Water Quality Analysis for the Anderson Watershed in Manhattan, Kansas

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Abstract:

Freshwater resources are important to the health and wellbeing of human life. Harmful effects to human health can occur when water quality is decreased. Agriculture, urban developments and golf courses commonly overuse pesticides and fertilizers which can cause water quality to decline. To understand the potential effects that a golf course can have on water quality, we collected samples in a watershed downstream of the Colbert Hills Golf Course in Manhattan, Kansas. During the spring of 2015, over a period of six weeks, we collected 30 water samples from five major geographical locations within the watershed. We found to a degree of 95% confidence that water sampled downstream in the watershed was not significantly different than water quality samples collected near the golf course. This observation suggests that the Colbert Hills Golf Course does not contribute to water quality degradation in the surrounding environment.

Introduction:

Background:

Earth has a finite amount of natural resources. Of all of those resources, water is one of the most precious that we have. It is used for drinking, cleaning, growing the crops we eat, and recreational enjoyment. The world's water supply is becoming more and more scarce and what available freshwater that is safe is becoming contaminated by human activity. The Anderson sub-watershed is located on the western edge of Manhattan, Kansas. The primary source of water is rainfall and a few spring fed ponds and creeks. Figure 1 below shows that a large portion of the land cover is urban development, with additional land covered by the Colbert Hills Golf Course.

Additionally there is a small natural site on the northern edge of the watershed. The city of Manhattan receives an average rainfall of about 35.7 inches of rain (U.S. Climate Data). During the study we used water quality testing kits with several easy tests to determine a plethora of various metrics.

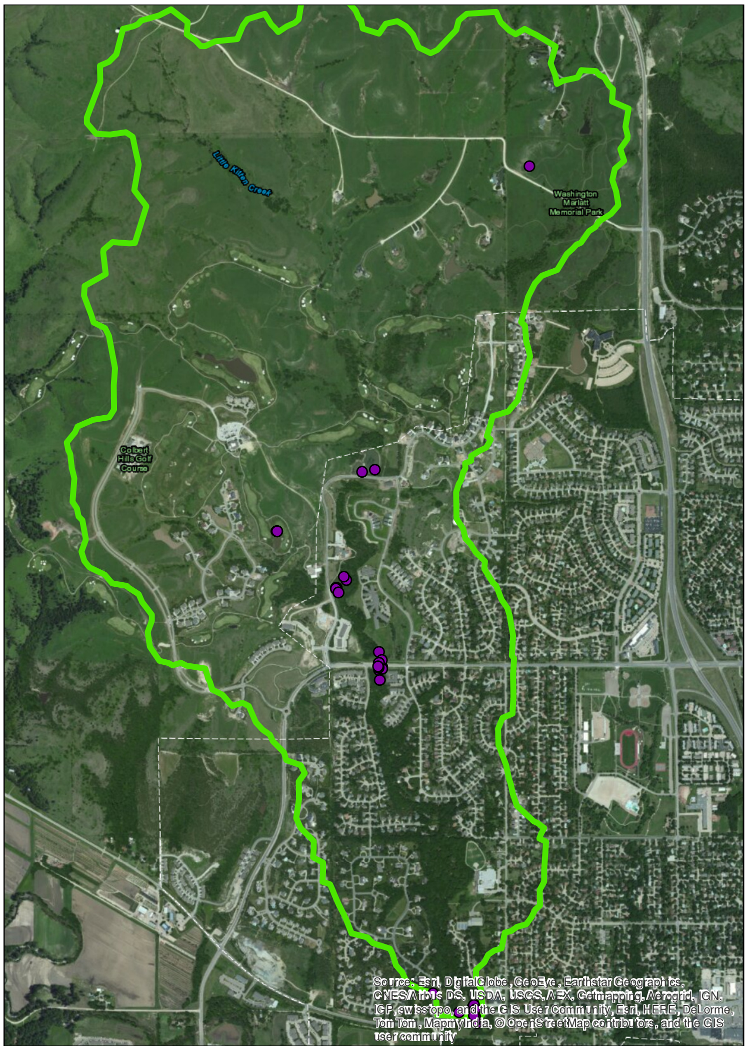


Figure 1 – An aerial mapped image of the Anderson watershed, outlined in green

The focus of our study is to look at the levels of pH, nitrates, phosphates, electrical conductivity (EC), and dissolved oxygen (DO) to determine if there is a difference in pollution levels from different land uses. The above measurements can be used to determine an ecosystem's health both natural and urban ecosystems and are defined as followed. Urban health can be defined by; settlement health, social health, ecosystem health, and human population health. Each of these definitions have different criteria that needs to be met in order to deem an urban area "healthy." The defining factor of a healthy ecosystem is that it can maintain biotic integrity and survive when faced with environmental issues. This can be determined by estimating ecosystem structure (natural patterns) and function (the result of the processes that occur within the ecosystem). Factors of ecosystem health include; denitrification, algal biomass, stable isotope analysis and aquatic plant sediment. Since both an intensively managed natural area and an urban developed area are present in this sub-watershed, they each have different land cover qualities. An overall goal of both areas is to be more efficient with both and nutrients. There are some ways to lower soil and nutrient losses. Land may experience very little sediment loss after intensive haying or mowing and litter removal, but may experience significant losses in nutrients applied to the surface through a lack of plant material to reduce the kinetic energy of precipitation events [Fen-Li, Et al. 2004], all of which can be monitored.

With only a handful of scientists in this country there needs to be additional help from ordinary citizens that can be used to help gather data. There is currently a movement called citizen science and if people take part in this movement there can be monitoring of all the above measurements throughout the year to provide a large amount of data for research. All of the progress made can then be introduced and mapped to determine progress in water quality, with the use of Geographical Information Systems (GIS). The data measurements collected by citizen scientists can be mapped and used to determine ways of using different land cover management types to increase both urban and environmental health.

Hypothesis/ Question:

The following data answers the question of how the management of Colbert Hills Golf Course affects the surrounding; watershed, streams, ponds, and waterways, when compared to the surrounding developing urban area. This study was based on the concept that the intensive management practices of the golf course causes there to be little impact to the watershed from the golf course. The overall hypothesis is that the management of Colbert Hills Golf Course does not affect the surrounding watershed with as much fertilizer pollution as compared to the urban developed area. We measured pH, nitrates, and phosphate levels within the Anderson watershed. Statistical analysis was used to compare the pollution levels from the golf course to the rest of the surrounding areas. We also looked at some temporal changes throughout the growing season.

Literature Reviews:

Water Quality Sampling and Indicators of Ecosystem Health:

Most studies evaluate stream health by investigating physicochemical and biological conditions in streams because these evaluations are fairly simple. Good quality air, water, and soil are needed for the survival of all living organisms in an ecosystem. One worldwide problem is water pollution due to excreta and chemical waste. These factors are not only harmful to drinking water but to recreational water and the fishing industry. Increase in these types of waste causes urban ecosystems to harm more broad areas outside the ecosystem. This information is relevant to water research on the Anderson watershed in Manhattan, Kansas because most of the land in this area is from urban development areas.

It is difficult to monitor nonpoint sources of water pollution. To do so, testing must be done and inferences must be made. One article focuses on denitrification and other water quality aspects in a Japanese grassland (Hayakawa, A. M. et. al). In this article, water samples were taken to study dissolved nitrogen, total nitrogen, particulate organic nitrogen, and inorganic nitrogen. The study showed that nitrates concentrations were higher in watersheds that had upland areas. Urban areas also showed high nitrate concentrations as well as high total nitrogen concentrations. This is mostly due to reduced vegetation and increased impervious surfaces. It is important to test the concentrations of various nitrogen compounds in our sampling because nutrification is a problem in Eastern Kansas.

One study looked into denitrification, by taking samples to test; ionic composition, turbidity, and nutrient levels (Udy, J. W. et. al.). The study showed that systems with high organic matter showed lower nitrate and nitrite concentrations. In one study, non-point sources were evaluated by; determining where to sample, assessing relationships between land use and sample data, and determining degradation sources (Wang, L., T. et. al.). Our group has decided that this is a good method to assess the water quality of the Anderson watershed. Land use data was obtained in order to determine what causes the results.

Soil Cover and Land Use:

Agricultural runoff is a common topic in a state that has seen numerous poisonous algae blooms in recent years and an increase in the number of acres now under tillage due to the expiration of the Conservation Reserve Program. Several of the studies reviewed in this work dealt with various agricultural cover crops and different methods of soil tillage and how these variables affect the runoff potential of an area.

Phosphorus runoff is main cause of eutrophication in Kansas. As much as eighty percent of the total phosphorus loading in watersheds occurs during precipitations events that occur only ten percent of the year. [Banner, Et, al.2009]. This shows that application of fertilizers prior to large precipitation events can be detrimental for ecosystems and consumers downstream. In addition to this, the method of application is also called into consideration; the use of broadcast pellet fertilizers such as urea versus subsoil applied liquid fertilizers. Some of the other potential strategies for nutrient entrapment may be buffer strips and other conservation strategies to be put into play to reduce the amount of sediment and phosphate traveling to downstream reservoirs and water treatment facilities. [Banner, Et, al.2009]

Litter removal at the time of harvest also is a noteworthy topic. This extends beyond the plant's leaf capacity but the relative amount of the plant that remains to promote soil stability. There can be differences in the amount of sediment lost from a site as opposed to the nutrients that can be removed with water. Land may experience very little sediment loss after intensive haying and litter removal, but may experience significant losses in nutrients applied to the surface through a lack of plant material to reduce the kinetic energy of precipitation events [Fen-Li, Et al. 2004].

GIS Mapping and Analysis Methods:

This planet has a finite amount of natural resource. And of all of those resources, water is the most precious that we have. It is used for everything. Drinking, cleaning, and growing the crops we eat, as well as providing recreational enjoyment. However the world's water supply is becoming more and more scares and what water that is safe is slowly getting poisoned by activities that humans, as a whole, have done. While the idea of cleaning the water and spending the money on expensive filtration works it does not address the issue. Instead it is a bandage to a problem that could be easier to fix now and will have a lower cost to mitigate if addressed now. The remaining portion of this paper does not necessarily provide a means to fix this problem, however it does provide a method of measuring and mapping the spread of toxins found in streams and other bodies of water. This can also help pinpoint where problematic areas are so that over time the sources of these pollutants can be determined and mitigated to decrease the amount of pollutants in the water. Over the course of this paper the methods of mapping the data using Geographical Information Systems or GIS will be discussed, and how they are used in conjunction with data collected during water quality analysis. It will then be following will be how to model the data using GIS, and potential future application of those models developed based on the data collected and input into the GIS models. The models will be based on the data gathered around the city of Manhattan, Kansas specifically on the northern half of town. While the data collected is very valuable the only downside of the collection is based on the assumption that there is enough precipitation for a larger study area. Based on the data collected we are looking at, there is an assumption that agricultural land will have a higher source of pollutants than urban land. The primary pollutants that are being measured is phosphorus and nitrates which will be primarily from fertilizers or manure. Other measurements include pH, air temperature, water temperature, electrical conductivity, dissolved oxygen, and turbidity. All of these measurements can help determine the source of pollution and the rate of spread that the pollutants go.

Methods & Analysis of Water Sampling:

Through the synthesis of many scientist's work, it was possible to get a further grasp on all of the techniques that are available for monitoring the health of a water body. Although in this project the "Grab Sampling" technique was the only viable option, there are many possibilities in existence for further study. It is especially interesting viewing all the new techniques that have been put into place for monitoring water. These are becoming more and more important with the current state of our environment, given that with global warming looming, drought in Kansas is almost eminent, and it will be important to be able to test the water during major precipitation events, as these may be the only times water is flowing in some places. Although it is expected that water will still flow regularly in many areas, the small, remote streams are the ones that we ought to be paying special attention to, and that was illustrated by the authors that helped contribute to this study of "Water Testing Analysis & Accuracy."

Something also worth considering is how beneficial biological organisms can be in testing for the changes in water. Speaking to things beyond just how fish react to stress levels, scientists have been able to put various forms of diatoms to work in their studies to truly witness up-close how highly sensitive organisms react to the changes of the water.

Impacts and Importance of Citizen Science:

Collecting significant quantities of water quality data requires considerable time and effort. Due to various constraints, many scientists do not have the resources needed to collect and analyze a large quantity of data. There are roughly 6.2 million scientists in the United States, only 2% of the total population; this leaves roughly 311 million people who have yet to be utilized for the procurement of scientific progress (Wilkinson, 2002). The implementation of non-scientists for scientific pursuits is known colloquially as "Citizen Science", which by definition is "The collection and analysis of data relating to the natural world by members of the general public".

While it is impossible to implement every citizen in the United States for scientific endeavors, it has become apparent over the last decade that appropriate applications of citizen science can not only drastically accelerate scientific advancement, but generate influential and original ideas (Bonney et al, 2009). Citizen science has been implemented in numerous scientific research projects, papers and journal articles. The usage of citizens in data collection have been utilized to analyze over 50 million images of galaxies (Prather et all, 2013), used to collect over 400,000 ornithological checklists (Sullivan et all, 2014), applied over a videogame medium to visualize new proteins and RNA structures (Waldispuhl, Kam & Gardner, 2015) and used to examine over 900 water monitoring stations across the United States (Loperfido, Beyer, Just & Schnoor, 2010). The full extent of the usefulness of Citizen Science is still being studied, but with just a quick analysis, it is apparent that many benefits can be gained through correct implementation. Due to this apparent usefulness, basic elements of citizen science were widely applied the water quality samples collected within the study area of the Anderson watershed.

Methods/Materials:

Study Area:

Our study area consisted of the Anderson Watershed of Riley County, KS, where we compared our independent and dependent variables, and also the Konza Prairie Biological Station, which provided us a natural control site for our study. For comparison, we compared the Northwest portion of the Anderson Watershed to the Southern portion of the Anderson Watershed. This allowed us to better understand how the maintenance of and effects of such of the Colbert Hills Golf Course compare to the maintenance and effects of such with regard to the Southern portion of the Anderson Watershed, which almost exclusively consisted of Little Kitten Creek.

Site Description:

For this study, the streams and ponds within the Anderson Watershed of Riley County, KS, was tested to show how the management of the Colbert Hills Golf Course compared to how the management of property in the residential areas of the Anderson Watershed affect the surrounding river beds. The areas that were tested in the Northwest portion of the Anderson

Watershed were; the Colbert Hills Golf Course, Vanesta Pond, located in a residential area North of Kimball Ave., and, the Washington Marlatt Memorial Park sewer outlet. For our studies in a residential area, we heavily tested two locations on Little Kitten Creek. Both of these locations were on a segment of Little Kitten Creed located in the Southern portion of the Anderson Watershed. They were located at Kimball Avenue and Anderson Avenue. These locations were chosen due to restraints regarding the private property that surrounds much of Little Kitten Creek. Much urban forestry surrounded each location on Little Kitten Creek. We also tested a stream running through the "Konza Prairie Biological Station," Southwest of Manhattan, KS to serve as a constant.

Figure 2 – A collected data point, located on Little Kitten Creek within the Anderson Watershed

Chemicals & Techniques:

We used to the “Grab Sampling” technique to gather the information needed to conduct this experiment, where we physically removed water from the sources and did our testing on site. We were able to borrow “Hach Water Analysis” Kits from Kansas State University, and used them to test for pH, conductivity, turbidity, and dissolved, nitrate, and phosphate amounts. The data from these tests were then compiled and evaluated.

Dissolved Oxygen

The amount of Dissolved Oxygen that the water source contained was seen as a critical test in our analysis because the water source needs a certain amount of oxygen for the biological species to survive. Dissolved Oxygen can arrive at the water source via three different methods, including; “diffusion from the surrounding air, aeration of water that has tumbled over falls and rapids, or as a waste product of photosynthesis” (Hach H2O University et al., 2007). It was important to the experiment to keep in mind that oxygen levels could also be reduced through heavy amounts of nutrient that runoff from agricultural fertilizers including phosphates and nitrates. Another consideration is that “if the weather becomes cloudy for several days, respiring plants will use much of the available D.O.” (Hach H2O University et al., 2007). This is important because after respiring plants die, the bacteria would break them down, and reproduce, which continues to reduce the amount of oxygen. Dissolved Oxygen was tested for using samples from *Permachem,* including “Dissolved Oxygen 1 Reagent (for 60 mL sample),” “Dissolved Oxygen 2 Reagent (for 60 mL sample),” and “Dissolved Oxygen 3 ‘Powder Pillows’ (for 60 mL sample).”

Nitrate

Nitrates were deemed important in our study due to the fact that although they occur naturally, excess amounts in water can be considered a contaminant of ground and surface waters. Most nitrates that end up in waters sources come from human activity as they are a "major ingredient of farm fertilizer" and can also come from "lawn-fertilizer runoff, leaking septic tanks, and discharges from car exhaust" among other sources (Hach H2O University et al., 2007). They can also affect human health as drinking from water sources that are high in nitrates can interfere with the ability of red blood cells to transport oxygen.

We compared two test tubes of water, one control, and another which included a small sample of *NitraVer 5* "Nitrate Reagent (5 mL sample). We recorded the amount of nitrate in the water of each spot that we were analyzing. The hatch kit included a disc that provided different stages of color with regards to Nitrate. We placed both samples of water into our "comparator box" to view the level of Nitrate in each location that was studied.

Phosphate

Phosphate is also an important factor in our study because they also contribute to eutrophication, and can cause dead zones in areas, especially oceans. Phosphates are known to originate in "fertilizers, pesticides, industry, and cleaning compounds." Also, "natural sources include phosphate-containing rocks and solid or liquid wastes" (Hach H2O University et al., 2007).

We tested for phosphate in the same way that we did for nitrate. Two test tubes of water were taken, one served as a control. We added a small sample of *PhosVer 3* "Phosphate Reagent (5 mL sample) in the other so that we could see the amount of Phosphate in each sample that we tested. We placed both samples of water into our “comparator box” and used the colored disk to determine the level of Phosphate in each location that was studied.

pH

We tested the pH of every site to study how basic or acidic the water is. This made it easy calculate the pH of the sites. Water sources naturally rise in pH when organic substances decay and release carbon dioxide, which produces carbonic acid. This area tends to have slightly basic water due to the local limestone. Human effects can also give rise to pH if various industrial chemicals are discharged into the source.

Electric Conductivity

Electric Conductivity is the measure of how well a given solution conducts electricity. This is important to our testing because it can be an indicator of dissolved solids. This is why it is unhealthy for a water source to have a large electric conductivity. We used an electric conductivity meter to calculate the electric conductivity of the sites.

Turbidity

Turbidity measures the cloudiness of the water. This "cloudiness" can be attributed to sunlight being blocked by large amounts of "silt, microorganisms, plant fibers, sawdust, wood ashes, chemicals, and coal dust" (Hach H2O University et al., 2007). The measurement of this was vital to our study because high amounts of turbidity reduce photosynthesis rates in the water which, reduces the oxygen levels in a stream. Fish and other aquatic life need the oxygen supplied from photosynthesis to survive. This test was conducted at each site using a turbidimeter. To use this, we filled the meter up, held a finger over the small hole near the bottom, and slowly released the water collected until the bottom of the turbidimeter can be visible.

After gathering each sample, we used the *ArcGIS* "Collector" application on our cellular phones to put in each sample gathered, along with the location, and also the temperature of the air and water. Using this data, we were able to create maps of our watershed, which further allowed us to study how one location influences another downstream. This made it possible for us to study and compare the Northwest Portion of the Anderson Watershed (Colbert Hills) to the

Southern portion of the Anderson Watershed (Little Kitten Creek at both Kimball Avenue & Anderson Avenue).

Study Procedure:

Over the course of six weeks, ranging from March 16th to April 26th, 2015, water quality samples were gathered from the Anderson watershed from five major conglomerate locations, representing a total of 30 collected samples, n=30. Two additional data points were taken to represent a control, one taken from the nature trail at Konza Prairie Biological Station and one taken from the northern end of the watershed along Marlatt Avenue. The selected five major conglomerate locations were labeled as Anderson Avenue, Kimball Avenue, Little Kitten Creek Sewer Outlet, Colbert Hills Golf Course Ponds and Vanesta Pond. The majority of data points collected were directly located on Little Kitten Creek, with the exception being data points taken from Vanesta Pond and Colbert Hills Golf Course. Each conglomerate of data points was given a distinction of either being more significantly affected by the Colbert Hills Golf Course or being more significantly affected by the local urban housing area. Both conglomerate locations near Kimball Avenue and Anderson Avenue were labeled as being more affected by the Urban Areas. This left Vanesta Pond, the Golf Course Ponds and the Sewer Outlet to be labeled as being more affected by the golf course.

Urban Area	***Colbert Hills***
1.) Anderson Avenue	1.) Vanesta Pond
2.) Kimball Avenue	2.) Colbert Hills Golf
	3.) Sewer Outlet

Table 1 – Summary of tested locations pertaining to designated spatial range.

Choosing whether the selected conglomerate represented water quality from either Colbert Hills or the Urban Area was based off a visual map of the collected samples. The map, displayed below, shows Anderson Avenue at the southern extent of the watershed and Marlatt

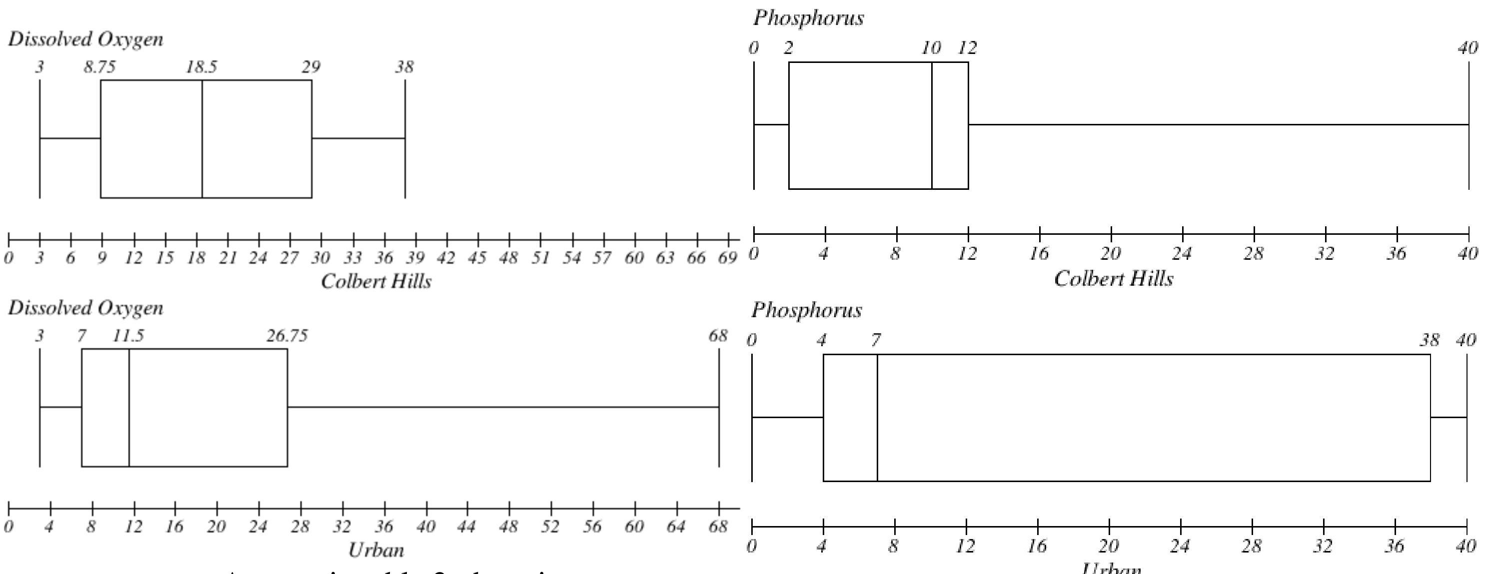
Avenue in the north. Colbert Hills is seen occupying close to a third of the overall watershed near the middle. Both Anderson and Kimball Avenue conglomerates were designated as being more impacted by urban areas due to the location of these data groups further downstream within the watershed. The Sewer Outlet, Vanesta Pond and the Golf Course Ponds were designated as being more impacted by Colbert Hills due to the location of these groups further upstream.

Results and Conclusions:

Overall, 10 samples were taken from within the area impacted by Colbert Hills, and 20 samples were taken from within the area impacted by Urban development. Due to an overall lack of significant differences between the watersheds for both temperature and turbidity, the primary focus of the analysis was primed to analyze the levels of DO, pH, nitrates, phosphorus and EC measured in the water samples.

Colbert Hills Spatial Range								
	Average	MIN	MAX	Q1	Q2	Q3	SD	SE
DO mg/L	19.6	3	38	8.75	18.5	29	12.7	4.1
pH	9.25	8.2	11.5	8.325	9.05	9.875	1.1	0.3
Nitrates mg/L	1.6	0	12	0	0	1.5	3.7	1.2
Phosphorus mg/L	13.33333	0	40	2	10	12	15.7	5
EC mg/L	639.5	48	1125	436	556.5	914.75	349	110.4
Urban Development Spatial Range								
	Average	MIN	MAX	Q1	Q2	Q3	SD	SE
DO mg/L	20.25	3	68	7	11.5	26.75	18.8	4.2
pH	9.34	8	10.2	9	9.4	9.65	0.5	0.1
Nitrates mg/L	0.9	0	5	0	0	2	1.4	0.3
Phosphorus mg/L	19.25	0	40	4	7	38	17.7	4
EC mg/L	575.8	39	1118	331	631	805	352	78.7

Table 2 – Summary table representing calculated values for each water quality indicator.



As seen in table 2, the primary differences observed between the two spatial locations include a difference in the calculated averages for DO, Phosphorus and EC levels. These measurements also indicate an overall varying distribution for each spatial location. Visual representations of these distributions are shown in figure 3. An independent two-sample t-test was conducted to determine if the differences in the spatial ranges were significant or simply a product of chance. Calculated t-values for DO, pH, nitrates, phosphorus and EC were determined to be .007, .233, .157, .057 and .001; respectively. The critical t-value was determined to be 2.048. At 95% confidence the analysis established that while averages and distributions are different for each variable; the data overall is not significantly different.

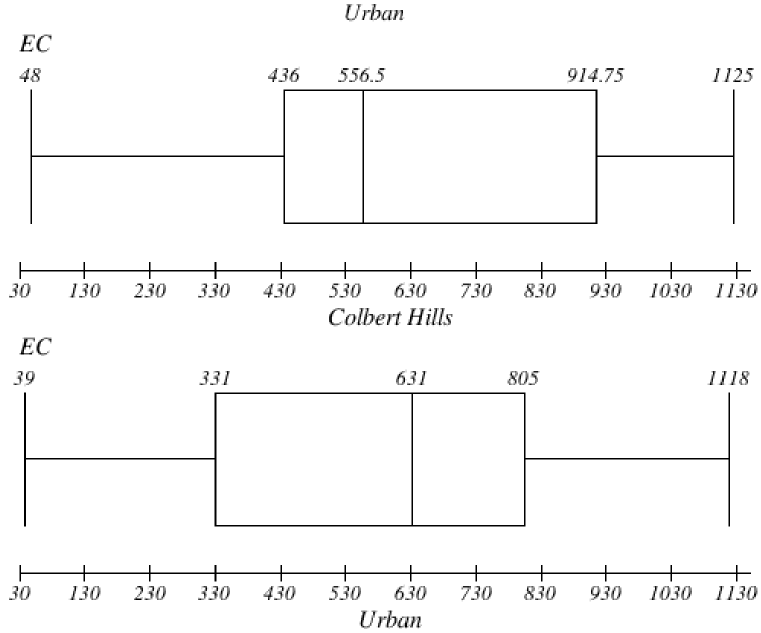


Figure 3 – Distributions of min, max and quartiles. Displays DO, phosphorus and EC pertaining to each spatial range.

While the data and analysis indicates no significant difference between the labeled spatial ranges, observable fluctuations and outliers do exist in the data. To better understand any other possible underlying effects observed in the data, additional analysis was conducted on data gathered from additional nearby water sources outside the effects of the golf course and other urban disturbances. This data was analyzed as our control variable. Using a two-tailed independent t-test, we found our critical t-value to be 2.042, with 95% confidence and a degree of freedom set to 30. Our calculated t-scores representing DO, pH, nitrates, phosphorus and EC, was determined to be .004, .856, .074, .018 and .003, respectively. Using the independent t-test, we found our control not to be significantly different than water quality data collected within the tested areas. While the data was not significantly different between our control and the entire watershed, obvious distributions are noted in the data for DO, pH and phosphorus. Distributions of DO, pH and phosphorus for the control and the entire watershed can be seen in figure 4.

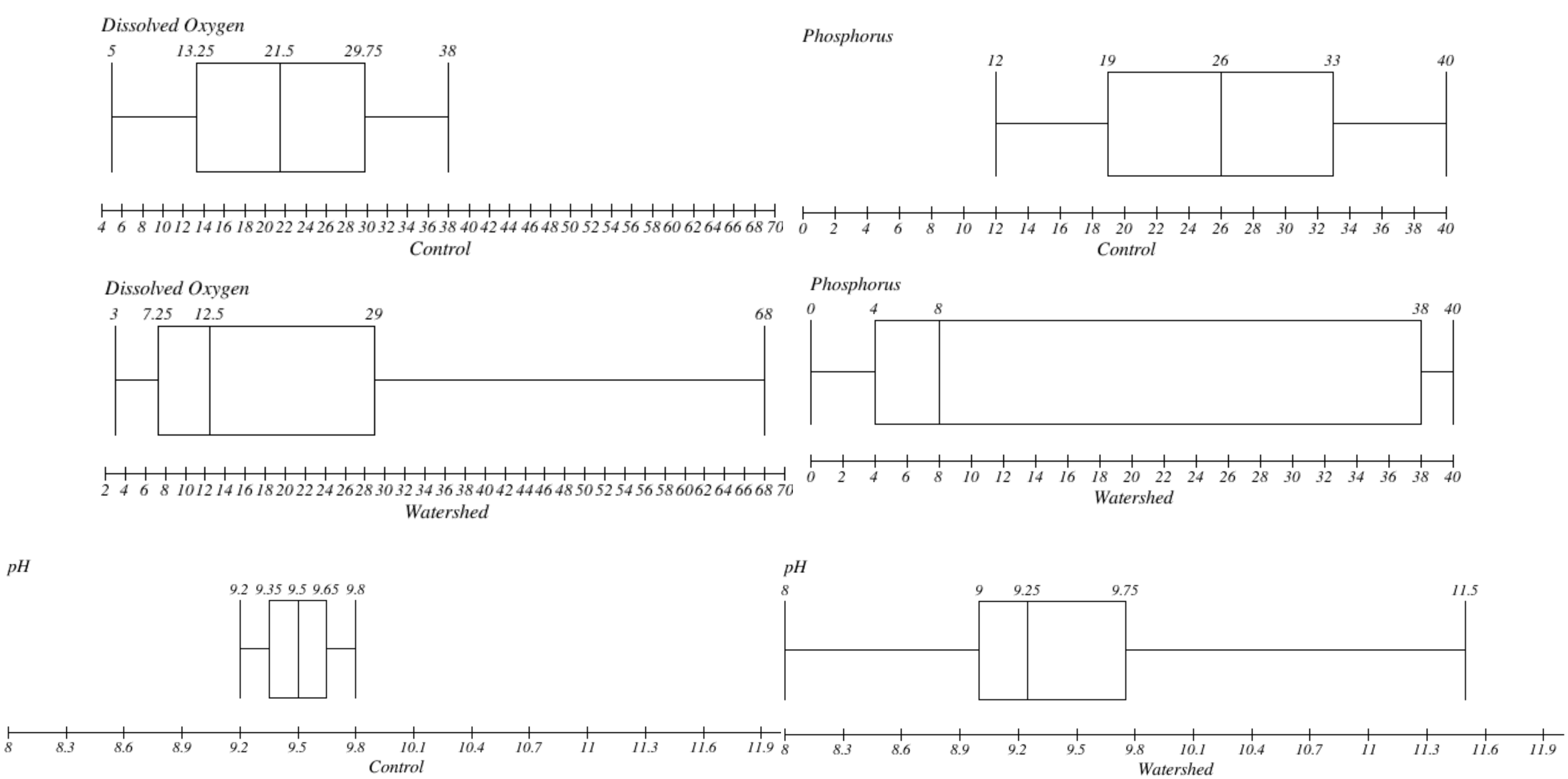


Figure 4 – Distributions of min, max and quartiles. Displays DO, pH and Phosphorus pertaining to the control and entire watershed.

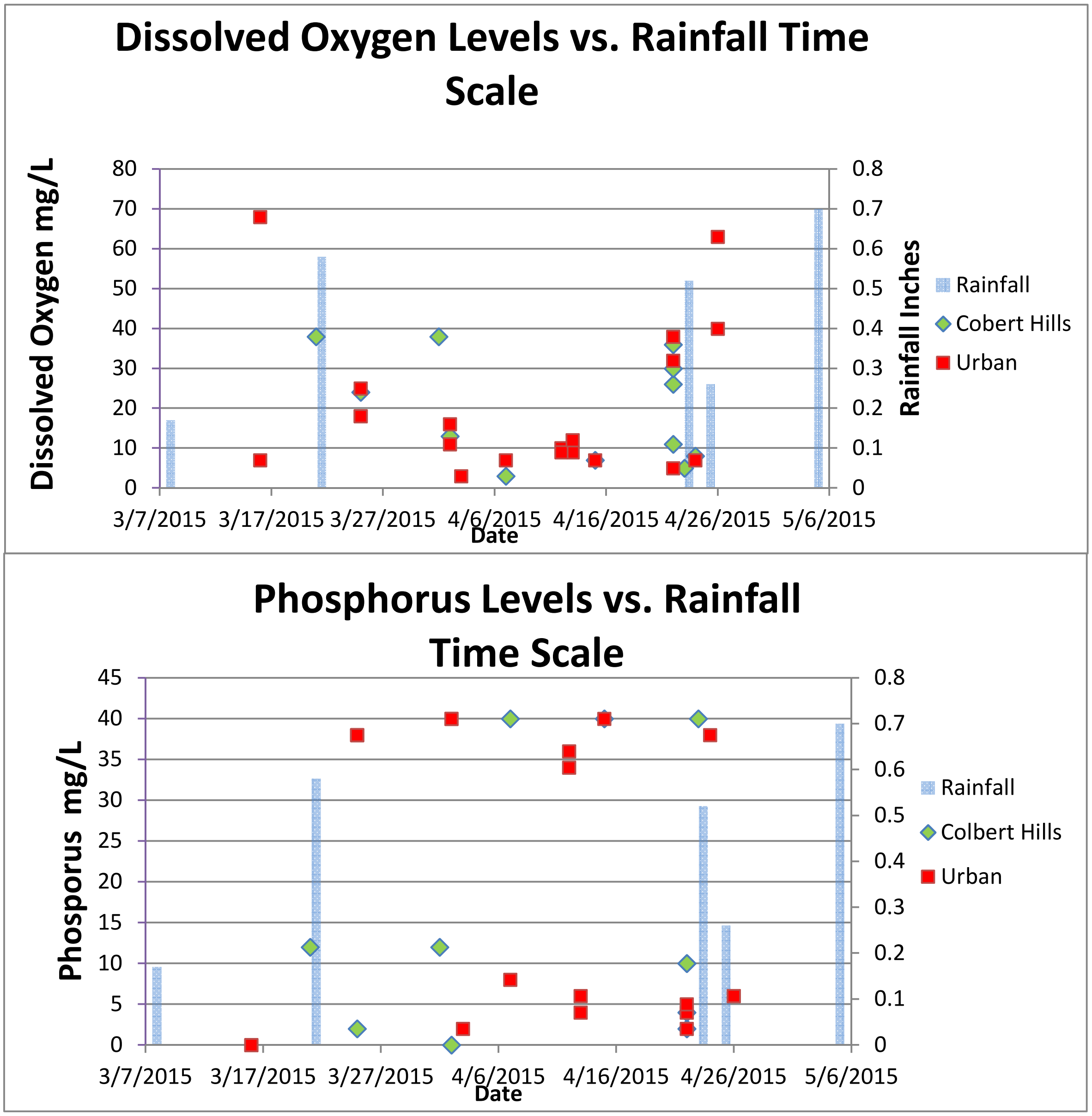


Figure 5 – Time scale graphs illustrating the relationship between major rainfall events and measured levels of DO and phosphorus

To further understand the distribution of data, additional analysis was conducted to compare the notable variation in DO and phosphorus to the seasonal fluctuations in major rainfall events. Each graph located in figure 5 displays the date range pertaining to when a data point was collected and identifies the data point as representing either Colbert Hills or Urban Development. Additionally, major rainfall events that accumulated more than .1 inches of total rainfall have been marked on the graph displaying the total rainfall for the specified date. Levels of DO appear to decrease after the rainfall event on the 21st of April, then increase directly before the rainfall event on the 24th of April, then continue to increase after the rainfall event on the 25th. The observed lack of correlation between rainfall and DO level suggests that rainfall did not significantly impact the fluctuations in measured DO levels. There appears to be a clear distribution of phosphorus levels for both spatial ranges, representing both higher and lower levels of measured phosphorus. The distribution of phosphorus levels does not correlate to rainfall events, which suggests that rainfall did not impact the measured variation in measured phosphorus levels.

Due to the overall lack of statistical difference observed between both spatial ranges, the null hypothesis that Colbert Hills does not significantly impact the surrounding water quality is supported. Additional analysis of rainfall patterns showed no apparent correlation between water quality and major rainfall events. If a correlation been detected between rainfall events and water quality, additional analysis could have been conducted to delineate the analyzed data. This data could then have been compared to the raw data to better understand the overall effects rainfall had on measured water quality indicators. Additional analysis found there to be no significant difference between water quality collected within the study area and water samples collected in natural areas. Due to a lack of statistical difference between natural areas and the study area, it can further be concluded that water quality is not significantly impacted by the Colbert Hills Golf Course, supporting the hypothesis.

Discussion:

Interpretation:

From the results of the experiment we concluded, that in spite of the intensive nutrient requirement for Colbert Hills Golf Course, the management of fertilizer application is commendable. With the EPA limit of 10 mg/L of nitrate and .05 mg/L of phosphate. The high phosphate levels however are not statistically significant. This is further supported by data collected on the golf course that showed an absence of significant difference over the values collected from the natural areas. Nutrient intensive practices are needed for golf courses to create the grass types and quality that patrons desire. Varying types of ground cover are essential for protection against not only nutrient loading but also for sediment runoff. [Hyakawa, Et al. 2006].The proactive management of Colbert Hills Golf Course is a potential explanation for our data. Sediment losses may be kept to a minimum but phosphorous and nitrogen losses can be significant during precipitation events because of the reduced time that water has to infiltrate the soil column from reduced total plant matter [Fen-li, Et al. 2004].

This suggests that large amounts of nutrients come from the urban development areas. It is simple to test whether the Colbert Hills Golf Course has an effect on the water quality because it is a point source, meaning that any pollution problem found would have come from one source. This would also make it easier to fix any problems that may have arose. Inferences must be made to determine when a problem comes from nonpoint sources, as this study suggests. It is also more difficult to monitor pollution problems that are caused by nonpoint sources.

This is important excess nutrients in the stream can cause problems downstream, particularly with recreational activities. This area of Kansas has had increased issues with algae in the past few years. The main problem has been blue green algae, which is harmful to humans and other mammals when consumed or inhaled.

Criticism for the Experiment:

This experiment encountered several obstacles that may have affected the data. The lack of precipitation throughout the project may have decreased the loss of nutrients from the golf course and test areas. Due to the necessity of intensive nutrient management to promote growth of plants under intensive mowing, the timing and type of fertilizer application is also a concern in golf course management. In some cases, 80% of nutrient loading in watersheds occur during precipitation events that constitute 10% of the year. [Banner, Et al. 2009]. There is potential for increased nutrient loss in years that have greater precipitation events. Though this experiment captures the initial applications of many common nutrients, it cannot account potential changes in the summer months as irrigation increases. Natural areas used in the experiment were only sampled once, and could not truly represent changes through time.

Another criticism for the experiment is the relatively low number of samples that were analyzed in addition to the spatial and chronological distribution. Many areas in the watershed were heavily sampled due to the availability of water during the earlier portion of the experiment. Several areas located in residential areas did not receive any attention due to lack of availability. The data collected from the later portion of the experiment constitutes a generally higher percentage of the total data because water became more available through precipitation events in April.

The two most common sampling types are grab sampling, as was done in this study, and automatic sampling. A study that took place in the Leon River Basin in central Texas noted potential concerns with grab sampling. The authors that wrote the report for this study stated that grab sampling shows the most accurate results when the data is taken during and regularly after storms. This would have been a problem for the Anderson watershed project because there was very little rain during the time period that testing was performed. The Leon River Basin study also concluded that grab samples "do not capture either the cross-sectional or temporal variability and likely will not produce an accurate estimate of the actual concentration."

Future Options:

There was a large amount of variance in data for some of the variables tested. Various methods may be able to improve the statistical accuracy of the study. One method would be an extension of the length of the experiment to include data collection throughout the year, particularly through the late summer months that were not covered in the scope of this experiment. Another method would be an incorporation of automated sampling. This would be benefit the study by giving another set of data, increasing the accuracy of the study.

Spatial sampling may also be a consideration. If additional data is input into the system other applications can be taken into account. This can be helpful for environmental agencies or construction agencies to determine the quality of a sight by comparing these models to the site based on the data gathered and determine if the site is healthier than anticipated. Another way these models could be used is for city planning to help slow the spread of urban and rural water pollutants. These models can be used to help make guidelines of storm water. The models can of course also be used by state and federal agencies to determine if a source of pollution exceeds standards and can be fixed.

The continued use of citizen science is another area with future possibilities. With clear instruction, the implementation of non-professionals in data collection can provide accurate data that is not significantly different than data collected by experienced scientists (Bodilis, Louisy & Draman, 2014). By closely following the included instructions, every member of the group was able to collect data in standardized method. By following a set procedure, the likelihood of error in collection is drastically decreased, thus providing data that is more accurate. As water quality becomes a greater concern, the use of trained citizens to collect data may be the most efficient way of identifying potential problems.

Works Cited:

Banner, E. B., K., Stahl, A. J., & Dodds, W. K. (2009). Stream Discharge and Riparian Land Use Influence In-Stream Concentrations and Loads of Phosphorus from Central Plains Watersheds. Environmental Management, 44(3), 552-65.

Bodilis, P., Louisy, P., Draman, M. (2014). Can citizen science survey non-indigenous fish species in the eastern Mediterranean Sea? Environmental Management, 53, 172-180.

Bonney, R., et al. (2009). Citizen science: A developing tool for expanding science knowledge and scientific literacy. Bioscience, 59(11), 977-984.

Cinnamon, J., Schuurman, N., (2013). Confronting the data-divide in a time of spatial turns and volunteered geographic information. GeoJournal, 78, 657-674.

Fen-li, Z., Merrill, S. D., Chi-hua, H., Tanaka, D. L., & al, e. (2004). Runoff, Soil Erosion, and Erodibility of Conservation Reserve Program Land Under Crop and Hay Production. Soil Science Society of America Journal, 68(4), 1332-1341.

Franzoni, C., & Sauermann, H. (2014). Crowd science: The organization of scientific research in open collaborative projects. Research Policy, 43(1), 1-20.

Harmel, R.D., R.M. Slade, Jr., and R.L. Haney. 2010. Impact of sampling techniques on measured stormwater quality data for small streams. American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America (39): 1734-42.

Hayakawa, A. M. Shimizu, K. P. Woli, K. Kuramochi, and R. Hatano. 2006. Evaluating Stream Water Quality through Land Use Analysis in Two Grassland Catchments: Impact of Wetlands on Stream Nitrogen Concentration. J. Environ. Qual. 35:617-627 (2006)

Kimerling, A. Jon. Map Use: Reading, Analysis, Interpretation. Redlands, CA: Esri Academic, 2012. Print.

Kountoupes, D. L., Oberhauser, K. S. (2008). Citizen science and youth audiences: Educational outcomes of the Monarch larva monitoring project. Journal of Community Engagement and Scholarship, 1(1), 10-20.

Link, W.,A., Sauer, J.R., Niven, D., K., (2007). Combining breeding bird survey and Christmas bird count data to evaluate seasonal components of population change in Northern Bobwhite. Journal of Wildlife Management, 72(1), 44-51.

Loperfido, J. V., Beyer, P., Just, C. L., & Schnoor, J. L. (2010). Uses and biases of volunteer water quality data. Environmental Science & Technology, 44(19), 7193-7199.

Luchette, Joesph, and Tom Crawford. "A Public Participation GIS Application for Citizen-based Watershed Monitoring in Pamlico- Tar River Basin, North Carolina." Southeastern

Geographer 48.2 (208): 184-200.

Management (2010): 868-80.

Meixler, Marcia S., and Mark B. Bain. "A Water Quality Model for Regional Stream Assessment and Conservation Strategy Development."Environmental

Michaud, Jene, and Tracy Wiegner. "Stream Nutrient Concentrations on the Windward Coast of Hawai'i Island and Their Relationship on Watershed Charactersitics."Pacific Science 65 (2011): 195-217.

Prather, E. E., et al. (2013). Measuring the conceptual understandings of citizen scientists participating in Zooniverse Projects: A first approach. Astronomy Education Review, 12(1)

Sugumaran, Ramanathan, James C. Meyer, and Jim Davis. "A Web-Based Environmental Decision Support System (WEDSS) for Environmental Planning and Watershed Management." Journal of Geographical Systems (2004): 307-22.

Sullivan, B.L., et al. (2014). The eBird enterprise: An integrated approach to development and application of citizen science. Biological Conservation, 169(1), 31-40

"Temperature - Precipitation - Sunshine - Snowfall." Climate Manhattan. N.p., n.d.

Udy, J. W., C. S. Fellows, M. E. Bartkow, S. E. Bunn, J. E. Clapcott, and B. D. Harch. 2006. Measures of Nutrient Processes as Indicators of Stream Ecosystem Health. Hydrobiologia (2006) 572: 89-102.

Waldispuhl, J., Kam, A., Gardner, P. P. (2015). Crowdsourcing RNA structural alignments with an online computer game. Pacific Symposium on Biocomputing 2015

Wang, L., T. Brenden, P. Seelbach, A. Cooper, D. Allan, R. Clark, and M. WIley. 2008. Landscape Based Identification of Human Disturbance Gradients and Reference Conditions for Michigan Streams. Environ Monit Assess (2008) 141:1-17.

Wilkinson, K.R. (2002). How Large is the U.S. S&E Workforce? National Science Foundation, 02(325), 1-4.

Wu, J. J., Bernardo, D. J., Mapp, H. P., Geleta, S., & al, e. (1997). An Evaluation of Nitrogen Runoff and Leaching Potential in the High Plains. Journal of Soil and Water Conservation, 52(1), 73-80.