ground water, are removed by roots of plants within the buffer (NCSU, 1997). **Error! Reference source not found.** shows which vegetation type is desirable for each particular waterway condition.

Table 1. Shows which vegetation type is best suited for each individual benefit in relation to other vegetation. For a well designed buffer, the designer must assess which benefits are most important to a particular waterway. (USDA National Agroforestry Center)

Benefit	Vegetation Type		
	Grass	Shrub	Tree
Stabilize bank erosion	low	high	high
Filter sediment	high	low	low
Filter nutrients, pesticides, microbes			
sediment-bound	high	low	low
soluble	medium	low	medium
Aquatic habitat	low	medium	high
Wildlife habitat			
range/pasture/prairie wildlife	high	medium	low
forest wildlife	low	medium	high
Economic products	medium	low	medium
Visual diversity	low	medium	high
Flood protection	low	medium	high

Although the idea of a buffer is widely accepted, the design practices implemented are still debated and therefore vary state to state. Typically, a buffer is divided into three zones. Zone one is usually the smallest zone and is the first zone along the shoreline. It is often comprised of mature trees. These trees have large roots which in turn can effectively stabilize banks and prevent erosion. Zone two usually contains a combination of shrubs and trees. This zone absorbs contamination in surface flow that passed through zone three. It also intercepts pollutants in subsurface water flow in combination with zone one. Zone three is the first barrier before runoff water reaches the stream. It consists of grasses and other low level vegetation. Its role is to slow runoff water and it also is the highest contaminant absorbing zone (NRCS, 2007; NCSU, 1997). Additionally, every attempt should be made to plant native species within the buffer to ensure a stable habitat. Figure 4 shows a common buffer setup.

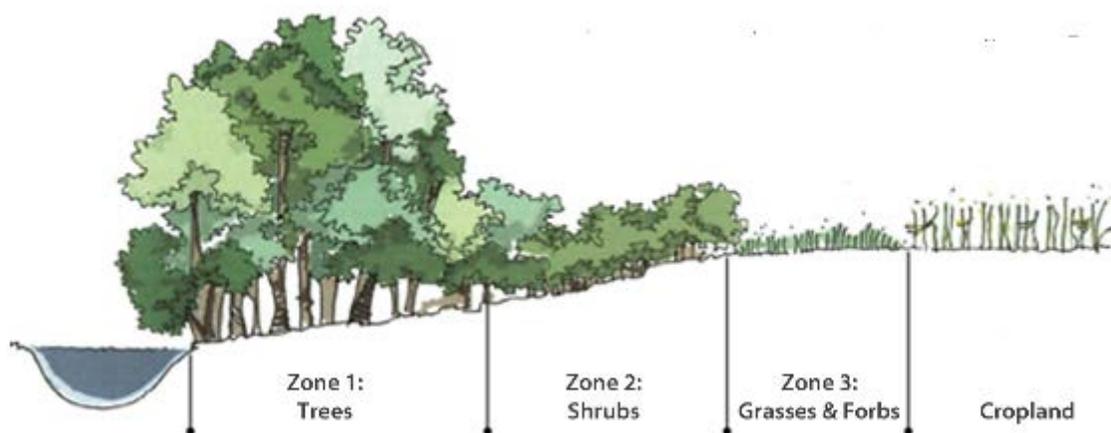


Figure 4. Illustrates a typical riparian buffer between a stream and agriculture land. The buffer is divided into three distinct sections, each serving a particular purpose. (University of Kentucky)

## Rain Gardens

A rain garden, also known as a bioretention filter, is a stormwater management technique that utilizes the land to capture excess water (Kaufman, 2011). They effectively remove “sediment, bacteria, heavy metals & phosphorous from stormwater” (Kaufman, 2011). Rain gardens contain six unique layers, each with its own purpose. The first layer is a grass buffer. This layer slows the momentum of the water as it enters the rain garden. Next is a mulch layer to keep the soil damp and support healthy growth. The third layer utilizes plant life to absorb moisture and collect contaminants. Following this layer is soil which is used to support plant life. The fifth layer is the most important. It is a depression in the ground that traps and stores excess runoff. And finally, a berm (dam) composed of soil and rocks is needed to keep the water from flowing out too quickly (VA Department of Forestry, 2008). Figure 5 shows one of 23 rain gardens that have been implemented on the JMU campus.

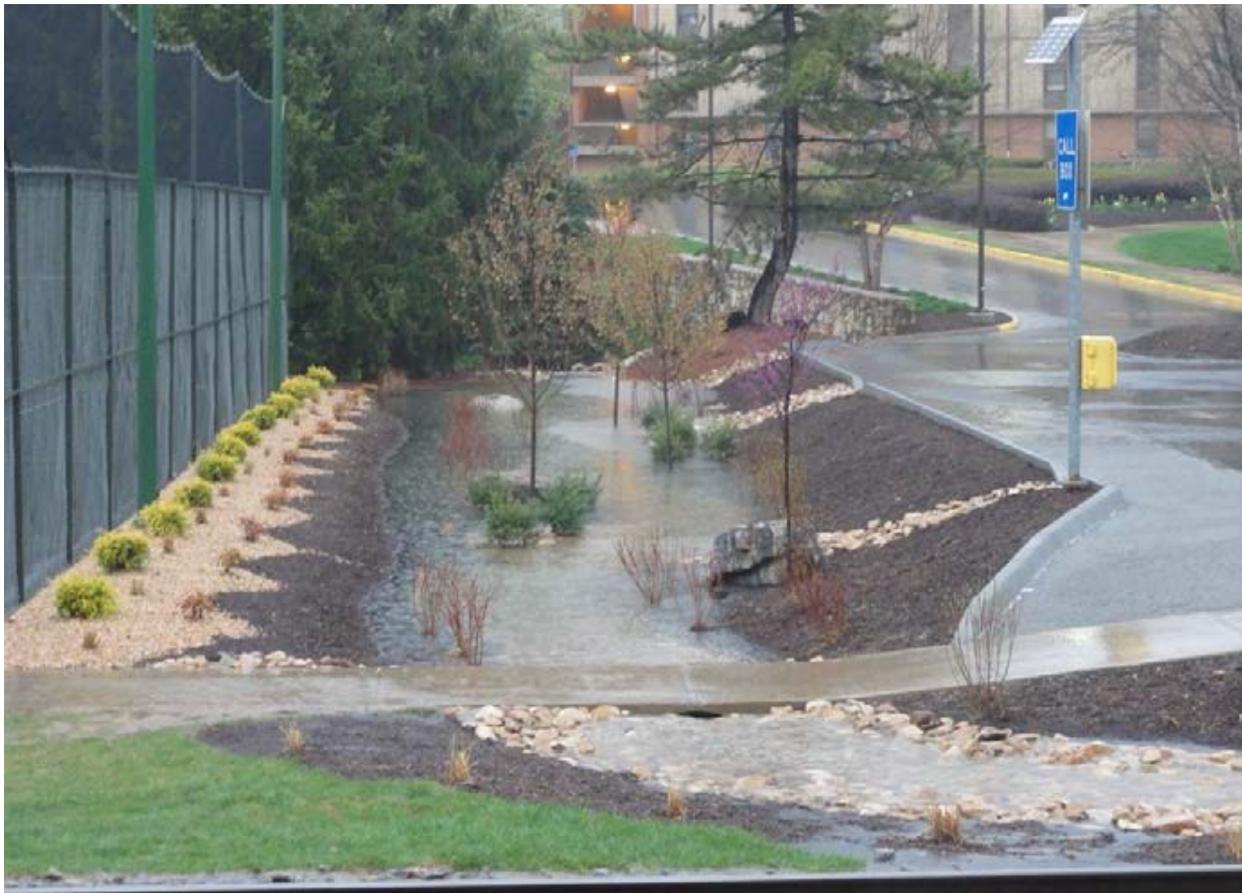


Figure 5. Shows the rain garden by the tennis courts bordering the Hillside Dormitories. This water if not impeded would rush directly into Siebert Creek. Each aspect of the rain garden is applied and visible. (Abe Kaufman)

## Green Roofing

Green roofing is an up and coming water management practice that addresses stormwater runoff originating from buildings. Much like a rain garden, green roofing incorporates vegetation and different layers (Figure 6) to impede the flow of water and help minimize the impact of stormwater on the surroundings (EPA, 2012). Green roofing can reduce runoff from building tops by 50-60 percent. Although these roofs are 2-3 times more expensive than the average roof, they last at least twice as long. In addition, they provide natural insulation which reduces the heating/cooling demand which in turn saves money (EPA, 2012).

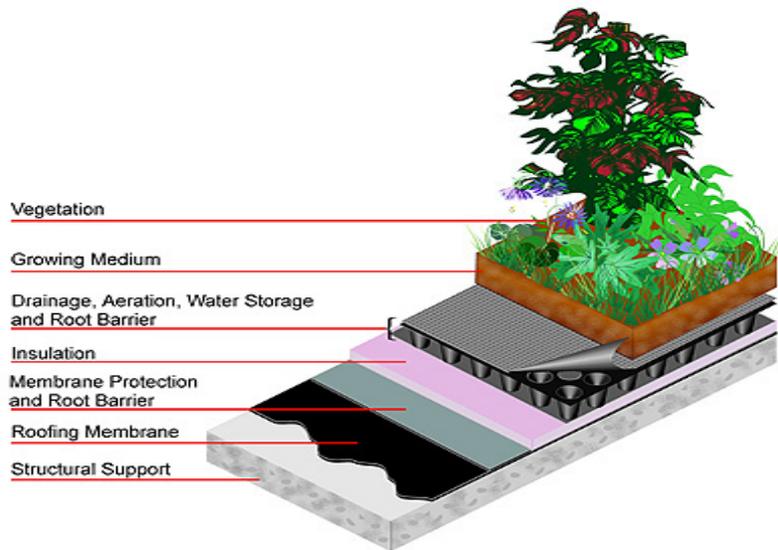


Figure 6. Shows the multitude of layers included within green roofing.

## Stormceptor Drop Inlet

The Stormceptor® is used in precast concrete frame and has a fiberglass insert to trap pollutants. Its particular focus is on total suspended solids and free oils/grease; it reduces these by 80 and 90 percent, respectively (Rinker Stormceptor). The process of how the device works is depicted in Figure 7.

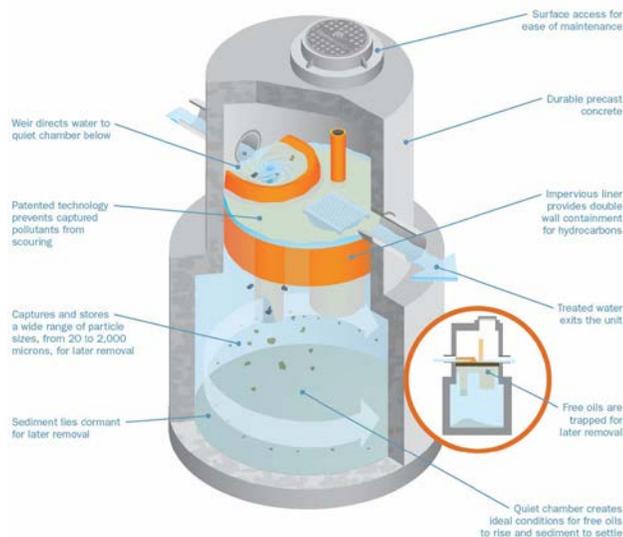


Figure 7. Shows how the inner working of the Stormceptor®

## Retention Ponds

Retention ponds are an integral part of the stormwater management system on East Campus. They are especially useful for capturing large amounts of runoff and are a practical way to decrease flooding. The main pollutants reduced by way of retention ponds are total suspended solids—50 to 90 percent removed—and phosphorus with 40 to 60 percent being taken out (Kaufman, 2011).

## Sand Filters

Sand filters are a low profile way to remove phosphorus and sediments from runoff stormwater. They are able to be installed within highly developed areas where other methods cannot. However, they are not recommended for areas that routinely get high levels of sediment because the sand filters can become clogged. The filters will remove 85 percent of sediment and 65 percent of phosphorus. Other pollutants that will be filtered out include hydrocarbons, bacteria, and trace metals (Idaho DEQ, 2005; Kaufman, 2011). Figure 8 is a picture of a sand filter in use near UREC.



Figure 8. Shows a sand filter that is located below the turf fields at UREC. There are three underlying drains for the water once it flows through the sand bed.

## Project Goals

The goal of this project was to monitor water quality on the James Madison campus during storm events as well as evaluate the effectiveness of JMU's water restoration projects. Water quality parameters included water flow and depth, total phosphorus, total suspended solids, chloride, sulfate, and nitrate. These can be used to assess stream health. It can also be used in conjunction with tests from other waterways to determine where specific pollutants are entering the water system.

This project focused on Siebert Creek, the East Campus Creek exit of the Arboretum, and Newman Lake. Both creeks are small waterways located in Harrisonburg, VA running through the James Madison University Campus. East Campus Creek is a tributary of Siebert Creek. The majority of rain water drains off the JMU campus and into Siebert Creek or Newman Lake.

# Methodology

## Sampling Locations

In order to assess the water quality of Siebert Creek located throughout James Madison University's campus, three key locations were chosen: the Arboretum, Siebert Creek near Godwin, and the exit of Newman Lake (also Siebert Creek). The site at Godwin was chosen because the majority of rain flows from campus into this stream and then flows into Newman Lake. The Newman Site, which is after the storm drain of Newman Lake, was chosen because of its location downstream from Godwin and because it's a tributary to Blacks-Run. The Arboretum site was selected for its potential for runoff from residential businesses in an urban area. These monitoring sites were selected for their land use and geographic location to monitor storm events. Samples were collected from each of these sites before, during, and after the occurrences of storm events.

Table 2 Show summary of sample collection sites

Data Collection Name	Map Label	Land Use
Arboretum	1	Urban/Forested/Developed
Godwin	2	Urban/Developed
Newman	3	Urban/Developed



Figure 9 Map of Monitoring Data on James Madison University's Campus. (Google Maps)



Figure 10. Shows the location of sample site 1 located at James Madison University's Arboretum. (Google Maps)



Figure 11. (Left) Shows the location of sample Site 2 located across from Godwin Hall at James Madison University. This site is at the heart of campus and receives the majority of the runoff from campus (Google Maps). (Right) Site 2 during a storm event with an average flow.



Figure 12. Shows the location of sample site 3 located across I-81 and after Newman Lake crosses Bluestone Drive. The water from this site eventually flows to Blacks Run meeting in Purcell Park. (Google Maps)

### General Water Quality Testing

Water sampling was collected at each of the three sites. Water quality data was taken using a multi-probe meter. This probe measured pH, specific conductivity, turbidity, dissolved oxygen levels and temperature in the field. Each of these measurements was recorded and placed in Excel for later analysis. This field test was performed once each semester to grasp a general understanding of the water quality.

Table 3. Shows the units specified for the WTW General Water Quality Test

Parameter	Units
Temperature	°C
Dissolved Oxygen	mg/L
pH	Standard pH scale
Specific Conductivity	us/cm
Turbidity	NTU



Figure 13. Shows the general water quality testing kit comprised of a meter and a sensor with a semi-permeable membrane tip. (WTW)

## Weather Data

James Madison University owns a small weather station which is located in the Arboretum. This weather station collects a plethora of data from wind speed/direction to precipitation. This report really focuses on water so the data which was required was the rain amount and rain rate which was recorded by the weather station.

## Flow Meters

For sampling to begin at each site, hobo water level sensors were used to calculate flow had to be installed. At each sampling site, screw anchors were drilled into the concrete to hold the pressure meters. The anchors were installed at the lowest location possible to ensure accurate data collection (e.g. Godwin site was at the point of the 'V' in the drainage ditch). The meter was inserted through a metal ring at the downstream end and secured using a torx screw at its upstream end. The metal ring ensured the meter did not swivel and would remain oriented downstream.

To extract the data, each pressure meter had to be physically visited. Once at the sampling location the device is unscrewed from the black heading and the device is inserted into HOBO Optic USB Base Station and uploaded to the Hoboware Software on the Laptop computer. From this program the data is synced with the atmospheric pressure data gathered from the land based probe in the arboretum. With the two pressures synchronized, the atmospheric pressure can be deducted from the measured pressure which leaves the pressure that the water exerted onto the probe. With this pressure and the calculations performed after surveying each site to determine water depth. With area and incline, the speed of the water could be calculated. This data provided an accurate measurement to the changes of flow during each storm event and could further help in our conclusions in other aspects of the sampling.

## Surveying

The surveying tripod was setup and positioned as close to level as possible. The instrument itself has an electronic leveler to correct minor imbalances. The surveying probe was then attached to a large measuring stick and moved until "beeping" was heard. Once the probe was centered, a constant "beep" sounded and the relative height was recorded. This process was repeated every measured foot on the slant up towards Gibbons Hall and then again towards Godwin Hall to calculate cross-sectional area of the stream channel. These measurements were then used to provide an accurate profile of the creek bed. Next, the surveying probe was placed 50 feet upstream from the pressure probe. The process was repeated there and again another 50-- total of 100-- feet upstream to calculate slope of the streambed.

## Total Phosphorus

The Asorbic Acid Method with potassium persulfate digestion was used for Total Phosphorus analysis. The exact protocol is attached in the Appendix A section at the end of this report; this protocol was adopted by Matt Penning.

The first step was to acid wash the desired glassware; this was usually performed before hand to help speed up the whole process. After collecting all the required materials the standards had to be made according to the desired concentrations. The actual dilution amounts can be found in Appendix A. Glassware was arranged according to number and samples recorded on the computer according to their respective number. Once the samples, standards, and glassware were ready a pH indicator was added along with sulfuric acid and potassium persulfate. The samples were placed on hot plates and allowed to



Figure 16. This depicts the digesting process where the samples and standards are on hot plates in the fume hood.

digest down to a small volume of roughly 10 milliliters. The digesting process can be seen in Figure 16. While the samples digested, the combined reagent was usually made. The directions to make this reagent can be found in Appendix A. After the digesting, 20 mL of DI water was added to dilute the samples and a drop of the pH indicator was added. Drops of 1 M NaOH solution are added until a faint pink appears. Next the samples were diluted to 100 mL, a drop of the pH indicator added as well as 8 mL of the combined reagent. After the combined reagent, a waiting period of 10 minutes is necessary before measuring absorbance using the spectrometer. The spectrometer should be set to 880 nm and zeroed out using the Blank. During the ten minutes waiting period before using the spectrometer, the samples and standards will change color and appear blue if there are high levels of phosphorus. Figure 15 shows a full phosphorus run where the color change was apparent and blue was seen in a handful of samples. If a sample reads higher than the highest standard, that sample was diluted and that dilution recorded, until the absorbance reading is below the highest standard.

Once all the data had been collected for the absorbance of our standards and samples a standard curve was made. The standards had been made with specific concentrations of phosphorus. A graph was created and a linear regression performed and a trendline was calculated.



Figure 14. This image was taken in Lab and includes the phosphorus glassware setup along with a few important items on the table in front.



Figure 15. This picture shows us the clear blue color change which occurs to indicate phosphorus levels.

This trendline shows the relationship between absorbance and concentration for our standards. The goal is to achieve a trendline with an  $R^2$  or coefficient of regression closest to one. Our third run was the first successful run where the  $R^2$  value was 0.97; more successful runs experienced  $R^2$  values up to 0.995. With this trendline, we were able to calculate the concentrations of the samples from their individual absorbance values.

### Ion Chromatograph

Ion Chromatograph automatically tested numerous samples for anion levels. The water samples that were collected for this report experienced ion levels for Chloride, Nitrate, and Sulfate. These three ions play a big role in analyzing the water quality of our stream and understanding how storm events affect the levels of these pollutants in our waters.

The Ion Chromatograph has an automatic sampler which uses trays to organize the samples. The only procedure which had to be conducted was the preparation of the samples and standards for the machine to analyze. However, standards were often already made and stored in the refrigerator. For each sample a small 5 mL vial was filled, capped, and labeled appropriately. A notebook was used to record in what order the vials were placed in the trays. A particular standard is then used periodically to ensure quality control. Once the trays had been prepared, Dr. Brent was contacted to begin the run. The IC machine itself can be seen in Figure 18. After the IC had been run the data was exported for analysis. Different ions take longer to run through the machine and come out at different time intervals. Based on the time and area of each peak we can determine which ion is present and the concentration of that ion. The concentration is found using the standards run at the beginning.



Figure 17. This displays the IC trays filled with samples and standards ready to be tested.



Figure 18. These two pictures were taken of the IC machine and the attached equipment. This machine was usually run by Dr. Brent or Dr. Benzing.

## Total Suspended Solids

A test for total suspended solids was another action performed on each individual sample we collected. This measurement determines how much dirt and other waste are being carried by the water at each specified time during an event. The full protocol which was followed can be found in Appendix B. The first step of the process is to wash the filters. After the wash, the filters are placed in marked aluminum trays and placed into a drying oven and left to dry for approximately 1 hour 15 minutes. After this time, the aluminum trays with the filters inside are taken to a balance accurate in grams to the hundredth milligram. Each tray is individually weighed out and the weight is recorded in Excel according to the marked tray. The trays are returned to the drying oven. The weighing process is then repeated. If the second weight is within four percent or 0.5 milligrams the weight is accepted. If not, the filters go through a third round of drying.

Once the weights are accepted, the samples have to be run through the filters. The sample is shaken up thoroughly and 50 milliliters is then poured on top of the filter (20 milliliters is used if the water source is running low). The filter is then washed three more times with 10 milliliters of water. Solid particulates should be left on the filter causing slight coloration. The filters are put into their respective aluminum trays and inserted back into the drying ovens at the same temperature for the same duration. The filters then went through the same exact steps as before filtering the samples-- drying oven and weighing for at least two rounds. Solid mass per unit volume is then calculated. Figure 19 depicts the equipment used during this procedure.



Figure 19. A picture of the total suspended solids process of filtering our samples through individual filters.

## Data and Results

### Sample Collection

Over the course of this project a total of sixty water samples were collected from the Arboretum Outlet, Sieberts Creek by Godwin, and after Newman Lake. Of the sixty samples it was determined that there were around thirty five samples taken during stormflow events while twenty five were taken during baseflow events.

### Weather Data

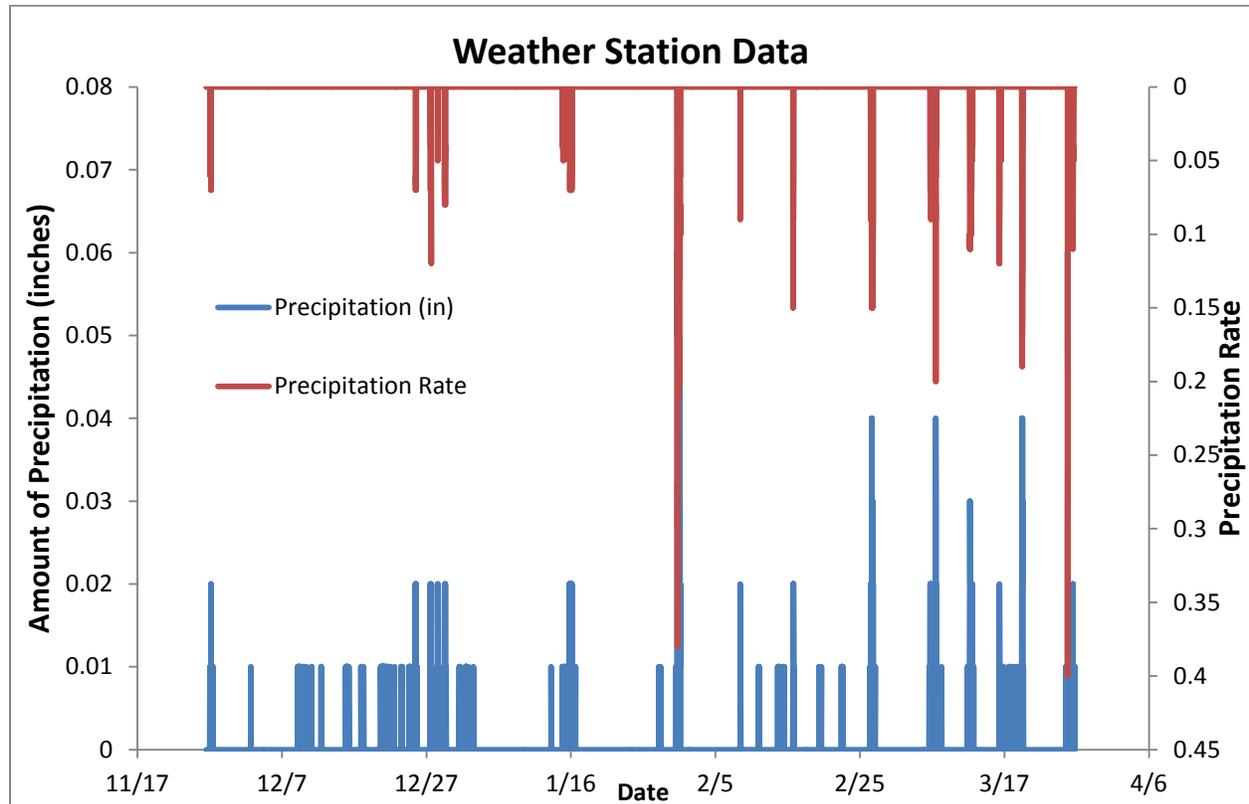


Figure 20. Data for Precipitation values recorded from a weather station located in the Arboretum.

The weather station located in the Arboretum collects a variety of weather data; however, for this project we mainly focused on rainfall and precipitation values. The precipitation values were extracted from the entire set of data and graphed during the period of study of this project. The main storm of focus for this project was located at the end of January. This storm event can be seen at the center of the graph in Figure 20 before February 5<sup>th</sup>. This storm event provided the best data because samples were collected frequently throughout the strong storm event and good data was observed. These precipitation data were used in conjunction with the pollutant concentrations of each sample to show a relationship between the storm event and the pollutant levels. Typically during a period of increased precipitation you will likely see elevated levels of pollution as runoff and stormflow increase.

## Sensor Depth Data

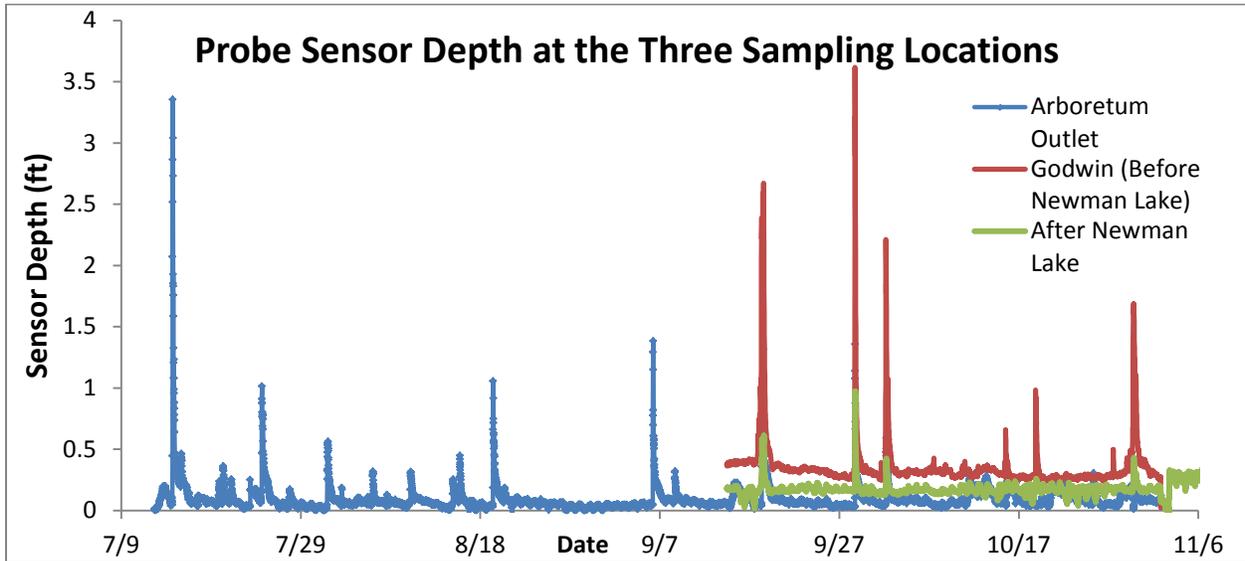


Figure 21. Depth Data measured from pressure probes implemented at the three sampling locations. This data shows the a longer period of study from previous probe data in the Arboretum.

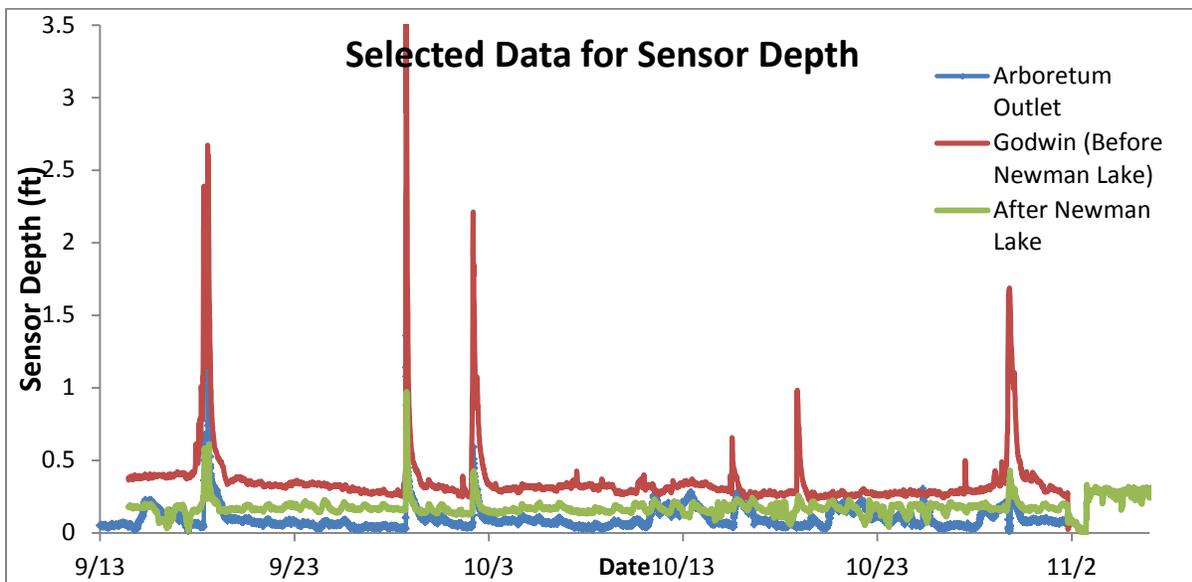


Figure 22 Sensor Depth data collected during this project's span of research. This data shows the three locations at the Arboretum outlet, Godwin, and after Newman Lake.

The sensor depth depicts the depth of the water at the three locations which was measured constantly by the three probes. You can see from Figure 22 that the Arboretum Outlet had the smallest flow overall. This was expected because during sampling of the Arboretum we noticed that the flow was characteristically low and sometime even nonexistent. On the other hand the Godwin location typically had the strongest flow and was most likely to overflow its banks during storm events. This can be seen from the graph with the red line consistently having the largest flow. The location after Newman Lake was somewhere in the middle of the other two flows and did not peak as seriously as the Godwin location.

## Total Phosphorus

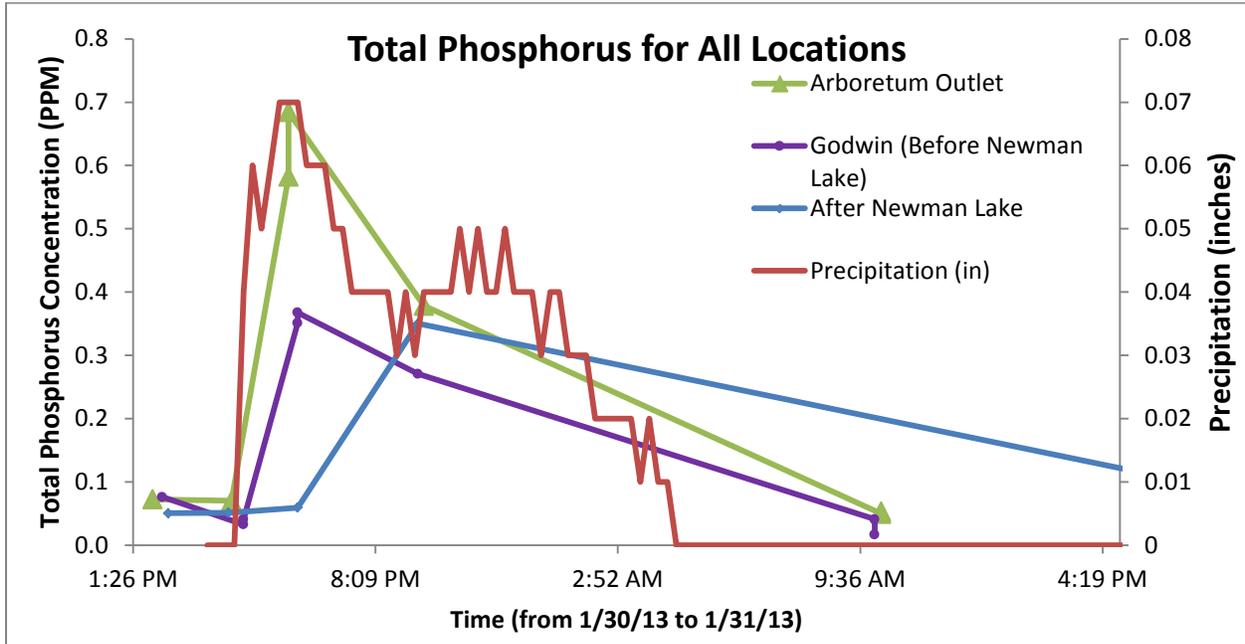


Figure 23. Total Phosphorus Concentrations measured from each sampling location throughout a storm in late January.

During a storm event on January 30<sup>th</sup> to the 31<sup>st</sup> a strong set of samples was taken and tested. The total phosphorus was then tested for each sample and recorded in excel. These data along with the precipitation data taken from the weather station were used to generate Figure 23. As you can see from the graph at the height of the storm we see a peak in phosphorus concentrations at the Arboretum and Godwin locations. The Arboretum concentration peaked at 0.68 ppm while at Godwin it was only 0.36 ppm. There is some delay when looking at the concentration after Newman Lake. This is explained by the fact that it is the farthest downstream location and the water has to travel through Newman Lake itself before reaching the site after the Lake. The concentration after Newman Lake was the lowest measuring at 0.35 ppm. The Arboretum outlet and the Godwin location both flow into Newman Lake. Therefore we expect the high concentration at the Arboretum location to spike the value after the lake. This is not expressed in the data because Newman Lake is seen to reduce pollutant concentrations as the water is allowed to settle and flow reduced.

The total phosphorus data was slightly uncharacteristic with respect to the other data collected. Typically we were expecting the Godwin location to have the highest pollutant concentrations; however, for phosphorus we see a peak at the Arboretum outlet. One idea is that the Arboretum has a higher use of fertilizers and more runs off into the Arboretum pond and therefore out of the arboretum as well. The high levels of phosphorus in fertilizers could account for this high value at the Arboretum.

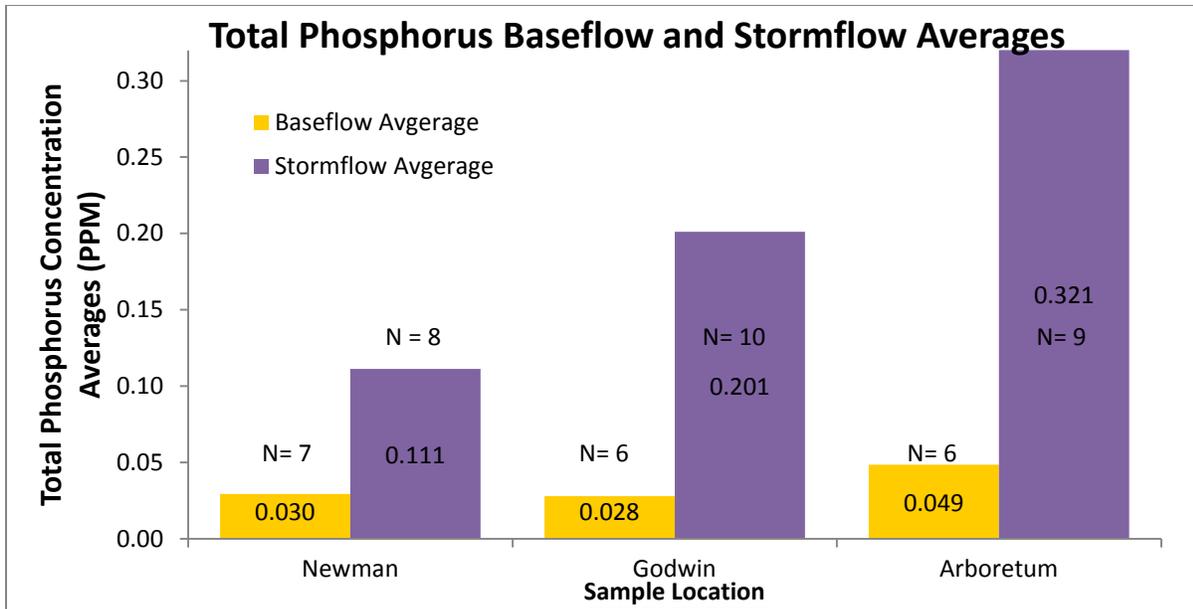


Figure 24. Average Total Phosphorus concentrations during baseflow and stormflow events.

After compiling all the phosphorus data, averages were taken for two types of events either a stormflow average or a baseflow average. The data were divided into two sets, samples taken during storms and those taken at other periods of time which demonstrate baseflow conditions. The two types of flow were then compared in **Error! Reference source not found.** During storm conditions we see a higher phosphorus concentration across the board and relatively constant baseflow value below 0.05 ppm. During storm events the concentrations experienced a serious increase when compared to baseflow. The percent increase was calculated and the Arboretum location experienced a significant increase of 561% while Newman only saw a 277% growth. The concentrations during storm conditions show that the Arboretum had the highest average concentration of 0.321 ppm while the samples after Newman Lake had the lowest concentration of 0.111. Again this low value after Newman Lake is expected as the lake acts as a BMP to reduce pollutant concentrations and allows the water to settle some and filter contaminants.

## Total Suspended Solids Data

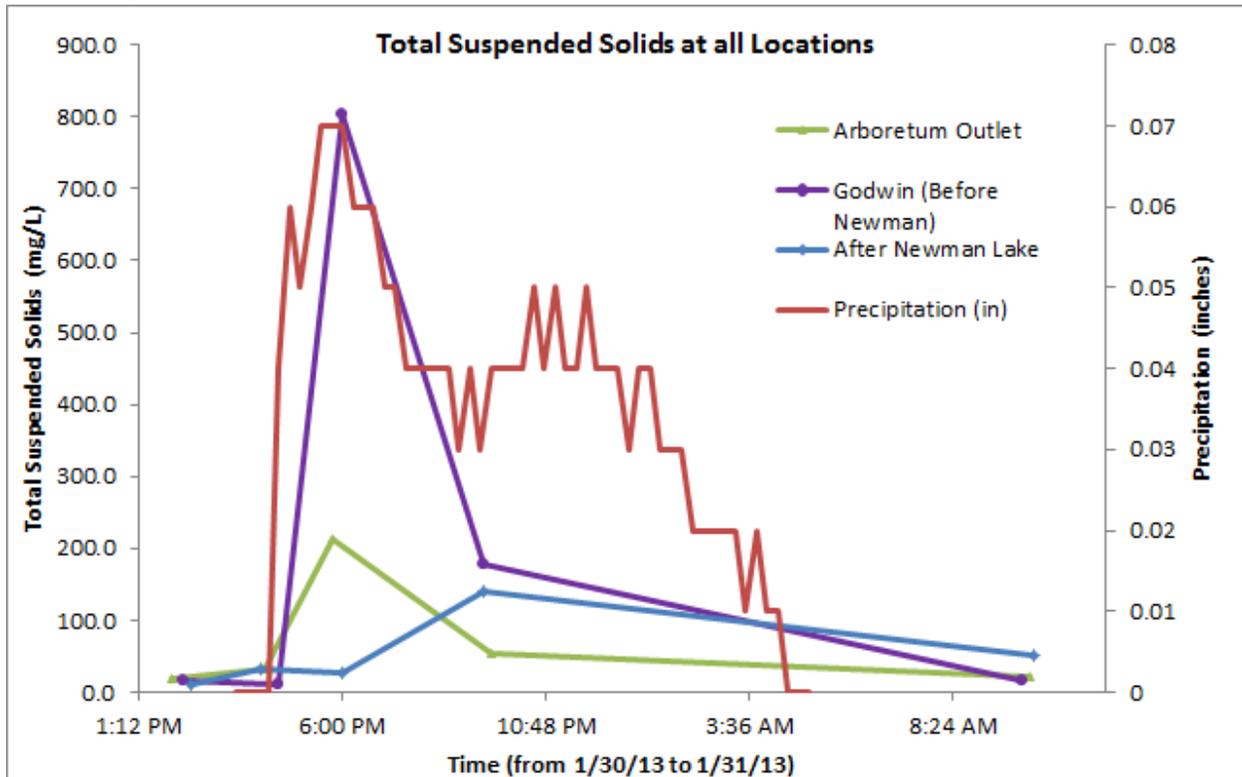


Figure 25. Total Suspended Solids measured from each sampling location throughout a storm in late January.

During a storm event which occurred from January 30<sup>th</sup> to the 31<sup>st</sup> a strong sample set was taken and tested. Total suspended solids test was performed for each sample then recorded in Excel. This data along with the precipitation data taken from the weather station was used to generate Figure 25. As shown in the graph Godwin had the highest total suspended solids with 802 mg/L, recorded at the height of the storm. The Godwin site had the highest amount out of all three of the sampling sites this is due to the concentrated flow of water. The location after Newman Lake peaked after the height of the storm event with 139 mg/L; this is expected because the majority of the sediment settles in the lake before reaching the sampling site. The Arboretum Outlet peaked during the storm event with 214 mg/L; this result again is expected because the site experiences runoff throughout the arboretum and surrounding basins where sediment erosion was observed.

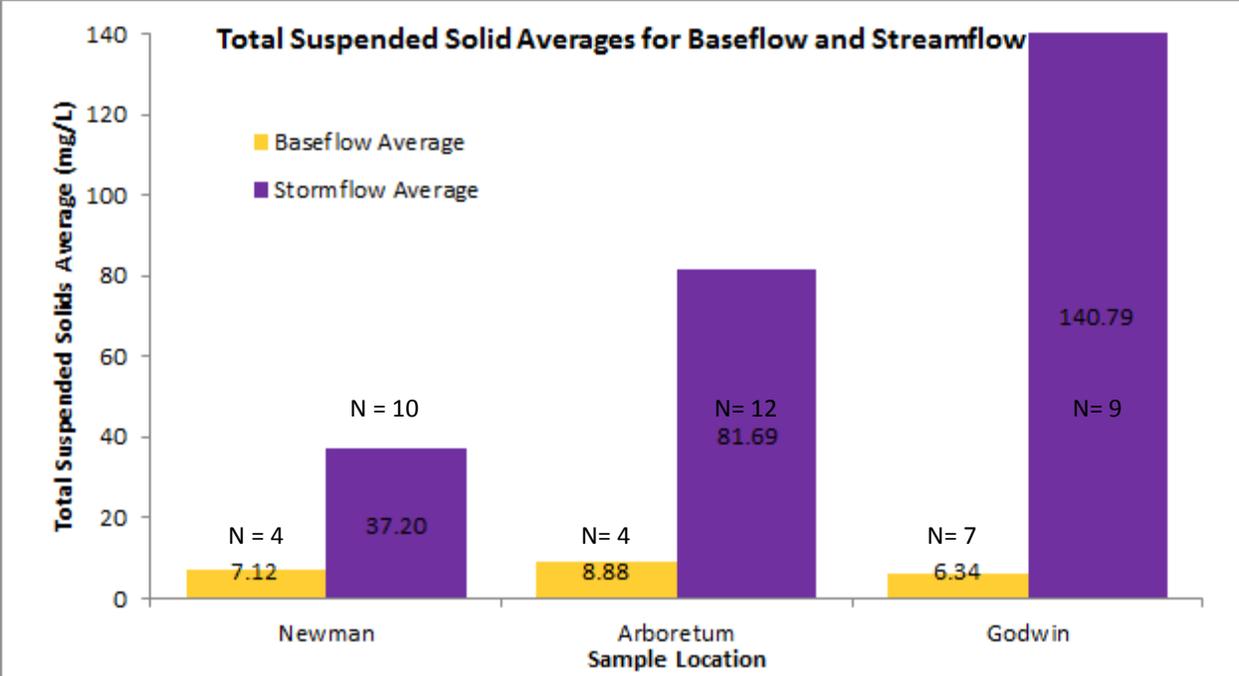


Figure 26. Average Total Suspended Solids during baseflow and stormflow events.

The results for the total suspended solids were compiled then averages were taken for two types of events baseflow and stormflow average. The data were divided into two types of data sets, samples which were taken during storms and those taken at other periods of time which demonstrated baseflow conditions. The base flow is significantly lower than the storm flow average; this is shown in Figure 26. During storm events we see significantly higher total suspended solids over all three locations. When looking at the increase during storm events the Godwin site had a huge jump of 2122% while the Newman location increased by 422%. The Godwin site is notably the highest with an average of 140 mg/L while the lowest was Newman 37 mg/L. The Godwin location again is expected to have the highest due to the concentrated flow. Newman is expected to be the lowest due to the lake acting as a BMP to reduce pollutants and sediment.

## Ion Chromatography Data

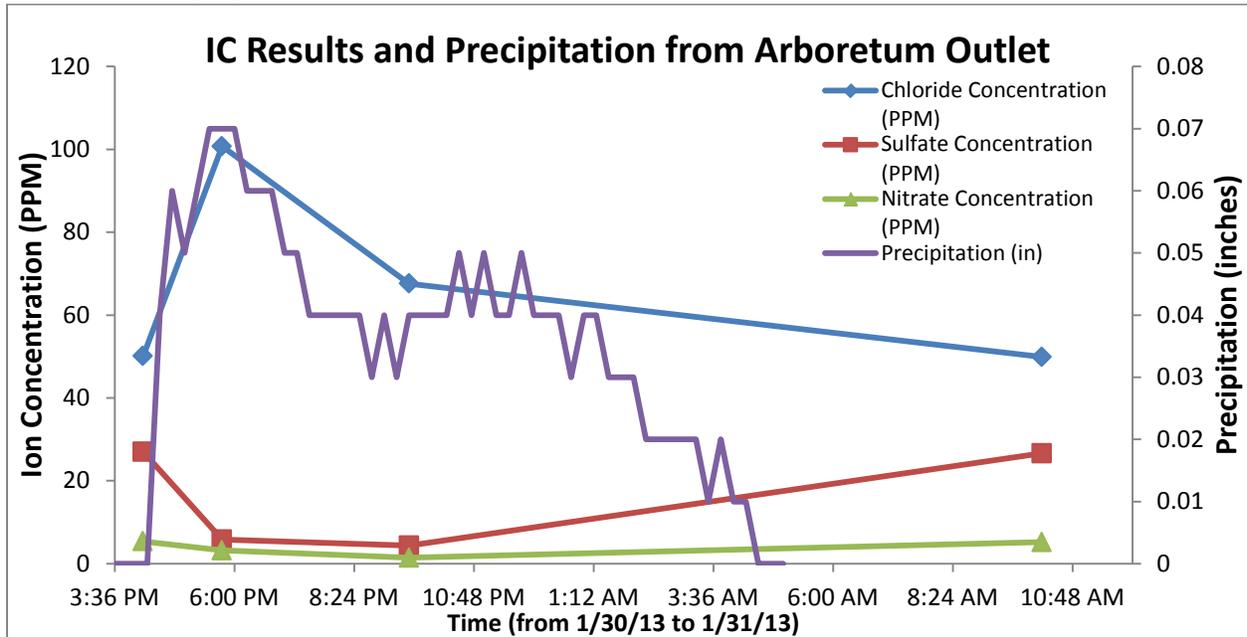


Figure 27. Shows Ion Chromatography data for the Arboretum from January 30, 2013 through January 31, 2013. The data for chloride, sulfate, and nitrate are able to be compared to precipitation over the period of the storm event.

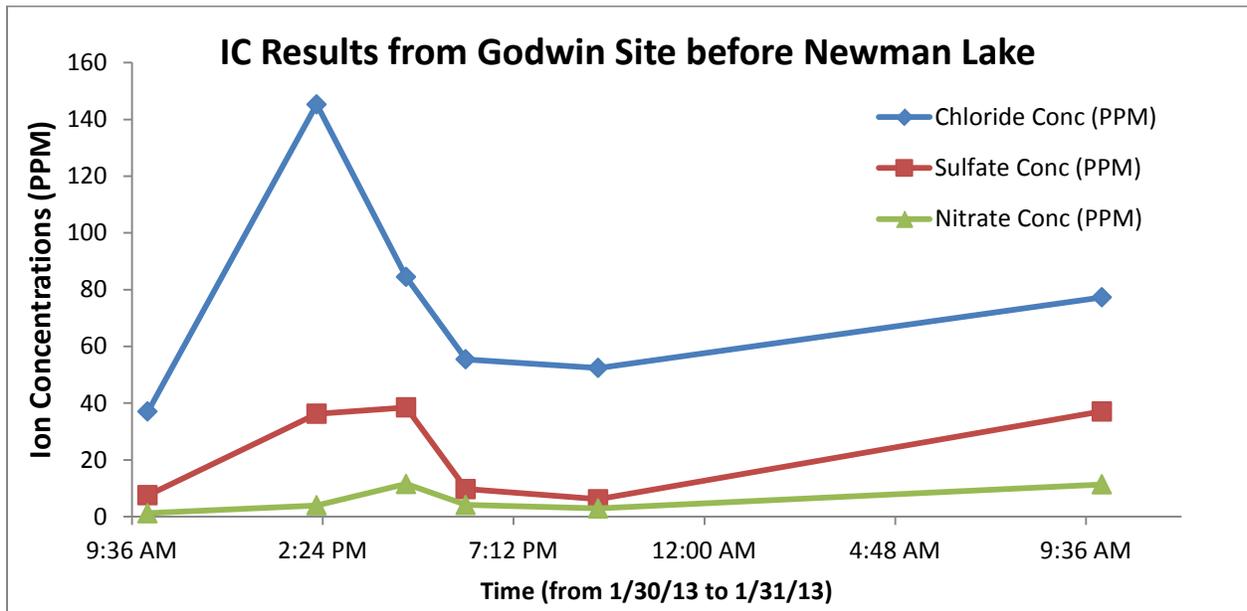


Figure 28. Shows Ion Chromatography data for the Godwin site from January 30, 2013 through January 31, 2013.

Ion Chromatography data collected from Newman Lake did not show consistent results.

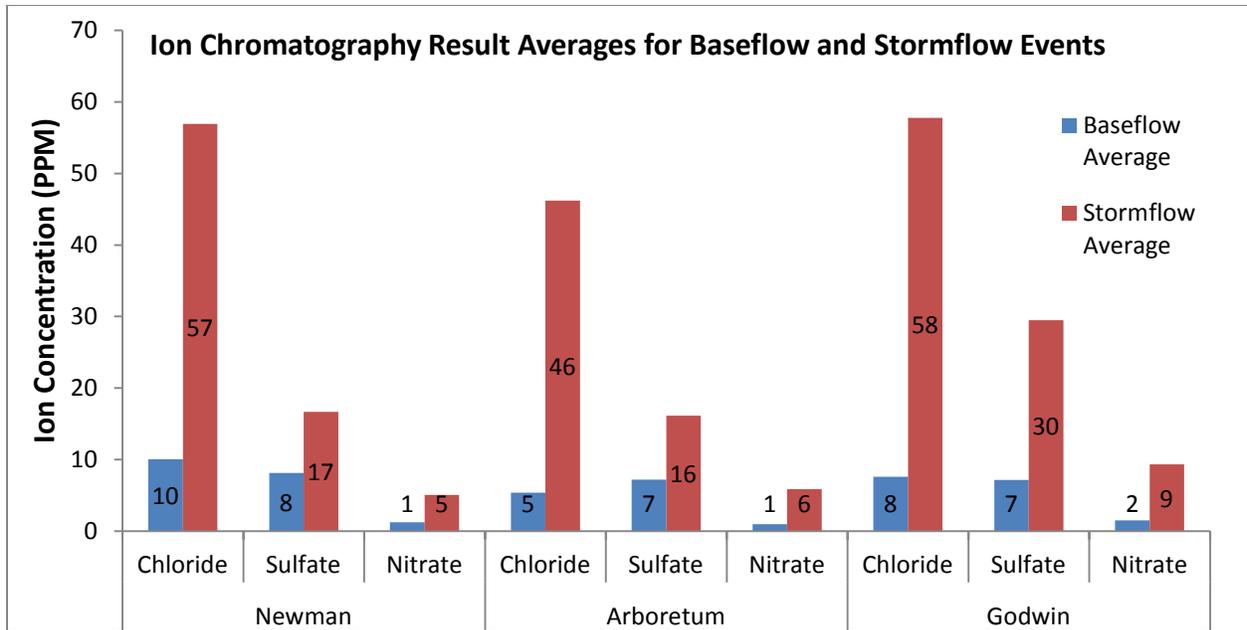


Figure 29. Shows a comparison between average baseflow and average stormflow for each ion at each testing site. Every site showed an increase in the average ion concentrations.

The IC data for the Arboretum showed a level of chloride that closely resembled the precipitation timing. The sulfate and nitrate levels dipped during the event but were elevated following the storm. The Godwin site experienced the same phenomena with chloride as the Arboretum, but at a higher concentration level. Additionally, nitrate and sulfate levels peaked during the storm at the Godwin location, but remained elevated at a level higher than the baseflow data. Overall, the sites experienced an increase in ion concentrations during and after storm events which demonstrates the water's ability to wash dissolved ions from the land surface during storm events.

## Discussion and Analysis

### Phosphorus

Once the data were consolidated we were able to assess the impact storm events had on phosphorus levels. During the height of precipitation events the total phosphorus concentrations experienced a significant increase. The recommended total phosphorus criterion for maximum aquatic diversity is 0.01 ppm with a more lenient recommendation of not exceeding 0.1 ppm. The data collected had only one sample meeting the recommendation for maximum aquatic diversity while the rest typically exceeded the more lenient recommendation of 0.1 ppm. The average values during stormflow conditions exceeded the recommended concentration while the baseflow averages were just under the recommendation of 0.1 ppm. This demonstrates that during normal flow conditions the phosphorus concentration in our waters on campus is actually at an acceptable level but during storm conditions this concentration is seriously effected and can reach significantly higher concentrations exceeding recommended standards. These criteria are simply recommended values and are not enforceable at this point in time. They simply set a value that people should try to meet if possible but no punishment or enforcement is necessary.

Phosphorus is a critical nutrient vital for plant and human life to exist. It is considered a determining factor when looking at plant growth. Phosphorus is therefore a crucial component of fertilizers which intend to help our lawns / plants grow faster. When fertilizer is over applied and precipitation occurs there is the likely chance that the excess phosphorus and nitrogen from the fertilizer will combine with the stormwater runoff and flow into our streams. These elevated phosphorus levels are unhealthy for our streams and can cause algal blooms. The Arboretum Pond is filled with algae and plant matter along with the other small waterways located in the arboretum. These are signs of excess nutrients in our waters and this is apparent when looking at the phosphorus concentrations in the Arboretum during storm events.

### Total Suspended Solids

Total Suspended Solids data was collected by running our samples through pre-weighted filters, then weighing the filter after drying to measure the difference in weight. This gain in weight is the dry weight measurement of present particles. High flow rate is a primary factor in total suspended solids concentration. Fast running water is capable of carrying more particles and sediment and significantly increases soil erosion. During storm events particles from urban areas can be washed into stream, due to the large amount of impervious surfaces and decreased infiltration. Large amounts of sediment are carried through storm runoff directly into streams.

Total suspended solids played a significant role in testing our samples and analyzing water quality. The recommended constant weight or a change of less than 4% of previous weight or 0.5 mg was used to determine each sample. A recommended standard deviation of 5.2 mg/L was used to determine precision.

## **Ion Chromatography**

Ion Chromatography is a method used to test for ion levels in stormwater for this project. The method itself uses a resin and separates ions “based on its interaction with the resin” (Bruckner). The ion chromatography data showed an overall increase in ion concentrations at each site during storm events. Chloride saw the highest average increase, followed by sulfate, and nitrate showing the smallest average increase.

Chloride is a salt that is a common ion found in urban stormwater. The most common source comes as a result of treating roads to prevent icing (EPA). This would be a reasonable conclusion because most of the project testing occurred from October through January and roads were treated a multitude of times during this period. Other possible sources include detergents, soaps, and other cleaning agents. Once chloride becomes dissolved in the water, it is costly to remove. This can have negative impacts on plant and wildlife when it reaches high concentrations (EPA).

Sulfate is another salt which contains sulfur. “The decay of plants, animals, and some industrial processes produce these salts. Mines, tanneries, steel mills, pulp mills, and textile plants also release sulfates into the environment” (EPA). It is estimated that three percent of the water of public water facilities is over the recommended guideline set forth by the EPA. Sulfate can also stimulate the methylation of mercury. This form of mercury is regarded as the most dangerous to the environment and could prove devastated to valley waterways that already show high levels of mercury. Additionally, sulfate aids in the release of other nutrients within soils into water (Orem).

Nitrates are naturally occurring within soil and also come from decaying organisms. Nitrates are essential for a healthy water system. Nitrogen promotes growth in plants and algae. However, too much nitrogen can lead to algae blooms which can limit life for the rest of the organisms within the ecosystem. Excess nitrogen is expected in the Shenandoah Valley because of its farming culture and use of fertilizers. High concentrations of nitrogen can also affect drinking water. Infants are particularly susceptible to these higher concentrations if not removed. The nitrate levels measured in this project were not particularly high. That being said, most of the data collection occurred outside the time frame for fertilization and heavy farming practices.

## **Conclusion**

The James Madison University Campus includes a variety of water systems leading into Newman Lake at the edge of campus before leaving campus and flowing into Blacks Run in Purcell Park. The two main streams on campus are Siebert’s Creek and East Campus Creek which flows out of the Arboretum. This project focused on studying Siebert’s Creek just before

Newman Lake, the water flowing out of the Arboretum, and the water leaving Newman Lake and later flowing into Black's Run.

It was observed from the data collected throughout this project that pollutant concentrations after Newman Lake were significantly smaller than levels measured before the Lake. This demonstrates the capacity of Newman Lake to act as a BMP and filter contaminants out of our water on campus. Newman Lake allows the water running through Siebert's Creek to slow down and settle some before leaving the JMU campus. The reduced flow will allow solids and any pollutants absorbed or associated with those solids to settle. Some pollutants are able to be removed from the water and this demonstrates how Newman Lake improves the water quality as water flows out of campus.

The Godwin location received the majority of the stormwater runoff from campus and had the strongest flow. As a result of the huge amount of runoff the water quality at this location was typically the worst. The Godwin location saw huge levels of Total Suspended Solids as well as significantly larger ion concentrations measured by the ion chromatograph. Total Phosphorus concentrations had different characteristics and were highest at the Arboretum location.

One analysis was done in comparing our measured concentrations to the EPA recommended standards. The phosphorus criterion was significantly exceeded during storm events. The recommended levels for chloride, sulfate, and nitrate were actually not exceeded during our study; however, the chloride concentration was significantly higher than the other two. There is no Total Suspended Solids criterion; however, the values measured were relatively high in comparison to other recorded values.

During storm conditions the pollutant concentrations experienced a severe peak at the height of the storm and proceeded to decline as the storm slowed down. This demonstrates the negative effects of stormwater on the general water quality on campus. During storm conditions practically every pollutant experienced a significant increase in their concentration due to the added stormwater. Total suspended solid concentrations at the Godwin location experienced a 2122% increase when comparing baseflow conditions to storm conditions. Another comparison of total phosphorus showed a 561% increase at the Arboretum location during storm conditions. Stormwater characteristically contains pollutants as the water flows over impervious surfaces and comes in contact with a variety of chemicals, oils, nutrients, and other contaminants. This stormwater has bad water quality characteristics and has detrimental effects on the water quality on JMU Campus.

## Appendices

### Appendix A – Phosphorus Protocol

*Based on the Total Phosphorus Method for Low Concentrations in Water  
“APHA Method 4500-P (B&E)”  
Revised by Matt Penning*

#### **Preparation → Acid Wash the Glassware**

- Fill a tub  $\frac{3}{4}$  full with 1% HCl acid wash
- Gather the necessary glassware for the phosphorus run
  - [1] Erlenmeyer flask, [1] 50 mL volumetric flask, and [1] 100 mL volumetric flask for EACH standard and sample to be analyzed
    - For example: Blank, Std 1, Std 2, Std 3, Std 4, Std 5, Std 6, = [7] Erlenmeyer flasks, [7] 50 mL volumetric flasks, and [7] 100 mL volumetric flasks = [21] pieces of glassware total
  - [4] 100 mL graduated cylinders
  - [1] 500 mL volumetric flask
  - [2] spectrometer cuvettes
- Submerge the glassware in the acid bath, wait 15 minutes, and rinse out each individual piece of glassware with DI water
- Place the rinsed out glassware on a tray to dry

#### **Gathering of Materials**

- Grab samples from the freezer or refrigerator
  - If frozen, add samples to a tub filled with warm water to thaw
- Grab the black container with opaque HDPE and dark, glass-stoppered bottles from Dr. Brent’s cabinet
- From the glassware/pipet storage closet, gather the following:
  - [1] 5-50  $\mu$ L micro-pipet (orange knob), along with the small pipet tips (in a yellow top box)
  - [1] 1-5 mL milli-pipet (grey knob), along with the large pipet tips (in a clear Ziploc bag)
  - Box of transfer pipets/droppers
- In Fred’s chemical closet:
  - Phenolphthalein indicator (small bottle encased in aluminum foil)
  - Potassium persulfate ( $K_2S_2O_8$ )
  - Ascorbic acid
  - Ammonium molybdate ( $(NH_4)_6MO_7O_{24} \cdot 4H_2O$ )
  - Potassium antimonyl tartrate  $K(SbO)C_4H_4O_6 \cdot 1/2H_2O$
  - Phosphorus stock solution
  - Sodium hydroxide (NaOH)
  - Sulfuric acid ( $H_2SO_4$ )
- Other materials scattered around lab:
  - [1] weigh tray for EACH standard and sample to be analyzed
  - Scale
  - Safety gloves
  - Parafilm (stretchy wax paper)
  - Spectrometer
  - DI water jug

- DI squirt bottle
- Kwik wipes

### Procedure

- Organize glassware in rows of Erlenmeyer flasks, 50 and 100 mL volumetric flasks, with the respective standard and sample glassware lined up accordingly
- Make the (Initial) Reagents as necessary
  - 1 M NaOH
    - 20 g NaOH in 500 mL OR 4 g NaOH in 100 mL
  - 30 % Sulfuric acid
    - Fill the 500 mL volumetric flask with 300 mL of DI water
    - Add 150 mL of H<sub>2</sub>SO<sub>4</sub> to 500 mL volumetric flask of DI
    - Fill to volume with DI water
  - Phenolphthalein indicator solution (if necessary)
    - In a 250 mL volumetric flask, prepare by dissolving 0.10 g in 188 mL reagent ethanol
    - Dilute to volume with DI water
- Pour the samples into respective 50 mL volumetric flasks
- Prepare the standards in respective 100 mL volumetric flasks, in this order:
 

○ Std 6 = 40 μL of Phosphorus stock, fill to volume with DI water	<b>[0.400 ppm]</b>
○ Std 5 = 20 μL of Phosphorus stock, fill to volume with DI water	<b>[0.200 ppm]</b>
○ Std 4 = 10 μL of Phosphorus stock, fill to volume with DI water	<b>[0.100 ppm]</b>
○ Std 3 = 5 μL of Phosphorus stock, fill to volume with DI water	<b>[0.050 ppm]</b>
○ Std 2 = 6.25 mL of Std 6, fill to volume with DI water	<b>[0.025 ppm]</b>
○ Std 1 = 2.5 mL of Std 6, fill to volume with DI water	<b>[0.010 ppm]</b>
○ Blank = All DI water	<b>[0.000 ppm]</b>
- Transfer standards into 50 mL volumetric flasks
- Transfer standards and samples into 125 mL Erlenmeyer flask
- Add 1 drop of phenolphthalein solution to each sample and standard
  - If a pink color is observed, add small drops of acid solution to decolorize
- Add 1 mL of 30% (H<sub>2</sub>SO<sub>4</sub>) to each sample and standard – use the tall pipet with the green attachment
- Measure out 0.5 g K<sub>2</sub>S<sub>2</sub>O<sub>8</sub> in weigh trays and add to each sample/standard
- Digest samples/standards on a hot plate at a setting of 7-8; be careful not to allow any splatter
  - In the meantime, make combined reagent (see “Combined Reagents” section)
- Allow the flasks to cool to near room temperature, and then add about 20 mL of DI water using squirt bottle to bring the total volume to about 30 mL
- Add 1 drop of phenolphthalein and swirl gently to mix
- Add drops of 1 M NaOH solution using dropper until faint pink is apparent and lasts more than a couple of minutes when swirled gently
  - Usually takes at least 5 full squeezes of M NaOH dropper
- Transfer to a 100 mL volumetric flask
- Dilute to volume with DI water (add so there’ll be 100 mL)
- Pipet 50 mL of the sample/standard back into the Erlenmeyer flasks
- Add 1 drop of phenolphthalein
  - If pink or red, add drops of 2.5 M sulfuric acid until color disappears
- Pipet 8 mL of combined reagent and mix thoroughly
- Set spectrometer to 880 nm
- Adjust the spectrometer with the Blank (tear/zero it)
- Collect the absorbance data 10 minutes after adding the combined reagent, but before 30 minutes

### Data Analysis

- Graph the calibration curve – plot the blank/standards' concentrations on the X-axis and their corresponding absorbances on the Y-axis
  - Generate the linear regression line and equation (set the intercept = 0)
  - Rearrange the trendline equation to solve for the concentration
  - Plug the samples' absorbance values into the rearranged trendline equation to determine the samples' unknown concentrations

### (Combined) Reagent Solutions and Instructions

- 2.5 M sulfuric acid ( $\text{H}_2\text{SO}_4$ ) solution
  - Fill the 500 mL volumetric flask with 400 mL of DI water
  - Slowly add 70 mL of concentrated sulfuric acid to the 500 mL volumetric flask of DI water
  - Allow to cool, fill to 500 mL with DI water, then transfer to a clean HDPE bottle
- Ammonium molybdate solution
  - Dissolve 20 g of  $(\text{NH}_4)_6\text{MO}_7\text{O}_{24}\cdot 4\text{H}_2\text{O}$  in 500 mL of DI water
  - Store in a dark, glass-stoppered bottle
- 0.1 M ascorbic acid solution
  - Dissolve 1.76 g of ascorbic acid in 100 mL of DI water
  - Store in a opaque plastic bottle
- Potassium antimonyl tartrate solution
  - Fill the 500 mL volumetric flask with 400 mL of DI water
  - Dissolve 1.3715 g  $\text{K}(\text{SbO})\text{C}_4\text{H}_4\text{O}_6\cdot 1/2\text{H}_2\text{O}$  in the 500 mL volumetric flask of DI water
  - Fill to 500 mL with DI water
  - Store in a dark, glass-stoppered bottle
- Combined reagent (200 mL) – make in plastic bottle labeled “Combined Reagent”
  - Add 100 mL of 2.5 M sulfuric acid solution
  - Add 10 mL of potassium antimonyl tartrate solution
  - Add 30 mL ammonium molybdate
  - Add 60 mL 0.1 M ascorbic acid solution

## Appendix B – Total Suspended Solids Protocol

2-56

### 2540 D. Total Suspended Solids Dried at 103–105°C

#### 1. General Discussion

*a. Principle:* A well-mixed sample is filtered through a weighed standard glass-fiber filter and the residue retained on the filter is dried to a constant weight at 103 to 105°C. The increase in weight of the filter represents the total suspended solids. If the suspended material clogs the filter and prolongs filtration, the difference between the total solids and the total dissolved solids may provide an estimate of the total suspended solids.

*b. Interferences:* See 2540A.2 and 2540B.1. Exclude large floating particles or submerged agglomerates of nonhomogeneous materials from the sample if it is determined that their inclusion is not desired in the final result. Because excessive residue on the filter may form a water-entrapping crust, limit the sample size to that yielding no more than 200 mg residue. For samples high in dissolved solids thoroughly wash the filter to ensure removal of dissolved material. Prolonged filtration times resulting from filter clogging may produce high results owing to increased colloidal materials captured on the clogged filter.

#### 2. Apparatus

Apparatus listed in Sections 2540B.2 and 2540C.2 is required, except for evaporating dishes, steam bath, and 180°C drying oven. In addition:

*Aluminum weighing dishes.*

#### 3. Procedure

*a. Preparation of glass-fiber filter disk:* Insert disk with wrinkled side up in filtration apparatus. Apply vacuum and wash disk with three successive 20-mL portions of reagent-grade water. Continue suction to remove all traces of water, and discard washings. Remove filter from filtration apparatus and transfer to an inert aluminum weighing dish. Take care to prevent the dried filter from adhering to the weighing dish. Alternatively weigh dried filter and weighing dish both before and after filtration. Filter material that sticks to the dish must be added to the filter to avoid error. If a Gooch crucible is used, remove crucible and filter combination. Dry in an oven at 103 to 105°C for 1 h. If volatile solids are to be measured, ignite at 550°C for 15 min in a muffle furnace. Cool in desiccator to balance temperature and weigh. Repeat cycle of drying or igniting, cooling, desiccating, and weighing until a constant weight is obtained or until weight change is less than 4% of the previous weighing or 0.5 mg, whichever is less. Store in desiccator until needed.

*b. Selection of filter and sample sizes:* See Section 2540C.3c. For nonhomogeneous samples such as raw wastewater, use a large filter to permit filtering a representative sample.

*c. Sample analysis:* Assemble filtering apparatus and filter and begin suction. Wet filter with a small volume of reagent-grade water to seat it. Stir sample with a magnetic stirrer, and while stirring, pipet a measured volume onto the seated glass-fiber filter. Wash with three successive 10-mL volumes of reagent-grade water, allowing complete drainage between washings, and continue suction for about 3 min after filtration is complete. Samples with high dissolved solids may require additional wash-

ings. Carefully remove filter from filtration apparatus and transfer to an aluminum weighing dish as a support. Alternatively, remove the crucible and filter combination from the crucible adapter if a Gooch crucible is used. Dry for at least 1 h at 103 to 105°C in an oven, cool in a desiccator to balance temperature, and weigh. Repeat the cycle of drying, cooling, desiccating, and weighing until a constant weight is obtained or until the weight change is less than 4% of the previous weight or 0.5 mg, whichever is less. Duplicate determinations should agree within 5% of their average. If volatile solids are to be determined, treat the residue according to 2540E.

#### 4. Calculation

$$\text{mg total suspended solids/L} = \frac{(A - B) \times 1000}{\text{sample volume, mL}}$$

where:

*A* = weight of filter + dried residue, mg, and  
*B* = weight of filter, mg.

#### 5. Precision

The standard deviation was 5.2 mg/L (coefficient of variation 33%) at 15 mg/L, 24 mg/L (10%) at 242 mg/L, and 13 mg/L (0.76%) at 1707 mg/L in studies by two analysts of four sets of 10 determinations each.

Single-laboratory duplicate analyses of 50 samples of water and wastewater were made with a standard deviation of differences of 2.8 mg/L.

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## Appendix C- The Talloires Declaration

### Association of University Leaders for a Sustainable Future The Talloires Declaration 10 Point Action Plan

We, the presidents, rectors, and vice chancellors of universities from all regions of the world are deeply concerned about the unprecedented scale and speed of environmental pollution and degradation, and the depletion of natural resources. Local, regional, and global air and water pollution; accumulation and distribution of toxic wastes; destruction and depletion of forests, soil, and water; depletion of the ozone layer and emission of “green house” gases threaten the survival of humans and thousands of other living species, the integrity of the earth and its biodiversity, the security of nations, and the heritage of future generations. These environmental changes are caused by inequitable and unsustainable production and consumption patterns that aggravate poverty in many regions of the world.

We believe that urgent actions are needed to address these fundamental problems and reverse the trends. Stabilization of human population, adoption of environmentally sound industrial and agricultural technologies, reforestation, and ecological restoration are crucial elements in creating an equitable and sustainable future for all humankind in harmony with nature.

Universities have a major role in the education, research, policy formation, and information exchange necessary to make these goals possible.

Thus, university leaders must initiate and support mobilization of internal and external resources so that their institutions respond to this urgent challenge.

We, therefore, agree to take the following actions:

#### ***1) Increase Awareness of Environmentally Sustainable Development***

Use every opportunity to raise public, government, industry, foundation, and university awareness by openly addressing the urgent need to move toward an environmentally sustainable future.

#### ***2) Create an Institutional Culture of Sustainability***

Encourage all universities to engage in education, research, policy formation, and information exchange on population, environment, and development to move toward global sustainability.

#### ***3) Educate for Environmentally Responsible Citizenship***

Establish programs to produce expertise in environmental management, sustainable economic development, population, and related fields to ensure that all university graduates are environmentally literate and have the awareness and understanding to be ecologically responsible citizens.

#### ***4) Foster Environmental Literacy For All***

Create programs to develop the capability of university faculty to teach environmental literacy to all undergraduate, graduate, and professional students.

#### ***5) Practice Institutional Ecology***

Set an example of environmental responsibility by establishing institutional ecology policies and practices of resource conservation, recycling, waste reduction, and environmentally sound operations.

#### ***6) Involve All Stakeholders***

Encourage involvement of government, foundations, and industry in supporting interdisciplinary research, education, policy formation, and

information exchange in environmentally sustainable development. Expand work with community and nongovernmental organizations to assist in finding solutions to environmental problems.

**7) Collaborate for Interdisciplinary Approaches**

Convene university faculty and administrators with environmental practitioners to develop interdisciplinary approaches to curricula, research initiatives, operations, and outreach activities that support an environmentally sustainable future.

**8) Enhance Capacity of Primary and Secondary Schools**

Establish partnerships with primary and secondary schools to help develop the capacity for interdisciplinary teaching about population, environment, and sustainable development.

**9) Broaden Service and Outreach Nationally and Internationally**

Work with national and international organizations to promote a worldwide university effort toward a sustainable future.

**10) Maintain the Movement**

Establish a Secretariat and a steering committee to continue this momentum, and to inform and support each other's efforts in carrying out this declaration.

1994 Updated Version

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