Citizen Science Water Quality Mapping

A Natural Resources & Environmental Sciences Capstone Project

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ABSTRACT

The purpose of this project was to build a public participation digital mapping for use by citizens to monitor and record water quality in their area, as a part of a Citizen Science initiative. Citizen Science is the gathering and testing of data prepared by non-professionals. For this project, water quality was tested throughout different points in, or near, Manhattan, KS. Pollutant levels and water properties including nitrate, phosphate, turbidity, dissolved oxygen, conductivity, and pH were measured to characterize overall water quality. Geographic information system (GIS) software was used to map and analyze the data. An Adobe Flex-based Web mapping application was created using Internet map and geoprocessing services developed for the project. Interested users can access the data, in map form, perform additional tasks using an Internet browser. Results from analysis of the water quality data and contributing watershed characteristics revealed several interesting relationships. Developed land decreased the turbidity, whereas, all other land types increased turbidity. For other pollutants, as the total area of developed land increased, there was a decrease in pollutants. This decreasing trend ran counter to the initial assumption that developed land would be a source of pollutants. However, preliminary results showed that landcover types such as grasslands, agriculture land, and forests contributed more to pollution loads. These results were derived from only a small number of data points (n = 19) collected over a short time frame (approximately 2 months). Collecting additional sample data over a longer time period will improve the assessment of Manhattan's water quality.

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1. Introduction

Our Citizen Science Water Monitoring group consisted of six students enrolled in the Natrual Resources and Environmental Sciences secondary major capstone course. As a group we chose to complete research over our common interest: water quality. The purpose of this project was to build a public participation mapping tool that the average citizen could use to monitor the water quality in their neighborhood. Concerned citizens would be able to go online and review the water quality in their area or upload water quality that they collected.

2. Literature Review

Following is a literature review on the use of citizen science to monitor water quality data, an assessment of water quality parameters, how urban areas influence water quality, how rural areas influence water quality, and finally how geographic information systems (GIS) can be incorporated into water quality mapping efforts.

2.1 Citizen Science Water Monitoring

Citizen Science is a form of crowdsourcing using trained volunteers to help collect data that traditionally was not financially, spatially, or temporally feasible in large scientific research projects (Gura, 2013). These projects are becoming increasingly popular in part due to their demonstrated success gathering data and because they are more easily funded since they are satisfying "broader impact on society" requirements in research grants (Gura, 2013). Citizen Science projects range anywhere from downloading software on personal computers to find protein folding patterns, to logging weather data read from scanned historical nautical journals, to more environmental projects like recording species numbers and diversity, and in our interest, collecting water quality data.

Citizen Science projects are very beneficial because they can gather vast amounts of data relatively cheaply through the use of unpaid volunteers managed by staffed professionals (Gura, 2013). Citizen Science water monitoring programs are informing their communities of the health of their surrounding environments, which is starting conversations and empowering the public to advocate for further research and political action (Connors, Lei, & Kelly, 2001: Kolok, Schoenfuss, Propper, & Vail, 2013).

Organizing citizen science projects, however, can be laborious. Essential tasks include marketing the project, training volunteers, creating data entry websites and mobile applications, and maintaining continued interest for data collection over the long term (Gura, 2013). Specifically, citizen science programs have to leave a positive impact on their volunteers to ensure their continued involvement in the program. One of the easiest ways to do this is to make sure that data entry websites, mobile applications, and mapping databases are user-friendly and interactive (Newman, Zimmerman, Crall, Laituri, Graham, & Stapel, 2010). Two areas of scrutiny by the scientific and public communities include the validity of data being collected and the social sustainability of these programs.

World Water Monitoring Day is a program that has been in existence since 2002 and is supported by the Water Environment Federation (Schnoor, 2007). Every year it campaigns to collect water quality data including measures of dissolved oxygen, transparency, temperature, and pH during the period September 18 to October 18. Their website sells water quality testing kits for roughly $20 and participants to map their results. In 2007, more than 80,000 people in 50 countries collected and mapped water quality data. Although this campaign uses basic water testing kits, the program helps educate participants (mainly primary education students) about water quality issues and creates "water watchdogs" (Schnoor, 2007).

Wet/dry mapping of the San Pedro River was carried out for 12 years to bring factual information to the public about the river's water levels (Turner & Ricter, 2011). The Nature Conservancy and US Bureau of Land Management trained and coordinated members of the general public investigate reaches of the San Pedro River to determine where water was flowing during the driest part of the summer each year (third week in June). They found that only 32% of the stream flowed all year round. This project not only engaged the public in stream monitoring, but it also initiated an active discussion about the importance of their local natural resource. Some thought that the river was already gone and conservation was a lost cause, while others thought that the river flowed continuously and no problems existed (Turner & Ricter, 2011). This project brought about factual knowledge to the public and jumpstarted conservation conversations.

2.2 Water Quality Assessment

Water quality assessment has become increasingly important as we move into the future as human populations continue to increase the amount of pollution in water bodies. Testing of water quality is needed worldwide, and the data requires frequent updates to remain accurate and relevant. There are a different number of ways to assess water quality data. This usually includes linking the elevated pollutant levels with its cause. Many times, GIS is used to help establish this linkage (Casper et al., 2012). Specific techniques include biological or statistical methods and an index method.

Rivers are spatially heterogeneous, which means that the characteristics of a river change often. However, water quality samples taken from rivers are collected at a discrete point. If the same test were to be conducted at a different location along the same river, results may differ and not accurately characterize conditions for the river as a whole. There is significant variability in measures of water quality at small spatial scales. Research has shown that current water sampling schemes may not be spatially adequate or accurate, and they challenge the perception that a river is a smooth homogeneous body. When testing water bodies it is important to choose testing points wisely, and understand why test results could be skewed or altered.

The quality of water is decided by its chemical, physical, and biological characteristics. The presence of harmful constituents degrade the water and make it harmful for aquatic life and human uses. A comprehensive environmental data information system helps to perform and complete common tasks in less time with less effort for data verification and calculations. Prasad and his colleagues focused on making a web-based system to show the quality of water in the environment. They analyzed eight different samples that tested for pH, dissolved oxygen, biochemical oxygen demand, and fecal coliform (Prasad et al., 2013).

Monitoring water quality and assessing water quality data is challenging. Attempts have been made to devise a water quality index using different parameters. Differences in rainfall, temperature, season, and other environmental factors may affect the test results. The surface water quality in a region largely depends on the nature and extent of the industrial, agricultural, and other anthropogenic activities in the area.

River, lake, and stream functions and conditions are evaluated by water quality measurements, which include spatial patterns and temperature trends. The National Sanitation Foundation (NSF) Water Quality Index (WQI), can be used to monitor water quality changes in a particular water supply over time. It can also be used to compare the quality of a water supply with other water supplies in the region or from around the world. The software developed by Prasad and his colleagues is easy to operate and allows easy viewing of the data. This proves that the Web can be used to improve our understanding of, and enhance, water quality (Prasad et al., 2013).

2.3 The Impact of Land Use and Land Condition Changes on Water Quality

Water is one of the most important compounds available on Earth as is one of the most essential chemicals needed for human survival. Water is necessary for our body's nourishment, to grow food crops, to make a variety of chemical compounds, and to help circulate energy around the Earth via ocean and atmospheric circulation. One aspect of water that is of great interest to many is it moves across a landscape. Water has a major impact on the multiple ecosystems and environments it encounters along a landscape. This hydrological and ecological component of water studies illustrates how important water is for habitats that are often out of sight and out of mind. A correlation is often found when examining the transformations of a landmass for human needs and the effects these modified landscapes have on water quality within a watershed.

The idea of "settlement expansion" describes the processes involved as humans develop the land to support improvements in quality of life (Su et al., 2012). Shiliang et al. (2012) makes note of the fact when we change the landscape in this "settlement expansion" style, unique ecosystems are often lost. Some of the services lost during this change include the conservation of water resources, filtering of water for drinking uses, nutrient conservation, and flood regulation or storage capabilities. Another effect of the urbanization process involves the construction of houses and the placement of roadways. These impervious surfaces decrease the landscape's ability to allow precipitation infiltration into the soils, increasing runoff during precipitation events (Shuster, 2005). Urbanization can redirect a large amount of water directly into local drainage system and which exacerbates flooding issues. To combat the potential for more flooding, more dams are often erected as a control mechanism. In a sense, a problem that we have created via urbanization is thought to be solved by another human induced landscape change. Reality sets in when native fish communities along these downstream rivers begin to decline because of the volume of water being expelled is not high enough or consistent, as some fish communities require stages of flooding and receding water levels while other communities rely upon the level of water for temperature related reasons (shallower waters are often more susceptible to temperature fluxes) to complete their life cycles. For parts of western Kansas alone along the Arkansas River and Smoky Hill River basins, as much as 20% of the native fish species where falling in population sizes in half a century alone (Gido et al., 2010).

In areas of western Kansas, where dry land production of wheat is common, individual farmers continue to try to develop systems that extract groundwater for irrigation. As more and more of the land was switched to well-pump systems, the water tables declined and farmers would sometimes be forced into adopting dry land production practices (Harrington et al., 2007). The article highlights the fact that areas that had the greatest amount of land uses change often had the most ground water depletion, while areas with the least amount of land use changes had fewer depletion levels. Groundwater sources like many other natural resources takes many years to recharge or redevelop to the point that it is cost effective for a farmer to even pump. However, when less and less of this water becomes available we lose a large quantity of this resource for non-agricultural uses. This point of interest, to some individuals, may have a quality of its own because some individuals place the ability to harvest more yields in front of having more stable aquifers in the area to support water tables that feed into river systems, which may impact many ecosystems.

Models are very useful in helping to provide details, ideas, or even images in such a fashion that simplifies the complexities involved within the subject being studied. Some models that are of great interest to understanding cause-effect scenarios for water conditions and land uses changes include the L-THIA Modeling system and the SWAT modeling system. The L-THIA model, (*https://engineering.purdue.edu/mapserve/LTHIA7/lthianew/tool2.php*) provides an easy way to input the type of land use and determine the amount of runoff that might occur if a change does happen to the amounts of land use in place. Tables 1 and 2 display the output information, which is similar in looks to the input form of the model that one receives upon completing the model.

Table 1: Distribution of land in terms of size (acresft) (Kyle Stropes L-THIA Model Example for Watershed Management – ATM 661).

SUMMARY OF SCENARIOS
State: Kansas
County: Riley
View as: Select

Land Use	Hydrologic Soil Group	Current	acres Scenario 1	Scenario 2
Grass/Pasture	A	950	750	550
Agricultural	A	0	175	350
Commercial	A	0	25	50

Table 2: Amount of Annual Runoff Volumes (acre-ft) expected with changes in land use (Kyle

RUNOFF RESULTS
Avg. Annual Runoff Volume (acre-ft)
View as: Select

Land Use	Current	Scenario 1	Scenario 2
Grass/Pasture	0	0	0
Agricultural	0	0.72	1.45
Commercial	0	4.27	8.54
Total Annual Volume (acre-ft)	0	5.00	10.00

This type of modeling provides useful initial estimates of the impact of land use change for particular areas of interest (AOI). For many applications, however, there is a need for more detailed modeling results. One modeling system that meets this need is the Soil and Water Assessment Tool (SWAT). Some examples of SWAT use includes a study that modeled the effects of farmer's reorienting their crop production systems for biofuel production and the hydrological impacts involved. Inputs included within the model ranged from natural reservoir functionality (average depth, nutrients, turbidity, and many others) to the farmer's best use fertilizer management techniques (Douglas-Mankin et al., 2013). The group of Dixon, Barnali, Julie, and Earls (2012) decided to try applying a cell growth simulation to the SWAT model as a way to estimate urbanization growth. Expected outputs for the model were determined prior to running the model, which included the chances of flooding, rainfall runoff dynamics, and reduced infiltration properties all within a set of standard weather conditions (a range of data points going from a 14 to 28 year period). The result of the study concluded that the SWAT model was effective in predicting storm flow rates and other outputs were successfully simulated.

2.4 Water Sampling in Urban Areas

Much of the water that is running into water treatment facilities contain chemicals that pose a serious human health threat. While filtration can be highly effective, it is also costly. To reduce such costs, many things can be done to the water before it is treated. Vaillant, Pouet, and Thomas' (2002) article over ultraviolet (UV) spectra for urban water quality has some interesting thoughts on the filtration issue, many of the current systems use what is known as "end of pipe" types of treatment. All of these treatments give us limited qualitative information and are very time consuming. A new system is needed to meet the needs of the new regulations. To achieve the required needs UV spectrophotometry is the solution. This will cause most organic compounds and a few soluble minerals to be absorbed in the near UV locations, however some materials are not absorbed such as industrial discharge and that is still an issue.

Another new method that could help to solve the filtration issue is what's called a Vermi – Bio filtration System (Tomar, 2011). What this system aims to do is filter out most or all of the hazardous pollutants and organic load that is going into the waterways using Earthworms and Coco – grass. They also used the same system without the worms as a control. After running the polluted water through the vermin – bio filtration system eight times, there was a definite reduction in the toxins and organic material.

Staying with the idea of using plants to help with the filtration process Stagge et al. (2012) presented another fairly simple plan to improve overall quality. Much of our storm water is being polluted by nonpoint source pollution (both water and air pollution from diffuse sources). This is the same storm water that is flowing into the urban environment and sometimes being treated and redistributed for human consumption. Many different methods were devised to counteract the pollution of the water, mainly highway runoff. These methods are called Low Impact Development (LID) technologies. These technologies are achieved through different filtration and infiltration practices. One particularly promising LID is the construction of grass swales. Swales are shallow, grass-lined, typically flat-bottomed channels that receive flow laterally through vegetated side slopes. The grass allows for most of the pollutants to be filtered, as well as the grass blades capturing some of the debris. This is an inexpensive method to use on newly built highways as well as retrofitting well established roadways as well.

Storm water runoff has always been a problem, because of the pollutants that are found with in the water. An example of this is from Voorde et al. (2012) who reported trace amounts of a chemical called benzalkonium chloride (Alkyldimethylbenzylammonium chloride) in urban runoff samples. This chemical is the same that is used in hospitals and the food industry to disinfect surfaces and equipment and is also applied to roofs to remove moss, lichen, and other plant life Benzalkonium is especially toxic to aquatic life and can also effect human health, including asthma, skin allergy or eye irritation.

When areas start to become more developed, they lose substantial vegetation that was filtering the storm water runoff (Barbosa et al., 2012) Many parts of the world are suffering from polluted storm water; this water contains many different hazardous materials that are affecting the health of the people in the area as well as the plants, or ecosystem. The parts of the world where this is especially a problem are Asia and Africa. A solution needs to be implemented that is both economically feasible and simple to implement.

Storm water management has become such an issue, because all of the vegetation is being replaced with concrete and other impervious surfaces. This promotes elevated levels of runoff and increased water velocities that minimize the opportunity for vegetated systems to filter and absorb the water.

2.5 Water Sampling Methods in Rural Areas

A rural setting is often influenced by input from the agriculture industry from both farmland and large herds of animals. Analyzing water samples allows the public to know what their water is contaminated with and give communities the power to take action. The sampling methods outlined here may not always pertain to the individual citizen. Technology used in the following studies can be expensive and would pertain to a community monitoring station.

The surface-grab method is collecting samples of water in an open container near the stream surface. Cross-sectional integrated methods use nozzles that fill with no change in stream velocity at various levels. The pros and cons of these methods correlate directly to our water sampling of rural environments. Limitations of the surface-grab method include only sampling what is on the surface of the water. This method costs less than the cross-sectional integrated methods and has been adopted by most states. More consistent results are achieved by using the surface-grab method. Cross-sectional integrated methods often vary due to the water churning and stirring particles below the surface. With an integrated sample new results can be seen due to suspended particles underneath the surface (Smith, Smoot and White, 2008). The EPA has approved sample-grab methods as a “representative point” that is suitable to “characterize water quality conditions in streams adequately.”

This study over nonpoint pollution primarily sediment, nutrients and pesticides introduced though the agriculture industry and methods of sampling are outlined here. Water quality issues rise from erosion or sedimentation, nitrogen leaching or runoff, phosphorus leaching or runoff and livestock manure. All of these factors influence water quality in rural environments.

The study notes that poor planning is often the biggest failure in the monitoring process. The study lists clear goals and precise objectives as the key to good planning. Monitoring practices listed in the study describe samples taken from the field and the water shed. Water samples taken from deep in the soil, near the root of the plants, indicate how much contaminates are being leached. While samples taken from nearby bodies of water indicate how much contaminates made it to the water after filtering through buffer strips.

Hewitt et al., (2013) outline a number of techniques for sampling water at points, including: (1) edges of fields using flumes or other constructed devices such as flow splitters, (2) bottom of root zone using suction cups, gravity, and lysimeters, (3) groundwater wells, and (4) surface water weirs and flumes. For surface water automated samplers are preferred, as they indicated the exact time that contaminates are introduced to the water supply. Hand sampling is still reliable, just not as time efficient as automatic samplers. For obtaining samples at the bottom of root zones suction or tension lysimeters are inserted into the soil and attached to a vacuum to remove all the water in the soil. The suction method can be hard to install and gravity draining into pipes for collection is often preferred.

In rural areas, water pollutants of interest include fecal bacteria, pesticides, nitrates, phosphorus, turbidity, and dissolved oxygen. Gustavo et al., (2010) examined the microbiological water quality in the Brazil Pinhal River at six sampling points. Each sample site was influenced by a combination of farm animals, crops and humans, with the exception of the control site. The sampling point influenced by dairy cattle resulted in the highest concentration of fecal matter and the control site resulted in the least amount of bacterial water. Results prove that different land uses and the presence of animals plays a critical role in identifying the sources of bacteria in the river.

Pesticides contamination in three agricultural watersheds in Canada were studies by Xing et al., (2012). They reported that grab sampling underestimated the level of pesticides in the water. Grab sampling is ineffective for pesticide testing because it only tests what is located on the surface at that time; this especially applies after a heavy rainfall. Instead, they adopted a hydrograph-based sampling approach using automated sample devices. The study was conducted between the year of 2003 and 2007. To set up the study a questionnaire was given to local farmers who identified 43 different pesticides that they applied to the farm ground that affected the watersheds in the study. 18 of these pesticides were actually identified in the watershed water samples. Over application of pesticides in these study areas have been linked to many mass fish deaths.

A common fear is that nitrite from agriculture is causing cancer when it enters our drinking water. One fact to remember about nitrogen levels in water is that nitrogen is only a problem when converted into nitrate. When this happens we do have human complications arise from drinking affected water supplies. Nitrate easily dissolves in water and levels have steadily been increasing as farmers discovered higher yields after applying nitrogen to their fields. A cut in the use of nitrogen on farmland will produces smaller yields, and will not need our growing nation.

Identifying nitrate loss from farmland will come from the root zone, where nitrate and excess water are leached. (Addiscott et al., 1991) A suction method, porous ceramic cups, is a cheap and easy way to measure water and nitrate levels at the root zone. A porous tube in which water can be drawn in by suction is attached to a longer bodied plastic or metal tube. This allows water, but not soil to enter the porous tube at the top and be collected in the plastic or metal tube at the bottom.

Chen et al., (2013) studies the rise of phosphorus levels in water after flooding in Taiwan, especially across agriculture fields. Data was collected during two flood events and results showed that areas with high animal density (agriculture) often leach more phosphorous into the water than those areas without. During heavy rainfall and flooding the team took samples every 15 minutes to an hour from the river, depending on the hazardous conditions.

A comparison of the water quality of urban and rural streams in North Carolina was made by Mallin et al., (2009). Testing was done for turbidity, bacterial content (fecal) and dissolved oxygen. Sampling was done on three streams, urban, agriculture, and a control, biweekly and after every major rainfall. Data was collected using a YSI 6920 Multiparameter Water Quality probe linked to a YSI 650 MDS display unit, a probe that is attached to a hand held monitoring device. The probe was lowered from the middle of bridges or from the bank. At the same time the team also took samples in bottles that they analyzed with lab equipment to test for more contaminates. The study also took into consideration the type of land cover around the streams. The test results were also compared to what North Carolina defined as “normal” for streams in that area. Results showed that the turbidity and nutrient levels were the same in the creeks. The difference was the amount of suspended particles in the water. The creeks also fell below North Carolina’s standard for dissolved oxygen on multiple samples.

2.6 Web-GIS

GIS is a powerful tool that allows users to both view and analyze spatial data. However, access to GIS functionality can be both costly and time consuming to learn to use properly. An increase in Web GIS has allowed the use of GIS to become more widespread and less limited by time and place. Maps play an important role in GIS, as they are how the results of analysis are often communicated. The rise of the World Wide Web (WWW) has allowed millions of maps to have been created by an audience who without the Internet wouldn't have been able to create them in the first place. The Internet has also allowed a much more widespread distribution of spatial data. The growth of WebGIS has allowed for the broader contribution of map designs and data inputs. Visualization of metadata is also another way that the use of maps has expanded. Using 'geospatial data infrastructures (GSDI's) users can now use maps as a part of a search engine to search a chosen geographic area at a certain time for a particular type of data. (Menno-Jan, 2004).

Web-based GIS can help streamline the work of geoscientists in two specific ways. Using a Web Server, a user or client can publish spatial data and maps to the Internet. If this data is published publicly via the Internet others can quickly and efficiently access it which in turn can help shorten any time required for evaluation. The Internet being as widespread as it is today also allows users to contribute to projects from any location with a sufficient Internet connection. Speed of data transfer seems to be one of the greatest limiting factors.

When designing a web GIS one has to decide whether the spatial data will be transmitted and displayed as vector or raster data. Both types of data have advantages and disadvantages and it is important to understand the differences between the two. As Web browsers display GIF and JPEG

raster data would not have to be altered before display, unlike vector data. If vector data is decided upon, preemptive steps must be taken to prepare the data for visualization in a Web-browser. This has typically been done by using 'plug-ins'. Advantages of vector data over raster data include the following. Vector data tends to be smaller in size which can make processing speeds up to three to four times faster (Nayak, 2000). Vector data also is seen as more user friendly than raster data, as individual vector objects can be highlighted and selected.
Interactive Web Maps

There are several levels of complexity when it comes to publishing maps on the Web. Static maps can be displayed for mere communication of data; where as more complicated maps are interactive and able to be customized. Interactive GIS applications separates the workflow into four tiers including selection, display element generator, rendering, and display of image. Features and data are gathered from the 'selection' process, display elements such as symbols and line styles are generated and an image is produced by the renderer.

Web-based GIS are essentially a communication between a server and clients. The server, known as an Internet Map Server (IMS), can be split into two core elements: the geo-processing engine and a Web server. The processing service processes raw data that is stored on the server according to the requests given by the client. These requests are communicated via the Web-server over the internet or a corporate server. The Internet Map Servers analyzed during the time of this article included: ArcView IMS 1.0a (ESRI), MapObjects IMS 2.0 (ESRI), Arc IMS 3.1 (ESRI), MapXtreme NT Ver 2.0 (MapInfo), MapGuide 4.0 (AutoDesk), GeoMedia Web Map (Intergraph), and Map Server 3.5 (Minnesota DNR).

Figure 1 models the workflows between the Web browser Client and the Server. Types of client architectures are divided into 'thin' and ‘thick' architectures. WebGIS systems with thin architectures have most of the geoprocessing done by the server. Thin server architecture can be advantageous as it is easy to maintain central control on the server side as the client is required to have little knowledge of the Internet Mapping Server. Despite these advantages, thin architecture does not readily support local processing making the resulting Web mapping application less interactive.

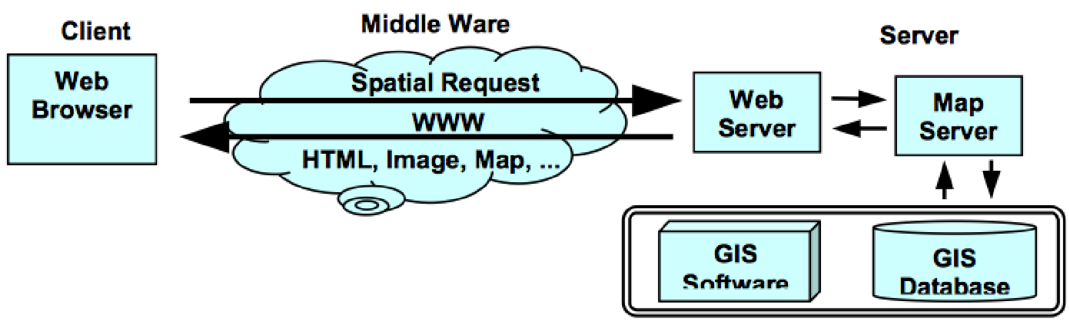

Figure 1: Diagram of how a typical web GIS model works (from Helali, 2001).

To make up for some of these disadvantages, thick client architecture is used in order to broaden the functionality of the browser. This is done to allow data types other than HTML documents and raster images to be used in the Web GIS Interface. If vector files are to be used in the site, thick architecture must be used. The client computer's browser is 'thickened' via either a plug-in or Java Applet.

One method to manage large raster images or sets of data is to organize them hierarchically or in a pyramid structure. In this form of structure, an image is split into different levels of detail which are made of tiles that are sized based on the level of detail needed and are connected depending on their location. A 'pyramid' is built on the fly each time, and so implementing them into a WebGIS takes too long to process. Caching is one method that is explored in this study to possibly enhance transfer of raster images, where 'caches' temporarily store data in order to be reused in the future (Chaowei, 2013).

In another study done, there were two frameworks of map generation discussed in order to improve efficiency. In the first, one set of highly accurate spatial data is stored on the server. Maps of lesser detail are then generalized on the fly to fit the scale designated by the user. In the other approach, there are previously made data sets for each possible scale that is able to be chosen by the user.

With the growth of internet GIS, analytical tools also grow alongside it. Three broad classes of methods were considered: outlier maps, smoothing procedures and spatial autocorrelation analysis. Standard choropleth maps have been categorized in a specific statistical method and show extreme values. Smoothing techniques are used to obtain safer estimates than those obtained from raw rate maps. When rates are obtained for groups of varying populations or number of samples, the results can be considered more unreliable than if all of the groups sampled had equal populations. *Empirical Bayes* and *spatial rate* are two 'smoothing' techniques that are discussed in the paper. Another method that is explored using internet based GIS is visualizing spatial autocorrelation using a *Moran Scatterplot.* A percentile map is one way of creating potential candidates for outliers. Values are divided into different 'bins" or categories of percent that are then colored certain color or shade. The highest and lowest groupings of percentiles are considered potential extreme values. Another, yet more thorough classification of outliers is a box map, similar to a standard box and whisker plot. Percentile and box maps both can be used for any forms of data. Excess rate maps on the other hand are used with specifically proportion data, or data that is quantifies the ratio of events recorded to the number of potential populations 'at risk' to these events (Anselin, 2004)

Watershed systems are complex making it difficult to create simple answers. Yet, simple clear answers are often needed for management decisions. In one study by Zandenbergen (1998), a model was created to analyze and assess ecological risks of watersheds impacted by urban development. The model was developed around the US Environmental Protection Agencies guidelines. Several indicators were identified based upon literature reviews. These included indicators such as impervious areas, Riparian Habitat, Pollutant Loadings, Water quality, Sediment quality, Public health, and Fish health. For each indicator a ranking of quality is assigned on a scale of 1 - 100. Each indicator is then divided into 5 categories from 'very poor' to excellent. Some indicators are based on single measurements. For the Water quality indicator, the British Columbia Ministry of Environment's Water Quality Index was modified for this study. This WQI takes into account several different parameters, many of which have been sampled for this project in Manhattan. These parameters included pH, temperature, turbidity, alkalinity, conductivity, nutrient loadings along with others. Several parameters were used as there is no one single parameter that can sufficiently indicate water quality on its own. This study applied its model to the Brunette River watershed, in the Vancouver area of British Columbia, Canada.

The U.S Environmental Protection Agency (EPA) has created the 'Better Assessment Science Integrating Point and Nonpoint Sources (BASINS), in order to further improve management of water resources. The EPA's BASINS is a system intended to studies related to water health on a variety of scales. BASINS use GIS to investigate and display the relationships between various sets of data and information dealing with land use and surface water. The three main objectives of BASINS are "(1) facilitate examination of environmental information, (2) support analysis of environmental systems, and (3) examine management alternatives" (U.S. EPA 1998).

In order to understand watershed management practices, it is important to know what a watershed itself is. A watershed is an area of land with boundaries that are distinguished by having surface runoff of water into a common stream. The watershed is considered to be a helpful tool for managing water resources as there are clear geographic relationships between a point on a stream or river and its watershed. That is that the quality of water at a certain location is the result of various qualities of variables of the watershed upstream.

Common non-point source pollutants include sediments from erosion, fertilizers, pesticides, and salts. Agriculture plays a large role in the contribution of non-point source pollution in surface and sub-surface waters (Humenik et al., 1987). NPS pollution can have significant influence on fish populations and wildlife habitat as well as alter the aesthetic value of a given stream or river. If pollutants, such as Nitrogen, are high enough it is possible have serious impacts on human wellbeing. Computer based GIS models are a cost effective way to analyze and predict levels of NPS pollution based on agricultural practices.

Ordinary Least Squares (OLS) is based off the assumptions of residuals having no autocorrelation and are homoscedasticity. If the model does not adhere to these two assumptions than the effectiveness of the model is decreased. They are often ignored when talking about environmental quality models such as water quality. "The above examples show that the relationships between land use and water quality vary significantly over space, because watershed characteristics and pollution sources are not the same in different regions." Global relationships presented by the OLS method are not able to show varying relationships over space. For example when there are multiple types of land use types in a drainage area, the OLS method cannot show the spatial significance as it relates to the water quality. The near Geographically Weighted Regression technique attempts to account for spatial variation of variables by using a distance decay function assuming that variables closer to each other will have greater significance to each other (Jun Tu, 2008).

3. Methods

3.1 Study Area

Easily accessible points along the Kansas River, Wildcat Creek, Big Blue River, Little Kitten Creek, Campus Creek, and various Manhattan stormwater infrastructure were tested *(Figure 2)*. A "shotgun" sampling method was used to include many different watersheds with various land uses and land cover to support later analysis of pollutants. However, the primary criteria used in site selection was accessibility for Citizen Scientists to continue monitoring our sites. Our timeline consisted of testing water between October 27, 2013 and November 25, 2013.

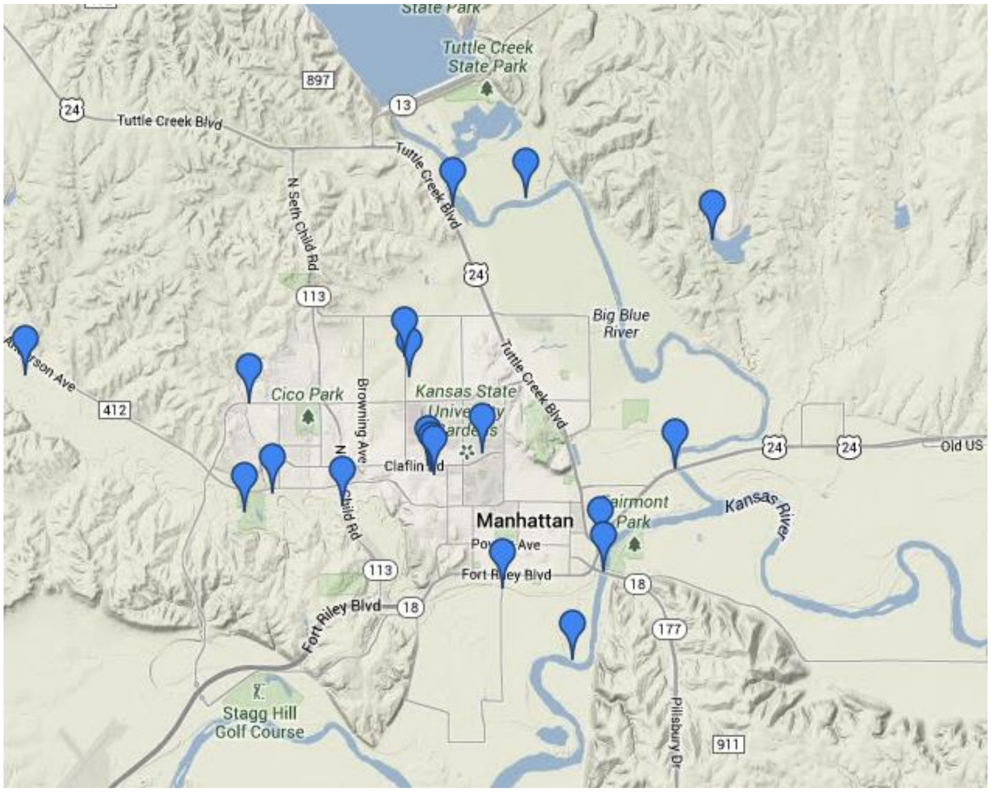

Figure 2: Map of surveyed points around Manhattan, KS

3.2 Water Testing

Two Hach® surface water testing kits (No 25598-33) were used to measure water temperature, water temperature, dissolved oxygen, pH, electrical conductivity, turbidity, phosphates, and nitrates. The ranges of the readouts for these kits can be seen in *Table* 3.

Table 3: Range of readout for Hach® surface water testing kit (No. 25598-33) (Hach, 1999).

Test	Range of Readout
Dissolved Oxygen	1-20 mg/L
Nitrate	0-50 mg/L
Phosphorus	0-50 mg/L
Temperature	-1-48*C
pH	0-14
Electrical Conductivity	10-1999 mg/L
Turbidity	0-400 NTU

Air temperature

Air temperature is measured to help indicate the weather conditions at the time of water quality testing. Air temperature was measured in Celsius a minimum of two minutes after the thermometer was exposed to air temperatures (Mitchell & Strap, 1996; Murdoch et al., 2001).

Water Temperature

Water temperature directly affects dissolved oxygen. Colder water is able to dissolve oxygen than warmer water and higher dissolved oxygen is favorable to sensitive macroinvertebrates in our streams. Water temperature was measured in Celsius a minimum of two minutes after the thermometer was placed in a shallow pool of the stream (Mitchell & Strap, 1996; Murdoch et al., 2001).

Dissolved Oxygen

Dissolved oxygen was a little more intensive of a process. First, the 60 mL DO bottle was rinsed and filled with stream water. The glass stopper was inserted to overflow any additional water and to make sure that the bottle did not have any air bubbles. DO 1 and DO 2 reagent packets were then added to the sample and the stopper put back on. Vigorous mixing occurred to create a flocculate precipitate. The bottle was then allowed to rest so that the flocculate would settle to the bottom. After settling, DO 3 reagent was added which dissolved the floc and turned the water an amber color. Finally, a small round plastic measuring tube was filled with the sample and poured into the square mixing bottle so that sodium thiosulfate could be titrated into the mixture. The number of drops it took to titrate the sample clear is how many mg/L there are of dissolved oxygen (Mitchell & Strap, 1996; Murdoch et al., 2001).

pH

pH indicates if the stream is acidic, basic, or neutral. Because these streams are in the flint hills, a limestone dominated area, pH is expected to be slightly basic. An electronic pH meter was used to determine the pH. With data refreshing frequently, an averaged number seen was recorded by the surveyor (Mitchell & Strap, 1996; Murdoch et al., 2001).

Electrical Conductivity

Referring to the dissolved solids in the stream, an electronic conductivity meter was used to sample. Similarly to the pH meter, an averaged number seen was recorded by the surveyor (Mitchell & Strap, 1996; Murdoch et al., 2001).

Turbidity

Measuring the suspended solids not dissolved in the soil, a turbidity tube with a Secchi disk at the bottom was used. First the tube was filled with stream water and the hole at the bottom was plugged. With the surveyor viewing the tube from above, the hole was unplugged allowing the water to drain through the tube. When the black and white Secchi disk was visible to the surveyor through the column of water, the surveyor plugged the hole and recorded the equivalent NTUs from the side of the tube. This was repeated twice and the second number was recorded, giving the surveyor some practice on this qualitative test (Mitchell & Strap, 1996; Murdoch et al., 2001).

Phosphate

Two color viewing tubes were filled with 5 mL of stream water. One tube was filled with PhosVer 3 reagent and shaken vigorously for one minute. This created a blue color and the tube was allowed to sit for one minute more. These color viewing tubes were placed in the black box with a blue colored disk. Surveyors rotated the color wheel until the plain stream water behind the blue color wheel was the same color as the tube filled with PhosVer 3 reagent. This number was then recorded in mg/L (Mitchell & Strap, 1996; Murdoch et al., 2001).

Nitrate
Two color viewing tubes were filled with 5 mL of stream water. One tube was filled with NitraVer 5 reagent and shaken vigorously for one minute. This created an amber color and the tube was allowed to sit for one minute more. These color viewing tubes were placed in the black box with an amber colored disk. Surveyors rotated the color wheel until the plain stream water behind the amber color wheel was the same color as the tube filled with NitraVer 5 reagent. This number was then recorded in mg/L (Mitchell & Strap, 1996; Murdoch et al., 2001).

4. Results

The following summarizes the group's water testing results and provides analysis of the results. The United States Environmental Protection Agency's drinking water quality standards were used to analyze our water quality data.

4.1 Summary of Pollutant Results

A summary of all 19 tested site locations for dissolved oxygen, pH, conductivity, turbidity, phosphate, and nitrate was analyzed and can be seen in table 4.

Table 4: Summary statistics from all 19 tested sites

	Average	**STDEV**	**Min**	**Max**
Dissolved Oxygen (mg/L)	7.7	1.5	5	10
pH	8.3	0.5	7.5	9.3
Conductivity (mg/L)	481	233	105	1130
Turbidity (NTUs)	54	94	0	400+
Phosphate (mg/L)	13.2	13.3	0	40
Nitrate (mg/L)	0.8	0.9	0	2

Dissolved Oxygen
Dissolved oxygen was similar throughout most locations with a few places showing a higher concentration of dissolved oxygen than what our tests could measure (Figure 3). Data points that were 26, 20, and 19 mg/L were deleted because it is assumed that these were incorrectly measured. This leaves the max concentration at 10 mg/L and the minimum is 5 mg/L. The average of all locations is 7.7 mg/L and the standard deviation is 1.5 mg/L. Dissolved oxygen is the amount of oxygen available to living species in the water. Higher values allow for more living species in the water.

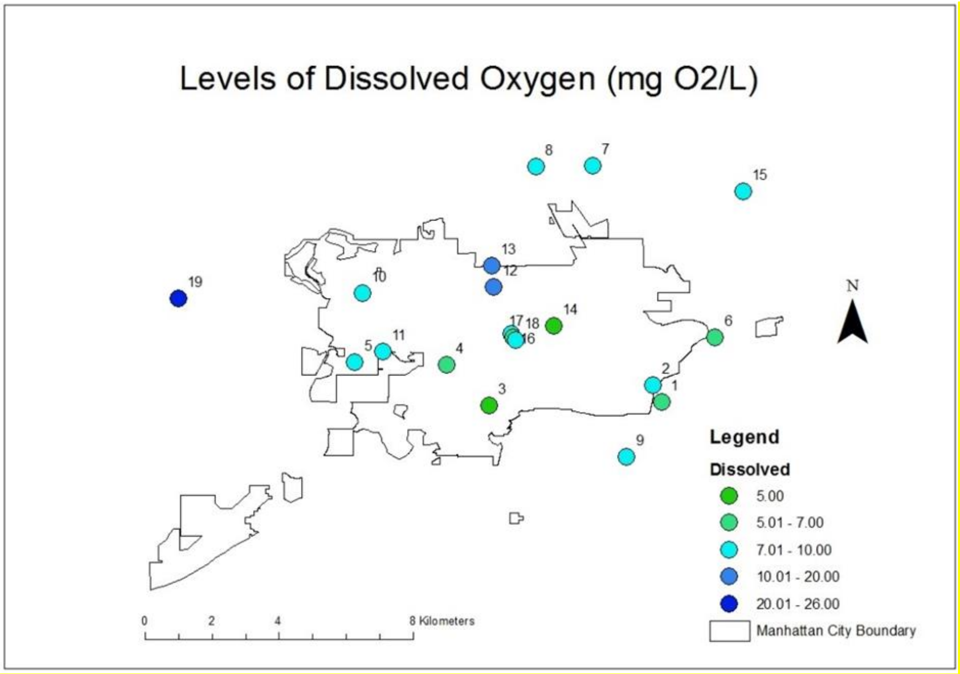

Figure 3: Map of dissolved oxygen levels (mg/L) among 19 tested sites.

pH

pH varied between 7.5 and 9.3 for the water testing locations (Figure 4). The Kansas State Agronomy farm had the lowest pH of 7.3 and the Kansas River had a pH of 9.3. The average of all water testing locations was 8.33 and the standard deviation was 0.50. A pH of seven is neutral. From our results, it can be seen that some results are close to neutral while some are slightly basic (around nine). pH affects many chemical and biological processes in the water. For example, different organisms flourish within different ranges of pH. According to the Environmental Protection Agency (EPA) the largest variety of aquatic animals prefer a range of 6.5-8.0. pH outside this range reduces the diversity in the stream. Changes in acidity can be caused by acid rain, surrounding rock, and some wastewater discharges.

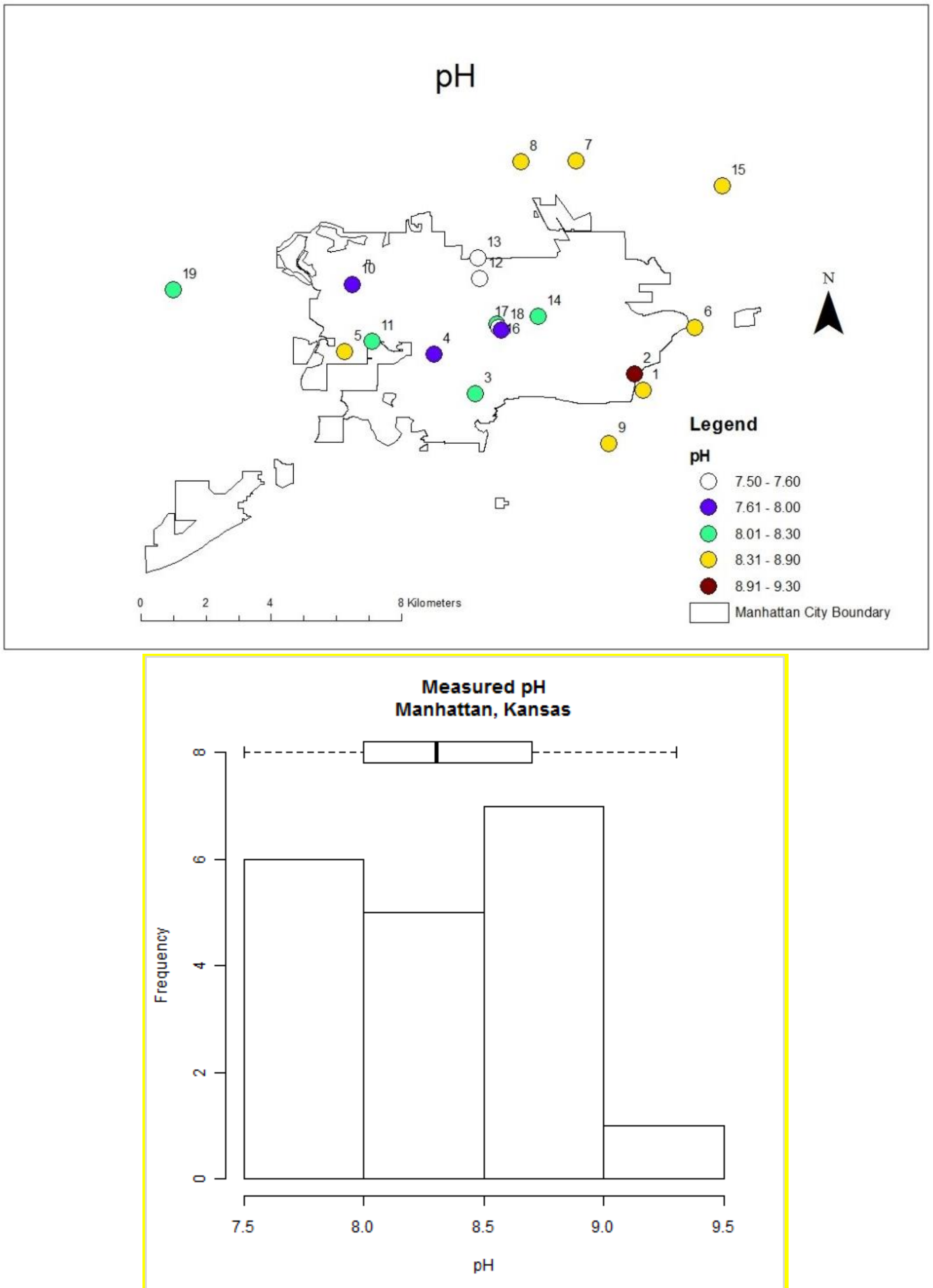

Figure 4: Map and graph of pH levels among 19 tested sites.

Electrical Conductivity

A reading of 1130 mg/L was the highest conductivity found at the Kansas River (Figure 5). The lowest conductivity was 105 mg/L at Campus Creek. The average from all testing locations was 481 mg/L and the standard deviation was 233.

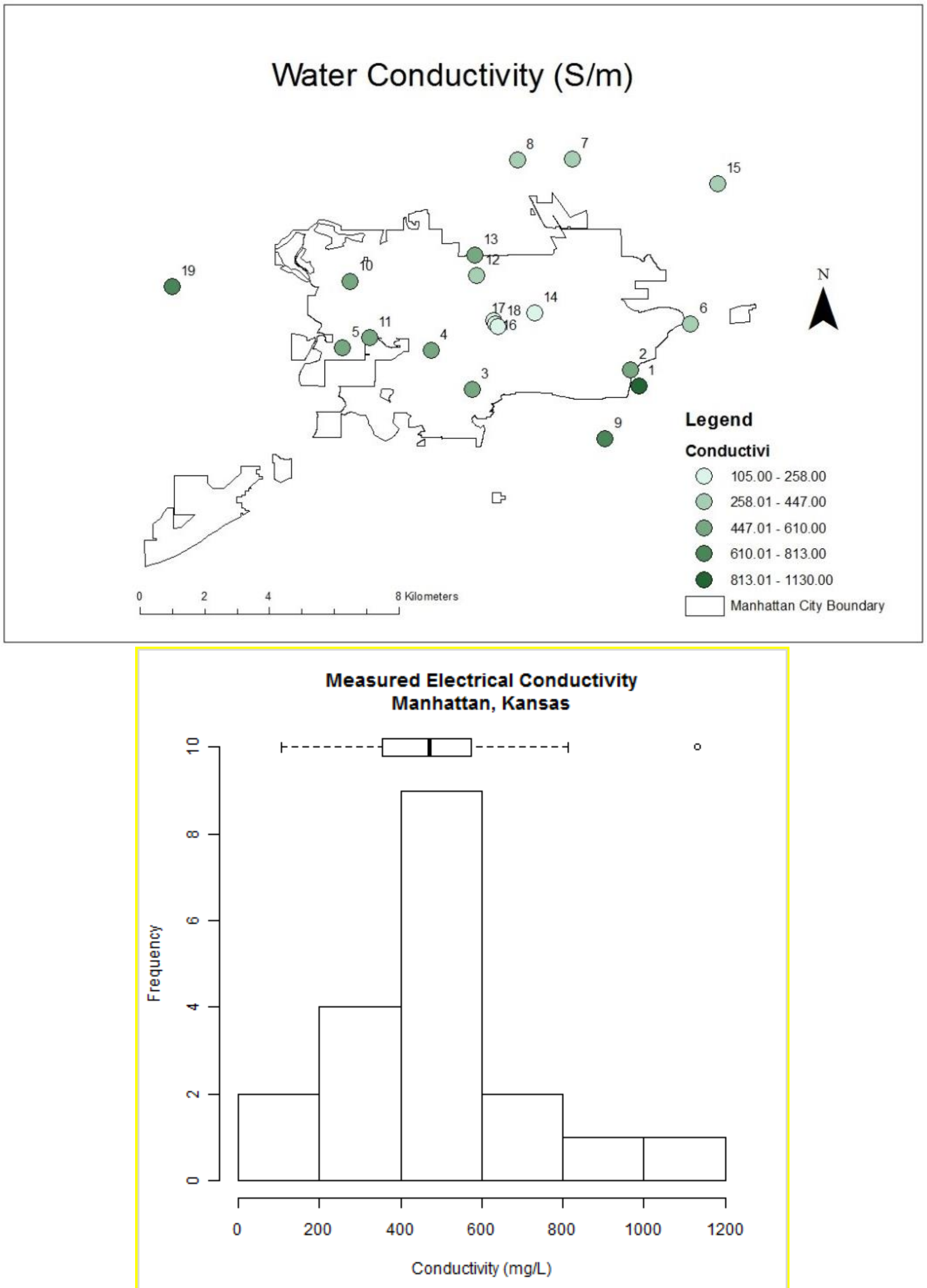

Figure 5: Map and graph of electrical conductivity levels (mg/L) among 19 tested sites.

Turbidity

Turbidity varied throughout the testing locations with most locations having a turbidity around 30-50 NTUs (Figure 6). The max turbidity was 400+ NTUs and the minimum was 0 NTUs with those amounts found at a stormwater drainage and Campus Creek, respectively. The average was 54 NTUs and the standard deviation was 94. Higher turbidity levels are often associated with higher levels of disease-causing microorganisms such as viruses, parasites and some bacteria. These organisms can cause symptoms such as nausea, cramps, diarrhea, and associated headaches.

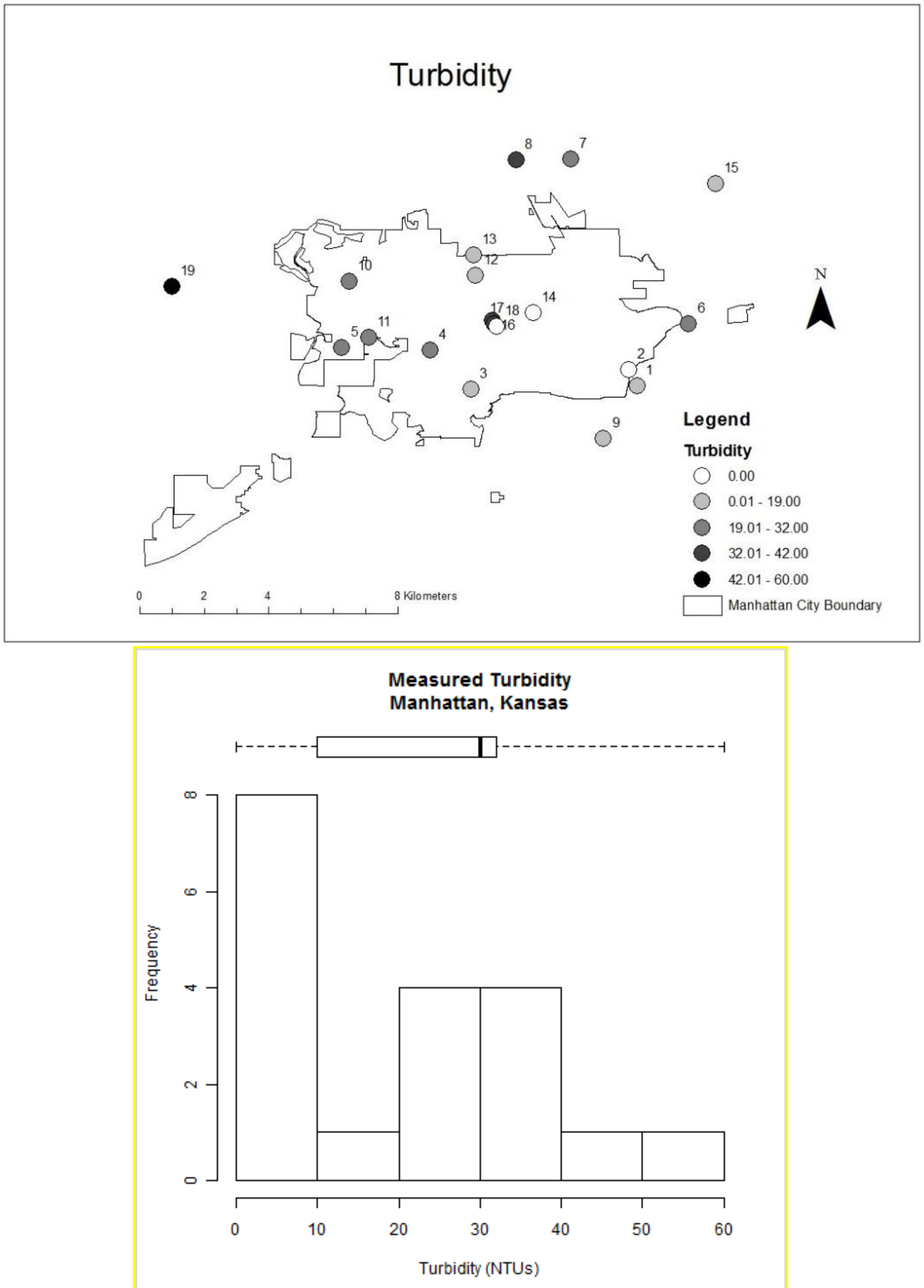

Figure 6: Map of turbidity levels (NTU) among 19 tested sites.

Phosphate

Phosphate amounts varied greatly in our testing points (Figure 7). The standard deviation was 13.3. Phosphate will be discussed in more detail during the correlation analysis. The maximum was 40 mg/L found at three locations; the Big Blue River, Kansas River, and the Kansas State Agronomy Farm creek. The minimum was 0 mg/L found at three different locations.

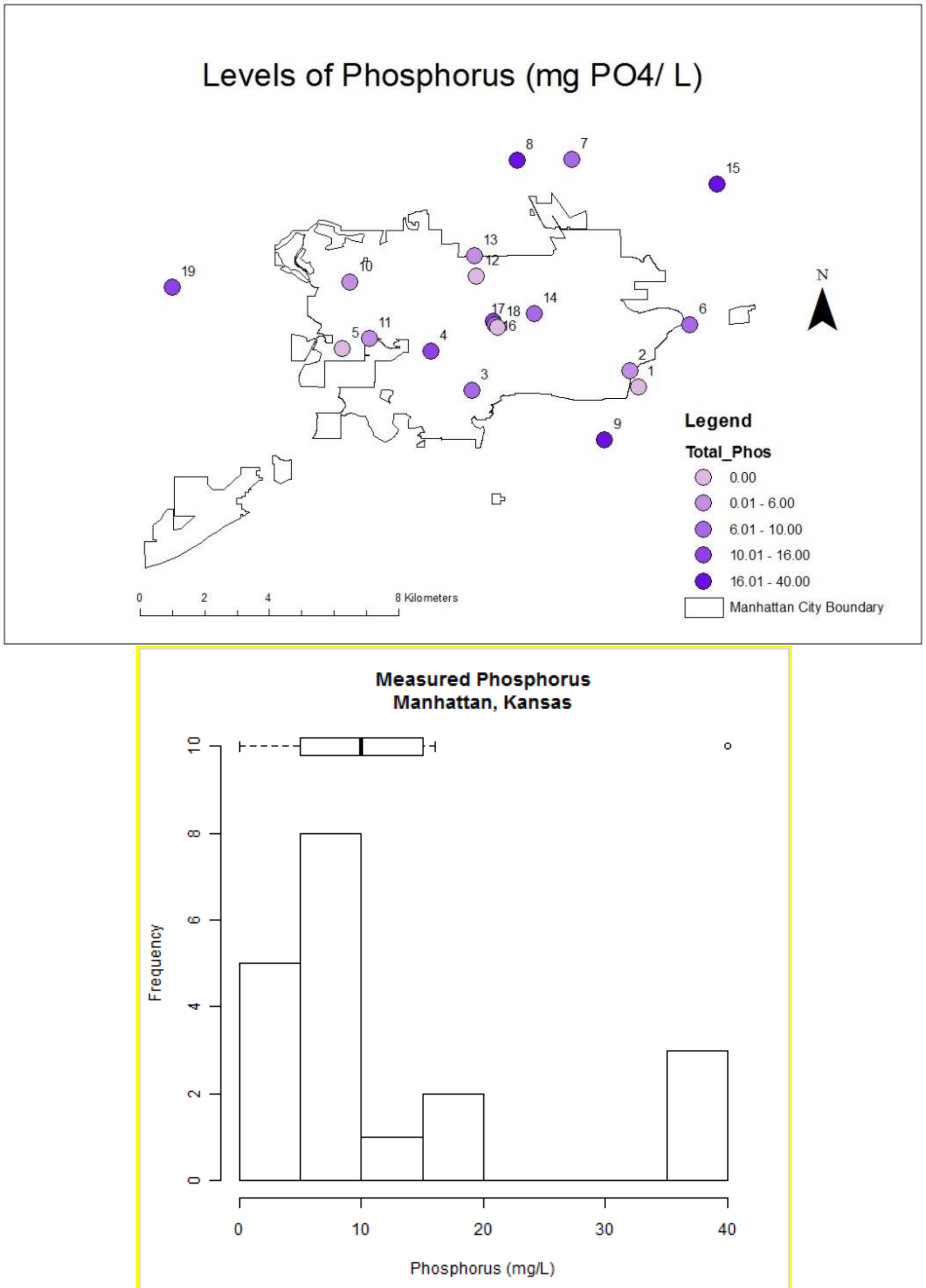

Figure 7: Map and graph of phosphate levels (mg/L) among 19 tested sites.

Nitrate

Nitrate concentrations were low at all locations tested with the max at two mg/L and the min at 0 mg/L (Figure 8). The average from all locations was 0 .78 mg/L and the standard deviation was 0.94. Nitrate has a Maximum Contaminate Level (MCL) of 10 mg/L. No water bodies tested had a level above the MCL. Therefore, nitrate is not a health risk according to the EPA's drinking water quality standards. It could be that this is not the season to apply fertilizer. Water samples that I took on the school farm were surrounded by milo, which was ready to be cut. Nitrogen fixating plants (soybeans) were cut in August and would have no affect to on our water samples. Fertilizer would have been applied when it was planted. Also urban sampling sites would not see much nitrates, as it is the wrong time of year to apply fertilizer on lawns. In conclusion, it's the wrong time of year to see nitrogen in the water.

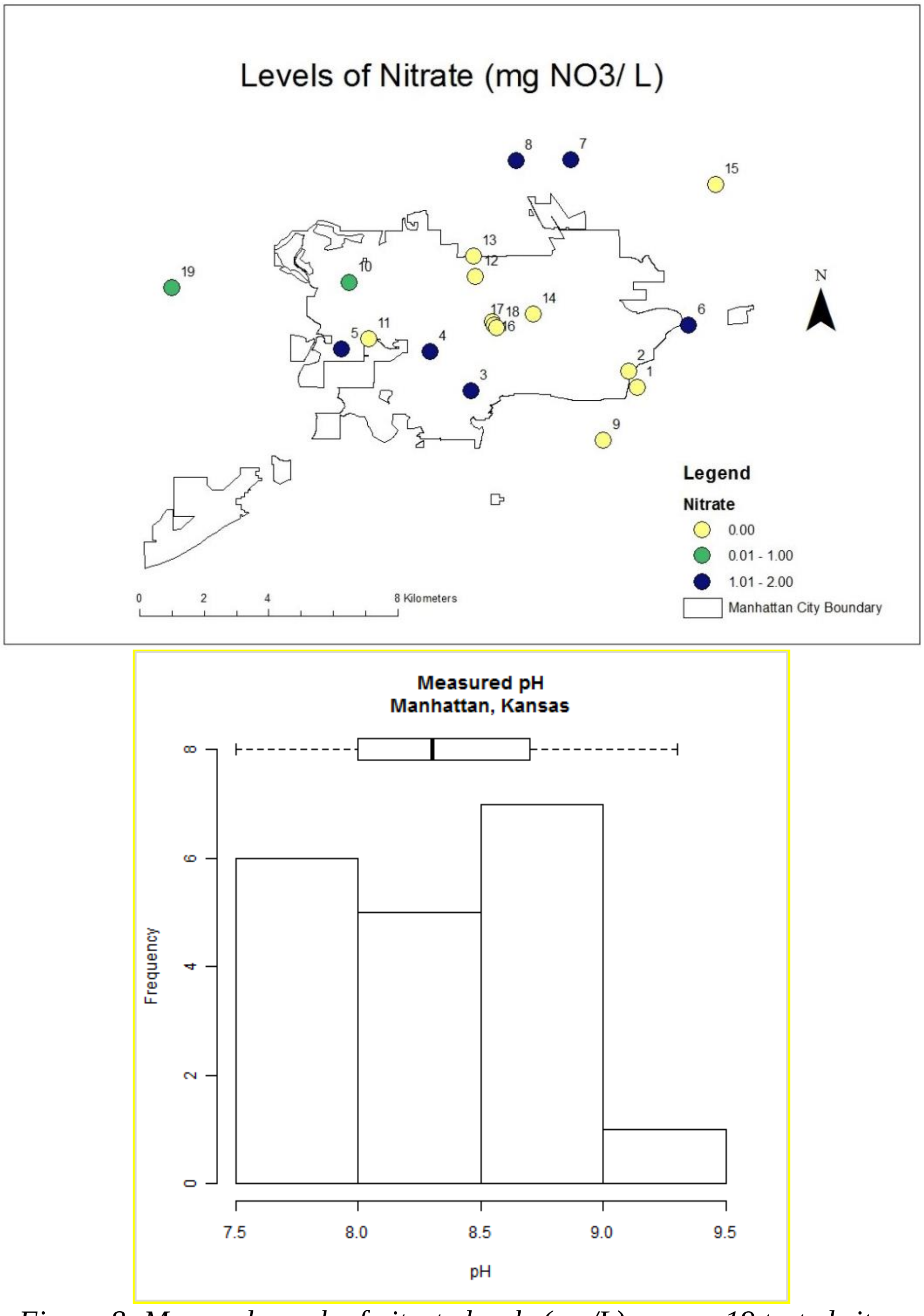

Figure 8: Map and graph of nitrate levels (mg/L) among 19 tested sites.

4.2 Correlation Analysis

After summarizing the results, it is important to find reasons why there are differences in our results. For some parameters, it is possible to correlate land use/land cover conditions and see how these conditions can impact water quality. From our results nitrogen showed little variation, with a max of 2 mg/L and minimum of 0 mg/L. Therefore, nitrate is not assessed here.

For the correlation analysis, ArcGIS was used to delineate each point's watershed. Following, each watershed's land use/landcover (LULC) was analyzed using National Landcover Dataset (NLCD) 2006. From here, many of the land use/land covers were combined to make five general categories: grassland/herbaceous, forest, agricultural, developed, and other (Figure 9).

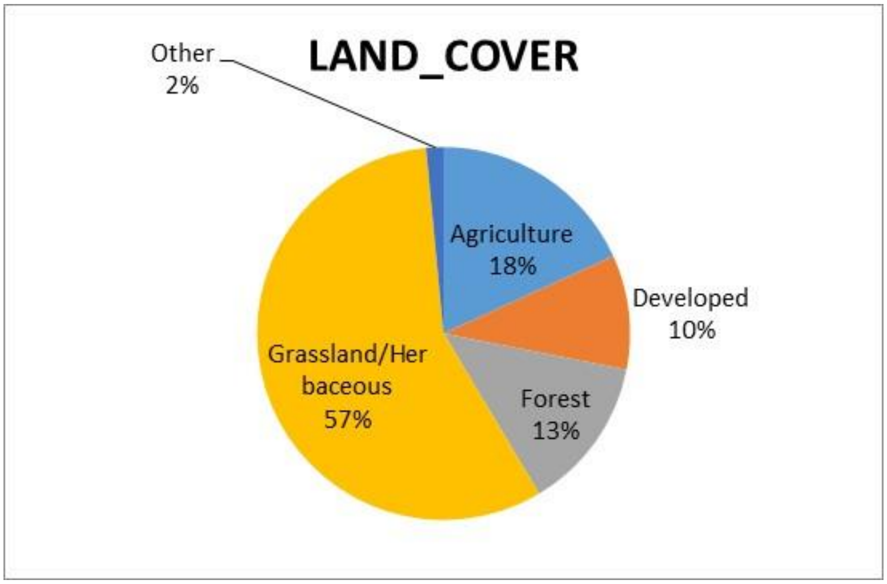

Figure 9: Graph of land cover that was found in the watersheds.

Dissolved oxygen is dependent upon stream temperatures where colder streams are able to dissolve more oxygen into the stream, with our findings backing this up (Figure 10).

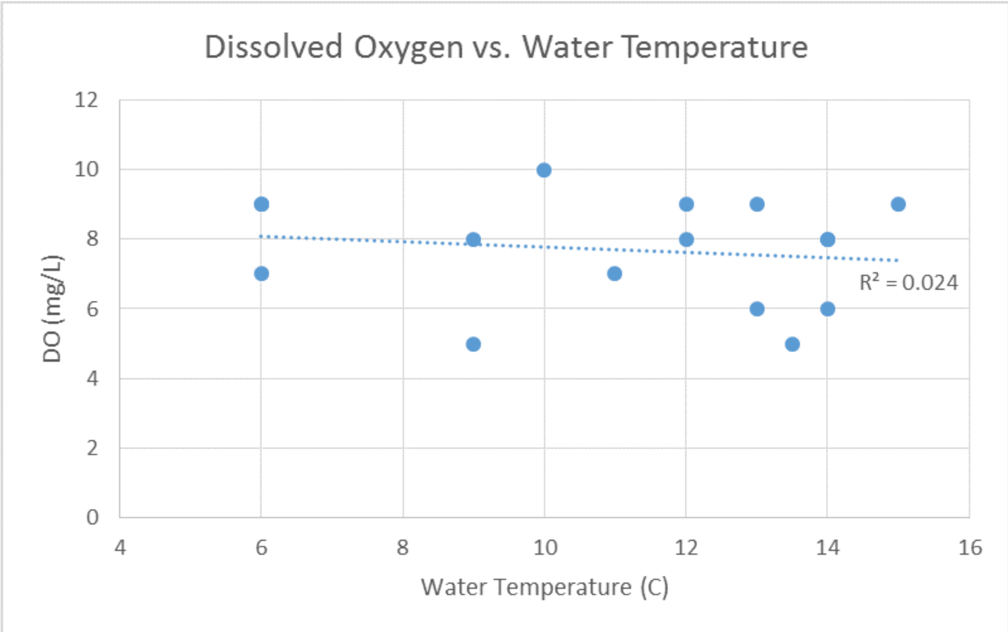

Figure 10: Graph of dissolved oxygen vs. water temperature with an R2 value of 0.024.

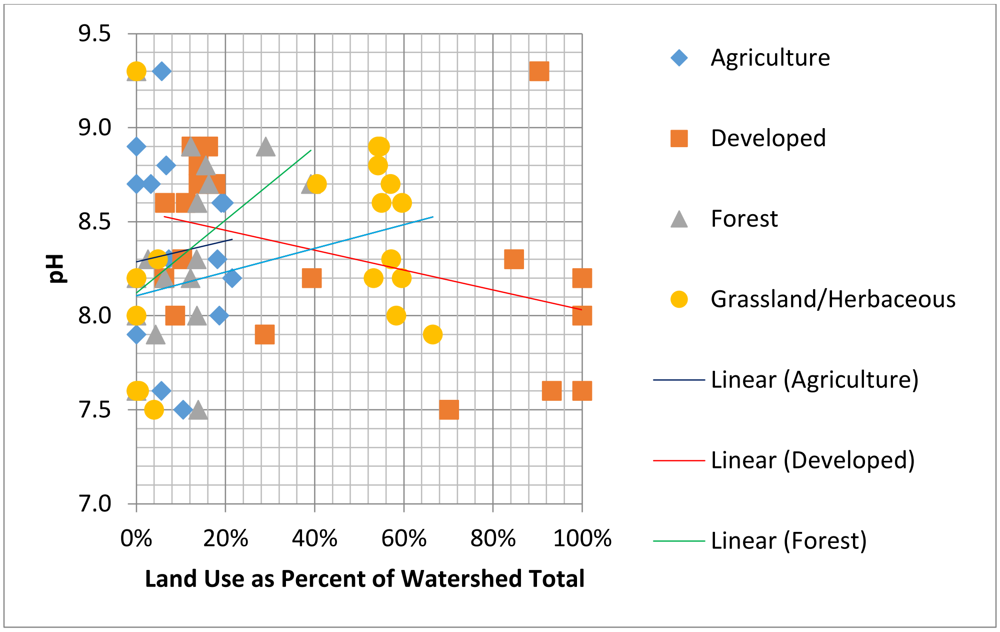

Figure 11: Graph of pH vs. LULC where with increasing percentage of agricultural land, pH increases (R^2 of 0.0091), with increasing natural land, pH increases (R^2 of 0.1879), and with increasing urban land, pH decreases (R^2 of 0.17).

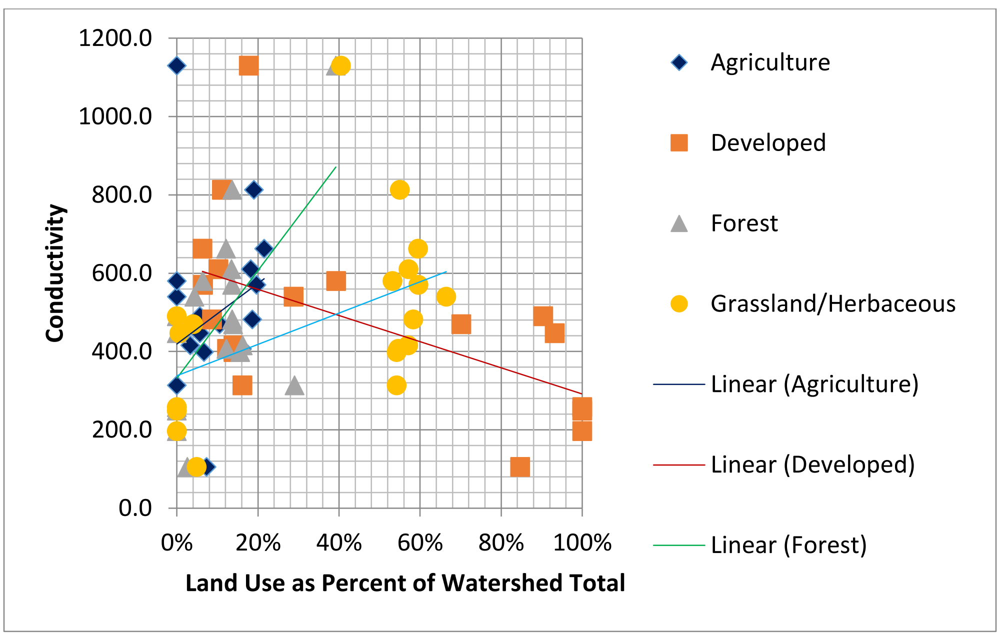

Figure 12: Graph of electrical conductivity (EC) vs. LULC where with increasing percentage of agricultural land, EC increases (R^2 of 0.0746), with increasing natural land, EC increases (R^2 of 0.3101), and with increasing urban land, EC decreases (R^2 of 0.3165).

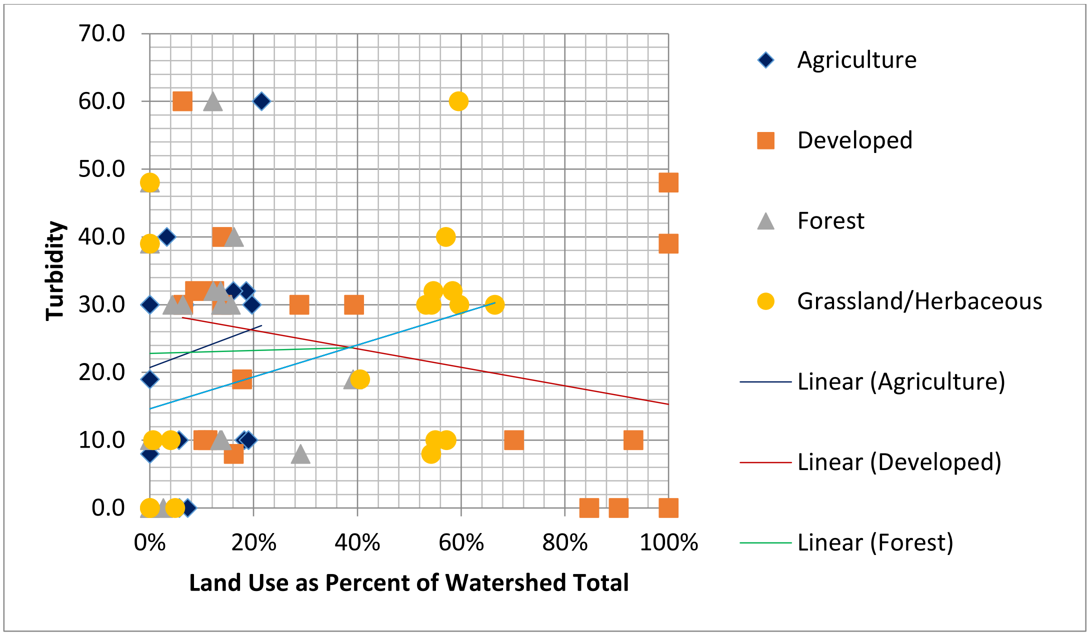

Figure 13: Graph of turbidity vs. LULC where with increasing percentage of agricultural, turbidity increases with increasing natural land, turbidity decreases (R^2 of 0.1735), and with increasing urban land, turbidity decreases (R^2 of 0.1827).

Overall, as developed land increases, conductivity decreases. As the percentage of the other land cover types increase, there is an increase in conductivity.

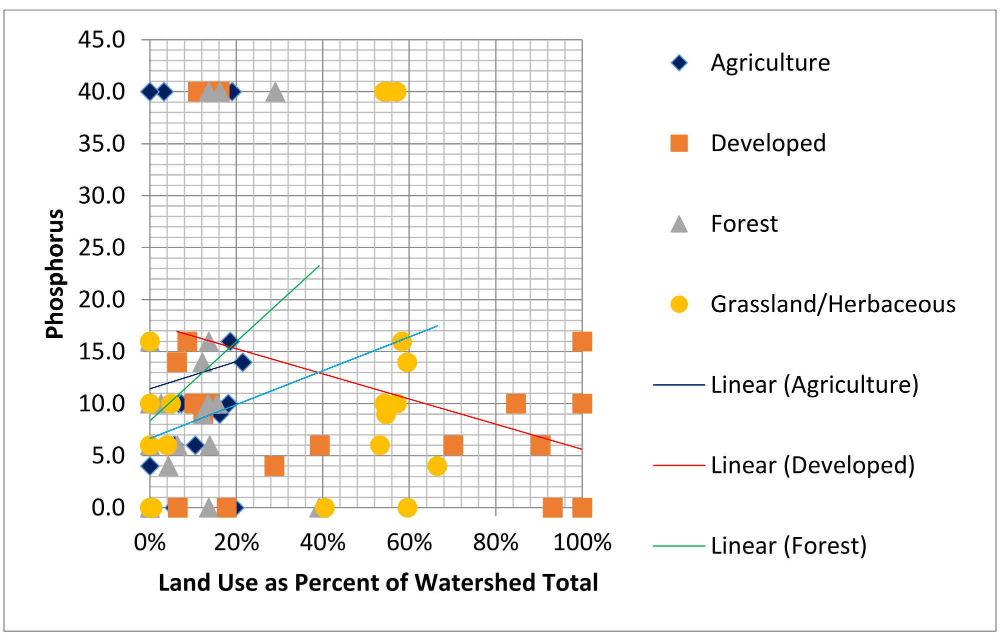

Figure 14: Graph of phosphate vs. LULC where with increasing percentage of agricultural land, phosphate increases (R^2 of 0.0074), with increasing natural land, phosphate increases (R^2 of 0.1388), and with increasing urban land, phosphate decreases (R^2 of 0.1255).

As developed land increases, there is a decrease in phosphorus. As the percentage of other land types increase, there is an increase in phosphorus.

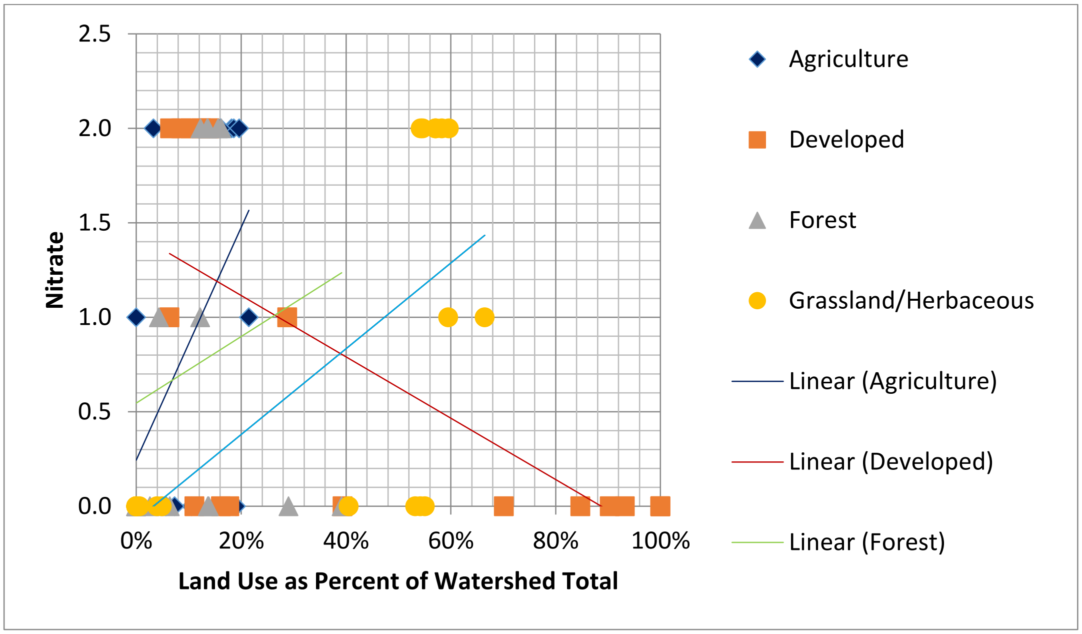

Figure 15: Relationship between nitrate and LULC. As developed land increases, there is a decrease in nitrate. As the percentage of other land types increase, there is an increase in the amount of nitrates.

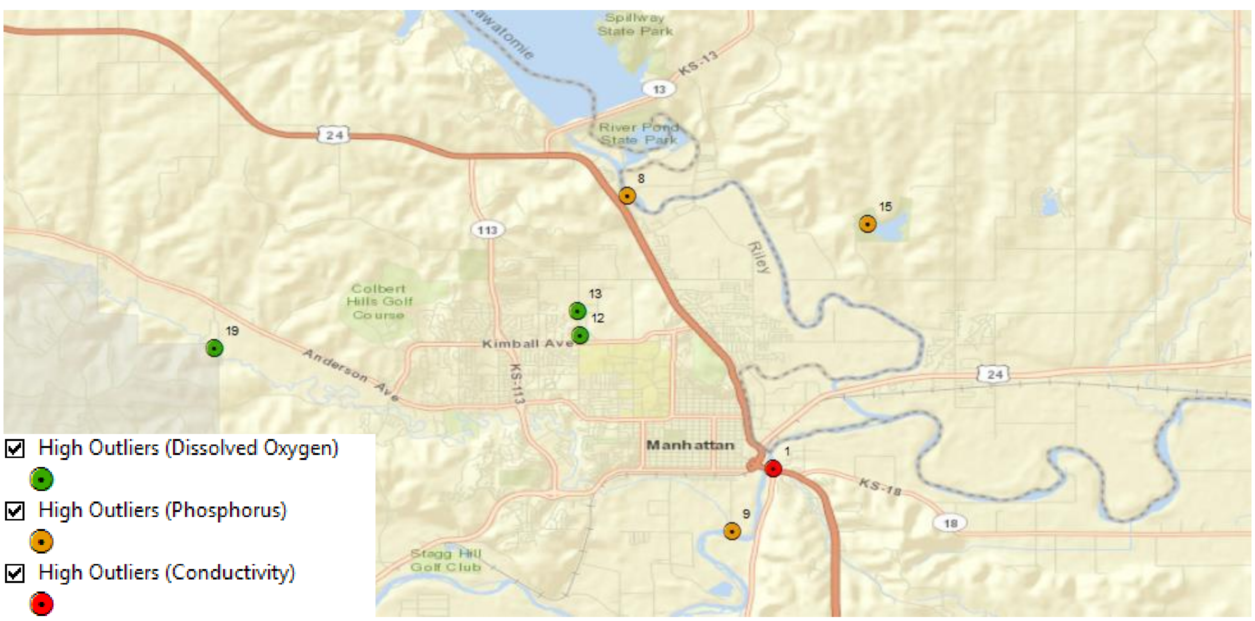

Figure 16: Shows outliers and where they are located.

There are a couple locations where high conductivity (Kansas River), high phosphorus, and high dissolved oxygen are present.

4.3 Case Study

An easy replicable experiment for Citizen Scientists was conducted on November 5, 2013 at the stormwater project located just south of Claflin and Hartford Roads in Manhattan. Water quality data was taken along three points of a stormwater control project which included the control site where 121.6 acres of suburban watershed flowed into a 300 ft long grassed waterway in good condition, that, in turn, flowed into a 300 ft long bare earth channel in poor condition (Figure 17). It should be noted that it was raining at the time and additional water was able to flow into the channels from their sides, but this additional water was deemed negligible.

Figure 17: Photographs of testing locations including the control (left), after 300 ft of grassed waterway (center), and after 300 ft of bare ground (right).

The three sets of data and their percent changes between one another are listed in Table 5. Water temperature did not change, and dissolved oxygen decreased at the end of the grassed waterway, but went back up to the control's value at the end of the bare earth channel. pH went down towards neutral at the grassed waterway, but increased slightly afterwards. Phosphates decreased after the grassed waterway, but because the water was so turbid, phosphate and nitrate tests could not be conducted accurately at the end of the bare earth channel. Notably, turbidity decreased by 7% by the end of the grassed waterway, but increased 1026% at the end of the bare channel. During testing, large sediment settled out so fast that the Secchi disk was covered in a layer of sediment before the test could be administered, giving its reading over 400 NTUs. Interestingly, conductivity increased ever so slightly after the grassed waterway, but remained about the same at the end of the bare channel. This case study demonstrates the importance of green stormwater management like grassed waterways, and the use of best management practices within construction sites to reduce erosion (figure 18).

Table 5: Recorded water quality data from case study with percent changes recorded between the control and grassed waterway, and the grassed waterway and the bare earth.

	Water Temp *C	**DO mg/L**	**pH -**	**Nitrate mg/L**	**Phosphate mg/L**	**Turbidity NTU**	**Conductivity mg/L**
Control (out of stormwater pipe)	14	8	8.2	0	16	42	197
After 300 ft of grassed waterway	14	6	7.6	0	10	39	258
%change	0%	25%	7%	0%	38%	7%	131%
After 300 ft of bare earth	14	8	8.0			400	249
% change	0%	133%	105%			1026%	97%

Figure 18: Photographs of bad (left) and good (right) stormwater management practices.

4.4 Creation of Web-Map Application

The intent of this project was to create a public water monitoring information portal for Manhattan, Kansas that uses data from citizen scientist. Web-based mapping is the tool that has been chosen for this purpose. The vision for this project is to have a live Web-map in which citizen scientists can contribute data of water quality in which they have collected themselves using simple water quality testing kits. The platform for such a Web-map should be simple and user friendly as Citizen Scientists will most likely have little experience with GIS software.

ArcGIS Viewer for Flex by ESRI was the chosen application to be used for building a web-map that filled the requirements of this project. ArcGIS Viewer for Flex is a "what-you-see-is-what-you-get" (WYSIWYG) Web-map builder that allows someone with little or no programming skills to use efficiently. Viewer for Flex is designed to work with an ArcGIS Server and ArcGIS online web services. This application gains functionality in its web-maps in the form of 'widgets'. Widgets are shown as icons in the application and serve as a link to a certain functional block of code. Widgets can be easily added or removed by the designer of the web-map. Certain widgets are included in the application and additional custom widgets can be created using ArcGIS API for Flex.

For this project map and geoprocessing services were created and published in ArcGis Server Manager using the ArcMap and ArcCatalog desktop GIS applications. Geospatial data that is communicated over the server included the original test site locations and the attribute data that went along with each site. A shape file that represents delineated watershed has also been included as a separate map layer. Current widgets in the Web-map allow the user to customize map layers to be shown, a tool to chart water data for selected sites, a tool to delineate a watershed for a selected point, a tool to allow for data extraction, and a print widget. Additional widgets can be created in the future to allow for more functionality in the web map. One widget that would be of great use for this project would be one in which allowed users of the web map to contribute to the map data by adding their sample data to current or new test locations.

5. Conclusions and Analysis

There are a number of relationships that we noticed from our graphs. Developed land decreased turbidity, whereas, the other land types increased turbidity. For the other pollutants, as developed land increased, there was a decrease in pollutants. That wasn't expected for all pollutants. We thought that developed land would be a source of pollutants. However, we found that the grasslands, agriculture land, and forests contributed more to pollution. This could be because these lands are impacted by humans more than we previous thought, and therefore contribute to pollution.

The methods outlined in this paper are applicable with individual citizen science. These methods allow citizens to know what is contaminating their water. They will then be able to address the issue on a local level and remediate the problem faster. There are several methods that can be utilized to collect these samples. The most common and efficient to use of sampling is the surface-grab method. Surface-grab method can be used to obtain all sample contaminates outlined in the paper.

Overall, this NRES project was a great learning experience and included many different aspects of environmental science. Each member went out and collected water quality data. Next, there was a process of mapping our results us. Then the results were analyzed and discussed. Analyzing the results was not the strength of this project, because of lack of data points and time. With more points and time, our results could be analyzed better. This project has the potential to be used in the future for other NRES groups. Their project could include testing more points or testing for different water quality parameters. Future NRES classes could benefit the community by increasing the number of water quality points. Our results contain a small number of data points collected in a small time frame. Adding more data points during different time periods will help analyze the overall water quality of the community's water. Also, a more in-depth analysis could be done once more points have been collected.

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